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SIMULATION OF RECEIVING, STORING AND LOADING GENERAL CARGO

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by

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SUMMARY

The receiving, checking, and storing of cargo in an export terminal and subsequent loading of the cargo into ships is simulated by computer. The paper gives a description of how the simulation model is designed.

The model can handle any quantity and pattern of cargo inflow and any combination of manning and pier layout. The report is based on a loading simulation of one ship per week and three loading gangs per ship, each loading for a maximum of three ports of destination, but this may be changed to suit different conditions.

The result of one day's simulation is presented in figures of cost per ton handled, loading capacity per gang hour and equipment and personnel utilization. Separate figures are given for different periods of the day and for overtime.

Decision for or against overtime is made as part of the simulation.

A complete listing of the computer program with comments are included. The program may be used to study the influence of changes in manning and equipment capacity on the cargo handling costs. Optimum solutions may be found for different cargo inflow patterns and technical layouts.

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1. INTRODUCTION

The cargo handling operations for general cargo ships are characterized by a chain of two or more sub-operations that are linked together. The sub-operations are, in many cases, interdependent.

The cargo handling capacity of a pier, therefore, depends both on the capacity of the individual types of equipment and on how well their speeds and capacities are adjusted to each other. This may be demonstrated by the following example: Consider a loading "chain" consisting of the following links,

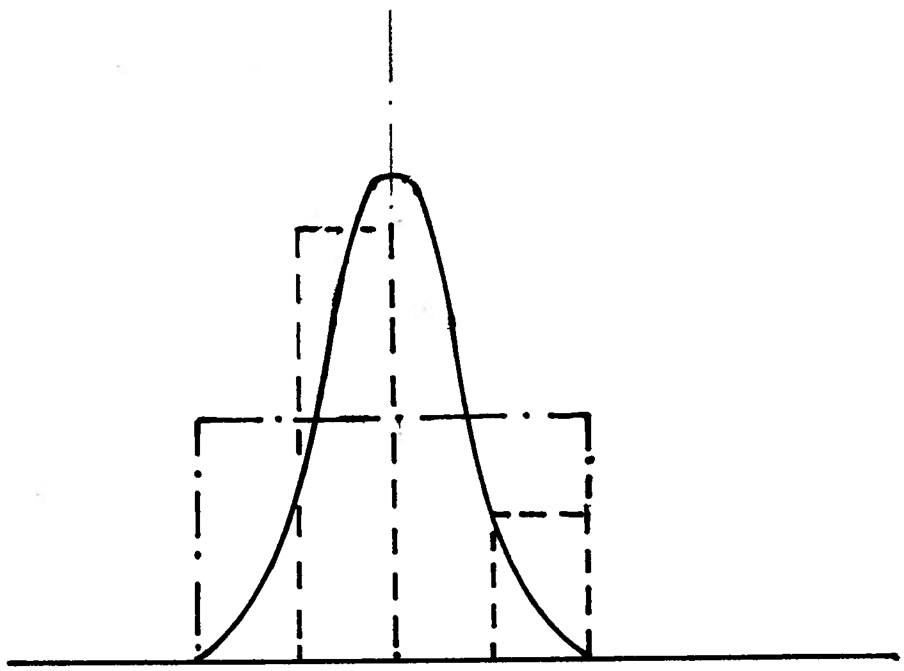
1. A forklift that brings cargo to the apron.
2. A pair of derricks in union purchase lifting the cargo on board.
3. A gang who stows the cargo on board the ship.

Let these three have the same mean working time per operation, two minutes, and let the time be evenly distributed between one and three minutes for the forklift and for the gang on board, but let the pair of derricks have different time distributions, as in the following table:

TIME DISTRIBUTION COMBINATIONS ON BOARD

Item	Forklift	Derricks	Gang
Case I	2 ± 1	2 ± 1	2 ± 1
Case II	2 ± 1	(See Fig. 1)	2 ± 1
Case III	2 ± 1	Normal, Mean = 2 Variance = .4	2 ± 1

These three loading chains have been simulated for an operation time of seven days of two shifts. The result shows no significant difference in total throughput, but the need for



<u>Fig. 1</u>

Cycle time distributions for derricks.

Case I: — · — · — · — · — · — · — · —

Case II: -

Case III: ————————————————

buffer or queue space varies considerably. The average queue time is 2.6, 1.3 and 0.9 minutes for Case I, II and III, respectively. The maximum number of units in the queue is 9, 7 and 4.

This simulation was run for a time that is too short to give statistically reliable results. But the purpose was only to demonstrate the interrelation between time distribution and space requirements. The following conclusions can be drawn:

> As long as there is unlimited queue space, the production will be the same for all handling and transportation chains whose links have the same mean time per operation.
>
> When queue space is limited, it is important to reduce the variance of the time distribution.

There is nothing new in these conclusions. The only thing is that for this paper, they have been derived by simulation so as to gain confidence in the further study.

We are now prepared to go into more detail, but out of consideration for those who may find the discussions of programming features too intricate to follow through to the end, let us at least try to take the chapters in their order of importance and not in their natural sequence. Let us start with the output.

2. SIMULATION OUTPUT

An example of edited output which is printed after each day's simulation is contained in Appendix I. There are graphs of trucks' arrivals and departures per hour, and last departure time both for general cargo trucks and trucks with other types of cargo.

Further, the output has data from checks made each hour on how many trucks there are in the waiting line, how many drivers who are waiting to clear cargo documents and how much cargo is waiting at different states in the handling chain. These waiting line checks are supplemented by similar checks on the capacity utilization. For clerks, checkers, forklift drivers and helpers, printouts for each hour show how many of them have had something to do.

Productivity of receiving and storing is measured in terms of cost per 40 cubic ft. general cargo and/or 1 long ton of other cargo. Loading production is calculated in tons per gang hour. Separate figures for morning, afternoon, and overtime offer a possibility of seeing how the productivity varies with the cargo inflow.

The information on loading gang performance includes whether or not overtime is worked and how long it eventually lasts. Besides, there are figures on the utilization of forklifts bringing cargo to the ships side and on the utilization of the lifting gear. There is a separate record of how long different categories of trucks have to wait for checkers. The model is so designed that checkers are the first assistants asked for when preparing for inloading. It is therefore of importance to know which influence scarcity of checkers may have.

Unofficial breaks are simulated for all categories of personnel on the terminal. As the duration of simulated breaks is made dependent on the workload, the average length of the breaks and their distribution on different categories of personnel have been included in the output.

Finally, there is information in matrix form as to quantity of cargo received, on storage and loaded.

The output offers a basis for comparing utilization of different personnel and equipment categories. It is possible to delete bottlenecks in the simulated organization and to try out the effect of changes. A systematic simulation of different combinations of personnel and equipment will make it possible to find optimum solutions for different cargo inflow patterns and loading schedules. The model may be used to study existing as well as planned cargo handling facilities.

To make an example for this paper a cargo inflow corresponding to about 125 trucks per day and a manning of 10 document clearing clerks, 50 drivers and forklifts, 40 checkers and 20 helpers for manual cargo handling, has been assumed. A simple redefinition may, however, change these figures to suit other conditions. The same is true for the figures used for storing capacities and unloading ramps.

A so-called output editor is used in order to get the result of the simulation presented in an easily readable form. The output editor makes it possible to organize the printout after one's own wishes at cost of a modest increase of computer time. It is a typical feature of the simulation language.

3. THE SIMULATION LANGUAGE

The computer "language" is "General Purpose Simulation System/360" (GPSS/360) of IBM. The language is explained in reference 1 through 3. Most of the terms are, however, so self-explanatory that the following few comments should be sufficient to read and understand the principal features of the program.

Real life occurences are simulated by so-called transactions that move through a system of subprograms. The subprograms are called blocks. In most cases the name of a block explains what the block does. For example:

```
TEST G       V1, 5, JUMP
```

Means: Check that Variable 1 is greater than 5, if it is not, go back to the block named JUMP. Other blocks that are frequently used are:

ADVANCE = Spend time
GENERATE = Create transactions
LOGIC = Operate a switch
LOOP = Repeat a sequence
MSAVEVALUE = Save a number in a matrix entry
SAVEVALUE = Save a number
SPLIT = Split off a prescribed number of transactions
TERMINATE = Kill transactions
TRANSFER = Route transactions to a nonsequential block

The transactions will move through the blocks in the sequence they are listed unless they are detoured by a test, transfer, loop or similar block.

In a program a loop block may have the appearance:

LOOP 4, PPALL

This does not mean that four loops shall be made, but that the transaction shall loop back to the block named PPALL, reducing the value of parameter 4 by one before each loop, and stop looping when parameter 4 is equal to zero. Other uses of parameters are explained a few sections farther below.

Independent part programs may be designed by using a generate block to create transactions for a certain sequence. An important such part program is the timer sequence. A timer transaction is created to govern the length of the simulation run. Usually it also initializes some time dependent computations and checks that certain conditions are fulfilled before it ends the simulation run. For practical purposes the timer sequence is listed in the beginning of the program, although some of the timer operations are so closely related to the rest of the simulation that the discussion of the timer sequence must come in the end--after the other parts of the program have been explained.

Real life production and service facilities are simulated by so-called storages. The capacity of a storage is defined in the beginning of the program. When a capacity is fully utilized, the program will prevent transactions from entering the storage until the capacity utilization has been reduced. Transactions that are waiting to gain entrance to a storage, may join a queue. Contents of storages and queues are controlled by pair of blocks:

ENTER = Ask for service of a storage
LEAVE = Finish service by a storage
QUEUE = Join a queue
DEPART = Leave a queue

Storages and queues are referred to by numbers. So-called indirect addressing may be used to get the right number. Parameters are frequently used for this purpose. Parameters are transaction attributes, each transaction may have up to 100 parameters. The value of a parameter is specified by ASSIGN blocks. We may, for example, have:

```
ASSIGN    1, FN$PARA = Set parameter 1 = value of
                                   function  PARA
QUEUE     P1,        = Join the queue whose number is
                       given by parameter 1
```

Here a function has been used to get a value for parameter 1. Functions are specified at the beginning of the program. The function value is defined for different values of the free variable. As free variables may be used any so-called standard numerical attribute, which may be the relative time, C1, a random number, Rn, a parameter, Pn, the content of storage, Sj, and many others.

Functions may be used as probability distribution in calculations and as a linkage between different standard numerical attributes. The function PARA may be defined like:

```
PARA FUNCTION C1, D9
             8,1 / 9,2 / 10,3 / 11,4 / etc.
```

The first line says that the function PARA has C1, relative time, as its free variable, and that it is discrete, having 9 function values. The second line specifies function value 1 when $C1 \leqq 8$, function value 2 when, $8 < C1 \leqq 9$, and so on.

Going back to our ASSIGN-QUEUE sequence, we see that the indirect addressing via parameter 1 causes the transaction to join queue 1 if they arrive before 8, queue 2 between 8 and 9, queue 3 between 9 and 10 and so on. The function has been used to get a chronologic grouping of arrivals on queues. In most cases however, the functions are used either as probability distributions or to reflect precalculated arithmetic relations.

Calculations that have to be made during the simulation run are done by "Variables". Also the variables may use standard numerical attributes, like for example:

```
41 VARIABLE  XH21 * FN$INFLO
```

XH21 is the value of halfword savevalue 21, variable 41 multiplies this value by the value of function INFLO. The outcome of all arithmetic suboperations of an ordinary variable as well as its end result are truncated. Truncation of subcalculations may be prevented by specifying an F- or floating point variable.

A third type, Boolean variables, is used to calculate true/false relations. For example:

```
16 BVARIABLE   C1'GE'7200*C1'L'7800+C1'GE'10200*C1'L'10800
```

Bvariable 16 is true when either the relative time is greater than or equal to 7200 and at the same time less than 7800, or when the relative time is greater than or equal to 10200 and at the same time less than 10800. In Bvariable relations * means "and", + means "or". Bvariables are used to test conditions. In the model we are operating with a time unit of 1/10 of a minute. When C1, relative clock, is equal to 7200 the time is 12 noon, 7800 = 1 PM, 10200 = 5 PM and 10800 = 6 PM. Thus Bvariable 16 may be used to test whether the time is between 12 noon and 1 PM or between 5 and 6 PM. These time intervals correspond to the lunch and evening breaks. There are numerous examples in the program listing on how BV16 is used to check whether there is a break. At breaks the transactions are allowed to pass through advance blocks that delay them for 1 hour, i.e. for 600 tenths of a minute.

Intermediate results of the simulation may be stored in so-called savevalues. Fullword savevalues may store numbers up to $2^{31}-1$. Halfword savevalues are denoted by XHn, fullword by Xn. Matrix savevalues are specified by MHn(a,b) and MXn(a,b) respectively, a = row number, b = column number.

Functions, variables, savevalues and also pure numbers are used to govern the operation of the blocks. For example:

```
ADVANCE 20, FN$UNLOD
```

means that the time spent shall be equal to 20 time units times a value of the function UNLOD. The function has a random number as free variable, the function values vary linearly from 0.75 to 1.25 as the random number goes from 0 to 1, thus causing the advance time to vary randomly between 15 and 25.

There are many examples of how variables, functions and numbers are used in blocks, but it would lead too far to deal in more detail with the simulation language. References 1 and 3 are recommended for those who want a thorough knowledge of GPSS; reference 2 offers a shorter description.

The few remarks made above should, however, make it possible to learn the main strategy of the program by reading it and its comments as they are listed in Appendix II. Those who either find it unsatisfying to jump directly to Appendix II or who want to make the programming the subject of a closer study, may benefit from reading the following more detailed discussion of simulation and cargo handling details.

4. THE PROGRAM

The program is designed on the largest version - Size C - of GPSS/360, which requires a computer capacity of at least 256,000 words. Sections of the program may be run on smaller computers, but this will for many of the variables and save-values require a renumbering to stay within GPSS standard format. The rather liberal limitation of Size C has been utilized to give variables and save-values numbers in sequences that identify their uses.

Functions having random numbers as free variables have been designed in a special way to get a realistic simulation. This is best explained by the following example:

> For a special category of trucks we want the cargo weight to vary randomly between 16 and 24 tons with equal probability for each weight. We then define a continuous function whose function value is 16 when the random number is 0 and <u>25</u> when the random number is 1. A GPSS random number will never be equal to 1, so we never get a function value of 25. The function value will, however, with a few exceptions always be truncated. Any function value between 16 and 16.99 will come out as 16; any value between 17 and 17.99, as 17; and so on. The result will be outcomes from 16 to 24, each with equal probability.

The same principle has been used for all continuous functions whose value is truncated. Continuous functions are not truncated in a generate or advance block; in those cases they have been designed as they ordinarily will appear.

The program is designed to simulate any number of working days, each simulated day being separated by a reset card. The timer transaction sets matrices, savevalues and storage capacities back to their start-of-the-day values at the beginning of each simulated day.

Each loading gang has been simulated by an individual subprogram. This makes it easier to demonstrate how the programs are built up. It is, however, possible to simulate more than one gang by one and the same subprogram if one makes more use of linkage functions and parameters, like for example, in the "Personnel Breaks" subprogram. As the number of blocks in the present set approaches the limit of GPSS-C, this possibility should be utilized if one wants to simulate more than 5 gangs.

Functions, variables, and savevalues are in the beginning of the program listing. Short comments explain their uses. There are also comments at every block

The background of the model, the underlying assumptions related to receiving, storing, and loading of general cargo, are dealt with in the following text.

5. RECEIVING AND LOADING CARGO

5.1. Terminology

Every profession has its own standard expressions and wording --so it is also in the stevedoring industry. It will be tried to avoid the most specialized terms, but for the sake of good order, a few words whose use and application may seem strange will be defined.

Apron	The part of the quay where the cargo is landed or picked up by the ship's gear.
Checker	A man who checks that the cargo received on the terminal is consistent with the shipping documents.
Clerk	A man who clears shipping documents or one who assists in supervising on the pier.
Delivering	To deliver cargo to somebody who comes to the pier to pick it up.
Discharging	Take cargo out of a ship's compartments and put it ashore.
Draft	A heave. The made-up unit of cargo that is lifted as one piece by lifting gear or forklift.
Forklift	In the report used as a name of driver with forklift.
Heave	The same as draft.
Longshoreman	A man who works on board the ship or on the terminal in connection with loading and discharging.
Loading	To load cargo into a ship.
Open Air Storage	An outside storage area for cargo that does not need to be stored in a shed.
Pallet	A portable platform of wood, metal or other material designed for handling by crane and forklift, and used to handle cargo consisting of small packages and similar.
Pallet Load	A quantity of cargo consolidated to a unit on a pallet.

Pre-palletized	Pre-palletized cargo is a pallet load that has been secured to the pallet.
Receiving	To receive cargo at a pier for further transport by ship.
Sidedoor	An opening in the side shell of the ship large enough to give access to one or two 'tween decks for pallet loads handled by forklifts.
Sling	A rope laid around one or more pieces of cargo to form a draft. In some connections, it means the same as draft.
Stevedore	The company that runs the quay, its equipment and facilities, and which supervises the work.
Terminal	A complete facility consisting of quay, sheds, open air storage, offices, etc.
Unitize	Consolidate cargo to a through moving unit.
Unit load	A unit load is unitized.
Union purchase	To connect the lifting wires of two different derricks to the same hook.
Unloading	Taking cargo off trucks.

5.2. Cycles of Events

On its way through the terminal the cargo will by and large pass the following stages:

1. Trucks (railcars) and lighters are checked in at the terminal.
2. The vehicles may join a waiting line.

2a. Truck drivers go and clear shipping documents.

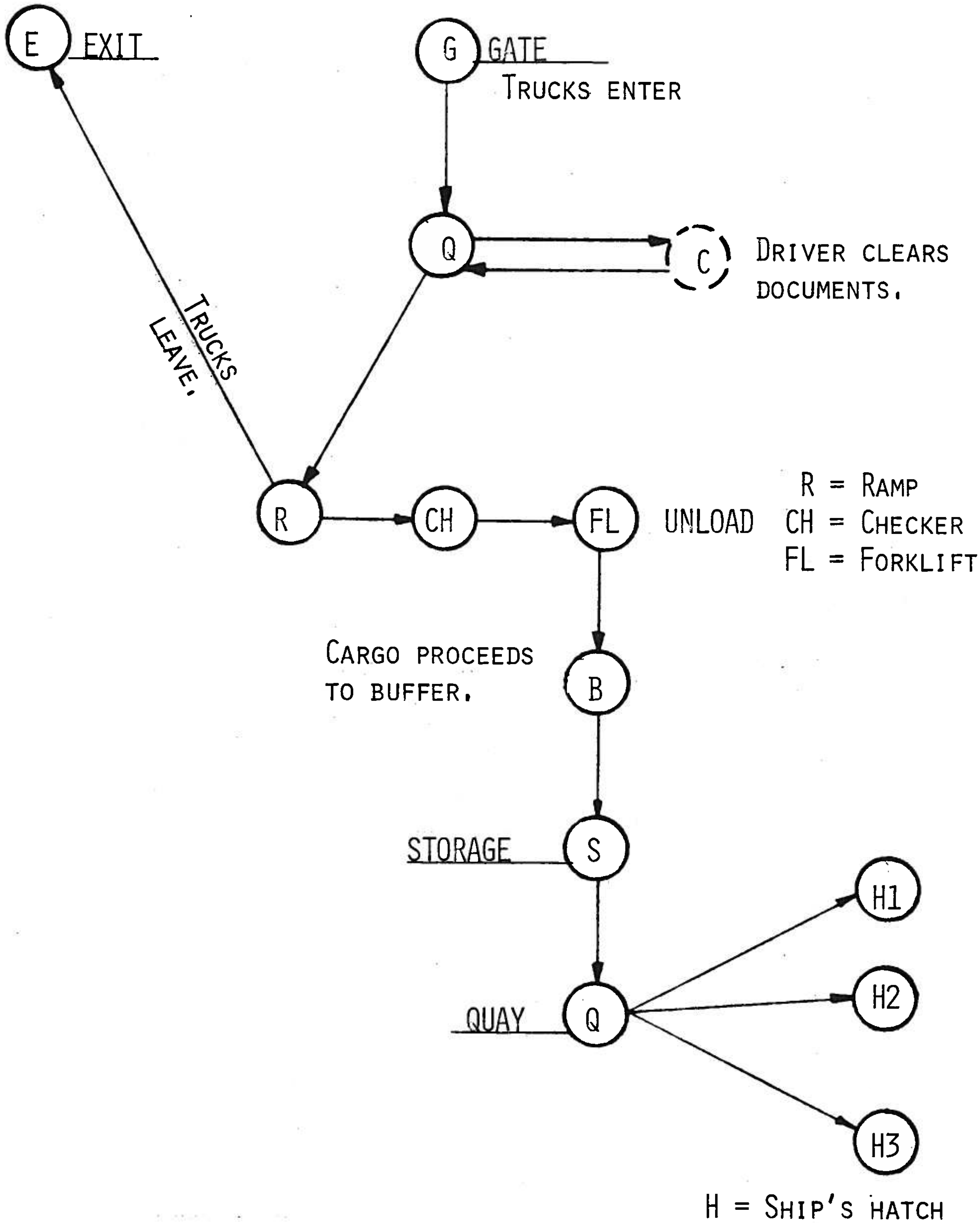
3. The vehicles are moved to an unloading place.
4. The vehicles are unloaded and the cargo is tallied and checked.
5. Loose cargo that is suitable for palletizing is put on pallets.

5a. If the shipping line's transport methods are based on through moving units, the cargo will be secured to the pallet.

6. The cargo may be brought to an intermediate storage place.
7. The cargo is placed (or stacked) at the storage.
8. The cargo is picked up from the storage place and brought to the apron or is taken directly from unloading vehicle to the apron.
9. Cargo is placed on the apron (if space is available)or may be placed directly on board the ship (if it has side-doors).
10. If the ship has no sidedoor, the cargo is taken onboard by lifting equipment.
11. The cargo is released from the hook (if it has been lifted) or taken from the sidedoor platform and stowed.
12. Empty slings, pallets, etc. are returned to the apron.

A flow chart appears in Fig.2.

In between some of these operations there is customs clearance, inspections and similar, but in most of the ports this will not interfere directly with the cargo handling and have therefore not been included in the simulation. Some cargo may be loaded directly from lighters and railcars, and thereby not pass through the terminal in the usual way, but also this will not be included in the study.



DELIVERY OF EXPORT CARGO
SIMPLIFIED FLOWCHART

FIG. 2

5.3. Underlying Assumptions

The following assumptions have been made for the case used as example:

a. The terminal has the shape as indicated by Fig.3, i.e., a finger pier with berths at both sides and a back up and open storage area at its root.

b. The effect of loading of heavy lifts and other types of special cargo is not included in the simulation.

c. Overtime may be worked from 6 PM onwards. The time from 5 to 6 PM being used for a break. The loading gangs will not continue after 8 PM unless it is sailing day and cargo remains to be loaded.

d. All of the cargo is delivered to the pier by truck.

e. All terminal personnel start work at 8 AM.

f. The loading gangs may start at 8 AM or 1 PM.

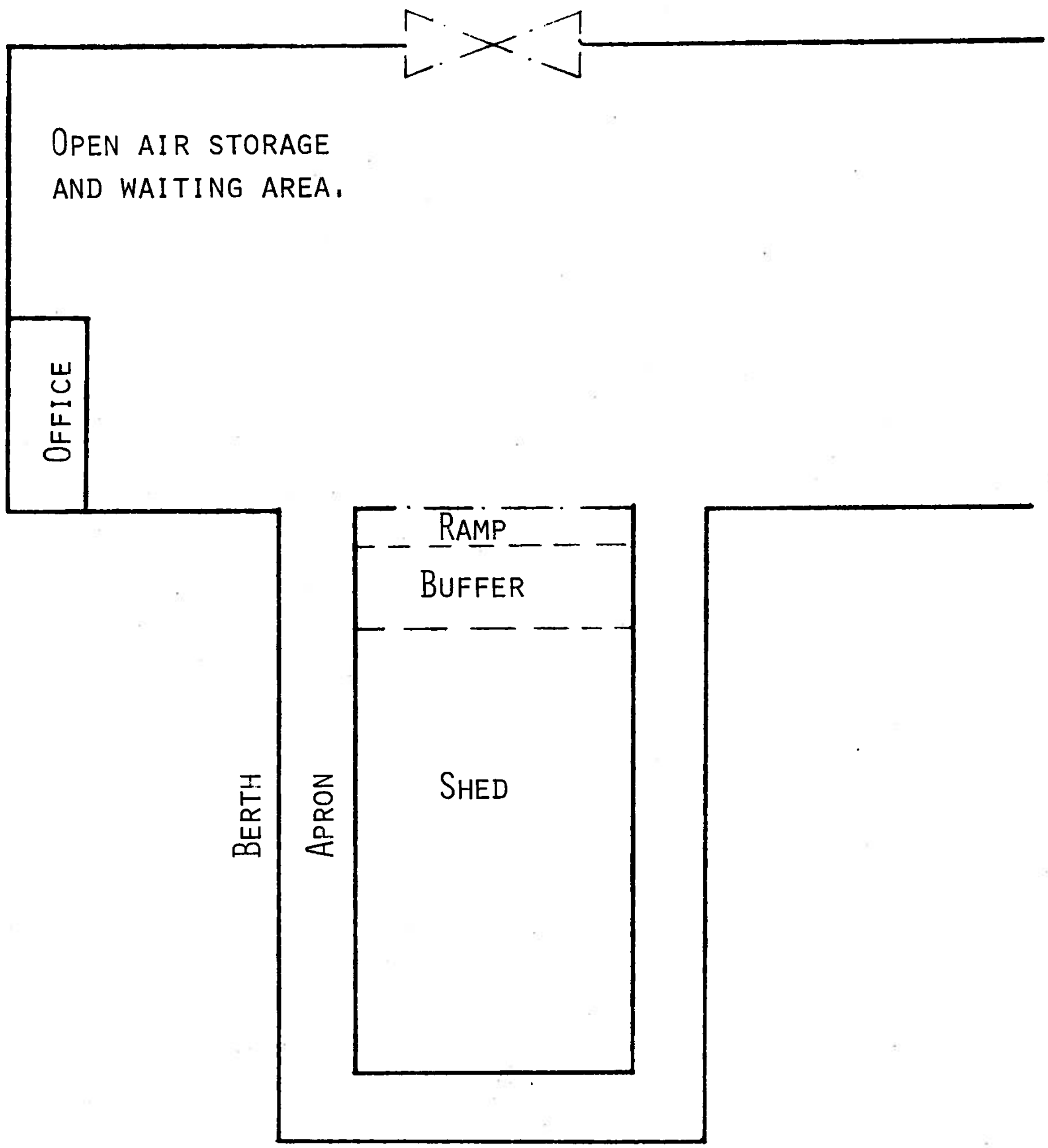
g. Ordinary forklifts have the same per hour cost as the gross pay per hour for longshoremen.

h. A checker's gross pay if 120% of a longshoreman's gross pay.

i. The cost of supervision is 15% of the labor cost.

j. Containers are not handled.

Other assumptions will be discussed when the different operations are dealt with.



OUTLINE OF TERMINAL

FIG. 3

6. DESCRIPTION OF SUB-ROUTINES AND HOW THEY ARE SIMULATED

With the outline of the flowchart and the underlying assumptions in mind, we can now turn to the individual operations and the conditions that govern them. The real life procedure and the way they have been simulated are in the following discussed under joint headings. It has been tried to follow the cargo from the time when the trucks enter the gate until it is finally stowed on board, although now and then it has been necessary to leave this natural sequence in order to deal with more general features and conditions. Let us, to begin with, discuss some basic questions, simulation of working time, trucks' arrivals and quantity of cargo per truck.

6.10. Daily Working Time

In real life, the following may take place:

The gate opens at 8 AM.
Closes at 12 noon and remains closed during the lunch-break. During this one hour period all work on the terminal rests.
At 1 PM, the gate re-opens and the work resumes.
At 5 PM, the gate closes again and work halts but the unloading of trucks that already have passed the gate will restart after a one hour break.

The opening and closing of the gate is simulated by a gate block that is set and reset by a timer transaction. The simulation of the breaks may be accomplished as explained below for the different operations.

6.101. Document Clearance

The first thing that takes place after a truck's arrival is the clearing of its cargo documents. Document clearance is simulated by the first sub-sequence after the GATE block. The gate is closed during breaks, and no new transaction will queue up for document clearance during this period. The simulated maximum time for document clearing is 30 minutes. This means that all simulated drivers that are in the document clearing process during a break will try to leave the process before the one hour break is over. The break may therefore be simulated by a sequence of blocks that checks the depart time of the drivers and delays them whenever they try to leave during a break.

There are two breaks during the day. We may as explained, check for both of them by Boolean variable 16. Simulated drivers who are leaving the document clearance when BV16 = 1 will be delayed for one hour. The details of this simulation appear under the heading, "Document Clearing Sequence", of the program listing.

6.102 Unloading Trucks

As explained later, the time needed for this operation may be considerably more than one hour. This means that trucks being in the unloading simulation during a break, in most cases will not come out of this simulation until the break is over. We can therefore not apply the same break simulation system as for the document clearing directly to the trucks. But, fortunately, at least for trucks bringing general cargo, the unloading operation is broken down to a sequence of sub-operations that is repeated several times during an hour.

As no simulated driver is released from the document clearance during a break, no simulated trucks will enter unloading simulations during this period. Again, it is sufficient to delay the sub-operations that normally would be simulated to end during the break.

For trucks bringing loose, general cargo, these sub-operations comprise rigging time of 15 minutes and a repeated cycle of 15 minutes for palletizing and unloading of the pallet load. Whenever any of these sub-operations are simulated to end during a break, they are delayed by one hour. The simulation is performed by the sequence under the heading, "Unloading Loose, General Cargo", in the program listing.

For the trucks with prepalletized cargo, the same procedure is followed. The details may be found under the heading, "Unload Prepalletized Cargo", in the listing.

The simulation becomes a little more complicated for trucks that unload in the open-air storage. Here there is no sub-sequence that lasts less than an hour. It becomes necessary not only to check the simulated leaving time of the trucks but also the simulated time for starting unloading. We may have five categories of trucks:

Finishing before noon.
Starting before and finishing after noon.
Starting before noon and finishing after 5 PM.
Starting after noon and finishing before 5 PM.
Starting after noon and finishing after 5 PM.

We have to keep track of some of the categories. In order to do this, the simulation marks the trucks according to their time of arrival in the unloading area. A join block operating on the function "GROUP" will put trucks that arrive before noon in Group 1, trucks arriving in the afternoon, in Group 11. Test blocks check the simulated departure time of the trucks, and examine blocks check their group number and thereby also their starting time. Trucks being ready to leave before noon are not delayed, trucks trying to leave in the afternoon are delayed for one hour if they started unloading before noon. Trucks trying to leave after 5 PM are delayed by two hours if they started unloading before noon, one hour if they started in the afternoon. These simulations are contained under the heading, "Unload in the Open-Air Storage", in the program listing.

6.103 Securing Cargo to Pallets and Bringing Cargo into the Shed

The case is in principle, the same as when unloading general cargo. Delays earlier in the model will prevent arrivals of additional cargo to be simulated during a break. The simulated maximum cycle times are so short that a check of departure time and a conditional delay of one hour will be sufficient. The sequences may be found in the program listing under the same headings as above.

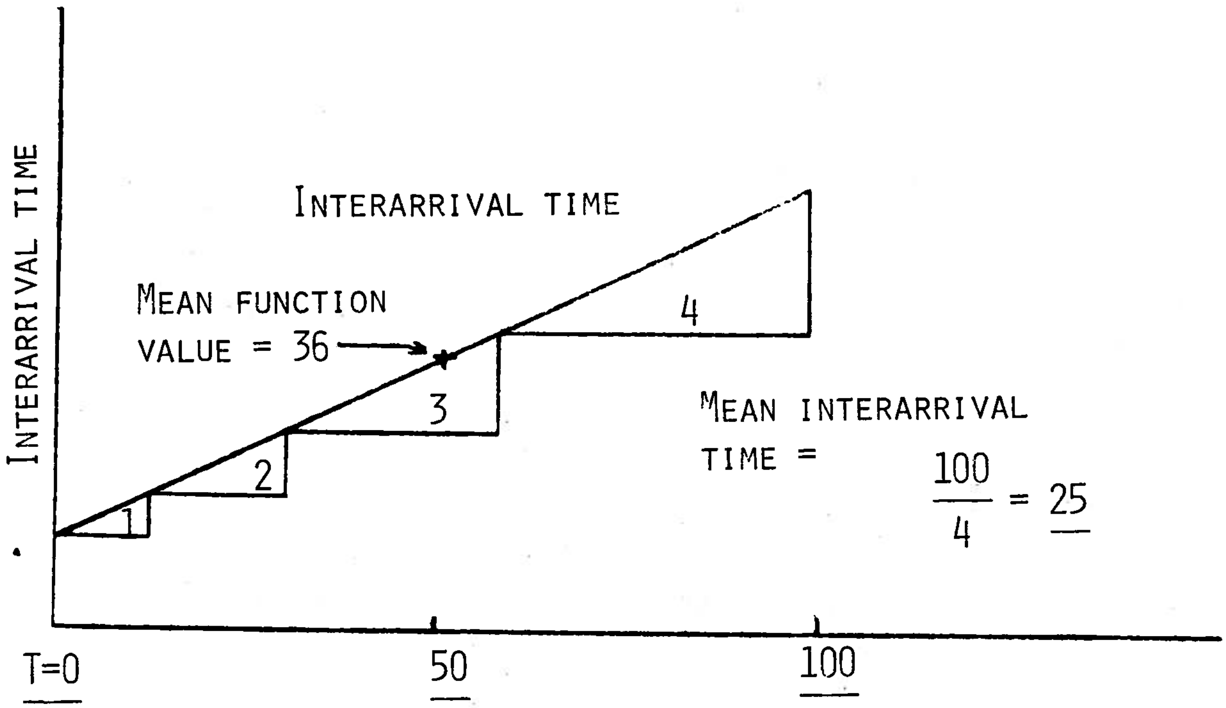
6.11 Truck's Arrival Rate - Functions as a Factor of the Inter-Arrival Time

Another more general problem is to simulate arrivals of trucks at specified time intervals. The arrival rate of trucks will usually vary with the time of the day. This means that the inter-arrival time most conveniently can be entered into the model via a time dependent function. In order to avoid abrupt changes in the inter-arrival time, the function should be continuous.

The difficulties caused by abrupt changes of the inter-arrival time come from the fact that a new transaction is not created by a generate block until the preceding one has left the block. If then the inter-arrival time changes abruptly from, say, 100 to 10 time units at, say, 9 AM, there may be cases where the creation of transaction at the shorter time interval does not start until almost 100 time units after 9, thus eliminating up to ten transactions that could have been generated between 9 AM to 9 AM + 100 time units. The problem could have been solved by starting the generation at the increased rate 100 time units earlier, but in our cases the interarrival time will vary not only with the time of the day but also with weekday number and besides it will be randomly modified by an exponential function. It becomes difficult to define exact limits for advanced starts of periods of different generating rates. With this in mind a continuous inter-arrival time function has been used.

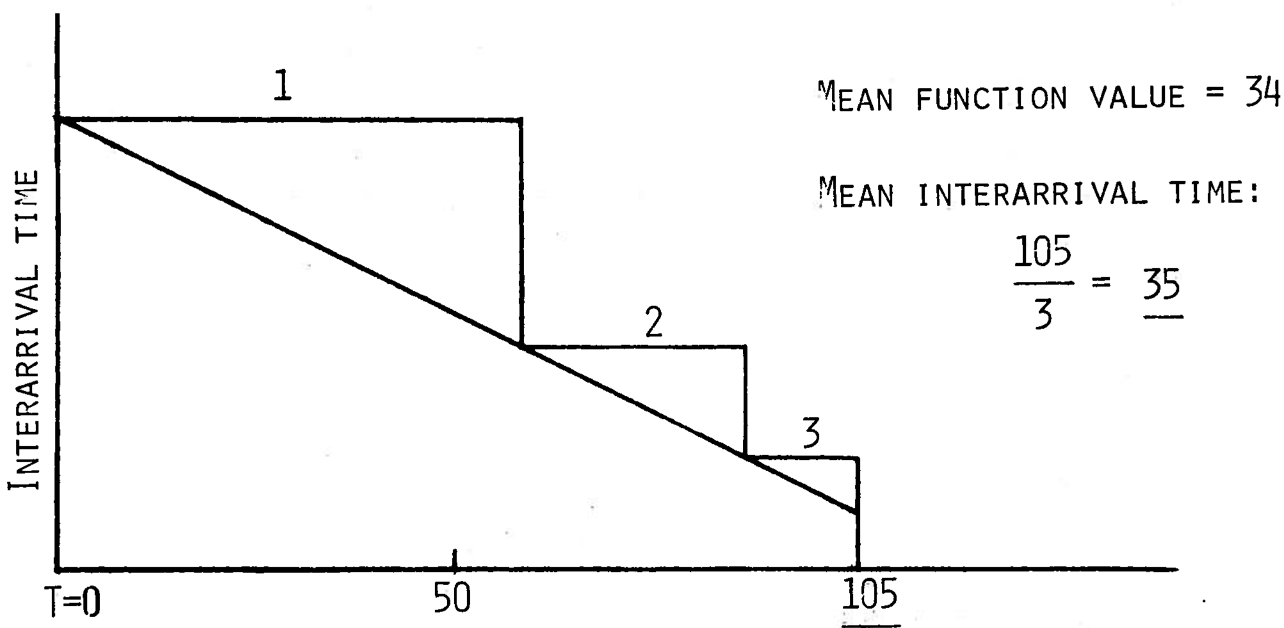
Care has been taken to define a gradual decrease of the inter-arrival time at the end of periods with low arrival rate. When going from a period of shorter to a period of longer inter-arrival times, there will not be the same overlap and the effect of the overlap will be small due to the larger inter-arrival time in the second period, although occasionally, exponentially and similarly distributed inter-arrival time modifiers may cause the first part of a period to be dominated by transactions from the preceding one.

The functions are straight lines between defined points. When creating transactions, the generator will read the mean inter-arrival time from its function. The next reading will be when the transaction leaves the generate block. Thus, the mean intercreation time for a period will not be the same as the corresponding mean value of the function. It will be less than the mean function value when the function is increasing, larger than the mean when it is decreasing. This may be seen from Figures 4 and 5.



RELATION BETWEEN FUNCTION VALUE AND REAL INTERARRIVAL TIME AT DECREASING RATE OF ARRIVALS.

FIG. 4



RELATION BETWEEN FUNCTION VALUE AND REAL INTERARRIVAL TIME AT INCREASING RATE OF ARRIVALS.

FIG. 5

If α is the inclination of the function and y_0 the value at the beginning of a linear interval, the first mean interarrival time will be: y_0;

$$\text{the next, } y_1 = y_0(1 + \alpha);$$

$$\text{the third, } y_2 = y_1(1 + \alpha) = y_0(1 + \alpha)^2.$$

$$\text{The } (n+1)\text{th interval} = y_0(1 + \alpha)^n.$$

The sum of all intervals,

$$S = y_0 + y_0(1 + \alpha) + \text{----} + y_0(1 + \alpha)^n = y_0 \frac{(1 + \alpha)^{n+1} - 1}{\alpha}.$$

The exponent $(n + 1)$ will give the number of arrivals during a period whose length is equal to S. Thus, we have a method of converting a specified number of arrivals during a certain period of time into a linear function. This method has been followed in designing a basic interarrival function, INTAR. The mean interarrival time has been used for the computations. The arrivals are assigned to occur randomly within the limitations set by the fluctuation of the mean interarrival time. We obtain this by multiplying the mean time by an inverse cumulative exponential distribution whose mean equals 1. The result will be a time dependent Poisson distribution of the arrivals.

The distribution of arrivals throughout the day is based on the assumptions that there will be a high peak at about 11 AM and a more moderate peak at about 2 PM, as it appears in the following tabulation.

TABULATION OF THE BASIC INTERARRIVAL TIME FUNCTION, INTAR

Length of period. 12 hr. clock and 24 hr. clock x 600.	Initial interarrival time in 1/10 min.	No.of arrivals in period.	Linear inclination of function, α
8 - 9 AM 4800 = 5400 Cl	100	7	- .05
9 - 10 AM 5400 - 6000	70	13	- .073
10 - 11:30 AM 6000 - 6900	26	40	- .008
11:30 - Noon 6900 - 7200	19	10	.10
Noon - 1 PM Lunchbreak. Gate closed. Abrupt changes in arrival rate permissible.	(49) 120	5	0
1 - 2 PM 7800 - 8400	120	8	- .14
2 - 5 PM 8400 - 10200	36	17	.122
5 PM 10200	255		
Total Arrivals		100	

The function is based on 100 arrivals per day. For any day the value given by INTAR may be modified to fit the actual number of simulated arrivals.

In addition to the daily variation of arrivals a weekly variation as per the following table, has been assumed:

Week day #:	1	2	3	4	5
% of Week's total:	10	15	25	30	20

Day number 1 is Monday, Friday, the fifth day, is assumed to be the sailing day. The table is stored by the function, VARWK. The function's free variable is VARIABLE 2, which computes the day number with the exception that the fifth day gets number zero.

The calculation of the mean interarrival time for any day at any time is performed by the variables 11 through 13 for palletized, loose and open-air cargo, respectively. As 100 trucks per day gives 500 trucks per week, the calculation will normally be as in the following example for palletized cargo:

FV11 = FN$INTAR * 500/XH11 * 20/FN$VARWK

Savevalue XH11 carries the total number of arrivals per week. FV11 is a floating point variable, but its end value will be truncated. The model will therefore not always produce exactly the number of arrivals that one wants to simulate. The simulated number of arrivals will, however, be given in the output, thus offering a basis for comparison.

At the beginning and end of day, INTAR may be replaced by other functions as explained in the following.

6.12 Quantity of Cargo Per Truck

At the end and beginning of each day there will usually be some interrelation between trucks' arrival time and their cargo. This interrelation will partly depend on the basic function for arrivals, INTAR, and the distribution of cargo per truck. Let us then next discuss the assignment of cargo to the trucks and to start with assume that the cargo distribution functions will be the same for the whole day.

A cargo liner carries an almost unlimited number of cargo types. As long as we are not simulating a specific line, it does not, however, seem reasonable to introduce a large variety of cargo groups. For the purpose of demonstrating our methods and principles of simulation, it is sufficient to work with three groups:

palletized general cargo
loose, general cargo
cargo that is stored in the open-air.

When we limit ourselves to these three groups, we may use one generate block to simulate truck arrivals for each group. Otherwise the same technique may be used as when creating transactions for the loading simulation.

In the generate block the simulated trucks are given a priority of 1, which means that they will have preference over ordinary terminal work. Parameter 1 is used to distinguish between the cargo groups:

P1 = 1 for palletized cargo
P1 = 2 for loose, general cargo
P1 = 3 for cargo in the open-air storage.

For these groups the following considerations have determined the distribution of cargo per truck. The assigned quantities will be stored in parameter 2.

6.121 Palletized and Loose, General Cargo

General cargo is a voluminous commodity, cubic capacity is usually the determining factor. It is very seldom that one truck has space for more than 1500 cu. ft. of cargo and it will practically never occur that a truck goes to a pier with less than 100. There will usually be a majority of larger truck-loads. Data on quantities of cargo per truck for any specific terminal will not be used.

On this background, it is assumed that under restricted conditions 50% of the general cargo trucks arrive with a load of 1500 cu. ft., the remaining 50% with a load that varies linearly between 100 and 1500 cu. ft. This is expressed by the function, GENQ, that has a random number as free variable.

6.122 Cargo for the Open Air-Storage

Cargo that may be stored in the open air will mainly be steel, drums, heavy boxes and other items, that are better characterized by their weight than by their cubic. This type of cargo is to a larger degree received in full truckloads. It is assumed that under unrestricted conditions the quantity per truck will be evenly distributed between 16 and 24 tons. The assignment of cargo per truck is done by referring to the function, AIRQ, that has a random number as a free variable.

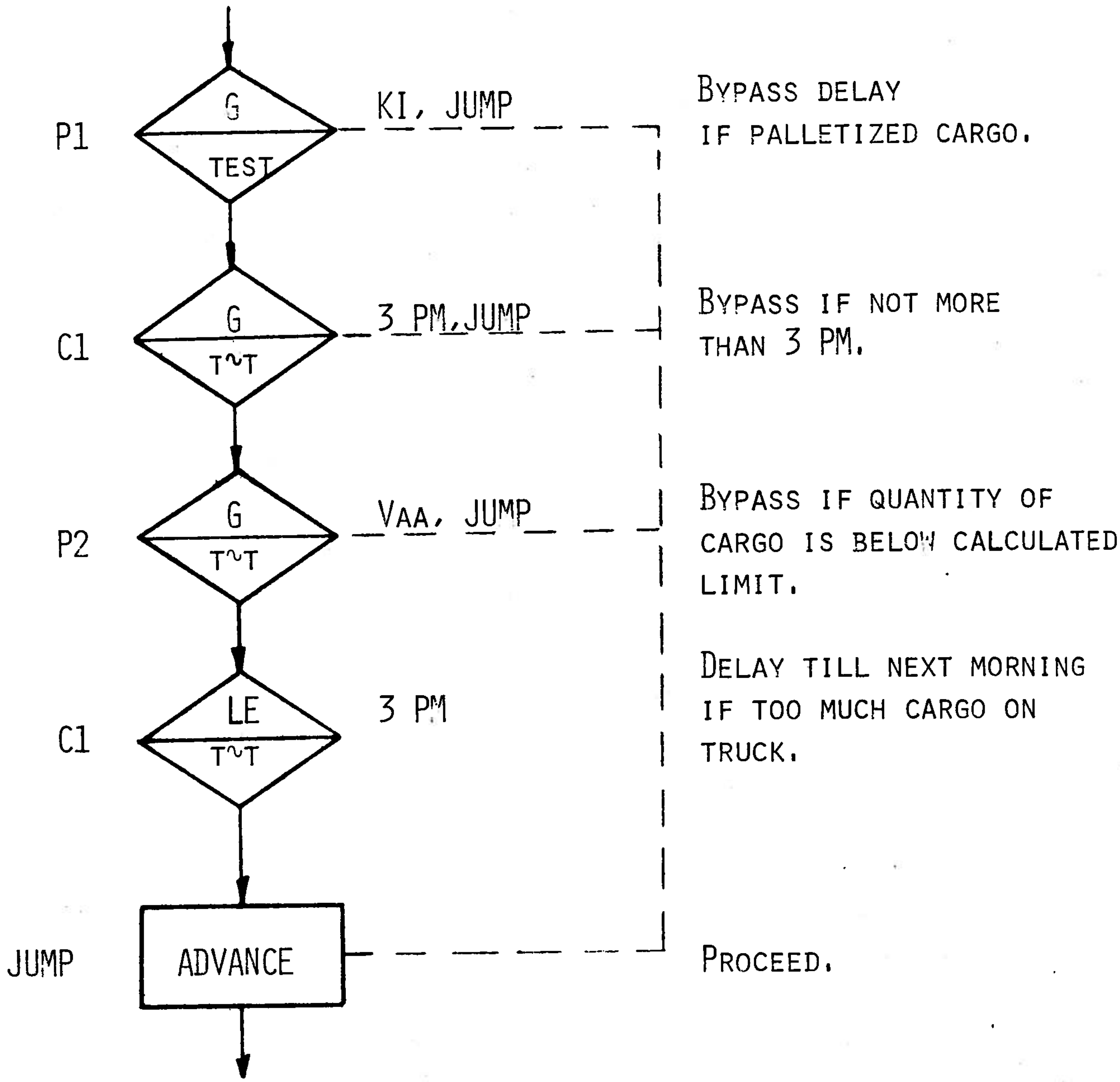
The cargo distributions derived in the foregoing are valid only if there are no quantity limitations for trucks delivering cargo. Such limitations may, however, be imposed in the afternoon. This will change both the interarrival times and the cargo distributions.

6.13 End of Day Arrivals

If a truck fully loaded with loose, general cargo arrives shortly before 5 PM, or is still in the waiting line at this time, it may not be completely unloaded until 10 - 11 o'clock in the evening. Most terminal operators will refuse to start on such a truck. Partly loaded trucks arriving late will, in most cases, be treated in accordance with the time which one needed to unload them. We will assume that any truck that does not require more than two hours overtime to be finished will be served; the rest will be sent home and served the next day. When checking or calculating the unloading time, not the mean working time per ton or cubic feet, but the maximum time will be used, in order to reduce the risk of having to work more than two hours overtime.

The maximum allowable cargo per truck depends on the remaining time until work should be finished. The actual quantity of each truck may be compared with the permissible maximum by a sequence mainly consisting of test blocks, as per figure 6. Trucks with too much cargo will thereby be delayed to the next morning, provided it is not a sailing day.

It is however, questionable whether it makes any sense to create transactions that will not be admitted to the simulation procedure until the next simulated day. Instead of this we adjust the interarrival and the cargo-per-truck functions so that there will be an increased percentage of fully loaded trucks during the first hour of the morning, and only trucks with acceptable small loads late in the afternoon. When reckoning half an hour for document clearing and 15 minutes for rigging, the calculations become as follows.



DELAYING TRUCKS WITH TOO MUCH
CARGO UNTIL FOLLOWING DAY
PRINCIPLE SKETCH
SEQUENCE NOT USED IN PROGRAM

FIG. 6

6.131 Palletized Cargo

Maximum number of pallet loads per truck:

$$\frac{(10200 + 1200 - 300 - 150 - Cl)}{37 \cdot 1.25} = \frac{10950 - Cl}{46}$$

where

10200 = simulated time at 5 PM

1200 = 2 hours available for overtime

300 = document clearing time

150 = rigging time

37·1.25 = unloading time per pallet load

At 5 PM, i.e. when Cl = 10200:

$$\frac{10950 - 10200}{46} = 16$$

This is above the global maximum of 1500 cu. ft. Accordingly, there will be no quantity limitations for trucks with palletized cargo, not even at time of closing the gate. For loose, general cargo, we get:

6.132 Loose, General Cargo

Maximum quantity of cargo per truck, cu. ft. $\left(\frac{(10950 - Cl)}{150.1.25}\right)$ truncated and multiplied by 100.

At 5 PM:

$$\frac{10950 - 10200}{188} = 4 \cdot 100 = 400$$

$$+ \text{ allowable fraction: } \underline{20}^{*}$$

$$420$$

* See section 6.17.

At 3 PM: $\frac{10950 - 9000}{188} = 10 \cdot 100 = 1000$

fraction:	20
Total	1020

It may seem justifiable to impose quantity limitations before 3 o'clock in the afternoon. It is, however, also necessary to take the relations to the customer into consideration. The earlier one starts to refuse entry to some trucks, the greater is the possibility that it may be accepted by a competing line. With this in mind, the following restriction will be simulated for trucks with loose, general cargo:

> Any quantity accepted up to 3 PM, not more than 820 cu. ft. between 3 and 4 PM and not more than 420 cu. ft. per truck after 4 PM.

Under our 100 trucks per day assumption, this restriction causes the following trucks to be "transferred" to the morning arrivals:

1500	cu.ft. per truck	4	trucks
821 - 1500	" " " "	1.92	"
421 - 820	" " " "	.43	"
	Total	6.35	trucks

If these trucks come back between 8 and 9 in the morning, the total number of arrivals during this period will be 13.35. The transferred trucks will probably try to come as early as possible giving arrivals closer to 8 than to 9 o'clock. It must be considered safe to assume that these arrivals will have no effect on the basic interarrival time function, INTAR, at 9 AM and later. This means that the interarrival time at the end of the period will be as per the table, Page 29, or 70 tenths of a minute. We have then two equations that may help us to determine the correct initial interarrival time, y_0, at the beginning, and the correct rate of change, α.

The length of the period from 8 to 9 is 600 tenths of a minute.

$$\frac{y_0 (1 + \alpha)^{\beta}}{\alpha} = 600$$

The mean interarrival time at end of period is 70.

$$y_0 + \alpha \cdot 600 = 70$$

The exponent, β, must be set so that an average of 13.35 arrivals will occur between 8 and 9. The mean time is as mentioned modified by an exponential distribution whose free variable is a random number. When the free variable is equal to 0.35, the function value is 0.432. This means that the 8 to 9 AM period must include 0.432 parts of its 14th interarrival time; $\beta = 13.432$. There will then be a probability of 0.35 to get the 14th arrival or a probability of one to get 13.35 arrivals. When $\beta = 13.432$, we get:

$$y_0 = 28.5$$
$$\alpha = .0692$$

When we treat the time from 3 to 5 PM as one period, a simular calculation gives mean interarrival time of 9500 tenths of a minute at 5 PM for the modified function. On the basis of the morning and afternoon adjustments, we design a new interarrival time function, LINTA, to be used for trucks with loose, general cargo.

The cargo distribution on trucks will follow the function,GENQ, during the "normal" period of the day, i.e. from 9 AM to 3 PM but we have to use other functions at the beginning and end. For the first hour in the morning the distribution is contained in the function, MORNL, between 3 and 5 in the afternoon the function, AFTNL, is applied. The discrete function, LOOSE, whose free variable is the time, C1, engage the different cargo distribution functions at appropriate times.

Then remain the modifications for trucks arriving with cargo for the open-air storage:

6.133 Cargo for Open-Air Storage

At 5 PM, the permissible maximum quantity will be:

$$\frac{11400 - (300 + 250 + 10200)\text{ tons}}{62.5} = \frac{10850 - 10200}{62.5} = \underline{10.4\text{ tons}}$$

where

300 = document clearing time

250 = rigging time

At 3 PM:

$$\frac{10850 - 9000}{62.5} = \underline{29.6\text{ tons}}$$

The global maximum load for trucks bringing in open-air cargo is 24 tons, the minimum 16 tons. This means that the quantity limitation does not need to be enforced until 3:35 PM and that all trucks arriving after 4:25 PM will have too much cargo. To avoid too short intervals, we set in accordance with this, a quantity limit of 20 tons at 3:30 and do not accept open-air cargo after 4 PM.

If we again assume that trucks which have too much cargo to be let in will come back next morning, revised interarrival and cargo distribution functions may be calculated in the same way as for trucks with loose, general cargo. The new interarrival time function has the name, AOINT; the new cargo distribution functions, MNOA and AFOA. The different cargo, distribution functions are engaged by the function DRUMS.

6.14 Clearing Cargo Documents and Waiting for Unloading

The first operation in the "natural sequence" is the clearing of cargo documents. In the simulation, the trucks, after they have passed the gate, simultaneously join Queue 1 and Queue 2. Queue 1 simulates the trucks' waiting line, Queue 2 is the drivers' queue for clearing documents. Document clearing is simulated by Storage 1 that has a capacity equal to ten clerks. It is assumed that the clearance will have a mean time of 20, evenly distributed between 10 and 30 minutes.

Queue 1 is needed to get statistics on the trucks waiting time; the Queue 2 statistics will tell us whether the document clearance is a bottleneck. The trucks' net waiting time for unloading facilities is equal to the difference between the waiting time in Queue 1 and Queue 2. How the transactions pass through the different blocks appears under the heading, "Document Clearing Sequence" in the listing.

6.15 Routing the Trucks

After the document clearance is finished, trucks bringing cargo for the open-air-storage follow a sequence that differs from the other ones. In the simulation a test block routes all trucks whose parameter 1 has value 3 to the open-air storage. This storage has been assigned a capacity of 75000 sq.ft.

The general cargo trucks continue to the unloading ramp in front of the storage shed, but before we simulate their unloading it is necessary to find out how many pallet loads their cargo will correspond to. This is done by the next sequence of blocks.

6.16 Determine Number of Pallet Loads Per Truck

To facilitate the cargo handling on a terminal, it is customary to place all general cargo on pallets as it is unloaded from trucks. If the cargo is intended to go as through-moving units in the ship, the cargo that has arrived loose are in addition secured to the pallets. But let us first discuss how we can calculate the number of pallet loads per truck.

Pallets that are used for the handling on the terminal only, usually measure almost 4 x 6 feet. The cargo is in the average stacked on them a little higher than four feet, making a mean of 100 cu.ft. of cargo per pallet.

Through-moving pallet loads are usually based on pallets measuring about 4 x 4-1/2 feet and as stacked to a gross height of about six feet. The net-cargo height will be about 5-1/2 feet, giving also these units a cargo cubic of 100 cu.ft.

The number of cargo units per general cargo truck will thus be about equal to the truckload in cubic feet divided by 100. In case the division comes out with a fraction, we assume that the fraction will increase the number of units by one provided it is larger than 20 cu.ft. A truckload of 630 cu.ft. would, for example, result in 7 cargo units, or in more general terms:

$$N = \frac{\text{Quantity per truck}}{100}$$

If Q - 100 * N > 20, then,

$$N = N + 1$$

where integer division has been used to simplify the calculation.

The calculation is performed by Variables 16, 17 and 18. A test block checks whether the fraction is larger or smaller than 20 cu.ft., and assigns the correct number of pallet loads to P4. The details appear under the same heading as above in the listing.

The number indicating the type of cargo is stored in parameter 1 and will be used to distinguish the 4 x 6 pallet from the 4 by 4-1/2 pallet when they enter the storage shed.

6.17 Unloading General Cargo

This unloading takes place at an unloading ramp at the root-end of the pier. It is assumed as explained later, that the ramp can take 28 trucks at a time. In general, the truck driver and his assistant will take part in the unloading work. If they deliver loose cargo, they will stack it on terminal pallets at the truck's tailgate. If they deliver palletized cargo, they will, as far as possible, assist the forklift driver when he drives into the truck to pick up the pallet loads. The terminal must supply a checker and a driver with a forklift per truck.

Trucks with pre-palletized and trucks with loose cargo will be unloaded in different ways due to the palletizing of the loose cargo, but they will have some things in common. They need both service of checkers and forklifts at the same time, and both have a rigging time before the real unloading work can start. The rigging corresponds to moving the truck to the ramp, opening up its tailgate, asking for assistance and similar.

In the simulation the rigging time is assumed to be 15 minutes per truck regardless of type and quantity of cargo.

Trucks are the only users of checkers. When the rigging time is over the first truck on turn will get the next available checker. The truck may keep the checker waiting until a fork-lift is secured. The sequence of blocks to simulate this will be:

ADVANCE	Rigging time
ENTER	Checker
ENTER	Forklift
(Do the unloading)	
LEAVE	Forklift, etc.

This is the general pattern in occupying storages as it also appears in the listing under the heading of "Unload Loose, General Cargo". With the exception of the rigging time, all mean cycle times are modified by the function UNLD, causing the mean time to vary evenly within ± 25%.

6.171 Loose Cargo

When unloading loose cargo, a forklift is required only each time cargo has been stacked to a full pallet load, or in average every 13 minutes. In the simulation the "truck-transaction" advances 13 minutes times FNØUNLOD, demands a forklift and splits off a pallet load to the buffer area. This sequence is repeated until P4 = 0 i.e. until there is no more cargo on the truck. The program appears in the loop starting at the block "PALL" in the listing.

When unloading we want to prevent truckmen and checker from waiting for forklifts longer than absolutely necessary. To simulate this the pallet loads are getting priority 4 before they leave the truck so that they will get a forklift before other users. The forklift picks up the pallet load at the truck's tailgate and brings it to the buffer area. It will have a mean travelling distance of 20 feet. There will be no high-stacking. According to Figure 7, the cycle will take about 1.5 minutes under average difficult conditions. In addition, comes 0.5 minute for picking up an empty pallet and bringing it to the truck.

6.172 Palletized Cargo

The simulation of unloading pre-palletized cargo follow the same pattern as for loose. But the forklift is occupied as long as the unloading operation continues. The pallet loads are brought out of the truck at an average loop time of 3.7 minutes per pallet. This time the split off transactions are transferred to the block "BZONE", thus omitting the securing sequence. Compared with a forklift time of two minutes per pallet load for loads that are made up at the truck's tailgate, the 3.7 minutes mean time for pre-palletized cargo may seem high. The difference is meant to reflect the more difficult working conditions when the forklift has to go into the truck to pick up the cargo. The simulation of unloading pallet loads starts with the block, "UNITS" under the heading "Unload Prepalletized Cargo" in the listing.

6.18 Securing Loose Cargo to Pallets

In case the loose cargo is intended to remain on pallets throughout the sea voyage, the built up units will as mentioned have to go through a securing process. The work is done by helpers and requires two men in ten minutes for each unit. The securing simulation starts with the block named "BUFF" under the heading "Secure Loose Cargo". The second block in the sequence is a test block that prevents securing from being simulated in odd numbered weeks. In that case, the cargo will be transferred directly to the buffer and thereafter to storage in the shed. The value of Pl is changed from 2 to 1 after securing. Pl = 1 indicates palletized cargo. The omittance of securing simulation in odd numbered weeks has been included to demonstrate the possibility of choosing between alternatives.

6.19 Bringing General Cargo to Storage

When the general cargo has been unloaded from the trucks and eventually secured to the pallets, only the storing operation remains to make the receiving procedure complete. Forklifts are used to bring the cargo from the buffer area to the storage area in the shed. The forklifts also do the high-stacking. We need to determine how much time is needed for this operation, but the time distribution depends on our assumptions regarding the size of the shed and the outlay of the storage area.

6.191 Shed Dimensions

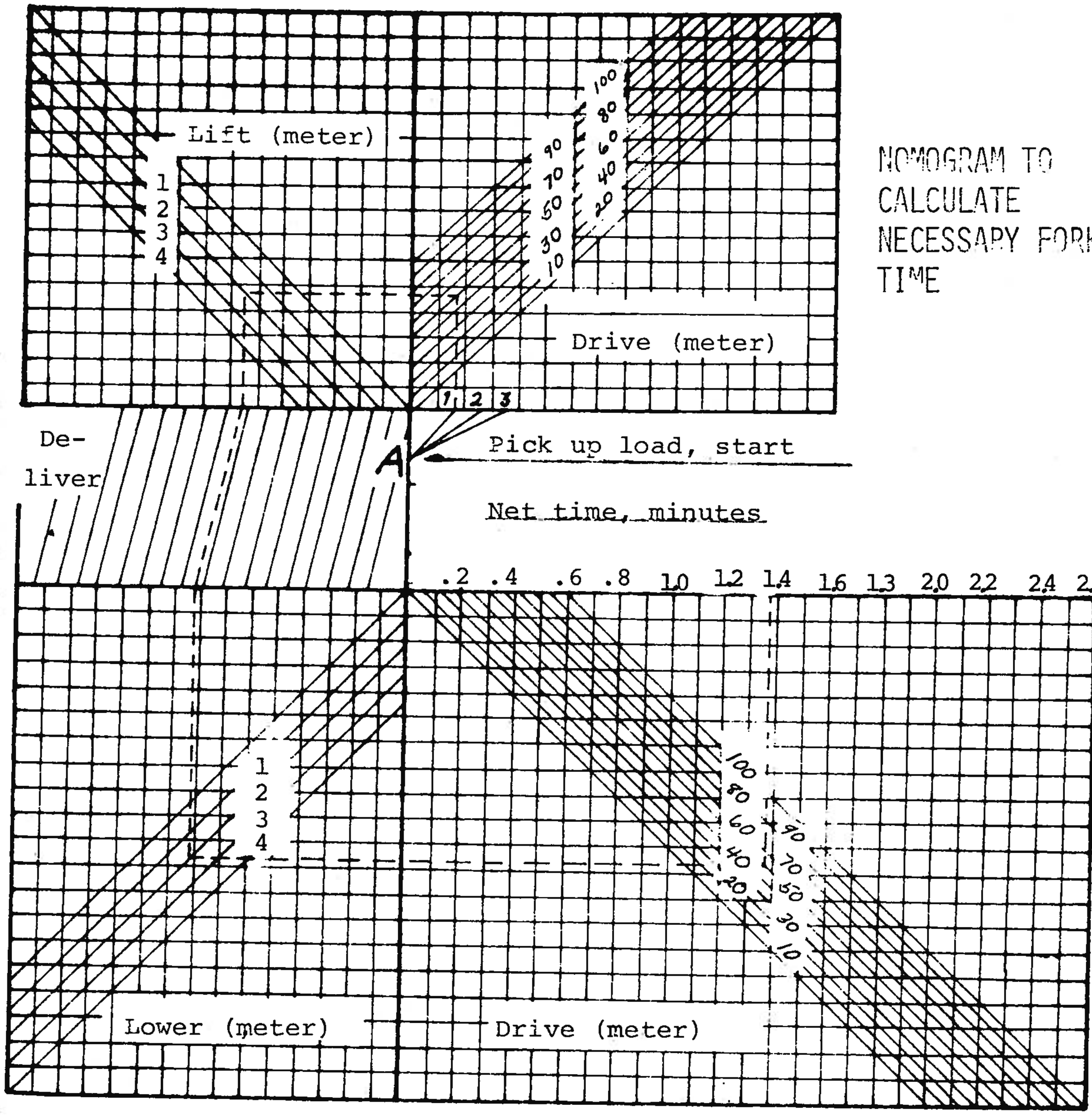
Let us base ourselves on a common finger pier as it appears in Figure 3. Say the shed measures 710 by 280 feet, offering space for 28 trucks at a time at the unloading ramp on the short side and with a buffer area between unloading ramp and storage area that extends 40 feet inwards, the center of gravity of the buffer area being 25 feet from the front of the ramp.

The distance from the center of gravity of the buffer area to the center of gravity of the remaining shed will then be:

$$\frac{710 - 40}{2} + 15 = 340 \text{ feet.}$$

When the cargo is brought into the shed, the forklifts will travel both in the longitudinal and crosswise direction. The average cross distance will be a little less than 50% of the width of the shed, say about 130 feet, whereas the average longitudinal distance will be 340 feet, making the total average travel distance 470 feet.

The shortest possible travel distance is zero, the longest possible distance will be a little less than the sum of the width and length of the storage area in the shed, say (280 + 670) - 10 = 940 feet.



NOMOGRAM TO CALCULATE NECESSARY FORKLIFT TIME

Start at point A (pick up load), follow the line A-1, A-2 or A-3, depending on the degree of difficulty when picking up the load.

The example shows how to calculate the necessary time for an average driving distance of 50 meter and a lifting height of 2 meter. It is assumed that there is no special difficulty in picking up the cargo, allowing a start along the line A-1.

By following the dashed line, a certain net time may be read off the time scale. Under difficult driving conditions it may be justified to increase the net time by 25% to 75%.
In addition to this comes ordinary time additions for the driver.

The nomogram has been designed by AB Transportkonsult, Stockholm, and is published with their kind permission.

FIG. 7

In addition to the driving time, the forklift needs time to pick up and stack the cargo. The average storing height in a shed like this will usually be three pallet loads on the top of each other; a pallet load will average about five feet high. Correspondingly, the forklift will have to lift the cargo units to a height of about 0, 5.5 or 11 feet when stacking them in the shed.

6.192 Cycle Time for Forklifts

How the time varies with the different forklift operations may be calculated by the help of Figure 7, which has been prepared by AB Transportkonsult, Stockholm, and which has been included by their kind permission.For different driving distances and lifting heights, the time per cycle will be as per the following table:

TABLE I

FORKLIFTS WORKING IN THE SHED

Variation of Cycle Time in Minutes

Distance travelled one-way (feet)	*Stacking Height (feet)								
	0			5.5			11		
	Deg.of Diff.			Deg.of Diff.			Deg.of Diff.		
	1	2	3	1	2	3	1	2	3
0	0.43	0.50	0.59	0.96	1.14	1.34	1.31	1.55	1.82
470	2.56	3.08	3.59	3.02	3.72	4.34	3.45	4.13	4.82
940	4.70	5.65	6.60	5.26	6.29	7.34	5.61	6.70	7.82

*The cargo is picked up from zero height and stacked at heights, as indicated.

The table contains figures for three different stacking heights and three different degrees of difficulty, corresponding to different working conditions. The working conditions in the shed will vary with the amount of cargo that is stored there and with the total number of forklifts that are working there at the same time. But let us first discuss how the mean and the variation of the cycle time should be varied and find a way to adjust for working conditions afterwards.

There may be two different layouts of cargo in the shed:

1. All cargo for a port is placed at one or a limited number of locations in the shed, but no location is permanently reserved for a specific port.

2. Each port has its specially designated area in the shed.

One truck may deliver cargo for several different ports. If we limit ourselves to the first case, it would seem natural to assume a mean cycle time corresponding to the average distance between buffer zone and storage area and corresponding to the average stacking height. This will give a mean travel time of 2.14 minutes and mean pickup and stacking time of 0.88 minutes, making a total mean of 3.02 minutes per cycle for first degree of difficulty. The lower limit of the cycle time for the same degree of difficulty would be for zero travel distance and zero stacking height. This would in practice correspond to a very short shifting of cargo out of the buffer zone. The time consumption is 0.43 minutes. The other extreme would be 5.61 minutes.

As concluded in the Introduction, the distribution of a cycle time does not influence the total throughput as long as there is ample buffer or queue space. This will be the case here. Without introducing errors, we may therefore assume that the cycle time for bringing cargo to storage will be evenly distributed between the extremes, i.e. with ± 86% around a mean time of 3.02 minutes for difficulty degree 1, corresponding to 2,4 minutes for degree zero.

When the cargo is stored in separate sections for each port of destination, the cycle time may be found by the same reasoning as above, but adjustments will have to be made to account for the location of sections and their limited area compared with the whole shed.

6.193 Working Conditions

At least 30% of the floor space must be reserved for driving alleys. Driving will be difficult before this limit is reached.

We have, however, no exact information on how the degree of congestion influences the cycle time. The matter is further complicated by the influence of the total traffic in the shed. If a forklift driver knows he is all alone, he may drive rather fast, even when the alleyways are narrow and the cargo stacked high. But when many forklifts are going around at the same time, the speed will have to be slowed down.

When the shed is full, it may also be difficult to find suitable space for the cargo, thus both the driving time and the handling time may be influenced by shed congestion.

Our aim must be to construct a function or variable that adjusts the degree of difficulty to -

1. The total quantity of cargo in the shed.
2. The total number of forklifts working in the shed.

To get a work basis let us assume that the interrelation between degree of difficulty, shed congestion, and mean cycle time is as per the table below:

TABLE II

Mean cycle time adjuster for forklifts storing cargo in shed.

Number of Forklifts Working in Shed	Percent Occupied Net Floor Space			
	$P < 25$	$25 \leqq P < 48$	$48 \leqq P < 67$	$67 \leqq P$
1 to 5	1.25	1.25	1.25	2.5
6 to 10	1.25	1.25	1.5	2.5
11 to 15	1.25	1.5	1.75	2.5
16 to 20	1.25	1.5	1.75	2.5
21 and above	1.25	1.75	2.50	2.5

The values of the table may be retrieved and applied in the simulation by the following method:

Define the shed as a storage of certain capacity.

Define a discrete function haveing shed utilization as free variable and four continuous functions as dependent variable.

Define each of these four functions to represent each one of the columns of the table above.

By this procedure we can apply continuous functions instead of the stepwise increase of working difficulty of the table columns. The function that has shed utilization as an independent variable, and four other functions as function variables, has the name, SHED . The four other functions are called, VELO , MELO , MEHI and VEHI .

assume that there are seven different ports of destination where the percent-wise distribution of cargo is as per the following table:

Odd week numbers:

Port #	1	2	3	4	5	6	7
Cargo %	12	15	8	20	20	8	17

Even week numbers:

Port #	1	2	3	4	5	6	7
Cargo %	16	10	11	15	15	13	20

These tables are stored by the discrete functions, PTS1 and PTS2, respectively. The free variable of the functions is a random number. Different inflow pattern for even and odd weeks have been chosen in order to illustrate the possibility to adapt the simulation to varying conditions.

The port number is assigned to parameter 3. For general cargo this is simulated as the pallet loads pass through the buffer area between the unloading ramp and the shed. Each pallet load gets its individual port number, thereby indicating that one truck may bring cargo for several different ports. In contrast to this, it is found correct to assume that each truckload for the open-air storage is for a separate port.

Figure 8 shows the sequence of text and assign blocks that apply the appropriate port numbers to the cargo, depending on whether the week number is odd or even. Variable 1 distinguishes between weeks.

When cargo is stacked 3 tiers high:

	393900 sq.ft.
10% stowage loss	39390 " "
Net Storage Area:	354510 sq.ft.

We define the storage with 354500 sq.ft. capacity.

6.195 Storage Area Per Cargo Unit

The terminal pallet has, as mentioned, a square area of 4 x 6 = 24 sq.ft., a through moving pallet load 4 x 4-1/2 = 18 sq.ft.

This must be taken into account when the cargo is entered into the storage area. One way of doing it is to define a discrete function whose free variable is parameter 1, like this:

```
TYPE,FUNCTION P1,D2: 1,18/2,24/3,30
```

Where open-air cargo has been included with a space demand of 30 sq.ft. floor space per ton. When the transactions enter the shed, they demand capacity as per function, "TYPE". But when they leave, their capacity attribute is equal to zero. By this, we steadily increase the utilization of the shed until loading of a ship starts.

Similarly, if we assume that a truck entering the open-air storage will need about 1000 sq.ft. of space for itself in addition to the space for its cargo, we simulate the truck to enter the storage area with a capacity demand equal to 1000 sq.ft. plus 30 sq.ft. per ton cargo, and to leave it with only 1000 sq.ft. The capacity demand when entering is calculated by:

```
V49 = 1000 + P2 * K30
```

This has brought the trucks with cargo for the open-air storage back into the discussion. All special features of the general cargo has now been dealt with and we can turn to the cargo for the open-air storage.

6.20 Unloading Cargo in the Open-Air Storage

Whereas the driver and his assistant may very well unload loose, general cargo, this task may be difficult when it comes to heavy pieces that frequently are stored in the open air. It is therefore assumed that every truck being unloaded in the open air needs two helpers from the terminal in addition to a forklift and a checker.

The unloading time is calculated by the floating point variable V3, indirectly addressed via parameter 1. The indirect addressing opens the possibility to adjust the unloading time to any particular type of cargo by defining additional variables. Unloading time for open-air cargo may vary considerably from one type of cargo to another.

In our case, we have used 12 tons per hour which is a good average for the type of unloading gang described above. In addition, there is a rigging time of 20 minutes. The rigging time has been included in the variable and is modified by the function UNLD together with the rest of the unloading time.

For the open-air unloading, the rigging time has been imposed also on the people from the terminal. This has been done because the open-air storage will not be located so close to the quarters of the checkers and forklift drivers as the unloading ramp. It will take more time to gather the whole gang at a more or less arbitrary place in the open-air storage than it will take to get started at the ramp. Besides, rigging work in the open-air storage may require a full unloading gang.

Based on the same reasoning as for the unloading of general cargo, the truck starts by asking for a checker. If a checker is available, a forklift will be the next requirement and when both a checker and a forklift have been secured, helpers are demanded. In their demand for checker and fork-lifts, the open-air trucks compete with the trucks at the ramp. There is no reason to give the open-air trucks any priority in this respect. But when it comes to helpers, their other job is to secure cargo to pallets. It is obvious that a truck with driver, checker and forklift is more important than a pallet load. Accordingly, when demanding helpers, the truck in the open air is given priority. The unloading simulation starts with the block named, "AIR", under the heading, "Unload Cargo in the Open-Air Storage" in the listing.

6.21 Trucks Leaving

After the unloading is finished, both general cargo trucks and trucks from the open-air storage are simulated to leave via the block, "EXIT". In GPSS there is an automatic record on how many transactions that pass through each block. We have previously routed all incoming trucks via the block "GOIN". By comparing the number of trucks that have passed through "GOIN" with the number that has terminated via "EXIT" it is possible to check how many that are on the terminal. This is done by the timer transaction which keeps the simulation going until all trucks have left.

6.22 Assign Port of Destination

The assumption we made on cargo layout in the shed made it possible to postpone any decision on how to assign ports of destination. The loading simulation which we will have to deal with after a few more sections, will, however, require that each cargo unit is destined for a certain port. Let us then assume that there are seven different ports of destination where the percent-wise distribution of cargo is as per the following table:

Odd week numbers:

Port #	1	2	3	4	5	6	7
Cargo %	12	15	8	20	20	8	17

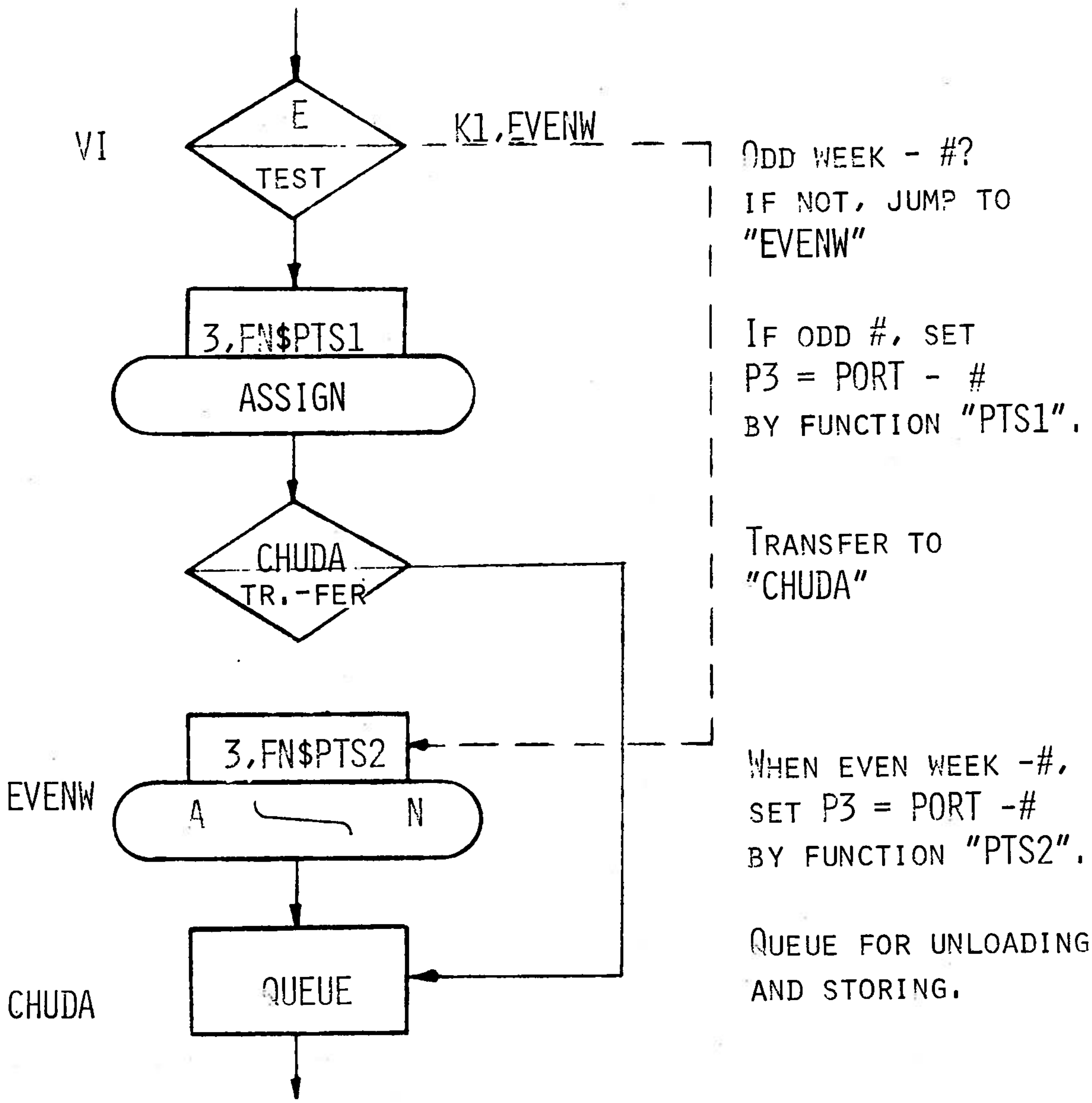
Even week numbers:

Port #	1	2	3	4	5	6	7
Cargo %	16	10	11	15	15	13	20

These tables are stored by the discrete functions, PTS1 and PTS2, respectively. The free variable of the functions is a random number. Different inflow pattern for even and odd weeks have been chosen in order to illustrate the possibility to adapt the simulation to varying conditions.

The port number is assigned to parameter 3. For general cargo this is simulated as the pallet loads pass through the buffer area between the unloading ramp and the shed. Each pallet load gets its individual port number, thereby indicating that one truck may bring cargo for several different ports. In contrast to this, it is found correct to assume that each truckload for the open-air storage is for a separate port.

Figure 8 shows the sequence of text and assign blocks that apply the appropriate port numbers to the cargo, depending on whether the week number is odd or even. Variable 1 distinguishes between weeks.



ASSIGNING PORT NUMBER

BLOCK DIAGRAM

FIG. 8

6.23 Storage Records

The introduction of port of destination numbers makes it possible to maintain diversified bookkeeping of simulated cargo on storage. This is done by matrix 11 which keeps record of cargo delivered per day, and matrix 12 which records total quantities on storage. The first seven rows of these matrices have numbers corresponding to the port of destination number, their column numbers correspond to the cargo type number. The eighth row of the matrices has the total quantity of cargo for the respective cargo type numbers.

6.24 Cost of Receiving and Handling

In addition to the storage records we need a cost figure to measure the efficiency of the terminal. The example which has served as basis for the edited output uses the following personnel and cost figures, the loading gangs not being included:

TERMINAL PERSONNEL & EQUIPMENT

Item	Number	Cost Factor	Cost Load
Clerks	10	1.2	12
Checkers	40	1.2	48
Forklifts & drivers	50	2	100
Helpers	20	1	20
Total labor and forklifts			180
Supervision 0.15 (180 - 50)			19.5
Total labor, forklifts and supervision. . . .			199.5

The real cost depends on the employer's cost per basic man hour. If we assume this to be six dollars, and the overtime differential to be 50% we get:

COST OF RECEIVING AND HANDLING

Ordinary work time:

Cost per hour: 199.5 · 6 = $1197

For a 4-hour period: = $4788

Overtime, full staff:

There will be a 50% increase in all costs except for the 50 forklifts -

Cost per hour: [(199.5 - 50) 1.5 + 50] · 6 = $1644 per hour

Overtime, reduced staff:

Cost per hour inclusive supervision

Document clerks and checkers:

6 · 1.2 · 1.5 · 1.15 =	$ 12.42

Drivers with forklifts:

6 + 6 · 1.5 · 1.15 =	16.35

Helpers:

6 · 1.5 · 1.15 =	10.35

Cost per weight and/or measurement ton is calculated by variable 50 for ordinary time by variable 51 for overtime 6 to 8 PM and by variable 55 after 8 PM. Separate calculations are made for the two four-hour periods forenoon and afternoon and for each one hour period after 5 PM. It is assumed that there are 2.5 measurement tons of 40 cu.ft. on each pallet. As not all general cargo trucks will have loads that comprise a whole number of 100 cu.ft. pallet loads, an error is created by this assumption. For comparison the real number of cu.ft. per pallet load is included in the edited output.

Variable 54 calculates the hourly overtime cost after the staff has been reduced. Its general term is

$$C \cdot (k - XH31a)$$

where

C = hourly overtime cost per man with equipment, as calculated above

k = Number of men of the category in question, at full staff

XH31a = Number of men simulated to have gone home = reduction performed on storage a.

In our example the terminal staff which is not engaged in loading the ship, is reduced at 8 PM provided the work has not come to an end before that time. How this is simulated is discussed in the next section.

6.25 Reduced Receiving Staff on Overtime

It is assumed that the full personnel as specified in the previous section is payed until 8 PM when all trucks have not left before. A mealbreak is, as mentioned, simulated between 5 and 6 PM. Thus, there will be two working hours on overtime at full staff. Different conditions may be simulated by altering the timings used below.

If at 8 PM there still are trucks on the terminal, the work force is reduced to the number of men actually employed with receiving and storing cargo. A similar capacity reduction is performed at 9 PM and every full hour later. The capacity reduction is simulated by entering the storages with a number of units equal to the wanted reduction of capacity.

For all categories except drivers with forklifts, the reduction has been made equal to the number of men not engaged, i.e. equal to the free capacity of the simulating storage. For the forklifts there is, however, a very intermittent use, especially at the end of the day when the main part of the remaining trucks will be such ones that have brought in loose, general cargo. The forklift will, therefore, be reduced with a quantity that is equal to:

Number of unemployed forklifts
- 1/3 of Number of trucks at ramp.
- Number of trucks at ramp divided a module by 3.

The last term is necessary to prevent the forklift park from being reduced to zero if less than three trucks are left at ramp. Variable 59 computes the reduction:

V59 = R5 - S2/3 - S2 @ 3

Because the work force for a period of an hour is determined on the basis of the demand at the beginning of that hour, the <u>total</u> cost has to be calculated at that time; the <u>specific</u> cost, however, can only be found at the end of the hour, after the quantity of cargo received has been computed. Simulation of cost calculations and work force reductions is performed by the part program under the heading "Cost Calculator" in the listing.

Workforce that has been reduced in the end of the day will be brought back to full capacity by the timer transaction the following simulated morning. This is done by leaving the corresponding storages by a number corresponding to their entries.

When reducing the simulated staff, the part of the personnel that is off on unofficial breaks has not been simulated to go home. Unofficial breaks have been considered a necessary part of the system, as may appear below.

6.26 Unofficial Breaks, Receiving and Handling

Any man will, during an eight-hour working day, need short rest and recreation periods. For the loading gangs these breaks may be considered included in the delays,for the rest of the personnel they are simulated by an independent part-program. The following distribution of breaks per man have been assumed for an eight-hour day:

4 Breaks, Duration from 5 to 10 minutes
4 Breaks, Duration from 10 to 20 minutes
Cumulative duration of breaks per man,
per day from 60 to 120 minutes.

The maximum has been applied when capacity utilization is low; the minimum when it is high. The continuous function, UFACT, varying between 1 at high utilization and 2 at low, makes the adjustment. When the utilization is high,the short breaks are assumed to be evenly distributed between 4 and 6 minutes, and the long breaks evenly between 8 and 12. The function, PTIME, distributes the breaks evenly between these two ranges.

The breaks are assumed to occur randomly throughout the day. With 8 breaks per man per day, a staff of 120 men will in average have an unofficial break at every half minute. By modifying their mean inter-occurance time by an exponential distribution, the breaks get a Poisson distribution for their time of occurrence.

The discrete function, STORG , which has a random number as free variable distributes the breaks on storages in accordance with the capacity of each storage. The function value is used three times for each break simulation. First, to determine which storage to enter, secondly, to find the utilization factor of the storage, and for the third time when leaving the storage. In order to use the same function value all three times, it is stored in Parameter 1 when first called for, and P1 is used as indirect address.

In order to get correct statistical output, we must keep track of where the breaks occur. This is done by queues 11, 14, 15 and 16 which is indirectly adressed via function, BREAK . BREAK links breaks occuring in storage 1 to Q 11, storage 4 to Q 14, and so on. Queue 5 keeps record of total number of breaks.

The mean inter-occurrence time and the distribution of breaks must be changed when any storage capacity is changed. We have stored the mean inter-occurrence time in savevalue 34, which, at each change, is adjusted to the actual total number of men employed. It is, however, assumed that the distribution of breaks between storages will not change when the manpower is reduced. The adjustment of XH34 is performed by the cost calculator in the same sequence as the one simulating the reduction of manpower.

The unofficial breaks may be regarded as a necessity. They therefore have priority 5 so that they will have preference before any ordinary operation, but not before the timer transaction. The subprogram may be found under the heading, "Personal Breaks", in the listing.

Having discussed the cost features and unofficial breaks for the receiving and storing personnel, we may pick up the "natural sequence" again. What comes next is the loading of cargo into the ship.

6.27 Loading the Ships

The loading may go on independently of receiving and storing, although when both operations are carried out at the same time some interferences may occur. Transport of cargo from storing place to ship may partly be hindered by the transport of cargo into the storage area, and in some cases the loading gangs may have to wait for cargo that is being unloaded from trucks. It is, however, correct to point out that as far as this model is concerned, receiving and storing on one side and loading the ships on the other may be simulated independently. When simulating loading separately, the storage matrix must be initialized in the start, and the discussion for or against overtime must be taken on the basis of actual quantity of cargo on storage and not on the basis of expected cargo inflow. The overtime decision will be discussed in a separate chapter.

In contrast to receiving and storing, the loading operations will take place under a changing physical environment. There may be a new type of ship for each time, imposing different restrictions on the operations. In principle, the simulation program must as far as possible be so designed that no major changes are required when one ship is replaced by another. This may be accomplished by referring to savevalues for all ship determined parameters, and then, initial these savevalues with the standards of the particular ship before each simulation run starts. In our case, this has been done for loading instructions, available space on the apron, and cycle time for the lifting gear, as explained later. But let us first discuss the gangs and their working conditions.

6.2701 The Loading Gangs

The loading gangs will pick up cargo where it is stored, bring it to the ship's tackle or side door, lift it on board and stow it. After stowing comes lashing and securing, but this work is in most cases done by the ship's crew or special shore gangs after the stowage is finished and will therefore not be included in the simulation.

A typical sequence of operations for a loading gang is:

1. Check cargo destination,
2. Pick up cargo and bring it to the apron,
3. Hook cargo (if lifting gear is used),
4. Lift cargo on board (if lifting gear is used),
5. Unhook cargo (if lifting gear is used),
6. Return empty pallets and slings (when stowing loose cargo),
7. Stow cargo.

As mentioned previously, the cargo may be grouped according to ports of destination when stored or it may be randomly located. This difference in stowage organization will influence the time distribution for the forklifts that bring cargo to the ship, but in principle it has no effect on the method of simulation. As for the receiving and storing operation, we therefore assume that cargo for each port is randomly located in the storage area.

It is of interest to test both modern and conventional loading/discharging equipment during the same simulation run. It is, therefore, assumed that the ship has one revolving deck crane, one set of derricks in union purchase, and one sidedoor combined with side hatch. A description of these types of loading gear may be found in refs.7 and 8. The deck crane will mainly handle cargo that is to be stowed loose, its spotting ability makes it suitable for stowage of loose cargo. The model of a gang may be seen in the listing starting right after the block, "GAWA1", under the heading, "LOADING".

In real life the cargo will as far as possible be loaded port by port, starting with cargo for the last ports of call. This routine may, however, be changed if there is only little cargo on storage. Then cargo may be brought directly from the receiving ramp to the quay. We will, however, first structure a simulation routine for loading cargo from storing areas and thereafter find a way to simulate loading directly from receiving ramp. Let us then discuss the simulation of loading instructions.

6.2702 Loading Instructions

The loading gangs take the cargo on board in accordance with instructions issued by the mate. We are going to simulate the same cycle times for a gang regardless of where in the hatch the cargo is stored, and is therefore only interested in

Which port each gang shall load for

In which sequence cargo for different ports shall be loaded.

This information is given by the "loading matrices", MH1 and MH2 Column number 1, 3 and 5 of these matrices contain port numbers for gang 1, 2 and 3 respectively and column number 2, 4 and 6 contain the cargo type numbers. The cargo specified in the first row of the matrix is meant to be loaded first, the second row thereafter and so on. A zero entry in the matrix indicates that cargo for no more ports is specified. A zero in the first row means that the gang shall not load. It is assumed that the gang will load all cargo on storage for a specified port, and that one pallet load general cargo, or one long ton open-air cargo, will be taken in each heave.

Our three loading gangs will, however, not be able to load as much cargo as the terminal can receive. It seems reasonable to simulate up to 400 trucks with general cargo and 100 trucks with cargo for the open-air storage per week. This gives a total quantity of about 3500 pallet loads general cargo and about 2000 tons open-air cargo. Depending on outfit and equipment, four to seven gangs are needed to load this into the ship during 3 - 4 days. When designing the loading matrix, it has been assumed that other gangs will take care of the cargo that is not specified. The aim is to develop simulation models for different types of gangs, not to simulate a large number of identical gangs.

Usually the loading instructions will vary from one call to another. A way to simulate this is to design an individual loading matrix for each week. In our case we use matrix No.1 on odd numbered weeks, matrix No.2 on even weeks, but a new matrix may be used each week. The matrices are used to check the cargo destination as explained in the following.

6.2703 Check of Cargo Destination

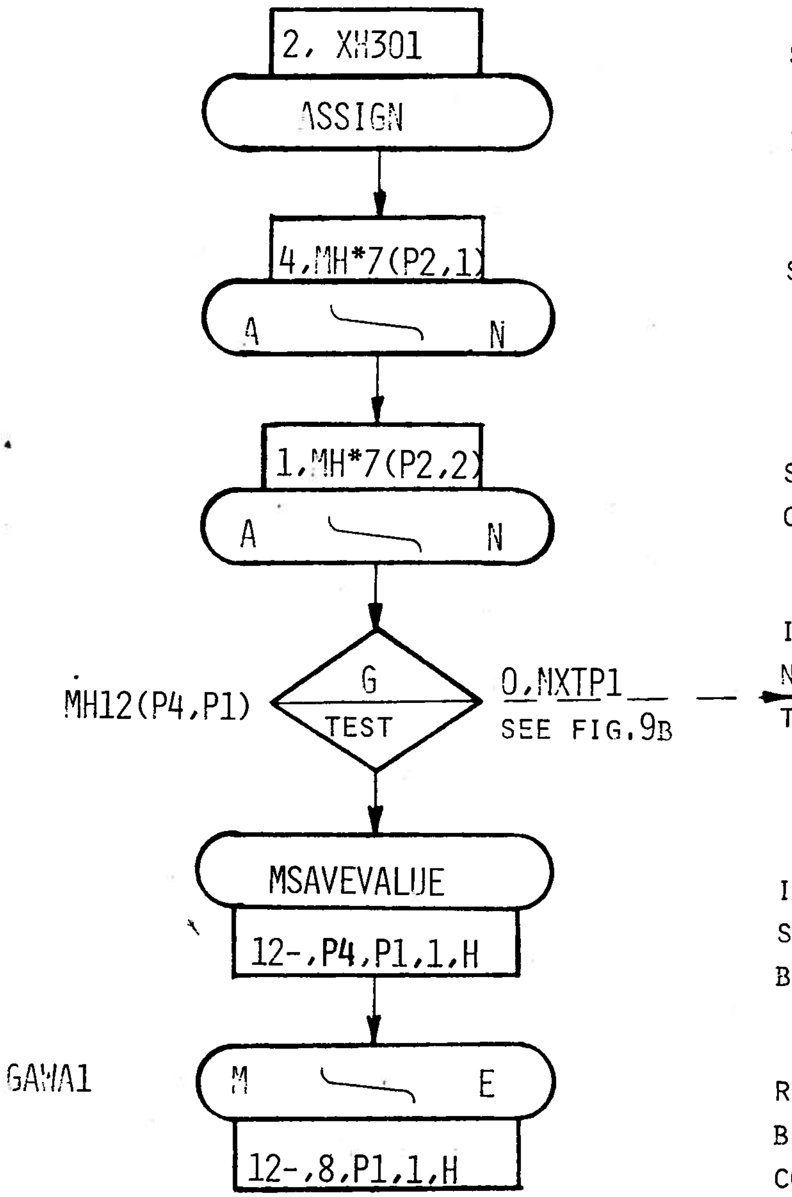
The loading matrix indicates which ports to load for. As the loading matrix changes from week to week, it is indirectly addressed via parameter 7. P7 is equal to Variable 1, which in turn is equal to one in odd numbered weeks, two in even numbered weeks. Thus, MH*7 will be matrix 1 or 2, depending on week number.

The first block of a gang's simulation checks whether cargo is specified at all, i.e., whether entry (1.1), (1.3) and (1.5) is larger than zero for gang 1,2 and 3, respectively. If cargo is specified, the next step is to check whether any of the specified cargo is on the terminal. This is done by checking matrix 12, the cargo-on-storage-matrix. The check utilizes the fact that the row number of matrix 12 corresponds to the port of destination number and its column number corresponds to the cargo type number.

The port number specified by the loading matrix is assigned to parameter 4, the cargo type number to parameter 1. Then by checking the entry to matrix 12 whose row number is given by parameter 4 and whose column number is given by parameter 1, we can see whether any of the specified cargo is on storage. If this check is ok a load is simulated to leave the storage, and the contents of the entry is decreased by one. The check and the entry reduction is made each time a heave is simulated to be loaded. In the end, the entry will be empty.

Parameter 2 carries the row number of the loading matrix. In the beginning it is equal to one. When an entry of matrix 12 is empty, P2 is increased by 1 and it is checked whether the next row of the loading matrix specifies cargo. If this is the case, parameters 4 and 1 will be assigned the port and cargo type numbers of this row, the check of matrix 12 will be repeated for a new entry and the simulation continued until the entry is empty. In the end, all entries of matrix 12 that correspond to specified cargo will be empty. Then the control will be given over to a control sequence which halts the loading simulation for the particular gang.

The block diagram of this procedure may be seen from figure 9, a and b which are for gang 1. In 9a we start by assigning the value of XH 301, which is one, to parameter 2 and proceed as explained above. When the entry of matrix 12 is or has become empty, the transaction is detoured to the block "NXTP1" in figure 9b. Here P2 is increased by 1, and the loading matrix is checked against zero. If no further cargo is specified, the control is transferred to the control sequence, "NLD1" otherwise XH 301 is increased by one and the transaction is killed in a terminate block. When the next transaction enters the assign block on top of figure 9a, XH 301 will have been increased by one. Correspondingly P2 will be increased by one and loading of the cargo specified by the next row of the loading matrix will be simulated.



XH301 = 1

SET P2 = XH301, I.E., START CHECK IN FIRST ROW.

SET P4 = SPECIFIED PORT #

SET P1 = SPECIFIED CARGO TYPE #

IF SPECIFIED CARGO NOT ON STORAGE, GO ON TO NEXT SPECIFIED PORT.

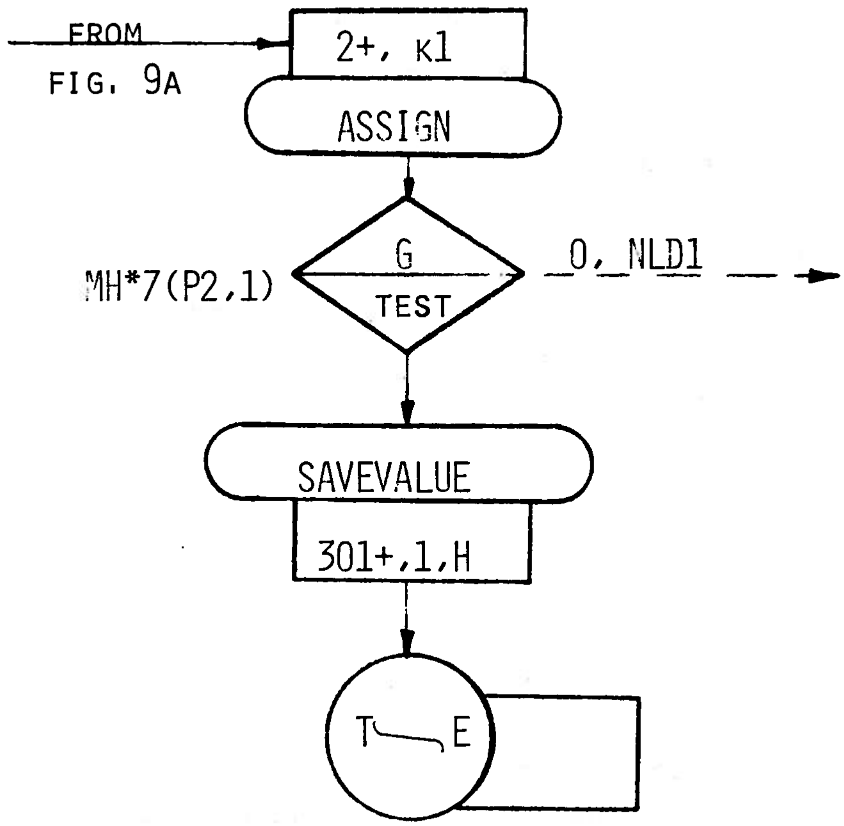
IF SPECIFIED CARGO ON STORAGE, REDUCE RECORD BY ONE.

REDUCE TOTAL BY ONE. BLOCK IS NAMED TO FACILITATE CONTROL OF WAITING LINE.

CHECKING THAT CARGO IS ON STORAGE

FIG. 9A

NEXT P1



INCREASE P2 BY CONSTANT 1.

CHECK WHETHER MOORE CARGO IS SPECIFIED. IF NOT, TRANSFER CONTROL TO "NLD1".

IF CARGO IS SPECIFIED, INCREASE VALUE OF XH301 BY 1, I.E., GO ON TO CHECK NEXT ROW OF STORAGE MATRIX.

KILL TRANSACTION IF LOADING SHALL CONTINUE.

CONTINUED CHECK FOR CARGO

FIG. 9B

This procedure will prevent the model from simulating a gang to load cargo for different ports at the same time. It reflects real life conditions. The cargo has to be stored port by port on board the ship.

Now it will always happen that cargo continues to come in as the loading goes on. After the storage matrix has been checked through one time and the cargo originally on storage have been loaded, it is necessary to check for more cargo. The control sequence will set XH301 back to one and thereby initial a new search and load sequence, but only after a delay. The delay simulates the time it takes to re-organize the work and find storage place for late incoming cargo destined for the last ports of discharge. The organizing of the second and consecutive checks will be discussed in connection with the control sequence at the end of this chapter.

6.2704 Time to Bring Cargo from Storing Areas to Ship

Each loading gang has one or more forklifts that brings cargo to the apron .For loading gangs working at either end of the shed, the mean distance from the storage area in the shed to the ship will be about the same as from the buffer area to the storage area. When loading from the shed we may then for the sake of simplicity, use the same time distribution for forklifts feeding these loading gangs as for the forklifts bringing cargo from the buffer zone to the storage in the shed. But it will be necessary to adjust for more difficult conditions when picking up the cargo.

The gangs working at the middle part of the shed have access to the shed through doors at its half-length. The average longitudinal distance to the storage area will be reduced to the half; the crosswise distance will be the same. Based on this and in line with the evaluation of time distribution for bringing cargo to storage on page 44, we assume a travel distance of

$(280 + 335) \cdot 0.5 = 308$ feet for the forklifts serving the loading gangs at the middle of the shed.

The random location of cargo in the shed may make it difficult for the forklift drivers to find the cargo locations. It seems correct to assume an extra delay of 0.5 minutes per cycle. Applying this and a degree of difficulty equal to three for picking up the cargo, figure 7, page 45, gives a net average mean time per cycle for the middle of the shed gangs of 2.58 minutes evenly distributed between 1.4 and 3.76 minutes, or by ±46%. The forklifts serving the end gangs will get a net mean time of 3.4 minutes evenly distributed between 1.4 and 5.4 minutes or by ±60%. Here, as for the forklifts storing cargo, the shed utilization and the traffic in the shed will influence the working time. We apply the same function to adjust the mean cycle time but due to the different mean cycle time distributions we have to design new variables:

For the middle of the shed forklifts:

Mean time	= K26 * FN$SHED/100
Modifier	= FN$MEGMO

For the end of the shed forklifts:

Mean time	= K34 * FN$SHED/100
Modifier	= FN$ENGMO

When cargo is loaded from the open-air storage, it will take a different time to get the cargo to the apron. The distance from the ship to the open-air storage will be different for each gang. we may however, assume that the side door gang will not load cargo from the open-air storage.As long as we only simulate one gang at midship and one at each end, we may then make one open-air addition to the end gangs and another to the midship gang. The end gang addition will never be applied to the sidedoor gang; it may therefore be adjusted solely to suit the conditions of the other end gang.

With reference to figures 3 and 7, it seems reasonable to assume a mean time that varies linearly between 2 and 7.5 minutes for the end gang, and between 3 and 8.5 minutes for the middle gang. To simulate the randomness of time distributions for work in the open-air storage, the mean time modifier is exponentially distributed.

The mean cycle time for the shed and the open-air storage will be stored in the same variables. By multiplying the shed term by (5 - P1)/3 it will only be applied when P1<3, and by multiplying the open air term by K4 @ P1, it will only be applied when P1 = 3. Variable 22 - 25 do the calculations.

6.2705 Number of Forklifts Feeding the Gangs

Running of the program has indicated that the number of forklifts bringing cargo from the shed or the open-air storage to the apron should be:

Gang 1, revolving deck crane: 2
Gang 2, derricks in union purchase: 2
Gang 3, side door: 3

The feeding forklifts are simulated by storage number 8 to 10 for gang 1 to 3 respectively.

6.2706 Cargo Waiting at Ship's Side

The forklifts that bring cargo from its place of storage to the ship must leave it in a place where lifting gear or forklifts working on board the ship can pick it up. The range within which the gear can pick up cargo vary with its type.

A revolving deck crane may cover a rather large area, derricks in union purchase will require the cargo to be placed more or less directly under the head of the quay side derrick and for a sidedoor the cargo must be delivered to a platform in the sidedoor opening. In line with this we allow a maximum queue of six drafts for the crane, three for the derricks and one for the sidedoor. In order to allow easy adjustment of these quantities, they are stored in savevalues XH1 to XH3 for Gangs 1 to 3, respectively.

It should be noted that this space limitations do not apply when a forklift brings out cargo directly from the receiving ramp. In that case, the forklift may leave the cargo some place on the quay where the gang's own forklifts will pick it up.

6.2707 Lifting and Stowing - Cycle Time

As explained in the following chapter, irregularities in working time will be simulated by additional delays. The time needed for handling the cargo itself may therefore be assumed to have a rather regular distribution.

Data from time studies on forklifts working from a sidedoor indicate a mean time of 1.4 minutes per cycle in good and modern ships. We assume a normal distribution with a standard deviation of 0.2 minutes. The function, NRM01 , is an inverse accumulated normal (0.1) density. If the function value is set equal to t, the expression X = 2t + 14 will distribute X "normally" with a mean of 14 and a variance of 2. The computation is performed by variable 80.

For the derricks in union purchase, observations give an average mean time of 2 minutes. The queue is allowed to be relatively large; there is no need to find an accurate distribution. We can assume 2 ± 0.5 minutes.

The revolving deck crane will usually have a larger spread of the cycle time. Observation data indicate a mean time of about 2,4 minutes; for the spread, we assume ± 1 minute.

Available data from time and motion studies on stowing of cargo on board ships show a large spread. But they indicate that as long as unitized cargo is handled it seems reasonable to let the stowing gangs have the same mean cycle time as the lifting gear. We assume the time to vary with ±1.0 minute. When the cargo is stowed loose, the capacity of the stowing gang will be considerably less. Space limitations make it impossible to assign enough men to keep pace with the lifting gear. Time and motion studies indicate an average of 20 slings per hour when delays have not been counted for. It seems correct to assume a rectangular distribution between two and four minutes.

As previously indicated, it should be taken into account that conditions may change. The above derived mean cycle times and variances are therefore stored in savevalues to make it easy to change them. The following table summarizes the results:

Gang #1, Revolving Deck Crane

Mean time, lift gear:	2.4 min. = XH210	
Mean time modifier, lift gear:	1.0 min. = XH213	
	Loose	Palletized
Mean time stowing:	3 min. = XH216	XH210
Mean time modifier, stowing:	1 min. = XH217	XH213

Variables 25 and 26 engage savevalues for right type of cargo by utilizing the expressions:

$$1/P1 = \begin{cases} 1 \text{ when } P1 = 1 \\ 0 \text{ when } P1 \neq 1 \end{cases}$$

$$P1/2 = \begin{cases} 0 \text{ when } P1 = 1 \\ 1 \text{ when } P1 = 2 \text{ or } 3 \end{cases}$$

P1 is either 1, 2 or 3 depending on cargo type.

Gang #2, Derricks in Union Purchase

Mean time, lift gear: 2 min. = XH211

Mean time modifier, lift gear: 0.5 min. = XH214

Gang handling only palletized,

Mean time, stowing: XH211

Mean time modifier, stowing: 1.0 min. = XH218

Gang #3, Side Door

Mean time forklift on board: 1.4 min. = XH212

Standard deviation: 0.2 min. = XH215

Cycle time calculated by

V80 = 2 * FN$NRM01 + 14

6.2708 Buffer Space on Board

The gangs on board will be able to land at most one more sling as long as the stowage at the previous one has not been finished. This has been simulated by test blocks that check that no sling is waiting for a stowing gang before the lifting gear is released. The location of the test block is further discussed in the next section.

6.2709 Utilization of Gang Equipment

Because of the simulated breaks and because the simulation starts at a simulated time different from zero, the standard outprint will not give correct information of the utilization of equipment. The utilization has therefore been calculated separately for forklifts feeding the gangs, for the lifting gear of gangs 1 and 2, and for the stowing forklift of gang 3. The calculations are performed by variables 91 through 93 and 101 through 103.

The utilization should reflect the need for the equipment or the degree of idle time. In order to obtain this, the periods of time when one type of equipment is waiting for another has not been included in the utilized time even if the equipment holds cargo during this period. For example, the time a heave is hanging in the crane waiting for the gang to finish stowing of the previous heave, has not been included in the utilized time of the crane.

To accomplish this, the checks that delay transfer of cargo from one equipment to another, has to be inserted before entry blocks otherwise the waiting time will be included in the utilized time. It is also necessary to use queue blocks to make it possible for a transaction to leave a simulated equipment regardless of the state of the next one. An example of a false and a correct procedure will appear in figure 10.

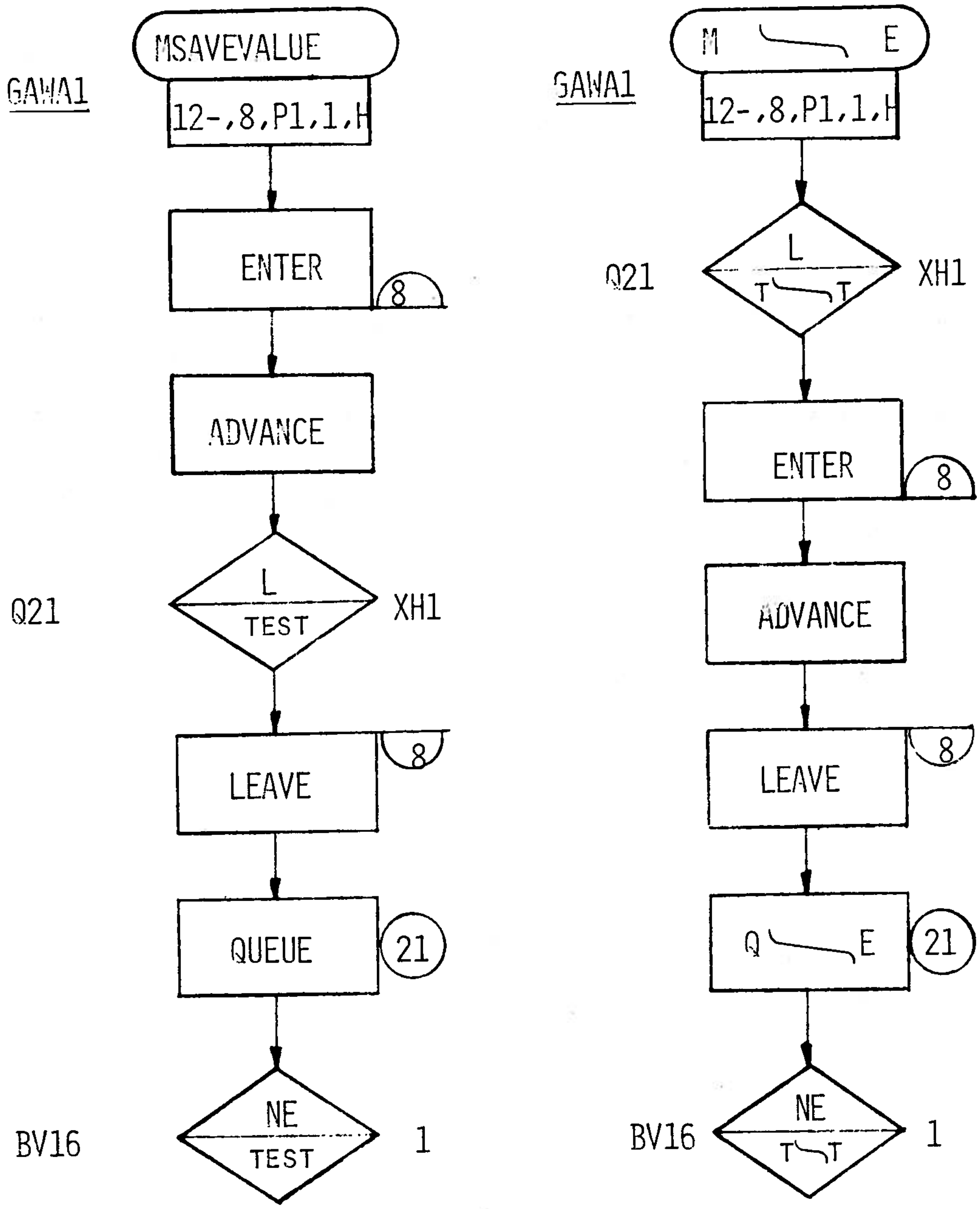
Utilization has only been calculated for the ordinary working time. This will be sufficient to judge how well the capacities are adjusted to each other.

Whereas the waiting time is excluded from the working time, other not directly productive times have been included. This goes for the time to return empty pallets and slings, rigging time and other delays. The reason for including the latter ones is that they may be considered necessary evils. They are discussed in the following.

6.2710 Return of Empty Pallets and Slings

This occurs for general cargo being stowed loose. The type of cargo is indicated by parameter 1. We let this parameter be the free variable of a function whose value is either zero or one, and get a method of assigning delay time only to the appropriate types of cargo. The function may be defined for

FIG. 10



FALSE

AS THERE IS A STEADY SUPPLY OF TRANSACTIONS AT "GAWA1", A NEW TRANSACTION WOULD GAIN ENTRANCE TO STORAGE 8 AS SOON AS THE PREVIOUS ONE HAD LEFT. THE STORAGE WOULD BE ALMOST CONTINUOUSLY OCCUPIED, THE CALCULATED UTILIZATION WOULD BE CLOSE TO 100 PERCENT.

CORRECT

THIS SEQUENCE WILL PREVENT STORAGE 8 TO SIMULATE WORK AS LONG AS Q21 IS GREATER THAN XH1. THE WAITING TIME WILL NOT BE INCLUDED IN THE CALCULATED WORKING TIME, THE CALCULATED UTILIZATION WILL REFLECT THE TIME SPENT ON TRANSPORT AND HANDLING OF CARGO.

a series of different cargo numbers, but will in our case be limited to the numbers we have, 1, 2 and 3. It will look like:

FUNCTION, EMPTY P1, D3: 1,0/2,1/3,1

The return of empties occurs on average only every third cycle. The delay it causes will be evenly distributed between 0.5 and 1.5 minutes. This must be taken care of by the mean time modifier. The problem may be solved by a function whose free variable is a random number. For two-thirds of the outcomes the function value must be zero, for one-third, it should vary linearly between 0.5 and 1.5 minutes. The following function will fit:

FUNCTION, EMTMO,RN5, C3: .66,0/.67,5/1.16

As maximum of RN is 0.999, 16 is specified as the highest function value.

The return of empties is the most frequently occurring delay. In addition, we have the rigging time and other more or less unforeseeable, interuptions that prevent the loading operation from running smoothly.

6.2711 Rigging

The rigging of derricks and deck cranes, opening of hatches and similar must in most of the port be done by longshoremen. This practice is usually laid down by union agreements.

This means that the loading of the ship will be delayed until the rigging is finished. For a modern sidedoor, the rigging time may be less than five minutes; for derricks in union purchase, it may by up to half an hour. The revolving deck crane comes in between.

In addition to delay caused by rigging comes delay from taking on board forklifts and other equipment, and from opening hatches.

In our case we will assume that:

1. There is one shipboard forklift for working through the sidedoor.
2. The sidedoor is opened and rigged in five minutes.
3. The derricks-in-union-purchase-gang needs 15 ± 5 minutes for rigging the derricks, another 5 minutes for bringing on board a forklift.
4. The revolving deck crane is rigged in 5 minutes. The gang needs no forklift to stow the loose cargo.
5. The hatches are opened during the rigging times specified above.
6. When the loading work is over, the ship's crew will de-rig the lifting gear.
7. At the end of the call, the gangs will bring any accumulated equipment and forklifts ashore, ten minutes per gang.

6.2712 Other Delays

In addition to the loss of productive time caused by the operations mentioned above, there will be other small, unavoidable delays that will occur irregularly. The causes of these delays may be small re-riggings, cargo shifting, dunnage handling, rests and others. Even for a new ship and a well planned operation, it may be difficult to keep the time lost on these delays under 10% of the total working time. On older ships where the working conditions are bad, this lost time percentage may be 15 to 20%.

In our case we are assuming:

10% for the union purchase gang
10% for the deck crane gang
7% for the sidedoor gang

The data used to estimate these delays have been derived from observation on the part of the gang that is working on board. They reflect the effect that delays throughout the loading chain will have on this part of the gang. The delays will therefore be simulated by an additional advance block for the stowing gangs.

It is assumed that half of the total delay is due to large stoppages occurring on average of every 15 cycles, the other half due to delays occuring on an average of every fifth cycle. It will be practical to use the same function as delay time modifier for all types of gangs. This may be accomplished by designing the function for an average delay of 10% and adjusting the mean delay time according to the delay percentages for the different gangs.

Applying a random number as free variable, the function may be like this:

FUNCTION DELAY RN6, D3: .733,0/.933,.25/1,.75

When multiplied by the mean cycle time, it will give an average delay of 75% every 15th cycle, plus a delay of 25% every 5th cycle.

The main features of the loading operation should by this have been discussed. Some general problems remain, however, the first one to be is a creation of transactions.

6.2713 Creating of Transactions

We can only have a limited number of transactions in the system at the same time. It is therefore impossible to use the same transactions throughout the simulation from receiving cargo until finally stowed on board. We must introduce an additional generate block.

This block may be found as the first block under the heading, "Loading the Ship" in the listing. It has no creation limit and is controlled by a test block in order that there shall be no overflow of transactions. The test block operates on Boolean variable number 15, whose status in turn is dependent on logic switch 10 and Boolean variables 1 through 3.

The logic switch 10 has to be "set" to allow transactions to pass through. The switch is operated by the timer and is "set" on the first loading day and onwards for the rest of the week, as may be seen from the fourth subsequence in the listing of the timer program. Thus, the timer has an overall control of the loading operation and will not start it until the first loading day, i.e.not until the ship has arrived.

In addition to the overall control, we need an individual control for each gang. This is accomplished by BV 1 to 3. Transactions are only created when either BV1, BV2 or BV3 are true. These three Boolean variables are in principle identical, therefore, only one of them is discussed in the following:

BV1 is true when:

a) Logic switch 2 is reset,

b) There is not more than one transaction waiting to enter the simulated gang,

c) There is no mealbreak.

a) Logic switch 2 is operated by the control sequence and will be dealt with in the related chapter.

b) BV1 checks the wait count at the block, "GAWA1". If this count is greater than zero there will be a transaction ready to enter the simulated gang (i.e., there will be a load waiting for the forklift). There is then no reason to create more transactions.

c) Transactions will only be created when BV16 is false, i.e., when there is no break.

After the test block an assign block operating on Variable 1, sets Parameter 7 equal to 1 on odd numbered weeks, 2 on even numbered weeks. Thereafter a TRANSFER ALL block distributes the transactions to the three gangs.

The simulation of lunch and evening breaks are mainly taken care of by BV16, but the transactions waiting at block GAWA1, 2 and 3, will simulate loading during the breaks if their flow is unrestricted in relation to the time. In order to keep them at the GAWA blocks during the breaks, we test the time before Queue 21,22 and 23 are departed and allow no transactions to depart the queues as long as it is a break. The related test block for gang 1 is the last block in figure 10. Transactions that have passed this test block and are at other locations in the simulated gang, will continue the simulation until they are terminated, and thereby cause some simulation to continue during the first part of the breaks. But this prolonged simulation will be counterweighed by a corresponding delay when starting up after the break. The end of a loading simulation will be on a sailing day. The end will then not be caused by breaks and all transactions waiting at GAWA blocks will be processed before close down. This is of importance because the records of cargo on storage are updated before transactions enter the GAWA blocks.

This brings us to the question of how to terminate the loading simulation. Shall we stop a 5 PM, or may it be necessary to work overtime on some occasions. Let us try to work out decision rules for starting overtime work.

6.2714 Overtime Work

In this section we are trying to simulate the making of decisions that involve a little more than a simple logic or mathematic relation. We are forced to collect information to get a basis for the decision. The problem will be worked through for the sake of the example, but it should be noted that the simulation model will be much simpler and less expensive to run if decisions of this kind are replaced by fixed time limits or similar.

The loading gangs may work overtime mainly under two conditions:

1) The expected cargo inflow is more than can be loaded in ordinary time.
2) It is sailing day and all cargo that has been received has to be loaded.

The last mentioned criteria is the easiest to deal with. BV8, 9 and 10 are true if V2 is equal to zero, and V2 is equal to zero on sailing days only. When BV8, 9 and 10 are true, logic switch 2, 3 and 4 are reset at simulated time 6 PM and more transactions may be created. On sailing days the switches are not changed again until all received cargo has been stored (BV19 = 1) and all cargo that is in the process of being handled by a gang has been loaded (V81 = 0). This may be seen from the listing under the heading "Overtime Control."

The first mentioned criterion requires a more comprehensive basis for decision. We need a measure of expected inflow of cargo and of expected quantity remaining to be loaded. The expected quantity to be loaded has to be compared with the gang's loading capacity. The previously tabulated variation of cargo delivery over the weekdays gives the following expected cargo inflow factors, where the inflow factor is equal to the total quantity of cargo expected within next day's end, divided by total cargo received at present day's end. We get -

Weekday Number	1	2	3	4	5 (0)
Cargo inflow factor:	2.5	2.	1.6	1.25	0.

Bearing in mind that day number five corresponds to V2 = 0, this table has been stored by the function, INFLO .

The calculation of total received cargo at day's end is performed by the first transaction in the loading sequence of each gang. The sequence starts under the heading, "Calculate Expected Quantity of Cargo" in the listing, as explained in the following for gang 1.

At the start of the first loading day, all cargo previously received for the gang is loaded into savevalue 21, thereafter the rigging of the gear is simulated. Then the transaction waits until 5 PM to add the cargo received during the day to savevalue 21. On the second and following loading days, the test block DEL1 will detour the transaction so that only the rigging and the addition of cargo received during the day is performed. Still at 5 PM, the expected quantity of cargo at next day's end, as calculated by V41, is loaded into savevalue 41:

$$XH41 \leftarrow V41 = XH21 * FN\$INFLO$$

And finally XH41 is reduced by the total quantity loaded up to that time. By this, the value of XH41 will be the expected quantity for the gang to load within the end of the following day. Boolean variable 8 then uses XH41 to check whether so much cargo is expected to be loaded that overtime work is necessary. BV8 is true if XH41 'GE'Quant., where Quant is the quantity that gang 1 is expected to load during the next day. But before we calculate this quantity some comments to the computations dealt with above are necessary.

The calculations are performed at simulated time 5PM. The decision on overtime has to be taken at that time, and so far the simulated point of time for the calculation may seem correct, but at 5 PM there may still be some loaded trucks on the terminals, and the cargo of these trucks should be added to the day's received count.

However, this has not been done. The error created by not having taken the unloaded trucks into account may prevent overtime from being simulated at a certain day, but the increased amount of cargo thus remaining on the terminal the following morning will weigh for overtime work at the following night. The end result will by and large be that overtime work is postponed one day. Taken into consideration that as much as possible of the cargo for the last ports of discharge should be loaded before one starts on the next ports, this delay is considered acceptable.

On the other hand, in order to have correct records for the following day it is necessary to correct XH21 when all cargo has been received. An update loop does this as soon as all cargo has been stored (BV19 = 1) and before the simulation is closed down. Savevalues 221 are used as intermediate storages for XH21. The test block ENDY1,, prevents the updating from being done more than once per day.

As the overtime decision is based on a check performed on the basis of total cargo received at 5PM, it seems correct to assume that overtime has to be worked if the expected quantity of cargo can not be loaded within that time on the following day. Based on the previously derived mean cycle times and delays, the average quantity loaded during an eight-hour day is estimated to be:

Gang #1: abt. 160 pallet loads/Ltons
Gang #2: abt. 200 pallet loads/Ltons
Gang #3: abt. 280 pallet loads/Ltons

The expected quantities are compared with these quantities by Boolean variables 8, 9 and 10 for gangs 1, 2 and 3 respectively. If any of the expected quantity is larger, the Boolean variable will be true and overtime worked.

With the overtime question settled, let us see how the gangs' performances may be measured.

6.2715 Performance

The performances of gangs 1 to 3 respectively are calculated by variables 61 to 63 for ordinary time, variables 67 to 69 for overtime. The performance is measured in heaves, i.e., pallet loads and/or long tons per hour. The entrance count of the storages simulating the stowing part of the gangs offers a measure of the number of drafts loaded. At 5PM this count is divided by a savevalue which is 8, provided the gang started at 8AM, 4 when it starts at 1PM. These savevalues, XH24 - 26, are initialized by the control sequence. The calculations of the overtime performance have the form:

100 * (SC22 - XH130)/(V64 - 18)

which is for Gang #1.

SC22 = Storage count at time of computation
XH130 = Storage count at 5PM
V64 = C1/600 + FN$HOUR = First full hour after gang is finished

$$FN\$HOUR = \begin{cases} 1 \text{ if } V65 \neq 0 \\ 0 \text{ if } V65 = 0 \end{cases}$$

V65 = C1 @ 600 = Fraction of hour

V64 is on the 24-hour clock

V64 - 18 gives the number of hours the gang should be paid for after the time 1800 (6PM), assuming the gang is entitled to get an hour's pay for the last fractional hour worked.

The performances are stored in savevalues 131 and 132 for gang 1, 141 and 142 for gang 2, 151 and 152 for gang 3 and are included in the edited output.

Then remains only one question related to the gangs: the control sequence.

6.2716 Control of the Loading Simulation

The creation of transactions starts not before 8AM and is controlled as explained in section 6.2713. The lunch and evening breaks are included in BV16 which in turn is a part of BV1, 2 and 3. The first transaction of each simulated gang opens for overtime work from 6 to 8 PM on ordinary days, as explained in section 6.2714. The rest of the control is directly or indirectly done by a control sequence, which may be found under the heading, "Sequence that Controls Loading from Shed" in the listing. The control may be given over to this sequence on two conditions:

1) No cargo is specified
2) There is no cargo to load.

In either case, the sequence immediately halts the loading simulation by setting the logic switch 2, 3 or 4. Our further discussion will use Gang 1 as example.

The second step is to check if no cargo is specified; if that is the case, the transaction is terminated; the switch remains "set"; there will be no further simulation.

If cargo is specified, control has been transferred to the sequence because there is no cargo on the terminal. In that case, storage count 22 is checked to see if any cargo has been loaded. If not, the loading is simulated to wait until 1PM, the working time (XH24) is reduced to four hours, the loading is set to start at the first specified port (XH301 = 1) and the logic switch reset again.

In case any cargo has been loaded, or if the simulated time is passed 1PM, the same procedure is repeated after a delay of half an hour, but the working time is not altered if any cargo has been loaded. The delay of half an hour is, as previously mentioned, intended to simulate the loss of time occuring when a gang has to shift the loading from one port to another. When control is given over to the control sequence, the last port that has been loaded for is the last one specified by the loading matrix; we start again with the first one specified.

As long as the simulated time is less than 8PM (C1 < 12000), the loading simulation will be restarted provided the other conditions permit this. If the control sequence is scheduled to restart the loading simulation at simulated time 8PM or later, it will first be checked whether it is sailing day. If it is not, the transactions are terminated by the block, WAIT1 and the simulation will not be restarted.

On sailing days one transaction will continue to the block, "OPEN1", making one restart after 8PM on these days.

However, the stops and restarts will only effect the loading from storage area, direct loading from the receiving ramp will not be influenced. Let us then at last explore how direct loading may be controlled .

6.28 Loading Directly from Receiving Ramp

There may, as mentioned, be cases when it is practical to take the cargo from the buffer area at the receiving ramp directly to the quay. We can assume that this procedure will be followed only on sailing days (V2 = 0) and only when the stored quantity of the category of cargo in question is under a certain limit. If we set this limit to ten pallet loads in the shed, the simulation may be as under the heading, "Check Whether the Cargo Should be Taken Directly to the Quay...", in the listing. Here the two above mentioned requirements are checked in the beginning:

1) Find out whether it is a sailing day (V2 = 0)

2) Find out whether cargo of this particular type,for this particular port does not amount to more than 10 pallet loads on storage.

If these checks are ok, the next task is to find out whether any gang is loading this type of cargo for a port. If not, the cargo should be stored. To check the loading gangs, we use a set of Boolean variables. Port number and cargo type number for the gangs are found in the loading matrix, whereas the cargo has its port number in P3, its type number in P1.

A right loading gang will have a row in the landing matrix where the entries correspond to P3 and P1. If, for example, a pallet has P3 equal to entry (3.3) and at the same time P1 equal to entry (3.4), gang 2 (working on columns 3 and 4) will be loading the cargo. Boolean variables 21 to 23 and 25 do the check. BV21 to 23 is one for each row of the loading matrix. In order not to have separate Boolean variables for each gang we use indirect addressing via P4 and P6 for column numbers. BV25 contains BV21 to 23 thus making it possible to include only the check of BV25 in the block sequence. The check is made for one gang after another.

If a right gang is found it is checked whether there is sufficient space on the quay, storage (31 - 33), for an additional pallet load. The quay is assumed to have sufficient space for 5 pallet loads at a time for each gang. If there is space on the quay, a forklift is engaged to bring out the cargo. Before a forklift is demanded, the cargo gets priority 2. This is to simulate efforts to bring late incoming cargo to the ship as fast as possible. After the transaction has gained entrance to the quay, the forklift is released and the transaction is transferred to the loading simulation via blocks DRCT1 to DRCT3 for gang 1 to 3 respectively.

In the loading cycle directly after these blocks there are subsequents governed by test blocks operating on the priority. For example, in gang 1, transactions with priority equal to 2 will "leave" the quay and will not "depart" queue 11. Cargo being loaded directly from the receiving ramp is the only category that has priority 2. The priority may thus be used to distinguish it from other cargo.

The mean cycle time for bringing cargo directly from the buffer area to the quay is assumed to be the same as when cargo is brought to storage in the shed. The mean time modifier is exponential.

The forklifts that usually bring cargo out of the shed to the apron will not be released when cargo is loaded directly from the ramp. They will be busy moving cargo that has been placed on the quay to under the ship's tackles.

Cargo for the open-air storage will be unloaded in the storage and later taken to the apron, regardless of sailing day and quantity on storage.

By this the main features of the simulating and performance recording part-programs should have been discussed. One important part-program remains, however, to be dealt with. This is the timer program which was briefly mentioned in the chapter on the simulation language.

7. OVERALL CONTROL OF SIMULATED TIME - TIMER

The timer sequence is the first part-program of the model, but it depends on or controls so much of the other part-programs that it is more natural to deal with it in the end of the report than in the beginning. There is only one timer transaction. The time unit is 1/10 of a minute, starting at 8AM giving an absolute clock start time of $8 \cdot 600 = 4800$. The timer has priority 10 in order that it shall have precedence over any other transaction in case of competition at some point of time.

To begin with, the timer loads and clears some matrices and savevalues, resets the switch controlling the main gate and the switches controlling the loading gangs, and empties, storages whose capacity previously has been partly occupied to simulate personnel going home.

Then XH50 is augmented by one to make the day count. Variable 2 calculates the day number of the week. V2 = XH50 @ 5, the fifth and last working day will get number zero but this makes no difference as long as we have taken it into consideration in our design. If V2 = 1, i.e., on first day of the week, the first loading day is taken from the function "DAY" and stored in XH30. Logic switch 10 is set; the loading simulation is started - as soon as we have the day when V2 = XH30. FN$DAY gives the first loading day a 5% probability of coming on the week's second day, 85% for the third day and 10% for the fourth. Thus the first loading day will never come on the last day of the week.

In order to keep chronologic record of simulated work load and queue contents the contents of storage 1 to 6 and queue 1 to 5 each hour are loaded into matrix 21 and 20, respectively. This is done by the loop starting at the block, AFTNR . Variables 71 to 76 calculate the net storage contents for storage 1 to 6. Net content of storage, a, is equal to:

V7a = Sa - Q1a - XH31a

where,

Sa = Total storage content

Q1a = Number of personnel on unofficial breaks for the storage

XH31a = Number of personnel sent home

For some storages(simulating unloading ramp and open-air storing area), Q1a and XH31a are constant equal to zero, but we still use the variables in order to avail the loop. The loop also stores number of trucks that have arrived during the preceding hour into savevalue 71 and onwards, and the number of departures in savevalue 91, onwards. The savevalues are used to make the mentioned graphical printout of arrivals and departures.

The logic invert block in the loop will invert logic switch 1 at 12 noon, 1PM and 5, thus, simulating the closing of the gate during lunch break and at 5PM. The block

```
TEST,E BV16, K1, AFTNR
```

will let one transaction through, accordingly one transaction will be split off to the subsequence starting at "OUTLT". This sequence controls the closure of the day's simulation and stores some of its results.

Last trucks' departure time from the open-air storage and last trucks' departure from the terminal are recorded. When the received count has been updated and BV18 is true, i.e., when all cargo is stored and gangs no longer are working, logic switch 25 is set to signal the cost calculator and the chronologic record loop to stop. Then logic switch 10 is set if it is a sailing day (no more loading this week).

In the end, two gate blocks delay the timer until cost and performance calculations and chronological records are finished. When these gate blocks are passed, some switches are reset, some savevalues cleared and finally the week number and average number of cubic feet per pallet are saved.

Then the simulation of the day is terminated.

ACKNOWLEDGEMENT

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I want to thank Professor Nowacki for having let me work so freely with this project under his auspices and for having gone through the manuscript and given valuable advice on the final presentation of the report.

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APPENDIX I

EDITED OUTPUT

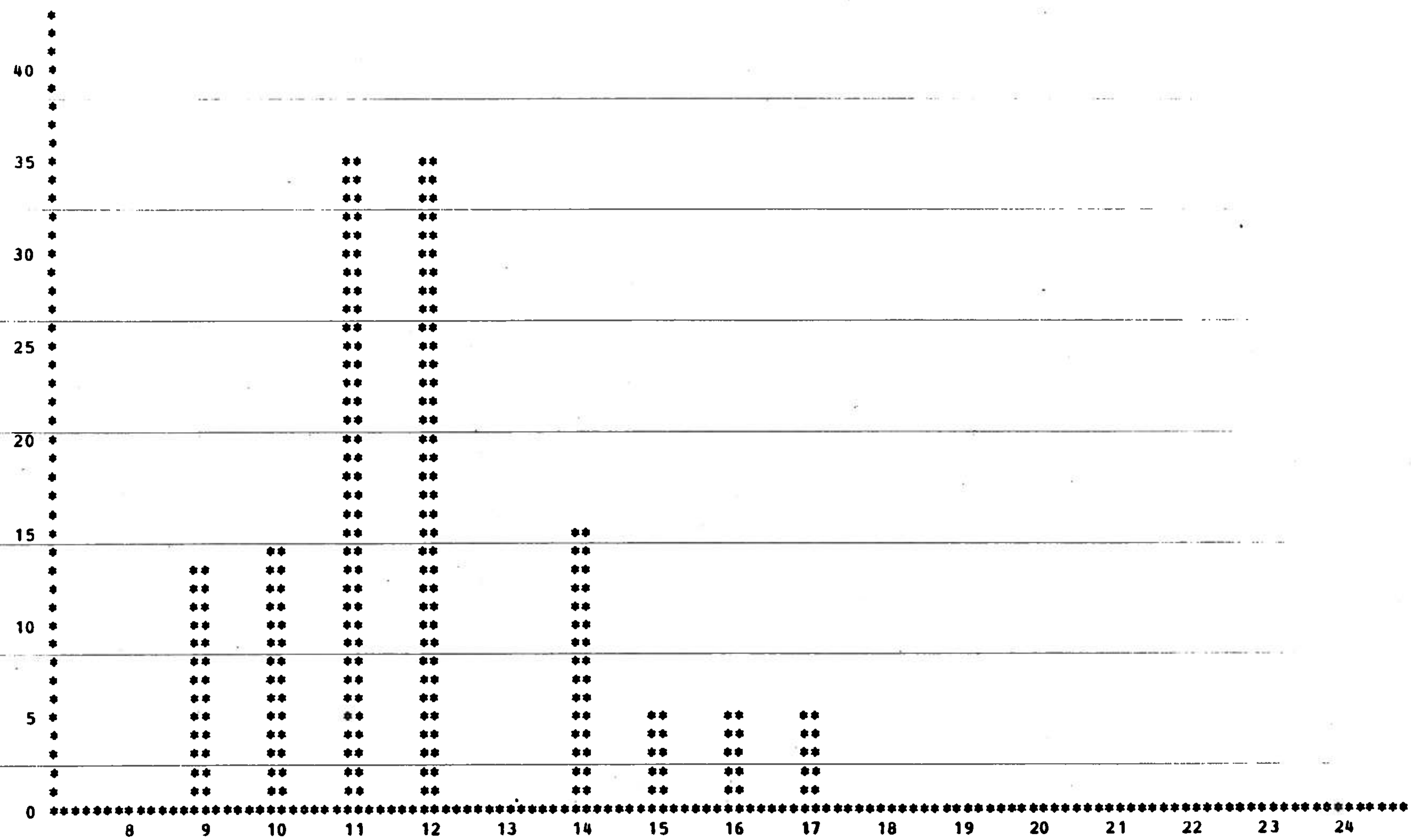
E D I T E D   O U T P U T
* * * * * *   * * * * * *

JUNE 12. 1970

RESULT OF SIMULATING CUMULATIVE DAY NO.: 3

WEEK NUMBER: 1

2

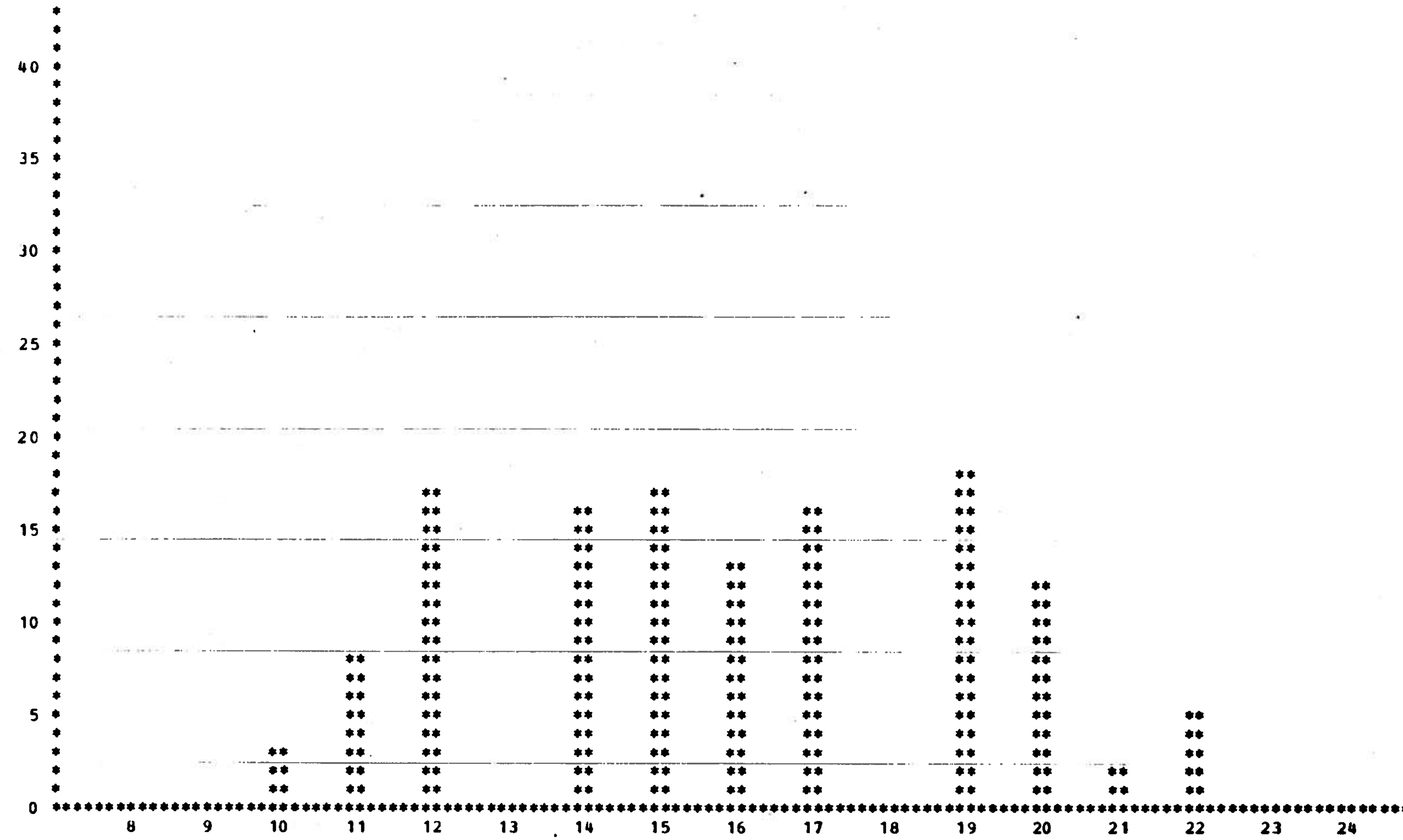


GRAPH OF ARRIVALS DURING PRECEDING HOUR

TIME SCALE: 24 HOUR CLOCK

TOTAL NUMBER OF TRUCKS ARRIVED 127

PREPALLETIZED CARGO ON 62 TRUCKS
LOOSE, GENERAL CARGO ON 44 TRUCKS
AND 21 TRUCKS WITH CARGO FOR THE OPEN AIR STORAGE



GRAPH OF DEPARTURES DURING PRECEDING HOUR

TIME SCALE: 24 HOUR CLOCK

THE LAST TRUCK LEFT THE TERMINAL AT 24.4 MINUTES AFTER 9 PM

IN THE OPEN AIR STORAGE THE LAST TRUCK WAS FINISHED AT 23.8 MINUTES AFTER 7 PM

CONTENTS OF QUEUES AT EACH FULL HOUR:

.MATRIX HALFWORD SAVEVALUE 20

ROW	COL. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0	3	4	18	38	38	37	19	12	4	4	0	0	0	0	0	0
2	0	0	0	10	21	21	16	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	30	41	31	36	36	32	32	29	27	27	27	22	2	2	0	0
6	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

ROW 1= TRUCKS PARKED, ROW 2= DRIVERS WAITING TO CLEAR DOCUMENTS, R 3= PALLETS TO BE SECURED, R 4= PALLET LOADS TO BE STORED
R 5= TOTAL NO. OF MEN HAVING TAKEN AN UNOFFICIAL BREAK,ROW 6= 24 HOUR CLOCK

PERSONEL AND EQUIPMENT WORKING AT EACH FULL HOUR:

MATRIX FULLWORD SAVEVALUE 21

ROW	COLUMN 1	2	3	4	5	6	7	8	9
1	0	3	4	8	6	6	6	2	1
2	0	7	13	27	28	28	28	28	28
3	0	7379	13149	12599	9539	9539	9569	19889	19429
4	0	9	18	27	25	25	27	29	29
5	0	15	23	33	34	34	33	32	27
6	0	6	14	12	6	6	6	14	16
7	8	9	10	11	12	13	14	15	16

ROW	COLUMN 10	11	12	13	14	15	16	17
1	3	3	0	0	0	0	0	0
2	28	28	18	7	5	0	0	0
3	16909	16909	12909	11909	11909	11909	0	0
4	27	27	19	7	5	0	0	0
5	22	22	14	11	10	8	0	0
6	10	10	2	0	0	0	0	0
7	17	18	19	20	21	22	23	24

ROW 1= DRIVERS CLEARING DOCUMENTS, ROW 2= TRUCKS UNLOADNG AT RAMP, R 3= SQFT OCCUPIED BY TRUCKS & CARGO IN OPEN AIR STORAGE
R 4= CHECKERS CHECKING CARGO, R 5= FORKLIFTS WORKING, R 6= HELPERS UNLOADING FROM TRUCKS AND/OR SECURING CARGO, ROW 7= 24
HOUR CLOCK

CARGO RECEIVED DURING THE DAY BY PORT # AND TYPE:

MATRIX HALFWORD SAVEVALUE 11

ROW	COL. 1	2	3
1	87	65	22
2	111	89	58
3	45	49	39
4	160	107	100
5	151	105	104
6	52	48	18
7	117	84	77
8	723	547	418

ROW # CORRESPONDS TO PORT # EXCEPT FOR ROW 8 WHICH CONTAINS TOTALS
COL.1= PALLETIZED, COL.2= LOOSE,GENERAL, BOTH BY NUMBER OF PALLET LOADS, COL.3= CARGO IN THE OPEN AIR STORAGE BY LONGTONS

WHEN COL.2= 0, ALL LOOSE,GENERAL CARGO HAS BEEN SECURED TO THE PALLETS
THE PALLET LOADS MAKE 71623 CU FT PREPALLETIZED AND 54020 CU FT RECEIVED AS LOOSE,GEN.CARGO

TOTAL CARGC ON STORAGE AT END OF WORK DAY:

MATRIX HALFWORD SAVEVALUE 12

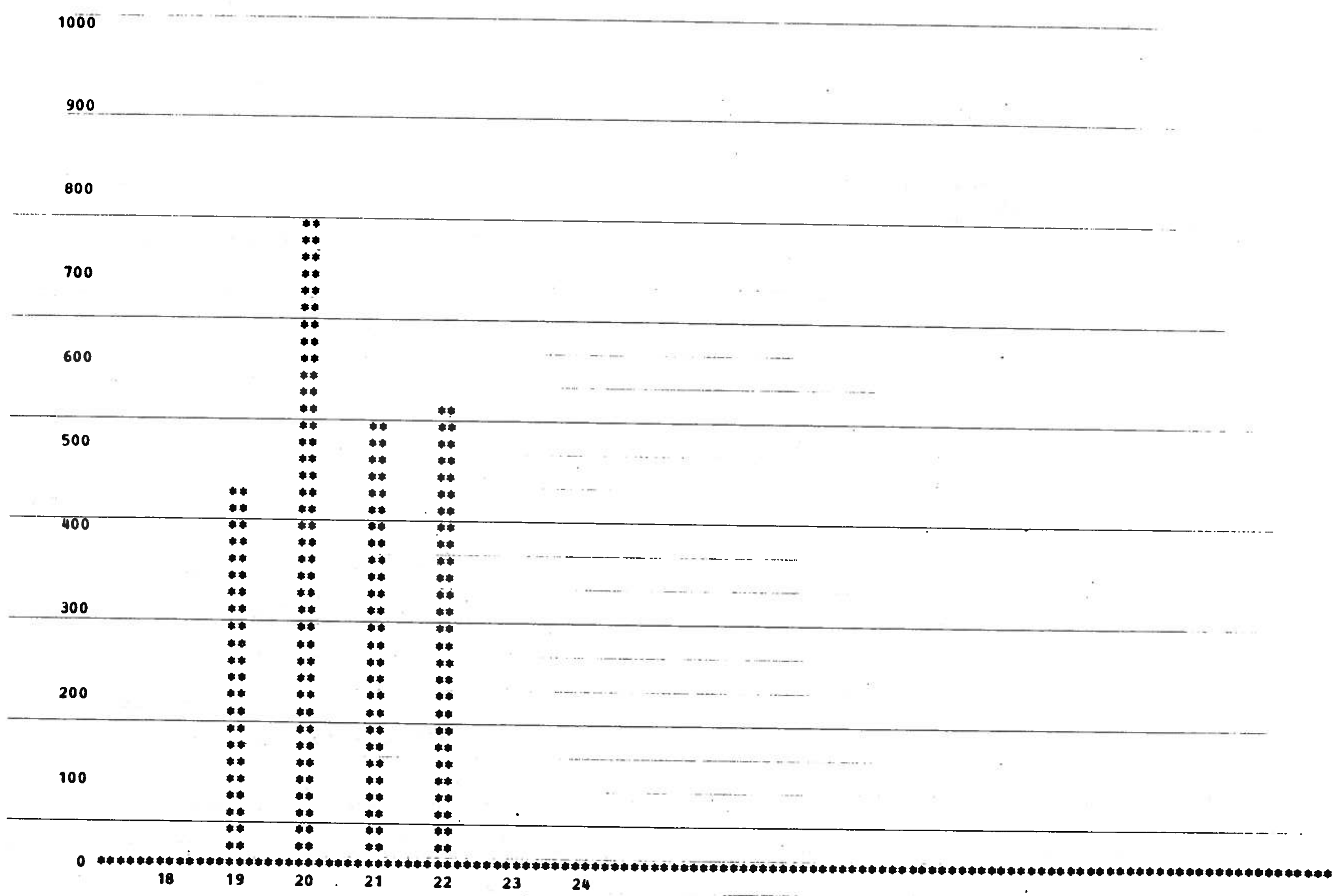
ROW	COL. 1	2	3
1	172	65	22
2	95	29	58
3	16	5	18
4	160	107	100
5	151	105	104
6	13	48	18
7	117	84	77
8	724	443	397

ROWS AND COLUMNS ARE RELATED TO PORT # AND CARGO TYPE AS ABOVE,QUANTITIES IN PALLET LOADS AND LONGTONS RESP.

AT NOON 358 PALLET LOADS LOOSE AND PREPALL. GENERAL CARGO AND 140 LTS FOR THE OPEN AIR ST.HAD BEEN RCVD
THE AVERAGE COST PR 40 CUFT/1 LT: 4.62 $

FROM 1 TO 5 PM RESPECTIVELY 673 PALLETLOADS AND 175 TONS WERE RECEIVED
THE AVERAGE COST PR 40 CUFT/1 LT: 2.70 $

TRUCKS THAT HAD ENTERED BEFCRE 5 PM WERE UNLOADED ON OVERTIME: 239 PALLETLOADS AND 103 LONGTONS
THE CVERTIME COST PR 40 CU FT/1 LT MAY B READ FRM THE FOLLOWING GRAPH:



COST IN CENT PR 40 CU FT AND/OR 1 LTON UNLOADED FROM TRUCKS AND STORED ON OVERTIME DURING THE PRECEDING HOUR

TIME SCALE: 24 HOUR CLOCK

REMAINING PERSONEL WAS PAID OVERTIME UP TO LAST TIME FOR WHICH COST FIGURE IS GRAPHED

ALL THE ABOVE COST FIGURES ASSUME 100 CU FT PR PALL,THE EXACT NUMBER IS 98 CU FT IN AVERAGE FOR WHOLE DAY

CARGO LOADED TO DAY BY PALLET LOADS & LONGTONS:

MATRIX HALFWORD SAVEVALUE 13

	CCL. 1	2	3	4	5	6	7	8	9
ROW 1	21	3	3	100	2	3	116	2	1
2	60	2	2	144	3	2	129	3	1
3	0	1	2	2	1	1	39	6	1
4	81	0	0	246	0	0	284	0	0

COL. 1-3 ARE FOR GANG 1, C4-6 FOR G 2, C 7-9 FOR G 3. ROW 1 HAS BEEN STOWED IN LOWER TIERS, ROW 2 ON TOP OF IT, AND SO ON
N O T E : THE FOURTH ROW CONTAINS THE TOTALS

COLUMN 1,4 AND 7 = QUANTITY, CCL.2,5,8 = PORT #, COL.3,6,9 = CARGO TYPE; 1 MEANS PREPALL, 2= LOOSE GEN, 3= CARGO FROM OPEN AIR ST.

TOTAL CARGO LOADED,BY PALLET LOADS AND LONGTON:

MATRIX HALFWORD SAVEVALUE 14

	CCL. 1	2	3	4	5	6	7	8	9
ROW 1	21	3	3	100	2	3	116	2	1
2	60	2	2	144	3	2	129	3	1
3	0	1	2	2	1	1	39	6	1
4	81	0	0	246	0	0	284	0	0

ROWS AND CCLUMNS CARRY THE SAME INFORMATION AS ABOVE

ON ORDINARY TIME THE LOADING CAPACITY WAS:

GANG 1 20.25 PALLET LOADS AND/OR LT PR HR
GANG 2 23.62 PALLET LOADS AND/OR LT PR HR
GANG 3 35.62 PALLET LOADS AND/OR LT PR HR

THE GANGS WORKED OVERTIME UNTIL:

GANG 1 ON 24 HR CLOCK
GANG 2 20 ON 24 HR CLOCK
GANG 3 ON 24 HR CLOCK

NO ENTRY FOR A GANG MEANS THAT THE GANG DID NOT WORK OVERTIME

THE OVERTIME LOADING STARTED AT 6 PM,THE CAPACITY PR GANG HOUR WAS:

GANG 1 .00 LT AND/OR PALLET LOADS
GANG 2 24.00 LT AND/OR PALLET LOADS
GANG 3 .00 LT AND/OR PALLET LOADS

THE AVERAGE UTILIZATION OF GANGS' EQUIPMENT DURING O R D I N A R Y TIME WAS:
FORKLIFTS BRINGING CARGO TO APRON:

GANG 1 78 %
GANG 2 81 %
GANG 3 86 %

LIFTING GEAR:

GANG 1 89 %
GANG 2 95 %

FORKLIFT STOWING FROM SIDEDOOR:

GANG 3 83 %

UNOFFICIAL BREAKS WERE DISTRIBUTED AS FOLLOWS:

10 PAPER CLERKS HAD 102 BREAKS OF AVERAGE LENGTH 15.7 MINUTES
40 CHECKERS HAD 481 BREAKS OF AVERAGE LENGTH 11.0 MINUTES
50 FORKLIFT DRIVERS HAD 593 BREAKS OF AVERAGE LENGTH 10.7 MINUTES
20 HELPERS HAD 198 BREAKS OF 10.4 MINUTES AVERAGE LENGTH

THE TRUCKS WERE WAITING FOR CHECKERS AN AVERAGE TIME AS FOLLOWS:

PREPALLETIZED 5.7 MINUTES
LOOSE,GENERAL 6.3 MINUTES
IN THE O-A ST. 5.0 MINUTES

APPENDIX II

PROGRAM LISTING

```
$SIGNON OOVA T=300 P=200 ' STIAN ERICHSEN: ONE DAY'S SIMULATION '


*
                                   P R O G R A M   L I S T I N G
*                                  * * * * * * *   * * * * * * *
*
*                                       JUNE 12. 1970
$RUN *GPSS PAR=SIZE=C
       SIMULATE
*
*
*                             C A R G O   R E C E I V I N G   A N D
*                                                     S H I P   L O A D I N G
*
*                             D E F I N I T I O N S
*
*****                         F U N C T I O N S
*
*                             MODIFIER OF UNLOADING TIME
 UNLD   FUNCTION    RN3,C3
0,.75/.50,1/1,1.25
*
*                             LOOSE,GENERAL CARGO PR TRUCK, 8 TO 9 AM
 MRNL   FUNCTION    RN2,C5
0,100/.06,420/.168,820/.438,1500/1,1501
*                             SAME AS ABOVE, 9 AM TO 3 PM
 GENQ   FUNCTION    RN2,C3
0,100/.5,1500/1,1501
*                             AS ABOVE, 3 TO 5 PM
 AFTL   FUNCTION    RN2,C3
0,100/.44,420/1,821
*                             SAME AS ABOVE,JOINT FUNCTION FOR WHOLE DAY
 LOOSE FUNCTION     C1,E3
5400,FN$MRNL/9000,FN$GENQ/10200,FN$AFTL
*
*                             OPEN AIR CARGO PR TRUCK, 8 TO 9 AM
 MNOA   FUNCTION    RN3,C3
0,16/.445,20/1,25
*                             SAME AS ABOVE, 9 AM TO 330 PM
 AIRQ   FUNCTION    RN3,C2
0,16/1,25
*                             SAME AS ABOVE, 330 TO 4 PM
 AFOA   FUNCTION    RN3,C2
0,16/1,21
*                             SAME AS ABOVE,JOINT FUNCTION FOR WHOLE DAY
 DRUMS FUNCTION     C1,E3
5400,FN$MNOA/9300,FN$AIRQ/10200,FN$AFOA

*                             TRUCKS WITH PREPALLET. CARGO USE FN$GENQ ALL D.
*
*                             MEAN INTER-ARRIVAL TIME FOR TRUCKS WITH PREPAL-
*                             LETIZED CARGO,BASIS: 100 TRUCKS PR DAY
 INTAR FUNCTION     C1,C9
4800,100/5400,70/6000,26/6900,19/7200,49/7201,120/7800,120/8400,36
10200,256
*
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```
*                               MEAN INTER-ARRIVAL TIME FOR TRUCKS BRINGING
*                               LOOSE,GENERAL CARGO. BASIS: 100 TRUCKS PR DAY
 LINTA FUNCTION    C1,C10
4800,28.5/5400,70/6000,26/6900,19/7200,49/7201,120/7800,120/8400,36
9000,109/10200,9500
*
*                               MEAN INTER-ARRIVAL TIME FOR TRUCKS BRINGING
*                               CARGO TO OPEN AIR STORAGE,BASIS: 100 TRUCKS/DAY
 ADINT FUNCTION    C1,C10
4800,44/5400,70/6000,26/6900,19/7200,49/7201,120/7800,120/8400,36
9300,146/9600,20000
*
*                               EXPONENTIAL INTER ARRIVAL TIME MODIFIER
 EXPO  FUNCTION    RN1,C24
0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
.8,1.6/.84,1.38/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
.97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8

*                               INVERSE CUMULATIVE NORMAL (0,1) DISTRIBUTION
 NRM01 FUNCTION    RN1,C13
0,-4.5/.006,-2.5/.029,-1.9/.115,-1.2/.184,-0.9/.309,-0.5/.5,0/.692,.5
.816,.9/.885,1.2/.971,1.9/.994,2.5/1,4.5
*
*                               LINKAGE BETWEEN TIME & GROUPING,OPEN AIR CARGO
 GROUP FUNCTION    C1,D3
7200,1/10799,11/10800,24
*
*                               THE FOLLOWING 5 FNS ADJUST MEAN TIME FOR FORK-
*                               LIFTS IN SHED ACCORDING TO THEIR WORKING COND.
 VELO  FUNCTION    V19,D2
1,125/25,125
 MELO  FUNCTION    V19,C4
1,125/10,125/20,150/25,175
 MEHI  FUNCTION    V19,C4
1,125/6,150/20,175/25,250
 VEHI  FUNCTION    V19,D2
1,250/25,250
 SHED  FUNCTION    SR7,E4
250,FN$VELO/480,FN$MELO/670,FN$MEHI/999,FN$VEHI
*
*                               MEAN TIME FOR FORKLIFTS BRINGING CARGO FROM OP-
*                               EN AIR STORAGE TO LOADING GANG AT SHIP'S
*                               CLOSEST END
 OAIRE FUNCTION    RN7,C2
0,20/1,75
*                               SAME AS ABOVE,LOADING GANGS AT MIDSHIP
 OAIRM FUNCTION    RN8,C2
0,30/1,85
*
*
*                               MEAN TIME MODIFIER,FORKLIFTS WORKING IN SHED
*
*                               PICK UP PALLET LOADS IN BUFFER,STACK IN SHED
 MOSHD FUNCTION    RN2,C2
0,.14/1,1.86
*
*                               TAKE CARGO IN SHED,DELIVER TO GANGS AT MIDSHIP
 MEGMO FUNCTION    RN4,C2
0,.54/1,1.46
*
```

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*                              TAKE CARGO IN SHED,DEL. TO GANGS AT SHIP'S ENDS
 ENGMO FUNCTION   RN1,C2
0,.40/1,1.60
*
*
*                              AREA OF PALLET AND ST.AREA PR.TON OA CARGO
 TYPE  FUNCTION   P1,D3
1,18/2,24/3,30
*
*                              LINKAGE BETWEEN CARGO TYPE AND STORAGE PLACE
 STRIN FUNCTION   P1,D2
2,7/3,3
*
*                              WHEN LOADING,MEAN TIME FOR RETURN OF EMPTIES
 EMPTY FUNCTION   P1,D3
1,0/2,1/3,1
*
*                              SAME AS ABOVE ,MEAN TIME MODIFIER
 EMTMO FUNCTION   RN5,C3
.66,0/.67,5/1,16
*
*                              RANDOMLY OCCURING DELAYS WHEN LOADING
 DELAY FUNCTION   RN6,D3
.733,0/.933,.25/1,.75
*
*                              EXPECTED CARGO INFLOW FACTOR
 INFLO FUNCTION   V2,D5
.5,0/1,2.5/2,2/3,1.6/4,1.25
*
*                              DAY NUMBER FOR STARTING LOADING
 DAY   FUNCTION   RN4,D3
.05,2/.9,3/1,4
*
*                              VARIATION OF CARGO INFLOW WITH WEEKDAY (XH50)
 VARWK FUNCTION   V2,D5
0,20/1,10/2,15/3,25/4,30
*
*                              ASSIGN PORT NUMBER,ODD WEEK NUMBERS
 PTS1  FUNCTION   RN7,D7
.12,1/.27,2/.35,3/.55,4/.75,5/.83,6/1,7
*                              AS ABOVE,EVEN WEEK NUMBERS
 PTS2  FUNCTION   RN7,D7
.16,1/.26,2/.37,3/.52,4/.67,5/.80,6/1,7

*                              FNS THAT GOVERN DELAYS DUE TO PERSONAL BREAKS
*
*                              MEAN TIME OF PERSONAL BREAKS
 PTIME FUNCTION   RN7,C4
0,40/.499,60/.5,80/1,121
*                              BREAK DISTRIBUTION ON STORAGES
 STORG FUNCTION   RN8,D4
.083,1/.417,4/.833,5/1,6
*                              ADJUSTMENT FACTOR VARYING WITH STORAGE UTIL.
 UFACT FUNCTION   SR*1,C2
0,2/1000,1
*                              LINKAGE BETWEEN STORAGES AND RECORDS OF UNOFFI-
*                              CIAL BREAKS
 BREAK FUNCTION   P1,D4
1,11/4,14/5,15/6,16
*
```

```
*
*                             ADDITIONAL HOUR FRACTION FOR GANGS ON OVERTIME
 HOUR   FUNCTION      V65,D2
0,0/600,1


*****                         V A R I A B L E S
*
*                             DIFFERENTIATING BETWEEN EVEN & ODD WEEK NUMBERS
 1      VARIABLE      1+(XH50-1)/5@2
*
*                             WKD. NUMBER.NOTE 0 CORRSPS TO 5,OTHERW. 1=#1 ET
 2      VARIABLE      XH50@5
*
*                             MEAN TIME TO RIG & UNLOAD TRUCKS WITH OA-CARGO
 3      FVARIABLE     P2*K600/K12+K200

*                             WEEK NUMBER
 4      VARIABLE      XH50/5+1
*
*                             MEAN INTERARRIVAL TIME FOR TRUCKS
*                                                   PALLETIZED CARGO
 11     FVARIABLE     FN$INTAR*500/XH11*20/FN$VARWK
*                                                   LOOSE,GEN. CARGO
 12     FVARIABLE     FN$LINTA*500/XH12*20/FN$VARWK
*                                                   CARGO FOR OPEN AIR ST.
 13     FVARIABLE     FN$AOINT*500/XH13*20/FN$VARWK
*
*                             CLCULATION OF NO.OF PALLET LOADS ON GC TRUCKS
 16     VARIABLE      P2/100
 17     VARIABLE      P2/100+K1
 18     VARIABLE      P2-K100*V16
*
*                             NUMBER OF FORKLIFTS WORKING IN THE SHED
 19     VARIABLE      S5-XH10
*
*                             MEAN CYCLE TIMES FOR FORKLIFTS WORKING IN THE
*                             SHED AND IN THE OPEN AIR STORAGE
*
*                             PICK UP PALLET LOADS IN BUFFER,STACK IN SHED
 20     FVARIABLE     K24*FN$SHED/100
*                             TAKE CARGO IN SHED OR OPEN AIR STORAGE,DELIVER
*                             TO LOADING GANGS AT SHIP'S ENDS
 21     VARIABLE      K34*FN$SHED/K100*((5-P1)/3)+FN$OAIRE*(K4@P1)
*                             SAME AS ABOVE,LOADING GANGS AT MIDSHIP
 23     VARIABLE      K26*FN$SHED/K100*((5-P1)/3)+FN$OAIRM*(K4@P1)
*
*                             MODIFIER OF MEAN CYCKLE TIME FOR FORKLIFTS WOR-
*                             KING IN THE SHED AND THE OPEN AIR STORAGE
*
*                             TAKE CARGO IN SHED OR OPEN AIR STORAGE,DELIVER
*                             TO LOADING GANGS AT SHIP'S ENDS
 22     VARIABLE      FN$ENGMO*((5-P1)/3)+FN$EXPO*(K4@P1)
*                             SAME AS ABOVE,LOADING GANGS AT MIDSHIP
 24     VARIABLE      FN$MEGMO*((5-P1)/3)+FN$EXPO*(K4@P1)

*                             MEAN TIME STOWING CARGO,GANG 1
 25     VARIABLE      XH210*(1/P1)+XH216*(P1/2)
*                             MEAN TIME MODIFIER,STOWING CARGO GANG 1
 26     VARIABLE      XH213*(1/P1)+XH217*(P1/2)
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5

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*
*                         CONVERT DEPART TIME INTO PM & 1/10 MINUTES
 31     VARIABLE    C1/600-12
 32     VARIABLE    C1@600
*
*                         MEAN INTER OCCURANCE TIME,PERSONAL BREAKS
 34     VARIABLE    600/(120-XH311-XH314-XH315-XH316)
*
*                         EXPECTED QUANT.OF CARGO WITHIN NEXT DAY'S END:
*                                                               GANG # 1
 41     VARIABLE    XH21*FN$INFLO
*                                                               GANG # 2
 42     VARIABLE    XH22*FN$INFLO
*                                                               GANG # 3
 43     VARIABLE    XH23*FN$INFLO
*
*                         SPACE REQ. FOR TRUCKS ENTERING OPEN AIR STORAGE
 49     VARIABLE    K1000+K30*P2
*
*                         COST PR 40 CU FT AND/OR LTON RECVD ON ORD. TIME
 50     FVARIABLE   4788000/(XH51*25+XH52*10)
*
*                         COST PR 40 CU FT AND/OR LT RCVD ON OVERTIME UP
*                         TO 8 PM
 51     FVARIABLE   1644000/(XH51*25+XH52*10)
*
*                         COST PR HOUR AFTER 8 PM
 54     VARIABLE    1242*(50-XH311-XH314)+1635*(50-XH315)+1035*(20-XH316)
*
*                         COST PR TON/PALLETLOAD RECEIVED DURING A 1 HOUR
*                         PERIOD THAT STARTS AT A FULL HOUR AFTER 8 PM
 55     VARIABLE    (X33*10)/(XH51*25+XH52*10)
*
*                         NO OF TRUCKS ARRIVED DURING LAST HOUR
 52     VARIABLE    N$GOIN-XH170
*
*                         NO OF TRUCKS THAT HAVE LEFT DURING LAST HOUR
 53     VARIABLE    N$EXIT-XH190
*                         NUMBER OF FLIFTS RELEASED WHN WRKLOAD DECREASES
 59     VARIABLE    R5-S2/3-S2@3
*                         TONS & PALLETLDS PR GANGHR,ORDINARY TIME,GANG 1
 61     VARIABLE    SC22*100/XH24
*                         TONS & PALLETLDS PR GANGHR,ORDINARY TIME,GANG 2
 62     VARIABLE    SC24*100/XH25
*                         TONS & PALLETLDS PR GANGHR,ORDINARY TIME,GANG 3
 63     VARIABLE    SC25*100/XH26

*                         LOADING GANG FINISHED
 64     VARIABLE    C1/600+FN$HOUR
*                         FRACTIONAL HOUR
 65     VARIABLE    C1@600

*                         TONS & PALLETLDS PR GANGHR,OVERTIME, GANG 1
 67     VARIABLE    100*(SC22-XH130)/(V64-18)
*                         TONS & PALLETLDS PR GANGHR,OVERTIME, GANG 2
 68     VARIABLE    100*(SC24-XH140)/(V64-18)
*                         TONS & PALLETLDS PR GANGHR,OVERTIME, GANG 3
 69     VARIABLE    100*(SC25-XH150)/(V64-18)
```

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*                           AVERAGE CU FT PR PALL,LOOSE & PREPALL
 70     VARIABLE   (X201+X202)/(MH11(8,1)+MH11(8,2))

*                           ENTRIES OF A ST MINUS UNOFFICIAL BREAK ENTRIES
 71     VARIABLE   S1-Q11-XH311
 72     VARIABLE   S2
 73     VARIABLE   S3
 74     VARIABLE   S4-Q14-XH314
 75     VARIABLE   S5-Q15-XH315
 76     VARIABLE   S6-Q16-XH316

*                           CYCLE TIME,FORKLIFT STOWING FROM SIDEDOOR
 80     FVARIABLE  FN$NRM01*XH215+XH212

*                           NO. OF DRAFTS BEING HANDLED BY GANG 1-3:
 81     VARIABLE   N$GAWA1+N$QUAY1-N$ONBD1
 82     VARIABLE   N$GAWA2+N$QUAY2-N$ONBD2
 83     VARIABLE   N$GAWA3+N$QUAY3-N$ONBD3

*                           UTILIZATION OF GANG EQUIPMENT ON ORDINARY TIME
*                           FEEDING FORKLIFTS,GANG 1-3:
 91     VARIABLE   (SC8*ST8*100)/(XH24*1200)
 92     VARIABLE   (SC9*ST9*100)/(XH25*1200)
 93     VARIABLE   (SC10*ST10*100)/(XH26*1800)
*                           LIFTING GEAR,GANG 1-2:
 101    VARIABLE   (SC21*ST21*100)/(XH24*600)
 102    VARIABLE   (SC23*ST23*100)/(XH25*600)
*                           FORKLIFT ON BOARD,GANG 3:
 103    VARIABLE   (SC25*ST25*100)/(XH26*600)


*                           BOOLEAN VARIABLES

*
*                           BVARIABLE THAT CHANGES AT LUNCH & EVENING BREAK
 16     BVARIABLE  C1'GE'7200*C1'L'7800+C1'GE'10200*C1'L'10800
*
*                           B-VARIABLE THAT GOVERNS CREATION OF TRANSACTI-
*                           ONS FOR THE LOADING GANGS
 15     BVARIABLE  LS10*((BV1'E'K1)+(BV2'E'K1)+(BV3'E'K1))
*
*                           BVARIABLES THAT CONTROL WORK TIME F.LOAD.GANGS
*                           BVARIABLE FOR GANG A HAS # A
 1      BVARIABLE  LR2*W$GAWA1'LE'K1*BV16'E'K0
 2      BVARIABLE  LR3*W$GAWA2'LE'K1*BV16'E'K0
 3      BVARIABLE  LR4*W$GAWA3'LE'K1*BV16'E'K0
*
*                           BVARIABLE THAT CONTROLS OVERTIME WORK,GANG 1-3
 8      BVARIABLE  XH41'GE'K160+V2'E'K0
 9      BVARIABLE  XH42'GE'K200+V2'E'K0
 10     BVARIABLE  XH43'GE'K280+V2'E'K0

*
*                           TRUE WHEN GANG PERFORMANCES RECORDED
 18     BVARIABLE  LS31*LS32*LS33
*
*                           ALL TRUCKS SERVED,ALL CARGO STORED
 19     BVARIABLE  N$GOIN'E'N$EXIT*N$STORE'E'N$STORD*N$NLUNS'E'N$SECRE
*
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7

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*                              BVARIABLES TO CHECK WETHER CARGO FOR A CERTAIN
*                              PORT AND OF A CERTAIN TYPE IS BEING LOADED BY
*                              A CERTAIN GANG. P4 AND P6 CARRY NUMBERS OF
*                              COLUMNS IN LOADING MATRIX TO BE CHECKED,P7 CAR-
*                              RIES VALUE OF V1,EVEN/ODD WEEK #. BV21 IS FOR
*                              THE GANG'S FIRST PORT TO LOAD FOR,AND SO ON.
*                              P1= RCVD CARGO'S TYPE #,P3= RCVD CARGO'S PORT #
*
 21      BVARIABLE   MH*7(1,P4)'E'P3*MH*7(1,P6)'E'P1
 22      BVARIABLE   MH*7(2,P4)'E'P3*MH*7(2,P6)'E'P1
 23      BVARIABLE   MH*7(3,P4)'E'P3*MH*7(3,P6)'E'P1
*
*                              CHECK WETHER CARGO FOR A CERT. PORT IS LOADED
*                              AT ALL
 25      BVARIABLE   BV21'E'K1+BV22'E'K1+BV23'E'K1+BV24'E'K1
*
*

*****                          M A T R I C E S
*
*                              LOADING MATRIX,ODD WEEK NUMBERS
 1       MATRIX      H,4,6
         INITIAL     MH1(1,1-2),3/MH1(1,3),2/MH1(1,4),3/MH1(1,5),2
         INITIAL     MH1(1-2,6),1/MH1(2,1-2),2/MH1(2,3),3/MH1(2,4),2
         INITIAL     MH1(2,5),3/MH1(3,1),1/MH1(3,2),2/MH1(3,3-4),1
         INITIAL     MH1(3,5),6/MH1(3,6),1
*
*                              LOADING MATRIX,EVEN WEEK NUMBERS
 2       MATRIX      H,4,6
         INITIAL     MH2(1,1),5/MH2(1-2,2),3/MH2(1,3),6/MH2(1,4),3
         INITIAL     MH2(1,5),6/MH2(1-2,6),1/MH2(2,1),4/MH2(2,3),5
         INITIAL     MH2(2,4),1/MH2(2,5),4
*
*                              CARGO RECEIVED PR. DAY
 11      MATRIX      H,8,3
*
*                              TOTAL QUANT. OF CARGO ON STORAGE
 12      MATRIX      H,8,3
*
*                              QUANTITY OF CARGO LOADED PR DAY
 13      MATRIX      H,4,9
*
*                              QUANTITY OF CARGO THAT HAS BEEN LOADED
 14      MATRIX      H,4,9
#
*                              CHRONOLOGIC LISTING OF QUEUE CONTENTS
 20      MATRIX      H,6,17
*
*                              CHRONOLOGIC LISTING OF STORAGE CONTENTS
*                              NOTE: IN GPSS "STORAGE" MEANS A SERVICE
*                              FACILITY
 21      MATRIX      X,7,17
*
*

*****                          S A V E V A L U E S
*
*                              # 1 = MAX. NO. OF PLOADS/SLINGS ON APRON,GANG 1
*                              # 2 = MAX. NO. OF PLOADS/SLINGS ON APRON,GANG 2
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*          # 3 = MAX. NO. OF PLOADS/SLINGS ON PLATFORM G.3
*          # 10= FORKLIFTS NOT WORKING IN SHED
*          # 11= NO. OF TRUCKS PR WEEK,PALLETIZED CARGO
*          # 12= NO. OF TRUCKS PR WEEK,LOOSE,GEN. CARGO
*          # 13= NO. OF TRUCKS PR WEEK,OPEN AIR CARGO
*          # 21= TOTAL CARGO RECEIVED DURING THE WEEK,GNG1
*          # 22= TOTAL CARGO RECEIVED DURING THE WEEK,GNG2
*          # 23= TOTAL CARGO RECEIVED DURING THE WEEK,GNG3
*          # 24-26= WORK HOURS ORDINARY TIME,GANG 1-3
*          # 30= WEEKDAY NUMBER TO START LOADING
*          # 31= MAX. NUMBER OF PORTS TO BE LOADED FOR BY
*                ONE GANG
*          # 32= MEAN INTEROCCURENCE TIME,PERSONAL BREAKS
*          # 33= COST PR HOUR RECEIV.& STORING AFTER 8 PM
*          # 41= EXPCT.QUANT.OF CARGO AT END NEXT DAY,G 1
*          # 42= EXPCT.QUANT.OF CARGO AT END NEXT DAY,G 2
*          # 43= EXPCT.QUANT.OF CARGO AT END NEXT DAY,G 3
*          # 50= DAY NUMBER OF SIMULATION
*          # 51= TOTAL NUMBER OF PALLET LOADS RECEIVED DU-
*                RING A PERIOD
*          # 52= TOTAL LTONS OA-CARGO RCVD DURING A PERIOD
*          # 53-60= DIFFERENT RECEIVED COUNTS
*          # 61-69= COST PR 40 CU FT AND/OR LTON RCVD & ST
*          # 71-89= NO OF TRUCK ARRIVALS DURING 1 HOUR
*          # 91-119= NO OF TRUCK DEPARTURES DURING 1 HOUR
*          # 122= HOUR WHEN LAST TR LEAVES OA-STORAGE
*          # 123= 1/10 MINUTES WN LAST TR LVS OA-STORAGE
*          # 124= HOUR WHEN LAST TR LEAVES TERMINAL
*          # 125= 1/10 MINUTES WN LAST TR LEAVES TERMINAL
*          # 130= TOT TNS & PALLETLDS LDED UP TO 5 PM,GN 1
*          # 131-132= TS AND/OR PALLETL. LDED PR GHR,GNG 1
*          # 133= TIME FINISHED,GANG 1
*          # 140= TOT TNS & PALLETLDS LDED UP TO 5 PM,GN 2
*          # 141-142= TS AND/OR PALLETL.LDED PR GNHR,GNG 2
*          # 143= TIME FINISHED LOADING,GANG 2
*          # 150= TOT TNS & PALLETLDS LDED UP TO 5 PM,GN 3
*          # 151-152= TS AND/OR PALLETL.LDED PR GNHR,GNG 3
*          # 153= TIME FINISHED LOADING,GANG 3
*          # 170= TOT. # OF ARRVLS UP TO END OF PRECDNG HR
*          # 190= TOT. # OF DPARTS UP TO END OF PRECDNG HR

*          # 201-202= CUBIC FEET OF DELIVERED CARGO
*          # 203= AVERAGE CU FT PR PALLET,LOOSE & PREPALL
*          # 209= WEEK NUMBER
*          # 210= MEAN CYCLE TIME,LIFT GEAR GANG 1
*          # 211= MEAN CYCLE TIME,LIFT GEAR GANG 2
*          # 212= MEAN CYCLE TIME,FORKLIFT ON BOARD,GANG 3
*          # 213= CYCLE TIME MODIFIER,LIFT GEAR GANG 1
*          # 214= CYCLE TIME MODIFIER,LIFT GEAR GANG 2
*          # 215= STANDARD DEV.,CYCLE TIME,FLIFT ON BOARD
*          # 216= MEAN CYCLE TIME STOWING LOOSE,GANG 1
*          # 217= CYCLE TIME MODIFIER STOWING LOOSE,GANG 1
*          # 218= CYCLE TIME MODIFIER STOWING PREPALL,GN 2
*          # 221-223= INTERMIDIATE RECEIVECOUNTS,GANG 1-3
*          # 301-303= ROW # IN LOADING MATRIX
*          # 311 & 314-316= MEN KNOCKED OFF,STRAGE 1 & 4-6
*          # 321-323= UTILIZATION OF FEEDING FLIFTS,GN 1-3
*          # 331-332= UTILIZATION OF LIFTING GEAR,GN 1-2
*          # 333= UTILIZATION OF FORKLIFT ON BOARD,GANG 3
*
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*
*
*                      I N I T I A L I Z A T I O N S
*
*
*                      MAX 6/3/1 DRAFTS ON APRON/PLATFORM FOR GANG
*                      1/2/3,AND 267/133/100 TRUCKS PR.WEEK:
      INITIAL     XH1,6/XH2,3/XH3,1/XH11,267/XH12,133/XH13,100
*
*                      NOT MORE THAN 3 PORTS PR GANG:
      INITIAL     XH31,K3
*
*                      DEFINE CAPACITIES:
*
*                      S1= PAPER CLERKS, S2= UNLD RAMP,S3= O-A STORAGE
*                      S4= CHECKERS, S5= FLIFTS & DRIVERS, S6= HELPERS
*                      S7= STORAGE SHED
*
      STORAGE     S1,10/S2,28/S3,75000/S4,40/S5,50/S6,20/S7,354500
*
*                      S8-S10= FLIFTS ON QUAY,GANG 1-3; S21,S22= LIFT
*                      GEAR & HOLD GANG,GANG 1; S23,S24= SAME,GANG 2;
*                      S25= FLIFT ON BOARD,GANG 3; S31-S33= SPACE ON
*                      QUAY GANG 1-3
      STORAGE     S8-S9,2/S10,3/S21-S25,1/S31-S33,5

*                      SET CYCLE TIMES & MODIFIER FOR LIFTING GEAR
*                      AND FORKLIFTS ON BOARD
      INITIAL     XH210,24/XH211,20/XH212,14/XH213,10/XH214,5
      INITIAL     XH215,2/XH216,30/XH217,10

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*                         S I M U L A T I O N
*
*                         T I M E R
*
*                         THIS SEQUENCE DETERMINES DAY NUMBER,EVEN OR ODD
*                         WEEK,LUNCH BREAK,AND START & STUP OF WORK
*                         IT ALSO DOES RECORDING OF Q-CONTENTS & STORAGE
*                         UTILIZATION FOR CHRONOLOGICAL STATISTICS,
*                         CALCULATES COST PR TON/PALLETLOAD RCVD.& LDED,&
*                         MAKES ARRIVALS AND DEPART COUNT FOR THE TERMNL.
*
*                         RESET CARDS WILL SEPARATE THE DAYS
*
*                         TIME UNIT= 1/10 MINUTE
       GENERATE    ,,4800,1,10,9,H                START AT 8 AM,1 XACT,
*                                                 TIMERS PRIORITY= 10
*
       ASSIGN      1,K17                          THIS
       ASSIGN      2,K8                               SEQUENCE
       ASSIGN      3,K1                                       LOADS
 INIT1 MSAVEVALUE  20,6,P3,P2,H                   8 TO 24,I.E. FULL HOUR
       ASSIGN      2+,K1                          CLOCK 8AM TO MIDNIGHT,
       ASSIGN      3+,K1                          INTO ROW 6 OF
       LOOP        1,INIT1                        MATRIX H 20
*
       ASSIGN      1,K17                          THIS
       ASSIGN      2,K8                              SEQUENCE
       ASSIGN      3,K1                                       LOADS
 INIT2 MSAVEVALUE  21,7,P3,P2                     8 TO 24,I.E. IJ HOUR
       ASSIGN      2+,K1                          CLOCK 8AM TO MIDNIGHT
       ASSIGN      3+,K1                          INTO ROW 7 OF
       LOOP        1,INIT2                        MATRIX 21
*
       ASSIGN      2,K3                           SET RECEIVED-PR-DAY
 ROW11 ASSIGN      1,K8                           MATRIX=0 BEFORE DAY
 COL11 MSAVEVALUE  11,P1,P2,K0,H                  STARTS
       LOOP        1,COL11
       LOOP        2,ROW11
*
       ASSIGN      1,K4                           SET PR-DAY-LOADED
 COL13 ASSIGN      2,K9                           MATRIX=0 BEFORE DAY
 ROW13 MSAVEVALUE  13,P1,P2,K0,H                  STARTS
       LOOP        2,ROW13
       LOOP        1,COL13
*
       SAVEVALUE   24,K8,H                        8 HOURS ORDINARY
       SAVEVALUE   25,K8,H                        WORKING
       SAVEVALUE   26,K8,H                        TIME
       SAVEVALUE   32,K5,H                        FULL WORK FORCE
       SAVEVALUE   311,K0,H                       NO-
       SAVEVALUE   314,K0,H                       BODY
       SAVEVALUE   315,K0,H                       AT
       SAVEVALUE   316,K0,H                       HOME
       LEAVE       1,S1                           SET STORAGES
       LEAVE       4,S4                           TO
       LEAVE       5,S5                           FULL
       LEAVE       6,S6                           CAPACITY
       SAVEVALUE   301,K1,H                       START LOADING AS
       SAVEVALUE   302,K1,H                       SPECIFIED BY FIRST ROW
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         SAVEVALUE  303,K1,H                                  OF LOADING MATRIX
         SAVEVALUE  201,K0                                    CLEAR X201-X202 OF
         SAVEVALUE  202,K0                                    LAST DAY'S RECORD
*
         LOGIC R    1                                         OPEN THE GATE
         LOGIC R    2                                         ALLOW GANG 1-3 TO CHCK
         LOGIC R    3                                         START OF LOADING DAY
         LOGIC R    4                                         AND FOR CARGO
         SAVEVALUE  50+,K1,H                                  RECORD DAY NUMBER
*
         TEST E     V2,K1,STLD1                               IS 1ST LOADINGDAY REC?
         SAVEVALUE  30,FN$DAY,H                               IF NOT,DO SO
         ASSIGN     1,K4                                      FIRST DAY OF WEEK:
COL14    ASSIGN     2,K9                                      CLEAR
ROW14    MSAVEVALUE 14,P1,P2,K0,H                             TOTAL-LOADED MATRIX
         LOOP       2,ROW14                                   TO ZERO
         LOOP       1,COL14                                   BY LOOPS
         LOGIC S    31                                        SIGNAL: DON'T WAIT FOR
         LOGIC S    32                                        LOADING GANGS ON
         LOGIC S    33                                        FIRST DAY OF WEEK
STLD1    TEST E     XH30,V2,RWEEK                             START LOADING TO DAY?
         LOGIC S    10                                        IF XH30=V2,START
         LOGIC R    31                                        RESET SWITCHES TO SIG-
         LOGIC R    32                                        NAL: CHECK LOADING
         LOGIC R    33                                        GANGS BEFORE CLOSEDOWN
*
*                       CHRONOLOGIC REC OF Q-CONT & STORAGE UTILIZATION
RWEEK    ASSIGN     2,K2                                      P2=COL.2 TO START WITH
         ASSIGN     6,K71                                     P 6= XH#,ARRIVAL COUNT
         ASSIGN     8,K91                                     P 8= XH#,DEPART COUNT
         SAVEVALUE  170,K0,H                                  SET TOTAL ENTRY & EXIT
         SAVEVALUE  190,K0,H                                  COUNTS TO ZERO
AFTNR    ASSIGN     1,K4                                      4 LOOPS FORE & AFTNOON
KRONO    GATE LR    25,GOHOM                                  LOOP AS LONG AS THERE
*                                                             IS WORK GOING ON
         ADVANCE    600                                       1 HR BETWEEN RECORDS
         MSAVEVALUE 20,1,P2,Q1,H                              MTX FOR QUEUES
         MSAVEVALUE 20,2,P2,Q2,H                              ROW # CORRESPONDS
         MSAVEVALUE 20,3,P2,Q3,H                              TO QUEUE #
         MSAVEVALUE 20,4,P2,Q4,H
         MSAVEVALUE 20,5,P2,Q5,H
         SAVEVALUE  P6,V52,H                                  SAVE LAST HR'S ENTR.CT
         SAVEVALUE  P8,V53,H                                  SAVE LAST HR'S DPT.CNT
         SAVEVALUE  170,N$GOIN,H                              SV ARRIVL CNT F NXT HR
         SAVEVALUE  190,N$EXIT,H                              SV EXIT COUNT F NXT HR
         ASSIGN     6+,K1
         ASSIGN     8+,K1
         ASSIGN     4,K6                                      6 LOOPS IN THE LOOP
         ASSIGN     3,K1                                      P3 CARRIES ROW #
         ASSIGN     5,K71                                     P5= # OF VARIABLE
SSTAT    MSAVEVALUE 21,P3,P2,V*5                              V*5=NET ENTR'S OF ST*3
         ASSIGN     3+,K1                                     ROW # CORRESPS TO ST.#
         ASSIGN     5+,K1
         LOOP       4,SSTAT
         ASSIGN     2+,K1                                     INCREAS COL.# BY 1
         LOOP       1,KRONO                                   MAKE THE BIG LOOP
*                                                             C1 LT 10500 MEANS 1ST
         TEST L     C1,10500,OTIME                            OTIME LOOP NOT DONE,IF
         LOGIC I    1                                         SO INVERT GATE
         TEST L     C1,10200,OTIME                            LOOP 1 HR IF PAST 5 PM
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       TEST E       BV16,K1,AFTNR                              4 HR IF NOT NOON
       SPLIT        1,OUTLT                                    OFFSPRING COUNTS EXITS
 OTIME ASSIGN       1,K1                                       ASSIGN FOR
       TRANSFER     ,KRONO                                               1 HR LOOP
*
 OUTLT ADVANCE      3000                                       DELAY EXITCOUNT TO 5PM
       TEST E       N$AIR,N$TROUT                              ALL TRUCKS LEFT OA-ST?
       SAVEVALUE    122,V31,H                                  SAVE DEPART TIME OF
       SAVEVALUE    123,V32,H                                  LAST TRUCK IN OA-ST.
       TEST E       N$GOIN,N$EXIT                              ALL OTHER TRUCKS LEFT?
       SAVEVALUE    124,V31,H                                  SAVE LAST TRUCK'S DE-
       SAVEVALUE    125,V32,H                                  PART TIME
       TEST NE      BV18,K0                                    WAIT TIL PROD IS RCRDD
       LOGIC S      25                                         STOP STASTISTIC ACCOUNT
       TEST E       V2,K0,WEEKD                                IS IT A SAILING DAY?
       LOGIC R      10                                         IF SO,DISMISS GANGS
 WEEKD GATE LS      23                                         WAIT FOR CHRON. RECORD
       GATE LS      24                                         WAIT TIL COSTCALC.FINI
       LOGIC R      23                                         RESET
       LOGIC R      24                                              SWITCHES
       LOGIC R      25                                         FOR NEXT DAY'S RUN
       SAVEVALUE    51,K0,H                                    AND CLEAR SAVEVALUES
       SAVEVALUE    52,K0,H
       TEST LE      XH30,V2,LAST                               ALL LONG DAS EXCPT LST:
       LOGIC R      31                                         RESET LOGIC SWITCHES
       LOGIC R      32                                         FOR NEXT DAY'S
       LOGIC R      33                                         LOADING
 LAST  SAVEVALUE    203,V70,H                                  SAVE AV. CU FT PR PALL
       SAVEVALUE    209,V4,H                                   SV WEEK NUMBER
       TERMINATE    1

 GOHOM LOGIC S      23                                         CLEAR-SIGNAL TO TIMER
       TERMINATE


*
*                            P E R S O N A L   B R E A K S
*
*                            1 TIME UNIT IS EQUAL TO 1/10 OF A MINUTE
*
*                            N*O*T*E:THE FUNCTION,STORG,AND THE MEAN TIME
*                            OF THE GENERATE BLOCK MUST BE CHANGED WHEN THE
*                            CAPACITY OF ST#1 OR ST#4-6 IS ALTERED,AND IF
*                            NEW STORAGES ARE ADDED
*
       GENERATE     XH32,FN$EXPO,4800,,5,1,H
       TEST NE      BV16,K1                                    WAIT WHEN BREAK
       ASSIGN       1,FN$STORG                                 ASSIGN STORAGE NUMBER
       ENTER        P1                                         ENTER ASSIGNED STORAGE
       QUEUE        FN$BREAK                                   ARTIFICL Q'S THAT REC
       QUEUE        5                                          UNOFFICIAL BREAKS
       ADVANCE      FN$PTIME,FN$UFACT                          1 PERSON TAKES A BR.
       TEST NE      BV16,K1                                    ALL LEAVE WHN OFFCL BR
       DEPART       5                                          Q 5 HAS TOTAL,Q-BREAKS
       DEPART       FN$BREAK                                   END
       LEAVE        P1                                         BREAK
       TERMINATE
*
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*                        R E C E I V I N G   C A R G O
*
*                        GENERATE 3 TYPES OF CARGO & ASSIGN QUANTITY
*                        FOR EACH TRUCK
       GENERATE   V11,FN$EXPO,4800,,1,7,H             ARR. OF PALLET CARGO
       TEST LE    C1,10200                            NO ARRIVALS AFTER 5 PM
       ASSIGN     1,K1                                P1=1,PALLET CARGO
       ASSIGN     2,FN$GENQ                           P2=QUANT OF CARGO
       TRANSFER   ,GOIN                               GO TO GATE
*
       GENERATE   V12,FN$EXPO,4800,,1,7,H             ARR.OF LOOSE GEN.CARGO
       TEST LE    C1,10200                            NO ARRIVALS AFTER 5 PM
       ASSIGN     1,K2                                 P1=2,LOOSE CARGO
       ASSIGN     2,FN$LOOSE
       TRANSFER   ,GOIN                               GO TO GATE
*
       GENERATE   V13,FN$EXPO,4800,,1,7,H             ARR. OF OPEN AIR CARGO
       TEST LE    C1,10200                            NO ARRIVALS AFTER 5 PM
       ASSIGN     1,K3                                P1=3,OPEN AIR CARGO
       ASSIGN     2,FN$DRUMS
       TRANSFER   ,GOIN                               GO TO GATE
*
 GOIN  GATE LR    1                                   GATE OPEN AT START
*
*                        DOCUMENT CLEARING SEQUENCE
       QUEU       1                                   TRUCK IS PARKED
       QUEU       2                                   DRIVERS Q FOR
       ENTER      1                                   CLEARING
       DEPART     2                                   CARGO
       ADVANCE    200,100                             DOCUMENTS
       TEST E     BV16,K1,FINIP                       LUNCH OR EVNG BRK? IF
       ADVANCE    600                                 SO,DELAY 1 HR,OTHERWISE
 FINIP LEAVE      1                                   FINISH DOC.CLEARING
*
*                        DETERMIN # OF PALLETS PR. TRUCK
       TEST L     P1,K3,AIR                           REROUTE OPEN AIR CARGO
       TEST GE    V18,K21,FRAC                        HOW LARGE FRCTN.OF UL
       ASSIGN     4,V17                               STORE #UL+FRACN.IN P4
       TRANSFER   ,TYPCK                              TRCK PRCDS TO CK CTYPE
 FRAC  ASSIGN     4,V16                               ST.# UL+OFRCN.INP4
 TYPCK TEST E     P1,K2,UNITS                         REROUTE PREPALLETIZED
*
*                        UNLOAD LOOSE,GENERAL CARGO
       ENTER      2                                   DEMAND RAMP
       DEPART     1                                   LEAVE QUEU
       SEIZE      2                                   DUMMY FAC TO COUNT TR-
       RELEASE    2                                   UCKS WITH LOOSE CARGO
       ADVANCE    150                                 RIGGING TIME LOOSE  C.
       TEST E     BV16,K1,NBRAK
       ADVANCE    600
 NBRAK QUEUE      42
       ENTER      4                                   DEMAND CHECKER
       DEPART     42
 PALL  ADVANCE    130,FN$UNLD                         PUT LOOSE CARG.ON PALL
       PRIORITY   4                                   INCREASE PRIORITY TO 4
       ENTER      5                                   & DEMAND FORKLIFT
       SAVEVALUE  10+,K1,H                            COUNT THE FORKLIFTS
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        ADVANCE     20,FN$UNLD                         FL.BRINGS PL.TO BUFFER
        TEST E      BV16,K1,NOLUN                      LUNCH OR EVNG BRK? IF
        ADVANCE     600                                SO,DELAY FOR 1 HOUR,OR
  NOLUN LEAVE       5                                  RELEASE FORKLIFT
        SAVEVALUE   10-,K1,H                           REDUCE FORKLIFT COUNT
*
        SPLIT       1,BUFF                             INCR.# UL IN BUFF.BY 1
        LOOP        4,PALL                             & CONT.UNT.TR.IS EMPTY
        LEAVE       4                                  RELEASE CHECKER
        LEAVE       2                                  LEAVE RAMP
        SAVEVALUE   202+,P2                            SV NO. OF CU FT
        TRANSFER    ,EXIT                              TRUCK GOES TO EXIT
*
*                       SECURE LOOSE CARGO TO PALLETS IF WANTED
  BUFF  PRIORITY    0                                  PR=0 WHN UL ENTR BUFF
        TEST E      V1,K2,BZONE                        SEC ONLY EVEN WEEKS
  SECRE QUEUE       3                                  WAIT TO BE SECURED
        ENTER       6,2                                DMND.SECURING MEN
        DEPART      3                                  LEAVE QUEUE
        ADVANCE     100                                CARGO IS SEC.TO PALLET
        TEST E      BV16,K1,NLUNS                      CHECK FOR BREAK AGAIN
        ADVANCE     600                                & DELAY IF NECESSARY
  NLUNS LEAVE       6,2                                OR RELEASE SEC. MEN
        ASSIGN      1,K1                               P1=1,=CARGO IS SEC.
*
*                       BUFFER AREA,GEN.CARGO ON PALLETS,SEC. & NOT SEC
  BZONE QUEU        4                                  CARGO WAITING IN BUFF-
        PRIORITY    0                                  ER AREA T B STORED
        TEST E      V1,K1,EVENW                        CHECK WEEK NUMBER
        ASSIGN      3,FN$PTS1                          P3=PORT#,ODD WEEKS,BY-
        TRANSFER    ,CHKDA                             PASS EVEN WEEK ASSIGN
  EVENW ASSIGN      3,FN$PTS2                          P3=PORT #,EVEN WEEKS.
******
*                       CHECK WETHER THE CARGO SHOULD BE TAKEN DIRECTLY
*                       TO THE QUAY. THIS IS ONLY DONE ON SAILING DAYS
*
  CHKDA TEST E      V2,K0,STORE                        SAILING DAY TO DAY?
        TEST L      MH12(P3,P1),K10,STORE              L TH 10 DRAFTS STORED?
        ASSIGN      4,K1                               IS THE CARGO FOR A GNG
        ASSIGN      6,K2                               P4=1,P6=2: TRY GANG 1
        TEST E      BV25,K1,HTCH2                      FIRST,THEN GANG 2
        PRIORITY    2                                  IF CARGO FITS,INCR PR.
        SAVEVALUE   51+,K1,H                           & INCR RCEIVCOUNT BY 1
        MSAVEVALUE  11+,P3,P1,K1,H                     INCREASE DAILY RECEIV-
        MSAVEVALUE  11+,8,P1,K1,H                      ED COUNT BY 1
        TEST LE     W$QUAY1,K0                         QUAY 1 FULL?
        ENTER       5                                  IF NOT,ENG FORKLIFT,&
        DEPART      4                                  LEAVE BUFF.-AREA.FLIFT
  QUAY1 ADVANCE     V20,FN$EXPO                        TAKES PALLET LOAD TO
        TEST E      BV16,K1,BRNT1                      GANG 1. BUT IF BREAK,
        ADVANCE     600                                WAITS TIL IT IS OVER
  BRNT1 ENTER       31                                 PLACE LOAD ON QUAY
        LEAVE       5                                  RELEASE FORKLIFT
        TRANSFER    ,DRCT1                             TRFER.TO LIFTING GEAR.
*
*                       DOES GANG 2 LOAD FOR THIS PORT?
  HTCH2 ASSIGN      4,K3                               CHANGE P-METERS TO
        ASSIGN      6,K4                               FIT GANG 2
        TEST E      BV25,K1,HTCH3
        PRIORITY    2                                  IF CARGO FITS,INCR PR.
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         SAVEVALUE   51+,K1,H                           & INCR RCEIVCOUNT BY 1
         MSAVEVALUE  11+,P3,P1,K1,H
         MSAVEVALUE  11+,8,P1,K1,H
         TEST LE     W$QUAY2,K0
         ENTER       5                                     C Y C L E
         DEPART      4
QUAY2    ADVANCE     V20,FN$EXPO
         TEST E      BV16,K1,BRNT2                          A S   F O R
         ADVANCE     600
BRNT2    ENTER       32
         LEAVE       5
         TRANSFER    ,DRCT2                                      G A N G  1
*
*                        DOES GANG 3 LOAD FOR THIS PORT?
HTCH3    ASSIGN      4,K5                               CHANGE P-METERS TO FIT
         ASSIGN      6,K6                               GANG3. IF CARGO IS NOT
         TEST E      BV25,K1,STORE                      FOR GANG,STORE IT
         PRIORITY    2                                  IF CARGO FITS,INCR PR.
         SAVEVALUE   51+,K1,H                           & INCR RCEIVCOUNT BY 1
         MSAVEVALUE  11+,P3,P1,K1,H
         MSAVEVALUE  11+,8,P1,K1,H
         TEST LE     W$QUAY3,K0
         ENTER       5                                  S A M E
         DEPART      4
QUAY3    ADVANCE     V20,FN$EXPO
         TEST E      BV16,K1,BRNT3                          A S   F O R
         ADVANCE     600
BRNT3    ENTER       33
         LEAVE       5
TOGN3    TRANSFER    ,DRCT3                                      G A N G  1
*****
*                        BRING CARGO INTO THE SHED
STORE    ENTER       5                                  DEMAND FORKLIFT
         ENTER       7,FN$TYPE                          DEMAND STORAGE AREA
         DEPART      4                                  LEAVE BUFFER,AND GO BY
         ADVANCE     V20,FN$MOSHD                       FORKLIFT TO STORAGE
         TEST E      BV16,K1,NONLS                      CHECK FOR BREAK AGAIN
         ADVANCE     600                                DELAY IF NECESSARY,OR
NONLS    LEAVE       5                                  RELEASE FORKLIFT
         LEAVE       7,0                                TRANSACTION LEAVES
*                                                       SHED BUT CARGO NOT
         MSAVEVALUE  12+,P3,P1,K1,H                     ADD 1 PL.TO STORG.MTX
         MSAVEVALUE  12+,8,P1,K1,H                      AND TO ITS TOTAL
         MSAVEVALUE  11+,P3,P1,K1,H                     ADD 1PL.TO DAY MATRIX
         MSAVEVALUE  11+,8,P1,K1,H                      AND TO ITS TOTAL
         SAVEVALUE   51+,K1,H                           INCR.RECEIV.COUNT BY 1
STORD    TERMINATE
*
*                        UNLOAD PREPALLETIZED CARGO
UNITS    ENTER       2                                  TRUCKS W.PREPALL.CARGO
         DEPART      1                                  LEAVE PARKING PLACE
         SEIZE       1                                  DUMMY FACILITY TO COU-
         RELEASE     1                                  NT TRUCKS WITH PALLETS
         ADVANCE     150                                RIGGING TIME PREPALL C
         TEST E      BV16,K1,NOBRK                      IF BREAK,
         ADVANCE     600                                DELAY
NOBRK    QUEUE       41                                 RECORD WAITING TIME
         ENTER       4                                  CHECKER WANTED
         DEPART      41
         ENTER       5                                  ENG FORKLIFT
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          SAVEVALUE  10+,K1,H                     COUNT THE FORKLIFTS
   PPALL  ADVANCE    37,FN$UNLD                   FORKLIFT ENTERS TRUCK
          TEST E     BV16,K1,NOTLS                WHEN BREAK, IT IS
          ADVANCE    600                          DELAYED FOR 1 HOUR,BUT
   NOTLS  SPLIT      1,BZONE                      FLIFT BRINGS OUT PLOAD
          LOOP       4,PPALL                      CONT'S TIL TRUCK=EMPTY
          LEAVE      5                            RELEASE FORKLIFT
          SAVEVALUE  10-,K1,H                     REDUCE FORKLIFT COUNT
          LEAVE      4                            RELEASE CHECKER
          LEAVE      2                            LEAVE RAMP
          SAVEVALUE  201+,P2                      SV NO. OF CU FT
          TRANSFER   ,EXIT                        GO TO EXIT
  *
  *
  *                        UNLOAD CARGO IN THE OPEN AIR STORAGE
   AIR    ENTER      3,V49                        RQUST OPEN AIR STORAGE
          SEIZE      3                            DUMMY FAC TO CNT TRCKS
          RELEASE    3                            WITH CARGO FOR OA-STR.
          JOIN       FN$GROUP                     MARK THE TRUCKS
          DEPART     1                            LEAVE TRUCK LINE
          TEST E     V1,K1,NOODD                  CHECK WEEK NUMBER
          ASSIGN     3,FN$PTS1                    P3=PORT# ODD WEEKS,BY-
          TRANSFER   ,UNLOD                       PASS EVEN WEEKS.ASSIGN
   NOODD  ASSIGN     3,FN$PTS2                    P3=PORT#,EVEN WEEKS.
   UNLOD  QUEUE      43                           RECORD WAITING TIME
          ENTER      4                            ASK FOR CHECKER,THERE-
          DEPART     43
          ENTER      5                            AFTER FOR FORKLIFT
          SAVEVALUE  10+,K1,H                     COUNT THE FORKLIFTS
          PRIORITY   4                            INCR.PRIORITY AND GET
          ENTER      6,2                          2 HELPERS FOR THE UNLD
          ADVANCE    V*1,FN$UNLD                  UNLOAD
          TEST G     C1,7200,LEAVE                IF STILL MORNING,LEAVE
          EXAMINE    1,,NIGHT                     DID U ARRIVE BFR NOON?
          ADVANCE    600                          IF SO,MAKE LUNCH BREAK
          TEST G     C1,10200,LEAVE               PAST 5 PM? IF SO, MAKE
          ADVANCE    600                          ALSO EVENING BREAK
   NIGHT  TEST G     C1,10200,LEAVE               PAST 5 PM? IF YOU ALSO
          EXAMINE    11,,LEAVE                    ARRIVED BEFORE 6 PM,
          ADVANCE    600                          DELAY FOR BREAK
   LEAVE  LEAVE      6,2                          RELEASE HELPERS
          LEAVE      5                            RELEASE FORKLIFT
          SAVEVALUE  10-,K1,H                     REDUCE FORKLIFT COUNT
          LEAVE      4                            RELEASE CHECKER
          MSAVEVALUE 12+,P3,P1,P2,H               ADD 1 TRUCKL.TO ST.MTX
          MSAVEVALUE 12+,8,P1,P2,H                AND TO ITS TOTAL
          MSAVEVALUE 11+,P3,P1,P2,H               ADD 1 TRUCKL.TO DAYMTX
          MSAVEVALUE 11+,8,P1,P2,H                AND TO ITS TOTAL
          SAVEVALUE  52+,P2,H                     INCR RCEIV-C.BY 1 TRLD
   TROUT  LEAVE      3,1000                       TRUCK LEAVES OPEN AIR
   EXIT   TERMINATE                               THROUGH EXIT
  *
  *
```

```
*                         L O A D I N G   T H E   S H I P
*
*                         1 GENERATOR SUPPLIES TRANSACTIONS FOR ALL GANGS
*
       GENERATE   ,,4800,,,7,H                    THE GENERATOR IS STOP-
       TEST E     BV15,K1                         PED IF NO XACT NEEDED
       ASSIGN     7,V1                            EVEN/ODD WEEK # IN P7
       TRANSFER   ALL,GAN3,GAN1,2                 XACTS TO ALL 3 GANGS
 GAN3  TEST E     BV3,K1                          DOES GANG 3 LOAD?IF SO
       TRANSFER   ,GAG3                           SUPPLY XACT
 GAN2  TEST E     BV2,K1                          DITTO FOR
       TRANSFER   ,GAG2                           GANG 2
 GAN1  TEST E     BV1,K1                          AND FOR GANG 1
*
*
*                         GANG # 1
*                         REVOLVING DECK CRANE,CARGO STOWED LOOSE
*
       TEST G     MH*7(1,1),K0,NLD1               IS CARGO SPECIFIED?
*
*                         CALCULATE EXPECTED QUANT. OF CARGO
*
       TEST L     N$DEL1,K1,LOAD1                 XACTS ARE DETOURED TO
*                                                 THE LOADING SIM,EXCEPT
*                                                 THE FIRST ONE WHICH
*                                                 LOADS TOTAL QUANT. ON
*                                                 STORAGE INTO SAVV. 21
*                                                 & DOES OTHR CMPUTATION
*
 DEL1  TEST E     XH30,V2,RIGG1                   IS IT 1ST LOADING DAY?
       SAVEVALUE  21,K0,H                         IF SO SET XH21=0
       ASSIGN     1,K1                            P1= LOOP P-METER FOR
 ADD11 ASSIGN     4,MH*7(P1,1)                    CHCKNG STORAGE MTX. P4
       ASSIGN     6,MH*7(P1,2)                    & P6=PORT/CARGOTYPE #.
       SAVEVALUE  21+,MH12(P4,P6),H               SV STORED CRGO IN XH21
       ASSIGN     1+,K1                           GO ON TO NEXT ROW
       TEST G     MH*7(P1,1),K0,STCK1             ANY CARGO SPECIFIED?
       TRANSFER   ,ADD11                          IF SO,LOOP
 STCK1 TEST E     XH21,K0,RIGG1                   CARGO ON STORAGE? IF
       TEST GE    C1,7800                         NOT,DELAY RIGGING TO 1PM
 RIGG1 ENTER      21                              ENG. LIFT GEAR. DELAYS
       ADVANCE    FN$PTIME                        IN START= UNOFF BREAK
       ADVANCE    50                              RIGGS CRANE
       LEAVE      21                              RELEASES CRANE
       SAVEVALUE  10-,K2,H                        2 MORE FLIFTS IN SHED
       ASSIGN     2,XH31                          P2= MAX. NO. OF PORTS
 RCPT1 MSAVEVALUE 13,P2,2,MH*7(P2,1),H            SAVE PORT # AND CARGO
       MSAVEVALUE 13,P2,3,MH*7(P2,2),H            TYPE # IN LDING MX.LO-
       MSAVEVALUE 14,P2,2,MH*7(P2,1),H
       MSAVEVALUE 14,P2,3,MH*7(P2,2),H
       LOOP       2,RCPT1                         OP UNTL.ALL PORTS REC.
 UPDT1 TEST GE    C1,10200                        WAITS TIL 5 PM
       SAVEVALUE  221,XH21,H                      SV MORNING VAL.OF XH21
       ASSIGN     1,K1                            PREPARE LOOP
 ADD12 ASSIGN     4,MH*7(P1,1)                    TO ADD CARGO
       ASSIGN     6,MH*7(P1,2)                    RECEIVED
       SAVEVALUE  21+,MH11(P4,P6),H               DURING THE DAY.
       ASSIGN     1+,K1
```

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         TEST G        MH*7(P1,1),K0,ENDY1
         TRANSFER      ,ADD12
ENDY1    TEST L        C1,10800,CLER1            IF UPDATE DONE, END.
         LOGIC S       2                         STOP LOADING
         SAVEVALUE     41,V41,H                  EXP QUANT NXT DAY 5 PM
         SAVEVALUE     41-,MH14(4,1),H           SUBTR CARGO LOADED
         SAVEVALUE     130,SC22,H                SV # OF PL & TS LOADED
         SAVEVALUE     131,V61,H                 SV TON+PALLET PR GNGHR
         SAVEVALUE     321,V91,H                 SV FLIFT UTILIZATION
         SAVEVALUE     331,V101,H                AND LIFTGEAR UTIL.
         ADVANCE       600                       5-6 BREAK
*
*                           OVERTIME CONTROL
*
         TEST E        BV8,K1,QUIT1              SHALL WE LOAD, IF SO
         LOGIC R       2                         ALLOW LOADING IF CARGO
         TEST GE       C1,12000                  WAIT ITL 8 PM
         TEST E        V2,K0,NOSL1               SAILING DAY? IF SO:
         TEST E        BV19,K1                   TERMINAL CLEAR?
         TEST E        V81,K0                    ALL CARGO ON BOARD?
         QUEUE         21                        WAIT FOR LIFTING GEAR
         ENTER         21                        ENG.LIFTING GEAR.
         DEPART        21
         ADVANCE       100                       ALLOW 10 MI TO GET EQ-
*                                                IPMENT ASHORE
         LEAVE         21                        RELEASE CRANE
NOSL1    SAVEVALUE     133,V64,H                 WN FINI,SV NXT HOUR A-
         SAVEVALUE     132,V67,H                 ND LOADING CAPACITY
         LOGIC S       2                         DISMISS GANG
QUIT1    SAVEVALUE     10+,K2,H                  FEEDNG FLIFTS STP WORK
         TEST E        BV19,K1                   WAIT TIL ALL CRGO STRD
         SAVEVALUE     21,XH221,H                SET XH21 BACK TO MORNG
         TRANSFER      ,UPDT1                    GO BACK AND UPDATE XH21
CLER1    LOGIC S       31                        CLEAR SIGNAL TO TIMER
         TERMINATE
*
*                           LOADING
*
*                           CHECK FIRST PORT TO LOAD FOR
*
LOAD1    ASSIGN        2,XH301                   P2=1; START IN ROW 1
         ASSIGN        4,MH*7(P2,1)              LOADING MTX,P4= PORT #
         ASSIGN        1,MH*7(P2,2)              P1= CARGO TYPE #,CHECK
         TEST G        MH12(P4,P1),K0,NXPT1      IF CARGO IS ON STORAGE
         LEAVE         FN$STRIN,FN$TYPE          RDUCE OCCUPIED SPACE
         MSAVEVALUE    12-,P4,P1,K1,H            REDUCE STORED QUANT BY
GAWA1    MSAVEVALUE    12-,8,P1,K1,H             1,AND TOTAL BY 1.
*
*                           LOAD
*

         TEST L        Q21,XH1                   ROOM UNDER LIFTTACKLE?
         ENTER         8                         ENGAGE FORKLIFT
         ADVANCE       V21,V22                   BRING FORTH A HEAVE
         LEAVE         8                         RELEASE THE FORKLIFT
         QUEUE         21
DRCT1    TEST E        W$UNH11,K0                ROOM TO LAND THE HEAVE
         ENTER         21                        ENG LIFTING GEAR
*                                                PR=2 MEANS THAT THE
*                                                CARGO IS LOADED DIRECT
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*                                              LY FROM BUFFER AT RAMP
        TEST NE     PR,K2,DICT1                IF SO DON'T DEPART Q21
        TEST NE     BV16,K1                    WAIT IF BREAK
        DEPART      21
        TRANSFER    ,OSHD1                     DIRECT CARGO LEAVES
  DICT1 LEAVE       31                         QUAY= ST 31
  OSHD1 ADVANCE     FN$EMPTY,FN$EMTMO          RETURN OF EMPTIES?
        ADVANCE     XH210,XH213                UP IT GOES
        TEST E      W$UNH11,K0                 ROOM TO LAND THE HEAVE
  UNH11 LEAVE       21                         IF SO,RELEASE GEAR
        ENTER       22                         ENG GANG TO STOW
        ADVANCE     V25,V26                    THE CARGO
        ADVANCE     XH216,FN$DELAY             ANY DELAY
        LEAVE       22                         RELEASE GANG
        MSAVEVALUE  13+,P2,1,K1,H              ADD 1 LOAD TO SHIP MTX
        MSAVEVALUE  14+,P2,1,K1,H              AND TO CUMMUL. SHP MTX
        MSAVEVALUE  13+,4,1,K1,H               AND TO
        MSAVEVALUE  14+,4,1,K1,H               THEIR TOTALS
  ONBD1 TERMINATE
*
*
  NXPT1 ASSIGN      2+,K1                      INCREASE P2 BY 1 TO CK
        TEST G      MH*7(P2,1),K0,NLD1         NXT ROW OF LOADING MTX
        SAVEVALUE   301+,K1,H                  INCR XH301 BY 1 IF
        TERMINATE                              CARGO IS SPECIFIED
*
*
*                       SEQUENCE THAT CONTROLS LOADING FROM SHED
*
  NLD1  LOGIC S     2                          NO START IF NO CRGO SP
        TEST G      MH*7(1,1),K0,WAIT1
        TEST E      SC22,K0,RORG1              IF NO CARGO ON STORAGE
        SAVEVALUE   24,K4,H                    IN START,SET WORKT=4HR
        TEST GE     C1,7500                    WAIT UNTIL 030 PM AND
  RORG1 ADVANCE     300                        WAIT HALF AN HOUR,STA-
        SAVEVALUE   301,K1,H                   RT SCAN AT FIRST SPEC.
        TEST L      C1,12000,SAIL1             PORT UNTIL 8 PM
        LOGIC R     2                          START SCAN
  WAIT1 TERMINATE
  SAIL1 TEST E      V2,K0,WAIT1
        TEST E      N$OPEN1,K0,WAIT1           SCAN ONCE AFTR 8 PM ON
  OPEN1 LOGIC R     2                          SAILING DAYS
        TERMINATE


*                       GANG # 2
*                       DERRICKS IN UNION PURCHASE,PALLETIZED CARGO
  GAG2  TEST G      MH*7(1,3),K0,NLD2
*
*                       CALCULATE EXPECTED QUANT OF CARGO
*
        TEST L      N$DEL2,K1,LOAD2
  DEL2  TEST E      XH30,V2,RIGG2
        SAVEVALUE   22,K0,H
        ASSIGN      1,K1
  ADD21 ASSIGN      4,MH*7(P1,3)
        ASSIGN      6,MH*7(P1,4)               GANG 2 IS PROGRAMMED
        SAVEVALUE   22+,MH12(P4,P6),H          ALMOST IDENTICALLY TO
        ASSIGN      1+,K1                      GANG 1. COMMENTS ONLY
        TEST G      MH*7(P1,3),K0,STCK2        WHEN DIFFERENCES
```

20

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         TRANSFER    ,ADD21
STCK2    TEST E      XH22,K0,RIGG2
         TEST GE     C1,7800
RIGG2    ENTER       23
         ADVANCE     FN$PTIME
         ADVANCE     150,50
         ADVANCE     50                          LIFT A FORKLIFT ON BRD
         LEAVE       23
         SAVEVALUE   10-,K2,H
         ASSIGN      2,XH31
RCPT2    MSAVEVALUE  13,P2,5,MH*7(P2,3),H
         MSAVEVALUE  13,P2,6,MH*7(P2,4),H
         MSAVEVALUE  14,P2,5,MH*7(P2,3),H
         MSAVEVALUE  14,P2,6,MH*7(P2,4),H
         LOOP        2,RCPT2
UPDT2    TEST GE     C1,10200
         SAVEVALUE   222,XH22,H
         ASSIGN      1,K1
ADD22    ASSIGN      4,MH*7(P1,3)
         ASSIGN      6,MH*7(P1,4)
         SAVEVALUE   22+,MH11(P4,P6),H
         ASSIGN      1+,K1
         TEST G      MH*7(P1,3),K0,ENDY2
         TRANSFER    ,ADD22
ENDY2    TEST L      C1,10800,CLER2
         LOGIC S     3
         SAVEVALUE   42,V42,H
         SAVEVALUE   42-,MH14(4,4),H
         SAVEVALUE   140,SC24,H
         SAVEVALUE   141,V62,H
         SAVEVALUE   322,V92,H
         SAVEVALUE   332,V102,H
         ADVANCE     600
*
*                           OVERTIME CONTROL
*
         TEST E      BV9,K1,QUIT2
         LOGIC R     3
         TEST GE     C1,12000
         TEST E      V2,K0,NOSL2
         TEST E      BV19,K1
         TEST E      V82,K0
         QUEUE       22
         ENTER       23
         DEPART      22
         ADVANCE     100                         TAKE FORKLIFT ASHORE
         LEAVE       23
NOSL2    SAVEVALUE   143,V64,H
         SAVEVALUE   142,V68,H
         LOGIC S     3
QUIT2    SAVEVALUE   10+,K2,H
         TEST E      BV19,K1
         SAVEVALUE   22,XH222,H
         TRANSFER    ,UPDT2
CLER2    LOGIC S     32
         TERMINATE
*
*                           LOADING
*                           CHECK FIRST PORT
*
```

```
LOAD2  ASSIGN      2,XH302
       ASSIGN      4,MH*7(P2,3)
       ASSIGN      1,MH*7(P2,4)
       TEST G      MH12(P4,P1),K0,NXPT2
       LEAVE       FN$STRIN,FN$TYPE
       MSAVEVALUE  12-,P4,P1,K1,H
GAWA2  MSAVEVALUE  12-,8,P1,K1,H
*
*                          LOAD
*
       TEST L      Q22,XH2
       ENTER       9
       ADVANCE     V23,V24                          MIDDLE OF SHED GANG
       LEAVE       9
       QUEUE       22
DRCT2  TEST E      W$UNH21,K0
       ENTER       23
       TEST NE     PR,K2,DICT2
       TEST NE     BV16,K1
       DEPART      22
       TRANSFER    ,OSHD2
DICT2  LEAVE       32
OSHD2  ADVANCE     FN$EMPTY,FN$EMTMO
       ADVANCE     XH211,XH214
UNH21  LEAVE       23
       ENTER       24
       ADVANCE     XH211,XH218
       ADVANCE     XH211,FN$DELAY
       LEAVE       24
       MSAVEVALUE  13+,P2,4,K1,H
       MSAVEVALUE  14+,P2,4,K1,H
       MSAVEVALUE  13+,4,4,K1,H
       MSAVEVALUE  14+,4,4,K1,H
ONBD2  TERMINATE
*
NXPT2  ASSIGN      2+,K1
       TEST G      MH*7(P2,3),K0,NLD2
       SAVEVALUE   302+,K1,H
       TERMINATE
*
*                          SEQUENCE THAT CONTROLS LOADING FROM SHED
*
NLD2   LOGIC S     3
       TEST G      MH*7(1,3),K0,WAIT2
       TEST E      SC24,K0,RORG2
       SAVEVALUE   25,K4,H
       TEST GE     C1,7500
RORG2  ADVANCE     300
       SAVEVALUE   302,K1,H
       TEST L      C1,12000,SAIL2
       LOGIC R     3
WAIT2  TERMINATE
SAIL2  TEST E      V2,K0,WAIT2
       TEST E      N$OPEN2,K0,WAIT2
OPEN2  LOGIC R     3
       TERMINATE
*
*
*                          GANG # 3
*                          SIDE DOOR
```

22

```
*
 GAG3   TEST G       MH*7(1,5),K0,NLD3
*
*                               CALCULATE EXPECTED QUANTITY OF CARGO
*
        TEST L       N$DEL3,K1,LOAD3
 DEL3   TEST E       XH30,V2,RIGG3                      S A M E
        SAVEVALUE    23,K0,H
        ASSIGN       1,K1                                    C O M M E N T S
 ADD31  ASSIGN       4,MH*7(P1,5)
        ASSIGN       6,MH*7(P1,6)                       AS FOR GANG NUMBER 2
        SAVEVALUE    23+,MH12(P4,P6),H
        ASSIGN       1+,K1
        TEST G       MH*7(P1,5),K0,STCK3
        TRANSFER     ,ADD31
 STCK3  TEST E       XH23,K0,RIGG3
        TEST GE      C1,7800
 RIGG3  ENTER        25
        ADVANCE      FN$PTIME
        ADVANCE      50
        LEAVE        25
        SAVEVALUE    10-,K3,H
        ASSIGN       2,XH31
 RCPT3  MSAVEVALUE   13,P2,8,MH*7(P2,5),H
        MSAVEVALUE   13,P2,9,MH*7(P2,6),H
        MSAVEVALUE   14,P2,8,MH*7(P2,5),H
        MSAVEVALUE   14,P2,9,MH*7(P2,6),H
        LOOP         2,RCPT3
 UPDT3  TEST GE      C1,10200
        SAVEVALUE    223,XH23,H
        ASSIGN       1,K1
 ADD32  ASSIGN       4,MH*7(P1,5)
        ASSIGN       6,MH*7(P1,6)
        SAVEVALUE    23+,MH11(P4,P6),H
        ASSIGN       1+,K1
        TEST G       MH*7(P1,5),K0,ENDY3
        TRANSFER     ,ADD32
 ENDY3  TEST L       C1,10800,CLER3
        LOGIC S      4
        SAVEVALUE    43,V43,H
        SAVEVALUE    43-,MH14(4,7),H
        SAVEVALUE    150,SC25,H
        SAVEVALUE    151,V63,H
        SAVEVALUE    323,V93,H
        SAVEVALUE    333,V103,H
*
        ADVANCE      600
*                               OVERTIME CONTROL
*
        TEST E       BV10,K1,QUIT3
        LOGIC R      4
        TEST GE      C1,12000
        TEST E       V2,K0,NOSL3
        TEST E       BV19,K1
        TEST E       V83,K0
        TEST E       W$TOGN3,K0
        ADVANCE      100                                PARK ONBOARD FORKLIFT
 NOSL3  SAVEVALUE    153,V64,H
        SAVEVALUE    152,V69,H
        LOGIC S      4
```

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 QUIT3 SAVEVALUE  10+,K3,H
       TEST E     BV19,K1
       SAVEVALUE  23,XH223,H
       TRANSFER   ,UPDT3
 CLER3 LOGIC S    33
       TERMINATE
*
*                          LOADING
*                          CHECK FIRST PORT
*
 LOAD3 ASSIGN     2,XH303
       ASSIGN     4,MH*7(P2,5)
       ASSIGN     1,MH*7(P2,6)
       TEST G     MH12(P4,P1),K0,NXPT3
       LEAVE      FN$STRIN,FN$TYPE
       MSAVEVALUE 12-,P4,P1,K1,H
 GAWA3 MSAVEVALUE 12-,8,P1,K1,H
*
*                          LOAD
*
       TEST L     Q23,XH3
       ENTER      10
       ADVANCE    V21,V22                       END OF SHED GANG
       LEAVE      10
       QUEUE      23
 DRCT3 ENTER      25
       TEST NE    PR,K2,DICT3
       TEST NE    BV16,K1
       DEPART     23
       TRANSFER   ,OSHD3
 DICT3 LEAVE      33                            NO RETURN OF EMPTIES
 OSHD3 ADVANCE    V80                           FORKLIFT STOWING
       ADVANCE    10,FN$DELAY
       LEAVE      25
       MSAVEVALUE 13+,P2,7,K1,H
       MSAVEVALUE 14+,P2,7,K1,H
       MSAVEVALUE 13+,4,7,K1,H
       MSAVEVALUE 14+,4,7,K1,H
 ONBD3 TERMINATE
*
 NXPT3 ASSIGN     2+,K1
       TEST G     MH*7(P2,5),K0,NLD3
       SAVEVALUE  303+,K1,H
       TERMINATE

*                          SEQUENCE THAT CONTROLS LOADING FROM SHED
*
 NLD3  LOGIC S    4
       TEST G     MH*7(1,5),K0,WAIT3
       TEST E     SC25,K0,RORG3
       SAVEVALUE  26,K4,H
       TEST GE    C1,7500
 RORG3 ADVANCE    300
       SAVEVALUE  303,K1,H
       TEST L     C1,12000,SAIL3
       LOGIC R    4
 WAIT3 TERMINATE
 SAIL3 TEST E     V2,K0,WAIT3
       TEST E     N$OPEN3,K0,WAIT3
 OPEN3 LOGIC R    4
```

```
      TERMINATE
*
*
*
*
*
*                          COST CALCULATOR
      GENERATE   ,,7200,1,,1,H                     START AT 12 NOON
      SAVEVALUE  61,V50,H                          SAVE COST/UNIT,MORNING
      SAVEVALUE  53,XH51,H                         SAVE QUANTITY OF CARGO
      SAVEVALUE  54,XH52,H                         RECEIVED BEFORE NOON
      SAVEVALUE  51,K0,H                           SET XH51 AND
      SAVEVALUE  52,K0,H                           XH52 BACK TO ZERO
      ADVANCE    3000                              WAIT TIL 5 PM
      SAVEVALUE  62,V50,H                          SAVE COST/UNIT,ANOON
      SAVEVALUE  55,XH51,H                         & RECEIVED CARGO
      SAVEVALUE  56,XH52,H
      ASSIGN     1,K63                             STORE NEXT XH# IN P1
MORE  GATE LR    25,CLEAR                          STILL WORKING?
      SAVEVALUE  51,K0,H                           SET XH51 AND
      SAVEVALUE  52,K0,H                           XH52 BACK TO ZERO
      ADVANCE    600                               WAIT 1 HOUR
      SAVEVALUE  P1,V51,H                          ST. COST IN XH*1
      SAVEVALUE  57+,XH51,H                        & QUANTITY RECEIVED
      SAVEVALUE  58+,XH52,H
      ASSIGN     1+,K1                             INCREASE P1 BY 1
      TEST GE    C1,12000,MORE                     IS IT 8 PM,
AFTR8 GATE LR    25,CLEAR                          STILL WORKING
      SAVEVALUE  311+,R1,H                         SEND MEN
      SAVEVALUE  314+,R4,H                         NOT NEEDED
      SAVEVALUE  315+,V59,H                        FOR FURTHER WORK
      SAVEVALUE  316+,R6,H                         HOME,
      ENTER      1,R1                              AND
      ENTER      4,R4                              REDUCE
      ENTER      5,V59                             CAPACITY
      ENTER      6,R6                              CORRESPONDIGNLY
      SAVEVALUE  33,V54                            SAVE NEW HOURLY COST
      SAVEVALUE  32,V34,H                          & NEW M-TIME BTW PBRKS
      SAVEVALUE  51,K0,H                           SET XH51 AND
      SAVEVALUE  52,K0,H                           XH52 BACK TO ZERO
      ADVANCE    600                               WAIT 1 HOUR
      SAVEVALUE  57+,XH51,H
      SAVEVALUE  58+,XH52,H
      SAVEVALUE  P1,V55,H                          SAVE COST PR TON/PALLL
      ASSIGN     1+,K1                             INCREASE P1 BY 1
      TRANSFER   ,AFTR8                            REPEAT
CLEAR LOGIC S    24                                CLEAR-SIGNAL TO TIMER
      TERMINATE
*
*



      START      1
```

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      REPORT
*                                      E D I T E D   O U T P U T
*                                      * * * * * *   * * * * * *
*
*                                            JUNE 12. 1970
      SPACE       3
 26   TEXT        RESULT OF SIMULATING CUMULATIVE DAY NO.: #XH50,2/XX#
      SPACE       1
 54   TEXT        WEEK NUMBER: #XH209,2/XX#
      EJECT
      GRAPH       XH,70,85
      ORIGIN      45,7
      X           ,2,5,,,,NO
      Y           0,5,8,5
 14   STATEMENT   46,113,8      9      10      11      12      13      14   1
  15    16     17      18     19     20      21      22      23      24
 43   STATEMENT   49,39,GRAPH OF ARRIVALS DURING PRECEDING HOUR
 50   STATEMENT   51,25,TIME SCALE: 24 HOUR CLOCK
      ENDGRAPH
      SPACE       3
 45   TEXT        TOTAL NUMBER OF TRUCKS ARRIVED #XH170,2/XXX#
      SPACE       1
 47   TEXT        PREPALLETIZED CARGO ON #F1,3/XX# TRUCKS
 47   TEXT        LOOSE,GENERAL CARGO ON #F2,3/XX# TRUCKS
 47   TEXT        AND #F3,3/XX# TRUCKS WITH CARGO FOR THE OPEN AIR STORC
AGE
      EJECT
      GRAPH       XH,90,105
      ORIGIN      45,7
      X           ,2,5,,,,NO
      Y           0,5,8,5
 14   STATEMENT   46,113,8      9      10      11      12      13      14   1
  15    16     17      18     19     20      21      22      23      24
 41   STATEMENT   49,42,GRAPH OF DEPARTURES DURING PRECEDING HOUR
 49   STATEMENT   51,25,TIME SCALE: 24 HOUR CLOCK
      ENDGRAPH
      SPACE       3
 33   TEXT        THE LAST TRUCK LEFT THE TERMINAL AT #XH125,2/1LXX.X# C
MINUTES AFTER #XH124,2/XX# PM
      SPACE       1
 33   TEXT        IN THE OPEN AIR STORAGE THE LAST TRUCK WAS FINISHED AC
T #XH123,2/1LXX.X# MINUTES AFTER #XH122,2/XX# PM
      EJECT
 MHSA TITLE       20,CONTENTS OF QUEUES AT EACH FULL HOUR:
      SPACE       1
*       ROW 1= TRUCKS PARKED, ROW 2= DRIVERS WAITING TO CLEAR DOCUMENTC
S, R 3= PALLETS TO BE SECURED, R 4= PALLET LOADS TO BE STORED
*       R 5= TOTAL NO. OF MEN HAVING TAKEN AN UNOFFICIAL BREAK,ROW 6= C
24 HOUR CLOCK
      SPACE       3
 MSAV TITLE       21,PERSONEL AND EQUIPMENT WORKING AT EACH FULL HOUR:
      SPACE       1
*       ROW 1= DRIVERS CLEARING DOCUMENTS, ROW 2= TRUCKS UNLOADNG AT  C
RAMP, R 3= SQFT OCCUPIED BY TRUCKS & CARGO IN OPEN AIR STORAGE,
*       R 4= CHECKERS CHECKING CARGO, R 5= FORKLIFTS WORKING, R 6= HELC
PERS UNLOADING FROM TRUCKS AND/OR SECURING CARGO, ROW 7= 24
*       HOUR CLOCK
      EJECT
 MHSA TITLE       11,CARGO RECEIVED DURING THE DAY BY PORT # AND TYPE:
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2

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         SPACE       1
*ROW # CORRESPONDS TO PORT # EXCEPT FOR ROW 8 WHICH CONTAINS TOTALS
*COL.1= PALLETIZED, COL.2= LOOSE,GENERAL, BOTH BY NUMBER OF PALLET LOADC
S, COL.3= CARGO IN THE OPEN AIR STORAGE BY LONGTONS
         SPACE       1
*WHEN COL.2= 0, ALL LOOSE,GENERAL CARGO HAS BEEN SECURED TO THE PALLETS
 2       TEXT        THE PALLET LOADS MAKE #X201,2/XXXXX# CU FT PREPALLETIC
ZED AND #X202,2/XXXXX# CU FT RECEIVED AS LOOSE,GEN.CARGO
         SPACE       1
         SPACE       3
 MHSA    TITLE       12,TOTAL CARGO ON STORAGE AT END OF WORK DAY:
         SPACE       1
*ROWS AND COLUMNS ARE RELATED TO PORT # AND CARGO TYPE AS ABOVE,QUANTITC
IES IN PALLET LOADS AND LONGTONS RESP.
         SPACE       3
 2       TEXT        AT NOON #XH53,2/XXX# PALLET LOADS LOOSE AND PREPALL. C
GENERAL CARGO AND #XH54,2/XXX# LTS FOR THE OPEN AIR ST.HAD BEEN RCVD
 2       TEXT        THE AVERAGE COST PR 40 CUFT/1 LT: #XH61,2/2LXX.XX# $
         SPACE       2
 2       TEXT        FROM 1 TO 5 PM RESPECTIVELY #XH55,2/XXX# PALLETLOADS C
AND #XH56,2/XXX# TONS WERE RECEIVED
 2       TEXT        THE AVERAGE COST PR 40 CUFT/1 LT: #XH62,2/2LXX.XX# $
         SPACE       2
 2       TEXT        TRUCKS THAT HAD ENTERED BEFORE 5 PM WERE UNLOADED ON C
OVERTIME: #XH57,2/XXX# PALLETLOADS AND #XH58,2/XXX# LONGTONS
*THE OVERTIME COST PR 40 CU FT/1 LT MAY B READ FRM THE FOLLOWING GRAPH:
         EJECT
         GRAPH       XH,63,69
         ORIGIN      51,7
         X           ,2,5,,,,NO
         Y           0,100,10,5
 13      STATEMENT   52,44,18       19       20       21       22       23       24
 13      STATEMENT   55,109,COST IN CENT PR 40 CU FT AND/OR 1 LTON UNLOADE1
D FROM TRUCKS AND STORED ON OVERTIME DURING THE PRECEDING HOUR
 55      STATEMENT   57,25,TIME SCALE: 24 HOUR CLOCK
 13      STATEMENT   58,85,REMAINING PERSONEL WAS PAID OVERTIME UP TO LAST1
 TIME FOR WHICH COST FIGURE IS GRAPHED
         ENDGRAPH
         SPACE       2
 2       TEXT        ALL THE ABOVE COST FIGURES ASSUME 100 CU FT PR PALL,TC
HE EXACT NUMBER IS #XH203,2/XXX# CU FT IN AVERAGE FOR WHOLE DAY
         EJECT
 MHSA    TITLE       13,CARGO LOADED TO DAY BY PALLET LOADS & LONGTONS:
         SPACE       1
*COL. 1-3 ARE FOR GANG 1, C4-6 FOR G 2, C 7-9 FOR G 3. ROW 1 HAS BEEN SD
TOWED IN LOWER TIERS, ROW 2 ON TOP OF IT, AND SO ON
* N O T E : THE FOURTH ROW CONTAINS THE TOTALS
         SPACE       1
*COLUMN 1,4 AND 7 = QUANTITY, COL.2,5,8 = PORT #, COL.3,6,9 = CARGO TYPC
E; 1 MEANS PREPALL, 2= LOOSE GEN, 3= CARGO FROM OPEN AIR ST.
         SPACE       3
 MHSA    TITLE       14,TOTAL CARGO LOADED,BY PALLET LOADS AND LONGTON:
         SPACE       1
*ROWS AND COLUMNS CARRY THE SAME INFORMATION AS ABOVE
         SPACE       3
*ON ORDINARY TIME THE LOADING CAPACITY WAS:
 43      TEXT        GANG 1 #XH131,2/2LXX.XX# PALLET LOADS AND/OR LT PR HR
 43      TEXT        GANG 2 #XH141,2/2LXX.XX# PALLET LOADS AND/OR LT PR HR
 43      TEXT        GANG 3 #XH151,2/2LXX.XX# PALLET LOADS AND/OR LT PR HR
         SPACE       3
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*THE GANGS WORKED OVERTIME UNTIL:
 35     TEXT        GANG 1 #XH133,2/XX# ON 24 HR CLOCK
 35     TEXT        GANG 2 #XH143,2/XX# ON 24 HR CLOCK
 35     TEXT        GANG 3 #XH153,2/XX# ON 24 HR CLOCK
        SPACE       1
*NO ENTRY FOR A GANG MEANS THAT THE GANG DID NOT WORK OVERTIME
        SPACE       2
*THE OVERTIME LOADING STARTED AT 6 PM,THE CAPACITY PR GANG HOUR WAS:
 68     TEXT        GANG 1 #XH132,2/2LXX.XX# LT AND/OR PALLET LOADS
 68     TEXT        GANG 2 #XH142,2/2LXX.XX# LT AND/OR PALLET LOADS
 68     TEXT        GANG 3 #XH152,2/2LXX.XX# LT AND/OR PALLET LOADS
        EJECT
*THE AVERAGE UTILIZATION OF GANGS' EQUIPMENT DURING  O R D I N A R Y  TC
IME WAS:
*FORKLIFTS BRINGING CARGO TO APRON:
 36     TEXT        GANG 1 #XH321,2/XX# %
 36     TEXT        GANG 2 #XH322,2/XX# %
 36     TEXT        GANG 3 #XH323,2/XX# %
*LIFTING GEAR:
 15     TEXT        GANG 1 #XH331,2/XX# %
 15     TEXT        GANG 2 #XH332,2/XX# %
*FORKLIFT STOWING FROM SIDEDOOR:
 33     TEXT        GANG 3 #XH333,2/XX# %
        SPACE       3
        EJECT
*UNOFFICIAL BREAKS WHERE DISTRIBUTED AS FOLLOWS:
 49     TEXT        10 PAPER CLERKS HAD #Q11,4/XXX# BREAKS OF AVERAGE LENC
GTH #Q11,7/1LXX.X# MINUTES
 49     TEXT        40 CHECKERS HAD #Q14,4/XXX# BREAKS OF AVERAGE LENGTH C
#Q14,7/1LXX.X# MINUTES
 49     TEXT        50 FORKLIFT DRIVERS HAD #Q15,4/XXX#  BREAKS OF AVERAGC
E LENGTH #Q15,7/1LXX.X# MINUTES
 49     TEXT        20 HELPERS HAD #Q16,4/XXX# BREAKS OF #Q16,7/1LXX.X# MC
INUTES AVERAGE LENGTH
        SPACE       3
*THE TRUCKS WERE WAITING FOR CHECKERS AN AVERAGE TIME AS FOLLOWS:
 66     TEXT        PREPALLETIZED #Q41,7/1LXX.X# MINUTES
 66     TEXT        LOOSE,GENERAL #Q42,7/1LXX.X# MINUTES
 66     TEXT        IN THE O-A ST. #Q43,7/1LXX.X# MINUTES
        EJECT
        END
$SIGNOFF
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APPENDIX III

QUEUES

Q - NUMBER	SIMULATES
1	Trucks' waiting line
2	Drivers waiting to clear documents
3	Cargo waiting to be secured to pallet
4	Cargo on pallets waiting to be stored
5	Total number of men making unofficial breaks
11	Paper clerks making unofficial breaks
14	Checkers making unofficial breaks
15	Forklift drivers making unofficial breaks
16	Helpers making unofficial breaks
21	Heaves waiting to be lifted on board, gang 1
22	Heaves waiting to be lifted on board, gang 2
23	Pallet loads on sidedoor platform, gang 3
41	Trucks with pallet cargo waiting for checker
42	Trucks with loose general cargo waiting for checker
43	Trucks with cargo for the open-air storage waiting for checker

APPENDIX IV

STORAGES

STORAGE NUMBER	CAPACITY	SIMULATES
1	10	Clerks for document clearing
2	28	Unloading ramp
3	75,000	Area of open-air storage in sq.ft.
4	40	Checkers
5	50	Drivers and forklifts
6	20	Helpers
7	345,500	Square footage of storing space in shed
8	2	Forklifts on quay, gang 1
9	2	Forklifts on quay, gang 2
10	3	Forklifts on quay, gang 3
21	1	Lifting gear, gang 1
22	1	Stowing gang, gang 1
23	1	Lifting gear, gang 2
24	1	Stowing gang, gang 2
25	1	Forklift on board, gang 3