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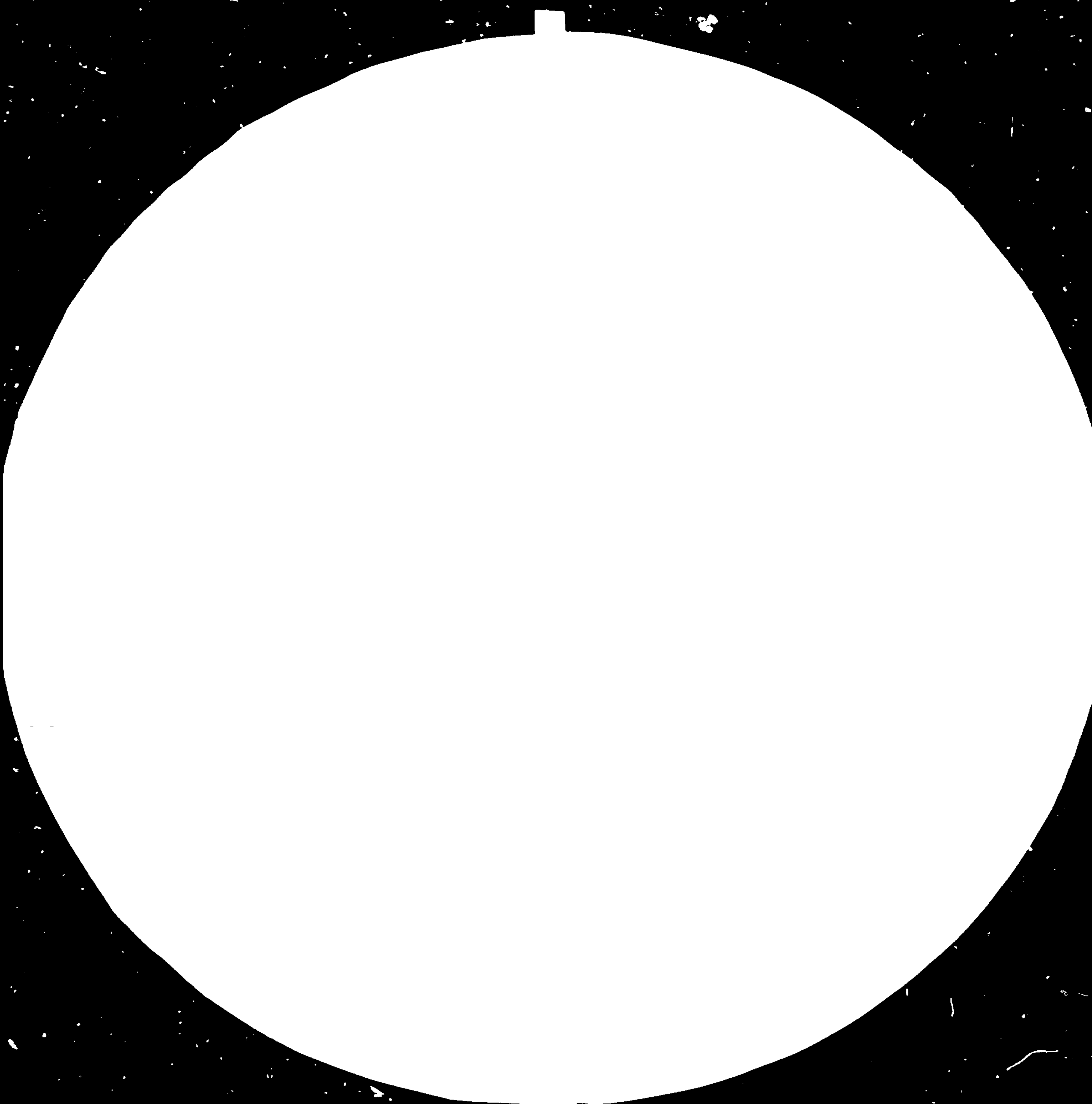

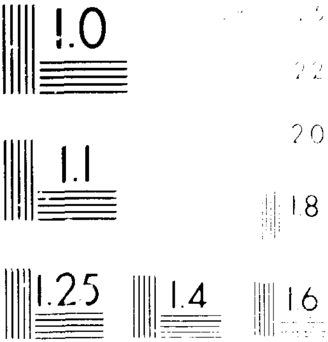
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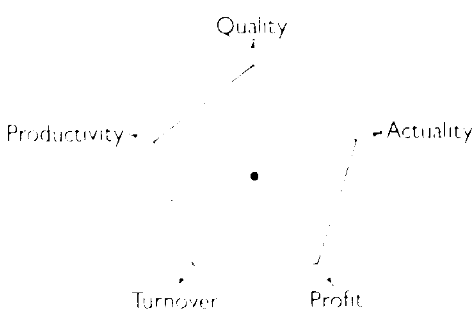

We aim at balanced growth.

Origin:	
Switzerland	60
Europe	20
Overseas	20
	100
Size of firms: (employees)	
less than 250	22
250–1000	33
over 1000	28
diverse (governmental and international organizations)	17
	100
Activity:	
Industry	74
Commerce	8
Other services (including governmental and international organizations)	18
	100

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Yemen PDR

Training Manual for
Initiating and Improving
Maintenance Systems in PDRY

UNIDO project no. UC/PDY/82/092

October 24, 1983

Prepared by

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CONTENTS

ICME

1. INTRODUCTION

This manual has been prepared for training supervisory maintenance personnel in industrial establishments in the People's Democratic Republic of Yemen (PDRY) and is intended to be used with the accompanying six-week training course.

The particular conditions of maintenance and plant management in PDRY were observed by the consultant's team leader in a ten-day mission to Aden in March 1983. At the end of the mission, the team leader, Head of Maintenance Section in the Ministry of Industry and the maintenance adviser to the Ministry elaborated an outline for the manual and the training course. The contents of each chapter of the manual and course were then elaborated in Switzerland by the three members of the consultant's team. The major works consulted are listed in Appendix 1, Documentation.

Since most of the more important factories in PDRY already have a maintenance system, some qualified maintenance personnel, and perform maintenance planning, the emphasis of the present manual and course is upon:

- improving the system of maintenance
- carrying out a fuller implementation of the system
- analyzing maintenance records and evaluating the performance of the maintenance service
- developing action plans for improvements to the maintenance service
- training maintenance personnel
- planning the maintenance service for new plants at the pre-investment and implementation stages.

Chapters 2 through 7 aim at reinforcing the knowledge of supervisory maintenance personnel and at instructing junior maintenance personnel. The chapters 8 through 15 have the objective of advancing the knowledge of all the participants in the course by starting with training in managing the maintenance system and progressing to planning the maintenance system of a new industrial facility from the pre-investment stage.

The final chapter deals with solving special problems in PDRY such as:

- maintenance and repair of water treatment systems
- maintenance of steam boilers
- electrical maintenance.

The participants in the course, will receive supplemental training materials such as check lists, reprints of articles, and special technical information to aid in procurement decisions. These materials should be bound into the manual by the participants.

A glossary is included as Appendix 2. Space has been provided for Arabic translations and for notes to be made by the participants. The glossary serves also as an index to the manual by giving page numbers where the term in question is explained in the manual.

2. AIMS, COSTS AND BENEFITS OF MAINTENANCE

Each equipment, machine, fixed asset, factory, tool, building, vehicule and so on, has originally been built, bought, or rented for a special purpose, which usually is to contribute to the production of some sort of goods or services.

Good maintenance requires many conditions:

- good knowledge and understanding of the equipment and of the way it works
- good sensivity of eyes, ears, touch, and even smell, to able to detect as quickly as possible what may be wrong
- availability of all the materials which machines need, such as lubricants, cooling water, cleaning materials as well as all the vital spare parts which might suddenly be necessary
- an attitude of responsibility by the people who use, operate, or look after the equipment for its productivity and for proper working conditions
- planning and preparation of all the various tasks to be done; men, tools, and materials must be ready and at hand. Then the work done in each task must be recorded as completely and precisely as possible for future use and for better efficiency
- a high sense of team-work and the understanding of the needs of production; general management must understand and promote team-work.

2.1 Aims and objectives

The aim of maintenance is to achieve the highest economic level of efficiency from plant and equipment, with satisfactory utilisation factors. To reach this goal, the production "downtime" has to be kept to a minimum. The equipment must be kept in good working order in such a way that production is satisfactory in quality and quantity.

In most cases it is advisable to define the objectives in clear terms. There are two main types of objectives:

- operational objectives
- cost objectives

The only way to avoid misunderstandings is to clearly define the expected results and the means by which they should be achieved.

Here are some examples of operational and cost objectives:

- Operational objectives
  - To maintain equipment in top operating condition and in good, safe working conditions for operators.
  - To ensure maximum availability of plant and equipment.
  - To provide service that will avoid breakdown at all times.
  - To extend plant life.
  - To maintain plant and equipment with maximum economy and to replace them at predetermined periods.
  - To ensure high-quality performance.
  - To ensure safe and efficient operation at all times.
  - To maximise output .
  - To maintain a reasonable appearance of plant.
  - To keep the plant clean at all times and free from obstructions to the flow of work, materials, vehicles, and people.

- Cost objectives

  - To minimise maintenance expenditure.
  - To provide maintenance service within the limits of the budgeted amount.
  - To proportion maintenance expenditures among the plant and equipment on the basis of age and rate of utilisation.

A complete revision of objectives and policies could take place at two-yearly intervals.

2.2 Costs

The costs of maintenance can and should be calculated in advance, especially as these costs are usually underestimated. All the costs must be budgeted, exactly recorded, controled and analysed. With an efficient organisation, the costs can be limited, reducing the price of the product and giving the factory a higher efficiency and productivity.

2.3 Benefits

The benefits of maintenance are considerable, but difficult to estimate in advance, as maintenance consists first of all in keeping production "downtime" to a minimum and achieving the highest economic level of efficiency from plant and equipment. Good maintenance prolongs the life of equipment and defers the need for outlay on replacement of fixed assets. One specific difficulty in estimating the benefits of efficient maintenance is that it can only be done by comparison with a former, less efficient, organisation inside the same plant, or by comparison with other, similar plants. For the maintenance personnel it is very important that the record-keeping and the analysis of breakdowns and corrective actions are done carefully in order to determine the level of their own efficiency.

3. CYCLE OF FIXED ASSETS

3.1 First phase

When a new industrial investment is considered, the planning engineers usually know practically all the conditions the planned equipment should fulfill. However, there is one important point - technically and financially - which is very often neglected: it is the total of the anticipated maintenance costs, the necessary quantities of spare parts and the period over which these costs are to be written off. With efficient maintenance, this period can be substantially prolonged, but with a lack of proper preparation at the planning stage, this period might be much shorter than foreseen and the firm might have losses as a result. Therefore, before deciding which firm will get the order for the new equipment, special caution is needed and guarantees will have to be carefully studied. All the possibilities of after-sale service, the possibilities of delivery of spare parts and the possibility to get, if necessary, the help of specialists of the maker of the equipment must be considered. All these problems should be discussed thoroughly with the persons responsible for the future maintenance services. Only then should the order be placed.

3.2 Second phase

Before the new equipment arrives on the site, the future maintenance crew must be ready. By far the best, cheapest and most efficient way to work is to have the maintenance crew doing all the installation with the help, direction and supervision of the specialists sent by the manufacturer of the new equipment. In this way, the crew learns from the very beginning all the characteristics, details and "tricks" of the new equipment. This method helps greatly to avoid mistakes and improper handling and can significantly reduce maintenance costs.

3.3 Third phase

Then comes the normal service period of the equipment. As explained in other chapters, each maintenance-work, the used materials and spare-parts should be exactly and completely recorded and accounted.

3.4 Fourth phase

The costs of necessary overhauls, the running repairs, the adjustments and the replacement of worn spare parts reach a relatively high level, the frequency of down-time increases and the down-time periods tend to get longer, and the production falls. Then the moment has come to decide whether the equipment has reached its "retiring age": is productivity too small to support the maintenance-costs?

3.5 Fifth and last phase

In certain special cases it may be possible to use the old equipment for a simpler and easier job, perhaps in another factory. Generally, however, its only remaining value is scrap, minus the cost of demolition.

4. ROLE OF MAINTENANCE IN PLANT MANAGEMENT

The foremost objective of plant management is the production of a maximum of goods of an optimum quality and at a minimum cost. The temptation to neglect maintenance is great, because maintenance does not actually produce, but does cost.

Therefore, general management must have the necessary knowledge and understanding of the vital importance of an efficient and well-organised maintenance service so that it can appreciate the benefits of maintenance compared to the costs.

It is too easy to see maintenance as a hindrance to short-term efficiency, especially since production managers want to produce the maximum in a minimum of time and at minimum cost.

The <u>plant</u> management, therefore, has to find a compromise between two opposite viewpoints, the first being efficient, energetic and active, and the second being wise, reasonable, prudent and thinking of the future. This second viewpoint is, of course, the one which recognizes the value of proper maintenance.

This compromise can lead to conflicts between two equally qualified persons: the production manager and the maintenance-engineer. The general manager has then to be the arbitrator.

In a well-organised plant, the production manager should have a good understanding of the absolute necessity of proper maintenance, and the maintenance-engineer should understand the pressure under which the production manager may sometimes be when he "absolutely" has to finish a certain order for a certain date - even if it means forcing the machinery and neglecting normal servicing.

In addition to all the technical, administrative and organising capabilities which a maintenance-manager should have, he should also be good at dealing with people.

Another apparent conflict between production and maintenance is that production seems to be, above all, a physical and creative activity of predominant importance in the factory, whereas maintenance seems to be a somewhat more intellectual activity requiring much foresight. If production ressembles the muscles, hands and arms of the body, maintenance is more like part of the brain. The results of production are immediately visible, whilst the fruits of maintenance show only in the long run. While production should be daring and aggressive, maintenance must be careful, prudent, and provident. Maintenance is a service available to production, but this does not mean that the importance of maintenance is secondary. In the long run, maintenance carries the responsibility of the future of the whole plant.

It is a mistake to put one service above the other, as both maintenance and production are absolutely indispensable and both have their own importance. Each service requires certain qualities and characteristics from its responsible leaders.

A well-run plant can be compared to a cart with two wheels, one being the production, the other the maintenance. If only one wheel turns, the cart will go in circles and will not advance. If the speed of both wheels is not harmonised, the cart will be zigzagging on its course.

The main role of maintenance in plant management is therefore to understand, to plan, and to foresee all the needs of the plant for remaining in good condition so that production can be efficient and cost effective as long as possible.

5. MAINTENANCE METHODS, PROCEDURES AND TERMINOLOGY

In efficient maintenance management, maintenance has four levels of priority. The general rule is to achieve a capability of responding to emergencies while taking care of the ongoing planned maintenance.

- Emergency

  Emergencies cannot in fact be "planned" - only the responses to them. The objective of "planned maintenance" is to maximize the non-emergency component of maintenance work.

- Routinely Scheduled

  After the emergencies, this is the basic core of the maintenance schedule: lubrication, inspection for wear, space and so on.

- Urgent

  Urgent tasks to get equipment back in operation are known to be needed at some point, and can be scheduled in a reasonably flexible manner, even around "emergencies". Urgent maintenance is not concerned with getting production going again, but with backstopping it with essential overhaul and remedial work.

- Normal

  Normal maintenance operations are worked in as staff and time become available. These tasks have a leeway of time. An example might be an engine overhaul, or rebuilding an aging piece of equipment. It has to be done, but does not have to be done immediately. Included in this category are such things as fixing the roof, arranging for new offices, and some kinds of equipment overhauls. In this category of maintenance work, there may be a substantial "capital" expenditure as well as direct labour and materials.

Routinely scheduled, urgent and normal maintenance are planned. Unplanned maintenance should be for emergencies only.

Good management can cope with most emergencies. One way is to have contingency plans. Police forces are a good analogy. The business of a police force, for domestic security, is to plan to be able to cope with unexpected emergencies. The objective is "response".

Deciding on the level of investment appropriate to emergency management is a difficult task for top management. Planning for emergenices almost seems anti-business: the well-run enterprise is not subject to such things. But emergencies do occur, and require a place in the planning of maintenance priorities.

Presented below are explanations of the usual terminology used in describing maintenance methods and procedures.

5.1 Routine maintenance

- Lubrication
- Cleaning
- Adjustment
- Replacement
- Inspection

5.2 Equipment Inspection

- Failure location, trouble shooting
- Service life estimation

5.3 Repairs

- Rehabilitation work
- Plating
- Welding
- Finishing

5.4 Prevention

- Rust prevention, corrosionproofing
- Dustproofing
- Frictionproofing
- Vibration damping
- Overhaul

5.5 Productive Maintenance

- Maintenance prevention is the careful selection of equipment during planning and installation for:

  . less trouble in general
  . less failure and break-down time
  . easy handling
  . longer service
  . easy, quick and less expensive maintenance

  It includes the provision for evaluation tests and inspection of equipment upon reception.

- Preventive Maintenance is done while equipment is in use:

  . Correction of improper operation of the machine
  . Routine maintenance to prevent deterioration
  . Lubrication
  . Cleaning
  . Adjustment
  . Replacement

- Improvement of maintainability

  . Perform preventive maintenance
  . Perform scheduled maintenance
  . Improve work methods for repair
  . Select tools and materials carefully

5.6 Corrective Maintenance

This term applies to work done:

- In case of failure, to analyse causes and take actions
- To improve and modify equipment for reducing deterioration and lengthening the service period.
- To improve and modify equipment to facilitate routine maintenance, inspection, and repair.

5.7 Total Productive Maintenance

This term means the set of maintenance measures required to ensure that equipment functions as expected at minimum cost and without failure.

The main duties of the maintenance department in "total productive maintenance" are to:

- Make recommendations to the operation (production) departement for performing overhauls, inspection, maintenance and repair; perform the required work
- Guide and consult operation department on methods of use of equipment and on maintenance
- Analyse failures and corrective measures
- Improve equipment
- Improve maintenance techniques and establish maintenance standards through research and development
- Record maintenance work and comprehensively evaluate maintenance performance
- Cooperate with planning department.

5.8 Failures and the service life of equipment

The time period in which equipment can function properly is limited by three types of failures:

- Initial failure, due to discrepancies in design and manufacture.
  Countermeasure: Perform test-run and inspection upon reception. Perform dynamic control during running in period.

- Random failure, due to improper handling in operation.
  Countermeasure: Proper handling in operation and proper routine maintenance.

- Wear-out failure, due to excessive wear.
  Countermeasure: Preventive and corrective maintenance.

5.9 Types of equipment deterioration

- Degradation failure

  Here, equipment gradually decreases in performance while in use and causes loss due to the degraded efficiency even if failures do not actually occur.

  (Examples: Chemical reactor tower, electrolytic cell, electric furnace, compressor for ammonia synthesis)

- Sudden failure

  In this case, although there is not much degradation in performance while in use, equipment suddenly fails or breaks down because of partial damage or for other reasons, but is recovered by replacement of parts.

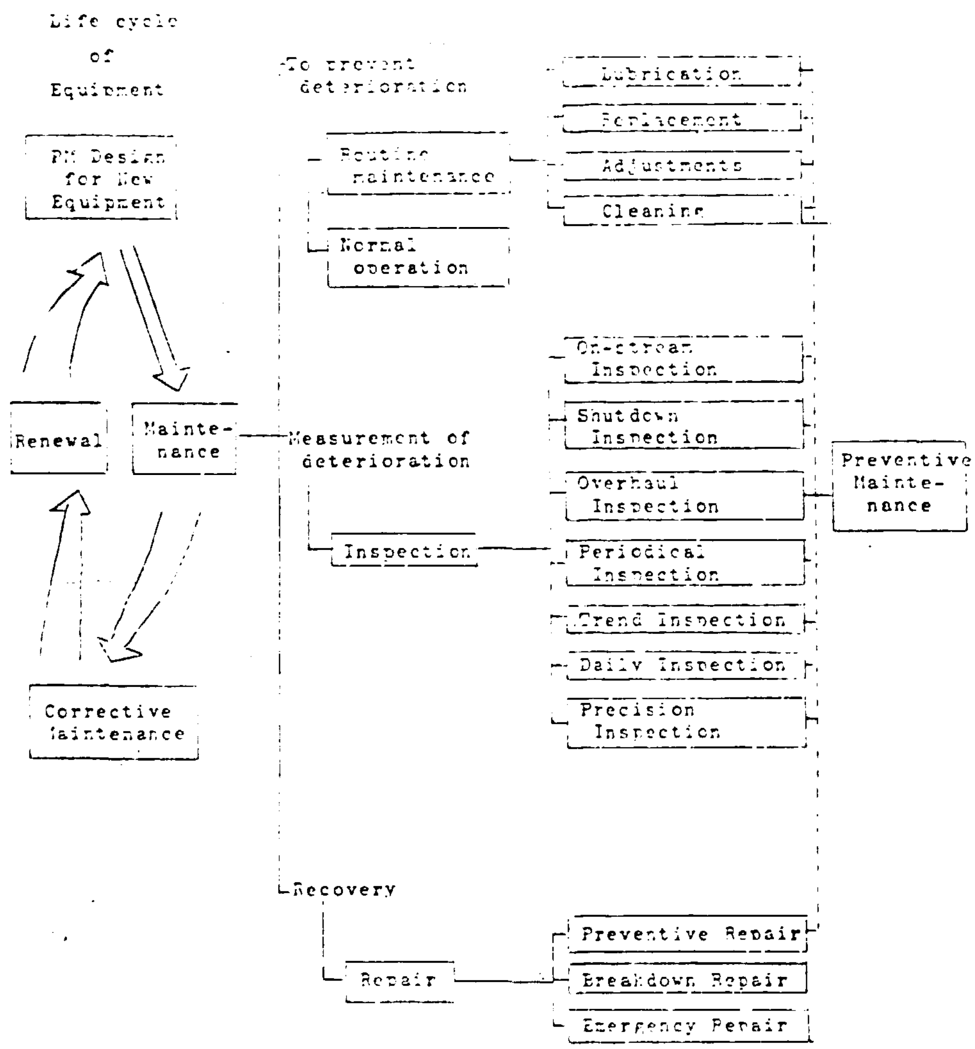
  (Examples: Broken shaft of a machine, broken electrical parts, broken internal pressure vessel)

- Quality Deterioration

  Here, equipment gradually deteriorates to the extent that the quality of products is lowered.

The methods for counteracting these types of equipment deterioration are shown in the figure below.

Figure 1: Countermeasures against equipment deterioration



6. STRUCTURE AND ORGANISATION OF MAINTENANCE

The establishment of an efficient maintenance service requires the combined efforts of all concerned; every member of the organisation must be receptive to it. It is up to management to issue the relevant directives and to give their full support to the maintenance executive. The effectiveness of the system depends on sound interaction of the main participating departments namely: plant engineering, production, cost accounting, stores, purchasing and personnel. Since each of these has a particular point of view, management may have to act as the arbitrator an to incorporate details in the plan which will lead to the best overall results.

Smooth operation of the service requires the following aspects to be clearly defined and understood:

- the position of maintenance within the company
- the internal organisation of the department
- the functions and responsibility of key personnel.

6.1 Structure

The position of maintenance within the overall structure of the company has a great impact on the effectiveness of this function.

Depending upon its position in the company structure, maintenance may be able to attract more co-operation from all functions, obtain more technical assistance or create more interest on the part of management.

The basic organisational guidelines for the maintenance function are as follow:

- All activities relating to installation of plant and maintenance of equipment should come under one authority, even in small companies where either the chief engineer or the manager himself will be in charge of maintenance.
- The chief maintenance executive should report to as high an authority as is feasible, preferably the plant manager who can ensure a balance in the clash of interests between production and maintenance.

- An organisation chart is helpful in establishing the position of maintenance and other functions

- A chart presents only the formal side of the system. Informaly, relationships will depend on personalities. Discussions leading to the adoption of a chart are always helpful. Above, all it is important to get management's approval of the final chart and backing for its implementation.

- The standing of all the maintenance staff is greatly enhanced by the status of their chief. The higher the authority the maintenance manager commands, the more favourable is the effect on his team.

- Maintenance should not be responsible to production. It is a primary function which cannot be managed as a part-time activity of the production manager. If in certain departments repairmen are required on a full-time bases they can be so assigned and still be responsible to maintenance. This is one aspect of decentralisation.

- There is no universal organisation chart which can fit all situations. Every company has features peculiar to itself and these, too, change sometimes.

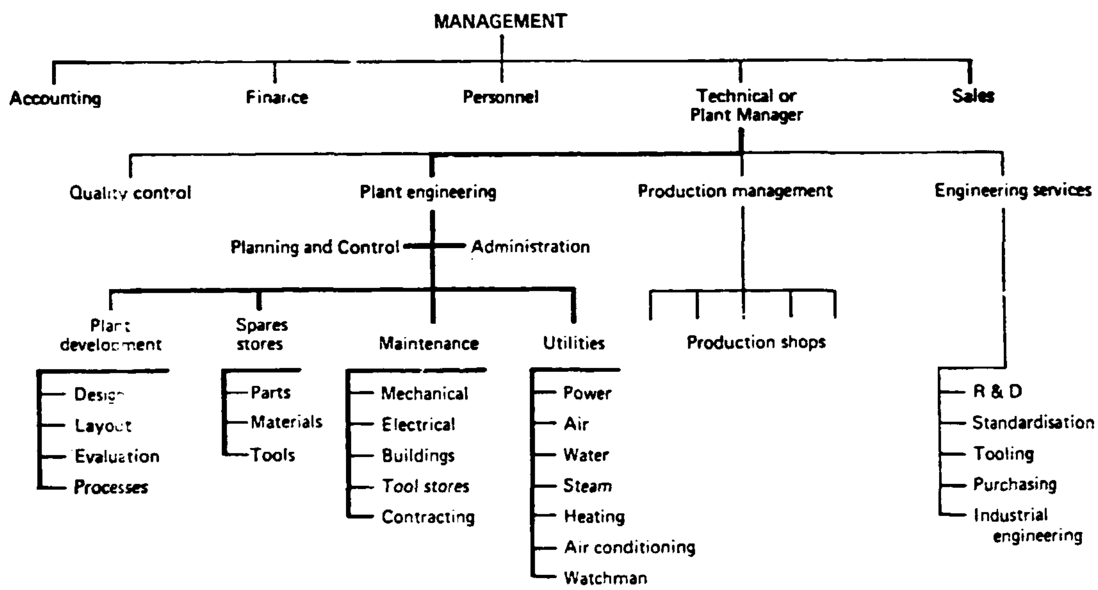
- It is usually accepted that plant engineering combines the function of planning for improvement and the expansion of installations with their upkeep. These functions complement each other. The supervision of power plant and utilities, e.g. steam, water, compressed air, are normally assigned to maintenance, sometimes under a separate foreman. Maintenance stores come undisputedly under plant engineering.

- Purchasing of spares, as well as maintenance of transportation vehicles, must be assigned according to the size of the enterprise and a designated degree of expediency.

- Figure 2 represents the basic relationship that could exist between the various technical functions and should be developed as changes occur.

It must again be emphasised that drawing up an organisation chart of this sort should involve all departments.

Figure 2: The Position of plant engineering and related departments within the organisational structure.



An organisation structure like the one in Figure 2 has the following advantages:

- Maintenance stores become the direct responsibility of the plant engineer and if stocks occasionally run out, he has nobody to blame but himself. Naturally, it implies that supplies are ordered and purchased according to the agreed budget. This will eliminate the passing on of responsibility to anybody else.
- Close co-ordination is possible between the purchase and installation of new plant and its subsequent maintenance. The plant engineer in many firms also develops special tooling and handling equipment. On a smaller scale, however, no distinction at all is made between these functions.
- From Figure 2 it becomes clear that everything that has to be maintained comes within the plant engineer's jurisdiction in one way or the another. Some of the disputed areas are power installations, transport and handling equipment, production tooling, building maintenance and instrumentation. Solution for providing services for these groups may be found in subcontracting or in subdividing the maintenance department into specialised teams.

Figure 2 shows that the proper position of authority to which maintenance should report is to the person who oversees production as well, namely the plant manager who can thus exert influence on both functions when this becomes necessary.

6.2 Internal organisation of maintenance service

The internal structure of the maintenance department also has an effort on its operation. If it is splintered into small groups, each responsible to a different department, it will be virtually useless to the company. Such is the case when various production departments have their own service-men responsible to a local supervisor. Or it may be that equipment is ordered by the engineering department and its installation is carried out by outside contractors, by-passing the maintenance department altogether.

In order to arrive at the best team organisation, the functions of maintenance can be classified as follows:

- trades, e,g, mechanical, electrical, building, instrumentation, etc.
- types of service, e.g. lubrication, inspection, repairs, overhauls, etc.
- areas or groups of equipment
- planning aspect of services, e.g. emergency repairs, routine or regular service, fixed location assignments (boiler-room), etc.

The organisational structure in any one factory will usually represent a mixture of these, since it is rarely possible to prescribe specific solutions. The examples in Figures 3 and 4 illustrate some of the more common cases.

Table 1 shows the advantages and disadvantages of centralisation and decentralisation of maintenance.

There are distinct advantages and disadvantages in each alternative. The final arrangement depends on the benfits to be derived when all factors have been taken into account.

The overall merits of decentralisation are decisive where both speed of service and specialised know-how are required. Where expensive materials are processed or machine time is very valuable, immediate service is essential. When repairmen are constantly away from the central shops while they are in fact required in other locations, the situation should be investigated. An analysis of calls will indicate whether decentralisation would be beneficial. In any case, a decision should be based on an objective evaluation of the known facts, such as the specialised requirements of certain shops, the walking time to location and the frequency of calls.

Decentralisation is a solution which should be selectively applied. Within the maintenance department, however, it will not harm the organisation if only one area or function is decentralised, for example, a traditional boiler-attendant who operates on his own away from the group.

Figure 3: Maintenance-team organisation in a small firm.

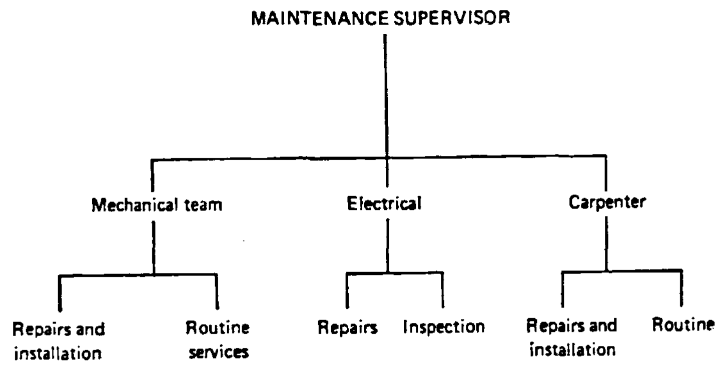


Figure 4: Maintenance-section organisation in a medium-sized manufacturing company.

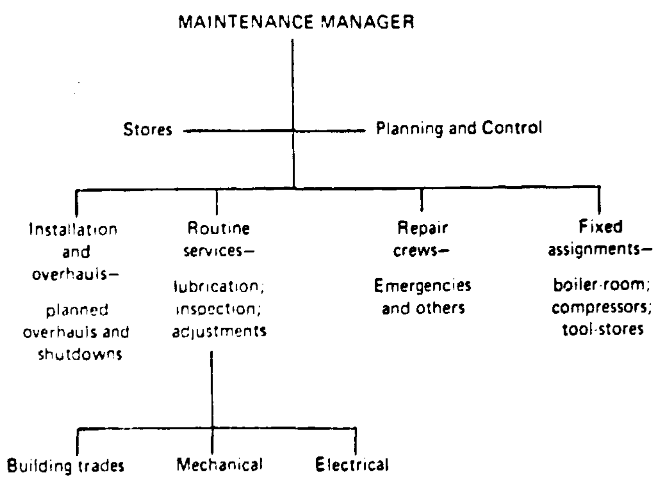


Table 1: Advantages and disadvantages of decentralisation.

	Advantages	*Disadvantages*
Centralised	Ease of planning Ease of supervision Well-equipped shops Effective control of manpower	Longer walking distances No specialisation possible
Decentralised	Speedy service Specialised know-how Constant attention to plant Less paperwork	Duplication of tools Dual authority Poor records Poor skill utilisation

6.3 Responsibilities of the key personnel

Definding the responsibility of key personnel is essential for ensuring their effective work. Figures 5, 6a and 6b show job descriptions for the works or plant engineer, the maintenance foreman, and the maintenance supervisor.

A periodical revision should be carried out to prevent job descriptions from becoming obsolete.

A function which is often missing in smaller teams is that of a clerk-planner. In a maintenance department of twelve craftsmen such a job may prove well justified. It must be borne in mind that most production workers have their regular assignments, work orders, inspectors, workteams, tools and materials, but in maintenance these elements are never constant; they have to be combined afresh for every job.

The issuing of job cards, the recording of work done and the time spent on jobs, the issue of service schedules and the follow-up on the availability of spares are routines that should exist in even the smallest operations. To expect a foreman to deal with them all would be both unrealistic and detrimental as his normal duties would inevitably suffer.

Job descriptions such as these enable a person to act with confidence within the defined limits. They should be well prepared; care should be taken to ensure that there are no gaps in procedures and that there is no overlapping in duties between related functions. They should also undergo periodic revision.

Since there is no guarantee against people moving on to other jobs, or retiring, job descriptions are a great help when new persons take over. They also provide a clear-cut framework for people seeking promotion. The title coupled with wider responsibilities often serves as an incentive for ambitious workers.

Eventually, it will be found that job evaluation and a sound salary structure become a necessity. It is wise, therefore, to anticipate such situations by laying the foundation at an early stage.

Figure 5: Job description of the plant engineer.

1.	*Position and title*	Plant engineer (works engineer)
2.	*Department*	Plant engineering and maintenance
3.	*Responsible to*	Plant manager (works manager)
4.	*Basic function*	Administration of plant engineering
5.	*Immediate subordinates*	Maintenance supervisors, plant utilities manager and plant development
6.	*Duties*	To manage the installation of new equipment and provide for suitable maintenance services To develop effective maintenance methods and procedures and to keep practices up to date To plan and submit yearly budget requirements To provide management with control data To maintain working relationships with all departments and other service functions
7.	*Responsibilities*	To supervise implementation of the maintenance programme To achieve the aims of his functions within the allocated budget To provide at all times safe working conditions for his subordinates To plan the installation of new equipment with provision for convenient access for servicing To utilise all resources in the most economical way
8.	*Authority*	To act within his engineering capacity To instruct his staff in their respective jobs To set down the scope and limits of his subordinates' jobs To organise the plant engineering and maintenance activities To act within the accepted expenditure practices To report to management on the activities of his department To advise on the purchase and replacement of equipment To act within his function so as to achieve maximum efficiency

Figure 6a: Job description of the maintenance foreman.

1.	*Position and title*	Maintenance foreman or craft foreman
2.	*Department*	Maintenance section
3.	*Responsible to*	Maintenance supervisor or manager
4.	*Immediate subordinates*	Craft workers and apprentices
5.	*Basic function*	Supervise repair and service teams
6.	*Duties*	To assign jobs to tradesmen, to follow up on progress and to inspect finished jobs
		To assist and train workers in the performance of their work
		To plan each day's work for all workers and to plan ahead
		To balance teams according to workload
		To determine priorities
		To maintain in efficient condition workshops, tools and stores
		To carry out the prescribed recording procedures
7.	*Responsibilities*	To submit reports on the use of workers' time, on attendance and overtime
		To use tools and materials efficiently
		To ensure safe working conditions
		To carry out management's instructions and policies
		To follow standard practices and procedures
8.	*Authority*	To withdraw necessary materials from stores
		To accept or reject work
		To advise on training needs and promotions
		To deal with grievances
		To approve overtime

Figure 6b: Job description of the maintenance supervisor.

1.	*Position and title*	Maintenance supervisor
2.	*Department*	Maintenance section
3.	*Responsible to*	Maintenance manager
4.	*Immediate subordinates*	Mechanical, electrical and building craft foremen
5.	*Basic function*	Management of maintenance services
6.	*Duties*	*(a)* To supervise installation, maintenance and overhaul of all mechanical and electrical equipment on the premises
		(b) To organise the maintenance procedures
		(c) To co-ordinate his section's work with production
		(d) To utilise information regarding all plant to the best advantage of the company
		(e) To report to management regularly
		(f) To assist production in the development of special tools
		(g) To maintain proper discipline in the shop
		(h) To supervise craft foremen and training of craftsmen
7.	*Responsibilities*	*(a)* To maximise availability of equipment for production
		(b) To ensure safe working conditions, and the provision of safety equipment
		(c) To ensure an adequate supply of tools and materials
8.	*Authority*	*(a)* To direct the work of his subordinates
		(b) To authorise repairs and overhauls involving costs of up to £200
		(c) To sub-contract jobs up to £50
		(d) To order spares, tools and materials as required with the allowed budget
		(e) To advise on the replacement of equipment
		(f) To advise on the yearly budget allocation
		(g) To authorise overtime work, training and promotion within his section
		(h) To advise on the employment of maintenance personnel

7. SETTING UP A MAINTENANCE SYSTEM

The system really begins with the determining of maintenance policies and objectives for the plant, which might be still in the planning stage or already commissioned and running for some time, as will be the case for some of the factories in PDRY.

The remaining steps are somewhat different for the planned factory and the existing factory.

7.1 Planned factory

For the planned factory the steps in setting up the system are:

- Ordering and approving purchase:
  - . Check machine speicification
  - . Compare utilisation capacity to demand
  - . Check for novel operating features
  - . Check for h.p. rating, floor space requirements
  - . Ascertain limitations in use
  - . Compare with existing equipment
  - . Make mental assessment of maintenance needs
  - . Request essential spares
- Initial maintenance planning:
  - . Formulate plan
  - . Formulate a budget and include it in the financing plan
  - . Recruit the necessary personnel
  - . Train the personnel in the plan, the completion of maintenance records and in carrying out the standard procedures
- Receipt and acceptance:
  - . Check receipt of all items
  - . Inspect for eventual damage
  - . Read owner's manual
  - . Check for protective measures, lubricants, coating, anti-vibration packing
  - . Check wrapping and packaging for components
  - . Preserve packing-list and other documents
  - . Open separate file, if one of a kind
  - . Prepare minimum spares list
  - . Assign plant number and fill in equipment record card

- <u>Installation and test-run (commissioning):</u>

  . Check proposed location for space, electrical connections, air attachment, drainage run-off, etc.
  . Issue work order for the installation
  . Prepare area and move equipment to location
  . Lubricate as per instructions
  . Inspect connections and test-run
  . Manual in hand, verify functions of all operating components
  . Test-run until proper sequence is established
  . Instruct operators in all details
  . Draw up operating and emergency instructions
  . Apply safety markings
  . Complete and sign job card

- <u>Producing:</u>

  . Perform planned maintenance
  . Make corrections to plan (correct, as necessary, schedules, procedures, instructions)
  . Test the forms for making maintenance records: are they providing the necessary information? Correct as required and train personnel to properly complete the modified forms.

7.2 Plant producing already

For a plant which has been <u>producing already</u>, the remaining steps in setting up the maintenance system are the following:

- <u>Initial survey of each items of equipment:</u>

  . Locate all documentation that the manufacturer supplied with the equipment
  . Ascertain completeness of documentation and order missing documents
  . Fill in an equipment card
  . Determine which spares are essential and check stores; order where missing

- <u>Control of operation:</u>

  Compare actual operating practices to those recommended by the manufacturer and correct as required.

- Control of lubricants:

  Compare lubricants actually used to those recommended by the manufacturer; correct as needed.

- Initial maintenance planning:

  . Formulate plan
  . Formulate budget and have it officially adopted by management (who must communicate it to the Ministry of Industry)
  . Secure financial resources required
  . Train required personnel - recruiting new personnel as needed - in the plan, the completion of maintenance records and in carrying out the standard procedures

- Introduction of the system:

  . Perform planned maintenance
  . Make corrections to plan (correct, as necessary, schedules, procedures, instructions)
  . Test the forms for making maintenance records: are they providing the necessary information? Correct as required and train personnel to properly complete the modified forms

7.3 The maintenance plan

It is useful here to recall the elements of the maintenance plan:

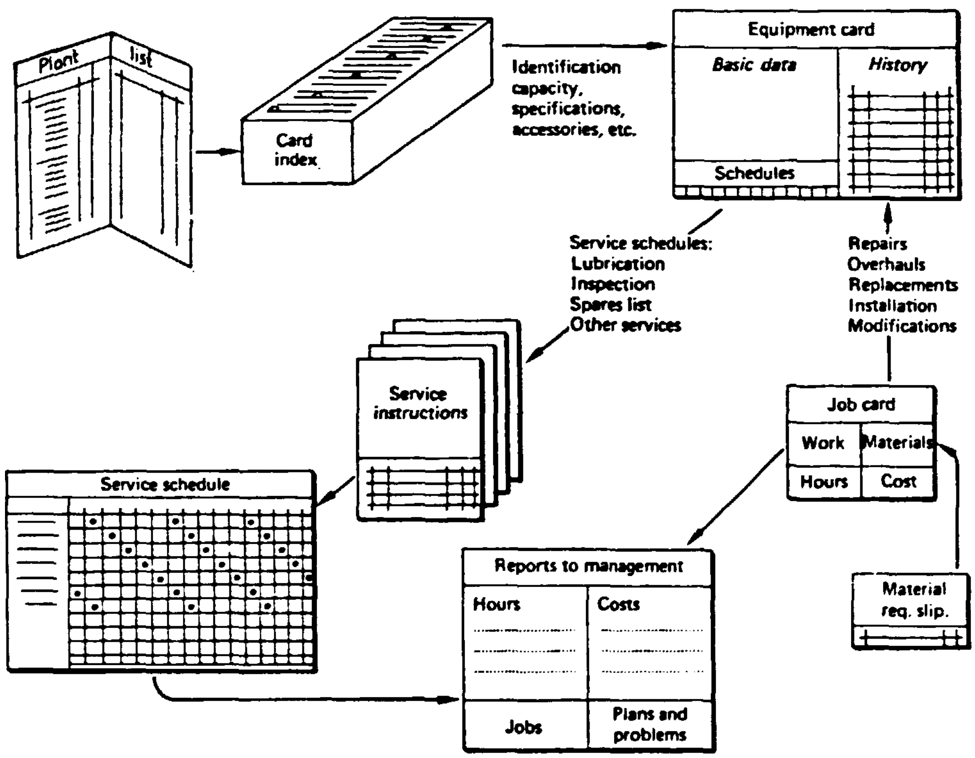
- Organisation of the maintenance system
- Inventory of equipment
- Maintenance schedules
- Maintenance work specifications
- Maintenance control system
- Manpower schedule
- Maintenance records (for work carried out and for reporting to management)
- Support (technical information, spare parts, tools, etc.)
- Communications (agreements with production, schedules for reporting to management and the Ministry)

- Schedules and plans for overhauls
- Costing procedures
- Training

7.4 Maintenance records

The basic required records and their "flow" are shown in the Figure below.

Figure 7: The basic components and flow of paperwork in the maintenance department.



The "Unified Maintenance Instruction" prepared for the Ministry of Industry in PDRY contains models for some of these basic records. Analysis of these by the IMCE team shows that some modifications of the records would be useful, and that some new records should be introduced. Each record is treated separately below.

- "Plant Inventory List"

  A useful addition would be the defining of the actual condition of the equipment. Then the record would appear as show below:

  Figure 8: A plant and equipment list representing data in elementary form.

Plant no.	Description	Serial no.	Location	Year installed	New or s/hand	Condition: perfect / good / fair / poor / to be scrapped

  This record gives answers to such questions as the following:

  . How much maintenance work is expected in Department A?
  . How many electric motors are there in the packaging department?
  . Which of the machines need replacing?
  . Which of the presses needs most attention?
  . What is the insurance value of our plant?

- "Plant Inventory Card"

  It is usefor for this card to be as complete as possible. The following additions, then, would be welcome:

  . Financial data
  . Service schedules
  . History of repairs (which can be written on the back of the card)

The existing "History of Maintenance" form could be used for this purpose, but it should be noted that complete information should be given on each spare part used, for example:

- Name of manufacturer
- Part number

An example of a more complete equipment record card is shown below.

<u>Figure 9:</u> An equipment record card (schematic) giving technical data, cost and servicing schedules. The reverse would normally contain the history of repairs.

EQUIPMENT RECORD CARD			
Name of unit	*Serial no.*	*Location*	*Plant no.*
Manufactured by Local agent	Year manufactured Date installed Date disposed of Reason Scrap value obtained	Purchase order no. Invoice reference	
Technical data and description: ☐ Speeds and feeds Capacities kW and hp rating Water, steam and air		Weight Dimensions / / Total floor space Foundations	
Accessories: Motors, A, V, W, phases, rev/min, hp, type Pumps, cfm, rev/min Controls and instrumentation			

Financial figures	*Service schedules*
Purchase price Cost of accessories Installation cost Total investment Life expectancy Yearly depreciation % Acct. no. Cost centre no.	Lubrication instruction sheet no. Inspection instruction sheet no. Spare parts list no. Overhaul instructions sheet no. Other schedules

Note the space reserved for "Service schedules". Here should also be included the references numbers of all documents relating to the particular equipment for which the card has been made. Thus, the list on the document "Annex IV-3, Plant File for Technical Information, Documents, and Forms" of the Unitary Maintenance Instruction should be included.

- "Maintenance Request" and "Repair Order"

These two different forms are part of, respectively the Maintenance Manual for Industries in PDR Yemen and the Unitary Maintenance Instruction

A standard "work order" or "job card" would be preferable. It would include more information as shown in the model form on the following pages.

It should be noted, however, that some jobs may not require a job card at all. For example, if there is a standing order for a certain operation to be done at regular intervals, or in the case of an occasional adjustment of a machine lasting not more than ten minutes, these jobs do not need a work order. Jobs lasting up to ten minutes (this practice may differ in various factories) can be accumulated on a weekly card made expressly for that purpose.

Acct. no.	Details	
	Shop no. 1	
	Shop no. 2	
	Assembly shop	
	Power house	
	Maintenance	
	Shipping	
	Transport	
	Emerg/repair	
	Installation	
	After/insp.	
	Development	
	Overhaul	
	Fitter/mech.	
	Electrician	
	Builder	
	Painter/carp.	
	Labourer	

IMMEDIATE		MAINTENANCE WORK ORDER NO	
REGULAR			Plant no.

Date ordered.................... To be ready.................... Date completed....................

Details of work: ....

....

....

....

....

Remarks/suggestions: ....

....

COST SUMMARY		
Items	Est.	Act.
Labour hrs.		
Purchases		
Matls. issued		
Contracted, etc.		

Figure 10: The maintenance work-order form, front.

icme

Figure 11: Reverse side of maintenance work-order form.

ON-JOB HOURS RECORD							
Worker no.	*Date*	*From*	*To*		*From*	*To*	*Hrs.*
Total				Total			
Sketch:							

Should the procedure normally require an estimate in man-hours and costs, space should be provided for that purpose. For jobs above a certain sum authorisation has to be obtained and recorded as well, with date and signature of the person authorising its implementation. In some cases the supervisor has to re-check and diagnose the fault on the spot and issue instructions accordingly. This could easily be accommodated in the space reserved for "Details of work". The hour of stoppage and of start-up is sometimes deemed important; however, this detail is best recorded by the machine operators who come under the responsibility of the production department. There is, after all, no way for a maintenance man to know or to find out the exact time of stoppage. Design of the form should be such that each person involved in the procedure should deal with a defined space on it, possibly framed by heavier lines and appearing in the sequence to be followed. The size should allow the card to be inserted into a breast-pocket and both sides of the form should be used. Space provided for an eventual sketch is usually wasted and it seems preferable to attach a separate sheet for that purpose.

7.5 Service instructions

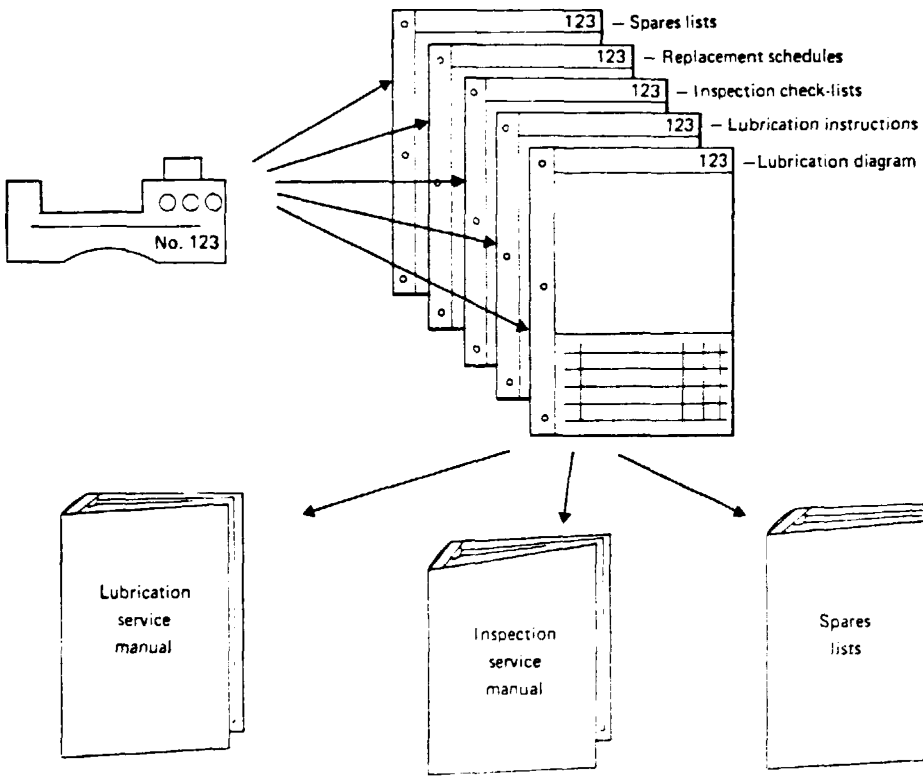
Service instructions relate to regular, repetitive operations that should be carried out during the lifetime of the equipment. These include:

- lubricating instructions
- inspection routines
- periodic adjustments
- "preventive replacement" of components
- cleaning and protective measures
- instructions for overhauls
- spare parts lists

Figure 12 shows the recommended method for handling service instructions. Different groups of instructions should be on separate sheets and each group filed in a separate binder. These can then be handed to persons responsible for the various services. The spares list binder, for instance should be made available to the spares stores and a copy kept with maintenance. Since they are only "recommended" lists they have only reference value. However, a final and approved list must also be to hand for stock-control purposes.

Looking in greater detail at lubrication services the following procedure emerges for each machine: usually there is a diagram of the machine indicating lubrication points and a list explaining how each point should be serviced. There may also be a sheet where the points have been grouped according to required periods of attention. The complete set of sheets referring to all the equipment constitutes the lubrication binder.

Figure 12: Reccmmended method of handling service instructions. Different groups of instructions have separate sheets, and each group is filed in a separate binder, since they will be carried out by different teams.

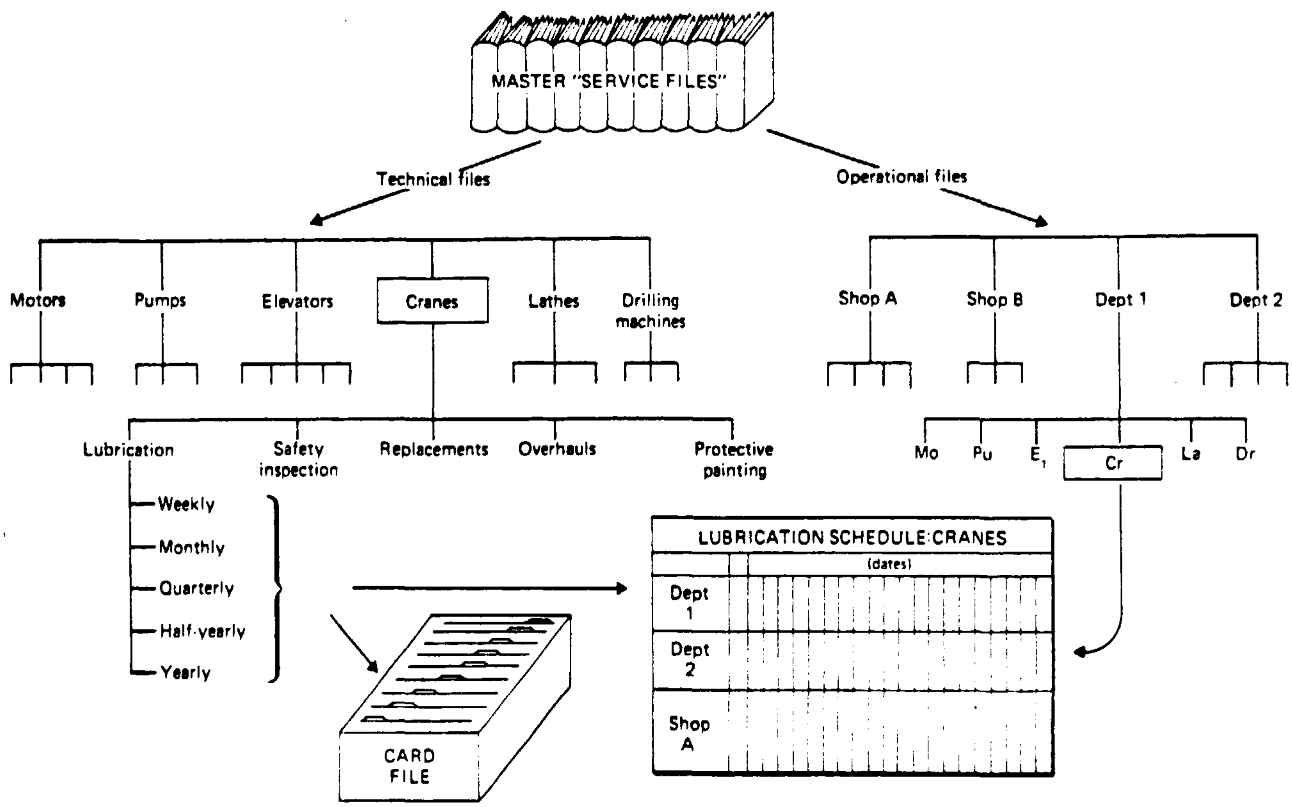


7.6 Organisation of the Service Files

Of course, it is important to keep good order in the service files.

The following figure illustrates an arrangement.

Figure 13: Schematic arrangement of service files. In this example a file for cranes is shown.



The basic documents to be included in the file are:

- inspection check lists (see Figure 14)
- frequency of service (see Figure 15)
- routine maintenance schedule (see Figure 15)

Figure 14: Four types of form for service instructions allowing repeated use either for one or for several units.

Type A

SEMI-ANNUAL INSPECTION CHECKLIST					Code no.
EQUIPMENT					Location
No.	Instructions	Craft	Check	Correction	Remarks

Type B

SEMI-ANNUAL INSPECTION CHECKLIST						Code no.
EQUIPMENT						Location
No.	Instructions	Craft	January 70		July 70	
			Ch.	Correction	Ch.	Correction

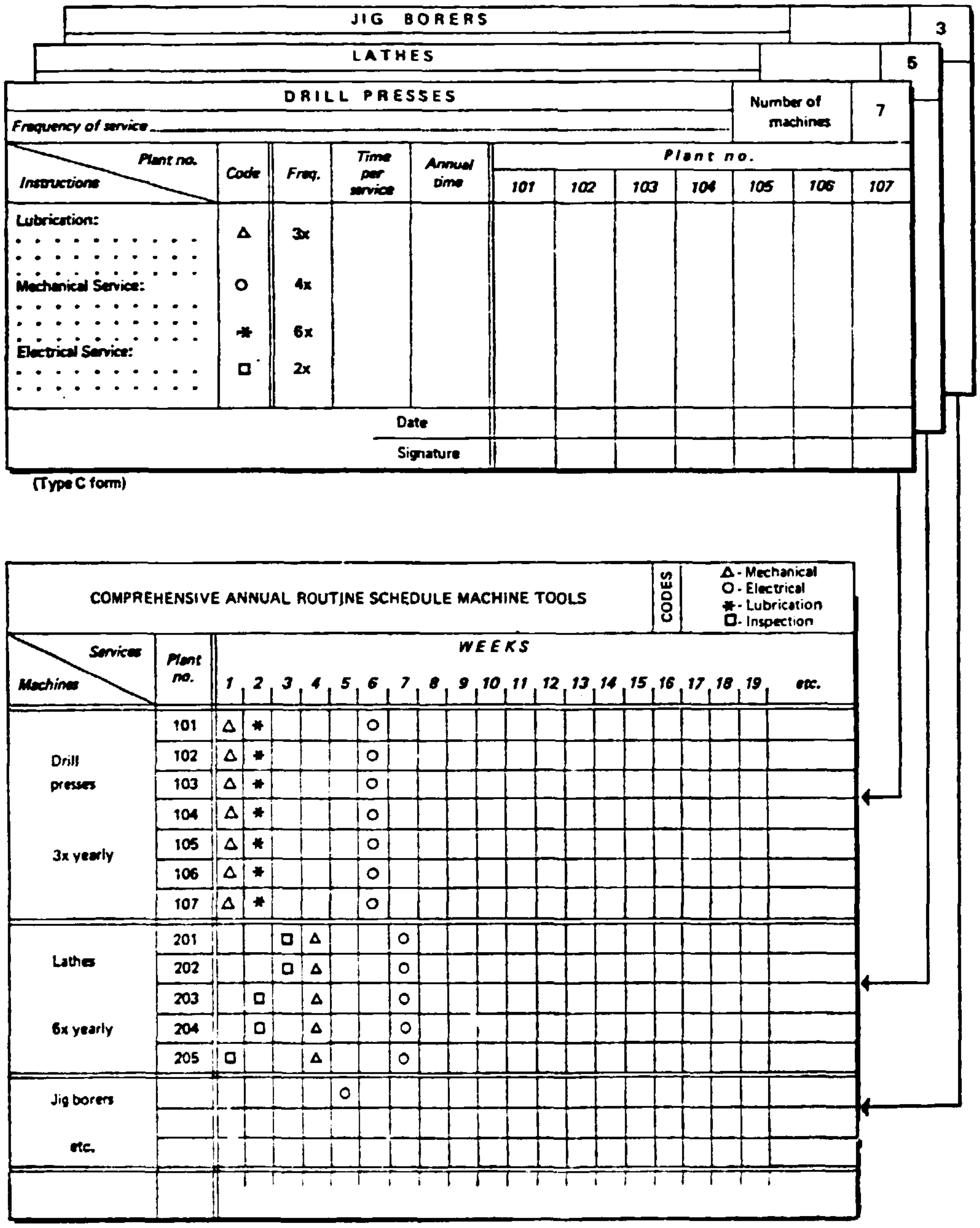
Type C

SEMI-ANNUAL INSPECTION CHECKLIST						Code no.
EQUIPMENT						Location
No.	Instructions	Craft	Boiler no. 1		Boiler no. 2	
			Ch.	Correction	Ch.	Correction

Type D

SEMI-ANNUAL INSPECTION CHECKLIST						Code no.
EQUIPMENT						Location
No.	Instructions	Craft	Boiler no. 1		Boiler no. 2	
			Jan.	Jul.	Jan.	Jul.

Figure 15: Routine servicing of machine tools. Planning and recording by groups of machines is more efficient.



JIG BORERS — 3

LATHES — 5

DRILL PRESSES — Number of machines: 7

Frequency of service ____

Instructions / Plant no.	Code	Freq.	Time per service	Annual time	101	102	103	104	105	106	107
Lubrication:	Δ	3x									
Mechanical Service:	O	4x									
. . . .	*	6x									
Electrical Service:	□	2x									
				Date							
				Signature							

(Type C form)

COMPREHENSIVE ANNUAL ROUTINE SCHEDULE MACHINE TOOLS

CODES: Δ - Mechanical; O - Electrical; * - Lubrication; □ - Inspection

Machines / Services	Plant no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	etc.
Drill presses 3x yearly	101	Δ	*				O														
	102	Δ	*				O														
	103	Δ	*				O														
	104	Δ	*				O														
	105	Δ	*				O														
	106	Δ	*				O														
	107	Δ	*				O														
Lathes 6x yearly	201			□	Δ			O													
	202			□	Δ			O													
	203		□		Δ			O													
	204		□		Δ			O													
	205	□			Δ			O													
Jig borers						O															
etc.																					

7.7 Other useful documents

Practice has confirmed the usefulness of several other types of maintenance records, namely the:

- visual check list (see Figure 16)

- performance test chart (see Figure 17)

- lubrication record (see Figure 18)

- stores issue voucher (see Figure 19)

Figure 16: A visual checklist for inspecting lathes: a typical type. A form that can easily be adapted for repeated use by extending the "remarks" column to the right.

THE UNIMATIC ENGINEERING CO. LTD.

VISUAL CHECK UP SHEET

LATHES

M/C Tool No.

MAKE AND TYPE

SHOP DATE INSTALLED DATE

	Parts to be checked: – ✓ – O.K.; X – Faulty; XX – Very bad	*Remarks on condition, lubrication, and operation*
	HEADSTOCK Bearings Gears and spindle Pilot bar Chuck (pneum, hand) or collet Guards	
	LATHE BED Slideways Bed covers Guards	
	SLIDING SADDLE Slides Lead screw and mechanism Feed mechanism (a) lengthwise Feed mechanism (b) across Stop carrier Covers	
	CROSS SLIDE Slides Feed screw and index dial Stops Tool post, front Tool post, rear	
	TAILSTOCK OR TURRET Base slide Capstan (or tailstock) slide Turret Stops and mechanism Star wheel Feed mechanism, traverse Tailstock barrel and lock (C.L.)	
	DRIVE Forward, stop, reverse Speed handles Brakes and clutch Gearbox Belts and guard	
	LUBRICANTS Oil pump and indicators Coolant pump Suds pipes	
	MISCELLANEOUS Lighting fixtures Electric switchgear Electric motor	

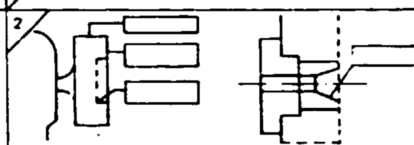
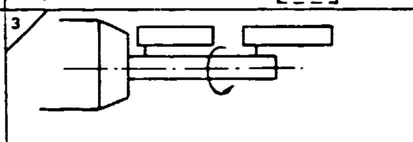
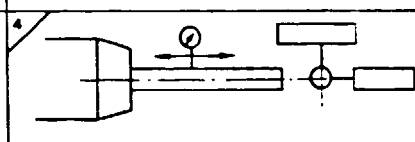
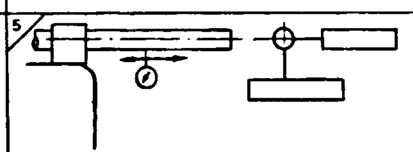
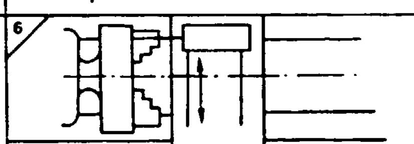
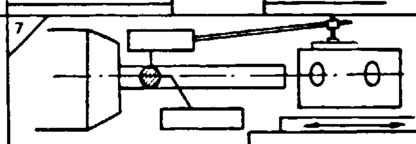
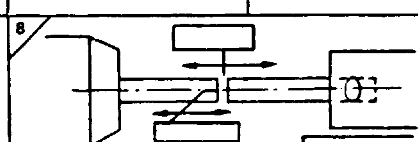
(a) What spares are required?
(b) Is a new coat of paint advisable?
(c) Is there excessive vibration when on heavy load?
Is there excessive vibration when on light load?
(d) Overall condition: Very good, Average, Poor.
(e) This plant is used: Continuously, Frequently, Occasionally.

Figure 17: Example of a performance test chart for capstan lathes.

PERFORMANCE TEST CHARTS FOR CAPSTAN LATHES — M/CT. no.

Make and type ....

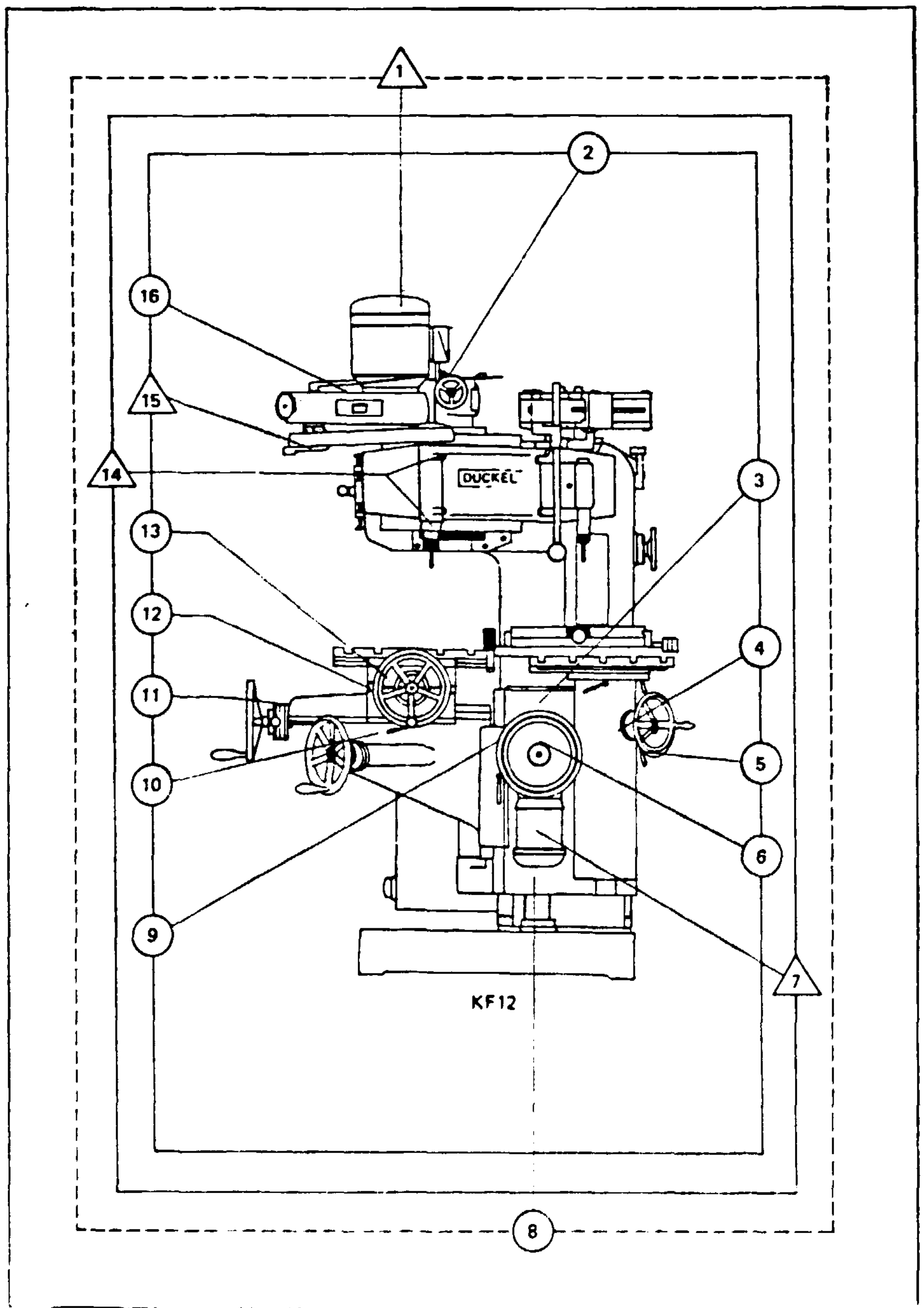
Shop .... *Inspected by* .... *Date* ....

Test	No. / Diagram	*Allowed tolerance*
Levelling Lengthwise and across	1	0 00025 in per foot
Spindle—slip or float. *Chuck*—outside and inside dia. *Collet*—seating	2 	0·00025 in
Spindle axis—true Test by spinning mandrel.	3 	(A)0·0005 in (B)0·0001 in
Spindle axis Parallel to bed. (Horizontally and vertically.)	4 	0·001 in per foot
Pilot bar Parallel to bar. (Horizontally and vertically.)	5 	0·001 in per foot
Cross slide Movement parallel with face of chuck.	6 	0·001 in per foot concave only
Concave slide In alignment to bed. (Horizontally and vertically.)	7 	0·001 in per foot forward or rising towards free end only
Turret tool holes In alignment with spindle axis. Turret play (horizontally and vertically).	8 	0·001 in upwards or forwards at free end only

	CROSS SLIDE		TURRET	
PRACTICAL TESTS	a Turning round		a Turning round	
	b Turning cylindrical		b Turning cylindrical	
	c Facing square		c Turret repeat position	
	d Tool post repeat position			
	e Feed dial repeat accuracy			

Fill in the boxes ☐ with the values found during measurement

Figure 18: A lubrication diagram in which the frames refer to different periods of service and the circles and triangles to the types of service.



STORES ISSUE VOUCHER No 951

To: Store Keeper .... Factory: ORIGINAL

From: (Section) ....

Date: ....

A/C. Code ....

Store Code	Item No.	Description of item	Destination of item: Equipment no. and description	Unit	Quantity		Rate	Value	
					Requir.	Suppl.		Y.D.	File

Requested By: ....   Issued By: ....

Approved By: ....   Received By: ....   Date ....

Figure 19: Stores issue voucher

8. CALCULATING THE COSTS OF MAINTENANCE

The costs of the maintenance service are calculated for two reasons:

- to determine how much of the total manufacturing cost is attributable to maintenance

- to determine variances from the budget for maintenance for the past year, in order to budget funds for maintenance for the coming year.

This first reason is the concern of general management. The determination of the costs of the maintenance service allows the management to:

- compare the costs of one year to those of another

- compare the ratio of maintenance costs to total manufacturing costs for the factory in PDRY to typical ratios for the industry.

These comparisons allow management to better control the operation of the factory.

The variances from the maintenance budget are just as important for the maintenance manager as for the general manager, because the former must be able to present to management:

- an evaluation of the maintenance service: why less money or more money was spent on maintenance during the year than was budgeted

- proposals for improving the maintenance service

- proposals for undertaking special maintenance projects

- proposals for acquiring new equipment

- analysis of the cost advantages or disadvantages of using outside contractors for some maintenance work.

If the maintenance manager is to convince management that more funds are needed for the coming year, his calculations of costs must be accurately done and well explained. The "explanation" is treated in the next chapter on analysis and budgeting.

There are two main classifications of maintenance costs: capital expenditures and revenue expenditures

8.1 Capital expenditures for the maintenance service

These are part of the maintenance costs and cover the various kinds of maintenance investments which are written off through depreciation to account for deterioration of the investments with time or for obsolence when maintenance equipment becomes out-of-date in terms of inadequate production, high operation costs or uneconomic services.

The capital expenditures cover:

- initial maintenance investments (workshops, tools, diagnostic equipment, etc.)
- renewal or replacement of equipment
- various improvements
- major parts or components.

These costs are usually handled by the general management and the accountants and do not directly concern maintenance personnel. Of course, by maintaining the maintenance department's machines, equipment, and premises, their useful service period will be longer and the capital expenditures reduced in the long run.

8.2 Revenue expenditures of the maintenance service

These are incurred in maintaining the plant's fixed assets and property in safe and satisfactory condition.

These expenditures are usually divided into four sub-classifications:

- Costs of routine or preventive maintenance including:
  - inspection
  - cleaning
  - lubrication
  - routine servicing
  - site overhaul
  - painting

- Costs fo repairs and overhauls (unscheduled maintenance) including:

  . running repairs and adjustments
  . miscellaneous repairs and overhauls
  . breakdown maintenance

- Costs of improvements to maintainability

- Costs of other tasks (such as special projects) done by maintenance personnel.

Each "revenue expenditure" directly concerns the maintenance manager and includes one or more cost elements, namely:

- Labour: the direct cost of the time chargeable to a specific job or activity.

- Materials: plant, equipment and supplies (for example, general stores and sundries, spare parts and components.

General overhead is left to the accounting department. This cost element comprises those portions of the firm's operational overheads allocated to maintenance, for example the maintenance service's proportionate "share" of the total costs to the firm for:

- purchasing and stores service
- transport service
- accident prevention and safety
- training
- canteen services
- medical services
- testing and research
- engineering
- administration.

In order to calculate the costs of the maintenance service one needs all the elements shown in the "Dual purpose form" shown in Figure 20 across the top line:

- manpower category
- time worked, including overtime (hours)
- salary per hour
- labour costs (product of the latter two items)
- costs of spare parts and other materials
- costs of tools and maintenance equipment
- costs of outside work done (under contract).

Adding all of these elements across yields the total cost for each of the four types types of maintenance work.

If the costing form is used periodically, for example for monthly cost reports, the yearly cost-report will be very easy to establish; and, in turn, the next year's budget can be prepared readily.

Figure 20: Dual purpose form:
1) Maintenance cost report
or 2) Budget for maintenance for 19..

	Manpower category	Time incl. overtime	Salary per hour	Labor costs	Costs for spare part +material	Costs for tools and main.equip.	Costs for outside work	TOTAL COSTS
	-	hours	Y.D.	Y.D.	Y.D.	Y.D.	Y.D.	Y.D.
ROUTINE OR PREVENTIVE MAINTENANCE								
REPAIRS AND OVERHAULS								
IMPROVEMENTS OF MAINTAINABILITY								
OTHER TASKS BY MAINTENANCE PERSONNEL								
TOTALS	X	hours	X	Y.D.	Y.D.	Y.D.	Y.D.	Y.D.

9. ANALYSIS AND BUDGETING

9.1 Ground rules

Each maintenance service, whatever the size or the type of industry should have a clear idea about its role, its position and its responsibility inside the firm, its objectives, the benefits expected from its work, the means by which it shall proceed, and the limits in which it shall work towards its objectives.

Knowing these ground rules, it becomes possible, after a certain period, to determine whether the maintenance service is completely and efficiently doing its job and attaining its objectives.

The ground rules must not only be the opinion of the person responsable for the maintenance but, above all, fit in with the general policy of the management and also be accepted by the other departments, especially by the production department.

9.2 "Snapshot"

In order to measure the results achieved by the maintenance service in a given year, it is useful to have a "snapshot" of the plant and the situation of maintenance at the beginning of the year. Such a "snapshot" is composed of a brief description of the following:

- Objectives of the maintenance department
- Position of maintenance within the company's structure
- Technology: modern, average, or old-fashioned
- Degree of mechanisation and automation of the plant
- Degree of standardisation
- Condition of the plant: good, average, or poor
- Percentage of down-time which is acceptable

- Frequency of shut-downs of the plant
- Number of work shifts
- Number and skills of maintenance men
- Equipment of the maintenance-service
- Stocks of spare parts:
  . sufficient?
  . properly organised?
- Skills of operators
- Use of contractors for maintenance-work

A comparison of one year's "snapshot" to another's shows a very general evolution of the plant and the maintenance function.

However, real analysis of the maintenance service is much more thorough, as is shown below.

9.3 Analysis of costs and budgeting

The different kinds of maintenance work to be analysed are:

- routine or preventive maintance
- prepairs and overhauls
- improvements of maintainability
- other tasks performed by maintenance personnel.

For each of these are determined:

- whether the work was done within the budget of the previous year
- the reasons for any variations
- the likely cost for the next year.

For "Improvements to maintainability" and "Other tasks", the projects done in the past year may be "one time" projects and have no carry over to the next year. In such cases, the analysis deals with evaluations of the maintenance department's performance during the past year, and new projects are costed for the coming year.

Table 2 illustrates an analysis done for a factory in Yemen using data from 1983. The costs for each kind of maintenance work are separated into labour costs and materials costs, and totals for each are found.

The column "Explanation of Results" is used for stating the reasons for variations from the past year's budget. A variation means either that:

- the budget for the past year was estimated inaccurately;

or that

- there are problems in the maintenance service which have to be resolved.

In the next column "Implications for Maintenance Plan 1984", one indicates the kinds of actions necessary to address the results stated in the previous column.

Finally, these actions are costed under the relevant columns of Table 2 in the section "Preparing Budget".

In either case, the budget for the next year takes both possibilities into account.

Table 2 is a very useful tool for the general manager as well as for the maintenance manager. On one or two pages a complete analysis is given for one year along with a budget for the next.

The work which goes into developing these one or two pages is not so simple. The following provides some useful tips on doing the background work for the analysis.

The material on which a serious analysis can be started are all the various documents and records. Secondly, by systematic observation and questionning, more facts can be collected.

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Table 2 : Carrying through the results of the analysis to the preparing of the maintenance budget

Legend : + indica…
(—) indica…
— indica…

	ANALYSIS				
	RESULTS FOR 1983		EXPLANATION OF RESULTS	IMPLICATIONS FOR MAINTENANCE PLAN FOR 1984	Manpo… Categ…
	HOURS	MATERIALS			
ROUTINE OR PREVENTIVE MAINTENANCE	Spent 6000 Planned 4500 Excess 1500		lack of proper tools low skill levels unclear maintenance instructions	Aim for 5000 hours Buy new tools Arrange training; plan time . Maintenance manager . Maintenance supervisor . Maintenance workers Plan time for maintenance manager to revise, correct	(— (— (— (— (—
		Spent 950 Budgeted 900 Differ. 50	o.k.	No change from 1983	
REPAIRS AND OVERHAULS	Spent 2500 Planned 2000 Excess 500		lack of proper equipment	Make equipment in-house, certain parts to be sub-contracted	(— (—
		Spent 21'000 Budg. 17'000 Diff. 4'000	Excessive spare parts cost: poor operating improper maintenance poor quality of spares poor design	(Responsibility of prod.dept. Plan time of maint. manager and subordinates to correct Purchase better spares Make improvements	 (— (— (—
IMPROVEMENTS TO MAINTAINABILITY	Spent 2000 Planned 2000 o.k.		Improvement project: Change from original design and replace shear pins	Plan maintenance manager's time Plan time and training for maintenance worker	(— (—
		Spent 900 Budgeted 1000 o.k.	Project terminated on budget New project: Improve quality of boiler feedwater	Buy tools and equipment Buy spares	
OTHER TASKS OF MAINTENANCE PERSONNEL	Spent 1000 Planned 1000 o.k.		Task was installing maintenance system. Work was efficiently done. Continue installation in 1984	Plan time: . Maintenance manager . Maintenance supervisor . Maintenance workers	 (— (— (—
		Spent 350 Budgeted 300 Differ. 50	o.k.	No materials needed for 1984	
TOTALS	Spent 11'500 Planned 9'500 Excess 2'000		Excess time paid is overtime		
		Spent 23'200 Budg. 19'200 Diff. 4'000	Entire difference is spare parts cost		

SECTION 1

Legend :
+ indicates increase for budget year
(—) indicates a budgeted quantity in either hours or dinars
— indicates the carry through from analysis to budget

	PREPARING BUDGET							
IMPLICATIONS FOR MAINTENANCE PLAN FOR 1984	Manpower Category	Time (hours)	Salary per hour	Labour costs	Costs of spare parts and materials	Costs of tools and mainten. equipment	Costs of outside work	TOTAL COSTS
Aim for 5000 hours →	(—)	(—)	(—)	(—)				
Buy new tools →						+		
Arrange training; plan time								
. Maintenance manager	(—)	(—)	(—)	(—)				
. Maintenance supervisor	(—)	(—)	(—)	(—)				
. Maintenance workers	(—)	(—)	(—)	(—)				
Plan time for maintenance manager to revise, correct	(—)	(—)	(—)	(—)				
No change from 1983								
Make equipment in-house, certain parts to be sub-contracted →	(—) (—)	(—) (—)	(—) (—)	(—) (—)	+	+	+	
(Responsibility of prod.dept.)								
Plan time of maint. manager and subordinates to correct	(—) (—)	(—) (—)	(—) (—)	(—) (—)		+		
Purchase better spares →					+			
Make improvements →	(—)	(—)	(—)	(—)	+	+	+	
Plan maintenance manager's time →	(—)	(—)	(—)	(—)				
Plan time and training for maintenance worker →	(—)	(—)	(—)	(—)			+ (training)	
Buy tools and equipment →						+		
Buy spares →					+			
Plan time:								
. Maintenance manager →	(—)	(—)	(—)	(—)				
. Maintenance supervisor →	(—)	(—)	(—)	(—)				
. Maintenance workers →	(—)	(—)	(—)	(—)				
No materials needed for 1984								
		(—) hours		(—) Yemeni dinars				
					(—) Yemeni dinars	(—) Yemeni dinars	(—) Yemeni dinars	(—) Yemeni dinars

The analysis should find answers to a great number of fundamental questions:

- Do the personnel:
  - understand the plant's policies and objectives?
  - have good knowledge of the plant's equipment, weak points, and origins of breakdowns?
  - know and understand all of the different kinds of maintenance work?
  - have a good sense for the plant's cost- problems?
  - have good knowledge of the materials used in maintenance?
- What is the level of maintenance standards?
  - what instructions are given?
  - has the plant the necessary tools, materials and equipment to reach the prescribed standards?
  - is the necessary paper-work done, filed properly and used?
- What is the quality of the lubrication instructions? Are they known and used properly by maintenance workers or operators?
- How well are repairs of failures organised and undertaken?
- How well is the spare part control organised and how well is the replacement of missing spare parts done?
- What are the plans for improving the maintenance by training courses, introduction of more modern and efficient methods, and continuous controls?
- What are the obstacles to improvements to the maintenance service?
- What incentives are being applied for encouraging improvements?

The analysis of the maintenance records for a given year should also lead to actions for improving the maintenance service. For example, the analysis should enable the maintenance manager to:

- Determine which equipment should be improved (modified) in order to prevent failures from occuring
- Determine which parts of equipment should be studied for estimating their useful service period
- Determine which equipment should be inspected in order to establish or revise inspection standards
- Determine which maintenance work would be more suitable for contracting rather than for performing in-plant
- Determine the maintenance work that can be done to shorten repair and preventive maintenance times
- Determine the parts for which drawings need to be made
- Determine the steps to take for establishing standard time limits for doing maintenance work
- Establish or revise spare parts standards as needed
- Revise operating manuals
- Clear up differences among different teams as to the responsibility for certain tasks
- Draw conclusions for design changes for improving reliability and maintainability.

Of course, the analysis must also treat costs, the subject of the previous chapter.

10. SPARE PARTS

Usually the supplier recommends which spares should be ordered with new equipment. Here one has to be careful, as some suppliers have the tendency to recommend the ordering of much too many spare parts. But it does happen sometimes that the supplier does not know the working conditions of the equipment (climate, type of energy, kind of available maintenance) in the client's country and recommends too little.

To determine the necessary quantities, one should know what is already in the plant, what can be easily bought in the country, and what could be made in the plant itself. It is also important to know what guarantees the supplier can offer in sending more spare parts, according to transport, export/import- and other administrative difficulties, delays, strikes, etc. The reliability, efficiency and commercial honesty of the supplier must also be taken into account, as well as the credibility of the given delivery-dates. This is especially important when the frequency of use of new spares is fixed in advance, as in planned complete overhauls.

The planning and organisation of a spare part service varies greatly according to the size and the kinds of fixed assets of the factory. However, a few basic principles always remain the same.

All the spare parts and materials have to be stored in such a way that they are kept in perfect working order, are easily found and obtainable. At any time, the quantities of each part must be known. This implies an administrative system adapted to the size and the needs of the plant. All the details of such systems are given in the "Maintenance Manual for Industries in PDR Yemen" prepared by Mr. F.H. Schueller. The chosen system must also allow a very easy and simple way to record the required quantities of new spares at the right time.

The most important aspects of spare parts stores are:

- the perfect order and cleanliness of the stocks
- the quick availability of the necessary spares
- the permanent control of the stocks
- routine and timely replacement of missing parts
- a well organised system of reconditioning of spares
- the scrapping of useless spares.

Finally, the responsibility of the stores must be entrusted to a qualified and very reliable person. The financial responsibility is immense, for, if he neglects to recorder spare parts in due time, it might lead to a long down-time and great losses to production. On the other hand, if the exact inventory is not kept, too many spare parts might be ordered and stored, thus blocking important financial means that might be urgently needed for meeting other needs.

11. MANAGING THE MAINTENANCE SYSTEM IN A FACTORY IN PDRY

While the various factories in the PDRY have different qualities and styles of general management and maintenance management, some general recommendations can be given for making step-by-step improvements in maintenance management. The latter can only be continuously improved if general management gives it an appropriately high priority. Moreover, communications between the maintenance manager, the general manager, and the manager of finance/accounting must improve.

11.1 Steps for improving the environment for maintenance management in the PDRY

- Improve communications with General Management

  Perhaps the most important step towards improving the environment for maintenance would be for the maintenance manager and the general manager to agree on a system for reporting the results of the maintenance department. Especially important would be the monthly reporting of costs and the analyzing of results and drawing-up of a new maintenance budget at the end of the year.

  By agreeing on and using this essential reporting system, both the maintenance manager and the general manager would be able to see in writing the results of a month's or a year's maintenance work and would be better able to arrive at decisions on policy, manpower, and purchasing for maintenance.

- Improve the system for maintenance

  The maintenance manager should, of course, apply the basic lessons of this training course: how to set up or improve a system for maintenance. The recommendations of the consultants for each factory's system should be acted on immediately.

- Transfer all physical maintenance of equipment from maintenance manager to the maintenance staff

  As stressed in the classroom portion of the training course, one of the main objectives of the course is to show the maintenance manager ways of getting free to manage rather than doing maintenance. Improving the basic system is not enough, of course; the maintenance staff must become responsible enough and skilled enough to do its part. In any case, the transfer cannot happen if general management does not make it a policy of high priority.

- Secure the resources necessary

  The maintenance manager, on his own initiative, must:

  - Negotiate for the funds, materials, and facilities he needs to improve the maintenance system:

    . printing of job cards, etc.
    . buying file storage equipment: card files, file cabinets, etc.
    . securing a proper office/appropriately upgrading the office of the maintenance manager.

  - Negotiate for funds to improve the quality of maintenance work:

    . procuring needed tools and diagnostic equipment
    . training staff.

- Develop and present to general management a plan for eliminating major obstacles to doing good maintenance work

  Much of the maintenance department's time - and especially that of the manager - is spent on trying to cope with chronic infrastructure problems such as those caused by faulty feed water treatment and marginal electrical systems.

By attacking such problems in a resolute way, the company would probably save money in the long run and the maintenance manager would be free to improve the maintenance of productive equipment.

Part of this plan, of course, is cost analysis. The maintenance manager must be able to support his plan with estimates of cost savings which would result.

Only after these basic steps are done can one seriously talk about the other aspects of managing maintenance such as:

- leadership
- supervision
- control.

All these are very nice, but first the maintenance manager must have:

- something to lead (a team)
- something to supervise (a team working in a maintenance system)
- something to control (team-work done in a maintenance system).

12. TRAINING MAINTENANCE PERSONNEL

As mentioned in the previous chapter, the maintenance staff must be trained adequately so that:

- the maintenance manager can be free to do managing instead of doing maintenance;
- maintenance can be done well and in a systematic way.

Training must become part of the system. The more that maintenance is done according to the system, the more time the maintenance manager will have for training. Below are given some recommendations on training.

12.1 Selection

It is assumed that maintenance workers have been selected carefully for their tasks.

Selection should be done so that workers with adequate basic skills are hired in order to minimize the need for training other than the required for the worker to:

- understand the objectives of the factory
- generally understand the processes in production
- learn his maintenance tasks.

It is not appropriate, for example, to hire "electricians" whose theoretical knowledge is so weak that they must be trained in electricity.

As personal qualities, maintenance workers should be cost-conscious and dependable.

12.2 Deciding on who will do training

It must be asked in each factory whether the maintenance manager really has any time to do training. The answer is that in all cases he must find time to do some training:

- in the application of the maintenance system
- in some maintenance tasks.

At the same time, he should delegate some of this responsibility to his assistant if he has one. Here, it can only be said that in factories where the maintenance manager is now overworked, he should have an assistant. The latter could be very helpful in coordinating the introduction and application of the maintenance system.

It must also be decided whether to call on sources outside the factory for training. For example, there are courses sponsored or scheduled by the Ministry of Industry (in lubrication for example), which might also be able to arrange courses in:

- water treatment
- electrical maintenance
- spare parts stores management.

Another very important source of training some factories is the periodic checking and servicing done by technician/trainers sent by equipment suppliers or joint venture partners. While maintenance staff are often working side by side with the technician/-trainer, the real training done is sometimes negligible because:

- the technician/trainer does not speak Arabic and no interpreter is provided
- the maintenance workers are not supervised
- the technician/trainer has developed a negative attitude toward trying to train in the particular environment.

With adequate supervision and some kind of control by the maintenance manager of what the maintenance workers have learned, the overall result can be greatly improved.

12.3 Determining the training programme

The programme should be kept simple and should first focus on correcting major problems and on the application of the maintenance system. For the latter, a standardized training programme can be developed, using for example, elements of this course. A training outline would have to be developed by the trainer for classroom-type training sessions. The training aimed at correcting major problems should be based on the results of the analysis (as in Chapter 9), and should be flexible.

The maintenance manager should carefully prepare for the visits of technician/trainers sent by equipment suppliers or joint venture partners.

12.4 Preparing the trainee for training

The trainee should be made aware of exactly what is expected of him, that he will be tested, and that there are certain standards to meet.

12.5 Controlling the training programme

As a first measure, records of time spent on different types of training should be kept; the costs of training must be known.

Classroom testing can be done for the more formal kinds of training. Tests should be short but comprehensive enough to give the trainer a good understanding of the progress being made.

Tests using machines and equipment can be done on productive equipment and, when available, on spare sub-assemblies of equipment. The maintenance manager must decide which equipment is best for training.

Standards for the performance of trainees must be developed by the trainer so that he can judge whether the training is effective, for the group as well as for each trainee.

The trainer should make an assessment of each trainee's performance and discuss it with him.

12.6 Following-up the training programme

After the programme, the performance of the trainees must be monitored to reveal their degree of retention of concepts and skills taught.

If the follow-up shows that very few trainees appear to have benefitted much from the training, then there are probably some deficiencies in the training programme which must be corrected.

13. PLANNING FOR MAINTENANCE IN A NEW INDUSTRIAL FACILITY IN PDRY

Two cases are treated in this chapter:

- New facility for an industrial branch where a factory already exists;

- New facility for implanting an industrial branch in PDRY for the first time.

Distinctions are also made between planning new facilities in the public and private sectors. This chapter supplements Chapter IV of UNIDO's "Introduction to Maintenance Planning in Manufacturing Establishments", which provides some useful guidelines and checklists.

13.1 Deciding on what new equipment to purchase in an industrial branch where a factory already exists in PDRY

In this case, quite a lot of knowledge on the maintainability of the machines and equipment of the existing factory has been amassed over the years by different people in the factory from operators and maintenance staff to the General Manager. This knowledge must be tapped, organized, and analyzed so that the new facility will reflect the positive aspects of the existing facility and have designed-in improvements over the negative aspects.

For public sector companies, this knowledge may be difficult to tap by the planners at the Ministry of Industry, because most of it is stored mentally by factory personnel rather than in well-organized, written reports. Likewise, the planner of a new private facility could have some of the same problems unless he has "hands-on" knowledge of the existing problems in maintainability at the existing factory. For both planners, accurate and complete maintenance records and yearly analyses at the existing factory would greatly facilitate the planning of the new facility. In any case, the planner would have to consult operators, maintenance staff, the General Manager to learn the exact reasons for any problems in maintainability; he should not rely completely on written records, however complete and precise they may appear.

Moreover, it should be stressed that experience with the existing plant is not sufficient in itself for guiding all decisions on purchasing new plant, because completely different machines and equipment might very well be under consideration for meeting, for example, the quality and output-rate specifications for the new facility.

In such a case, the planner needs quite a lot of new information on maintainability in order to make a proper evaluation. Once he has all the information from the equipment supplier, the planner should make a tentative evaluation and then discuss it with the key personnel at the existing factory. They can help the planner to establish the correct priorities in his evaluation.

The views of outside experts might also be very helpful, and UNIDO's field advisers might be able to give advice.

13.2 Deciding on what equipment to purchase for implanting a new industrial branch in the PDRY

For such a facility, the evaluation cannot take into account past experience in the country, and good outside advice is essential. Of course, the planner, whether from the public or private sector, can do much of the evaluation himself, but he should collaborate with at least two others:

- an experienced maintenance manager from one of the more modern factories in the PDRY

- a foreign, neutral engineer/consultant; a UNIDO adviser, for example.

Such collaboration would help to prevent the overlooking of some critical points (or at worst, even the entire question of maintainability) and would promote the consideration of an adequately wide range of alternatives.

13.3 Integrating new equipment into an existing planned maintenance system

For the case of an extension to, or an upgrading of, existing facilities, the maintenance manager should prepare the necessary documents and start to train maintenance workers during procurement and commissioning. He must revise his maintenance plan and his budget.

During installation, the maintenance workers should do as much of the fitting as practicable so that they become familiar with the special features of the new equipment. If necessary, an interpreter should work with the foreign installation/start-up crew, who should provide training in maintenance as well as in operation. The chief of this crew can be consulted on the adequacy of the maintenance manager's plan for maintaining the equipment, including his budget for spares.

13.4 Providing a planned maintenance system for an entirely new facility

For any entirely new facility, public or private, the maintenance system starts, of course, with the choice of easily maintainable equipment. The evaluation of maintainability for each item (done before purchasing) provides the planner with all the information he needs to start setting up a planned maintenance system, for example:

- number and types of maintenance personnel
- allowable split (if any) in maintenance tasks between operators and maintenance workers
- maintenance tasks required
- spare parts requirements and estimates of frequency of replacement of parts
- training requirements.

Thus, even during procurement, the maintenance planner can set out a tentative plan and budget for maintenance at the new facility.

At installation and start-up, the plan and budget can be modified to reflect the advice of the suppliers' technicians. During this period, the maintenance "system" is initiated by involving the maintenance workers in the installation and start-up work. This is "hands-on" training and may be just as valuable as the "system" itself. The maintenance manager, of course, is also trained in this way, and he must verify that his subordinates understand the instructions given by the suppliers' technicians.

Moreover, the maintenance manager must organize the large number of technical documents which accompany the new equipment and must see that the maintenance planning documents indicate correct references to the technical data and instructions for each item of equipment.

In PDRY; the success of the maintenance function in a new facility may depend largely upon the degree of understanding by the maintenance manager of the requirements of the new equipment. For this reason, he must have enough time and initiative to see that all his questions on maintaining the equipment are answered early.

14. SPECIAL PROBLEMS IN PDRY

During the consultant's preliminary mission it was found that several chronic problems in maintenance in PDRY merit special attention in training in maintenance:

- steam boiler operation and maintanence
- electrical maintenance.

These are treated separately below:

14.1 Steam boiler operation and maintenance; water treatment

Steam boilers are used to provide process heat in several factories in PDRY including:

- Dairy
- Soft drinks
- Rubber sandals
- Tomato paste.

The degree of proper operation and maintenance of the boilers in each factory varies greatly, with the rubber sandals factory apparently showing the best performance.

The skills for operating and maintaining boilers correctly do exist in PDRY, but they are dispersed thinly. An expert attached to the Ministry of Agriculture appears to be very knowledgeable and capable, and he has been called upon frequently to remedy problems in several factories. He has been invited to present a lecture to the participants.

14. Special Problems in PDRY

It should be emphasized that proper operation and maintenance of boilers is a requirement for safety as well as for achieving operating efficiency, high performance, and extending the service period.

A useful reference on safety is:

Handbook of Industrial Loss Prevention, Factory Mutual System, second edition, McGraw-Hill, 1976.

Reference no. in Information and Documentation Center of the Ministry of Industry:

614.8 (021)
FMEC
1218

Chapter 38, "Boiler furnaces - fuel explosions", provides useful information on:

- causes and prevention of explosions
- safety recommendations
- permissive start and firing sequence
- components of boilers
- diagrams and drawings showing piping, functioning, etc.

The remaining part of this section deals with water treatment for boilers. Proper water treatment is necessary for:

- maximizing operating efficiency
- optimizing the use of fuel and water
- extending the service period.

14. Special Problems in PDRY

Make-up water for boilers in PDRY must be treated in two stages:

- treatment of the water from the source to remove hardness
- treatment of the boiler feed water.

In short, the treatment is done to prevent deposits from forming in the heat transfer elements of the boiler. Deposits are an undesirable insulation and impede the transfer of heat. Deposits can also attack the metal tubes in the boiler so that the tube walls become thin and prone to failure.

Deposits of scale will reduce heat transfer and eventually elevate the temperatures of working surfaces. Scale coupled with overheating will start an accelerating process which must be stopped. If not, the boiler will become less efficient and prone to failure.

Even if deposits do not cause failure, they always waste fuel.

In modern boilers, the temperatures of boiler tubes are high and the heat transfer rate is high. For new boilers, then, high quality water is needed and deposits must be prevented.

A particular problem occurs with the use of returned condensate in order to increase energy efficiency. When the condensate is returned at higher "cycles of concentration", it may contain high concentrations of metallic corrosive products:

- iron, in particular
- copper, to a lesser extent.

Many chemical treatment programs do not handle these elements well enough.

The presence of porous deposits aggravates the problem of iron by leading to a concentration of hydroxyl ions beneath the deposits.

The result is corrosion under the deposits which degrades tube metal and increases the levels of corrosive products in boiler water.

Ion exchangers for make-up water softening or demineralization can increase the cycle of feed-water concentration and minimize blowdown. However, ion exchange reduces make-up water hardness and thus returns iron and copper to the boiler in higher quantities. Iron and copper then become a higher percentage of the total impurities in the feed-water. This must be counteracted.

Another problem of higher cycles of concentration is that if the quality of feed water changes suddenly, scale can form rapidly. Therefore, the water treatment program should allow for such shocks to the system.

There are two types of treatment for boiler feed-water:

- Precipitating treatment
- Solubilizing treatment.

The most common precipitating treatment is the "conventional phosphate" type. The principle is based on the presence of orthophosphate, silica, and hydroxide in water to prevent the formation of calcium and magnesium scale on boiler surfaces. Calcium and magnesium ions are precipitated as a "sludge" which is much less adherent than scale. To reduce even further the adherence of the sludge, organic and polymeric conditioners can be added.

It should be remembered that any sludge is detrimental to modern boilers.

Some limitations of the precipitating method are the following:

- the process has no ability to prevent the formation of iron hydroxide deposits
- magnesium phosphate, highly adherent, can form during periods of excessive phosphate concentration; this often occurs in plants where sodium zeolite softeners are frequently overrun.

14. Special Problems in PDRY

Solubilizing treatment methods keep hardness ions in soluble form, rather than forming precipitates. Thus, fewer suspended solids are present in the boiler water.

This method reduces the potential for:

- agglomeration
- "baking-on" of deposits
- sludge binding.

In addition, precipitation of "side-reaction sludges" cannot occur (basic magnesium and iron phosphate).

There are two kinds of chemicals used in solubilizing treatment:

- those which change the chemical structure of impurities
- those which alter the action of the impurities.

The first are called "chelants" and are sodium salts of the organic acids EDTA or NTA.

Chelants result in better control of iron than in precipitating treatment. Magnesium sludges can occur, but can be dispersed by organic or polymeric conditioners.

A major disadvantage of using chelants is that a high degree of control is required: a low residual value of chelant must be kept, because:

- chelants are expensive
- high chelant concentrations can cause corrosion.

For these reasons it is recommended that treatment of boiler feed-water by chelants not be practiced in PDRY.

The investment department of the Ministry of Industry should not approve such treatment.

14. Special Problems in PDRY

The other type of solubilizing treatment is preferable for PDRY. This type changes the action of the impurities rather than their chemical structure. The chemicals used for treatment abort the growth of scale crystals and disperse the aborted crystals.

The advantage is that exact control is not required.

Another advantage, over precipitating treatment, is that sludge formation is minimized, resulting in a lower potential for problems with iron-bound or baked-on sludges

Iron dispersion is better than with the use of chelants.

Additional chemicals can be added to control deposits. Iron and copper can be chemically reduced by the addition of hydrazine.

* * *

In summary, the following points are stressed:

- the precipitating method and the solubilizing method are both suitable for PDRY, but the chelant method is not suitable.

- treatment of boiler feed-water must be done and done carefully; operators and maintenance personnel must be adequately trained.

- adequate skills exist in PDRY but they are thinly dispersed.

- treatment programs must be carefully designed and implemented.

- corrective treatment systems can be designed: it is possible to remove old deposits by modifying the treatment of boiler feed-water. Much know-how is required, however.

14. Special Problems in PDRY

14.2 Electrical maintenance

The consultants found during the first two missions that many factories in PDRY do not have complete electrical schematic diagrams for the plant as a whole as well as for individual pieces of equipment. The electrical schematic diagram for the whole plant is absolutely necessary for the proper running and maintaining of the factory. A suggested remedy for this problem is that electrical engineers from the Ministry of Industry of from the Technical College assist plant electricians in establishing the necessary diagrams. Students at the Technical College could satisfy the requirement for in-plant experience in this way and at the same time render a most valuable service to industry.

Without such schematic diagrams, the electrical maintenance worker loses much time in finding and repairing fault and may even cause severe damage by being forced to use a trial-and-error approach.

The following are some practical tips on electrical maintenance.

The expense of preventive maintenance is small compared to the cost of repairing extensive damage when unexpected trouble develops in electrical equipment important to plant production. Major mechanical or electrical changes found necessary by periodic inspections can usually be planned so that the equipment can be shut down without affecting plant output. With improper maintenance a failure or breakdown may occur at a time when a machine is loaded and full output is required. Such unexpected shutdowns may seriously affect production.

14. Special Problems in PDRY

A regularly scheduled preventive-maintenance program is the most important factor in correcting electrical defects and preventing electrical breakdowns. Following are the fundamentals:

- Keep equipment clean, dry, tight, and friction-free.
- Check periodically for signs of overheating.
- Lubricate regularly and properly (too much oil or grease may be as bad as too little).
- Keep protective devices in good operating condition, check ratings or settings to be sure they are correct, and make periodic tests under actual overload conditions.
- Set up a maintenance schedule for important equipment.

Inspections should be made by a competent electrician, familiar with the manufacturer's instructions, and equipped with instruments, gages, tools, and other accessories for all necessary tests. Special attention should be given to equipment in hazardous locations.

Electrical equipment manufacturers and electric field service organizations are available to provide maintenance inspections of electrical equipment to supplement the plant's regular maintenance procedures.

Complete records should be kept for each unit of electrical equipment. They are extremely helpful in emergencies to identify quickly and secure replacement parts or even entire units needed before operations can be resumed. Properly recorded data will indicate when repairs can be anticipated or a general overhauling should be scheduled. Certain types of record, for example, periodic insulations-resistance tests may show that failure is imminent and corrective measures urgent.

Include all pertinent information, such as unit number, complete electrical rating or nameplate data, winding connections, coil design, references to electrical drawings of the installation, location, and use. Show the dates when the device was installed, inspected, rebuilt, repaired, or cleaned, and the results of inspections or tests.

14. Special Problems in PDRY

An adequate supply of spare parts for important production units, which experience shows are likely to fail or wear rapidly, should be kept on hand.

Dust, lint, dirt, oil, and moisture separately or in combination are injurious to electrical insulation. Cleanless is very important.

A separate hand-out copied from the Factory Mutual System's "Handbook of Industrial Loss Prevention" indicates maintenance procedures for:

- wiring
- cabinets and conduit boxes
- fuses and thermal cutouts
- light fixtures
- motors
- motor-control equipment
- A-C generators
- D-C generators, rotary converters
- oil circuit breakers
- air circuit breakers
- oil-insulated or Askarel-insulated transformers
- self-cooled dry transformers
- sealed-tank, gas-filled dry transformers
- induction voltage regulators
- current and potential transformers.

Additional topics treated in this hand-out are:

- insulation-resistance tests
- minor electrical defects
- drying wet electrical equipment.

ICME

Chapter 32

ELECTRICAL MAINTENANCE

Approximately one out of every five industrial fires is of electrical origin. Loss experience shows that proper maintenance would prevent about half of these fires. Proper maintenance also increases the useful life of electrical equipment.

The procedures outlined for the care of the common types of industrial electrical equipment are intended to serve as a guide to good maintenance. The recommended program should help prevent electrical breakdowns. It is based on average or specified conditions: the frequency of inspections, cleaning, and other maintenance is subject to modification, depending upon the duty imposed on the equipment and upon local conditions. Special apparatus not mentioned should be cared for as directed by the manufacturer.

Three kinds of maintenance are recognized: (1) repairs after a failure or breakdown; (2) ordinary maintenance, which consists of repairs, adjustment, or replacement of parts shown to be necessary by visual inspections at irregular intervals before a breakdown occurs; and (3) preventive maintenance, which consists of regularly scheduled inspections and periodic dismantling of equipment to check every detail likely to cause trouble.

The expense of preventive maintenance is small compared to the cost of repairing extensive damage when unexpected trouble develops in electrical equipment important to plant production. Major mechanical or electrical changes found necessary by periodic inspections can usually be plannned so that the equipment can be shut down without affecting plant output. With improper maintenance a failure or breakdown may occur at a time when a machine is loaded and full output is required. Such unexpected shutdowns may seriously affect production.

A regularly scheduled preventive-maintenance program is the most important factor in correcting electrical defects and preventing electrical breakdowns. Following are the fundamentals:

1. Keep equipment clean, dry, tight, and friction-free.
2. Check periodically for signs of overheating.
3. Lubricate regularly and properly (too much oil or grease may be as bad as too little).
4. Keep protective devices in good operating condition, check ratings or settings to be sure they are correct, and make periodic tests under actual overload conditions.
5. Set up a maintenance schedule for important equipment.

Inspections should be made by a competent electrician, familiar with the manufacturer's instructions and equipped with instruments, gages, tools, and other accessories for all necessary tests. Special attention should be given to equipment in hazardous locations.

Electrical equipment manufacturers and electric field service organizations are available to provide maintenance inspections of electrical equipment to supplement the plant's regular maintenance procedures.

Complete records should be kept for each unit of electrical equipment (Figs. 32–1 and 32–2). They are extremely helpful in emergencies to identify quickly and secure replacement parts or even entire units needed before operations can be resumed. Properly recorded data will indicate when repairs can be anticipated or a general overhauling should be scheduled. Certain types of record, for example, periodic insulation-resistance tests (Fig. 32–3), may show that failure is imminent and corrective measures urgent.

Include all pertinent information, such as unit number, complete electrical rating or nameplate data, winding connections, coil design, references to electrical drawings of the installation, location, and use. Show the dates when the device was installed, inspected, rebuilt, repaired, or cleaned, and the results of inspections or tests.

An adequate supply of spare parts for important production units, which experience shows are likely to fail or wear rapidly, should be kept on hand.

Dust, lint, dirt, oil, and moisture separately or in combination are injurious to electrical insulation. Cleanliness is very important.

Wiring. Approximately one-third of the fires of electrical origin are caused by wiring.

Monthly

1. Examine wiring that is subject to considerable vibration. Tighten loose fittings, loose supports, lock nuts, and bushings.

Annually

1. Make a complete inspection of wiring.
2. Check ampere load on important circuits. If excessive, provide additional circuits or redistribute the excess to other circuits that are not loaded to capacity.
3. Note the condition and amount of temporary wiring. Replace with permanent construction any

PLANT NO ______ MACHINE NO ______ INVENTORY NO ______ MOTOR NO ______

H. P ______ MANUFACTURED BY ______

SERIES ______ SHUNT ______ COMPOUND ______ SYNCHRONOUS ______ INDUCTION ______

TYPE ______ FRAME ______ SPEED ______ VOLTS ______ AMPERES ______

PHASE ______ CYCLES ______ TEMP RISE ______ EXCITATION AMPS ______ ROTOR OR ARM SER NO ______

MODEL NO ______ FORM NO ______ STYLE OR S O NO ______ SERIAL NO ______

MFGRS ORDER NO ______ OUR ORDER NO ______ DATE ______

CONNECTION DIAGRAM - ROTOR OR ARMATURE ______ STATOR ______

SPECIFICATION	BEARINGS	SHAFT EXTENSION	PULLEY	GEAR	V BELT DRIVE
OPEN ☐	SLEEVE ☐	DIA ______	DIA ______	TEETH ______	NO GROOVES ______ BELT SECTION ☐ A—1/2 X 11/32
EXP PROOF ☐	BALL ☐	LENGTH ______		PITCH ______	☐ B—21/32 X 7/16
DRIP PROOF ☐	ROLLER ☐	KEYWAY ______	FACE ______	FACE ______	PITCH DIA ______ ☐ C—7/8 X 17/32
TOTALLY ENCL ☐					☐ D—1-1/4 X 3/4
VERTICAL ☐					

MOTOR SERVICE RECORD

DATE INSTALLED	LOCATION	APPLICATION

DATE REPAIRED	REPAIRS OR PARTS REPLACED	CAUSE	REPAIRED BY	TOTAL COST

MOTOR SERVICE RECORD

RENEWAL PARTS PUBLICATION NO ______

NAME OF PART	NO PER MOTOR	STYLE NO	PARTS PURCHASED					
			DATE QUAN	TOTAL COST	DATE QUAN	TOTAL COST	DATE QUAN	TOTAL COST
ROTOR OR ARMATURE COILS								
STATOR COILS								
FIELD COILS - SHUNT								
FIELD COILS - SERIES								
FIELD COILS - COMMUTATING								
ASSEMBLED SEG OR COLL RINGS								
BRUSHES								
BRUSHHOLDERS								
BRUSHHOLDER SPRINGS								
BRUSHHOLDER FINGERS								
BEARING - FRONT								
BEARING - REAR								
OIL RING - FRONT								
OIL RING - REAR								

STARTER

CLASS	H P	STYLE OR S O	REMARKS

MOTOR SERVICE RECORD

FIG. 32-1. Typical motor-service record.

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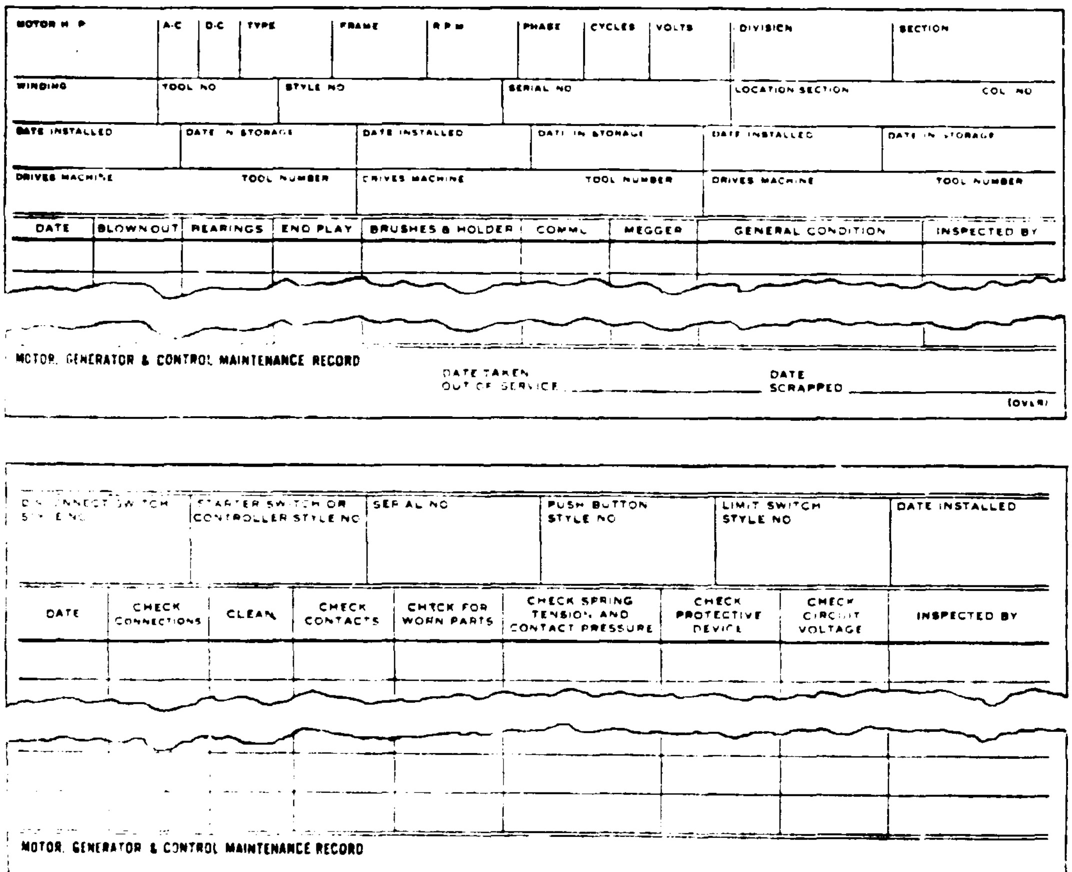

MOTOR H. P. | A-C | D-C | TYPE | FRAME | R P M | PHASE | CYCLES | VOLTS | DIVISION | SECTION

WINDING | TOOL NO | STYLE NO | SERIAL NO | LOCATION SECTION | COL NO

DATE INSTALLED | DATE IN STORAGE | DATE INSTALLED | DATE IN STORAGE | DATE INSTALLED | DATE IN STORAGE

DRIVES MACHINE | TOOL NUMBER | DRIVES MACHINE | TOOL NUMBER | DRIVES MACHINE | TOOL NUMBER

DATE | BLOWN OUT | BEARINGS | END PLAY | BRUSHES & HOLDER | COMM | MEGGER | GENERAL CONDITION | INSPECTED BY

MOTOR, GENERATOR & CONTROL MAINTENANCE RECORD

DATE TAKEN OUT OF SERVICE ______ DATE SCRAPPED ______

(OVER)

DISCONNECT SWITCH STYLE NO | STARTER SWITCH OR CONTROLLER STYLE NO | SERIAL NO | PUSH BUTTON STYLE NO | LIMIT SWITCH STYLE NO | DATE INSTALLED

DATE | CHECK CONNECTIONS | CLEAN | CHECK CONTACTS | CHECK FOR WORN PARTS | CHECK SPRING TENSION AND CONTACT PRESSURE | CHECK PROTECTIVE DEVICE | CHECK CIRCUIT VOLTAGE | INSPECTED BY

MOTOR, GENERATOR & CONTROL MAINTENANCE RECORD

FIG. 32-2. Typical motor, generator, and control maintenance record.

temporary wiring that is in regular use. Remove temporary wiring no longer needed.

4. Support loose wires, cables, or conduit.

5. Clean and paint corroded conduit and boxes.

6. Protect wires at motor terminals that are exposed to physical damage or oily conditions. If flexibility is required and there is considerable vibration, use Type SO or oil-resistant Type ST cord with watertight fittings.

7. Check the protective-grounding connections of low-voltage wiring systems and conduit or metal-raceway systems.

8. Inspect manholes of underground-cable systems. See that the flameproofing of the cables is in good condition.

9. Measure the insulation resistance of wiring. Resistance should be at least 1 megohm per 1,000-volt rating of the conductor insulation.

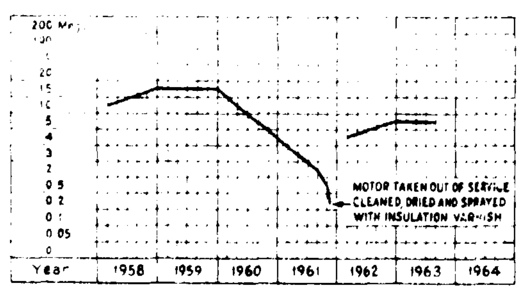

FIG. 32-3. Typical insulation-resistance curve for motor. The pronounced drop in insulation resistance shows the windings to be in a precarious condition and in need of prompt attention. Later tests show the insulation again in safe condition as a result of cleaning and varnishing the windings.

Cabinets and Conduit Boxes

Monthly. Inspect and clean cabinets and conduit boxes in locations where there is considerable lint or dust. If conditions are bad, a weekly cleaning may be desirable.

1. Blow out dust and lint with compressed air.
2. Remove any foreign material.
3. Cover all unused conduit openings.
4. See that doors and covers are in good condition and kept closed. Cover gaskets should be in good condition and in place.

5. See that units are solidly bonded together for grounding.

Fuses and Thermal Cutouts

Semiannually. Inspect fuses and thermal cutouts, unless experience indicates that more frequent checks are needed. The proper frequency of inspections of fuses and thermal cutouts varies in different industries and with different local conditions.

1. Check the ratings of all fuses and thermal cutouts. Attach a list of the correct fuse ratings for each circuit to the inside of the cover of cabinets and cutout boxes to insure correct replacement of blown fuses.

2. Watch for evidence of overheating of cartridge fuses. Replace those having discolored and weakened fiber casings and remove the cause of overheating. Use suitable clamps to maintain good contacts where fuse clips have lost their tension, or replace the fuse clips.

3. Watch for fuses that have been bridged with wire, metal strips, disks, etc. Replace with fuses and take steps to eliminate the practice.

4. See that covers of thermal cutouts are in place, and check heater ratings.

Light Fixtures. The following recommendations apply both to incandescent and fluorescent fixtures:

Semiannually

1. Replace worn or damaged pendent cords, preferably with pipe pendants so that eventually all cord pendants will be eliminated.

2. Replace broken lamp or tube holders, and install substantial guards if the lamps or fixtures are exposed to physical damage.

Motors. Approximately one-fifth of all electrical fires in industrial plants are caused by motors, more than by any other type of electrical equipment except wiring. About two-thirds of the motor fires occur in open motors of over 5 hp.

Weekly

1. Blow out open motors in moderately dusty or linty locations with dry compressed air under pressure not exceeding 50 psi. (Blow out more often if there is considerable dust or lint.) Suction cleaning devices are also available for cleaning motors.

2. Check oil in sleeve bearings. See that oil rings move freely. Make sure that the proper oil is being used.

3. Check the temperature of bearings and other parts by hand. If uncomfortably hot, measure temperature with thermometer. For average applications, temperatures of bearings and other parts should not exceed 90°C (194°F).

4. Check the condition of commutators, slip rings, brush holders, and brushes.

Semiannually

1. Drain, wash out, and renew oil in sleeve bearings.

2. Check grease in ball and roller bearings. Bearings sealed for life require no additional lubrication.

3. Check motor input (amperes).

4. Check motor hold-down bolts, end-shield bolts and pulley, coupling, gear, and journal keys or set screws.

Annually. Dismantle, clean, and overhaul open motors of over 5-hp rating as follows.

1. Wash off oily deposits with a petroleum naphtha solvent having a flash point of at least 110°F. Approved wash cans and tanks should be used for washing with flammable solvents. Avoid the use of low-flash-point solvents; they introduce severe fire and explosion hazards. If motors are too large for wash tanks, cleaning should be performed in a well-ventilated safe location. Various nonflammable chlorinated solvents or practically nonflammable mixtures may be used. They introduce problems of toxicity, however, unless proper ventilation is provided, and they may be injurious to certain insulations.

2. Check all electrical connections for looseness.

3. Check the condition of coil insulation; replace loose slot wedges and loose or corroded banding wires. Examine amortisseur windings on synchronous motors and squirrel-cage windings on induction motors for broken brazed joints or loose connections.

4. Check bearing wear and rotor clearance. Check more often than yearly, if necessary, depending on the type of motor and bearing and type of drive. Examine noisy bearings promptly.

5. Clean out and renew grease in ball- or roller-bearing housings. Do not use too much grease. Make sure the proper grade and quality are supplied. Bearings sealed for life require no lubrication.

6. Measure insulation resistance. If it is low and the presence of moisture in the insulation is indicated dry out the motor at not over 115 C (239 F) for 6 to 12 hr or until insulation resistance remains constant. The insulation resistance of the armature of motors having Class A or Class B insulation should be at least 1 additional megohm per 1,000-volt rating of the machine.

7. If varnish has deteriorated, dip windings in insulating varnish and bake two to four times depending on operating conditions. Follow varnish maker's recommendations regarding type of varnish, baking time, and temperature. Follow recommended safeguards for dipping and baking in order to prevent fires and explosions. If facilities for dipping and baking are not available, apply a coat of air-drying insulating varnish to the insulated windings.

Every Three Years

Dismantle, clean, and overhaul totally enclosed motors of over 5-hp rating, following the same procedure as for open motors.

Motor-control Equipment

Monthly. Under average conditions inspect and clean motor-control equipment monthly, but if it operates many times a day, inspect and clean weekly. The proper frequency of inspecting and overhauling of this equipment depends upon the frequency of motor starts and other local conditions.

1. Inspect copper-arcing tips; if rough, dress with sandpaper or a fine file.

2. Clean and tighten all connections and lubricate bearings.
3. Check the level and condition of oil in oil-immersed equipment.
4. Keep covers closed and latched and enclosures tight.

Annually

1. Renew contacts when approximately two-thirds of their thickness is worn away.
2. Remove deposits from arc chutes and barriers.
3. Renew barriers before they are burned through.
4. Check contact pressure and alignment.
5. Check controllers for undesirable grounds.
6. Check settings of all automatic-tripping units, and test their operation, including that of the tripping mechanism.

A-C Generators

A. Steam-turbine-driven, Air-cooled

Annually, except as noted

1. *a.* Make a thorough visual internal examination of both the recirculating and nonrecirculating types. Have the examination done by a qualified person, preferably a representative of the manufacturer. After the first two years of operation of the recirculating air-cooled types, however, the examination may be made every two years for the next 18 years and annually thereafter.

b. In addition to the visual examination, include the following:

Remove the end bells.

Clean the stator and field windings.

Revarnish stator coils where conditions require.

Check stator and field windings for looseness in slots, tightness of slot wedges, condition and tightness of blocks and spacers, condition and tightness of twine lashings, evidence of tape separation, and evidence of damage to the insulation due to corona discharge.

Examine rotor-retaining rings and slot wedge for signs of overheating and cracking.

Check the bearings.

Check collector rings, brushes, and brush holders.

Service the exciter.

Immediately correct any improper condition such as looseness, abrasion, tape separation, etc.

Check vibration of machine before and after each overhaul.

2. Test the insulation resistance of the rotor and stator windings.
3. Following a satisfactory insulation-resistance test, make a dielectric absorption, overpotential, or insulation power factor test. After the first two years, this examination may be made every two years for the next 18 years but annually thereafter.
4. Carefully inspect the oil lines, steam lines, valves, fittings, and other hot surfaces of the turbine.

Inspect all oil lines for the generator.

Immediately eliminate all oil leaks and vibration in parts that might cause leaks.

Protect connections for gages and similar accessories from mechanical damage.

Maintain adequate insulation on all steam pipes, steam chests, stop valves, and other hot surfaces to prevent ignition in event of oil escape.

B. Steam-turbine-driven, Hydrogen-cooled

Annually, except as noted

1. Make a thorough visual examination. After the first two years of operation, the examination may be made every four years for the next 16 years and annually thereafter.
2. Carefully service each machine as outlined in detail under items 1*b* and 2 to 4, inclusive, for Air-cooled Generators.

C. Hydraulic Turbine- and Engine-driven Synchronous Condensers and Frequency Changers

Annually, except as noted

1. Carefully inspect, test, and service air-cooled machines as outlined in items 1, 2, and 3 under Steam-turbine-driven A-C Air-cooled Generators.
2. Examine and service hydrogen-cooled hydraulic turbine-driven generators and hydrogen-cooled synchronous condensers as specified for steam-turbine-driven, hydrogen-cooled A-C generators.

D-C Generators, Rotary Converters

Weekly. Inspect bearings, commutators, brushes, and brush holders. Recondition if needed.

Annually. Test insulation resistance.

Every Two Years

1. Check bearings and air gaps.
2. Recondition commutators, brushes, brush rigging, and slip rings.
3. Clean windings and revarnish them if conditions require.
4. Examine rotor-band wires for corrosion or looseness. Replace if necessary.
5. Check rotor coils, washers, and coil braces for looseness or mechanical defects.

Oil Circuit Breakers

After Every Automatic Operation during Fault Conditions. Inspect breaker and test condition of oil and contacts of important breakers.

Annually. Make complete inspection and overhaul at least once a year, according to the following outline. The frequency of complete maintenance inspections is usually based on the number of circuit-breaker operations or the condition of the oil.

1. Test oil. If the dielectric strength of the oil tests lower than 22 kv, recondition or replace it.
2. Thoroughly clean all parts, inside and outside, and lubricate parts requiring it. Particular attention should be given to cleaning of operating and tripping mechanisms and bushings.
3. Check contact alignment and adjustment, and replace contacts if necessary.
4. Dress lightly rough places on contacts with sandpaper or a fine file.
5. See that lift rods of oil circuit breakers are not warped or cracked.

6. See that latches and triggers are properly adjusted and not badly worn or corroded.

7. See that flexible shunts, if any, are in good condition and securely fastened.

8. Examine main-current path for evidence of overheating, which may be caused by poor main contacts, insufficient capacity of leads, or defective soldered joints.

9. Check pins, bolts, nuts, and general hardware; tighten where necessary and replace damaged or worn parts.

10. See that auxiliary switches are tightly mounted and that contacts are in good condition.

11. Check control wiring for loose connections.

12. Check settings of automatic-tripping units and test their operation, including a test of the minimum control-circuit voltage required to trip important breakers.

13. Check adequacy and reliability of circuit-breaker tripping current source (motor generator sets, rectifiers, batteries).

14. Lubricate bearings, gears, etc., in accordance with manufacturer's recommendations.

15. Check adequacy of the interrupting capacity whenever changes are made that would increase the available short-circuit current.

Air Circuit Breakers

After Every Automatic Operation during Fault Conditions. Inspect breaker and check condition of contacts of important breakers.

Annually

Make a complete inspection following the procedure outlined in items 2 to 15 inclusive, under Oil Circuit Breakers. Clean the arc-quenching or deionizing mechanism of air circuit breakers. See that arc chambers are properly aligned and securely fastened.

Oil-insulated or Askarel-insulated Transformers.

These transformers usually operate for years with little attention and are often neglected unless a regular schedule of inspections is followed.

Weekly

1. Check transformer temperature. The oil temperature of self-cooled transformers should not exceed 80°C and that of oil-immersed water-cooled transformers should not exceed 75°C even for short periods.

2. Check liquid level and look for leaks.

3. Check frangible relief diaphragm of the conservator type.

4. Investigate the cause of any unusual noise.

Monthly

1. Check the load (amperes) on important transformers if changes have been made in power consumption.

2. Clean dirt and dust from exterior.

Semiannually. Service transformer 10,000 kva and larger as follows.

1. Test the dielectric strength and acidity of the oil or askarel. If the oil tests lower than 22 kv or the askarel lower than 25 kv, replace or recondition it.

2. Clean and test bushings for invisible cracks and other defects.

3. Measure insulation resistance of primary and secondary windings.

4. Check tap changers and load-ratio-control apparatus when provided.

5. Check ground connections of transformer cases.

Annually

Service transformers rated 100 to 10,000 kva. Follow the same procedure as for 10,000 kva and larger units.

Every Five Years

1. Remove manhole covers and make an internal inspection.

2. Check internal connections and check for evidence of moisture and heating, such as charred insulation or odor of overheated insulation.

3. Check surfaces of coils and core for dirt or sludge. If sludging is evident, it may be necessary to lift the core and clean the core, coils, and inside of the case.

Every Ten Years

1. Drop the liquid level to expose the core sufficiently to determine the extent of sludge [illegible] tions and need for [illegible].

2. Make a careful internal inspection [illegible]

3. If dirty, clean coils [illegible] with a stream of clean dry air [illegible]

Air-blast Dry Transformers. These units may be used with rotary-converter installations.

Weekly

1. Check the in and out temperatures of cooling air and transformer temperature.

2. Blow out accumulated dirt and dust with dry compressed air at pressure of about 25 psi.

3. Remove dirt and all foreign combustible material from the air chamber.

Annually

Service transformers [illegible] follows.

1. Measure insulation resistance [illegible] secondary windings.

2. Clean the windings and air passages thoroughly.

3. Check operation and tightness of dampers.

4. Check for any loose connections and deteriorated insulation.

Self-cooled Dry Transformers. Above [illegible] and above 600 volts.

Preferably install only in clean, dry locations.

Weekly. Blow out with dry compressed air at pressure of about 25 psi if conducting dusts are found.

Every Three Months

1. Check load (amperes) and temperature of the transformers. Increasing transformer temperatures at normal loads indicate need of more frequent cleaning.

2. Blow out accumulated dust or lint with dry compressed air at pressure of about 25 psi.

Annually

1. Remove all covers and clean windings with a vacuum cleaner, blower, or clean, dry compressed air at pressure of about 25 psi. Give particular attention to cleaning top and bottom ends of winding assemblies and to cleaning out ventilating ducts. Liquid cleaners are undesirable because of deteriorating effects on most insulating materials.
2. Clean bushings, lead supports, tap changers, terminal boards, and insulating surfaces.
3. Tighten loose connections.
4. Look for signs of overheating and of voltage creepage over insulating surfaces.
5. Service tap changers and fan motors if provided.
6. Measure insulation resistance of primary and secondary windings.

For Class B dry-type transformers, the insulation resistance should be at least 2 megohms per 1,000 volts of rating but in no case less than 2 megohms total.

Sealed-tank, Gas-filled Dry Transformers. The sealed, gas-filled dry transformer is enclosed in a steel tank that is filled with nitrogen or perfluoropropane under several pounds' pressure and hermetically sealed.

Weekly. Check gas pressure to make sure that there is proper internal pressure.

Every Three Months. Check load (amperes).

Annually

1. Measure insulation resistance of primary and secondary windings
2. Keep exterior finish clean and prevent corrosion.

Induction Voltage Regulators

Annually

1. Service the external operating mechanism.
2. Measure the insulation resistance of the windings.
3. Test the dielectric strength of the oil. If the oil tests lower than 22 kv, replace or recondition it.

Every Five Years. Remove cover and make careful internal inspection.

Current and Potential Transformers

Annually

1. Inspect, clean if dirty or dusty.
2. Measure insulation resistance.

Relays

Semiannually. Inspect relays a[illegible] of contacts.

Annually

1. Clean relay contacts and replac[illegible]essary
2. Inspect bearings for wear.
3. Check the calibration of relays; operate them to determine whether they will function as intended under fault conditions by setting up artificial conditions under simulated loads.

Lightning Arresters

Annually (preferably in the spring)

1. Inspect; clean exposed insulating surfaces if dirty or dusty.
2. Note any mechanical damage.
3. Check connections and test resistance of ground connection. If resistance to ground is more than 5 ohms, make necessary changes to reduce it to 5 ohms or less. If arresters fail to give proper protection although resistance to ground is satisfactory, they should be tested and reconditioned by the manufacturer or replaced.

Storage Batteries

Daily. Check the voltage of important batteries.
Monthly. Check the liquid level and specific gravity.

INSULATION-RESISTANCE TESTS

Insulation-resistance tests should be made periodically, as previously indicated, and the results plotted. The trend shown by the graph is much more valuable than individual readings. Exceptionally low readings or sudden changes should be carefully investigated.

The insulation resistance of wiring on a winding is the resistance (in megohms) offered to a d-c voltage, tending to produce a leakage of current through the insulation and over the surface of the insulation. Insulation resistance is a function of the winding temperature and of the moisture and dirt present, as well as the condition of the insulation material. Although the insulation resistance is not a definite measure of the dielectric strength of the insulation, insulation-resistance values will give an indication of the suitability of a winding for operation or for an overpotential test.

The insulation-resistance test mainly indicates the contamination of the insulation surface and solid insulation by moisture and other contaminants. Usually a high value of insulation resistance is an indication of clean, dry insulation but is not evidence that the insulation is free from physical or mechanical weakness. Such weakness may be of a type that does not affect insulation resistance at low voltage but may be the cause of breakdown upon the application of normal working voltage.

Insulation-resistance measurements can usually be made with an instrument known as a "megger." This instrument consists essentially of a direct-indicating ohmmeter with a hand- or motor-operated d-c generator. When tests are made, the electrical equipment should be disconnected from all sources of power and windings should be short-circuited and grounded before and after each test to drain off all residual charges.

Insulation resistance varies with changes in temperature, in humidity, in test voltage, and in duration of test voltage application. Consequently, when insulation resistances measured at different times are to be compared or plotted, they should be measured at a definite temperature, voltage, and duration of applied voltage.

The insulation-resistance test should preferably be made by applying 500 volts of direct current for 1 min at a winding temperature or conductor temperature of 40°C. If the tests cannot be made at the same winding or conductor temperature, all readings should be reduced to a common temperature basis.

In applying a temperature correction the insulation resistance of Class A[1] insulated armature windings of rotating machines and dry transformers can be assumed to double for each 9°C reduction in winding temperature; that of Class B[2] insulated armature windings of rotating machines and dry transformers to double for each 18°C reduction in winding temperature; and that of oil-insulated transformers to double for each 10°C reduction in winding temperature.

Insulation Resistance of Rotating Machines. Graphs of the insulation resistance with all readings corrected to 40°C should be kept, and a relatively low value or a sudden change in insulation resistance should be carefully investigated. If the measured value of the insulation resistance after correction to 40°C is found to be less than the computed minimum insulation-resistance value and cannot be brought up to this value by cleaning, drying, and varnishing the windings and making other minor repairs, the insulation is not suitable for an overpotential test and the machine is not considered suitable for continued service unless the winding is replaced.

Following is the insulation-resistance formula commonly used for testing windings of rotating machines:

Recommended minimum insulation-resistance (R_m) formula for a-c and d-c machine armature windings and for field windings of a-c and d-c machines.

$$R_m = kv + 1$$

where R_m is the recommended (*computed*) minimum insulation resistance in megohms at 40°C of the entire machine winding (R_m at 40°C is the effect of 1 megohm per 1,000 volts plus 1 megohm) and kv is the rated machine voltage in kilovolts

Measured Value of Insulation Resistance

The measured value of insulation resistance R corrected to 40°C should be determined by applying 500 volts direct current between the winding and frame for 1 min. The value of insulation resistance observed and the temperature of the winding at the time of the insulation-resistance test (t°C) should be recorded.

$$R = R_t \times k_t \; 40°C$$

where R = *measured* value of insulation resistance corrected to 40°C, megohms

R_t = observed value of insulation resistance at t°C, megohms

k = 40°C temperature coefficient of insulation resistance as observed for temperature t°C. It is 1.0 when the temperature of the winding is 40°C; for Class A insulation the coefficient is approximately halved for 5 to 10°C reduction in winding temperature; for Class B insulation the coefficient is approximately halved for 15 to 20°C reduction in winding temperature.

R, the measured value of insulation resistance after correction to 40°C, should be at least that of the recommended (*computed*) value R_m.

[1] Class A insulation consists of (1) cotton, silk, paper, and similar organic materials when either impregnated with or immersed in a liquid dielectric; (2) molded and laminated materials with cellulose filler, phenolic resins, and other resins of similar properties; (3) films and sheets of cellulose acetate and other cellulose derivatives of similar properties; and (4) organic varnishes (enamel) as applied to conductors.

[2] Class B insulation consists of mica, asbestos, glass fiber, and similar materials with suitable bonding substances.

Dielectric Absorption Test of Rotating Machines. The dielectric absorption (time-resistance) method for measuring the resistance of electrical insulation principally differs from the short-time or spot insulation-resistance test in that the time of the test is lengthened. A dielectric absorption test essentially furnishes data concerning the relative condition of the insulation with respect to moisture and other contaminants. It is included among the nondestructive types of maintenance tests.

The value of insulation resistance of a winding will generally increase as the time of application of the d-c test voltage is extended. For a clean and dry winding in good condition, the increase will usually reach a fairly steady value in about 10 to 15 min. If the winding is dirty or wet, a steady value will generally be reached in only 1 to 2 min after the voltage is applied. This variation is caused by the dielectric absorption in the insulation.

Insulation-resistance measurements for dielectric absorption tests can be made with insulation-resistance testers in which the test voltage is supplied by motor-operated generators, rectifiers, or batteries. In making the dielectric absorption test, a test voltage of 500 volts direct current should be applied for 10 min. A graph of the insulation resistance in megohms as a function of time should be plotted with readings taken at 2- to 3-min intervals. Temperature readings are not necessary as long as the machine temperature does not change appreciably during the test.

An appreciable increase in insulation resistance during the time that the voltage is applied or a steadily rising curve is usually an indication that the winding is clean and dry. A quickly flattening curve generally indicates a moist or dirty winding. This curve is the result of current leaking through or over the surface of the winding insulation, offsetting the current due to dielectric absorption.

The slope of the insulation resistance vs. time curve is often expressed as the "Polarization Index." The index is the ratio of the 10 to 1 min insulation resistance. The polarization index for a-c or d-c machine windings should be at least 1.5 for units with Class A (105°C) insulation and at least 2.0 for units with Class B (130°C) insulation.

If the results of the dielectric absorption test are found to be unsatisfactory and cannot be improved by cleaning, drying, and varnishing the windings and making other minor repairs, the insulation is not suitable for an overpotential test and the machine is not considered suitable for continued service unless the winding is replaced.

Overpotential Tests of Rotating Machines. Overpotential tests indicate the insulating strength of the winding insulation. Essentially, this test is the only way to establish that the winding is capable of withstanding the specific applied voltage. Alternating potential overvoltage or direct potential overvoltage test, may be used. The test, whether alternating current or direct current, stresses the insulation at a predetermined value above the normal operating voltage. Such a test helps to guard against unscheduled outages of equipment that may be caused by insulation deterioration. If the winding withstands the test, it is presumed to be strong enough to stand up under operating conditions until the next test is made. If the insulation fails during the test, the current and energy involved are small. There is no danger of extensive arc damage such as often occurs if the failure happens during normal operation.

An overpotential test should not be made on machines rated 10,000 kva or less unless either the short-time insulation resistance or polarization index values are satisfactory. Before overpotential tests are made on machines rated above 10,000 kva, it is advisable that both the insulation resistance and polarization index values be satisfactory.

Overpotential tests are made with high-voltage insulation testers having an output range at least as high as the voltage to be applied to the windings. Low-output current is employed in this test.

In making the overpotential test, a specified test voltage to ground should be applied to the armature or field winding for 1 min. Recommended values of a-c or d-c voltages that may be used are indicated below.

Overpotential Tests of Armature Windings

[illegible]	[illegible]
where E is rated voltage of machine	where E is rated voltage of machine

If the armature insulation does not successfully withstand one of these overpotential tests, the armature should preferably be completely rewound. By replacing defective coils, however, the armature may withstand the overpotential test. In this case, if the winding is 20 years or less old, it can be considered suitable for two more years of continued service. Over 20 years old, it is suitable for one more year of service provided the next annual insulation-resistance test is satisfactory.

Overpotential Tests of Field Windings

Rated voltage of field winding	*A-C (rms) test, voltage to ground applied for 1 min*
125	1,000
250	1,500

If the field winding does not withstand the overpotential test, either the field winding should be replaced or the defective coils replaced and the overpotential test repeated.

Insulation Power-factor Tests of Rotating Machines. Power-factor tests are used to detect specific types of insulation deterioration. Indication of moisture, dirt, voids in the insulation, and deterioration by ionization (corona) can be determined. Insulation testing companies can perform the tests or provide test equipment to the machine user. The tests are generally classified as nondestructive.

The power factor of the stator insulation is principally affected by the type of insulation, the test voltage, and the moisture and voids in the insulation. An increase in the power factor over a period of time indicates deterioration. Power-factor tests are generally made with specially designed medium-voltage test equipment. In making the tests, a-c voltages over a range not exceeding 125 per cent of the phase-to-ground rated voltage are normally applied to the windings. The results recorded are compared with those from previous tests on the same or similar machines. If the results are unsatisfactory and cannot be improved by cleaning, drying, and making minor repairs, the insulation is not suitable for an overpotential test and the machine is not suitable for continued service unless the winding is replaced.

MINOR ELECTRICAL DEFECTS

Minor defects are responsible for about half of the fires resulting from electrical causes. The necessary corrective measures are obvious in most cases. It is particularly important to make corrections in occupancies where process materials are readily ignited by electrical defects, as, for instance, in textile plants.

The following is a list of the more common minor electrical defects and their remedies.

Wiring

1. Loose open wiring: wires hanging on pipes, beams, or nails; wires touching each other; or wires exposed to mechanical injury. *Remedy.* Tighten open wires; replace missing or loose knobs and cleats; or insulate with porcelain tubes where wires are in contact with beams, pipes, or other objects. Guard against mechanical damage.

2. Conduit or electrical metallic tubing: loose, poorly supported, badly corroded, or broken fittings. *Remedy.* Fasten conduit rigidly with proper clips or hangers. Replace and tighten missing or loose lock nuts and bushings. Replace corroded conduit and broken fittings.

3. Oil-soaked wiring. *Remedy.* Replace with oil-resistant wires.

4. Flexible metal-clad cable: corroded, oil-soaked, pulled out of connectors, or metal covering broken or flattened. *Remedy.* Support with clips or staples, replace corroded and oil-soaked sections, protect against oil, or use oil-resistant wires in conduit. Keep cable tightly fastened in connectors and replace damaged sections.

5. Temporary wiring. *Remedy.* Replace with permanent installation.

Lighting Equipment

Pendent Fixtures

1. Missing or loose brass shells on lamp sockets or broken or loose porcelain or composition sockets. *Remedy.* Replace missing brass shells; keep shells

snapped tightly in place. Replace broken porcelain or composition sockets, and keep tightly assembled.

2. Lamp holders loose on threaded pipe stems. *Remedy.* Screw socket up firmly, and tighten set screw in cap. Replace fixture wire if worn.

3. Missing guards or missing vaportight or explosionproof globes on lamps in occupancies with highly combustible or readily ignitible materials or gases. *Remedy.* Provide substantial guards, vaportight globes, or explosionproof or dust-ignition-proof fixtures. Keep storage of any combustible material away from lamps.

4. Makeshift paper lamp shades. *Remedy.* Remove paper shades and replace with metal or glass shades.

5. Chain-pull or key sockets in linty occupancies. *Remedy.* Provide keyless sockets controlled by wall switches or ceiling pull switches.

6. Fiber bushings broken or missing from cap of brass lamp socket. *Remedy.* Replace fiber bushing.

7. Cords badly worn. *Remedy.* Replace with Type SO flexible cord.

8. Cord pendants in hazardous locations. *Remedy.* Replace with fixed ceiling units or rigid pipe pendants.

9. Long drop cords wound around nails, pipes, or beams. *Remedy.* Remove cords from nails or other supports. If necessary, relocate fixture to give light where needed.

Extension Lamps

1. Cords worn or oil-soaked. *Remedy.* Replace cord with Type SO flexible cord.

2. Ordinary attachment plugs in linty areas. *Remedy.* Install arc-confining attachment plugs.

3. No lamp guard. *Remedy.* Provide guard. If in linty location provide heavy glass globe also.

Motors

1. Windings: oily or dirty ventiating passages plugged with dust, lint, etc. *Remedy.* Dismantle motors. Wash windings with safe solvents, paint with insulating varnish if conditions require, and clean ventilating passages.

2. Hot bearings. *Remedy.* Check for faulty lubrication, misalignment, improper belt tension, or worn bearings.

3. Severe sparking at brushes on commutators or slip rings. *Remedy.* Resurface commutators or slip rings if badly worn. Replace worn brushes; keep brush rigging clean.

4. Leads oily or dirty. Insulation worn and exposed to mechanical damage. *Remedy.* Replace with leads having oil-resistant insulation, and protect with flexible metal conduit or rigid conduit.

Motor Controllers

1. Handle of starting compensator tied or blocked in running position. *Remedy.* Repair latch or holding coil.

2. Hot case on starting compensator. *Remedy.* Inspect for low or dirty oil or poor contacts. Clean oil reservoir, renew oil, and keep reservoir filled to proper level. Dress or replace contacts.

3. Grid resistances poorly located or not insulated from combustible surfaces. *Remedy.* Locate where dust and lint cannot accumulate and where ventilation is adequate. Provide noncombustible heat insulation between grids and combustible surfaces.

4. Dirt, dust, or corrosion on magnet faces or other metal parts. *Remedy.* Clean magnet faces and other metal parts periodically.

5. Covers not tightly closed or so damaged that they cannot be closed; open knockouts on sides of controller enclosures. *Remedy.* Keep covers in good condition and tightly closed at all times. Plug all unnecessary openings.

6. Cases covered with oil or interior oil-soaked. *Remedy.* Relocate or otherwise arrange controller so that oil does not accumulate on or in it, and clean thoroughly. Replace oil-soaked wires.

7. Contacts arcing unduly. *Remedy.* Dress or replace contacts.

8. Arc chutes or barriers between contacts burned, broken, or missing. *Remedy.* Replace with new arc chutes or barriers.

9. Controller cases filled with dust, lint, or foreign material. *Remedy.* Keep interiors clean. If exposed to severe dust or dirt conditions, relocate or replace with dusttight cases.

10. Loose connections where vibration is severe. *Remedy.* Check frequently and keep connections tight.

Overcurrent Protective Devices

Fuses

1. Ferrule or knife-blade cartridge fuses: contacts corroded or oxidized. *Remedy.* Clean and polish contact surfaces.

2. Fuse clips broken or oxidized from overheating [illegible] clean clips, and [illegible] contact.

3. Cases burned, broken, or [illegible] Provide new cases, assemble fuse tightly.

4. Fuse jumped with wire, nail, copper bar, or other jumper. *Remedy.* Remove jumper and provide proper size fuse for circuit.

5. Circuit overfused: rating of fuse links in refillable fuse exceeds ampere rating of fuse. *Remedy.* Provide fuses of proper rating, and install only proper number of fuse links as determined by ampere rating of fuse.

6. Edison-base plug fuses: coin or metal disk back of fuse shunting fuse. *Remedy.* Remove coin or disk and provide fuse of proper rating.

7. Fuses not enclosed in metal box in areas containing combustible fibers or other easily ignitible combustibles. *Remedy.* Provide tight metal enclosure.

8. Ordinary fuses in hazardous locations. *Remedy.* Remove or install in explosionproof or dust-ignition-proof enclosure suitable for the location.

Thermal Overload Cutouts

1. Caps missing. *Remedy.* Provide new caps.

2. Fusible links replaced with wire loops. *Remedy.* Replace wire loops with fusible links.

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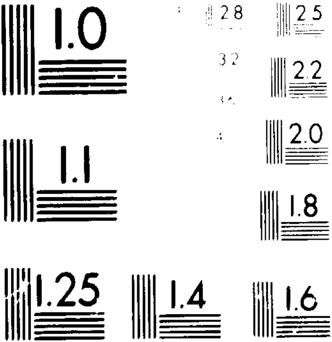

MICROCOPY RESOLUTION TEST CHART

Relays

1. Plunger overload relays with leather bellows: leather stiff from lack of attention. *Remedy.* This relay is obsolete. Replace with new overload relay.

2. Thermal relays for motor running protection too large for proper protection of motor. *Remedy.* Replace with relays that will not permit overloading in excess of 25 per cent for 40 C rise motors and 15 per cent for all other types of motors.

3. Thermal relays bypassed. *Remedy.* Remove bypass and provide proper thermal relay.

4. T[illegible] time-overload relay blocked to prevent [illegible] *Remedy.* Remove block and correct con- [illegible] to be blocked.

Enclosed Disconnecting Switches

1. Switch blades loose where fastened to insulating bar. *Remedy.* Tighten blades or provide new switch.

2. Switch blades burned or oxidized from overheating or poor contacts. *Remedy.* Clean and dress blades, provide new contact clips if tension is gone, or replace with new switch.

3. Rod attached to handle for external operation disconnected from insulating bar attached to switch blade. *Remedy.* Attach rod to insulating bar if spare attachments available or replace switch.

4. Spring for snap action broken, disconnected, or missing. *Remedy.* Replace or reconnect spring.

Transformers

1. Leaking tanks. *Remedy.* Repair leak; refill to proper level.

2. Dirty bushings. *Remedy.* Clean bushings.

3. Wooden platform or timber supports rotted and weakened. *Remedy.* Replace with steel or concrete supports.

4. Low insulating liquid. *Remedy.* Keep liquid at proper level as indicated on gage.

5. Low dielectric strength of insulating liquid. *Remedy.* Test insulating liquid. The dielectric strength of oil and of askarel should be not less than 22,000 and 25,000 volts, respectively.

6. Air-cooled types: accumulations of dirt or conducting dusts on windings. *Remedy.* Blow out windings and clean insulators periodically.

7. Cracked glass on liquid gage. *Remedy.* Replace glass.

Switchboards

Clothes lockers and other combustibles stored behind or in close proximity to switchboard. *Remedy.* Keep area around switchboard clean and free of combustibles at all times.

Lightning Rods

1. Air terminals corroded or broken off. *Remedy.* Replace with new air terminals extending 30 in above top of protected structure.

2. Down conductor broken. *Remedy.* Repair conductor.

3. Down conductor guarded against injury at ground with iron pipe. *Remedy.* Replace pipe with nonferrous pipe or bond both ends of iron pipe to down conductor.

Lightning Arresters

1. Arresters covered with dirt or chemical deposits. *Remedy.* Clean thoroughly and keep clean.

2. Line lead to arrester broken or disconnected. *Remedy.* Reconnect.

3. Ground leads broken off or disconnected. *Remedy.* Reconnect.

DRYING WET ELECTRICAL EQUIPMENT

Electrical equipment that has been submerged in fresh water usually can be dried out with little damage if promptly and properly handled. Delay may result in breakdown of insulation and short circuits that will damage equipment. It is not safe to apply full voltage to wet electrical systems until tests show that they have sufficient insulation resistance.

Salt water presents a more difficult problem. Washing with warm fresh water and drying is sometimes successful, but rewinding motors and generators and replacing wires and cables are often necessary.

Drying Wires and Cables. *Open wiring systems* will probably require no attention except at cabinets, cutout boxes, and outlets.

Conduit systems should be drained, cleared of foreign material, and thoroughly dried out. Covers of conduit fittings should be removed, and, where necessary, low points in the system should be opened up to assure thorough draining. After the conduit system is drained, the safest and most economical procedure is to pull out the wires, swab out the conduit, and install new wires. In any case, short runs of small wiring should be replaced, permitting prompt restoration of service and avoiding serious interruptions later. If excessive heating of insulation occurs, it is usually difficult to withdraw the wires and it may be necessary to replace both conduit and wires.

Compressed air can frequently be used to dry out conduits if suitable means are available for testing the insulation resistance of the conductors. If the insulation resistance of wires and cables tests very low after blowing out conduits and drying the terminals, it is best to replace the wires and cables at once, as it is doubtful that they can be safely restored.

If compressed air or air from industrial blowers is not available and quick restoration of service is imperative, it may be advisable temporarily to install new cables suspended in the open. These should be kept free from contact with metal or wet objects and should be of sufficient length for later use in the conduit.

Metal-clad Cable and Devices. Special attention should be given to circuits consisting in whole or in part of metal-clad cable and to brass-shell lighting sockets and receptacles, snap switches, or other devices containing paper or fiber insulation that may have been so affected as to make complete replacement necessary.

Fuses. All wet fuses should be replaced with new ones. The fiber casing of cartridge-type fuses will probably be distorted and it still damp may carry leakage current. The filler of powder-filled fuses may be caked, making them unfit for service. Plug fuses, even the glass body type, may also be seriously affected by water.

Drying Electrical Apparatus. Electrical apparatus should be washed clean with fresh water and wiped as dry as possible with clean rags.

Full voltage should never be applied to apparatus until insulation-resistance tests indicate that it is safe to do so. Hurried drying may result in a burnout that could be avoided if sufficient time were taken.

Small apparatus such as motors, motor starters, controllers, and protective equipment, can best be dried in well-ventilated baking ovens at temperatures not exceeding 180°F. The drying process should not be hastened by too much heat. Vacuum in addition to heat is effective in hastening the drying-out process. Oil-immersed apparatus should be free of water and moisture before it is put back into service.

Generators and large apparatus can be dried by erecting enclosures around them and applying external heat or by allowing low-voltage current to flow through their windings. Enclosures of noncombustible material, such as corrugated iron, corrugated asbestos, or gypsum board, are recommended; canvas enclosures may become ignited and seriously damage the apparatus. Drying enclosures should be well ventilated, using a motor-driven blower where possible. Temperatures not exceeding 180°F should be maintained in the enclosure by steam pipes, portable electric heaters, or infrared heat lamps kept at a safe distance from the insulation.

If large apparatus is to be dried by the electrical method, it should first be partly dried by external heat, followed by current through the windings at low voltage, sufficient only to produce a temperature not exceeding 180°F inside the windings or 150°F on the exterior of the windings.

Separately excited generators may be dried by short-circuiting the windings at the terminals and running the machines at low speed with just enough field current to produce rated-full-load current in the main windings.

Insulation-resistance Tests. *Electric Circuits.* Insulation-resistance tests are necessary before restoring electric circuits to service because fuses and other overcurrent protective devices cannot give complete protection against high-resistance short circuits or leakage through wet or impaired insulation. Such leakage might be too small to blow fuses or trip circuit breakers but might cause heating and fire.

Insulation-resistance tests are best made with a direct-reading insulation-resistance tester (megger) capable of applying at least 500 volts.

Tests may also be made with a high-resistance d-c voltmeter and a source of d-c supply. The insulation resistance can be computed from the following formula:

$$R_X = R_V \left(\frac{E}{E_V} - 1\right)$$

where R_X = insulation resistance, ohms
R_V = voltmeter resistance, ohms
E = voltage of power supply, volts
E_V = voltmeter reading when connected to the current supply in series with the insulation resistance to be tested

A source of direct current of at least 110 volts is preferable for making these tests. Insulation-resistance measurements made with an a-c voltmeter and alternating current may be inaccurate and misleading.

Tests with an ohmmeter with a battery of low voltage will indicate circuits that are in very poor condition, but a high reading obtained with such an instrument is not an assurance that the circuit will be entirely safe against breakdown when full circuit voltage is applied.

If none of the above test methods is available, an indication of the circuits can sometimes be obtained with a good electrician's magneto. Some magnetos will ring through a resistance of 20,000 to 40,000 ohms and assist in picking out the circuits that have too low an insulation resistance to be returned to service with reasonable safety.

Circuits of 2,300 volts and higher should be given expert attention before being connected to their source of supply.

Electrical Apparatus. Insulation resistance between conductors and frames of apparatus being dried should be measured at intervals to ascertain progress. This can be done by the application of direct current through a voltmeter or preferably by a megger. The insulation resistance of motors, generators, or transformer windings in otherwise good condition is practically inversely proportional to the amount of moisture absorbed by the insulation. The rate of increase of insulation resistance, however, is more significant than any individual value of insulation resistance.

When apparatus is being dried, under the supervision of an experienced electrician, it may be reasonably safe to put the apparatus in operation, carrying light loads, before the resistances indicated by the formula are obtained, as the windage and heat due to the load will usually result in further improvement

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APPENDIX I: DOCUMENTATION

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APPENDIX I: DOCUMENTATION (continued)

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4. Maintenance Scheduling System, James H. Davis, Industrial Engineering, May, 1975

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ICME

APPENDIX 2: GLOSSARY

A

Accessability امكانية الحصول ، الوصول الى شيء

Accounting مايتعلق بالحسابات

Adequate يلائم

Adviser مستشار ، موجّه

Analysis تحليل ، تحليل

Annual سنوي

Assembly تركيب ، تجميع

Assessment تقدير ، تقييم

Assistant مساعد

Auxiliary مساعد اضافي ، احتياطي

Availability وفرة ،

B

Benefit فائدة، مصلحة

Boiler غلاية

Book value سجل اسعار، قيمة دفترية

Breakdown انهيار، توقف

Budget ميزانية، خطة حسابية او مالية

C

Capacity طاقة ، حجم ، سعة

Capital رئيسي ،

Carry out ينجز ، ينفذ ، عمل خارج

Catalogue كتيب المواصفات

Cause دافع ، سبب

Centralised مركز

Certainty احتمال حدوث الشيء بالتأكيد

Chart رسم ايضاحي ، جدول بياني

Checklist قائمة الفحص

Chronic (e.g. chronic problem) معضل ، مشكلة مستعصية

Cleanliness عملية تنظيف الالات لسهولة اصلاحها

Code (equipment codification) ترقيم الماكينات

Communication علاقات ، اتصالات

Component جزء ، وحدة

Condition وضع ، حالة

C (continued)

Contamination تلوث البيئة، الانتاج، السوائل

Continuous مستمر

Contract maintenance تنفيذ مقاولة الصيانة

Control تحكم، ضبط

Cooling تبريد

Correct صائب، صحيح

Correcting تصحيح

Correction عملية التصحيح

Corrosion تآكل، صدأ

Cost قيمة، كلفة

Craftsman العمال الفنيين

Critical حاسم، انتقادي

Critical Path Method (CPM) طريقة مجازيم الأعقد

Crucial وحصيف، حاسم

Cycle دورة

D

Damage ضرب يلزم تغيير

Data بيانات ، معلومات

De-centralised لا متمركز

Defect خلل ، عطب ممكن اصلاحه

Design تصميم

Deterioration تلف

Diagnosis تشخيص

Diagnostic equipment ادوات التشخيص

Diagram رسم بياني

Discipline احترام مصحوب بنظام

Documentation تجميع ، تسجيل الوثائق

Downtime توقف الالة خلال الدوام

E

Economy	مقتصر ، عدم الإسراف ، اقتصاد
Effectiveness	مدى التأثير ، فعالية
Efficiency (of equipment)	كفاءة
Emergency	فجائي ، طارئ
Energy	طاقة
Engi ner	مهندس
Enterprise	مغامرة ، مشروع
Evaluation	تخمين ، تثمين
Expense	كلفة ، صرف ، نفقة

F

Factory مصنع

Failure اخفاق ، عجز

Fault خطأ ، غلط ، جنح

Filter مصفاة ، مرشحة

Fixed asset الاصول الثابتة (الابنية ، المكائن)

Foreman مقدم العمال

Frequency تكرار ، تردد

Friction احتكاك

Function عمل الجهاز ، وظيفة

G

Gantt chart ، Anees chart

Goal منتهى الشوط ، هدف ، مرمى

H

Heat حرارة

History (of repairs, of maintenance, of production) فترة ، عمرة ، تاريخ

Hydraulic يعمل بالسوائل

I

Idle (عمل ماكنة السيارة حتى عند توقفها) عاطل، غير عامل

Implementation تنفيذ - انجاز

Improvement تقدم ، تحسين

Inadequate لا يلائم

Incentive محفز ، باعث

Industry مثابرة ، صناعة

Initial اسم علم ، اولي

Input مدخلات - المال الداخل

Inspection معاينة - فحص

Inspector مفتش ، فاحص

Inventory جرد الموجودات

Investment استثمار ، تقليد منصب ، تطويق

J

Job عمل

K

Know-how المام ، ادراك

L

Layout يُظهر ، يُبرز ، تباعد ، يُجهّز — تصميم عام

Long-range عمل على المدى البعيد

Long-term على المدى الطويل

Loss خسارة ، فقدان

Lost time الوقت الضائع

Lubricant مواد التشحيم

Lubrification عملية التشحيم

M

Machining اشتغال القطع على المكائن (المخرطة ، الكشاطة)

Maintenance contract عقد مقاولة لعمل صيانة ، مراجعة برنامج الصيانة

Manager مدير

Man-hour رجل / ساعة

Manpower الطاقة البشرية

Manufacturing cost الايدي العاملة + كلفة الصناعة من غير ربح

Maintainability مدى امكانية المحافظة (سهلة ام غير سهلة)

Method طريقة ، وسيلة

Modifications تطوير

Monitor مراقب

Motivation دفع ، تحريض ، حث

Motor محرك

N

Network analysis : تحليل شبكات العمل

O

Objective ذو علاقة بهدف معين

Obsolete استبدال ، ازاحة او استبعاد آلة جيدة العطاء ولكنها لا تتناسب مع الاستهلاك

Operating cost - تكاليف التشغيل

Operation rate (of equipment) معدل كفاءة الجهاز

Optimum (Best) نوعية احسن ، نوعية افضل

Organisation مؤسسة ، هيئة ، منظمة

Output نتاج ، مردود ، الخارج

Overhaul صيانة شاملة ، فحص كل الاجزاء

Overhead كل ما يمتد فوق مستوى الرأس -

[illegible]

P

Performance إنجاز ، تأدية عمل

Plan خطة

Policy سياسة

Potential كامن ، جهدي

Power نفوذ ، قوة

Practice عمل ، تطبيق

Pre-condition تهيئة ، تحضير ، إعداد مسبق

Pre-investment إجراء ، تجهيز ، ترتيب سبل الاستثمار

Preliminary أولي ، تمهيد

Preparation إعداد ، تحضير

Priority الأسبقية ، الأولوية

Probable على الأرجح ، أغلب الظن ، probable غالب الظن ، مرجح ، محتمل

Probability أرجحية ، إمكانية الرجحان

Problem مشكل

Procedure إجراء

P (continued)

Process كيفية، امكانية، وسيلة التعامل

Procurement تدبير

Production انتاج

Productivity مدى الانتاجية

Programme برنامج

Properties of materials خواص المواد

Protection حماية، وقاية

Pump مضخة

Purchase يشتري

Q

Qualification مؤهلات

Quality نوعية

Quality assurance سلامة النوعية

R

Range مدى ، مسافة

Rate قيمة ، سعر

Readiness تأهب

Recommendation وصايا ، ترحيب

Recondition تجديد

Record سجل

Reduction تخفيض ، تقليل

Redundancy ، بطالة

Refrigeration تكييف ، تثليج

Reliability كفاءة ، ثبات ، ثقة
شخص

Remedy ما يجب عمله

Renewal استبدال ، تجديد ، تجديد

Renewing تجديد

Repair يصلح ، يرمم

Replace يستبدل - يغير

R (continued)

Replacement تغيير ، استبدال

Report تقرير ، محضر ، سجل

Risk مخاطر .

Routine عادي ، روتيني

Running-in تسليك المكائن

Rust صدأ ، ترب

S

Safety أمان، سلامة

Saving (s) ادخار، نقد

Schedule جدول، برنامج

Scrap خردة

Scrapping تخريد

Service life (of equipment) مدة الخدمة، عمر الآلة

Service manual (كتيب إرشادات الخدمة او الصيانة)

Shift (work shift) نوبة.

Shortage نقصان، تقصير، شح

Short-term قصيرة العمر (أقل من سنة)

Skill مهارة

Skilled workman عامل ماهر

Solution مزيج، حل

Solvent ايا سائل منظف، مذيب، مخفف

Spare parts قطع غيار

S (continued)

Standards ثابت

Steam generation توليد بالبخار

Storage تخزين ، خزان

Supervisor مشرف

Supplier ممون

Supply تموين

Support يدعم

System نظام

Systematic approach
اتباع الخطوات للوصول الى حل مشكلة او اصلاح عطب

T

Table جدول

Task خطوه او مهمه من برنامج العمل

Teamwork فريق عمل

Technician عامل فني

Technique تكنيك

Technology تكنولوجيا

Terotechnology باحث في التكنولوجيا

Test equipment اداة الفحص

Time consuming الوقت المستهلك ، استهلاك الوقت

Tolerance تجاوز حدود التسامح بالقياس

Tools ادوات

Trainer مدرب

Training تدريب

Transport نقل ، مواصلات

Transportation عملية ادارة المواصلات

Trouble shooting ضبط الاخطاء

U

Unit وحدة

Urgent مستعجل

Utility الحاجة

Utilities احتياجات، متطلبات

V

Valve صمام

W

Waste يرف

Wastage خسائر ، فقدان ، اسراف

Water treatment تحليل او معالجة المياه

Wear قابل للتلف

Wear-out التلف

Work-in-process العمل الساري

Work method نظام ، اسلوب العمل

ICME

En tant que société de conseils d'entreprises reconnue et forte d'une longue expérience, nous offrons à nos mandants un ensemble complet de services, dans quatre domaines principaux.

Domaine d'intervention 1: gestion d'entreprise
- objectifs et stratégies d'entreprise
- analyse de l'entreprise
- concepts d'organisation et de direction
- sélection de cadres
- concepts de gestion du personnel
- solution des problèmes de succession
- calcul des coûts
- programmes d'amélioration de la rentabilité
- mandats de gestion temporaires

Domaine d'intervention 2: marketing
- stratégies produits/marchés
- études de marché et analyse de la concurrence
- réseau international de vente
- recherche de partenaires à l'échelon mondial
- expansion aux USA/Japon
- promotion des ventes
- diversification
- innovation/développement
- logistique

Domaine d'intervention 3: engineering
- concepts de production
- conception et projets d'usine
- concepts des flux de matériaux et de stockage
- gestion de projets (project-management)
- analyse de valeur des frais généraux
- rationalisation des flux de documents
- logistique et gestion des matériaux

Domaine d'intervention 4: informatique
- stratégies et concepts globaux de l'information
- concepts de réalisation EDP et choix du Hardware-Software
- planification de détail et mise en fonction
- expertise de votre système informatique
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