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TRAINING OF MANPOWER FOR MAINTENANCE FROM PRODUCERS' STANDPOINT

by

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1. Introduction

It is beyond any doubt that rapid and efficient development of developing countries requires their economies to be advanced as fast as possible, so that they could provide consumer and capital goods to their population, either from their own production or through the international trade. This assumes a number and variety of capital goods, machines, mechanization, motor and other vehicles, and a complex system of infrastructure, energy capacities, raw materials, traffic communication, information and other elements of logistic support.

As a rule, developing countries resolve their problems and needs for capital goods, manufacturing and other technologies, communication and system support elements primarily through imports from developed countries, the economical and intellectual capacity of which allows economic and efficient production of all products necessary to the present-day man and the modern way of life. For a start, this is probably the only possible way. The very first steps in developing a country's own economy may be quite difficult to make without an appropriate support from developed countries, especially if it is well-measured and applied in the proper way. Viewed in long-range terms, however, developing countries should undertake increased efforts in order to provide the development of their own technology, manufacturing systems and know-how, so as to ensure sufficiently fast and intensive development leading to an independent economy capable of satisfying most of their needs in food and other consumer goods and consumer durables. This is strongly imposed also by the obvious need to have the development brought into accord with the countries' own environments, with respect to available raw materials, energy resources, way of life, climate and other local conditions.

Without dwelling on the ways in which funds to import machines and technology from developed countries are provided, and how much these are paid for, it is obvious that importing countries have to ensure a number of conditions associated with supplying raw materials and energy, transport, communications, product distribution on the market, service after products have been sold, etc., in order to allow imported basic assets (machines, plants, technology) are well utilized. This also requires considerable material facilities, but firts of all, imposes the need for a lot of knowledge. This is to say that essential matters of the further development of developing countries cannot be resolved by merely importing equipment and technology. It is essential to work simultaneously on the creation of intellectual potential and knowledge. For imported basic assets and technology to give what they potentially can do, it requires a lot of preliminary knowledge, a lot to be studeid and learned.

This confirms the well known opinion that for rapid development developing countries have to acquire as much of their own knowledge as possible. Without knowledge there can be no progress, there will be no conditions to overcome underdevelopment. The scope of the knowledge has to be as large as possible. The efforts towards acquiring more knowledge must not be contained only to proper utilization of imported machinery and technology, although this probably has to be one of the first stages in the training and education scheme, but also to the development of own technologies, new machines and plants, adapted to the local conditions and based on modern scientific achievments, information and computer technologies, electronics and other disciplines representing the framework of the contemporary world. Reqired are, therefore, applied knowledge but even more creative knowledge. This should be taken into consideration already in the initial stages of planned development. If left for a later point of time, assuming that one can talk about education for modern technologies not before certain development level has been reached, not only that precious time will be lost but it will actually prevent the required rate of development to be achieved.

The problems associated with maintenance are of particular importance. The maintenance of technical systems, i.e. of all types of basic assets such as machines and mechanization, represents in principle complex technical and technological process, covering a number of relatively different problems of a high degree of complexity. On the other hand, maintenance affects to a large extent the total amount of funds invested in the purchase or construction of basic assets, and hence on the achievement of targets and assignements set to any technical system. This is of particular importance for developing countries, which do not have sufficient assets to cover their needs, and in which inadequate investments make serious problems. It is therefore extremely important for developing countries to ensure that their basic assets are given the utmost care and the highest quality maintenance.

The high quality maintenance of technical systems requires many prerequisite conditions material and subjective in nature to be met. Within this framework, knowledge comes again in the first place. Quality maintenance systems ensuring that basic assets, machines and plants are operable without long downtimes, at a high efficiency, require a lot of knowledge of all levels, begining from operators and maintenance personnel to those that make decisions about maintenance in the sense of planning and technological defining of maintenance procedures, including those responsible for providing the required workshops, energy, communications, information technologies, planning and purchasing spare parts and supply materials. Therefore, training and education for maintenance is vital not only for high quality service, but also for a higher efficiency of basic assets, i.e. machines and plants, and hence for a higher return on investment.

The purpose of this paper is to point out to several essential questions relating to the problem of training and education for maintenance from the manufacturer's point of view, or from the machines and capital goods designer's standpoint. Accordingly, we are talking here about an education system segment which has to provide creative knowledge in this area, necessary for the development of a country's own know-how and its own technology. Within this framework, an attempt will be made to throw some more lights on associated questions relating to the problems of spare parts supplies and to the problem of purchasing new capital goods. In other words, the paper will discuss main factors which have to be taken into account with respect to maintenance when a new machine is to be designed and produced or when it has to be imported or otherwise acquired.

For clarity reasons, some basic notions on the maintenance as a scientific discipline dealing with these processes will be given.

2. Life cycle and cost effectiveness

Every technical system can be used over a determined and comparatively limited time period. If the time period within which a system is used is added to the periods of time required to design and manufacture the system, a time period corresponding to the total life cycle is obtained. This means that the life cycle of a technical system is a complex category comprising a number of activities /1/. This is shown schematically in Fig. 1 /2/. As it can be seen there are three characteristic groups of activities: development, production and utilization, which are mutually interrelated in many ways.

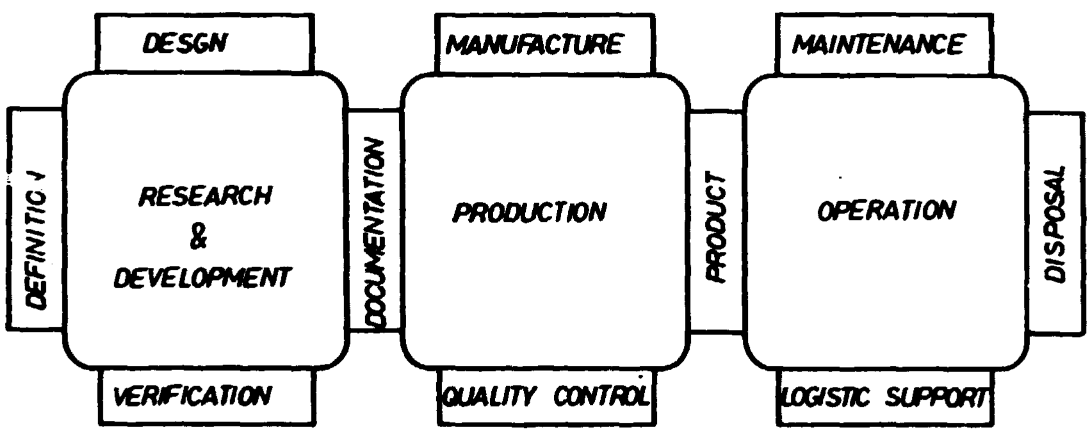

Fig. 1

The implementation of each activity in the life cycle, and even of each segment therefrom, requires certain "efforts" or material assets to be invested. In this sense, we could talk about the total costs of life cycle or about the total funds invested. A schematical presentation of partial costs comprising the total cost of life cycle is shown in Fig. 2. This is sufficiently selfexplanatory and requires no additional comments. It should be only pointed out that the presentation is strictly general and that it includes only those costs which have the largest effects. In individual cases the structure of costs may be somewhat different.

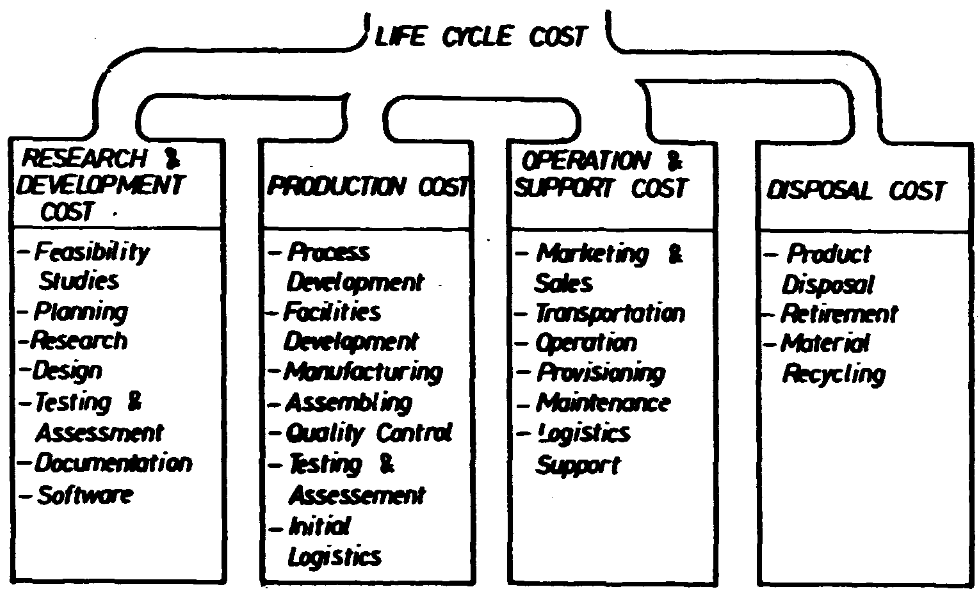

Fig. 2

The evaluation of whether funds will be appropriately invested can be perfcrmed only if all effects that the technical system is capable of providing are taken into account. The measure of these system properties is "system effectiveness", which, taken roughly, indicates the degree of satisfying the requirements, i.e. the measure of fulfilling planned or desired targets. Theoretically is proved that system effectiveness depends primarily on reliability, which represents capability of a system to operate without failure, and on availability, which essentially represents the measure of the system quality with respect to maintenance.

On this basis, the effectiveness of invested funds or the effectiveness of the total life cycle cost can be expressed as schematically shown in Fig. 3. In other words, the effectiveness of invested funds represents the effectiveness of the observed technical system (capital goods, machines, plant) expressed per unit of assets invested in all stages of life cycle.

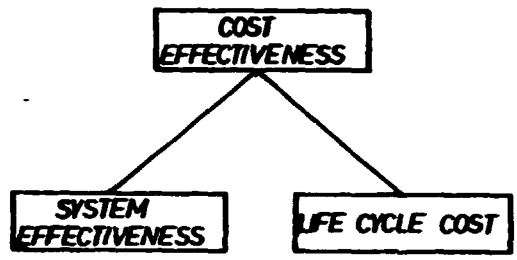

Fig. 3

In order to ensure the highest possible effectiveness of invested funds, a number of requirements has to be met. First of all, the technical system itself should have favourable properties of reliability and suitability for maintenance from the design point of view. In addition to these essentially internal factors, important outer factors, such as material supplies, servicing, maintenance, spare parts provisioning, etc., have to be satisfied as well. This involves servicing and maintenance facilities, warehouses, operation and maintenance personnel, their qualifications and knowledge, availability of technical and other documentation, etc. All these elements are covered by the term Integral Logistic Support, and are studied within a separate scientific discipline - Logistics. A schematical presentation of the contents and targets involved in Logistics is shown in Fig. 4.

It is beyond any doubt that the activities and procedures covered by the Integral Logistic Support also impose certain investment or determined "efforts". These cost are part of the total life cycle costs, as explained in Fig. 2.

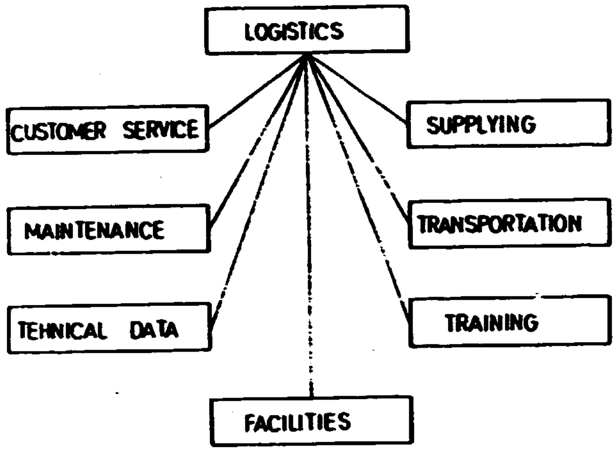

Fig. 4

The share of logistics cost in the total life cycle cost is generally very large. This is shown schematically in Fig. 5 /1/, which illustrates the total life cycle cost as an iceberg, with only one its part projecting above the water surface. This is the part paid for purchasing a macine, i.e. capital good, or its selling price. It is known that the selling price covers the

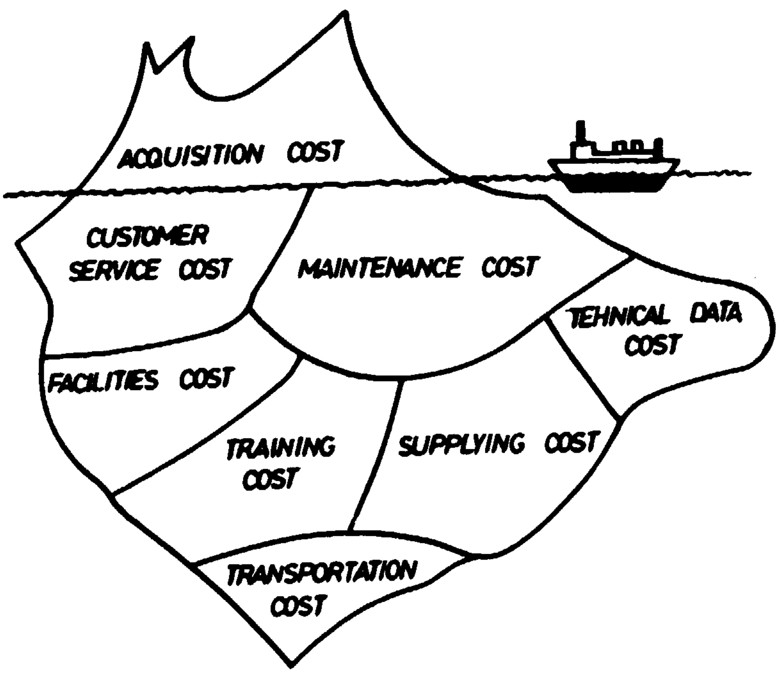

Fig. 5

manufacturer's costs (development, manufacture) and a certain amount of profit. In this way, by selling the machine the manufacturer resolves his main problems. The remaining life cycle costs, which are frequently "invisible" at purchasing, are born by customer (with the exception of warranty claims). These are, therefore, customers' problems. They are usually higher than the purchasing costs and affect the customers' problems accordingly. It can be seen from the illustration that a larger share of these costs originates from maintenance. This is to say that maintenance affects appreciably the total life cycle costs of modern machines and equipment, taking frequently the largest share of the total logistics costs.

The illustrated relations of individual sections of the total life cycle cost are of general, but in essence of principal importance. They apply more or less to all types of technical systems and to all conditions of their operation and use. There are in literature abundant information on them. It is stated, for example, that the cost of maintenance of crawler tractors over a period of eight years exceeds the purchase price by 4 to 5 times /3/, while the costs of maintenance for light trucks over a period of 5 years and about 200,000 km of travel exceed the purchase price for approximately 3.5 times. Similar data are available for machine tools, agricultural machinery, but also for computers and electronic systems /4, 5/. There is enough ground to beleive that these relations will be even more expressive in developing countries emphasizing more sharply the costs of maintenance and other logistics support.

3. Maintenance process

The process of maintenance represents the sum of all activities undertaken to remove failures, or to prevent their occurrence. This process is characterized by specific relations between individual activities and times in which the activities are conducted. Since it is usually assumed that a system is restored to its fully operable condition with maintenance procedures accomplished, i.e. that it is "as new", the process of maintenance is called also the proces of renewal /6/.

The process of maintaining technical systems has the characteristics of an entirely stochastic or random process. This results from two random events determining the process. The first random is the accumulated time of operation before a maintenance procedure has to be performed, which is generally determined by the failure occurrence, i.e. by the system reliability characteristics. The other incidental variable represents the time required to perform the maintenance procedure, or to bring the system from a "failure condition" into operable condition again. These two incidental point of time interchange alternately in the process of maintenance, marking decisively its character and quality. Along with this, it should be pointed out that any technical system besides in use may be held in a storage. Storage is necessary sometimes (if operation is seasonal, like with agricultural machinery), and it must be taken into account.

The basic status of a system could be best analized using the "the status time picture", which is shown in general terms in Fig. 6. It is shown in relation to the total (calender) time, which means that all time intervals have been included: time in operation or "up-time" (t_u), time in failure or "down-time" (t_d) and storage time (t_s). The example has been processed so as to cover all other important elements affecting "the status time picture" of the system, begining from its manufacture and start-up (zero-point).

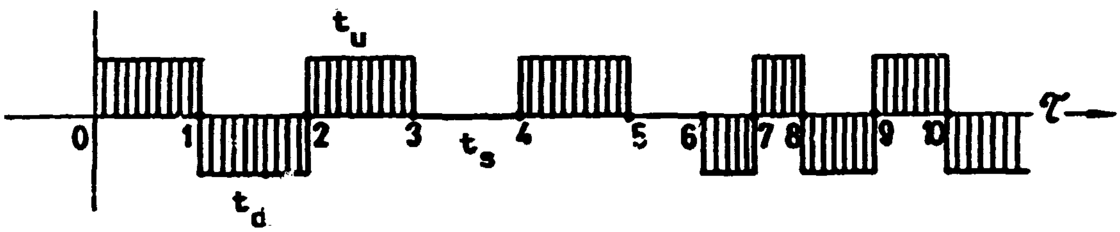

Fig. 6

It is assumed that immediately after leaving the manufacturing plant there is a need for the system to be operated, and that the system was operable in the period 0 - 1, being in a proper condition and performing adequately. At the pcint of time 1, however, a failure occurred and the system changed its status. Since a repairable system is in question, the malfunction of which can be removed with maintenance procedure applied, these were performed in the period 1 - 2 and the system was restored to its operable condition. At the point of time 3 the need for operation ceased and it was anticipated that the shut-down would continue through a longer period of time. The system was put in storage, therefore, after it has been specially prepared for storage. It was known that the system was fully operable when stored. The actual condition of the system during the time period 3 - 4 is, however, not known without special checking or tests conducted. In the given example it was assumed that such cheks were not accomplished, so that the "time status picture" for the period 3 - 4 does not provide the information on the system status. At the point of time 4 a need arised again for the system to be operated, and it was taken out of storage and responded to the demand for operation. The need for operation was present until the point of time 5, when the system was put to storage again. However, the system did not respond positively to the next call for operation at the point of time 6. During storage in the time period 5 - 6 a malfunction occurred in the system and it was not capable to be directly included in operation. The system was then in a down-time condition until corresponding maintenance procedures were applied, i.e. till the point of time 7. During the period 7 - 8 the system again functions properly, but at the point of time 8 a need for resuming certain maintenance procedure occurred again (preventive maintenance, which will be discussed later on), so that the system was put again into the down-time condition. After the specified work has been accomplished, the system continued operation, but at the point of time 10 another failure occurred,etc.

All time intervals shown in Fig. 6 represent in their essence incidental or random values. Incidental is the time interval until the failure occurred and incidental are the factors determining the duration of maintenance procedures, while many random factors affect the time period in storage. Accordingly, the whole process of a technical system usage is a random process. The same applies to maintenance and factors affecting its process.

It is important to emphasize that time intervals describing individual conditions of a technical systems have a complex structure. This applies separately to up-times and down-times. For a simplified presentation it will be sufficient to note that the up-time includes all shut-downs caused by power failures, climate conditions, abscence of operators, waiting for work, time required for washing and lubrication, time for feeding with energy fluids, etc. The same applies to down-time, which includes the time of waiting for maintenance due to occupied facilities, transportation problems, shortage in labour and particularly due to shortage in spare parts. Both these require a detailed analysis aimed to find out those vital factors which will allow the system to be operable as much as possible with the least possible down-times. Even without this, it may be pointed out that in many cases and in developing countries particularly, the time of waiting for spare parts is a factor which extremely affects the total time status picture, i.e. the duration of down-time under failure and the utilization of the total available time.

The process of maintenance can be evaluated in many ways. One of the simplest but good indicator is the so called "readiness", expressed by the ratio between the time in operation and the total available time. It is obvious that readiness will be higher at shorter down-times. Because reduction in failure shut-downs is achieved through a better maintenance system, having adequate logistics support (primarily with respect to spare parts supplies), it is concluded that readiness can be increased by an improved maintenance system. This obviously increases the total effectiveness and reduce the costs of the achieved effectiveness.

The duration of down-time under failure is affected to a large extent by the machine to be maintained. In this case, we are talking about properties built into the technical system relating to maintenance. This is usually evaluated by means of the so called "maintainability", which describes the measure of the time necessary to accomplish a maintenance procedure. The higher is the maintainability, the higher is the probability that maintenance procedures will take less time. This means that a technical system has to be specially adapted to maintenance. In addition to satisfying the performance requirements, providing a production output at determined quality, and along with the capability of operation over longer period of time without failures, modern machines and other capital goods have to be designed so as to ensure they are suitable for maintenance.

4. Maintenance system

The maintenance system of a technical system can be realized in several ways and in several different alternatives. Individual alternatives or solutions for maintenance systems may be different in a number of details, but also in the basic features essential for the system. This applies first of all to the maintenance system concept, and then to the applied technolgy and organization. Under the maintenance system concept we understand the principles on the basis of which decisions on the time when maintenance procedures are to be carried out are made. In this respect there are two basic concepts: preventive and corrective maintenance. With the preventive maintenance the required procedures are carried out before a failure occurred, while with the corrective maintenance it is failure that occurrs first. The technologial aspect relates to the type and method of carrying out maintenance procedures, and the system organization is connected to the relation of individual levels at which maintenance procedures are accomplished.

The concept of a maintenance system represents its most important feature affecting very much the general quality of the system. This term relates to the feature of the system depending on the principle on the basis of which decisions on conducitng maintenance procedures are brought. It is explained that there are two essential conceptual possibilities: preventive and corrective maintenance (PM and CM in Fig. 7). In the first case, maintenance procedures are carried out before failures and they are undertaken in order to prevent or delay a failure. The corrective maintenance concept, on the contrary, is designed to apply maintenance procedure not before a failure has occurred. In this case, their task is to restore the system from "failed" into "operable" status. Both those concepts can be used in conjunction, and then we have combined maintenance (OM). Combined maintenance can be relized in several ways, but usually so that certain parts of the technical system are maintained preventively, while the remaining parts are maintained after a failure has occurred.

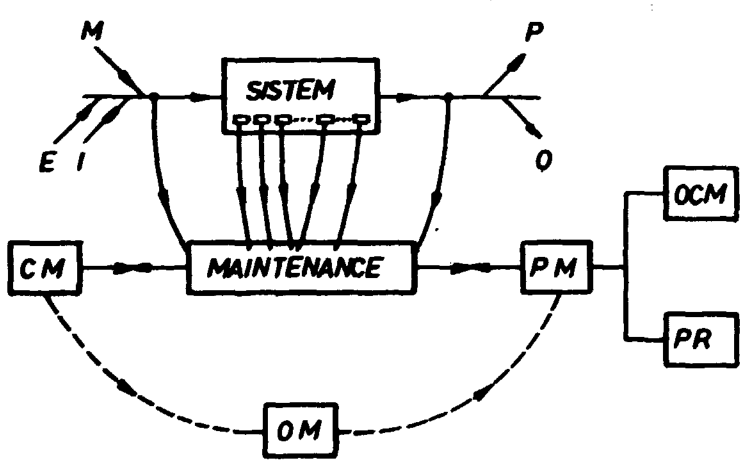

Fig. 7

Preventive maintenance, which is obviously much more attractive (it is better to prevent than to remedy), can be realized in several ways. This applies especially to the type and character of a preventive maintenance procedure, and then on the time determined to conduct such procedure. In this sense, preventive maintenance can be relized as "on condition maintenance" (OCM), rather then "preventive replacement" (PR), which had been popular up to some time ago. The "on condition maintenance" provides not only better economy, but contributes also to an increased level of readiness.

In addition to the above explained conceptual elements, the two other elements - organization and technology for individual maintenance procedures - are of importance for the quality of a maintenance system. However, these are questions which have to be resolved for each individual case separately, depending on the type of machines or capital goods and other circumstances. These segments of a maintenance system will not be analyzed in details therefore. It will be necessary only to indicate that a successful maintenance system assumes also that a powerful information system is available to provide the necessary information on operation for machines to be maintained, about all events affecting the process of their maintenance (failures, operating conditions under which the machine has been used and the failure in question has occurred, operating load, climate conditions, quality of operators or their knowledge, spare parts supply, etc.). These are also specific problems, but have to be mentioned in order to get a clear picture about the knowledge required for maintenance.

5. Designing technical systems for maintenance

It follows from the above given basic explanations, among other things, that each machine or other basic asset has to be so designed as to provide the required operating performance and high reliability along with satisfactory characteristics with regard to maintenance. Simply stated, a modern machine must perform reliably with the least possible number of failures and cause a minimum down-time possible, and in case of a failure its design and other features must allow rapid remedy, i.e. quick recovery to operable condition. Environment in which machine is used must be taken into account, as well as the conditions under which it is maintained. All this may impose specific requirements in developing countries with regard to machines or other capital goods purchased.

From the point of view of maintenance, the process of designing a technical system can be resolved in different ways and by applying various procedures and methods. This applies to all sort of technical systems. It is not possible, therefore, to give some firm instructions that should be followed in designing a machine so as to achieve high maintenance properties. It is possible, however, to reveal general principles providing objective possibilities for easier and safer meeting the requirements of maintenance during designing process. It should be taken into account that the very old rules says that a good technical system having high operating performance is also highy reliable and it usually has good maintainability.

The principal approach to the design of technical systems from the point of view of maintenance could be presented in the form of a simple algorithm or block dijagram - Fig. 8.

From this quite simplified and general presentation, it may be concluded that initial analyses of maintenance problems should find their place already in the stage of defining the basic concept of the system to be designed, i.e. already in the preliminary analyses and elaboration of design assignments (1, Fig. 8). On this basis, maintenance requirements are "built-in" the product designed, already in the stage of elaborating prototype documentation (2). An analysis is carried out on all the required input information for detailed analyses of the maintenance system, and especially on data

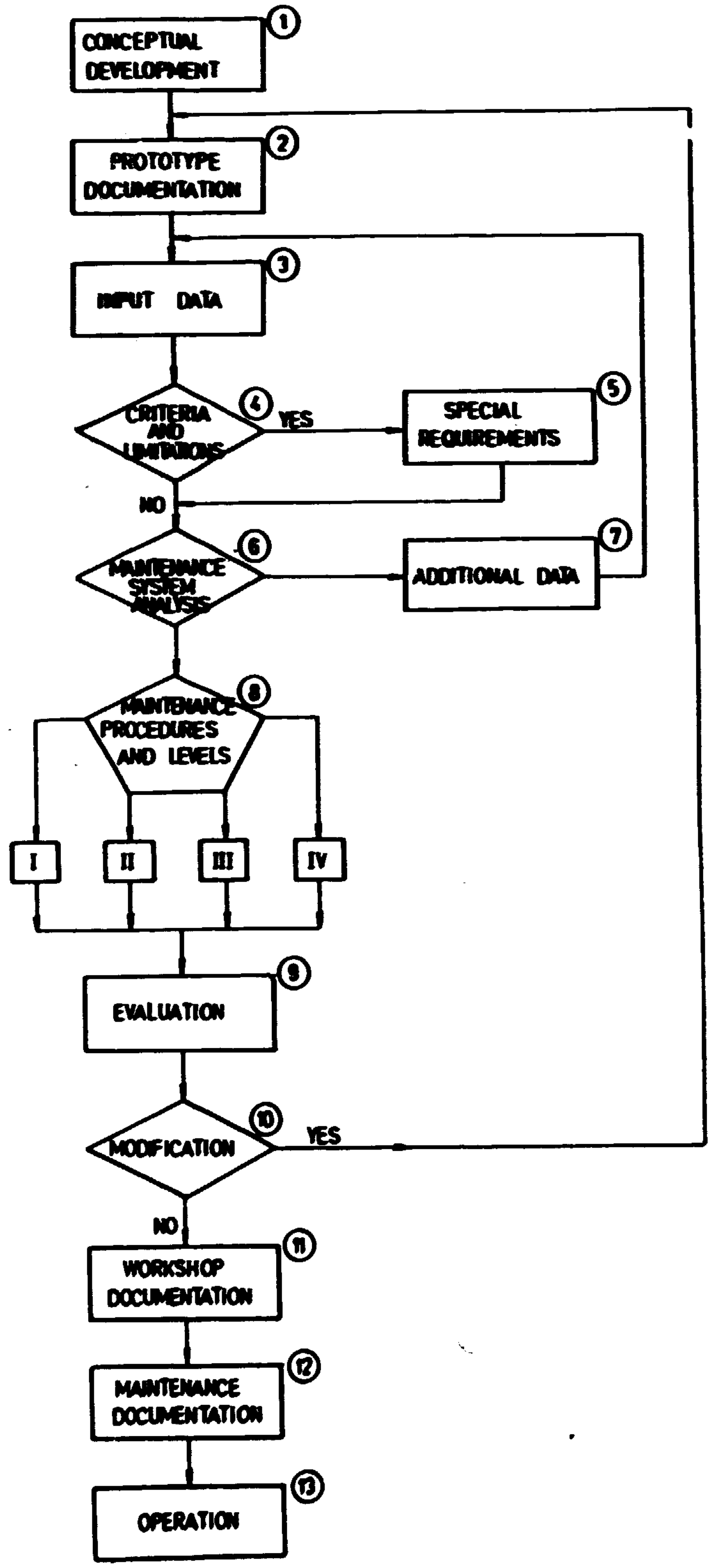
CONCEPTUAL DEVELOPMENT
1
PROTOTYPE DOCUMENTATION
2
INPUT DATA
3
CRITERIA AND LIMITATIONS
4
YES
SPECIAL REQUIREMENTS
5
NO
MAINTENANCE SYSTEM ANALYSIS
6
ADDITIONAL DATA
7
MAINTENANCE PROCEDURES AND LEVELS
8
I
II
III
IV
EVALUATION
9
MODIFICATION
10
YES
NO
WORKSHOP DOCUMENTATION
11
MAINTENANCE DOCUMENTATION
12
OPERATION
13

Fig. 8

about estimated failure occurrences (3). In other words, the input information includes the estimated reliability characteristics of individual elements, as well as estimated duration and costs of maintenance and other important information. This is particularly delicate stage in the whole process of analyzing a maintenance system. The next stage is to define the criteria and possible limitations (4). Namely, an analysis on a maintenance system is based usually on optimization from the point of view of costs (decision about preventive or corrective maintenance, time periods in which individual procedures are applied, and similar). In certain cases, however, priority should be given to specific requirements such as required readiness, safety, etc. (5).

Based on the prototype documentation, accumulated initial information and defined criteria or limitations, an analysis is carried out on each anticipated maintenance procedure (6). The first part of this analysis evaluates whether there is sufficient information for the conceptual solution on the maintenance system, and if found that no sufficient information is available, additional input data are looked for, new experiments are conducted, etc. (7). If determined that the process of maintenance is sufficiently defined, procedures are established for each individual maintenance activity and the level at which it should be performed is determined (8). It is very important that along with the so defined maintenance system estimates have to be made on the duration of each individual maintenance procedure (active maintenance times), the required qualification of labour has to be determined, including the required tools and accessories, consumption and other materials, etc., as well as the total cost of conducting procedures. Accordingly, we are talking here about a comparatively complex undertaking requiring considerable effort.

After the whole maintenance system has been determined in this way, it is then evaluated in general terms (9). If found that no required results had been achieved, for example that maintainability is below the required limit, suggestions for modifications of improvement are determined (10). However, if the general evaluation is satisfactory, then work is proceeded on preparing the final workshop documentation (11), and then extended to cover also the maintenance documentation (12). Finaly, with other common procedures accomplished (tests, homologation), the system is put into service (13).

6. Basic approach to training for maintenance

From the above given concise explanation on the maintenance process and system, it may be easily concluded that the problems involved are quite complex , with a number of segments different in their theoretical essence and practical content. It is natural therefore that a separate scientific discipline has been developed for the needs of studying these problems,called Theory of maintenance or the Renewal theory.. The theory of maintenance is actually part of the Theory of Effectiveness, which is a general scientific discipline studying the problems of operation and maintenance of technical systems. It is worth mentioning that the theory of maintenance is a relatively young branch of science. Its formation started several decades ago, and it was not before some twenty years ago that it had been rounded up as a separate discipline. Its development, however, is a continous process. New approaches are being developed and new contributions are given both in theory and in application, new contents are included and new methods introduced. In this framework, particularly distinguished are the works directed towards bringing maintenance systems in accord with the environment in which the technical system operates. This is extremely important for developing countries, the operating environments of which have certain specific features as a rule.

All this suggests that maintenance problems have to be studied separately and that personnel involved in maintenance has to be specially trained for that purpose. This applies particularly to the personnel employed on key managing positions such as directors and superintendents in manufacturing plants, managers in maintenance divisions, all engineers and technicians working in development, design or purchasing departments, in factories or in ministries, state agencies, governmental or private import organizations, including corresponding personnel in banks, various agencies and institutions deciding or participating in decisions on purchases concerning basic assets, capital gooods, machines or technical systems of any kind.

Particular needs for training for maintenance are present in relation to personnel working on the design of maintenance systems, maintenance workshop and equipment, planning the requirements for maintenance,spare parts, etc. This personnel should be capable not only to apply the laws of the theory of maintenance and associate scientific disciplines, but it must be able also to provide its own solutions for maintenance systems, accomodate to local conditions, work loads, environmental loads, manpower, and similar.

And finally, a separate segment of training for maintenance should be dedicated to those that are to transfer the knowledge from this area to others which will be involved in teaching and training. We are talking here about pesonnel at universities and faculties, institutions and schools of all levels, including the schools for basic training of workers in factories or in areas where manufacturing plants are erected or mechanization applied.

As it can be seen, a very wide circle of experts and personnel at various levels and with a very different degree of prior education are invloved. This implies that the training system for maintenance must be very comprehensive and very diversified in structure, adapted to the direct needs of the trainees. For each personnel profile a separate training programme should be elaborated so as to ensure in all cases an active attitude of trainees to the problem is stimulated to the maximum possible extent and that development of creative knowledge is initiated. This is most important for personnel working on these problems in plants producing machines, or working on the development of technical systems and their maintenance. It is exactly this segment that is frequently forgotten when developing countries are in question.

7. Possible programmes and activities in training for maintenance from manufacturers' point of view

Training for maintenance from manufacturers' point of view should actually make part of the general education for maintenance, and it should be created in every developing country to cover a larger or smaller scope. Since in many developing countries UNIDO has already done a lot in spreading the idea about the need for the training of this kind /7, 8, 9, 10/, the segment of training for maintenace from manufacturers' standpoint should be fitted in an appropriate way into the already developed forms of education. This segment should represent a "superstructure" over the already established training system for maintenance. In this case, however, the main target should be to acquire knowledge which would allow country to attain its own development goals, i.e. to gain the creative knowledge which would provide conditions for the development of own maintenance technologies. Programmes and activities in training for maintenance must be sufficiently directed towards acquiring the basic theoretical knowledge, studying the essential maintenance phenomena and laws describing them. In other words, programmes and activities must in this case cover to a sufficient extent the theory and themes relating to the theoretical bases characterizing and describing the individual phases and problems of maintenance systems.

Generally speaking, educational programmes for personnel working on development, design and manufacture of machines and other capital goods, in purchasing them from import or local sources, and engaged in the design of maintenance systems for such machines, should cover the following groups of questions or basic themes:

- Elements of the theory of maintenance and associated disciplines (theory of effectiveness, theory of reliability), which should be studied for better understanding of how technical system behave with time, and to see what are the laws of failure occurrence and what is their distribution, as essentials from which the need for maintenance arises.

- Maintenance objectives and economics, covering the essential segments of life cycle costs of achieved effectiveness, i.e. actual possibilities to control these costs primarily from the maintenance point of view.

- Maintenance management, covering the management strategies and factors affecting maintenance particularly with respect to the properties of machines maintained.

- Maintainability, as suitability of machines and other capital gooods for maintenance, including methods allowing a machine to be adapted to maintenance under given operating conditions and to a given environment.
- Maintenance system, its basic concept (preventive or corrective maintenance) and system structure (organization). This should provide the required knowledge for engineering and design work involving maintenance aspects.
- Maintenance documentation and data processing, which should be studied in order to understand the principles of information systems which should provide the data necessary for maintenance design and planning (data on failures, down-times, maintenance procedures acomplished, costs, etc.), and also to acquire knowledge on data processing and analysis, with help of modern informatioln technologies, computers and attending equipment applied.
- Integral logistic support, which should be studied in order to understand dominant factors affecting the operation of technical systems especially from the point of view of maintenance and spare parts supply. This section should provide the necessary knowledge on how to control inventories as they affect the total costs and costs of achieved effectiveness.
- Elements of optimization methods, or selection of the most favourable solution, which should allow practical problems to be solved by selecting one from several possible alternatives of the maintenance system and its individual segments to meet the set criteria and limitations.

8. Conclusions

This paper discusses only generally some questions indicating the need of introducing a system of training for maintenance from the manufacturers' standpoint, or from the machine designer standpoint. The idea is to emphasize the need of organizing the training system on higher levels which in some developing countries have not been covered yet, but which represents in any case a basis for the development of own technologies, both in developing new technical systems, machines and other basic assets and in developing systems for their maintenance. The starting premise is that for an increased rate of development developing countries have to ensure their own knowledge, their own creative forces or personnel which will fulfill their assignments at the level of modern knowledge based on the achievements of science and technology in the developed world. This applies fully to the segment of training for maintenance or to the education of those working on the development of new machines and equipment and systems for their maintenance.

The practical implementation of the explained standpoints requires detailed elaboration for each particular case, depending on actual conditions, achieved level of development, existing education system, types of machines and capital goods to be maintained, operating conditions, environment, etc. A certain level of unification for a larger number of countries at a similar level of development, or for a larger number of relatively different types of technical systems is not excluded. In this framework there is room for serious consideration to be given to possibilities for international cooperation with a view of organizing specialized training courses, schools and other forms of training activities for individual countries, regions, branches of economy, in a similar way to that applied in training personnel employed to maintain machinery and equipment. Experience which UNIDO has had so far in this area represents the basic assumption for a full success in such a widened scope of training manpower in developing countries.

9. References

1. Blanchard, B., Design and Manage to Life Cycle Cost, M/A Press, Portland, 1978
2. Todorović, J., Cost effectiveness optimization - An important system target, Int. J. Prod. Res., 1982, No.3
3. Kuznjecov, E.S., Problems in automobile reliability and maintainability control (in Russian), Vissaja Skola, Moskva, 1977
4. Ankenbrandt, F.L., Electronic Maintainability, Chapman-Hill, New York, 1960
5. Kuznjecov, E.S., Maintenance and reliability of motor vehicles (in Russian), Transport, Moskva, 1972
6. Cox, D.R., Renewal Theory, John Willex & Sons, New York, 1963
7. UNIDO Report on the First Consultation on the Training of Industrial Manpower, Stuttgart, 1982
8. Lorenzo, I., UNIDO'S training activities in the area of industrial maintenance, UNIDO Document V.86 52210
9. UNIDO Report on the Regional Expert Group Meeting on Human Resources Development in Industrial Maintenance in Africa Preparatory to the Second Consultation on the Training of Industrial Manpower, Nairobi, 1986
10. UNIDO Aide-Memoire for the Second Consultation on the Training of Industrial Manpower, Paris, 1987