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# Size and Composition of Inventories of Spare Parts and Maintenance Materials

A paper based on a draft

submitted by

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Instead, we build up a stock of spare parts which will enable us to meet most of the situations which might take place. When the machine is finally scrapped, a number of spare parts will have to be scrapped together with the machine.

For group b the situation is somewhat better. The sales value of this material will, for instance, be considerably better.

In total, however, the stock control possibilities for group b and d are very limited. The production department, and the maintenance group serving production, would like to have a well assorted stock of materials and spare parts in order to meet production programmes without too many difficult problems. The controller of the company will have a tendency to see these stocks more or less as an unnecessary cost and a failure of investment.

## FACTORS WHICH HAVE INFLUENCE ON STOCK OF MAINTENANCE MATERIALS AND SPARE PARTS

The factors mentioned below will vary considerably from one part of the world to the other, from one country to the next, be different in different parts of the same country, be different in different branches of industry, and even vary from company to company.

In general they have, however, an influence on the set-up of spare parts and maintenance materials which each company must make for itself.

1. The possibility of getting a fast supply of spare parts.
   - a. From the firms own stores.
   - b. From a local dealer
   - c. From another enterprise which has the same machine.
   - d. From a nearby machine shop.
   - e. From the manufacturer's storeroom.

2. Influence on production and productivity.

a. Can production temporarily be transferred to another machine?

b. Can production be recaptured through overtime, extra shifts, weekend work, etc.?

c. Is the machine, or unit, a bottleneck in production? (The main crusher in an ore extraction plant, a compressor, a large electric motor, an engine, etc.)

The machine units can be grouped in the following different catagories:

a. Highly critical
b. Critical
c. Of less importance
d. Unimportant

If we are able to classify the machines in these groups, we would also be able to set a base for the spare parts stock.

3. Standardization of production equipment and components.

a. Does the company have an internal standardization policy and programme?

b. Are we able to use the same unit several places in the factory?

c. How can we practice standardization to get lower cost, less stock and better maintenance service?

4. Preventive maintenance procedures.

a. Do we have a preventive maintenance programme which can tell us about most breakdowns before it will happen?

b. Can we measure the condition of the equipment and be able to tell when we will need a special spare part? (A large new ball bearing, for instance).

c. How can preventive maintenance be able to reduce our own stock of spare parts and materials?

5. Detailed drawings of machine parts, with correct dimensions, tolerances, etc.

   a. Are we able to get these drawings delivered together with the machine?

   b. Can we get our technicians to make acceptable drawings to be used in case of emergency?

6. Location of the factory.

   A factory located far from industrial centres, main transport roads, airports, railways, etc. is in a less favourable position.

7. Government rules and regulations.

   To what extent will rules for foreign currency license, import license, customs control, etc. delay delivery?

8. Branch of industry and degree of automation.

   Consequences of missing a desired spare part can be very different in the different branches of industry, mainly in connection with automation and in process industries which operate around the clock.

In the next chapter these factors which influence the determination of stock of spare parts and maintenance materials will be discussed further.

B. **THE TOTAL COST OF MAINTENANCE DURING THE LIFETIME OF PRODUCTION EQUIPMENT.**

Statistical figures available today indicate that total maintenance cost during the lifetime of different production equipment varies between 25% and over 300% of the cost of buying and installing. A figure of about 75 - 100% seems to be most common, and the very low and very high figures are more rare as indicated in fig. 1.

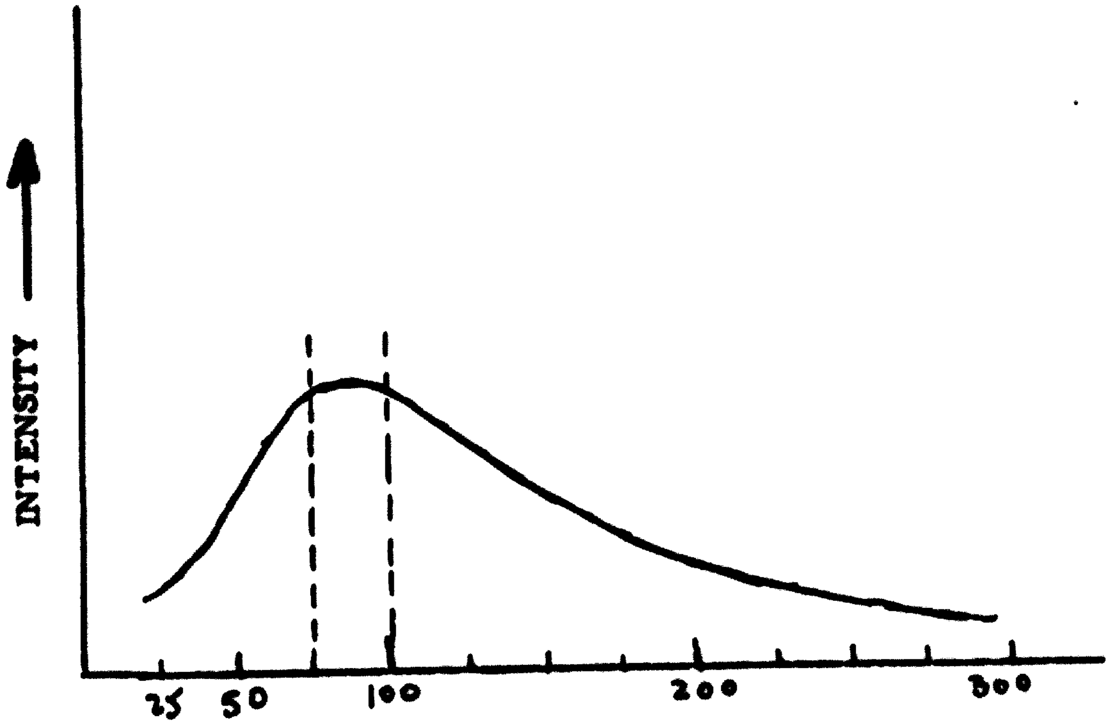



Fig. 1 Maintenance cost during lifetime of equipment as a percentage of its buying and installation cost.

The maintenance cost consists of:

- cost of different spare parts and maintenance materials,
- cost of maintenance labour and maintenance management.

If, for example, the maintenance cost of a machine during its lifetime is equal to purchase price and installation, and if 40% of this maintenance cost is labour and management and 60% spare parts and maintenance material, then we have to reckon with spare parts and maintenance material cost worth $6.00 during the lifetime of the machine for every $10.00 of the purchase and installation cost of the machine.

Frequently these facts are neglected, both in the economic planning in the industrial enterprise and in the country as a whole.

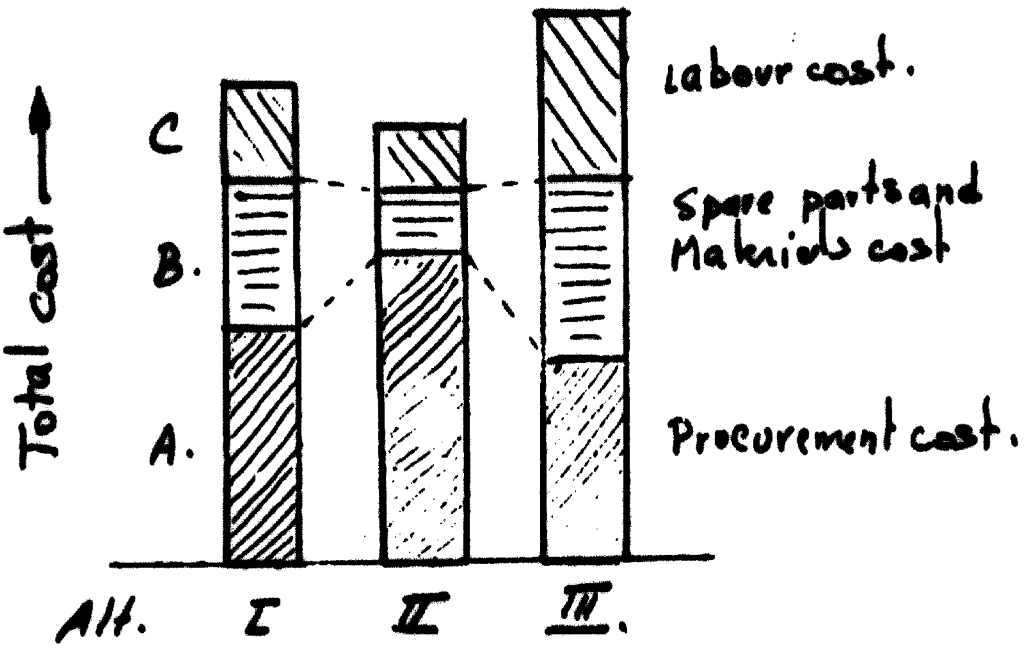



Fig. 2

Statistics have also frequently shown that alternative machines, which have the same production capacity, have quite different consumptions of maintenance materials and labour cost.

From a total cost concept, the most expensive machine to buy might be the cheapest in the long run, as indicated in alternative II in Fig. 2. The reason being the use of better steel or other materials, bigger dimensions in design to absorb overload.

In general we can thus reduce the store of spare parts and other maintenance materials, if we buy high quality production equipment, which are more expensive.

This has very often been neglected in procurement procedures and regulations set by different corporations, companies or government agencies.

It is important to remember that maintenance starts when we are evaluating the purchase of production equipment - not the day this equipment has a failure or a breakdown.

Capital and foreign currency will be needed for spare parts during the whole lifetime of the machine.

The purchasing of spare parts can in principle be considered to take place as in Fig. 3. The spare parts supply period consists of:

a. Period of basic stock and major supplement to stock. This includes the parts we buy together with the machine, and the parts the first period of operation tells us we need.
b. Period of "normal consumption", with a slight tendency to increase.
c. "Trapping down" period. Decision has been made to take the machine out of production in a year or two. New spare parts must only be bought under very special circumstances.

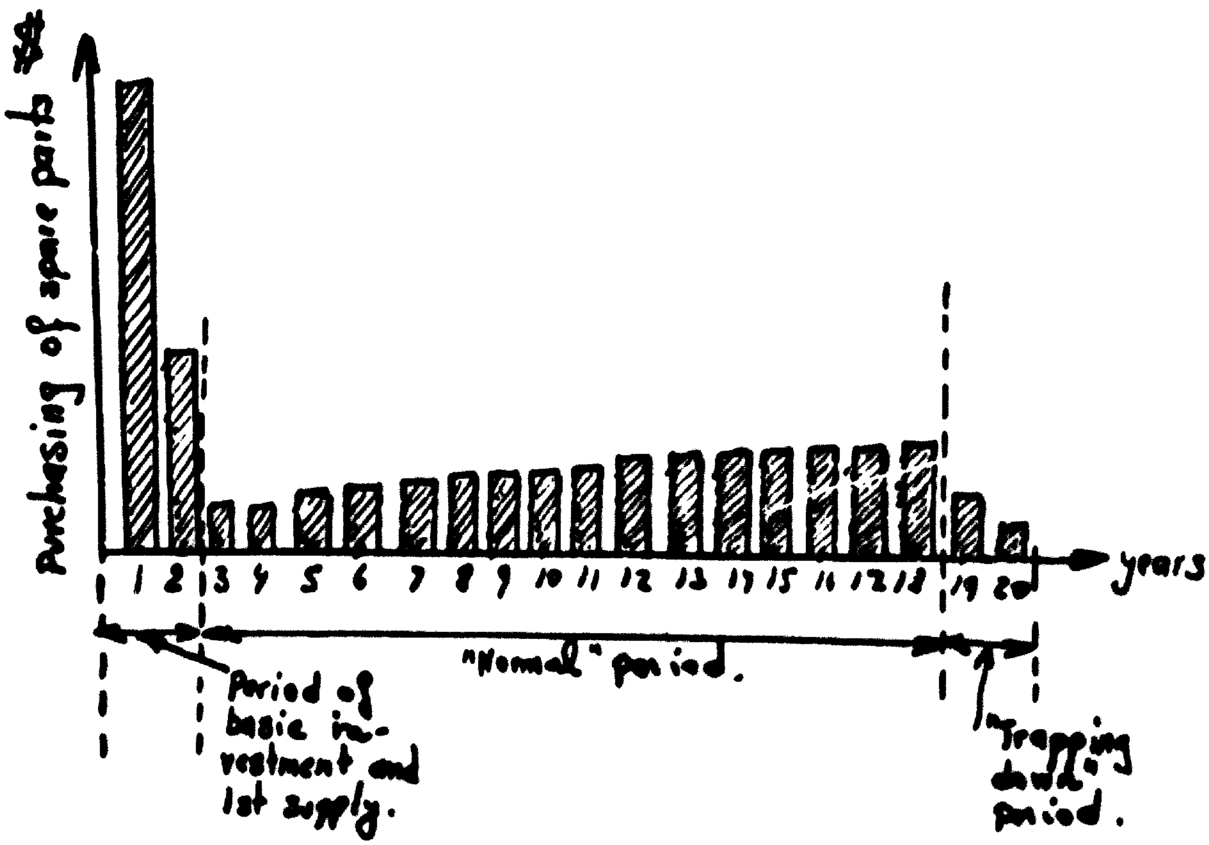



Fig. 3

Capital for spare parts in the first period, when the new enterprise has not yet been able to operate with a profit, must be considered as a part of the total investment.

In case spare parts are delivered from hard currency countries the necessary currency for supply of spare parts must be included in the financial plan of the new enterprise. It is important, especially for the international development banks, to be aware of thise.

Lack of capital in the company, or lack of currency for this purpose in the country, will result in none or very limited supply of spare parts and increase in production downtime.

## C. THE DETERMINATION OF THE OPTIMUM SIZE AND COMPOSITION OF STOCK OF SPARE PARTS AND MAINTENANCE MATERIALS FOR MACHINERY AND EQUIPMENT OF A MANUFACTURING PLANT.

This termination is for the individual industrial enterprise a very complicated and difficult matter. Only to a limited extent can it be based on theoretic economic methods and formulars.

Decisions are usually based on the manufacturers general recommendation, general experience, technical know-how and a good deal of common sense.

Composition and size of spare parts must first of all be determined when the plant is planned and layed out, and decided at the same time as the different production units are decided.

Later on, the composition will be varied with supplementation of spare parts in stock. At this stage the firm will have a growing experience from operation of the plant on the basis of which the stock is determined.

In this situation a systematic and complete record of the consumption of spare parts and maintenance materials are very valuable and necessary material.

Factors affecting spare parts stock:

As a background for the determination of spare parts stocks, it would be of help to be acquainted with the following reasons for the requirement of spare parts:

1. Normal wear.
   Some parts will, due to normal friction and wear, have a considerable shorter lifetime than the machine or plant as a whole. Examples are bearings, V-belts, motors, engine components, packings and electric, hydraulic and pneumatic control units.

2. Unusual working conditions.
Some production units will have to work under exceptional conditions of heat, humidity, dust, corrotive atmosphere, etc. and these are worse than the conditions they are designed for.

3. Overlaod of machines.
A common reason for repair is that somebody tries to let the machine handle a much bigger workload than the one it is designed for. This might rapidly result in breakdowns in electric motors, engine parts, gears, transmission units, etc.

4. Faults in the material of the part.
Some parts are supplied from the manufacturer with a hidden fault in the material. Later a sudden and unexpected breakdown might take place due to such fault.

5. Accidents.
Like a crash, an explosion or any other unusual event will create a sudden demand for some spare parts.

Of these five major reasons for needing spare parts it is only point 1 (normal wear) and partly point 2 (working conditions) which are of such a type that the consumption of spare parts can be calculated in advance with reasonable tolerances.

This includes both the determination of:
a. which spare parts to keep in stock, and
b. annual consumption of each of these spare parts.

For point 3 (overload) it is not generally known whether spare parts will be necessary at all. If we imagine that the machine is highly overloaded we should, however, with our technical know-how, to some extent be able to anticipate which parts are likely to break. It will be impossible to guess in advance when such breakdowns will take place, and the annual consumption of the different parts.

Later on the history of repair and spare parts consumption record will give some lead, if this record is properly kept.

For point 4 (faults in material) the situation is still worse. Theoretically, any part can break for this reason, an axel, a casting, a part of a steel construction, etc. The background for making evaluations at the planning stage is very limited indeed.

Point 5 (accidents) will come in the same or even a worse category.

Expensive and inexpensive spare parts.

For the determination of which parts to carry in stock, and for the decision of the quantity of each item, it is of great importance to distinguish between expensive and inexpensive spare parts. (High and low value items).

Some parts are very cheap to buy, especially if they are bought together with the machine or plant. It might be small bearings, a spring, a gadget, and many other components. However, if they are not available they might be the reason for a complete or partial stop of production. Let us call those inexpensive spare parts or "low value items".

Other parts are comparatively expensive to purchase, for example, a large roller bearing, a spare gear transmission or even a complete spare machine. These can be called expensive parts or "high value items". It is natural to apply a different "policy" for low value items and high value items.

The determination of the border between the two categories will depend upon a number of circumstances, but can in most cases be something in the order of 5 - 10 U.S. dollars

Which parts to carry in stock.

When a company decides which parts to carry in stock, it is important to consider their value (purchasing cost) in addition to their calculated necessity or desirability.

The low value items represent a small investment and a relatively low figure compared to calculated cost of production downtime.

For this group it is logical to apply a very liberal policy, especially in the determination of spare part composition.

The high value items represent, first of all, a much greater financial problem.

Secondly, the ratio between cost of parts (or units) and cost of production downtime will be quite different for this than for the other group. In some cases the most economical solution might be not to carry the parts in stock, but to supply them if a breakdown should take place.

For this group of high value items a different and much more critical policy must be applied. Only items for which calculated risk of breakdown is comparatively high, or where the consequences of a breakdown are extensive, stocking of spare parts is justified.

In the case of high value items delivery time also comes into the picture as a complicating factor. If the part can be supplied from a local dealer the next day, the situation is quite different from having 3 - 5 months delivery time from Europe.

On the average high value items represent only 20% of the number of items, but 80% of the stock value. Low value articles represent 80% of the number of items, but only 20% of the stock value.

Different determination "policy" has to be applied for low value items and high value parts.

**Determination of stock sise.**

When a company had decided which parts to carry in stock, the next question is to determine the stock sise or how many pieces of the different units should be in stock.

We can classify the parts in two major groups:

1. A stock sise of two or more (Parts or units).
2. A stock sise of one (Part or unit).

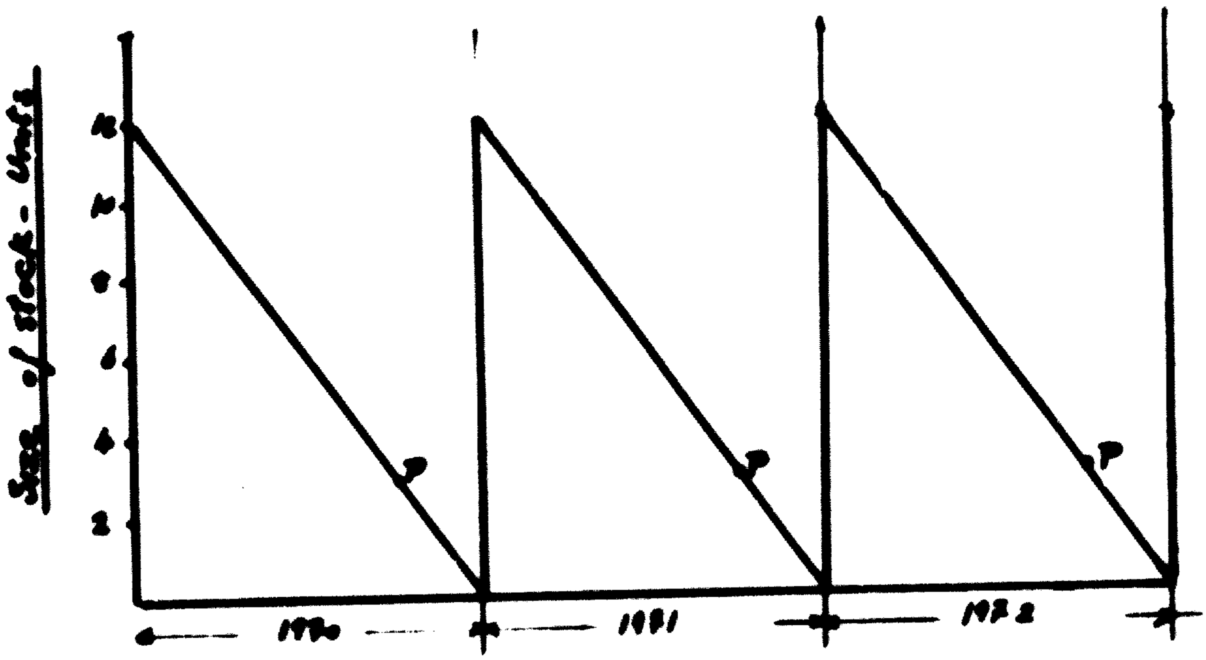



Fig. 4

Before proceeding any further, the difinition of the important terms will be classified.

Purchasing order size: Is the number of items to be ordered at one time. The cost of ordering, of transport, etc. does not usually increase materially with the size of the order. Also, with a big order a lower price may be obtained. From this point of view it is better to increase the size of the order. On the other hand, a big order at one time means tying up a big amount of money in stocks and increasing storage expenses. A balance has to be made between the savings gained by increasing the size of the order and the resulting cost of a larger stock. Adequate costing data is necessary to enable management to decide on the size of the order which keeps a balance between the savings in ordering and cost of stocking parts. This size is called the purchasing order size or economic lot size. If, for instance, in the example given in Fig. 4, the purchasing was found to be 12 units per year and the ordered stock is received at the beginning of each year. Fig. 4 will give the position of the stock at the different times.

Ordering stock size: Spare parts and maintenance material ordered do not usually arrive over-night. The delivery time is estimated and the new stock is ordered when the number of units in stock are enough for consumption during the delivery period and until the new stock arrives. This is called the ordering stock size. In the example given in Fig. 4, if the delivery time is assumed to be three months, the consumption during this period is 3 units and point P shows the ordering stock size. The delivery time here means the time between initiating ordering in the factory and the arrival of the goods in the stores.

Minimum stock size: If the consumption of the parts is absolutely regular, with no emergency breakage or an unexpected over-consumption, and if delivery time is not subjected to any variations due to financial procedures, import regulations, etc. then the variation of stock is as shown in Fig. 4. Under these conditions on the day of arrival of the parts ordered in the stores, we will have zero stock.

In practice variation in consumption will occur and delivery time will vary, sometimes materially. The ordered parts would arrive in the stores later or earlier than expected and the variation of stock in the stores will be as shown in Fig. 5a.

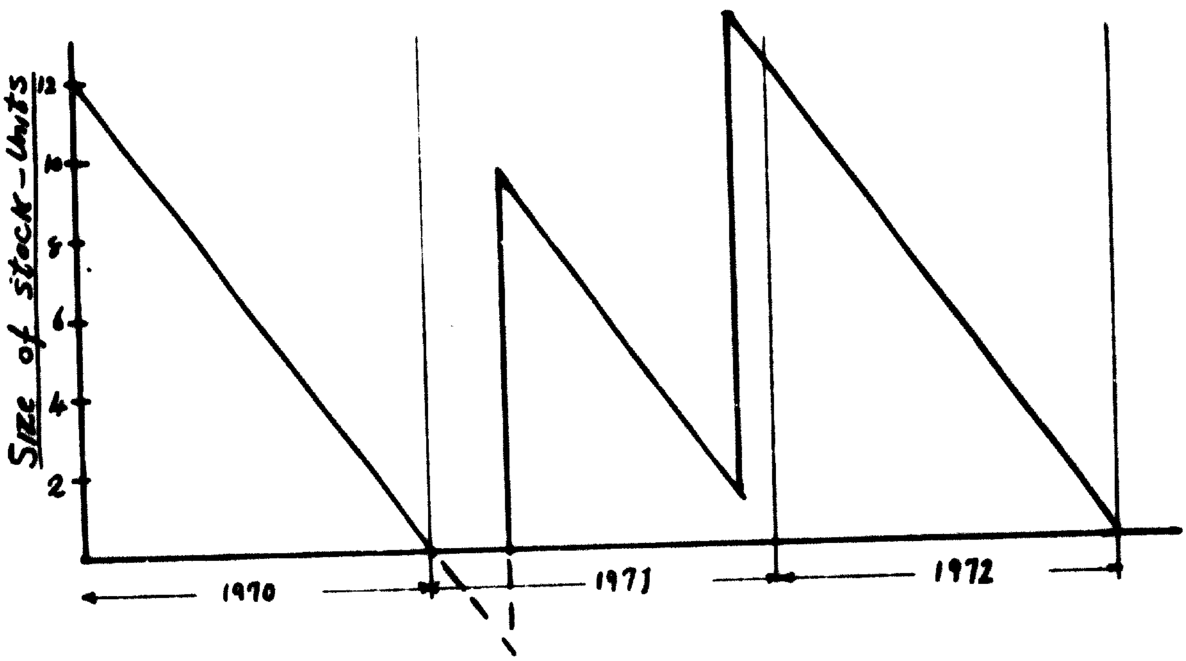



Fig. 5a

In this case a certain amount of safety stock must be kept continuously in the stores to cover these fluctuations and to guarantee that at any time, inspite of fluctuations in consumption and delivery time, there will always be a stock available. This is called the minimum stock. The size of this minimum safety stock depends on the magnitude of fluctuation of consumption and delivery time and must be decided by the management of the enterprise according to local conditions and experience. It should be, however, re-adjusted every now and then when delivery and other conditions change.

In our example, if we assume the minimum stock is 4 units, Fig. 5b shows the modification of Fig. 4 to include minimum stock.

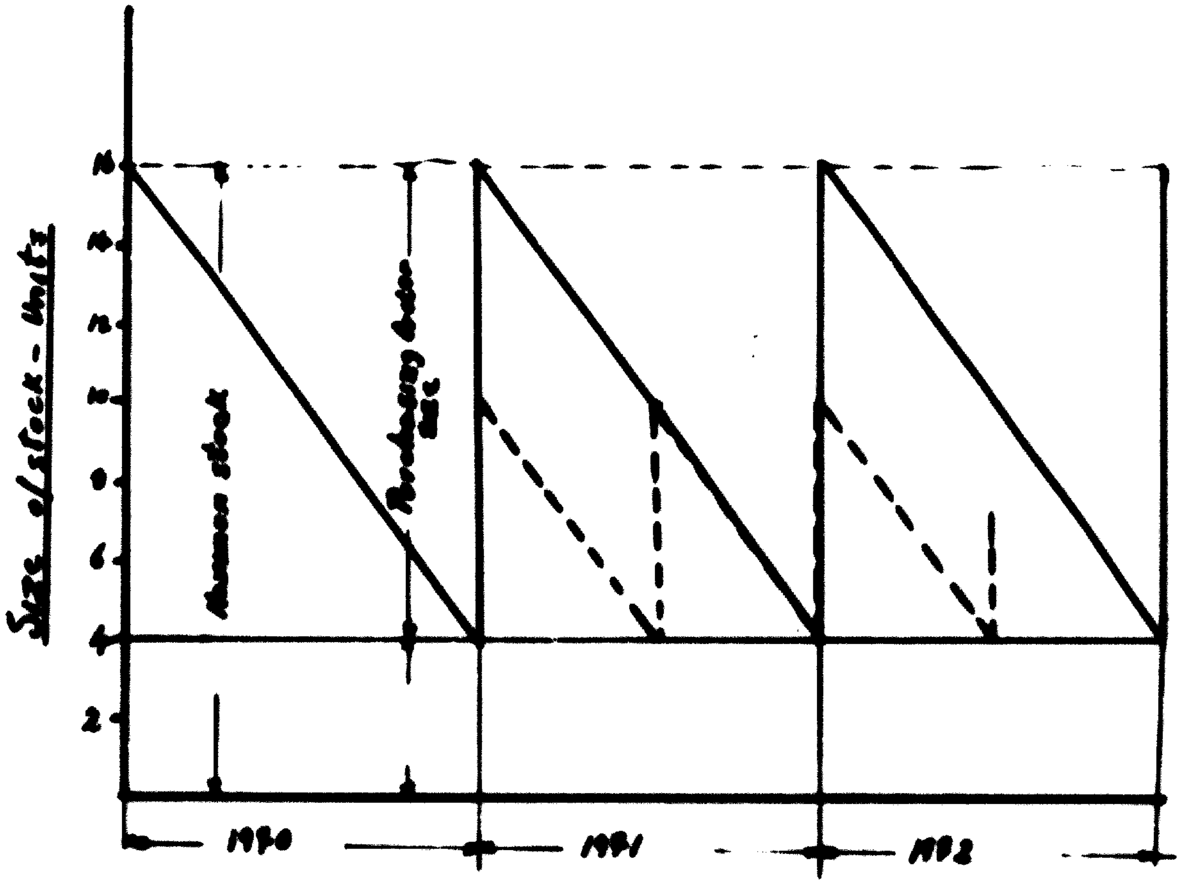



Fig. 5b

In this case the maximum stock will be the purchasing order size plus the minimum stock or 12 + 4 = 16 units. The ordering stock size will be the consumption during the delivery period plus minimum stock or 3 + 4 = 7 units. It is to be remembered that the minimum stock size is a financial liability and extra cost resulting from the variation in consumption and delivery.

The above covers the case where the stock size is two or more. If the stock size is one, the stock size is one, the purchasing order size is zero and there is no minimum stock.

In the previous given example, it is assumed that the parts are ordered and delivered once a year. If it is agreed that delivery will be in two batches instead of one, the average stock size will be reduced as shown by the dotted lines in the right hand side of Fig. 5b.

Summary and recommended procedure.

1. Collect all background material for the determination of compo-sition and optimum size of spare parts stock.

   (Manufacturers recommendation, drawings and specifications of machine units, repair history of comparable production equipment, general maintenance experience, purchasing cost of spare parts, delivery time, etc.).

2. Find out the spare parts desirable to have in own stock in order to carry out the planned production programme.

3. Separate these desirable units in high and low value items.

4. Establish different policies for these two groups.

5. Make final decision on which parts to have in stock.

6. Decide which parts to have in stock in one unit, and which to store in two or more units.

7. Decide minimum stock size and purchasing order size for the different spare parts.

8. Order the spare parts to be delivered together with the machine or plant.

9. Review decision on spare parts stock regularly and not less than once a year.

## II. FACTORS DETERMINING THE SIZE OF STOCK

### A. DOWNTIME COST DUE TO LACK OF SPARE PARTS. THE UTILIZATION OF CAPACITY AND ITS IMPACT ON THE NEED FOR SPARE PARTS.

The composition and size of stock of spare parts is primarily not decided only by the cost involved in carrying this stock, but also and to a greater extent by the cost or lack of income of being without them, generally considered as downtime cost.

The cost for an industrial enterprise of having a diversified stock of spare parts and maintenance materials can be specified exactly in the annual bookkeeping records.

The cost of being without them is considerably more complicated and difficult to specify, and depends upon a number of factors, such as:

1. Production capacity compared to marketing possibilities.
2. Available stock of finished products.
3. Time of the year, -peak or low season period.
4. Raw materials ability to be stored without being destroyed (for instance, steel versus sardines).
5. Loss of customers in the future.
6. Penalties for late delivery.
7. Cost of labour.
8. Degree of mechanisation and automation.

Downtime cost is composed of:

a. Profit lost due to lost sales resulting from lack of production.
b. Direct labour paid but not producing.
c. Spoilage of products preceding, during and following the stoppage.

d. Cost of bringing back equipment to working conditions after repair.

e. Interest on idle investment.

f. Penalties for late delivery and loss of customers.

The profit lost due to lost sales is a serious item when sales volume is equal or exceeds production. In this case any production loss due to downtime will result in a corresponding sales loss. If production capacity is greater than sales demand, downtime effect will be little. The company will be able to take production stops and still satisfy the market. Extra production can be stored to enable coping with peaks of market demand. For perishable goods, such as food, where freezers are necessary, a breakdown of the freezing system will result in a loss of the products. Downtime in this case will become very expensive.

Frequently other enterprises are dependent upon our delivery, as for instance raw materials or parts for assembly. If we fail to deliver on time because of downtime in our own production equipment, our customer will be in trouble. In his eyes we will become an unreliable vendor. We will lose future delivery contracts, which might have enormous influence on the total company economy.

If the delivery contract includes a daily penalty for late delivery we get the downtime cost right in our face. In this situation it is important for management to secure production by all possible means, and a satisfactory stock of spare parts is one of them.

During a production stop due to a breakdown, we will still have to pay all people involved in that production. In an industrially developed country with high labour cost, this factor has a much greater economic influence than in a developing country with comparatively lower labour costs. This is one reason why spare parts stock generally are perhaps more important than in industrially advanced countries.

A highly mechanized or automated plant is very sensitive to breakdowns of components in production equipment. A sudden failure in one out of 10.000 parts might put the whole assembly line, or even a complete factory, out of production. Even if the reliability of each part is 99,9% the reliability of the whole unit is only 80%.

Summary and recommendations.

In this chapter is discussed the influence that lack of spare parts will have on production and total company economy. In a given situation we will (or should) have figures for the costs of having spare parts and maintenance materials in stock, the downtime cost and added value cost.

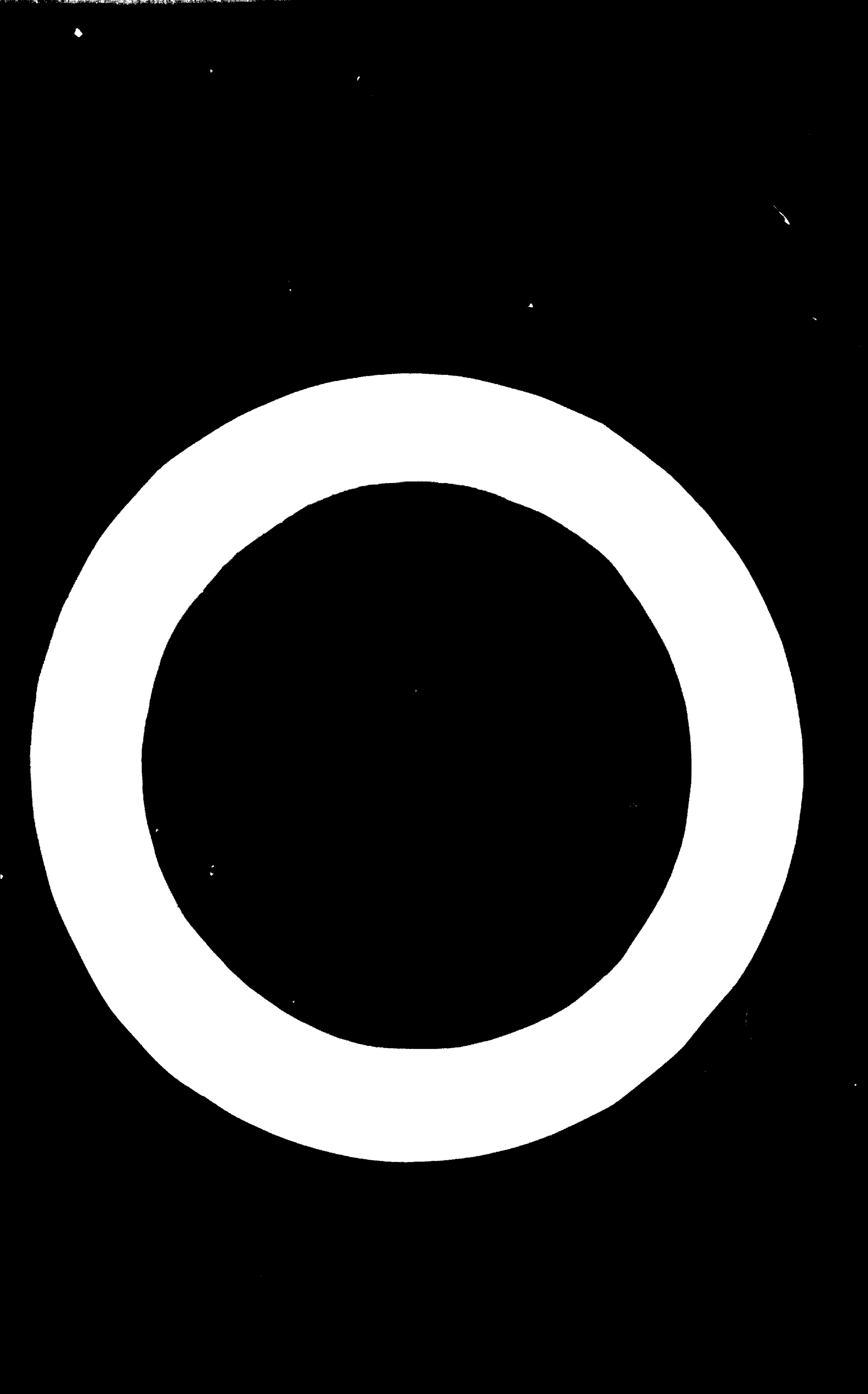
Unfortunately only a limited group of industrial enterprises have reliable figures for loss due to downtime due to different reasons, -waiting for spare parts for instance. This is the case all over the world, but mainly in developing countries. This is unfortunate because downtime due to lack of spare parts is a very important figure for the evaluation of the economy of our present stock. If we by an increase of spare parts stock and costs of $10,000.- a year can gain for instance $20,000.- it is a good investment. If we, on the other hand, can reduce the spare parts stock by $5,000,- a year without any measureable decrease in production for this reason, -it also is a good improvement of total company economy.

General comparison like this can be somewhat dangerous, as they assume that the spare parts stock in any way has a sensible composition and size (of each unit).

This is most often not true. Maintenance people get the impression that the storeroom has almost anything except the part they need.

Frequently can be found that the stock contains great quantities of some parts and materials (and not even critical items), while others (and critical) parts are not there at all.

1. Develop figures for stock cost of spare parts and and materials.
2. Record figures for downtime due to waiting for spare parts and maintenance materials. (This recording might take several years.
3. Compare the two figures and evaluate changes which will improve total company economy.
4. Evaluate at the same time the composition and size of the different elements in the stock.



# Chemical consern

## Stock, consumption and standardized spare parts and materials, 1958-1969.

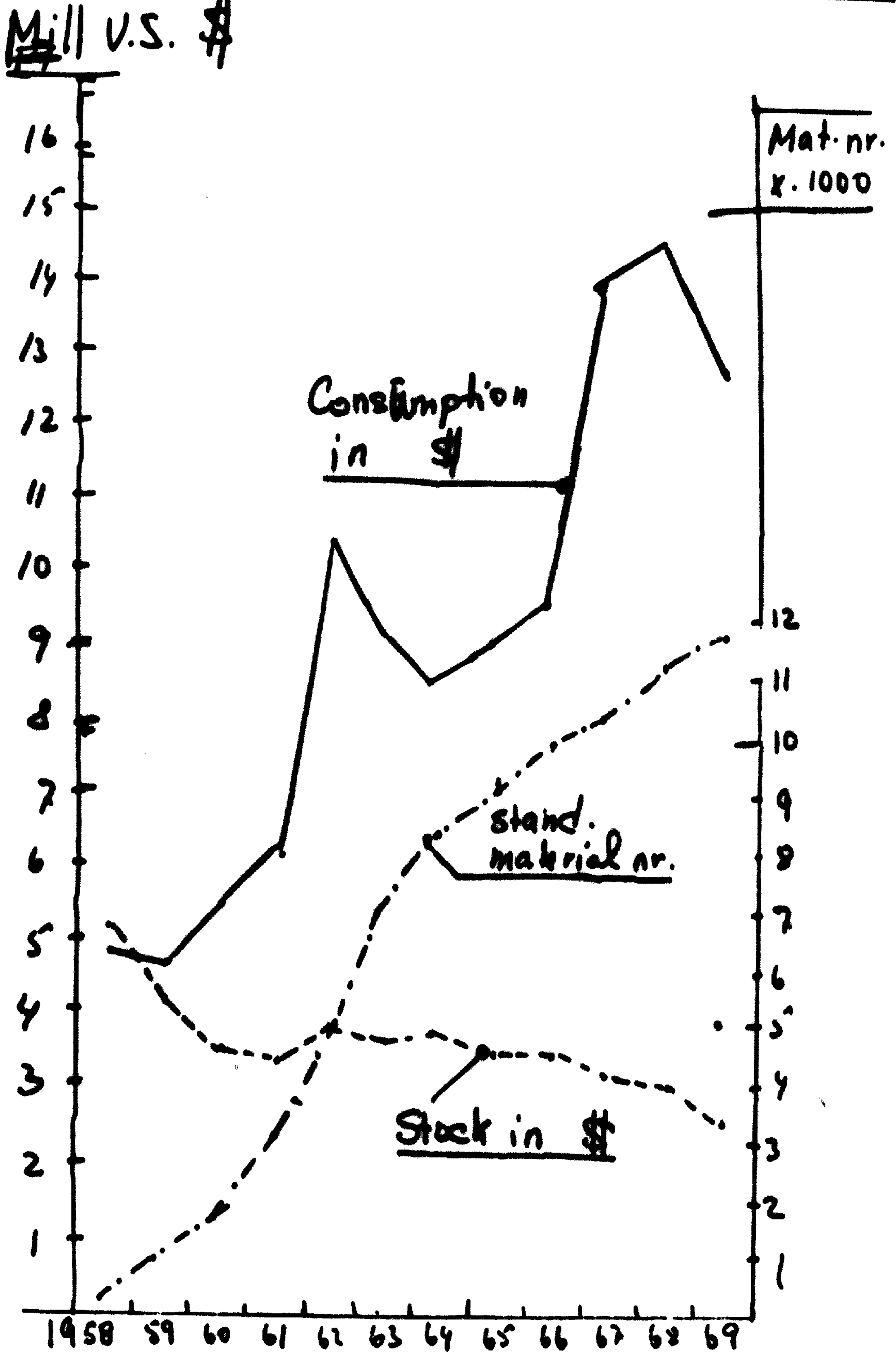
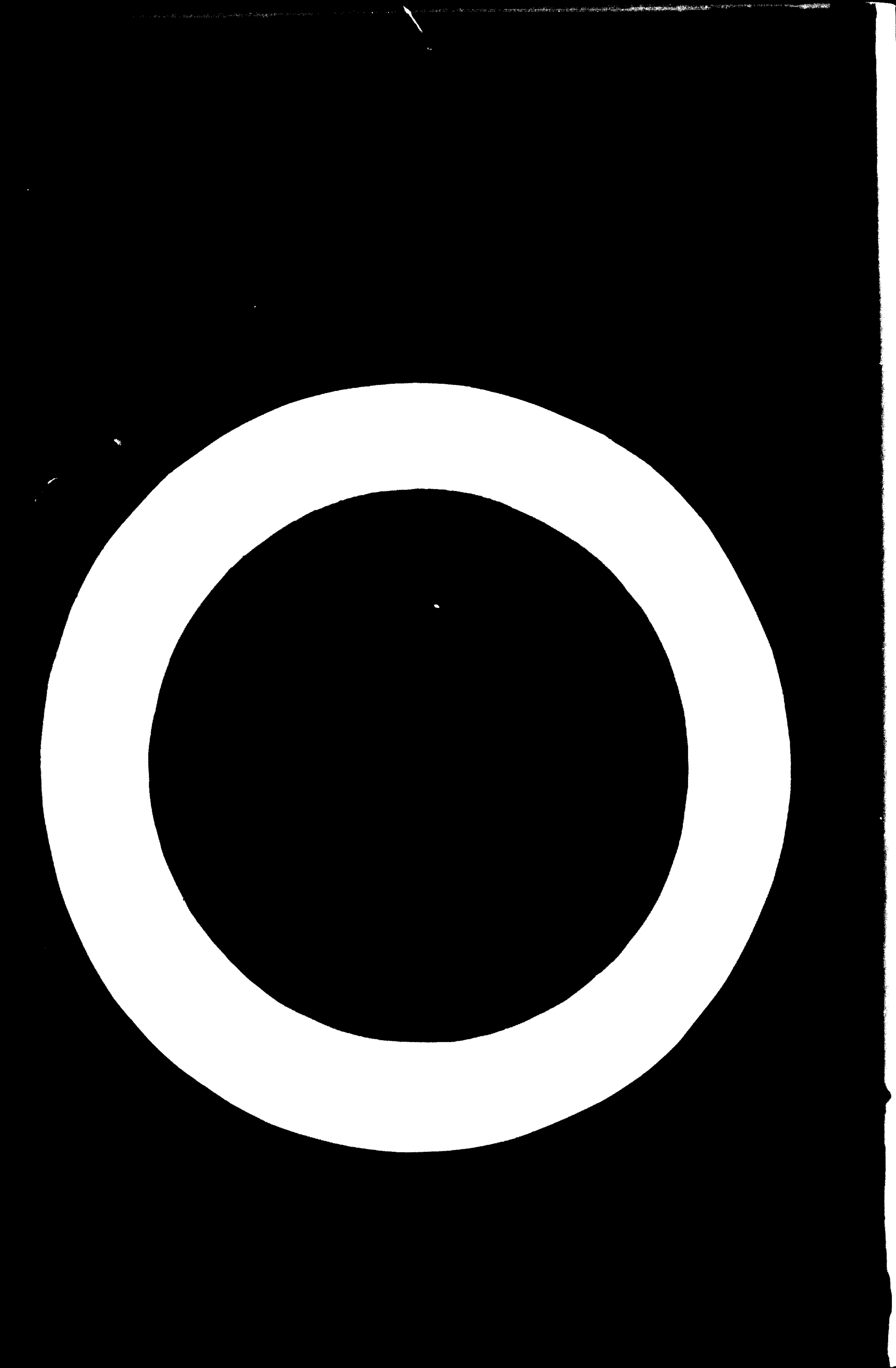



Fig. 6



## B. THE IMPACT OF STANDARDIZATION OF PRODUCTION EQUIPMENT AND COMPONENTS.

### Economic influence of standardization.

In the long run, an in-plant standardization of production equipment is the factor which will reduce to the greatest extent the number of spare parts and maintenance materials in stock, and thus decrease the capital tied up in these articles.

This standardization includes:

1. Complete machine units, as tool machinery, material handling devises, boilers, compressors, furnaces, etc.
2. Machine components, as electric motors, pumps, valves, bearings, fittings, pipes, etc.
3. Regular consumed maintenance materials, as steel bars, plates, oil, metals, etc.

An example from a large chemical concern gives a good illustration (Fig. 6).

In 1958 this concern started its internal standardisation programme. At that time the four factories of the concern had a total maintenance stock of about 5 mill, US$ and an annual consumption of spare parts and maintenance materials of the same size.

In 1969, -after 11 years of standardization work-, the value of the stock had been reduced to less than 3 mill, US$. This had been possible in spite of the fact that production had increased considerably, and the annual consumption of spare parts and materials was in 1969 close to 15 mill US$.

From a 1:1 ratio between stock and consumption in 1958 the company had moved to a 1:5 ratio in 1969. In this period between 11,000 and 12,000 different units and dimensions had been standardised.

The economic advantages were not only a reduced stock, but also reduced prices for a number of articles. Some steel material could be bought direct from the steel mill and all ball bearings direct from the manufacturer. With standardization and unification of spare parts small manufacturers were able to produce spare parts in competition with the manufacturer of the machine, in most cases to acceptable quality and with a price down one-third.

Delivery and supply circumstances were improved, because the local dealers found it possible to carry stock of components for standardised machine units.

Organization of standardisation.

Background.

The basis for standardisation are international standards, national standards (DIN - normes for instance) and standard dimensions set up by different manufacturers (SKF - ball bearing catalogue, etc.

An internal company standard or norm is a very limited fraction of standards mentioned above. In practice this will turn out to be a book of norms.

Use of norms.

The material collected in the book of norms will be used at:

1. Design of new production equipment, both in the companies' own drawing office and by a manufacturer or an engineering firm from outside.

2. Purchasing of materials and spare parts to the factory.
3. Requisition of materials and spare parts from the storeroom.

It is not allowed to go outside the norms. Only people at a certain high level in the company's organisation may authorize the use of off-standard dimensions under special circumstances.

Standardisation office/committee.

There are two main possibilities for organising standardisation work.

1. A standardisation committee, consisting of people who most of their time are engaged in other types of work.
2. A standardisation office, with one man or a group of people working full time on this subject.

   In addition the office will operate with supporting and decision-making committees.

Experience has shown that the 2nd alternative by far has given the best practical result. The people in the group have been able to secure a rather rapid and constant progress of work.

Lack of progress has been the main criticism of the first alternative. The members of the committee have in practice not been able to devote the expected amount of work on standardisation. Others and more urgent problems get priority and the standardisation programme is delayed.

A small or medium-sized company will have the problem of affording a qualified man for standardisation work alone.

In any case the establishment of norms must work according to the "Management of Objectives" principles. Certain goals for the number of items standardized must be set up for each time period.

Book of norms.

As mentioned earlier, the product of the standardization office is a steadily growing book of norms.

This book will have one blade for each type of material.

In Fig. 7 is indicated a normblad for steel pipes of cast iron.

It contains the following information:

a. Type of article - Steel plate for boilers

b. Blade no.- here 002.007, which identifies the blade. It is different from any other norm blade.

c. Material used - here H II DIN 17155, certified according to the standard German DIN-norms. This is a precise description of the steel used in these plates.

d. Example of ordering - is the description to be used when the company shall order material from the outside vendor.

e. Stock term - the description to be used when the workshop shall order this material from the store. Note that the internal material no. (002.007.03) is used in this requisition and not in the purchasing order.

f. The date this norm blade was official (4th January 1968).

## STOCK NORMS

| | |
|---|---|
| Article' STEEL PLATES FOR BILERS Over 4,75 mm | Blade nr. 002.007 |
| Material: M II DIN 17155 , certificert | Date 4.Jan. 1968 |

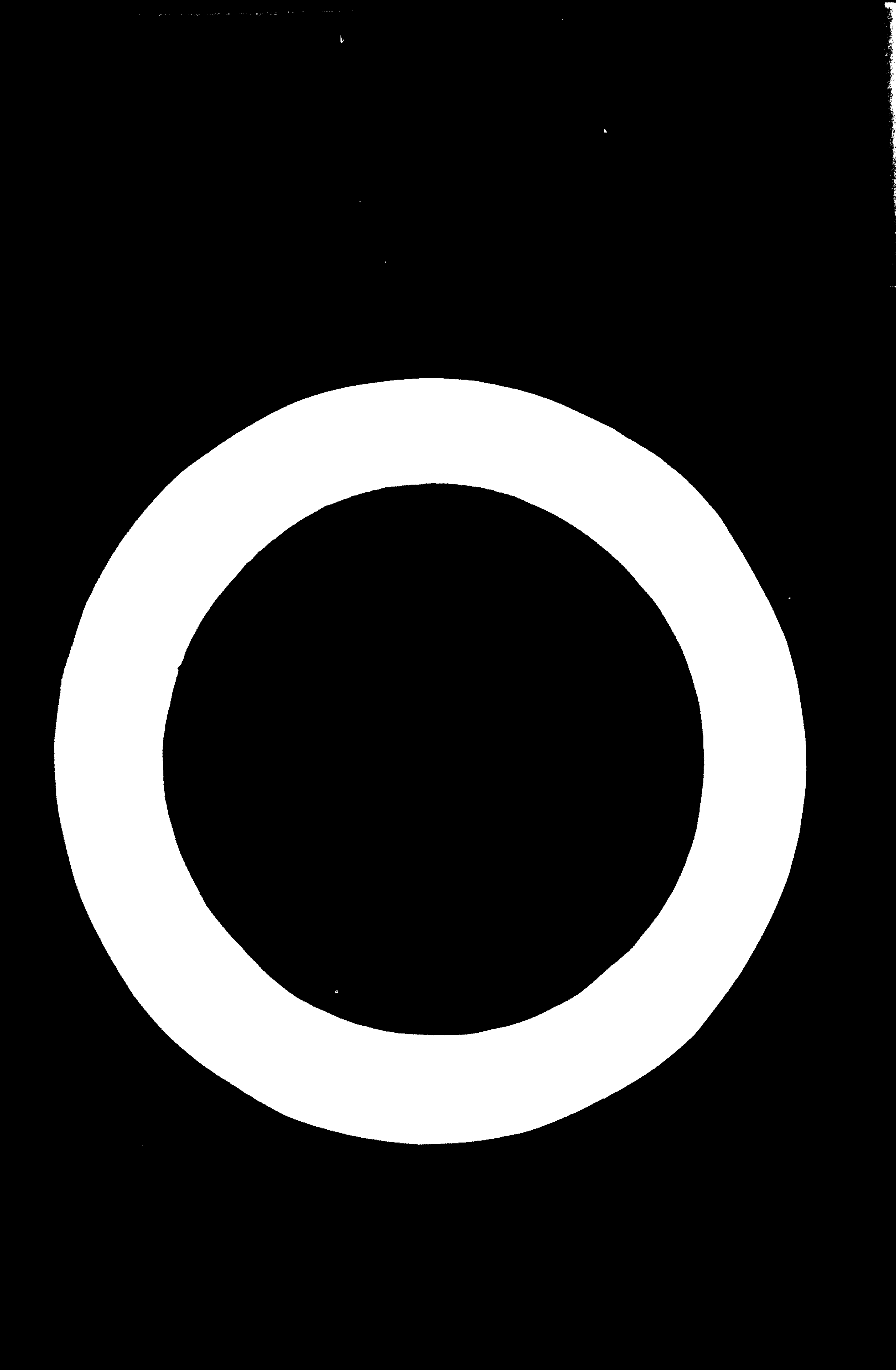
**Example of ordering:** Steel plates for boilers 16x1250x2500
DIN 1543
M II DIN 17155, certificet

**Stock term:** Steel plates for boilers 16x1250 x 2500 M II
Material nr. 002.007.09

Thickness and toleranses according to DIN 1543

| Mat. nr. | Thickness t | Dimention w x l | Toleranses t | w | l | Weight ca. | | On stock by | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | mm | mm | mm | mm | mm | kg/pl | kg/? | N | E | U | ' |
| 002.007.03 | 5 | 1250 x 2500 | -0,3 | +10 | +12,5 | 125 | 40 | | x | | |
| .04 | 6 | 1250 x 2500 | -0,3 | +10 | +12,5 | 150 | 48 | | x | | |
| .06 | 8 | 1250 x 2500 | -0,3 | +10 | +12,5 | 200 | 64 | | x | | |
| .07 | 10 | 1250 x 2500 | -0,3 | +10 | +12,5 | 250 | 80 | | x | | |
| .08 | 12 | 1250 x 2500 | -0,5 | +10 | +12,5 | 300 | 96 | | x | | |
| .09 | 16 | 1250 x 2500 | -0,5 | +10 | +12,5 | 400 | 128 | | x | x | x |

Fig. 7



g. Material no., thickness, dimensions, tolerances, weight, etc. - which are all necessary technical information.

h. Where in stock. The company has four factories, Rjukan, Eidanger, Glomfjord and Notodden (Norsk Hydro). A mark in the last column R E G N (the first letter in the factory names) will tell which factories have this material in stock.

Where it is desirable, the normblades also includes a cross-section drawing of the normed item - a valve for example.

Up to August 1970 a total of approximately 400 normblades have been worked out, which covers between 18,000 - 19,000 items.

This also includes standardised items which are not in stock today, but are used in production equipment now being designed or bought, and thus will be in stock in the future.

This proves that standardisation starts in the factory-planning period, not after the factory is finished.

Responsibility for standardisation

Standardisation can be handled by:

1. The user/buyer of the equipment
2. The manufacturers of production equipment.
3. The organization of consulting firm responsible for a "key door project".

Experience has shown that plant standardisation is only successful if the buyer himself is pushing the work forward.

The different manufacturers will produce a certain number of standard dimensions. But each one shall satisfy a wide range of different customers in many industries. The individual plant only needs a fraction of these dimensions.

Electric motors are a good example. As a part of standardisation, a company's policy would be to buy from one manufacturer, but in the company's norm only 5-10% of all different units produced by that factory will be included.

An organization or consulting firm making a "key door factory" should have excellent possibilities for standardizing production components. This is also done to some extent, but, sorry to say, rather seldom and to a very limited extent.

There exist a number of new factories where standardisation is almost totally neglected, especially in developing countries. Even in cases where standardisation is most natural, it is possible to find the most horrible examples.

In an ammonia factory there were four high-pressure compressors placed next to each other. They were of three different makes. "I think the contractor must have bought them on sale", said the maintenance manager.

It might very well be so, as the contractor mainly is interested in procuring the different units at the lowest possible price. The total cost concept of procurement and maintenance, as mentioned earlier in this paper does not interest him very much. Only the buyer has this interest in full.

# P R E F A C E

The basic aim of this paper is to serve as a guideline for managers and their subordinates in industrial enterprises, and to clarify the scope of the problem of spare parts inventories and stock of other materials used in the maintenance of production equipment.

A paper on this subject must necessarily, to some extent, be general, and is meant as background material for the reader to give him impulses and ideas of different kinds.

The presentation aims at being as practical as possible, based on the fact that the subject itself and its solution in real life in industry is of a very practical nature, with none or very limited scientific background.

The different types of spare parts and maintenance materials are analysed, and the reasons for their necessity are thoroughly discussed. Spare parts and materials are considered as a part of maintenance, and maintenance as an integrated part of production. Emphasis is given to the ways of obtaining the optimum solution taking the overall economy of the enterprise into consideration.

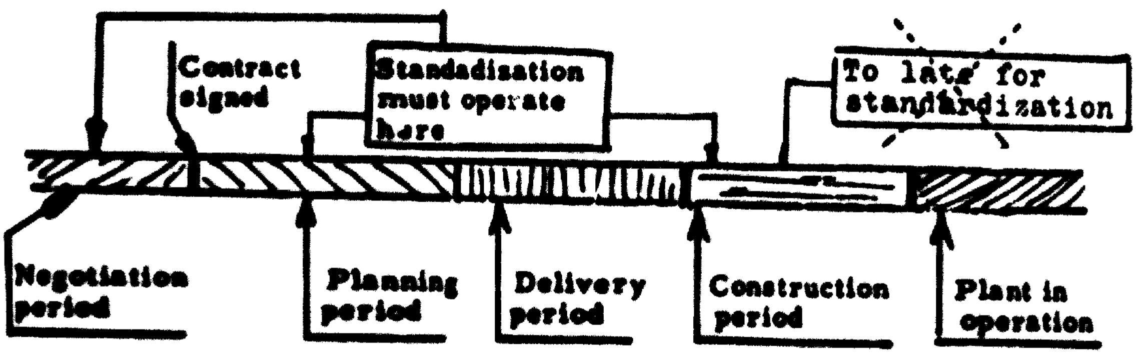
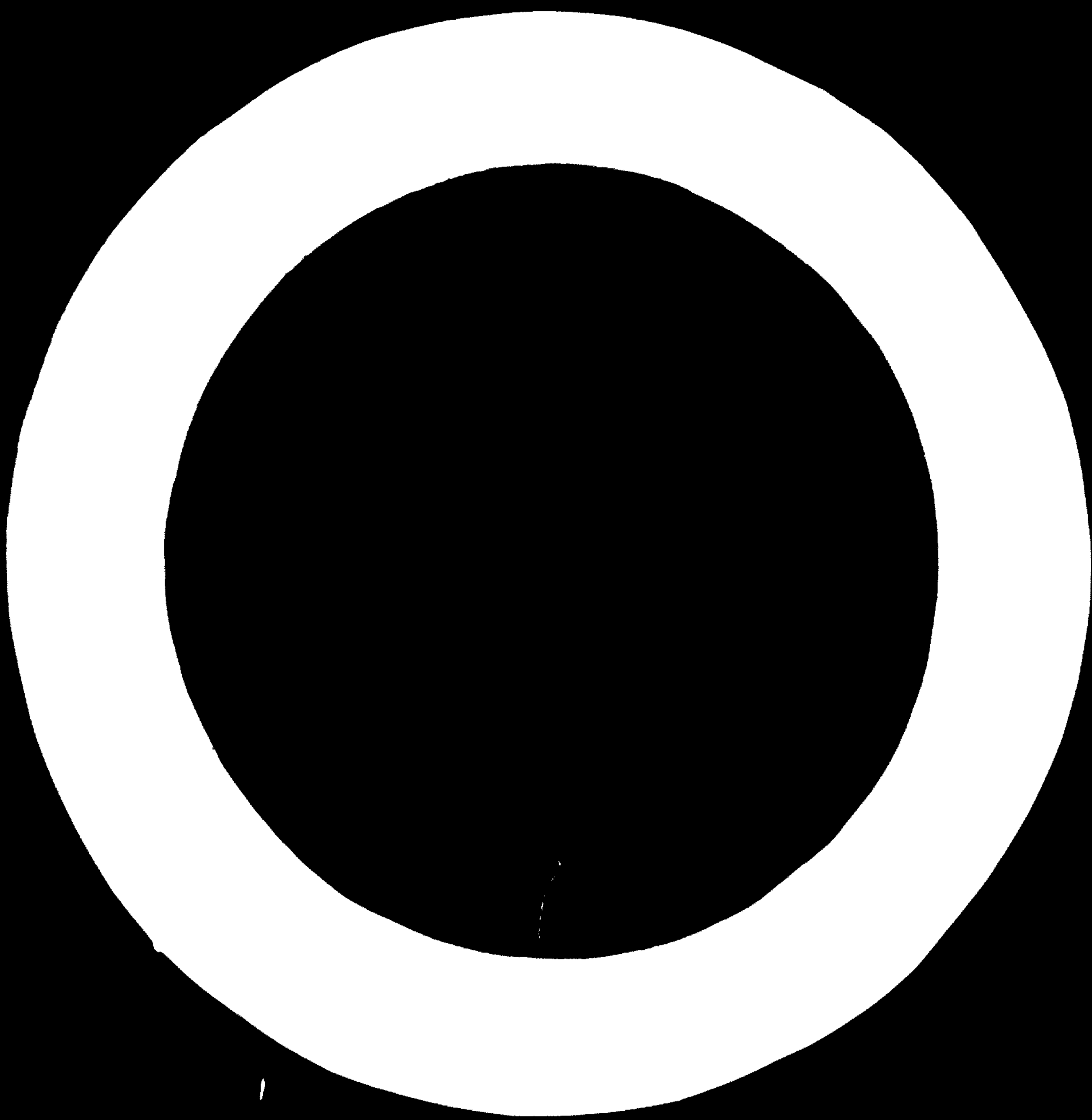

Contract
signed
Standadization
must operate
here
To late for
standardization
Negotiation
period
Planning
period
Delivery
period
Construction
period
Plant in
operation

Fig. 8



Buyer's authority.

In a buyer's market the receiver of a new factory has the authority to decide in detail the components to be used. This must, however be discussed with the contractors before the agreement is signed and must be included in the contract. If not, the buyer will get a nice extra bill, -whether it is realistic or not.

The well-organized enterprises in Europe and North America have detailed specified books of norms which are used for all new installations. Furthermore, this book of norms is strictly adhered to in practice.

A developing country which gets a key door factory delivered through a contract or low range loan or gifts, should have the same possibility to influence standardization.

The receiving country is, however, often short of qualified people to take on this job. Furthermore, the technicians come into the picture at a comparatively late stage. When the plant is under construction, it is much too late to do anything about it.

Standardization must come into the picture at the planning stage, as indicated in Fig. 8.

With the great influence standardization and internal norms of different materials, parts, etc. have on the spare parts stock and spare parts service, it is of great importance for any industrial enterprise of some size to get this function organized and operating properly.

## C. THE IMPACT OF PREVENTIVE MAINTENANCE AND REGULAR CONTROL OF MACHINE UNIT CONDITION.

The purpose of inspection of production equipment as a part of a preventive maintenance programme, is to discover failure, wear, corrosion, etc. before the situation is critical and before a sudden breakdown takes place.

This will give a time interval between the moment the failure is discovered and the day the spare parts or maintenance material really are needed.

This can be a period of a couple of days, a week, or even more, and can help the maintenance department to reduce or eliminate the production downtime effect due to lack of spare parts and materials.

Especially for high-value items the preventive maintenance programme can result in a considerable reduction in capital tied up in spare parts etc., and in the cost of keeping this stock.

It is realistic under these circumstances to reduce the minimum quantity in stock, and even cut some items out of stock record completely.

Large ball- and roller bearings can be good examples. Instruments which are able to indicate that something is wrong with a bearing, and that it should be changed within a limited time have been available for some years.

The SKF Ballbearing Company can today market a high frequency shock puls measurement instrument. This can tell when a small failure starts in a ball or in the sliding track.

Regular measurements, and comparison with curves recorded from previous bearings can also tell rather exactly how many weeks or months it is possible to run the machine without a risk of a sudden breakdown.

For machine units like this we can rather safely eliminate the spare stock completely, and base the supply of new bearings on the results of the measurements of condition.

This of course will depend upon a reasonable delivery time. It is, however, possible to discover such a fault a long time in advance so that it will satisfy most industrial enterprises.

However a considerable research and development activity is going on in developing new and better none-destructive control methods for machine units. It seems that the methods which are most developing are the more advanced and complex condition control systems. Primarily this is the condition of different tests built into the machine unit when it is designed, and connected with automatic recording and alarm systems.

It is natural that this will have a great influence on how the spare part stock is set up.

Preventive maintenance will mainly have impact on the size and composition of stock of spare parts based on "normal wear" or "normal working conditions". "Overload" on a machine can, however, easily result in breakdown in a unit today, -even if it was reported to be quite o.k. yesterday.

Summary and conclusion.

The steadily more applied and improved systems for preventive maintenance and control of machine units condition will have a great influence on the size and composition of stock of spare parts.

It is important that this composition and size is evaluated in close cooperation with the existing and planned programmes for preventive maintenance and condition control.

## D. COST OF MAINTAINING A STOCK OF SPARE PARTS AND MAINTENANCE MATERIALS.

Costs arise from the following:

a. Making the purchasing order.
b. Follow up with the vendor.
c. Receive, control and put in store received material.
d. Invoice cost
e. Customs and freight cost
f. Capital costs of materials in store
g. Storerooms cost (building, supplies, shelves, transportation, equipment and other facilities)
h. Cost of storeroom, labour and supervisors
i. Deterioration cost (some material will be destroyed during storage, especially in tropical climates).
j. Shrinking cost (theft, misplacing, etc.)

These costs can be grouped in:

1. Total purchasing cost (from point a to e above)
2. Storage cost (from point f to j above)

### Economic lot size in purchasing.

The cost of making one purchase order can for practical calculations be considered as constant.

It is mainly the cost of own personnel which is involved (Maintenance Dept., Purchasing Dept. storeroom, bookkeeping, etc.).

Whether 10 or 100 units are ordered, and whether one order consists of 1 or 3 different items makes comparatively small difference. Companies which have made calculations of their cost of making <u>one purchase order</u> have come out with figures which vary from 5 to 15 US$. For <u>inexpensive materials</u>, routines for procurement can be drastically simplified with a comparative reduction in cost.

If the Maintenance Dept. (or storeroom) orders material at a <u>local dealer</u> over the telephone, and gets a monthly invoice on such deliveries, purchasing costs may be reduced to a couple of dollars.

In the following example we will however operate with $7.- as purchasing cost for an order of some size.

<u>Storing cost</u> consists on the average of:

| | | |
|---|---|---|
| Interest | 8% | |
| Storeroom, supplies, etc. | 3% | |
| Personnel | 3% | |
| Shrinking, etc. | 3% | |
| Insurance | 1% | |
| Total | 18% | of cost of material in stores |

which we will use in the example. In industry, storing costs vary from 15 to 30%, depending upon many factors.

<u>Mathematical equation for economic lot size in purchasing.</u>

The minimum stock size is considered as a fixed overhead, permanently existing in stores, and thus does not affect the calculation of economic lot size. Minimum stock is not included in the calculation of total storing cost.

The material passing through the stores will be in our case, equal to total purchase per year.

- e = cost price per unit
- o = purchasing cost ($7) per order
- l = storing cost per year per $ in store (18% or 0,18)
- N = annual consumption in units
- x = economic lot size in purchasing

Total purchasing cost per year:

$$P = e.N + \frac{N}{X}$$

Total storing cost per year:

$$L = (e + \frac{o}{x}) . \frac{x}{2} . l$$

The minimum reserve stock is considered to be zero, as it will have no influence on the economic lot size.

Average number of units in store will thus be: $\frac{x}{2}$

The <u>total annual cost</u> will be:

$$K = I + L$$

$$K = e . N + o . \frac{N}{x} + (e + \frac{o}{x}) \frac{x}{2} l$$

Derivation of this question on x gives:

$$K' = + o . \frac{N}{x^2} + \frac{1}{2} e . l$$

With minimum K' = o and we get

$$0 = + o . \frac{N}{x^2} + \frac{1}{2} e . 1$$

$$x = \sqrt{\frac{2 . o . N}{e . 1}}$$

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Graphicly this is shown in Fig. 9.

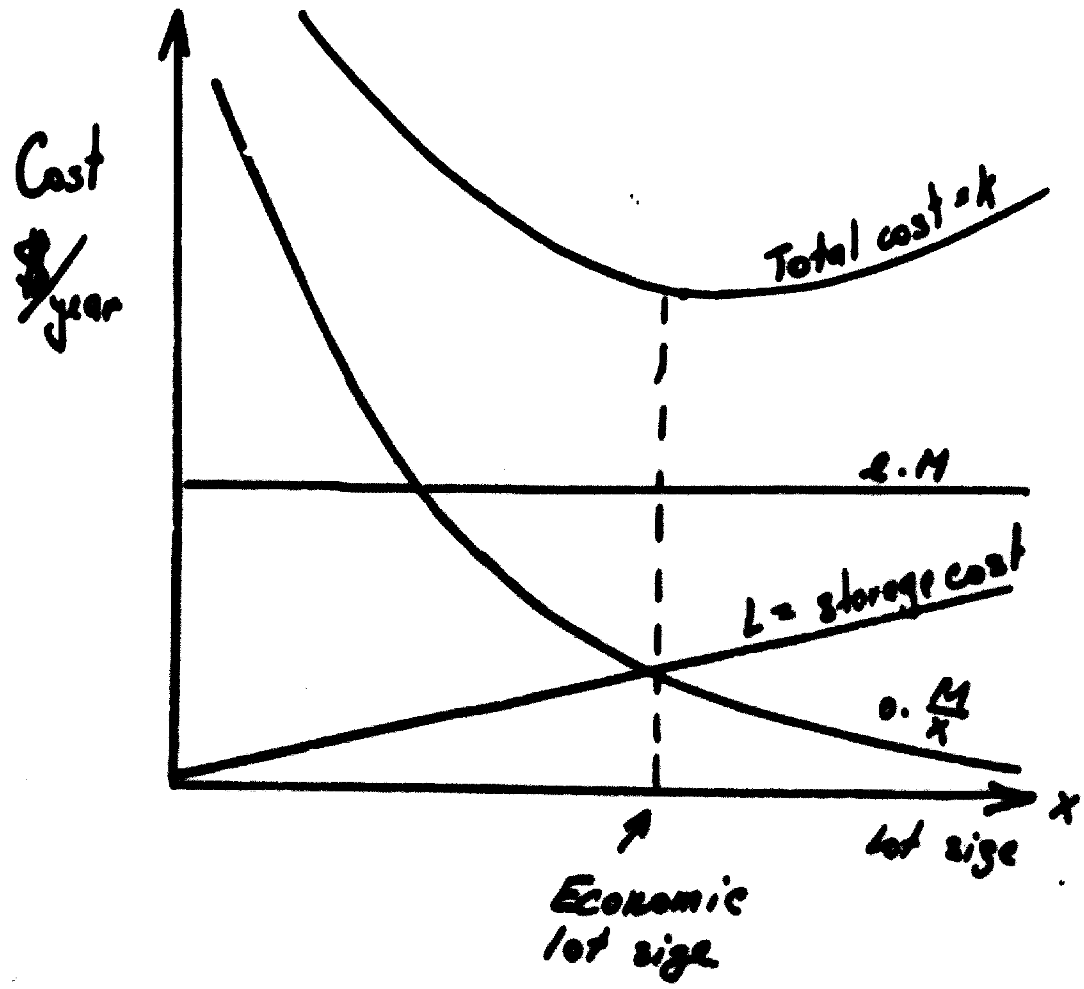


Fig. 9

**Example:**

| | | | | |
|---|---|---|---|---|
| c | = | cost per unit | = | $10 |
| o | = | purchasing cost | = | $ 7 |
| l | = | storing cost = 18% | = | 0,18 |
| M | = | annium consumption | = | 300 units |

Economic lot size:

$$x = \sqrt{\frac{2 \cdot o \cdot N}{e \cdot 1}} = \sqrt{\frac{2 \cdot 7 \cdot 300}{10 \cdot 0{,}18}}$$

$$x = 49 \approx 50$$

This means <u>it is most economical</u> to order 50 units every 2nd month.

The <u>curve for total cost</u> will in practice be <u>very flat near the minimum point.</u>

Furthermore we must realise that a number of factors considered in the formular do not happen 100% ( for instance that consumption is constant).

It is therefore more realistic to talk about an <u>economic area</u> than an economic lot size, as indicated in Fig. 10

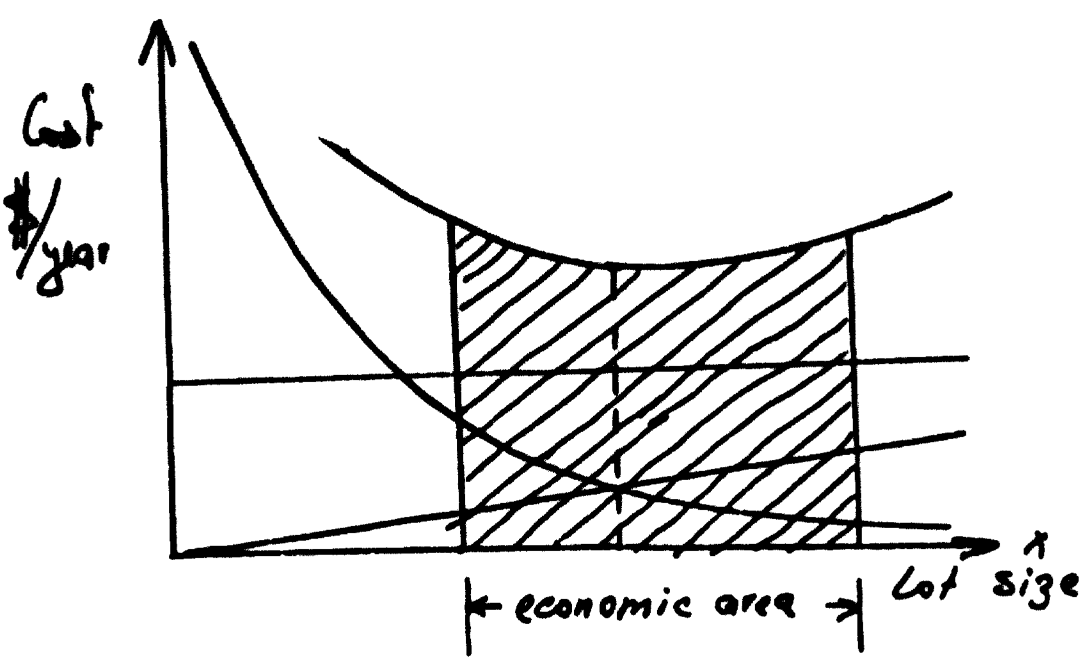


Fig. 10

In practice it is in most cases possible to operate with such big tolerances as

<u>+ 50% and + 100% of economic lot size.</u>

Purchasing lot size <u>outside</u> these borders should be avoided.

In our example it means that we should <u>not have</u> a lot size less than 25 or more than 100 units.

<u>Use of economic lot size in purchasing.</u>

It is only practical to use this formular for:

Group of High Value materials or spare parts (see page 12)

<u>Group a and c:</u> Regular consumed materials and spare parts (see page 1)

Based on the most common distribution of materials and spare parts between the different groups this means that

<u>less than 10%</u>

of the articles on stock can be calculated this way.

In total they do however represent

<u>between 50 and 60%</u>

of the <u>value</u> of the stored material and spare parts.

## E. STOCK SIZE DEPENDING UPON THE NUMBER OF PLACES THE ITEM IS USED IN THE MANUFACTURING PLANT.

If one component is used only in one place in the factory, we are faced with this problem: Shall we have one spare part on stock, or shall we not carry it at all?

If this unit is critical for production quantities, we will have to bear the cost to have a spare on stock. This is based on the cost of production downtime in the case of a sudden breakdown or failure.

If the same unit is used on 5, 10 or 20 different places, we will in case of category D, irregularly consumed spare parts, of maintenance materials, still have the same problem, which is:

One piece on stock or none at all.

The cost of having a stock will however per installed unit be considerably less. In the case of only one installed unit we will have:

$$\text{Annual cost:} \quad L = \frac{(e + o)\,l}{2}$$

If the same unit is used on N different places, we will have:

$$\text{Annual cost:} \quad \frac{L}{N} = \frac{(e + o)\,l}{2N}$$

where:

- e = cost price of unit
- o = purchasing cost
- l = storing cost (in % of e)
- N = number of places the part is used

In case of category C of maintenance materials - regular consumed spare parts, it might be economically adviseable to have more than one unit on stock if the part is used a number of places in the factory. (Fig. 11)

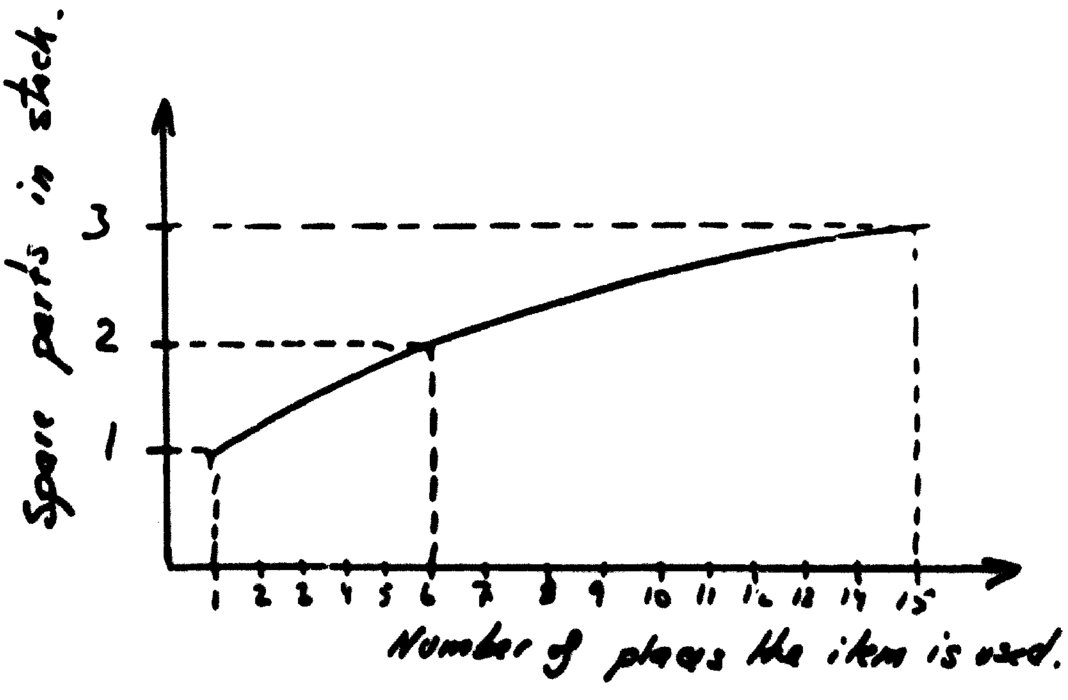


Fig. 11

In the example in Fig. 11 is indicated 2 units on stock when the part is used in 6 different places, and 3 parts when used on 15 places.

These figures will, however vary depending upon:

- -frequency of consumption
- -delivery time of new parts
- -number of critical places where the part is used
- -downtime cost.

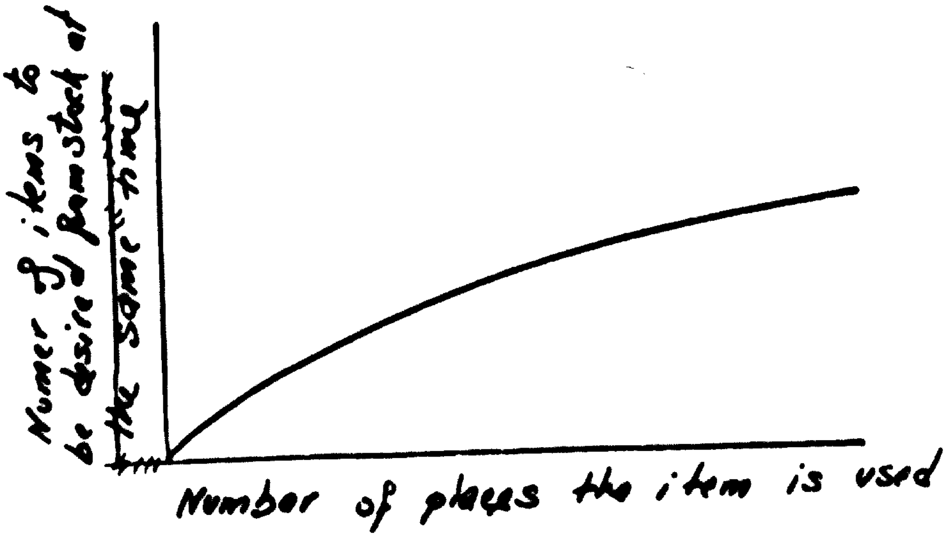


Fig. 12

In any case the curve will have a falling tendency. The mathematical possibility for the part being desired at the same time on different places will relatively go down as the number of places increases (Fig. 12).

If we for instance have one part installed in 30 different places, the possibility for a sudden breakdown on 10 of these units at the same time is far less than a sudden breakdown on one unit which is installed in 3 different places.

It must be realised that standardisation of units used in production equipment gives quite enormous possibilities for:

1. Reduction of spare parts in stock
2. Increase in stock service (availability of spare parts)

In one chemical factory it was found 125 different units (manufacture and size) of one type of valve.

The standardisation program brought this number down to 12. It was at the same time made clear that if standardisation had been done before the plant was designed, 8 different units would have been sufficient.

It is quite obvious which reductions in spare parts stock and increase in the availability of parts, this made possible.

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# I. INTRODUCTION

## A. DEFINITION OF SPARE PARTS AND MAINTENANCE MATERIALS IN THE BROADEST SENSE, THE MAIN GROUPS OF THESE ITEMS, THE POSSIBILITIES FOR CONTROL AND A SUMMARY OF THE FACTORS DETERMINING THE DECISION.

Maintenance materials and spare parts is a common term which covers all kinds of supplies necessary to keep production equipment operating satisfactorily, and turn out production to the desired quantity and quality at the desired time.

Main groups of maintenance materials and spare parts.

a. Regularly used materials:
For instance oil, grease, lamps, fuses, washers, overcoats, shoes, bolts, nuts, etc. - under special corrative atmosphere, also steel and metal plates, bars, pipes, fittings, etc.

For practical purpose this consumption can be considered as regular.

b. Irregularly used materials:
For instance steel plates and bars, metal, etc. which we suddenly need because something unforeseen happens. It might be fault in the original material, accidents, etc.

The consumption is impossible to forecast and is highly irregular.

c. Regularly used spare parts:
These are parts manufactured to be identical to certain parts in a machine, but all have a life time which is less than the machine as a whole, and they will be replaced at least once, perhaps several times during the period the machine is in operation. Examples of these are: ball bearings, gears, electric motors, electric controls, V-belts, filters, etc.

d. Irregularly used spare parts:

These are also parts manufactured to be identical to one or more parts in the machine, but they are supposed to have a lifetime which in most cases is the same, or longer, than the lifetime of the machine. When the machine is scraped, the parts in the machine may be still in a satisfactory condition.

Examples are a propeller in a ship, an axel in a machine, a casting, etc.

These parts might be used during the lifetime of the machine, but usually when we finally scrap the machine we will have a considerable amount of such parts in our storeroom.

POSSIBILITIES FOR CONTROL:

When a control system is established for maintenance materials and spare parts, it is very important to distinguish between the above mentioned four groups.

In catagories a and c the advantage is that the material or spare parts included will almost entirely be used sooner or later. They certainly represent a company investment and cost, but with careful evaluation and experience it is possible to control these two groups in a way which will satisfy both production, maintenance and economical points of view.

The categories b and d are in a less favourable position. To have parts from group d in stock can best be compared with having fire insurance on a house. If the house burns down, it is very convenient to have insurance. If we had a crystal ball which could tell us that we will not have a fire in the house, we could have saved the insurance cost.

Unfortunately, we do not have any crystal ball to tell us which special components of which machines are going to have a breakdown, and when that will happen.

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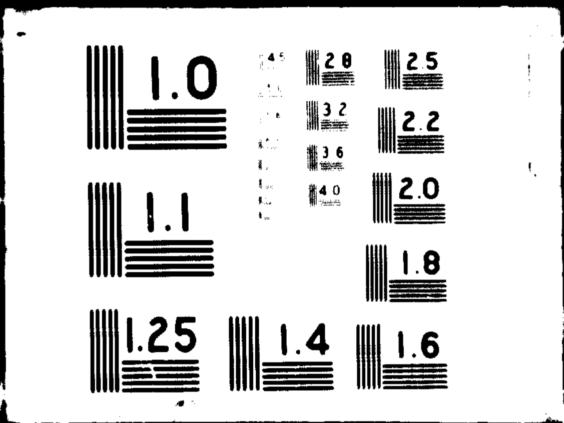

## F. THE IMPACT OF BRANCH OF INDUSTRY, TYPE OF MACHINERY AND DEGREE OF AUTOMATION.

### Branch of Industry.

The determination of the size and composition of spare parts stock must primarily be affected by the special circumstances for each individual company.

The general recommendations which can be made for each branch of industry is thus rather limited.

However enterprises could be divided into:

a) 1 shift operation
b) 2 shift operation
c) 3 shift operation
d) continuous production during the week
e) continuous operation

The machinery availability for maintenance work in general, is reduced as we go from a to c.

Furthermore the possibility to recapture lost production due to lack of spare parts or materials decreases in the same order.

Process industries, like oil refineries, iron and steel mills, paper mills, chemical factories, sugar mills, cement works, etc., are most dependent upon a comparatively large stock of spare parts, both in composition and size.

The cost of production downtime adds up around the clock and will rapidly reach very high figures. The possibility to recapture lost production is none or extremely limited.

c. Is there a clear and precise top management instruotion for the use of standards or norm blades?

d. Does the maintenance department check that the norms are used in practice?

3. Internal maintenance workshop.

a. Which tool machinery, etc. are available in the workshop?

b. What kind of work can they do?

c. To which tolerances can they work?

d. Has the workshop enough qualified craftsmen?

e. Which average workload has the workshop? Is it overloaded or has it idle capacity?

f. Will it be desirable to supply the workshop with more machines?

4. External maintenance workshops.

a. Which workshops are in the same area?

b. What kind of work can they do?

c. What are their delivery time and price?

d. Are there workshops available in other manufacturing plants?

e. Are there other workshops in the country?

f. What is the situation with type of work, deliverytime and price?

5. Technical drawings.

a. Have we been able to get drawings together with the delivery of the machine or plant?

b. If not, have we tried to get such drawings?

c. Can we make a satisfactory drawing ourself, in case of emergency?

d. Are drawings filed in a way which makes it easy to find them in a hurry?

e. Are copies of drawings controlled so that we can be sure of not loosing an important drawing?

6. Types and value of spare parts and materials.

a. Have we divided all units in:

- Regular consumed materials?
- Irregular consumed materials?
- Regular consumed spare parts?
- Irregular consumed spare parts?

and in:

- low value items?
- high value items?

b. Have we established different stock policy for these different groups?

7. <u>Statistical figures.</u>

a. Which figures from production and maintenance are recorded?

b. Are they satisfactory for an economic calculation of spare parts stock?

c. Are production downtime or lost added value due to lack of spare parts recorded?

d. Are statistical figures easily available, for instance through electronic data processing?

8. <u>Preventive and protective maintenance.</u>

a. Is the present preventive maintenance programme good enough to have realistic influence on size and composition of spare parts stock?

b. If not, what can be done to improve conditions?

c. To which extent can a more advanced control be applied?

d. Is enough training done to secure a reasonably correct handling of the equipment?

e. Is production equipment where necessary redesigned reinforced to prevent or reduce future maintenance?

9. <u>Size of stock.</u>

a. Is a realistic minimum stock size decided upon?

b. Is purchasing order size calculated for items where it is possible?

c. Is there a system for re-evaluating of minimum stock size and purchasing order size?

10. <u>Storeroom routines.</u>

a. Does the storeroom file of spare parts and materials give the up-to-date figures of available units?

b. Is ordering stock size calculated, based on consumption and delivery time?

c. Does the routine for ordering of new parts function properly?

d. Does somebody check changes in delivery time?

e. Are stock figures changed correspondingly?

f. Is the storeroom well layed out, so the parts can be easily found and identified?

g. Does the storeroom protect sufficiently spare parts and materials in stock against dust, heat humidity, etc.?

h. Is everything done to cut out "red tape" in the procurement procedure?

i. Is stock size checked and compared with file figures?

11. Organization.

a. How is the spare parts and materials supply system organized?

b. How is authority and responsibility delegated?

c. Has one man (or a group of people) spare parts and materials as his special area of work and responsibility?

d. Can organization be improved, and thereby improve the entire service of spare parts and maintenance materials?

## IV. SPARE PARTS PROBLEMS IN DEVELOPING COUNTRIES.

### Developing countries compared to industrially developed countries.

The author of this paper has had the opportunity to see and discourse the spare part problem in different parts of the world with different degrees of industrial development.

The situation concerning:

- -Spare parts on stock
- -Possibility to get fast delivery
- -Possibility to make spare parts

is indicated in Fig. 13 below

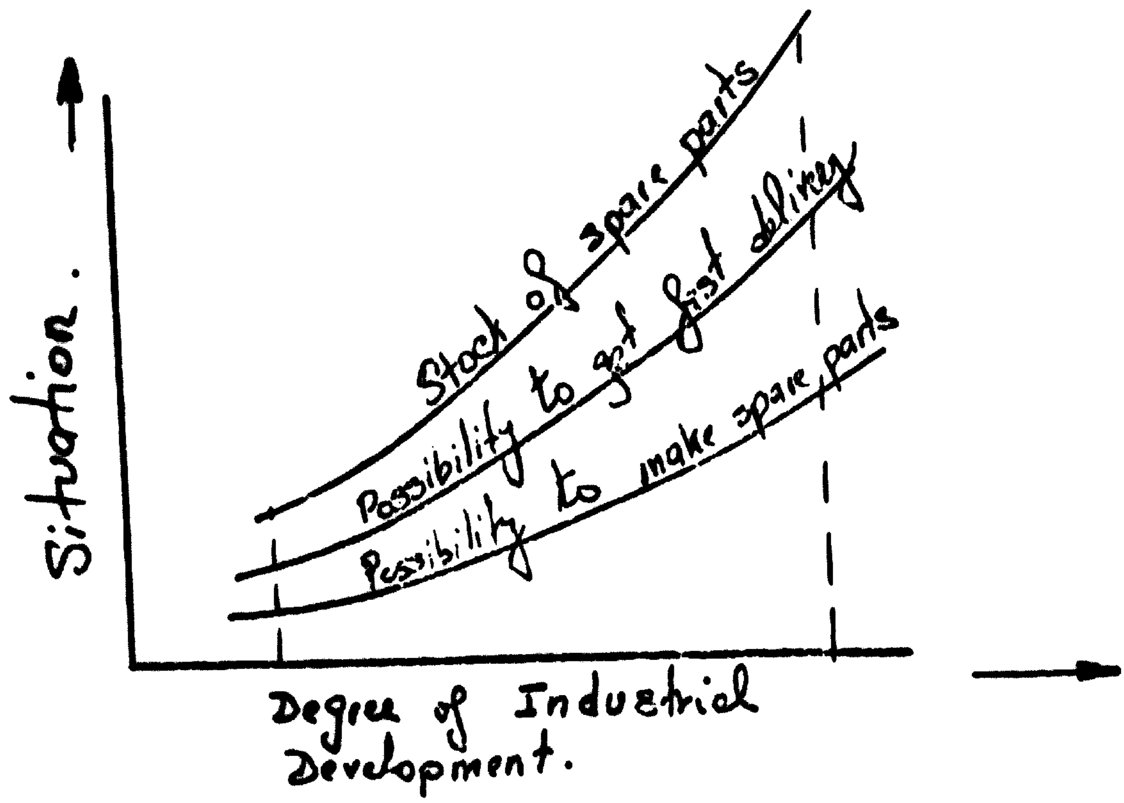


Fig. 13

In a developing country where it takes a long time to get a new supply of spare parts, where the possibilities for making parts inside the company or country are very limited, we will in general also find the smallest stock of spare parts, both in size and composition.

Enterprises in industrially developed countries not only have the advantage of getting fast supply, or getting a needed part made in their own or nearby workshop, they also have a very well-equipped stock of spare parts, especially in composition.

It is more logical to have the opposite situation, with a well-equipped stock of spare parts when the possibility of getting parts made or supplied in a hurry are rather limited.

What is wrong with the organisation of spare part service in developing countries?

To the best knowledge of the author, there is no special paper on spare parts in developing countries. In a number of maintenance surveys, however, spare parts are mentioned as one of several important factors.

Even if it is possible in any country to find individual companies where the situation is different and often quite satisfactory, the general conditions are as follows:

1. Board of directors and top management in industrial corporations do not seem to have the right understanding for a reasonable stock of spare parts and maintenance materials.

2. Government bodies, like Ministry of Industry or Industrial Development Boards seem to be still further away from practical reality in the question of necessity of a diversified spare part stock.

3. Maintenance managers and very often plant managers have on the other hand a very clear opinion that production plans cannot be carried through without spare parts, but have in practice, unfortunately, been able to do comparatively little about it

4. Factories which belong to international concerns have in general a much better stock of spare parts both in composition and size than the government-owned plant in the same country.

   This can only be explained as a result of top management attitude, as there is no difference in opinion at the maintenance management level.

5. Financing of future spare parts is not done together with the financing of the plant.

   This is true especially in countries who lack the necessary foreign currency, but frequently it also is the case in corporations which lack the available capital.

6. Supply routines create a longer total delivery time. Authorization to bypass through a number of different people, time spent getting a currency license and customs procedures delay the delivery of important parts.

7. The plants workshops are in general too poorly equipped. the difficult supply situation taken into consideration.

8. The country in total is lacking facilities for making spare parts inside the country. Special gear-cutting machinery, steel foundry, etc. are major examples.

9. The utilization of available machinery and capacity inside the country could be better.
   If a maintenance workshop in one factory has specialized tool machinery, it will in most cases have an ideal capacity for making parts for other manufacturers. This is a matter of coordination, of knowledge and of company policy.

10. Very few manufacturers of production equipment have built up a satisfactory spare parts service in countries where machines have been delivered.

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Mechanical industries, and shoe, textile, clothing, woodworking industries have normally 1 or 2 shift operations, and only partly 3 shifts. The consequences of lack of a spare part is far less, and it is natural to apply a different policy in determining the composition and size of spare parts stock.

Figures available can also confirm that branches of industry to a very great extent have influence on the spare parts stock.

The technical magazine "Factory Management and Maintenance" (Mc Graw-Hill, New York) has made some studies of total maintenance costs compared with annual sales and total investment in some one hundred American enterprises of all branches.

Maintenance cost is normally 8 - 10% in typical process industries, and 1 - 3% in the other category.

The survey does not separate cost of spare parts and cost of labour and maintenance management. If we anticipate that the spare parts cost to some extent is proportional to the total maintenance cost, we can from this survey get a rough picture of the situation in different branches of industry.

Type of machinery.

Factors of importance are:

1. The machinery needs for spare parts and its ability to take overload and rough treatment.
2. The possibility of fast supply of spare parts, from a dealers stock in the same country, or from the manufacturer.

3. The cost of spare parts. Some manufacturers seem to have the policy to sell the machine itself at a low price and charge very high prices for spare parts.
4. Technical drawings, with correct dimensions and tolerances.

If these factors are favourable it will have an extensive impact on the spare parts stock. For a machine which does not need many spare parts, where any spare part can be delivered from the stock of a local dealer at reasonable cost, we can safely reduce our own stock to a minimum, and only to parts which have regular consumption.

If a machine, on the other hand, is produced on the other side of the globe, and there is no local dealer with spare parts in stock, we have to order parts from the manufacturer. If we will also be unable to obtain technical drawings, our own stock must both in composition and size be quite different.

The four factors mentioned vary considerably from one manufacturer to the other, and are in general of a greater influence on spare parts stock than type of machinery.

Before a machine is bought it is of great importance to investigate and evaluate its need for spare parts, from where spare parts can be delivered, at what price and if specific drawings can be obtained.

Degree of Automation.

Typical for automation is that a large number of machines are built together in a huge production unit.

A failure of one component in a machine might stop the entire production, with enormous cost of production downtime.

Even with a reliability of each unit of 99,9%, we can easily ocme out with a total reliability for the automatic plant of 50 - 80%.

A high degree of automation requires a very good and fast maintenance service in general, -included an extensive stock of spare parts, both in composition and sise.

G. THE SUPPLY SYSTEM FOR SPARE PARTS, SPEED OF DELIVERY, RISKS, QUALITY AND ALTERNATIVE TRANSPORT COSTS.

Spare parts supply system.

From the users point of view it is obvious that the manufacturer of machines and production equipment must be responsible for building up a satisfactory supply system for spare parts.

Such a system includes:

1. Exact identification of any part. Each part must have an identification number, which is clear and precise and will distinguish it from other parts.

2. Assembly drawings of the machine with all the different components marked with its spare part number.

3. Spare parts production and stock policy. How many years after sales of the machine will the manufacturer guarantee supply of parts? Which parts does this policy include?

4. Location and size of spare parts stock. Where will stock be kept? -At the manufacturer only? -at dealers in different parts of the world? -in different countries or in different industrial areas?

   Which parts are kept in each of these stocks?

5. A spare parts price list. Economic calculations can only be done if we know the price of spare parts, for instance in connection with evaluation of repair or renewal.

A relatively small manufacturer with a wide-spread distribution naturally will not have the possibility to build up a spare parts service which will satisfy users.

The large enterprises usually have a better background for service. This is generally true in practice. In one developing country one foreign manufacturer of tractors had 80% of the market. Its maintenance service also proved to be completely superior to the others, with a main stock in the capital city and a number of local stocks in the different agricultural areas.

In many cases the manufacturers are unable to cope with spare parts service to the extent the users want. This requires capital investment and lots of work. Even if the prices seem high from the users point of view, it is not at all an attractive business for the manufacturer.

It is however fully realised that a good spare parts service has an extensive sales promotion effect.

From a spare parts point of view it is generally recommendable to use domestic manufacturers, or the large manufacturers which have a major portion of the domestic market.

The question of spare parts supply system includes also the routines for ordering new parts at the users plant.

It is important that this routine be flexible enough to meet critical situations.

The maintenance department must in such a case have the authority to take direct contact with the dealer through telephone or cable, -and afterwards inform the purchasing department that the order has been made.

Speed of delivery.

1. Time to get the order approved
2. Mailing time for the order.

3. Possible delivery time at the vendor.
4. Time for the vendor to receive and ship the order.
5. Transportation of shipment.
6. Delay in harbor, airport and customs.
7. Time for local transportation and information to the maintenance department.

Of these factors Nos. 3 and 4 which are mainly out of control from the customers point of view. To some extent they can however be influenced to our favour, if we have been able to establish good personal relations and contact with the vendor.

All the other factors are more or less under control for the buyer, to some extent even a fast service from customs.

Air freight is more and more used for transportation of urgently desired spare parts, and an economic evaluation of freight cost compared to cost of production downtime will in most cases justify the high transportation cost.

The maintenance manager of a Scandinavian paper mill took once a morning plane to a manufacturer in Germany, and in the evening he went back with the part he needed so desperately. Even if this case is very unusual, it is a good example of increasing speed of delivery with all possible means.

Risks.

To be without a spare part always involves a risk, and it is up to the enterprise to decide at which risk limit he will operate.

Figures on reliability, lifetime, etc. for all different components are, however, only available to a very limited extent. It is fair to say that risk primarily must be based on experience, technical know-how and common sense, and that more sophisticated methods can only be used for a small group of items.

Risks are in general reduced by concentrating on a wide composition of spare parts, and have a smaller stock size of each unit.

Quality.

It is a fair and necessary requirement that a part made in the maintenance workshop, or ordered to be made in an outside shop should have the same quality standard as the original piece.

In emergency situations we can however in many cases be able to keep production going for some time with a part of poorer quality.

It has been, and still is, a tendency to practice the philosophy that a machine which no longer can be used in production can be transfered to the maintenance workshop. If this redundancy is due to production over-capacity, then it is o.k., but more frequently a machine is handed over to maintenance because of wear and reduced ability to produce at high tolerances.

Transportation cost.

In principle the user is interested in the lowest possible transportation cost of spare parts and maintenance materials, either by boat, train or truck. A good planned and well organised supply system will also be able to get close to 100% of the materials reduced. In emergency situations, a comparison should be made between cost of air freight and cost of downtime.

## III. METHODS AND CRITERIA TO BE USED FOR DETERMINING THE SIZE AND COMPOSITION OF SPARE PARTS INVENTORIES.

In the first two chapters of this paper is discussed the different types of spare parts and maintenance materials, the "total cost concept" of procurement and maintenance were discussed and also the different factors influencing the issue.

This chapter is given as a guideline, check list or manual for the people at manufacturing plant who are responsible for building up a stock of spare parts and materials which should be the optimum for the total economy of the company.

The stock must be decided individually for each different factory. If, however, all factors in this "check list" are evaluated, and all questions answered, it could be reasonably well guaranteed that all efforts for getting a "correct spare parts stock" are done.

1. Spare parts and procurement of a piece of production equipment.
   a. Is the need for spare parts evaluated?
   b. Is the need for spare parts surveyed through contact with other factories which have the machine in question.
   c. What does the manufacturer recommend?
   d. Does the vendor keep a stock of spare parts?
   e. Which parts does he keep in stock?
   f. What is his price?
   g. How fast can the vendor get new supplies from the manufacturer?
   h. Can we get technical drawings of critical parts delivered together with the machine?
   i. For how many years does the manufacturer/vendor guarantee spare parts stock?

2. Internal standardization programme.
   a. Has the enterprise developed internal standards or is it decided to do so?
   b. Is this programme being used, or is it more a "programme on paper" than a reality?