OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

D01152

Distr.
LIMITED

ID/WG.62/6
25 May 1970

ORIGINAL: ENGLISH

United Nations Industrial Development Organization

Symposium on Maintenance and Repair in Developing Countries

Duisburg, Federal Republic of Germany, 10-17 November 1970

MAINTENANCE GUIDELINES AT A TENDERING STAGE

by

K. Swärd
Konsultbyran IKO AB
Tumba, Sweden

Organized in co-operation with the German Foundation for Developing Countries and the Association of German Machinery Manufacturers (VDMA).

---

id.70-1939

MAINTENANCE GUIDELINES AT A TENDERING STAGE.

Tabel of content:

MAINTENANCE GUIDELINES AT A TENDERING STAGE.

The purpose of this booklet is to give some informations about the importance of maintenance considerations at the tendering stage, as well as some practical wiewpoints, based on practical experience from more than 30 years of maintenance engineering work.

It is practically speaking impossible to find any plant or machine that does not need maintenance. Yet, according to the authors experience, too many people design, manufacture, sell, buy and use machines and plants without considering maintenance as its importance justifies. This fact might depend on inferior knowledge about the nature of maintenance, but surely also in many cases a conscious suppression of inconvenient informations.

The lack of knowledge about the influence of maintenance on the total cost for production is to some degree understandable, because in most cases the maintenance situation is not clearly documentated in the records of an enterprise. To most accountants the maintenance cost is an unknown mixture of labour cost, spare part cost and overhead. The indirect costs are unknown as well. For decades the accountants were allowed to make their cost records for accounting purposes only. First when modern management control systems were introduced the maintenance and production managers were given a suitable tool to reveal and control the direct and indirect costs of maintaining the equipment.

Many plants and machines have been decided on without the full and complete knowledge of the future maintenance costs. Complete factories have been delivered from industrialised countries without spare parts and necessary information about the absolute minimum of maintenance activities to keep the factory running at the desired capacity and quality level. It may not be possible to prove, but surely some investments have been made, that would have been turned down, if the full cost situation had been reveald at the tendering stage.

It may sound as if the author looked upon maintenance as the one and only technique to be considered at the tendering stage. The true fact is, that it is impossible to have any kind of industrial production without maintenance, but the only justification for maintenance is ----production.

A consequence of this fact is, that both the production function and the maintenance function should be involved in all activi- ties concerning a machine or plant, from the first discussions about possible production process and possible machine or plant alternatives. If the choosen plant or machine has such qualities, that much maintenance is required to keep it running at the de- sired capacity and quality level, the production function undoubt- ly will encounter difficulties.

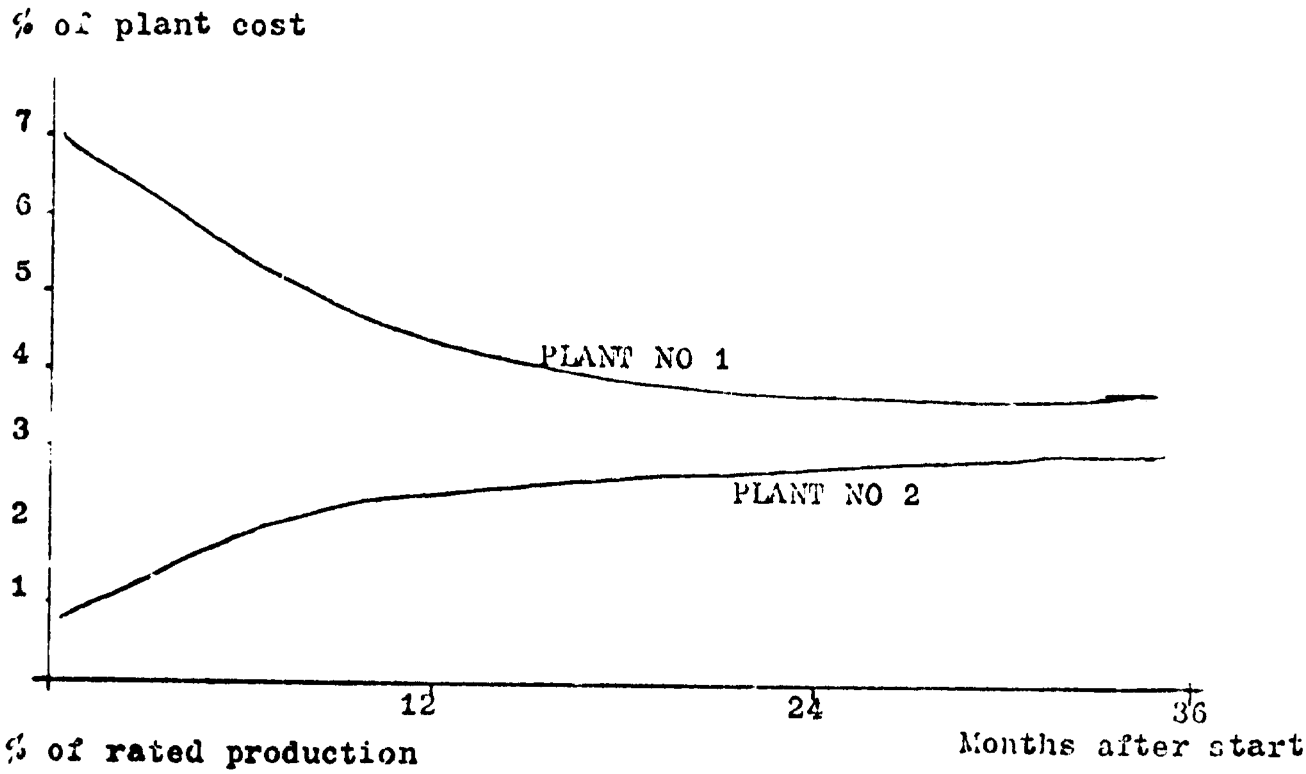
It is to some extent difficult to find evidence from the practi- cal life, but a swedish industry can provide one. It is a chemi- cal factory and the example involves two identical plants, bought 1954 and 1959.

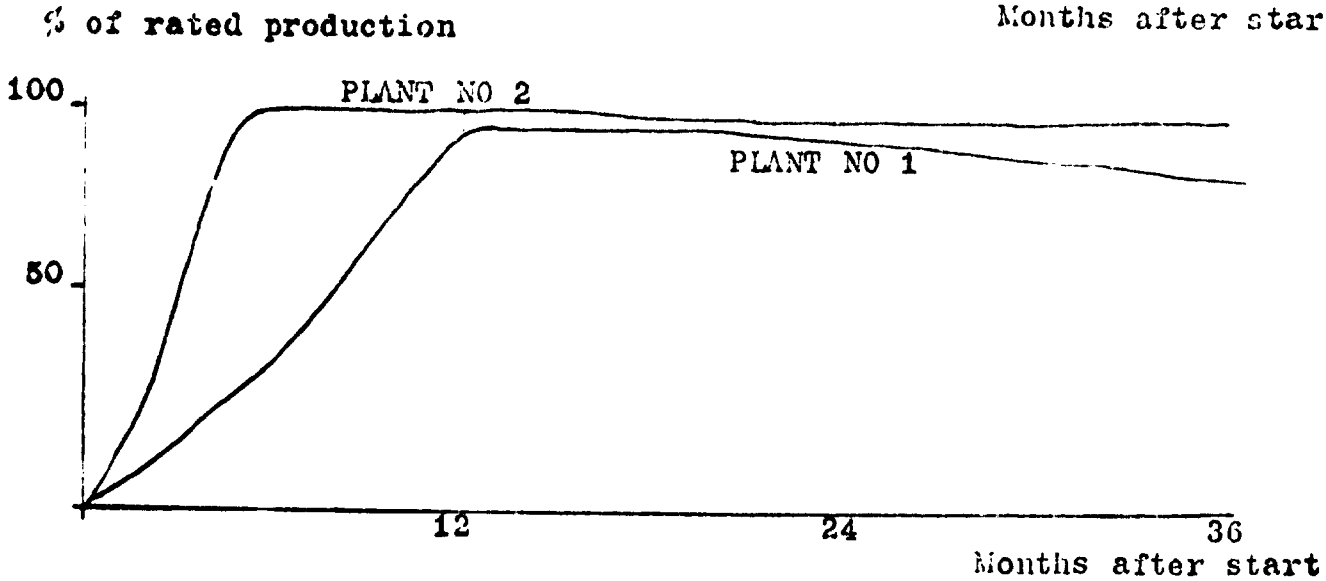
First plant. Chief of project: Manager of the purchase department.
The design of the plant was worked out by the manufacturer.
The chief of project exerted a heavy pressure on the price of the plant, but no attention was paid to the maintenance problems.
The plant was installed and started. The maintenance depart- ment had to take care of a whole lot of problems. Many mo- difications were required, and as the plant met all speci- fications when delivered, the costs were recorded as main- tenance cost.
It took more than 12 months to get the plant up to full capacity.

Second plant. Chief of project: Maintenance manager.
This plant was designed by the plant engineering depart- ment, in this plant the maintenance manager also was chief of the plant engineering department. To quote the maintenance manager:"The design and manufacturing was made with 'love and care' and the reliability of the plant components was considered more important than the price."
The same manufacturer was appointed.
The plant was installed and started, and after only 4 months full production was reached.

Both these plants were run for several years, side by side. The records showed, that the first plant always had difficulties, in spite of all modifications done to it. The second plant showed lower maintenance cost and lower shut-down time.

Shown below are two diagrams, showing the maintenance costs and the production level.





The initial cost for plant no 2 was 10 % higher than for plant no 1. However, the difference in initial cost was eliminated after the first production year by lower maintenance cost only. Besides, the production value during the first year was for the second plant about the double amount, compared to plant no 1.

Some people consider a low initial investment more important than future low costs, thereby pushing the future problems and difficulties to get a good economy over to other people. This must be avoided, because it might mean ruin to an otherwise profitable idea or hampering a really needed development.

PRODUCTION AND MAINTENANCE.

Provided there are no limits in supply of raw material, power, workers and other similar factors, the total annual output from a machine will be determined by

- the rated capacity of the machine at a certain level of production quality and
- the available number of production hours per annum.

The rated capacity of the machine is mainly determined by its size, the process involved, power, construction material. The quality level of product is determined by the accuracy of the machine and stability or ability to retain the necessary accuracy at the existing work load. These are all physical qualities, which to a large extent are possible to establish at the design and at the manufacturing stage.

The available number of production hours per annum are of course related to hours, during which the machine is in such condition, that production at the rated capacity and desired product quality level is possible.

Practically all machines are subject to wear and corrosion. If the wear and corrosion are not compensated by maintenance activities, the rated capacity as well as the machine's ability to retain the desired level of product quality will be gradually reduced. Sooner or later the lower limit will be reached and the machine has to be stopped, or the production economy will become too low and not acceptable.

Maintenance means that both time and cost have to be spent. If the number of hours for maintenance increases too much it will reduce the number of hours for production.

All these factors, rated capacity, possible level of product quality, available production hours, are combined into one expression,

Operation Availability.

Utilization of the Operation Availability is the responsibility of the Production Management, and to keep a predetermined level of Operation Availability is the responsibility of the Mainte-
Management.

OPERATION AVAILABILITY.

The operation availability is determined by three factors

- the Reliability of machine or plant
- the Maintainability
- the Supply Effectiveness of Maintenance resources.

The first of these, Reliability, is determined by the physical qualities of the machine or plant, the design, choice of material in different parts, machining accuracy, the rated load and the safety factors, the realiability and life time of components, and also by the number of components connected to each other in circuits.

The second of these, Maintainability, is depending on the accesability for maintenance activities and operations, facilities for fault localisation and identification, and facilities for continous follow-up of the service performance of the equipment.

The third, Supply Effectiveness of Maintenance Resources, is depending on the number of skilled people in the Maintenance department, their efficiency, if proper and effective tools are available or not, if spare parts and necessary material is available when needed, supply of machine instructions, maintenance plans, the maintenance work shops and their equipment, planning and scheduling routines, supervision, engineering services and service from manufacturers and contractors.

A high Operation Availability may also be described in terms of cost. In a popular way

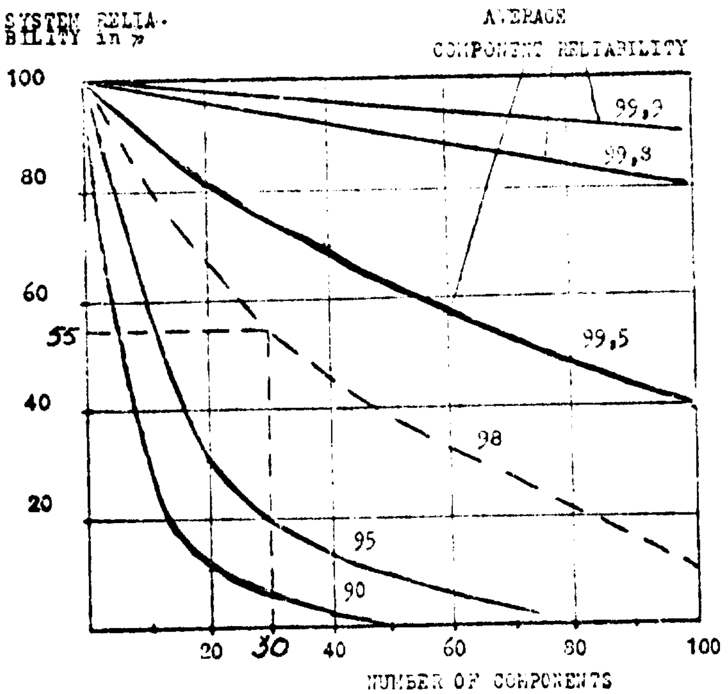
- Reliability is the cost for a high initial quality of the equipment with low requirements of maintenance
- Maintainability is the cost for reducing the time for maintenance operations when needed
- Supply Effectiveness of Maintenance Resources is the cost for meeting the required quantity of maintenance operations when needed.

RELIABILITY.

Reliability is usually an expression for the physical quality of a component, but it may also be used as a term, describing the safety of operation of a component under predetermined operating conditions. Usually the probability of safe and correct function is used as a measurement for Reliability.

A component with a reliability of 99,9 % is likely to give one unsafe or incorrect functioning, meaning failure, in 1.000 operations, but it does not mean it fails after 1.000 operations.

It is not so important to know the reliability of a component, operating single. Usually modern industrial components have a rather high reliability. But when several components are connected into circuits the reliability of the circuit itself becomes important. The reason is, that the total reliability is a function of the number of components and the reliability of each one of the components in the circuit. The diagram below shows that clearly.



The dotted line indicates, that a circuit, consisting of 30 components, each with an average reliability of 98 %, is likely to have a total reliability of only 55 %, which is far from acceptable in most industrial applications.

Most of the manufacturers of electronic components, electric components, pneumatic and hydraulic components used in industries know very well the reliability of their products. In many cases these components are made under an official specification and the qualities of the component stated. The official specifications are often based on extensive tests and scientific research work for military and government research establishments. Their application to components for industrial applications have during the last decade meant very much to the understanding of the maintenance problems in industry and transportation industries.

A high reliability means high quality but also high cost. In practice the choice of the component is a compromise between the initial cost of the component, the cost of a failure, the repair cost, the availability of maintenance resources and the cost of lost production during repair. The higher the total cost of a failure, the better justification for a reliable but high-priced component.

It is, however, sometimes possible to use components with a lower reliability, provided actions are taken in advance to reduce the losses by shortening the repair time, for instance quick switch-over devices to a spare component.

The cost factors are possible to calculate by operation analyses methods, but this is very seldom done in civil industrial applications. During the coming period the O A methods are likely to become more used than before, especially for larger plants and bigger machines, such as power plants, oil refineries and other plants of similar size, working more or less continously. The experiences collected from OA applications on military weapon systems, space rocket programmes and nuclear reactors will undoubtly be brought out for industrial applications.

Even if the reliability is not specified according to an official specification for each component the total realiability of the machine or plant should be discussed and, if possible, estimated.

The total reliability of a machine changes with age. During the first period after a new machine or plant has been started some failures, usually described as "children deseases", are likely to come. This fact is one of the reasons for a guarantee period, during which period the manufacturer will replace failing components free of charge.

After this initial period the number of failures is likely to decrease. But after some time certain components are likely to have reached their close of life and will cease to function. As time goes on more and more components will fail and finally the operation availability will become too low.

In many cases the functioning of the components can be tested and their actual reliability established through measuring or testing.

MEAN TIME BETWEEN FAILURES, MTBF.

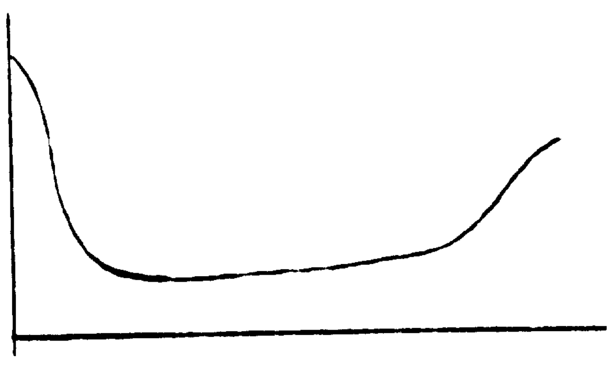
Mean Time Between Failures is an expression for the probability of failures in an operating system. From a practical point of view it is very useful, because it gives a practical value for calculations of maintenance activities over a period of time.

The real value may be determined or estimated as a part of the initial calculation of reliability and presumed operating conditions. This calculation is a part of the Operation Analyses programme usually applied on new machinery.

MTBF depends partly on the reliability of the system and partly on the operating conditions. A machinery, working under heavy load, usually is subject to severe stresses on certain components, which might reduce the reliability of these components because they work near or over their rated load. This means a greater probability for failures, which may be recorded as a shorter MTBF than usually is observed for that kind of machine.

The normal value for MTBF for a certain machine under normal conditions may be calculated by the manufacturer, based on his collected experience from equal or similar machines.

The value of MTBF is not constant during the lifetime of a machine The reliability is not constant, because there are always some components, who will fail during the running-in period. These failures or "children diseases" give of course a lower MTBF in the beginning of the running-in period. When they are overcome the MTBF value increases, until the general wear has reached a certain level. The process is usually described by the "bath-tub curve".



The vertical axis gives the number of failures per time unit, the horizontal axis is the time of operation.

The curve is a wear curve and is used in connection with many problems in maintenance.

For machines working under specified conditions, such as paper mills, computers, chemical process equipment, the normal MTBF can be calculated and the real practical value will not deviate much from the calculated value, provided the established maintenance procedures, such as lubrication, adjustments to compensate for wear, protecting against corrosion and replacement of worn parts, are followed. In these cases a maintenance programme must be followed to the letter.

In practice the MTBF should be recorded and used to control the maintenance programme. Many maintenance operations, such as inspections, lubrication, condition checks, should be performed when needed rather than at established points of time. When a maintenance department controls the MTBF it is possible to time these operations, reducing the amount spent on maintenance without increasing the probabilities for failures. This procedure, however, is rather difficult and can be done without hazards only by very experienced maintenance technicians.

MAINTAINABILITY.

The expression "Maintainability" is used to describe the qualitie of the machine, related to the performing of maintenance activities, such as lubrication, inspection, condition checks, fault-finding and repair. The Maintainability may be measured as the mean time for preventive and corrective maintenance actions. It has a great influence on the Operation Availability and must be analyzed.

One way to analyze Maintainability may be described as follows:

A. Collect drawings, diagrams, instructions, operators instructions, maintenance plans, spare part catalogue, assembly and disassembly instructions and similar information about the proposed machine or plant.

B. Collect information from own sources, equipment records, statements of account, budgets, and also, if possible, from other sources such as other industries, about the same, similar or comparable machines.

C. Use the collected information to
   1. establish necessary preventive actions such as lubrication, inspections, condition checks and tests
   2. estimate possible failures and break-downs and establish necessary operations to correct
   3. estimate necessary operations to replace worn parts
   4. use a dependable time standard to calculate the time needed to perform the operations under C1 - C3 and also calculate the cost for spare parts and material.

   This estimation should cover more than one year, a practical recommendation is to calculate for at least half of the expected life time of the equipment, up to 10 years will give a good picture of the economic situation.

D. Use Work Simplification technique and/or Value Analyses technique to find out, if the proposed machine or plant could be changed or improved to give
   1. less requirements on maintenance operations
   2. less time to perform necessary operations of preventive nature
   3. less time for estimated repairs.

E. When analyzing the maintenance operations do not forget to state the demand on the competence of the maintenance workers, the maintenance workshop, spare part store, special tools and aids, instructions and maintenance plans.

F. Use your findings as a base for your requirements to the manufacturer at the tendering stage. Remember
- need for training courses and training material for both maintenance workers and operators
- need for special tools, instruments and aids,
- need for operators instructions, maintenance plans, disassembly and assembly instructions, drawings, spare parts catalogues
- need for spare parts and material, if possible for the next five years, but distributed over this period.

The figures found under C and D may be used to compare alternatives of design, also to compare plants or machines offered by different manufacturers.

In this connection should be remembered, that a survay was made in Germany about 1960. More than 7.000 machine tools were analyzed and the total maintenance cost during their life time was stated. Only a very few of these machines had a total maintenance cost lower than the initial purchase price of the same machine. This fact is not well known or regarded by purchasers of machines but several manufacturers have made great efforts to improve the design of their products in order to reduce both the need for maintenance activities as well as the necessary time for performing these activities.

The Maintainability, however, is not very well known, especially in development countries, and is seldom given regard in comparision to the economical consequences.

When the Maintainability of a machine or plant is analyzed the following might be used as a guide.

Accessibility for performance of maintenance operations means shorter time and sometimes less effort in the performance of preventive maintenance, lubrication, cleaning, inspection, testing, adjustment, replacement and repair. If some part shall be inspected, checked or repaired it happens far too often, that the designer has placed some other parts in such a way, that they must be removed before the actual part can be reached. The dismounting of these parts may take a considerable time. It might be so, that the parts cou'd have been placed somewhere else or mounted a little otherwise, had only the designer thought about it.

Another annoying design feature is the lack of drilled holes for pushers and threaded holes for mounting pullers for ball bearings, roller bearings, seals, flanges, gears, wheels, covers etc. Once the machineparts are assembled it might sometimes be impossible to remove such parts without much labour, even destruction of parts may be necessary.

Especially in hydraulic systems, but also in pneumatic, electric and electronic systems, connection points for function testing, measuring of pressure, flow, voltage and current are a good help for fault-finding and condition checking. In this connection the marking of components, pipes, tubes, fittings etc and cables, leads, relays etc should be mentioned. These markings should be in accordance with the markings on the circuit diagram, in order to make fault-finding easier and quicker.

Sometimes it is rather difficult even for an experienced maintenance man to find out, how and in which order a machine should be taken apart. The manufacturer can give good aid in providing sketches, drawings or special instructions about disassembly and assembly, showing how and with what means a machine is taken to pieces for repair or replacement of parts.

It is rather difficult to improve the Maintainability of an already finished machine, but if the difficulties are recorded the design may be improved, when a machine is taken apart for general overhaul.

RATED NORMAL LOAD AND LIFETIME OF EQUIPMENT.

When a designer works on his lay-out of a machine he calculates the normal load on parts like bearings, shafts, gears, couplings, motors, stand and carriers. The calculated normal load corresponds usually to the load these parts will have to carry under normal conditions and a safety factor is used to give a certain safety margin for overload.

If the safety margin is too wide the parts will be heavy, strong and expensive, but the reliability and lifetime high. Such a machine will normally not give high maintenance cost, in spite of the more expensive parts, because the lifetime of these parts is longer and replacement has to be made very seldom. But these machines are often expensive to buy.

If the safety margin is too narrow the machine will be light, weak and cheap, but reliability and lifetime low. It will normally work well for a short time, then the necessary maintenance will increase and operation availability will become too low. Such a machine is often cheap to buy, but expensive to run, because the maintenance cost is high and down-time also high, giving too low production per time unit.

The total lifetime of a machine is usually considered when designing it. Heavy machinery, such as mills, big kilns and furnaces, turbines and power generators, boilers, crushers, are given a longer lifetime than lighter machinery, such as machine tools, smaller pumps and blowers.

The physical lifetime of a machine should not be so very much longer than the economical lifetime. Machine design is improved continously, and after some years a machine is no longer giving a good economy compared to a new machine. The initially invested capital in the machine should be spent when the end of the economical lifetime is reached. A used machine of a special design is sometimes very difficult to sell at a price, higher than the scrap value. In such case all essential parts of the machine ought to be worn out just when the machine is taken out of production.

Some types of machines, especially machine tools, very often may be used for other purposes than the original one when they no longer have the full and good economy in the primary application. An example could be seen in a motor factory some years ago, where an old, but of course overhauled, gear cutting machine was installed between two very modern transfer machines, doing a special operation on the parts processed in these very modern and efficient machines.

The quality of maintenance, both the daily maintenance in the form av lubrication and inspection performed by the operators, and the more specialized maintenance, performed by skilled maintenance workers, has great influence both on the physical and the economical lifetime of a machine. A complete and efficiently performed maintenance programme has great influence on the lifetime and the economy of an investment.

SUPPLY EFFECTIVENESS OF MAINTENANCE RESOURCES.

The third main factor influencing the Operation Availability, Supply Effectiveness of Maintenance Resources, covers

- the maintenance personnel
- the maintenance work shops
- the machine tools and other equipment in the maintenance workshop
- the recording of instructions, drawings and diagrams
- the supply of spare parts and material
- the maintenance control system.

THE MAINTENANCE PERSONNEL.

When a new machine or plant is set up and put into operation, usually also new techniques and methods for the maintenance operations have to be introduced.

These new methods and techniques should be introduced before they are actually needed, because training of the personnel does take time, and when the machine has stopped for a break-down it is far too late to start training. In too many cases repairs are performed by unskilled people, resulting in a poor quality of workmanship and, sometimes, great damages to the machine.

The training of the maintenance personnel must in most cases be done locally. Sometimes the manufacturer of the equipment invites operators and maintenance personnel for training and retraining in his plant during the manufacturing or testing period. This way is sometimes rather expensive and also only a small number of people can be sent for training. If this possibility exists it should be reserved for people, who after returning are competent to train people in the plant.

As already mentioned, the training and retraining of both operators and maintenance personnel should be started as early as possible. Sometimes it will be impossible to finish this training period until the machine has been installed and started up. It should also be remembered, that both operators and maintenance personnel need training also in old plants, on already installed and used machines. A new man in an old factory can sometimes make mistakes, resulting in break-downs and detoriation of machines.

Even a skilled maintenance engineer or foreman needs training and retraining from time to time. Especially the maintenance engineer should make it one of his most important work tasks to take an active part in training programmes for his own personnel. The engineer should be more competent to perform any of the maintenance work tasks than the craftsmen themselves, so that he can show them the correct methods and techniques, also evaluate their performance.

THE MAINTENANCE WORKSHOP.

The maintenance workshops and the spare part stores form important parts of the maintenance resources. Without suitable premises and equipment even the most skilled maintenance craftsman is unable to perform his duties efficiently.

The workshops should be of ample size and located preferably as near as possible to those parts of the plant, giving the major part of the total work load on the maintenance workshop. By locating them near these parts the time for walking and transportation is reduced, resulting in increased efficiency.

The store rooms for spare parts should be equipped with necessary conditioning facilities to protect parts from corrosion and detoriation. The orderliness should be kept well up, so that needed parts can be found quickly. There should be a spare part record and someone should be made responsible for ordering parts according to general or special rules, insuring that the supply is sufficient, but not uneconomical.

The maintenance office should be as close as possible to the workshop, at least the foremen office and the planning office. The planning office should be big enough to house the records, instructions, drawings, diagrams, spare part catalogues and material catalogues. The most important and used papers should be in duplicate, one set for reference and one set for daily use. If possible the reference set should be translucent to allow local copying, when needed.

Sometimes it is found feasible to locate the spare part store room so near the workshop, that the personnel also can take care of the workshops toolroom.

THE WORKSHOP EQUIPMENT.

If subcontractors are not available to take care of the larger machining jobs the workshop should be equipped with suitable machine tools. It should be remembered, however, that the profitability should be calculated carefully before deciding on the purchase of heavier machine tools such as boring mills, arboring machines and vertical turret lathes. These machines will usually be very poorly utilized, causing heavy cost for each machining hour.

When deciding on the equipment it should be borne in mind, that the machine tools in a maintenance workshop must be more accurate than usually considered necessary. It is usually not a good solution to buy second hand machine tools or use machine tools from production.

The maintenance work needs good lifting equipment, such as overhead cranes or traverses, with ample lifting capacity. The controls should be operated from the floor, only very rarely from a cabin on the traverse.

The demand on transportation equipment should be considered. In this case second hand fork trucks could be used, but equipped with special arms and hooks. They are handy, because they can be utilized both in the workshop, for transportation to the different parts of the factory and for lifting on the spot in the factory.

For lifting of heavy machine parts in the production departments sometimes their lifting cranes could be used, but it is handy and feasible to have smaller movable cranes, either with mecanical hoists or hydraulic lifting arms.

The hand tools are important. They should be of good quality and suitable for the jobs to be performed. It is always profitabl to spend money on good tools, as the cost of the workers time and the stop time of the production machinery is much higher than the tool cost.

Each craftsman should have his own set of standard hand tools and a box or trolley for storing and transportation. Special power tools and hand tools like pullers should be stored in the tool room. A simple and dependable tool control system should be used. The old system with one numbered set of badges for each man is not very good. A system using a receipt in duplicate, one for the man and one for the tool control system, is much better, because it gives a much better control of the tools.

THE MAINTENANCE RECORDS.

All papers concerning one machine or a certain part of a plant should be carefully recorded. This machine record should be in duplicate, one set for reference and one for daily use. The set for daily use may be borrowed against a receipt and should be checked before it again is filed in the record file.

The reference set is used to replace dirty papers in the daily set and should be translucent to allow easy copying.

The daily set should be held in binders, if possible, and some blank forms put into it in front of the other papers. These blank forms are filled out with notes about special tools for special jobs on the machine, notes about operation sequence for repetitive jobs etc.

One file should be reserved for the job orders concerning the machine. It is the base for the maintenance history of the machine. If these job orders are taken good care of it has no purpose to have a special card file for recording the history. If some information is needed it is easy to collect it from the record file. To write the same information twice is a waste of time and it does not add anything valuable to the record.

The maintenance records should be easilyaccesible for the maintenance personnel, especially the personnel for planning and scheduling of the maintenance work.

If modifications to the machines are done this must be recorded and the diagrams brought up-to-date. If not fault-finding and repair might be hampered seriously, causing long and unnecessary stops.

SUBCONTRACTORS FOR MAINTENANCE.

In many plants it is possible to utilize subcontractors for some types of maintenance work, such as general repairs, overhauls and repairs as a result of severe break-downs.

In industrialised countries suitable subcontractors usually are available. A suitable subcontractor should have

- skilled craftsmen
- a well equipped workshop (if the work should be brought to the contractors shop)
- good and suitable mobile equipment (if the work should be performed at the place)
- skilled supervisors.

Even if the subcontractor meets the requirements the engagement will involve an increased work load on the maintenance department. The reason is, that the necessary local knowledge of plant and equipment is found in the maintenance department and that it will be necessary to let someone from the own department act as an information supplier for the subcontractor.

In several development countries such maintenance contractors have been established. If an investment is considered, where such subcontractors for maintenance will be involved, the investment project group must investigate their possibilities and take the result into the total picture. If not, the investment may be based on misstatements, causing unexpected costs and production difficulties in the future.

THE SUPPLY OF SPARE PARTS AND MATERIAL.

The supply of spare parts and material for maintenance jobs is very important, especially if the factory or plant is located far from the supplier. To have big stores of spare parts and material means to bind much money and the cost is heavy.

Spare parts and material may be devided in two groups, depending on the cause for their use. One group contains parts and material for replacing worn parts, the other group spare parts and material for emergency use.

Normally the first group is easy to handle. Once the life time of the different components is known it is fairly easy to order these components in time for the replacement. A normal stock control system can be used.

The spare parts for emergency are mostly considered as an insurance against too long stops in case of a break-down. Which parts should be ordered is sometimes very difficult to decide on, but in most cases the manufacturer is able to give advice about that. If possible information about these parts should be collected from industries, that already have the same or similar machines.

The normal size of the spare part stock depends also on the performance of the maintenance programme and the operators handling of the machines. With a good preventive maintenance programme most of the wear of machine parts is revealed in good time, and parts can be ordered and shipped from the manufacturer some time before they are needed.

If the operators are unskilled, untrained or careless they will cause much trouble for the maintenance department as well as for the man responsible for ordering spare parts. Some of the need of parts may be foreseen, but the rest is impossible to reveal before something happens. The cure in such cases is to train the operators better and supervise them more closely.

LOCAL MANUFACTURING OF SPARE PARTS.

In many countries it might be impossible to raise the necessary foreign currency for the purchase of spare parts from the manufacturer of a plant or machine. Also other circumstances might justify a local manufacturing of spare parts.

Manufacturing of spare parts for high quality machinery, at least heat treated parts, parts machined to close tolerances, gears, hydraulic components, pneumatic components, electric and electronic components, bigger parts of steel or cast iron, ball and roller bearings and similar machine or plant components, will demand highly skilled craftsmen and high quality machine tools, as well as supply of suitable raw material. Another important fact is that drawings and process descriptions for the manufacturing is not very often supplied by the manufacturer, at least in the case the discussion about such supply is taken up with the manufacturer after the original purchase contract is signed. These informations to the manufacturer represents a high value, often patented or secret design and manufacturing features.

Another fact is, that local manufacturing of spare parts in many cases is more expensive than purchase, even if the manufacturers usually demand a rather high price compared to the real manufacturing costs. A manufacturer, however, usually is in a position to be able to manufacture more than one part at a time and also has the necessary special tools, jigs, fixtures, suitable machine tools etc.

If the situation is such, that a local manufacturing of spare parts is the only solution, the machine or plant should be carefully analysed to establish, which spare parts are needed, which informations are needed to facilitate the manufacturing, which raw material is needed, which machine tools and other machines and facilities for the manufacturing are needed and how much the manufacturing procedure will cost in local currency.

The necessary extra purchases and the entire organization of the local manufacturing must be established and considered as a part of the proposed investment for the machine or plant. If not these additional qualifications are filled the whole base for the initial investment is false. If the plant or machine is bought and installed, the production situation will soon become impossible, or production hampered because the necessary maintenance can not be performed.

Unfortunately, the situation is not unusual. A sugar factory lost production at a value of about 250.000 US $ because it was impossible to raise some 5.000 US $ to buy rubber tyres for the tractors used to haul cane from the fields to the factory. The country has a rubber tyre factory which made tractor tyres, but not the same dimension. It was also impossible to modify the tractor wheels to take the available dimension, because there was no supply of rims and no possibility to rework the existing rims.

Another practical situation: 10 big earthmoving machines were bought for a certain project, but no spare parts were ordered. The maintenance manager proposed that only 9 should be bought and the rest of the available money used for spare parts. The proposal was not accepted. The result was, that after only a few months 6 of these expensive machines were idle, because some wear parts could not be obtained. These parts called for a big forging press and no one such was available in the country. Relining the parts with welding was possible, but the necessary welding material was not available.

With a little forethought these situations would have been avoided and big losses, delayed harvest, delayed work programmes and a lot of human stresses eliminated.

The maintenance man should be the one, who knows most about the need for spare parts, the possibilities to make these parts locally and how important to the production the supply of spare parts really is.

The analysing procedure is sometimes difficult, because the knowledge about the proposed plant or machine might be insufficient. An open discussion with the manufacturer, with other buyers and users, even consultants with experience of maintenance, would sometimes be helpful and necessary to clarify the importance of spare part supply and the possibilities to solve the problems.

THE MAINTENANCE CONTROL SYSTEM.

The only way to insure a good supply effectiveness of the maintenance resources is to have a suitable Maintenance Control System. Such a system contains

- machine and plant records
- maintenance personnel records
- spare parts and material records
- maintenance cost records
- a preventive maintenance programme
- a suitable job order system
- rules for ordering maintenance work
- priority rules
- statistics.

The purpose of the Maintenance Control System is to guide the managers, both the general manager, the production manager and the maintenance manager, in their efforts to realize the objectives set for the enterprise. The MCS is a part of the total information system in the enterprise, but it is a special part. It is impossible to use the same control system in a maintenance department as in a production department.

A production department is usually controlled according to the "Management by Objectives" philosophy, while a maintenance department is controlled both according to the same philosophy and the "Management by Exception' philosophy. The reason is, that the maintenance department nearly always has very many maintenance subjects to deal with, while production has only a few.

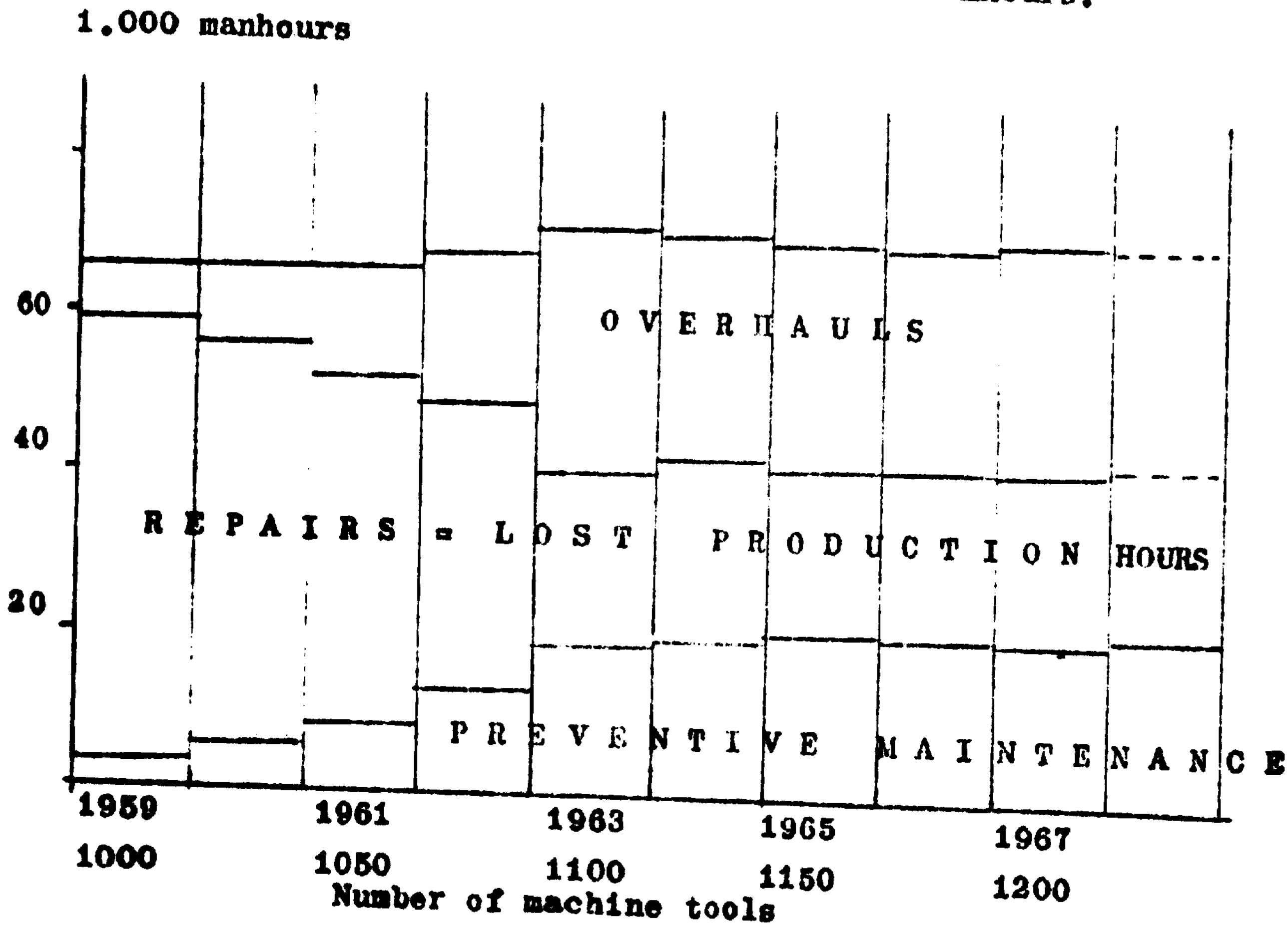
The collected experince from many industries shows, that about 20 % only of the maintenance subjects cause about 80 % of the total maintenance cost. To locate these 20 % is of essential interrest to the maintenance manager, and this demands a special control system, where these costs are revealed as early as possible.

The application of a complete maintenance control system is always giving good profit. What is important in this connection is, that the maintenance cost itself is of less importance to the enterprise than the losses in production.

An example from a swedish industry may be used to prove this. The enterprise is a fairly large industrial engineering company. The number of machine tools is between 1.000 and 1.200, as shown below.

1959 a complete maintenance programme was launched. It started with training of the maintenance personnel and a real Preventive Maintenance programme was started 1961. At the same time the general manager stated, that the overhauling of machine tools was to be increased from 20 machines to 70 machines annually.

During the years the production rate was increased with about 50 %. In spite of that the increase in maintenance manhours is only fractional, not counting the overhaul manhours.



MAINTENANCE GUIDELINES, GENERAL.

General maintenance guidelines to be used at the tendering stage have been discussed for many years in the industrialized countries in Europe. In Western Germany these discussions have resulted in a serie of 5 booklets, issued by the Association of German Engineers, VDI, in cooperation with the Association of German Electrotehhnical Engineers, VDE.

The work was done by a committee of manufacturers of machine tools and a number of wellknown maintenance engineers from the german industry. During the later part of the work a number of specialists in international and national law were taking part.

The final name of these booklets is:

TECHNISCHE AUSFUHRUNGSRICHTLINIEN FÜR WERKZEUGMASCHINEN UND ÄHNLICHE FERTIGUNGSMITTEL, in a free translation

Technical Guidelines for Machine tools and similar Production equipment.

They can be bought from VDI in Düsseldorf, Germany, and they have an official number for each part as shown below.

VDI 3227 GENERAL GUIDELINES AND PURCHASE PROCEDURES

- Standa[illegible] Guidelines, official
- Asking for a tender
- The tender
- The order
- General technical guidelines for operating devices, safety devices, signs, noise levels.
- Recommendations on delivery procedures, transportation and installations of machinery.

VDI 3228 MECHANICAL COMPONENTS

- Guidelines for bearings, couplings, clutches, bolts and chains, plain flat surface bearings, counterweights, limit devices, packings and gaskets, screws, hoses.
- Assembled groups of components, power packs, gear boxes, pumps and pipes for coolant, tanks and filters for coolant.
- Lubrication systems. Lubrication plans.

VDI 3229 PNEUMATIC COMPONENTS.

- Circuit diagrams, symbols, list of components.
- Guidelines for compressors, tanks, valves of different types, motors, cylinders, pipes and connectors.

VDI 3230 HYDRAULIC COMPONENTS.

- Circuit diagrams, symbols, list of components.
- Guidelines for pumps, motors, cylinders, filters, strainers, valves of different types, pipes and connectors.
- The circuit diagram.
- Testpoints.

VDI 3231 ELECTRIC COMPONENTS.

- Circuit diagrams, symbols, list of components.
- Guide lines for different components.

(This part is not yet finished because an international standard is under work.)

These guidelines contain a lot of practical and useful information, both to the maintenance man and to the purchaser of machine tools. Most of these information is applicable to other types of machinery as well. They are based on many years of practical experience, mainly from maintenance engineers, who had to take care of machines of all types. The disadvantages of a certain design pattern, for example the splash lubrication of gears, was discussed with the designers in the committe. After that discussicn the guidelines for splash lubrication were established.

These guidelines can be used at the tendering stage for

- analyzing the design of a machine to avoid design features, which have proved to be unreliable
- to find design features improving the maintainability
- to set up critical points to be discussed with the manufacturer before placing the order
- to avoid mistakes in the final formulation of the order
- to remind about all the hundreds of details in the project work, and especially those concerned with maintenance.

THE PROJECT WORK.

The base for the future total economy of any plant, machine or other equipment is laid when the decision about design is made. In most cases errors and mistakes at this early stage are impossible to correct later on. That is the reason for a careful and thorough consideration of all facts about the plant or machine at the tendering stage.

These considerations should in most cases take place in a team, consisting of experts from all fields and functions within the enterprise, finance, marketing, purchase, production, process planning, plant engineering, maintenance, personnel and social wellfare, trade union and sometimes also official authorities.

During the years the collected experience from industrial enterprises as well as from government departments and military organizations has resulted in a more or less standardized procedure, in this booklet referred to as INVESTMENT PROJECT GROUP.

THE INVESTMENT PROJECT GROUP.

In most cases the investment project procedure should be applied to all investment activities, large or small. This procedure includes the following activities:

1. The general outline of the project is formulated.
2. Different possible alternatives are calculated and analyzed.
3. Requests for tenders are sent out, tenders recieved and prepared for decision. Decision taken.
4. Purchase order placed. Procedure for delivery and installation established.
5. Installation and starting-up. Production starts.
6. The running-in period. Modifications and corrections made. This period ends when full production is reached.

The procedure also contains rules for these different parts or phases of the project and the first activity in each phase is to make a plan for the groups work, including a list of people to be involved in that phase.

Sometimes different groups are founded for different phases of the project. For bigger projects one group takes the first two phases, another group phases 3 - 5 and a third group phase 6. For smaller investments one group could be responsible for all 6 phases.

In order to assure a continous process in the groups and that the established rules for the project work are followed, the planning officer or secretary of the group is a trained project man, who follows the project from start to finish. The project manager is always appointed by the general manager, he might be either a specialized project man or one of the ordinary top or middle managers of the enterprise. Of course, if the investment project is small someone on a lower level might be appointed as the project manager, but the secretary or planning officer of the project always is a specialized man.

This procedure limits the number of people, responsible for a project, to at least two. The procedure rules, however, also give established order to the project groups about the different considerations and which people should be involved in the work, such as the maintenance manager, the power engineer etc.

Once such rules have been introduced in an enterprise the personnel will soon get accustomed to the procedures and accept them as something natural. It must be remembered, however, that when a man is asked to work with the group, his ordinary job volume must be reduced. In most cases it is impossible to have two jobs at the same time. As a consequence the project manager should take actions to relieve a project member from his daily duties for the amount of time the project member is going to spend on the project work. It might be a full time job, but it may also be part time job. The essential idea is, that the project work is just as important as the ordinary daily work, and that these jobs must not be allowed to interfere.

The maintenance function of the enterprise is involved in all phases of such projects, as the Operation Availability of the future plant or machine is of essential interrest to know. It founds one of the important bases for the future economy, and if the plant is imported, also in the future foreign currency may be needed for purchase of spare parts, service from contractors or the manufacturer etc.

AN EXAMPLE OF THE WORK OF AN INVESTMENT PROJECT GROUP.

The example comes from a steel plant, refining raw iron to high grade steel for ship plates. The capacity should be increased from 400.000 tons per annum to 600.000 tons per annum, and at the same time the process should be modified. Two new furnaces should be added and the building extended to house a third furnace during the relining work.

Phase 1. The general manager appointed a process engineer as project manager. The planning engineer was elected. The project manager appointed a marketing man and a production engineer for this phase.

Studies of existing plants were made, and discussions started with possible manufacturers of furnaces. Two alternative design ideas were analyzed. The maintenance manager was asked to join the group for 4 weeks.

A market survey was made. The marketing man in the group let his own department do this survey. Time about 2 months.

After 4 months the two alternatives were ready for the plant engineers. The plant engineering department made to survey lay-outs and calculated approximate prices for buildings with cranes and other transportation devices needed. The power station was analyzed and found capable to deal with the increased load.

After another 2 months the basis for a decision by the board of directors were finished. In this case the cost for a tender were so high that it would have been impossible to have alternative tenders, so instead an evaluation of the two possible contractors was included in the material.

The decision was made in the board meeting, and at the same meeting the project manager was appointed for the second phase of the project. The former project manager was now relieved of that duty and a production manager appointed instead.

Phase 2.
Stage 1.

The project manager and the planning engineer made a plan for the next phases, corresponding to points 3, 4 and 5 of the general procedure. The following people were appointed as full time members of the investment project group:

1 maintenance engineer, also acting as contact man to the manufacturer of the furnaces
1 engineer from the manufacturer of furnaces
1 plant engineer, also plant lay-out engineer
1 designer for mechanical aids, such as cranes
1 electrical designer for the electric equipment
1 personnel training officer
1 production engineer
and as part time members:
1 expert in transportation
1 power engineer
1 expert in adminstrative routines.

The work started with a modification of the choosen alternative. Then from this project lay-out the objectives for each one of the involved departments and the main contractors were formulated. In each department a subgroup was set up, mostly with part-time working members.

The major design features were soon established and the detail work on designing and manufacturing could start after only one month.

The maintenance survey was made, and as a result the personnel on the engineers and foreman level were appointed. The detail work on the maintenance plans started, during that work close cooperation was established with the contractors and the designers in the own departments. Reliability and Maintainability of the different parts of the plant was carefully considered.

The training of both the maintenance personnel and the production foremen and instructors started.

Phase 2. Stage 2. The second part of phase 2 started when the building work started. Some of the furnace parts and other equipment started to arrive from the manufacturer.

The installation of the machines started as soon as the builders had proceeded far enough. The first machine to be installed was a big overhead crane.

From the start of phase 2 now 6 months had elapsed.

The maintenance personnel took an active part in the installation work, but still some time was spent on training.

The preliminary maintenance plans were made and the routines for both production and maintenance were established. Simulation was used to test the routines and the plans.

The mounting of the furnaces took 3 months.

Phase 2. Stage 3. 9 months after start of phase 2 the testing of the production equipment could be started.

The training of the operators started a little before the actual production started up.

During the testing period the established maintenance routines were operative. All experience was carefully recorded and analyzed. Corrections were made when found necessary.

The testing period also contained checking of all the equipment according to established routines. The safety rules were carefully checked and corrected.

Stage 3 ended when full production was reached, it took only 6 weeks from the start of the furnaces.

The investment project group was now dismissed and a new group appointed for the last phase.

Phase 3. The production was now running well, but of course still the "children diseases" of the plant had to be overcome.

The maintenance engineer was a full time member of this group. The project manager was now another production engineer, but the secretary of the group was still the same person as during phase 2.

The running-in period was established to 12 months. During this time all modifications were made and the necessary retraining of both operators and maintenance craftsmen done. As a result a special introduction course for operators was established by the personnel department.

At the end of the running-in period a detailed survey and an analysis of the Operation Availability as well as the utilization of the Operation Availability was done.

The final result was excellent. The plant was running smoothly and the maintenance procedures well established as a part of the normal daily routine. The production cost was lower than originally calculated, which was aknowledged as a result of the maintenance routines in the plant. The total sum of investment was only 1 % above the final calculated sum.

On the following page is shown graphically, how this investment project proceeded. It should be observed, that only the tasks for the maintenance department are shown in detail.

	PROJECT GROUP NO 1	PROJECT GROUP NO 2	PROJECT GROUP NO 3
FURNACE MANUFACTURER	Discussions —— Preliminary tender—	Design —— Manufacturing —— Installation ——	
BUILDING CONTRACTOR	Preliminary tenders	Building ——	
PLANT ENGINEERING DEPT	Preliminary layout - Layout ——	Design —— Inspection ——	
PRODUCTION PLANNING DEPT	Preliminary prod.plan	Definite production plans ——	
PRODUCTION DEPARTMENT	Production survey—	Preliminary production instructions ——	START Corrections—— Definite production instructions
PERSONNEL DEPARTMENT	Personnel survey——	Personnal plan —— Recruitment maintenance personnel —— Training maintenance personnel —— Recruitment production personnel — Training production personnel ——	
MAINTENANCE DEPARTMENT	Maintenance survey— Guide lines, tenders	Preliminary maintenance plan —— Maintenance instructions —— Training maintenance personnel —— Training production personnel ——	Corrections— Maintenance plan operative

DESIGN CHECKING.

It is of course impossible to give detailed and accurate recommendations about what to look at, when checking the design of a machine from the maintenance point of wiew. Listed below are a few points, where the authors experience tells him to be observant.

Cleaning. The cleaning is the start for a good maintenance. A machine shoučd be easy to clean with flat surfaces without any pockets, where dirt can collect. The designer often trys to make his machine attractive to the eye, then someone else adds boxes, pipes, hoses and other necessary part, thus spoiling the look, but also hampering the cleaning.

Sometimes protective covers are used, f.i. on flat surface bearings of machine tools. This will give the operator the impression, that the machine is protected and does not need cleaning under these covers. Thes covers have to be removed from time to time for cleaning under them, and they be rather tim consuming to dismount and mount again.

Lubrication. It isvery easy for a designer to add lubrication fittings to a machine, but he seldom thinks on the time it will take to grease those fittings. There are now available in the market very good and dependable lubricators. If such one is used it is fairly easy to fill it up with grease or oil, and it is also easy to adjust the amount of lubricant for each lubrication point separately, thus avoiding overlubrication.

For gear boxes splash lubrication has been found to be less dependable. Force feed lubrication with a pump is now recommended. The lubrication system should of course have a strainer to prevent foreign particles to enter the lubrication points.

All lubrication points must be well marked and easy to access.

Lifting. Heavier machine parts should have facilities for attaching lifting ropes or hooks. Threaded holes for the application of eyebolts, hooks or lifting beams are simple to make, when the manufacturing is going on, but very difficult to add afterwards.

Milling machines are often lifted in the table, which might destroy the machine accuracy entirely. Holes in the stand for entering bars or threaded holes for hooks should be provided.

Lifting instructions, sketches or similar, should be delivered with any machine. These instructions should be placed on the outer surface of the box or crate and easy to observe, not, as has happened, inside the crate.

Pullers. Machine compónents like wheels, sleeves, gears, pulleys, covers and bushings, with a tight fit, should be provided with facilities for removing them without much labour. Threaded holes for attaching pullers is a good solution. For covers two or three equally spaced holes for pushbolts around the circumference is handy. The thread dimension should preferably be the same as the fastening bolts.

Ball and roller bearings can be removed with ordinary standard pullers, but they are often destroyed and may not be used again. Sometimes a milled recess behind the bearing would make puller application easier.

Testing. Electric, pneumatic and hydraulic systems should be equipped with test outlets, and the components must be well marked in accordance with the diagrams.

Corrosion. The corrosion protection is too often forgotten. The climate in a country may be damp and hot, and in such case even painted steel rusts easily. Stainless steel is costly, but in many cases it is well worth to spend some money on a better material and avoid future maintenance problems, f.i. spare parts.

In many cases the oil system is not cooled enough to carry away the heat from the moving parts. If the lubrication oil is subjected to a high temperature it will soon loose its ability to lubricate, also it may crack, forming hard particles, which will cause wear instead of preventing it.

In systems working at a higher temperature an oil cooler and a full flow filter is necessary.

Bearings.

Ball and roller bearings are sometimes protected against water and grit with a seal. It should be a lipseal, not a felt ring, especially if some pressure or velocity is involved.

These seals are pressed into a recess and are sometimes very difficult to take out of the recess. There should be two small drilled holes behind the seal, so that two steel pins can be used to force the seal out.

Bearings are very often pressed on a shaft and resting against a shoulder or another part, a sleeve or a gear. These bearings are difficult to remove without destroying their accuracy.

Bigger bearings and other parts like couplings should be fitted with drilled holes and recesses facilitating the use of high pressure oil for both dismounting and mounting. In such case a bearing might be used again, if not damaged from use.

Flat surface bearings should always have a high safety factor for overload, and the hardness of the matching surfaces must be about the same. If not the wear will be great and there will be great hazards for scoring. The lubrication of flat surface bearings is always a problem and should be checked very carefully.

Plain bearings of greater dimensions should have pressure lubrication, at least during the start period.

Standard. It is very difficult to give recommendations about standard. Standard components are interchangible. Such parts as valves, pipes, switches, circuit breakers and similar can be find in many dimensions in one machine or plant. It might be better to have one or two of each type, because the spare part store may be decreased and yet the safety high.

If several machinesuse the same type and size of components, such as hydraulic valves, pumps etc, the safety store of spare parts can be reduced.

If a certain function needs one special component it should be analysed, if the same function can be obtained with two standardised components already stored.

Generally speaking the maintenance engineer must collect and record experience from his own industry to be able to check the design features of proposed machines for his industry, as sometimes local conditions will influence greatly on what is essential and what has little value. In development countries even such normal parts as screws, nuts, washers, standard bearings, packing and gasket material, seals, push buttons, lamps, cables and pipes, valves, fittings, sockets and connectors are not made locally. When analysing the design he must be open for the need of spare parts and the possibilities to get them.

THE INQUIERY.

When the internal discussions about a proposed plant or machine have resulted in major outlines, preferably as described in the chapter dealing with Investment Project Group, inquieries to manufacturers or contractors can be sent out. It is recommended, that the number is limited, especially if the machine or plant is special and large, because to prepare a tender will take a considerable time and labour and the cost has to be covered in some or other way.

Sometimes the decision on contractor or manufacturer is made before a tender is recieved, just because larger tenders cost so much money, that the contractors do not want to work without being sure they will get the order. In such case the decision is usually based on an Evaluation of contractor.

In order to get the most complete tender the inquiry should be rather detailed, giving as much information as possible to the contractor.

The data about raw material, production, power etc are not often forgotten, but that happens to such details as

- which national laws, standards and rules are applied on the tender, the design, delivery, installation and guarranty period.
- the climatic conditions
- supply of power, water, steam, gases etc.
- ground conditions
- availability of local service, machining facilities, material stock, spare parts, subcontractors for installation
- what is required included in the delivery in the form of drawings, transparent drawings for copying, operators instructions, maintenance plans, spare parts catalogues
- how much training of operators and maintenance craftsmen is expected, local training and training abroad
- which language should be used in the written instructions.
- the Operation Av ilability of the machine or plant and how these informat ons are desired
- that information about spare part supply, cost, need for special tools and maintenance equipment should be inclu ded in the tender.

THE TENDER.

When the tender has arrived it should be checked in every detail against the inquiery and the information, collected in the investment project group.

The maintenance engineer should devote great interrest to those parts of the tnder, containing information of interrest for the future maintenance situation. He is probably the one in the investment project group, who knows most about the essential Operation Availability, Reliability, Maintainability and Supply Effectiveness of the Maintenance Resources.

Based on the information in the tender and his knowledge of local conditions, the maintenance engineer should make careful calculations on the maintenance situation for the next years. It has no purpose to limit the calculation time to one year only, as the enterprise probably has to live with the plant or machine for 10 to 30 years, depending on the lifetime of the equipment. On the other hand, it is practically impossible to find data of sufficient accuracy for a longer period than 5 to 7 years.

In a certain investment profitability calculation method, the american MAPI-method, usually only figures for the next years maintenance cost is used. This method is not sufficient to give a clear wiew on the important role of maintenance in the future. If this method is used a separate calculation of the Operation Availability must be made as a base for estimation of the total profitability for the future, at least 5 years.

At the same time the spare part situation must be analysed and the necessary money calculated. In developing countries the foreign currency situation is sometimes difficult and if the investment is done and currency for the spare parts not reserved it might happen, that the expected production can not be reached because spare parts are not avilable.

If information about instructions, maintenance plans etc is not included in the tender, the contractor should be asked to provide these before his tender is considered. Once the order is definite the contractor does not easily concede to include such things, but at the tendering stage it is in most cases much easier to convince him to include these necessary parts.

DELIVERY AND INSTALLATION OF A MACHINE?

The maintenance department is usually best suited to take care of a new machine and install it. Even in plants with a special plant engineering department the maintenance department has the necessary craftsmen, shop and other facilities.

Before the machine is shipped from the manufacturer it is usually checked and tested, sometimes also run for a short period. But during the transport it might be damaged. The very first thing to do is to inspect the crates or boxes. If they have damages on the outside the insurance people should be called immediately. If not the insurance people might turn down a complaint, that is done later.

The place, where the machine is to be installed, should be prepared in advance, cables for electric power. pipes for cooling water, for compressed air, ducts for ventilation etc. should be ready when the machine arrives to the factory. If the machine needs a concrete base or foundation the manufacturer usually mails the drawings well in advance, so that the preparations can be done. But be sure to ask for them, it happens too often that these informations are kept in the purchase department...

Make sure the lifting facilities are suitable for the machine installation. Test all beams, hooks, ropes and wires, so that nothing happens when they are used.

Before starting the unpacking, read the instructions from the manufacturer. Be careful to apply the lifting hooks, wires or ropes in such a way, that the machine is not damaged when lifted.

Place the machine on the place and level it roughly first. Then start the cleaning. Wash away the coating applied for protection during transport. Inspect everything to insure the machine is not damaged. Clean the machine carefully.

If the machine is shipped dismounted, be careful to follow the instructions supplied by the manufacturer. Instruct the men carefully and do not let them start to work until quite sure, that they know what to do, and especially what they must not do.

When the assembly work is finished the final levelling is done. Be sure to follow the instructions.

Before the machine is started it should be checked. If the manufacturer has not supplied such a checklist, make one and enter the results of the checking. This list should be recorded in the machine record.

Sometimes an accuracy test is done, according to staddard rules. This applies to machine tools, but also to some other machinery.

Then the machine is carefully lubricated and started. The first to do is to test all the functions of the machine. This is rather a part of the machine test and should be recorded.

Then the machine is ready for the production department. But the maintenance department also should take part in the necessary and very important training of the operator.

During the first months the machine should be checked frequently by the maintenance department. Especially function tests are of great importance, as these tests will reveal unsafe functioning of components at an early stage, which will prevent breakdowns to a large extent.

All papers containing information about the machine should be recorded and filed in the maintenance department for future reference and use.

MANUFACTURERS SERVICE.

Many people believe they may rely on the manufacturers service for maintaining the machines or the plant. It may be possible to do so to some extent and under certain circumstances.

The suppliers interest must, of course, be to deliver a plant or a machine, that will satisfy the customer, not only a short time after the delivery has taken place, but as long as the machine or plant is used. He may insure that by providing:

- a suitable design of plant or machine
- good quality control of the machine or plant at the manufacturing and installation stage
- apropriate instructions for the operation and for the maintenance of the plant or machine
- assistance in training of the operators, instructors and the maintenance personnel
- a well dimensioned spare part stock with quick delivery service
- well trained servicemen.

Even if the manufacturer meets these requirements it will, in most cases, be impossible to rely entirely on these services. Especially when the manufacturer is situated far away from the place, the acute situations must be dealt with by own personnel and with own resources. In the long run the best solution will be to utilize the manufacturers service for the building-up of own maintenance resources to such a level, that they are sufficient for the normal annual requirements. Only such maintenance tasks, that may be foreseen and planned, could be hold pending the manufacturers or other outside service.

One thing must be quite clear to all people responsible for production and maintenance:

If the instructions about operation and maintenance, delivered by the manufacturer, are not followed by the customers personnel, no plant or machine, regardless of design and quality, could be run properly.

CHECKLIST AT THE TENDERING STAGE.

Project:			Project no
Checked by:	Date:	Approved by:	Date:
Short description:			

		Yes	No	Remarks
A	PRODUCTION, ACTUAL AND FUTURE			
	1. Are there any plans to change the actual product within the next future?			
	2. How long time is the product actual?			
	3. Can the design or material be changed to eliminate the actual operation?			
	4. Is it possible to increase the capacity of existing machines to cover the needed quantity?			
	5. Will the new machine become a key machine?			
	6. How much of its capacity will be utilized during the first year?			
	7. Is the size choosen big enough to allow new products?			
B.	PROCESS TECHNIQUE			
	1. Which is the peak value for production per hour?			
	2. How much time of production is required to cover the production programme for the next years?			
	3. Is it poswible to increase the product quality level? How much?			
	4. Which are the required production data and does the machine have sufficient possibilities to change or adjust these data to meet future demand?			
	5. How long time is needed for setting up the machine for prodution, or to change from one product to another?			

		Yes	No	Remarks
	6. Is the machine design and construction correct from view of method study?			
	7. Does the operation of the machine comply with biotechnological rules?			
	8. Are informations about the efficiency of the machine at various loads available?			
	9. Does the machine meet the safety rules?			
C.	MACHINE DESIGN.			
	1. Is the machine sturdy enough to meet all possible load situations?			
	2. Does the machine need a foundation?			
	3. Is a simple set-up permitted?			
	4. Are figures available about the total reliability of the machine?			
	5. Are such figures available for the most important components?			
	6. Do the components quality meet the company standards?			
	7. Is the protection against corrosion dirt, steam, vapor etc sufficient?			
	8. Is the electric equipment of the right class?			
	9. Are special equipment outside the machine necessary?			
D.	SPACE, [illegible], TRANSPORT			
	1. Are necessary lifting and transportation equipment for the installation available?			
	2. Is it possible to locate an.ev. fundamentation on the most suitable place in the fabtory?			
	3. Does the machine need ventilation? Air conditioning? Filters?			
	4. Fire protection? Explosion hazards?			
	5. Does the machine cause vibrations in the building, that may harm other machines?			
	6. Any demands on special lighting?			
	7. Does the machine in production increase the need for storing space around the machine?			

		Yes	No	Remarks
	8. Is there a demand for extra space for tools?			
	9. Does the machine need compressed Air? Is the supply good enough?			
	10. Does the machine need cooling water, steam, gases? Are these available?			
	11. Is the power supply sufficient? Correct voltage? New cables? New switchgears?			
	12. How much power is needed? Power contract limits?			
E.	MAINTENANCE			
	1. Has the machines maintainability been analysed?			
	2. Is the accesibility for maintenance good enough?			
	3. Are there extra facilities for locating faults? Instructions on fault-finding procedures?			
	4. Are lubrication instructions included in the delivery? Do they meet our standards? Is it possible to buy the lubricants in our country?			
	5. Is a maintenance plan delivered? Does it meet our standards?			
	6. Has the spare part supply been discussed and checked? Are spare parts ordered? For how long time?			
	7. Are drawings and circuit diagrams included? Is the marking of the components done?			
	8. Is our personnel competent to perform preventive maintenance? Repairs?			
	9. Are special tools or aids for maintenance and repair needed? Have those been supplyed or are they ordered?			
	10. How is the manufacturers service for maintenance and repair? Contracts?			

		Yes	No	Remarks
F.	DELIVERY AND INSTALLATION			
	1. Is the machine run for testing before delivery from manufacturer?			
	2. Are we going to send a representative to watch the test?			
	3. Shall the final delivery test be done in the manufacturers shop or after the installation in our premises?			
	4. Are function tests or accuracy tests arranged? Where and when? Standards?			
	5. Are any special production difficulties expected during the installation period?			
	6. How is the machine shipped? Knocked-down or assembled?			
	7. Are the internal transports checked? Any extra work to be done? Reinforcement of bridges? Knocking down walls?			
	8. Shall the machine be stored? How should it be protected during storage?			
	9. Who is responsible for the installation?			
	10. How with competent workers for installation?			
	11. Which requirements are expressed regarding painting and corrosion protection?			
	12. Which changes in production are necessary because of the installation?			
	13. Board and lodging for foreign people needed for the installation?			
	14. Special craftsmen for the installation?			
	15. How long time for the installation? Is an installation time plan made?			
	16. Who is responsible for the final testing of the machine after installation?			

		Yes	No	Remarks
G.	PURCHASE. 1. Is the tender correct? 2. Any complementary information needed? 3. How with guarranty period? 4. How with fine for delayed delivery? 5. Payment terms acceptable? 6. Have all requirements from production been met? 7. Have all requirements from maintenance been met? 8. Are all problems with shipping, storing, installation, starting, testing and checking solved? 9. Are all possible costs calculated? Transport, shipping, packing, testing, insurance, duty? 10. Have all people in the company, concerned with the purchase, had an opportunity to discuss this purchase?			
H.	THE DELIVERY SHOULD INCLUDE: 1. Complete installation instructions should be mailed 4 weeks or more before the machine is planned to arrive. Value of weight, external measurements of the machine should be included. Instructions for lifting and transport. 2 models in scale 1:50 for lay-out purposes. Fundament drawing. 2. A complete set of circuit diagrams for the electric, hydraulic and pneumatic circuits. Assemebly drawings or special drawings with instructions about disassembly and assembly for repairs. 3. Spare part catalogue and/or spare part list in 3 copies. If possible a spare part stock recommendation, based on our conditions, covering ....years.			

	Yes	No	Remarks
4. A complete list of components, if possible with the manufacturers own number, also local representatives name should be included, if possible			
5. A detailed description of the machine and its functions, giving technical data for work study, production planning and design purposes (product.)			
6. A complete operators instruction, redigated according to the training system TWI, including setting-up, checking before, during and after running the machine, daily lubrication and function tests. 3 copies.			
7. A complete lubrication plan, in accordance with the german standard DIN 8579, with sketches. Lubricants must be available locally. 3 copies.			
8. A complete set of indication marks for levers, pushbuttons, handles and other opertion devices in our language or with understandable symbols. 2 cop.			
9. A complete maintenance plan in two copies.			
10. Two copies of machine accuracy record chart, if applicable, with the measured deviations entered.			
11. A declaration from the manufacturer, that the machine meets all legäl prescriptions regarding personnel safety, electric equipment, pressure vessels and pipes, air and water pollution, electric disturbances on television, telephone, cable connections, railway signal systems etc.			

RECOMMENDED BOOKS

MAINTAINABILITY, Goldman & Slattery, John Wiley & Sons Ltd, London, New York, Sydney

MACHINE TOOL MAINTENANCE, Knut Swärd, Business Publications Ltd, London

MAINTENANCE ENGINEERING HANDBOOK, L C Morrow, McGraw Hill, New York

SYSTEMATIC MAINTENANCE, Lecture notes, International Centre for Advanced Technical and Vocational Training, Turin.

RECOMMENDED MONTHLY PAPERS

FACTORY, The magazine of Manufacturing, McGraw Hill, New York

MAINTENANCE ENGINEERING, London

74.10.9