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THE MANAGEMENT OF MAINTENANCE IN THE INDUSTRIAL SECTOR

Background paper

Prepared by the  
System of Consultations Division

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## INTRODUCTION

1. Maintenance systems are essential in all economic sectors - industry; agriculture; tourism; construction; electricity and water supply; rail, road, sea and air transport; health services; banking; administration etc, owing to the ever-increasing use of machinery, equipment and instrumentation, which need to be maintained and kept running optimally in order to realize their full potential. The focus of this paper will be maintenance in the industrial sector.

2. Properly planned and managed maintenance systems permit the full exploitation of capital assets by ensuring that machinery and equipment function properly for their predicted life-span or even beyond. Conversely, poorly planned maintenance systems lead to early plant obsolescence and unwarranted replacement costs. Proper maintenance is conducive to higher productivity per unit of capital investment because of the increased availability of equipment. It ensures that products are of better quality, and by increasing efficiency in the use of costly materials, reduces waste and the number of rejects. Proper maintenance forestalls the necessity of correcting or redoing poorly done work, thus avoiding frustration on the part of operators and increasing their productivity rates. It also saves on the cost of consumables and spare parts, as well as on overhead costs, including overtime and energy. In turn, higher productivity and better quality result in a larger output of goods, leading to increased sales and profit. Properly planned and managed maintenance systems help to eliminate hazards at work, thus decreasing the danger to operators and the likelihood of the disruption of production.

3. At the macro-economic level the benefits of maintenance are reflected in a higher gross domestic product; the saving of foreign exchange by the avoidance of the premature scrapping of equipment and excessive importation of spare parts; increased export earnings; and improved balance of trade and balance of payments.

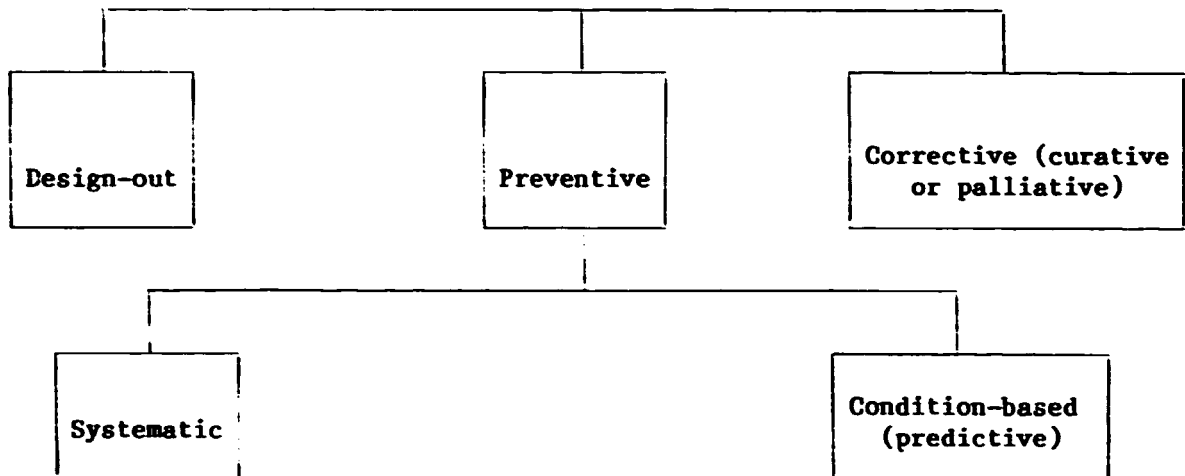
### I. DEFINITION OF MAINTENANCE

4. Maintenance is often defined as total physical assets management. An expansion of this definition is that maintenance is the function of optimizing the effectiveness of capital investment by a real increase in the availability of capital equipment and by adequate conservation methods at a minimum cost. The objective of maintenance is to achieve the lowest combination of the life-span cost and the opportunity cost of production lost by machine unavailability or poor machine performance.

5. This definition implies that maintenance does not start and finish at the shop-floor level, as many people believe. It does not consist simply of oiling, greasing and tightening nuts, or worse, in making repairs after breakdowns. Maintenance requiring integration into a project at all its stages: from project concept through investment studies, specification and tender documents, equipment design, negotiation and acquisition of capital goods, to planning and construction of buildings, and finally installation and operation of the plant.

6. Various descriptions of maintenance, depending on the form that it takes, are given below (see also the figure).

### Forms of maintenance



7. Design-out maintenance is incorporated into the original design or further development of equipment in order to limit the need for maintenance, to improve the maintainability of equipment, to adapt equipment to prevailing conditions in the user's country and plant, to improve the quality and quantity of production and to introduce safety measures in order to avoid accidents. It requires interaction between equipment designer, constructor, supplier and user.

8. Preventive maintenance is the care of equipment to prevent faulty performance or breakdown. It takes two forms:

(a) Systematic maintenance consists in periodic inspection for the purpose of detecting abnormalities and premature wear, and taking remedial action before breakdown. Its aims are the following:

- (i) To limit deterioration of the equipment;
- (ii) To improve the condition of the equipment before it jeopardizes production in terms of quality, quantity or price;
- (iii) To act before the cost of the repair becomes excessive;
- (iv) To eliminate or limit the risk of breakdowns in the case of equipment for which failure entails particularly high costs;
- (v) To reduce equipment down-time during inspections or malfunctions;
- (vi) To facilitate repairs being made under optimum conditions;
- (vii) To avoid excessive input consumption;
- (viii) To eliminate the causes of serious accidents that, apart from social aspects, might result in civil liability on the part of the enterprise;
- (ix) To improve staff morale;
- (x) To reduce the maintenance required;

(b) Condition-based or predictive maintenance is the monitoring of the condition of equipment by measuring and analysing noise, vibration, thermovision, thermography, shock waves, ultrasound, frequency spectra and using spectrometrical oil analysis. This type of maintenance is particularly suitable for expensive, heavy equipment and is attractive, since it does not involve the dismantling of the equipment. Condition-based maintenance consists in taking remedial measures before equipment deteriorates in order to forestall costly breakdowns.

9. Corrective or curative (or palliative) maintenance is the emergency repair of equipment the condition of which requires total or partial shut-down, or operating under unacceptable conditions.

## II. FREQUENT MAINTENANCE PROBLEMS IN INDUSTRY

10. In UNIDO studies, it has been estimated that the life-span of equipment in developing countries is reduced by about 30 per cent owing to a lack of proper maintenance. In a survey carried out in certain Asian countries, it was found that the effective availability of equipment in fertilizer plants and power stations was 65 and 75 per cent respectively; production losses due to poor maintenance amounted to 25 per cent (UNIDO/IPCT.13). In more than 300 maintenance audits carried out in many developing countries, mainly in Africa, it was found that the average technical availability of equipment was only 32 per cent. In 80 per cent of the cases, maintenance-related problems were the cause. In some developing countries, parks of abandoned machinery and equipment, machinery exploited beyond the limits of endurance and safety, spare parts that have been misplaced and cannot be found in the store, reordering of new equipment instead of maintenance and repair are common.

11. Similar maintenance problems exist in many firms in developed and developing countries. For example, the Department of Trade and Industry of the United Kingdom of Great Britain and Northern Ireland is currently undertaking a campaign under the title "Managing into the 1990s" to improve management in industry. One important element that the campaign is addressing is maintenance. In a leaflet entitled "Optimizing plant availability - the Cinderella of UK manufacturing", published to promote good management practices in maintenance, it is stated that:

- . Most companies do not know the cost of down-time ... especially in terms of lost sales opportunities.
- . The competitive advantage obtained from expensive and complex machines and systems is only as good as that company's ability to ensure optimum availability.
- . There is evidence that less than half of British industry monitors its down-time levels and cost.
- . £8 billion (or 3.7 per cent of the value of annual sales in the United Kingdom is spent each year on maintaining direct productive assets ... This does not always represent good value for money.

12. Causes of maintenance problems at the enterprise level include:

(a) The importance of maintenance in the production process is underestimated and as a result is not planned and systematically considered in the overall operations;

(b) Maintenance is looked upon only as a cost rather than as an investment to prolong the life-span of equipment and improve productivity. Insufficient financial, human and material means are therefore allocated to maintenance;

(c) The maintenance department is placed in a minor position on the organization chart (if there is one);

(d) Under-qualified personnel are allocated to the maintenance department;

(e) Insufficient attention is paid to maintenance at the pre-investment and implementation stages, and during the acquisition of equipment;

(f) Methods, programming, job preparation and scheduling, spare-parts inventory control, and data collection and analysis are either non-existent or greatly underestimated;

(g) Data collection on maintenance is deficient, information is not defined, and there is no feed-back of data for evaluation, formulation of policies and improvement of maintenance activities. Technical documentation is not kept in order;

(h) Training in maintenance organization, method and management, especially for engineers and foremen, is not well appreciated by top management.

### III. DIVIDENDS EARNED BY MAINTENANCE

13. The maintenance problems mentioned above are caused by poor management as their importance is underestimated by general managers, financial managers, technical and production managers and supervisory personnel. A corollary is that the measures to overcome such problems are primarily a management function. It is the responsibility of management to formulate maintenance policy and determine the departmental organization of an enterprise, giving the necessary importance to the maintenance department; to allocate the necessary financial, human and material resources for effective maintenance; to recruit and train maintenance personnel; and to provide the necessary workshops, tools and materials. In other words, to create and sustain what could be termed a "maintenance culture" in the enterprise. It is also management that should interact with suppliers, contractors, training institutes, government authorities, and manufacturers' and workers' associations, in order to enhance maintenance. It is therefore imperative to convince managers of the dire necessity of good maintenance practices.

14. As the language that managers understand is expressed in terms of costs and profits, it is necessary to carry out a cost-benefit analysis of maintenance in order to convince managers that maintenance pays. Such an analysis presents difficulties, however, for while the costs of maintenance (labour, consumable materials, spare parts, tools, apportionment of overhead costs) are known and entered in the accounts, benefits cannot be easily quantified. Some managers, therefore, may be tempted to cut maintenance costs, forgetting that they represent an investment that will improve productivity and quality, thereby increasing sales and profit.

15. By utilizing a maintenance information system that allows feedback and comparison of data between periods, however, benefits can be quantified in

technical or monetary terms. There might be, for example, a reduction of the time that machinery is out of action from 20 to 6 hours a month. The value of increased production can then be estimated for the 14 hours gained of machine availability. Reductions in the cost of overtime paid attributable to proper maintenance and of consumables and spare parts can easily be evaluated. The decrease in costs associated with faulty production, waste of materials and rejects also becomes apparent and quantifiable.

16. Other benefits, more difficult to evaluate with precision, include the value of the extended life of the equipment, the increase in business and profits arising from better quality products and the ability to adhere to delivery dates, and the greater motivation and better performance of workers by avoiding the frustration that arises due to poor maintenance. Furthermore, as machines do not operate in isolation, but as part of a production line, the breakdown of one machine may disrupt or cause bottlenecks in that line. The increased availability of one machine has a positive multiplier effect on the whole production. Even the most rudimentary cost estimates of such benefits should be sufficient to convince all managers that a properly planned maintenance system pays dividends.

17. In a project of the International Labour Organisation (ILO) on results-oriented maintenance in Ethiopia (ID/WG.469/4(SPEC.)), 27 industrial enterprises took part in an exercise to move away from the concept of "maintenance after breakdown" to that of "preventive maintenance" by simple good housekeeping methods. The evaluation of the first phase of this exercise by ILO experts, when comparing the second quarter 1983 with the fourth quarter of 1982 revealed striking results:

<u>Results obtained</u>	<u>US dollars</u>
Production increase	5,916,000
Waste reduction	223,700
Saving on spare parts	498,600
Value of extended machine life	<u>323,100</u>
Total	6,961,400
Average improvement per enterprise for the quarter	258,000

18. In the second phase of the exercise involving 45 factories minor modifications to plant and equipment were made to improve maintainability and reduce the incidence of breakdowns, and more sophisticated maintenance technology and managed maintenance systems were introduced. The resulting improvements were quantified at an average of \$US 184,000 per factory over a period of three months. These were additional to the results of improvements obtained in the first phase of the exercise. Thus, factories that took part in both phases made an average gain of \$US 442,000 in three months.

19. In recent case studies on maintenance management carried out in the United Kingdom, it was found that by optimizing plant availability (defined as the point at which the total of down-time costs plus maintenance costs is at its lowest) the following results were obtained:

(a) One capital equipment manufacturer saved £1 million in two years, based on an investment of £100,000;

(b) A food manufacturer increased up-time from 60 to 90 per cent and was able to defer plant expenditure of over £1 million;



(c) A cable manufacturer reduced breakdowns by 52 per cent in one year;

(d) A confectionary manufacturer reduced the hours spent on maintenance by 20 per cent.

#### IV. ORGANIZATION AND METHODS OF MAINTENANCE

20. Maintenance should be seen in the context of the enterprise as a whole. While the enterprise looks to maintenance as a means of keeping its production plant and equipment in good operating order, successful maintenance depends on the rest of the enterprise for support and resources. This interrelationship must be reflected in enterprise policies, which, for example, should include: financial policies facilitating access to fixed capital for equipment, measuring and other tools as well as to working capital for stocking spare parts; personnel policies that allow the recruitment and retention of suitably qualified people; and training policies that ensure the continuous upgrading of maintenance skills.

21. As policies have to be translated into working practices if they are to be effective, it is important to decide which of various forms of organization should be used for maintenance. Some enterprises use a fully centralized maintenance department, with skilled technicians servicing the operating units as required. Others prefer a decentralized structure, with each operating unit having its own complement of maintenance personnel. Yet others use a combination of the two. Similarly, the operating maintenance budget might be centralized in a maintenance department or decentralized under the control of the operational units. Spare-parts inventory control might be assigned to management, maintenance, operations or procurement. Technical documentation could be the responsibility of engineering, operations or maintenance. Each enterprise should use the structure that best suits its particular circumstances.

22. In many cases, poor operational performance is the consequence of unclear policies that imply that the task of maintenance is to keep the machines operating by repairing breakdowns. These implicit policies lead to operating difficulties. Because they do not clearly define authority and responsibility, nobody knows precisely what is to be done, when and by whom. Maintenance policies must be explicit, written policies that assign authority and responsibility by nominating personnel to be permanently in charge of and held accountable for maintenance. These policies must be implemented by management, otherwise they are useless.

23. Like all functions in an enterprise, maintenance must be managed, and good management depends critically on good information systems. The maintenance department should have an internal information system on such things as machine inspection reports and work orders from other departments, which are needed for day-to-day management and which can be used to develop machine histories and spare-parts consumption forecasts. A system of reporting on the effectiveness of maintenance is also necessary, covering such items as the loss of production due to shutdowns (scheduled and unscheduled) and to poor quality attributable to inadequate maintenance. These reports can be used to compare performance with accepted standard figures for the industry, showing monthly or annual improvement or deterioration. Enterprises should develop their own systems for estimating the benefits of improved maintenance as a tool for preparing maintenance budgets on a rational basis. Information obtained by comparisons between firms and by participation in professional associations is useful in this process.

24. Developing and implementing effective maintenance policies is a complex matter. It is often necessary to recruit an experienced maintenance specialist at the senior management level who can take charge of this process. It may also be necessary to seek assistance from outside the enterprise, from consultants or training institutions. Although the actual operation of a well-organized maintenance system is not particularly difficult, setting up such a system can be very complex, involving the following simultaneous steps: establishing new documentation flows and procedures; reorganizing procedures for the procurement of spare parts and inventory control; training mechanics and operators; and negotiating and arranging new procedures and relationships between the maintenance department and other departments. Few enterprises can make available the management, technical and training resources to handle the entire process themselves. Nevertheless, if the enterprise is to be able to continue operating the new system, it is essential that all its managers and other personnel concerned should be actively involved in the implementation process.

25. Maintenance policies, if they are to be effective, must be soundly based on practical considerations. A recurring problem is that managers at the policy-making level have difficulty in distinguishing between maintenance management and maintenance activities. The shop-floor activities of lubrication, machine repair, periodic overhaul etc. are mistakenly taken to constitute the whole range of maintenance activities, so that the supervisor in charge of the maintenance crew is considered to be the maintenance manager, although the real management decisions on these activities are made elsewhere.

26. Methods for organizing maintenance include:

(a) Undertaking a maintenance audit conducted internally or by independent management consultants to diagnose problems. A maintenance audit increases internal awareness of the importance of maintenance, alerts managers to problems in performance, highlights areas for improvement and encourages improvements;

(b) Preparing a directive on maintenance policy to define objectives for and activities throughout the enterprise, and informing all the personnel concerned of the maintenance policy to raise awareness and create a maintenance culture;

(c) Drawing up an organizational chart of the enterprise, putting the maintenance department at the correct hierarchical level in relation to the production department, and placing one person in charge of all maintenance activities;

(d) Drawing up a maintenance chart as well as job descriptions. Initially, this chart should be simple but sufficiently flexible to permit adaptation as the maintenance plan develops. In this chart, special attention must be paid to functions, methods, stock administration, and to the programming, preparation and scheduling of jobs;

(e) Preparing a system of data collection and determining an information flow circuit to permit the evaluation of the data collected, which should include data related to down-time levels and costs;

(f) Introducing a system of control for costs associated with maintenance;

(g) Introducing a system of control for the inventory of spare parts;

- (h) Centralizing the filing of technical documentation;
- (i) Organizing the programming, preparation and scheduling of jobs;
- (j) Improving the central maintenance workshop;

(k) Organizing subcontracting for specific types of maintenance that exceed the capability of the firm;

(l) Drawing up a preventive maintenance programme, if necessary with the help of consultants, and implementing it. Such a programme would eliminate or reduce unnecessary maintenance, and introduce or strengthen maintenance activities in critical areas. It would detect pending failures by monitoring performance conditions and the cause of equipment failure, by maintaining equipment on a regular basis and by ensuring preparedness for breakdowns, which can never be totally eliminated;

(m) Developing a training programme for foremen in methods, the programming, preparation and scheduling of jobs, stock administration and management of the preventive maintenance programme.

#### V. NEGOTIATION FOR AND ACQUISITION OF MACHINERY AND EQUIPMENT

27. In the early stages of project development, careful attention must be given to the choice of technology, which should have been tested and proven successful elsewhere, and which the enterprise and the country should be capable of maintaining. The design of equipment is extremely important, with regard to not only its maintainability but also its adaptability to climatic and other conditions particular to the user's country. During negotiations it should be made clear what adaptations have to be made to suit the user's conditions and the additional cost involved. It is important to ascertain that equipment and components are standardized as far as possible in order to facilitate maintenance and reduce the variety and volume of spare parts to be kept in stock. The initial list of spare parts to be supplied with new equipment should be carefully selected to ensure that only essential spares are included, according to their rate of consumption, and that slow-moving stock is avoided. Spare-parts inventories, which cost substantial amounts of money, constitute idle capital and badly affect the cash-flow.

28. Enterprises in developing countries are at a disadvantage, since they often do not have the capability of drawing up detailed technical specifications. They have largely to rely on the advice of the supplier, who may not be the machine constructor. Project planners may not be in a position to estimate the investment cost in maintenance. In such cases it might be desirable for enterprises to make use of consultancy services to assist their personnel, since the work involved is not of a recurrent nature. It may also be necessary to include a maintenance specialist in the team that negotiates the acquisition of equipment.

29. In the actual negotiation of contractual arrangements for the acquisition of equipment, it is important to ensure that suitable clauses or subsidiary agreements to the principal agreement are included on the following features:

(a) Detailed specification of plant, machinery and equipment, which should show both the maximum and the optimal rates for capacity and scheduled down-time in order to work out realistic rates of production;

(b) Standardization of equipment, sub-assemblies and components, to the extent possible, in order to facilitate maintenance and limit the volume and cost of stocks of spares;

(c) Provision of adequate and detailed technical documentation including blow-ups of components and parts, article number etc. to facilitate installation, codification and reordering of parts;

(d) Continuity of availability of spare parts under suitable price arrangements;

(e) Continuity of after-sales service and competent technical support in the operation and maintenance of equipment;

(f) Supervision by the user of construction, installation of internal services, machine installation and commissioning where the user's maintenance personnel should be involved from the outset;

(g) Detailed lists and specifications of the initial supply of spare parts and their individual rates of consumption;

(h) Adequate provision for training of personnel at all levels and functions, with emphasis on maintenance personnel, who may need to be trained before beginning the installation;

(i) Constructing and equipping maintenance workshops and spare-parts stores on a priority basis in order to provide adequate services during the installation of equipment and for the pretraining of maintenance personnel;

(j) Production of drawings for selected spare parts that are subject to wear to facilitate repair or fabrication of parts, if necessary.

30. The costs associated with most of the above features must be included in cost estimates for the supply of equipment. While negotiators endeavour to strike the best deal at minimum cost, they must take precautions to ensure that their requirements are fully met in terms of initial stocks of spare parts, technical documentation, after-sales service, and particularly training and maintenance. Bidders, who are intent on making their bid look the most favourable, are liable to omit such features or to supply a minimum of them in order to clinch a deal. As the cheapest offer is not always the best one, it is important to deal with reputable and proven suppliers only and, if necessary, to obtain objective, independent advice from professional consultants or international organizations.

## VI. TECHNICAL DOCUMENTATION

31. Technical documentation is essential to the organization of a maintenance management system. Without it, preventive and corrective maintenance, quick problem-solving, and dismantling and remounting equipment would be extremely difficult, as would the correct selection and administration of spare parts; the repair, reclamation, reproduction or manufacture of spare parts; and the effective training of maintenance personnel.

32. The importance of technical documentation is frequently not sufficiently recognized. It is often left to the supplier of equipment to decide on how much documentation to deliver. Detailed technical documentation is expensive, therefore, if it is not properly budgeted for, and just left to the machine

supplier, only a minimum of documentation, perhaps useless, is likely to be supplied. There have been cases where machines were supplied, and accepted, with hardly any accompanying documentation apart from a sales brochure.

33. It is of paramount importance, therefore, that requirements for technical documentation should be firmly set down in the terms of reference, the detailed specifications of the tender documents and the contract for the acquisition of the equipment. Documentation must be supplied in a manner and language that is readily understood by the user. It should arrive preferably before the equipment itself in order to allow for preparation for the physical work and provision of the internal services required for the installation of the machinery, and in order to train the installation and maintenance crews. Documentation must be checked on arrival, just as any other item supplied, otherwise it might not be realized that necessary documentation is missing until a crisis occurs.

34. It is desirable to centralize the keeping of technical documentation in order to ensure that it is well preserved, codified and classified. Documentation should be updated in accordance with changes due to new technological developments or modifications made during installation and operation of equipment. For this purpose, machine files should be opened for equipment that is critical to the production process. Copies of original documentation may then be distributed as necessary to the relevant users within the enterprise.

35. In view of the importance of technical documentation, an enterprise should ensure that its training policies and programmes include the training of personnel in the preparation of terms of reference and specifications for technical documentation to be included in tender bids for equipment; in the building up of documentation files for the more important machines that may cause bottlenecks in production, in the interpretation of documentation and technical drawings; and in the building up of technical documentation where none exists.

## VII. SPARE-PART MANAGEMENT

36. The unavailability of the right spare parts at the right time is perhaps the gravest single problem in maintenance management. In developing countries, the unavailability of spare parts often stems from the lack of allocation of foreign exchange for imports or bureaucratic delays connected with the issue of import licences and other permits. But more often, problems with spare parts are the fault of management because of poor stock administration. Many enterprises face problems connected with spare parts because they have been badly stored and cannot be located, because the wrong spares have been ordered, because they were inadequately packed for long-term storage and could not be utilized when they were most needed or because inadequate allowance was made for delivery lead-time.

37. A stock administration system starts with criteria for ordering the right spare parts in adequate amounts, depending on the rate of wear and the frequency of replacement of moving parts. Minimum and maximum stock levels have to be established for every stock item. Reordering points have to be fixed depending on delivery times and administrative delays. On receipt, goods have to be checked thoroughly to see that they conform to orders, part numbers, quality and condition. Designation, codification and proper stacking ensure quick retrieval of urgently needed spare parts. Goods must be well-preserved in the store by greasing, putting in plastic bags etc. A stock administration system involves paper work, such as cards giving particulars of

supplier, article number, average periodic consumption, landed price, delivery time from the date of ordering, mini-maxi stock levels and reordering points; and bin cards to record physical receipt and issues from the store. Computerized inventory control may be considered worthwhile, especially since the price of both hardware and software is currently within easy reach of most enterprises.

38. In the proper implementation of stock administration there is a linkage with aspects covered in other sections of the current report. For example, ordering, classification and codification of spare parts can only be done if adequate and detailed technical documentation is available. The volume of spare parts to be stored can be reduced substantially if, at the stage of project planning and acquisition of capital goods, consideration is given to the standardization of equipment and components. Only if the maintenance specialists have been involved in calculating the frequency of change of moving parts can the right spare parts in the right volume be ordered. Parts can be well-stocked in the store if problems concerning size, location and equipment for the store (ample space, shelves, pallets, fork-lifters etc.) are considered when construction plans are drawn up. These objectives can be achieved only if the finance manager is convinced of the importance of maintenance and allocates the funds necessary for the acquisition of the required physical assets and for the recruitment and adequate training of personnel.

39. Many enterprises have ventured, with varying degrees of success, into the repair, reconditioning and even complete reproduction or manufacture of spare parts. The repair and reclamation of parts is of great importance since it can be less costly than ordering new parts and simpler to carry out than their reproduction or manufacture. Modern methods of welding, metallization, electrolytic filling and re-machining, have often proven useful and economical in many developing countries.

40. The repair and reconditioning of spare parts, as well as the full reproduction of parts, however, require specialized skills, tools and special materials not always available within a single enterprise. Cooperation between companies may therefore reap benefits. Individual enterprises may specialize in repairs, reconditioning and reproduction of parts on an industrial subsectoral basis, for example, repair and reconditioning of parts of ferrous as against non-ferrous metals; cast, forged or machined parts; and instrumentation repair. It would be desirable if enterprises, through their professional associations, would communicate to each other what facilities or capabilities they dispose of and the services they might render in this regard to fellow manufacturers.

41. Before the fabrication or manufacture of spare parts is undertaken, it might be advisable for enterprises to carry out detailed studies to identify the items that could be economically manufactured locally. Other preconditions include the availability of skills, requisite machine and cutting tools, technical information (workshop drawings, specification of materials, knowledge of tolerances); industrial infrastructure (foundry, forge, heat treatment, instruments for accurate measurements, metallurgical and physical analysis); and the possibility of procurement of the materials of the right specification (special steels, chemicals). Quality control is essential, since imperfect spare parts might result in products that are poor in quality or might even cause damage to equipment.

42. Small-scale enterprises depending mostly on small or even single production runs may prove to be well-adapted to the repair, reclamation and manufacture of spare parts because of their smallness and flexibility, and their

capability of switching production from one item to another. Small-scale units may therefore be subcontracted by larger ones in these fields.

43. Activities in the management of spare parts at the stage of acquisition of equipment include:

- (a) Compiling lists of spare parts required for a two-year period of operation, taking special care not to accept too many slow-moving items and to avoid idle stocks;
- (b) Standardizing spare parts to the extent possible;
- (c) Identifying suppliers, who may not be the same as machine suppliers or constructors;
- (d) Supplying workshop drawings to facilitate repair or fabrication of parts;
- (e) Guaranteeing a continuing supply of spare parts at reasonable prices;
- (f) Determining prices, delivery and payment conditions.

44. Activities in the management of spare parts at the stage of project implementation and operation include:

- (a) Ensuring availability of adequate space, shelving, handling equipment;
- (b) Conducting quality controls and checking the spare parts received;
- (c) Coding items on stock cards;
- (d) Classifying items in the store to facilitate retrieval;
- (e) Analysing existing stocks to identify missing items and eliminate dead stock;
- (f) Setting up a data collection system for inventory control and reordering;
- (g) Assessing the desirability of introducing a computerized system of stock administration;
- (h) Training personnel in stock management.

#### VIII. TRAINING IN MAINTENANCE AT THE ENTERPRISE LEVEL

45. Training in maintenance should be carried out throughout the enterprise. All personnel in top management should be sensitized to the necessity for proper maintenance and understand what it involves, both as a management and a shop-floor activity.

46. The finance manager may need additional training in order to be able to specify all maintenance costs and, more importantly, to be able to set up a system for estimating the benefits arising from maintenance. This would permit the finance manager to exercise better budgetary control of maintenance, and allocate the necessary financial resources to it in order to reap maximum

benefits. The sales manager would only need to appreciate how plant overhaul programmes affect stock levels of finished goods in order to avoid promising customers unrealistic delivery dates. The accountant may need training in how to set up procedures for smooth running and cost-control of the maintenance system and stock administration system and related paperwork. The production manager needs training to liaise with the maintenance manager on programming and scheduling of maintenance without undue disruption of production. Probably the best way to receive such training is by attendance at seminars.

47. Machine operators need training in how to operate a production plant without abusing it, how to detect incipient trouble in the equipment, how to make minor adjustments to ensure optimum performance of machinery, and how to liaise with the maintenance personnel. This calls for on-the-job training by production and maintenance supervisors so that workers may acquire a feel for maintenance by practical experience.

48. The training of maintenance personnel themselves should be a carefully programmed long-term concern, which should take into account the following special characteristics of maintenance work:

(a) In almost all enterprises, plant and equipment are specialized to some degree, so that newly recruited maintenance personnel, even those with previous work experience, need corresponding training or retraining;

(b) Newly qualified apprentices and graduates of vocational training institutes, however competent they might be technically, do not have sufficient specialized knowledge and experience to be entrusted with the care of expensive equipment. These qualities should not be allowed to develop by chance but should be nurtured by programmes of personal and skills' development;

(c) Graduates of vocational training institutes and apprenticeship schemes, such as fitters, welders and electricians, are invariably specialized in one trade. Most maintenance workers, however, must be multiskilled. For example, when a mechanic makes a routine inspection of a centrifugal pump he/she must report not only on the pump itself but also on its associated piping and fittings, its electric drive motor, and the motor's switching and control gear. Learning the basic theory and practice of these other trades requires a programme of training of some length. Maintenance workers have also to be trained in diagnostic skills and practical problem-solving;

(d) The emergence on the industrial scene of new technologies (i.e. electronic control gear) and new materials (i.e. industrial ceramics, plastics and industrial adhesives) creates a need for a corresponding upgrading and updating of the skills of maintenance personnel. This career-long training is essential in maintenance work.

49. Much of such training involves people already employed, as is the case with in-service training. It may be done in the enterprise or in outside training institutes. It may use both formal classroom methods and informal on-the-job methods. Whatever combination of training sources and methods is used, the training programme must be consciously managed by the enterprise, preferably by a competent trainer working in collaboration with the maintenance manager. An integral part of a training policy should ensure that trainees are given incentives and rewards. Successful trainees in the maintenance department must be able to look forward to the same recognition, respect and career development as employees in other departments.



50. Training in maintenance may however involve new or improved technology or equipment that is not available within the enterprise or the country. In such a case, trainees may have to be trained abroad, either in the country of origin of the equipment or in countries where such technologies exist, or perhaps, at a lower cost, in nearby developing countries.

51. It is important that for new projects, or new installations of internal services or machinery, the maintenance personnel are attached very closely to the contractors or suppliers who are undertaking construction, erection and commissioning works. This is certainly one of the best ways of on-the-job training, which solves many later problems in diagnosing faults in machinery and equipment and in internal installations, and in rectifying such problems.

52. A final point is that training for maintenance does not begin in the enterprise. It should begin with the appropriate programmes in the curricula of secondary and technical schools, trade schools, training institutes and universities, all of which are normally under the control of the Government. Enterprise managers should, through their associations, lobby and provide advice to the relevant authorities with a view to introducing and strengthening the treatment of subjects in curricula that pertain to the maintenance function. The university curriculum of electrical and mechanical engineers should certainly cover maintenance aspects. (Some people believe that maintenance should be developed as a scientific discipline in its own right, for example, by the establishment of a post-graduate degree in maintenance engineering.) The establishment of an association of maintenance engineers should be encouraged.

53. Most enterprises do not have the facilities or enough candidates to organize in-plant training in maintenance. Enterprise managers may therefore promote through their associations or institutes the organization of training seminars on different aspects of maintenance and they should be ready to release and pay the fees for their employees to attend such courses. They should also insist that employees who have attended external training courses should hold training sessions for their colleagues in the enterprise in order to pass on the knowledge they have gained, thus obtaining a multiplier effect and generating cooperation and the development of a maintenance culture in the enterprise.