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SYSTEMS ANALYSIS AND NEW SYSTEM DESIGN
of
SPARE PARTS INVENTORY CONTROL SYSTEM
for
SÜMERBANK BAKIRKÖY COTTON TEXTILE INDUSTRY

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by

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THESIS

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CHAPTER I

INTRODUCTION

Statement of the Problem

The question, "What is the function of inventory?" is best answered by saying that it depends on the company or the industry involved. In general, inventories can provide prompt service and competitive advantage, cut lead times and provide for smooth production. If the demand varies significantly from month to month and there were no inventory to provide a buffer between demand and production, there would be a problem of overtime and lay-offs in the company, in addition to other relevant costs.

To be weighed against the advantages that inventories provide, is their cost. Whenever there is money associated with a business function, there exists a problem of efficiently managing this money to minimize waste and secure the greatest return on investment.

One of the problems facing the inventory analyst is how to evaluate a set of decision rules. This problem manifests itself when the analyst tries two sets of decision rules and gets two slightly differing results. The problem can be best handled by saying, "Choose the decision rules that best meet management's

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objectives." The prime task of the inventory control function should be to evaluate the various proposed decision rules in the light of management's stated inventory objectives and to reconcile those decision rules in the best interests of the company.

Needless to say, resources of industrial organizations are limited. Funds that are tied up to inventories can be used in a variety of ways to provide extra return on this investment. However excess inventory serves no purpose and simply causes loss. Then the function of inventory control is to establish a reasonable balance between inventory investment and other uses of capital, considering the costs related to both alternatives.

The main concern of this study is to establish the above mentioned balance as far as spare part stocks in Sümerbank Cotton Textile Industry are concerned. Spare parts inventory control problem faced by Sümerbank textile industries can be classified into two:

- Maintaining stocks at an optimum level, and
- Designing an optimum ordering and procurement procedure to keep the stocks at an optimum level.

For the purpose of illustrating the present situation in Sümerbank textile industries, the following table on actual and objective spare part inventory levels in different plants is given.

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<u>Institution</u>	<u>Year</u>	<u>Program(L)</u>	<u>Actual (L)</u>
Bakirköy	1969	3,656,000	4,843,338
Merinos	1968	2,970,000	5,005,700
Defterdar	1968	2,218,223	2,218,223
Izmir Basma	1968	3,100,000	3,121,200
Sümerbank	1968	38,905,800	59,204,500

As seen in the above table, Sümerbank plants are confronted with the problem of inventory control as far as the spare parts are concerned.

Reports of studies of stocks of spares in the Sümerbank textile industry have shown that a large proportion of the stocks is of items with low consumption. Also a large proportion of the stock value is contained in the relatively few expensive spares which are held.

Throughout this study the main concern will be on the control of these expensive low consumption spares. These are held as security against the very high costs which might be realized if they are not kept in stock if the item in use failed. In short, the purpose of this study is to analyze the present inventory control system in Sümerbank Bakirköy Cotton Textile Industry, to discuss some of the problems, to show the weak points of the existing inventory control function and to present an insight into the

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new manual and electronic inventory control system which has been designed for use in the textile industries under the community of Sümerbank, the methodology followed in conducting this study is given in the subsequent section.

Methodology

The methodology of this study can be broken down into main sections which are in themselves divided into subsections. The study consists of the following stages in the order of analysis.

- . Analysis of the present inventory control system,
- . Analysis of demand and lead time, and
- . New system design

The first phase of the analysis is composed of the following sequence of study.

- . Financial Analysis of the existing spare part stocks,
- . Estimation of inventory costs parameters,
- . Analysis of the present repair and maintenance system as well as the operation of the machine shop,
- . Analysis of the present practice of storing and ordering procedure.

In the second phase of the study, past consumption patterns of demand and distributions of lead times have been analyzed by the

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use of historical data which have been analyzed by a series of programs on a digital computer.

The last and third phase of the study involves the objective of establishing a new revised inventory control system, manual and electronic system design of the inventory control function which will set up the optimum decision rules on inventories at a relatively fast rate with a minimum amount of human error. This section of the study includes theoretical analysis on the inventory control theory as well as the application of scientific management techniques such as Monte Carlo, Simulation, and Heuristic Decision Rule to the problems of the inventory control system.

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CHAPTER 2

INVENTORY CONTROL SYSTEM

Inventory Control Problem

Spare parts inventory control problem faced by Sümerbank can be classified into two:

- a. Inventory levels,
- b. Ordering and procurement procedure.

High inventories result in an overall increase in the storage costs such as rent, insurance, obsolescence and spoilage costs as well as in capital costs. Delays in the machines operating in the plant and loss of production capacity occur if one of the critical spares in use fails when that spare is not available.

Problems of ordering and procurement procedure arise because of uneconomic and improper handling of the size and frequency of orders for spare parts that are essential for the operation of the plant.

Objectives

Spare parts inventory control system aims at determining techniques of maintaining stocks at a minimum level and at the same time preventing the danger of running out of stocks.

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Among the costs which directly influence spare parts inventory policy are:

- . Costs of holding,
- . Costs of shortage,
- . Costs of ordering and procurement.

The system to be designed is supposed to minimize the sum of these three cost categories.

In minimizing the costs of holding inventory, the following factors must be taken into consideration:

- . Minimization of capital tied up in inventories.
- . Minimization of storage costs,
- . Minimization of insurance expense paid for the spare parts in stocks,
- . Sale of technologically obsolete spares, thus eliminating the above three cost factors.

In minimizing the costs of shortage, the factor to be considered is to maintain spare parts stocks at such a level that machines in the plant will operate continuously without any delay.

The factors to be considered in keeping the ordering and/or machine shop production costs at a minimum level are:

- . Making a comparison between machine shop and outside vendors from the point of cost when an order is to be

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- placed and choosing the most economic one,
- . Placing orders in as much big lots as possible.

Demand and Lead Time Distributions

There are two main variables other than cost parameters directly influencing the inventory control model.

- . Demand, and
- . Lead time.

Demand for spare parts may be either deterministic or probabilistic. Since demand for spares is dependent upon the wear of the part in time and random breakdown, it is quite safe to assume probabilistic demand. The objective is to arrive at a reasonable balance between the amount of excess inventory and the protection obtained against shortage. Safety stock is needed to cover the demand during the replenishment lead time in excess of the expected demand. To determine how much additional inventory as safety stock can be economically justified, one needs to investigate the past records to give reliable estimates of past consumption of spares or life characteristics of parts. In looking for past consumptions for spares it will generally be necessary to look over as long a period as possible since, by the nature of the spares, demand will be virtually stationary. Many spares will be held for machines which have only been in operation a short time,

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four or five years, and these spares will often have a zero consumption over such a relatively short period. However, statistical distributions can be obtained by studying the past frequency distribution of demand for each spare part. These can either be one of the known distributions such as Normal, Poisson, Beta or Gamma, or fit none of the known distributions. In the system design section of this study demand distributions have been elaborately touched upon by using the Monte Carlo technique.

Lead Time

Lead time is defined as the time that elapses from the moment it is determined that a replenishment order must be placed until the material covered by this order has been received into stock and is ready for use. Inventory control models assume that management should fix the stocks at a level which will be sufficient to meet the reasonable maximum usage during the lead time within the confidence limits allowed by the management for stock-outs.

Unfortunately, due to the inadequate documentation of past records, the distribution of lead time for spare parts is not definitely known and cannot be predicted exactly. The method of estimating lead time and the assumptions used in determining lead time distribution are shown in the system design section of this study.

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Other Functions Related to Inventory Control

The management functions within the establishment that are directly involved with spare parts stock levels are the following:

- . Production,
- . Finance,
- . Purchasing and sales,
- . Machine and energy.

The departments undertaking these functions tend to adopt the inventory control system in accordance with their needs and interests. Each function within the management group tends to influence the spare parts stock level from its point of view. They usually fail to recognize costs outside their usual framework. Each function thinks of inventories in isolation from other functions. For instance, the production manager wishes to have large spare parts inventories against any possible breakdowns to complete the production schedule smoothly. Finance manager says that large inventories drain off cash which could otherwise be used to make a profit, and parts should be procured whenever the need arises. The purchasing and sales manager commonly says that the company must place orders in as much big lots as possible from the sources where procurement is easy and lead time is short.

The machine-energy manager wants to withdraw the machines in

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the establishment from the production cycle for preplanned overhaul and periodic maintenance according to the machine maintenance regulation and replace the parts that have been worn out beyond the accepted tolerance limits. The production manager becomes unhappy with the frequent interruption of the production program, and the finance manager considers the replacement of wear parts which have not completely lost their service ability, as an unnecessary expense. Therefore for the optimum operation of the total system it is necessary to balance conflicting objectives of the above mentioned functions and design an integrated inventory control system.

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CHAPTER 3

FINANCIAL ANALYSIS OF SPARE PART STOCKS

Sümerbank

Actual spare parts stock levels in comparison with program targets as of September 1969 in all of the organizations, establishments and plants of Sümerbank are shown below:

1969	Program	38 905.8	1000%
1969	September actual	59 304.5	
1968	September actual	58 240.0	
1969	Actual/Program	152.4%	
1969	Actual/1968 Actual	100.1%	

As seen from the above values spare parts stocks in all of the Sümerbank organizations, establishments and plants add up to a big sum. The reasons for such huge inventories in spare parts will be examined in detail in later sections of this study. The financial analysis of spare parts stocks is given below:

Bakırköy Cotton Textile Factory

The funds tied up to total stocks in this institution for the years 1964-1969 are shown below:

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<u>Years</u>	<u>Total Stocks (L)</u>	<u>Ratio to Previous Year %</u>
1964	28,324,864.23	-
1965	20,750,650.46	73
1966	15,250,032.45	74
1967	22,447,822.88	147
1968	24,272,259.40	108
1969	22,046,853.45	91

Total stock level started to decline in 1965 and reached its lowest level in 1966. But stock levels kept on rising in 1967 and 1968. The movements of spare parts stock levels in terms of actual and program values are shown below for the same years.

<u>Year</u>	<u>Program (L)</u>	<u>Actual (L)</u>	<u>Actual/Program %</u>
1964	3,670,200	4,341,882	118
1965	3,500,000	4,459,637	127
1966	3,445,000	4,321,631	125
1967	3,415,000	4,583,568	134
1968	3,462,000	5,095,784	147
1969	3,656,000	4,843,338	132

As seen from the above table, spare parts stocks in Bakırköy Cotton Textile Industry have always been above the program targets between 1964 and 1969. This can be attributed to two factors;

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either program targets are kept low consciously or unconsciously, or for some reason actual stocks tend to increase beyond the program targets. Actual spare parts stocks as compared to the previous year in 1965, 1967, 1968 increased by 3%, 6%, 11%, and in 1966 and 1969 decreased by 3% and 5%, respectively. When the average of the last six years is taken, it is seen that the greatest portion of the total stocks is composed of finished goods inventory, 37%, production goods follow it with 28.7%, and in the third place spare parts constitute the 21.14 % of the total stocks.

The distribution of the portion of the spare parts stocks in total stocks for the years 1964-1969 is shown below:

<u>Years</u>	<u>Spare Parts/Total (%)</u>
1964	15.3
1965	21.5
1966	28.5
1967	20.4
1968	21.0
1969	22.0

As seen from the above table, the percentage of spare parts in the total stocks has been the highest, 28.5%, in 1966 when the total stocks have taken the lowest value 15,250,092 L.

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The following table illustrates the calculation of the financial burden of carrying excess inventory over program targets. Cost of holding inventory has been taken as 18%. The derivation of this figure is shown in later sections.

As seen additional cost of holding excess spare parts inventory above the program targets during the last six years is 1,169,500 ₺ which is equal to the 60.9% of the sum of the net profits of the establishment during these years.

Table 1

BAKIRKÖY COTTON TEXTILE INDUSTRY

ADDITIONAL FINANCIAL BURDEN DUE TO THE EXCESS
SPARE PARTS INVENTORIES ABOVE THE PROGRAM TARGETS

<u>Year</u>	<u>Spare Parts Stocks (L)</u>		<u>Excess Over Program (%)</u>	<u>Net Profit (L)</u>	<u>Additional Holding Cost (L)</u>	
	<u>Program</u>	<u>Actual</u>				<u>Difference</u>
1964	3670200	4341882	671 682	18	-4,109,380	120,902
1965	3500000	4459637	959637	27	820,852	172,734
1966	3445000	4321631	876,631	25	3,155,301	157,793
1967	3415000	4583168	1,168,168	34	3,208,688	210,270
1968	3462000	5095784	1,633,784	47	598,438	294,081
1969	3656000	4843338	1,187,338	32	-1,754,423	213,720
Totals ...					1,919,476	1,169,500

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CHAPTER 4

INVENTORY CONTROL PARAMETERS

Cost of Holding

Cost of holding spare parts inventory in the non-manufactured goods storeroom varies directly with the level of stocks. Cost of holding inventory is composed of the following:

- . Opportunity cost of Money,
- . Insurance expense for stocks,
- . Cost of storage,
- . Cost of Obsolescence.

Opportunity Cost of Money

The revenue that would be generated if the funds tied up to inventories are released constitutes the opportunity cost of money. Opportunity cost of money may be based on the cost of obtaining funds for investment from a bank, on the return that could be earned by alternative uses of released internal funds, or on both. The rate of interest goes up to 19% including the taxes when funds are obtained from banks. However, it might be pointed out that the cost of the Turkish Lira invested in inventory may be underestimated if bank interest rate is used as the basis, ignoring the risk-bearing or entrepreneur's compensation. Since

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State Economic Enterprises cannot utilize their free funds as easily as banks, the opportunity cost of money for the State Economic Enterprises has been assumed to be 15%.

Insurance Expense

Insurance premium paid for spare parts inventory is determined by the insurance policy signed by Güven Sigorta T.A.Ş.

Subscribed insurance percentages are listed below:

Over the value of the goods	0.450 %
Reduction for paid in advance	15 %
Expense	10 %
Expenditure tax over the total	20 %

Insurance premium paid for a spare part worth of 1 ₺ in the inventory is calculated as follows:

$$(1) \times (0.0045) \times (1-0.15) \times (1 + 0.10) \times (1 + 0.20) \\ = 0.00505$$

That is the percentage of insurance premium of 1 ₺ is 0.505%.

Cost of Storage

To show the calculation of storage costs, related cost categories are given below for the year 1969.

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Accounting	40,000	₺
Personnel in Storehouse	68,071	
Labor	227,985	
Materials	67,466	
Storehouse insurance	<u>2,000</u>	
	405,522	₺

Storage costs do not vary directly with the number of items in the stocks. Cost of storage for an item worth of ₺ can be obtained by dividing total storage cost by the total value of non-manufactured goods inventory. This ratio happens to be;

$$\frac{405,522}{31,027,218} = 0.01307 \quad 1.31 \%$$

Cost of Obsolescence:

By the nature of the spares, they do not deteriorate as other goods do. On the other hand, the parts of the scrapped machines become obsolete when these machines are withdrawn from the production process. Such parts are sold out at a lower price than their book value after a certain length of time elapses and sales permit is issued. Hence, cost of obsolescence of spare parts is assumed to be 1% annually.

As a result, the overall cost of carrying in inventory a spare part worth of ₺ is shown below:

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Opportunity cost of money	15.000 %
Insurance	0.505 %
Cost of Storage	1.310 %
Cost of obsolescence	<u>1.000 %</u>
	17.815 %

As seen, the cost of carrying in inventory a spare part worth of 1L to the establishment is 17.815 kuruş per year.

Cost of Shortage

Cost of shortage can be determined in two ways:

- . Direct method
- . Imputed cost of shortage

In the first method, the total cost of being unable to meet a demand for spares is calculated. For instance, the costs that will be incurred in the production process if one of the machines breaks down and cannot be repaired immediately due to the inavailability of the required spare are taken into account. It is very difficult or even impossible to arrive at a cost of a shortage in this way since in many instances intangible cost factors are involved in the loss function. However, there are some alternative ways of determining cost of shortage even when loss functions are not available. In the second method it may be necessary to secure from the management a statement of the degree of risk of

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running out of stock at a given time during the year which the management is willing to tolerate, as a matter of company policy. The management can intuitively arrive at this estimate by considering the possible and relevant-cost elements involved in being unable to fill an order over a substantial period of time. First, the safety stock level at the tolerated degree of risk of stock out is calculated, then going in the reverse order the coefficient of cost of shortage is estimated by substituting the safety stock level in the mathematical model.

In this study, the second method has been employed, and inventory control system is designed by allowing a certain degree of risk of shortage.

Cost of Ordering

Cost of ordering includes such items as the cost of making out a requisition and placing an order and cost of telephone calls as well as other related clerical costs. However, the sum of all these clerical costs do not add up to a great sum. The purchasing agents in charge of purchasing the orders from outside are paid 250 ₺ each as travelling-expense. Transportation does not cost much if goods are purchased within the city, but varies directly with the distance travelled if they are purchased outside of the city. If the order is procured through the institution of

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purchasing and Sales, a commission of 4% is paid over the sum of the cost of goods procured, transportation and other costs.

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CHAPTER 5

MACHINE REPAIR AND MAINTENANCE SYSTEM IN RELATION TO SPARE PARTS

Machine Repair and Maintenance System

The repair and maintenance of machines is carried out by the Machine Maintenance Master's Office. The daily planned maintenance and incident reports compiled by this office are used to obtain the definite knowledge of annual production losses and reasons for stoppages.

Machine repair and maintenance system is separated into two as big maintenance and small maintenance. Small maintenance consists of periodic review of the machines in every six months. In big maintenance, the machines are withdrawn from the production process for overhaul and revision at every three years in accordance with the maintenance regulation, and the parts that have exceeded the norm limits are replaced by their spares. In the establishment under investigation, machine records that could be helpful in forecasting demand for spare parts are not kept.

Those records would contain:

- . Name and trademark of the manufacturing firm
- . Date of manufacture and modernization,
- . Machine number,
- . Name of the machine,

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- . Period of maintenance,
- . Name of the man in charge of maintenance,
- . Code numbers and names of the parts replaced,
- . Condition of the machine after maintenance.

These records are not kept by the management, consequently various difficulties in inventory control arise from the inadequacy of records and the manual operation of the system.

Effect of Machine Breakdowns on Production Process

The objective of handling spare parts stocks is to provide spares for the broken parts or those parts which are supposed to be replaced during maintenance in a substantially short period of time without hindering the smooth operation of the production process. Stopping of any one of the looms in the production cycle due to the inavailability of a spare causes delays in the looms working in accord with that broken loom, thus production schedule is hindered and rate of production falls down as a consequence.

Machine breakdown percentages and their reasons in the Yarn and Weaving department of Bakarköy Cotton Textile Industry are given in the following table.

As seen from the table, the loss in production capacity in the yarn department due to repair and maintenance has been 0.60%

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in both years, 1967, and 1968. In the weaving department, however, the loss in the production capacity caused by machine breakdowns in 1967 and 1968 has been 1.9% and 2.2%, respectively, which constitute 15.2% and 18.3% of the total stoppages in those years.

Machine Shop

The machine shop in the plant works under the administration of Machine-Energy Master's Office which is supervised by the technical vice-presidency. Machine Shop is established to carry out repair and maintenance within the plant and to devote remaining time to manufacturing. Generally, in preparing the annual work schedule of the machine shop, 50% of the total working hours is separated for manufacturing to meet the orders placed at the beginning of the year, and the rest of the time is devoted to repair and maintenance. The number of workers and staff working in the machine shop is sufficient under normal circumstances. On the other hand, for some reason, it is often impossible to have all the personnel begin work everyday. Since the hourly wage rates paid by Sümerbank are rather low compared to the private sector, experienced personnel tend to work either abroad or in jobs which are paid better. The private sector is able to gather the most qualified men available in the market in return for

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Table 2
BREAKDOWNS INFLUENCING OUTPUT

<u>Reasons</u>	(%) Yarn Department		Weaving Department	
	<u>1967</u>	<u>1968</u>	<u>1967</u>	<u>1968</u>
Energy Cutting	0.90	0.40	0.70	0.30
Machine Breakdowns	-	-	1.90	2.30
General Repair and Mntance	0.60	0.60	1.10	0.80
Cleaning and Lubrication	0.60	0.10	0.60	0.10
Lack of Material	-	-	0.30	0.40
Other	0.30	2.10	0.10	0.10
Removing a set	2.50	4.00	-	-
Free Spinning of Spindles	0.30	0.40	-	-
Breakage	1.60	2.20	-	-
Lack of "Levent"	-	-	0.30	0.50
Weft Breakage	-	-	4.80	4.50
Cotton Warp Breakage	-	-	6.60	7.00
"Levent" Replacement	-	-	0.40	0.40
Removing Crude Linen	-	-	0.10	0.10
Removing Scrapped Clothing	-	-	0.20	0.30
TOTAL	<u>6.80</u>	<u>9.80</u>	<u>17.10</u>	<u>17.40</u>

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rather low wages. These people tend to leave their jobs and shift to private sector which offers higher wages after they have gained some experience and increased their proficiency.

In short, State Economic Enterprises act as training centers for educating unqualified labor force for the benefit of the private sector. This fact is true for other production units as well as for the machine shop.

Management Policy and Objectives with Respect to the Machineshop

The machine shop is expected to undertake the function of repair and maintenance against any irregularities in the production process. Besides this, the greatest advantage of having a machine shop in the plant is its ability to manufacture those critical parts without which the production process would stop and whose procurement will take a long time, when the spare is not available in the stocks. The parts manufactured by the machine shop are generally superior to those obtained from the market. This may be attributed to the more careful selection of the raw material and the practicability of seeking alternative solutions in case of necessity with the cooperation of the production function.

The management follows the policy of manufacturing in the machine shop as many of the parts needed as possible. The two

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main reasons for the application of this policy are:

- . Shortness of lead time
- . Possibility of making required modifications on the part

However, technical inadequacies, lack of qualified personnel and excess work load constitute an obstacle for the implementation of this policy completely. In the meantime, to improve the present condition of the machine shops in Sümerbank establishments, central machine shops can be set up in different geographical regions. These regional machine shops will be superior to the local ones as far as the variety and number of work-benches the capacity and qualified personnel are concerned and will be more serviceable to the Sümerbank establishments provided that the following problems are solved.

- . Lead time,
- . Transportation possibilities,
- . Technical specifications of the parts.

Technical specifications of the parts must be communicated exactly to the central shop. Manufacture of a part in central shops operating under more orderly conditions will not take any longer than it would take if it were manufactured by a shop within the plant. Transportation of parts to the plants where they are needed does not constitute a problem at all with the existing means of transportation. A regional central machine shop will

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<u>Months</u>	<u>Expense Percentage</u>	<u>Expense/part ₺</u>
January	35.8	2.96
February	23.6	1.67
March	27.5	1.26
April	23.5	3.26
May	34.7	2.39
June	38.3	7.51
July	26.8	3.36
August	29.0	2.94
September	26.6	5.81
October	35.3	3.99
November	28.9	4.10
December	26.5	10.58

In the machine shop, on the average an expense of 4.15 ₺ per part manufactured is incurred, and general expenses constitute 29.6% of the total expenditures of the machine shop. As seen from the above table, the share of expenses in the total expenditures varies from month to month. This is another reason for having two different cost figures for the same item manufactured in different times. For example, a spare part which is sold for 19.25 in the market, has cost 20.23 ₺ in one order and 12.34 in another order.

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be in a better position than a local one as far as operational capabilities are concerned and will be able to manufacture a greater variety of parts at a lower cost in a shorter time.

Cost Of Manufacturing

Cost of parts manufactured in the machine shop is calculated in the following manner :

$$\begin{aligned} \text{Cost of a part} &= \text{Labor} + \text{Raw material} + \text{Expense allocation} \\ &+ \text{Extra pay} \end{aligned}$$

Extra pay is the share of the part manufactured in a particular month from the additional expenditures made in that month, such as premiums and weekend pays. This formula yields different cost figures of the same item manufactured at different times.

The difference is due to employing laborers with different skills and hourly wage rates, and to the variations in the extra pay from month to month. In 1969, the distribution of the total expenditures made by the machine shop is as follows : 45.0 % for materials, 25.9 % for labor and 29.1 % for expenses. The monthly percentage distribution of the general expenses in the total expenditures of the machine shop in 1969 is shown below :

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CHAPTER 6

PROCUREMENT AND STORING SYSTEM

Organization

In Simerbank Textile industries, there are two sorts of storehouses; manufactured goods and non-manufactured goods. Storehouses are administered by storeroom head officials who work under the supervision of the Manager of Commerce. Although the storehouses are directly tied to the manager of Commerce, they are always in contact with the managers of Production, Finance, and Machine-Energy.

The predetermined staff list for those who work in the storeroom is changed slightly every year. The actual staff list is more or less the same as the predetermined staff list. The number of porters working in the storeroom is adjusted seasonally according to the need for them.

The division of the personnel in terms of their tasks in the non-manufactured goods storeroom is shown below:

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	1970 predetermined <u>Staff list</u>	Actual Staff <u>list</u>
Materials handler	7	9
Balance operator	1	1
Fork-lift driver	1	1
Crane operator	1	1
Clerk	2	2
Head porter	1	1
Porter	15	12
Archivist	<u>1</u>	<u>1</u>
	29	28

In addition to this list, there are four clerks two in the Accounting department, and the other two in the Purchasing and Sales department, working to keep the records related to the storehouses.

Storerroom

One of the problems present in the storeroom under investigation is lack of space. It has been observed that the non-manufactured goods stockroom is full of a big variety of parts. Undoubtedly, the present situation of the storeroom can be traced to improper arrangement of the existing stocks. Unfortunately, this creates difficulties in putting the incoming materials to the right places and in locating the items without any loss of time

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when they are required as well as in maintaining accurate records. The space problem can best be eliminated by one of the following alternative ways of solution:

- . Constructing of new storehouses
- . Constructing new stories over the existing buildings.
- . Reorganization of the existing storehouses and making additional bins or shelves.

To avoid unnecessary expenses, the last alternative turns out to be the best solution. The storehouses build from sheet-iron are not in good condition. The items in the stocks are damaged by the leaking rain water. It is, therefore, necessary to demolish the existing sheet-iron storehouses and replace them by modern concrete storehouses. Each item in inventory has space permanently assigned to it. The company uses zone storage system. Using this system, all related parts are located in the same general zone within the storeroom. This method is expected to reduce the amount of back-and-forth travelling by the material handlers in collecting related components.

Withdrawal Procedure

In case of a breakdown of a part, specified type and number of spares are withdrawn from the storeroom by a document signed by department foreman, department head and production manager in the respective order. Although the first signature is sufficient to

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withdraw the spare from stocks, the visual control of the owners of the other signatures is found to be useful. Generally, order amounts are exaggerated when a requisition form is filled in, and the spares in excess for the actual need are stored in an auxiliary storeroom called "armpit storeroom". The withdrawal of the spares stored in the armpit storeroom is not recorded in the inventory records until they are actually used or installed on a machine. In some instances, the number of parts available in the bins or shelves does not conform with the balance-on-hand quantities in the inventory records which is the deficiency and inconvenience of this system.

Material handlers are often confronted with the difficulty of locating a part in the storeroom. This difficulty could be overcome by means of locator cards for each item listing its bin location. These cards duplicate inventory records to the extent of part number, description, place of use and balance-on-hand quantities. They can be referred to each time a receipt or issue of parts is handled.

One of the problems faced by inventory control system is the clerical errors in the inventory records. The sources of these errors are outlined below:

- . Direct delivery of urgently needed parts from the machine shop to production departments without going through store-

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room and having the proper paperwork made out. Rigid enforcement of material movement procedure will eliminate this problem at the expense of delaying the movement of urgent parts, Therefore it is not justified. A compromise system that can determine whether or not there are any emergency requirements, deducting these from the records will avoid this problem.

- . Misidentification of parts, particularly if two parts are similar and the material handler cannot recognize the requested part causes clerical errors and additional work.

- . Delayed flow of paperwork between material handling personnel and the inventory records constitute another problem. This can be eliminated by having all paperwork getting into the records serially numbered to trace and control all the documents.

Most of the problems in inventory control can be traced to poor training, lack of attention and lax discipline. Personnel involved in the inventory control sometimes fail to follow the proper procedure, which in turn influences the accuracy of records. However, perfect inventory control cannot be attained unless control of information flow at all levels of management is achieved.

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Armpit Store

The physical location of the non-manufactured goods storeroom and its remoteness from the production units created a need to set up an auxiliary storeroom within the easy and quick reach of the production units. The spares in the armpit storeroom are recorded in the inventory records of the main storeroom and carried as asset until they are actually used. Fundamentally, there is no need for such an auxiliary storeroom. The presence of the armpit storeroom can be justified on the basis of the physical location of the storeroom and the inadequacy of the control of information flow and lack of a unique coding system used uniformly by all functions of the management.

Stock Entries

The spares which do not exist in the stock and for which a requisition is issued are procured either from the machine shop or outside sources depending on the technical specifications of the parts and workload of the machine shop. In placing an order outside of the plant, the Purchasing Regulation is used and the receipt of materials is carried out by an authorized commission.

The procedure followed so far in determining the order size is to take the arithmetic average of the past three years consumption as annual mean demand and increase the stock level to the point which will be sufficient to meet this annual mean demand for one and

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and a half years. However, demand for spare parts shows different characteristics, since future consumption is solely dependent on random breakdowns. Hence, the acceptance of the arithmetic average of the past three years consumption as the mean annual demand is a wrong assumption which leads to the spare parts stock levels take higher values than optimum levels.

Unused Parts

In dynamic systems, managements take the economically and technologically infeasible machines out of the production process one after the other and replace them by technologically more advanced ones. Entry of the new machines having technological variations into the production process to attain a certain degree of quality and smooth production process, creates a problem as far as the spare parts stocks are concerned. The spares that belong to the machines extracted from the production process, become obsolete and constitute a loss as far as the opportunity cost of money tied up, insurance and storage costs are concerned. Generally, the new machines purchased are accompanied by their spares. Since the parts that have lost the capacity of being used still lie on the shelves, a space problem comes into existence when the new parts arrive.

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The machines of approximately one fourth of the 4827 different spares available in Bakırköy Cotton Textile Industry, are already extracted from the production process. A sales permit is necessary to sell these spares. So far, sales permits have been issued for only half of these unusable spares.

Lists of materials in the stocks of establishments which have already lost the ability of being used in these institutions, are prepared by the order of the General Directorate of Sümerbank and distributed to other establishments within the community of Sümerbank. These lists are expected to facilitate the transfer of materials among establishments. However, this system so far has not yielded successful results.

Coding System

To ensure the transformation to electronic inventory control system from the present manual inventory control system, all of the materials in the stocks of Sümerbank establishments have been coded by a uniform system in accordance with the circular issued by the General Directorate of Sümerbank. Since the need and use of a uniform coding system has not been explained and taught explicitly at the transformation stage, some management functions within an establishment will still use different coding systems for their own use. The prior coding system has been altered significantly in time, but despite the additions and modifications in the coding

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system the old system has not disappeared completely. As a result today more than one coding system are being used in Bakarköy plant. For instance, computerized coding system prescribed by the General Directorate is employed in accounting records, and an entirely different coding system is used by the storehouses and production units.

New coding system consists of 8 figures. The first two digits (33) shows that the material belongs to the spare parts inventory. The third and fourth digits shows the machine group of the part, and the remaining four digits are used to show the sequence number of the part. In this way items can be separated into machine groups and in case of introducing a new item into a certain machine group, the next sequential number after the last number in this machine group is given to the new part. Thus, one can easily code 10,000 different kinds of items in a single machine group.

In the system design section, a uniform and unique coding system for the whole establishment is explained explicitly.

Sources of Supply

There are mainly four sources of supply where spare parts can be procured. These are:

- . Plant machine shop,
- . Other establishments in the community of Sümerbank,
- . Internal market, and

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. Imports

In the selection of a source of supply for a spare part, technical specifications for the spare, workload of the source, availability and cost of the spare and lead time are taken into account as the main factors. For example, certain spares can only be obtained from the internal market, and if they are not available in the market, they are imported through the Purchasing and Sales Institution. The lists of excess inventories prepared by the same institutions within the community of Sümerbank and distributed to the other institutions in accordance with the will of the General Directorate, form another source of supply.

First choice in the selection of a source of supply is given to the machine in the plant. However, the machine shop is able to meet only a small percentage of the requests due to the various limitations. Consequently, other sources of supply play an important role in meeting the demand for spare parts.

The investigations conducted have revealed that there is no distinct policy as to what might be the best source of obtaining a spare when the need arises. The machine shop does not work regularly and harmoniously and there is not any preplanned work schedule in the machine shop. Since the capacity of the machine shop is not definitely known, orders are placed beyond the capacity of the machine shop. None of these orders are reversed but put in order for manufacturing.

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The machine shop stops the regular production process whenever an immediate and urgent need for a spare arises and starts working on the requested part.

There is no coding system as to the sources of supply. The experience of the people in the machine-maintenance department and their acquaintance with the parts partially eliminate this difficulty. It is apparent that some difficulties will arise in the absence of these people.

Due to the great variety of big orders from all other plants and inefficiency of the present communication channels, the machine shops in Defterdar cannot be considered as a reliable and quick source of supply.

In case of procuring from the internal market, the long formalities, preparation of the technical specifications of the parts and similar reasons prolong the lead time and increase the probability of stock-out. Importation of a spare necessitates many long formalities. First of all, it has to be confirmed that the part is not available and cannot be manufactured in Turkey before an official assignment of foreign currency is obtained to import the required part. Normally, these formalities take a long time, which results in higher safety stock levels for those parts procured from foreign sources to avoid the risk of stock-out.

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Ordering Procedure

Orders are placed whenever a need for a spare which is not available at all or insufficient to meet the present demand, or stocks go below a certain specified level. The inefficiency of the present inventory control system makes it hard to trace the stock levels accurately at all levels of the information flow. This results in with the fact that often orders are placed when they are not actually necessary or in wrong quantities.

The machine maintenance department is informed when a need for a spare arises. Then by forming an informal connection between that department and the storeroom, the availability of the particular spare is investigated. If sufficient number of spares are available in the storehouse, the requested spares are withdrawn from the storeroom by a formal requisition slip which contains the name, code number and order size of the part. If the spares are not available in the market, two different ordering procedures are followed according to the source of supply. The general flow chart of the ordering procedure is given below.

In placing an order the following factors are taken into account:

- . Financial considerations,
- . Stock levels.
- . Lead time,

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- . Price variations,
- . Difficulties of transfer of foreign currency.

To place an order the requisition slip is supposed to follow the following procedure:

Requisition slips consist of four copies. A requisition form can be used only for one item. The four copies of the requisition form are sent to the manager of Commerce, the purchasing employee, storeroom and to the interested service. The requisition slip is filled in by the foreman of the service where the spare is needed and then the slip goes through the control of the department head who fills in the following information:

- . Place of use,
- . Desired lead time,
- . Code number
- . Quantity,
- . Measure,
- . Name and specifications,
- . Service to be reported when the order arrives.

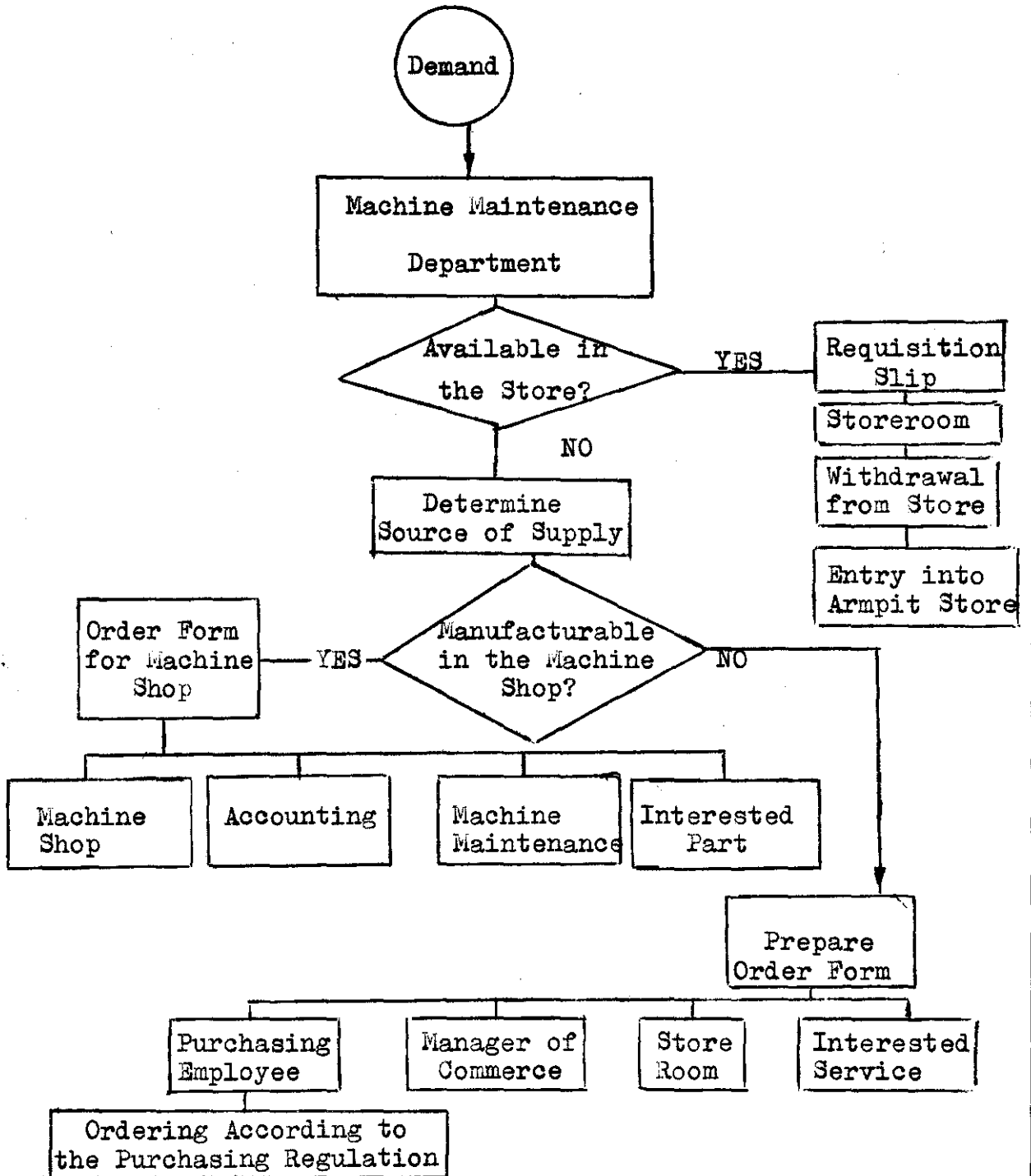
The slip is then sent to the storeroom where the actual stock level of the particular material and its minimum and maximum stock levels on the basis of the past consumption pattern are recorded on the slip. The relevant information about the department responsible for the inspection of the materials when they are received

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SPARE PARTS ORDERING PROCEDURE FLOW CHART



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and the date, price, quantity, specification and the selling firm of the last purchase of the particular item and remarks are added to the requisition slip sent to the manager of Commerce from the storeroom. Then the task of purchasing the item is delegated to the man in charge of purchasing materials from market according to the rules of the Purchasing Regulation.

Replenishment Time

The time that elapses from the moment an order is placed until the material covered by this order has been received into stock varies with the source of supply, quantity ordered and qualifications of the material. In this respect, it is impossible to determine lead times for sources of supply. Orders placed in the machine shop are often delayed if the materials needed are not of critical importance for the production process, because priority is given to the manufacture of more immediate and urgent items. Since lead time for the materials of vital importance, which are imported, is rather long, orders for these materials are placed quite ahead of time. On the other hand, if the material can be obtained from the internal market, lead time is variable depending on whether the material covered by the order is a ready item or to be manufactured. Due to the insufficiency of the records, it has been impossible to determine the distribution of lead times with respect to sources of supply. Variable lead times

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present a problem of quantitative importance which will be explained in the system design section. It will be shown later that if,

- . The shortest lead time,
- . The most likely lead time, and
- . The longest lead time

are known, the mean lead time can be estimated.

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CHAPTER 7

DEMAND ANALYSIS

Computer Programs Used in the Analysis of Spare Parts Inventory Movements

Past consumption patterns of spares and the present stock levels have been analyzed by a series of Computer programs using the past and present records of the establishment concerned. These programs are :

- . Transformation of the Raw Data,
- . Analysis with Respect to Depletion Periods,
- . Analysis of Demand in the Past Years,
- . Analysis with Respect to Last Year of Use and Mean Annual Demand.

The comprehensive system flow charts along with the FORTRAN programs are given and operational procedures are described below :

Transformation of Raw Data :

In this section,

- . Machinery Groups,
- . Stock Levels,
- . Sources of Supply
- . Total Stock Value, and
- . Values of the Demand in the Previous Years

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are used as input data in computing,

- . Unit Price of the Spares,
- . Last Year of Use,
- . Arithmetic Mean, Variance, and Standard Deviation of the Past Demand,
- . Upper and lower limits of the normal Demand Distribution within 10 percent confidence limit,

and the output is punched into IBM cards to be used as input for the other programs.

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TRANSFORMATION OF RAW DATA

SYSTEM FLOW CHART

START

MACHINERY GROUPS
STOCK LEVELS
SOURCES OF SUPPLY
TOTAL STOCK VALUES
DEMAND VALUES BETWEEN 1963-1969

COMPUTE UNIT PRICE AND LAST YEAR
OF USE OF THE SPARE

COMPUTE ARITHMETIC MEAN- VARIANCE
AND STANDARD DEVIATION OF DEMAND

COMPUTE UPPER AND LOWER LIMITS OF
THE DEMAND DISTRIBUTION WITHIN 10
PERCENT CONFIDENCE INTERVAL

C *** ENGIN UYSAL ***

ROBERT COLLEGE COMPUTER CENTER

C DIMENSION KSARF(7),SARF(7),S(16,7),DE(16),NUM(16),ROWTOT(16),
COLTOT(7)

C INITIALIZATION

DO 6 I=1,16

DO 44 J=1,7

ROWTOT(I) = 0.

DE(I) = 0.

NUM(I) = 0.

S(I,J) = 0.

COLTOT(J) = 0.

44 CONTINUE

60 CONTINUE

NUMTOT = 0.

DETOT = 0.

C PRINT 18

PUNCH 918

PRINT 21

PUNCH 921

C READING THE DATA

READ 1, N

N1 =

40 N1 = N1+1

IF(N1-N) 10, 10, 9999

10 READ 5, KK, JJ, NU, KSTOK, KTEM1, KTEM2, KTOKIY, (KSARF(J), J=1,7)

DO 7 J=1,7

70 SARF(J) = KSARF(J)

TOKIY = KTOKIY

STOK = KSTOK

IF(STOK) 3, 4, 3

4 BIRDE = 0.

GO TO 7

3 BIRDE = TOKIY/STOK/100.

7 JT = 7

KSOKSE = 1969

30 IF(SARF(JT)) 19, 15, 19

15 JT = JT-1

KSOKSE = KSOKSE-1

IF(JT) 30, 19, 30

19 CONTINUE

VAR = 0

SUM = 0

DO 2 J=1,7

20 SUM = SUM+SARF(J)

ARORT = SUM/7.

DO 5 J=1,7

```

STDEV = SQRTF(VAR/6.)
ALT = ARORT-1.96*STDEV
UST = ARORT+1.96*STDEV
IF(ARORT) 131, 132, 131
132 ERSUR = 10.
GO TO 134
131 ERSUR = STOK/ARORT
134 ICC = ARORT*BIRDE
IF(ALT) 128, 129, 129
128 ALT = 0.
C
129 IF(JJ-1) 33, 74, 75
C
74 DE(JJ) = DE(JJ)+TOKIY
NUM(JJ) = NUM(JJ)+1
DO 8 J=1,7
80 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
GO TO 66
75 IF(JJ-2) 33,76,78
76 DE(JJ) = DE(JJ)+TOKIY
NUM(JJ) = NUM(JJ)+1
DO 9 J=1,7
90 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
GO TO 66
78 IF(JJ-3) 33,79,81
79 DE(JJ) = DE(JJ)+TOKIY
NUM(JJ) = NUM(JJ)+1
DO 1 J=1,7
100 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
GO TO 66
81 IF(JJ-4) 33,82,83
82 DE(JJ) = DE(JJ)+TOKIY
NUM(JJ) = NUM(JJ)+1
DO 110 J=1,7
110 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
GO TO 66
83 IF(JJ-5) 33,84,85
84 DE(JJ) = DE(JJ)+TOKIY
NUM(JJ) = NUM(JJ)+1
DO 120 J=1,7
120 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
GO TO 66
85 IF(JJ-6) 33,86,87
86 DE(JJ) = DE(JJ)+TOKIY
NUM(JJ) = NUM(JJ)+1
DO 130 J=1,7
130 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
GO TO 66
87 IF(JJ-7) 33,89,91
89 DE(JJ) = DE(JJ)+TOKIY
NUM(JJ) = NUM(JJ)+1
DO 140 J=1,7
140 S(JJ,J) = S(JJ,J)+BIRDF*SARF(J)
GO TO 66
91 IF(JJ-8) 33,92,93
92 DE(JJ) = DE(JJ)+TOKIY
NUM(JJ) = NUM(JJ)+1
DO 150 J=1,7
150 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)

```

C
C
C

```

93 IF (JJ-9) 33,94,95
94 DE(JJ) = DE(JJ)+TOKIY
   NUM(JJ) = NUM(JJ)+1
   DO 160 J=1,7
160 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
   GO TO 66
95 IF (JJ-10) 33,96,97
96 DE(JJ) = DE(JJ)+TOKIY
   NUM(JJ) = NUM(JJ)+1
   DO 170 J=1,7
170 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
   GO TO 66
97 IF (JJ-11) 33,98,101
98 DE(JJ) = DE(JJ)+TOKIY
   NUM(JJ) = NUM(JJ)+1
   DO 180 J=1,7
180 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
   GO TO 66
101 IF (JJ-12) 33,102,103
102 DE(JJ) = DE(JJ)+TOKIY
   NUM(JJ) = NUM(JJ)+1
   DO 190 J=1,7
190 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
   GO TO 66
103 IF (JJ-13) 33,104,105
104 DE(JJ) = DE(JJ)+TOKIY
   NUM(JJ) = NUM(JJ)+1
   DO 2 J=1,7
200 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
   GO TO 66
105 IF (JJ-14) 33,106,107
106 DE(JJ) = DE(JJ)+TOKIY
   NUM(JJ) = NUM(JJ)+1
   DO 210 J=1,7
210 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
   GO TO 66
107 IF (JJ-15) 33,108,109
108 DE(JJ) = DE(JJ)+TOKIY
   NUM(JJ) = NUM(JJ)+1
   DO 220 J=1,7
220 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
   GO TO 66
109 IF (JJ-16) 33,112,33
112 DE(JJ) = DE(JJ)+TOKIY
   NUM(JJ) = NUM(JJ)+1
   DO 230 J=1,7
230 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
   GO TO 66
33 TYPE 99, JJ,NU
   PAUSE
   N1 = N1-1
   GO TO 40
66 PRINT 88, KK, JJ, NU, KSTOK, BIRDE, KSOKSE, KTEM1, KTEM2, ARORT, STDEV, ALT,
1UST, ERSUR, TCC
   PUNCH 988, KK, JJ, NU, KSTOK, BIRDE, KSOKSE, KTEM1, KTEM2, ARORT, STDEV, ALT,
1UST, ERSUR, TCC
   GO TO 40
9999 PRINT 77
   PUNCH 111

```

C
C
C

```

PUNCH 114
PRINT 115
PUNCH 116
DO 240 LL=1,16
DETOT = DETOT+DE(LL)
NUMTOT = NUMTOT+NUM(LL)
PRINT 117, LL, NUM(LL), DE(LL)
PUNCH 118, LL, NUM(LL), DE(LL)
240 CONTINUE
PRINT 124, NUMTOT, DETOT
PUNCH 125, NUMTOT, DETOT
PRINT 77
PRINT 111
PUNCH 111
PRINT 122
PUNCH 123
DO 250 MM=1,16
DO 260 J=1,7
ROWTOT(MM) = ROWTOT(MM)+S(I,M,J)
260 COLTOT(J) = COLTOT(J)+S(MM,J)
PRINT 119, MM, (S(MM,J),J=1,7), ROWTOT(MM)
PUNCH 121, MM, (S(MM,J),J=1,7), ROWTOT(MM)
250 CONTINUE
PRINT 126, (COLTOT(J),J=1,7)
PUNCH 127, (COLTOT(J),J=1,7)

```

C
C
C
C

FORMAT STATEMENTS

```

1 FORMAT(I4)
5 FORMAT(2I2,I4,18X,I5,2I1,I7,7I3)
18 FORMAT(1H //,15X,35H SUMERBANK BAKIRKOY PAMUKLU SANAYII ///)
21 FORMAT(1H ,27X,9HLAST YEAR,12X,7HAVERAGE,3X,8HSTANDARD/1H ,1X,7HCO
1DE NO,3X,5HSTOCK,3X,5HPRICE,4X,6HOF USE,5X,6HSOURCE,5X,3HUSE,5X,9H
2DEVIATION,3X,3HALT,4X,3HUST/)
77 FOPMAT(1H1)
88 FOI.MAT(1H ,1X,2I2,I4,1X,I5,F9.2,5X,I4,6X,I2,2X,I2,F10.2,1X,F9.2,
1F7.1,F7.1,2X,F6.2,2X,F10.2)
99 FORMAT(1X,14HCHECK THE CARD,2X,I2,I4,2X,32HTHEN PUSH START AFTER C
1ORRECTION)
111 FORMAT(///)
113 FORMAT(//,1H ,25X,39HTOTAL VALUE OF SPARE PARTS USED IN 1969 ///)
114 FORMAT(/// 20X,39HTOTAL VALUE OF SPARE PARTS USED IN 1969///)
115 FÖRMAT(1H ,2X,13HMACHINE GROUP,5X,15HNUMBER OF PARTS,5X,10HFUNDS T
1IED/)
116 FORMAT(13HMACHINE GROUP,5X,15HNUMBER OF PARTS,5X,10HFUNDS TIED/)
117 FORMAT(1H ,7X,I2,14X,I5,10X,E14.6)
118 FORMAT(7X,I2,14X,I5,10X,E15.4)
119 FORMAT(1H ,1X,I2,4X,7(2X,E14.8),4X,E14.8)
121 FORMAT(5X,I2,1X,8E9.3)
122 FORMAT(1H ,7HMACHINE,121X,3HROW/1H ,5HGROUP,9X,4H1963,12X,4H1964,
112X,4H1965,12X,4H1966,12X,4H1967,12X,4H1968,12X,4H1969,13X,6HTOTAL
2S //)
123 FORMAT(5HMACH.,5X,4H1963,5X,4H1964,5X,4H1965,5X,4H1966,5X,4H1967,
15X,4H1968,5X,4H1969,3X,9HROW TOTAL/)
124 FORMAT(/1H ,2X,5HTOTAL,16X,I5,10X,E14.6)
125 FORMAT(/1X,5HTOTAL,18X,I5,70.,E15.5)
126 FORMAT(/1H ,6HTOTALS,1X,7(2X,E14.8))
127 FORMAT(/8HCOL. TOY,2X7E9.2)

```

C
C
C

```
918 FORMAT(20X,35H SUMERBANK BAKIRKOY PAMUKLU SANAYII ///)
921 FORMAT(27X,9H LAST YEAR,12X,7H AVERAGE,3X,8H STANDARD/7H CODE NO,4X,5H
1STOCK,3X,5H PRICE,4X,6H OF USE,5X,6H SOURCE,5X,3H USE,5X,9H DEVIATION,
23X,3H ALT,4X,3H UST/)
988 FORMAT(2I2,I4,1X,I5,F9.2,I4,2I1,F10.2,1X,F10.2,2F7.1,1X,F6.2,F9.2)
CALL EXIT
END
```

THESIS

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Analysis of Depletion Periods :

This program is used to estimate the length of time the existing stocks will be sufficient to meet the demand under the assumption that demand will follow the same trend of the past years. The depletion periods are computed for the spares in each machinery group. The program is also designed to calculate the total funds tied up to stocks in each machinery group.

Analysis of Past Demand :

Given stock levels, stock values and frequency distribution of demand in the past years, this program computes the following :

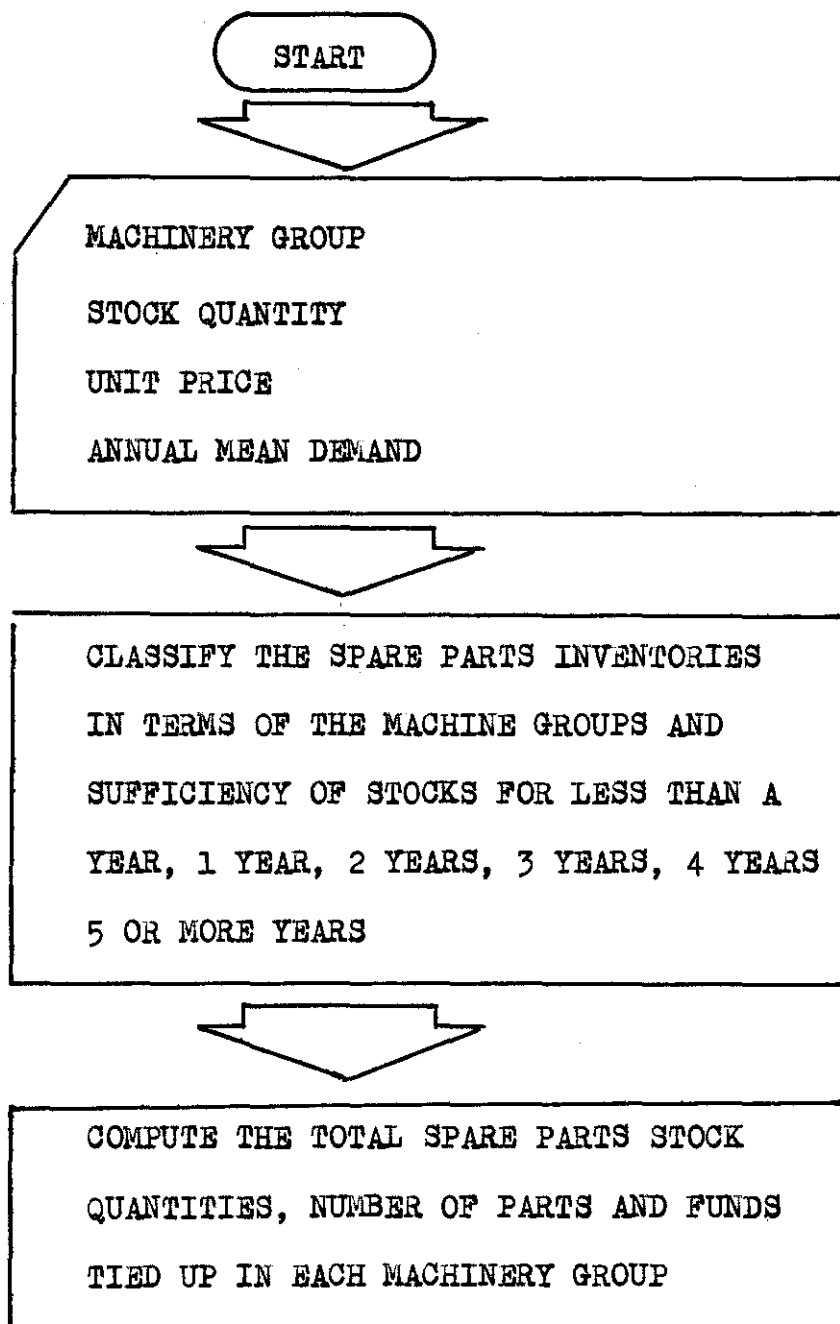
- . Number of Spare Parts in the Stocks and percentage Distribution of These with Respect to the Machinery Groups in Total Inventories,
- . Funds Tied up to Inventories with Respect to the Machinery Groups and their Percentage Distribution in Total Stocks by Years,
- . Movements of Demand for Spare Parts in the Past Years,
- . Graphics of Demand Distributions of the Machinery Groups in the Past Years.

THESIS

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ANALYSIS OF SPARE PARTS STOCKS
WITH RESPECT TO DEPLETION PERIODS
SYSTEM FLOW CHART



C **** ANALYSIS WITH RESPECT TO DEPLETION PERIODS ****

C *FANDK1005

C **; ENGIN UYSAL ***

ROBERT COLLEGE COMPUTER CENT

C DIMENSION KK(16,6),KS(16,6), FU(16,6),SUM(6)

C DO 1 J=1,6

SUM(J) = 0.0

DO 1 I=1,16

KK(I,J) = 0.0

KS(I,J) = 0.0

10 FU(I,J) = 0.0

C 66 READ 1, JJ,KST, PR, ES

IF(JJ) 5, 99, 5

5 K = ES+1.0

IF(K 5) 9, 9, 7

7 K = 6

9 KK(JJ,K) = KK(JJ,K)+1

KS(JJ,K) = KS(JJ,K)+KST

AST = KST

FU(JJ,K) = FU(JJ,K)+AST*PR

GO TO 66

99 PRINT 25

PRINT 26

DO 28 JJ=1,16

28 PRINT 30, JJ, (KK(JJ,K),KS(JJ,K), FU(JJ,K),K=1,6)

DO 39 K=1,6

DO 4 JJ=1,16

40 SUM(K) = SUM(K)+FU(JJ,K)

39 CONTINUE

PRINT 49, (SUM(K),K=1,6)

PRINT 50

C FORMAT STATEMENTS

1 FORMAT(2X,I2,5X,I5,F9.2,41X,F7.2)

25 FORMAT(//1H ,3X,67H ANALYSIS WITH RESPECT TO THE DEPLETION PERIOD
IF THE STOCKS ON HAND ///

26 FOF MAT(1H ,20X,16H LESS THAN 1 YEAR,9X,6H 1 YEAR,13X,7H 2 YEARS,13X,
17H 3 YEARS,13X,7H 4 YEARS,9X,15H 5 OR MORE YEARS//1H ,3X,13HMACHINE
2ROUP,2X,6(1X,3H A ,1X,4 H B ,11H C)///)

30 FORMAT(1H ,8X,I2,7X,6(13,1X, I5 ,1X,F10.2))

49 FORMAT(//1H ,8X,5HTOTAL,7X,6(5X,E14.6))

50 FORMAT(///1H ,5X,4HA = ,25HNUMBER OF DIFFERENT PARTS/1H ,5X,4HB :
1,21HTOTAL NUMBER OF PARTS/1H ,5X,4HC = ,10HFUNDS TIED)

CALL EXIT

END

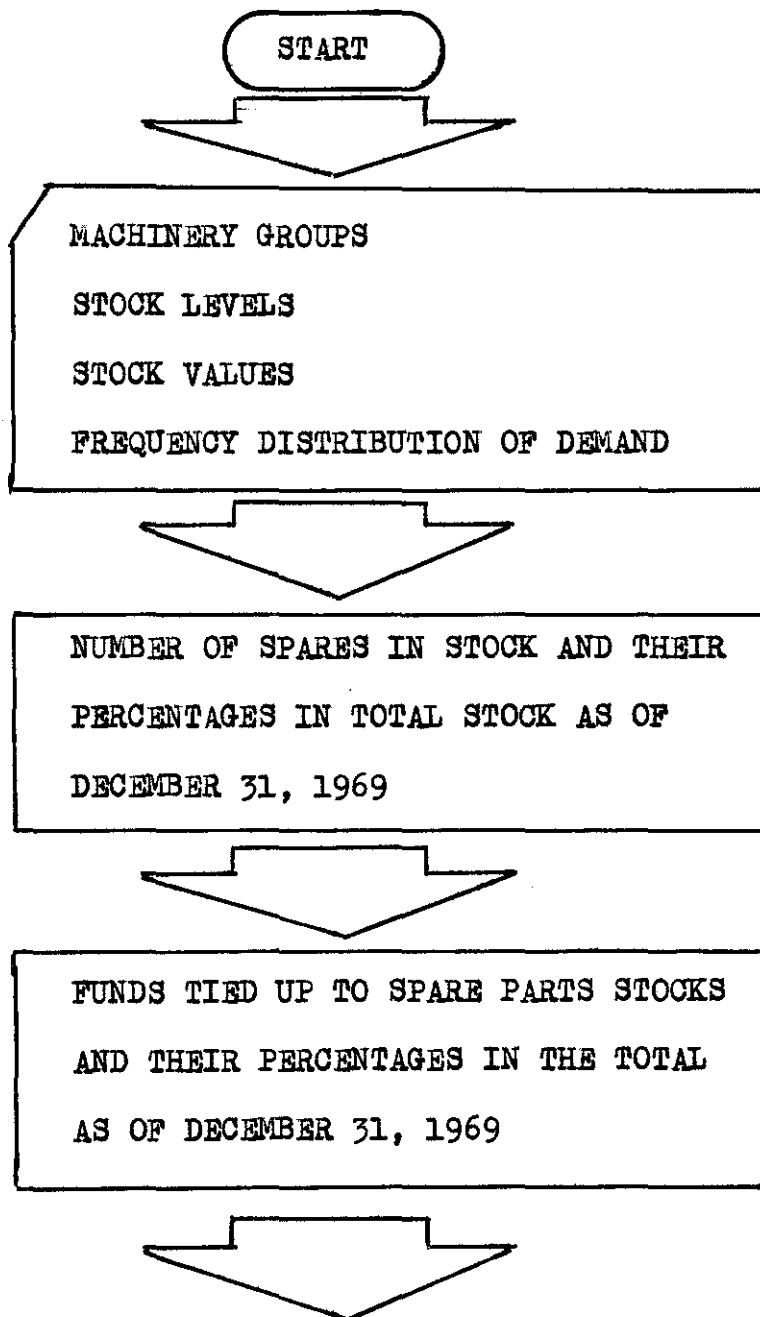
THESIS

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ANALYSIS OF PAST DEMAND

SYSTEM FLOW CHART




THESIS


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DEMAND FOR SPARE PARTS AND THEIR
PERCENTAGE DISTRIBUTION IN TOTAL
DEMAND IN 1963-1969




GRAPH OF THE TOTAL SPARE PART
DEMAND DISTRIBUTION BY YEARS



GRAPHS OF THE SPARE PART DEMAND
DISTRIBUTION OF EACH MACHINERY
GROUP BY YEARS



GRAPHS OF THE PERCENTAGE YEARLY
DISTRIBUTION OF DEMAND FOR SPARE
PARTS OF EACH MACHINERY GROUP IN
TOTAL DEMAND FOR SPARES



STOP

*** ENGIN UYSAL ***

ROBERT COLLEGE COMPUTER CENTER

DIMENSION KSARF(7),SARF(7),S(16,7),DE(16),NUM(16),ROWTOT(16),
COLTOT(7), FX(7), FY(7),YF(7),PERSA(16,7),PERPAR(16),PERDE(16)
DIMENSION XNUM(16)

INITIALIZATION

DO 6 I=1,16

ROWTOT(I) = 0.

DE(I) = 0.

NUM(I) = 0.

DO 44 J=1,7

S(I,J) = 0.

COLTOT(J) = 0.

44 CONTINUE

60 CONTINUE

FX(1) = 963

NUMTOT = 0.

DETOT = 0.

66 READ 5, JJ, STOK, TOKIY, (SARF(J),J=1,7)

IF(JJ) 30, 19, 30

30 IF(STOK) 3, 4, 3

4 BIRDE = 0.

GO TO 7

3 BIRDE = TOKIY/STOK/100.

7 GO TO (74,76,79,82,84,86,89,92,94,96,98,102,104,106,108,112),JJ

74 DE(JJ) = DE(JJ)+TOKIY

NUM(JJ) = NUM(JJ)+1

DO 8 J=1,7

80 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)

GO TO 66

76 DE(JJ) = DE(JJ)+TOKIY

NUM(JJ) = NUM(JJ)+1

DO 9 J=1,7

90 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)

GO TO 66

79 DE(JJ) = DE(JJ)+TOKIY

NUM(JJ) = NUM(JJ)+1

DO 1 J=1,7

100 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)

GO TO 66

82 DE(JJ) = DE(JJ)+TOKIY

NUM(JJ) = NUM(JJ)+1

DO 110 J=1,7

110 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)

GO TO 66

84 DE(JJ) = DE(JJ)+TOKIY

NUM(JJ) = NUM(JJ)+1

DO 120 J=1,7

120 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)

GO TO 66

86 DE(JJ) = DE(JJ)+TOKIY

NUM(JJ) = NUM(JJ)+1

C
C
C

```
DO 130 J=1,7
130 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
GO TO 66
89 DE(JJ) = DE(JJ)+TOKIY
NUM(JJ) = NUM(JJ)+1
DO 140 J=1,7
140 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
GO TO 66
92 DE(JJ) = DE(JJ)+TOKIY
NUM(JJ) = NUM(JJ)+1
DO 150 J=1,7
150 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
GO TO 66
94 DE(JJ) = DE(JJ)+TOKIY
NUM(JJ) = NUM(JJ)+1
DO 160 J=1,7
160 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
GO TO 66
96 DE(JJ) = DE(JJ)+TOKIY
NUM(JJ) = NUM(JJ)+1
DO 170 J=1,7
170 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
GO TO 66
98 DE(JJ) = DE(JJ)+TOKIY
NUM(JJ) = NUM(JJ)+1
DO 180 J=1,7
180 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
GO TO 66
102 DE(JJ) = DE(JJ)+TOKIY
NUM(JJ) = NUM(JJ)+1
DO 190 J=1,7
190 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
GO TO 66
104 DE(JJ) = DE(JJ)+TOKIY
NUM(JJ) = NUM(JJ)+1
DO 2 J=1,7
200 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
GO TO 66
106 DE(JJ) = DE(JJ)+TOKIY
NUM(JJ) = NUM(JJ)+1
DO 210 J=1,7
210 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
GO TO 66
108 DE(JJ) = DE(JJ)+TOKIY
NUM(JJ) = NUM(JJ)+1
DO 220 J=1,7
220 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
GO TO 66
112 DE(JJ) = DE(JJ)+TOKIY
NUM(JJ) = NUM(JJ)+1
DO 230 J=1,7
230 S(JJ,J) = S(JJ,J)+BIRDE*SARF(J)
GO TO 66
19 DO 250 MM=1,16
DETOT = DETOT+DE(MM)
NUMTOT = NUMTOT+NUM(MM)
DO 260 J=1,7
ROWTOT(MM) = ROWTOT(MM)+S(MM,J)
260 COLTOT(J) = COLTOT(J)+S(MM,J)
250 CONTINUE
```

C
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C

```

C
  XNUMT = NUMTOT
  DO 280 MLM=1,16
  XNUM(MLM) = NUM(MLM)
  PERPAR(MLM) = XNUM(MLM)/XNUMT
  PERDE(MLM)=DE(MLM)/DETOT
  DO 290 KMK=1,7
290  PERSA(MLM,KMK)= S(MLM,KMK)/COLTOT(KMK)
280  CONTINUE
      DO 5   MMM=1,3
      PRINT 111
      PRINT 18
      PRINT 113
      PRINT 115
      DO 245 LL=1,16
245  PRINT 117,LL,NUM(LL),PERPAR(LL),DE(LL),PERDE(LL)
      PRINT 124, NUMTOT, DETOT
      PRINT 77
      PRINT 111
      PRINT 121
      PRINT 122
      DO 255 MM=1,16
255  PRINT 119, MM, (S(MM,J),J=1,7), ROWTOT(MM)
      PRINT 126, (COLTOT(J),J=1,7)
      PRINT 77
      PRINT 111
      PRINT 129
      PRINT 128
      DO 285 MLM=1,16
285  PRINT 127,MLM,(PERSA(MLM,KMK),KMK=1,7)
      DO 4   JK=1,16
      PRINT 77
      FY(1) = S(JK,1)
      DO 450 L=2,7
      FX(L) = FX(L-1)+1.
450  FY(L) = S(JK,L)
      PRINT 88
      CALL GRAPH2 (9.,9.,7,FX,FY)
      PRINT 182, JK
400  CONTINUE
      PRINT 77
      PRINT 77
      PRINT 88
      CALL GRAPH2 (9.,9.,7,FX,COLT(T))
      PRINT 184
      PRINT 77
      DO 315 IJK=1,16
      DO 316 JJJ=1,7
316  YF(JJJ) = PERSA(IJK,JJJ)
      PRINT 88
      CALL GRAPH2 (9.,9.,7,FX,YF)
      PRINT 185, IJK
315  CONTINUE
      PRINT 77
      PRINT 77
500  CONTINUE

```

```

C
C
C   FORMAT STATEMENTS
C

```

```

5  FORMAT(2X,I2,22X,F5.0,2X,F7.0,7F3.0)
C
C
C

```

18 FORMAT(1H //,30X,35H SUMERBANK BAKIRKOY PAMUKLU SANAYII ///) 63
77 FORMAT(1H1)
88 FORMAT(/)
111 FORMAT(///)
113 FORMAT(//,1H ,25X,39HTOTAL VALUE OF SPARE PARTS USED IN 1969 ///)
115 FORMAT(1H ,2X,13HMACHINE GROUP,5X,15HNUMBER OF PARTS,11X,7HPERCENT
1,12X,10HFUNDS TIED,15X,7HPERCENT/)
117 FORMAT(1H ,7X,I2,14X,I5,14X,F10.4,10X,E14.6,10X,F10.4)
119 FORMAT(1H ,1X,I2,4X,7(2X,E14.8),4X,E14.8)
121 FORMAT(1H ,45X,39HEXPENDITURES ON MACHINE GROUPS BY YEARS/1H ,61X,
16H(TL))
122 FORMAT(1H ,7HMACHINE,121X,3HROW/1H ,5HGROUP,9X,4H1963,12X,4H1964,
112X,4H1965,12X,4H1966,12X,4H1967,12X,4H1968,12X,4H1969,13X,6HTOTAL
25 //)
124 FORMAT(/1H ,2X,5HTOTAL,16X,I5,34X,E14.6)
126 FORMAT(/1H ,6HTOTALS,1X,7(2X,E14.8))
127 FORMAT(1H ,1X,I2,4X,7(2X,F10.4))
128 FORMAT(1H ,7HMACHINE,7(5X,7HPERCENT)/1H ,5HGROUP,9X,4H1963,8X,4H19
164,8X,4H1965,8X,4H1966,8X,4H1967,8X,4H1968,8X,4H1969//)
129 FORMAT(1H ,30X,39HPERCENTAGE DISTRIBUTION OF EXPENDITURES/1H ,36X,
126HON MACHINE GROUPS BY YEARS///)
182 FORMAT(//1H ,11X,54HGRAPH SHOWING THE CONSUMPTION PATTERN ON MACHI
1NE GROUP,1X,I2,1X,23HIN THE PAST SEVEN YEARS)
184 FORMAT(//1H ,11X,83HGRAPH SHOWING THE CONSUMPTION PATTERN ON ALL M
1ACHINE GROUPS IN THE PAST SEVEN YEARS)
185 FORMAT(//1H ,11X,65HGRAPH SHOWING THE PERCENTAGE CONSUMPTION PATTE
1RN ON MACHINE GROUP,1X,I2,1X,27HDURING THE PAST SEVEN YEARS)
CALL EXIT
END

THESIS

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BEBEK, ISTANBUL

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Analysis of Last Year of Use and Annual Mean Demand Distribution :

The following data on spare parts,

- . Stock Levels,
- . Unit Prices,
- . Last Years of Use, and
- . Annual Mean Demand,

obtained from the company records are used as input to this program to compute

- . Number of spares in each machinery group,
- . Spare parts stock level in each machinery group with respect to last year of use, and
- . Funds tied up to spare parts stocks in each machinery group with respect to last year of use, and

for the purpose of periodic control, spare parts are divided into three groups according to their annual mean demand.

THESIS

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BEBEK, ISTANBUL

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ANALYSIS OF LAST YEAR OF USE AND ANNUAL MEAN DEMAND DISTRIBUTION

SYSTEM FLOW CHART

START

```
graph TD; Start([START]) --> Box1[MACHINERY GROUP  
STOCK LEVEL  
UNIT PRICE  
LAST YEAR OF USE  
YEARLY DEMAND AVERAGES 1963-1969]; Box1 --> Box2[NUMBER OF SPARES IN EACH  
MACHINERY GROUP]; Box2 --> Box3[SPARE PARTS STOCK LEVELS IN EACH  
MACHINERY GROUP WITH RESPECT TO  
LAST YEAR OF USE];
```

MACHINERY GROUP

STOCK LEVEL

UNIT PRICE

LAST YEAR OF USE

YEARLY DEMAND AVERAGES 1963-1969

NUMBER OF SPARES IN EACH

MACHINERY GROUP

SPARE PARTS STOCK LEVELS IN EACH

MACHINERY GROUP WITH RESPECT TO

LAST YEAR OF USE

THESIS

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BEBEK, ISTANBUL

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FUNDS TIED UP TO SPARE PARTS
STOCKS IN EACH MACHINERY GROUP
WITH RESPECT TO LAST YEAR OF USE



SEPARATION OF SPARES INTO 3 MAIN
GROUPS FOR MONTHLY- 3 MONTHLY AND
YEARLY PERIODIC INVENTORY CONTROL
ON THE BASIS OF THEIR ANNUAL MEAN
DEMAND

<u>CONTROL PERIOD</u>	<u>ANNUAL MEAN DEMAND</u>
ONE MONTH	MORE THAN 20
THREE MONTHS	6-20
ONE YEAR	5 OR LESS



STOP

THESIS

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BEBEK, İSTANBUL

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Spare Parts Inventory Movements in Bakırköy Cotton Textile Industry

Stock Depletion Periods:

Estimates of the depletion periods of spare part stocks are based on the movements of 4827 kinds of parts during the last seven years (1963-1969). Arithmetic average of the past consumption of a spare in the last seven years is assumed to be the annual mean demand for that spare in estimating the depletion period.

$$\text{Depletion Period} = \text{Stock Level} / \text{Annual Mean Demand}$$

The following tables show the depletion period of stocks and the funds that will be tied up to inventory during these periods.

Four thousand eight hundred twenty seven (4827) different spares in the stocks as of December 31, 1969 have been analyzed by utilizing the storeroom records and the archive of Bakırköy Textile Industry. It has been observed that 1791 spares worth of TL 1,005,412, in the stocks have not shown any movement at all since 1962. A summary of the number of spares and funds tied up with respect to last year of use is given below:

<u>Last Year of Use</u>	<u>Number of Spares</u>	<u>Funds Tied Up (TL)</u>
1962	1791	1,005,412
1963	103	55,440
1964	181	104,667
1965	235	124,416
1966	205	113,344
1967	392	<u>214,654</u>
		1,617,933

Table 3A
 BAKIRKÖY COTTON TEXTILE INDUSTRY
 DISTRIBUTION OF SPARE PART STOCKS WITH RESPECT TO DEPLETION PERIODS
 (Number of Spares)

<u>Machinery</u> <u>Group</u>	<u>Less than</u> <u>a year</u>	<u>One</u> <u>Year</u>	<u>Two</u> <u>Years</u>	<u>Three</u> <u>Years</u>	<u>Four</u> <u>Years</u>	<u>5 or more</u> <u>Years</u>
SCRUTCHER	15	10	14	15	10	202
COMBING	23	6	18	8	9	224
DRAWING	6	3	3	3	5	56
ROWING	6	7	3	4	5	194
YARN	43	20	24	22	5	301
WINDING	24	14	10	14	9	117
VeFT	19	12	9	8	3	188
STARCHING	45	32	33	30	20	542
WEAVING	301	176	127	104	65	1039
DYEING	6	7	6	7	5	164
BOILER 1	-	-	-	-	-	5
BOILER 2	2	1	-	-	-	46
BOILER 3	-	1	3	2	-	54
"ŞERİT GÖZ"	-	-	-	-	-	1
"ŞERİT"	-	-	-	-	-	1
KNOTTING	1	3	5	1	5	296
Total	491	292	255	218	141	3430

Table 3B

BAKIRKÖY COTTON TEXTILE INDUSTRY

FUNDS TIED UP TO SPARE PARTS STOCKS WITH RESPECT TO DEPLETION PERIODS

(L)

<u>Machinery Group</u>	<u>Less than a Year</u>	<u>One Year</u>	<u>Two Years</u>	<u>Three Years</u>	<u>Four Years</u>	<u>5 or more Years</u>
SCRUTCHER	1,088	2,518	2,850	5,683	2,634	107,504
COMBING	4,488	2,267	4,190	1,621	1,609	112,988
DRAWING	1,102	405	1,448	152	1,580	31,900
ROWING	4,432	5,741	3,529	2,591	573	166,578
YARN	12,741	20,426	10,372	11,176	9,242	288,078
WINDING	12,885	23,034	6,270	19,531	1,856	111,912
VEFT	2,491	9,396	2,772	5,494	233	95,326
STARCHING	3,774	15,154	39,494	21,888	15,510	313,243
WEAVING	214,547	98,393	77,869	69,285	79,883	754,925
DYEING	406	7,389	1,823	3,720	4,814	78,352
Boiler 1	-	-	-	-	-	654
BOILER 2	3	1	-	-	-	25,131
BOILER 3	-	740	3,326	405	-	101,821
"ŞERİT GÖZ"	-	-	-	-	-	23
"ŞERİT"	-	-	-	-	-	277
KNOTTING	18	686	793	189	1,087	75,043

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A great number of these stationary spares belong to the machines that are no longer in production line.

As seen in the above table, the distribution of the funds tied up to spares is as follows:

Less than a year	TL	257,980
One year		186,605
Two years		154,743
Three years		141,741
Four years		119,025
Five or more years		2,263,744

If stocks that will be sufficient more than a year are roughly assumed as excessive inventories, it is seen that TL 2,679,253 is tied up to the excess inventories. It should also be pointed out that spare part stocks are accumulated especially in certain machinery groups.

Parts with Zero Consumption:

A great number of spares in the stocks have not been used at all for a long time. Most of these spares are not expected to be used from now on, because the machines which they belong to are out of use now. The thing to be done is to determine carefully which of these 2907 spares that constitute 60 percent of the total spares should be sold, and to reduce the funds, TL 1,617,933, tied up to unusable spares to a minimum.

Table 4
BAKIRKÖY COTTON TEXTILE INDUSTRY
LAST YEARS OF USE OF SPARES AND FUNDS TIED UP

Machinery Group	1962		1963		1964		1965	
	No	L	No	L	No	L	No	L
SCRUTCHER	83	39,939	10	3,220	15	8,031	15	3,640
COMBING	108	45,368	18	10,657	25	9,666	19	14,092
DRAWING	30	14,204	1	172	7	4,179	12	3,590
ROWING	106	91,633	8	2,519	19	7,904	19	8,900
YARN	164	113,005	8	4,552	23	42,247	30	9,904
WINDING	64	33,770	1	497	5	805	15	7,366
VEFT	120	49,581	9	4,264	8	2,568	8	9,632
STARCHING	250	96,692	26	6,025	15	4,199	50	18,717
WEAVING	488	364,188	22	23,894	36	19,187	49	39,360
DYEING	86	42,079	-	-	4	1,973	3	240
BOILER 1	4	631	-	-	-	-	-	-
BOILER 2	33	10,837	-	-	1	165	1	1
BOILER 3	31	57,031	-	-	-	-	2	1,290
"ŞERİT GÖZ"	1	23	-	-	-	-	-	-
"ŞERİT"	1	277	-	-	-	-	-	-
KNOTTING	222	46,154	-	-	23	745	12	5,523
Total	1791	1,005,412	103	55,440	181	104,667	235	124,416

Cont'd

Machinery <u>Group</u>	1966		1967		1968		1969	
	<u>No</u>	<u>L</u>	<u>No</u>	<u>L</u>	<u>No</u>	<u>L</u>	<u>No</u>	<u>L</u>
SCRUTCHER	14	4,110	12	6,419	62	22,012	55	34,904
COMBING	13	5,563	26	7,996	46	16,088	33	17,730
DRAWING	2	1,001	3	1,425	3	7,726	18	4,288
ROWING	14	7,716	13	8,331	12	4,245	28	52,557
YARN	19	29,791	47	31,260	57	56,990	67	64,286
WINDING	9	3,957	23	47,429	26	19,356	45	62,308
VEFT	10	6,515	39	20,832	23	18,744	22	3,576
STARCHING	26	10,521	58	20,222	102	71,951	175	180,736
WEAVING	65	28,410	133	53,282	283	226,192	736	540,388
DYEING	13	7,195	14	9,106	22	11,776	53	22,423
BOILER 1	-	-	-	-	1	3	-	-
BOILER 2	-	-	1	1,550	5	9,418	8	3,165
BOILER 3	7	3,485	3	3,102	9	6,421	8	34,963
"ŞERİT GÖZ"	-	-	-	-	-	-	-	-
"ŞERİT"	-	-	-	-	-	-	-	-
KNOTTING	15	5,090	20	3,700	1	610	20	12,994
Total	205	113,344	392	214,654	652	471,532	1268	1,034,318

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Demand Distributions:

Demand for spares arises mainly in two ways:

- . Demand generated by breakdowns,
- . Demand generated by preventive maintenance.

It is almost impossible to estimate demand generated by breakdowns of parts since no one can tell exactly when a breakdown will occur. However, it is known that machine breakdowns are due to random occurrence of a variety of independent factors. Then, it can be theoretically assumed that demand generated by casual machine breakdowns has a normal distribution.

As for demand generated by preventive maintenance, it can be statistically estimated which spares in what quantities have been used during maintenance if reliable past records are available. Then demand for spares generated by preventive maintenance can be forecasted on the basis of past records of maintenance, assuming that these are properly maintained. However, records for such a statistical estimation do not exist. The firm is highly recommended to keep these records for future use. Since demand for spares generated by maintenance can be directly estimated, safety stock levels will be considerably decreased provided that proper records are kept. Then, it is necessary to maintain stocks only for random breakdown of parts, which can be significantly reduced under a careful maintenance system.

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Analysis of Annual Spare Part Consumption:

All spare parts can be subjected to a periodic review on the basis of their past consumption patterns. In this analysis, average annual consumption of each spare and its standard deviation has been calculated by using the past seven years data. All spares are grouped into three: those which are consumed five or less in a year, those which are used between six and twenty in a year, and those whose average annual consumption is more than twenty.

In the system design section, it is recommended to make periodic control of all spares under the following criteria:

<u>Average Annual Consumption</u>	<u>Length of Period</u>
5 or less	One year
6 - 20	Three months
More than 20	One month

The distribution of average annual consumption of 4827 spares during the period between 1963 and 1969 is given below.

As seen from the table, the distribution of average annual consumption of spares is as follows:

<u>Average Annual Consumption</u>	<u>%</u>
5 or less	73
6 - 20	12
21 or above	14

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Table 5
DISTRIBUTION OF AVERAGE
ANNUAL CONSUMPTION OF SPARES
(1963-1969)

<u>Machinery Group</u>	<u>5 or Less</u>	<u>6-20</u>	<u>More than 20</u>	<u>Total</u>
SCRUTCHER	243	12	11	266
COMBING	236	35	17	288
DRAWING	70	3	3	76
ROWING	196	20	3	219
YARN	294	65	56	415
WINDING	109	31	48	188
VEFT	170	31	38	239
STARCHING	520	101	81	702
WEAVING	1062	339	411	1812
DYEING	177	8	10	195
BOILER 1	5	-	-	5
BOILER 2	46	3	-	49
BOILER 3	57	2	1	60
"ŞERİT GÖZ"	1	-	-	1
ŞERİT	1	-	-	1
KNOTTING	296	11	4	311
Total	3483	661	683	4827

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Stock Levels:

The distribution of spare parts stocks among the machinery groups as of December 31, 1969 is given below.

The greatest number of spares, 1813, 37.55%, belong to the Weaving Department. On the other hand, in the departments of Banding machines and Hole Banding two spares, one in each, are carried in stocks for seven years without any movement.

As seen, spares and capitals tied up to them are approximately evenly distributed among the machinery groups. Though, the percentages of funds tied up to the stocks in the departments of Weaving, Starching, and Yarn are relatively higher compared to the others.

Spare Part Expenditures:

Expenditures on spares in the previous years with respect to the machinery groups are shown below.

As will be seen in the tables, expenditures on spares in the past seven years are almost evenly distributed among the machinery groups. The weaving department is the section of the plant where a majority of expenditures on spares go. This is certainly due to relatively large number of looms and machines in that particular department.

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Table 6
DISTRIBUTION OF SPARE PARTS STOCKS
AMONG MACHINERY GROUPS
as of December 31, 1969

<u>Machinery Group</u>	<u>Number of Parts</u>	<u>%</u>	<u>Capital Tied Up</u>	<u>%</u> -----
SCRUTCHER	266	5.51	122,416.12	3.90
COMBING	288	5.96	127,218.40	4.05
DRAWING	76	1.57	36,594.06	1.16
ROWING	219	4.53	183,500.36	5.84
YARN	414	8.57	352,007.11	11.21
WINDING	188	3.89	175,559.78	5.59
VEFT	239	4.95	115,806.54	3.68
STARCHING	702	14.54	409,292.15	13.04
WEAVING	1813	37.55	1,309,039.90	41.70
DYEING	195	4.03	96,981.22	3.08
BOILER 1	5	.10	634.98	.02
BOILER 2	49	1.01	25,140.53	.80
BOILER 3	60	1.24	106,298.70	3.38
"ŞERİT GÖZ"	1	.02	23.19	.00
"ŞERİT"	1	0.02	277.85	.00
KNOTTING	311	6.44	77,873.95	2.48
Total	4827		3,138,664.84	

Table 7 A

BAKIRKÖY COTTON TEXTILE INDUSTRY

DISTRIBUTION OF EXPENDITURES ON SPARES AMONG THE MACHINERY

(L)

<u>Machinery</u>	<u>1963</u>	<u>1964</u>	<u>1965</u>	<u>1966</u>	<u>1967</u>	<u>1968</u>	<u>1969</u>	<u>Total</u>
SCRUTCHER	12600	12509	12390	10584	10951	20531	9391	88596
COMBING	28043	27713	34012	18444	21196	33706	12960	176074
DRAWING	4451	8401	7402	2711	1793	4456	1886	31100
ROWING	15587	13172	19485	16112	17587	19490	13920	115353
YARN	56226	90379	48336	59684	53129	92900	14286	414940
WINDING	48216	45307	61369	41420	93175	61910	45114	396511
VEFT	25670	24751	18722	19527	22120	14786	2340	127916
STARCHING	67000	57070	71383	55431	70069	59188	31596	411737
WEAVING	911062	626074	415618	665998	734442	764622	450200	4568016
DYEING	545	1481	2627	42265	13322	11414	16851	88505
BOILER 1	-	-	-	-	-	2	-	2
BOILER 2	-	114	13	26	49	965	305	1472
BOILER 3	-	235	782	2164	8878	6492	4851	23402
"ŞERİT GÖZ"	-	-	-	-	-	-	-	-
"ŞERİT"	-	-	-	-	-	-	-	-
KNOTTING	472	7440	4088	3925	3252	610	5750	25537
Total	1169872	914546	696227	938291	1049963	1091072	609450	

Table 7B

DISTRIBUTION OF EXPENDITURES ON SPARES AMONG THE MACHINERY GROUPS

(%)

<u>Machinery</u>	<u>1963</u>	<u>1964</u>	<u>1965</u>	<u>1966</u>	<u>1967</u>	<u>1968</u>	<u>1969</u>
SCRUTCHER	1.07	1.36	1.77	1.12	1.04	1.88	1.54
COMBING	2.39	3.02	4.88	1.96	2.01	3.08	2.12
DRAWING	0.38	0.91	1.06	0.28	0.17	0.40	0.30
ROWING	1.33	1.44	2.79	1.71	1.67	1.78	2.28
YARN	4.80	9.88	6.94	6.36	5.06	8.51	2.34
WINDING	4.12	4.95	8.81	4.41	8.87	5.67	7.40
VEFT	2.19	2.70	2.68	2.08	2.10	1.35	0.38
STARCHING	5.72	6.23	10.25	5.90	6.67	5.42	5.18
WEAVING	77.87	68.44	59.69	70.97	69.94	70.07	73.86
DYEING	0.04	0.16	0.37	4.50	1.26	1.04	2.76
BOILER 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BOILER 2	0.00	0.01	0.00	0.00	0.00	0.08	0.05
BOILER 3	0.00	0.02	0.11	0.23	0.84	0.59	0.79
"ŞERİT GÖZ"	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"ŞERİT"	0.00	0.00	0.00	0.00	0.00	0.00	0.00
KNOTTING	0.04	0.81	0.58	0.41	0.30	0.05	0.94

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CHAPTER 8

SYSTEM DESIGN

Objectives

The goal of Spare Parts Inventory Control System design is to maintain optimum spare part stocks under the condition specified in the system analysis section of this study. Thus, system design will ensure

- . harmonious operation of the inventory control system
- . economy of time and personnel
- . continuous control of inventories and inventory control parameters.

The factors considered in the system design section can be summarized as follows:

- . simplicity of the new system as much as possible, thus
- . the present personnel can easily put it into practice, and
- . adaptability of the system to the possible changes in the parameters.

The parameters that are likely to change in time are:

- . Allowed risk of running into stock-out,
- . Cost of holding,
- . Cost of shortage,
- . Cost of ordering,
- . Lead time.

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A change in one of the above parameters necessitates the adjustment of the formulas used in the inventory control system.

Manual and Electronic Control Systems

Spare part inventory control system has been designed both for manual and computerized control. Operational procedures of both of the alternative systems are described in detail in later sections of this chapter. Due to the minimization of human error, quicker control of stock levels and the elimination of human factor, electronic system seems to be more advantageous than manual system. However, in the absence of a computer, the manual system proves to be satisfactory provided that staff working on inventory control are trained and experienced.

The success of the new system is also dependent on the implementation of a uniform coding system.

New Coding System

The present coding system has been analyzed and described in detail in the system analysis section. To facilitate the transfer of spares among the establishments of Sümerbank and central holding of stocks, a standard coding system is to be developed and uniformly used by all of the Sümerbank institutions.

The new coding system should convey as much information as possible. The proposed coding system for all Sümerbank textile institutions should contain the following information:

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- . Material code,
- . Machine group code,
- . Sequence number,
- . Institution or plant code.

The proposed coding system is slightly different from the one that is being used in Bakırköy Cotton Textile industry. This coding system is composed of eight digits.

<u>Digits</u>	<u>Information</u>	<u>Code</u>
1 - 2	Material group	33
3 - 4	Machinery group	01
5 - 8	Sequence number	0001

The above example (33010001) designates the first material in machine group one in the group of spare parts. This system necessitates coding of all machinery groups starting from 01. In this system a maximum of 100 machinery groups can be coded. Practically, there will not be more than 100 machinery groups in an industrial concern. Sequence number of a material can be indicated by a four digit code. Thus, a maximum of ten thousand sorts of material can be coded in a single machinery department.

If two digits are added to the end of the presently practised coding system to indicate the institution transformation of the present system to the central holding system, which will be discussed later, is highly facilitated.

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In the new coding system, code number of a non-existing or a sold material cannot be assigned to any other material. A new spare part entering the stocks is assigned the next sequential number after the last spare in the machinery department where the spare belongs to.

The firm under concern is recommended to use in its records only the new code numbers together with the names of parts when necessary.

Central Holding

Holding spares for several user points in one central store has been thought of as an alternative solution to the problem of spare part inventory control in institutions with more than one production unit. In case of central holding, records of all spare parts must be kept centrally by a computer.

This method proposes a system in which records are kept centrally by a computer and spares are held in local stores instead of a single central store. In this model when a need for a spare arises, by learning from the central records the local store where the spare is available, the particular spare is delivered to its point of use.

However, to build such a system,

- . a study of the substitutability of spare parts,
and
- . application of a single uniform coding system in
all local units

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are necessary. The substitutability of spare parts is dependent upon

- . having the same types of machinery in local plants, or
- . usage ability of a part on more than one type of machinery.

It is recommended that this study is carried out with extreme care by a special commission composed of trained personnel who possess technical knowledge of machinery and parts. After this study is completed, the same commission should meet periodically to code newspares. This system turns out to be practical and economic if transformation of parts can be carried out in a short time and at a low cost. Under the present circumstances, transportation of a spare from one plant to another will approximately take one or two days and will not cost much.

The advantage of the model can be proved as follows:

If x_1, x_2, \dots, x_n are the elements of x set,

$$\sigma_x = \sqrt{\sigma_{x_1}^2 + \sigma_{x_2}^2 + \dots + \sigma_{x_n}^2}$$

That is, instead of having safety stocks scattered to n different locations, collecting these together into one group results in a fall in the safety stock level as a consequence of the decrease in the total standard deviation. Numerically, if

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$\sigma_{x_1} = \sigma_{x_2} = \dots = \sigma_{x_5} = 5$, and safety stock levels estimated to be 20_{x_n} , the safety stock size in 5 plants will be $2 \times 5 \times 5 = 50$. Whereas, if these are gathered together, using the same risk of stock-out

$$\sigma_x = \sqrt{5 \times 25} = 11.2$$

and the safety stock level will be 22.4.

Second advantage of the proposed system is that it does not necessitate physical gathering of all spares in a single store. Only the information flow will be centralized by making use of a computer. Under the present circumstances, this can be easily achieved in Sümerbank plants.

The central holding system is used by the Turkish Army. Makine Kimya Endüstrisi has also attempted to use this system.

Manual System

In this section the principals and operational procedure of a manual inventory control system are examined. The accomplishment of a manual inventory control system is dependent first of all on the clear definition of the obligations, authorities, and responsibilities of the management functions related to the inventories. The following procedure has been followed to identify the place of manual inventory control in the total system and to fix the operational procedure.

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- . Organization of the company and functions of the parts related to inventory control in this organization,
- . Determination of inventory control parameters,
- . Determination of source of supply,
- . Information flow,
- . Inventory control procedure,
- . Periodic control of spare parts consumption.

Organization:

Obligations, authorities, and responsibilities of every management function in Sümerbank Textile Industries are fixed by a regulation. The proposed manual inventory control system brings slight changes in the obligations, authorities, and responsibilities of management functions that are directly involved in the inventory control function. The following management functions are directly or indirectly involved in spare parts inventory control.

- . Production manager,
- . Planning manager,
- . Finance manager,
- . Commerce manager
 - Non-manufactured goods store
 - Manufactured goods store
- . Machine - Energy manager.

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In the present system, a great portion of the inventory control function is entrusted to the Purchasing and Sales (Commerce) Department. The proposed manual inventory control system reduces the load of the Purchasing and Sales Department and assigns the responsibility and authority of fixing stock control parameters to the Planning Department.

In the organization of the plant under study, there is no department in charge of controlling stock levels. Authorities and responsibilities are distributed among various departments. This is erroneous as far as the organization of control functions in an industrial concern is concerned. In the present system Commerce Department deals with purchasing; Accounting Department keeps the necessary records and Auxiliary Production Department tries to estimate the need for spares. Naturally, all of these functions cannot be handled by a single department. Though, the coordination of all of these inventory control functions can be undertaken by a single department which bears the responsibility of inventory control. Alternatives for the department in charge of inventory control are given below:

- . Planning bureau or a separate division within the planning bureau,
- . A separate group within the structure of Commerce or Finance Departments, or
- . An independent group in charge of inventory control.

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Since these alternatives necessitate fundamental changes in the present organization, obligations and authorities of the departments involved in the spare part manual inventory control system under the existing conditions are summarized below.

Production Department:

- . Prepares spare part requisition slip whenever a need arises.
- . Prepares the list of spares of critical importance for the production process.
- . Prepares the list of spares which are not likely to be used at all.

Planning Department:

- . Fixes inventory control parameters,
- . Investigates possible sources of supply and chooses the most economic one,
- . Checks the order size specified in the requisition slip, makes alterations if necessary,
- . Studies distributions of demand for spares with respect to sources of supply, searches the reasons beyond abnormal demand patterns,
- . Makes sure that orders for critical spares are placed ahead of time considering the possible variations in lead times,
- . Takes the necessary measures to discard the spares that belong to out of use machines.

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Finance Department:

- . Traces spare part expenditures to the point of use of the spares for accurate cost estimation,
- . Allocates funds for materials and spares to be purchased from outside.

Commerce Department:

- . Undertakes purchasing of materials, seeks the cheapest sources of supply,
- . Non-manufactured goods store,
 - Maintains store records,
 - Identifies critical spares with tags,
 - Records the withdrawal of spares from the store and informs the Planning Department of the quantity withdrawn and remaining stock in the store,
 - Refers the requisition slips for those spares non-existent in the stocks to the Planning Department to secure to place an order,
 - Sends the records of goods received to the interested parties through the Department of Commerce,
 - Arranges the goods in the store in an orderly manner.

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Machine-Energy Department:

- . Keeps machine records,
- . Takes the necessary measures for continuous and smooth operation of the machines and looms,
- . Arranges and controls the activities of the machine shop.

The obligations, authorities, and responsibilities of the functions in relation with inventory control have been described above.

Coordination and integration of these functions to achieve an optimum inventory control system necessitates an improved information flow system, which will be examined and described in detail in a later section of this chapter.

Two-Bin System:

Two-bin system of inventory control is used in spare part manual inventory control system. In this system, spares are considered to be kept in two bins. One bin contains spares for immediate supply, the second bin contains spares which are to be used during the replenishment period. In this system, spares do not have to be contained physically in two separate bins, but inventory records are to be maintained in accordance with this scheme. Spares are withdrawn from the first bin to begin with; when the stock in the first bin is exhausted an order is placed, and withdrawals are made from the second bin. When new spares arrive, the second bin is

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conditions in the short and long run, and for assisting in the decision making process of the top management who are confronted with many daily problems. Growth of industrial concerns has led to enlargement of the problems faced by them, and as an inevitable consequence of this situation, every management function today constitutes a branch of the management science. In the management science, determination, and implementation of inventory control policy require some sort of specialization and competence. Therefore, determination of inventory control parameters is left to the administration and control of a group of people embodied in the planning departments where statistical analysis can be handled easily.

The following inventory control parameters,

- . Order size,
- . Reorder point, and
- . Safety stock level

are calculated once for every spare available. Calculation of parameters is shown below:

Order Size:

Optimum economic order quantity is determined by the following formula. In this formula demand is assumed to be stationary.

$$EOQ^* = \sqrt{\frac{2(CO)(D)}{CH}}$$

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where,

EOQ^* = optimum economic order quantity, quantity per year

CO = cost of ordering, TL

D = annual demand, quantity per year

CH = cost of holding, TL/quantity/year

Safety Stock:

Safety stock is the quantity of materials that must be kept in stock to absorb variations in demand and to meet maximum reasonable demand during the replenishment period. Safety stock level is calculated in the following way.

$$ORSAY^* = D/EOQ^*$$

$$SDPO = \hat{S}_T/ORSAY^*$$

$$PSPO = AROS/ORSAY^*$$

$$PP = 1 - PSPO$$

$$SS = SDNUM \times SDPO, \text{ where}$$

$ORSAY^*$ = optimum number of orders,

SDPO = standard deviations per order,

PSPO = probability of shortage per order,

PP = probability of not running into shortage per order,

SDNUM = number of standard deviations corresponding to the probability of PP,

SS = safety stock level,

\hat{S}_T = standard deviation of the annual demand distribution.

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Reorder Point:

Reorder point is the quantity which protects against a shortage during the replenishment period. This quantity is determined by adding average demand during the replenishment period to the safety stock level.

$$DELT = D/300 \times LT$$

$$REORPT = SS + DELT, \text{ where}$$

DELT = demand during the replenishment period,

LT = replenishment period,

REORPT = reorder point.

Replenishment time varies with source of supply and quantity ordered. Statistical distribution of replenishment time is not known. Generally, under the assumptions of PERT model, β distribution can be used to show the characteristics of the distribution of replenishment time.

The shortest, the longest and average lead times of each source of supply can be obtained from the records of the Purchasing and Sales Department. Average lead time used in the determination of reorder level is estimated as follows:

$$\text{Average Lead Time} = \frac{(KLT) + 4(OLT) + (ULT)}{6}, \text{ where}$$

KLT = the shortest lead time,

OLT = the mean lead time,

ULT = the longest lead time.

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The manual system proposes the determination of inventory control parameters for every material in stock. When there is a large number of items in stock (i.e., 4500 spares), the manual system turns out to be impractical.

Selection of Source of Supply:

If the need for a spare cannot be satisfied by the storeroom, the problem of determining the source of supply arises. The system proposes to employ dual preference coding system for possible sources of supply. The Machine-Energy Department is in charge of coding the spares according to the sources of supply. The main possible sources of supply are:

- . Machine shop within the plant,
- . Other plants under the community of Sümerbank,
- . Internal market, and
- . Imports.

Alternative sources of supply are supposed to be indicated in the records kept by storeroom as well as in every requisition slip, if the spare sought is not available and requisition form is reversed for purchasing from outside.

Information Flow:

This section specifies the alternative information channels to be used whenever a need for a spare arises and/or an entry to the stocks is made. Information flow starts in two ways.

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- . Demand for a spare is realized, or
- . Previously ordered material is received.

The number of memoranda is reduced to two as shown in the information flow diagram for spare parts. Each department receives the copy of the memorandum that contains relevant information for the use of that particular department. The only two memoranda used solely for the movements of stocks are the following:

- . Requisition form
- . Order form.

Inventory Control Procedure:

In the new system inventory control function is executed before an order is placed. The men in the Planning Department who are in charge of controlling the inventory control parameters try to implement the optimum inventory control policy by careful and consistent control of the stock levels and order sizes.

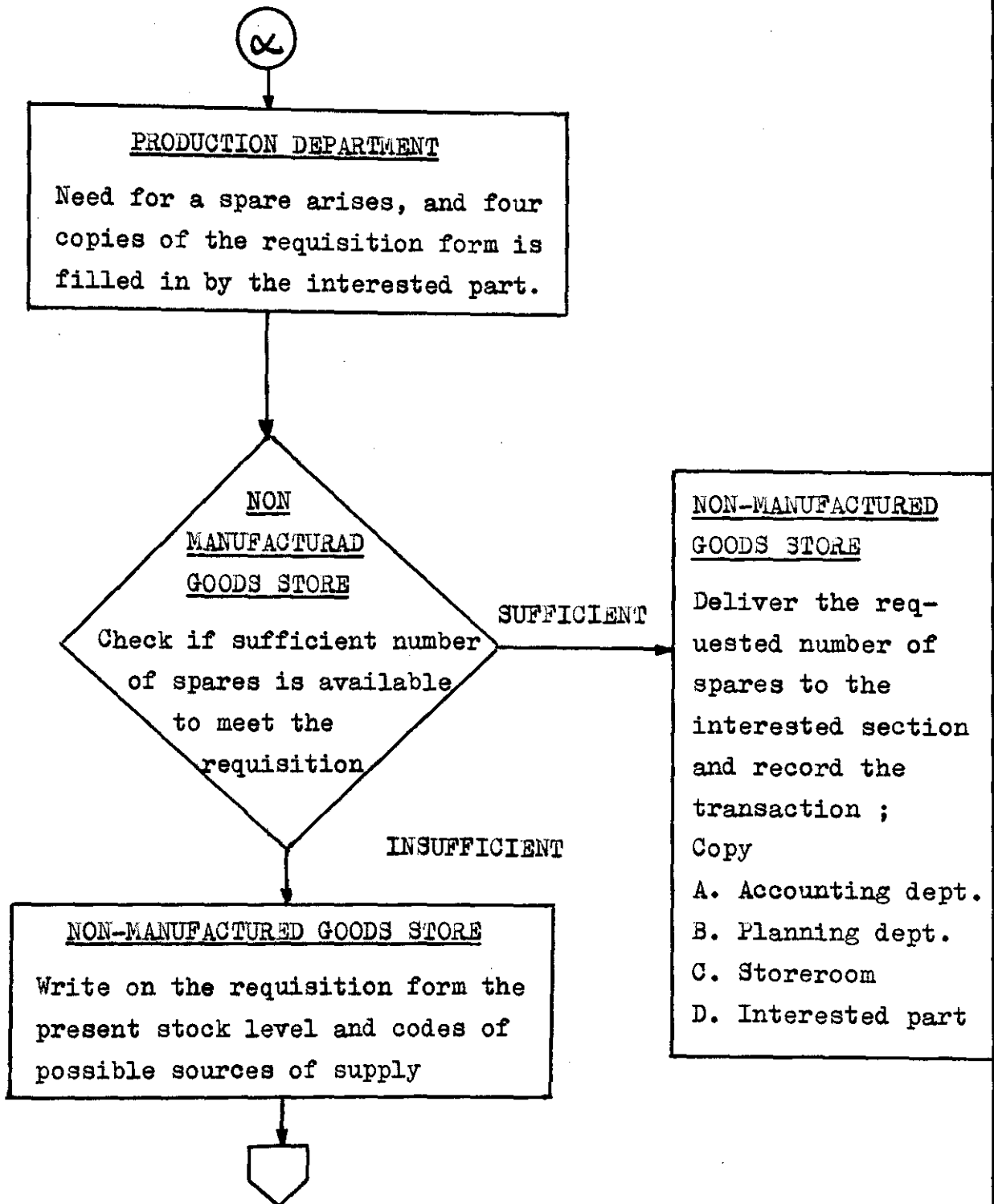
In the manual inventory control system, source of supply is determined from the codes available in spare part records and order size is fixed in accordance with the parameters whose calculation methods are shown in detail in electronic inventory control system section.

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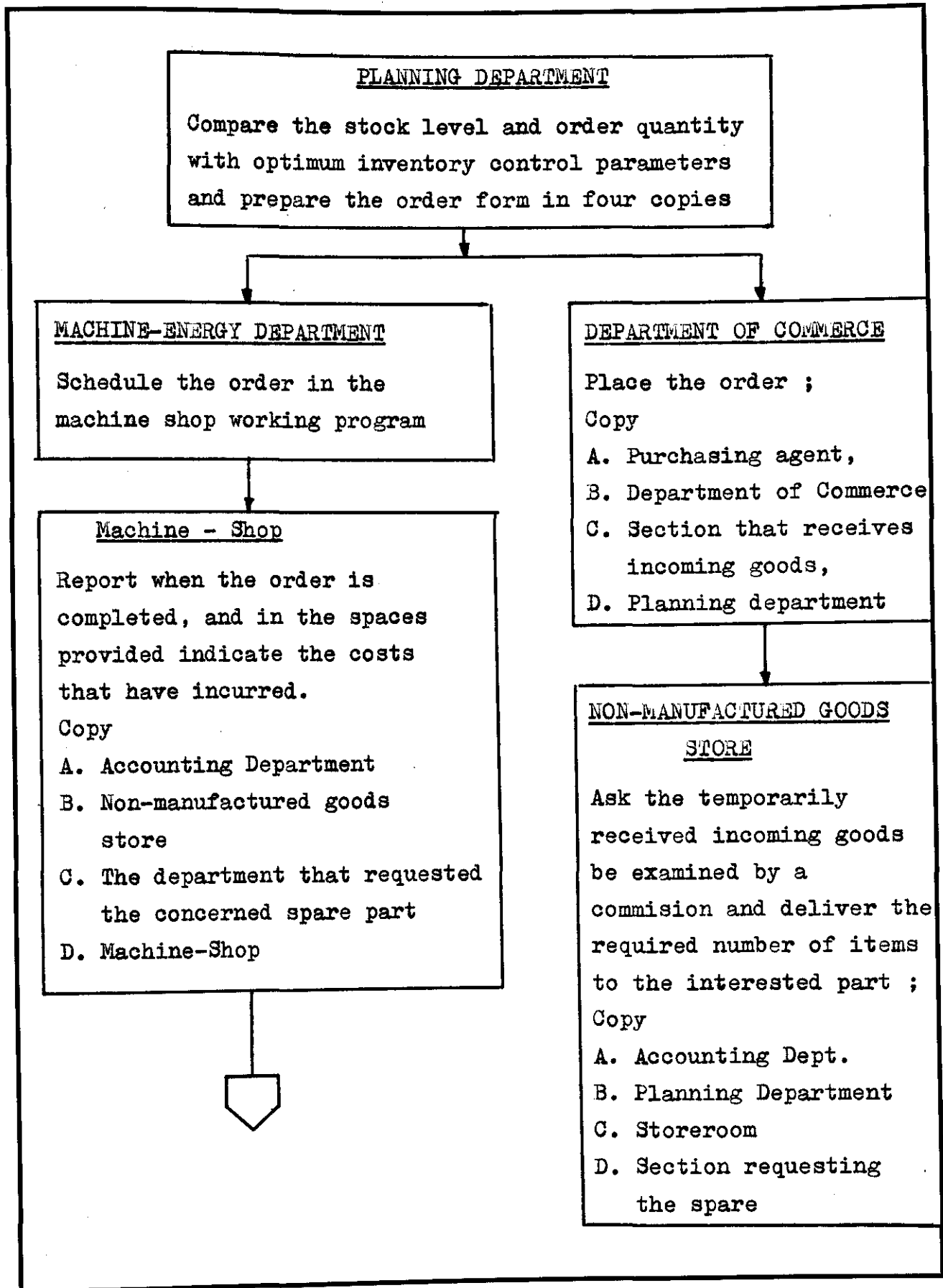
SPARE PARTS INFORMATION FLOW DIAGRAM



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NON-MANUFACTURED GOODS

STORE

Record the quantity manufactured as entry to stocks, and deliver the quantity requested by the interested department, and deduct this as withdrawal of the item from the storehouse ;

Copy

- A. Accounting Department,
- B. Planning Department,
- C. Storeroom,
- D. The section requesting the spare.

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Periodic Review:

The aim of this review is to find out if annual actual demand for spares which have been previously divided into three groups in terms of their average annual consumption, exceeds the upper and lower limits of the normal demand distribution, and to investigate those spares whose consumption pattern is significantly different from the past consumption pattern.

The spares whose actual demand falls outside the limits of the normal demand are divided into two groups:

- . Those below the minimum consumption
- . Those above the maximum consumption.

The upper and lower limits are estimated as follows:

$$\text{Lower limit} = \bar{x} - 1.645\sigma$$

$$\text{Upper limit} = \bar{x} + 1.645\sigma$$

\bar{x} = average demand

$$\bar{x} = \frac{\sum_{i=1}^N x_i}{N}$$

x_i = actual demand in the i^{th} period,

N = number of periods.

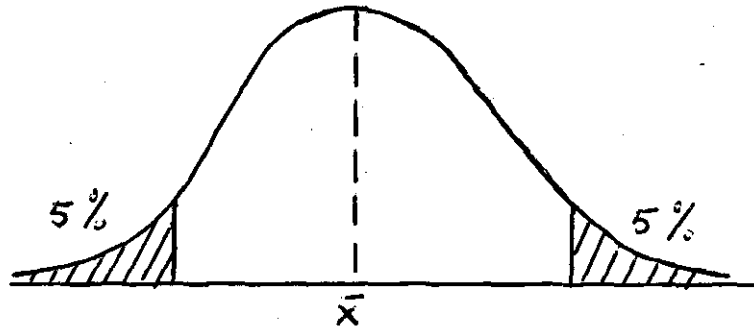
The standard deviation of the demand distribution is estimated by the following equation:

$$\sigma = \sqrt{\frac{\sum_{i=1}^N (x_i - \bar{x})^2}{N-1}}$$

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NORMAL DEMAND DISTRIBUTION

Probability of demand falling in the shaded regions is 10 percent.

Each spare whose demand falls in the shaded region is subjected to an investigation to find out the reasons of the significant change in the consumption pattern.

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Electronic Inventory Control System

Objective:

The objective of designing an electronic inventory control system is to facilitate the inventory control procedure by utilizing a computer, whereby more objective, consistent, unbiased, and effective inventory control than that provided by a staff of humans is assured at a relatively fast rate. The main uses of electronic processing system are:

- . Prompt and accurate recording of stocks,
- . Periodic updated information on spare part, stocks in each machinery group,
- . Economy of time,
- . Execution of optimum ordering policy.

General Procedure:

Electronic inventory control system consists of two separate phases. Methods of determining optimum inventory parameters are shown in the first phase, and the procedure of implementing the inventory control function under the given parameters and other inputs is described in the second phase.

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Optimum Parameters

As it has been pointed out before optimum economic order, quantities and safety stock levels are closely related to each other. A theoretical analysis of this relation is given in the following pages.

In the first phase of the system design a simulation program has been written to determine the impact of various economic order quantities upon such variables as inventory levels, number of orders placed and the total cost of inventory. Given the allowed degree of risk of running into stock-out, safety stock, economic order quantity, and number of orders are determined in such a way that the sum of

- . Cost of ordering,
- . Cost of carrying in stock between two order points,
and
- . Cost of holding safety stock

is minimized.

Optimum inventory control parameters can be determined for every spare part by using the same simulation program. However, due to the great number of spares and the necessity of recalculation of these parameters, every time a change in the inputs occurs, makes this process unworthy and tedious. Therefore, in the second stage of the first phase a heuristic approach has been developed to determine the optimum order quantity by using a multiple regression analysis.

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Heuristic is defined as a method of control by limiting the amount of search the decision-maker must use to achieve a workable solution to his problem. It is something that contributes to the reduction of search in problem solving activity. It should be pointed out that heuristic solutions to problems are not necessarily the best or optimum solutions, since many alternatives are excluded from consideration which are hopefully irrelevant but, in fact, may not be.

In this way, making use of the simulation results obtained previously, optimum order quantity is calculated through the regression equation given the following information:

- . Annual mean demand,
- . Standard deviation of the demand distribution,
- . Cost of ordering, and
- . Cost of holding in inventory.

Periodic Inventory Control Procedure

All spares are first of all divided into three groups according to their annual consumption rates as it has been mentioned in the earlier sections of this study. From the inputs provided for each spare, the computer calculates:

- . Annual mean demand, its standard deviation,
- . Optimum order quantity through the regression equation,

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- . Safety stock level as a function of order quantity and lead time,
- . Reorder point, and
- . Stock on hand.

Then, the computer prints out the following information:

- . Report on present stock levels and inventory control parameters of spare part stocks,
- . Report on spares for which orders are to be placed, and
- . Report on spare part stocks which need to be reduced to a reasonable level.

Relation Between Safety Stock and Order Size

Safety stock is determined by the lead time and the degree of reliability of demand predicted, and the order size is determined by the costs of carrying in inventory, cost of ordering, and annual mean demand. In fix order size system, the safety stock fixes the risk to be borne each time the stocks on hand approaches the reorder point. The order size determines the frequency of exposure to risk. The greater the order size, the less frequently will the inventory be exposed to stock-out. The risk of stock-out varies inversely with the size of the order quantity for a given safety stock level.

Dependence of safety stock on order size and the lead time is related directly to the frequency of stock-out allowed and the

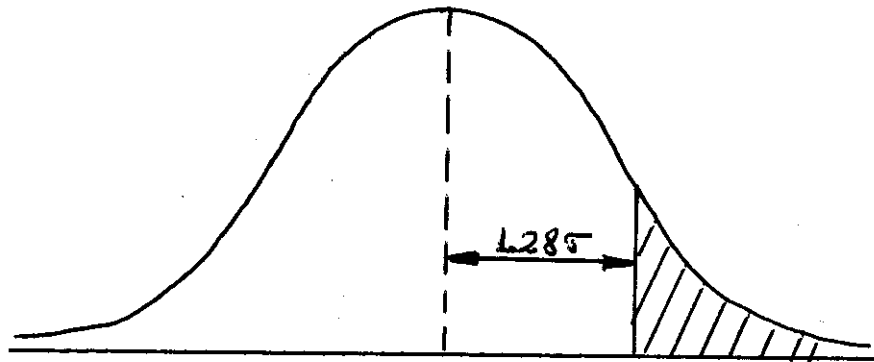
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distribution of actual demand during the replenishment period. For instance, a stock-out on the average of once every ten years is allowed, and the order quantity equals an average of 36 days' usage, then a safety stock is needed to bring the chance of stock-out on each order to one percent. However, if the order quantity is enough to meet six months' usage, the risk of stock-out on each order is increased to five percent, decreasing the safety stock requirements.

The relationship between order quantity and safety stock is illustrated by the following graphs. The allowed risk of stock-out for the firm is assumed to be ten percent.



DEMAND DISTRIBUTION

Number of orders: 1

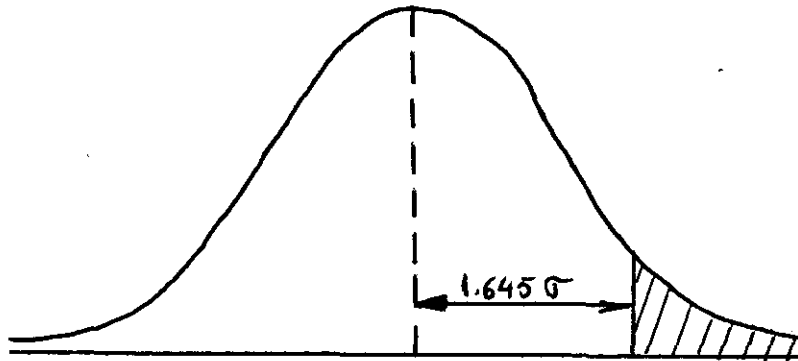
Probability of shortage per order: .100

Number of standard deviations: 1.28

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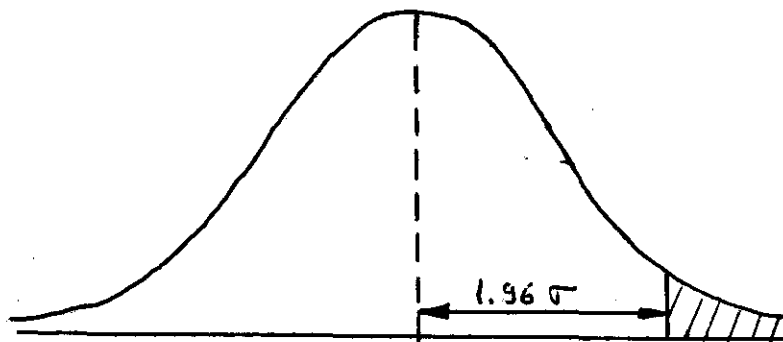


DEMAND DISTRIBUTION

Number of orders: 2

Probability of shortage per order: 0.050

Number of standard deviations: 1.645



DEMAND DISTRIBUTION

Number of orders: 4

Probability of shortage per order: 0.025

Number of standard deviations: 1.96

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The relationship between order size and safety stock level can be worked out numerically in the following table.

Assumptions:

- . Annual demand for spare parts (D) is 1000 units,
- . Standard deviation of demand distribution (σ) is 100,
- . Allowed risk of stock-out per year (AROS) is 10%.

The following table illustrates numerically the variations in safety stock levels for three different order sizes, 1000, 500, 250.

Simulation or Computer Search Technique

Simulation is a technique in which a model is built to represent a real-world system or subsystem. Sampling experiments are performed on the model rather than on the real system, because the latter would be inconvenient, time-consuming, and expensive.

The first step in simulation is to develop a model that represents the system under investigation. The essence of simulation lies in the fact that systems are generally complex, and it is quite difficult to investigate a complex system as a whole. Models are constructed to investigate, explain, and predict the dynamic behavior of the systems. Simulation usually involves a mathematical model which is run rather than solved.

Table 8

RELATION BETWEEN SAFETY STOCK AND ORDER SIZE

	<u>ALTERNATIVE 1</u>	<u>ALTERNATIVE 2</u>	<u>ALTERNATIVE 3</u>
Annual Demand (D)	1000 units	1000 units	1000 units
Standard Deviation of Demand Distribution (5)	100	100	100
Order Size (Q)	1000	500	250
Number of Orders (ORSAY)	1	2	4
Number of Standard Deviations per Order (SDPO)	100	71	50
Probability of Shortage per Order (PSPO)	.100	.050	.025
Number of Standard Deviations for the Probability of not having stock-out per order (SDNUM)	1.28	1.645	1.96
Safety Stock Level (SS)	128 units	117 units	98 units

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To be able to simulate a system, a fairly good knowledge of the components of the system is required. The system is therefore broken down into a set of components for which operating rules may be obtained. These operating rules are used to predict the situations that will be generated in the real system. After operating rules, components and logical flow diagram of the system are specified, the model is tested a number of times on an electronic data processing system. Since simulation usually involves handling of a vast amount of data, and many calculations, the numerical computations are carried out by a computer.

Simulation can be used in predicting the behavior of a business operation even in the face of uncertainty. Using past history of occurrence of events, possible circumstances can be simulated in terms of probability distributions. If the behavior of a component cannot be predicted exactly, random observations are taken from the probability distributions involved. Where probability distributions are explicitly included, the technique is frequently called Monte Carlo Simulation.

Monte Carlo Technique

It is a process whereby data are generated by use of some random number generator. Implementing a simulation model requires the use of random numbers to obtain random observations from the probability distributions.

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An example of this procedure should make the procedure clearer. Suppose the probability distribution of the outcome of throwing two dice. The probability of throwing ^atwo is $1/36$, the probability of a three is $2/36$. In this technique $1/36$ of the possible values of a random number 0,277 if four digit random numbers are being used, can be associated with throwing a two. In order to demonstrate the use of Monte Carlo technique, the probability distribution and the use of random numbers in the example of throwing two dice is given below.

<u>Combination</u>	<u>Probability</u>	<u>Cumulative Probability Distribution</u>
2	$1/36$	0.0277
3	$2/36$	0.0833
4	$3/36$	0.1666
5	$4/36$	0.2777
6	$5/36$	0.4166
7	$6/36$	0.5833
8	$5/36$	0.7222
9	$4/36$	0.8333
10	$3/36$	0.9166
11	$2/36$	0.9721
12	$1/36$	0.9999

Each random number or sequence of generated numbers is used as a decimal value of the cumulative probability. The number corresponding to this cumulative probability value is taken then as the random observation. If the sequence of

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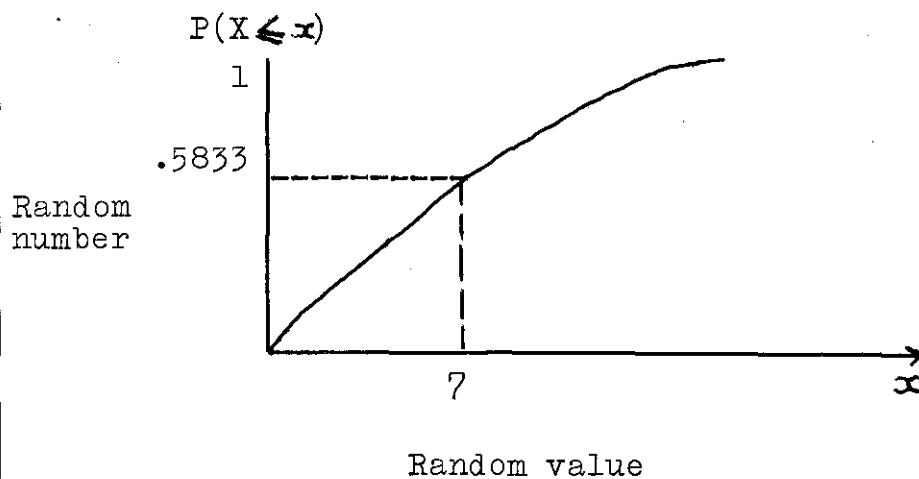
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random numbers happens to be 129,219,373,186,747, the corresponding random combinations are 4,5,6,5,9, respectively.

The first step in utilizing the Monte Carlo technique is to construct the cumulative probability distribution of the past history.

$F(X) = P(X \leq x)$, where X is the random variable.

The function, $F(X)$, takes values between 0 and 1. The second step is to draw a random number between 0 and 1. The third step is to set $P(X \leq x)$ equal to the random decimal number which is obtained by placing a decimal point in front of the random integer number and solve for x . The value of x is the random observation desired to draw from the given probability distribution. The method of finding the random value when the random number happens to be 0.5833 is illustrated graphically in the following figure.



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Demand Generation

In the electronic inventory control system, the annual demand for spare parts needs to be predicted in determining the parameters. Demand is one of the uncontrollable variables of an inventory system. Since demand cannot be predicted exactly, in testing the performance of the model, the value of demand has been simulated from the past probability distributions of demand.

Demand for spare parts may have a variety of distributions for different spares, therefore, it has been considered best to use the frequency distribution of historical data instead of assuming the theoretical probability distributions, and demand for spares can be predicted from the frequency distribution of historical data by the use of the Monte Carlo technique. The procedure followed in predicting demand is described in the system flow chart for the "Demand Generator". The computer is used in predicting demand, because a random-number generator is stored on its disc and the demand generation program is used as a subroutine program in the simulation of the total system. The subroutine program generates monthly demand. It is assumed that demand for spares does not have any seasonal variations, by the nature of spares, and annual demand is estimated by multiplying the monthly demand generated by 12. The system flow chart, FORTRAN flow chart and FORTRAN program are given in the subsequent pages.

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DEMAND GENERATION

by

MONTE CARLO TECHNIQUE

SYSTEM FLOW CHART

START

HISTORICAL DEMAND DATA

UPPER AND LOWER LIMITS OF THE
PAST DEMAND DISTRIBUTION

CUMULATIVE PROBABILITY DISTRIBUTION
OF THE FREQUENCY DISTRIBUTION OF
DEMAND DATA

RANDOM NUMBER GENERATION

GENERATION OF DEMAND CORRESPONDING
TO THE RANDOM NUMBER IN THE CUMULATIVE
DEMAND DISTRIBUTION

```

C      SUBROUTINE FOR DEMAND GENERATION FROM THE FREQUENCY DISTRIBUTION
C
C      *** ENGIN UYSAL ***                                ROBERT COLLEGE COMPUTER CENTER
C
C*LDISKDEMAND
C      SUBROUTINE DEMAND (XRAND,X,DEM,Y)
C      DIMENSION X(30), BL(10), BU(10), FQ(10), XM(10), CFQ(10),
C      1DISLIM(10)
C      THIS PART COMPUTES THE MINIMUM AND MAXIMUM NUMBER OF PARTS
C      DEMANDED WITHIN THE PAST 24 MONTHS AND GENERATES THE FREQUENCY
C      DISTRIBUTION OF DEMAND DURING THAT PERIOD
C      SMALL = X(1)
C      BIG = X(1)
C      DO 1 I=2,22
C      IF(X(I)-SMALL) 12, 15, 15
12 SMALL = X(I)
15 IF(X(I)-BIG) 10, 10, 18
18 BIG = X(I)
10 CONTINUE
C
C      RANGE = BIG-SMALL
C      W = RANGE/7.
C      BL(1) = SMALL
C      BU(1) = BL(1)+W
C      DO 2 I=2,7
C      BL(I) = BU(I-1)
20 BU(I) = BL(I)+W
C
C      DO 35 I=1,7
C      FQ(I) = 0.
C      DO 4 J=1,22
C      IF(BL(I)-X(J)) 25, 25, 40
25 IF(BU(I)-X(J)) 40, 30, 30
30 FQ(I) = FQ(I)+1.0
40 CONTINUE
C      XM(I) = (BU(I)+BL(I))/2.0
35 CONTINUE
C      CFQ(1) = FQ(1)
C      DO 42 I=2,7
42 CFQ(I) = CFQ(I-1)+FQ(I)
C      A = 1./CFQ(7)
C      DO 5 I=1,7
50 DISLIM(I) = A*CFQ(I)
C      DEMAND GENERATION FROM THE FREQUENCY DISTRIBUTION
51 Y = RAND(XRAND)
C      DO 55 I=1,7
C      IF(Y DISLIM(I)) 56, 56, 55
56 B = BU(I+1)-BU(I)
C      C = DISLIM(I+1)-DISLIM(I)
C      IF(C) 60, 59, 60
59 C = DISLIM(I+1)
60 D = DISLIM(I+1)-Y
C      D = DISLIM(I+1)-Y
C      DEM = BU(I+1)-B*D/C
C      GO TO 58
55 CONTINUE
58 RETURN
END

```

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Formulating a Simulation Model for the Determinations of Optimum Order Quantity

This program is used for simulating demand for 20 spares having different demand distributions and prices to see what effects various demand values will have on inventory costs and order quantities. The main criteria is the minimization of the following items of inventory costs:

- . Cost of ordering
- . Cost of holding in stocks between two order points
- . Cost of holding safety stock:

Main sections of the simulation program and methods of calculations are given in the subsequent pages.

- . Generating demand by the use of Monte Carlo technique
- . Calculation of the standard deviation of the annual demand distribution

$$\sigma = \sqrt{\frac{\sum_{i=1}^N (X_{T_i} - \bar{x}_T)^2}{N-1}}$$

, where

σ = standard deviation

X_{T_i} = demand in the i^{th} period

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\bar{X}_T = demand generated by Monte Carlo technique

N = number of periods

- . Calculation of economic order quantity

$$ELS = \sqrt{\frac{2(CO)(\bar{X}_T)}{CH}}, \text{ where}$$

ELS = economic order quantity,

CO = cost of ordering,

CH = cost of holding inventory.

- . Generating a series of possible order quantities around ELS.
- . The procedure from here on is repeated for each value of order quantity generated around ELS.
- . Multiply the number of orders by the cost of ordering to obtain the annual ordering costs under each possible order size.

Total cost of ordering = Cost of making an order X number of orders

- . Determine the annual holding cost of cycle stock by multiplying one-half the order quantity by the annual unit holding cost.

Annual holding cost of cycle stock = $\frac{X}{2}$ 1/2 X order quantity X annual unit holding cost

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- . Determine allowed risk of stock-out on each order by dividing the allowed annual risk of stock-out by the number of orders per year

Allowed risk of stock out per order = Annual risk of
stock-out permitted / number of orders per year

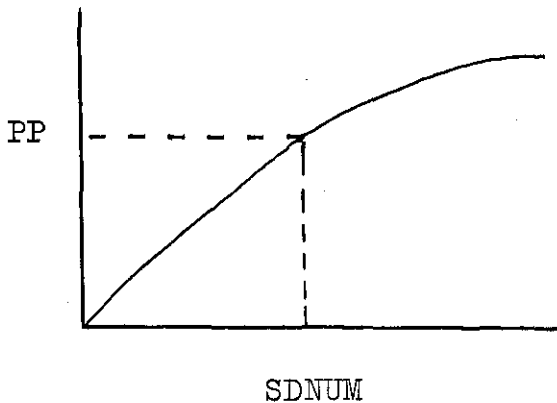
- . Number of standard deviations on each order

PP = 1 - PSPO, where

PP = cumulative probability of a stock-out

PSPO = probability of shortage per order,

SDNUM = number of standard deviations.



- . Determine the required safety stock level

Safety stock level = Number of standard deviations X
standard deviations per order.

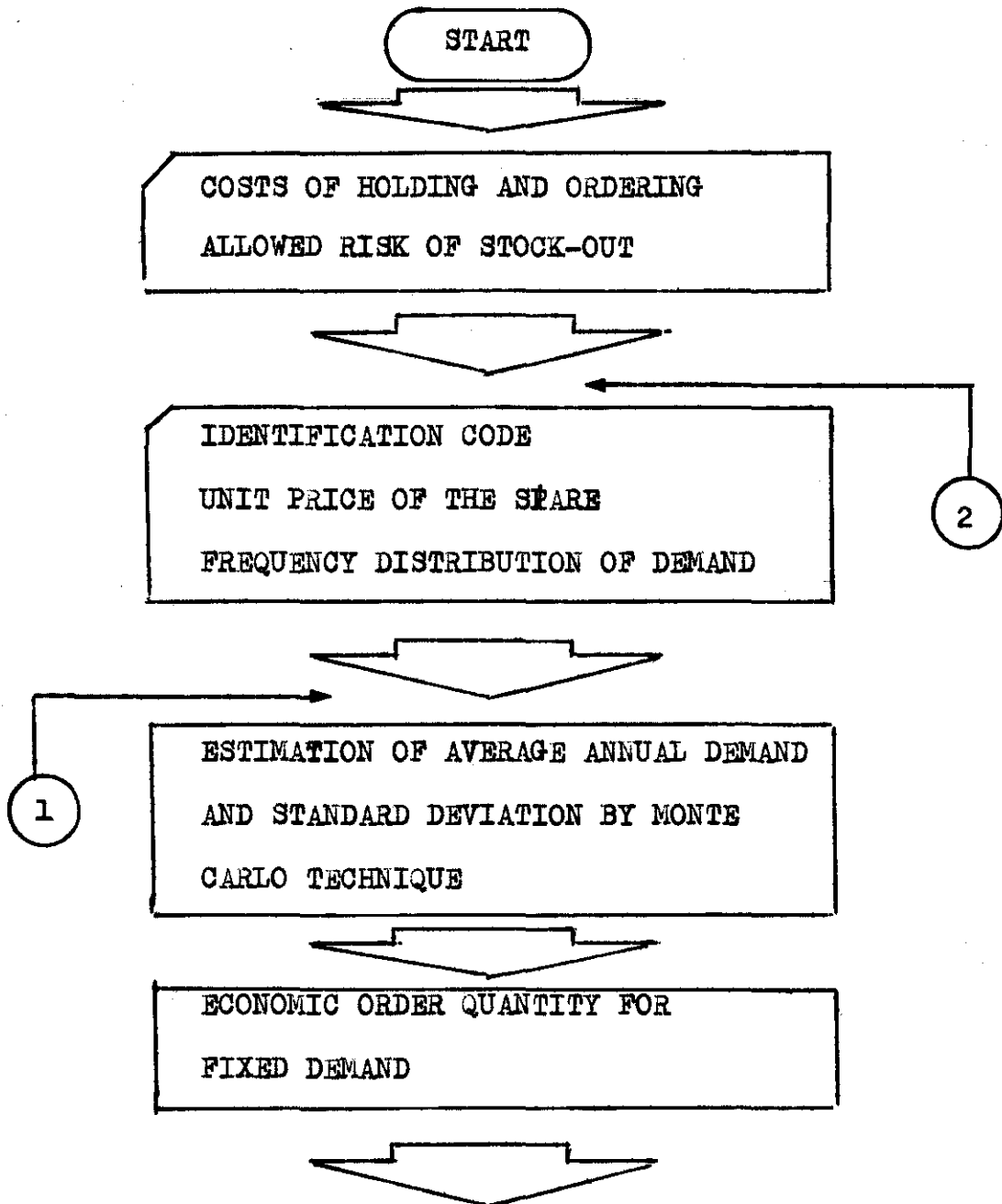
- . Calculate safety stock carrying costs by multiplying safety stock level by the annual unit inventory holding cost.
- . Determine total inventory costs by adding the cost of ordering, cycle inventory costs and safety stock costs.

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SIMULATION OF INVENTORY CONTROL SYSTEM SYSTEM FLOW CHART



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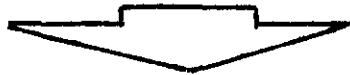
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GENERATION OF POSSIBLE ORDER
QUANTITIES AROUND EOQ



AVERAGE NUMBER OF ORDERS
PER YEAR



COMPUTATION OF ANNUAL
ORDERING COSTS



ANNUAL CARRYING COST
OF CYCLE INVENTORY



NUMBER OF STANDARD
DEVIATIONS PER ORDER



PROBABILITY OF STOCK-OUT
PER ORDER



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NUMBER OF STANDARD DEVIATIONS
CORRESPONDING TO THE PROBABILITY
OF SHORTAGE PER ORDER



SAFETY STOCK LEVEL



SAFETY STOCK CARRYING COST



TOTAL INVENTORY COSTS



SELECTION OF THE ORDER QUANTITY
WITH THE LOWEST TOTAL INVENTORY
COSTS

1



REPETITION OF THIS PROCEDURE 100
TIMES FOR VALUES OF DEMAND SIMULATED
BY MONTE CARLO AND SELECTION OF THE
OPTIMUM ORDER QUANTITY



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PUNCHING OUT THE OPTIMUM
ANNUAL DEMAND, STANDARD
DEVIATION, COST OF HOLDING
INVENTORY AND COST OF
ORDERING

2



REPETITION OF THE SAME
PROCEDURE FOR 20 DIFFERENT
SPARE PARTS



STOP

THIS PROGRAM SIMULATES INVENTORY CONTROL PARAMETERS
 WRITTEN BY ENGIN UYSAL * ROBERT COLLEGE GRADUATE SCHOOL * MAY 1970

*** ENGIN UYSAL ***

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THE VARIABLES USED IN THE PROGRAM ARE

ACC = ANNUAL CARRYING COST

CO = COST OF ORDERING (TL)

CH = COST OF HOLDING INVENTORY

NORMAL DISTRIBUTION TABLE

X(I) = NO OF STANDARD DEVIATIONS

P(I) = PROBABILITY CORRESPONDING TO THE NO. OF STANDARD DEV.

ELS = ECONOMIC LOT SIZE

EOQ = ECONOMIC ORDER QUANTITY

ORSAY = NUMBER OF ORDERS

ORCO = ORDERING COST

CYINV = CYCLE INVENTORY

SDPO = STANDARD DEVIATIONS PER ORDER

PSIY = PROBABILITY OF SHORTAGE IN A YEAR

PSPO = PROBABILITY OF SHORTAGE PER ORDER

SS = SAFETY STOCK

ASSCC = ANNUAL SAFETY STOCK CARRYING COST

ATC = ANNUAL TOTAL COST

SDNUM = NUMBER OF STANDARD DEVIATIONS

DIMENSION X(32), P(32), EOQ(31), ATC(31), SAR(22), S(30)

DIMENSION C(100), KELS(100), L(100), KAD(100), R(100), SIGMA(100)

LL =

READ 29, XRAN

DO 1 I=1,32

10 READ 2, X(I), P(I)

92 READ 1, JJ, K1, K2, PR, (SAR(I), I=1,22)

IF(JJ) 99, 99, 67

67 READ 3, CO, CH, AROS

LL = LL+1

THIS PART HAS TWO BRANCHES

SWITCH 1 ON IF DEMAND IS DETERMINISTIC

OFF IF DEMAND IS PROBABILISTIC

T = 2.*CO/(CH*PR)

PRINT 77

PRINT 52

DO 1 KK=1,20

SUM = 0

VAR = 0

THIS PART COMPUTES MEAN ANNUAL DEMAND, VARIANCE AND STANDARD
 DEVIATION FROM THE FREQUENCY DISTRIBUTION WHEN DEMAND IS
 DETERMINISTIC

IF(SENSE SWITCH 1) 5, 6

5 DO 7 I=1,22

7 SUM = SUM+SAR(I)

XBAR = SUM/22.

AD = 12.*XBAR

DO 8 J=1,22

8 VAR = VAR+(ABS(SAR(I)-XBAR))**2

SIGMA(KK) = SQRTF(12.*VAR/21.)

GO TO 11

C THIS PART COMPUTES MEAN ANNUAL DEMAND, VARIANCE AND STANDARD
 C DEVIATION FROM THE FREQUENCY DISTRIBUTION THROUGH A
 C PROBABILISTIC DEMAND GENERATOR.

6 CALL DEMAND (XBAR,SAR,XBAR,Y)
 AD = 12.*ABSF(XBAR)
 DO 9 I=1,22
 9 VAR = VAR+(ABSF(SAR(I))-XBAR)**2
 SIGMA(KK) = SQRTF(12.*VAR/21.)

11 ELS = SQRTF(T*AD)

C THIS PART FINDS THE ECONOMIC LOT SIZE AND GENERATES POSSIBLE
 C ECONOMIC ORDER QUANTITIES AROUND ELS
 C

FARK = ELS/20.
 EOQ(1) = ELS-15.*FARK
 DO 2 I=2,31
 20 EOQ(I) = EOQ(I-1)+FARK

DO 3 J=1,31
 ORSAY = AD/EOQ(J)
 ORCO = ORSAY*CO
 CYINV = 0.5*EOQ(J)*PR*CH
 SDPO = SIGMA(KK)/SQRTF(ORSAY)

C THIS PART FINDS THE NUMBER OF STANDARD DEVIATIONS

PSPO = AROS/ORSAY
 PP = 1.-PSPO
 DO 4 K=1,32
 IF(PP-P(K)) 40, 45, 46
 45 SDNUM = X(K)
 GO TO 48
 46 SDNUM = X(K-1)
 GO TO 48
 40 CONTINUE

48 SS = SDNUM*SDPO
 ASSCC = SS*PR*CH
 ATC(J) = ORCO+CYINV+ASSCC
 30 CONTINUE

C THIS PART FINDS THE OPTIMUM ECONOMIC ORDER QUANTITY WITH
 C THE LOWEST COST
 C

M = 1
 SMALL = ATC(1)
 DO 6 I=2,31
 IF(ATC(I)-SMALL) 65, 6!, 60
 65 SMALL = ATC(I)
 M = I
 60 CONTINUE
 C(KK) = ATC(M)
 KELS(KK) = ELS+.5
 L(KK) = EOQ(M)+0.5
 KAD(KK) = AD+0.5
 R(KK) = EOQ(M)/ELS
 S(KK) = Y
 100 CONTINUE
 DO 74 KK=1,20
 74 PRINT 75 , KK, S(KK), KAD(KK), L(KK), C(KK), KELS(KK),R(KK)
 N = 1
 XMIN = C(1)
 DO 5 J=2,20

```
IF(C(J)-XMIN) 55, 55, 50
55 XMIN = C(J)
   N = J
50 CONTINUE
   PRINT 77
   PRINT 76, KAD(N), L(N), C(N), R(N)
   XL = L(N)
   D = KAD(N)
   PUNCH 69, XL, D, SIGMA(N), R(N)
69 FORMAT(4F10.6)
   PRINT 88
   IF(LL-20) 92, 99, 99
   1 FORMAT(I2,2I1,F10.2,22F3.0)
   2 FORMAT(2F10.6)
   3 FOFMAT(3F10.4)
29 FOFMAT(F10.7)
52 FORMAT(1H ,5X,4HSIM.,8X,6HRANDOM,8X,6HANNUAL,8X,13HOPTIMUM ECON.,9
1X,14HOPTIMUM ANNUAL,8X,3HECONOMIC,9X,8HRATIO OF/1H ,5X4HNUM.,8X6HN
2UMBER,8X,6HDEMAND,8X,14HORDER QUANTITY,10X,10HTOTAL COST,10X,8HLOT
3 SIZE,8X,10HEOQ TO ELS/1H ,5X,4(1H*),8X,6(1H*),8X,6(1H*),8X,14(1H*
4),8X,14(1H*),8X,8(1H*),8X,10(1H*))
75 FORMAT(1H ,4X,I4,6X,F9.6,8X,I4,14X,I4, 14X,F12.2,9X,I6,11X,F10.7)
76 FORMAT(1H ,10X,21HOPTIMUM ANNUAL DEMAND,28(1H.),1H=,4XI6/1H ,10X31
1HOPTIMUM ECONOMIC ORDER QUANTITY,18(1H.),1H=,4X,I6/1H ,10X,25HOPTI
2MUM ANNUAL TOTAL COST,24(1H.),1H=,F10.2/1H ,10X,46HCOEFFICIENT OF
3OPTIMUM ECONOMIC ORDER QUANTITY,4H...=,F10.4)
77 FORMAT(///)
88 FORMAT(1H1)
99 CALL EXIT
   END
```

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- . Choose the order quantity which yields the lowest inventory costs.

The procedure outlined above is carried out a hundred times and the same procedure is repeated for 20 separate spares.

Heuristic Decision Rule-Regression Analysis

Heuristic procedures are generally applied when a decision-making process consists of a wide variety of alternatives and components that complete evaluation would either be impossible or impractical. In this way, a complex system is decomposed into its components hoping that individual components, when combined, will provide a solution to the problem. Heuristic problem-solving techniques are best fit to complex systems where variables are difficult to define precisely and mathematical models are not clearly defined.

A statistical approach may be used to draw inferences about the value of a variable from other variables. It can be statistically proved that some variables could be correlated with some of the other variables of a system. For example, multiple regression equations could be formulated to show the dependence of a variable on other independent variables. Mathematical formulation of this dependence is given below.

$$Y = a_0 + a_1x_1 + a_2x_2 + \dots + a_nx_n, \text{ where}$$

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Y = dependent variable

a_0 = y-coordinate intercept

a_i = multiple regression coefficient

x_i = independent variable

Dependence among the variables might be either linear or curvilinear. In order to test this, degree of dependence among variables requires a correlation analysis, while the form of dependence requires regression analysis. Optimum order quantity is a function of mean annual demand, variance of the demand distribution, and costs of ordering and holding in inventory. Certain cautions concerning the above dependence among the mentioned variables should be pointed out that many significant variables may have been excluded from consideration, which may influence the accuracy of the prediction.

To avoid any assumption on the form of interaction, the dependence among the variables concerned is expressed in the following regression equation.

$$EOQ = a_0 \cdot D^{a_1} \cdot V^{a_2} \cdot CO^{a_3} \cdot CH^{a_4}$$

When the logarithm of the above function is taken, the following equation

$$\ln EOQ = \ln a_0 + a_1 \ln D + a_2 \ln V + a_3 \ln CO + a_4 \ln CH$$

is derived, where EOQ , D , V , CO , and CH denote optimum order quantity, annual mean demand, variance of the demand distribution,

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cost of ordering and cost of holding inventory, respectively.

The coefficients a_1 , a_2 , a_3 , and a_4 show how the optimum order quantity varies with the above mentioned variables. In the designed electronic inventory control system, the coefficients of the regression equation are used to determine the optimum order quantity.

The accuracy of this model can be tested statistically by determining the multiple correlation coefficient for two order quantities computed by using the multiple regression coefficients, and the firm's specific values for the independent variables. The multiple correlation of this analysis is $.83$, which indicates a fairly high degree of correlation. That is $.69$, the coefficient $.83$ squared, represents that portion of the total variance explained by the model. The reasons why the multiple correlation coefficient differs from 1.00 can be explained. First of all the model does not include all the variables which influence the dependent variable. Erroneous measurement of the variables is another reason. This is true especially of the cost elements.

Operational Principles of Electronic Inventory Control System

The system designed proposes the application of a computer in carrying out the inventory control function. The information required by the new system can be divided into two:

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- . Information needed only once,
- . Information required at every periodic control.

The information required only once provided that they do not change, are:

- . Allowed risk of stock-out,
- . Code for source of supply,
- . Stock on hand,
- . Actual demand in the previous periods.

A change in any one of these parameters will not necessitate a change in the program.

The information required at every periodic control are:

- . Withdrawals from the store in the preceding period
- . Entries to the store in the preceding period.

Periodic control is conducted by a computer in monthly, three monthly, and yearly periods. The method of differentiating which spares will get into which periodic control has been explained elaborately in the previous sections. The master file of the spare parts cards is divided into three decks in accordance with the group of periodic control. The information on spare part stocks that constitutes an input to the electronic inventory control system, and the input format of the data cards are shown below.

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<u>Colons</u>	<u>Information</u>	<u>Format</u>
1- 8	Part code	I2, I2, I4
9-10	Source of supply	I2
11-14	Stock on hand	F4.0
16-19	Entry in the preceding period	F4.0
21-77	Historical demand data	19F3.0
78-80	Withdrawal in the preceding period	F3.0

The decks of mater file cards are kept by the storeroom. The colons 16-19 and 78-80 are left blank so as to punch into these colons the information on entry and/or withdrawal of spares in the preceding period before the cards are processed. The cards processed are repunched with colons 16-19 and 78-80 as blank to await for the next periodic process.

Reports Generated by Computer

The periodic electronic inventory control program issues three reports:

- . Report on present stock levels and inventory control parameters:

The following information on each spare is relieved from this report:

- Code number,
- Stock on hand,

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- Maximum stock level,
- Safety stock level,
- Reorder point,
- Order quantity.

This report assures prompt and accurate knowledge of inventories for the management. The report is sent to the Planning Department to be used in controlling orders and order quantities.

The other two reports are punched into cards which can be easily printed out. The two reports punched into cards are discriminated by an IDCOD code punched in the 15th colon of the cards. The IDCOD specifies the following distribution of codes punched into the 15th colon of the cards.

<u>IDCOD</u>	<u>Card specification</u>
1	Card belongs to the master file deck
2	Card belongs to the deck of cards which list the spares for which an order is to be placed.
3	Card belongs to the deck of cards which reports on the spares whose stock levels exceed the maximum inventory level.

- . Report on spares for which orders are to be placed.

This report contains the following information:
code number, IDCOD code, source of supply, and
economic order quantity.

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. Report on spares which are to be reduced in stock.

It reports on the spares which somehow exceed the maximum stock level, and contains:

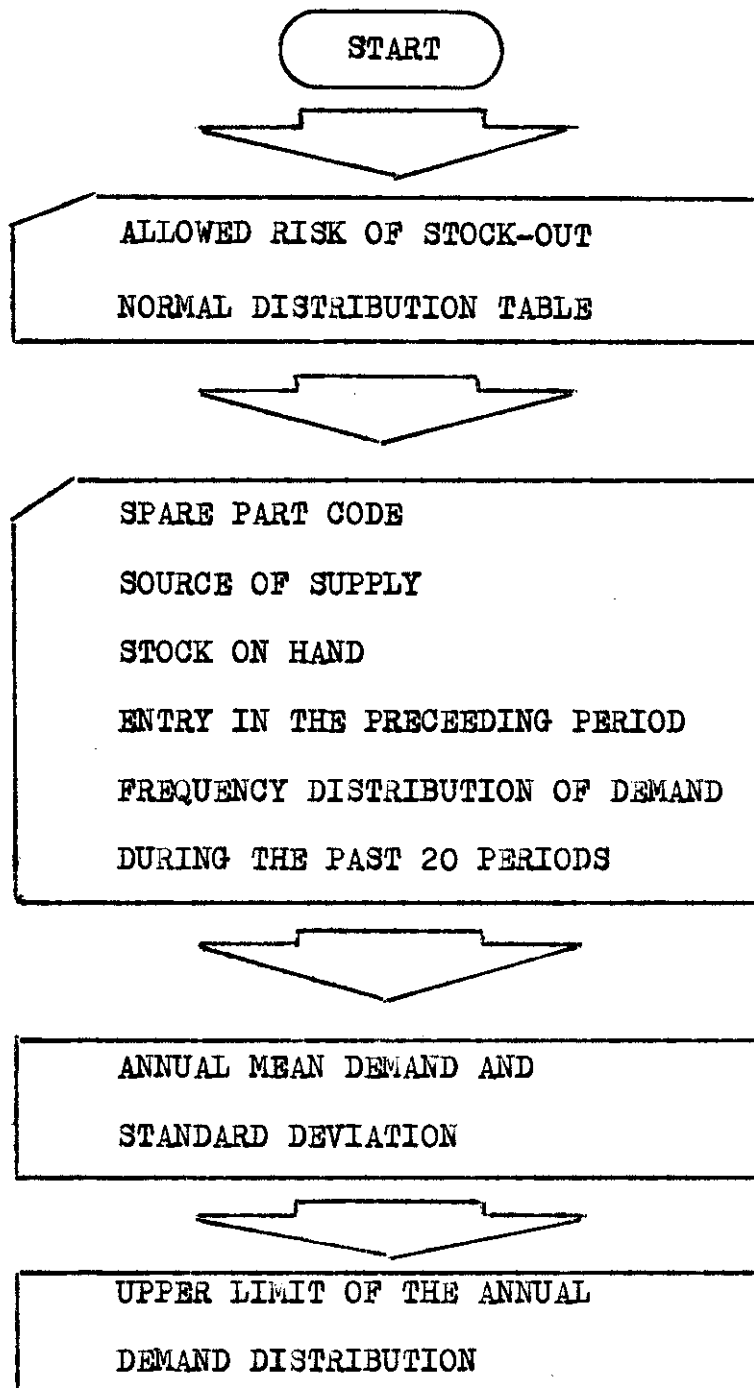
- Code number
- IDCOD code
- Quantity on hand
- Amount to be reduced.

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ELECTRONIC INVENTORY CONTROL SYSTEM FLOW CHART



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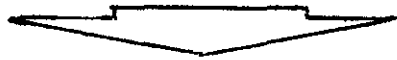
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OPTIMUM ORDER QUANTITY BY
THE REGRESSION EQUATION



NUMBER OF ORDERS IN A YEAR



STANDARD DEVIATIONS PER ORDER



PROBABILITY OF SHORTAGE PER ORDER



SAFETY STOCK LEVEL



DEMAND DURING REPLENISHMENT PERIOD



REORDER POINT



UPDATED STOCK RECORDS



REPRODUCTION OF UPDATED
MASTER FILES



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REPORTS ISSUED :

1. STOCK ON HAND

REORDER POINT

2. ORDERS TO BE PLACED

3. ITEMS TO BE REDUCED

IN STOCK QUANTITY



STOP

*** ENGIN UYSAL ***

ROBERT COLLEGE COMPUTER CENTER

THIS PROGRAM IS USED FOR PERIODIC INVENTORY CONTROL
 WRITTEN BY ENGIN UYSAL * ROBERT COLLEGE GRADUATE SCHOOL * MAY 1970

IT COMPUTES ECONOMIC ORDER QUANTITY, MAXIMUM INVENTORY LEVEL,
 SAFETY STOCK LEVEL, REORDER POINT, OVERSTOCKS AND ORDER SIZE
 FOR A SERIES OF ITEMS THAT EXIST IN STOCKS

IT OPERATES ON A DECK OF MASTER FILE WHICH IS UPDATED AT EVERY
 PERIODIC CONTROL

*** INPUTS ***

CARD 1 COL. 1-10 ALROS = ALLOWED RISK OF STOCKOUT IN
 F10.6 FORMAT
 CARD 2 COL. 1-10 X(1) = NUMBER OF STANDARD DEVIATIONS
 FROM THE CUMULATIVE NORMAL
 DISTRIBUTION TABLE
 . . 11-20 P(1) = CUMULATIVE PROBABILITY
 CORRESPONDING TO X(1) STANDARD
 DEVIATIONS
 CARD 3 COL. 1-10 X(2) = . . .
 11-20 P(2) = . . .
 REPEATED UNTIL ALL THE VALUES IN NORMAL DISTRIBUTION
 TABLE ARE EXHAUSTED.

DATA CARDS

COL. 1- 2 JJ = GROUP CODE IN I2 FORMAT
 3- 4 KK = DEPARTMENT CODE
 5- 8 NU = SEQUENCE NUMBER IN I4 FORMAT
 10 K1 = CODE FOR SOURCE OF SUPPLY
 1 IF MANUFACTURED IN THE MACHINE SHOP
 2 IF FROM CONTRACTOR
 3 IF FROM MARKET
 4 IF IMPORTED
 11-14 STOCK = STOCK ON HAND
 16-19 ENTRY = ENTRY OF OF THE ITEM TO THE
 STORE DURING THE PREVIOUS
 PERIOD
 21-23 S(1) = WITHDRAWAL OF THE ITEM
 78-80 S(20) = WITHDRAWAL OF THE ITEM IN THE
 PREVIOUS PERIOD

*** OUTPUTS ***

REPORT 1 LISTS THE FOLLOWING INFORMATION
 STOCK LEVEL
 UPPER LIMIT FOR STOCK LEVEL
 SAFETY STOCK LEVEL
 REORDER POINT
 ECONOMIC ORDER QUANTITY
 REPORT 2 REPRODUCES THE MASTER FILE FOR NEXT PERIODIC
 INVENTORY CONTROL
 REPORT 3 LISTS THE ITEMS FOR WHICH AN ORDER IS TO BE
 PLACED
 REPORT 4 LISTS THE ITEMS THAT HAVE EXCEEDED THE
 MAXIMUM INVENTORY LEVEL

```

C
  DIMENSION S(20), P(32), X(32), KS(20)
  READ 1, ALROS
  READ 2, CO, CH
  DO 5 I=1,32
5  READ 3, X(I), P(I)
  PRINT 401
  PRINT 402
  PRINT 404
100 READ 10, JJ, KK, NU, K1, STOCK, ENTRY, (S(J), J=1, 20)
  IF(JJ) 99, 99, 12

```

```

C
  12 SUM = 0
  VAY = 0
  DO 15 I=1,20
  15 SUM = SUM+S(I)
  DEME = SUM/20.
  DO 16 I=1,20
  16 VAY = VAY+(ABS(S(I)-DEME)**2)
  VAF = VAY/19.
  IF(VAF) 21, 22, 21
  22 VAR = 1

```

```

C
  21 ASIGMA = SQRTF(12.*VAR)
  ANDEME = DEME*12.
  UPLIM = ANDEME+1.96*ASIGMA
  EQ = SQRTF(2.*CO*ANDEME/CH)
  IF(EQ) 44, 45, 44
  45 GO TO 17
  44 ORNU = ANDEME/EQ

```

```

C
  IF(ORNU) 17, 17, 18
  17 ORNU = 1
  18 SDPO = ASIGMA/SQRTF(ORNU)
  PSPO = ALROS/ORNU

```

```

C
  PP = 1.-PSPO
  DO 2 K=1,32
  IF(PP-P(K)) 20, 25, 26
  25 SDNUM = X(K)
  GO TO 28
  26 SDNUM = X(K-1)
  GO TO 28
  20 CONTINUE
  28 SS = SDNUM*SDPO

```

```

C
C   THIS PART DETERMINE THE LEAD TIME
  GO TO (31,33,35,37), K1
  31 XLT = 3
  GO TO 41
  33 XLT = 30
  GO TO 41
  35 XLT = 45
  GO TO 41
  37 XLT = 450
  41 DELT = ANDEME/300.*XLT
  REORPT = SS+DELT
  KSTOCK = STOCK+ENTRY-S(20)
  KUFLIM = UPLIM+0.5

```

```

C
C
C
C

```

KSS = SS+0.5
KRORPT = REORPT+0.5
KQ = EQQ+0.5

C
C

PRINT 403, JJ, KK, NU, KSTOCK, KUPLIM, KSS, KRORPT, KQ

C
C

PUNCHING MASTER FILE

DO 8 I=1,20

80 KS(I) = S(I)

IDCOD = 1

PUNCH 501, JJ, KK, NU, IDCOD, K1, KSTOCK, (KS(J),J=2,20)

IF(STOCK-REORPT) 59, 59, 61

C
C

PUNCHING ORDERS TO BE PLACED

59 IDCOD = 2

KORDER = UPLIM-STOCK

PUNCH 505, JJ, KK, NU, IDCOD, K1, KORDER

GO TO 66

C
C

PUNCHING STOCKS TO BE REDUCED

61 IF(STOCK-UPLIM) 66, 66, 63

63 IDCOD = 3

KREDUC = STOCK-UPLIM

PUNCH 509, JJ, KK, NU, K1, KREDUC

66 GO TO 100

C
C
C
C

FORMAT STATEMENTS

1 FORMAT(F10.6)

2 FOFMAT(2F10.4)

3 FOFMAT(2F10.6)

10 FORMAT(2I2,I4,1X,I1,F4.0,1X,F4.0,1X,20F3.0)

401 FORMAT(///1H ,15X,70HLIST OF SPARE PARTS INVENTORY AND RELEVANT INFORMATION ON STOCK LEVELS ///

402 FORMAT(1H ,5X,11HPART NUMBER,5X,13HSTOCK ON HAND,5X,11HUPPER LIMIT 1,5X,12HSAFETY STOCK,5X,13HREORDER POINT,5X,10HORDER SIZE)

403 FORMAT(1H ,6X,2I2,I4,10X,I6,4(11X,I6))

404 FORMAT(1H ,5X,11(1H*),5X,13(1H*),5X,11(1H*),5X,12(1H*),5X,13(1H*), 15X,1 (1H*)/)

501 FORMAT(2I2,I4,2I1,I4,5X,19I3)

505 FORMAT(2I2,I4,2I1,5X,I6)

509 FORMAT(2I2,I4,I1,6X,F10.2)

99 CALL EXIT

END

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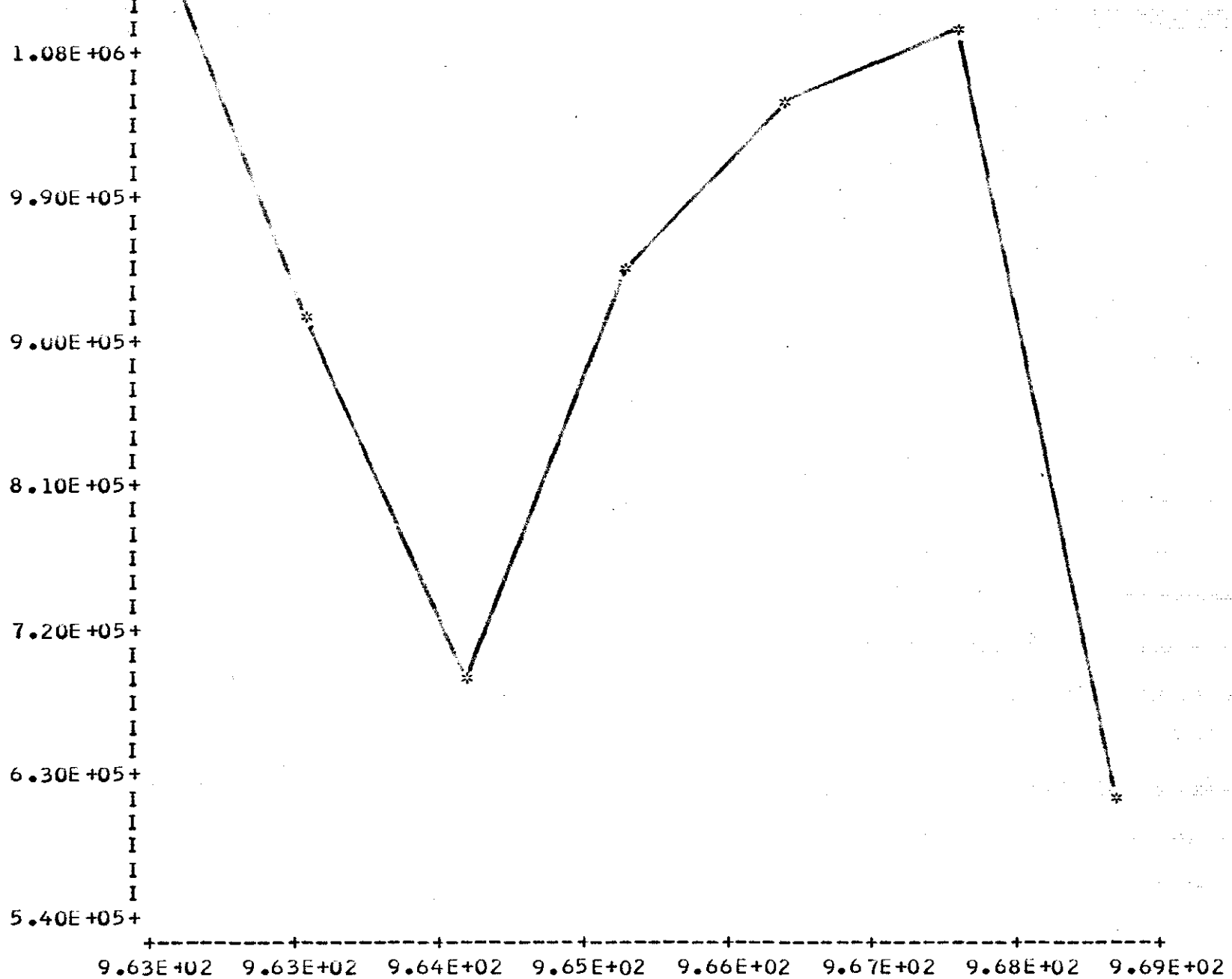
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APPENDIX I

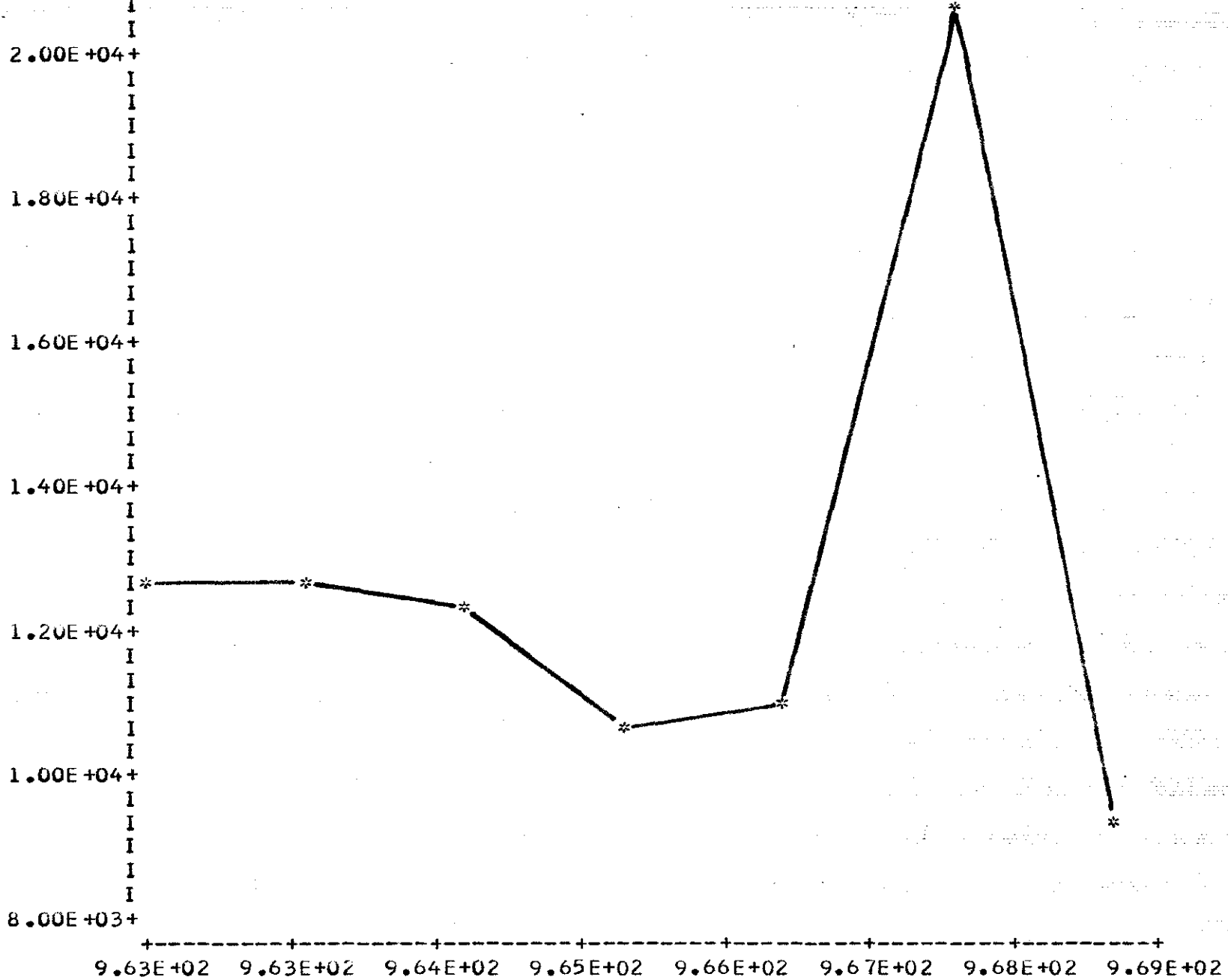
GRAPHS OF SPARE PARTS PAST CONSUMPTION

PATTERNS ON EACH MACHINERY GROUP



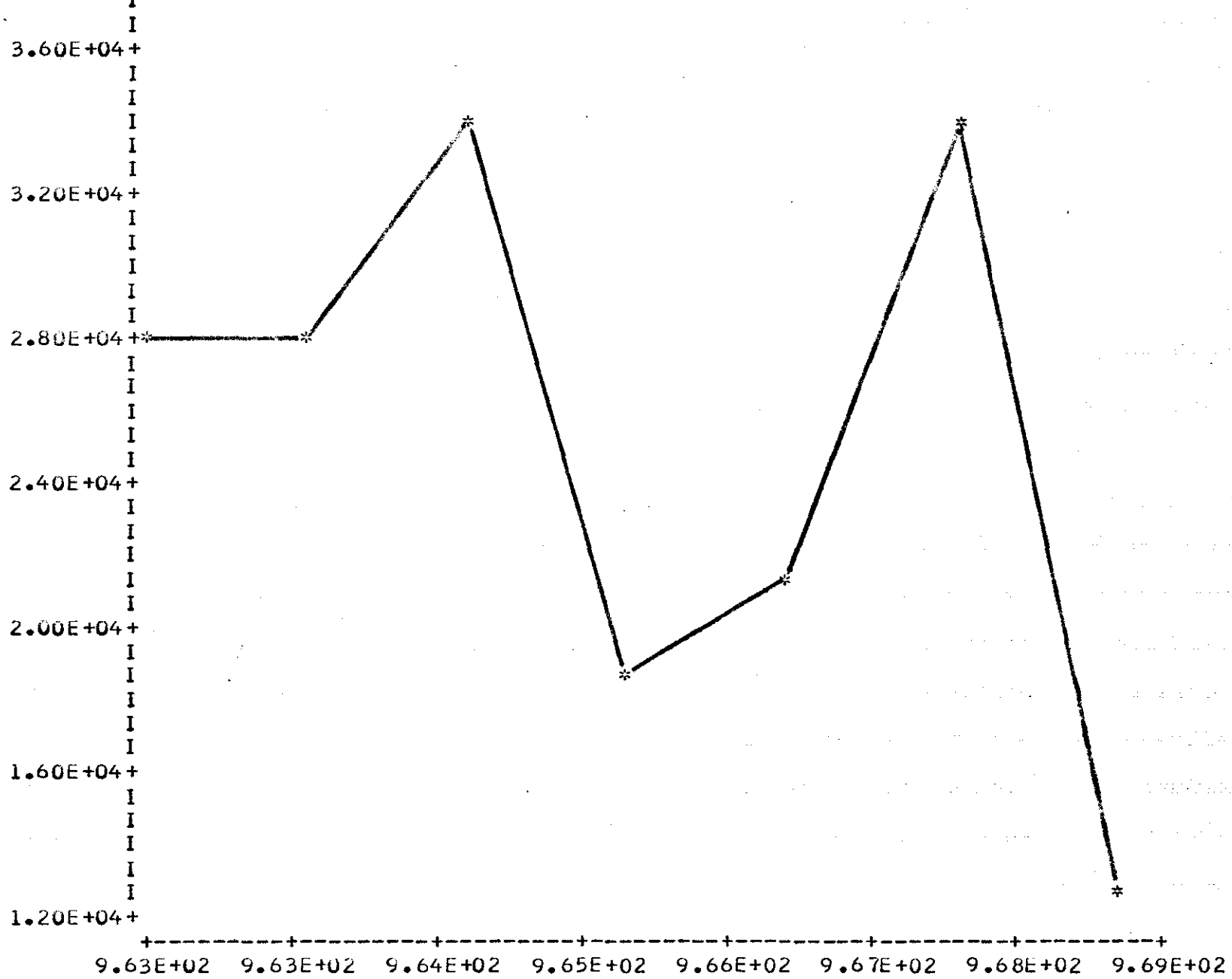
GRAPH SHOWING THE PAST CONSUMPTION PATTERN ON ALL MACHINES

YEARS



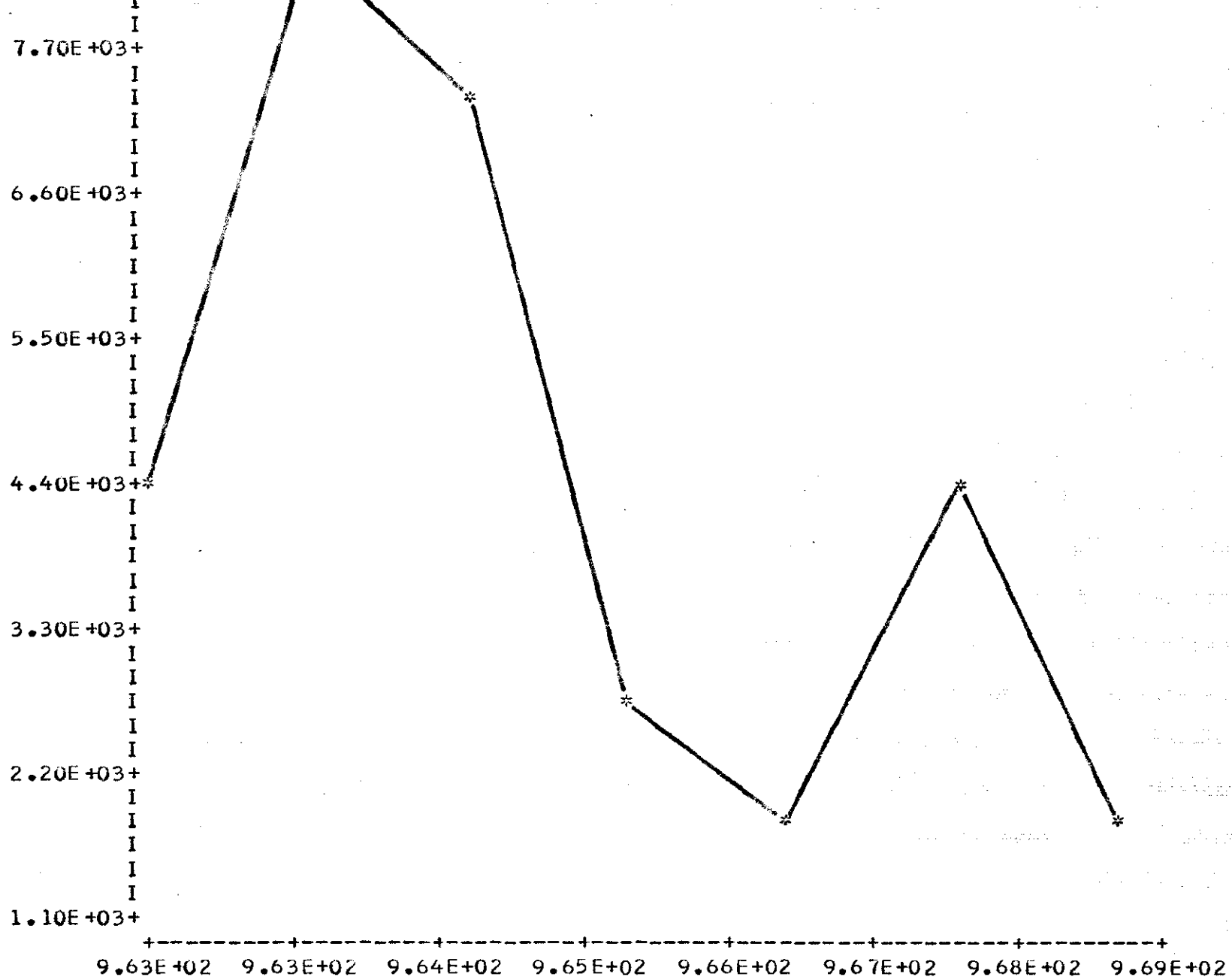
GRAPH SHOWING THE PAST CONSUMPTION PATTERN ON SCRATCHER MACHINES

YEARS



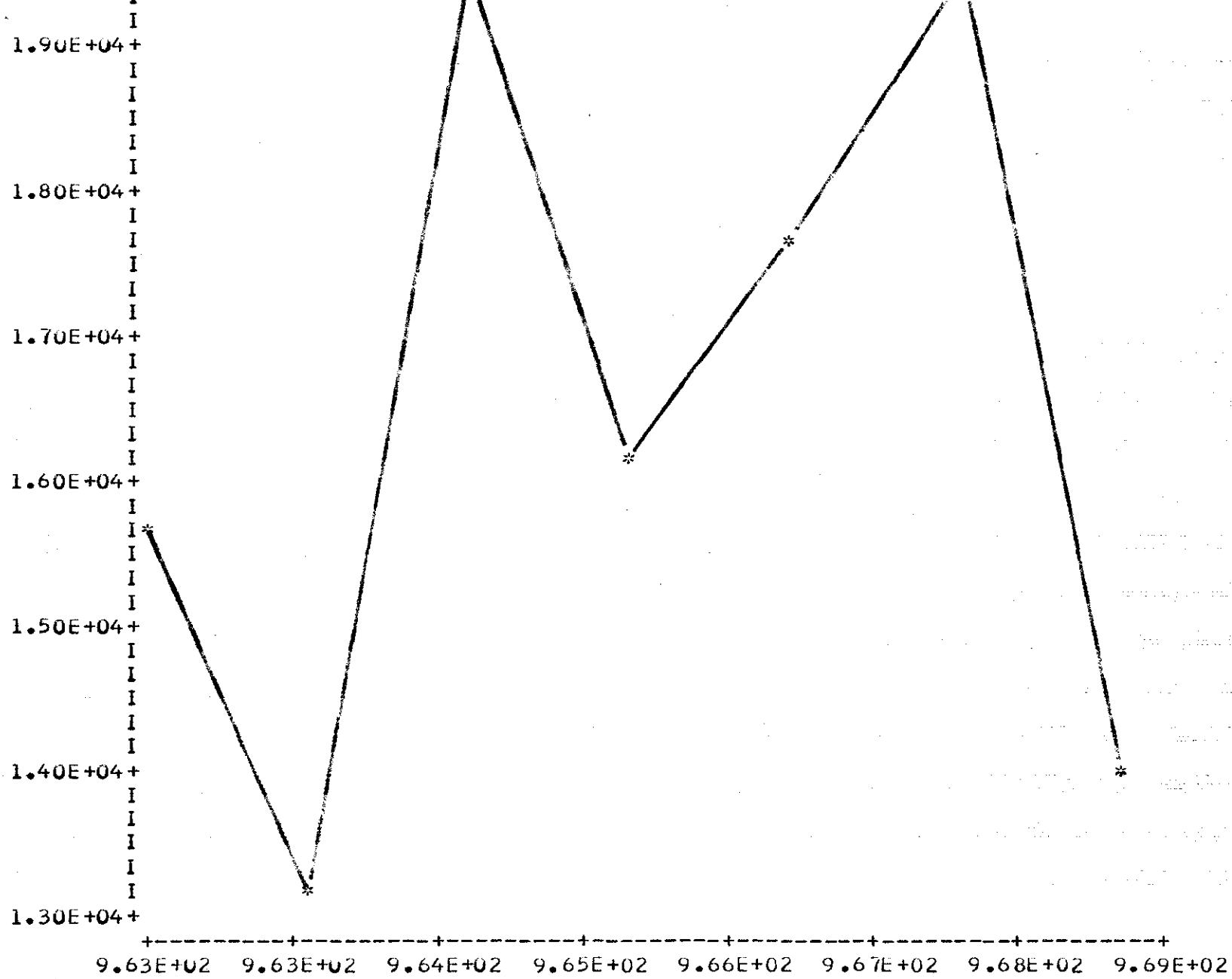
GRAPH SHOWING THE PAST CONSUMPTION PATTERN ON COMBING MACHINES

YEARS



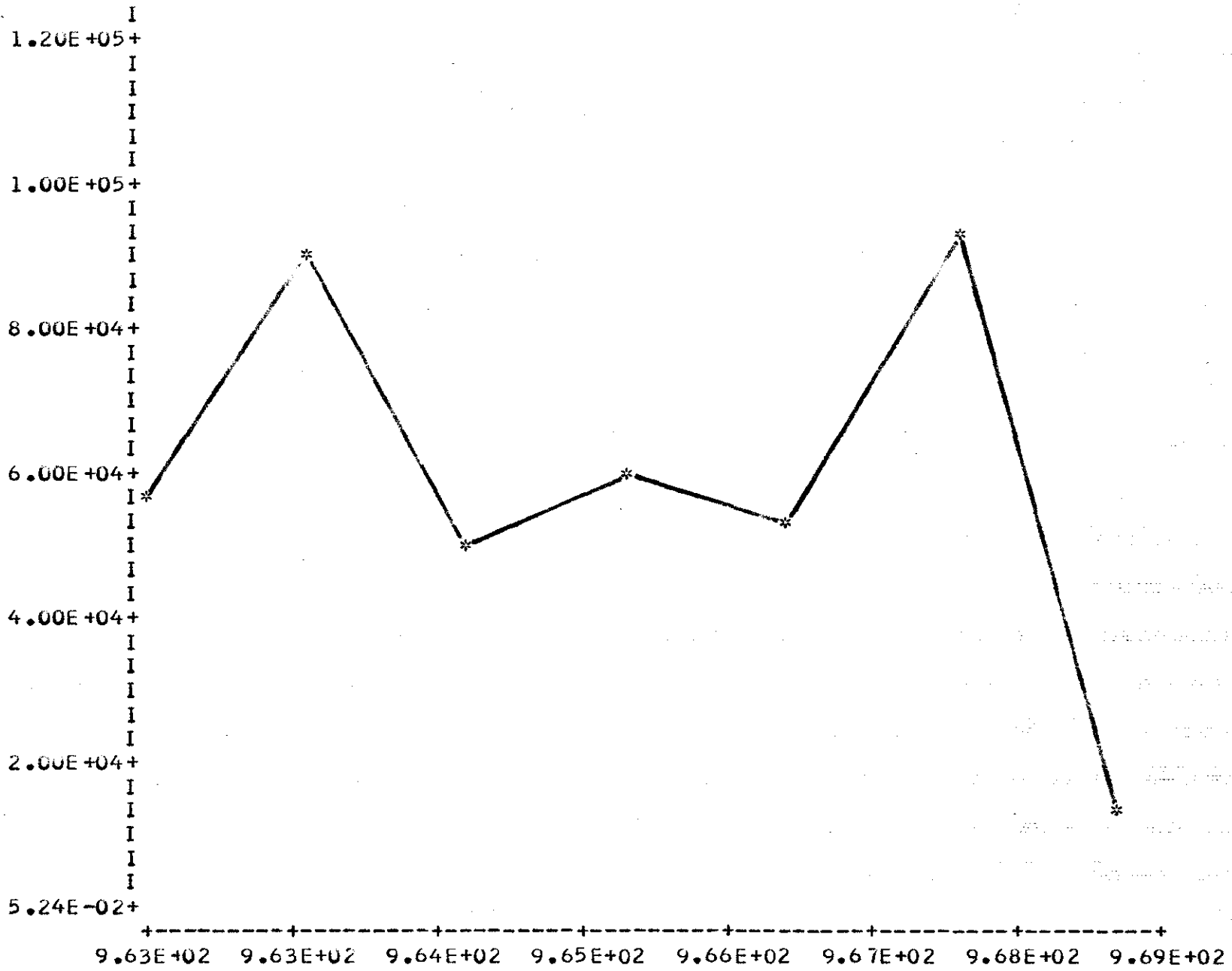
GRAPH SHOWING THE PAST CONSUMPTION PATTERN ON DRAWING MACHINES

YEARS



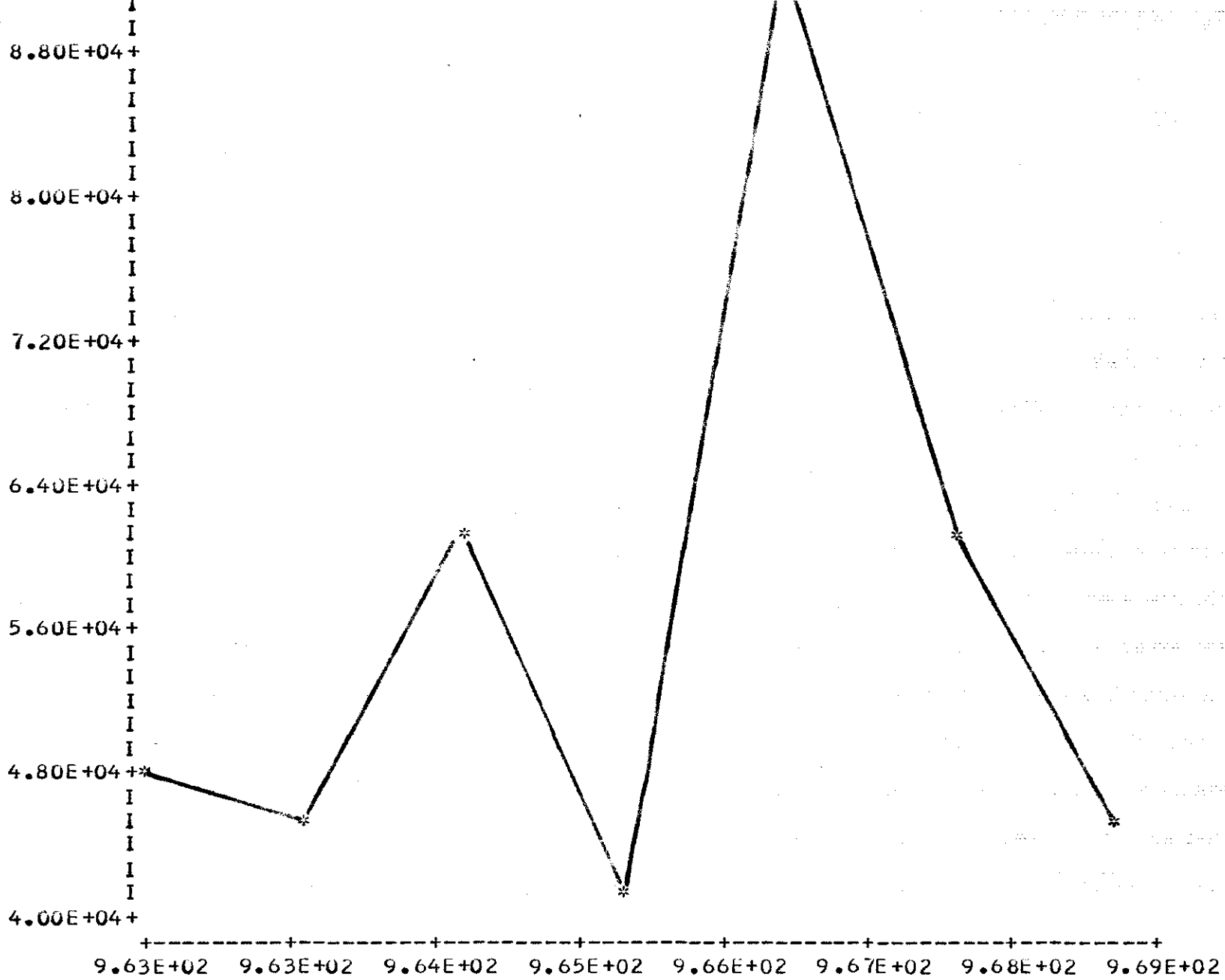
GRAPH SHOWING THE PAST CONSUMPTION PATTERN ON ROVING MACHINES

YEARS



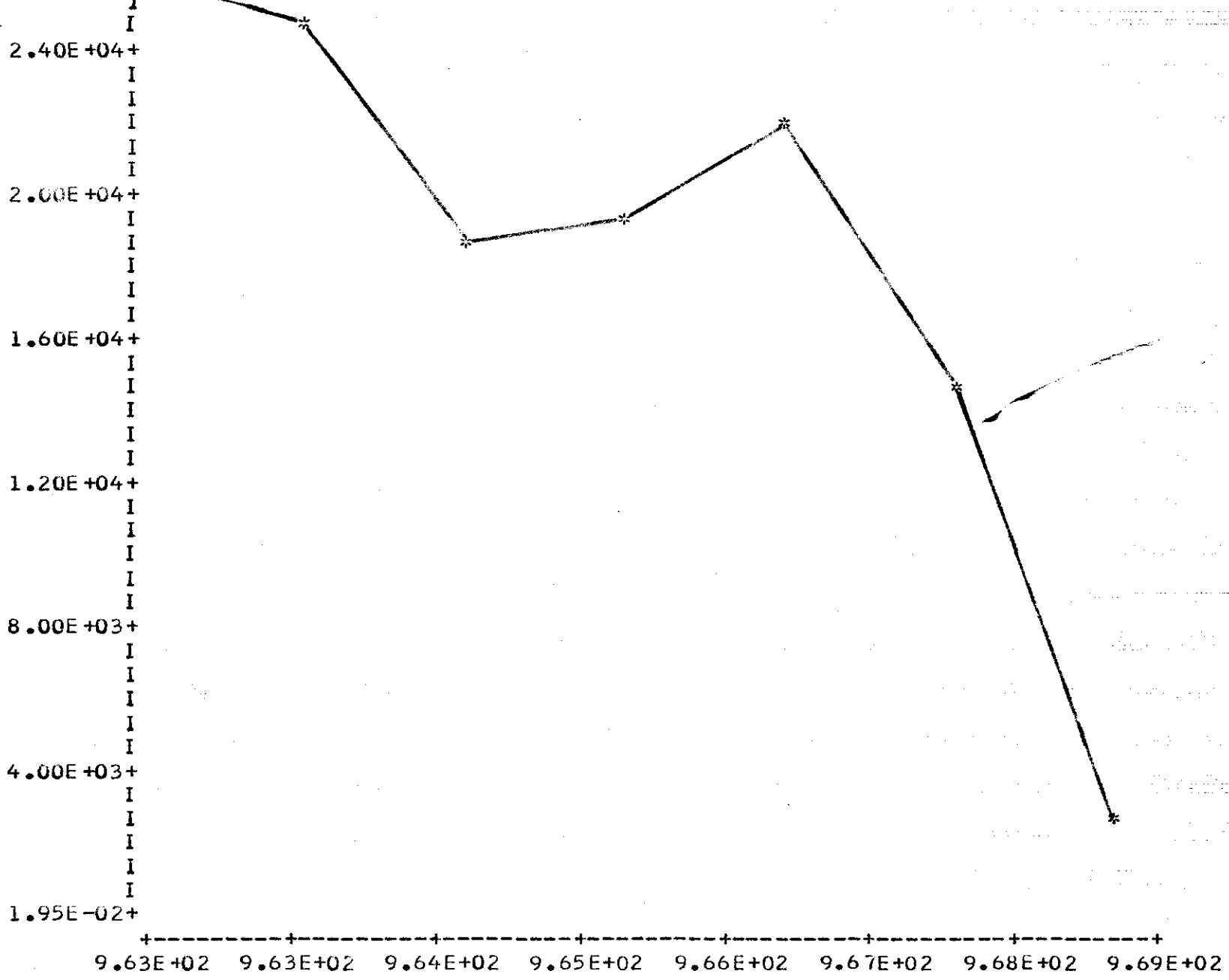
GRAPH SHOWING THE PAST CONSUMPTION PATTERN ON YARN MACHINES

YEARS



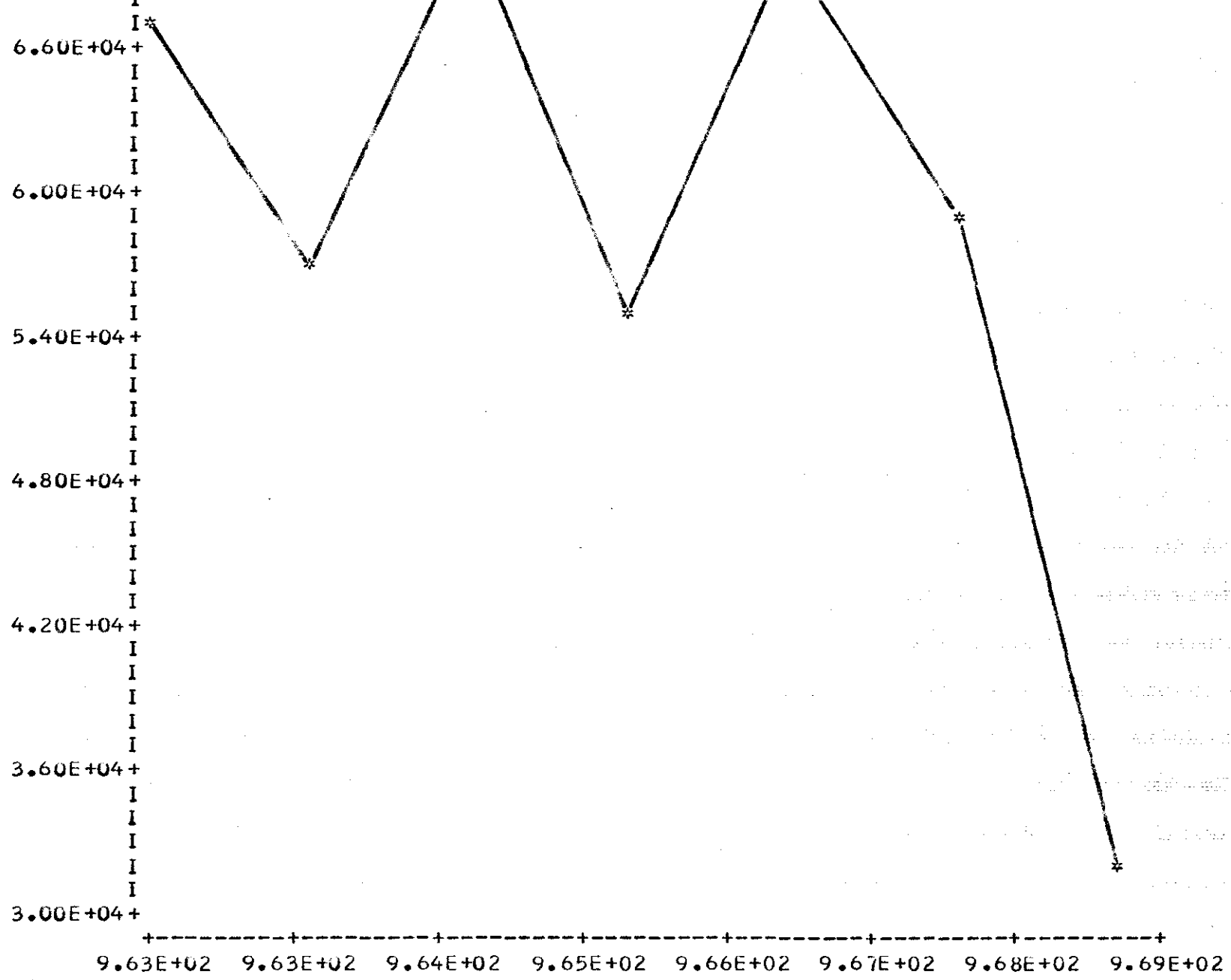
GRAPH SHOWING THE PAST CONSUMPTION PATTERN ON WIND MACHINES

YEARS



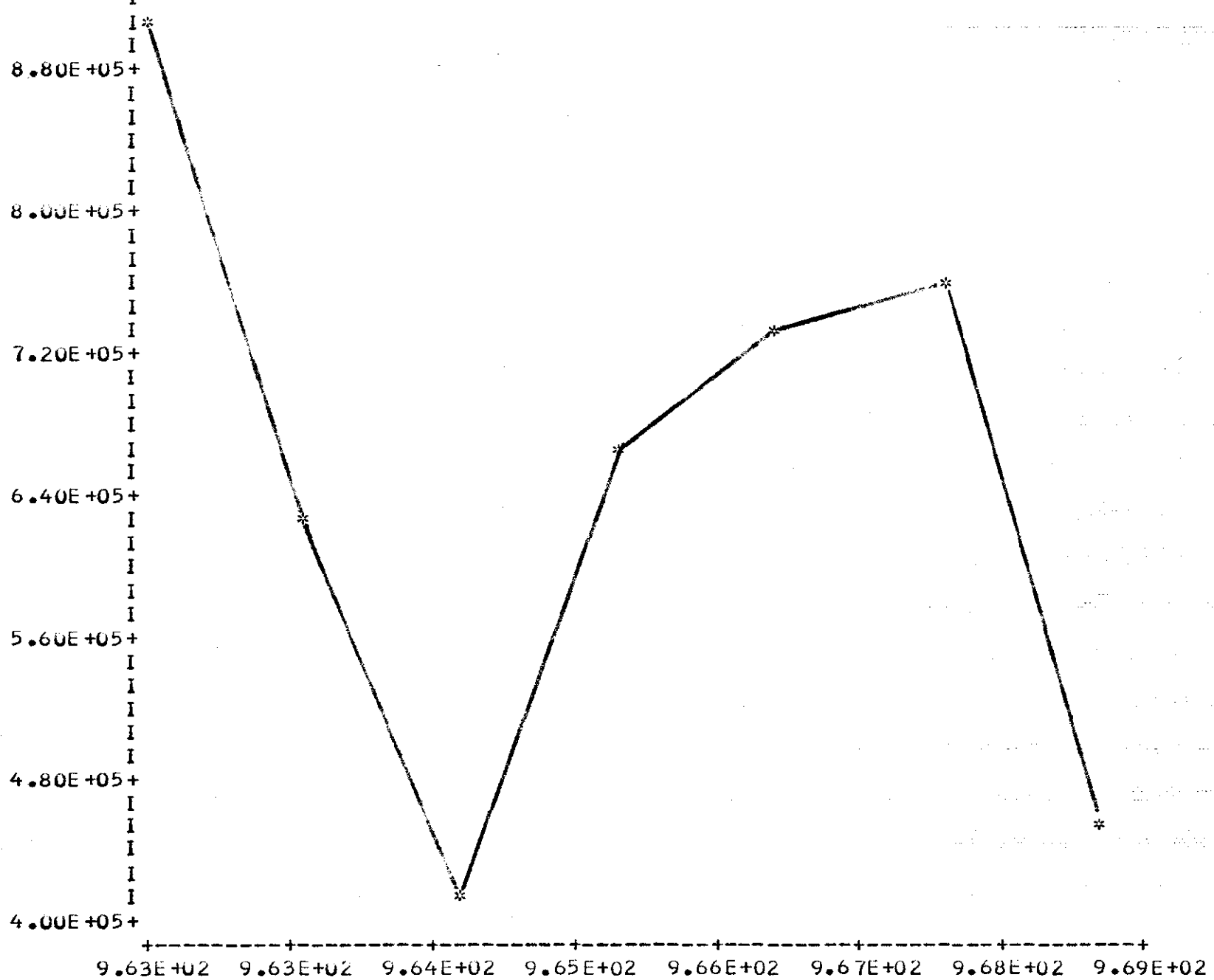
GRAPH SHOWING THE PAST CONSUMPTION PATTERN ON VFT MACHINES

YEARS



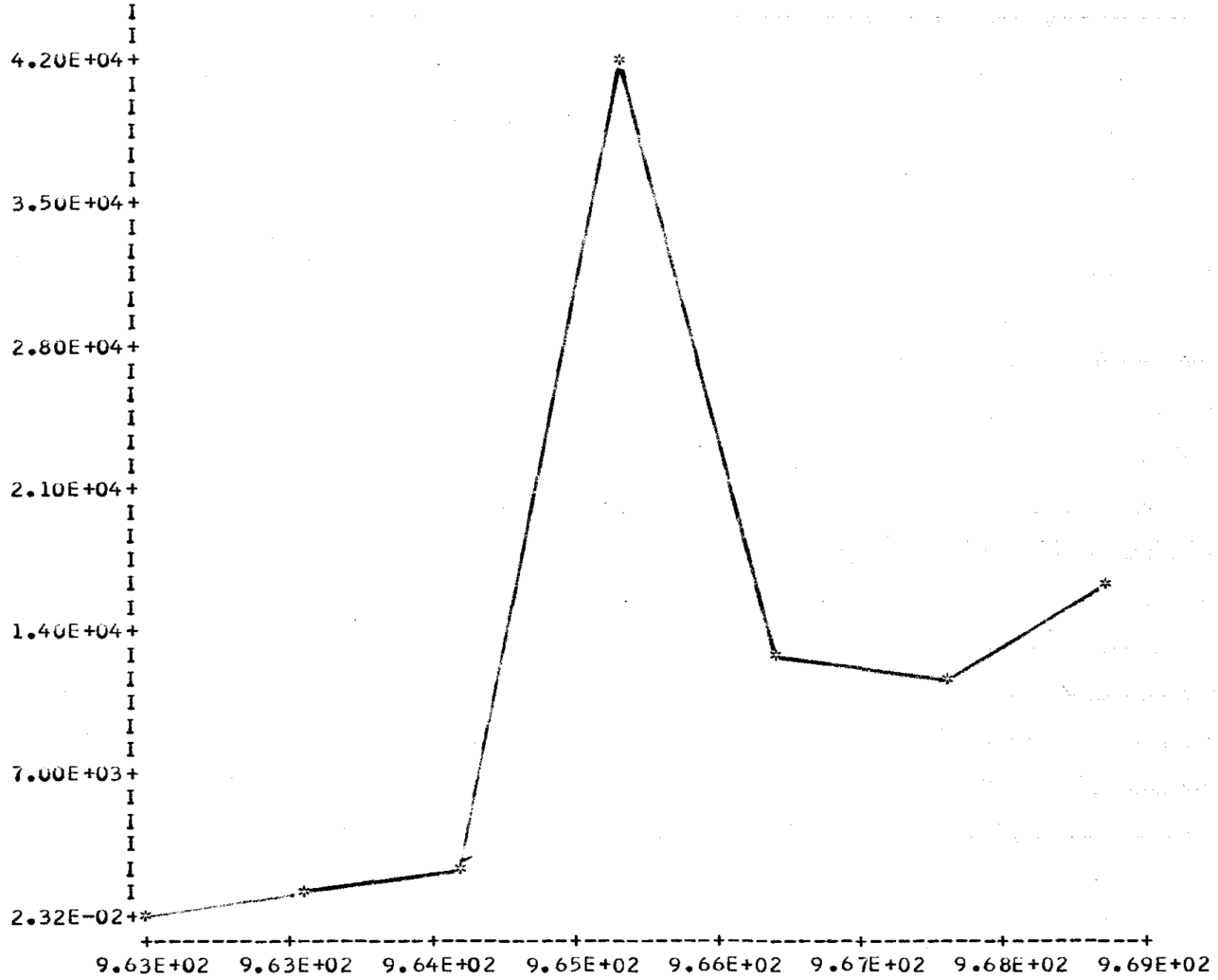
GRAPH SHOWING THE PAST CONSUMPTION PATTERN ON STARCHING MACHINES

YEARS



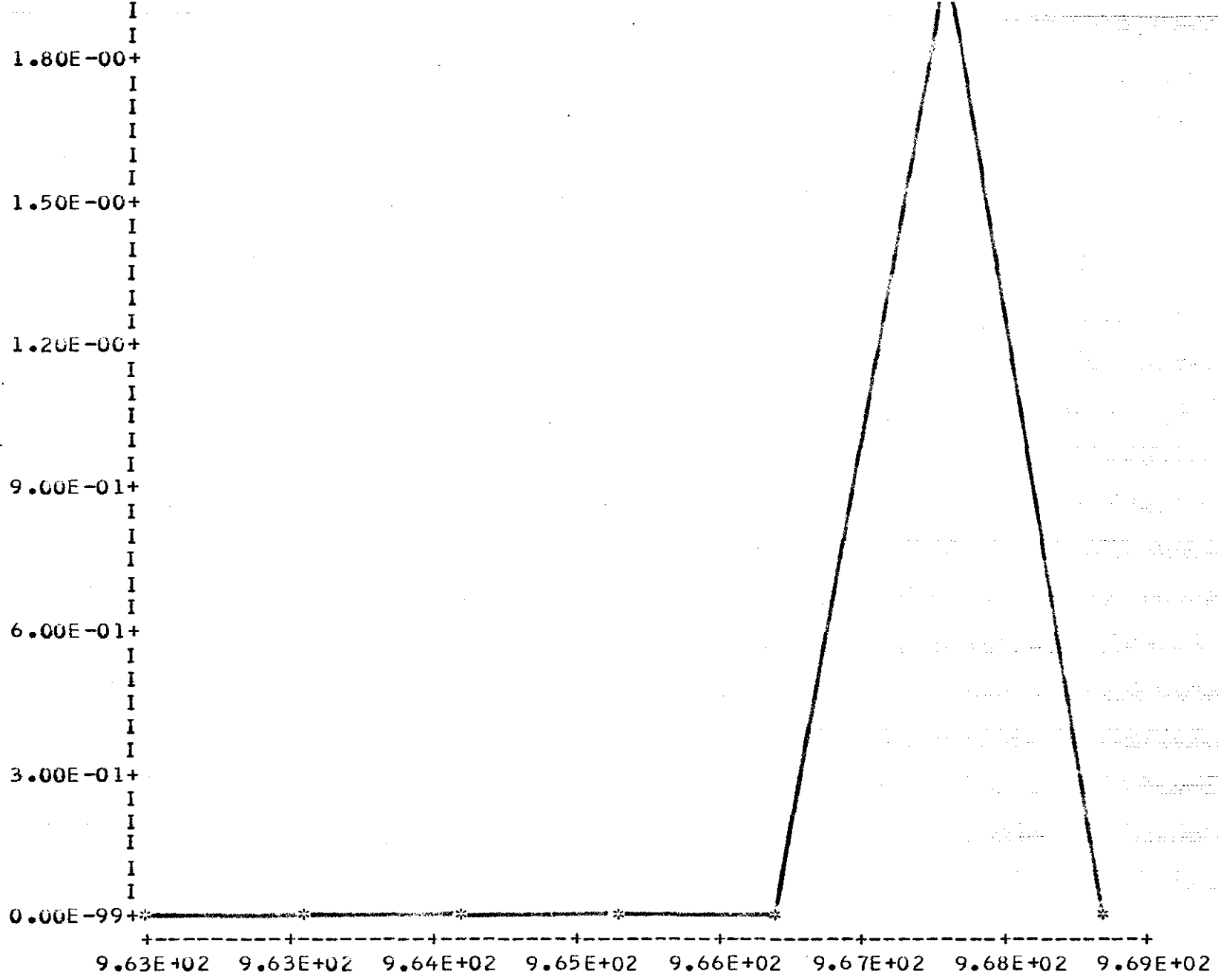
GRAPH SHOWING THE PAST CONSUMPTION PATTERN ON WEAVING MACHINES

YEARS



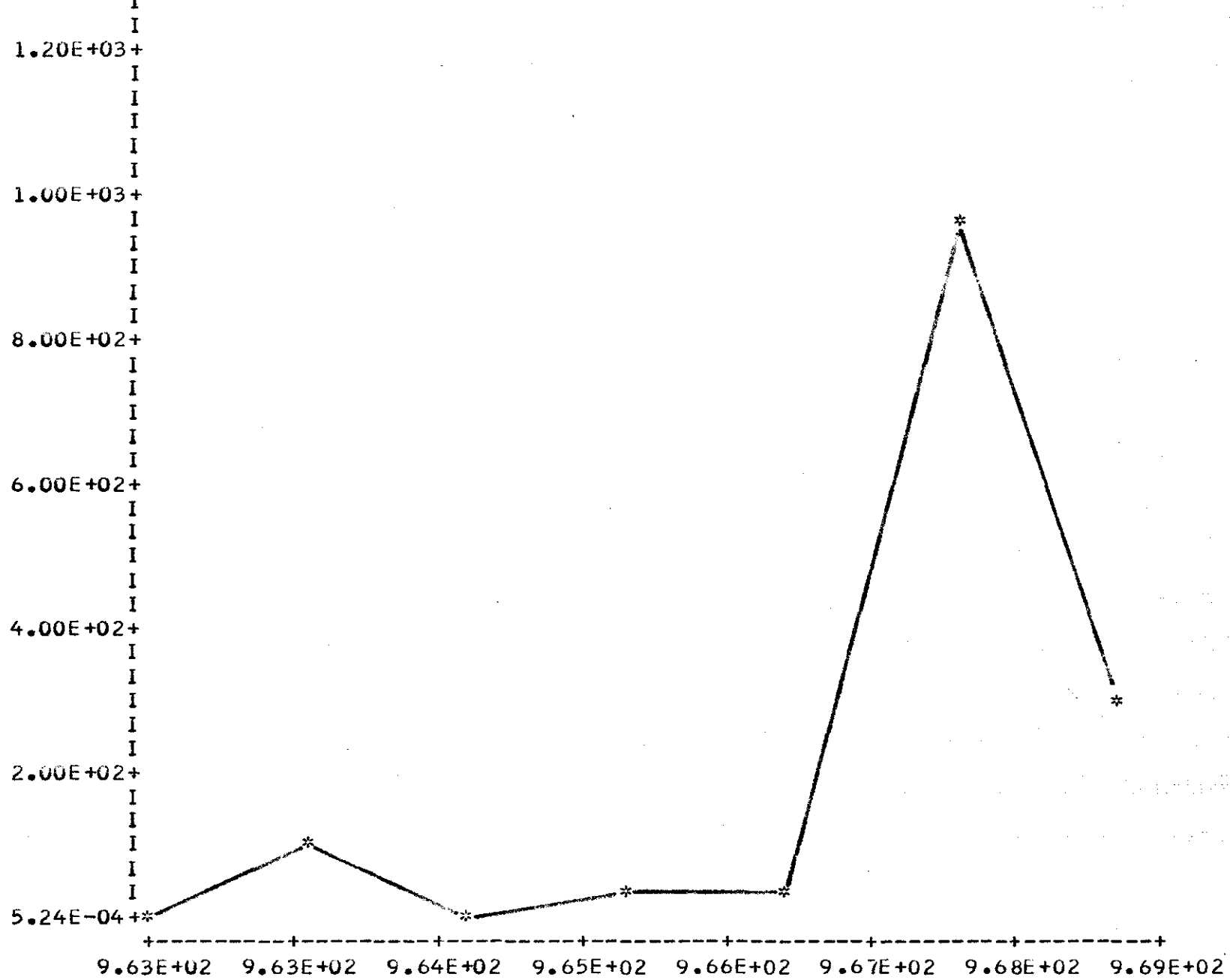
GRAPH SHOWING THE PAST CONSUMPTION PATTERN ON DYEING MACHINES

YEARS



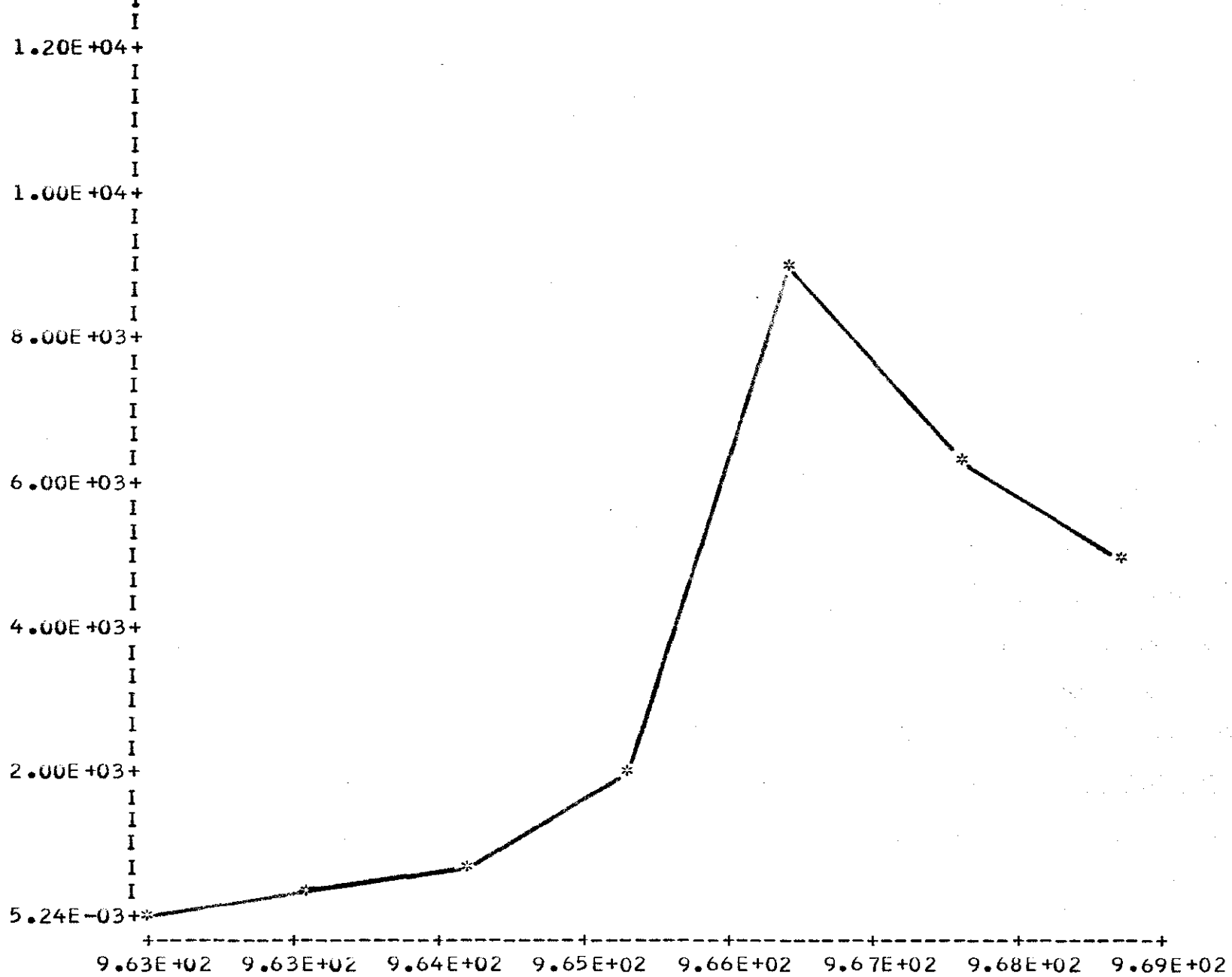
GRAPH SHOWING THE PAST CONSUMPTION PATTERN ON BOILER 1 MACHINES

YEARS



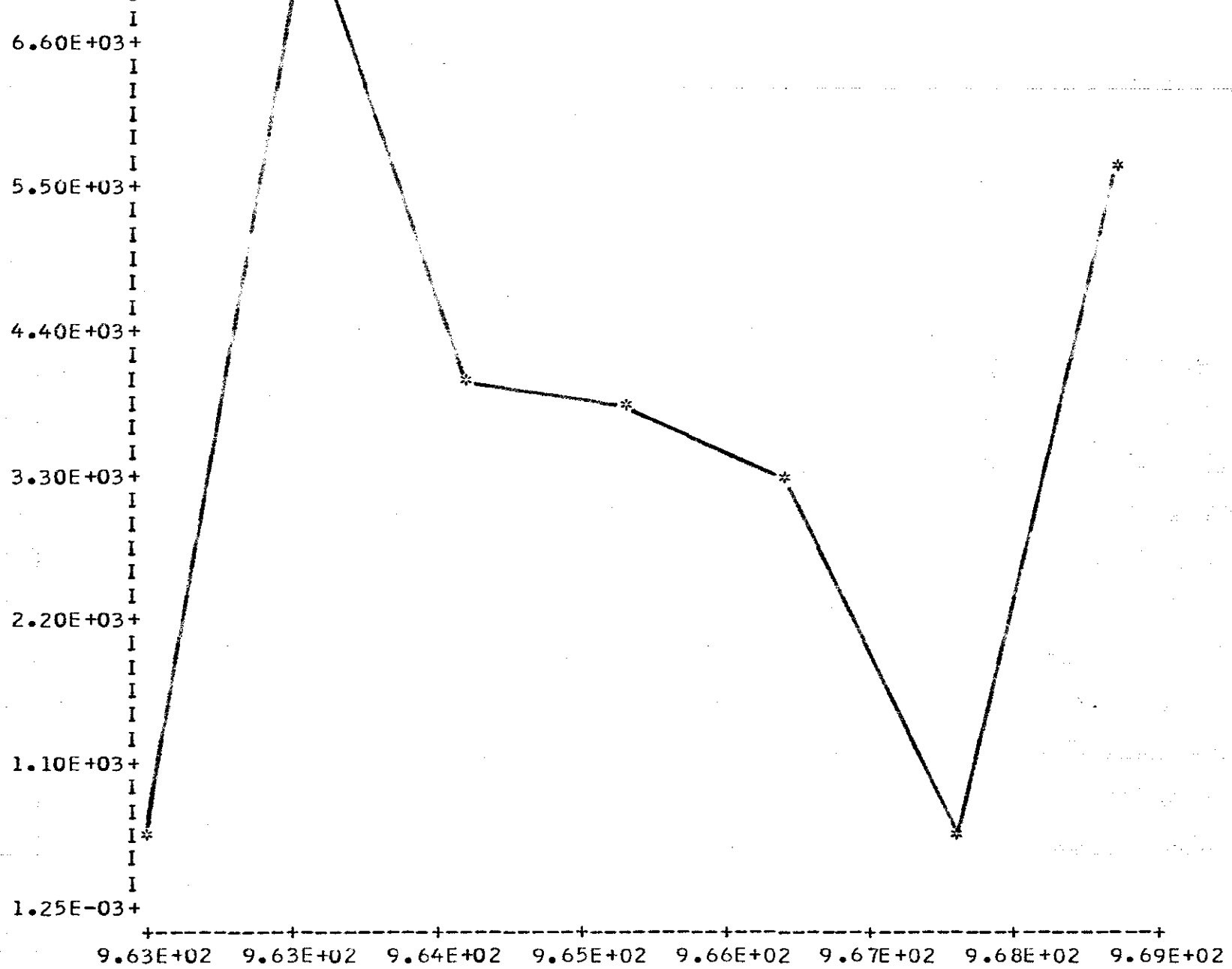
GRAPH SHOWING THE PAST CONSUMPTION PATTERN ON BOILER 2 MACHINES

YEARS



GRAPH SHOWING THE PAST CONSUMPTION PATTERN ON BOILER 3 MACHINES

YEARS



GRAPH SHOWING THE PAST CONSUMPTION PATTERN ON KNOTTING MACHINES

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APPENDIX II

OUTPUT OF MULTIPLE REGRESSION

ANALYSIS

MULTIPLE REGRESSION
 DATA BLOCK NUMBER 1
 REGRESSION NUMBER 1

NUMBER OF OBSERVATIONS IN THIS REGRESSION 20
 NUMBER OF VARIABLES IN THIS REGRESSION 5
 INDEX(ES) OF INDEPENDENT VARIABLE(S) 1 2 3 5
 INDEX OF DEPENDENT VARIABLE 4

OBSERVATION 1

2.814210 1.942375 4.094344 1.504077 1.386294

OBSERVATION 20

2.667228 1.624602 4.094344 1.504077 1.386294

INDEX	MEANS	STANDARD DEVIATIONS	COEFF. OF VARIATION	MEAN(1)	MEAN(4)
1	.40722826E+01	.23016441E+01	.56519753E+00	.1	3427E+01
2	.36706835E+01	.23453718E+01	.63894688E+00	.1	9124E+01
3	.48223892E+01	.13174000E+01	.27318408E+00	.1	0756E+01
5	.36521101E+01	.18036831E+01	.49387423E+00	.1	6201E+01
4	.35095515E+01	.25820284E+01	.73571463E+00	.1	0000E+01

CORRELATION COEFFICIENTS

1	1.00000				
2	-.35557	1.00000			
3	-.32426	.93623	.99999		
5	-.20399	.89261	.84662	1.00000	
4	-.15268	.79037	.85846	.69550	1.00000
1	2	3	5	4	

INDEX	REG. COEFFICIENT	STANDARD ERROR	T-RATIO	PARTI
0	-5.819813	2.253287	-2.582810	
1	.182032	.157042	1.159128	
2	.127028	.486112	.261314	
3	1.891957	.704576	2.685239	
5	-.274350	.416316	-.658993	

R-BAR SQUARED = .6983
 R-BAR = .8356
 R-SQUARED = .7737
 R = .8796

STANDARD ERROR OF ESTIMATE = 1.4182
 DEGREES OF FREEDOM = 15

ACTUAL PREDICTED RESIDUAL

1	1.504077	2.305193	-.801116
2	7.050000	6.893321	.156678
3	2.870169	1.949316	.920852
4	1.390000	1.529129	-.139129
5	.536493	2.017677	-1.481184
6	6.720000	6.078806	.641193
7	4.143134	2.390917	1.752216
8	.300104	1.860463	-1.560359
9	1.504077	2.259674	-.755597
10	5.970000	3.834594	2.135405
11	7.970000	8.677021	-.707021
12	6.630000	5.914845	.715154
13	3.600000	2.337107	1.262892
14	.976444	2.245532	-1.269088
15	2.500000	4.361488	-1.861488
16	.536493	1.719907	-1.183414
17	7.410000	7.606127	-.196127
18	3.798630	1.569038	2.229591
19	3.277333	2.402784	.874548
20	1.504077	2.238072	-.733995

DURBIN-WATSON STATISTIC = 1.9572
 VON NEUMANN RATIO = 2.0602

TOTAL SUMS OF SQUARES.. = 2.5332660E+02
 RESIDUAL SUMS OF SQUARES= 9.6500509E+01

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