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# PRODUCTIVITY

## *Special on Maintenance Management & Engineering—I*

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## Editorial

## OF VITAL IMPORTANCE TO DEVELOPING COUNTRIES

DEVELOPING countries setting out on the path of independent industrial development are being obliged—and still more will be so in the future—to import various kinds of equipment, machine tools and other machinery while at the same time establishing their own industries to produce these goods. They are being confronted with the problems of repairing and maintaining all this stock of valuable machinery, machine tools and industrial equipment. It is now being recognised that scientific organisation of repair and maintenance of a country's machinery and industrial equipment can considerably extend their useful life and thus meet part of the constantly growing demand for new machines and equipment.

In the following pages we present our effort at an issue devoted solely to one subject, "Maintenance Management and Engineering." We wanted material in keeping with our editorial aim —'articles authored by men recognised as leaders in their respective fields'. Fortunately, we could achieve this aim, and for that we are grateful to the United Nations Industrial Development Organisation, particularly Mr. MI Fawzy, Special Adviser, for permitting us to publish papers presented by the world's eminent authorities at the recent Symposium on Maintenance and Repair in Developing Countries held at Duisburg, West Germany. The papers have covered the whole gamut of Maintenance Management and are of particular importance to developing economies like India. All copyrights and title rights of the papers are retained by UNIDO.

Considering the volume of the material, particularly its usefulness to our readers, we decided to have two special issues on the subject—this issue and the next one—so that between the two issues, a very comprehensive treatment could be given.

## NEW MEMBER OF PRODUCTIVITY FAMILY

I am new to this Journal, but not quite so to the editorial profession. Yet I am occupying the chair of my predecessor with diffidence. It will, however, be my constant endeavour to keep up the high standards set for this journal.

While taking the liberty of introducing myself, I must say how privileged I am to join the 'Productivity' family. My background is business administration and over a decade-long association with small-scale industries and foreign trade may possibly help me in the challenges ahead.

I also take this opportunity to wish the readers and the contributors a happy new year and to seek their continued cooperation. I shall always welcome with gratitude their suggestions to make PRODUCTIVITY more useful and thus serve the cause of productivity.

—V.S.C.


SYSTEMATIC REPAIR
PLANNED REPLACEMENT
MACHINERY
PREVENTIVE MAINTENANCE
PRODUCTIVE MAINTENANCE
PROPER SPARE INVENTORY
BREAKDOWNS
DOWN TIME
PRODUCTION LOSSES
WASTES
SPARE INVENTORY
DISLOCATION
RAPID DEPRECIATION
MACHINE WEAR
TEAR

# Strategy for Introducing and Operating Systems of Maintenance and Repair in Developing Countries : An Institutional Approach

**BN Bhattasali***

Economic and industrial growth of developing countries like India requires increased production from investments already made in plant and machinery. Since replacement of costly equipment is not so easy and spares for imported machines are not readily available, it brings forth the imperative need for introducing and operating appropriate systems of maintenance and repair. To bring consciousness and awareness about the urgency as well as importance of proper maintenance and repair among the developing countries, institutional arrangements at various levels—national, industrial, regional and enterprise—are called for.

BY and large, most of the developing countries have to import their capital equipments—plant, machinery, appliance and their spare parts—from abroad. Almost all of them have low capital bases. Whatever liquid capital they may be able to mobilise, are again not readily convertible into foreign currencies, because of the prevailing trade gaps and unfavourable balance of payment positions.

In spite of such basic handicaps, the industrialisation of developing countries, modernisation of their agriculture and of the public utilities have to proceed, and proceed at a much faster rate than what had taken place in the past, if the widening gaps between them and the developed economies are to be bridged, or at any rate halted. One of the redeeming features in this difficult situation, however, is that in the developed countries, their decision models for maintenance, repair and replacements, are based on high labour costs, which is not the case in the developing countries. In other words, the high cost of maintenance and repair, often make them discard their equipments and seek replacements rather early—purely on economic grounds. In the developing countries, where the labour costs are much lower, such equipments could otherwise be conveniently used for substantially longer periods through added efforts in the way of extra care in maintenance and repairs. This is certainly an advantage for the developing countries, whose benefit could be properly realised, by organising satisfactory systems of maintenance and repair, and trained manpower for operating the same.

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## I—NATURE AND CLASSIFICATION OF MAINTENANCE AND REPAIR SERVICES IN DEVELOPING COUNTRIES

In developing suitable organizations and trained manpower for operating such maintenance and repair systems, though the models of the developed countries could be accepted as broad guides, these could by no means be copied for wholesale adoption, without the requisite additions and alterations, so as to conform to the actual physical needs and economic realities of the developing countries. This calls for a good deal of imagination and improvisation.

Some of the special features of the maintenance and repair services, which stand out rather prominently in most of the developing countries, could be described as follows:

1. Though the requirements of maintenance and repair services in the developing countries both in quantity as well as in quality are by far greater than the developed countries, these are yet to take even elementary institutional and organizational roots in the former.

2. Most of the developing countries having been feudal economies in the past are yet to have modern industrial bases and technological skills. The workers, supervisors and managers there do not always have requisite skills to operate and maintain modern equipments upto the requisite standards of proficiencies, resulting in more frequent breakages, malfunctioning, wear and tear. This calls for extra efforts towards skill development, both in quality as well as quantity and at all levels.

3. Most of the developing countries are importers of capital equipments. They are unable to keep readily available stocks for replacement as spares in adequate numbers, thus causing serious economic losses through shutdowns and interruptions in production.

4. Many of the developing countries buy their equipments from heterogenous sources in different countries, with different sets of standards and specifications. It is often difficult to provide proper technical facilities and skilled manpower to cater to the maintance and repair needs of such heterogenous equipments.

5. Most of the developing countries at their present stages of industrial development have rather a limited scale of consumption of industrial equipments and spares. In the absence of the benefits of economies of scale, it is difficult for the suppliers to provide facilities for major repairs or after-sales services. The consumer also cannot always make proper arrangements for major repairs locally, nor undertake indigenous manufacture of spares —which means more dislocation and interruption in production.

The adverse cost repercussions of all the above factors on the industries of the developing countries could be incredibly high. And these could be substantially reduced by introducing and operating appropriate systems of maintenance and repair, catering for the actual needs of the developing countries. The additional costs involved in this process would only be a small fraction of the total losses which would have been sustained otherwise through interruption in production and shutdowns.

The maintenance and repairs systems cover extensive ranges of activitie at an enterprise. These could be classified into many groups and sub-groups depending upon the areas of coverage or types of services provided by them. For the sake of convenience and cogency in presentation, however, these are being divided into the following six broad categories in terms of the services which could be provided to the different areas of the enterprise:

1 Maintenance of the buildings and grounds

2 Maintenance of the plant equipments

3. Lubrication and inspection of equipments including material handling equipment and transport vehicles.
4. Electricity, water, sanitation, ventilation and other utility generation and distribution services.
5. Alterations and additions to the existing plant equipments.
6. Alterations and additions to the existing buildings, grounds, utility generation and distribution services.

In addition to the above categories, certain other related or supporting activities would also fall under maintenance and repair services as follows:

1. Plant protection—fire, sanitation, ventilation, general safety and noise control.
2. Store-keeping for maintenance work.
3. Management of maintenance and repair workshops and liaison with production departments for manufacture of spares, major overhauls and major repairs as relevant.
4. Waste disposal.
5. Administrative and accounting work.

Depending upon the type and size of the enterprise, it may often be convenient to provide these services for the maintenance work from within the existing organisational arrangements of the enterpri. operations. For example, maintenance stores could be looked after by the normal storekeeping organization. Similarly the engineering departments could also be used for plant protection, production of spares, major overhauls, waste disposal, etc.

Apart from the above classifications of the maintenance and repair activities based on the types of services provided to the different areas of the enterprise operations, these could also be viewed from their functional aspects in the context of time available for systematic planning, scheduling and executing such activities as follows:

*Preventive Maintenance involves observance of systematic maintenance routines by operatives as well as servicing departments.*

**Preventive Maintenance**

This stands for regular inspection of plant and equipments at stipulated intervals, to detect the adverse operating conditions, structural or functional deteriorations, which might lead to their breakdowns, damages or excessive depreciations, with a view to taking timely remedial measures to lubricate, adjust, repair or take such other appropriate steps which prevent losses to the enterprise. Preventive maintenance involves ovservance of systematic maintenance routines by the operatives as well as by the servicing departments. In some of the enterprises, preventive maintenance is used in rather a narrow sense, confining the activities to inspection, lubrication, adjustments and testing—informing the user departments defects noticed by them which require repair, replacement, overhaul, modifications, etc., to be followed up by them. This is done with a view to conforming to the time-schedule preventive maintenance. In the light of the experiences in the developing countries, in certain situations, it is often desirable to involve the maintenance departments with the directior and inspection of such repair, replacement overhaul and modifications. This does no mean that the user departments are absolved c the basic responsibilities, for ensuring that pre ventive maintenance of their equipments a carried out systematically and satisfactoril but to ensure that the maintenance departme has a complete picture for discharging its se vice obligation to the users.

**Operational Maintenance**

In a running factory, interruption in prod tion may take place due to accidents, breakd of equipments, power supply, gas, water, veyors, etc., for which operational mainten staff are provided, to set the defects righ resumption of production work. Some o

*Breakdowns of plant equipments are often the cumulative results of several minor breakages, damages, distortions and maladjustments.*

operational maintenance staff are required to function round the clock even though the factory may be working on one or two-shift basis. Operational maintenance is mostly inter linked with breakdown repairs.

**Repair**

From a broader perspective repair services are really part of maintenance services. From a narrower point of view, the necessity for the upkeep of proper systems of repair basically emanates from three different sources:

(a) *Preventive Repairs*

In a number of cases, particularly in the developing countries, actual breakdowns of plant equipments are often the cumulative results of several minor breakages, damages, distortions and maladjustments. Whereas most adjustments could be rectified on the spot, breakages, damages and distortions may require timely repairs or replacements, if more serious shutdowns are to be avoided. Proper systems of preventive maintenance, therefore, have to be complemented by preventive repairs in those cases where wholesale replacement might not be necessary. This aspect gains added importance in the material-scarce economies of the developing countries. Minor repairs or adjustments could be carried out by technical staff engaged in preventive maintenance on the spot, but where this would upset the time-schedule for preventive maintenance, these should be undertaken separately.

(b) *Breakdown Repairs*

Breakdown repairs on an emergency footing are required to be undertaken, when the equipments have actually failed, causing interruption in the factory work or in the factory services. Just as minor preventive repairs are executed by the preventive maintenance departments, minor breakdown repairs could also be attended to by operational maintenance staff. When this is not practicable, the defective part is replaced by a good one, sending the former to factory for repair, it repairable, or scrapping it altogether if not. When spares for replacements are not available as often happens in many factories in the developing countries, emergency repairs on top priority may have to be undertaken to reduce the period of interruption in factory operations.

**Alterations and Additions**

These emanate from periodical reviews, designed to bring about the necessary improvements in the operation of the plant equipments, buildings, sanitation, utility generation and distribution, etc., so as to ensure uninterrupted flow of work. Where existing equipments and facilities are mainfestly defective, or which persistently fail, efforts are made to alter these or add to these with a view to bringing about the necessary improvements.

## II—INSTITUTIONAL ARRANGEMENTS

The institutional arrangements for preventive maintenance and repair services could be organised at four different levels : (1) National level (2) Industry levels (3) Regional levels (4) Enterprise levels.

**National Level**

The fact that the resource-scarce economies of the developing countries, with lower labour costs, should give added importance to maintenance and repair services had been stressed earlier. But in actual practice, this is seldom the case. Not only adequte facilities for operating these services in the developing countries are not available, the extent of harm which such a state of affairs is doing to the interest of these countries is seldom realised by them. In other words, there is a conspicuous inadequacy of consciousness on the urgency as well as the importance of the problem in the developing countries. The primary objective of making institutional arrangements at the national level, therefore, is to generate a satisfactory level of repair and maintenance consciousness, through the length and breadth of the country, amongst the corporate bodies, the management and the engineering personnel at different enterprises, public utilities—in fact at all establishments wherever sizable technical operations are undertaken.

The task of generating such a widespread consciousness becomes most effective, when the cost implications of maintaining such services in terms of anticipated gains through cost reduction and better output, both in quantity as well as in quality are explained in clear terms to the business managers, engineers and the financial administrators through proper publicity materials. To make this proposition clearer, it is desirable to explain the situation in terms of the productivity of the capital deployed for organising and operating maintenance and repair services. In order to be really effective, publicity materials on techno-managerial themes have to be expressed in the simplest possible language supported by adequate number of illustrations.

Apart from preparation of publicity material, the national institution could also undertake data collection and research through work sampling, could organise short seminars explaining the benefits and the methodologies of operating such services among the top-managers, to begin with, stimulating dicussions and their active involvement in the process. Once the topics get some foothold among the top managers, systematic follow-up action for ensuring the spread of the relevant ideas among the middle managers, supervisors and workers could be initiated at the national level. But such efforts towards the spread of the ideas, and what is even more important, the practical methodologies in organising and operating maintenance and repair services at different enterprises, need the co-operation and co-ordination with more specialised institutions and local organisations. The national institution has a basic responsibility in promoting such institutions and organisations throughout the country if maintenance and repair services are to be really effective vehicles for raising the level of productivity of the developing countries.

Apart from generating the satisfactory level of consciousness and other services mentioned above, the national institution could also provide information on latest developments in such fields, by maintaining contact with similar organisations in the developed and developing countries. It could promote study-missions and exchange of experience with different countries seeking to strengthen their maintenance and repair services. It could provide publicity literature, audio-visual aids, to different institutions and organisations interested in propagating the subject, and where circumstances permit, it could promote symposia and discussions for exchange of technical and methodological knowledge and experience within the country.

**Industry Levels**

Notwithstanding the basic role of the national institutions in promoting maintenance and repair services, it will be readily recognised tha such services have considerable amount variations in their organisational structures operational procedures for different lines . production. For example, the sort of tenance and repair which are required in a mill will be substantially different from t maintenance and repair required in engaged in manufacturing transistor shoes, or optical instruments.

Since the production processes in diffe factories in a country are far too numerous f each one of these to have its own body for supporting maintenance and activities, it will be convenient to classify a such production processes cogently under appropriate generic heads, for the purpose of such industry-wise institutional support. Classifications of this nature for different countries, will naturally assume different forms, so as to cater to their own peculiarities, viz.. the type of industries, and state of industrial development, resources, climatic conditions, etc. For example, in a medium-sized country, it may be necessary to have industry-wise institutional arrangement on a fairly broad foundation, i.e., chemical industries providing coverage to refineries and petrochemicals, pharmaceuticals, fertilisers, rubber and plastics—all functioning under the same roof. In a bigger country, provision for such institutional support could be diversified and specialised for providing coverage to different areas.

In view of the special importance of the repair and maintenance services in the developing countries, one might think of having an exclusive institution restricting its coverage to maintenance and repair services only. But in practice, this is neither desirable nor practicable. Successful operation of maintenance and repair services involve intimate knowledge and relationship of such activities with those of other departments of the enterprise, particularly production and engineering departments. The technological bases in most of the developing countries are much weaker as compared to the developing countries. The problems of operating such services can seldom be successfully solved when dealt with in isolation from other activities of the engineering and production departments. In the circumstances, rather than setting up institutions to provide exclusive coverage to maintenance and repair services for certain groups of industries, by far the most effective solution will be to set up maintenance and repair cells in the professional engineering institutions functioning in major technical lines, i.e., Institution of Metallurgy, Institutions of Chemical, Electrical, Civil, Electronic, Ceramic or Aeronautical Engineering. Each one of these could promote a specialised cell within the existing organisational and technical set-up to provide specialised coverage to maintenance and repair aspects relevant to the lines.

As distinct from the general coverage provided by the national institution, the types of services provided by such institutions are much more elaborate and specific in character. These professional institutions could conveniently organise short-term training courses for the middle managers, supervisors and technicians on maintenance and repair activities in their own lines. They could also give a hand in publishing manuals and guides for such personnel on maintenance and repair work in their respective lines, and at a reasonable price.

Apart from training activities, such specialised institutions could also become repository of more detailed knowledge and information in different lines, in terms of contemporary developments taking place elsewhere. After developing a satisfactory degree of expertise in different production lines, such institutions could also undertake consultancy assignments, which will not only provide a testing ground in the actual field of such information and knowledge, but will also provide valuable feedback and research material for the national organisation and to others interested in the same.

**Regional Level**

Both the national as well as industry-wise institutional support for operating repair and maintenance services have pronounced promotional bias. But support at the regional level has a service bias and is primarily intended to provide such maintenance and repair services which are normally beyond the capabilities of individual enterprises on payment of prescribed fees. Thus, such regional maintenance and repair establishments are run on a commercial basis, but have to be promoted as a calculated measure, with a social purpose in view. This aspect is particularly important for small and medium scale industries, which do not always possess the requisite technical competence to cope with all their maintenance and repair problems. As mentioned earlier, in the developing countries, suppliers of plants and equipments do not often maintain their after-sale service nor workshops for major overhaul and repair, nor is it always practicable to send the equipments abroad for such servicing, overhaul and repair. This means that in the developing countries, major overhaul and repairs, beyond the technical capabilities of the enterprise, must be attended to within the country, and at not too distant a place, if serious interruption to production is to be avoided. This is precisely the justification of providing highly-developed professional services to undertake maintenance and repair contracts for the different enterprises in different regions of the country. Owing to a fairly common tendency for the industries in different lines, to get localised in different areas in the country, it is desirable and convenient to operate such regional servicing institutes to specialise in maintenance and repair work on one or two major lines of production, i.e., textiles, foundry, etc. Indeed, when this is the case, suppliers of plants and equipments who sell these under a guarantee may find it convenient to appoint them as their authorised repairers. Many other manufacturers may be quite happy to supply the necessary technical information on maintenance and repair to retain the good name of their products in the market.

### Enterprise Level

Enterprise level maintenance and repair services in the developing countries must not only receive the normal care and attention as is in vogue in the developed countries, but a lot more in view of the added cost repercussions as elaborated earlier. In practice, however, maintenance and repair service in the developing countries are often dealt with in a perfunctory manner, with an overwhelming preponderance of breakdown repair carried out by the production and the engineering departments, without any systematic planning. implementation, or up-keep of records. Irrespective of whether it is testing of the lifting appliances, servicing of the conveyors, checking of the gauges, or maintenance of the blast furnaces, it is necessary to drive home at all levels of the enterprise the extent of losses it would suffer because of these—how the safety, health and smooth functioning at the enterprise would be affected if these are not carried out properly. Apart from educating and training the managers, supervisers, and workers on these services through lectures, demonstrations and film shows, the co-operation of workers, organisations should also be sought in this regard. These aspects, however, have been elaborated further in subsequent pages and for the present, it will be sufficient to stress that maintenance and repair services at the enterprises need special attention and care in planning, organization and implementation covering all engineering including store preservation activities at an enterprise.

## III—STRATEGY OF INTRODUCTION

Whenever introducing a new techno-managerial theme, naturally the basic strategy to be adopted towards this should be to convince those in commanding positions who are primarily responsible to implement the ideas. Such a process of implementation of new ideas is made a lot easier, if there is a basic appreciation and acceptance of the themes among those directly involved below the top-management, i.e., the middle managers, the supervisors and the workers, and of course the all important trade union leaders.

Maintenance and repair services are, however not new themes. These have been known and practised in almost all human societies in some form or the other and from the remotest days of antiquity. What is new in these, however, is a proper scientific approach, both in planning and organisation, as well as in terms of rapidly advancing technologies. This paper, however, is not concerned with the technological aspect of maintenance and repair services, but with the popularisation and extension of such services at engineering and manufacturing establishments on a proper scientific basis.

In most of the developing countries, how ever, enough published materials are already available on maintenance and repair services. Yet these are not catching up. The implementation of the relevant ideas are inadequate, particularly in the context of their basic economic and operational importance to the developing countries. Amidst such a sluggish and tardy operation of the maintenance and repair services, some sort of shock treatment which will make people "wake up" is often necessary. Social psychologists tell us that such a shock treatment for awakening a mass consciousness, can be best done in terms of three basic emotions i.e., pleasure, grief or indignation. Of these three, the last named, i.e., indignation could be used very successfully to awaken consciousness on the importance of maintenance and repair services, when acceptance of the ideas and their implementation are sluggish and tardy.

This could be best done, with a degree of dramatisation to generate some popular sensation from the top political levels, i.e., by the Finance Minister, Industries Minister, or even the leader of the opposition, by publicly accusing that the country is losing so many million rupees, pounds or dollars every year, because of indifference and neglect to operate proper systems of maintenance and repair. Pecuniary data for this could be broadly mobilised through work sampling and scrutiny of past records on interruptions and stoppages of work and the cost figures appertaining to these from a few representative institutions.

Before such a popular sensation is created, a good deal of preparatory work is involved to plan and organise "What next?" Popular indignation when excited is rather a hungry phenomenon, and wants its food. By all means provide food for it—up to a limited extent but well below the point of satiety. Fill up the rest with fuel, so that such indignation keeps on burning. All these require careful and advance planning.

When the political V.I.P. creates a public sensation, by his indignant statement about the losses which the country is suffering through neglect and carelessness in the field of maintenance and repair, he must also have, at least a broad outline of the solutions which will mitigate the problem, followed by an exhortation to set up a national organisation of managers, engineers and scientists who shall provide the country with the necessary leadership and guidance in the field of maintenance and repair services. He must clearly mention the government's anxiety to promote such services on a country-wide basis, and announce a grant for setting up a national institution or at least for adding a new department to an existing national institution in the field of engineering or management, for providing coverage to repair and maintenance services. He may also like to make two additional announcements, the first one on convening a national conference or a seminar of top technocrats for organising industry-wise, regional and enterprise-level maintenance and repair services, and the second one declaring a few national awards annually for contributions towards the arts and the sciences of maintenance and repair by the engineers and the scientists, by the managers and by the workers.

In convening the national conference, it must be ensured that the participants represent different industries, different geographical areas where sizable engineering and manufacturing works are carried out or are to be carried out, different professional interests, i.e., managers, scientists, engineers and their professional institutions, trade union, manufacturers or importers of capital goods and spare parts, etc. Such a national conference must come up with specific plans and recommendations for setting up industry-wise, regional and enterprise level organisations, and also set up sub-committees to follow these up systematically, reporting results to the national organisation at periodic intervals. It will be a valuable contribution to the cause of maintenance and repair services, if this conference agrees to publish a quarterly a monthly, or journal on repair and maintenance services under the auspices of the national organisation which would disseminate relevant information, at home and abroad, publish important contributions by the technocrats on the subject, and report progress on the various aspects of the movement, at the national, industry-wise, regional and enterprise levels.

The fact that governmental patronage to the maintenance and repair services is provided or that a limited amount of public funds are deployed for this purpose could not be construed to mean that responsibility in introducing and operating such services rests with the governments. In fact nothing is further away from truth than this. By and large, most of the developing countries are emerging from feudal traditions, with shaky industrial bases, traditions and resources. Few of them have such corporate organisations of technocrats, which could stand on their own feet without governmental patronage. Governmental patronage towards maintenance and repair services is, therefore, not only necessary, but also desirable to ensure smooth functioning and broad acceptance of themes at different levels of the nation's economy. But the techno-managerial organisations and their activities in a country must necessarily be such as are planned and operated through the corporate efforts of technocrats, enterprises, and institutions, if these are to make the desired impacts. In other words, governmental patronage could be compared to a decorative and protective garment for the corporate bodies of technical and professional people, engaged in introducing and operating maintenance and repair services in the country and on an extensive front.

## IV—STRATEGY OF OPERATION

After the modern maintenance and repair services had been introduced to the enterprises and engineering establishments through the activities mentioned earlier, these have to be organised for physical operation, at least in a few model plants on a selective basis to start with. In applying the principle of selectivity in the process of organising and operating such services, the basic objective would be to generate the requisite multiplier effects. While selecting suitable firms for generation of multiplier effects in this field, following factors should be kept in the forefront:

1. The firm must have progressive managers and should enjoy public esteem for their techno-managerial excellence.
2. The firm has a high turnover, and there should be good scope of demonstrating the effectiveness of maintenance and repair systems in pecuniary terms which could impress and inspire others.
3. The firm should be in a major line of production in the country, so that its example and experience could be readily followed by other firms lar lines of production.

Systematic operation of mai repair services in a few firms havin characteristics, results in emul examples and spread of such firms quite rapidly. On the top competitive spirit is also set into mot the enterprises so as to excel this direction. If the managers are also members of one or more tutions mentioned earlier, then s the situation warms up and a f is created for further spread and of the maintance and repair servi

There is another important principle of selectivity which importance, particularly at the i when additional resources for tenance and repair services, i ısi manpower are rather meagre. selecting more important areas of tion for intensifying the quality and of maintenance and repair servi importance to other areas. principle for operating selectivity is : higher the cost implication of greater is the attention required. ing this aspect, it might be wort the following questions:

1. Is this a critical item? cause a major shutdown, damage, or harm to an for proper maintenance tain.
2. Is standby equipment avai of failure? One can compressors or package short notice. If the load be easily shifted to need for proper mai gent on other factors, "breakdown" maintenance
3. Does cost of proper main expense of downtime and or replacement? If it

tear down a machine to repair a repetitive wear point than the over-all cost of the repair itself, the value of proper maintenance is questionable.

4. Does the normal life of the equipment without maintenance exceed manufacturing needs? If obsolescence is expected sooner than decay, maintenance may be a waste of money.

In the context of the information elicited from the above scrutiny, the maintenance and repair work covering the entire plant could be divided into four categories, carrying out what may be popularly called a VEIN Analysis—

(V=Vital, E=Essential, I=Important, N=Normal)

(a) **Vital Areas**

Areas where any breakdown would result in very costly repairs or replacement and almost a complete closure of the plant operation, for which no standby facilities are available, resulting cessation of production work for a considerable period of time. The example of this is a cupola in a foundry or a turbine in a thermal plant, for which local repair facilities might not be available.

(b) **Essential Areas**

Areas where any breakdown would result in expensive repairs and replacements and cessation of work in a major area of the plant operations, for which no standby facilities are available, resulting in serious interruption in production for a substantial period. Example of this could be found in the failure of the main power unit in a conveyor system or failure of a major heat treatment furnace used for softening forged materials before machining in the direct line of production.

(c) **Important Areas**

This refers to major areas of enterprise operatioor for which though standby or local repair facilities might be available, they would nevertheless involve substantial expenditure in repairs or replacement and serious interruption in production work.

(d) **Normal Areas**

Normal areas of maintenance operation are those where a breakdown will entail nominal expenditure in repair or replacement or minor interruption or delays in plant operation.

The VEIN analysis mentioned above operates around the direct cost implications of repair or replacements, as well as indirect cost implications due to interruptions in plant opreation. In developing model for classifying the maintenance and repair services in terms of direct and indirect cost implications into four categories as mentioned above, a broad analytical estimate is all that is needed to start with. Such an analytical estimate would no doubt vary depending on the nature of the enterprise, and the facilities, particularly stores and repair facilities that could be mobilised both within and outside the enterprise.

Apart from applying the principle of selectivity in the above context, the strategy of operation of the maintenance and repair services within an enterprise is also vitally concerned with organisational arrangements and the costs for operating the same, giving due regard to efficiency and progressive improvement in such services over a period of time. In operating maintenance and repair services, ultimately it is the economic consideration that is the basic deciding factor, and a purely engineering approach might lead one astray. It may be possible to eliminate breakdowns even of ordinary items from engineering point of view, but it may not often be worthwhile to do so from the economic point of view, as it is futile to spend pounds to save the pennies. It is, however, relevant to reiterate here that the method of categorisation of maintenance and repair work in terms of economic onsiderations must be the developing country's own and cannot be copied even from similar factories of the Western counsties, where labour costs are high and replacement costs often cheaper.

Whereas repair work irrespective of whether it is preventive repair or breakdown repair must necessarily be carried out with appropriate priorities whenever replacement is not called for on economic grounds, it may not be practicable to cater for the requirements of preventive maintenance covering the whole establishment all at once. The VEIN analysis elaborated above, operates the principle of selectivity on economic consideration, and not on physical or functional division of the enterprise. The question which automatically arises at this point is how and on what organisational arrangements one is to get on with the job to start with. Along with this, one also has to consider as to how much of the maintenance work could be carrived out by the shop managers, or supervisors of different work centres.

Normally the maintenance work at an industrial enterprise would, by and large, cover the following areas:

1. *Process equipment*—furnaces, heat exchangers, piping, pumps, compressors, motors, stills, instruments.

2. *Safety equipment*—vacuum and pressure-relief valves, flashback or flame arrestors, breathing and emergency-relief equipment.

3 *Utility equipment*—main boilers, electric generators, supply, storage, and distribution systems for water, steam, and compressed-air pipelines.

4 *Tanks and auxiliary equipment*—storage tanks, pipelines, dykes, drains, gauges, and measuring instruments.

5 *Plant buildings*—including shipping and storage areas, also transportation equipment such as tank cars and transfer pumps.

6 *Fire-protection equipment*—water supply and pipelines, pumps, permanent fire-extinguishing installations of foam, fog, gas, spray, or dry powder, first-aid extinguishers, fire trucks, alarm systems.

But during the early stages, ance staff are still being mobili for the job it will be desirable to and "Essential" items from the centralised maintenance gating the responsibility for ı of "Important" and "Normal' shops. In apportioning such however, the technical and of the maintenance department shops would be supreme, so as and ease in operations rather t any rigid formula. As more a ence is gained, the pattern responsibilities, could be ra

The VEIN analysis indicat fies maintenance work in repercussions. This would of reducing losses by adjusti and depth of inspection for is a technical question req engineering analysis on the fo

1. *Age, condition and* poorer equipment services. But if or soon to be obso to inspect on a ske at all.

2. *Severity of service:* cations of identical shorter cycles. In a might need to i every day, the same metal-working plant

3. *Safety requirements:* gin for safety. For inspects the solen ches on presses eve

4. *Hours of operation.* turers suggest freq on an 8-hr day, ot mileage). Buildi vices operate on Sometimes two ever comes first. cleaning may be

operations, or at least every 30 days.

5. *Susceptibility to wear:* What is exposure to dirt, friction, fatigue, stress, corrosion? What is life expectancy?
6. *Susceptibility to damage:* Is it subject to vibration, overloading, abuse?
7. *Susceptibility to losing adjustment:* How will maladjustment or misalignment affect it? Where manufacturing tolerances are tight, shorter inspection cycle is needed.

Such an engineering analysis, however, throws up the basic issues in the process of decision making. In the developing countries, experience has proved that many of the items which manufacturer would suggest replacement after a certain defect had appeared, are eminently suitable for repair. A critical technical examination of the possibilities of satisfactory repair, (even though a manufacturer who is often too anxious to sell extra spare parts might recommend far too early replacements) could be a source of considerable economy to an enterprise.

As far as repair services are concerned, apart from breakdown repairs, for the purpose of administration and organisation, it is convenient to include preventive and upkeep repairs under this, irrespective of whether the work involved is derusting of pipes, painting of buildings, welding, or electro-deposition of metals on worn-out parts. One of the reasons why in the developed countries simple repair works are often not undertaken by the maintenance staff, even when this is well within their technical competence, is that the latter have to work on highly organised and tight time schedule. It will not be possible for them to adhere to the pre-determined maintenance schedule if they were to undertake even simple routine repair works. This is, however, not the case in most of the developing countries, particularly at the initial stages, when the maintenance programmes considerable amount of flexibility. In such matters, what is most important is to alive a spirit of service, particularly among supervisors of the maintenance teams. It should be impressed upon all maintenance operatives that shop managers are their clients and maintenance staff should go to the farthest extent to satisfy them, soliciting their goodwill and co-operation in the process.

As regards basic additions and alterations to the existing plant facilities, normally these should be specially scheduled and accounted for. But when the nature of work involved is such that these could be undertaken without much dislocation of normal work, then on economic consideration these may well be undertaken by the maintenance and repair departments. Before accepting any such additional responsibility, the precise technical and economic implications of this must be made clear to the top management.

There are two other basic issues concerning the repair services which deserve special consideration. The first one amongst these relate to the organizational arrangements for executing repair work and the second one concerns priority administration. It has been envisaged earlier that routine and simple repair works could be undertaken by the maintenance staff for which a special maintenance workshop could be provided. Apart from the special facilities which a particular enterprise might require, following equipments, by and large, would cater for the general requirements of an average maintenance workshop:

1. General Purpose Lathe
2. Drilling Machine
3. Shaper
4. Planer
5. Double Ended Grinder
6. Tool Post Grinder
7. Forge and Smithy equipments
8. Heat treatment furnace, cyanide bath and quenching tank
9. Gas and Electric Welding
10. Hand and Power Hacksaw
11. Abrasive Cut-Off Wheels
12. Assorted hand tools and measuring instruments.

The advantage of having such a workshop under the maintenance department would be expeditious clearance of work depending upon urgency of the situation, without seeking extra-departmental assistance. Naturally workshop of this nature will not be able to carry out major repairs. For this purpose, assistance of regular engineering departments and, when suchr epairs are beyond the technical competence of such departments, outside assistance may have to be sought. This means that the supervisors in the maintenance shops should be familiar with the technical capabilities of the enterprise, as well as of those outside workshops, which might be located in the vicinity. Irrespective of whether major repair and overhauls are undertaken by the enterprise or placed on an outside shop, an effective pattern of priority administration for executing breakdown and maintenance repair work has to be developed under the authority of the top management.

It will be appreciated that operation of satisfactory systems of maintenance and repair are matured and built up over several years even in the developed countries. The published literature and guidelines on these are at once vast and complex. In the above paragraphs attempts have been made only to highlight some of the major areas which are of specific importance to the developing countries. Managers and engineers desirous of having further information on the subject should consult the bibliography listed at the end of this paper, paying particular attention to modify these to conform to the physical, technical and economic realities in and around their enterprises.

## V—COST CALCULATIONS AND EVALUATION

Cost calculations constitute an essential part for introducing, operating and evaluating maintenance and repair services. Unless the extent of loss which a developing country might be suffering is expressed in pecuniary terms, it seldom produces the degree of seriousness for effective and widespread introduction of such services. Unless economics of the different aspects and areas of such services are properly comprehended, it is difficult to operate such services on scientific lines. Unless pecuniary

*Cost calculation essential part for intro operating and maintenance and repair*

parameters are used, it is di the effectiveness of such s seen therefore that without a factory method of cost ca ness of maintenance and repair be seriously handicapped.

In spite of its basic i culations operating amidst so some of which are little approximations if not speculat expect to attain that degree of is normally expected by the fession. Yet this limitation ha attempting to make the situation, particularly during t

As far as the direct costs and repair are concerned, t tively easy to compile, based and could be estimated on But the indirect costs on tions are likely to suffer wide adequately supervised at In any case the broad cost e for operating VEIN analysis the earliersection, could be doing so the best answer the loss of production in costs, added by proport

In most factories in the records of time lost for repairs may not be available. over of such events are fai be computed statistically pling. As regards major ruption in production, well be available, and in be computed in terms of gested earlier. If these are not available, then major breakdowns being important events, and since workers and supervisors should know their frequency and extent, necessary information could be extracted from these for computing the pecuniary figures. This would mean reliance on verbal statements, but this is the best which could be done in the absence of more precise information. The importance of proper upkeep of necessary records for cost calculation, however, has to be stressed on the management, and perhaps, from that time onward cost calculations would become easier and more accurate propositions.

As regards evaluation of the benefits of the maintenance and repair services, this is best done in terms of productivity of additional capital deployed. As it is well known, productivity is the relationship of the output over the input, i.e.,

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}}$$

Productivity of the money spent on operating the maintenance and repair services would be

$$\begin{array}{l}\text{Productivity of}\\ \text{additional capi-}\\ \text{tal deployed for}\\ \text{maintenance}\\ \text{and repair}\end{array} = \frac{\text{Economic gains}}{\text{Additional costs for maintenance and repair}}$$

As regards the economic gains generated through strengthening the maintenance and repair services, these could be computed in terms of reduction in interruption of production, reduction in repair and replacements, inclusive of proportional addition of overheads to the figures. It is not necessary to add such proportional overheads to the additional costs for maintenance and repair, as the latter is a precise figure of actual incremental cost incurred, which would include elements of overhead if any that had been spent in the process.

For the purpose of a reasonably satisfactory and broad cost calculation and evaluation, the methods indicated above could be generally accepted. If, however, further refinements are required in any particular direction, then these could be easily constructed, more or less, on the very same foundations.

**Acknowledgement**

In compiling the material for 'Strategy of Operation'. the author has at a few places followed the pattern of the check list prepared by Mr. Carl G. Wyder on Preventive Maintenance, published in 'Maintenance Engineering Hand Book.'

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# Organization and Importance of Company Standards

G H Weber*

**Company standards are necessary in order to meet demand for standardised information required for tasks of design and development. Standardisation makes it possible to save time when seeking information and to avoid duplication of work. Another advantage of company standards is the reduced diversification of parts and materials.**

**A few exceptions apart, company standards are usually the revised forms of basic or metrological or national standards. To ensure long-term effect of standardisation, a company standards programme must have management support. Application of company standards can be ensured only by an efficient standards department.**

IN view of the standards established by the International Organization for Standardization (ISO), the national standards institution and the standards organizations of industrialized countries, the management of an industrial enterprise is faced with the question as to the need to standardize within the enterprise. Before decision is made to set up a standards department, the aspects of benefit and expenditure must be examined. The purpose of this remark is to provide management with suggestions concerning the bases of decisions and the establishment of company standards.

It is indisputable that standardization is one of the most important factors promoting industrialization. The earlier standardization is planned, propagated and applied, the greater its rationalization effect. Here the developing countries have a great advantage. Drawing on the experiences made in industrialized countries, they can ensure that the introduction of standardization goes hand in hand with the development of the national economy. If standardization is introduced at a later stage, i.e. when inefficiency becomes obvious due to haphazardly applied foreign standards or a lack of standards altogether, it will be less successful and far more costly.

Company standardization should be introduced simultaneously with standardization at national level.

It is a pre-requisite to the infra-structure development of a national economy that parallel to the building up of industry, the transport system, energy economy, agriculture, health system, and research and cultural ties at horizontal level, the vertical structure, including individual industries and associations of industry are established.

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Although national standards provide the pre-requisites for company standards, their application can be ensured only by efficiently operating standards departments in the various companies. It is important to correctly recognize and assess the interaction of national and company standards. The standards departments in the industries of the developing countries have to be organized under far more complex conditions than those which prevail in the industrialized countries. On the one hand industry itself is still in a stage of development, on the other hand the number of available engineering staff is completely inadequate. It is of great importance that the government support the preparation of national as well as company standards, since they create the pre-requisites for training the necessary standards experts.

As the companies themselves are responsible for the drafting of company standards, their view of standardization is company-oriented, standardization activities at national level being only of second concern. This article deals primarily with company standards.

**Why Do We Need Company Standards?**

In view of the great number of international standards and recommendations in existence, the following facts must be taken into account in seeking an answer to this question. Established national standards apply to all commonly used sizes and varieties of the items in question. These standards may be compared to a dictionary which contains all words of a language. Just as a writer cannot use all existing words, so no industrial enterprise will be in a position to use the entire range of sizes and varieties covered by a national standard.

The majority of national standards have been developed from already existing trade standards or from company standards. While they have been improved and adjusted with a view to general applicability, they are (based and this is an essential pre-requisite) on the experiences gained in the companies.

Company standards are selected from available sources and adapted to the specific requirements of the individual companies. They frequently include many items which can never be taken over in national or international standards. On the other hand, they will need and include only a limited part of the national standards.

The essential difference between national standards and company standards, i.e. between theory and practice, has been described by an American standards engineer as follows:

"Theory takes all known possibilities into consideration; practice takes only all existing possibilities into consideration."

ISO and IEC recommendations are not often applied in their original form when introducing company standards.

Company standards are necessary in order to meet the demand for standardized information which, in turn, is needed for tasks of design and development. This information includes not only the data necessary for communication between design department and workshop or between supplier and consumer, but also data concerning the market supply of components and raw materials and production possibilities in the plant. Standardized information is available in the form of standard material, catalogues, standard sheets, specifications, drafting room handbooks, etc. This concentration of information is a valuable time-saving aid for the designer. By consulting catalogue lists of repetitive parts, he can sometimes avoid having to design such parts.

Standardization makes it possible to save time when seeking information and to avoid duplication of work. Another advantage of company standards is the reduced diversification of parts and materials. This, of course, saves the firms considerable sums of money, particularly storage costs.

It is quite normal that in the course of time stocks on hand increase and larger numbers of varieties are manufactured. They are often an indicator of an upward trend in business and the continuous improvement of the products. It goes without saying that new parts and materials are constantly being produced.

Since the impovement of existing parts and the design of new parts goes hand in hand with the dropping of older parts which are no longer needed, it becomes evident that the reduction of varieties must be planned systematically. One of the main aims of company standardization is, therefore, to reduce the number of varieties.

As already mentioned, another important objective of standardization is to avoid duplication of work. for example, with regard to the design of simple components or to administrative work in the offices. If we take a look at the offices, we often find that Mr. Baker, who is working in the warehouse, is doing the same thing Mr. Smith is doing in the purchasing office; they are both entering ordered stocks on index cards. Neither knows what the other is doing: perhaps they don't even know each other. This may not be a catastrophe, but it is certainly a waste of time and money. There are many Bakers and Smiths in our offices. Duplication of work can be avoided if forms, work-flow charts and job descriptions are standardized. It is a matter of organization whether this task is taken over by the standards engineer or by an associated office.

Another important task of the standards engineer is the introduction of foreign standards and specifications and their adaptation to conditions in the company. Frequently these documents are provided by the purchasers of a product. They differ considerably with regard to the make and arrangement, and are often written in a foreign language. These documents cannot be handed out to the offices in their original form. One of the tasks of the standards department is to revise these documents and comment or abridge them where necessary, so that the various departments can apply them correctly and economically.

*Company standardisation should be introduced simultaneously with standardisation at national level.*

If we compare the books on standards of various companies, we find that the majority of standards compiled are company standards. Secondly, trade standards are included, a large number of which have had to be adapted for company use. Apart from a few exceptions, usually basic standards and metrological standards, the national standards have been taken over in revised form. International recommendations—if included at all—have also been revised extensively. As a rule over 75 per cent of the standards in these books are company standards.

The advantages of company standards can be summarized as follows:

—reduction of the number of purchase orders

—reduction of stocks

—simplification of design recommendations

—improved enforcement of safety regulations

—rationalization of warehouse administration

—reduction of costs involved in testing.

**The Role of Standardization**

In order to be able to assess the significance of company standards, we must consider the spheres where standardization can be introduced. Since there are different types of production on which company standards have to be based, we must first study these differences. In view of their influence on company standardization the following two types of production should be mentioned:

1. Products consisting of components from several manufacturing stages:

   (a) Series production (catalogue-type business), e.g. the production of tractors—standard types with a number of varieties which can be ordered through a catalogue;

   (b) Single production (requisition-type business),e.g. the production of power plant machinery and equipment which differ with each order—size and design are largely determined by the buyer.

2. Single-stage production, e.g. the production of detergents or cement.

With regard to company standardization a distinction must be made between industrial enterprises manufacturing products consisting of components from supplier firms, apparatuses manufactured externally, and components designed and manufactured in the company itself, and enterprises where products are manufactured in a single stage and where only the raw material must be purchased but where extensive and often complex plants are required. The type of production (single production or series production) will considerably determine the effect company standards will have.

Whereas specifications for the procurement of materials and correlation of the component parts of the products in connection with the maintenance are of predominant importance in mass production, the reduction of variety, the use of repetition parts and the selection of the most suitable materials are the factors of main emphasis in individual construction. In single stage production emphasis is laid on the standardization of manufacturing supplies, spare parts for production equipment, operation materials, tools and appliances. The sphere of influence differs accordingly. When company standards are adopted in multi-stage production, they have a considerable effect on design and development; in single stage production, however, there will be a negligible effect, if any, on the efficiency of the design and development departments.

The main spheres in which company standards contribute to nationalization are:

—product planning

—development and design

—graphic reproduction and documentation

—construction of tools and manufacturing supplies

—production planning and control

—procurement of materials

—goods entry control

—storage

—materials testing

—quality control.

One area in which standardization is very desirable is electronic data processing. Standardization greatly facilitates the processing of information. Due attention should be paid to this fact in the initial stages of company standardization. If computers are not used, it must be borne in mind that the information selected for processing must meet computer requirements. If this is not done in the initial stage, it is inevitable that when electronic data processing is introduced at a later date the costs will be much higher, due to the necessary adjustment of the data to be processed. Electronic data processing is being introduced in all sectors of industry today, and account must be taken of this fact when introducing company standards.

In series production company standardization will as a rule facilitate the work of the departments responsible for the abovementioned tasks. In single production, the areas of application are the same; there will only be shifts of emphasis in the various functional spheres.

For example, economization possibilities will be of more importance in single production than in series production, where, due to the large amounts ordered, economization by reducing the number of varieties is not very promising. In the automobile industry which is a good example for modern mass production, we speak of a standardization threshold beyond which no savings can be achieved by reducing the number of models and increasing piece numbers. In other words, it does not make any difference whether a standardized or non-standardized part is used. Apart from the favourable cost factor, there is also the advantage, among others, of improved maintenance possibilities when standardized parts are used.

In single-stage production the influence of company standards covers the followings fields:

—construction of plant facilities
—production control (in some cases)
—maintenance
—procurement of materials
—goods entry control
—storage of spare parts for production facilities.

These are mainly departments which concern themselves with planning, administration and maintenance of production facilities.

## To What Extent Can Costs Be Influenced By Company Standardization?

It is well known that the more evident the possibilities of economizing through planned action, the easier the decision to carry it through. Standardization clearly has the advantage of saving costs. As the effect of standardization makes itself felt in such a large number of fields, it is impossible to assess its overall effect. Every attempt to justify a company standardization programme on the basis of cost accounting gives rise to problems, the majority of which have remained unsolved.

With a few exceptions, the literature on standardization contains information on individual measures only. Especially in European literature no information on the actual amounts saved is provided. In principle it is not difficult to assess these amounts. However, actual figures in terms of money indicating the overall success of standardization would reveal too much about the enterprise and are, therefore, not published. For this reason the discipline concerned with these problems in Germany lacks the basic data which is essential in ascertaining the economic benefit derived from standardization.

The following should, therefore, be understood simply as an attempt to show the possibilities of a standardization programme. Figures indicated are not generally valid. In practice the pre-requisites for standardization differ to such an extent that at present generally applicable values cannot be indicated.

Having ascertained in which spheres standardization can be applied, we must determine the costs arising in these spheres and their share in the total turnover.

The turnover of an enterprise consists of:

| | |
|---|---|
| —direct material costs | 30 per cent |
| —direct wage costs | 10 per cent |
| —indirect or fixed costs | 50 per cent |
| —taxes, etc. | 10 per cent |

Material costs may be affected by standardization to a considerable extent. Labour costs are only indirectly affected. The effect of standardization on labour costs will be investigated in another context. Costs such as taxes, etc., are only indirectly affected by standardization. Due to a reduction in goods on hand, for example, taxes may be reduced.

The most important factor in this analysis are the fixed costs; they usually account for the largest share of the company's turnover. They comprize

—sales
—engineering
—production
—finance
—staff and legal matters.

The effects of standardization are felt in the sphere of engineering and production and to a lesser extent also in other spheres.

The next step will be to ascertain the costs of the various spheres in the total turnover. According to studies carried out in the United States, standardization affects 40 per cent of the fixed costs, 70 per cent of the material costs and 55 per cent of the total turnover. Since there is a higher degree of automation in American industry these amounts should be higher in Europe and most certainly so in the developing countries.

Even if these figures do not reveal the results obtainable through standardization, they clearly emphasize the significance of company standards. A forecast of the extent to which costs may be reduced in spheres influenced by standardization is difficult and dependent on many factors, and the decisive importance of these numerous factors is easily overlooked.

The results of the American study show that the savings resulting from standardization fluctuate between 0.3 and 5 per cent, the average being nearly 1 per cent. It became clear that the costs saved in the larger spheres where standardization is carried through cannot be ascertained.

How the effect of standardization on a company's cost structure can be represented and assessed, is explained in the following paragraphs:

In a table subdivided according to the elements of costs the spheres where standardization has been carried through are listed in the first column. Costs such as sales, finance and staff which are not affected by standardization are not included. The second column lists those departments which are either directly or indirectly affected by standardization. The third column contains the annual costs (in the relevant currency) incurred in these departments. The last column indicates the share of these departments in the total annual turnover in per cent.

The next step, that of assessing the savings possibilities arising from the introduction of company standards, requires a good knowledge of the structure of the company and much objectivity and insight into the possibilities of standardization.

The probable success is calculated on the basis of the following elements:

—the minimum success which must be achieved

—the presumable success

—the maximum success which can be achieved.

The success achieved by an average standards department under unfavourable conditions and without incurring high expenditures is taken as **minimum success**.

The assessment of the **presumable success** is much more difficult. First, the technical standard of the individual fields of application is ascertained. Then the willingness of staff to accept changes and improvements in their methods is studied. In this context psychological aspects are of great importance. Another important factor is the efficiency of the standards departments, especially its capacity to carry through a measure.

The following examples may illustrate this situation. A time study revealed that a designer spends 6.3 hours a week seeking information on tools, semi-finished products, attachments, seals, design details, construction elements, etc., which is essential for his work. Only 60 per cent of his efforts are successful. By standardizing and classifying information, this time loss can be eliminated. If the annual costs for a designer amount to $25,000, including the costs for his place of work, an amount of $1,60.000 (6.4 per cent of the total costs) can be saved in an office where 100 designers are employed.

The costs of the drawing office can be reduced by 10 per cent by rationalizing the preparation

| Functional Area of Standards | Influence | Annual Costs $ 1000 | Percent of Total Costs % | Estimation of Savings min. % a | probable % m | max. % b | Savings to be expected Calculated % E | $ 1000 | Percent of Total Costs % |
|---|---|---|---|---|---|---|---|---|---|
| Marketing | — | 3550 | 8 | — | — | — | — | — | — |
| Finance, Accounting, Banking | — | 1900 | 4 | — | — | — | — | — | — |
| Employee Relations and Legal | — | 1050 | 2 | — | — | — | — | — | — |
| Engineering | 0 | 8670 | 20 | — | — | — | — | 236 | 0.5 |
| Advance Engineering and Research | — | 1300 | | | | | | | |
| Product Planning and Development | 0 | 1200 | | 1 | 2 | 4 | 1.5 | 18 | |
| Development and Design | 0 | 3300 | | 2 | 6 | 10 | 4 | 132 | |
| Drafting and Graph Reproduction | 0 | 2000 | | 3 | 7 | 10 | 4.5 | 90 | |
| Testing | — | 800 | | — | — | — | — | — | |
| Patents and Complaint Expense | — | 70 | | | | | | | |
| Manufacturing | 0 | 4320 | 10 | | | | | 256 | 5.9 |
| Process and Equipment Development | 0 | 400 | | 1 | 2 | 7 | 2 | 8 | |
| Tools and Fixture Design | 0 | 520 | | 6 | 10 | 30 | 9.3 | 48 | |
| Operation Planning and Scheduling | 0 | 800 | | 1 | 3 | 8 | 2.5 | 2 | |
| Materials Disposition | 0 | 700 | | 5 | 14 | 25 | 9.7 | 68 | |
| Purchasing | 0 | 400 | | 5 | 15 | 23 | 9.7 | 39 | |
| Receiving and Incoming Inspection | 0 | 120 | | 1 | 3 | 8 | 2.5 | 3 | |
| Stock-keeping | 0 | 480 | | 5 | 10 | 20 | 7.5 | 36 | |
| Quality Control/Production Cont. | 0 | 400 | | 1 | 2 | 4 | 1.5 | 6 | |
| Maintenance | 0 | 500 | | 5 | 15 | 20 | 9.2 | 46 | |
| Direct Labor | 0 | 6000 | 14 | 1 | 3 | 5 | 2 | 120 | 0.3 |
| Direct Material | 0 | 18000 | 41 | 5 | 10 | 20 | 7.5 | 1350 | 3.1 |

Total annual costs $ 43000

Expected cost reduction 1962

Cost reduction — 1962

$$E = \frac{a+4m+b}{6}$$

Net costs 1000$ 41038

of drawings. At the same time the paper should be fully utilized. The costs involved in reproduction can then be reduced considerably.

A reduction of stocks goes hand in hand with a reduction in storage costs and also in the number of items to be handled. The store department will handle less orders, but due to the increased turnover, there will be larger piece numbers, which means a reduction of unit costs. Thanks to the smaller number of purchase orders, the work of the goods entry control department is reduced. The costs for a purchase order lie between $5 and $100, the administrative costs for a stored item between $160 and $300. Consequently the varieties stored are reduced, possible savings in other areas of the materials sector can be assessed.

A **maximum success** is defined as the results which can be achieved in a field of application under most favourable conditions. The probable success is calculated by means of the equation

$$E = \frac{a + 4m + b}{6}$$

which is used for other types of statistics.

E = expected probable success
a = minimum success
m = estimated presumable success
b = maximum success

Taking as basis the percentage of the calculated probable success, the amount of the probable savings can be calculated on the basis of the annual costs. Total expected savings are obtained by adding together the individual values. In addition, the share in the annual turnover can now also be ascertained.

Attention must be paid to the following points:

1. The success calculated in this manner cannot be achieved within a short period of time. During the first years after the introduction of standardization, the progress made will be negligible.
2. Once the calculated success has been achieved, it is either not repeatable or only at large time intervals and to a much lesser extent. Permanent efforts are, therefore, necessary to maintain the level achieved.
3. Changes in the spheres of application can overshadow the effects of standardization. These changes may take the form of a change of the number of orders, high investments in the fields of application, reduction or increase of staff, programme changes, etc. Such changes are common to all dynamic enterprises.

When considering the question of costs, it should be emphasized that the decision to introduce company standardization does not depend exclusively on savings anticipated. There are numerous cases where the introduction of company standards is necessary and where a standards department is set up even if savings cannot immediately be reckoned with. This is due to external influence or internal measures. For example, the introduction of electronic data processing requires the establishment of a standards department. An inquiry carried through in several hundreds of industrial establishments revealed that as a rule one dollar invested in standardization will result in savings up to $50. On an average the savings amount to $5 for each dollar invested in standardization.

**Organization of Company Standardization Activities.**

When organizing a modern standards department, it is necessary to take into consideration those principles which render possible effective and economical work. These are:

—the scientific principle in standardization work
—the cybernetic principle of organizing standardization
—the principle of progressiveness of the development of standardization
—the principle of coordination of the effects.

*For effective standardisation, application and recognition of standards must be added to the category of systematizing, controlling and informing.*

The scientific principle underlying the work of standardization serves to guarantee good results by organizing the flow of work systematically, methodically and logically.

The various stages involved in this task are as follows:-

1. Definition of the requirements or the problem.
2. Collection of information and data.
3. Analysis and organization of data.
4. Ascertainment of the chief tasks or the statistical accumulation points.
5. Ascertainment of the maximum limits of manufacturing or operational costs.
6. Ascertainment of the technical standard of the company itself, ascertainment of competitors, and clarification of legal questions.
7. Preparation of the standard involved and relevant documents.
8. Informing and instructing the departments concerned.
9. Observation of the effect of standardization in order to be able to suggest improvements or changes.
10. Improvement of the standard involved.

The structure of a standards department, regardless of its tasks and size, should take into account the cybernetic principle of the control cycle. This means that the application and recognition of standards must be added to the category of systematizing, controlling and informing, if standardization is to be more than just theory. Feedback through application gives new impetus to standardization, shows where improvements are necessary and where gaps exist, and indicates the degree to which implemented measures have proved expedient. Feedback occurs when material is requested for externally manufactured parts, semi-finished products and drawings for company-constructed parts. Feedback through standardization results from the arrangement of drawings and lists of parts. Another point of feedback contact is storage administration and quality control.

On the basis of the principle of progressiveness, the harmonious interaction of the individual standards is ensured. A standard which is widely applied in an industrial enterprise serves to ensure that the functions of the departments concerned are harmonized. This effect of a standard has to be taken into consideration when it is being developed.

The abovementioned principles must be taken into account when standardization becomes an integral part of management policy. In this context questions relating to the size a department and the establishment of sub-departments should be discussed.

The optimal size of a standards department depends on the type of production, the size of the company and the frequency with which varieties are changed. The standards department of an enterprise with single-stage or continuous production will require fewer staff than that of an enterprise of the same size which is engaged in multi-stage production. Frequent changes of programmes or models require numerous new designs, materials, new semi-finished products, new tools, etc. This means an increased workload for the standards department and a corresponding increase in staff. The same arises when we compare a company engaged in single production with one involved in series production. Less work will fall to a standards department in a series-production enterprise than in a single-production one where many adjustments in design are required. The standards department should consist of a standards engineer, a standards tester and a technical assistant. Its structure is determined by the type of tasks, the size of the company, and the workload. No generally valid suggestion can be made as the departments will differ from firm to firm. Too large a standards department will be disadvantageous, as inter-departmental administrative work would then take up too much time, especially at the leading personnel level.

The standards department should be subordinate to a manager who also supervises the engineering and production departments, the two main spheres influenced by standardization. The standards department would lose its neutrality if it were integrated into one of these spheres, and the result would be a considerable drop in efficiency. This also holds true for companies with continuous single production.

In practice the standards departments often have sub-departments responsible for:

—design a. ministration

—graphic reproduction

—microfilms

—technical documentation.

The expediency of this arrangement has, however, been contested. It is recommendable only if the designated activities are directly related to the work of the standards department, if a feedback effect is ensured, or if other advantages can be derived. The standards department should not be entrusted with tasks not directly related with its work: otherwise Parkinson's law would become manifest.

The standards engineer entrusted with organizing a standards department will start his work by compiling data. By means of an analysis of the stock of drawings, he will determine the need for basic standards. The necessary data on tools and semi-finished products is derived from an analysis of lists of parts and of manufacturing plans compiled for the clearance of stocks which can be obtained by analyzing the frequency with which items are moved from the stock. The use of the ABC analysis helps to determine which parts benefit most from being standardized. Other important sectors can be ascertained as a result of cooperation between development and construction. There are many signs indicating the fields where stadardization is necessary. Duplication of work is one such signal. The standards engineer must focus his attention on objects, processes, and problems which repeatedly occur (for example, different people doing the same job in different places). Disturbances and difficulties also indicate the need for standardization. The standards engineer then has sufficient basic information at hand and can formulate a concept of standardization and prepare a work programme. The standards engineer should consider it imperative to coordinate his work with other departments.

It is very important that management support the company standardization programme. Only then can a long-term effect of standardization be ensured.

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# Role of Maintenance and Repair in Economic Development of Manufacturing Industry

**J Molsberger***

**Developing countries suffer from an unduly high rate of depletion of capital assets and a chronic waste of productive capacity which even economically stronger countries could hardly afford. The article stresses the role of maintenance and repair in the economic development in these countries. Recommendations, to tide over maintenance problems which include planning activities, policy measures, standardisation of machinery, creation of technical supervisory agencies and the training of special repair workers, have been clearly spelled out.**

THE subject of the present study is maintenance and repair and spare part supply in manufacturing industry with reference to the problems of developing countries. The subject is treated within the framework of a market economy with planning ingredients which is the prevalent economic system in developing countries. It is the purpose of this study:

- to describe the role of maintenance and repair for economic development,
- to review the situation in developing countries,
- to highlight specific aspects of maintenance and repair activities which should be focussed at the national level, and
- to outline some possible ways and means for improving or rationalizing maintenance and repair in developing countries, taking into consideration their specific problems.

Section I portrays the present general state in developing countries. The importance of maintenance policy is emphasized by sketching out the losses in production and growth which typically result from poor maintenance and repair. A theoretical analysis of optimal maintenance and repair activities of a country under different sets of conditions provides the basis for a thorough discussion of the problem of maintenance and repair for reviewing the specific situation of developing countries. The quantity and quality of available labour as well as alternative choices of capital goods and maintenance techniques are taken into consideration. Special attention is drawn to the balance-of-payments aspect of maintenance policy.

Specific problems of maintenance and repair which should be dealt with at the national level are described extensively in Section II. The *pros* and *cons* regarding the import of new *versus* second-hand equipment are discussed under the aspect of maintenance and repair. The availability of spare parts is treated at some length; particular attention is paid to the establishment of central stocks of spare parts, and the possibilities for import substitution of spares and other maintenance materials are reviewed. Some considerations concerning the setting-up of repair shops in the context of industrial estates follow. The last paragraph gives a statistical survey of maintenance and

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repair activities in an industrialized country with a view to finding clues for estimating present and future needs for maintenance and repair in developing countries.

The problems of maintenance and repair are analysed with regard to their relevance for economic policy. Conclusions and recommendations are made in the context of the theoretical discussion. Section III reviews some additional ways and means of improving the maintenance and repair performance in developing countries. Recommendations include planning activities, policy measures, standardization of machinery, creation of technical supervisory agencies, and the training of special repair workers.

For the sake of simplifying the terminology, the concept of "maintenance" is often used in this study in a broader sense, including also "repair", especially in such standard terms as "maintenance cost", "maintenance workers", etc., instead of "maintenance and repair costs", etc. If, however, the context required a clear distinction between "repair" as replacing or mending of parts after breakdown of equipment, and "maintenance" as the set of measures to keep plant and equipment in good operating condition and to prevent breakdowns as far as possible, the term "maintenance" has been used with explanatory additions such as "preventive maintenance" or "maintenance proper".

# I. EXAMINATION OF THE PROBLEM

## 1. Importance of Maintenance and Repair for Economic Development

### A. The Situation of Maintenance and Repair in Developing Countries

One of the characteristics of developing countries is the great scarcity of capital. It should be expected, therefore, that capital goods in these countries are maintained better than in industrially developed nations which have a relative abundance of capital goods. Besides, the natural conditions in many developing countries call for *special* care of machinery and structures: tropical claimate, extremely high or low humidities pose their own maintenance problems unknown in temperate zones.

Unfortunately, the actual situation is anything but adequate to the conditions prevailing. Since many years, experts have stressed the lack of proper maintenance and repair in developing countries. In 1958, Hirschman wrote in his '*Strategy of Economic Development*:

> "This is perhaps one of the most characteristic failings of underdeveloped countries and one that is spread over the whole economic landscape. Eroding soils, stalled trucks, leaking roofs, prematurely run-down machines, unsafe bridges, clogged-up irrigation ditches—all testify to the same pervasive and paradoxical trait: the inadequate care for existing capital in capital-poor countries."[1]

In the same year, the United Nations Secretariat stated:

> "Because of inadequate maintenance, industry in many underdeveloped countries suffers from an unduly high rate of depletion of capital assets and a chronic waste of production capacity which even economically stronger countries could hardly afford."[2]

The situation has hardly changed since this was written. The same complaints about neglect of maintenance and inadequacy of spare parts supply which were made in a report of United Nations Technical Assistance Experts

1. Albert O. Hirschman, *The Strategy of Economic Development*, Yale University Press, New Haven and London, Tenth Printing (Paperbound), 1966, p. 141.
2. United Nations, *Management of Industrial Enterprises in Under-developed Countries*, para. 84, as cited in *Industrialization and Productivity*, Bulletin 2, United Nations, Department of Economic and Social Affairs, New York, March 1959, p. 55.

1959[3] reappear in a case study of the Steel ndustry in a developing country, published in 966.[4] So the United Nations Secretrariat's stion for urgent action, made in 1958, has lost its topicality:

"The attention of governments and industry is drawn to the urgent need for adopting proper maintenance methods and practices, and to establish proper facilities for training of maintenance personnel."[5]

The lack of proper maintenance practices has serious consequences on the economic development. Possible losses in production and growth resulting from, and possible gains foregone by, inadequate maintenance and repair are the subject of the following section.

**B. Possible Losses in Production and Growth due to Poor Maintenance and Repair**

(*a*) *Destruction of Equipment:* The most eye-catching loss caused by poor maintenance or inadequate repair is the premature deterioration or total destruction of productive capital. The already cited report of the United Nations Technical Assistance Experts mention numerous instances of "equipment being allowed to deteriorate beyond repair and having to be replaced".[6] Negligence in the maintenance of buildings and structures can cause—in addition to direct losses—secondary damages to the machinery that is inadequately protected.

*Lack of proper maintenance practices has serious consequences on the economic development.*

Since capital is scarce in developing countries, the relative importance of capital destructions is much greater than it would be in an industrialized country. Thus, the marginal impact on growth is likewise greater.

*b*) *Production Losses:* Deterioration or destruction of equipment leads to losses in production. These losses are twofold: a falling-off in product quality and frequent disruptions of the production process (or even a combination of both).

Undetected or unredressed wear and tear of machinery, or lack of care for control devices, typically results in deterioration of *product quality*. In other cases, inadequate maintenance or incompetent repair causes frequent breakdowns of machinery leading to *disruptions* in the production process. During downtimes, when the production factors do not render productive services, wages of idled labour and capital cost for idled equipment still have to be paid, The consequent effects are enhanced if the repair cannot be carried out, or the spare parts cannot be delivered, immediately. The economic penalty for stoppage of operation is highest in continuous process-type industries. The cost of interruption to operations is lower in the case of fabrication or assembly of discrete units.[7]

(*c*) *Induced* (*secondary*) *Losses:* Primary production losses caused by poor maintenance

3. "Some Problems of Industrial Management Reported by Technical Assistance Experts", *Industrialization and Productivity,* Bulletin 2, United Nations, Department of Economic and Social Affairs, New York, March 1959, pp. 53-57.
4. William A. Johnson, *The Steel Industry of India*, Harvard University Press, Cambridge, Massachusetts, 1966, pp. 174 ff.
5. United Nations, *Management of Industry Enterprises in Under-developed Countries, op. cit.*, as cited in *Industrialization and Productivity,* Bulletin 2, *op. cit.*, p. 57.
6. "Some Problems of Industrial Management Reported by Technical Assistance Experts", *op. cit.*, p. 55.
7. *Cf.* "Better Way to Compare Your Plant's Maintenance Practices", *Factory,* Management and Maintenance, August 1958, p. 140.

and repair have negative effects on those firms which are customers of the firm in question.

*Poor quality* of intermediate goods deteriorates the quality of the final products as well—or requires additional treatment or processing by the final manufacturer. If the quality is so poor that the material cannot be used at all but is still passed on to the customer, the waste is even greater because of needless haulage by railways or trucks.[8] Again, it should be mentioned that the losses through waste impair economic growth and development relatively more in a developing country, where resources are particularly limited and the industrial sector is only small.

*Frequent breakdowns* of machinery which reduce the output of a firm or industry, or lead to irregular deliveries, also affect the industry that is supplied by these products. Here too, disruptions in production may become unavoidable. In order to reduce their dependency on unreliable suppliers and, thus, to keep their production flow more constant, it has become common practice with many firms to keep—normally unnecessary—high stocks of intermediate products. This, of course, is an uneconomical tying up of scarce capital and hence a waste of resources, too.

The *construction industries* illustrate particularly well the case of induced losses. Negligence in the maintenance of construction equipment brings about delays in the completion of buildings and structures. If important industrial projects are concerned, this delay will cause new delays and inconveniences in the "interrelated" industries; the set-back in programmed industrial performance, i.e. in the implementation of the nation's economic plan, will altogether be multiplied.

Other induced losses occur because of bottlenecks in the supply of *spare parts*, be it that their import is restricted or that their shipment is just impossible without longthy delays.[9] The consequence is that many firms try to hold an abnormally large stock of spare parts. From the individual firm's point of view, this is an absolutely rational policy, but for the overall national economy this is a waste of resources detrimental to growth; it might be overcome by a revision of the country's spare part supply policy.

(*d*) *Disguised Losses:* It is well-known today that in many developing countries installed capacities are *under-utilized.*[10] It is less known that excess capacity quite often disguises inadequate maintenance, at least temporarily. The breakdown of an ill-kept machine need not disrupt the firm's production process: a switch-over to idle equipment is an often used device. Only if the practice of poor maintenance and incompetent repair is continued over a longer period of time, deterioration and frequent breakdowns of the whole set of equipment will become apparent.

The cannibalization of machines also belongs to the category of disguised losses due to excess capacity: parts are stripped from idle machines in order to obtain the spares needed for broken machinery. Again, this can only be a short-lived practice averting from the real problem: shortcomings in the country's development policy to provide for an adequate supply of spare parts, and, as a consequence, uneconomic investment decisions on the part of the single firm.

Deterioration and delays in delivery can be disguised in a situation generally described as a *seller's market.* Producers are able to dispose of poor-quality products—at any time—where there is a serious shortage of supply. The situation is not unfamiliar to developing countries where tariffs or quotas bar the im-

8. *Cf.* W. A. Johnson, *op. cit.*, p. 163.

9. *Cf. e.g.* "Some Problems of Industrial Management Reported by Technical Assistance Experts," *op. cit.*, pp. 55-56.

10. *Cf. eg. Under-util zation of Industrial Capacity*, National Council of Applicd Economic Research, New Delhi, 1966, esp. pp. 44-49.

port of competing goods. Poor performance is particularly well disguised if the product allocation is no longer left to the market forces of supply and demand, but is replaced by an administrative distribution system which forces cornsumers to purchase from firms not necessarily of their own choosing."[11] Here, consumrs will have to accept whatever quality is made available at whatever time.

(*e*) *Foreign Exchange Losses and Damage to Goodwill:* The developing countries generally have to import most of their industrial equipment for investment and most of the spare parts to maintain this equipment. Inadequacy of maintenance makes it necessary to replace parts excessively often, sometimes even to exchange the whole machine before it reaches its normal service life. This implies an unnecessary loss in foreign exchange, it is an absurd situation in countries which suffer notoriously from severe shortages in hard currencies.

Possible losses on the export side should not be overlooked, either. The supply of poor quality products and lengthy times of delivery are badly suited to gain export markets. Once the deterioration of quality has been realized, future exports might become jeopardized. The "MADE IN..." mark of origin may lose its attraction, and the loss of confidence need not remain confined to the actual low-quality product: it may just as well affect other export products of the country. The loss of prestige might become so serious that not even expensive marketing campaigns abroad or participation in international trade-fairs will fully restore it.

## 2. Optimal Maintenance and Repair Activities of A Country: A Theoretical Analysis*

### A. The Effects of Differences in the Interest Rate

(*a*) *Longevity, Durability Outlays and Maintenance Outlays:* Maintenance and repair costs can be conceived as outlays aimed at extending the service life of the equipment which occur only after the equipment has been installed and began to operate. Spending on maintenance is only one way to extend the service life, the "longevity" of capital goods. The other way is spending on higher quality at the time of purchase of the capital goods, so that it is less prone to wear and tear. Longevity outlays can thus be broken down, as suggested by Blitz,[12] into durability outlays and maintenance outlays. Both are interrelated and are to be considered together.

Durability outlays are made for the built-in enduring quality of capital goods. The price of higher durability can be compared with the cost of maintenance of initially less durable equipment which can only reach the same longevity if it receives better care and if parts are changed more often.

It should be pointed out that the variations in durability are assumed for equipment having the *same* operating characteristics.[13] Whereas greater durability could be reached by dispensing with accuracy of operation, speed, versatility, complicated control devices of a machine—in short, by simpler construction and hence at a cheaper price—the operating characteristics of the machine would be altered. On the other hand, greater durability for equipment of the same kind is only possible by making it more expensive: by choosing better materials, a costilier construction, by assembling the parts more carefully and inspecting the work more often and more thoroughly. Thus, greater durability has its price.

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11. *Cf.* W.A. Johnson, *op. cit.*, pp. 158, 162.

* A graphical presentation is given in the Appendix.

12. Rudolph C. Blitz, "Capital Longevity and Economic mic Development", *The American Economic Review*, Vol. 48, No. 3, June 1958, pp. 313 ff.—Rudolph C. Blitz, "Maintenance Costs and Economic Development", *The Journal of Political Economy*, Vol. 67, 1959, pp. 560 ff. (In the following cited as: *AER*, 1958, resp. *JPE*, 1959.)—The discussion in this paragraph has benefited particularly from this author.

13. *Cf.* W. Paul Strassmann, *Technological Change and Economic Development*, Cornell University Press, Ithaca, N. Y., 1968, pp. 195 ff.

*To get a certain desired longevity of equipment, a firm can spend more on durability and less on maintenance or vice versa.*

To get a certain desired longevity of equipment, a firm can spend more on durability and less on maintenance, or *vice versa*. Generally a mix of both durability and maintenance outlays is needed. In an extreme case, longevity can be obtained by spending only on durability, without any maintenance.[14] On the other hand, it is not possible to get longevity only by maintenance; some durability outlay is always required.

Blitz draws an analogy to the factors determining the life-pan of a human being: "This initial durable endowment is to be conceived as similar to the innate physical endowment of a human being; on the other hand, maintenance expenditures are analogous to subsequent efforts of doctors to extend longevity."[15]

Within the a.m. limits which are imposed by technical constraints, a substitution of maintenance outlays for durability outlays is possible. For every investment the optimal combination of both kinds of outlays is to be defined. The optimal combination is that which, for any assumed longevity, minimizes the total cost of longevity.

(*b*) *The Influence of the Interest Rate on the Combination of Durability and Maintenance Outlays:* Durability outlays occur immediately at the time of the initial investment. Maintenance outlays are to be made only in the future. To compare both, the future costs of maintenance have to be discounted to the present, using the given rate of interest. The level of the interest rate will influence the present value of the maintenance costs occurring in the future: Discounted at a higher (lower) interest rate the present value of future costs will be less (higher). In other words: The amount of money to be put out at interest now, can be lower if the interest rate is high; it has to be higher if the interest rate is low.

Assume two countries, one having a relatively low, the other one having a relatively high, interest rate. The equipment invested and the maintenance techniques are supposed to be identical in both countries, and it is also assumed that the *future* price of a "maintenance unit" (labour plus materials) is the same in both countries. The same technical combination of durability and maintenance contains, in the high interest country, a lower present value of future maintenance outlays. That is, the present sum of money that is necessary for maintenance outlays in the future is lower because the interest rate is high. The same longevity can be reached, in the high interest country, at a lower present cost.

A technical combination of durability and maintenance which results in minimal total outlays for a given longevity in a low-interest country is, however, not the optimal policy under the different conditions of a high-interest country. Since in the latter country the factor "maintenance" is relatively cheaper than the factor "durability", economic rationality requires to buy relatively more maintenance and relatively less durability than is optimal in the former country. The minimal-cost combination of durability and maintenance for any given longevity is thus, in the high-interest country, not only at a lower level of total (present) costs than in the low-interest country (*price*

14. This is possible in the case of capital goods such as buildings, etc. For example: more expensive construction material is used which need not be painted, instead of a cheaper material which has to be painted periodically to reach the same longevity.

15. R.C. Blitz, *JPE*, 1959, p. 561.

*effect*); it reflects also another combination of the two cost ingredients: relatively more will be spent on maintenance and relatively less on durability, compared to the low-interest country (*substitution effect*).

Hence follows the first recommendation for an optimal policy: Provided that all other things are equal, the country with a higher interest rate should spend more on maintenance and less on built-in durability to obtain a given longevity, than the country where capital is available at a cheaper rate.

c) *The Influence of the Interest Rate on the Longevity Chosen:* So far our analysis started from the assumption that the longevity of the equipment was given, and the question was which mix of durability and maintenance would be optimal to obtain this longevity. Now we ask which longevity will be chosen. The decision, again, is influenced by the prevailing interest rate.

In determining the optimal longevity of equipment at the moment when the investment decision is made, two factors have to be taken into consideration. One is the cost of additional longevity, the other the "savings" which result from postponing the capital replacements in the future.[16]

Suppose that a machine of higher longevity is chosen for initial investment. It follows that we have an increment in cost, but the next and all successive replacements can be postponed by the increment in lifetime. Postponing all future replacements brings about a stream of "savings". These savings may be considered as a capital gain or a marginal revenue of increased longevity. The present value of this stream of future savings can be determined by discounting it at the prevailing interest rate.

The capitalized value of the savings has to be compared with the increment in cost caused by the greater longevity. It is economical to choose a higher longevity—and thus to increase the total cost of longevity—as long as the marginal revenue of longevity is greater than the marginal cost of longevity. The optimum is reached when the capitalized value of the stream of savings equals the increment in cost for higher longevity. At this point the sum of the cost of the initial investment and the discounted values of all future replacements is a minimum.[17]

*The country with a higher interest rate should spend more on maintenance and less on built-in durability than the country where capital is available at cheaper rate.*

The interest rtae has a decisive influence on this compuation. The present value of the stream of future savings will be less if it is discounted at a higher interest rate. If the savings are smaller, the increment in cost of longevity has to be smaller. It follows that the optimal longevity will be shorter if the interest rate is higher.

*All other things being equal,* the opti choice of capital longevity in the coutry with a relatively higher interest rate would thus be a lower capital longevity compared to the country where the interest rate is relatively low.

d) *The combined Effect of the Interest Rate: Level and Structure of Longevity:* In section (b) and (c), the effects of differences in the interest rates were analysed separately. Now the combination of the effects is examined.

16. *Cf.* R. C. Blitz, *AER*, 1958, pp. 314 ff.—W.P. Strassmann, *op. cit.*, pp. 195 ff.

17. For a mathematical treatment see: Fred M. Westfield, "A Mathematical Note on Optimum Longevity," *The American Economic Review*, Vol. 48, No. 2, June 1958, pp. 329-332.

The longevity impact of a higher interest rate is a combination of the effects on the *level* and on the *structure* of the longevity of equipment. The effect on the structure of longevity (the mix of durability and maintenance) always has an unequivocal direction, towards more maintenance (*cf* section b), The effect on the level of longevity (*i.e.* the longevity chosen) consists of a direct tendency towards shorter lifetimes of capital goods (*cf.* section c), combined with an indirect effect via the substitution of maintenance for durability. The indirect effect goes in the opposite direction: it lowers total cost of longevity (*cf.* section b) and therefore curbs the tendency towards shorter lifetime. The change in direction of the level of longevity is, therefore not determinable on *a priori* grounds. It is likely that the direct incentive to shorten longevity will not be counteracted entirely by the a.m. indirect effect.

This is assumed because of the following consideration: *All* savings occur in the future, and therefore the interest rate affects the savings *in toto*. As to the cost aspect, only part of the longevity mix, *viz.*, expenditure on maintenance, will occur in the future. So, the fact that the interest rate is higher will affect *only part of* the cost side. Thus, the impact on the savings side should be greater. The higher the share of maintenance costs in total longevity costs, the less the longevity will be reduced by impact of a high interest rate.

All other things being equal, the country with a relatively high interest rate should tend to reduce the longevity of its capital goods. However, if the country can rely heavily on maintenance (and less on built-in durability) in order to obtain a desired longevity, the optimal policy would be to realize this substitution as far as possible; then longevity will not be reduced very much—in the extreme case, it may remain almost unaltered.

## B. The Effects of Differences in the Wage Rate

Up to this point, the analysis was concerned with the isolated effect of differences in the interest rate, resulting in differences in the *present* (discounted) value of future costs and revenues. It was assumed that the technical composition of a "maintenance unit" as well as the *future* price of such a unit were identical in either country, regardless of whether the countries had high or low interest rates. This assumption is now dropped.

Differences in the interest rate between two countries—if we disregard distortions of the market forces by political interventions—reflect differences in the factor endowments in these countries. A high interest rate indicates a relative scarcity, a low interest rate, a relative abundance, of capital. A relative scarcity of capital corresponds to a relative abundance of labour, and *vice versa*. That is why a country with a relatively high interest rate will have a relatively low wage rate, and a country with a relatively low interest rate will have a relatively high wage rate.

Differences in the wage rate influence the (future) value of maintenance costs. Suppose that the same techniques for maintenance and repair are applied in either country, the maintenance wage per hour, and therefore the total cost of maintenance, will be less in the low-wage country.

Now, maintenance and repair costs are not composed only of wage outlays but also of outlays for spare parts, tools, materials, mechanical aids. To a certain degree a substitution between labour and capital is possible: maintenance work can be done with more or less mechanical aid; repair may be more or less labour-intensive depending upon whether a broken part, or a whole aggregate, is replaced by a new one or fixed again.

If the price of maintenance capital is the same in both countries, economic rationality should induce the low-wage country to substitute labour for capital in maintenance and repair activities; and all the more so if the price of maintenance capital in the low-wage country is relatively higher. In the ideal case, this substitution would take place until the marginal costs of labour and capital were equal to one another and to their marginal products. The subsititution of relatively cheaper maintenance labour for maintenance capital will result in an even greater reduction of total (future) maintenance costs.

The same longevity can be obtained at a considerably lower (discounted) cost; or by spend the same amount, the low-wage/high-interest country can obtain a higher longevity than the other country. In other words, a reduction in cost of longevity, induced by the high interest rate, is possible without reducing longevity, perhaps even extending it.

The conclusion drawn in section A(d) ought to be modified now, taking into account the influence of wage differentials: The combined effect of a high interest rate and a low wage rate will make it economically optimal for a country to choose a *greater* capital longevity than a low-interest/high-wage country. The higher longevity should be achieved by substituting maintenance for durability and, in addition, by choosing maintenance techniques which are more labour-intensive. On the other hand, the optimal policy for a country with a low interest rate and a high wage rate would be to choose equipment of less longevity, to spend relatively more on built-in durability than on maintenance, and to apply capital-intensive maintenance techniques.

## C. The Effects of Differences in the Price of Capital Goods

If the capital goods which two countries invest, and some of the "maintenance capital" (*e.g.* spare parts) which is used in both, are produced only in one of the countries, viz. the low-interest/high-wage country, it is most likely that the price of these capital goods will be higher in the other country which has to import these goods: Transportation cost and customs duties will raise the price.

It has already been pointed out in section B that a higher price of maintenance capital will reinforce the, already existing, tendency in the high-interest/low-wage country to substitute maintenance labour for maintenance capital. A higher price for investment will also make the (initial) capital expenditure on built-in durability less attractive.

## D. The Combined Impact of Differences in Interest Rates, Wages, and Prices of Capital Goods

(*a*) *Conclusions:* The combined impact of differences in interest rates, wages, and prices of capital goods between two countries can now be summarized:

Suppose there are two countries: country A has a relatively low interest rate, a high wage rate, and low prices for capital goods; country B has a relatively high interest rate, a low wage rate, and high prices for capital goods. Under these assumptions it is optimal for country A to invest in capital goods of a relatively short lifetime, to obtain the chosen longevity by spending relatively more on built-in durability and less on maintenance, and to carry out the indispensable maintenance and repair work by relatively capital-intensive methods. The optimal policy for country B would be to choose capital goods of a relatively long service life, to obtain this longevity by spending less on built-in durability and more on maintenance, and rely for the maintenance and repair activities on relatively more labour-intensive techniques.

(*b*) *A numerical example.* The preceding analysis can be illustrated by a numerical example computed by the United Nations Bureau of Economic Affairs. (*Cf.* Table 1). The example compares the average yearly costs of depreciation and maintenance for a nitrogenous fertilizer plant in the United States and in Central America. Alternative lifetimes of 10 and 15 years are assumed in both regions. The computation does not take into account differences in interest rates but gives due weight to wage and price differences.[18]

18. For another example *cf.* "Use of Industrial Equipment in Under-developed Countries : Problems of Maintenance, Repairs, Replacement and Obsolescence", *Industrialization and Productivty,* Bulletin 4, United Nations, Department of Economic and Social Affairs, New York, April 1961, pp. 33-36,

TABLE 1

**Comparative cost data on depreciation and maintenance for a nitrogenous fertilizer plant with alternative lifetimes of 10 and 15 years: United States and Central America.**

**(Thousands of U.S. dollars, per year, per one million dollars of investment in the United States)**

| | United States | | Central America | | | |
|---|---|---|---|---|---|---|
| | | | Same techniques in M&R as in the USA | | Greater relative use of labour in M&R | |
| | 10 years | 15 years | 10 years | 15 years | 10 years | 15 years |
| Depreciation | 100 | 67 | 135 | 90 | 135 | 90 |
| Maintenance and repair | 40 | 80 | 35 | 70 | 29 | 58 |
| thereof labour | (20) | (40) | (8) | (16) | (14.5) | (29) |
| thereof spare Parts | (20) | (40) | (27) | (54) | (14.5) | (29) |
| Total | 140 | 147 | 170 | 160 | 164 | 148 |

Source : "Problems of Size of Plant in Industry in Underdeveloped Countries", *Industrialization and Productivity*, Bulletin 2, United Nations, Department of Economic and Social Affairs, New York, March 1959, p. 22.

It is assumed that the extension of longevity of the fertilizer plants can be achieved by increasing the outlays on maintenance and repair. According to the practice in the United States, maintenance costs are equally divided between labour cost and outlays for spare parts. Plant equipment and spare parts are only produced in the United States and have to be imported to Central America. This raises their costs in Central America to 135 percent of the cost in the United States. On the other hand, labour cost in Central America is estimated at 40 percent of the labour cost in the US.

It appears that the shorter lifetime of 10 years is most economical in the United States, whereas in Central America the extension of longevity to 15 years is the economically rational choice, even if the same techniques in maintenance and repair were applied as in the US. Central America could even gain a higher cost advantage from the extension of longevity to 15 years, if relatively more labour was used in maintenance. According to the example, the optimum is reached in Central America when the substitution hits the point where the costs of labour and spare parts are equal.

It may be added that the cost of longevity, in *absolute* terms, is lower in the United States even if a lifetime of 15 years is chosen; Central America achieves a *relative* cost advantage only by extending the service life of the capital goods.

## E. The Applicability of the Model

Empirical evidence shows that the theoretical model presented here may fairly well be applied to maintenance and longevity decisions in the United States as compared to industrialized Europe.

There is enough evidence, indeed, that the United States—which had a relatively high wage rate and a relatively low interest rate during the post-World-War II period—acted according to the principles deducted in the preceding theoretical analysis : it is a well-known tendency in the US economy to make the equipment easily serviceable, to exchange parts and units rather than to repair them, to design the equipment in a way that repairs and replacement of parts can be executed with a maximum of mechanical aid. All this is done in order to avoid high costs of labour-intensive maintenance and repair.

Unlike the US, wages in industralized Europe were lower and interest rates higher. Labour-intensive maintenance and repair used to be of much greater importance.

As to the longevity of capital goods, there is not much reliable information. In the US, many "durable" consumer goods as well as less valuable production goods are cheap to buy and disposable after a relatively short service life. There are some indications that the longevity of capital in general is lower in the United States than in Europe and that it is declining over time in all industrialized countries.[19] This issue, however, presents too many statistical uncertainties to be decided unambiguously.

The model may be applied particularly well to industrialized countries, on the one hand, and to developing countries on the other. Generally, the developing countries have relatively high interest rates and low wage rates and the prices of capital goods are high, compared to industrialized countries. However, some modifications have to be introduced that take the specific conditions of developing countries into full account.

## 3. THE PROBLEM OF MAINTENANCE AND REPAIR UNDER THE SPECIFIC CONDITIONS OF DEVELOPING COUNTRIES

### A. The Quantity and Quality of Available Labour

So far it has been assumed that the quality of labour available in a country is homogeneous and thus the single "labour units' (manhours) interchangeable. In reality, however, this is not the case, and we have to consider the impact of this fact on our model.

Generally, there exists a relative abundance of aggregate labour in developing countries, but *skilled* labour is usually scarce. Consequently, unskilled labour is cheap while the wages of the skilled workers are high, in some instances even extremely high compared with the wage relations in industrialized countries. Since most of the maintenance and repair activities require skilled or even highly skilled (specialized) workers, the cost of labour intensive maintenance and repair may be extremely high in the developing countries, too.

The real situation in the developing countries requires that we differentiate again and consider *short-run* and *long-run* solutions and *different kinds of developing countries.*

For our purpose here, developing countries can be divided into two groups:[20]

(i) Traditionally purely agrarian countries which are now making first steps towards industrialization, which have only a poor tradition in handicrafts, and are not familiar with even the simpler modern technologies (countries of type I).

(ii) Countries which have already a certain industrial tradition, which can dispose of a cadre of industrially trained workers and, in addition, have a considerable number of craftsmen familiar with the basic techniques of working metal and wood (countries of type II).

(*a*) *Countries of Type I:* What is the optimum policy for countries of type I in the *short*

19. Cf, R.C. Blitz, *AER*, 1958, pp. 326-7.—R.C, Blitz *JPE*, 1959, pp. 562-4.—L.Rostas, *Comparative Productivity in British and American Industry.* New York, 1948.

20 Under certain circumstances, this distinction may reflect stages of development, too.

*run* where skilled maintenance workers are practically not available? The most obvious solution would be to choose those projects which do not require maintenance and repair because they have enough built-in durability to reach a certain longevity. However, this is only possible in very restricted cases: for projects such as buildings, roads, or bridges, All kinds of machinery with moving parts need a certain amount of maintenance.[21] Hence, other solutions have to be looked for.

In the short run, these countries have to employ foreign specialists for practically all maintenance and repair work of complicated industrial devices. These specialists receive an even higher remuneration than in their home countries. On the other hand, investment goods and maintenance equipment, too, have to be imported completely from industrialized countries and hence will be more expensive than in the exporting countries. In this situation the factor-price relations will not induce a substitution of maintenance labour for maintenance capital, nor of maintenance outlays in general for durability outlays. The only influencing factor will be the higher interest rate inducing a substitution of (future) maintenance outlays for (present) durability outlays, and, eventually, a slight shortening of the life time of equipment. If, however, as is usual in the early stage of industrialization, very favourable credit conditions are offered for the initial investment, the burden of durability outlays will be reduced, and hence the interest rate effect will be moderated or totally equalized.

Under these conditions, the optimum short-run policy for a country of type I would be to choose the same production technique as an industrialized country short of skilled labour: i.e. to rely less on maintenance and more on durability and to extend the lifetime of the equipment only to the point that is optimal in developed countries.

If there is a choice between two types of equipment, one requiring highly specialized production workers but less skill in maintenance and repair (simple machinery), the other doing with semi-skilled workers in production but requiring highly skilled maintenance workers (sophisticated equipment), the decision should be in favour of the second type of equipment (what, by the way, would also be the optimal choice in the industrialized country). This is so because maintenance workers have to be "imported" anyway—for both types of equipment. The differences in wage pay for these more or less specialized foreign workers are only "marginal"; so it is economically rational to employ them in maintenance activities where professional skill requirements are highest. Semiskilled production workers, on the other hand, can be trained in a relatively short time, hence foreign assistance is needed here only in the very beginning of industrialization.

The *long-run* aspect adds a new angle to this policy. Here, the dynamic effects of economic development come into play. Within the context of our theoretical model, the most important effect of economic development is the development of manpower skills. We have seen that countries in the early stages of industrialization do not command over a labour force whose skills are comparable to those of workers in industrialized countries, and optimal policy in the short run has to follow the pattern of investment as if there was no abundance of labour. Optimal policy in the long run has to develop highly skilled labour force because this is the only way for a country in early stages of development to reach eventaully the point of substituting scarce capital by abundant skilled labour, i.e. profiting from its natural comparative advantage by using its cheaper (abundant) factor of production.

The training of workers, the type of training offered, is closely related to the type of industry chosen. Whether it is easier to train people for production rather than for maintenance is controversial; experts have expressed both opinions. Hirschman, for example, considers preventive maintenance (not repairs) as an administrative process which is "intrinsically

21. *C.F,* A.O, Hirschman, *op. cit,.* pp. 141-2. —R.C. Blitz, *AER* 1958, p. 324

harder to master than production jobs".[22] Consequently it presents a particular problem in early stage of industrialization. Hirschman states:

> "Any production activity has these three assests: the target is clear-cut, we know it can be reached, and success in doing so is subject to an objective test....
> The basic difficulty about maintenance of capital—as opposed to operation on the one hand and repair on the other—is that it is *preventive* activity which must be performed at fairly long intervals that are neither known with precision nor signalled by the capital itself....For maintenance to be effective, people must be similarly made to act *as though* it had to be undertaken at precise intervals, suppressing their better knowledge that deferment by a day, a week, or a month may not matter; they must organize this fiction, submit to it, and set up a signalling system to enforce it. In other words, maintenance is predominantly an administrative process if we so define an activity whose performance is not directly invited or compelled by the production process or the product itself, and as such it requires an especially high degree of organizational ability."[23]

The opposite opinion is expressed by an American steel engineer:

> "Lack of experienced and technically skilled workers can best be offset by using methods and processes in which the operations requiring skill are entrusted to machinery to the greatest possible extent. Skill in maintenance, mechanical and electrical work seems to be more easily found or developed than that required for complicated manual operations such as in sheet or tinplate rolling."[24]

Perhaps it is not possible to make a generally valid statement deciding *a priori* that maintenance skills or production skills are easier to transmit. Different cultural backgrounds of the developing countries may partly induce the different attitudes of labour towards a certain job. The general underevaluation of maintenence activitivities is most likely, however, to affect the professional status of the repair and maintenance man negatively, hence the psychological obstacles for maintenance training may be substantial.

The type of industry that is best fitted for vocational training in maintenance skills in developing countries depends to some extent on the "weakest" point in skill deficiencies which again is a matter of the degree of industrialisation already obtained: in the very early stages of development manual abilities as well as a "maintenance habit" are lacking.

The generally accepted expert opinion seems to be that maintenance habits are the most difficult to promote. Some experts therefore give preference to those industries which have the highest "educational" effect. Hirschman, for example, recommends that developing countries should concentrate on new ventures with a complicated technology (preferably machine-paced, process centered) which presents a compulsion to maintain:[25]

> "industries and processes where lack of maintenance carries stiff penalties in the form of serious breakdowns and accidents instead of simply leading to a slow deterioration in the quality and quantity of output or to brief outages of single machines that do not disrupt the whole production schedule."

According to Hirschman, "simple" industries present too many ''Latitudes', too much tolerance for poor performance in maintenance. Hirschman's propositions imply that the capital

22. A.O. Hirschman, *op. cit.*, p. 154.
23. A.O. Hirschman, *op. cit.*, pp. 154 and 141.
24. William A. Haven, "Selection of Steelmaking Processes and of Locations for Integrated Iron and Steel works", *A Study of the Iron and Steel Industry in Latin America*, United Nations, New York, 1954, Vol. II, p. 354. Cited by W. P. Strassmann, *op. cit.*, p. 201.
25. A. O. Hirschman, *op. cit.*, p. 142.

and maintenance-intensive productions chosen at the early stages of industrialization should not only be continued but even be expanded during the progressing stage of industrialization. This however raises the question of the availability of capital. The United Nations Department of Economic and Social Affairs, for example, pointed out that the proposition is "generally too expensive in terms of capital and skilled labour to be introduced on a mass scale".[26]

The cost argument is indeed fundamental. The limited access to foreign capital has actually induced oost developing countries to pursue more modest industrial projects as well. This may allow another way of training professional skills and advancing the development of maintenance habits: "breakdown maintenance", in case of simpler technical devices.

Repair after breakdown is said to have the same psychological assets as production activity: success or failure in performance are immediately apparent.[26] Moreover, "breakdown maintenance" or "replacement at failure" is by no means an inferior way of maintaining equipment: (1) It may be cost saving, in case the cost of downtimes is smaller than the cost of preventive maintenance. (2) It is the optimal policy for all equipment with a failure rate that is independent of age or decreases with age-wether or not replacement cost is higher after failure than before. Investigations have shown that a wide variety of devices falls into this category.[27] Examples cited are: Power hand-tools, ball-bearings, electric motor centrifugal switches, linotype machines, automatic calculating machines, bus motors (subsequent to the second major overhaual), most electronic components, etc.

The training of repairmen for "breakdown maintenance" of simpler industrial equipment has the advantage of familiarizing the workers with relatively simple techniques but avoiding the discouraging "latitudes" and the high organizational requirements of preventive maintenance.[28] This form of training appears to be particularly suitable for developing countries with a poor stock of skilled maintenance workers. By comparison, the training of experienced repairmen for preventive maintenance would be the "second" step. The country would eventually reach the stage which is typical for countries of type II.

(*b*) *Countries of type II:* In countries of type II the situation of labour supply is "better", compared with the situation in predominantly agrarian countries: countries of type II can count already on a cadre of workers familiar with maintaining and repairing simpler, conventional devices. In the *short run*, these countries may have to rely on foreign specialists for the servicing of some complicated, modern industrial equipment; but their main task is that as advisers, training people rather than doing the job themselves for a longer period of time.

The problem of training in manual skills might satisfactorily be solved within relatively short periods of time but the problem of developing a maintenance habit remains the pivotal point of long-term development efforts. As pointed out before, maintenance and repair do not enjoy high evaluation in almost any developing country where the mentality of negligence is not confined to the labour force; equal indifference, even strong aversion, is found on the part of the management to engage in maintenance activities.

A change in the mentality of management is, therefore, as important as the acquisition of maintenance and repair skills by the worker. The training of supervisory skills ("to organize, to instruct, and to motivate subordinates") and the instruction of foremen ("a necessary social stratum lacking in preindustrial societies")[29]

26. "Use of Industrial Equipment in Underdeveloped Countries" *op. cit.*, p. 31.
27. A. O. Hirschman, *op. cit.*, p. 154.
28. D. W. Jorgenson, J. Mc Call, R. Radner, *Optimal Replacement Policy*, North-Holland Publishing Company, Amsterdam, 1967, esp, pp. 45 ff., 70-71, 132 ff, 146 ff, 156 ff.
29. 'Use of Industrial Equipment in Underdeveloped Countries", *op. cit.*, p. 43.

may be added to the catalogue of preconditions which are necessary to raise the "production factor" labour to a level comparable to industrialized countries.

Once this problem of developing a maintenance habit is however solved, the developing countries in the *long run* should gain an advantage in maintenance and repair costs compared to the industrialized countries.[30] Although training and upgrading of maintenance workers as well as greater awareness of the maintenance problem will eventually cause a rise in wages, it is most likely that maintenance labour will remian cheaper than in industrialized countries. On the other hand, capital—which is not only needed in real assets but also for education and training—will continue to be scarce; therefore, the interest rate will tend to be higher than in already industrialized countries.

Regarding our theoretical two-country model, we may conclude that developing countries of type II, especially in the long run, are adequately presented in the low wage/high interest-country model, whereas paradoxically the model of the high wage/low interest-country (normally the industrialized country) is applicable for the short-run conditions of countries of type I.

### B. Alternative choices of Capital and Techniques in Developing Countries

After having discussed the production factor labour in developing countries the choice of capital will now be taken into consideration. Except for the case of a country of type I under short-run conditions, the factor relations in developing countries suggested, as optimal policy, a "two-stage" substitution of labour for capital: (1) by spending less on durability than in industrialized economies, but extending the lifetime of equipment by more intensive maintenance and repair; and (2) by relying on more labour-intensive methods of maintenance and repair than is customary in developed countries.

How far can those propositions be followed under present-day conditions?

(*a*) *Degree of durability of equipment:* Let us first consider the decision for more or less built-in durability at the time the initial investment is made. Enterprises in a developing country have to buy most of the investment goods from producers in industrialized countries. Naturally, this equipment is generally designed to the needs and requirements of firms in industrialized countries that make up the bulk of the customers. In these cases, the developing countries will have no choice between more or less durable capital goods. They will have to put up with the equipment that is more properly suitable in industrially advanced countries. The only means to approach the desired optimum is to extend the longevity of equipment over a longer period than is customary in industrialized economies—in other words, to repair installed plants and equipment when they would have been replaced in developed countries.

The choice of-capital is, however, not always restricted to such an extent. In particular, there are three possibilities of which developing countries could take advantage to get less built-in durability of equipment and hence to lower present cost of investment:

(i) Some of the equipment which developed countries supply has different degrees of built-in durability and repairability, that is, require more or less maintenance. Firms in industrialized countries make use of this choice, and so could the industrially less developed countries. Sometimes changes in maintenance requirements entail changes in operating characteristics, too.[31] As long as these changes do not impair the quality of the final product, they are unobjectionable. They may sometimes suit the typical needs of developing economies even better (smaller scale production, lower speeds of output, etc).

30. *Cf.* also R.C. Blitz, *JPE*, 1959, pp. 560 and 564 ff.

31. *e.g.* machines may be run at different speeds, etc.

(ii) In the more advanced developing countries (countries of type II) where machinery is already produced locally, foreign prototype machines may be redesigned to fit local materials, standards, or skills of operators. Maintenance and repair requirements may also be subjected to redesigning.[32] Initial costs for durability can be reduced (at the expense of higher maintenance and repair costs) by using cheaper material, a simpler construction, or by permitting less accuracy in assembling.

(iii) A third way to purchase less durability is the import of second-hand equipment from industrialized countries. High-wage/low-interest countries replace their equipment when the cost of maintenance and repair rises with the growing age of the equipment. At this point, it can still be economically used in developing countries. (of type II) which have cheaper skilled labour available for maintenance. Provided that the cost of transportation and mounting is not excessive and that spare parts will be available, it pays for a low-wage/high interest country to use second-hand machinery.

Second-hand equipment may be all the more advantageous if the equipment was replaced in the industrialized country only because more modern equipment needing less maintenance had become available. In other words: labour-displacing inventions can make replacement of old machinery profitable in the high-wage countries without doing so in the low-wage countries; the latter may make a bargain by buying these machines. The problems involved in the use of second-hand machinery will be analysed more thoroughly in Section II of this study.

(*b*) *Capital-intensity of maintenance and repair:* Compelled by rising wage rates, firms in industrialized countries try to substitute capital for labour in production and maintenance as far as possible. But the possibilities of labour-saving operations in maintenance are more limited than in the manufacturing processes where capital intensity can be pursued up to the point of automation. Most maintenance and repair work can never be done on a large scale; it is more in the nature of "made-to-order" work and, therefore, more labour-intensive.

*Most maintenance and repair work can never be done on a large scale; it is more in the nature of 'made to order' work and, therefore, more labour-intensive.*

Capital/labour substitution in maintenance and repair is achieved in three ways:

(i) Auxiliary work may be mechanized by introducing mechanical aids for mounting and dismounting of machines, handling of machine parts and in transportation work.[33]

(ii) The labour content of repairs may be lowered by a policy of "unrepairability and expendability" of components: not the single broken part is identified, removed, repaired and replaced, but

32. *Cf.* Gerard Karel Boon, *Economic Choice of Human and Physical Factors in Production*, North-Holland Publishing Company, Amsterdam, 1964, pp. 55 ff.

33. *Cf.* Productivity Report: *Plant Maintenance*, Report of a Visit to the U.S.A. in 1952 of a Specialist Team on Plant Maintenance, British Productivity Council, London, December 1952, pp. 46-49.

a "package" of parts, a "functional unit" is replaced by a new one; the old unit is not disassembled and repaired any more.[34] By this method (1) the time and manpower involved in fault identification is reduced, and (2) handicraft repair (regrinding, reconditioning, soldering, etc.) is made unnecessary.

(iii) Economies of scale can be realized by specialized shops for overhauls in case of mass-produced goods (*e.g.* truck engines).

These relatively limited technological possibilities of reducing the labour content in maintenance and repair work demonstrate that the odds are in favour of developing countries of type II, where wages of skilled workers are comparatively low. These countries may realize their comparative advantage by:

(i) avoiding all capital-intensive forms of maintenance and repair,

(ii) relying on more conventional practices for auxiliary work as well as repair work proper.

(iii) aiming at additional capital-saving methods of maintaining and restoring the proper functioning of the equipment.

This includes the identification and exact localization of the broken component so that the number of machine parts that have to be exchanged is minimal. Also, the reconditioning of parts would be preferable to replacing them by new ones.

It should also be pointed out that it may pay for a low-wage country to produce itself at least some of the spare parts instead of importing them. There is a definite advantage if local production of spares is labour-intensive; the substitution of labour for capital would make the price of the spare parts attractive.[35] Production of spare parts in industrialized countries may, however, have reached a point of capital-intensity and large-scale output where their price is lower than any price at which a low-wage country is able to produce without economic losses. Import substitution for economic reasons should then be avoided.

## C. The Balance-of-Payments Aspect

Shortages of foreign exchange has become a common criterion for all but a fortunate few of the developing countries regardless of the degree of industrialization they may have reached already. The foreign exchange aspect, therefore, is a limiting factor imposing itself on all economic plans for industrial development. Import substitution and export promotion have been popular recommendations, whereas the maintenance and repair aspect has enjoyed much less attention. Its influence on the balance of payments, however, is anything but negligible.

It is evident that the premature destruction of equipment due to poor—or lack of any—maintenance causes premature import needs for replacement and thus an unnecessary burden on the balance of payments. But there is more to maintenance and repair policy than this general aspect might suggest. The decision on the type of equipment and the kind of maintenance applied will affect the amount and timing of imports, as well.

If the choice of machinery follows the pattern of industrialized countries, i.e. if machines are chosen with high built-in durability requiring relatively little but capital-intensive maintenance, the burden on the balance of payments will be heaviest: it means choosing a high import value at the time the initial investment is made, high expenditure on spare parts and other "maintenance capital", finally high replacement outlays after a relatively short time.

A foreign-exchange conscious, cost-saving investment, taking the developing country's

34. *Cf.* "Maintainability of equipment" in : *McGraw-Hill Encyclopoedia of Science and Technology*, Vol. 8, McGraw-Hill, New York etc., 1960, p. 75.

35. *Cf.* also: "Use of Industrial Equipment in Under-developed Countries", *op.cit.*, pp. 32, 46.

factor endowments into account, would be determined by the following considerations:

(i) Expenditure on the initial investment as well as on later replacements can be cut down by choosing equipment of less built-in durability, be it new or second-hand.

(ii) The period between the necessary replacements can be prolonged by attaching more importance to maintenance and repair, thereby increasing the longevity of equipment. The number of replacements within a certain period of time is reduced, and so is the total amount of requisite foreign exchange.

(iii) The foreign exchange content of maintenance and repair outlays can be reduced by relying more on labour-intensive maintenance and repair methods and by a policy of import substitution for spare parts.

At first sight the highest savings in foreign exchange seem to follow from an import-substituting production of the equipment itself. In this case, however, raw materials and components must often be imported all the same, and this makes for smaller overall savings. (Of course, the development of a domestic machinery industry may still be economically advantageous for other reasons.)

It appears that a policy which is directed towards saving a maximum of foreign exchange is a policy which, in the long run, promotes the most economic use of the production factors available in a developing country.

## II. SPECIFIC ASPECTS OF MAINTENANCE AND REPAIR TO BE FOCUSSED AT THE NATIONAL LEVEL

### 1. BASIC CONSIDERATIONS WITH REGARD TO THE IMPORT OF NEW *versus* SECOND-HAND EQUIPMENT

#### A. The role of Second-hand Equipment in Industrialized and Developing Countries

The import of second-hand machinery by developing countries has been mentioned on various occasions as one of the ways to choose investment goods of less built-in durability. This problem deserves some further considerations here.

In market economies, investment decisions are made by the individual firms; but most market economies today are mixed economies. Especially in developing countries the "planning ingredient" is considerable. Many of the industrial ventures are promoted or owned by the government. Hence, the question of importing used or new equipment has its bearings also on the public authorities. Moreover, the system of import licensing and foreign exchange control practiced in most developing countries makes decisions of the government relating to this problem necessary.

It may be useful to point out that the utilization of second-hand machinery in developing countries by no means relegates these countries to a second-class status, nor perpetuates the technological gap between industrialized and developing countries. In fact, most of the second-hand equipment that is available in industrialized countries is installed again in these countries: In the mid-1960's, almost 95 percent of the second-hand machinery that was offered on the US market was purchased by US firms.[36] At least two second-hand machine-tools were sold in the United States for every new one.[37] In Japan, too, the use of second-hand equipment is widespread, particularly among small and medium-size firms, as may be seen from table 2.

36. *Report of the Group of Experts on Second-hand Industrial Equipment for Developing Countries*, United Nations, Economic and Social Council, E/C 5/104, 28 January 1966, (mimeographed), para. 15.
37. Albert Waterston, "Good Enough for Developing Countries ?" The Fund and Bank Review: *Finance and Development*, Vol. I, No. 2, September 1964, p. 91.

**Table 2**

**Second-hand equipment as percentage of total fixed assets in Japanese industry, by size of firms**

| Number of employees | Percentage of second-hand equipment 1954 | 1955 | 1956 | 1957 | 1958 |
|---|---|---|---|---|---|
| 4 — 9 | 48.8 | 40.2 | 34.3 | n.a. | n.a. |
| 10 — 19 | 44.1 | 40.8 | 29.9 | n.a. | n.a. |
| 20 — 29 | 39.5 | 34.3 | 28.7 | n.a. | n.a. |
| 30 — 49 | 35.0 | 28.9 | 26.1 | 26.8 | 26.5 |
| 50 — 99 | 31.5 | 22.0 | 22.3 | 21.9 | 20.9 |
| 100 — 199 | 23.0 | 16.3 | 16.8 | 14.5 | 13.8 |
| 200 — 299 | 15.2 | 9.1 | 9.9 | 9.3 | 10.0 |
| 300 — 499 | 13.9 | 10.1 | 9.1 | 7.4 | 7.6 |
| 500 — 999 | 11.2 | 5.2 | 4.2 | 4.6 | 6.3 |
| over 1000 | 4.6 | 4.1 | 4.9 | 3.3 | 3.1 |

*Source*: M. Shinohara, *Sangyokozo* (*Industrial Structure*,) 1959, p. 120, as reproduced by Amartya Kumar Sen, "On the Usefulness of Used Machines", *The Review of Economics and Statistics*, Vol. 44, No. 3, August 1962, p. 346.

There has been a certain tendency among developing nations to refuse the import of second-hand equipment. The situation in industrialized countries like the USA or Japan suggests that the arguments against using second-hand equipment need some rethinking. No one, of course, should advise a developing country to acquire *only* used machinery, no more than a developed country should be advised not to use it at all.

The causes for the generation of second-hand equipment are many, and so are the motives for using it. Main factors that have obviously influenced the employment of second-hand equipment are the size of the firm, type of ownership, the physical characteristics of processes (metal working *versus* chemical industry) and their rate of obsolescence.[38]

Preference for second-hand equipment has been relatively strong in metal working, in the production of lower precision items, for equipment with an average rate of technical obsolescence, and as a means to obtain equipment relatively cheap initially, therefore popular with smaller firms which have scarce financial resources. As to ownership, foreign firms establishing subsidiaries in a developing country have been found to employ *more* used equipment than local entrepreneurs, partly because of their

38. *Cf.* W.P. Strassmann, *op. cit.*, pp. 201-205.

**Table 3**

**Second-hand Equipment Policy in Major Processes of 70 Mexican and Peurto Rican Mfg. Firms**

| Type of firm | Began and replaces or expands with used equipment | Began and replaces or expands with new equipment | Began with used equipment, but replaces or expands with new equipment | Began with new equipment but replaces or expands with used equipment | no response or undecided |
|---|---|---|---|---|---|
| Small | 10 | 6 | 1 | — | — |
| Medium | 11 | 7 | 2 | 1 | 5 |
| Large | 7 | 16 | 3 | 1 | — |
| U.S. subsidiaries | 17 | 10 | — | — | 1 |
| European subsidiaries | 1 | 1 | 1 | 1 | 1 |
| Immigrant | 1 | 6 | 1 | — | 1 |
| Private national | 9 | 8 | 5 | 1 | 3 |
| Public national | — | 4 | — | 1 | — |
| Nondurables producers | 9 | 20 | 4 | 1 | 1 |
| Durables producers | 19 | 9 | 2 | 1 | 4 |
| Total | 28 | 29 | 6 | 2 | 5 |

*Source*: W. Paul Strassmann, *Technological Change and Economic Development*, Cornell University Press, Ithaca, New York, 1968, p. 208.

greater familiarity with the market of second-hand equipment.

To illustrate the use of second-hand equipment in developing countries, the results of an investigation covering 70 Central-American manufacturing firms are partly reproduced in table 3. The most general pre-requisite for the use of second-hand machinery is satisfactory performance. In the words of a Group of Experts of the United Nations: "Second-hand equipment which only produces goods which are not competitive in price and quality at least domestically is not a bargain at any price and should be rejected outright.[39] If a machine does not produce goods of the absolutely best quality, these goods can still be competitive provided the consumers accept their quality—possibly at a lower price. Under these conditions it can be advisable to acquire older equip-

39. *Report of the Group of Experts.., op. cit.*, para. 62.

ment that was replaced because new machines had been available which produce improved goods. Yet in most cases lucrative acquisitions of second-hand equipment pertain to machinery which produces goods of the same quality as the new one, but does it under the conditions of a developed country at a higher cost—under the conditions of a developing country, however, at a lower cost, than new equipment. In the following discussion we have only this latter case in mind, the analysis being limited to the maintenance aspect.[40]

**B. The Isolated Effect of Differences in Maintenance Costs**

In the absence of technological progress, the operating characteristics of a new machine will be the same as those of the replaced machine, that is, the new machine is not superior to the used one. The only reason for installing a new machine is the increase in maintenance costs of the machine in use. Theoretically, this would be the case for a low-wage country to buy the old machine if its maintenance costs are below the costs incurred in the country of origin of the machine.

In reality, however, this may not be a sufficiently strong incentive to buy used equipment. If no improved models are on the market to induce an earlier ("premature") replacement of the old machines, the potential buyer may fear—and his apprehension may actually be justified—that the old equipment is replaced only when physically worn out and that satisfactory performance may no longer be expected from such equipment. Even if the said equipment still works rather well, the difference in maintenance cost may not exceed the "threshold of perceptibility"; whether it does or not, depends largely on the extent of the wage differentials.

While in reality differences in maintenance costs are likely to affect the decision in favour of second-hand equipment only in connection with other factors (which are discussed in section C), the influence of differences in maintenance costs is isolated in the following discussion so that their proper effects become more distinct.

The rising maintenance costs of older equipment are largely due to a higher probability of unexpected breakdowns. Their impact varies, depending upon different sets of conditions. For the individual firm, the cost of breakdowns consists of the fixed cost of idled equipment and of the wages of idled operators. Part of the variable costs are down during disruption of production, especially the consumption of materials and power is reduced. So the cost of breakdowns for the individual firm is not identical with the production loss during downtimes.[41]

(a) In case of highly capital-intensive production of process type or continuous production lines, a breakdown at one point of the production line affects other stages, and sometimes the whole, of the manufacturing process.[42] In these cases the fixed cost of idled equipment will be rather high and will outweigh the cost of idled labour. If breakdowns are frequent and have adverse effects even on those industries which are supplied by the afflicted industry, a temporal setback in economic growth might result. A developing country should, therefore, refrain from buying used equipment of the a.m. kind with a high probability of breakdowns. A sample study of two Central-American countries demonstrates very convincingly an awareness of the risks involved : among the firms that did not use second-hand equipment, about half did so in apprehension of production losses in their integrated plants.[43]

(b) The situation is different in case of industries of fabrication-and-assembly type or benchwork type that use light equipment and

40. For a more comprehensive discussion *cf. Report of the Group of Experts*.., *op. cit.*; A.K. Sen, *op. cit.*; W. P. Strassmann, *op. cit.* As to second-hand transportation equipment *cf.* John R. Meyer, "Transport Technologies for Developing Countries", *The American Economic Review*, Vol. 56, Nr. 2, May 1966, pp. 83-90.

41. *Cf.* R.C. Blitz, *JPE*, 1959, *op. cit.*, p. 568.—W.P. Strassmann, *op. cit.*, p. 203.

42. *Cf.* "Better Way to Compare Your Plant's Maintenance Practices", *op. cit.*, pp. 139-140.

43. W.P. Strassmann. *op. cit.*, p. 213.

are less capital-intensive. Here, the breakdown of one machine will affect the operation at other production stages very little, or not at all. The cost of breakdowns consists mostly of the wages of idled operators of the machine in question; and these are low in developing countries. Under these conditions, a low-wage/capital-scarce country could still make a "bargain" buying second-hand machinery even if the machines were liable to more frequent breakdowns.

The considerable advantage which developing countries may gain by using second-hand equipment in productions of type (b) can be illustrated in an arithmetical example (*of* table 4).

In this example, yearly interest and breakdown costs of a new *versus* a used machine are compared in an industrially advanced and a developing country respectively. The wage-cost relation between the two countries is assumed to be $25:$2. As expected, the high cost of idled labour makes the utilization of the second hand machine with its higher frequency of breakdowns unattractive in the high-wage

**Table 4**

**Arithmetical example : Net Savings for Industrialised and Developing Country on New and Used Machine, respectively**

| | Industrialized country | | Developing country | |
|---|---|---|---|---|
| | New machine | Used machine | New machine | Used machine |
| (1) Price of machine | $10,000 | $5,000 | $10,000 | $5,000 |
| (2) Interest rate prevailing (percent) | 3.65 | 3.65 | 7.30 | 7.30 |
| (3) Opportunity cost of outlay on machine | $365per year<br>$1 per day | $182.50 per year<br>$0.50 per day | $730 p.y.<br>$2 p.d. | $365 p.y.<br>$1 p.d. |
| (4) Labour cost per day per machine | $25 | $25 | $2 | $2 |
| (5) Expected number of breakdowns per year | 1 | 9 | 1 | 9 |
| (6) Expected cost of annual breakdowns in terms of idled labour and idled capital | $26<br>1×(25+1) | $229.50<br>9×(25+50) | $4<br>1×(2+2) | $27<br>9×(2+1) |
| (7) Expected yearly interest and breakdown cost per machine | $365.00<br>26.00<br>$391.00 | $182.50<br>229.50<br>$412.00 | $730.00<br>4.00<br>$734.00 | $365.00<br>27.00<br>$392.00 |
| (8) Expected "Net savings" (±) of new overused machine | +$21 | ...... | —$342 | ...... |

*Source*: Rudolph C. Blitz. "Maintenance Costs and Economic Development." *The Journal of Political Economy*, Vol. 67, 1959. p. 569.

country despite the low capital cost of the used machine *versus* a new one. But the low-wage country is able to make "net savings" totalling $342 by prefering the second-hand machine to a new one (line 8), In other words: as long as net maintenance and repair cost of the used machine is below this amount, it is economically advantageous to prefer a used machine to a new one. In the arithmetical example presented here, the cost of each repairing may even be ten times as high as daily operating costs, i.e. $20 per repair executed, the advantage of using an old machine instead of a new one would still be substantial: $342—$160=$182.

This is an extremely favourable result regarding the use of second-hand equipment, which is due, of course, to the assumed high wage differentials between an industrially advanced and a developing country. But even if we assume a higher daily labour cost in the developing country, e.g. $8 instead of $ 2, all other things being equal, the case for second-hand equipment would still be impressive: the annual interest and breakdown cost of the new machine (line 7) would be $ 740; that of the used machine $ 446. The "net savings" of the used machine (line 8) would thus be $ 294. The used machine is preferable to a new one as long as repair costs for each breakdown are less than four times the daily operating costs, i.e., less than $ 32 per repair. The cost advantage afforded by the used machine would still be: $294—$256 = $ 38. It should be noted that the price assumptions in the example even understate somewhat the advantage of the used machine.

### C. The Effect of Premature Obsolescence

So far our analysis was based on the simplifying assumption of unchanged technological standards. In the absence of technological progress, machines will be replaced when they become physically worn out, and can no longer be economically maintained. They will be replaced by the same type of machine.

For a developing country which plans to import second-hand equipment, the physical condition of this equipment is, of course, very important. The physical condition is primarily influenced by the factors which have caused the generation of second-hand machinery.

The principal causes for the generation of second-hand equipment in an industrialized country, besides mergers of firms and liquidations of plants, are:

(i) the switch-over to a larger scale of operations, caused by increased market demand;

(ii) modernization of plants and equipment up to the point of automation, caused by labour shortage and high wages.

In both cases, the equipment is replaced by technically improved machinery which will suit the changed market demands or factor-supply conditions better than the old machines. We may say, the technical progress has casused premature obsolescence, in the industrialized country, of machinery which actually is working still well, but the conditions in that country do not permit an economic use of these machines.[44]

The very reasons that caused premature obsolescence of equipment in an industrialized country make these machines particularly suitable for a developing country: smaller markets call for smaller outputs, and production on a smaller scale may be more economical than under-utilzation of large-scale capacities; and, as pointed out before, the factor-price relations in developing countries suggest the use of machinery which need relatively more labour than capital, both in operation and in maintenance. Premature technical obsolescence (in industrialized countries) will, therefore, become a special incentive, in addition to the maintenance aspect, to prefer second-hand to new equipment in developing countries.

44. Regarding the optimum replacement policy cf.,: George Terborgh, *Dynamic Equipment Policy*, McGraw-Hill, New York-Toronto-London, 1949.—Vernon L. Smith, *Investment and Production*, Harvard University Press, Cambridge, Mass., 1961.—Ingrid and Per Welin, *The impact of Technological Progress on the Economic-Life of Industrial Equipment*, Handelshogskolan i Goteborg, Skrifter 1967-2, Akademiforlaget, Goteborg, 1967.

*The purchase of second-hand equipment is only recommendable if the supply of spare parts can be secured.*

**D. Special Problems of Maintenance and Spare-Part Supply for Second-hand Equipment**

As a United Nations Group of Experts on Second-hand Machinery already pointed out some years ago, "there is no clear-cut difference in the magnitude and nature of maintenance problems between new and second-hand equipment".[45] Much depends, however, on the existence or absence of technological improvements of the equipment in use.

Under the assumptions made in section B, the nature of maintenance is the same for new and used equipment, but the magnitude of required work is greater for used equipment. In the case discussed in section C, the magnitude of the maintenance work may be the same for old and new equipment, whereas the nature of this work is different.

It is often assumed that the *maintenance* of equipment of older design requires less skills than that of modern machinery, whereas the skill requirements for the *operation* of old machines are higher than for new ones.[46] But there is no simple solution to this question; it may also be true that modern machines are made easily-serviceable, with unrepairable and expendable units, in order to save on highly paid, skilled maintenance workers. The situation differs from industry to industry.

The special problems of maintaining second-hand machinery are mainly of a *practical* nature. Sometimes, maintenance manuals and schedules, or part catalogues, are missing, or even blueprints of a machine are not available. Service arrangements are generally not made for a single machine, but may be obtainable for a number of integrated machine units or complete plants. In the latter case, management in developing countries has often shown reluctance to rely on outside repair services. Strassmann, for example, observed:

> "Willingness to buy used equipment was determined largely by confidence in one's own maintenance and repair abilities. A metalworking plant can grind bearing or shaft for its own machines; an electrical manufacturer is as good at rewiring circuits for his own as at rewiring those for sale."[47]

The purchase of second-hand equipment is only recommendable if the supply of *spare parts* can be secured. But the difficulties of getting spare parts should not be over-estimated. No doubt, spare parts are more easily available for new machines than for old ones, in particular if they are supplied by the machine-producing firm. However, machine manufacturers generally do produce spare parts for some years after the particular type of machine has gone out of production. When production of these spares is discontinued as well, manufacturers are wont to hold a certain stock for some more years. It has been reported that some manufacturers of textile machinery continue to make spare parts for machines they produced forty years ago.[48]

There will be a time, of course, when the availability of spares becomes a real problem: when stocks are depleted, or when the manufacturer of the machinery is no longer in busi-

45. *Report of the Group of Experts..*, *op. cit.*, para. 45.

46. *Ibid.*, para. 69.

47. W.P. Strassmann, *op. cit.*, p. 213.

48. *Report of the Group of Experts..*, *op. cit.*, para. 48.

ness. Missing catalogues or blueprints that are needed to identify the spare part exactly will add to the difficulties.

Before deciding upon the import of second-hand machinery, a country would do well to explore the availability of spare parts thoroughly, including the possibilities to produce spare parts in local machine shops. Frequently, second-hand machines are less complicated than newer models, are made from simpler materials and have parts of less sophisticated design. In this case, the local production of spares in developing countries (of type II) should not encounter insurmountable difficulties, provided the necessary steps are taken in time. Local production of spare parts for very complicated modern machinery is apt to face many more difficulties.

The preference of second-hand equipment *versus* new equipment combines several advantages: saving in foreign exchange because the price of used machines is substantially lower than of new equipment; more labour-intensive production and maintenance and hence lower production cost; inducement of local production of spare parts which means adding a labour-intensive spare parts supply to a labour-intensive production.

## 2. AVAILABILITY OF SPARE PARTS

### A. The Importance of a Regular Spare Parts Supply

Availability of spare parts is an integral part of a good maintenance policy. In a developing countries the lack of spares is often one of the most serious bottlenecks in uninterrupted production. The supply of spare parts, therefore, deserves all the attention of the policy makers concerned.

In a mixed economy a good spare parts policy on the part of the individual firm is not possible without the cooperation of the public authorities. Problems of priority allocation arise between public and private enterprises

*Availability of spare parts is an integral part of a good maintenance policy.*

if spare parts are generally scarce or not easily obtainable on other grounds. The public authority may exercise its influence on the allocation of spare parts by way of a whole set of instruments of commercial policy such as import licensing, foreign exchange control, multiple exchange rates, etc.

An essential aspect of the spare parts problem is stock-piling. There should be no question today regarding the general importance of keeping adequate stocks of spares, although time and again experts' reports disclose a lack of recognition of this fact, especially during the first phase of new industrial ventures.[49] The effects on production are always detrimental.

One of the solutions which have been recommended is that individual enterprises keep *large* stocks of parts, in particular when poor transportation facilities, rigid foreign exchange controls, and coincidences of all kinds impede their quick supply. Other solutions that have been proposed are to establish central stocks of spare parts at the national, regional, and branch level, and to envisage their domestic production.

The advantages and shortcomings of these propositions will be given special attention in the following sections.

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49. See *e.g.* "Solveen Report on Rourkela Steel Plant", *The Eastern Economist*, Vol. 34, No. 7, *August* 17, 1962, pp. 304, 307.—"Some Problems of Industrial Management Reported by Technical Experts", *op. cit.*, Assistance pp. 55-56.

*The particular conditions in developing countries induce firms to keep greater stocks of parts than is customary and necessary in similar industries in developed countries.*

**B. Decentralized Large Stocks of Spare Parts at the Individual Plant**

The advantage of large stocks of spare parts at the plant level is that spares are quickly and easily available if needed. Downtimes of equipment can be kept as short as possible. This is especially important in case of heavy process-type production or continuous lines, where the economic penalty for any stoppage of operations is highest.

The most serious handicap of decentralized large stocks is that considerable amounts of capital are tied up. It has been observed that many firms initially tend to keep spare parts inventories at a very low level but after their bad experiences they fall into the other extreme of hoarding whatever spare parts they are able to get.

The particular conditions in developing countries induce firms to keep greater stocks of parts than is customary and necessary in similar industries in developed countries.[50] The reasons are:

(i) Specific climatic conditions in many developing countries make for deterioration of parts that usually have not to be replaced in countries of temperate zones. Wrong treatment and overloading of machines by operators who are not sufficiently trained as well as incompetent maintenance—both more frequent in developing countries—also contribute to higher degrees of deterioration.

(ii) The poor communication and distribution systems in many developing countries make it often impossible to place emergency orders for spare parts and have them delivered within a short time. If parts have to be ordered from abroad, the customs clearing retards delivery substantially; delays of ten days and more caused only by customs clearing of spare parts flown into a developing country are not unusual.

(iii) Import licensing and foreign exchange controls which are practised in most developing countries prompt many firms to stock more spares than are needed. Uncertainty of future quotas makes it appear safer to utilize import opportunities fully when they are offered rather than to trust future allocation of import licences of foreign exchange when spares would be needed. Under import control systems anticipated replacement needs, as reflected in import licence applications, tend to be overstated. Fear of sudden changes in import regulations (e.g. introduction of new controls, higher import duties, etc.) also accounts for excessive stock keeping. It may be pointed out that it is the economic system rather than disability on the side of the managers which leads to the wasteful use of scarce capital resources, to a discrepancy between a single firm's gains and losses and the overall economic gains and losses of a country.

Where conditions in manufacturing proces-

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50. The Indian National Council of Applied Economic Research has estimated that in a large number of Industries spare parts constitute almost 15 percent of the total inventories, which is considered as a rather high proportion. *Cf. Maintenance Imports*, National Council of Applied Economic Research, New Delhi, 1967, P.74.

ses require prompt availability of spare parts, the system of decentralized stock keeping of spares has many advantages no other system offers. If this system is chosen, it is necessary, however, to do everything to realize optimum stocking levels, that is to say:

(i) Operators and maintenance workers should be well trained to work with the equipment so that breakdowns are minimized.

(ii) Communication and distribution systems for spare parts should be improved. Much could be gained by facilitating and accelerating the customs clearing of spares imports.

(iii) Controls of spares imports should become less arbitrary and should be freed from lengthy administrative procedures.

**C. The Establishing and Keeping of Central Stocks of Spare Parts at the National, Regional, and Branch Level**

Less capital will be tied up if stock-keeping of spare parts is centralized. The higher the centralization, the smaller the inventories needed for every kind of spares, because a sort of "insurance principle" comes into effect. From this point of view, the highest degree of centralization, i.e. central stock keeping *at the national level*, would be most preferable. Other arguments in favour of centralizing stocks are:

(i) A central agency has better information of possible suppliers of spare parts both at home and abroad.

(ii) Orders for the domestic fabrication of spare parts can be pooled and production thus rationalized.

(iii) Spare parts for older models that are no longer produced are better identified; central stock-keeping makes their availability much easier.

(iv) Administration of import licences and customs clearing is facilitated and accelerated.

The smooth functioning of central stock-keeping is, however, dependent on a number of conditions which have to be met in order to avoid damages to the economy which are more serious than any possible gains:

(i) The communication system must be well developed; it must permit the prompt placement of orders.

(ii) Management of the central stocks must have excellent professional standards. Accurate book-keeping and inventory control should be a matter of course. Moreover, the men in charge of planning the inventories and purchasing the parts must be qualified technicians, familiar with the technologies in the various industries.

(iii) Sufficient facilities for rapid transportation of ordered parts must exist both from the suppliers of these parts to the central stock and from there to the manufacturers who demand them and these facilities must be available irrespective of monsoons, droughts, and the other seasonal impacts.

The actual situation in most developing countries is still far from complying with these conditions: their communication and transportation systems have bottlenecks of one kind or the other; besides, the distances within many developing countries are enormous by European standards. Yet, the most crucial point seems to be to master the administrative task of such a central agency securing the supply for so many and different firms. Even in a country with a small industrial sector the centralization of stocks will require a highly sophisticated management.

The best way to run efficiently a central agency for spare parts might be in the form of a commercial enterprise, e.g., as a purchasing and storing cooperative or agency. The individual firms must have confidence in this agency as a prompt supplier. Quick supply, in turn, is only possible for the agency if it has secured access to spare parts, be it by imports or local production. The main role of the central agency would be to rationalize the storage of spare parts, and thus to save scarce capital.

The central agency if conceived as a public authority and endowed with the power to control and approve the individual firms' orders for spare parts, would be in danger to turn into a super-bureaucratic institution that is an obstacle rather than a promoter of economic investment, maintenance, and replacement of capital. The experiences of European countries under the regime of rationing and controlled supply (*Bewirtschaftung*) during World War II and the early post-war years may be worthwhile taking into consideration. The experiences of a large steel mill in the public sector in a rather advanced developing country may also illustrate our point:

> "The handling of the orders placed by the individual plants with the purchasing department in respect of urgently required spare parts and accessories threatens seriously the production operations. In some cases urgent requisitions of the plants were not forwarded by offices which are not in a position to judge the necessity or urgency of the purchases. Repeated requests of the plants were unsuccessful."[51]

The difficulties at the level of a national central agency for spare part supply would multiply, compared to those arising at the level of a single firm.

From the preceding discussion it appears that a central stocking of spare parts at the national level is likely to be rational policy only in a very small country with a fairly well developed communication and transportation system and serving an industry which is not too diversified. Even then, complete centralization should not be aimed at: inexpensive parts that are needed frequently are better stored at the individual plant as are the important spares for continuous production. The central stock would assume the role of a "wholesaler", a general purchasing agency; it could be run privately or by a public authority whichever would be more appropriate within the context of the economy; it should, however, be run on a commercial basis.

In all other cases the, odds seem to be more in favour of a modified solution: to establish central stocks of spare parts *at the regional level.* This solution would be similar to the central stocking at the national level in a small country. The distances between the various firms and the regional spare parts stock are shorter, transport problems are reduced, the difficulties for management decreased. The qualifications and limitations that were outlined when discussing spare parts stocks at the national level will, of course, apply here, too. Generally speaking, central stocks of spares at the regional level are a reasonable compromise between easy availability of spare parts and the tying up of as little capital as possible.

One problem that may be better solved at the national than at the regional level is the allocation of orders for domestic spare parts production. If preference is given to those machine shops which are *within* the region (to reduce communication and transportation problems), capacities become unevenly utilized between the different regions, unless machine shops are evenly distributed, too.

Central stocks of spares *at the branch level* can be established for the country as a whole or on a regional basis. Unless it is a small country, centralization at the national level will bring hardly any advantages to a developing country for the same reasons as mentioned before. Splitting up regional stocks of spare parts, according to the various industrial branches, into independent stock-keeping units may be economical, provided the

51 "Solveen Report on Rourkela Steel Plant" *op. cit.*, p. 304.

pre-conditions of good communication and transportation are met.

Specialized spares stocks for individual branches may reduce the technical and administrative standards which are required when keeping large general stocks for all industries. But certain derogations should not be overlooked: if an industry is not regionally concentrated, the choice would be either to keep fewer stocks, thus rationalising the storage problem but creating transportation and communication problems, or to keep a larger number of stocks within good reach of all firms but giving up possible capital savings in storage. Regional spare parts stocks on the branch level would be favourable if industries are regionally concentrated; they would be very economical if different kinds of industries are concentrated in different regions.

## D. Possibilities for Import Substitution of Spare Parts

In a developing country of type I all equipment has to be imported, and so have the spare parts. This may continue for a rather long period. It will be the normal situation even in the earlier stages of industrialization of a developing country of type II.[52] The step towards domestic machinery production is usually undertaken in the later process of development. In many developing countries as well as in the now industrialized countries, the local machinery production evolved from repair shops which branched out at a later stage.

In developing countries of type II which have machine building and engineering industries of their own, the spares for domestically manufactured equipment can be, and are, produced by domestic manufacturers as well. Most spare parts for imported equipment—either new or second-hand—are imported, though. It is true that big business firms often produce the parts they need in their own workshops and, occasionally, spares for imported machine are ordered from local machine or repair shops. But this is not a general rule. There are various reasons why these countries defer domestic production of spares for imported equipment:

(i) Local facilities may not permit the production of technically complicated or high-precision items.

(ii) Imported parts are produced large-scale and are offered at comparatively low prices that leave little possibilities for domestic substitution at competitive prices.

(iii) Drawings and designs may not be obtainable from foreign producers, or patent rights may preclude reproductions.

(iv) Customers often prefer imported spares to their domestic substitutes because they apprehend inferior quality of the locally produced items. The inferiority of substitutes need not be due to incompetent or less careful work of the local machine shops, but may be due to poor quality available raw materials, e.g. steel.

(v) In a situation of acute shortage of raw materials it can be as lengthy or as costly to have spare parts produced locally as to get their import licensed.

It was reported, for example, that during a longer period of rationing strategic raw materials the mainly small-scale-ancillary firms were left without any quota of essential raw materials, and if they wanted to continue production at all, they were

52 In India, for example, almost all the machinery and equipment needed for industrial development during the first planning period (1950/51-1955/56) was imported *Cf. Fourth Five Year Plan*, A Draft Outline, Government of India, Planning Commission, (1966), p. 264.

forced to procure them at a higher price.[53]

(vi) Inducement for the local production of spare parts may be lacking because the import of spares is not restricted, or because the national currency is overvalued. The import of spare parts may be just a habit developed during times of liberal import policies,[54] and may reflect sluggishness to look for other solutions, but by far it may be the cheapest way of obtaining spares if the currency of the developing country is considerably overvalued in relation to hard currencies. Even if there is a local machinery industry, it will not be able to compete with a foreign supply which is artificially cheapened by unrealistic exchange rates.

(vii) Sometimes, especially if the machine shops are of small scale and not locally concentrated, lack of information on the demand for spares may cause the producers aloofness from import substituting production. This lack of information, in turn, may reflect neglect of the spare parts problem on the side of the public authorities.

The possibilities for import substitution in a developing country may be larger or smaller depending on the obstacles which so far have prevented the substitution from gaining momentum. Any policy decisions must take these "barriers" into consideration.

The first two instances cited above indicate a situation where the comparative cost advantage is not—or not yet—on the side of the developing country. It would be a very costly policy for a country to force import substituting production of spare parts in such cases. This policy would compel a country to impose high import duties and initiate other administrative measures that are difficult to enforce. The possible outcome might be far from desirable.

In all other instances a developing country may—but must not—have a comparative advantage in the domestic production of spares. Before encouraging local production, the cost situation must thoroughly be analysed. It is of equal importance to identify—and to remove—those obstacles which impair the realization of comparative cost advantages.

(i) A more realistic exchange rate policy discontinuing the over-valuation of the domestic currency could bring about true comparative advantages in spare parts production, especially if production can be made labour-intensive. The distorting effects of an unrealistic exchange rate, of course, are not limited to spare parts imports.

(ii) The supply of raw materials for spares is a crucial point. The improvement of quality would require changes in pre-conditions the study of which goes beyond the scope of this paper. One of them, however, is better maintenance and repair. Where a shortage of raw materials has prompted a system of quota allocation, the discrimination of producers of spare parts should be avoided.

(iii) There are various possibilities to disseminate information on the local market of spare parts. The function of collector and transmitter of information could be assumed by the public authorities, professional organizations, e.g. employers' associations, or by a spares stocking agency on the regional or branch level. The agency would be particularly suited as a "clearing house" for potential purchasers and manufacturers of parts.

53 Saroj Kumar Basu, Alak Ghosh, Subrata Ray, *Problems and Possibilities of Ancillary Industries in a Developing Ecomomy*, The world Press Private Ltd., Calcutta, 1965. p, 91.

54 *Cf. Maintenance Imports, op. cit*, p.73

(iv) If agreements on patent rights, designs and drawings have to be obtained from foreign owners of rights and documents, the spare parts agency or a professional organization may take the initiative here, too. The necessary negotiations may be conducted under the sponsorship of International Organizations.

### 3. ESTABLISHING OF SPECIALIZED REPAIR AND MAINTENANCE SHOPS IN THE CONTEXT OF INDUSTRIAL ESTATES

Medium and small-scale firms face particular difficulties in maintenance and repair. They are often too small to make the hiring of full-time specialists for maintenance and repair economical: these men cannot be employed to their full capacity. And what is more, the repair shop of a firm has to be supplied with a certain minimum of machines and tools. These, too, cannot be adequately utilized in a small-scale enterprise. The smaller firms, therefore, have to rely generally on outside contractors who are not easily found in developing countries. If maintenance is assigned to own employees who have not undergone appropriate training, most likely the performance is not of the desirable quality.

The maintenance problem of small-scale and medium-sized industries could be solved to the best advantage by establishing nearby specialized repair and maintenance shops. The creation of such repair shops might be promoted by the government or a special public agency, or they may be established by joint action of the industrialists themselves, possibly on a cooperative basis. In some cases, where several firms pool their demand for maintenance and repair services and hence constitute a regular clientele, private industry may be induced to set up repair shops. In the earlier stages of economic development, however, repair services should be regarded as promotional rather than commercial; initial steps for their provision should be taken by public authorities.

A pre-condition for setting up specialized repair shops is, of course, a certain regional

*The maintenance problem of small-scale and medium sized industries could be solved best by establishing nearby specialised repair and maintenance shops.*

concentration of firms demanding these services. The condition is particularly well met in so-called industrial estates.

Industrial estates have been founded, within the last decade, in almost all developing countries, with the general purpose to promote the development of small-scale industries. Industrial estates have been defined as "a planned clustering of industrial enterprises, offering developed sites, pre-built factory accommodation and provision of services and facilities to the occupants".[55] Whereas in industrialized countries only general services—such as power, water, sewage, roads and railroads, etc.—are usually provided, the services and facilities offered in developing countries are of a broader scope: the special services (which differ, of course, from country to country, or even from estate to estate) include e.g. training facilities, technical counselling, marketing assistance, tool rooms, and machine shops. In some countries, maintenance and repair shops have already been added to this programme of subsidizing small-scale industries.

Industrial estates must be large enough to guarantee the sufficient utilization of capacity of the equipment which is installed in the repair shops. When planning the shops, the number of firms outside the industrial estate proper

55 United Nations, Department of Economic and Social Affairs, *Industrial Estates : Policies, Plans and Progress,* A Comparative Analysis of International Experience, United Nations, New York, 1966, p. 4.

which may share in the services of these shops could be taken into consideration, but special allowance must be made for the regional factor: longer distances impair fast servicing. The transportation conditions in developing countries make this factor relatively more restrictive than would be the case in developed economies.

Repair shops in industrial estates could be established in connection with regional spare parts stocks. It would permit the production of some of the spares in the repair shops, or where existing, in the machine shops of the estate. It might also be envisaged using repair shops as training centres where employees of the customers firms are trained in routine maintenance work so that specialized craftsmen at the repair shops are free for the more complicated maintenance jobs, check-ups and repairs.

Most of the industrial estates which are promoted in developing countries are non-specialized general-purpose estates accommodating all categories of small-scale industries. Servicing of firms which belong to a variety of branches makes higher demands on the skills of the craftsmen and the outfit of the shop: different specialists for several branches and a variety of machines and tools are needed. On the other hand, better utilization of capacity may be guaranteed by a multi-branch clientele: electric motors, for instance, are used in almost every industry.

In single-trade estates which provide accommodation only to firms belonging to the same trade, repair shops can be smaller since narrowly specialized. Special advantages could ensue from connecting such shops with regional spare parts stocks at the branch level.

If well equipped and manned, maintenance and repair shops that are already operating in industrial estates might provide good opportunities for on-the-training of craftsmen, who may later be placed in newly established estates.

## 4. QUANTITATIVE ASPECTS OF MAINTENANCE AND REPAIR

It is of particular interest for the individual firm facing an investment decision as well as for the public authorities engaged in national economic planning to have estimates on present and future maintenance requirements: the total cost, import content, and the manpower needed. In this paragraph, maintenance and repair costs in an industrialized country are analysed on the basis of the statistics available. Some of the findings are used to estimate present and future needs for maintenance and repair in developing countries.

### A. Maintenance and Repair in Industrialized Countries :

### The Case of the USA

(*a*) *The cost of maintenance and repair in manufactures:* Surprisingly there exists very little statistical information on maintenance and repair activities in the manufacturing industry of developed countries. Only one comprehensive report has been published by the U.S. Bureau of Census as part of the 1958 Census of Manufactures programme. The data on maintenance and repair cost, together with other data on selected costs and asset values, were collected in a special sample survey. The investigation covers the year 1957; neither in the half century before, nor in the decade after this date have maintenance and repair costs been included in the Census of Manufactures.

The results of this survey are reproduced in Table 5. The data shows that, in 1957, over 9 billion dollars were spent in the USA for maintenance and repair on structures, grounds, and equipment of all operating manufacturing establishments. This sum is rather remarkable. In the same year, expenditures of the manufacuring industry for *new* plant and equipment totalled 12·145 billion dollars, expenditures for new machinery and equipment coming to 8·281 billion dollars thereof, a sum that is lower than the total spent on maintenance and repair.[56]

56 U.S. Bureau of the Census, *Statistical Abstract of the United States*: 1959, Washington, D. C., 1959, table 1061, p. 796.

**Table 5**

**Cost of Maintenance and Repair in U. S. manufactures: 1957**

| Industry Group | Gross book value of depreciable assets, on Dec. 31, 1957 | Expenditures for M&R on structures, grounds and equipment in 1957 | | | M&R expendiutre as % of gross book value | M&R wages as % of total M&R expenditure |
|---|---|---|---|---|---|---|
| | | Total | Salaries and wages paid to own employees | Other M&R costs | | |
| | Mil. dol. | Mil. dol. | Mil. dol. | Mil. dol. | Percent | Percent |
| All industries | 110,489 | 9,011 | 4,539 | 4,472 | 8 | 50 |
| Food | 11,731 | 777 | 357 | 421 | 7 | 46 |
| Tobacco | 400 | 24 | 11 | 13 | 6 | 45 |
| Textile | 4,984 | 354 | 148 | 206 | 7 | 42 |
| Apparel | 1,006 | 98 | 43 | 55 | 10 | 44 |
| Lumber | 2,917 | 292 | 111 | 181 | 10 | 38 |
| Furniture | 1,041 | 69 | 32 | 36 | 7 | 47 |
| Pulp, Paper | 7,165 | 514 | 239 | 226 | 7 | 46 |
| Printing | 3,697 | 172 | 78 | 94 | 5 | 45 |
| Chemicals | 13,105 | 909 | 459 | 451 | 7 | 50 |
| Petroleum, Coal | 7,936 | 501 | 263 | 238 | 6 | 53 |
| Rubber | 1,782 | 149 | 78 | 71 | 8 | 52 |
| Leather | 467 | 55 | 23 | 32 | 12 | 42 |
| Stone, Glass | 5,153 | 391 | 174 | 216 | 8 | 45 |
| Primary Metals | 17,329 | 2,000 | 1,064 | 936 | 12 | 53 |
| Fabricated Metal | 5,713 | 450 | 234 | 216 | 8 | 52 |
| Machinery | 9,421 | 624 | 326 | 298 | 7 | 52 |
| Electr. Machinery | 4,089 | 360 | 186 | 174 | 9 | 52 |
| Transport Equip. | 9,303 | 986 | 563 | 423 | 11 | 57 |
| Instruments | 1,263 | 97 | 54 | 44 | 8 | 55 |
| Miscellaneous | 1,987 | 188 | 96 | 92 | 9 | 51 |

*Source* : U.S. Bureau of the Census, *U.S. Census of Manufactures*: 1958, Vol. I: Summary Statistics, U.S. Government Printing Office, Washington, D.C., 1961, pp. 98 and 99. Percentages: own computation.

The outlays for maintenance and repair amount to 8 percent of the gross book value of the fixed assets (that is the actual cost of the assets at the time of the purchase, including transportation and installation costs). The data for the individual industry groups show a very even and narrow distribution around this mark of 8 percent (which is the same as the median): 16 out of 20 industry groups spent between 6 and 10 percent of the value of their fixed assets for maintenance and repair; for 12 out of these 16, the percentages range from 7 to 9.

Total maintenance and repair expenditure is broken down into "salaries and wages paid to own employees" and "other maintenance and repair costs". On the average, within all manufacturing industries of the United States, half the sum of the 9 billion dollars spent on maintenance and repair was in the form of salaries and wages paid to own employees. Again the data for the different industry groups show only small deviations from this average; 15 out of 20 industry groups spent between 45 and 55 percent. Here again, the median proves to be equal to the average. There is no correlation between the deviations from the average observed here and the deviations from the average of total outlay figures.

The so-called "other maintenance and repair costs" include *materials* and *supplies* used for maintenance and repair activities as well as maintenance and repair *services* purchased from other companies. Hence, the breakdown does *not* distinguish between labour cost and cost of material for total maintenance and repair. It is not reported which part of the "other costs" is spent for outside services, that is on the salaries and wages of employees of other firms. In all probability, this share varies between different industry groups; not only technical reasons but also the cost aspect will influence the expenditure pattern: due to economies of scale, maintenance and repair work may be performed at lower costs by outside specialists than by own employees. There has been a vague indication cited by Morrow that expenditure on maintenance materials, equipment, and supplies makes up 90 percent of the amount paid for maintenance wages and salaries.[57] This implies a relationship between labour cost and cost of material in the order of 53 percent to 47 percent. *Modern Manufacturing*, an American review which is mainly concerned with management and maintenance problems, uses for its *Maintenance Cost Index* the relation of 60 percent labour to 40 percent materials outlays. This breakdown seems to be realistic, and it is used in the later computations.[58]

Several conclusions may be drawn from the statistics of table 5 that are relevant for the purpose of the present study.

(i) First, the average manufacturing firm in the United States spends about 8 percent per annum of the gross book value of its fixed assets on maintenance and repair. Since the different industry groups show very little deviations from the average in this one year for which figures are available, it can be assumed that for the total manufacturing industry the percentage will not vary too much over time either. Thus, a percentage from 7 to 9 should be representative for a number of years around 1957.

(ii) About 50 percent of maintenance and repair outlays are in the form of wages and salaries paid to *own* employees of the manufacturing establishment. Again, there is very little deviation from this average in the different industry groups; so it can be regarded as a typical situation over some time, too. The share of *total* labour cost in maintenance and repair expenditure will be around 60 percent.

(iii) Since the aggregate "U.S. manufacturing industry" covers an exceptionally

57. L.C. Morrow, "Introduction" to *Techniques of Plant Maintenance and Engineering* 1955, Plant Maintenance Show, Inc., New York, 1955, p. 7.
58. Cf. "Maintenance Cost Index—Retooled for the 1970's, *Modern Manufacturing*, February, 1970, p. 86.

wide range of establishments it can be assumed that the total capital stock recorded on December 31, 1957, was composed of plants and machinery of every age (the only exception being equipment using very recently developed techniques). To say that a sum of about 8 percent of the total gross book value is spent, in one year, on maintenance and repair of all fixed assets of every age, is the same as to say that over the whole lifetime of every unit of equipment an *average* yearly expenditure of approximately 8 percent of its purchase price is made. Because of the uncertainties involved, a margin of at least ±10 percent should be allowed here, too, so that a percentage range of 7 to 9 would be realistic.

It should be emphasised that this average is true only of the *total* manufacturing industry. The individual industry groups will show deviations from this average; the deviations will be greater the more the statistical total is split up. By no means should this percentage be regarded as an average that is applicable for the individual machine. It is even less true that this average amount is to be spent actually every year in the course of the lifetime of a machine; the expenses will rather be lower for new pieces of equipment and then increase with its age. Since we are concerned with the macroeconomic aspects of maintenance and repair, we can disregard the deviations from the average.

(iv) If the average annual expenditure for maintenance and repair is multiplied by the average life time of fixed assets, we get the average total cost of maintenance and repair incurred during the life-time of plants and equipment.

The concept of average service life of all fixed assets is rather artificial: there are great differences in the economic lives of capital goods, not only between buildings and machines, but also between different kinds of machinery, etc. Estimates of the average service life of capital goods—if available at all—vary substantially. Nevertheless, the concept is useful for obtaining a global figure that indicates the order of magnitudes involved. If, for example, we assume an average lifetime of 15 years, a figure which can be considered conservative,[59] then a total amount equivalent to 120 percent of the purchase price of the fixed assets has to be spent on maintenance and repair during this period. In other words, every dollar invested in manufactures entails *on average* at least another dollar in expenses for maintenance and repair.

(*b*) *Salaries and wages of maintenance employees*: Table 6 illustrates another aspect of the cost of maintenance and repair: The amount of salaries and wages paid to own employees occupied in maintenance and repair is compared to the total payroll as well as to the sum of production workers' wages.

On average, 6 percent of the payroll costs in manufactures is spent on maintenance and repair activities. A somewhat higher percentage results if maintenance workers' wages are related to production workers' wages only; for the total manufacturing industry it is 9 percent.

Here, in both relations, the individual industry groups show greater deviations from the average than in table 5. The actual values range from 1 to 23 percent for the share of maintenance workers' wages in total payroll, and from 2 to 34 percent if maintenance workers' wages are related to production workers' wages. The highest percentages are shown by the industry groups "Petroleum and coal products", "Primary metal industries", "Chemicals and Products", and "Pulp, paper and products." All of them are highly capital-intensive industries. On the other hand, in the industry groups with the lowest percentage of maintenance workers' wages in total payroll and in production workers' wages—"Apparel

59, *Cf.* Vaclav Nesvera, *Study on Renewal, Repair and Maintenance*, Manuscript, p. 13.

## Table 6

### Salaries and Wages Paid to Own Maintenance and Repair Workers in U. S. Manufacturing Industry : 1957

| Industry Group | Total payroll | Wages of production workers Share in total payroll | Salaries and wages of M&R workers | |
|---|---|---|---|---|
| | | | Share in total payroll | As percentage of the sum of production workers wages |
| | Mil. dol. | Percent | Percent | Percent |
| All industries | 76,379 | 69 | 6 | 9 |
| Food | 7,143 | 59 | 5 | 9 |
| Tobacco | 284 | 85 | 4 | 5 |
| Textile | 3,183 | 83 | 5 | 6 |
| Apparel | 3,664 | 78 | 1 | 2 |
| Lumber | 2,110 | 82 | 5 | 7 |
| Furniture | 1,432 | 73 | 2 | 3 |
| Pulp, Paper | 2,734 | 74 | 9 | 12 |
| Printing | 4,301 | 57 | 2 | 3 |
| Chemicals | 4,090 | 57 | 11 | 20 |
| Petroleum, Coal | 1,150 | 67 | 23 | 34 |
| Rubber | 1,310 | 73 | 6 | 8 |
| Leather | 1,157 | 81 | 2 | 2 |
| Stone, Glass | 2,354 | 77 | 7 | 10 |
| Primary Metal | 7,019 | 78 | 15 | 20 |
| Fabricated Metal | 5,383 | 71 | 4 | 6 |
| Machinery | 9,050 | 67 | 4 | 5 |
| Electr. Machinery | 5,133 | 64 | 4 | 6 |
| Transport Equip. | 10,486 | 68 | 5 | 8 |
| Instruments | 1,571 | 60 | 3 | 6 |
| Miscellaneous | 2,826 | 65 | 3 | 5 |

*Source:* U.S. Bureau of the Census, *U.S. Census of Manufactures*: 1958, Vol. I: Summary Statistics. U.S. Government Printing Office, Washington, D.C., 1961, pp. 98 and 99.
U.S. Bureau of the Census, *Statistical Abstract of the United States*: 1959, (Eightieth edition), Washington, D.C., 1959, table no. 1054, pp. 782ff.
Percentages: own computation.

and rated products" and "Leather and leather products"—the capital intensity is very low. This suggests that the share of maintenance workers' wages in total payroll is related to the degree of capital intensity.

Table 7 gives closer attention to this relationship. Here, the capital/labour ratios of the individual industry groups (i. e. the ratios of fixed assets to total payroll) are comparad with the share of maintenance workers' wages in total payroll; the industries are grouped in order of their capital/labour ratio. There proves to be a strong positive correlation between these two sets of values.[60]

It can therefore be concluded that the share of maintenance workers' wages in the total payroll of the US manufactures varies with the ratio of the gross book value of fixed assets to total payroll. Since the correlation of the respective values for 1957 proves to be very strong, there is good reason to assume that this dependency will also be true for other years, and perhaps indicate a general regularity.[61]

(*c*) *The number of maintenance and repair employees*: Table 8 presents an estimate of the number of maintenance and repair workers in the United States manufacturing industries. The estimate is based on the data on maintenance and repair cost in manufactures in 1957 and on statistics on the number of employees in manufactures in 1957.

The number of employees occupied in in-plant maintenance could be calculated by dividing the sum of the salaries and wages paid to maintenance workers (as given in table 5) by the average wage of these workers. Howver, on the basis of the statistics obtainable, the average wage of maintenance and repair workers cannot be computed exactly. The statistical sources allow only to calculate the average earnings of all employees, of production workers, and of all non-production employees. The average wage of production workers in every industry group proves to be lower than the general average wage—the average earnings of non-production workers and employees being, logically, above the general average.

Several considerations which cannot be further expounded in this study lead us to assume a maintenance workers' wage which is below the non-production workers' wage but above the production workers' wage, the non-production and the production workers' wages being the upper and lower limit. The values that are computed for the number of maintenance workers are therefore margins determined by these limits.

The results of our computation are listed in column 3 of table 8: the minimum figure is 722,000 and the maximum figure 1,109,000 employees occupied in maintenance and repair activites in total US manufactures, in 1957. This corresponds to 4 to 7 percent of the total working force in manufactures (column 4). Again, the highest, or respectively the lowest, percentages are shown by the same industry groups as in table 6.[62]

These results obtained from the statistical survey of 1957 are surprisingly in line with an earlier survey and with the latest figures available.

According to data collected for 1935 which cover a "cross section of plants engaged in manufacturing many kinds of products", the average proportion of maintenance to total plant employees was 6 per cent, the proportion actually varying between 4 and 10 percent.[63]

60. Analogous results are obtained if, instead of the capital/labour ratio used in table 7, the ratio of fixed assets to number of employees ("capital per employee") is used, or if both ratios are applied only to production workers, not to all employees.—Only one industry group, "Primary metal industries", does not fit into this correlation. The data available do not present enough clues to explain sufficiently this deviation.

61. *Cf.* also V. Nesvera, *op. cit.* p. 25.

62. This is not surprising since simple arithemetic proves that the values listed in column 4 of table 8 are only margins around the figures listed in column 3 of table 6.

63. L. C. Morrow, "Maintenance Organization and Management", *Factory Management and Maintenance*, Vol. 93, No. 12, December 1935, Supplement: Plant Operation Library, ps. 163. Reprinted in: *Factory Management and Maintenance Plant Operation Library*, Massachusetts Institute of Technology, Cambridge, Mass., 1941.

## Table 7

**Capital / labour ratio and share of maintenance workers' wages in total payroll in U. S. manufactures 1957**

| Industry Group | Gross book value of fixed assets: Total payroll ("Capital/Labour Ratio") | | Share of maintenance workers' wages in toal payroll | |
|---|---|---|---|---|
| | Value | Ranking | Percent | Ranking |
| Petroleum, Coal | 6.90 | 1 | 23 | 1 |
| Chemicals | 3.20 | 2 | 11 | 3 |
| Pulp, Paper | 2.62 | 3 | 9 | 4 |
| Primary Metal | 2.47 | 4 | 15 | 2 |
| Stone, Glass | 2.19 | 5 | 7 | 5 |
| Food | 1.64 | 6 | 5 | 7 |
| Textile | 1.57 | 7 | 5 | 8 |
| All industries, average | 1.45 | | 6 | |
| Tobacco | 1.41 | 8 | 4 | 11 |
| Lumber | 1.38 | 9 | 5 | 9 |
| Rubber | 1.36 | 10 | 6 | 6 |
| Fabricated Metal | 1.06 | 11 | 4 | 12 |
| Machinery | 1.04 | 12 | 4 | 13 |
| Transportation Equipt | 0.89 | 13 | 5 | 10 |
| Printing | 0.86 | 14 | 2 | 17 |
| Electr. Machinery | 0.80 | 15 | 4 | 14 |
| Instruments | 0.80 | 16 | 3 | 15 |
| Furniture | 0.73 | 17 | 2 | 18 |
| Miscellaneous | 0.70 | 18 | 3 | 16 |
| Leather | 0.40 | 19 | 2 | 19 |
| Apparel | 0.27 | 20 | 1 | 20 |

*Source:* Own computation from data presented in Table 5 and Table 6.

## TABLE 8

**Number of Maintenance and Repair Workers in the U.S. Manufacturing Industry: 1957**

| Industry group | All employees Number 1,000 | Production workers Number 1,000 | M&R workers (Min.-max.) 1,000 | Number of M&R workers as % of total number of employees (min.-max.) Percent |
|---|---|---|---|---|
| All industries | 16,630 | 12,842 | 722 — 1,109 | 4—7 |
| Food | 1,688 | 1,134 | 71 — 95 | 4—6 |
| Tobacco | 88 | 81 | 2 — 4 | 2—4 |
| Textile | 989 | 893 | 26 — 57 | 3—6 |
| Apparel | 1,264 | 1,123 | 8 — 17 | 1—2 |
| Lumber | 646 | 579 | 19 — 37 | 3—6 |
| Furniture | 375 | 311 | 5 — 10 | 1—3 |
| Pulp, Paper | 566 | 458 | 36 — 54 | 6—10 |
| Printing | 867 | 534 | 14 — 17 | 1—2 |
| Chemicals | 767 | 508 | 67 —100 | 9—13 |
| Petroleum, Coal | 186 | 135 | 36 — 46 | 19—24 |
| Rubber | 260 | 205 | 12 — 17 | 5—7 |
| Leather | 362 | 323 | 4 — 8 | 1—2 |
| Stone, Glass | 526 | 437 | 28 — 43 | 5—8 |
| Primary Metal | 1,272 | 1,053 | 148 — 205 | 12—16 |
| Fabricated Metal | 1,114 | 880 | 34 — 54 | 3—5 |
| Machinery | 1,707 | 1,266 | 59 — 68 | 3—4 |
| Electric. Machinery | 1,084 | 795 | 29 — 45 | 3—4 |
| Transport. Equip. | 1,900 | 1,401 | 85 — 110 | 4—6 |
| Instruments | 307 | 212 | 8 — 12 | 3—4 |
| Miscellaneous | 665 | 514 | 15 — 27 | 2—4 |

*Source:* U.S. Bureau of the Census, *Statistical Abstract of the United States*: 1959, (Eightieth edition), Washington, D.C., 1959, table no. 1054, pp. 782ff.

Columns 3 and 4: own computation on basis of data published in U.S. Bureau of the Census, *U.S. Census of Manufactures:* Vol. I: Summary Statistics. U.S. Government Printing Office, Washington, D.C., 1961, pp. 98 and 99.

**TABLE 9**

**Share of Maintenance Employees to Total Plant Employees in US Manufactures, in Percent**

| Industry classification | Share in percent |
|---|---|
| Heavy equipment, fabrication-and-assembly type | 2.5 |
| Light equipment, fabr.-and-assembly type | 4.0 |
| Services | 5.5 |
| Heavy equipment, process-type | 8.3 |
| Light equipment, process-type | 8.3 |
| Miscellaneous | 11.1 |
| Average, all industries | 6.6 |

*Source*: Computed from data in "Survey Mirrors Today's Maintenance Management", *Modern Manufacturing*, March 1970, p. 77.

Exact comparison between these data and those given in table 8 is, however, not feasible because the industry groups covered in the 1935 investigation are not indicated.

The latest figures available are listed in table 9. They are part of a sample survey, published in March 1970, which covers 502 firms, mostly of medium to large size (59 percent of the sample firms had over 500 employees, 40 percent over 1,000). The data are probably of 1969.

In this survey, industries are grouped according to *Modern Manufacturing's* industry classification system. "Heavy equipment, fabrication-and assembly type" or "Heavy fabricating" covers electrical equipment, non-electric machinery, aircraft an spacecraft, etc. "Light fabricating" refers to fabricated metal products, electronics, instruments, etc. "Heavy process' covers petroleum refining, chemicals, rubber, primary metal, stone, clay and glass, pulp and papers. "Light process" includes foods, textiles, apparel, tobacco, part of chemicals, etc.[64]

The new classification makes comparison of percentages with the 1957 survey rather difficult because the 1957 survey followed the Standard Industrial Classification system. In both statistics, however, the higher share of maintenance workers in process-type industries than in fabrication-and-assembly type industries is a common feature. The more comprehensive data of the Census of Manufactures show that maintenance labour and maintenance wage costs are relatively most important in heavy process-type industries (*cf.* table 7 and 8). Comparing the average figures between the two surveys, a slight increase in the share of maintenance workers in total plant force, from 1957 to 1969, cannot be excluded.[65]

64. *Cf.* "Better Way to Compare Your Plant's Maintenance Practices', *Factory*, Management and Maintenance, August 1958, pp. 138 ff.
65. Two other sample surveys giving, *i.a.*, information on the importance of maintenance workers in total plant force, are even less comparable: "Mtaintenance Management Practices in Industry Today", *Factory*, Management and Maintenance, September 1958, pp. 90 ff., and "The Pulsebeat of maintenance Today", *Factory*, June 1966, pp. 98 ff.

## B. Conclusions for the planning of maintenance and repair in developing countries

The results of this study of the quantitative aspects of maintenance and repair in the United States present valuable clues for estimating the needs in developing countries. They can be particularly helpful for estimating aggregate manpower requirements, overall capital needs, and foreign exchange demands regarding future maintenance of new investment projects in manufactures.

(*a*) *Maintenance and repair costs*: As we have seen, average annual cost of maintenance and repair in US manufacturing industry amounts to about 8 percent of the capital invested; labour costs account for 60 percent and cost of material for 40 percent of total maintenance and repair expenses. The amount of maintenance cost is, of course, determined by the existing wage rates, prices for spares, and maintenance techniques. These may be different in a developing country, and any estimate of aggregate maintenance costs in a developing country on the basis of the American experiences must take these differences into consideration. In the following, three numerical examples have been computed in order to illustrate what the average cost of maintenance will be in in the manufacturing industry of a developing country where conditions differ from the American example. The import content of maintenance costs, i.e. necessary foreign exchange outlays, is also computed.

In case 1, it is assumed that the developing country uses the same maintenance and repair techniques as the USA, and that all maintenance materials have to be imported. In case 2, it is assumed that the same maintenance techniques as in the USA are used but that only 50 percent of the spare parts and other maintenance equipment is imported. In case 3, the same import content of 50 percent of maintenance materials is assumed, but maintenance techniques are assumed to be more labour-intensive.

In all three cases, wages in the developing country make up only 40 percent of the wage rate in the USA, and the equipment used in production is always imported. This latter assumption entails that transportation cost and import duties have to be added to the price of the production equipment as well as to the price of the spares. In other words, the value of the fixed assets—to which the maintenance costs are related—is higher in the developing country by the amount of these additional charges. In our examples, they are assumed to be 40 percent of the value of the fixed assets. The same additional charge is imposed on the import price of spare parts and other maintenance materials.

*United States*:

| | | $ |
|---|---|---|
| Investment | | 1,000 |
| M&R costs per annum*: 8% of investment | | 80 |
| Wages thereof: | 60% | 48 |
| Materials ,, | 40% | 32 |

*Developing country*:

| | | $ |
|---|---|---|
| Investment, f.o.b. US port | | 1,000 |
| Transportation and import duties: | 40% | 400 |
| Total cost of investment | | 1,400 |

COST OF MAINTENANCE AND REPAIR IN A DEVELOPING COUNTRY:

**Case 1**

(Same maintenance techniques as in the US, all spares imported)

| | $ |
|---|---|
| Wage rate: 40% of US wage rate | |
| M&R wages per annum | 19·2 |
| Import content of M&R materials: 100% | |
| Cost of imported materials: 140% of US cost | |
| M&R materials per annum | 44·8 |
| Total M&R cost per annum | 64·0 |
| Foreign exchange outlays thereof | 44·8 |

* M&R = Maintenance and Repair

**Case 2**

(Same maintenance techniques as in the US, 50% of spares imported)

| | $ | $ |
|---|---|---|
| Wage rate: 40% of US wage rate M&R wages per annum | | 19·2 |
| Import content of M&R materials: 50% | | |
| Cost of imported materials: 140% of US cost | 22·4 | |
| Cost of locally produced materials: 80% of US | 12·8 | |
| Total cost of materials per annum | | 35·2 |
| Total M&R cost per annum | | 54·4 |
| Foreign exchange outlays thereof | | 22·4 |

**Case 3**

(More labour-intensive maintenance techniques than in the US, 50% of spares imported)

| | $ | $ |
|---|---|---|
| Relation of M&R wages to materials: 70:30 | | |
| Wage rate: 40% of US wage rate M&R wages per annum | | 22·4 |
| Import content of M&R materials: 50% | | |
| Cost of imported materials: 140% of US cost | 16·8 | |
| Cost of locally produced materials: 80 % of US | 9·6 | |
| Total cost of materials per annum | | 26·4 |
| Total M&R cost per annum | | 48·8 |
| Whereof foreign exchange outlays | | 16·8 |

(*b*) *Number of maintenance workers and wage cost of maintenance and repair*: National industrial development plans generally contain some estimates on the employment effeets of industrial projects. Here, too, the results of the US statistical survey may be useful economic guides for developing countries. It will be remembered that the share of maintenance and repair workers within the total labour force of US manufactures averages 4 to 7 percent, depending on the kind of computation used. Planning authorities in developing countries should regard these percentages as *minimum* figures which should be reached at least, but in most cases rather be surpassed. The reason is that while developing countries may have little possibility to adapt production techniques to their factor endowments, this is not the case with maintenance techniques. Developing countries realize their comparative advantage by using labour intensive methods and should therefore employ a higher maintenance force than industrialized countries.

As to the percentage of maintenance workers and the share of maintenance wages in total payroll in individual industry groups, the figures of table 7 and 8 may be helpful for more detailed manpower planning. Here, the relation between capital intensity and the number of maintenance workers required deserves due regard: the higher the capital/labour ratio of an industry, the higher the manpower needed in maintenance. Again, the percentages given for the single industry groups in the US ought to be considered as minimum figures, provided more labour-intensive maintenance techniques are applicable.

## III- WAYS AND MEANS OF IMPROVING THE MAINTENANCE AND REPAIR PERFORMANCE IN DEVELOPING COUNTRIES

Generally speaking, maintenance and repair can be looked upon as a means to activate unutilized production capacities. By employing labour which is relatively cheap in activities which can be made relatively labour-intensive, developing countries will be able to realize their specific comparative advantages of production. Maintenance is a way to save capital by applying labour skills.

The problems of maintenance and repair have been analysed in this study with regard to their relevance for economic policy. Conclusions and recommendations resulting from the analysis have always been made in the context of the theoretical discussion. There remain some reflections on the practical implications for policy making which will be outlined in the following section.

## 1. Planning Activities

The planning of industrialization cannot confine itself to the simple installation of new plant and equipment. The amount of costs to be spent on maintenance and repair and the manpower needed in these activities are so considerable, they cannot be neglected when planning investments. On the average of all manufacturing industries in the United States, the same amount that is spent initially on investment is spent again in less than 15 years on the maintenance and repair of this plant and equipment. In developing countries this amount will be somewhat lower if optimal maintenance policies are chosen, but it will still be remarkable.

Investment plans should, therefore, always include estimates on the *future needs for maintenance and repair* and the possibilities to meet these requirements. The import needs deserve special attention in countries which are short of hard currencies. Some examples of global computations for total manufactures are given in this study. Similar but more detailed computations should be made for individual industries.

Where studies of the actual situation disclose lack of proper maintenance and repair. the public authorities could improve the performance by establishing regional *repair shops*, or by promoting private initiative to set up such shops perhaps on a cooperative basis. Plans for the creation of industrial estates should always include the establishment of a common repair shop.

Special steps should be taken to secure the supply of *spare parts*. The setting-up of regional stocks of spares will often contribute to solve the problem. Spare parts stocks should preferably be linked with a regional repair shop. Possibilities for a domestic production of spare parts should be explored thoroughly. The production of spares may be the appropriate first step towards an own machinery production.

In public sector enterprises, *plan targets* should not be set in a way that allows or even provokes negligence in the maintenance of equipment. If the plan targets are fixed in terms of quantity of output (instead of the value of the salable products, or profitability of the enterprise), and if this is the only criterion used to judge the performance of the firms, sacrifice of other important objectives which may conflict with production is encouraged. Instances are cited where preoccupation with maximizing output in the short run resulted in total neglect of product quality as well as maintenance and inplant training programmes. Not only was the management interested in achieving high levels of output, even at the cost of destroying capital, because output was the only criterion by which management was judged, but the workers, too, were similarly motivated since bonuses were related only to physical output.[66] Plan targets as well as wage policy should avoid such encouragement to englect maintenance. On the contrary, maintaining the capital in good condition should be a *declared target*, for which incentives are provided.

## 2. Other Policy Measures

The scarcity of capital in developing countries suggests that even greater attention is paid to maintenance and repair than in industrially developed countries, and it suggests that it is done in a labour-intensive way. Policy measures should be directed towards encouraging

66. Cf. W.A. Johnson, *op. cit.*, pp. 156-7, 163-64, 180-1. Economic history of the USSR and other centrally planned economies provide similar examples which induced these countries to change their original emphasis on tons of output.

optimal maintenance activities. At least, they should not penalize them. Actually, negligence of maintenance on the side of the management, or a bias against labour-intensive methods of maintaining capital, has often been encouraged by public policy.

*Payroll taxes* discriminate against labour-intensive techniques in production as well as maintenance. Instead of relying on payroll taxes public revenues should be secured by other tax forms which do not penalize the hiring of workers in a situation of relative abundance of labour. A bias against employing more labour may also originate from minimum wage regulations which do not take the actual situation in a country into consideration.

A discrimination in favour of capital-intensive methods of production likewise results from *tax incentives to reinvest profits.* Part of the income or corporation tax, *e.g.* a dividends tax, is forgiven if the profits are reinvested.[67] The hiring of additional workers, however, does not give rise to tax benefits.

The incentive towards greater capital intensity is highest if in addition to the deduction of investment costs from income, even from the tax due—the taxable income in later years can again be lowered by normal depreciation of the assets bought with the tax credit. It is less if later deduction of depreciation is not allowed. In this case, the investment incentive consists not in a tax abatement but only in a deferral, an interest-free loan.

One way to correct this bias towards greater capital intensity would be to discontinue the system of tax incentives for investment. But since the objective of the tax incentive is to promote industrial expansion and economic growth, this solution would be inappropriate. A better way to end the discrimination of labour-using techniques would be to grant the re-investment allowance also for the employment of additional workers.[68] Such incentives would be particularly suitable for hiring trained maintenance workers and thus for improving maintenance performance.

The use of *second-hand equipment* should be decided on grounds of economic efficiency. It may have decisive advantages in a developing country. Policy measures should therefore not discriminate *a priori* against using second-hand equipment. Instances of discrimination that were reported are: difficulties in getting credits for the purchase of second-hand equipment and the imposition of high excise taxes on used vehicles.

### 3. Import Regulations

As long as equipment and spare parts have to be imported by a developing country, the import regulations remain a crucial point of maintenance policy. Under-estimation of the importance of maintenance and repair on the part of the public authorities is reflected by refusing e.g. import licences or delaying imports by cumbersome administrative procedures.

A quick and unimpaired import of spare parts is of the utmost importance for the full utilization of installed capacity, a problem which most of the developing countries have to cope with. Refusal to grant foreign exchange for one missing spare part may put a unit out of operation for a long time, a unit the installation of which may have cost a multiple of the price of the missing spare in foreign exchange outlays. This is "saving" in the wrong place.

The undelayed supply of spares imported, furthermore, prevents their unnecessary and wasteful hoarding and the tying-up of capital. National import quotas should be "balanced": the import regulations must avoid discrimination against either machinery or spares. The import of second-hand equipment, too, should be regulated purely on the basis of economic

67. For details of a concrete case, see W.P. Strassmann, *op. cit.*, p. 127

68. An interesting recommendation to promote labour-intensive methods of production by way of a tax deferral has been made by Strassmann. Cf. W.P. Strassmann, *op. cit.*, p. 128

considerations. In many instances this will mean removal of restrictive practices.

### 4. Standardization of Machinery and Equipment

In many of the developing countries the great variety of types of installed machinery is confusing—and posing maintenance problems of their own. Especially the procurement and stocking of spare parts is complicated. As to the domestic production of machines, the adoption of a standardization system on the national, or preferably international level could help to reduce the inconveniences substantially. Foreign prototype machinery might also be redesigned partially to fit the national standardization system. The supply of spares for older, non-standardized equipment must remain secured, nevertheless, so that capital is not prematurely inactivated in a capital-scarce economy.

Regarding the equipment which has to be purchased from abroad, the simplest solution to get largely standardized products would be to concentrate on a single foreign country, even on the most limited number of firms. This would ensure a minimum of different types of machinery but reliance on a single supplier country or even one firm may create undesirable secondary problems, political or economic dependencies which are unacceptable for the country. Higher prices of the products possibly offset the advantages of standardized machinery. While these extreme limitations should be avoided, a certain concentration on a group of supplier countries whose standards are compatible will bring advantages.

### 5. Technical Information

Lack of information makes for a great deal of difficulties in maintenance and repair. The indigenous maintenance staff quite frequently lacks proper information on the maintenance and repair of complicated foreign machine devices. Directions for the handling of these machines may be incomplete, or may pose "language" problems.

*Lack of information*
*makes for a great deal of difficulties*
*in Maintenance and Repair.*

Apart from this, management as well as workers are often not aware of the maintenance problem since the adverse effects of inadequate maintenance cannot be seen immediately. Fragmentary information on buying and selling possibilities often causes difficulties in the supply of spare parts, and sometimes induces firms not to choose optimal production techniques.

Governments can promote cooperation of firms on the branch level to furnish better information on maintenance problems that are specific to that branch. Where this is not a feasible solution they could set up an organization which will collect and forward technical information. The organization may be a technical supervisory agency—as outlined in the following paragraph.

Governments should request the assistance of international organizations to improve information on maintenance requirements and to rationalize actual performance. Information on second-hand equipment could also be propagated by international cooperation.

### 6. Creation of Technical Supervisory Agencies and Statutory Check-ups

Technical information alone is not sufficient to improve the actual performance of maintenance. In many industrialised countries maintenance of machinery and vehicles is enforced by statutory periodical check-ups which are aimed primarily at promoting occupational safety. These check-ups may, however, also be considered under the aspect of enforcing maintenance standards. In industrialized countries special supervisory agencies are sometimes entrusted with these check-ups, e.g. the *Technischer Uberwachungsverein* (TUV) in the Federal Republic of Germany.

Developing countries might follow these examples and set up similar agencies. Their formal legal status may be that of a private institution commissioned by the government with the public function of supervision and endowed with statutory power of enforcement, such as the TUV in the Federal Republic of Germany, or they may be a public institution which is directly responsible to a government. The establishment of such an agency should in both cases be considered as a public task.

Checking safety devices and the safe operation of equipment should be the main functions of this supervisory agency. This would already cover a wide field of activity and would include controlling most of the important maintenance operations. Beyond this, the periodical check-ups could be given a broader scope: additional technical counselling on appropriate maintenance and repair could be provided on these occasions, especially for small-scale and medium-sized firms. Another task could be to draw up maintenance manuals and standards designed especially for developing countries, e.g. to give guidelines for the use of anti-corrosion material under special climatic conditions.

## 7. Training of Maintenance Personnel

In the now industrialized countries a cadre of maintenance workers has developed step by step simultaneously with—and induced by—the gradual development of the capital goods production. Developing countries, on the other hand, skip most of these stages. They import modern equipment at a time when their own capital goods production if it exists at all, is still in its infancy and a "spontaneous" formation of maintenance labour has not yet taken place.[69] Therefore, governments should take deliberate action to ensure the training of maintenance personnel within their manpower planning programmes.

*Lack of appreciation of good maintenance organization has more detrimental effects than deficiencies in skills.*

Training for maintenance has a double aspect. One is the training of technical skills, the other the creation of a maintenance habit. Experts agree on the point that lack of appreciation of good maintenance and inadequate organization have more detrimental effects than deficiencies in skills. It is consequently of vital importance that management is made aware of the role of maintenance and repair in modern industry. Education programmes should include executives as well as foremen and supervisors. They should cover subjects such as staffing, supervision methods, and organizational and clerical work pertinent to efficient maintenance.

Since the present state of maintenance and repair in most developing countries calls for urgent action, methods of *accelerated training* which have proved successful in industrialized countries would be recommendable for developing countries, too. Accelerated training has been defined as "a form of systematic concentrated training of a limited character, in order to transfer specific knowledge in a short period.[70]

69. Cf. R.C. Blitz, *JPE*, 1959, p. 570.
70. G.K. Boon, *op. cit.*, p. 69-70.

The description of experiences made in the Netherlands may be interesting in this connection.

> "Several systems are followed, the main feature being to analyse a specific operation or group of operations, which will be qualified as a skill. The people are trained in the different aspects of the skill in a very systematic and clear way, theoretically as well as practically. Beforehand, the workers are tested in a simple way in ordar to ascertain such things as work-experience, intelligence, talents for the specific skill, character and physical qualities.
>
> In the Netherlands amazing results with this accelerated training have been achieved in the post-war rapid industrialization period. All kinds of metal-workers were trained, including maintenance and repair personnel; and also spinners and weavers, operators for mechanized agricultural equipment, lower and middle management—and administrative personnel."[71]

Avalanche effects are obtained by training first a group of instructors in accelerated training courses. These instructors could then be assigned to regional repair shops or technical supervisory agencies to organize accelerated training in maintenance and repair for the firms settled in the region.

To prevent government-sponsored training centres from becoming over-crowded, a compulsory set-up of maintenance training shops in big business firms could be envisaged, e.g. by tax exemptions. The training in regional repair shops or by technical supervisory agencies could be concentrated on the needs of small-scale and medium-sized firms.

In industrialized countries advanced specialized training is sometimes offered by so-called *mobile repair shops* or *maintenance trucks*. The German railways, e.g., employ mobile training shops for practical training in welding. Training in these shops is particularly economical; since they can be moved to different towns, a maximum amount of people may be trained by the same equipment, and by the same instructors. The use of mobile training shops seems to be particularly suitable for developing countries.

APPENDIX

# A GRAPHICAL PRESENTATION OF OPTIMAL MAINTENANCE AND REPAIR ACTIVITIES OF A COUNTRY

## A. Effects of Differences in the Interest Rate

The formal relationship between (present) durability outlays and (discounted future) maintenance outlays is shown in Fig. 1. a and 1. b. In both graphs the 45-degree lines—in Fig. 1. a marked 1, 2, 3, 4, 5 (thousands)—are constant-outlay curves. They indicate combinations of durability outlays and discounted maintenance outlays which together make up 1, 2, etc. thousand dollars: For every point on the same constant outlay curve the sum of the coordinates is the same, namely the value given by the intersections with the axes.

The isoquants marked 5 years, 12 years, etc. show which combinations of durability

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71. G.K. Boon, *op. cit.*, p. 70

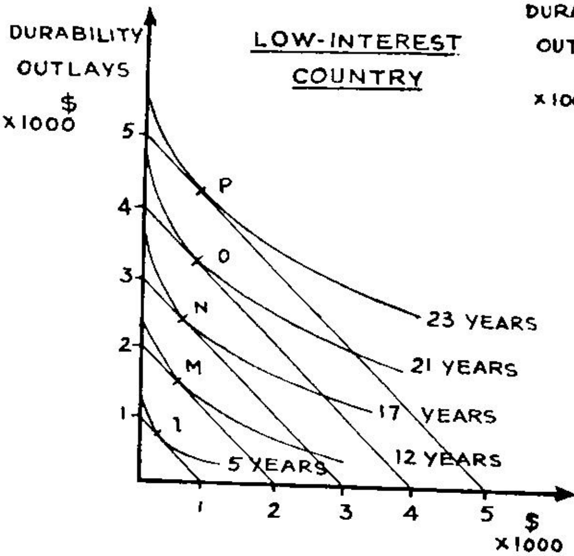


Fig. 1. a*

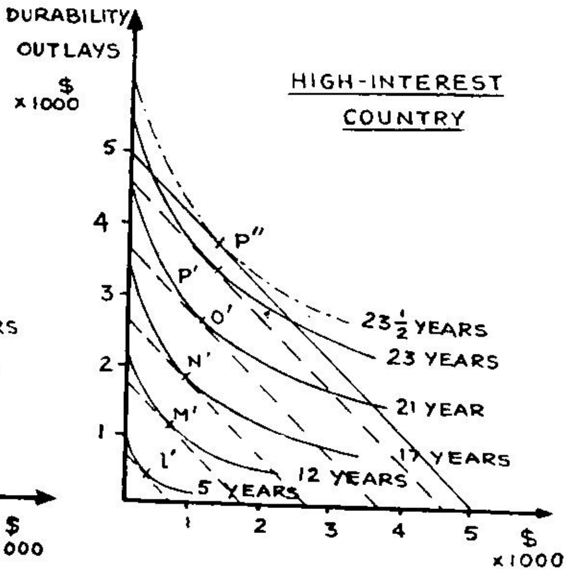


Fig. 1. b

Maintenance Outlays, Discounted to Present

outlays and discounted maintenance outlays are *technically* possible for obtaining a longevity of 5 years, 12 years, etc. They start from the durability-outlay axis to indicate that, in the extreme case, a certain desired longevity can be obtained by spending on durability alone without adding any maintenance. Since it is not possible to obtain a desired longevity with outlays on maintenance only and no outlay on durability at all, the isoquants do not intersect with the maintenance-outlay axis. The downward convex shape of the isoquants demonstrates that the rate of substitution decreases with rising share of either component of the cost combination.

The optimal combination of (present) durability outlays and (discounted future) maintenance outlays which minimizes the total cost of a chosen longevity is given by the tangential point of the isoquant of that longevity and a constant-outlay curve. For example: for a longevity of 21 years the point O in Fig. 1. a indicates the optimal combination of maintenance and durability costs which together amount to 4,000 dollars. Every other combination of maintenance and durability outlays procuring a longevity of 21 years—that is: every other point on the 21-years isoquant—will result in a higher total cost than 4,000 dollars.

The assumptions underlying Fig. 1. a and 1. b differ in only one point, all other things being equal: Fig. 1. a represents a country where the interest rate is relatively low, Fig. 1. b represents a country where the interest rate is higher. The purely technical relations remain unchanged, and it is also assumed that the *future* price of a "maintenance unit" is the same in both countries. The same technical combination of durability and maintenance contains, in the high-interest country, a lower present value of future main-

* Figure 1. a is a slight modification of a graph used by R.C. Blitz, *AER*, 1958, p. 322.

tenance outlays. That is, the present sum of money which is necessary for maintenance outlays in the future is lower because the interest rate is high. Therefore, the isoquants in Fig. 1. b—as compared to those in Fig. 1. a —are shifted to the left in all points but one: the intersection with the durability-outlay axis. (The curves swing around the intersection points.) In the high-interest country, the same longevity of 5, 12, etc. years can be reached at a lower present cost except for the extreme case in which the longevity is obtained by durability outlays alone.

The shifted isoquants in Figure 1.b do not touch the same constant-outlay curves as in Figure 1.a. Other optimal combinations of durability and maintenance costs for every chosen longevity are shown by the tangential points of the shifted isoquants and lower constant-outlay curves (dotted lines). In the high-interest country, the minimal cost combinations 1′, m′, etc′. for the same longevities are not only at a lower level of total (present) costs than in the low-interest country (price effect), but reflect also other combinations of the two cost ingredients: when the interest rate is higher, relatively more will be spent on maintenance and relatively less on durability (substitution effect). A comparison of the coordinates of the points O and O′ shows this very clearly.

If the interest rate is higher, the *same longevity* of equipment can be obtained *at a lower total cost* than in the low-interest country because of the shift from a relatively higher spending on durability to a relatively higher spending on maintenance. If, however, the *same total outlay* as before is made, a *higher longevity* can be reached. The corresponding isoquant for the constant-outlay curve 5 is drawn in Figure 1 b (dotted isoquant). The optimal combination in this case also contains relatively more maintenance outlays and less durability outlays (cf. point p″ in Figure 1.b and point p in Figure 1.a).

The combined effect of differences in the interest rates on level and structure of longevity can be demonstrated as follows. In a high-interest country, the effect described in section C of the text will tend to shorten the chosen longevity of the capital goods (in order to reduce the cost of longevity). This can be demonstrated graphically by the shift from one isoquant, e.g. "23 years", to another isoquant, e.g. "21 years", in Fig. 1.a.

But not only the present value of future *savings* is reduced in case of a higher interest rate. At the same time, the effect of the higher interest rate discussed in section B of the text will come into play: future maintenance *costs*, too, will have a lower present value and, by substituting maintenance for durability outlays, the "longevity mix" will be changed towards a greater share of maintenance outlays. The substitution will lower total cost for the same longevity: the isoquants themselves are shifted towards the left (Figure 1.b.) For a total outlay of, e.g. 4,000 dollars a longevity of 22 years instead of 21 years (as in the low interest country, Figure 1.a) may now be purchased. The optimum point on this shifted isoquant is situated more towards the maintenance outlay axis.

## B. The Effects of Differences in Wage Rate

The combination of a high interest rate with a low wage rate causes a substantially larger shift of the isoquants to the left (turning around the intersection points with the durability-outlay axis) than is shown in Figure 1.b. The shifted isoquants are tangent to lower constant-outlay curves: The same longevity can be obtained at a considerably lower (discounted) cost; or by spending the same amount as in a high-wage/low-interest country, the low-wage/high-interest country can obtain a higher longevity. A reduction in total cost of longevity, induced by the high interest rate, is possible without reducing longevity, perhaps even extending it.

## C. The Effects of Differences in Price of Capital Goods

Those effects may be demonstrated graphically, too. An isoquant for the same capital longevity intersects the axis at a higher value for durability in the high-interest/low-wage

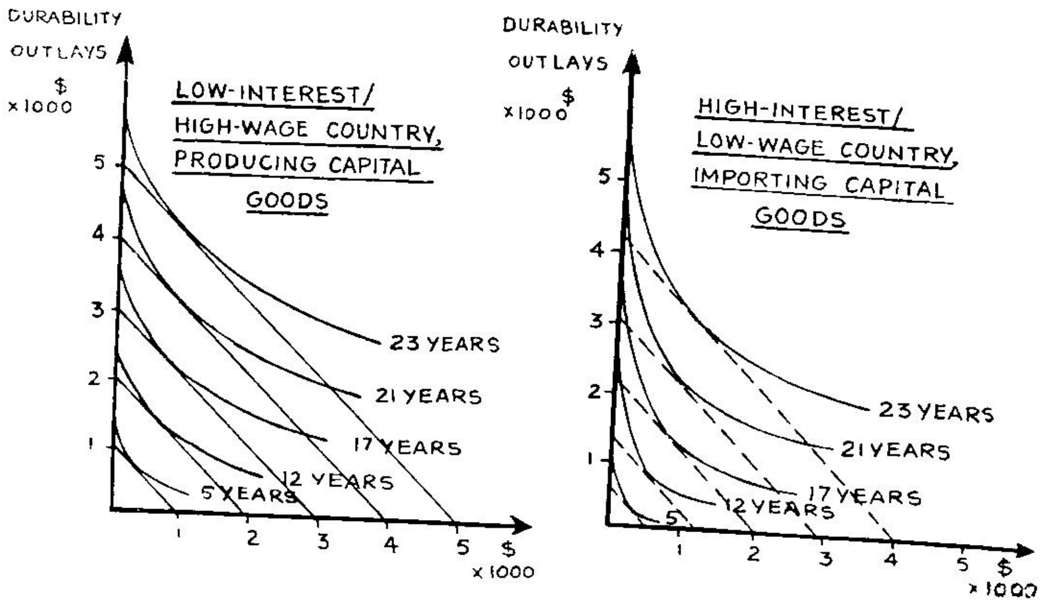


Fig. 2.a Fig. 2.b

Maintenance Outlays, Discounted to Present

country which imports the investment goods, than in the other country. A higher price of durability, together with a higher price of "maintenance capital" will shift the optimum still more towards a greater share of labour-intensive maintenance in total longevity outlays (*cf.* Fig. 2.b.)

### D. The Combined Impact of Differences in Interest Rates, Wages, and Prices of Capital Goods

The combined effects of the a.m. three variables can be presented graphically, using the isoquant method as before (cf. figure 2.a and 2.b.)

A comparison of these new graphs with Fig. 1.a. and Fig. 1.b proves the additional influence of wages and price differentials very clearly; the isoquants in figure 2.b intersect with the durability outlay axis at higher values and are shifted much more to the left.

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## PRE-CONDITIONS OF SUCCESSFUL PREVENTIVE MAINTENANCE

**The benefits derived by implementing preventive maintenance programmes will depend largely on the gegraphical location of the plant, the process, the method of manufacture, the products produced, the cleanliness of the plant and surroundings, the effectiveness of the preventive maintenance programmes and the intensity with which it is carried out and lastly, the fervour of the persons carrying out the programmes.**

—from *Machine Building Industry*, Vol. 9, No. 5, p. 35.

# Upgrading of Maintenance and Repair Personnel*

**The specialised training and upgrading of maintenance personnel is tied closely to the type of equipment used in an enterprise. While the basic skills needed for maintenance can be taught in a training institution, the range of the plant to be effectively covered could entail on-the-job training. Training should not interfere with production but lead to improved production and more effective machine utilisation.**

IN its approach to training in maintenance activities and occupations, ILO is guided by conceptual and planning principles which underly all its attitudes to training. These principles are set out in Vocational Training Recommendation No. 117, 1962.

## Fundamental Principles

Training should be a life-long process starting before the working life and continuing at determined critical times to permit the promotion of the individual to tasks providing not only improved work satisfaction but also better social and living conditions which are, to a large extent, geared to improved income earning capacity. Within this over-all concept, training should be given to all people to enable them to use their abilities to the advantage of themselves and the community.

Training will be most effectively implemented when it is done within an over-all plan which takes due account of existing and planned national structures. Thus when sectoral training approaches are used in the initial stages, and this is frequently necessary in developing countries, these should as soon as feasible be integrated into the national plan for vocational training. At the same time the various levels of competence required and the techniques to be applied in the country must take into account not only economic requirements but also the human needs of society.

## Approaches to and Methods of Training

It is seldom that new ideas or inventions occur only in one country. Usually, these build up in several places simultaneously; so it is with new and improved approaches to training. The cost of training is increasing due to higher salaries of trainers, the more sophisticated equipment needed and the trend in many countries to pay stipends and allowances to trainees. Efforts to develop approaches to combat this increase are being explored.

Certain figures published recently seem to indicate that increased investment in general educational systems has not led to comparable increases in economic growth. If this is the case, it is obvious that education and training must be much more closely geared to employment

*Contributed by: International Labour Office, Geneva needs and possibilities and to economic improvement. Systems of step-by-step training tied to employable skills may well yield the desired results at a lower cost than the present block systems, especially if they are firmly based on careful job analysis of the occupations in the country. However, in establishing such systems, care must be taken to make sure that training will be available at the correct time in every man and woman's career to avoid the phenomenon commonly called the "Peter Principle". (The promotion of people until they reach their level of incompetency.)

It is estimated that over 40.000 occupations have been classified but if we study the various training schemes available on a world-wide basis, it is doubtful whether specific training is available for more than one-quater of these. This has been brought about largely by the conservatism of trainers and educationists and the tendency to establish self-perpetuating institutions and courses into which human material is fed on the basis of past attainment in a limited range of subjects rather than of aptitudes. After processing in these education machines, the product is fed into an end-usage market which is much more highly sophisticated and sensitive to change than is the producing machine.

There has been a traditional tendency to regard the job (the 'trade') as an established mould into which the individual must be fitted. Some success might be claimed for this system but it is probable that had work started with the man, even better results might have been achieved. For example, the so-called "drop-outs", (this is really an unacceptable term today) are frequently regarded as failures but in many cases they may represent the forerunners of those who see the "system" as being archaic, inflexible and destructive of human invention. Employment markets act as efficient selection mechanisms and it is remarkable how many of these "drop-outs" not only find employment but frequently rise to success in their respective spheres. Thus again, training schemes must take full account both of needs of the employment markets and the desires and potential of the individual. "Tap off" is also an important feature in developing countries in the numbers leaving training institutions before completing long-term training. "Tap off" occurs when the acquired skill already represents a marketable commodity and attempts to improve the commodity (trainee) by the addition of further skills at the tap off time probably makes little or no additional contribution to the economy.

## TRAINING FOR MAINTENANCE ACTIVITIES

With these basic considerations in mind, training for maintenance activities will be discussed under the following heads:

(a) first-line maintenance—the operator;
(b) the maintenance man;
(c) supervisory functions in maintenance.

### The Operator

It is well known that the driver of a motor car has a great bearing on its life. In fact, tyre, steering, brake and gear wear are directly related to driving habits and can within limits be controlled by driver training and driver supervision. The example of the motor vehicle has been used but most machines requiring manual control fall into this category. Therefore, training in maintenance starts with the basic training of the operator.

The depth to which such training should go is subject to considerable variation; obviously where the value of the machine is ten times the annual salary of the operator, the training should be deeper than when the tool used is only valued at one hour of a man's salary. When considering this question, the desired standard of maintenance must take into account the period of planned obsolescence for the equipment.

"Housekeeping" is a critically important factor as a determinant of the quantity of second line maintenance needed. If good housekeeping is practised—and certainly training can bring about better housekeeping—the maintenance needs caused by dirt and by bad materials, stacking, and handling, will be reduced. Good housekeeping, good operation and safety consciousness go hand-in-hand in avoiding the still too common "working to breakdown".

If the basic training of operators includes also the elements of first line maintenance, it should be possible to arrive at a situation where a machine will, in fact, have a useful life sufficient for the purpose for which it was designed and manufactured. In other words, the operator will no longer be the first link in the chain of destruction. Such training should include:

correct operational sequences;

regular lubrication with the correct oil;

cleanliness;

maximum loading and speeds;

trouble shooting and the use of charts to diagnose simple problems.

**The Maintenance Man**

To define the exact duties ot a maintenance man is difficult. Certain occupations are wholly concerned with maintenance and repair, e.g., the motor mechanic and related trades. The basic and further training is all concerned with keeping a vehicle on the road in a safe condition. In other occupations, such as building workers, their training should permit them to construct a new building or part of it, but many of those trained will use their skills to maintain an existing structure. Many examples could be quoted from other occupations but it seems probable that training for almost all maintenance activities starts with initial training in specific occupational tasks not defined as maintenance. However, it is true that people who received their initial training through an institutionalised system may not be able to relate this specifically to maintenance without further training.

This further training may aim at (a) extending their range of skills for maintenance activities; (b) giving greater depth to the existing skills; or (c) relating these skills to a specific maintenance and repair type of activity. Such training might include for example:

(a) the adding of certain welding skills to a fitter; the adding of certain fitting skills to a welder;

(b) the deepening of a machinist's skills to include a greater understanding of tolerances, and fits and limits; adding a knowledge of machine design to eliminate breakdown due to improper machining;

(c) aiding a fitter in the understanding of the principles of machine construction, including the necessary practice to permit him to dismantle and assemble; to train electrical wiremen in the wiring of electric motors.

It is established that of all probable causes of breakdown, approximately 80 per cent can be traced to some 20 per cent of possible causes. By using an analytical approach, training can be concentrated upon those factors which create the highest needs for maintenance. Thus, with this acquired knowledge, the training planner can gear training to produce maximum effectiveness with a minimum input and ensure that the correct numbers will be trained to undertake the various activities related to equipment maintenance. For example, in the automotive trade many more mechanics must be trained to maintain braking systems than are needed for transmission maintenance.

The specialised training and upgrading of maintenance personnel is tied very closely to the type of equipment used in an enterprise. While the basic skills needed for maintenance can be taught in a training institution, it is obviously impossible either to provide the range of plant which is used in most industries or to simulate the conditions under which this plant operates on the job. For these reasons, much of the training must be done either in the operator's plant or in the enterprise which manufactures the equipment. The production of a newspaper, for example, requires large complex machines which cannot be duplicated in a training institution. Therefore, the training of the maintenance staff can only be done economically in the individual company or in the manufacturer's plant. As in most countries, the equipment has been in operation for several years and the supplier no longer has a responsibility, the training scheme will have to be established in the user's plant.

## Supervisory Functions in Maintenance

It should be remembered that maintenance applies to all organisations whether it is that of a one-man entrepreneur, a large industrial organisation, an office, or a farm, and the aggregate losses due to poor maintenance may well be greater in the sum of the small enterprises than in the sum of the large. This is particularly so in industrially developing countries where there is little background in the use of mechanical devices. Training schemes must, therefore, take into account the small unit. It is not the purpose of this paper to discuss the relative merits of promotion to supervisory rank of people from the workforce and of direct appointment of supervisors but the social implications of blocking promotion of the workforce must be faced. It is probable that the bulk of first line supervisors or maintenance activities come and will continue to come from the workforce; this is particularly true of maintenance supervisors where work experience and an understanding of machine failure are so important. If it is assumed that the supervisor will come from the workforce, will he have the neccessary practical skills to make him acceptable to the workforce? If he has, his training should be geared towards man and materials management; if not, he must be given the opportunity to acquire new skills and to improve those he has. Considering specifically the maintenance activities, he must be trained:

(a) to guide and supervise plant operation in general and to establish preventive maintenance schedules. A few simple case studies are appended to illustrate the fact that the maintenance of equipment is largely a matter of changing the habits of people. This can most effectively be done through training or retraining operators or modifying equipment to fit in with the normal habits of the people;

(b) to instruct and supervise the operators or mechanics engaged in the first line maintenance of the equipment through cleanliness, correct lubrication, adjustment and control of the machines under his control;

(c) to advise upward in the management chain on the need for more specific maintenance or repair action.

In an enterprise, the needs of training and production are often in conflict and it has frequently happened that well prepared and effective training programmes have lapsed due to this conflict if the same man is responsible both for production and for training for maintenance. If training programmes are to be a useful instrument in improving plant maintenance, it is essential that a training officer be appointed who would not be directly involved with the production process. Training must however be implemented with the full knowledge and support of production personnel so that stand-down time can be fully utilised for training. Training must not interfere with production but should lead to improved production, better appliction of good techinques and more effective machine utilisation. This in turn will bring about a decrease in lost machine hours caused by breakdown, or by planned maintenance shut-downs which have proved to be a very costly way of organising maintenece.

### CASE I

In one Asian country, for example, it was found that over 50 per cent of the heavy-duty ore-carrying trucks were out of service because of breakage of the third gear. The first conclusion was that these vehicles had defective third gears. An analysis, however, showed quite clearly that the real cause could be found in two factors of operation: first, the ore trucks were consistently being overloaded by from 100 per cent to 150 per cent since the iron ore being mined was of such high quality as to make a full truck an overloaded truck; second, the drivers had not been trained to use the gears correctly and drove almost constantly using only two gears, the first going up, and the third going down. Because the down-hill trip was the loaded trip, the third gear fractured. A brief training programme for the shovel operators, as to loading limits, and for the drivers, as to upshifting and downshifting while driving, solved this hitherto unsolvable "maintenance problem".

## CASE II

In a North African country a new batch of lathes was put into operation. The handbooks sent with the lathes were in a language not understood by the operators.

After three months of normal operation, it was found that 4 out of 12 lathes were out of action due to the leadscrew seizing in the head bearing. The operators and maintenance mechanics condemned the lathes as being badly constructed because they had received exactly the same treatment as all other lathes in the workshop.

After the handbooks were translated, it was found that the instructions called for oil to be inserted in the bearing after every four hours of operation. The other lathes in the workshop required lubrication only once each week. The operators and maintenance staff were given new instructions but within a few months, the same problem recurred because they returned to their old-established practice.

The solution to the problem was found only after a drip feed lubricator was fitted which held a week's supply of oil so that long established routines could be maintained.

## CASE III

In another Asain country a large number of marine diesel engines were supplied to the Inland Water Transport out of war surplus stock. These engines for war reasons were rated at a higher brake horsepower by the installation of special injectors and increasing the revolution per minute. After installation of the engines in ships and running them at a rating as prescribed in the manuals, high fuel consumption was the result. After putting one engine on the dynamometer test bench the reason for the high fuel consumption was found and the right injectors were installed in conjunction with the proper phasing and calibration of fuel pumps. In consequence of this, specialists were trained for making the proper modifications on all the engines in operation.

## CASE IV

On a larger scale the example of the CHINA-7 UNDP/ILO project—*Auto-Technician and Instructor Training Centre*—could be cited. Any economy undergoing rapid industrialization needs a well-developed transportation system, and this system is often a very costly sector of economy particularly in that it usually involves the use of capital for the importation of vehicles and plant abroad. In the Republic of China it was found that both on the score of capital costs and of frequent breakdowns, the transportation system posed a problem. Accordingly, international assistance was sought in expanding and improving the Centre for the training of auto-technicians and instructors.

Very early in the life of the project evidence from transport operators and highway construction enterprises both in the public and private sectors established that substantial savings in operating costs were being made as the result of training. This in turn resulted in industry turning more and more to the Centre for help. Progressively, better technicians, better instructors, better supervisors, found their echo in longer life of engines and vehicles, fewer breakdowns, less frequent overhauls, lower fuel consumption, lower repair and maintenance charges, and lower labour costs. To quote from the published final report on this project:

> "It is estimated that since the establishment of the Centre, the service life of vehicles has been lengthened from 250,000 to 650,000 km. and the service life of engines after overhaul from 30,000 to 120,000 km. The service life of batteries has been prolonged from 4 to 12 months and of tyres from 25,000 to 126,000 km. The gasoline consumption of buses has been improved from 2.6 to 3.4 km per litre and the road breakdown mileage has been increased from 15,000 to around 255,000 km."

It is pertinent to add that apart from the above benefits of training, on the personnel side, a large percentage of trainees received after graduation salary increases and promotions. ●●●


COAL TAR
ROAD UNDER REPAIR
1964
1971

This resulted in an unfavourable trend in the number and cost of M-workers over production workers. Equipment downtime tended to go up because of a shortage and subsequent high turnover of M-workers. Management was forced to do something—and they did it.

Industrial Engineering principles were applied to M and gradually modified to suit the particular needs and problems of M. To begin with the aim was mainly to optimise the quality of M services and minimise the M costs. Later on, a more over-all and broad-minded approach has come into the picture. This development has recently been further aggravated because of the approach to M problems as they appear in military systems, where M factors like Reliability and Availability of equipment in many cases may be a question of survival or not. Although this criteria may be the best incentive for man and mankind to do something constructively, it falls outside the scope of this paper. But the achievements will undoubtedly make their impact felt even in the design of industrial machinery and equipment in the future.

Effective administration of M activities can only be excercised through sound application of three well-known elements of scientific management:

1. Organization
2. Measurement
3. Control.

Experience from industries in Europe and North America shows that it is possible to reduce M costs from 15-45% and at the same time increase the availability of machinery and equipment (reduce down-time). What can the developing countries learn from this experience?

The following is an attempt to describe the experience of I for M in industrialized countries so it can serve as foundation for a discussion on what industries in developing countries can apply. And in this connection it should not be forgotten that industries in developing countries are not something uniform or standardized. One can find industries where everything from equipment to management is at par with similar enterprises in the old industrialized countries. But one can also find industries of a very low standard. Most are somewhere in between.

*Effective administration of maintenance activities can only be exercised through sound application of organisation measurement and control.*

## PRE-REQUISITES FOR OPTIMIZATION OF M EFFORTS

Before we can think of optimizing M efforts through the introduction of various forms of incentives at the plant level, a number of pre-requisites have to be met.

M must function within a well-defined organizational structure. An appropriate flow of information and data on M must be designed. Proper planning, scheduling and control of M must be introduced. Supply of spare parts and material must be properly arranged. M manpower must be brought up to a specified level of competence. The M workshops must have a layout that satisfies the needs for repair and overhaul, and the bulk of the working methods must be standardized according to the best principles of work simplification.

### Organizational Structure

The organizational structure within the M department and between M and other departments is an extremely important pre-requisite for successful M operations. A successful structure in one company will, however, not necessarily suit another company. It must be tailor-made in each case. Some rules can, however, be given.

Aims and objectives for the M department must be defined. A possible set of objectives would be to :

—Minimize lost production time due to M.

—Reduce M costs and achieve the best use of money spent.

—Optimize use of M manpower, tools, equipment and materials.

—Improve M in the broadest sense—including both the technical aspects and the service given to the production department.

—Achieve better management control of quality, time used and material concerned :

Definite lines of authority and responsibility must be established for the M department(s) and other departments concerned with M in any way.

The internal M organizational structure can be designed according to two basic concepts : centralized and de-centralized M. In the centralized case all requests go to a central M-planning function and from there to a suitable team. In the de-centralized case all major production departments have been assigned M crews to fit their needs in terms of specialization and volume of work. In almost every case, when the de-centralised concept is used, there should be a central group responsible for administration, stores, machining operations and levelling of work between the de-centralised groups.

*No maintenance work can proceed effectively in the long run without some type of information system*

Which concept is to be preferred ? This will depend on local conditions and problems, in particular :

*Type of operation :* If M chiefly is restricted to a few fields of opeation, (process piping, electrical equipment) the character of the work and the amount and type of supervision will be affected.

*Geographical situation and size of plant :* One type of organization is more effective in a compact plant while another may be more suitable when operations are spread over a vast area. If the plant is very big, highly specialized workforces should be considered in some fields.

*Scope of the M Operations:* Should M not only maintain the equipment, but also assist and perhaps be responsible for construction work as well as installation and renovation of machinery and equipment, the scope of the organization should be wide enough to handle these more varied activities. This is especially the case when project administration is applied.

**Flow of Information and Data**

No M work can proceed effectively in the long run without some type of an information system. The purpose of such a system is :

—to handle the routine flow of requests for work, work orders and material requisitions through the M organization,

—to collect information for management purposes,

—to distribute impulses from management.

To cover these activities there must as a back-bone be some sort of a work request and work order system with a material requisition sub-system. This system is also used to give

# Incentives for Maintenance*

**Some motivational factors are universal while some vary from country to country, depending on social conditions and cultural heritage. Preparation of a good maintenance system at the planning stage itself assists in the installation of an incentive system to keep actual operating results in line with the original plans. The establishment of sound policies and design of useful incentiveschemes for maintenance in developing countries requires alot of imagination and hard work.**

An Incentive (I) is something that incites to action—stimulates, and motivates man and mankind to perform, e.g. to turn out more and better work. This paper deals with Incentives for Maintenance (M), in particular industrial M as applied in manufacturing and service industries.

The basic function of M is to keep plant, machinery and equipment in a condition that will meet normal operating requirements. There are many sub-functions within M, e.g. M Inspection, Preventive M, Corrective M, Breakdown M and Overhaul. And these sub-functions can again be divided in sub-sub-functions which furthermore can be looked upon from a technological as well as an organizational angle. Other papers deal with these functions and subjects in detail.

In order to discuss I for M it is, however, necessary to have a clear picture of the many components and facets of M. We must know where we are, and where we want to move. We must know what can, and should, be accomplished through the introduction of improved technological and orgonizational methods and techniques and we must know where the introduction and up-keep of the improved methods and techniques can be supported through I. And we must have a base from where to measure the performance in order to calculate the remuneration or reward for the extra efforts applied.

We must also know what motivates man. Some motivational factors are universal while some vary from country to country, depending on social conditions and cultural heritage.

The installation of a sound incentive system involves many applied sciences such as engineering, administration, sociology and psychology.

M is not a function that can, or should, be looked upon in splendid isolation. M's performance depends heavily on other functions within an enterprise, in particular Production and Procurement. And first and foremost, performance depends on the attitude and outlook of top-management and its ability to organize and administer all functions within the enterprise in a balanced and well co-ordinated manner.

*Contributed by HB Maynard & Co., Denmark.

I for M at the plant level is not the the first or even one of the first tools to use to improve the M situation within an enterprise. There are many pre-requisites that have to be met before we should think of introducing I for M—pre-requisites which by themselves will assist in improved M.

## THE DUAL ASPECTS OF M

As already mentioned earlier, M can be looked upon in a number of ways. Two aspects appear to be of particular significance:

1. M as a function that keeps machinery and equipment downtime below desired levels.
2. M as an indirect cost element that increases product price without adding to its value.

It is tempting to overemphasize the first one in order to achieve a low level of machinery and equipment downtime. This is in the interest of the operating departments although it may result in increased M costs.

Increased M costs will attract the eye of the cost control department and efforts are likely to be initiated to reduce the M costs. This may result in less M work which again may result in more breakdowns and less availability of machinery and equipment; the operating department will suffer and output will decrease.

It is up to top-management of an enterprise to keep a happy balance between the two opposing M aspects.

M work, as any other work, can be organized according to good industrial management principles and practices. But the organization of M can also be faced with an almost impossible task, namely if the machinery and equipment are not suited for the production, not suited for the operators that attend to it and not suited for the environment in which it works. Any machinery and equipment is designed to function under certain conditions. It is up to those who plan the factory and order the machinery and equipment to consider these factors carefully. And it is up to top-management—and perhaps Government officials in particular, in developing countries, to see that it is done.

The cost of production facilities and their contribution to the manufacturing costs should not just be based upon the purchase price of the facilities. How many years will it be usable? What is required every year to keep it in desired operating condition? What will this cost in respect of M labour, material and overhead? These costs must be estimated and added to the purchase price. And we may find that the equipment with the lowest price may not be the equipment that generates the lowest over-all cost.

It is much easier to prepare for a good M system when the enterprise is at the planning stage than when it has started production. And it will be much easier to install an I system that will assist management's efforts to keep actual operating results in line with the original plans.

## MAINTENANCE IN RETROSPECT

The history of organized M is short. It is only within the last couple of decades that advanced management principles have been applied to M in enterprises in the industrialized countries.

The need for managing M more effectively arises from several reasons, some of which are:

1. Introduction of more and more sophisticated equipment requiring higher and higher skilled craftsmen for M.
2. Limited supply of skilled craftsmen with requisite qualifications.
3. Rapidly increasing wages for the craftsmen.

The sophisticated manufacturing equipment was introduced partly as a result of the incessantly accelerating technological development and partly because of the need to offset increased labour wages and shortage of labour.

has so far been the major stimulus for motivating man to do more and better work. Very little of modern motivation theory has yet been systematically incorporated into industrial incentive systems. Most of what has been done is for salaried personnel and of an experimental nature.

As most of the developing countries have not yet run into these problems, we shall only briefly mention a few of the elements. Without going into details it is felt that even with the differences in motivation in the industrialized and the developing countries, it should be stressed that there is more to motivation than can be rewarded by I plans. Such motivational factors are mainly : Supervision, job contents, job level, specialization, influence on decision making and knowledge of results, work group relationships.

The needs that are usually taken as the starting point for motivation theory are according to the American Social Psychologist A.H. Maslow the so-called physiological drives. The human being who is missing everything in life will hunger for food, water, somewhere to live with his family and the like, rather than safety, esteem and knowledge. As long as the problem for the individual is to cover his basic needs, his thoughts will be focussed on them. To cover basic needs primarily motivates him to work—it is survival of the fittest. When his basic needs are satisfied, other and "higher" needs tend to play a greater role to him The physiological—basic—needs are still there, but not so dominating. The needs for safety come into the picture. The safety factor includes coping with elements as medical and dental care, unemployment, disability, old age as well as security for the family. If both the physiological and the safety needs are satisfied, the next "higher" needs that will emerge are the belongingness and love needs. The person will now feel keenly the absence of friends, a wife and children, i.e., he will hunger for a place in his work group. The esteem needs are the next ones to appear. All people in society have a sound drive for self-respect, usually high evaluation of themselves and also for the esteem of others. To self-respect belongs a wish to perform something, to develop, to be competent and well educated with a specific field and also to have a certain amount of independence. The person feels he has a function and is esteemed in society.

*The design and subsequent installation of an incentive plan must follow certain principles and requirements*

When looking at the sequence in which Maslow puts the needs that form the motivation, one may not agree and it is also still let to prove whether or not this theory can be transferred to the developing countries. The theory is built upon man's situation in dynamic societies. We do not know if it applies to man in static societies too. When the basic needs are overcome the environmental conceptions may strongly influence man's motivation, thus bringing cultural and religious aspects of the different countries into the pattern.

## PRINCIPLES AND METHODS FOR SOUND INCENTIVE PLANS

The design and subsequent installation of an I for M plan must follow certain principles and requirements :

*Design of plan :* Make a detailed demand analysis before starting on the design. What is expected from the I plan ? What is the company willing to invest in installation costs—such as setting time standards, orientation and training of personnel, required physical and organizational changes etc ? What is the company willing to spend on recurring administrative costs to operate the plan ? What savings can be expected ? What is the expected lifetime of the basic data and the application model ? A demand analysis will indicate the correct level of aspiration to aim at.

*Establishment of standards :* Firm standards covering most parts of the work for the crafts involved must be established before the plan is fixed. Standards should not prove to be too loose, nor too tight, shortly after the start of the plan. Revising standards too soon after implemenation may have bad effects on the M workers It is not necessary to cover all M crafts from the very beginning.

*Correct reporting :* A correct reporting and control system must be operational at the same time as the I plan is put in force to see if any standar is too loose or too tight, and if the standards are applied correctly ; this is helpful because facts and figures may be useful in labour union negotiations, or are required in the M information system.

*Revision of standards :* Methods and means for revision of standards must be built into the system alrea y during the design phase. Production equipment changes very fast in an industrial world with rapid technological development. There is a similar development of M methods, tools and equipment.

*Acceptance by everybody involved :* Three groups have to be taken into confidence during the design phase in order to obtain a positive attitude and co-operative spirit. These groups are the workers, the supervisors and, if standard data are used, the applicators—the individuals who apply standard data in order to estimate job standards. The introduction of an incentive plan in the M department will not only change working conditions for operators but also the tasks for foremen and supervisors. Resistance against chan e can be a problem and an extensive training and orientation programme must therefore be an integrated part of the implementation plan.

H.B. Maynard, one of the fathers of advanced management, summarises in his Industrial Engineering Handbook the characteristics of a sound wage-incentive plan as follows :

1. There must be a direct relationship between something of value which is measured (frequently output) and the performance in terms of the measure.
2. It should be simple enough for each employee to understand readily and to compute his own incentive pay.
3. The standards upon which the wage-incentive plan is basedshould be accurately established by thorough engineering analysis and, whenever pertinent, by time study.
4. The plan should provide for the changing of production standards whenever changes in methods, materials, equipment, or other controlling conditions are made in the operations represented by the standards.
5. Standards should be guaranteed, however, unless changes occur which clearly alter the work measured.
6. To be effective, the plan should be sufficiently generous to convince workers that they are being adequately repaid for turning out good work more rapidly.
7. It should be unrestricted as to the amount of earnings. However, no wage-incentive plan can continue to be effective very long if high earnings can be made without a high output of effort.
8. Under ordinary circumstances, management should guarantee that the employees' basic rates of pay which existed prior to the plan will become minimum rates of pay under the plan.
9. In fairness to owners and consumers, the plan should usually result in a reduction of the unit factory cost of manufacture, making lowered prices possible.
10. Desired simplicity of records will be achieved when labour cost remains unchanged at any level of output in excess of that established as standard.
11. The plan should be so established that it may be related readily to other management controls, such as quality control, production control, or cost and budgetary controls.

management necessary control and guidance information.

The M information system helps everybody concerned within production and maintenance as well as higher management to obtain systematic answers to the following questions :

1. *Before the job is performed:*

   What work needs to be done ? In what order of priority ?

   What crafts from what area should do the work ?

   When should the work be done ?

   How long should it take ?

   What will it cost ?

   What methods should be used ?

   What materials and what quantities are needed?

   Do we have too much, the right amount, or not enough manpower ?

2. *While the work is in progress:*

   Are we keeping up with our schedule ?

   Are we doing the work that we do, when we should do it ?

   Are we using the proper methods to do the work ?

3. *After the work has been completed:*

   Did we do the work on time ?

   Did we meet our labour/material estimates ?

   How effective was our M-force ? Emergencies *vesus* routine jobs ? Utilization ?

   How can we further improve our M operations ?

   The questions sound simple and so are the answers, if we have the appropriate information system.

In large enterprises the flow of information and data is of such a magnitude that the cost of computerizing the flow may well pay off within one year or so. The reason for this is that the speed with which cost control, planning and scheduling can be accomplished will result in additional savings. There are such systems readily available as computer software packages covering virtually all information needed within a M organization.

**Planning, Scheduling and Control**

The purpose of M planning (How a job is to be done) and scheduling (When a job is to be done) is to define the objectives and content of a job and then get the right men and facilities, at the right place at the right time. A well designed and well functioning planning and scheduling system will :

1. Reduce delays caused by lack of coordination between production and M schedules.
2. Reduce wasted manpower by eliminating unnecessary travel time for tools and materials needed.
3. Reduce labour charges to a minimum by proper manning for each job. If a job is a one-man job, it should be carried out by one man.
4. Coordinating multi-craft jobs so that delays created by crafts waiting for other crafts to finish up are minimized.
5. Reduce waiting time between jobs because the next order is already prepared.
6. Prevent searching for materials which are ordered but not yet received.

The purpose of M control (What has been done?) is to provide managers and supervisors with a tool that will exhibit deviations from the plans and schedules in order to enable them to take orrective actions.

**Stores and Procurement**

"We do not have parts when we need them", is one of the most often heard complaints from the M staff. If a M crew has to wait for spare parts and materials it does not only delay the time required to bring machinery and equipment back to operational performance, but may also create irritation amongst the crew, in particular if it works under an incentive system. The anticipated bonus may be reduced. The crew may have to change to another job. And when the missing part has come, the crew may rush back. This is against all accepted rules of job satisfaction.

It is, of course, not feasible to keep all parts and materials in stock. What to keep in stock and how much can be decided through simple calculations. It must be a part of the planning and scheduling not to start any M job without checking the availability of parts and materials with the store departments.

**M-shops, M-tools and M-methods**

The same systematic thinking which is used in a layout for a production department can, and should, be used when organizing an M shop. Consideration must be given to flow of machinery and equipment when it comes for repair or overhaul : Space for disassembling, cleaning, intermediate storage, reconditioning, testing, painting etc., must be properly arranged for. Where should the facilities used for reconditioning be placed? What can be stationary and what must be mobile ? What tools can be readily available and what tools must be kept under lock and key? and so on. Should each M worker have a set of tools selected to suit each one's particular needs in accordance with the type of M jobs attended to ?

The systematic thinking should also be applied to individual workplaces in the M shop, in particular when certain M operations are of repetitive nature.

The M methods should be as standardized as possible. The MTM (Methods Time Measurement) system and related systems can provide valuable assistance in building up standard methods and data. It is not uncommon that large industries in Europe and the US have around 80% of their M work covered by effective standard methods and standard times. The significance of this for introducing I are obvious because we then have norms on which to base the actual performance.

*The manpower engaged in maintenance must be well qualified within their respective crafts.*

**Trained Manpower**

The manpower engaged in M must be well qualified within their respective crafts. They must be well informed about the objectives and scope of their work as well as the M function as a whole. And they must receive regular upgrading in order to be able to handle more and more sophisticated machinery and equipment.

When a special efficiency or I scheme is introduced, the M workers must receive detailed orientation about its purpose and training in its application.

## ELEMENTS OF JOB MOTIVATION

The problems and questions of job motivation have long attracted the interest of many people in the industrialized countries, as a natural consequence of the evolution in these countries, where the basic needs have been overcome.

Much research has been done, but many questions remain unsolved when it comes to making definite rules for man's motivation to work. The prospects of making more monety

12. In general, the plan will be most effective when applied to individuals or small groups rather than to large groups.

13. The plan should have the continued attention of those directly responsible for its operation and the continued attention and support of top executives.

14. The plan should be fair to employees, managers, and owners in its establishment and in its administration.

15. Definite instructions covering policy and method of operation should be provided so that the plan may be maintained.

16. Management and employees or their representatives should be in real agreement as to the adoption or modification of the incentive plan.

Maynard also gives the following advice as to pitfalls that should be avoided in establishing and operating a wage-incentive plan :

1. Failure to fully inform employees and their bargaining agents regarding plans and proposed procedures in establishing incentives.

2. Failure to have supervision play a major role in the setting up of incentive plans.

3. Failure to recognize the calibre of men and the high level of competency required to establish and maintain wage-incentives properly.

4. Failure to take into account, analyse, and establish standards for materials and spoilage or bases whereby there is a clear understanding that incentive payment applies only to the production of acceptable work.

5. Failure to properly and continuously maintain measured standards and wage-incentives once they have been established.

The operation of an incentive plan over a period of time is fully difficult—probably more difficult—than its design and installation.

6. The practice of setting a temporary standard in new plants or on new operations should be kept to a minimum. In any event it should be clear to all that the standards are temporary for a relatively short period of time.

## M PERFORMANCE MEASUREMENT

### M Operation Time

For years, industrial engineers have been trying to find ways of developing accurate standards for maintenance work, following the same approach as used in measuring production. They have been trying to set standards which would represent the exact time required by the qualified maintenance worker to do each job. Not only is this very costly and time-consuming, but it ignores one of the basic characteristics of maintenance work—the wide variety of conditions encountered. Engineers always asked how they could set an exact standard on, say a pipe repair job when they could not tell in advance how badly the pipe was rusted. Once it was accepted that this was actually impossible, the foundation of the Universal Maintenance System (UMS) started to take shape. It was realized that it was feasible to say that a given job could be performed within a "range of time". For instance, while it was not possible to say that changing a bearing on a press would take exactly 3.1485 hours, we could say with certainty that it would take somewhere between 2·5 and 3·5 hours.

Working on this principle, the Maynard Group has built up a library of data on maintenance work, covering all trades and most industries. The standards represent the time required by an average craftsman to do a job under normal conditions using a good method—not necessarily the method that has been used in the past. One standards "applicator" is required for about twenty craftsmen. The craftsman's performance, and hence his bonus entitlement, is not measured on a single job, but over a period of, say, a week.

Using the "range of time" concept, managers can easily develop standard job times for representative or bench-mark jobs and have them catalogued in a series of standard work groupings by type of craft involved and according to the range of time or work group into which they fall. These time ranges are illustrated by the standard work groupings and work group time as shown below :

| Time Group | Standard median hours | Time Range (Hours) |
|---|---|---|
| A | 0.1 | 0.00-0.15 |
| B | 0.2 | 0.15—0.25 |
| C | 0.4 | 0.25—0.50 |
| D | 0.7 | 0.5—0.9 |
| E | 1.2 | 0.0—1.5 |
| F | 2.0 | 1.5—2.5 |
| G | 3.0 | 2.5—3.5 |
| H | 4.0 | 3.5—4.5 |
| I | 5.0 | 4.5—5.5 |

When a catalogue of reasonably accurate bench-mark jobs has been developed, the next step is to compare the work content of a given job with the work content of a job already in the catalogue. When there is an appreciable similarity in this work content, the same work group time can safely be used.

The development of standards is rather complex if it has to be done from scratch. However, there are thousands of bench-marks from all types of industries available which with very little effort can be validated to fit any plant. Revision of data is often facilitated by computer programmes.

When a data bank for bench-mark jobs has been developed, this can be used as the base for incentives in a wide variety of ways.

**Production Output**

In some cases it is also possible to measure M performance through production output. Comparing the number of M hours with a fixed base (i.e. production output) is one way to indicate an efficiency. It is, however, hard to avoid influence from changes in sales or from shortage of material. Comparing the number of M hours with an input/output relation is also difficult to measure with decent accuracy and also in this case to avoid influence from irrelevant factors.

The performance may also be expressed as the reduction in downtime (hours or %) registered. As this includes only a limited part of the total M work it is not a clear cut expression for M performance. It may, however, be used as a temporary measure because it can be installed quickly.

**Merit Award**

In a merit award system management determines to underline certain aspects of the workers' knowledge or behaviour by relating them to factors in an evaluation system. The system must consequently be tailor-made to each company. Examples of merit award factors are :

Knowledge of work and work experience

Quality of job performed

Application to job

Co-operation

Attention to safety

Care of materials, equipment and tools.

Each factor carries usually a certain weight. A committee of supervisors, foremen and perhaps also a labour union representative periodically reviews each M worker in respect to the award scale. The individual's number of points are converted to the amount of money he will receive until the next review.

Unfortunately, the design of the system means that reward for good performance comes too late to have a motivational effect on the worker. The correct selection of factors and their weight can be discussed and the supervisors are seldom experienced enough to make reasonable correct assessment of the factors. Although the first results when implementing merit awards are often encouraging, the system is not really to be recommended. The reason for this is that worthwhile results can seldom be sustained.

**Other Methods**

Some companies use work sampling in measuring M efforts. Combined with improvement steps in other areas, work sampling has been useful in indicating trends. Also, it can be exceedingly useful for highlighting areas where improvement is required and then for indicating the amount of improvement that is achieved. However, it offers no real measure of the actual performance or effectiveness of people, only indications of the way things are going. It does not measure the work with respect to skill and effort applid to the job or the adequacy of the methods used.

## I PLANS

Based upon the different M performance measurement methods previously described, a wide variety of I plans can be developed. M work and I plans can be broadly classified and grouped in the table below:

The figure establishes a relationship between types of M work and the basic approaches to I plans. We will now investigate some interesting I payment schemes more in detail.

**I Based on Operation Time**

I based on operation time usually have a strong motivational effect. They are best used on M work group I. They are hard to measure and follow up in group II if most of the time is assigned to trouble shooting.

A. Actual performance is measured against standards. Incentives usually start at 100% performance (sometimes lower) and wages rise as performance goes up. A typical pay formula could be:

| | M work | | I plans and base for bonus |
|---|---|---|---|
| I | M workers attending chiefly to scheduled and pre-planned M and repair either in an M shop or in a production department. | 1<br>2<br>3 | M operation time<br>Production output<br>Merit award |
| II | M workers assigned to specific areas or equipment, and acting as trouble shooters and attending to numerous small M and repair jobs. Supervision mainly from production department. | 4<br>2<br>3<br>1 | Work load bonus plan<br>Production output of group serviced<br>Merit awards<br>M operation time |
| III | Service personnel such as storekeepers and tool room attendants with intermittent work requirements. | 2<br>1 | Merit awards<br>Bonus based on efficiency on area or group serviced |

$$\text{Total pay} = B + B\left(\frac{\text{time allowed} - \text{time taken}}{\text{time allowed}}\right)$$

Where B=Base wage and "time allowed" is compiled from the standard data system.

The base wage can be determined in three different ways:

1. Individually for each worker through merit award system,
2. Be fixed for all workers, or
3. Be grouped after, i.e., years with the company.

B. An alternative to the plan above is the following formula:

$$\text{Total pay} = B \quad \frac{\text{time taken}}{\text{time allowed}}$$

Here the total pay is highly influenced by the workers' productivity. To even out variations, which are hard to avoid in maintenance work, the productivity could instead be measured on a work group, i.e. the M people in a certain production department.

C. A more rough approach is to measure productivity of a work group, divide productivity into three sections and measure say 10% of all jobs against standards. Each productivity section has its own wage rate and the work group consequently can receive only one of three wage rates each period, dependant upon which productivity section this work has been assigned to through the measurement against standards.

**I Based on Production Output**

This method can be used in all the groups I, II and III. It fits best to a trouble shooting group and for service personnel where we otherwise have a measurement problem. Production output or input/output relations could be measured in a wide variety of ways. Here follows some suggestions.

A. This plan includes all direct and indirect personnel influencing production output.

Base wage can be determined in the same way as with typical pay formula given already.

The bonus received is dependent on the production volume approved. The total wage then amounts to:

$B + B \times f \times \text{production output approved}$

where B=Base wage

f=A factor assigning a relationship between wage and output.

For instance:

f could be 0,0001 if production is under 1000 tons
f could be 0,00015 if production is unde 1100 tons
f could be 0,0002 if production is unde 1200 tons

The motivational effect of such a plan i not as strong as an operation time system.

B. Service personnel can have bonus on low idling time for the M workers.

C. If the majority of the M workers covered by direct M work me ment and are receiving incentive pay some provision must be made to avo pay-differential problems among assi ed M personnel, service personne and the scheduled direct M personnel In some instances, the assigned sonnel could be the better craftsme and yet receive less pay. The problem exists with service pers If other M workers receive i bonus, it is necessary to provide a method to increase their earnings with incentive pay. There have been various plans to measure store-room work etc., but none has proved very successful. The most satisfactory arrangement to avoid pay discrimination is to pay a bonus based on the efficiency of the M workers serviced. The assumption is that the store's attendant will give prompt service to help worker reaching a high efficiency by avoiding delays caused by careless servicing.

D. Trouble shooters can have bonus on low equipment down-time caused by machine troubles. Work load bonus plans are also often constructed according to this philosophy.

E. Equipment utilization and maintenance costs can be favourably influenced by this plan:

$$\text{Total wage} = B + f_1 \frac{\text{equipment time scheduled} - \text{breakdown hours}}{\text{equipment time scheduled}} + f_2 \frac{\text{maint. cost budget}}{\text{maint. cost outcome}}$$

"Maintenance cost" can be substituted with "Maintenance labour cost".

where B = Base wage
$f_1$ and $f_2$ = factors defined in the same way as under A above.

There are a great variety of different possible wage solutions under each of these plans, and all details must be prepared at both country and plant level.

## I Based on Merit Award

A pure merit award system is not recommended. I can, however, be used as part of an I system based on e.g., operation time. The system described under 'Operation Time, A (see page 299) is an example where the basic wage rate can be determined by a merit award system.

## Individual or Group I

Most incentive plans can operate with either group or individual payments, without upsetting the basic plan. It is just a question of distributing incentive earnings.

When making the choice between the Group and Individual I plan, the following points are considered in favour of the Group payment:

1. Group payment average earnings, so that the total pay maintains virtually the same position from period to period.
2. Group payment average earnings, so that each employee in the same craft receives the same incentive pay.
3. Group payment average difficult work with easy work.
4. Group payment may be extended to cover all hours—even those without standards (nonrated productive workers, sweepers, toolroom attendants, etc).
5. Group payment simplifies the administration of the plan.

There is a risk though that the group-payment system will result in a failure because:

1. It can be a compensation for potential errors or inefficient management.
2. Individuals or small groups feel they are "carrying" less efficient fellow workers.
3. Individuals or small groups feel they contributed more incentive earnings to the common "pot" than toolroom attendants, etc who are included in the same plan.

The following points are advanced in favour of individual incentive systems.

1. Each employee receives pay in proportion to what he produces; high producers tend to produce more and low producers have the incentive to continually improve.

2. High producers receive high earnings which are not to be shared with low producers.

3. Individual incentive can be basis for the foreman to appraise the efficiency of each employee.

With these qualities the individual-incentive plan tends to promote a higher individual performance level than the group plan.

We think that, when making the choice, first preference should be given to group payment. That is because the most important advantage of group payment is in promoting team work, to maintain a level of quality and to stimulate mutual assistance on jobs. If group incentive payment is installed together with well developed control functions and accurate, properly maintained standards as basis of the incentive standards, a group plan achieves the best total result in the long run.

**Recommended I plans**

In accordance with the earlier discussion we again stress the necessity that an I system for M work must be based upon a good organization and the I plan has to follow the principles summarised by H. B. Maynard. As the ideal I plan that fulfils everything desired has still to be found, one has to compromise. In our judgement the following should be covered in an I plan for M workers in developing countries:

A. Individual base wage rated against a merit award plan.

B. Group application of bonus to promote team spirit and high quality level.

C. The bonus cumulative period should be one or two weeks—not more.

D. The bonus accumulation should be gradually reproduced in a graphic way, e.g., on a "thermometer" in order to be understood by workers who may be illiterate.

E. The bonus must be based on measurable criteria that can be pre-estimated. The more advanced industries are recommended to implement the advanced operation time systems used in Europe and North America. An organization that cannot meet the prerequisites of such a system might very well start out with an I plan based on production output.

Such a plan could be designed in the following way:

Total wage $= B + B_1 + B_2$

where : $B$ = Base wage
$B_1$ = Bonus for meeting production output estimates
$B_2$ = Bonus for achieving desired production overestimates

**1 Plans for Supervisory and Managerial M Staff**

It is extremely rare that supervisory and managerial staff participate in an I plan for M in the more highly industrialized countries. The information and control system will provide top-management with data required to assess over-all performance as well as performance of different departments and activities. And top-management will review the performance with those responsible, appraise performance above desired standards, and discuss remedial actions in cases where performance is below standard. This contact and joint review is considered an important part in top-management's function in coaching, educating and motivating subordinates.

This top-management function is hardly less important in developing countries, and cannot easily be substituted by any I plan.

If, however, one wants to apply an I plan to supervisory staff performance it is of course possible, as long as certain prerequisites are fulfilled. First of all, and whether the plan is related to output or costs, the supervisor must be able to influence the results in an appreciable way.

The Industrial Engineering Handbook by H.B. Maynard gives the following rules:

To be properly included under an incentive-pay system the supervisor should:

1. Have the responsibility for costs properly assigned to him as part of his over-all job responsibility. If this is assigned to him through the level of a formal position analysis, so much the better.

2. Be able to exercise significant influence on the costs of his department's operation by virtue of increasing his skill and effort in managing.

3. Have a sufficient amount of controllable cost in his area to make the application of an incentive plan worthwhile to the company and to him.

4. Be assigned to an area of responsibility which corresponds to an accounting reporting area, so that his performance can be measured by the regular system of cost reporting.

The elements of a sound incentive plan for foremen are quite similar to those of any good wage-incentive plan. A plan must be:

1. Spelled out in the form of a policy and procedure manual.

2. Easy to understand on the part of the foreman, simple in design.

3. Easy to administer, it should avoid high clerical expenses in calculation of performance and pay.

*The elements of a sound incentive plan for foremen are quite similar to those of any good wage incentive plan*

4. Designed to reflect directly in higher incentive-pay the extra effort and accomplishment by the foreman; it should contain enough incentive-pay possibility to evoke active interest.

5. Able to reflect a reasonable relationship between effort (cause) and cost improvement (effect); the foreman must be able to see the results of his endeavour and to evaluate the results in terms of his improved performance.

6. Designed to promote teamwork among the supervisory group and not cause competition among the foremen at the expense of the over-all good for the company.

7. The plan should promote the "consultative" approach to management; the plan should evoke the attitude of "how can I help you to do a better job?" from the foreman's immediate superior.

**Managers**

An increasing number of firms have been installing salary-evaluation plans for managers and staff personnel. Salary evaluation is, of course, not a universal procedure, especially not for higher levels of management. On the other hand, as a very big number of companies are using these procedures, it is a good indication that they are worth major consideration.

**Achievements**

Here we will make a brief description of typical results achieved from implementation of I for M work in two different industries.

*Case I:* A PAPER AND PULP MILL

Before the plant manager decided to invest money in increasing productivity in his M department, a study showed that utilization was about 60% and performance about 85% compared to standard data performance. This meant a productivity of 60%x 85%=50% with a total crew of 150 workers. The implementation of I was preceded by a thorough overhaul of the M organization, and sub-projects were carried through covering the following areas:

(a) Organizational structure
(b) Training and information
(c) Preventive maintenance
(d) Stores and transports
(e) Work order system
(f) Planning and scheduling
(g) Management control system
(h) Tools and equipment.

Standard data incentives were installed according roughly to plan A based on operation time (see page 299).

One year after installation, the following results were observed:

Utilization had increased from 60% to 78%.
Performance had increased from 85% to 110%.
Thus productivity was now 78% x 110= 86%. Productivity increase equalled 72%.

This means that while the plant expanded its production output from 200,000 tons/year to 340,000 tons/year in connection with a plant enlargement, they could maintain their original crew size. At the same time they obtained a higher level of maintenance quality.

*Case II.* A WEEKLY MAGAZINE PRINTING PLANT

In this company M costs increased steadily and they were having more and more difficulties to overcome delays due to breakdowns in the production equipment.

To promote higher efficiency out of their M crew of 101 workers, they started a programme with the same sub-projects as in case I. An I plan was installed and within 2 years results were evident.

Although production output had increased rougly 10 percent, the M crew had decreased from 101 to 81 workers and the printing plant had virtually no delay troubles caused by breakdowns any more.

**National Interests in M**

When a country has comparatively limited domestic manufacturing resourses, as is the case in most developing countries, it is self-evident that everybody concerned with the well-being of the national economy is interested to see that all installed manufacturing capacity is utilized to the maximum possible extent.

This manufacturing capacity is established under conditions that are characterized by limited financial resources and have most often caused heavy expenditure of scarce foreign exchange. An optimal return on this investment is in the National interest of any government, government department, government organization and industrial association.

M is, of course, only one of many factors that influences the optimal utilization of installed capacity within a manufacturing enterprise or a service industry. Capacity may be idle because of lack of orders, lack of material and supplies, poor management which may result in poor production scheduling and control and so on, and so forth. Some factors are more tangible than others and some factors may be of far greater importance to the overall utilization than M. However, when a factory or a part of it is idle because of some of its machinery and equipment being out of order, it is a very tangible reason for reduced utilization. And any other current factor will hide nicely and pleasantly behind the M factor.

It is commonly recognized that manufacturing equipment in general lasts shorter, and is more idle because of breakdowns, in less industrialized countries than in the more industrialized countries. And the countries with a lower degree of industrialization can actually less afford it because their financial situation and their foreign exchange resources in most cases are extremely strained.

In the industrialized countries it is difficult to envisage that maintenance should be dealt with at any other level than the enterprise level. Management of all categories realize that proper utilization of installed capacity is of utmost importance to the productivity of the enterprise.

*With comparatively limited domestic manufacturing resources, the national economies of dveloping countries must ensure maximum utilisation of all installed manufacturing capacity*

The environment creating this attitude and understanding does not yet exist in most developing countries. It may, therefore, be necessary and justified to accelerate an evolution in the right direction.

It should, therefore, be amongst the objectives of any National industrial policy in a developing country to urge manufacturers to keep plant, machinery and equipment in good working order.

As with other Is, policies and subsidies created to promote rapid industrialization and efficient operations, it should be revised at regular intervals in the light of changing environment. Any subsidy or I that becomes of a permanent nature may upset or delay a healthy industrial development process.

The encouragement of good M for keeping plant breakdown to a minimum should not be limited to efforts for the introduction and upkeep of an efficient M system within enterprises. The productivity and in particular the costs of operating a M system is to a large extent affected when the plant is built and the machinery and equipment is selected. A National policy for I on M should not forget this factor. Many M problems in the developing countries have been seriously magnified because machinery and equipment has been installed which was neither suited for the prevailing climatic condtions, nor suited for the quality of local operators repairmen and supervision, nor suited to the repair facilities available locally, nor supported by local stores of parts and components, and did not match already existing machinery and equipment and so on. A National I scheme for M must consider these serious problems and encourage a comprehensive approach. And the comprehensive approach should not be limited to the enterprise function such as procurement, production, M and financial control but also include the many governmental departments and organizations dealing with industrial development, import control, technical assistance, finance and investment, technical education, etc.

*The national industrial policy in a developing country should urge manufacturers to keep plant, machinery and equipment in good working order*

## Enforcement of National Interest in M

In most developing countries it is necessary to obtain permission from one or more Government departments or organizations when a party wants to:

(a) Establish a manufacturing enterprise
(b) Procure machinery and equipment from abroad.

This fact provides the concerned National authorities with an unique opportunity to see to it that enterprises are established and/or expanded according to sound economic principles and fixed industrial development policies.

It may need some discussion to reach agreement on what sound economic principles are and how the policies on industrial development should be. However, this paper is limited to the area of industrial M. What would we, as responsible politicians and civil servants, do in order to promote better M? The subject seems to fall in two parts:

1. How can we promote better M in new enterprises?
2. How can we promote better M in existing enterprises?

Design engineers, procurement officers and industrial engineers can provide a lot of criteria that have to be met when we want to operate machinery and equipment within certain levels of availability and reliability. A number of papers deal specifically with these subjects.

The paper on Maintainability, e.g., lists the following major factors that affect availability and reliability:

Design characteristics
Operational characteristics
M manpower qualifications
M organization
Repair shop facilities
Spare parts logistics
Inspection and test equipment
Tools and methods
Manuals and handbooks

The desired level can be expressed in terms of one or more criteria like:

Operability of machinery and equipment
Time for M
Cost of M
Risk of injury to personnel
Time required for training

What can politicians and civil servants then do about M when they institute policies on establishment of enterprises and when they screen schemes submitted? The answer is easy—at least in principle:

(a) Policies must be based on sound technological and financial principles.
(b) Schemes must be evaluated in the light of established policies and criteria.

In real life, however, it is extremely intricate because it is difficult to spell out and agree on policies and criteria that are detailed enough to be of practical use and it is difficult to recruit local manpower that has the qualifications and the integrity to exercise the evaluation. And what kind of I can be introduced to encourage everybody concerned to follow established policies and to meet M criteria? Who should participate? How should the I be calculated? What should the base be? Is it realistic to think of an I scheme for M for politicians and/or administrators? In most cases the answer is No. This does not imply that one should not try to educate and upgrade everybody concerned with M. The aim should be to promote broad and balanced looks and consideration of overall efficiency rather than that of a single element, e.g., purchase price or power consumption.

Much can be said about the problems that confront officials concerned with industrialization in a developing country. Funds for investment are in short supply. What kind of industry should receive priority? Procurement may have to be made from countries or suppliers who offer grants or loan on easy terms. Will the machinery and equipment suit local conditions? What will it cost to operate the factory? What will the cost of the product(s) be? Who can distinguish the interests of the supplier from the ambitions and needs of the buyer? And who thinks of M?

It is recognized by well established suppliers of industrial machinery and equipment that their continued success depends on the satisfaction of those who use their products. Developing countries could most probably make extensive advantage of this fact. It should be possible to introduce a rating system that would evaluate the performance of machinery and equipment and collect the data centrally. If the rating is below a certain level, it should have an impact on import licences. Several suppliers and importers may object to this and, with some rights, claim that the operability of machinery and equipment depends on a wide variety of factors including several on which they have little or no influence, e.g., poor operators, poor materials, fluctuations in electric power supply, unauthorized laubricants or spare parts. Many of these factors can be compensated through instruction and training as well as after-sales service and follow-up. Suppliers and importers that can provide this, or assist National efforts (e.g. technical schools), should receive preferential treatment. A reasonable choice of spare parts should be placed in consumer stores so they are readily available. Optimum standardization should be aimed at in order to keep stores within reasonable limits. The major problem with an I scheme of this kind lies with its administration and the reliability of the data on which to base it.

**Conclusions**

I systems are an integral part of remuneration systems and designed in order to stimulate participants to extra efforts through an award that is related to the performance.

I systems, and in particular wage I systems, are well described in the literature related to industrial management and industrial engineering. They can be applied to all kinds of manufacturing and service activities. In principle there is not much difference between their application at the plant level in developed and underdeveloped countries. The main difference comes from the environments and the educational level of the individuals involved, in particular their ability to receive, interpret and dispatch exact information and data in writing.

*Incentive systems aim at stimulating participants to extra effort*

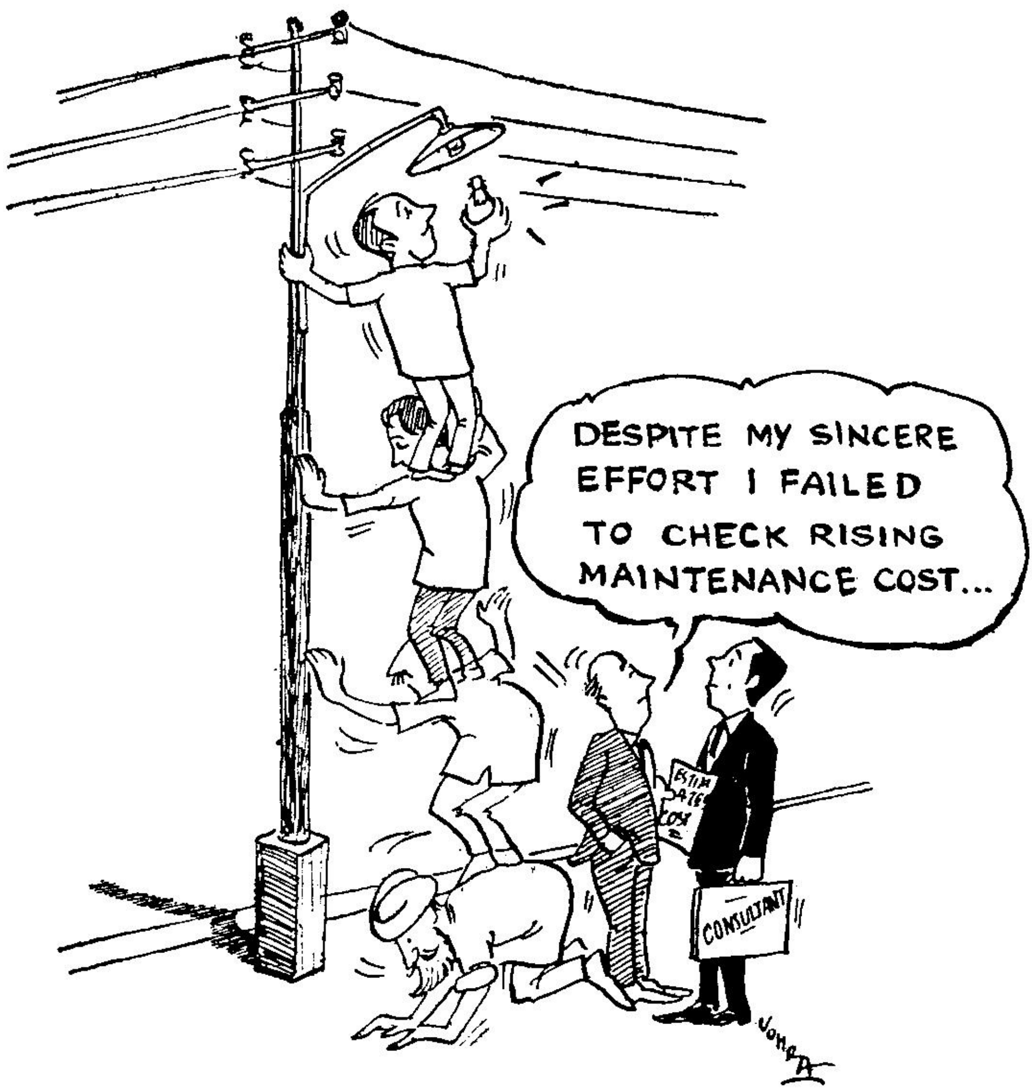
In environments where there is no or little tradition for I systems, e.g., in repetitive production work it is difficult to introduce I schemes for M. If introduced, they must be simple and easily understood. The best results may be achieved through I schemes covering first-line supervisors.

It is tempting to think of I for M at the country level, but it is difficult to establish standards on which to base an I plan, in particular for Government officials. As most M problems can be anticipated at the procurement stage, efforts should aim at a careful technological and financial examination of the criteria used for selecting machinery and equipment.

Importers and suppliers play an important role in this process and in backstopping M activities. The efficiency in these respects can be evaluated and hence stimulated through increasing licences to those who are most successful.

Industrial associations can arrange special M campaigns at regular or irregular intervals. Enterprises may compete on the basis of who can reduce M costs the most, or who has the least breakdown time in relation to productive time etc., etc. Awards can be financial or just honourable.

I is normally one of the last, if not the least, management tool used to increase productivity. Much can and should be achieved through improving the organizational structure and by simplifying methods and procedures. The establishment of sound policies and the design of useful I for M in developing countries require a lot of imagination and hard work. ●●●


DESPITE MY SINCERE EFFORT I FAILED TO CHECK RISING MAINTENANCE COST...
CONSULTANT

# Preventive Maintenance*

**It is now recognised that unplanned maintenance or what is generally termed "fire-fighting technique" should be completely avoided. Planned and preventive maintenance is a system which results in lower production costs, safeguarding equipment and increase in both quality and quantity of production. Any such system has, however, to be carefully planned, skillfully introduced and given time to show the expected results.**

PRODUCTION equipment is procured in order to obtain a pre-determined volume of production, of specific quantity and quality. In order to obtain this objective, such equipment must be fully supported in the field particularly in connection with the maintenance activity.

Maintenance is already an expensive item, especially considering the complicated and sophisticated equipment of today. On the average, and under good conditions, the cost of maintenance of equipment during its lifetime is equal to or exceeds its purchase price. With some equipment this cost may reach two to three times the purchase price.

Such expense is justified only if it helps in attaining the main objectives of maintenance, i.e. increased productivity of equipment and decreased downtime and overall cost of production, and safeguarding the equipment itself. This can only be achieved if maintenance is planned carefully and rationally. Under haphazard maintenance, not only the cost of maintenance will increase with resulting increase in total production cost, but the main objectives of maintenance will not be reached in spite of the cost increase. The lifetime of equipment will be shortened, downtime will increase and production will be reduced both in quantity and quality.

It is generally agreed today that unplanned maintenance, or what is generally termed "fire-fighting technique" should be completely avoided. The main theme of discussions in maintenance circles today is how the planning of maintenance should be carried out.

### Definitions and Objectives

Within the sphere of planned maintenance many definitions are heard, such as planned maintenance, scheduled maintenance, corrective maintenance, productive maintenance, preventive maintenance and maintenance prevention. These terms are understood and conceived very differently even among the maintenance experts. This is particularly true in the case of preventive maintenance.

Definitions are made to outline a particular activity so that it becomes clear what the activity entails and how to go about it. What is important is not the understanding of the definitions themselves, but an understanding of the different phases and aspects of maintenance activities, the aim of each phase and how these aims are attained. It would be thus appropriate to explain and clarify just the different

*Contributed by UNIDO Secretariat

maintenance activities, hoping that this will lead to a rationalization of definitions.

**Planned Maintenance**

The term planned maintenance does not describe a particular type of maintenance, but it implies that maintenance is planned in advance as against haphazard or unplanned maintenance. It is agreed today that all maintenance should be planned and this implies that all maintenance activities should come under planned maintenance. Breakdowns will always occur unexpectedly and handling of such breakdowns is called emergency maintenance. Such emergency operations should be planned, to a large extent, in advance. The reporting of breakdowns, the rapid diagnosis of the failure, the speedy allocation of task to a specialized repair gang of the support of this repair gang, particularly concerning the speedy spare part delivery and availability of repair tools and equipment, the speedy attendance to the failure; all should be organized and planned to the greatest possible extent. Although the stoppage of equipment due to the failure is not planned, what we mean here by planning is that when the failure occurs, everyone concerned would know what to do: where spare parts and repair tools are to be obtained, how to diagnose the failure quickly, and how the repair expert are transported with the necessary equipment to the location of the failure. This is the opposite to haphazard handling of emergency failures where everyone is running all over the place without achieving a great deal. No one knows who does what or where the repair equipment or parts are. However, such maintenance could be classified as **emergency repair** and it is understood that it cannot be completely planned.

Apart from emergency maintenance, all other maintenance activities come under the following headings or phases or aspects:

(a) *Maintenance Prevention:* This first aspect or phase covers all measures to be taken in order to avoid maintenance completely. This takes place in two distinct steps. The first is when the equipment is being designed and ordered, by paying attention to the maintainability of equipment, thus reducing the maintenance effort required during the lifetime of the equipment. This aspect or phase is called **Maintenance Prevention**. The second step is sometimes called **Corrective Maintenance** and it usually takes place when the equipment is actually in operation: by studying failures and changing design, materials or working conditions to avoid the repetition of these failures. It does not entail any operation where the repair or replacement of a part brings it back only to the original condition without the above-mentioned changes. It is interesting to notice that training of maintenance personnel and machine operators could be considered as part of corrective maintenance.

(b) *Routine Maintenance:* This entails all operations which are necessary to keep the production equipment going efficiently. It includes lubrication, periodic inspection, adjustment, cleaning, periodic overhaul, repair, replacement, etc. All these operations are carried out either while equipment is running or during pre-planned shutdowns. All such operations can be included in one maintenance plan with timing of operation and the personnel to which each operation is assigned. This phase of maintenance forms the bulk of continuous maintenance activity during the lifetime of the equipment.

(c) *Preventive Maintenance:* Although operations coming under this title could as well form a part of routine maintenance, they entail a philosophy and conception which differentiate them from other routine maintenance operations. The idea behind preventive maintenance is based on the fact that it is difficult to determine accurately the lifetime of an equipment or when it will break down. When the breakdown of an equipment or part of an equipment has grave consequences, a safety measure is introduced. In an American publication, preventive maintenance is defined as the maintenance undertaken before the need develops to minimize the possibility of an unanticipated production interruption and breakdown and this is the nearest to the conception of Preventive Maintenance, in this paper. The equipment or part of the equipment in question is changed before the end of its lifetime is reached. This, in fact, entails the sacrifice of part of the lifetime of the equipment for safety; the magnitude of the part sacrificed depends on the consequences of the failure if it occurs prematurely. There should be, of course, a balance between the cost to the enterprise of the part of the life of the equipment sacrificed and the cost of the possible damage which would occur if this part fails unexpectedly in service. A typical example is the aeroplane. Changing the blades of a turbine or a bearing of a compressor before the expected end of their life may cost a few hundred dollars. This is insignificant compared to the money-loss incurred and the loss of life if the engine fails in the air. Another example is that in a continuous process plant where a small pump, for example, is needed in the operation of the whole plant. The failure of such a pump will stop the whole plant with possible damage to other bigger and more expensive parts of the plant and to the product itself. In this case the cost of changing the whole pump periodically before the end of its lifetime would be very small compared with the cost of possible damage if it fails. It is generally accepted that preventive maintenance should be considered when corrective maintenance cannot be justified, predictive maintenance cannot be applied and as required maintenance, i.e., maintenance after failure occurs, cannot be tolerated.

This distinction between preventive maintenance and routine maintenance, although both contain a series of planned operations carried out according to a pre-planned schedule, is necessary because of the following: All routine operations are carried out on all equipment and there is no scope for determining and deciding whether the operation is economically necessary or not. All equipment requires lubrication, periodic overhaul and there is no question of suppressing such operations on economic bases. Without them equipment will not go on producing and maintenance operations become costly and unorganized, and the life of the equipment will be shortened. On the other hand, preventive maintenance operations become necessary only as a safety measure against possible risk. With preventive maintenance each case should be studied and a decision made on whether to carry out the preventive maintenance operation or not and the part of the lifetime of the equipment or part of the equipment to be sacrificed according to economic and safety considerations. This insinuates that preventive maintenance, as outlined here, may be a waste if adopted. In other words if the lifetime of equipment parts and the exact time when failure is expected is accurately known, then there will be no need for preventive maintenance outlined in this paper, while routine maintenance will still be required.

(d) *Predictive Maintenance:* Maintenance prevention, routine maintenance and preventive maintenance need fact-finding activities to help in their planning. It is necessary and useful to know what is happening to different parts of equipment under actual working conditions. This will help in obtaining a better estimation of the lifetime of the different parts of the equipment for the preventive maintenance, or in a better assessment of the frequency of routine maintenance or to know beforehand if an unexpected deterioration is taking place in certain parts. Many techniques are being developed for this purpose, such as noise and vibration measurement. This phase of maintenance is composed of auxiliary operations which help in better planning of the other phases.

The distinction between the different phases of maintenance is useful since it draws attention to different approaches leading to different aims. However, all are necessary for a successful maintenance operation.

Unfortunately in many serious text books and technical articles on maintenance, preventive maintenance is defined in different ways. For example, in one technical book, preventive maintenance is defined thus: "Its purpose is to minimize breakdowns and excessive depreciation resulting from neglect." This is the main aim of maintenance activity as a whole. In another publication preventive maintenance is defined as the "Planned maintenance of plant and equipment, resulting from periodic inspections that disclose faulty conditions". This definition also is not complete since there are many routine maintenance and preventive maintenance operations which are based on past-equipment history. Again it does not include the safety measure stipulated in this paper. Another definition for preventive maintenance is that it is the maintenance of production means in the non-failed state with the objective to prevent or reduce failure. This involves routine maintenance, routine adjustment and non-destructive or non-stoppage testing. This definition is also too drastic and entails operations of maintenance prevention and predictive maintenance.

**Planning and Installation**

Whether preventive maintenance is conceived in the narrow sense stipulated in this paper or in the very broad sense of being a synonym to planned maintenance, the steps to be taken for and the requirement of the installation of a preventive maintenance programme are the same. These will be explained briefly in the following:

The first requirement for the success of a preventive maintenance programme is that equipment must be in a good condition to start with. It is extremely difficult to install a successful programme if the equipment, due to neglect and lack of planned maintenance in the past, has reached such a state that breakdown or emergency maintenance has become the prevailing activity. As a rule of thumb if the enterprise is spending between 50% to 70% or more of its maintenance effort on breakdowns, then it will be extremely difficult to install a preventive maintenance programme. Under such conditions, such a programme will be extremely difficult to implement and will become very costly without giving the enterprise the anticipated advantages.

*It is extremely difficult to install a successful preventive maintenance programme; if the equipment, due to neglect and lack of planned maintenance in the past has reached a state that breakdown or emergency maintenance has become prevailing activity.*

The first step would thus be to start with a programme of overhauling and putting in good condition all equipment. This is, of course, quite costly, but this is the price the enterprise has to pay for past neglect and lack of organized maintenance. However, if such a step is not carried out because of the expense involved, the conditions will continue to worsen and an almost complete plant shutdown will be the price to be paid for such a policy.

The second point is that a successful planned maintenance or preventive maintenance programme cannot be implemented overnight. This will require from several months to several years according to the type of plant, available past maintenance records, type of maintenance carried out before, etc. Usually a rough programme is determined first according to the suggestions explained below. Then such a programme is modified and re-planned continuously on the basis of records and figures fed back to it from the factory until it reaches a stage where it becomes suitable to the conditions prevailing in the factory.

The third point to be noted is that any degree of sophistication can be built into a preventive maintenance plan. Establishing a PM programme should not become an end in itself, but it should be always looked at as a means of attaining certain desired objectives for the enterprise as a whole. Over-planning and over-sophistication should be avoided especially at the early stages of installing the programme. Such a programme should be designed to suit conditions of the enterprise and should not be just an imitation of a programme installed somewhere else. It is generally recommended to start with a simple programme which would gradually be built up to a complete one. Consensus is that it is also too big a bite to start the work by applying a PM programme to the entire plant at once. It is better to start with certain machines or a department and then extend it gradually. The advantage of building up the programme gradually and start with one department is to give a chance for the training of personnel and for all concerned to absorb and get acquainted with the procedures to be followed. In many instances it was found that the main reason for the failure of a PM programme is that the personnel concerned were not given a fair chance to understand and get acquainted with the programme. Building up the team of personnel who will carry out the programme is a most important step and should be given the necessary effort and consideration.

The initial step in establishing a first and rough preventive maintenance programme is to establish an equipment identification system. Such information as machine make, place and date of purchase would be recorded on a card or a file or similar system. Each machine should also be given a code number. Such identification system is essential for the PM programme and also for the inventory system.

The next step is to establish for each machine a history card, with records of all breakdowns and length of time required for repair. Such a record is essential for organizing the details of the works required in the programme. It is also advisable to include in the history card the cost of all maintenance and repair operations carried out on this machine during a certain period. This should include labour, material and spare part costs separately. It is very important, particularly at the early stages of introducing a PM programme, to follow up progress. A base should thus be established to measure progress, and equipment history cards are an essential element for such a base. Usually in an enterprise, there is some information available on past repairs and breakdowns of equipment, but this is usually scattered in a way that is of very little value. It is essential to collect such available information in an understandable form such as equipment history cards, etc.

The third step is to organize all technical information, such as manuals, pamphlets, etc. on equipment in a form which makes them easily accessible. Such technical documents are usually laid in different places so that it becomes difficult for personnel concerned to get hold of them when they are needed. An equipment service library could be established and documents arranged and classified with the help of the machinery code number.

Next, an inventory of all maintenance and repair operations required for all machinery is compiled. Equipment manufacturers' technical documents and recommendations, equipment history cards and information obtained from other enterprises using the same type of equipment should form the basis of such inventory.

A work programme is then established with timing of every operation and the personnel required to carry it out. The programme should be constructed to have a more or less even work load in the maintenance departments. From the work programme the maintenance personnel force should be estimated and steps taken to employ and train them in advance. The necessary equipment should also be procured. Competent personnel and adequate equipment is a necessity for the success of the programme.

It should be remembered that a PM programme does not entail only maintenance operations, but also stoppage of production equipment for maintenance. Thus such a programme should be established with the full co-operation and understanding of the production department. This will also create a precedent of co-operation between the production and maintenance departments which is essential for a successful maintenance.

**Introducing the Prcgramme**

Once the programme is planned, great care must be paid to how it is introduced. The programme must be sold to all concerned. A series of meetings should be arranged with both production and maintenance personnel, and the programme, its procedures and aims should be fully discussed. It is only natural that the introduction of such a new activity in the enterprise will be watched carefully by all concerned, especially the top management. They will be anxious to watch whether the programme is really worthwhile and if it is giving the expected results. No preventive maintenance programme will give immediate results, but it will take some time before a tangible outcome is obtained. The programme of introducing the system should be realistic and factual, otherwise, the result will be only frustration. It would be a damaging blow to the programme if enthusiasm and sympathy were lost by both top management and personnel because of unjustified expectation and frustration. As a matter of fact, since preventive maintenance does not show results in reducing repair load maintenance cost except after some time, the programme will pass through a phase where there is no reduction in maintenance work while the cost of personnel and equipment carrying out the programme will be added to the normal running maintenance cost of the enterprise. This temporary increase in maintenance cost is natural and must be expected. This should be explained fully to management. Starting the programme gradually, department by department will help enormously in passing through this critical phase comfortably.

Any new PM programme needs modifications and alterations until it reaches a standard suitable for the enterprise. An efficient follow up system is necessary in order to be aware of the necessary modifications and to make sure that the programme is progressing along the right lines. The responsibility of this follow-up system should be clearly defined and should not be delegated to certain personnel who already have other responsibilities and are engaged in other activities. It is usual that when urgent work crops up within their other areas of responsibility, such personnel will forget completely about the programme and the follow-up system and concentrate on handling this urgent work.

A monthly report should be prepared showing the number of operations scheduled, number of services completed and behind schedule, and also failures which have stopped occuring after introducing this programme.

**Conclusion**

Planned and preventive maintenance is a system which certainly results in lowering production costs, safeguard equipment and increasing both the quality and quantity of production. This is the view of almost everybody who has introduced such a system in a plant.

However, planned and preventive maintenance programmes should be carefully planned, skillfully introduced and should be given time to show the expected results. ●●●

# Preventive Maintenance : Planning and Organization

Wolfgang Mannel*

**The least degree of preventive repair planning is involved in planning based on occasional inspection. Long-term preventive repair planning is involved when it is decided to repair a machine when a certain degree of wear is noticeable. The planning and organisation of preventive maintenance raises many problems of economy for which numerous models that aid decision-making can be effectively made use of.**

THE term "preventive maintenance" comprises particular measures which in theory and in practice serve the maintenance of installations at regular intervals, i.e., measures which are taken in order to prevent breakdown and damage. Preventive maintenance measures may be classified as:

i. Direct measures of preventive maintenance

ii. Indirect measures of preventive maintenance.

Direct measures of preventive maintenance are those included in maintenance and servicing, intended to reduce wear on the one hand and measures intended to prevent wear on the other (preventive repair work).

Wear reduction measures are intended to reduce or at least slow down wear in equipment (i.e., the reduction of changes in the widest sense—arising from routine operation or a harmful environment—in the material and technical structure of equipment). They either serve to improve the resistance of the equipment concerned or reduce the strain on it.

It is a feature of preventive repair work that when wear appears it is dealt with in good time so that the equipment does not break down or damage does not occur. Technically, this may be achieved not only by preventive repair work on the worn component, but also by its preventive exchange, which contributes to attaining the original production capacity. Another feature of preventive repair work is that it may be subdivided into measures taken prior to breakdown, and those measures which—although taken after breakdown—are yet taken in good time before any damage arises. This kind of repair "in good time" is of practical importance only for equipment which is damaged during stand-still time, and such equipment which may be replaced immediately by other equipment in case of breakdown.

Indirect measures of preventive maintenance include preventive inspections, performance tests, and the setting up of statistics on service life. Altogether, they supply the data required for the planning of direct preventive maintenance operations.

All these measures have one thing in common, namely, the ultimate aim of preventing or reducing breakdown of equipment and the damage involved. There is a fundamental difference between these measures and the repair and inspection work undertaken only

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when an enterprise has already suffered loss caused by the breakdown of a machine, a piece of apparatus or any other equipment. These measures do not fall under preventive maintenance.

If the advantages of preventive maintenance have so far been neglected in spite of the rapidly advancing mechanization and automatization of the means of production and the ever-increasing integration of equipment into the production process, this is mainly attributable to the fact that the economic benefits of preventive maintenance have been underestimated.

It is therefore of particular importance to emphasize once more the numerous economic advantages of preventive maintenance of machines and other equipment, including the progress made in the field of rationalization which derives from preventive repair work.

**Main Advantages of Preventive Repair**

1. Prevention of accidents and destruction of or damage to materials and equipment.

2. Avoidance of immediate losses caused by unforeseen interruptions in production, e.g.,

   losses incurred by non-delivery of goods urgently required for marketing or other purposes (additional costs);

   losses resulting from failure to meet the stipulated delivery date, e.g., decrease in profits due to delayed delivery, payment of compensation, penalty for non-performance; decrease in earnings, if the customer places no further orders;

   costs for standby machine operators who usually cannot immediately be given other work;

   additional costs resulting from the prolonged operating procedure;

   losses due to additional negative effects on other equipment and other departments of the enterprise.

3. Increase of the periodical capacity by the reduction of periods out of service due to damage. The advantages are:

   repair work can be prepared more efficiently;

   time is no longer wasted in detecting defects;

   possibly, repair work can be started while the machine is still operating;

   execution of repair work during breaks, on Sundays and holidays, during works holidays, and out-of-season periods;

   concentration of different repair jobs.

   In this way sales and profits are increased, viz., the costs of outside financing or capital expenditure for increasing the capacity are reduced.

4. Prevention of economic losses resulting from:

   machinery breakdown costs due to rejection;

   repair of faulty products;

   decrease in profits due to poor quality of the end product.

5. Reduction of actual repair costs:

   by combining several repair jobs (e.g., costs of preparatory measures are saved) and

   by better coordination of supplies (e.g., reduction of stocks in the spare part depot).

6. Other advantages:

   elimination of disadvantages resulting from a decrease in machinery performance;

a smaller number of spare parts is required;

the intermediate stores (emergency supplies) can be reduced in size.

Measures intended to prevent wear have similar advantages. By intensifying the measures intended to prevent wear, not only frequency of damage, but the actual repair costs can be reduced because intervals between repairs can be extended.

**Introduction of Preventive Maintenance**

Firms wishing to introduce preventive maintenance should have an idea of the type and extent of damage resulting from the breakdown of various types of machinery. They should therefore compile statistics of damage and disturbances. These should be subdivided according to the type of installation and parts, and according to department, because a decision for or against preventive maintenance cannot be taken for the entire machine park.

Apart from the statistical analysis, however, possible consequences of machine failure should also be analysed theoretically. On this basis a type of priority list can be prepared which shows in what order the various machines require preventive maintenance.

Before introducing preventive maintenance the types of breakdown should also be analysed to discover which occur most frequently in the various machines or machine elements, because not all failures can be anticipated by preventive maintenance. Some breakdowns are due to age or accident, others occur quite early in the service life of a machine. Preventive repairs can forestall only breakdowns caused by normal, gradually advancing wear and at best some of the breakdowns caused by accident.

In practice, the type of damage will often suggest the reason for the machine failure. Therefore the damage statistics should, if possible, also state the technical "diagnosis" of the damage. The statistics often clearly reflect to what extent the three types of breakdown are relevant. Such statistics can also be used for planning the repair schedule.

**Preventive Repair Procedure**

Repair work after breakdown and preventive maintenance differ insofar as the latter is carried out at regular intervals. The repair schedule is based mainly on :

i. type, frequency and date of the preventive repairs;

ii. type, frequency and date of preventive inspections, and

iii. type and extent of wear reduction measures.

In this connection the planning of the inspection schedule is of particular importance, especially with regard to preventive repairs. Both in theory and practice different procedures have been developed for planning such measures, i.e., schedules which indicate on what date and for what reason a particular measure has to be taken. We want to discuss here the procedure applied in case of sudden breakdown of a machine or machine part, i.e., the sort of machine that, after remaining fully operational (despite constant wear), suddenly breaks down completely once a critical stage of wear is reached. Such equipment can be preventively repaired especially when it is of the type which breaks down because of wear.

The least degree of preventive repair planning is involved in planning based on occasional inspections. Long-term preventive repair planning is involved when it is decided to preventively repair a machine once a certain degree of wear is noticeable. When this procedure is applied inspections are also required. As such control measures are in some cases difficult to carry out, and often very expensive, the repair work is scheduled without direct examination of the machinery.

In these cases planning can be based only on the expected service life. Such information can be gained by keeping a record of expected service life for each machine, making spot checks on the wear characteristics of test equipment, evaluating the experience of other firms, or by obtaining information from the manufacturer of the equipment concerned. If such data are available and are representative of what can be expected in future, it is advisable to carry out preventive repairs on a machine once it has reached a certain age. According to the factors determining machine wear, the service life is measured in different ways, e.g., output, number of hours, weeks, months, etc., the equipment has been in operation. When establishing criteria for repair cycles, the average life of the various machines should by no means be taken as a basis, because the service life differs considerably even if breakdowns occur early in service life and accidental breakdowns are both infrequent. On the other hand it is in no way always advisable to carry out the preventive repair before the earliest possible date of breakdown. A certain risk of breakdown must be taken. To what extent the service life can determine the repair cycle must be analyzed by means of a profitability calculation. If the intervals between the repairs are shorter, more repairs have to be carried out, but machine breakdown and resulting damage are less frequent.

Similar considerations apply when deciding to introduce a strictly periodical repair cycle. In this case repairs are carried out at fixed intervals, not according to the amount of time elapsed since the last repair. A problem arises when a machine breaks down between these fixed intervals. In such a case it is difficult to realign repair periods with the long-term repair schedule, unless the equipment concerned is repaired again at the appointed time.

It will often be economical to coordinate repair jobs on similar machinery. By means of such economical repair procedure considerable time and costs can be saved, especially if vital production equipment is concerned which can be repaired only when out of service. This is especially important in enterprises working to full capacity because the reduction of periods out of service due to repairs will make it possible to increase the production and sales volume.

**Inspection Procedures**

This section deals with installations and installation elements that break down suddenly. Inspection procedures for this sort of plant and equipment are determined by the aims that are being pursued. If preventive inspections concentrate only on normal, gradually increasing wear, a sequential inspection procedure is to be recommended. The main feature of this sort of procedure is that the length of time allowed to elapse between inspections is dependent on the findings of the previous inspection. Sequential planning is therefore involved.

If inspection is to reveal in good time unusual wear relative to the age of the installation, it is advisable to carry out inspections at regular intervals. The handbooks recommend such regular inspections as a measure for the discovery of failure in equipment that should always be ready for use and where failure is not immediately noticeable, e.g., alarm systems, fire extinguishers, lightning conductors, military equpiment, etc. Regular inspection is recommended only if accidental circumstances occurring while the equipment is not in use can cause failure.

There is a choice of wear reduction procedures. Wear causes changes in the material and technical characteristics of plant and equipment and reduces its usefulness; in principle, these changes can be reduced in different ways or even be completely eliminated.

**Important Wear Reduction Measures**

1. *Improving wear resistance:* Measures should be taken at the design and production stages, by:

   the use of materials, or combinations of materials, that are especially wear-resistant;

   use of protective layers;

   creation of favourable shape of surface;

   selection of materials having complementary properties wherever friction occurs between materials;

careful repairs;

thorough quality control at the end of the production process or repair process.

2. *Wear reduction:* Reduction of normal wear through:

preventive measures against harmful environmental conditions (e.g., elimination of harmful waste gases, dust, etc.);

guarding against harmful environmental effects with coats of paint, coverings, protective layers, sheeting, and other anti-corrosion measures;

choosing a location where conditions are favourable from the start.

Wear occurring during periods out of service could be reduced by:

taking care of plant and equipment, e.g., greasing, covering, etc.;

storage in special storage space under particularly favourable conditions.

Reduction of "chemical wear" whilst equipment is in use, by:

improving the characteristics of the material to be processed and/or stored, e.g. pre-cooling or pre-heating, advance removal of harmful substances, advance addition of wear-reducing substances;

creation of favourable production conditions and storage conditions, e.g., favourable temperatures;

lining production containers and storage containers.

Reduction of "mechanical" wear whilst equipment is in use, by:

taking measures against dust and other forms of air pollution;

taking measures to prevent any foreign bodies—dust, emery dust, swarf, etc.—from entering between two sliding surfaces, e.g., by sealing bearings, filtering air intakes of combustion engines and compressed air tools, fuel filtering, frequent cleaning, etc.;

use of lubricants suitable for the degree of movement and material properties of the moving parts;

frequent lubricant changes;

establishing a favourable production rate;

avoiding frequent changes of speed and load;

drawing up of operating instructions, bringing them to the operators' attention, and controlling regularly whether they are adhered to;

careful selection and training of operators;

awarding bonuses to careful machine operators;

taking constructive measures to make it impossible to overload plant and equipment (taking precautions against overloading, e.g., the fitting of slipper clutches, lead seals on machines, etc.).

In practice several of the measures listed above can be applied at the same time. Indeed many of them can be applied, but some less actively than others. Those responsible for keeping plant and equipment in order should not strive to attain technical optimum values. It is not worthwhile to apply the whole range of wear reduction measures, because they usually entail certain costs which must be compared with the economic advantages expected from wear reduction. These advantages are primarily that repair and replacement cycles are shortened, whereby the costs of repair and replacement can be reduced. In the case of equipment which, even in a state of advanced wear, remains fully operative until it suddenly breaksdown, this planning must aim at minimizing the sum of additional wear reduction costs and replacement and repair costs. As long as the service life of the plant in question is unknown all efforts should be made to keep average total costs per unit of time down to a minimum.

**Conclusion**

The planning and organization of preventive maintenance raises many problems of economy. These become more complex, when more thought is given to economic requirements in planning different preventive maintenance measures for simultaneous application. Numerous models that aid decision-making have been developed in Anglo-American and German publications, however, permitting an approach to be made towards an optimal solution of a large proportion of these problems, if the necessary information can be obtained.

In this short paper I have tried to show not only the importance and advantages of preventive maintenance, but also to give you an introduction to organization and planning. You can take up the idea of preventive maintenance and introduce it as far as possible within your spheres of influence. ●●●

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## LUBRICATION: ESSENTIAL PRE-REQUISITE FOR PREVENTIVE MAINTENANCE

**Lubrication is an essential pre-requisite for any preventive maintenance plan. A direct result of a good lubrication programme is a gradual increase in production. Properly selected and correctly applied modern lubricants provide adequate protection against friction for longer periods of time. As a result consumption and costs are lowered and equipment breakdowns are eventually reduced to the barest minimum. Elimination of unnecessary friction also reduces power costs. A wearing surface, improperly lubricated, will generate heat. This loss of energy may actually in some cases overload the prime mover. Bearings are precision devices and relatively expensive. The labour required to replace bearings is also expensive. A good lubrication programme can help increases bearing life and consequently reduce maintenance costs.**

—*Machine Building Industry*, Vol. 9, No. 5, p. 35

# Central Maintenance & Repair Shops

**Ing A Laberenz***

**The establishment of central repair workshop for the maintenance and repair of all types of machines and equipment is essential. Repair shops which are well laid out, equipped with efficient machinery and skilled workers contribute significantly to a country's progress towards industrialisation.**

UNLIKE industrial enterprises in typically industrial countries, industrial enterprises in developing countries find it difficult to maintain, service and repair their mechanical equipment and car fleets. Industrial enterprises in industrial countries have the advantage of being located in relative proximity to the manufacturers of their mechanical equipment. Furthermore, the problem of covering long distances is of minor importance once the road network is well developed. Moreover, postal and railway systems are so highly developed in industrial countries that it is possible to deliver spare parts and parts subject to wear within a very short period. Orders placed by telephone or teleprinter reach the producer within minutes, thus enabling a well-organized enterprise to despatch the ordered articles the same day.

Of course, a complete and well-kept stock of spare parts must be considered a first requirement. This, in turn, presupposes knowledge of the weak points of machinery or equipment. Naturally an entrepreneur will never carry stocks of those parts which are known to be indestructible, but he will be farsighted enough to provide for an adequate stock of those parts, which by experience are subject to extensive wear and tear or break easily if handled carelessly.

In buying machines and other mechanical equipment, the purchaser sees to it that the respective spare parts are delivered in sufficient quantity. These are mainly transmission belts, seals, etc. The spare parts are clearly listed in an illustrated catalogue, thus enabling the machine operator to quickly find the order number of the damaged part and place his order by telephone, teleprinter, or any other means of communication.

The consumer may also consult the well-organized customer service which is taken for granted now-a-days. Well-trained personnel, equipped with special customer service vehicles, with tools and spare parts, do not only help in case of need but also improve the reputation of their firm by providing a fast service.

Repair work may be put in hand at short notice and the amount of time machines stand idle reduced to a minimum when there are only short distances between producer and consumer, and it is possible to place orders in a relatively short period of time, when there is a well-developed road system and a smoothly functioning transport system, when the stores are well

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*Well-trained personnel, equipped with special customer service vehicles, with tools and spare parts, not only help in case of need but improve the reputation of the firm by providing a fast service—*

equipped with spare parts that are clearly listed in illustrated catalogues, and when the customer service is staffed by experienced personnel. Delays in delivery thus become negligible.

In developing countries the situation is completely different as distances between the manufacturer and the purchaser of the machines are very great. In the country itself there are no facilities for the production of machines, they must therefore be supplied from industrial countries. The first problem will be finding the cause of breakdown because of the lack of trained personnel. Written material such as operating instructions, data on mechanical equipment and spare part catalogues does not always appear in the language of the country concerned, so that interpreters must be consulted, which may easily lead to misunderstandings. The transmission of orders to the producer depends on the means of communication available.

Enquiries—which are quickly dealt with in industrialized countries—may take weeks in developing countries. Transportation by sea or air contributes considerably to the increased repair costs. Customer services which are readily available in industrialized countries are still lacking in the majority of developing countries.

All these problems call for a solution having the effect of making the consumer as far as possible independent of the manufacturer as far as spare parts and repairs are concerned. The way in which this could be achieved is explained below.

The problem is how to manufacture and repair the machine parts needed by small businesses when there is a lack of skilled workers and necessary equipment.

For this reason it is important that the enterprises in the developing countries be divided into the following groups:

i. Enterprises which are not confronted with the problem, i.e., those with their own skilled personnel and spare part depots or spare part production. These include power plants, large-scale industrial enterprises such as motor works, etc., broadcasting and television companies, mineral oil drilling plants, mines, etc.

ii. Enterprises which either hold limited stocks of spare parts or are able to obtain them, but which lack the technical personnel required. These include hospitals, food processing plants such as sugar factories, mills, bread and bakery products industries, slaughter houses, canneries, cigarette plants, and breweries.

iii. Enterprises which entirely lack technical personnel as well as the facilities for manufacturing and storing spare parts. These include transport organizations carrying passengers and freight on land and water, authorities with community-owned vehicles (street cleaning, refuse disposal), small textile processing enterprises, sawmills and woodworking enterprises, road construction firms with road building machinery, producers of building materials and associated machines, enterprises with limited power production facilities.

In this context enterprises mentioned under iii avove are of particular interest, i.e., enterprises which are short of technical personnel and spare parts.

Special problems have arisen in cases where the introduction of machinery is part of the development aid contributions made by various industrialized countries. So it may occur that an enterprise will possess many different machines, all of which differ considerably from one another as to servicing and maintenance requirements. Hydraulic machines need a specific type of oil recommended by the manufacturer because of their oil seals. In cases where these machines are supplied by different firms or countries the first difficulty consists in selecting the correct oil, not to mention the problem of spare parts.

If it is necessary to contact every manufacturer when a machine breaks down in order to obtain spare parts, an organization is required for purposes of coordination, and it can often happen that a machine has gone out of production and the spare parts required are no longer available.

In order to remedy this situation, a way must be found to repair machinery that has broken down and even produce the required spare parts.

One way would be the establishment of central workshops which, once equipped with skilled personnel and adequate machinery, would be able to provide help where needed.

The term "central repair shop" means an enterprise which is centrally located and can be reached from every place in about the same time. Centrally located does not mean that the exact centre is determined with dividers. The available network of waterways and roads determines the location of the central repair shop. In addition, the density of industrial enterprises and the proximity of an airport must be taken into consideration.

Another important factor is the availability of a mains electricity supply and a telephone network. Generating equipment belonging to the rapair shop can temporarily replace the mains electricity supply. For long-term solutions a mains electricity supply should be available.

Persons who visited and studied the developing countries confirmed that a skilled worker can find a job in every city. Thanks to his wage, he can afford a flat in the town, which he would hesitate to exchange for living quarters in an unsettled area. When selecting the location of the central repair shop attention must also be paid to the transport facilities to the next housing area or town.

The suply of water must obviously be taken into consideration. Water purification plants can be used in cases where there is merely a shortage of drinking water.

It will be difficult to immediately find the right location. On the one hand, all mentioned requirements should be fulfilled but on the other hand the customer, namely, the enterprises for which the rapair shops are intended, should be able to contact the repair shop quickly.

It would be wrong to begin immediately with the construction of sheds, workshop and living quarters without previous experience. At first the volume of work should be determined, taking into consideration the distances involved. The construction of dismountable living quarters is therefore recommended. The systematic construction of sheds, office buildings, and living quarters should not commence before a site has been finally decided upon.

The tasks of a central repair shop can be divided into three groups:

(a) repair of machinery and equipment belonging to enterprises not having skilled personnel, and the production of spare parts;

(b) training of apprentices, skilled workers, masters, training of unskilled workers, organization of training courses and demonstration of machinery;

(c) carrying out work as subcontractor; perhaps a consumer goods production line.

Due to the difficulties mentioned with regard to personnel and materials it is not possible for industrial enterprises in developing countries to maintain their own mechanical engineering shops. While the central repair shop can train its skilled personnel to be turners, welders, and milling machine workers, for example, these workers would not be employed to full capacity in small industrial enterprises. Therefore, the businessman has to rely upon the central repair shop.

The relationship between the businessman and the central repair shop can be seen as follows: A company's machines break down, and the staff are not sure what is wrong with it. They are uncertain whether the machine can be repaired on the spot by a skilled worker, and so the central repair shop is informed and asked for expert advice.

At this point the use of the mobile workshop is recommended, which has proved useful all over the world, and which is also known in developing countries. Mechanical troubles to motor vehicles, agricultural machinery, road construction machines and equipment can be quickly found and in most cases, be expertly repaired.

A mobile workshop is a workshop mounted on a normal or crawler-type vehicle, equipped with the required tools; the mobile repair shop must have easy access to the object to be repaired. The size of the mobile repair shop depends on the jobs to be done. For maintenance and lubricating jobs a station wagon suffices. If large-scale repairs have to be carried out, a large number of tools, machines and test instruments must be available. As the vehicle carrying the workshop does not only serve to transport the mentioned equipment, but should also provide working space, which will not be sufficient for a large number of craftsmen. For this reason craftsmen who have been trained in as many skills as possible should be employed. This also applies to the driver.

If the roads permit the use of a mobile workshop, it will be driven to the businessman who has reported a mechanical fault. The skilled worker decides whether he can effect the repair with the equipment he has at his disposal, i.e., turning, drilling, grinding, and welding apparatus.

*An important function of the Central Repair Workshops is to train skilled workers. A well-equipped central workshop can easily prepare 20 to 30 apprentices per year*

Straightforward repair work and the production of simple replacement parts can be carried out on the spot. Machines and equipment are occupied for short periods only and are soon available for other work. If, when a piece of machinery is dismantled, the shop proves inadequately equipped to deal with it because, for example, urgently required milling operations cannot be carried out, the damaged part is removed and taken back to the central repair shop to be repaired or remade. If the whole machine is found in need of a general overhaul, it must be sent to the central repair shop. For this purpose a fleet of transport vehicles belonging to the central repair shops must be available on request. An initial period of operation must elapse before it is possible to determine how many of these vehicles are required, and what their capacity should be. It is not possible to state exactly what size of vehicles are required, because this will be revealed only by experience.

The main function of the central repair shops is, therefore, the repair of machinery and equipment belonging to small businessmen, where this work cannot be undertaken by the mobile repair shops, the production of replacement parts such as gear wheels and all other parts requiring turning and milling operations which can be carried out with the mechanical equipment available.

The second important function of the central repair shops is to train skilled workers. A well-equipped central repair shop can easily prepare 20 to 30 apprentices per year for the skilled worker's examination. That means that with a 3½ to 4-year apprenticeship the shop will always have 80 to 120 apprentices in training. A well-equipped workshop is necessary for the first two years training of mechanics, precision mechanics and toolmakers, blacksmiths, motor mechanics, electricians, and perhaps also joiners. The number of apprentices is determined by the size of the shop, its mechanical equipment, and, not least, the number of skilled workers in a position to pass on their knowledge and skill to another person. The future technological development of a country is dependent on the quality of training given to apprentices, and it is essential that those who set the standards appreciate this fact.

Training shops specializing in the training of skilled workers are left out in this paper. What is being considered here are apprentice shops which have been established with the development aid of individual countries, but which are independent of central repair shops. The skilled workers produced by these apprentice shops could later develop into the new generation of technicians and engineers.

Advanced training courses for skilled workers leading to a master's certificate must be held in addition to apprentice training courses. Short training courses for unskilled workers must be held in conjunction with apprentice training courses in order to create a labour force capable of carrying out work that does not require a craftsman's skill. This will considerably reduce the cost of repair work.

The further training of workers for specialized work must also be considered. The training of workers in special skills such as autogenous and electric welders, shielded are welders, etc., is in the interest of the central repair shops, because this will later help small enterprises to have repair work carried out locally. This will then reduce the central repair shop's workload.

The planning of a central repair shop must be based on the expected volume of repair work. Personnel and mechanical equipment must be available in order to ensure that work may be smoothly carried out. If the inflow of work is not continuously in correct proportion to the size of the shop, a compromise is necessary, i.e., work of a different type is undertaken. Setting up a production line for the manufacture of consumer goods would be a paying proposition. Household utensils, for example, are products for which there would be sufficient domestic demand. They could be produced on the presses available, and this would fill the gaps between repair work. Care must be taken, however, not to allow repair work on vital machinery and equipment to suffer as is result of the consumer goods production line. Repair work and the production of replacement parts must always be given priority.

The location and activities of the central repair shop have now been dealt with, and it remains to describe what type of machinery, tools, and equipment are required. It may be stated that the essentials are as follows:

A sufficient number of machine tools of different sizes and working capacities, and of the most straightforward design and construction, possessing all the usual fittings, together with special attachments, and a complete set of tools.

Special machines which remain unused most of the time and, therefore, represent a bad investment, and also automatic and semi-automatic machines should be avoided and preference be given to manually-operated machinery. The work sent to the central repair shops is of the one-off variety, and any production line must make use of simple machinery.

This type of central repair shop may be equipped as follows

(a) *Machine Tools:* Lathes of various types, bench and column-type drilling machines, milling machines of various sizes, planing machines of various sizes, grinding machines of various types, e.g., tool grinding machines, cylindrical grinding machines, surface grinding machines, double wheel stand grinders, sawing machines.

(b) *welding shop:* electric and autogenous welding and cutting equipment, spot welding equipment.

(c) *smithy:* blacksmith's forge, anvil and swage blocks.

(d) *tinsmith's shop:* tin shears, universal machine, folding press, embossment and bending machine, flanging and wiring machine, hydraulic presses.

(e) *joinery:* planing machines, band saw, circular saw, carpenter's benches.

(f) *toolroom:* various hand-operated electric machine tools and complete tool sets.

(g) *apprentice workshop:* workbenches and vices.

(h) *classroom:* corresponding equipment.

Should the planned central repair shop be extended to include vehicle repairs, the following shops and equipment are needed:

(a) *engine repair shop:* equipment required for repair of valves, cylinders and pistons.

(b) *shop for the repair of electric units:* test stand for dynamo and starter.

(c) *battery-charging station:* battery-charging equipment.

(d) *chassis repair shop:* pits, lifting stages, lubricating bays, brake testers, tyre repair equipment, balancing machines.

(e) *car washing plant*

(f) *paint-spraying plant.*

The above-mentioned list of equipment does not claim to be complete. It is intented to show what equipment a good repair shop should have if it is to carry out a wide range of repair work and cannot exactly anticipate the tasks it will be confronted.

When planning the repair shop, it must be ensured that sufficient materials are available. The same applies to tools which are subject to wear. Special emphasis must be placed on the supply of technical gases.

Due to the large number of machines and equipment from various countries, tools of both the metric and the British systems must be available. This applies above all to drills, screw taps, reamers, and spanners.

Another important point should not be overlooked: Safety measures should be taken against fire, theft and accident; sanitary installations must be provided.

Office space must be provided for the technical management, administration and personnel office. This must be taken into consideration when planning such an enterprise. In addition, meeting rooms, recreation rooms and canteens are needed.

So far only the advantages of establishing central repair shops have been pointed out. There is no doubt that in most developing countries there is a real demand for such workshops. Discussions with persons working in various authorities, who have had the opportunity of studying the situation in developing countries, confirmed that much has been done in the field of training, especially the training of apprentices, but that there is no institution where repairs, training and perhaps the production of consumer goods are carried out under the same roof; the establishment of such an institution would be commendable.

Apart from the advantages, mention must be made of the difficulties which may arise. The list of these points does not claim to be complete. Certainly a number of other objections will be raised against the establishment of central repair shops, partly in those countries providing development aid. Nevertheless the fact remains that, due to further development of industry and small handicraft enterprises, the times of primitive production without machinery have come to an end.

Following points, however, must be taken into consideration.

(1) In many regions where businessmen are already operating relatively simple machinery, it was possible to find workers who were prepared to carry out repairs on this machinery. The repairs, which can be made in a central repair shop in a few hours, are carried out by these persons with primitive means in many days of laborious work. These persons lose their jobs when a central repair shop is established.

(2) There is the danger that in a modern enterprise, like a central repair shop, an unnecessarily large administrative organization develops out of all proportion to the size and profitability of the enterprise. As a consequence the costs for the jobs to be done would be too high. The customer will carefully consider whether the repairs would not be cheaper when carried out in the old traditional way with hammer and chisel, even if he has to wait longer.

(3) It has not been decided whether the central repair shop should be a governmental or private enterprise. Who should provide the funds and administer the enterprise? Are there funds available from development aid or does the government have to provide the money? Should such an enterprise be run privately? If so, how can prices be controlled:

When all the advantages and disadvantages have been taken into consideration, the establishment of central repair shops for the maintenance and repair of all types of machines and equipment cannot but be recommended. Repair shops which are well laid out, equipped with efficient machinery and skilled workers contribute to a country's progress towards industrialization.

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## Reason for Low Productivity

**"Many industrialists", says MASS PRODUCTION, "would rather spend £100,000 on new plant and equjpment than £1,000 on planning how to use it. . ."**


EXECUTIVE
THE BACK WALL HAS CRACKED. THE STAFF IS ON STRIKE
STRIKE
STRIKE
THE GENERATOR HAS BURNT, NO-BODY TO REPAIR
SOMETHING IS STINKING. I CAN'T WORK UNDER TENSION...
GREAT SPACE PROBLEM, SIR! IT IS BECOMING A MESS...
I CAN WEEP BEFORE TELLING THE POSITION...
VOHRA

# A Study on Renewal, Repair and Maintenance

**Vaclav Nesvera***

**Industrialisation brings in its wake many problems connected with replacement, repair and maintenance, especially so in material-scarce economies of developing countries. Renewal, repair and maintenance place specific demands on economic resources. Adequate maintenance forms part of the industrial infrastructure which is represented by maintenance and repair capacities of enterprises. The programme of modernisation and rational utilisation of older machinery acquire strategic importance as this is definitely less costly than renewal and it facilitates adapting of machinery to the optimum conditions of production.**

THE specific aim of this study is to provide planners in developing countries with a set of methodological instruments for assessing the nature and volume of needs for replacement, repair and maintenance and for identifying the material resources—labour, materials and machinery—required to meet these needs. At the same time, the study gives a review of the main technical and organizational procedures used in this important area of economic activity. The main emphasis is, of course, being laid upon methodological instruments for analysis and projections.

An attempt is being made in this study at analysing the problems at various levels, i.e. the plant, sectoral, national and international levels. Admittedly, the bulk of technical and organizational problems must be solved at the level of enterprise; on one hand, as an integral part of current utilization of installed capital, on the other hand, through the specialized activities of maintenance and repair units.

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Considerations are also given to analyse the problem at sectoral levels. By applying a sectoral approach, it is possible to assess the demand for replacement and repair and, consequently, the needs for specific economic resources in various sectors. In the process, important conclusions usually emerge which are relevant to the formulation of the over-all economic strategy and economic policies. At the same time the sectoral approach can also contribute to the bridging of the existing gap between micro and macro-economic levels of analysis and of solving the problems of industrial development. Some aspects of the problem area under discussion are undoubtedly of macro-economic nature, e.g., the balance of payments impact of different replacement and repair policies. Certain problems can be successfully solved by coordinative and indicative measures of the Government.

Problems connected with replacement, repair and maintenance assume a great importance from the very start of the industrialization process. Sound policy in this field is a necessary

> *Efficient and safe operation of built-up capacities requires highly qualified personnel, various material supplies and an appropriate organisational framework.*

condition for rational investment outlays and capital utilization. The more so in developing countries where scarcity of investment resources is often being considered as the main limitation of economic growth. Efficient and safe operation of built-up capacities requires highly qualified personnel, various material supplies, and an appropriate organizational framework which in the conditions of industrially developed countries are taken for granted are, however, in developing countries often lacking.

The aim of this study is not to put forward uniform or normative solutions to problems dealt with. Instead, by suggesting alternative solutions we will aim to create preconditions for a choice of an optimum approach in the given specific conditions of individual countries and/or sectors. In fact, even the basic concepts of renewal, repair and maintenance have to be defined in an alternative way.

This study will deal with replacement, repair and maintenance of fixed capital stock in industrial sector. Main attention will be devoted to plant equipment.

## BASIC CONCEPTS

### A. Wear and Obsolescence

Here we review the causes of depreciation of individual plants and equipment and outline the factors determining the various requirements for their renewal and repair

While buildings, machinery and other equipment get worn out physically, they also lose their value due to the continuous economic and technical progress. Thus, there are two types of depreciation with entirely different causes. The classification of causes of depreciation is given in a schematic way in Table 1

**Table 1**

CLASSIFICATION OF CAUSES OF DEPRECIATION

1. *Causes of deterioration*
   - 1·1· By gradual wear
     - 1·1·1· Through operation
     - 1·1·2· Due to environment
   - 1·2· Breakdown
2. *Causes of depreciation in economic terms*
   - 2·1 Obsolescence
     - 2·1·1 Due to the development of new, more efficient types of capital means
     - 2·1·2· Due to changes in production technology
     - 2·1·3· Due to changes in market conditions
   - 2·2· Reduction in the actual purchase cost.

### 1. Physical Wear

Physical wear is a process which changes the original qualities—physical, chemical, mechanical, etc.—of plants and equipment.

The rate of physical wear of plants and equipment is determined by the following factors:

- rate of utilization and load characteristics of the equipment
- environment in which the plants and equipment are utilized
- care extended in operation and maintenance

In contrast to the wear connected with operation, the wear caused by adverse effect

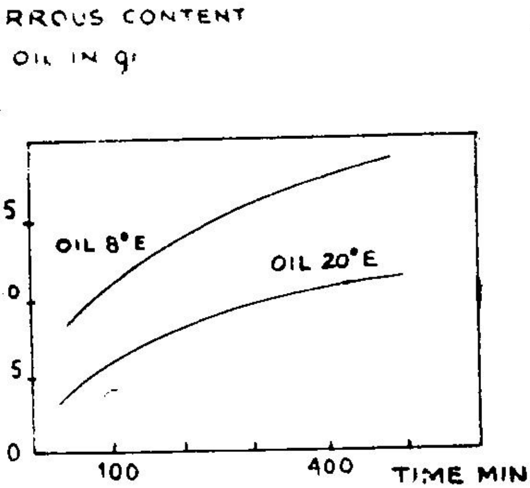



**FIG. A**

**Dependence of engine wear on usage of oil**

*Source:* Voinov H.R., Issledovanie obkladki dvigateley trenija, Sbornik IV, Moscow, 1949.

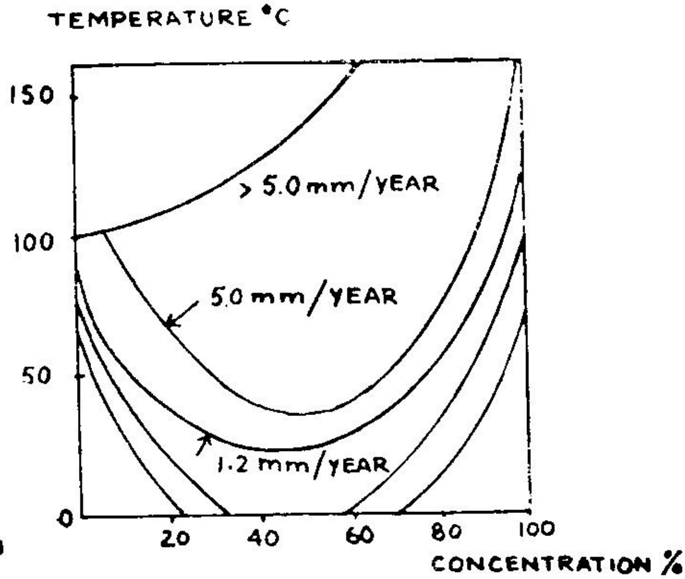



**FIG. B**

**Dependence of loss of material on temperature and concentration of environment**

*Source:* Fontana M.G., Ind. Eng. Chem. Vol. **44, No. 4,** 1952, p. 89a

of environment is not positively related to the degree of equipment utilization. On the contrary, the adverse effects of environment are often greater in case of less utilized or completely unutilized equipment.

To illustrate possible factors which determine the degree of physical wear two examples are presented in Fig. A (dependence of wear on usage of oil) and Fig. B (dependence of changes of dimensions of a part on temperature and concentration of the environment.

Two basic apparent forms of physical wear can be distinguished:

*Mechanical wear*, resulting in

— surface damage of the parts (components) of plants and equipment
— changes of original dimensions and shape
— reduction of their functions (precision and performance), etc.

*Chemical wear*, resulting in

— material being eaten away (corrosion)
— mechanical qualities of parts deteriorate
— functional failure.

An illustrative example of the mechanical wear of simple elements of a machine (e.g. bearing, pin) is given in Fig. C. In the first, rather short period after the equipment is put into operation, wear increases very markedly. This period is the running-in period. In the subsequent, long period wear does not increase substantially. Finally, in the last period, wear increases very steeply.

An illustrative example of chemical wear is a case of a pipe-line wear due to gradual decarburization (see Fig. D).

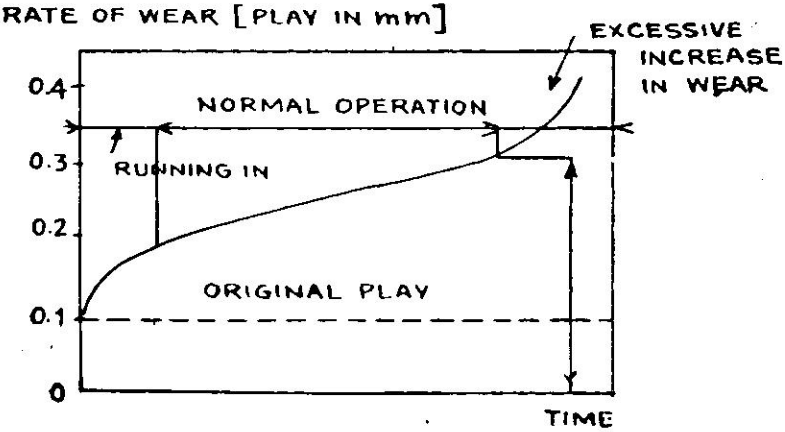



FIG. C

**FIG. C**

**Course of wear of a simple element**

*Source:* Zelenkov G. I., Technologija remonta dorozhnyhk mashin Dorizdat 1951, Moscow

Some elements of plants and equipment lose their functional qualities suddenly (e.g. bulb, certain elements of measuring devices). It is, of course, not possible to make a reliable and exact prediction of such a functional failure.

Two specific cases of physical wear are to be introduced: So-called *infant illnesses*, caused usually by unexpected defects (deficiencies) in production, assembly, method of installation, etc.

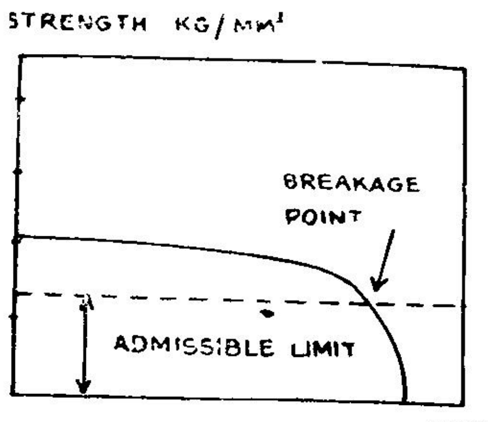



**FIG. D**

**Course of pipe-line wear due to gradual decarburization**

*Accidental depreciation* or break-down: the wear does not proceed gradually but suddenly, caused either by external or internal factors.

As a typical example of accidental depreciation can be mentioned fire, explosion, flood, typhoon and other disasters.

## 2. Economic Depreciation

In a dynamic economic system the bulk of the plants and equipment is depreciated and scrapped due to economic causes rather than due to its physical wear.

Economic depreciation is a process in which plants and equipment lose their value due to the introduction of technical innovations and to changes in the economic conditions.

Generally, three different cases of economic depreciation can be distinguished:

i. Appearance of a "challenger", e.g. a new, more efficient machine, which can replace the installed machine. This is the case of obsolescence due to technical progress in newly manufactured capital goods. The use of the new, more efficient machine usually causes a reduction of production cost, an improvement in quality of the product, and/or an increment of safety and improvements of labour conditions, etc.

The rate and the pace of depreciation of installed machines is above all determined by economic parameters of those new machines, which can replace the installed machines in their functions. The pace of technical progress and, consequently, the pace of depreciation of the installed equipment vary substantially from one branch of industry to another and differ also for various kinds of equipment. In general, it can be said that the fastest changes in design are observed in equipment used in most progressive lines of production—most progressive from the point of view of technology and requirements of the market.

ii. Changes in the technology and organization of production.

These changes can be caused by:

— innovations resulting in substantial changes in material inputs;

— changes in product design;

— transition from small to large-scale production.

In engineering industry, for instance, a shift from metal-cutting to metal-forming tends to accelerate the depreciation of currently used metal-cutting machine tools. Transition to large-scale production leads to accelerated scrapping of universal machine tools and to their replacement by specialized equipment.

iii. Changes in market conditions. This can cause a decline in demand for products produced on the given equipment.

Thus extensive replacement of classical electron tubes by transistors accelerated the depreciation and scrapping of many types of vacuum techniques equipment.

A specific case of "economic" depreciation—exceptionally appreciation—of installed capital means is a decline (increase) in reproduction purchase cost of these means.

It is thus necessary to consider the changes of value of the given plants and equipment both from the point of view of their physical state and their efficiency of operation, in the context of over-all economic conditions.

## 3. Service Life

Depreciation of the individual capital means usually proceeds gradually. The final stage of this process is scrapping. The time period, during which a given piece of equipment fulfills its technical and economic functions is the period of service life. A quantitative analysis of the service life usually is a starting point for an estimation of renewal needs.

The following different concepts of service life are of a special practical significance:

— "Total" service life which is the age at which a machine is being scrapped;

— "Primary" service life. This can be defined as that part of the total service life, in which a machine brings the highest effects;

— "Economically useful" or "optimal" service life.

Normally, the service life of plants and equipment can physically be extended almost without limits through repair and careful maintenance. However, capital means are usually scrapped as soon as their operation does not meet certain economic requirements.

Estimates of the length of service life can, for the same machine, vary between 10 to 30 years. The same machine can really reach a completely different "active" age depending on the way and conditions of utilization both from the view point of the process of physical wear and from the view point of different conditions of "economic depreciation". Therefore, the illustrative example of service life given in Table 2 serves only as a very rough orientation.

**Table 2**

ESTIMATES OF SERVICE LIFE AND COST OF OVERHAULS OF VARIOUS KINDS OF PLANTS AND EQUIPMENT*

| *Examples* | *Service Life (years)* | *Average Yearly Cost of Overhaul (% of the purchase cost)* |
|---|---|---|
| 1 | 2 | 3 |
| **Buildings** | | |
| industrial | 60 — 80 | 0.6 — 1.7 |
| office and residential | 100 | 0.5 |
| **Structures** | | |
| bridges—reinforced concrete | 200 | 0.3 |
| railway roadbeds and superstructures | 120 | 1.5 |
| dams | 80 —120 | 0.5 — 1.0 |
| melioration systems | 30 — 50 | 1.6 — 1.0 |
| sewer pipes—cement | 20 | 1.4 |
| concrete cooling towers | 50 | 2.0 |
| steel drilling derricks | 12 | 8.7 |
| **Machinery and Equipment** | | |
| Power and driving equipment | | |
| mobile compressors | 10 | 8.0 |
| mine ventilators | 40 | 2.0 |
| transformers | 30 | 1.0 |
| steam turbines with generator | 30 | 2.0 |
| hydraulic turbines with generator | 40 | 1.8 |
| mobile combustion engines | 15 | 4.0 |
| distribution mains 200 kv and 100 kv | 40 | 0.5 |
| switchgear cubicles 200 kv and 100 kv | 30 | 1.0 |
| Mining industry equipment | | |
| mining equipment | 35 — 40 | 1.5 — 3.2 |
| stripping shovels | 10 — 25 | 2.4 —30.0 |
| drilling sets | 4 — 12 | 4.0 —20.0 |
| mills and crushers | 15 — 20 | 5.0 —20.0 |
| Food industry equipment | | |
| masticating mills | 15 — 30 | 1.2 — 5.0 |
| sifting/screening machines | 15 — 40 | 1.5 — 5.0 |
| oven/bakery | 20 | 2.5 |
| bottle washing machines | 10 | 3.0 |
| milk and canning evaporators | 20 | 2.2 — 4.0 |
| Wood-working industry equipment | | |
| wood drilling machine | 15 | 0 |
| knot borers | 15 | 3.2 |
| wood-working lathes | 15 | 6.6 |
| sanders | 15 | 3.8 |

*Experts' estimate for the sake of depreciation charges

*Table 2 Contd.*

| 1 | 2 | 3 |
|---|---|---|
| Paper industry equipment | | |
| diffusers | 20 | 5.0 |
| paper machines | 30 | 5.0 |
| cutting machines | 20 | 5.0 |
| Printing industry equipment | | |
| composing machines | 20 | 4.0 |
| rotary printing machines | 20 | 2.0 |
| gravure printing presses | 8 | 3.2 |
| cutting machines | 30 | 0 |
| Chemical and rubber industry equipment | | |
| homogenizators | 20 | 4.0 |
| absorbing towers/sulphuric acid production | 15 | 5.3 |
| storage tanks for gasolin, oil | 40 | 2.0 |
| reactors/sulphuric acid production | 12 | 5.5 |
| roasting furnaces for pyrites | 30 | 6.7 |
| Non-metallic minerals industry | | |
| building materials equipment | 10 | 7.0 |
| cementation furnaces | 25 | 2.8 |
| baking ovens/ceramics | 40 | 2.5 |
| drying and annealing kilns | 20 | 7.0 |
| Basic metals industries | | |
| blast furnaces | 30 | 5.3 |
| coke ovens | 18 | 2.0 |
| steel melting furnaces | 24 | 10.0 |
| moulding machines | 12 | 3.3 |
| casting machines and equipment | 20 | 3.3 |
| rolling mills | 20 — 30 | 2.5 — 3.3 |
| Metal-working industry | | |
| reheating furnace | 20 | 4.0 |
| power presses | 20 | 5.6 |
| centre lathes | 12 — 25 | 3.8 — 7.1 |
| automatic lathes | 12 | 5.2 |
| horizontal boring machines | 15 — 20 | 3.5 |
| planing machines | 20 — 25 | 3.1 — 4.0 |
| grinders | 12 — 15 | 5.8 — 9.0 |
| welding equipment | 12 — 15 | 5.5 — 7.1 |
| coil winding machines | 15 | 4.5 |
| Construction industry | | |
| concrete and mortar mixers | 10 | 8.0 |
| dozers, scrapers, graders | 5 — 6 | 10 — 35 |
| building cranes | 8 — 12 | 9 — 12 |
| Transport and communication | | |
| trunk cables | 30 — 35 | 0.7 |
| main gas lines | 30 | 0.5 |
| telephone exchanges | 25 | 1.0 |
| diesel-electric locomotives | 10 | 8.0 |
| covered wagons | 45 | 0.7 |
| cargo boats | 40 | 1.8 |
| airplanes | 5 — 12 | 2.7 — 16.2 |

*Source :* Ministry of Finance (CSSR), Laws and Orders, 1954.

Estimates of service life are generally quite different from the service life periods actually achieved. For cutting-machine tools and forming machines estimates of service life generally vary around 15 years. But, in all countries where an inventory of installed machine tools has been made according to their age, a large number of machines older than 20 years has been foun still in operation.

From the data contained in the inventories of machinery in metal-working industry in USA which were carried out by American Machinists in 1949 and 1958, we can conclude that between the 10th and 20th year of their age only 14.5 per cent of the original number of metal-forming machines and 26 per cent of metal-cutting machine tools were scrapped. A very detailed analysis by the Research Institute for Engineering Technology and Economics in Prague has shown that in the Czechoslovak engineering industry machine tools are kept in operation on average for 25 to 30 years. Even after this period, however, most of them are not scrapped. More than 70 per cent of discarded machines are resold or transferred to plants, shops and schools outside the engineering industry.

Not all of the causes for depreciation have a direct bearing on the service life. Thus, physical wear may have no impact on the length of service time, if the consequences of physical wear can be made good by repairs. Physical wear plays a decisive role only in case repair would be more costly than the purchase of a new machine or would not be technically feasible at all. Therefore the bulk of machinery and equipment and also of buildings and structures is being scrapped--discarded--due to "economic" depreciation, caused in turn by the appearance of new, more efficient machines and equipment, the changes in technology of production and by market conditions for the products.

It is being asserted that machines are being scrapped before they are completely physically worn out. In the junk-yards we can, however, see that the machines brought there are usually both physically worn out and technically obsolete. The question—which of the two basic causes of depreciation determines the service life—cannot be answered univocally in most cases. The technical obsolescence generally is the basic cause, whereas the technical condition of a machine, i.e. the degree of its physical wear is often the direct (immediate) cause of scrapping.

**Table 3**

AGE-COMPOSITION OF MACHINE TOOLS IN THE INDUSTRIALIZED COUNTRIES

| *Country* | *Year* | *Percentage of Machine Tools older than* 10 years | 20 years |
|---|---|---|---|
| USA | 1958 | 60 | 18 |
| United Kingdom* | 1955 | 52 | 12 |
| | 1961 | 59 | 22 |
| Western Germany | 1953 | 62 | 21 |
| | 1961 | 55 | 20 |
| France | 1955 | 62 | 43 |
| | 1961 | 59 | ... |
| Italy* | 1958 | 59 | 33 |
| | 1961 | 56 | ... |
| Canada | 1958 | 58 | 18 |
| Czechoslovakia | 1962 | 61 | 23 |

*Machine-tools in metal-working industries only

It should be mentioned in this context that the technical condition of a machine is to a certain extent dependent on economic factors, since to the machines which cannot meet certain economic criteria proper maintenance and repair care is not being extended.

Machines which are "prematurely" scrapped due to their technical obsolescence are considered to cause a loss, amounting to the portion of balance value not written off. However, it is hardly a loss in case of really obsolete machines. The loss is actually incurred at the time when the investment was made into an obsolete machine and should therefore be charged on the past period, during which the machine was purchased. Otherwise there is the danger that obsolete equipment is kept in operation.

Some of the factors that determine the service life as dependent upon the intensity of physical wear can be quantified or estimated on the basis of past experience. An example of such estimates is presented in Table 4.

*Some of the factors that determine the service life as dependent upon the intensity of physical wear can be quantified or estimated.*

**Table 4**

COEFFICIENTS FOR CALCULATING SERVICE LIFE OF MACHINERY UNDER DIFFERENT CONDITIONS OF UTILIZATION

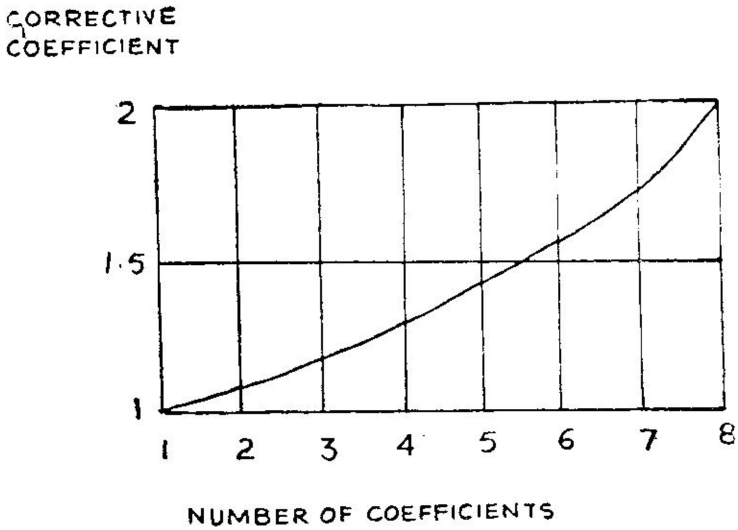
| *Conditions of Utilization* | *Coefficient* |
|---|---|
| Normal operation in two shifts | 0.6—0.8 |
| in three shifts | 0.4—0.6 |
| for less than 8 hours a day (x number of hours in operation a day) | $\frac{8}{x}$ |
| When used in laboratories or research units (shops) | 1.2—1.3 |
| in assembly shops | 1.4—1.4 |
| Incidental usage | 0.6—0.8 |
| Usage in humid rooms or outdoors | 0.6—0.8 |
| in excessively dusty rooms | 0.6—0.8 |
| Usage in rooms with adverse chemical environment | 0.4—0.8 |
| in rooms without heating | 0.7—0.9 |
| in rooms exposed to intensive shocks (vibration) | 0.6—0.8 |
| Usage without adequate footing (foundation) | 0.7—0.9 |
| Work in wetness | 0.7—0.9 |
| Prevailing work with continuous mesh (machining) | 0.8—0.9 |
| Work under difficult cutting conditions | 0.7—0.9 |
| Cast iron machining | 0.8—0.9 |
| Plastic material machining | 0.8—0.9 |
| Incidental usage of grinding preparations on cutting machine tools | 0.7—0.8 |
| Deficient operation (vocational training shops) | 0.6—0.8 |

*Note:* A multiple of all the relevant coefficients has to be multiplied by a corrective coefficient which is graphically described on next page.

According to the coefficients contained in this table the physical wear of a lathe utilized in two shifts (coefficient 0.7), operated in dusty environment (coefficient 0.7), exposed to shocks and vibration (coefficient 0.7) and operating under adverse difficult cutting conditions (coefficient 0.8) would be so high that compared to the normal conditions of the lathe utilization in one shift, the service life would be reduced to almost one third. A corrective coefficient of 1.25 corresponds to the use of four partial coefficients; therefore 0.7 x 0.7 x 0.7 x 0.8 x 1.25=0.343.

If the same lathe is used as a piece of ancillary equipment in an assembly shop in good condition, its service life might be extended by 50 per cent over the standard service time.

The rather complex process of depreciation and scrapping of the plants and equipment allows only exceptionally the establishment of a direct link between the scrapping, the service life of individual pieces of plants and equipment and the renewal of a particular plant or machine. Individual machines are replaced in their economic functions without it being possible to follow and quantify this process. Therefore, it is appropriate to set the problems of renewal in the context of the whole system of capital means installed in an industry or in the economy as a whole (see Appendix II). Besides, the problem of renewal is not to be reduced to the mere replacement of plants and




*Source:* Simonis, F. W. : "Die Bewertung von gebrauchten Werkzeug-machinen und machinellen Anlagen", VDI No. 18/1956.

equipment. Renewal connected with modernization of equipment, buildings and structure is depending on or conditioned by the development of technology, production, demand, etc.

## B. Renewal, Repair and Maintenance

### 1. Renewal

Renewal is defined here as the volume of investment needed for replacing plants and equipment depreciated in a given period. In a broader sense renewal would mean not only actual replacement but als repairs of worn out parts of machinery, equipment, buildings, etc. In this case repairs of machinery particularly so-called general repair (overhauls) fall under the concept of replacement. Usually, however, only the replacement of the whole machines or eventually of complete lines of productive equipment by new machines is considered as renewal.

In the over-all national economy context also the construction of new capacities can be considered as renewal, even if there is no visible connection with the old capacities being liquidated. In that case the value of renewal is corresponding to the part of the total investment that equals the depreciation of the existing plants and equipment in the given period.

The most common interpretation of renewal is physical replacement of worn out machinery, equipment, buildings, etc., within given productive units by new ones. This interpretation is being applied in this study.

The purpose of renewal is not only to replace physically worn out plants and equipment, but also to modernize the whole system of equipment, according to the needs of modern technology and the requirements of the market. *Active renewal policy* means the adoption of a consistent and economically rational investment policy. Above all it takes into account the aspect of modernization and transfer of machines. For estimating the investment resources required by the needs for renewal, it is also necessary to consider the time-lag between replacement investment and discarding of the obsolete capital means. As a rule, active renewal takes place earlier than the actual scrapping of the replaced items.

Frequently used machines are transferred within a plant, i.e. the location and/or the function of the machine is changed to better meet the overall requirements of the plant. Trade statistics of industrialized countries show that there is also a considerable transfer of used machines between various plants.

Normally worn out machinery is not replaced by exactly the same type of machinery due to the technical progress. Replacement thus is mostly carried out with the aim to modernize the existing fixed capital stock. Consequently, replacement and modernization cannot be considered as two separate phenomena. Replacement usually expresses quantitative, and modernization qualitative aspects of the same process.

Modernization can be carried out in various ways. One way is the modernization of existing machinery with a view to increasing the performance, minimizing losses from failures, lowering the labour cost, improving the safety of operation, etc. Another form of modernization consists in actual replacement of individual obsolete pieces of equipment by new, more efficient ones. The largest effects can be usually achieved by a systematic total modernization of the whole productive unit.

Modernization in a narrower sense is the modernization of individual units of equipment installed in accordance with the requirements of modern production technology. Two basic approaches can be mentioned:

i. Adaptation of machines, equipment, buildings or construction to the specific way of its utilization, e.g. reconstruction of an older lathe to a machine tool for centrifugal casting;

ii. Standard modernization aiming to increase the qualities of older models of machines. Impulses for such a modernization are given usually by producers of the machines.

The best occasion for modernization is usually by a major overhaul. Thus, major overhaul and repair as a whole are to be considered not only as a way of removing the traces of deterioration of a machine, but also of increasing its adaptability to new conditions of its utilization.

Modernization is sometimes connected with reconstruction, i.e. a functional adaptation of machinery, equipment and/or buildings through changes in technical design. Reconstruction and modernization are not identical concepts, but reconstruction is usually undertaken with the aim to modernize the capital assets.

*Replacement usually expresses quantitative and modernisation qualitative aspects of the same process.*

## 2. Repair

As has been already mentioned, the distinction between renewal and repair is far from being clear-cut. However, renewal normally means total replacement of worn out or obsolete machinery, equipment, buildings, etc. while repairs consist in replacement of only certain parts of machinery, equipment, buildings, as well as their restoration and renovation.

Two basic categories of repairs can be distinguished:

i. *routine* (small) repairs, consisting usually of replacement or repair of individual parts and elements of the machine,i.e., those which have a shorter service life.

ii. *overhaul* (rather extensive repair of the whole machine, building, etc.) of all worn out and damaged parts, with the object of renewing the original technical condition and operational efficiency. As a rule, the cycle of major overhauls is longer than one year.

The causes of physical wear vary for individual parts of plants and equipment. Individual parts therefore have different periods of service life. The different prevailing working conditions determine the wear of individual parts and of the whole machines, equipment, buildings and structures and can give an accidental character to the course of physical wear. The distribution of admissible wear values of individual parts determines the degree of risk of failure of the whole machine.

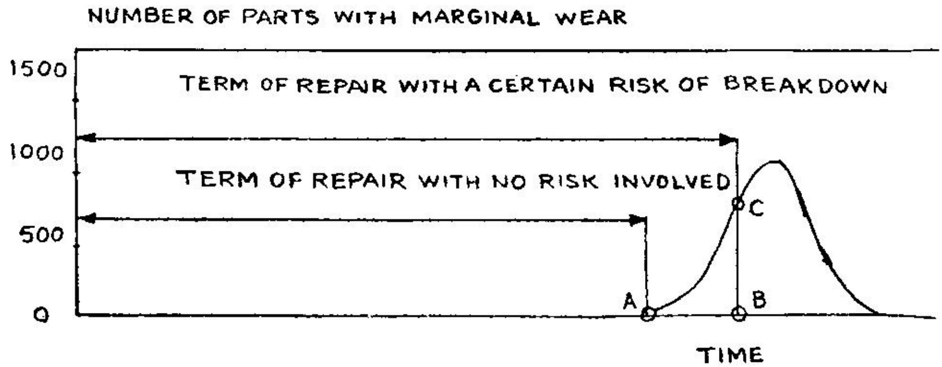



**FIG. E**

**Repair Timing in Regard to the Degree of Risk of Break-down**

*Source*: Vybrene kapiboly z ekonomiky chemickeho prumyslu slatni pedagogicke nakladatelstri Prague 1966, p. 111 (collective work of several authors)

From Fig. E it can be seen that if the repair is carried out in a point A,the risk of failure is almost nil since all the parts of the machine will not yet have reached the level of admissible wear. However, if the date for repair is fixed into the point B, a risk is being taken that some parts wear before the repair is undertaken. The curve reflects the spread of physical wear periods of individual parts and their numbers.

The course of wear of individual parts and the general cost of their repar or renewrl determine the volume and timing of repair cycle.

The graph in Fig. E has been worked out according to the norms of preventive repair applied in the Czechosovak engineering industry. In the period between two overhauls, following are to be carried out:

—two "medium" repairs,

—six small repairs,

—a number of inspections,

—precision measuring before and after each "medium" repair and overhaul.

There is no standard repair system which could generally be applied. The obvious reasons for this are the different courses of wear of individual machines, the different requirements in regard to the reliability of operation of equipment, differences in working donditions of the equipment in individual countries and a number of other factors. The repair systems to be used therefore should be based on an objective evaluation of the actual situation in regard to the equipment, plant, industry and country. A classification of repair systems is introduced in Table 5 (on page 342).

The needs for overhauls and for other repairs are interdependent. Thus, careful and regular carrying out of small repairs can reduce the need for overhauls.

This interrelationship has been proved by a sample inquiry in the Czechoslovak engineering industry: whereas in individual plants both the cost f overhauls and the cost of small repairs (in relation to the purchase cost of machinery) widely fluctuate, their aggregate values come much closer to each other. On average, the small repair cost was 50 per cent higher than the overhaul cost.

## 3. Maintenance

According to generally accepted terminology, maintenance means the whole set of measures for keeping the plant in good operating

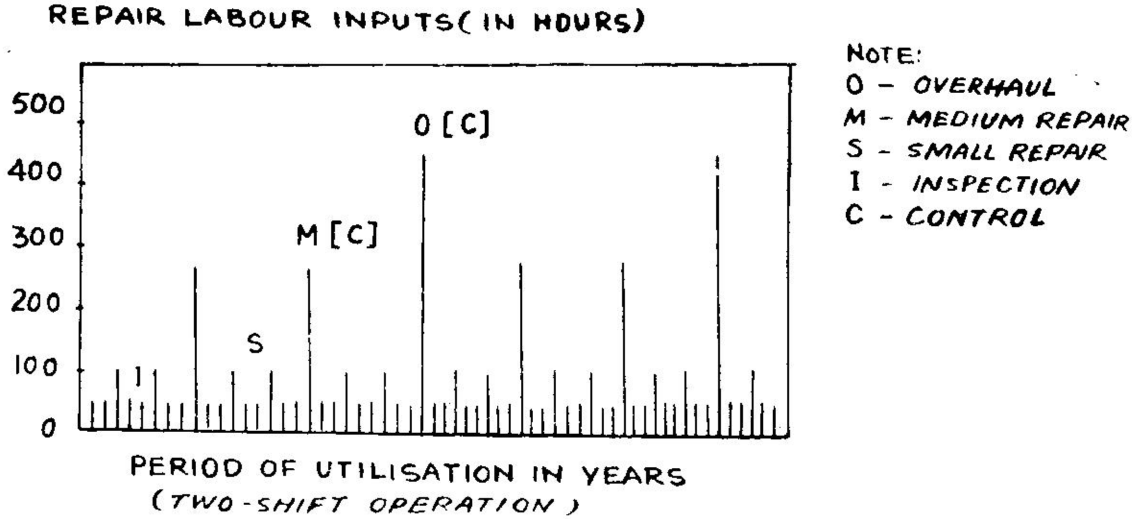



Fig. F

**Period of utilization in years (two shifts operation)**

Cycle of Repairs According to the Standards for Preventive Periodical Repairs of a Lathe

tion. The concept of maintenance thus would include repairs and sometimes even renewal. In this study, however, a narrower concept will be used, covering only the routine care, such as:

- cleaning
- painting, anticorrosion protection
- lubrication
- inspection control.

Some secondary functions usually are being organized closely together with maintenance, such as:

- stock keeping
- generation and distribution of power and other utilities
- plant protection including fire protection
- pollution and noise abatement, etc.

The treatment of these activities does not fall within the framework of this study.

Special importance should be attached to anticorrosion protection, lubrication and inspection control, since these activities require specific resources and skills.

**Anticorrosion** protection ensures the surface protection of machinery, equipment, buildings and structures against the aggression of environment. Anticorrosion protection which mainly consists of protective coatings and conservation is quite labour-intensive and requires a wide variety of special materials. Losses caused by corrosion are estimated at $ 6.5 billion p.a. in USA, £195 mil. in U.K. and DM 2-3 billion (only steel corrosion) in the Federal Republic of Germany.

In a number of industries corrosion is the main cause of repair. Therefore increasing attention is being paid to coating and painting. The cost of anticorrosion measures in US chemical industry represents 20 per cent of investment cost and 80 per cent of repair and maintenance cost.

**Lubrication** is to be regulated by exact rules determining the kind of lubricants, their quantity and the timing and method for their use. Proper

## Table 5

CLASSIFICATION OF REPAIR SYSTEMS

| | *Complex repair* | *Standard repair* | *Planned preventive (periodical) repair* | *After checking scheduled repair* | *Breakdown repair* |
|---|---|---|---|---|---|
| Characteristics | Complex repair planned and prepared long time ahead | Rigid repair cycle, replacement of all parts according to the prescribed standards[1] | Repairs planned on the basis of standards[3], definite decisions about timing taken after checking | Repairs planned on the basis of regular inspections | Repairs carried out in case of imminent danger of a break-down or after actual breakdown |
| Advisable for | Whole sets of electrical power plants and metallurgy, chemical and food industry equipment[2] | Equipment involving great safety risks or excessive losses in case of breakdown; equipment with low cost spare parts | Great number of identical machines; in large-scale production; in production requiring high accuracy | In cases where the service life periods of individual parts differ widely or the course of wear is ambiguous[4] | Auxiliary equipment, equipment with a completely incidental nature of course of wear |
| Pre-conditions | Co-ordinated repair activities with production programme, synchronization of the process of wear of individual components of equipment | Discipline and regularity of the repair process, scientifically elaborated system of standards | System of scientifically worked out standards of the cycles, the volume, and the duration of repairs | Qualified and experienced personnel checking the equipment; measuring devices and laboratory facilities, advanced operative planning of repair activities, adequate stock of spare parts | Reserves in equipment, great stocks of spare parts, high flexibility of repair capacities |
| Effects | Minimal losses in output; minimal time needed for repairs | Lower requirements for the qualification and flexibility of repair personnel; possible planning of repair activities | High utilization of repair capacities | Repairs are planned and carried out at most appropriate points of time | Timing of repairs incidental; difficult planning of repair activities |

1 Repairs are timed according to the course of wear of the component with the shortest service life.
2 Individual components are functionally interdependent.
3 Repairs planned with certain degree of flexibility as compared to standard repairs.
4 Equipment exposed to intensive corrosion, buildings and structures.

lubrication, accordingly, demands specific qualification of personnel (lubrication technicians), materials and organizational measures. It can be assumed that on average one specialist for lubrication is required for every thousand employees in an engineering plant.

Different pieces of equipment and their individual components have specific requirements for the quality of lubricants. Therefore a large variety of lubricants is needed, requiring specific purchases and large stocks.

The organization and control of lubrication in a plant is handled by the maintenance chief. The lubrication technicians are usually organized in maintenance crews. A proper organization of lubrication requires:

— equipment records,

— lubrication prescriptions, lubrication plans

— indications of lubrication points

— organization ot deliveries, stocks and distribution of lubricants

— system of utilization of used lubricants.

**Inspection** means a check up of the condition and the functioning of plants and equipment. This requires a variety of activities including the removal of minor defects, largely without stopping the operation. These activities are carried out by both the operating personnel and by special "inspection repair-men". Which of these two categories is to carry out each of the various functions depends on the specific conditions as well as the safety requirements of the plant.

The professional supervision of plants and equipment is usually undertaken by a special group of maintenance workers. These workers are to be at permanent positions, especially in the case of continuous production. Special problems in regard to the staffing are the underutilization of the specialized inspection maintenance workers as well as the control of their work.

*Professional supervision of plants and equipment is usually undertaken by a special group of maintenance workers.*

## C. Preconditions for Repair and Maintenance

### 1. Labour (Maintenance Workers)

It is not possible to draw a clear-cut line between maintenance workers and workers who operate machinery and other equipment. In enterprise statistics repair workers usually fall within the category of auxiliary personnel. The broader term "maintenance workers" often includes not only workers carrying out maintenance and repair but also workers producing spare parts and parts or whole pieces of equipment. In addition, firemen and members of factory guard are sometimes included here as well.

The main factors determining the number of maintenance workers needed (i.e. the ratio of the number of repair workers to the total manpower in a plant) are:

i. Capital intensity of the production; the manpower requirements tend to be high in capital intensive industries (e.g. power, metalworking and chemical industry), while it is low in textile, garment, tanning, and wood working industries.

ii. Structure of capital means to be maintained; machinery and equipment naturally have a different demand for repair than buildings and structures.

iii. Standardization, design and material characteristics of plants and equipment; manpower requirements thus depend to a great extent on the choice of equipment, on the technology and production of given equipment.

iv. Factors determining the deterioration of plants and equipment (see Physical Wear on p. 330).

v. Efficiency of the applied system of maintenance.

The data in Table 6 and 7 serve as an illustration of differences in repair intensities of various industries. Equipment requires about 4-5 times more labour per value of installed capital than buildings and structures. Also within the category of "equipment" there are substantial differences between repair work requirements of technological equipment, power plants, and instruments. In more elaborated systems the needs for repair workers are determined on the basis of standards of repair intensity for individual kinds of capital means. The data in Table 7 which is based on standards for Czechoslovak machinery can serve as an illustration for this.

**Table 7**

LABOUR STANDARDS FOR PREVENTIVE REPAIRS OF A BENCH DRILLING MACHINE

| *Type of repair* | *Norm of labour intensity in hours* |
|---|---|
| Inspection | 0.75 |
| Control | 1.0 |
| Minor Repair | 10 |
| Medium Repair | 27 |
| Overhaul | 54 |

**Table 6**

INDICATORS OF REPAIR ACTIVITIES INTENSITY IN VARIOUS INDUSTRIES

| *Industry* | *Number of all personnel* | *Installed HP* | *Plant area in m²* | *Area of repair shops in m²* | *Share of repair workers in total personnel (%)* | *Area of repair shops as a percentage of the total plant area* |
|---|---|---|---|---|---|---|
| | per one repair worker | | | | x | x |
| Oil refineries | 5 | 41 | — | 6.6 | 33.3 | — |
| Chemical industry | 8 | 59 | 720 | 13.8 | 12.5 | 1.92 |
| Metallurgy | 9 | 153 | 970 | 17.3 | 11.0 | 1.78 |
| Rubber | 13 | 94 | 475 | 7.7 | 7.8 | 1.62 |
| Textile | 20 | 68 | 725 | 20.3 | 5.0 | 2.8 |
| Electro-engineering | 27 | 105 | 660 | 12.8 | 3.7 | 1.94 |
| Engineering | 28 | 92 | 740 | 12.8 | 3.6 | 1.73 |
| Precision tools | 37 | 60 | 495 | 9.2 | 2.7 | 1.86 |

*Source:* FACTORY 110/1958/No. 8, pp. 52-63.

Fig. G shows that the number of maintenance workers depends on the technical capacity of the equipment. The repair of an electromotor, for instance, of 10 kw. takes about 15 minutes repair per 1 kw, whereas the repair of an 100 k w-motor takes only about 7 minutes per kw.

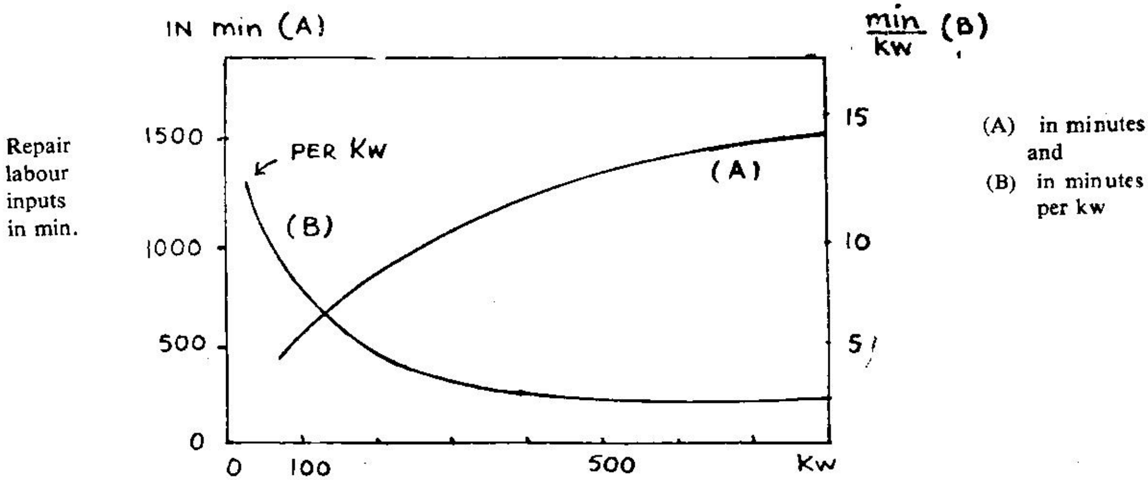
As technical development progresses, the ratio of repair workers to the total number of personnel tends to increase. Particularly, the process of automation increases the complexity of equipment and its repair requirements.

Thus, for instance, in Du Pont de Nemours chemical concern the number of production workers was increased in 1940-1955 by 50 per cent, while the number of repair workers grew with 250 per cent.

Repair and maintenance place special requirements on the skills of labour. In several types of industries the skill requirements for maintenance workers are higher than for production workers. In case of automatic or programme-controlled machines, for instance, the production worker must only have an ability to repeat relatively simple tasks, i.e. manual skills for fixing and handling the finished products and to switch the machine on and off. The maintenance worker on the other hand should not only have the manual skills but also a deep professional knowledge, in particular, regarding the basic mechanical, electric and hydraulic principles. These skill requirements obviously make the specialization and division of labour within a plant necessary.

The opinion on the specialization of maintenance professions is far from uniform. Generally, two basic professions are recommended: maintenance workers for mechanical systems and maintenance workers for electrical systems.

Special training is necessary for maintenance and repair personnel. The training should aim at both the broadening of the general know-




Capacity of the electro-motor

**FIG. G**

**Volume of repair and the capacity of the equipment (electro-motor)**

*Source:* Zigmund J. Informace o udribe. No. 6050/1966, VUTECHP, Prague ledge and the mastering of specific technical problems.

In addition to the formal education at appropriate level (vocational schools, technical high schools, technical universities), the qualification of technicians requires specialized practical knowledge of maintenance. An example of a basic training programme for repair workers is given in Table 8.

**Table 8**

REPAIR WORKER TRAINING PROGRAMME (*Example*)

| *General Millwright Assignment* | *Hours* |
|---|---|
| 1. Assembling and erecting and general maintenance of machines & shop equipment | 2920 |
| 2. Construction of special equipment | 1000 |
| 3. Installation and maintenance of hydraulic and pneumatic equipment | 1000 |
| 4. Fitting bearing and scraping ways | 500 |
| 5. Lubrication of machines | 500 |
| 6. Welding and cutting arc and aeetylene | 1000 |
| 7. Operation of various machines | 500 |
| 8. Related classroom instruction | 580 |
| Total | 8 000 |

*Source:* Morrow L.C.: Maintenance Engineering Handbook, McGraw-Hill, NY.1957 pp. 2-19

## 2. Spare Parts and Materials

Spare parts are used to replace the parts of a machine which get worn out faster than the machine as a whole. A spare part can be defined as that part of a machine and/or equipment, which can be used separately as a replacement for the identical, worn out or damaged part of the machine. Also a separate functional unit can be considered as a spare part, e.g. electric motor, pump, etc. On the other hand clamping and cutting implements of lathes, for instance, are not regarded as spare parts, but instead as material inputs. They are not depreciated as a part of the value of installed equipment.

The need for spare parts and materials for maintenance is determined similarly to the need for maintenance workers. However, there is generally a need for a wide range of different parts. Special importance therefore must be ascribed to the supply and stock keeping of spare parts.

In various industries the annual consumption of spare parts amounts to 1-4 per cent of the purchase cost of installed machine and equipment. Spare parts stocks represent 1 to 2 years' consumption.

In an average sized chemical plant there are about 10,000 items on the list of spare parts and about 15,000 items on the list of repair materials.

The need for spare parts is especially influenced by the degree of standardization of equipment. For 100 machines of the same type it is necessary to keep in stock only about one third of spare parts compared to what is needed for 100 machines of five different types.

## 3. Equipment in Repair Shops

Only a certain part of repair and maintenance activities require special floor and equipment capacities. By their nature, repair and maintenance mainly are ambulatory. A large part of repairs and the dominant part of maintenance is carried out on the spot of installation without moving the machine or equipment.

Capital requirements of repair and maintenance are given by

- the technical outfit of repair shops (machinery and equipment)
- the working area of repair shops
- mechanical implements (tools) and instruments (e.g.) measuring
- the stock of spare parts and materials (mentioned in preceding section).

The technical outfit of repair shops is partly characterized by the large proportion of universal machines (general purpose lathes, drilling, grinding and milling machines of normal sizes) and partly by expensive and complex measuring devices. Data on the technological structure of machine-tools in repair shops in USSR are contained in Table 9.

**Table 9**

COMPOSITION OF MACHINE-TOOLS IN REPAIR SHOPS IN ENGINEERING INDUSTRY

| *Kind of the machine* | *Share (per cent) in the total number of machines in repair shops* |
|---|---|
| Centre and turret lathes | 40—50 |
| Vertical and chucking lathes | 2— 3 |
| Boring machines | 3— 4 |
| Vertical drilling machines | 7— 8 |
| Radial drilling machines | 2— 3 |
| Milling machines | 7— 9 |
| Planing machines | 7— 8 |
| Shaping (slotting) machine | 2— 3 |
| Grinders | 10—12 |
| Gear milling machines | 6— 7 |
| Other machines | 3— 4 |

*Source:* Jakobson M.C.: Jedinaja sistema planovopredupreditelnovo remonta masinostreitelnych predprijatij, Masinostrojenije, Moskva 1967

The outfit of repair shops in big plants outside the engineering industry (e.g. metallurgical, chemical works) is generally more complex and costly. There are special anticorrosion shops usually linked to the material testing department, boiler shops, pipe shops, stainless steel welding shops, etc. Relatively more equipped and bigger are also electroshops and particularly shops for the repair of measuring and regulation devices.

The working area of repair shops is, as a rule, relatively larger than the area devoted to basic activities in machine-tool works. In repair shops there is a working area of about 30-35 $M^2$ per worker, which is three times more than the average area in processing shops in the machine-tool industry. It must be stressed that this estimate concerns the relation between the number of workers and the extent of the area of repair shops and not the—different—relation between the total number of maintenance and repair workers and the area to repair shops (see Table 6).

The investment cost of building up and equipping repair shops is determined by the technical outfit of the shops, the working area needed, the costs connected with the initial outfitting with tools, and the necessary spare parts and repair materials. The fixed investment costs into repair shops generally represent about 1-3 per cent of the total fixed investment into a plant. For smaller plants higher values are valid.

The value of the stock of spare parts is approximately at the same level, i.e. 1-3 per cent of the investment.

## 4. Downtime of Equipment

One of the specific implications of repair activities is the down-time during which the machinery partly or ertirely is taken out of production and which accordingly causes loss of production.

In order to keep these production losses at their minimum the plant manager can undertake specific organizational and technical measures for shortening the down-time during the given repair work. Furthermore, losses can be reduced by utilizing normal idle periods of equipment for the repair or utilizing reserve capacities. Finally, all mentioned activities reducing the deterioration of equipment and the risks for breakdowns naturaly play an important role in this context. The choice of repair system is largely determined by the estimated risk for down-time of the machines.

The length of time during which the machine is put out of operation due to repairs depends on the magnitude of the repair. The down-time of equipment in repair can accordingly be reduced by rationalizing the repairs and planning them well in advance. Technically repairs can be prepared beforehand, mainly by:

- preparing the necessary technical documentation
- securing the availability of spare parts needed
- calculating the repair time and scheduling the repair work sequence.

In many cases it is possible to prepare the scheduled repair by dismounting the equipment for a short time and make a diagnosis of the repair and spare part needs.

Finally, the risk of losses due to down-time of machinery caused by failures and repairs can be minimized by means of reserve equipment. These reserves can be kept either in installed equipment of productive units or in the repair shops (system of repair through exchange).

The feasibility of keeping such reserves is shown by the ratio between the investment cost of such a solution and the volume of probable losses that could be avoided. Hence it is usually not feasible to keep reserves of costly and complex machinery. One can also regard the possibility to use more intensively other machines of the same kind in the case of break-down and down-time as one kind of spare capacity. In the engineering industry a universal machine tool could be used for this purpose.

## 5. Specialized Repair and Maintenance Shops

In order to rationalize repair services at the sectoral and national levels specialized repair shops can be established. Generally three types of such repair shops can be distinguished:

- sectoral shops,
- repair shops for specific kinds and brands of machines,
- regional repair shops.

In addition, it should be mentioned that the most common external specialized repair and maintenance service is the one carried out by producers of the equipment.

Sectoral repair shops are usually established for repair and maintenance of special equipment of a certain industry such as oil refineries, electro energy and construction industries.

A sectoral repair shop can be organized as a separate plant or as a repair shop attached to some plant within the specific industrial sector. Either the personnel of such a specialized repair shop is sent out to carry out service in the plants, or the machines and equipment are sent to the repair shop.

Repair shops dealing with specific kind and brands of machines represent a porgressive form of specialized repair shops. They mainly perform overhauls. This kind of specialization makes it feasible to introduce methods of large-scale production into repair activities. In this way, overhauls can be carried out at much lower cost than if they are done individually by the plants themselves. As a result of specialization of overhauls in the Czechoslovak engineering industry, the time needed for overhauls of certain types of machines was reduced by 75 per cent and the labour costs by 50 per cent. The experience shows that in order to achieve such substantial savings, the number of machines of a certain type to be repaired must reach 35 pieces annually.

Some experiments in USSR and in Czechoslovakia show a possibility to reduce the down-time of equipment through the "system of repairs through exchange". In this system the specialized repair shop concurrently with demounting the machine for overhaul delivers another machine of the same type in good working conditions as permanent replacement. This system can only function if the repairs are of high quality and if the repaired machines have the same technical parameters as a new machine. Another precondition for the rational use of this system is the existence of a sufficiently large inoustrial sector and of a sufficient number of machines.

Regional repair shops can be used in regions which have a great concentration of industrial—mainly small-sized—establishments with the same repair requirements. The main items to be repaired in this case are buildings, electro-motors, coatings, pipes, electro-distribution systems and climatization equipment.

## RENEWAL, REPAIR AND MAINTENANCE POLICY AND STRATEGY

This section deals with the economic and organizational aspects of renewal, repair and maintenance on the plant and the aggregate levels. Emphasis is placed on the plant level and mainly on explaining the organization, the management and control, the book-keeping and recording system as well as the analysis of renewal, repair and maintenance. The aggregation of these problems will then be discussed, i.e. the national planning of renewal, repair and maintenance, and the strategy in the context of industrial development.

### A. PLANT LEVEL

#### 1. Organization and Management

The specific problems of the organization and management of repair and maintenance are to decide upon:

i. the degree of specialization of repair shops and repair teams in the plant;*

ii. the centralization or decentralization of repair capacities; and

iii. the organization of management for the repair and maintenance activities.

The choice of the appropriate degree of specialization depends mainly on the size of the enterprise. The larger the plant is, the more can the repair facilities be specialized. In smaller enterprises all the maintenance and repair activities are concentrated in one maintenance department, while overhauls and special services are carried out by external shops. In large plants the specialization can lead to the establishment of a system of internal maintenance units. Such a system could include:

*The choice of the appropriate degree of specialisation depends mainly on the size of the enterprise.*

a) *maintenance of machines and equipment*
   i. mechanical shops (machine tool shops)
   ii. welding shops (pipe shops, tinsmith shops, boiler shops, etc.)

b) *transportation equipment maintenance*

c) *electrical maintenance* (*shops for electro-motors, etc.*)

d) *maintenance of radio-technique, measuring and regulation devices*

e) *joiner's maintenance*

f) *construction maintenance* (bricklayer crew, scaffolding crew, etc.).

The specialization of maintenance capacities depends, however, not only on the size of the plant, but also on the technology and organization of the main production activity. Thus, in the chemical industry, in the production of electrical energy, and in such metallurgy or engineering industries which require a high precision of machine-tools, the specialization generally is rather far-reaching.

The second mentioned problem to be solved by the management is the choice between *centralized and decentralized maintenance capa-*

* The problems of specialized repair and maintenance shops functioning at the sectoral or regional basis have been dealt with in the section on Policy and strategy.

*cities*. The following alternatives are possible:

*a) Centralized maintenance capacities*, organized either as:

i. an independent repair plant of an enterprise (or a trust),

ii. a central workshop within the plant, or as

iii. several workshops, one for each major section of the plant.

*b) Decentralized workshops within the productive sections*

*c) A combination of (a) and (b)* based on several smaller detached shops which are combined with the central workshop. This can be organized either as:

i. decentralized workshops, with the planning, the spare parts stocking and the inspection being centralized in the chief maintenance department; or

ii. decentralized workshops in the large productive sections and centralized maintenance for smaller departments, and also centralized maintenance for certain kinds of equipment which have special requirements for maintenance.

The choice of the appropriate degree of specialization depends on the actual costs, the quality and the quantity of activities as well as the actual down-time of machines in repair.

Finally, there is a basic organizational problem in regard to *management of repair and maintenance activities*. A decision must be taken on the degree of centralization of management and on the incorporation of maintenance and repair activities within the organizational set-up of the enterprise. Two alternative solutions are possible for the latter problem:

i. all personnel is subordinated to the chief of the whole repair section (usually for electro-maintenance, maintenance of measuring devices and maintenance of buildings);

ii. the personnel is partly subordinated to the chiefs of various production sections, and to the maintenance chief only in regard to methodology and professional aspects of maintenance and repair.

The maintenance chief is alternatively subordinated to:

i. the production manager,
ii. the technical manager or
iii. the director.

The subordination to the production director is often problematic, since maintenance in the short term may conflict with the aim to maximize the output. There may be a tendency to postpone or neglect repairs. This risk can be avoided or reduced, if the technical manager is in charge. The direct subordination of the maintenance manager to the director, finally is particularly suitable for large plants with complex equipment and a great number of repair and maintenance workers.

As can be seen, there are no fixed criteria for choosing one of these alternatives. The choice depends on the actual conditions in the enterprise and its experiences from the past.

## 2. The Recording System

The analysis and planning of repair and renewal necessarily requires a systematic collection of information on the existing capital stock and its development. This information usually serves as a basis not only for the actual managing of repair and maintenance activities, but also for tax calculation, capacity planning, etc.

The two basic kinds of records are the financial book-keeping and the operational technical recording.

The **financial book-keeping** deals with money-value of installed plants and equipment, of depreciation, of maintenance and repair costs, etc.

It requires a stock-taking of plants and equipment which is a problem in itself, since it depends on the method of evaluation. In general, there are three ways of evaluating the existing capital stock:

— in terms of the original purchase cost,
— in terms of contemporary purchase cost,
— in terms of balance value (net, after depreciation).

Generally, however, the method to be used for evaluating installed plants and equipment is determined by governmental regulations.

The value of installed plants and equipment includes the purchase cost, transportation cost and the cost of putting them into operation, i.e. the assembling, mounting and installation.

The **operational technical recording** is the source of primary information for the control of renewal, repair and maintenance activities. Basic elements are the inventory list and the inventory card.

The *inventory list* summarizes the installation of plants and equipment in a chronological order, while the *inventory card* gives the detailed basic information on plants and equipment. The inventory card usually serves both the financial accounting and technical decisions. The contents and form of such a card naturally depend upon the kind of plant and equipment and the maintenance system. An illustrative example is given in *Table* 10.

Usually, the necessary details and records concerning maintenance, lubrication and spare parts are noted on the card. Records on the costs of individual pieces of equipment on the other hand are only kept for valuable equipment and if highly developed systems of accounting are used. These records serve as a basis for a systematic evaluation of renewal alternatives.

To enable a rational decision on renewal, repair and maintenance it is important to have a constant flow of up-to-date information on innovations, i.e. new technologies and new lines, which offer possible alternatives to those currently in use.

*To enable a rational decision on renewal, repair and maintenance, it is important to have a constant flow of uptodate information on innovations.*

The introduction of a rational information system on installed plants and equipment requires various methodological and organizational preconditions, such as:

i. the definition of an "inventory item"
ii. the determination of its code number
iii. the classification of plants and equipment
iv. introduction of the new plants and equipment in the control records
v. regulations concerning periodical inventories.

An **"inventory item"** is the smallest separate unit of plants and equipment. The concept "inventory item" is usually determined in tax laws which define the minimum value of an "inventory item" or the minimum period of its service life. In this way a dividing line is drawn between investment items and other minor or short-lived items. In the case of buildings, each separate building is an inventory item, irrespective of whether it actually stands alone or is located within a block of buildings. In the case of structures, each separate part which fulfills a certain technical or economic function and has all accessories of the whole complex forms an inventory item. More complicated is the definition of an inventory item in those kinds of equipment which have a large number of components and various accessories. The telephone system of a plant, for instance, can be considered as one item including connecting lines and telephone sets. In the case of a boiler house it is, however, opportune to use the boiler with the supporting frame, gallery and foundation as a separate inventory item, and the economizer, the ventilator, pipes, stock,

**Table 10**

## EQUIPMENT RECORD

*Inventory No.* *W—*

*Item*
Purchased from
Manufacturer

| | | | |
|---|---|---|---|
| Horse Power | AMPs. | Serial No. | Type |
| Speed (PRM) | Ouput Speed | Model No. | Size |
| Volts | Ratio | Style No. | Capacity |
| Phase | Frame | Cat No. | Dimensions |
| Cycles | Job No. | Drawing No. | Shipping Weight |

Additional Descriptive Data and Comments
Drives W. Item
Driven by H.P.
Used in connection with W. Item

Through Transmission speed reducer and Inv. No.

| *Date of Purchase Transfer* or Salvage | *Reg. No.* | *Branch* | *Location* | *Remarks* |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |

Packing specification
Bearing data
Lubrication data
Drive specifications
Frequency of P.M. Inspection
Item for P.M. Inspection
Inventory No. of auxiliary equipment

Daily | Weekly | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec

Spare parts stock list

| *Symbol No.* | *Description* | *Mfgs. Part number* | *Max* | *Min* | *Unit cost* |
|---|---|---|---|---|---|
| | | | | | |

*Source:* L.C. Morrow: Maintenance Engineering Handbook, Mc Graw-Hill Book Company, Inc. 1957 fly ash handling equipment, etc. each as separate inventory items.

**Code numbering** of inventory items enables a permanent, uniform and univocal identification of plants and equipment by a symbol, usually a number. Code numbering is the best solution also for mechanized recording. Since the number of inventory items generally arrives at thousands, in such cases it is not possible to make a separate coding for the technical characteristics of each item.

*Code numbering of Inventory items enables a permanent, uniform and univocal identification of items and equipment.*

As a rule, the items are numbered chronologically. Sometimes it is useful to combine the identification number with the classification number, as shown in Table 11.

The further basic step for introducing an information system is the *classification of plants and equipment*. The simplest and most general way of classifying capital means is to divide them into two groups: buildings and machinery. These two groups can be divided further in a more detailed classification. The machinery component, for instance, can be broken down into : production machinery and equipment, power equipment, driving and transmission equipment, transportation means, instruments, etc. However, even this type of classification is usually too rough to serve as an operational technical information system. An example of a more detailed classification is given in Table 12, which shows the decimal classification system used in the Czechoslovak engineering industry. In this case a classification number stands for a rather detailed technical characteristic.

The introduction of the new plants and equipment in the control records is an important measure for the information system. Obviously, the starting point for the record-keeping of plants and equipment is the installation during

**Table 11**

AN EXAMPLE OF A SYSTEM OF CODE-NUMBERING OF PLANTS AND EQUIPMENT

| *Classification number* | *Group of plants and equipment* | *Inventory number* | *Number of possible items* |
|---|---|---|---|
| 1 | Buildings | 101—199 | 99 |
| 2 | Structures | 201—299 | 99 |
| 3 | Power equipment | 3001—3999 | 999 |
| 4 | Production machinery and equipment | 40001—49999 | 9999 |
| 5 | Power distribution equipment | 5001—5999 | 999 |
| 6 | Transportation equipment | 6001—6999 | 999 |
| 7 | Instruments etc. | 7001—7999 | 999 |
| 8 | Animals | 801—899 | 99 |
| 9 | Land, land improvements | 901—999 | 99 |

which the following actions are to be taken:

i. the item is given an "inventory number";

ii. the item is registered in an inventory list;

iii. a permanent equipment record (inventory card) is established;

iv. the technical documentation is registered.

The **periodical inventories** are the revisions of the records which from time to time are necessary. They are based on a comparison of the records with the real state of plants and equipment.

An inventory of plants and equipment is usually combined with the inventories of other items of the capital assets, such as unfinished investments, unfinished production, stocks of material, stocks of products, etc. The inventory of plants and equipment can be carried out in connection with a technical inspection. A special case of inventory is the so-called "general inventory", organized for the whole industry or country.

### 3. Analysis of the Economic Efficiency

The analysis of "needs and resources" of renewal, repair, etc. is explicitly or implicitly an optimization analysis. Repair requirements of a machine are not determined exclusively by the technical circumstances. i.e. by its physical wear and technical functions. Ultimately, also criteria of economic efficiency play a decisive role, since a decision to carry out a repair also means an extension of the "life" of the existing part of installed capacities. Such a decision therefore necessarily is an outcome of economic rather than purely technological considerations.

The methodology of assessing the economic efficiency for decisions on new investment as well as on repair and renewal is subject to profound theoretical discussions in the literature. In the following some of the basic methodological concepts will be introduced. It should be noted that the problem of evaluation cannot be solved by a mere application of simple or even complex formulas based on a system of indicators. It must also include the utilization of relevant broader experiences and qualified prognoses.

**Table 12**

DECIMAL CLASSIFICATION SYSTEM

(example)

| *Classification code* | *Description* |
|---|---|
| 4 | Machines |
| 402 | Machines in engineering industry |
| 4024 | Metal-cutting machines |
| 40241 | Centre lathes |
| 402412 | Centre lathes with 250-315 mm turning diameter |
| 4024122 | Centre lathes with 250-315 mm turning diameter and 750-1000 mm bed length |

The logical structure of the efficiency evaluation is the confrontation of the aimed utility function with the given restrictions. The first methodological precondition for such an evaluation therefore is the establishing of an *utility function*. Usually, the maximization of profit is considered to be the main utility function. In the case of repair vis-a-vis renewal the maximization of profit is identical with the minimization of production costs. Thus, the first step of efficiency evaluation is the calculation of the operation costs.

The **Calculation of the operation costs of** a repaired machine as compared with the costs of a new machine is usually rather complicated. Such a calculation, therefore, both can and should be limited to consider those items which are specifically subject to changes due to renewal, such as:

— basic wages
— depreciation charges
— materials cost
— instruments cost
— repair and maintenance cost
— energy
— technical preparation of production.

## Table 13

EVALUATION OF THE ECONOMIC EFFICIENCY OF A REPAIR AND/OR REPLACEMENT OF A MACHINE

### I. Characteristics

| | | | |
|---|---|---|---|
| Subject of analysis: | Replacement of two universal lathes by a semi-automatic profiling lathe | | |
| Product-mix and volume of output: | No changes | | |
| Description of alternative solutions: | | *Alternative A* | *Alternative B* |
| | | Maintaining the old technology: production on two universal lathes utilized for more than two shifts a day; lathes require major overhaul. | Introduction of a new technology, usage of one new semi-automatic lathe. |

### II. Operational cost (in $)

| | *Alternative* | | *Differences between alternatives* |
|---|---|---|---|
| | A | B | (A-B) |
| Wages | 3030 | 1310 | 1720 |
| Materials (basic) | | | |
| Materials (overhead) | | | |
| Energy | 1030 | 1200 | —170 |
| Instruments | 330 | 350 | —20 |
| Routine repairs and maintenance | 500 | 400 | 100 |
| Depreication charges | 690 | 1300 | —610 |
| Rejects | 200 | 30 | 170 |
| Technical preparation of production | | 80 | —80 |
| Total savings in case of alternative B | | | 1110 |

### III. Resource Requirements (in $)

| | *Alternative* | | *Differences between alternatives* |
|---|---|---|---|
| | A | B | (B-A) |
| Investment outlays | — | 8750 | 8750 |
| Overhaul cost | 5430 | | —5430 |
| Balance (resale) value of discarded lathes | | —2008 | —2000 |
| Start-up costs associated with new machine | | 250 | 250 |
| Difference in outlays | | | 1570 |

### IV. Results

| | |
|---|---|
| a) Annual savings in production cost | 1110 U.S.$ |
| b) Difference in investment (once for all) outlays | 1570 U.S.$ |

The main restriction for achieving the given utility function are the *investment* funds or the investment costs respectively. These consist not only of the actual investment outlays (purchasing or repair costs, respectively), but also of the costs of introducing the new technology, the costs of installation, the costs connected with the demontage, etc.

An illustrative example of a calculation of operation costs and investment costs is given in Table 13. In the example we assume that two universal centre lathes are in operation. One of the lathes is now due for an overhaul, and the other will be due for an overhaul in two years time.

The two alternatives to be evaluated are:

(A) the carrying out of these overhauls

(B) the replacement of the two lathes by one semi-automatic lathe.

If the replacement is carried out instead of the two overhauls, the wage costs will be reduced. On the other hand, the costs of electro-energy, maintenance and routine repairs, of instruments and of the technical preparation of production will increase. The costs of an overhaul of an universal lathe are estimated at US$ 3,000. The present value of the second machine-tool overhaul is naturally less, since it occurs first in two years' time. The cost of a new semi-automatic lathe is estimated at US$ 10,000. The costs for introducing the new technology represent about US$ 300. The replacement of two universal lathes by one semi-automatic lathe will reduce the floor area by 10 $m^2$. It is appropriate to include the reduction in floor area (expressed in investment outlays per 10 $m^2$ of floor area) in the calculations, since all rationalization measures within the given plant also should economize on floor area, thereby reducing the requirements for extensions.

## Evaluation of Efficiency

There are different methods for evaluating the efficiency of renewal and repair. The simplest methods are based on the following criteria:

— the length of the pay-off time (minimizing)
— the rate of return (maximizing)
— the average cost (minimizing).

Each of these methods can be applied in a variety of forms. Here, however, we will only deal with the simplest forms of application.

The method based on the length of **pay-off** is applied in the following procedure: The annual cost savings resulting from the use of the new machine vis-a-vis the utilization of the old machine, are compared with the amount of investment according to the formula:

$$k = \frac{I_2 - I_1}{C_1 - C_2}$$

where k is the coefficient of economic efficiency of the renewal (2) as compared with the overhaul (1);

$I_1, I_2$ are the purchasing costs involved in the overhaul ($I_1$) or renewal ($I_2$); and $C_1$, $C_2$ are the annual costs of production of the old repaired machine ($C_1$) or the new machine ($C_2$).

The results of the calculation are then confronted with a "normative" pay-off period, which plays the decisive role in evaluating the results of an efficiency analysis of this kind.

In the case mentioned in Table 13, the coefficient representing the pay-off time is

$$k = \frac{1570}{1110} = 1.4$$

This result is usually interpreted in that way that the new machine pays for itself in 1.4 years. If the minimum pay-off period has been determined to, for instance, 2 years* the alternative of renewal is acceptable.

*According to the Journal *Manufacturing Industries* Vol. XV, No. 1, p. 27, about 60% of US companies require the pay-off period in the range of between 1.5 and 3 years.

The **rate of return method** is in its simplest version very similar to the above pay-off method. Its basic component is a coefficient representing the inverted value of the above mentioned formula, viz.:

$$k = \frac{C_1 - C_2}{I_2 - I_1}$$

$C_1 - C_2$ is reduced by the depreciation charges caused by the installation of the new machine. The empirical value of the calculation is then compared with the required rate of return. In the case presented in Table 13, the value of the coefficient is

$$k = \frac{1110}{1570} = 0.71$$

This value is—explicitly or implicitly—compared with an internal rate of return. If this internal rate is set at for instance 20%, the renewal (which has a rate of return of 71%) would in this case be recommended.

The **minimum average cost method** basically means that an item is to be replaced when the sum of the lowest combined annual average of operating costs and capital costs of a new machine is smaller than the corresponding average of costs caused hereafter by the old machine.

This method can be illustrated by a hypothetical example. According to the figures given in Table 14, the minimum average cost of a new machine with seven years service life is $ 4386. The replacement is carried out when the old, repaired machine causes a minimum average cost which is higher than this figure. As a rule, the present annual operating costs of an old machine are considered to be at their minimum, since it is assumed that the costs are rising from year to year.

A problem common to each form of efficiency analysis is the *time adjustment* of capital costs and operating costs. This adjustment is carried out to discount receipts and expenditures spread unevenly over time. Theoretically, the internal rate of return for replacement should be higher than (or equal to) the rate of return obtainable from alternative investments with comparable risk and tax status; and lower than (or equal to) the costs for obtaining outside financing.

In Table 14 an example is given also of a calculation with time adjustment. The interest rate used is 10 per cent. In this case the renewal is effcient if the annual average costs of the old machine are higher than $ 4173, compared with time-adjusted total cost.

## 4. Planning

Planning of renewal and repair can be defined as the explicit coordination of future requirements and supplies. Thus, it is the establishing of a material balance of the requirements for renewal, repair and maintenance in physical and/or value terms against available repair and maintenance capacities, including allowance for external services and supplies. Two different kinds of plans can be distinguished, i.e. general plans and operational plans.

**General plans** mainly aim at balancing on a long-term basis the requirements of renewal, repair and maintenance against available resources within the framework of the system of plans of the enterprises. In the case of long and medium-term plans, ranging from about 4-10 years, great attention has to be paid to the choice between renewal and overhauls as alternatives of the equipment strategy. Another crucial point of long-term planning is the assessment of future capacity resources for repair and maintenance.

While the long-term plan consists of a system of rather aggregated indicators, the **annual plan** for renewal, repair and maintenance is more detailed. The example given in Appendix I of this paper can be regarded as an illustration of a system of indicators suitable for annual planning of repair.

The concrete programming of repair and maintenance activities is a matter of **operational plans.** Their character and form depend on the choice of maintenance system (see Table 5). Two basic kinds of operational plans for maintenance can be distinguished: (i) plans based on inspection regulations, viz. "after-checking planning", and (ii) plans based on fixed maintenance and repair standards.

**After-checking operational planning** of repair requires qualified and experienced personnel (inspectors), advanced operative planning in repair shops and a relatively large stock of spare parts. It is primarily suitable for buildings and structures and for equipment with an ambiguous course of wear. An illustrative example of planning on the basis of inspection regulations is given in Table 15.

**Operational planning based on fixed repair standards** is the basic characteristic of standard repair and planned preventive (periodical) repair. Its basic precondition is an elaborated system of standards. It is suitable for equipment involving a great safety risk and for a great number of identical machines of equipment in

**Table 14**

CALCULATION OF MINIMUM AVERAGE COST OF A NEW MACHINE ($)

| | Annual average for period ending with year indicated | | | | | |
|---|---|---|---|---|---|---|
| | Without time-adjustment | | | With time-adjustment | | |
| *Years of service* | *Operating cost* | *Capital cost* | *Total cost* | *Operating cost* | *Capital cost* | *Total Cost* |
| 1 | 3000 | 5500 | 8500 | 3000 | 5500 | 8500 |
| 2 | 3100 | 2750 | 5850 | 3048 | 2881 | 5929 |
| 3 | 3200 | 1833 | 5033 | 3094 | 2011 | 5104 |
| 4 | 3300 | 1375 | 4675 | 3138 | 1577 | 4716 |
| 5 | 3400 | 1100 | 4500 | 3181 | 1319 | 4500 |
| 6 | 3500 | 917 | 4417 | 3222 | 1148 | 4371 |
| 7 | 3600 | 786 | 4386 | 3262 | 1027 | 4289 |
| 8 | 3700 | 688 | 4388 | 3300 | 937 | 4238 |
| 9 | 3800 | 611 | 4411 | 3337 | 868 | 4205 |
| 10 | 3900 | 550 | 4450 | 3373 | 814 | 4186 |
| 11 | 4000 | 500 | 4500 | 3406 | 770 | 4176 |
| 12 | 4100 | 458 | 4558 | 3439 | 734 | 4173 |
| 13 | 4200 | 423 | 4623 | 3470 | 704 | 4174 |
| 14 | 4300 | 393 | 4693 | 3500 | 679 | 4178 |
| 15 | 4400 | 367 | 4767 | 3528 | 657 | 4185 |

(Figures do not always add, because of rounding.)

*Source:* G. Terborgh, Dynamic Equipment Policy, McGraw-Hill, New York, 1949

**Table 15**

DAILY INSPECTION SHEET

*Dept.* *Date*...................
*Inspector*
*Torn* 2

| **Mech** | | **Elect** | **Lubr.** | **Hydr.** | **Pneu** | **Misc** |
|---|---|---|---|---|---|---|

| **No.** | **Equipment** | **SYM. SCH.** | **Remarks** | **Reason for Repairs** | **No.** |
|---|---|---|---|---|---|
| 1 | Stiff leg | A | | 1. Sub linea broken | |
| 2 | Pit covers | A | | | |
| 3 | Ingot buggy | B | | 2. Sub linea off | |
| 4 | P.C. cranes | E | 1 | on 4 lead rollera | |
| 5 | Charge crane | A | | | |
| 6 | F.B. Tables | E | 2 | | |

One sheet each turn for type of inspection

MAINTENANCE INSPECTION LOG SHEET

| **No.** | **Equipment** | **T.C.** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Stiff Leg | | | | | | | | | | | | | | | | | | | | | | |
| | Mechanical | 3 | | | | | | | A | | | | | | | A | | | | | | | A |
| | Electrical | 3 | | | | | | | A | | | | | | | A | | | | | | | C |
| | Lubrication | 3 | | | | | | | A | | | | | | | A | | | | | | | E |
| 2 | Pit covers | | | | | | | | | | | | | | | | | | | | | | |
| | Mechanical | 3 | | | | | | | C | | | | | | | C | | | | | | | A |
| | Electrical | 3 | | | | | | | A | | | | | | | A | | | | | | | A |
| | Lubrication | 2 | A | A | A | A | A | A | A | A | A | B | A | C | B | B | C | A | B | A | A | A | B |
| 3 | Ingot Buggy | | | | | | | | | | | | | | | | | | | | | | |
| | Mechanical | 2 | A | A | B | B | A | B | C | B | A | A | A | A | C | B | A | A | A | C | B | B | B |
| | Electrical | 2 | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A |
| | Lubrication | 2 | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A |

T.C.=Time cycle
1—Every 8 hours
2—Every 24 hours
3—Every 7 days
4—Every 28 days

Symbol schedule:
A—No repairs
B—Minor repairs
C—Routine repairs
E—Emergency repairs

*Source:* Morrow L.C.: Maintenance Engineering Handbook, Mc. Graw-Hill Book comp. Inc. New York 1957

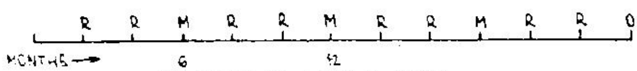
## Table 16

REPAIR STANDARD

EQUIPMENT: COMPRESSOR

| KIND OF REPAIR | REPAIR CYCLE (HOURS) | REPAIR TIME (HOURS) | REPAIR LABOUR INPUT (HOURS) | AVERAGE NUMBER OF REPAIRS PER YEAR | COST OF ONE REPAIR IN 1000 Kcs | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | MATERIALS | WAGES | OVERHEAD | EXTERNAL SERVICES | TOTAL |
| O | 17 520 | 300 | 1600 | 1/2 | 30 | 16 | 20 | 5 | 71 |
| M | 4 380 | 60 | 250 | 3/2 | 4 | 2,5 | 2,5 | - | 9 |
| R | 1 460 | 15 | 50 | 2 | 1 | 0,5 | 0,5 | - | 2 |
| YEARLY AVERAGE | | 270 | 1 265 | x | 23 | 12,7 | 14,7 | 2,5 | 53,0 |

NOTE: O - OVER-HAUL
M - MEDIUM REPAIR
R - ROUTINE REPAIR



STRUCTURE OF A REPAIR CYCLE

| PRODUCTION UNIT: | ANNUAL PLAN OF REPAIRS FOR 19 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EQUIPMENT NUMBER | MONTH | | | | | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | 15/50 R [1] | R | 60/250 M | R | R | M | R | R | M | R | R | 300/1600 O |
| 2 | | M | | | 70/300 M | | | M | | | M | |
| 3 | | 10/50 R | | R | | | 200/3000 O | | R | | R | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| REPAIR TIME (DURATION OF R.) (HOURS) | 15 | 70 | 60 | 15 | 70 | 60 | 200 | 70 | 60 | 15 | 70 | 300 |
| REPAIR LABOUR INPUT (HOURS) | 50 | 430 | 250 | 430 | 350 | 250 | 3050 | 350 | 330 | 50 | 430 | 1600 |
| REPAIR COST: M PLUS R PLUS OTHER MINOR REPAIRS | | | | | | | | | | | | |
| REPAIR OUTLAYS | x | x | x | x | x | x | 120 | x | x | x | x | 71 |

ANNUAL DATA FOR FINANCIAL PLAN ... 240 PLUS 191 THOUSAND Kcs

ANNUAL DATA FOR PLANNING REPAIR LABOUR ... 7270 HOURS OF LABOUR INPUTS

ANNUAL DATA FOR PRODUCTION (OUTPUT) PLANNING (EQUIPMENT UTILIZATION) 1035 HOURS - 11,8 PERCENT OUT OF 8 760 HOURS

[1] NOTE 15/50: 15 DURATION OF REPAIR IN HOURS; 50 REPAIR LABOUR INPUTS IN HOURS

**Table 17**

STANDARDS FOR REPAIR IN THE CHEMICAL INDUSTRY (USSR)

*Equipment:* Centrifugal vertical pump, 10=25 $m^3$/hr. 70m, 2900 r.p.m. 8kw
Type of repair cycle: 7B-25-60

R = Routine repair

M = medium repair

O = Over-haul

| Kind of repair | Cycle of the first over-haul (hours) | Repair cycles (hours) | Duration of one repair (hours) | Number of repairs in one cycle | Volume of one repair (hours) | Costs (Roubles) | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Total machinery | materials | spare parts |
| O | 8640 | 8200 | 168 | 1 | 68 | 27 | 200 | 300 |
| M | | 2880 | 48 | 2 | 34 | 13 | 100 | 150 |
| R | | 720 | 8 | 7 | 10 | 4 | 50 | 80 |
| Total in one cycle | x | x | x | 10 | 206 | 81 | 750 | 1160 |

large-scale production. An example of standards for this kind of operational planning is shown in Figure F and in Tables 16 and 17.

The basic distinction between the mentioned systems of operation planning is the different degree of the flexibility of plans. Taking into consideration that in reality the needs for renewal and repair are to a certain degree influenced by factors of accidental nature, it is realized that operation planning must always be flexible to some extent. Even in the most developed systems of maintenance, certain decisions remain to be made from day to day.

## B. THE AGGREGATE LEVEL

There are a number of problems of rational maintenance, repair and renewal policy which exceeds both the technical and economic capacities of a plant and must be solved at the multi-plant, sectoral and/or national levels. The setting of these problems and their methodological solution depend on the over-all context of economic policy. Thus, the formulation of the problems and the proposed solutions will obviously be different in a market economy and in a centrally planned economy.

### 1. Analysis and Planning

The aggregate analysis and planning of repair and renewal of plants and equipment, aiming at coordinating future requirements and supplies, differ from the methods and the objectives used at the plant level.

In sectoral and macro-economic considerations regarding the process of industrialization, the assessment of requirements and resources for renewal, repair and maintenance is obviously based on highly aggregated indicators.

*With the increase in the volume of capital means in a given sector or country, the demand for renewal, repair and maintenance services increases as well.*

## *a) Demand*

The preceding paragraphs dealt with repair and maintenance of individual machines, pieces of equipment, buildings and structures. The analysis of a system of e.g. a machine park must describe the process of depreciation, renewal, modernization, etc. with quite different methods. The model of the development of machine-tools shown in Appendix II gives a relevant illustration of the content and methodology of planning and analysis at that level.

As will be explained below, the aggregate demand for renewal, repair and maintenance depends on the **characteristics of the installed capital,** i.e. the volume and the age characteristic and the structure from the point of view of service life.

*The extent of wear and the requirements for renewal, repair and maintenance are a function of the age of the stock of plants and equipment.*

It is self-explanatory that with the increase in the **volume of capital means** in a given sector or country, the demand for renewal, repair and maintenance services increases as well. It is, however, difficult to make generalizations of the ratio of this demand to the value of capital stock. On the one hand, the importance of the demand tends to increase not only in absolute terms, but also in relative terms due to the continuing process of mechanization and automation. On the other hand, the demand can be reduced through the pursuance of a rational policy of renewal, by means of rationalizing designs of machinery and, last but not least, by rationalization of the repair and maintenance activities.

In general, it can be assumed that the extent of wear and the requirements for renewal, repair and maintenance are a function of the **age of the stock of plants and equipment.** With increasing age the maintenance and repair requirements are growing, mostly with an accelerated rate. The age characteristics of plants and equipment therefore play an important role in time scheduling the requirements. But the rule is not without exceptions. Old equipment (and buildings as well) is often used for auxiliary purposes only, their precision and performance requirements are usually less strict. This can reduce their needs for renewal, repair and maintenance.

The various categories of capital means differ in regard to their needs for repair. The simplest example for this can be found in the differences between the volume of renewal, repair and maintenance requirements for buildings and that for machines. Thus, depending on these **structural characteristics** the same volume of capital can be associated with entirely different volume of repair needs. A larger share of machinery and equipment results obviously in relatively bigger requirements.

In Table 18 data are given of the share of machinery and equipment in the total value of fixed capital assets in various manufacturing industries in the USA. From these data conclusions can be drawn about the relatively higher requirements for renewal, repair and mainten-

**Table 18**

CAPITAL OUTPUT RATIOS OF MANUFACTURING INDUSTRIES IN THE UNITED STATES

| *Industries branches* | *Total* | *Machinery including electrical and transportation equipment* | |
|---|---|---|---|
| | US$* | US$ | per cent of total |
| Food, beverages and tobacco | 0.81 | 0.41 | 51 |
| Textiles | 0.91 | 0.51 | 45 |
| Wood and wood products | 0.78 | 0.39 | 50 |
| Pulp and paper | 1.13 | 0.65 | 58 |
| Printing and publishing | 0.66 | 0.42 | 64 |
| Rubber | 0.70 | 0.44 | 63 |
| Leather | 0.43 | 0.19 | 44 |
| Clothing | 0.38 | 0.18 | 53 |
| Non-metallic minerals | 1.18 | 0.67 | 43 |
| Chemicals | 0.89 | 0.35 | 61 |
| Petroleum | 5.64 | 0.94 | 17 |
| Basic metals | 2.34 | 0.92 | 39 |
| Metal products | 0.83 | 0.51 | 62 |

*Dollar of purchasing cost of capital per dollar value added in 1953 prices.

*Source:* Compiled on the basis of unpublished materials supplied by Harvard Economic Research Project.

ance of the installed capital in metal-working industries, printing and publishing, chemicals and rubber, as compared with e.g. the petroleum industry.

The data contained in Table 2 show very different requirements for renewal and repair for different kinds of buildings, structures and equipment. Equipment in the construction industry, for instance, has much greater repair requirements (the costs of an overhaul represent in average more than 10 per cent of the purchase costs per year) than machine tools in the machinery (in average about 5 per cent).†

There is a special relationship between the cost of machines and the cost of their over-haul. As a rule, overhauls of costly machines have

† These estimates of service life and cost of overhauls were originally designed for financing renewal and overhauls out of a special fund. Mainly the following data were used : estimates of average service life, standards for a cycle of major overhauls (according to the system of planned preventive repairs), and the relationship between the overhaul costs and purchase costs of a machine.

relatively lower costs of repair as related to their purchasing cost than cheaper machines. This applies, for instance, for machine tools. There are several causes for this relationship. The most important cause is probably the fact that low-cost machines mainly are produced in large series, whereas their overhauls are carried out individually. The difference in labour productivity of repair shops and or production units of new machines is in this case more pronounced than in case of larger and complex machines, which are often produced as unique pieces.

Repair and renewal requirements are, generally, interdependent: Machinery and equipment with higher renewal requirements also demand more repair. However, in some cases the accelerated renewal of equipment (shortening of service life) can result in the reduction of needs for repair. In such a situation, the renewal requirements and repair requirements exclude each other.

*b) Supply*

From the national or sectoral point of view the resources required for renewal, repair and maintenance consist of specialized labour, capital, material supplies and stocks and specific imports of goods (equipments and spare parts).

Repair activities are characterized by large **labour inputs** both in regard to the quantity and the quality of the labour required. This is partly due to the fact that manual work prevails in the actual productive time and partly to the relatively low share of actual productive time (35% - 50%) of the total working time of repair personnel. Even with a good organization, the bulk of the working time of repair workers is spent on preparatory activities.

In the framework of the whole economy large resources of labour usually are engaged in repair activities. Out of the population of 14 million of Czechoslovakia for instance there are about 500,000 repair workers.

Compared to the labour input in repair activities the **capital inputs** are generally not large. Thus, in Czechoslovak repair shops there is only 28,000 Kcs worth of fixed capital stock per worker, whereas in the chemical industry the figure is 220,000 Kcs.

**Material inputs** are also not large in volume. The variety of materials required in repair shops on the other hand is generally large. Keeping an adequate level of stocks of spare parts and materials therefore requires relatively large amounts of **working capital.**

A country's requirements for maintenance can normally be met only partially by domestic resources. The degree of self-sufficiency in maintenance services, in supplies of spare parts, etc. depends primarily on the size of the economy and on the level of the economic, particularly the industrial development achieved. Developing countries are to a large extent dependent on imports of capital goods, especially machinery. This is reflected in the high **import rates** of maintenance services and deliveries of spare parts and components for renewal.

*c) Techniques of planning*

A country's plans for renewal, repair and maintenance at the aggregate level are generally not prepared in details, and they only exceptionally have the form of material balance sheets. This also is true for centralised planning systems, where in most cases only partial analysis and plans are made with a view to applying specific policy measures.

Such a partial analysis can for instance aim at assessing the needs for renewal. **Sectoral studies** would then be the most suitable method of analysis. The sectoral studies are generally examining the existing state of installed capital means and the overall investment climate and will include the evaluation of installed machines from the viewpoint of their replacement by new machines. For the latter purpose the technological level of machines has to be reviewed and be compared with the technological innvovations.

The analysis of the needs for renewal, based on the examination of the economic efficiency of replacement investment, usually requires plenty of data and large inputs of highly qualified labour. When these prerequisites are not available, a different, less demanding method of comparative analysis is being used. The technological level and structure, the age and composition of machinery and equipment in a certain sector of the country in question are then compared with the situation in another country in which this specific sector is more developed. The volume of resources needed can subsequently be calculated by using approximative methods.

## 2. Policy Measures

Governmental action in solving renewal, repair and maintenance problems mostly takes the form of technical, organizational as well as financial policy measures. The **technical measures** include the promotion or eventually the actual establishing of:

- specialized repair shops and servicing facilities
- central stocks of spare parts
- design and technical bureaus, research institutes and organs of state inspection
- educational and training facilities, etc.

These actions must be based on a systematic analysis of the economic and technical feasibility from the national point of view. Thus, the question of the establishment and the size of specialized repair shops, stocks, and the various institutions must be thoroughly investigated.

**Specialized repair shops** as the technical basis for rational supplies and services have been discussed in an earlier section. In regard to the organization of specialized repair shops it is necessary to consider on one hand the savings, resulting from higher productivity of the shops and the improved quality and shorter time of the repair services and on the other hand the losses. These are mainly increased transport costs, the reduced flexibility and speed in coping with breakdowns and the lack of knowledge of concrete conditions of equipment operation.

To determine a general, appropriate ratio between (a) the volume of repair and maintenance to be carried out by workshops of plants and (b) the volume performed by external suppliers is not possible. The ratios of different industries vary substantially. They also depend on the type of capital means in use. Large differences exist even between different countries. These differences cannot be explained merely by the different levels of industrial development, but also by actual habits, traditions and the institutional set-up. In USA, for instance, about 80 per cent of all plants use external repair services, but the external suppliers perform on average only 7.6 per cent of the total volume of repair work. In the Federal Republic of Germany and in Eastern Germany, on the other hand, chemical plants use external services to a very little extent. In Japan, repairs are usually performed by external firms, particularly by the suppliers of the equipment.

*Governmental action in solving renewal, repair and maintenance problems mostly takes the form oftechnical, organisational as well as financial policy measures.*

Decisions regarding **central stocks of spare parts** at the national, sectoral or regional levels are based on similar considerations. Specialized repair shops also form a natural basis for storing and distributing the spare parts.

The design and technical bureaus, research institutes and organs of state inspections have the following functions:

- to provide consultative services in regard to the rational repair and maintenance of equipment;
- to develop the "type" project of the organization and the techniques of repair and maintenance;
- to adapt the design of imported machinery and equipment to localconditions:
- to develop a system of technical standards, which would promote the unification and standardization of the equipment;
- to establish a system of state inspection for crucial parts of plants and equipment (electro energy, hydropower plants, etc.), especially in cases where major safety risks are involved.

The government plays an important role in promoting or establishing these institutions. Many developing countries lack this necessary institutional set-up.

In the field of **education and training** the governmental policy comprises the following measures:

- promotion of the education of skilled labour by establishing training centres and vocational schools;
- encouragement of closer contacts between industries and educational institutions;
- inclusion of the problems of maintenance, repair and proper operation of equipment into the curricula of vocational schools;
- the organization of exchanging experience among repair and maintenance personnel.

In addition to these various direct actions, the government can apply **indirect measures.** In order to promote proper maintenance, repair and renewal, the government can specifically impose some of the following policies:

i. a rational depreciation policy aiming to create conditions for efficient modernization of installed plants and equipment;

ii tax and credit policy measures, or subsidies and/or state capital participation to promote the establishing of specialized repair shops, stores of spare parts, and specialized plants producing spare parts;

iii. foreign exchange and tariff regulations to create conditions for adequate imports of spare parts and technical services as well as for the rational policy of renewal of machines which are not produced domestically.

Taking into account the adverse balance of payment and scarcity of foreign exchange, generally prevailing in developing countries, the **policy decisions related to foreign exchange outlays** on imports of replacement parts and maintenance services require special attention. In short, it can be said that the policy maker in developing country has a two-fold task. Firstly, he must minimize foreign exchange outlays on imports of spare parts and maintenance services. Secondly, he has to assure the continuous and adequate supply of these items to all public and private enterprises.

To achieve these aims, the government could adopt several measures. First of all the government should endeavour to increase the efficiency of maintenance and the economy in spare parts utilization. In this connection it is important to improve the skills of maintenance and repair personnel assigned to identify the causes of breakdown and to specify the ordering of spare parts and services. In regard to administrative restrictions and tariffs on imports of spare parts a flexible policy is needed which could allow to speed up the delivery of spare parts. Imports of spare parts should be given a special treatment from the point of view of both customs procedures and tariff policies. Finally the government could take measures aiming at rigorous import substitution policy with a view to building up domestic repair shops and workshops producing spare parts.

*Imports of spare parts should be given a special treatment from the point of view of both customs procedures and tariff policies.*

In promoting the domestic production and services the government should not restrict itself to levying high tariffs on imports of spare parts to protect the local producers from foreign competition. Temporary tariff barriers have to be accompanied by additional, positive measures from the part of the government. Thus, local production could be stimulated by technical services, cerdits, training facilities, etc. A mere introduction of administrative or tariff restrictions on imports of spare parts and maintenance services may bring certain foreign exchange savings in the short run, but will inevitably lead to under utilization of equipment. Since generally large amounts of foreign exchange had been spent on the equipment, there will then be no saving in the long run.

If, in the case of export industries, the foreign exchange savings achieved through reducing the imports of spare parts and maintenance services have adverse effects on the output, the savings could be easily compared with the eventual losses in export proceeds. In domestic market oriented industries the corresponding cost-benefit calculation involves a comparison of losses in output against the foreign exchange savings. Here a shadow price will be used for the foreign exchange in order to evaluate the losses in supplies for the domestic market. In addition it must be taken into account that the demand for other imported goods may increase. This could be due to the fact that certain domestic industries are forced to operate at a lower capacity because of lack of spare parts, etc. and that the demand therefore cannot be fully met by the domestic production.

### 3. Data Requirements

For the above-mentioned measures the governmental bodies and other relevant institutions require information on existing plants and their equipment.

The system for collecting the data as well as the type of data asked for are obviously related to the given economic system. In a market economy capital means are only exceptionally subject to centralized stock-taking, whereas in centrally planned economies usually very detailed information on capital stock in the whole national economy are collected and used in ministries, planning agencies, etc.

For the first group of countries, usually indirect **methods of estimates** are applied. The necessary data is arrived at from:

— balance sheets of individual companies,

— retrospective data on investment,

— data on output, imports and exports of capital goods, and

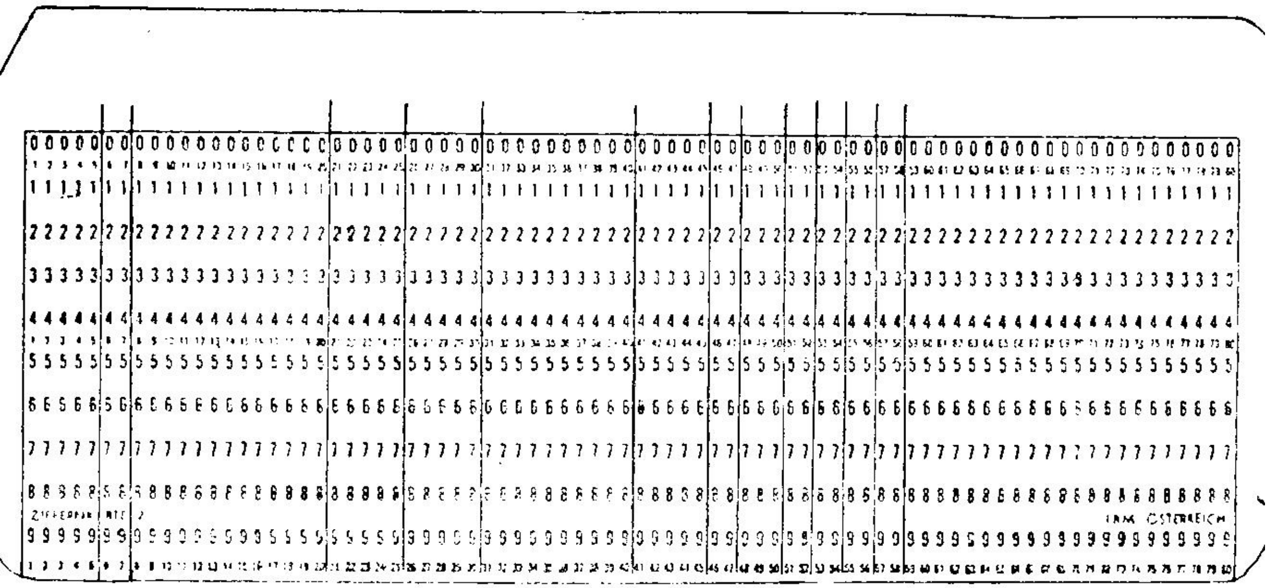
— inquiries, mainly by sampling method.*

In a centrally planned economy the fixed capital stock and its development is normally subject to a very **detailed system of information.** In Czechoslovakia, for instance, a centralized system was introduced to obtain information on the state and the annual changes of all machinery in engineering industry, of railway wagons,

*As an example can be mentioned that the US journal *American Machinist* sent out questionnaires to ascertain the state of machinery in the metal-working industry.

**Table 19**

**Description of a Punch Card for the Statistics of Installed Machines**



| *Column* | *Data* | *Column* | *Data* |
|---|---|---|---|
| 0— 5 | Classification Code | 46—47 | Year of production |
| 6— 7 | Country of origin | 48—50 | Central organ (industry) |
| 8—20 | Producer, model | 51—52 | Trust |
| 21—25 | Purchasing value | 53—54 | Enterprise |
| 26—30 | Weight in kgs. | 55—56 | Plant |
| 31—40 | Technical characteristics | 57—58 | Shop |
| 41—45 | Maintenance characteristics | 59— | Free columns |

important machines in coal mining, etc.

The data collected are not only in terms of value but also of technical nature. The whole system is based on a rational computing technique (punch cards). The contents of the system can be seen from the illustrative example of a punch card in Table 19.

Such a detailed system of centralized information requires a whole complex of organizational prescriptions, normative definitions, classification and code numbers. This is necessary to enable the identification of a given machine and to get information about the extent and composition of machine park in different enterprises, industries, regions, etc. The system is based on primary records provided in plants according to a standard form. It becomes an efficient means for the rationalization of the information system within individual enterprises.

In all economic systems governmental tax policy requires some basic **unification of recording** on installed capital. Special regulations usually define the methods of the book-keeping on plants and equipment and their definition and evaluation as well as the periodical inventories.

Most problems connected with these regulations were already discussed from the point of view of plant level. A specific problem is the **re-evaluation** of installed plants and equipment in such cases, when the nominal values differ widely from the present real values. The process of re-evaluation of installed plants and equipment is a very expensive and complicated one. The aim of such a unified way of evaluation is to create a more reliable basis for the calculation of amortization charges. The evaluation is based alternatively on price indices or on price lists. A new evaluation can be combined with the so-called "general inventory" (inventory of existing plants, equipment in the country, region, industry). Such measure was undertaken in 1954 in Czechoslovakia, in 1960 in the USSR.

## 4. Recommendations for Development Strategy

Developing countries execute their industrialization programmes in the conditions of much higher investment intensity of the industrialization process than it used to be in the nineteenth century in now industrialized countries. In addition, a rather pronounced division of labour has developed between the actual operation and the maintenance of plants and equipment. That is the reason why the problems of repair and maintenance have gained such importance and consequently have become an inherent part of a sound development policy.

The lack of capacity to assure adequate maintenance and repairs is one of the reasons why some developing countries often are not capable to adopt new technologies. In such a situation even equipment provided through grants can become a burden for the receiving country.

The problem area of renewal, repair and maintenance has a number of aspects relevant for the formulation of fundamental principles which underly the setting of long-term aims of economic development:

i. The renewal, repair and maintenance of the existing plants and equipment is one of the essential conditions for the economic development;

ii. renewal and, to a certain extent, repairs represent an alternative to the building up of new capacities.

Renewal, repair and maintenance place specific demands on economic resources and they, consequently, represent an important limitation to ecomomic development in an optimalization exercise.

The needs for renewal, repair and maintenance also determine to a certain extent a substantial part of the demand structure for commodities. We can therefore speak about a structural limitation of the process of. economic development.

A certain similarity can be found between the supplies of services, spare parts and machines for renewal on the one hand and the supplies of intermediates on the other hand. Problems of repair and renewal are treated accordingly. All supplies mentioned are described in the matrix of inter-industry relationship (technical coefficients). Further-more, renewal, repair and maintenance place specific demands on qualified labour and material supplies. In this context we can speak about a limitation of economic development from the viewpoint of available resources.

*Maintenance, repair and renewal require productive factors of the same technological nature as those required by the supplies for the new investments.*

Maintenance, repair and renewal require productive factors of the same technological nature as those required by the supplies for the new investments. Essentially, the factors of engineering industries and construction are involved. Maintenance, repair and renewal thus create a competing demand in relation to the building up of new productive plants. They, in particular, need a great number of skilled personnel at intermediate levels which is the very scarce factor in developing countries.

In the conditons of severe scarcity of investment resources—both financial and material—renewal can be considered as an **alternative to development.** In order to concentrate investment resources on important development projects it is possible to delay the renewal of existing plants and equipment, i.e. to prolong their service life. Developing countries usually do not need to economize labour costs through innovations and modernization of equipment in the same degree as industrialized countries. On the contrary, investment is often motivated by the aim to create additional employment opportunities. Thus abundance of labour stimulates a rational extension of the service life of the installed capital.

In developing countries the share of machinery older than 10 or even 20 years of the total equipment is rather large. This is a natural reflection of the delayed renewal of equipment in favour of extensive new investment and the increase in industrial employment.

To a certain extent it is possible to delay also major overhauls. Technical possibilities of postponing renewal and/or repair have, of course, certain technological and economic limits the trespassing of which results in the misallocation of resources.

As an example of such misallocation, inefficient or too costly repairs may be mentioned. Introduction of measures limiting investment outlays on renewal may lead to the situation when the cost of overhauls become higher than the cost of purchase of new equipment.

In the pursuing of an industrialization programme the **modernization and rational utilization of older machinery** acquire strategic importance, since in this way the existing equipment of several industries can be adapted to the requirements of modern technology. Modernization is usually less costly (in terms of investment funds) than renewal, and it facilitates the adapting of machinery to the concrete conditions of production.

Another important way of reducing investment outlays for the industrial development is the purchase and use of second-hand machines and equipment. Such a utilization of older machines can obviously be considered rational, only if the cost of their repair and modernization is less than the cost of new machines. The application of the efficiency analysis is therefore absolutely necessary. Installation of second-hand equipment can on one hand reduce the purchasing cost, but on the other hand, it usually increases the repair and maintenance costs. Furthermore, the use of second-hand equipment generally is a hindrance to the unification of installed equipment. Efficiency considerations are therefore necessary even in cases of very favourable purchasing conditions.

Various material and organizational preconditions are required to assure adequate maintenance, repair and renewal. These preconditions form an important part of the **industrial infrastructure.** A large part of this infrastructure is represented by maintenance and repair capacities of enterprises. As was discussed already in connexion with the policy measures, the building up of specialized repair shops, plants for production of spare parts and their stocks form a specific problem for the policy maker. Among the institutional conditions for facilitating a smooth operation of plants and equipment an important role is played by the whole set-up of training, consulting and research institutions.

The problem of maintenance, repair and renewal also has an impact on the **time-scheduling** in economic programming. The demand for renewal and/or overhaul usually arises several years after the plant and equipment had been put into operation. However, from the very beginning of the operation, an adequate maintenance and repair work is required. The conditions for assuring these services must be created from the very outset of the execution of the investment programme.

The rules governing the needs for repair (mainly overhauls) and renewal are of stochastic character. Most of the requirements appear after a period corresponding approximately to the average service life of given equipment and its parts. The necessity to have maintenance and repair capacities installed from the beginning is enhanced by the frequent incidence of the so-called infant-illnesses of the equipment.

The time-scheduling must include the advance training of an adequate number of repair and maintenance workers and lubrication specialists. Approximately half the number of these workers must be available during the running-in periods of equipment. Analogically, the primary stock of spare parts and maintenance materials must be available from the very beginning.

Finally, it can be mentioned that maintenance and repair activities can be viewed upon as the natural basis for the development of domestic engineering industries.

APPENDIX I

# A SYSTEM OF INDICATORS FOR PLANNING REPAIR

The simplified example of a repair plan represents a system of the most important indicators reflecting the inter-relationships between needs and resources of repair activities. The data are obtained from empirical studies.*

The repair needs are here calculated for various types of plants and equipment, which differ in the intensity of repair or in the labour or material requirements. The following example classifies four groups of plants and equipment:

i. machinery
ii. electro equipment
iii. measuring devices
iv. buildings and constructions.

The necessary resources are classified as follows:

i. labour inputs:
 — repair workers
 — technical and administrative personnel
ii. material inputs:
 — spare parts (flows and stocks)
 — produced in own workshops
 — external deliveries
 — other materials (flows and stocks)
iii. external repair (services delivered from outside)

The final balance of the requirements for repair against resources is obtained on the basis of cost calculation.

Under "preconditions" we understand here a system of standards which form the basis of a repair plan and which define:

i. the relative needs of repairs for the different categories of fixed assets,
ii. the relative inputs of labour & material,
iii. the relative volume of stocks of spare parts and materials, and
iv. the degree of self-sufficiency of the enterprise or industry in repair services and production of spare parts.

The determination of these standards is based on thorough analyses which precede the actual planning process.

The example is meant to cover a period of up to 5 years. It can be applied both for an individual enterprise and for more aggregated units. According to the length of the plan period and the level of planning, the needs and resources for repair can be disaggregated. Thus, the needs can be divided according to different kinds of machines, different kinds of repairs, etc. The classification of spare parts and material inputs can be done according to technological, organizational or other criteria.

*The studies were undertaken in the Czechoslovak chemical industry.

**Table I/1**

A PLAN OF REPAIR

| *Item* | *Indicator* | *Unit* | *Total* | *Machinery* | *Electro equipment* | *Apparatus* | *Construction* |
|---|---|---|---|---|---|---|---|
| | I. PRECONDITIONS | | | | | | |
| A | Value of fixed assets | 1000 $ | 50000 | 24500 | 5000 | 3000 | 17500 |
| B | Cost of repairs related to the value of fixed assets | % | x | 8.0 | 7.0 | 12.0 | 1.3 |
| C | Degree of repair self-sufficiency | % | x | 70.0 | 70.0 | 60.0 | 20 |
| D | Degree of self-sufficiency in the production of spare parts | % | x | 25.0 | 20.0 | 15.0 | x |
| E | Annual volume of repair per repair worker | 1000 $ | x | 8.0 | 7.0 | 8.3 | 5.5 |
| E' | Volume of fixed assets per repair worker | 1000 $ | x | 100.0 | 100.0 | 70.0 | 440.0 |
| F | Annual consumption of spare parts per 1000 $ of fixed assets | $ | x | 14.3 | 10.4 | 16.2 | x |
| G | Annual consumption of materials per 1000 $ of fixed assets | $ | x | 4.1 | 5.6 | 7.0 | 0.9 |
| H | Stock of spare parts per 1000 $ of the fixed assets | $ | x | 21.5 | 18.7 | 26.0 | x |
| H' | Stock of spare parts in relation to the annual consumption | years | x | 1.5 | 1.8 | 1.6 | x |
| I | Stock of material per 1000 $ of fixed assets | $ | x | 4.1 | 5.6 | 7.0 | 0.6 |
| I' | Stock of material in relation to annual consumption | years | x | 1.0 | 1.0 | 1.0 | 0.7 |
| J | Average wage of repair workers per year | $ | x | 2680 | 2490 | 3080 | 2000 |
| K | Overhead costs in relation to wage costs | % | x | 100 | 90 | 80 | 70 |
| I | Technical and administrative staff in relation to the number of workers | % | x | 18.0 | 16.0 | 17.0 | 12.0 |
| | II. CALCULATION OF THE VOLUME OF REPAIR ACTIVITIES | | | | | | |
| a | Total cost of repair per year $(A \cdot \frac{B}{100})$ | 1000 $ | 2900 | 1960 | 350 | 360 | 230 |
| b | Cost of repairs realized with own capacities $(a \cdot \frac{C}{100})$ | 1000 $ | 1875 | 1370 | 245 | 215 | 45 |

**Table I/1** *(Contd.)*

| *Item* | *Indicator* | *Unit* | *Total* | *Machinery* | *Electro-equipment* | *Appa-ratus* | *Const-ruction* |
|---|---|---|---|---|---|---|---|
| c | External repairs value $(a - b = a . \frac{100 - C}{100})$ | 1000 $ | 1025 | 590 | 105 | 145 | 185 |
| | III. CALCULATION OF THE NUMBER OF REPAIR WORKERS | | | | | | |
| d | Number of repair workers $(b.E = \frac{A}{E} . \frac{C}{100})$ | Persons | 241 | 172 | 35 | 26 | 8 |
| e | Technical and adminsitrative personnel $(d . \frac{L}{100})$ | Persons | 42 | 31 | 6 | 4 | 1 |
| f | Total number of repair personnel (d+e) | Persons | 283 | 203 | 41 | 30 | 9 |
| | IV. CALCULATION OF THE SPARE PARTS AND MATERIALS | | | | | | |
| g | Annual needs of spare parts $(A . \frac{F}{1000})$ | 1000 $ | 451 | 350 | 52 | 49 | x |
| h | Annual needs of materials $(A . \frac{G}{1\,00})$ | 1000 $ | 164 | 100 | 28 | 21 | 15 |
| i | Total spare parts and material (g+h) | 1000 $ | 615 | 450 | 80 | 70 | 15 |
| j | Own production of spare parts $(g . \frac{D}{100})$ | 1000 $ | 105 | 88 | 10 | 7 | x |
| k | External purchases of spare parts (g−j) | 1000 $ | 346 | 262 | 42 | 42 | x |
| l | Stock of spare parts $(A . \frac{H}{1000} = g. H')$ | 1000 $ | 698 | 527 | 93 | 78 | x |
| m | Stock of materials $(A . \frac{I}{1000} . \frac{C}{100} = h. I')$ | 1000 $ | 159 | 100 | 28 | 21 | 10 |
| n | Stock of spare parts and materials (l+m) | 1000 $ | 857 | 627 | 121 | 99 | 10 |
| | V. COST CALCULATION | | | | | | |
| o | Labour costs per year (d.J) | 1000 $ | 643 | 460 | 87 | 80 | 16 |
| p | Material and spare parts costs (i) | 1000 $ | 615 | 450 | 80 | 70 | 15 |
| q | Overhead costs $(o . \frac{K}{100})$ | 1000 $ | 614 | 460 | 78 | 65 | 11 |
| r | Total cost (o+p+q=b) | 1000 $ | 1872 | 1370 | 245 | 215 | 42 |
| | (Differences because of rounding) | | | | | | |

APPENDIX II

# A MODEL FOR THE ANALYSIS AND PLANNING RENEWAL

The analysis of renewal requirement is a specific problem on the over-plant (sectoral, nationwide) level and in the long-term prospects. The following model is introduced here to highlight this problem. The data used for this model result from empirical studies in the metal-working industry* and they can therefore serve not only as a methodological instrument, but also as an actual illustration to the described rules governing the development of a system of plants and equipment.

The aim of the model is to enable a quantitative analysis of the volume of renewal of a system of plants and equipment, such as a park of machine tools, looms or a fleet of vehicles. The whole set-up of plants and equipment is usually far from being homogeneous. Therefore, special attention is being paid to the structure of plants and equipment and its changes as well as to the impact of these changes on the volume and composition of renewal requirements.

The calculation of renewal requirements is based both on the physical terms and on money value terms.

## Renewal Requirements in Physical Terms

The volume of requirements for renewal, expressed in physical units (e.g. number of machines) depends on the following factors:

i. the length of period to be considered
ii. the size of the plant and its growth
iii. the age composition of the plant and the equipment
iv. the service life.

The availability of data on the volume, the rate of growth, the age and the service life is thus the precondition for an analysis of the renewal requirements. The model describes the inter-relationships of these data and their utilization for an analysis (see Table II/I.).

Special attention must be paid to the characteristics of the service life. For an analysis of the requirements for renewal the information on the average service life is not sufficient. Empirical analyses show that the service life of individual items can substantially differ from the average, since the process of renewal is of a stochastic nature. A precise calculation must therefore be based not only on data of the average service life, but also on data on the survival curve (see next page).

The survival curve describes the pace of discarding the number of machines installed in a given time. Based on this curve the number of machines of various age groups which are to be discarded during the plan period can be estimated. According to the "rate of discarding" in the Table II/I, about 12 per cent of the initial number of installed machines which at 1.1.1960 reached the age of 11-15 years were discarded during the following five years. There are substantial differences in the intensity of discarding the machines in the individual age groups. About 10% survive the age of 50 years. In the given case the average service life of the machines—determined as a median to the survival curve (age at which 50% of the original number has been discarded)—is 27.5 years.

In the given case the requirements for renewal which are considered to be identical with the number of machines discarded, during the years 1961-1965 is 1378.

This illustrates how far from reality the results of the planning of future needs can be if it is based on the age composition and estimates of a "normal" service life.

*Nesvera, Rozvoj technicke zakladny strojirenstvi, Prag, SNTL, 1963.

In this scheme the analysis and projection of the survival curve is the basis on which the number of discarded machines and the volume of necessary renewal is being determined (the number of machines and their age composition being given).

The model enables a follow-up of structural changes. These changes can then be taken into consideration for analysing the needs of renewal. Renewal, as a part of rational investment policy, plays an important role in the process of technical innovations.

In the example, an important trend of changes in the structure of machines is shown in the case of grinding machines. These machines are characterized firstly by their increasing number within the total installed machine tools (from 20.0% in 1961 to 22.8% in 1965) and secondly, by their relatively short service life (cf. the higher rates of discarding). The share of these machines in the number of new machine tools was about twice as high as their share in the total number of installed machines (see Table II/1).

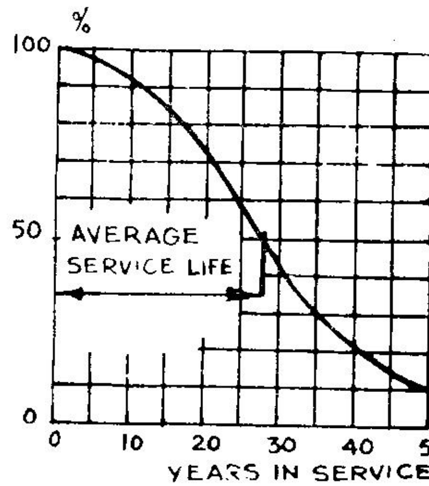
**Renewal Requirements in Money Value**

The requirements for renewal of plants and equipment are more often calculated on the basis of value terms, derived from investment outlays. Two alternative concepts are possible:

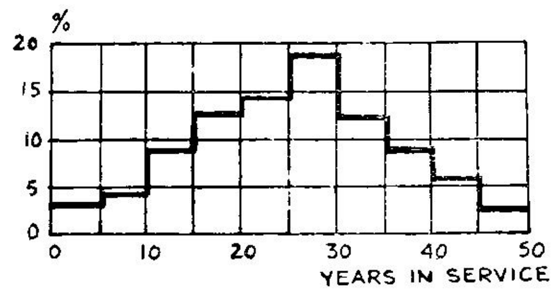
i. gross values (purchase cost); and

ii. net values (purchase cost reduced by the amortization charges).

If the calculations are based on the gross value of installed plants and equipment, the length of the plan period, the volume of fixed assets and the age and service life must be considered. In addition, the changes in purchase cost of the physical items must be included in the calculations. Empirical analyses show that generally the money value of plants and equipment increases in a higher rate than their physical volume (expressed in the number of machines, extent of floor space, etc.). This is due to the improvements of the technical




**Gradual decrease in the number of installed machines and their average service life (survival curve)**




**Number of discarded machines in individual periods of utilization (expressed as a percentage of the number of originally installed machines)**

parameters, to changes in the composition, etc. Thus, in Table II/2 the average purchase cost of new machine tools was trebled during 1930-1965 (in terms of constant prices). The number of installed machine tools increased in a 5-year period by about 9 per cent, whereas their value increased by 25-30 per cent.

Under these circumstances, the requirements for renewal which are identical with the volume

## Table II/1

AN ILLUSTRATIVE MODEL FOR THE ANALYSIS OF RENEWAL IN PHYSICAL TERMS

| | | Age of capital means in years | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Total | to 5 | 6-10 | 11–15 | 16–20 | 21–25 | 26–30 | over 30 |
| Total number of MACHINE TOOLS (1.1.1961) | 10000 | 2200 | 1900 | 1300 | 2300 | 1200 | 500 | 600 |
| Rate of discarding (5 years) | x | 3.8 | 6.4 | 11.6 | 17.0 | 25.8 | 31.4 | 27.7 |
| Number of discarded machines (1951-1965) | 1378 | 83 | 122 | 151 | 390 | 309 | 157 | 166 |
| Gross increments—new machines (1961-1965) | 2248 | | | | | | | |
| Total number of machine tools (31.12.1965) | 10870 | 2248 | 2117 | 1778 | 1149 | 1910 | 891 | 777 |
| Number of GRINDING MACHINES (1.1.1961) | 2000 | 770 | 510 | 310 | 210 | 110 | 50 | 40 |
| Rate of discarding (5 years) | x | 13.0 | 28.0 | 27.9 | 27.1 | 27.3 | 28.0 | 27.5 |
| Discarded machines (1961-65) | 450 | 100 | 143 | 95 | 57 | 30 | 14 | 11 |
| Gross increments (1961-65) | 930 | | | | | | | |
| Number of grinding machines (31.12.1965) | 2480 | 930 | 670 | 367 | 215 | 153 | 80 | 65 |
| Percentage of grinding machines | | | | | | | | |
| —in total number of machine tools (1.1.1961) | 20.0 | | | | | | | |
| —in total number of machine tools (31.12.1965) | 22.8 | | | | | | | |
| in gross increment (1961=1965) | 41.4 | | | | | | | |

## Table II/2

ILLUSTRATIVE MODEL FOR THE ANALYSIS OF RENEWAL IN TERMS OF VALUE

| | | Age of capital means in years | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Total | to 5 | 6–10 | 11–15 | 16–20 | 21–25 | 26–30 | over 30 |
| Number of machine tools INSTALLED (1.1.1961) | 10000 | 2200 | 1900 | 1300 | 2300 | 1200 | 500 | 600 |
| Their purchasing value ($ million) | 42.61 | 13.20 | 9.12 | 5.55 | 8.95 | 3.25 | 1.15 | 1.39 |
| Average purchasing value of a machine (1000 $) | 4.26 | 6.00 | 4.80 | 4.27 | 3.89 | 2.71 | 2.30 | 2.32 |
| Number of machine tools DISCARDED | 1378 | 83 | 122 | 151 | 390 | 309 | 157 | 166 |
| Their purchasing value ($ million) | 4.36 | 0.25 | 0.47 | 0.60 | 1.48 | 0.82 | 0.36 | 0.38 |
| Average purchasing value of machine (1000 $) | 4.00 | 2.97 | 3.83 | 3.97 | 3.80 | 2.66 | 2.27 | 2.30 |
| Number of machine tools NEW | 2248 | | | | | | | |
| Their purchasing value ($ million) | 16.03 | | | | | | | |
| Average purchasing value (1000 $) | 7.13 | | | | | | | |
| Number of machine tools INSTALLED (31.12.1965) | 10870 | 2248 | 2117 | 1778 | 1149 | 1910 | 891 | 777 |
| Their purchasing value ($ million) | 54.29 | 16.03 | 12.95 | 8.65 | 4.95 | 7.47 | 2.44 | 1.80 |
| Average purchasing value (1000 $) | 4.99 | 7.13 | 6.09 | 4.86 | 4.31 | 3.91 | 2.74 | 2.32 |
| PERCENTAGE AGE STRUCTURE | | | | | | | | |
| —of the number of machines (1961) | 100.0 | 22.0 | 19.0 | 13.0 | 23.0 | 12.0 | 5.0 | 6.0 |
| —of the value of machines (1961) | 100.0 | 31.0 | 21.4 | 13.0 | 21.0 | 7.6 | 2.7 | 3.3 |
| —of the number of machines (1965) | 100.0 | 20.7 | 19.5 | 16.4 | 10.6 | 17.6 | 8.2 | 7.1 |
| —of the value of machines (1965) | 100.0 | 29.5 | 23.9 | 15.9 | 9.1 | 13.7 | 4.5 | 3.3 |

*For establishing a realistic renewal policy, it is recommended to use the system based on physical terms.*

of discarded machines are low. The average value of discarded machines amounts roughly to the cost of machines; which were purchased before the period corresponding to their average service life.

In the case of machine tools park, the number of yearly discarded machines represented 2.5—3 per cent of installed machines, in terms of value it was about 2 per cent only. This example shows a further rule: the service life of machine tools is positively correlated to their average value, the service life of more expensive machines is on average longer.

If the requirements for renewal are calculated on the basis of the net value of plants and equipment, they are identified through the depreciation charges. The renewal requirements thus depend on the value of plants and equipment (amortization basis), on the method of depreciating and—of course—on the length of the plan period. They money value of depreciation charges usually exceeds the real value of renewal requirements. The reason for this is that the depreciation charges are calculated from the very beginning of the functioning of plants and equipment, while the real requirements for renewal follow with a considerable time-lag. This lag thus plays a big role, especially in the case of a high rate of growth of the fixed assets. It must also be mentioned that tax considerations generally dominate the depreciation rate and that it is very problematic to use the depreciation charges or net value of fixed assets as the basis for calculating the service life and the requirements for renewal.

The different concepts of calculating the requirements for renewal lead to different sults. For establishing a realistic renewal policy it is recommended to use the system based on physical terms. This system of indicators makes it possible to confront the state of plants and equipment with the technical innovations and changes on the market. Innovations are after all to be considered as the primary motives and impulses for renewal. ●●●

## Adaptation to Change

The principles that everyone can be, and that everyone needs to be, trained and retrained in the face of change has to be accompanied by one other associated strategy because change is by no means always a welcome phenomenon, and institutions as well as persons often question, and even resist, change. An understanding of the forces affecting change, and a perception of the need for meeting its consequences, should be part of the educational process itself with emphasis upon the obligation of the individual to keep in as adaptable as possible a stance to cope with and benefit from it.

—Dr. Seymour Wolfbein in *American Labour*, December, 1970

# Maintenance or Renewal

**A Ullman***

**The decision to renew a process machinery involves investment which must be based on effective management information system for setting up models which could be tested under different conditions and environments in different branches and different types of equipment. However, this does not mean that the old-fashioned sound judgement and common business sense can be by-passed. Judicious blending of the mathematical aids with the old practices would lead to sound maintenance/renewal decisions.**

THE aim of this paper is to describe the problem of finding the correct moment to cease from maintenance and instead renew machinery and equipment in the manufacturing industry. The environment in which to decide will be the market economy and the decision is meant to fall upon the factory management, which principally has to base all its decisions on profitability as the main criteria. In the factory we have two levels for work of this type. The decision to renew a process machinery or a piece of equipment involves an investment. Investments are decided upon by the board, which, when choosing between continued maintenance or renewal, has to consider other questions than just the profitableness of two or more competing suggestions. Such questions are: Do we dispose of the money necessary for the investment? If so, are there other urgent objects for investment to compete for the money either at the moment or later on, for which the money then should be saved? Are possibly available investment credits limited to the use of certain types of production?

The production manager or chief engineer of that certain department, in which the machinery should rather be renewed, has no possibilities to survey the investment situation. He should just find out the straightforward profitableness of possible alternative ways of action of maintenance or renewal and present them to the management, which then could very well decide because of such reason as mentioned, that for the time being a less profitable suggestion should be chosen.

Another of such motives could be the question of tax. Investments are generally exposed to regulations by law. There could be tax on investments above a certain limit, or for certain types of installations or equipment. Or there can be tax relief on investments in certain areas where governments see a need for raised employment.

This paper will generally deal with the problem of the production manager or chief engineer, but will also touch on finance and tax problems.

## FACTORS DETERMINING THE DECISION

### Normal Profit Calculation

The total cost for operating a processing machinery, a set of machines, or any piece of equipment, comprises the costs for:

a. invested capital in machines, buildings, installations, necessary new training, running in time when production is

*Expert from Sweden

limited etc. the depreciation of which has to be charged to the production by piece, by amount per time unit, by time unit or otherwise suitable in each case,

b. material, such as raw material and semi-manufactures used in the process,

c. manpower, operators, watch keepers, other forms of direct labour,

d. operation, electrical power, workshop administration, lubrication oil and other consumed articles, other than (b) above, indirect labour for all necessary services to facilitate the operation such as workshop cleaning and transports etc., all being such costs, which cannot always be added as a certain addition to direct labour, but is rather related to production,

e. maintenance, maintainers' wages, raw material for maintenance, spare parts, costs for maintenance workshops, including administration costs for these, transport, lifting, disassembling and reassembling equipment, test rigs, etc.

All costs under these headings build up the total cost, that has to be charged to the products. They must be determined for all interesting alternatives under consideration, such as :

a. Preventive maintenance and necessary corrective maintenance on existing equipment, continously carried out in slack production periods.

b. Renovation to bring existing equipment into condition as new and after that preventive and corrective maintenance, which then will be cheaper. (Decide whether the renovation is radical enough to motivate that from finance and tax aspects it could be considered as investment).

c. Modernization as well as renovation to bring the equipment not only into condition as new but to raise productivity or to improve precision to raise product quality, and thus attain a higher technical level. The result will be a cheaper maintenance. (The same investment consideration as under (b) will be necessary).

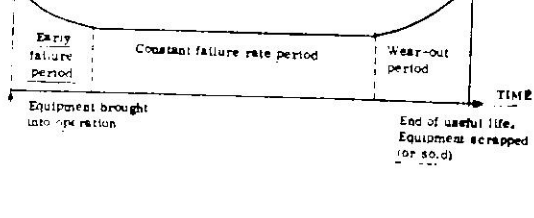
d. Replace the equipment by similar one of same productivity and precision, which will be an investment, that should correspond to the depreciation of the old equipment (including what is gained by selling this) and will bring down maintenance costs.

e. Replace the equipment by similar one of higher productivity and higher precision, probably also easier operation where precision as well as operation are improved not only by precision manufacturing but also by modern control equipment.

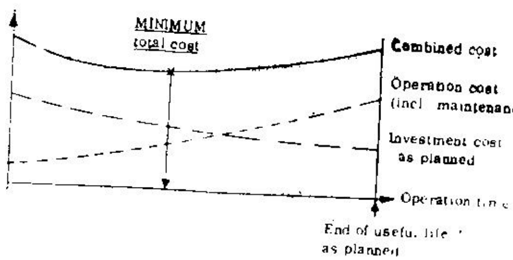
It should be noted that investment costs are spent in alternatives (c) and (e) not only to maintain the same production in quantity and quality as before but as well to raise the production as to improve the quality. It is of interest to keep apart these two parts of the investment.

Summing up these total costs for each of the alternatives, which seem to be interesting to compare and charging them to the expected production by unit or by some other usable measure will make it possible to rank the alternatives after profitableness from the production engineer's point of view. Apart from the fact that the management might choose an alternative that does not top the list, there are a few considerations, which will make the decision a bit more complicated than it might seem from what is said so far.

A look at this diagram shows that we have to deal with an aspect of time.



When does the failure rate or preventive maintenance cost rise to an unacceptable measure? This form of the so-called "bath tub curve" is principally general. If we for the "wear-out period" draw a curve showing total operating cost including maintenance and combine it with a curve showing the cost (in same unit as maintenance cost, per product unit, per year etc) for the actual 'still not depreciated' investment, we might get a diagram like this:




Somewhere, depending on expected total operation cost year by year and on the rate of cost year by year for spent investment capital, we can get a minimum total cost at a certain point of time. If we take that as a point of interest where renewal should be considered, we might not have utilized the invested capital. The capital cost curve presupposes a certain operative useful life. If equipment is scrapped earlier, the curve should have been different and the point of minimum total cost probably displaced. Obviously it is necessary not only to look at profitableness at a certain point of time but to survey a period of time ahead and find out if the equipment should be replaced but when this must be done.

Considering this it is further obvious, that the different cost items as given above under (a) to (c) should be found out not only at the present actual time but at successive points of time ahead. This makes heavy demands on judgement and foresight upon those involved. Many of the important factors in the calculation are uncertain. For instance:

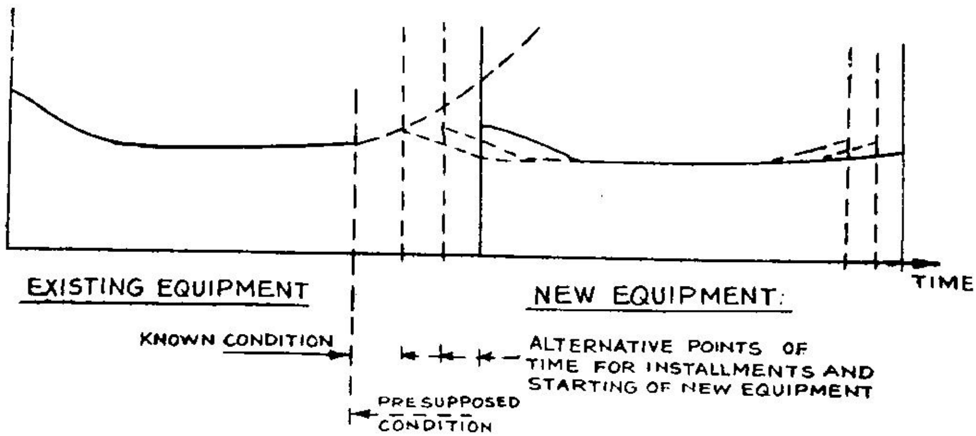
What is the future demand for produced quantity? As each product unit has to bear its part of fixed costs this figure has a great influence on the investment decision. It is necessary that the management decides as a question of policy for what productivity (or what possible alternative productivities), during the time to come, the calculation should be carried out.

How about the technical development? When will there be a demand for a product of higher technical quality or of different design or generally with different qualities or characteristics? This will have effect on the useful life of our equipment, which obviously is not a question only of maintenance cost. This also falls on management to decide as a matter of policy on which to base the calculations.

How about the technical development in the field of our processing machinery? Will there shortly come in the market better, more reliable equipment with higher productivity, better precision, lower failure rate, better maintainability, and lower price for which it would be wise to wait?

How about the failure rate? What frequency of failures must we expect notwithstanding a thoroghly planned preventive maintenance? And for each considered alternative? What resources must be spent on preventive and on corrective maintenance? For present equipment there will probably exist an experience on which to base the judgement but for prospective new equipment we have less experience and have to ask the manufacturer for his opinion and more or less rely on that. What will the running-in time be for new equipment? Is the maintenance planned by the manufacturer, so that the "teething troubles" will be overcome in short time? When will we thus attain the planned productivity?

If failures during operations occur, causing production to stop, what will be the cost for shutdown at different periods of time? Obviously we do not get paid for products not delivered. If, however, the product is demanded intermittently and, therefore, pro-




duced to stock, the deliveries are not always upset by a failure. How important is an undisturbed production and what will a disturbed production cost in money at different intervals? If an undisturbed production is inescapable, what will necessary spare capacity cost? What will a maintenance organization cost, in the different alternatives, which can deal with all possible failures within short time?

Generally, these various points of uncertainty show that the matter of maintenance or renewal has to take into account all considerations due in an investment calculation, where a clever judgement about the future is necessary. In other words, maintenance is not just a question for the maintenance department but for the management as well.

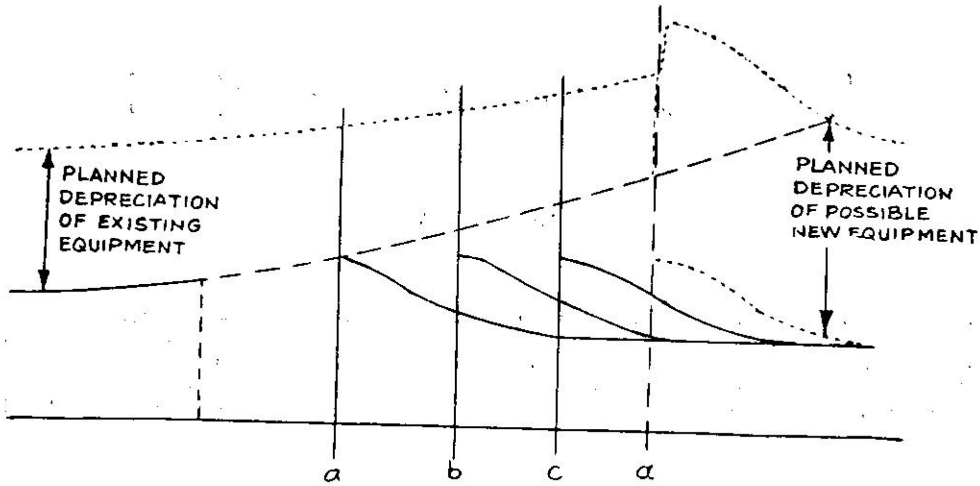
*Maintenance is not just a question for the Maintenance department, but for the management as well*

In the following sections of this paper some of the aspects given hitherto will be examined a bit further.

**Maintenance and Repair Costs of Existing and New Equipment**

Let us look at the "bath-tub curve" as demonstrated above. We also draw the corresponding curve for tentative new equipment installed to replace the first one. If we have reliable statistics for the existing one and can judge about the future for the new one based on reliable figures from tentative contractors, we would be able to make a diagram good enough to use for decisions, like the one above.

Let the curves represent not only the rate of failure, but total operating costs including maintenance costs but excluding investment costs. The maintenance cost should also include cost for shutdown operation when unexpected failures have occurred (or can be presupposed to occur) which prevent operation while being repaired. If we cut out the interesting part of the diagram and add the curve for depreciation costs for invested capital (which




costs should be planned to be heavier in the beginning of the useful life) we get the above diagram

From the bare operation cost point of view we should renew the equipment in question as soon as possible, say at point (a), that is obvious. If we take capital cost into account and merely add this cost in the same unit we might get a diagram according to the dotted lines, which means to say, that the machine has not earned its own investment until point (d). If we renew at points (b) or (c) we must pay the remaining depreciation by income from the new machinery or by selling the old or in some other way.

These simple diagrams might serve the purpose to show the importance of considering all costs as well as of having as good and reliable information as possible about operation and maintenance costs, about future productivity demand, about how maintenance might be split into preventive and corrective maintenance, what might be the frequency of necessary shutdown for repair and what might be the cost for interrupted production in case of such shutdown.

The first and primary care is to have statistics on existing equipment showing all actual, important facts to make it possible to forecast with reasonable security what will be the maintenance frequency and cost for this equipment. Secondly, the possible new equipment should at tendering stage be sufficiently known to facilitate the corresponding forecast, and of course, to plan in beforehand the necessary maintenance resources and training.

The cost for shutting down operation unexpectedly is of great importance in case there is a considerable risk for such shutdowns and we have to reckon with a great deal of corrective maintenance. We can conclude that from our operation statistics. If so our organization for maintenance must have a high degree of readiness for quick corrective actions, which is more expensive than working strictly to a plan of preventive maintenance. To decide what the shutdown cost is in different operation environment is important and must fall upon management. To stop operation in a moment when any produced item is immediately consumed by the customer must apparently cost more than if we produce to stock and delivery is not interrupted. Of course, keeping a stock will cost, but might be necessary just for this purpose. If so, this cost is a maintenance or operation cost to be taken into account and like the rest charged to the produced items. Another solution to avoid delivery interruption in case of failure is to have

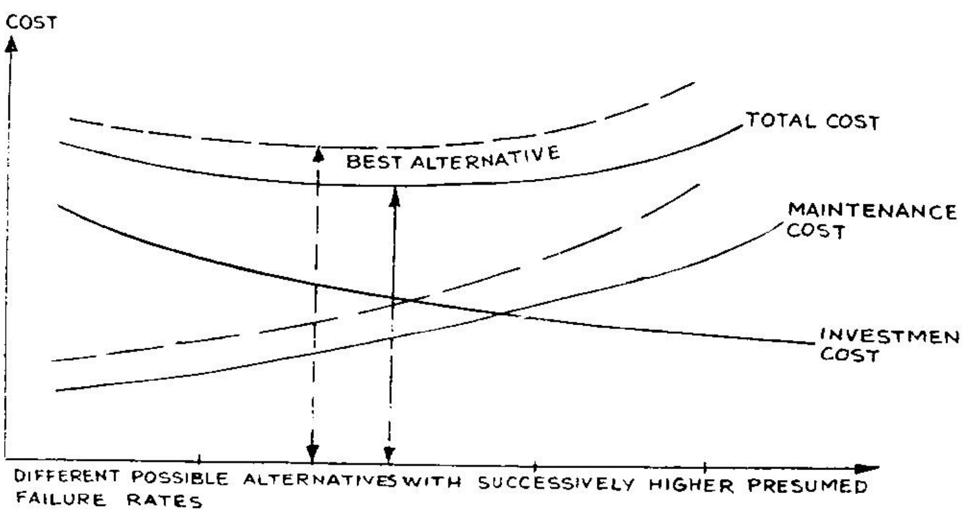
*Cost for shutdowns and possible costs for remedies against interrupted delivery must be judged with care,*

double equipment, one in operation and one standby ready to shutin. This cost is also heavy, but is in some application necessary when interrupted delivery just cannot be accepted. When comparing the cost for existing and new (or renovated and modernized) equipment, this calculated risk of failure is of utmost importance. Cost for shutdowns and possible costs for remedies against interrupted delivery must be judged with care and taken into account.

**Investment Costs *vs.* Operation Costs**

*Cost trends:* To avoid failures or diminish the risk for failures, equipment could be built with a high degree of security of function, such as with best material and high accuracy and after thorough and careful prototype testing. This costs much under the heading of investment and reduces the maintenance cost. The maintenance cost can also be reduced by raising investment costs if the designer gives the equipment a high degree of maintainability which means mainly two equipment qualities. The one is the possibility to take quick corrective actions in case of failure by seeing to it that defects can be quickly localized by indication routines and measuring points, by easy opening up for inspection and by easiness to change all parts exposed to stress and wear. The other is to include indication devices, where possible, for indication of successive wear of exposed parts, so that preventive actions can be planned and performed in due course in production slack period.

If different alternatives of equipment design are considered, it might be possible to represent the variations of the cost for investment *vs.* cost for maintenance in a diagram like the following (costs are broken down to each produced unit or can be discounted to present moment)



The diagram is principally valid but can naturally not be generally applied to industrial equipment in this simple way. It shows, however, that it is possible to find some design, where total cost is lowest. A lower failure rate would be too expensive on the investment side. A higher would be too expensive on the maintenance side. The presupposed shutdown costs could be or could not be included in the maintenance cost when calculation is done. In certain applications where failure is prohibitive the best solution might be to have a moderate failure rate at a comparatively low investment cost and to have a standby reserve unit to fall in case of failure. A single unit with very high security of function i.e. extremely low failure rate would cause a prohibitively high investment cost.

A main point in this section is to discuss the trends in changes of costs or how to find a good solution which is good even after years of service. Two main points in the industrial price trend are the raising wages and the resulting higher mechanization of production. When using successively less manpower to produce a certain amount of equipment, it is obvious that it will be comparatively cheaper to produce and more expensive to maintain, as maintenance is a handwork. A machine, which is built in series on a production line with efficient methods, efficient tools and a high degree of mechanization, still takes a certain number of manhours to pick apart and to reassemble not to speak of the time to measure and inspect all the parts to decide whether they must be exchanged for new ones. If we look at that diagram again we might judge, that after a few years the maintenance curve would be like the dotted one which would result in a new total cost curve and a new point for minimum cost more in favour for higher investment and lower maintenance. As the equipment is meant to live for a number of years one must consider the mean maintenance cost during the life of the equipment. Again, therefore, these maintenance calculations require good judgement about how long a time the equipment must serve and how the manpower costs will develop during that time.

This tendency of successively less maintenance is accelerating in the developed industry areas of today and is stronger as industrialation is pronounced. The actual situation in an area and swiftness of the trend of changing towards quicker scrapping and renewal may be considered as an indication of the degree of industrial development. If one can judge about this trend and compare this with the trend in manpower cost one has a good ground for judging the future best combination of investment and operation costs.

There are, of course, reservations to be done here. As touched on before, the investment/maintenance cost combination is not always the only criteria. There might, in some cases, be special operational reasons for limiting the failure rate more than would be dictated by cost considerations. Consequences of failure might be prohibited for reasons, which cannot be valued in a cost calculation. Further, even the more expensive, more secure-of-function equipment needs maintenance. This maintenance, though less frequent and more planned, less corrective and more preventive, needs skill and accuracy and might well be more expensive per manhour, which must be taken into account and prepared for.

**Useful Life of Machinery, Market Requirements, Effectiveness, Cost-relation Aspects**

In the first two sections it was presumed that the useful life of the machinery ends when it is worn to such an extent that further maintenance would be uneconomical and that no other circumstances would influence the point of time where renewal would be due. In many cases however, the problem is more complicated as the flow of income from the production of the machinery, intended to pay for investment and operation costs, is not as steady as presumed. The production is sold on a market with the usual conditions. Suppose, that the trend of the market is such that the price drops for some reason, perhaps a competing product, better and cheaper as a result of the technological development. Or suppose that the demand at the same price drops to a lower rate for similar reasons. Or suppose even, that the demand rises as we might deal with a modern product which is coming into extended use.

What happens then to our calculation? In the first case the income drops. The production could be the same, as the demand for the product does not drop. The cost for the production, investment as well as operation costs, are constant. Our income does not pay enough any more and further operation would be at a loss. If this new situation prevails, our useful life is up. A new machinery with lower costs, cheaper maintenance, less shutdown, generally cheaper in operation per product unit and perhaps by a higher, more mechanized production would be the solution. if we want to stay in the market.

The second case is similar. We want to stay in the market notwithstanding the fact that the demand drops. To do that we must lower our costs per unit. Our lifetime for the existing machinery is up and a new machinery lifetime must begin. The market can, however, change the other way. Suppose that we have a machinery, perhaps a bit uneconomical but it pays for its costs, while it is used a certain number of hours per week. We are considering renewal for reasons of investment and operation costs. Suppose that the demand rises. We can meet the demand by running two shifts. The operation costs per unit might be raised a bit but the investment capital is utilized better and we could operate the machinery in a new economical situation that lengthens the useful life until we have still higher operation costs because of maintenance demands.

In this case we might be tempted to invest in a new, better machinery in order to utilize the new situation and serve our clients by a higher production, but that is another story. Our old machinery did no doubt get a bit longer life.

Conditions in that part of the surrounding market, where we ourselves act as buyers, namely, where we aquire material, will, of course, affect our calculations in a significant way. Prices can vary to or against our favour and the supply of material can diminish or stop entirely.

For maintenance, the supply of spare parts is thus a specially important point. Suppliers of equipment keep spare parts in stock for a limited time after stopping the production of certain equipment models. After that, spare parts, on special order, will be very expensive if at all possible to aquire. Suppliers of equipment can vanish from the market entirely and nobody takes up their production. Suppliers sometimes have an unpleasant habit of changing their models, to improve them, without saying a word, which can mean different spare parts, which then suddenly do not fit into our equipment when we want them to. All these things about spare parts have to be thoroughly investigated when we consider the interesting alternatives, as under 'Normal Profit calculation' In other words, speaking of lifetime, when will the useful life of our equipment end just because the spare part will rise in price to a prohibitive level or because they cannot be aquired at all!

Still another situation for us as buyers can arise. If, for instance, a machine appears on the market, which can do the same job at a lower total price per produced unit than can be done with our existing machine, then it would be profitable for us to change, provided our 'still not depreciated capital costs' can be taken care of within our calculation. In that situation we would consider the useful life as ended. We might even be able to sell the old machine and let the income help the remaining depreciation.

Our conclusions of this discussion is that our machinery is a part of a system, a link in a production-distribution chain, where more circumstances than just maintenance conditions and maintenance costs decide the length of the useful life. These circumstances can be represented by a model of our machinery which could be called the effectiveness-cost-relation. The effectiveness of our equipment is represented by the services it can, and does, accomplish and the price that is paid for these services, whereas the resources to be spent for the purpose are represented by the costs, specified under "Normal profit calculation". These services and spent resources must be in balance and even give the necessary surplus to pay for general overheads and the profit by which investment capital can be raised. When such balance no more can be supported, the machinery is not "alive" and if this situation turns out to be stable the useful lifetime is up.

The conditions which dictate prices and costs can differ from what was once presumed and so the once planned lifetime can unexpectedly be shortened. If then the invested capital is not depreciated or, in other words, not fully utilized, that will mean a loss. Therefore, it is always advisable to depreciate at a higher rate in the beginning of existence of the machinery, when it is possible to survey the conditions with more security and later on, when unexpected changes might occur, be sure to minimize the possible loss if conditions should turn out to be such that the machinery must be taken out of operation.

It is further advisable sincerely to consider an overcapacity in the beginning, if calculations show that the then somewhat higher costs, because of the limited utilization of the equipment, can be accepted even with the relatively higher depreciation in the beginning. Should then the market turn out to be able to consume a bigger production, such one is prepared for and possible to accept. This means, in other words, that a lower profit is accepted in favour of a possibility to accept variations in the market requirements.

This discussion is principally valid also for a piece of machinery which is part of a complex installation, where the market prices are valid only for the products of the latter. The raising maintenance costs for the piece of machinery in question is affecting the total production cost and the market price and market demand will limit the costs that can be accepted. Each piece of equipment has not only a cost but also a price for its services, which, though only calculated as part of the market price, has to be in balance with the costs.

**Facilities for Maintenance**

From what is said above it can be concluded, that the maintenance cost as part of the operation costs must be known or presupposed with a certain security or confidence, if we want our calculation to show itself as reliable. So we must be able to predict not only the maintenance demand, planned preventive or unplanned corrective, as well as the failure rate. When and how often will corrective maintenance be necessary? What disturbances of operation and of product delivery do we have to take into account? We must as well know how the necessary maintenance actions should be performed best and how much they will cost. This in turn makes it necessary for us to know how we should build up and arrange the necessary maintenance resources to make these as fit as possible for the job. This is to say that the maintenance department should be able to cope with any maintenance requirements that arise and still be continuously occupied with essential jobs, or in other words capable to do its part of the job to keep operation costs within the limits and still be as cheap as possible.

There have been found examples where maintainers sat alongside with steelmilling machines in steel works day and night, in three shifts, doing nothing but wait for failures to occur, to be able to set about the corrective job immediately. It would be much better not only for pure economical reasons to do a preventive job on these mills once in a while, to ensure that they work satisfactorily, in between preventive maintenance occasions.

This is not an example with general validity. In many cases it is better to have spare standby equipment, if operation must be uninterrupted and to do corrective maintenance jobs when necessary. Examples of this is modern electronic equipment, where preventive jobs do not meet with the requirement to really be preventive, as many of the components often break down on irregular intervals, which cannot be predicted. Preventive jobs, that require opening up of equipment, can also insert new defects. Of course, such preventive jobs as regular testing and measurement of operating standard, without opening up, are done.

So the relative importance between preventive and corrective maintenance is individual for each kind of equipment and depending on such things as the requirements for uninterrupted service. Whatever the case, it is important to know as far as possible, which maintenance jobs, preventive and corrective, must be reckoned with. This knowledge is the base on which the maintenance resources must be built. This knowledge must be acquired in all possible ways by pressing the contractor, by collecting information from other sources where possible, and specially by maintaining an own reporting and information collecting system for following up experiences of one's own equipment. Contractors are often eager in these days to collect information about their delivered equipment in operation.

So all actual jobs should be listed as far as it is possible to know anything about them. Each job should be specified as much in detail as possible, giving:

— frequency, fixed or predicted,

— whether initiated by calendar or operation time or by indication,

— whether preventive or corrective,

— efficient working time for the job,

— manhours and, thus, number of men as an average,

— necessary tools, transport equipment, other workshop facilities etc.

— estimated requirement of spare parts and other material,

— appropriate instructions and drawings,

— necessary capability or training standard of the maintainer responsible for the job,

— which part of the organization (operators, inspection squads, maintenance workshop specialists etc) is most suitable to do the job.

The summing up of these facilities, manhours, instructions, etc., makes up the necessary maintenance facilities of the factory in question. Of course, it is not possible to cover all jobs by this listing. A number of small jobs, one different from the others will always arise so an addition of workshop capacity to make up for this balance will be necessary.Further it must be kept in mind that the frequency of the different jobs as given mostly in operation hours will vary when speaking in calendar terms, weeks, months, etc. with the production rate or the utilization of the machinery in operation hours per month. Thus the capacity of the maintenance department varies with the actual production rate, in so far as a certain number of operation hours will generate a certain amount of maintenance necessary to bring the equipment back into top trim.

However, this list of specified jobs (each specification being a rough instruction, with reference to a special instruction book, when necessary for more intricate jobs) is the nucleus of what can be termed as the Maintenance System.

This maintenance system can be looked upon as a maintenance planning and control device with the aim of keeping the material of whole technical system at specified operation availability and at a controlled and lowest possible-cost.

Such a system, in its general lines and build-up, is generally applicable to maintenance of any complicated technical system, and is of course, already used in many applications, however, under various labels and vocabularies.

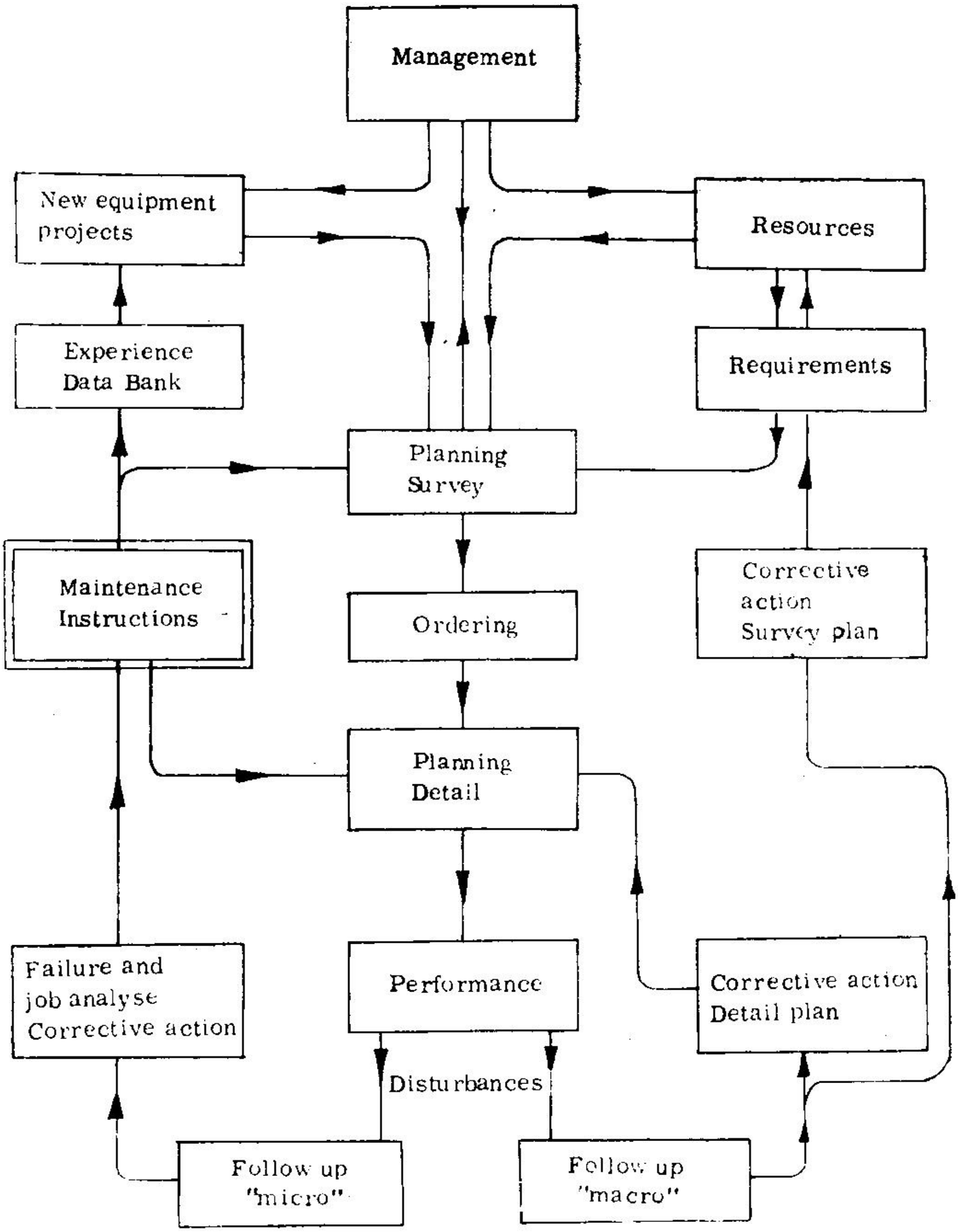
The main parts of such an administrative planning and control system would be as follows:

Planning, survey

Ordering

Maintenance Instruction

Planning, detail




Maintenance System

**Administrative Maintenance Planning System**

Performance

Follow up, survey (macro)

Correction of survey planning

Follow up, detail (micro)

Correction of detail planning

Correction of Maintenance Instructions.

These headlines do not say much as they are. Take, however, a look at the diagram.

The main planning function comes directly under the management. This planning is done in rather broad lines, budgeting, say a year ahead, but also a somewhat less fixed planning for say 3 years ahead and a long-ange prespective for say 6 or 7 years ahead. This planning is reconsidered each year and "rolling" forward a year each time.

The input data are mainly the requirements, predicted for the time to come, based on planned production, machinery condition and the resources such as money, labour, space, buildings etc., put at the mainteance department's disposal by management. Requirements for maintenance and resources must correspond, hence the two-way communication.

Plans must be put into activity by an ordering function at the right instant, not too late (for too detail planning) and not too early (creating too much possibilities for disturbing ordering).

Ordering from Survey planning is followed by a Detail Planning function comprising all sorts of necessary workshop planning and work preparation.

This is followed in due course by the Maintenance Performance, the actual trouble shooting-dungaree-spanner-oil can phase of the job.

In the diagram has been omitted, for simplicity reasons, the pointing out of various administrative connections with the different production activities.

Input information signals to the planning functions can be executed by routines such as consumed service time which makes preventive maintenance due, or service capability data, which reveal that gradual failures are to be expected.

If now all input information and all planning was correct, everything would be just fine. Nothing in this world, however, turns out as good as expected.

So is the case with maintenance. All sorts of disturbances occur. For instance, the demand for maintenance will turn out to be different. The failures will occur when production for a demanding sales department is at its peak and when the machinery just must not stop, the lack for skilled people will suddenly become apparent when we did not expect, to mention just a few examples.

The "Macro follow up routine" should be able to catch and report such things and turn them into corrective action at the different planning levels. If the disturbances are such as to require substantial alterations of the volume of maintenance and therefore make alteration of resources supply necessary, it must be taken care of by the survey planning function, which might require new resources at disposal by management decision. In our diagram we also had a space called Maintenance Instructions. These are actually the nucleus of the system and therefore specially marked by a double frame.

These instructions describe the different jobs to be done on each item (and subitem, exchange item etc.) and also state for each job the different details as given above. All these information data are required for planning such things as

— required resources, economical, technical and others,

— downtime for machinery,

- most efficient use of the maintenance organization,

- development of maintenance organization to meet future demands etc.

Above was mentioned the "macro" disturbances. It can, however, also be experienced how maintenance instructions turn out to need modification. The "Micro follow up routine" should be able to catch all such occurances as when the bitter reality differs from written instructions. The source of this information are the failures with the corrective maintenance actions as well as the prescribed or as necessary judged, preventive jobs. These should be efficiently reported and analysed and if this analysis points out that a modification could be of value a corrective action in the form of new editions of instruction means new input information to the planning functions.

This analysis of failures and jobs also adds to the experience of machinery service and design and reveals possibilities of improving security of function and maintainability of the machinery as well as of improving the maintenance organization to give a more efficient maintenance supply.

This experience can be used for modernizing the existing production equipment (which for the sake of simplicity has not been indicated in the diagram) but also for formulating the reliability and maintenance requirements and predictions when specifying new equipment.

Two main points in using this Maintenance System are to be specially underlined in this connection. One is the possibility to maintain an actual knowledge of maintenance requirements of the different machinery pieces. We have earlier underlined the necessity of knowing as much as possible of our maintenance requirements. By means of the reporting which is a part of the System we always get new actual information to correct the one we already have and to fill in the gap, where our knowledge was not sufficient. The other which is already touched upon, is the possiblity to maintain an actual plan over the necessary maintenance resources, their capacity now and in the future. This means a practically working plan over the buiding-up for new production equipment and—if lacking—for the present production equipment of :

- maintenance requirement knowledge for completing the instructions,

- personnel capacity, training recruitment, and

- material capacity, i.e. workshops, tools, spare parts, transport equipment, other working utilities, etc.

The knowledge of maintenance requirement might call for work studies in traditional meaning to be carried through either at home or through the contractor of new equipment. The personnel and material capacity might often, when we are uncertain of the exact amount and when this is expected to vary to a great extent especially in the way of difficult-to-acquire specialists, with advantage be brought from other companies, maintenance contractors.

### Type of Machinery, Equipment and Branch

The reader, undoubtedly, will ask for more detailed information for actual, generally valid maintenance costs, lifetimes, failure rates and appropriate maintenance resources for different types of machinery, equipment and branches. Such information used with care could, it is natural to think, be a good guideline for the maintenance and production engineers when tackling these problems.

Such information could, however, be very misleading, and will not be given. Above is shown a great number of interfering conditions, typical for each factory, that affect the profitableness in a determining way. This will specially be valid for developing countries, where individual conditions for each country are known only by executives and experts this country, or can be found by special studies. Furthermore each enterprise has its routines of normal profit calculation and as we here deal with profit problems, which are not different, principally, than other such problems, the best way is for the production and maintenance engineers to find out all the different factors, which affect their profit, predict their possible trends of change in the near and distant future, sit down with the accountant experts and see which alternatives can be satisfying. Then design their Maintenance Systems and make their maintenance plans for the time to come and plans for an appropriate and efficient maintenance department. This requires a thorough look into the future for many different affecting factors. As the saying goes: "It is difficult to predict, specially about the future!" It has, however, to be done, and doing so one must judge the rate of uncertainty valid for the different factors and how a misjudgement could affect the result. And further by the reporting system find out how these factors really come true.

### Financial and Tax Aspects

Financing of big modernization schemes or of renewal of machinery involves tax aspects of which nothing generally can be said. The tax laws vary not only from country to country but also from time to time. The governments want to control the industry in such a way that it will be beneficial for employment or generally for development and to direct employment-creating investments to areas or branches where this is thought to give desired results. Investments can, therefore, cause tax allowances in some areas (or countries) as well as extra taxes in others. These will have to be considered as plus or minus in the investment calculations, according to normally used methods.

The economy of investment will be strongly affected by the source of the money. If the enterprise has its own money set aside for investments, a decided annuity of interest and depreciation has to be calculated. If the money is borrowed this annuity is fixed by the conditions of the loan. Any possible subsidies, governmental or others, dictate their own conditions. The different scientific models designed for maintenance/renewal problems touched upon in the following section are sometimes designed to take these financial interest and tax aspects into account.

All these questions are, however, normal in connection with investment calculations, which do not fall within the frame of this paper.

## METHODOLOGIES FOR SUPPORTING DECISION ON MAINTENANCE OR RENEWAL AND THEIR APPLICATION

From what is said above under the section 'Normal Profit Calculation', it should be obvious that the proper method to support a decision on maintenance or renewal is a regular investment calculation, where different alternatives are compared with reference to profitability and where the cost of a suitably arranged maintenance is playing its proper part. As investment calculations are beside the aim of this paper, it is not the proper place to describe or evaluate different such methods.

As many of the important factors, that influence the result considerably, have to be based on judgement or even qualified guesswork, the soundness and probability of these are more important than whether a more or less sophisticated method is used.

Here will however be presented, in short, one method, worked out by the Machinery and Allied Products Institute, USA. It was presented for practical use in 1951 and is adopted by several industries in the USA and Europe. Among the published works on the method are the following:

G. Terborgh: Dynamic Equipment Policy. (Giving the theoretical background)

MAPI Replacement Manual, (Background in short)

Company Procedural Manual on Equipment Analyses, (Practical instructions, forms etc.)

Business Investment Policy, (Certain revision of earlier recommendations, where the influence of taxes are taken into consideration).

## The MAPI Principles

MAPI holds the position, that the most important problem of an investment calculation for machinery and other equipment is a question of time:

"When must an equipment be replaced by a new one?"

"What does it cost to use the old one another year?"

If one waits too long, the operation costs of the old one will be too high, if one changes too soon, the capital is not utilized correctly. Both cases represent too high costs.

To answer the question whether it is profitable to change an existing equipment for a new one, the MAPI-method compares the costs for the existing and the new equipment if either is used for next year ahead.

As is touched on earlier, the economical lifetime of an equipment depends on, among others, on which competitors have this equipment and will have. With the successive technical development it is necessary to reckon with the fact, that an equipment used today, sooner or later will be replaced by a new one, as well as that an equipment obtained today, must be replaced some time. In a calculation method, intended to answer the question when this replacement must occur, these new equipments and the costs for them must be taken into consideration.

As it is difficult to predict correctly necessary data for all in the future available machinery, the MAPI method simplifies the calculation by replacing those with presumptions, on which a calculation model is based.

*The first presumption* is that: All equipments, available on the future market have same optimal cost as the most economical, that can be acquired today. The optimal cost is here the minimum combined cost of average capital cost and operation cost, which includes an average "inferiority of operation costs"*

*The second presumption* is that: The equipment, which can be obtained today will, with time, be successively more worn by operation and older. Consequently it will be more and more inferior to equipments available in the future. Regarding the course of this inferiority of operation costs it is possible to do alternative presumptions. The MAPI method has three alternatives, namely:

i. The inferiority is linear to time

ii. The inferiority is stronger towards later parts of the useful life.

iii. The inferiority is stronger during the first part of the useful life.

*The third presumption* is that: For an equipment, already acquired and in use, the sum of inferiority of operation costs (compared to a new equipment) and capital costs will be *lowest during "next year"*. In other words, the operation costs will increase more than the capital costs decrease if the operation time is extended over next year. The total yearly costs will increase year by year.

With these principles we have simplified the problem. As all future equipments are

*Suppose that every year we could have the best machine on the market and that this one can do the actual job at constant operational costs. Our existing machine will then be successively more inferior to this "every year best machine" because of wear and age. This "inferiority of operation costs" is given as a sum of money by which the difference of operation costs is increasing each year.

assumed to have the same optimal cost we can limit the investment calculation to a comparison of next year's costs for existing equipment and the best that can be obtained today.

## Next Year's Costs

For *existing* equipment next year's costs consist partly of operation costs, caused by the utilization and partly of a capital cost, caused by the diminishing value during next year and the interest on the capital investment in the equipment.

For *new equipment*,** which can be obtained today, next year's costs must be calculated differently. We can divide this cost into the following parts:

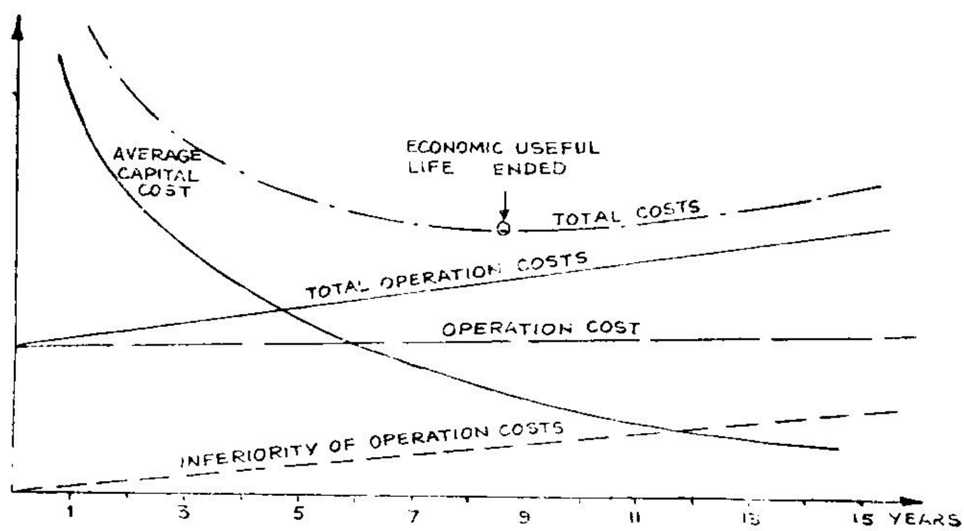
1. Operation costs
2. Capital costs
3. Inferiority of operation costs.

**When considering new equipment one assumes that it is totally depreciated at the end of the useful life. Earlier it is assumed that when considering replacement of existing equipment, this might not be totally depreciated. This will be taken care of by his method.

Operation costs as for existing equipment, are,those current costs caused by next year's utilization. Capital costs depend on the presupposed best useful life. Obviously we must first find this.

If for the presumed new equipment we have calculated the average capital cost per year for a successively extended useful life (lower per year as life is longer) and the operation costs and have added to this the inferiority of operation costs and represented these in a diagram by curves, we will find that the total added yearly cost will have a minimum. The point of time for this minimum will show the economical useful life.

It is now possible to compare the total yearly cost for "next year". If this is done for a number of successive "next years" it will be possible to find out, which year the total costs of a new equipment will be less than those of the existing equipment (at least according to this simplified method) and when consequently this one should be replaced. The mathematical development and a nomogram, based thereupon avail-



able for simplifying the use of the method, will not be shown here.

## Scientific Work

It is natural, that problems concerning maintenance or renewal have attracted interest from scientists of economy in cases where the equipment turnover is a heavy item among the costs of an enterprise.

An example of such work found in the science literature[1] concerns a company operating 140 electrical fork-lift trucks. Two problems are posed :

i. What is the optimum working life of an average truck in the fleet and to what extent is this life affected by discounted cash flow (DCF) considerations?

ii. Should the optimal replacement policy for the average truck be imposed for every truck in the fleet, or should a separate policy be formulated for those trucks the maintenance cost of which differ much from the average?

The effect of capital allowances for tax purposes is included. The author designs and compares two mathematical models, the first of which is associated with the total average costs per year, the other with the present value of all future costs and comes to the following conclusions:

1. The study has well demonstrated the importance of considering capital allowances for tax purposes.

2. The two investigated models have yielded comparatively flat objective functions near their optimum points, which suggests that it would be more meaningful and practical to specify an optimum range of equipment life in a replacement policy, rather than a single value of the economic life.

3. The two models give somewhat different results. Model 2 is more appropriate theoretically, if technical obsolescence could be taken into account. Model 1, which suggests replacing the equipment more frequently than Model 2, has the advantage of providing an opportunity of assessing technical innovation and new design of equipment at shorter time intervals.

Apparently this work discusses possible models for supporting decisions of maintenance or renewal and is using an example of strictly limited structure. Furthermore the statistically acquired information of how maintenance costs of these trucks vary with time does not seem to be very reliable. It might have been worthwhile by using all maintenance costs instead of as in this case, the costs for just 10 trucks out of, some 140, to find out a more realistic function of maintenance cost against operation time.

A later example of scientific work is concerned with simultaneous determination of optimal repair policy and service life.[2] The author says, that the problem of determining optimal service life of a machine has been discussed during a long time in the literature under the assumption that repair costs are given. Empirical findings and theoretical discussions suggest, however, that repair costs and service life are related and should be determined simultaneously.

The cash flow associated with a machine is treated in this paper as a continuous process.

[1] A Study in Equipment Replacement by S. Eilon, J.R. King, D.E. Hutchinson Imperia lCollege of Science and Technology, *Operational Research Quarterly* Vol. 17 No. 1, March 1966, Pergamon Press, Oxford, London., New York, Paris for Operational Research Societety, London.

[2] Simultaneous Determination of Optimal Repair Policy and Service Life, B. Naslund, University of Stockholm, Reprint, Dept. of Busines s Administration, Box 23015, Stockholm 23.

*Empirical findings and theoretical discussions suggest that repair costs and service life are related and should be determined simultaneously,*

The flow is affected by the two decision variables, repair and service life. The aim of the decision maker is assumed to be the maximization of the present value of the cash flow.

The author claims that among various methods suggested in recent development of control theory one of the most promising is Pontryagin Maximum Principle. Built on this principle the work suggests a mathematical model by which it would be possible to find the optimal form of "repair policy" i.e. money successively spent on preventive and corrective maintenance as well as "service life" or operation time.

A later work[3] suggests a modification of the model of reference[2] using also the Pontryagin's Maximum Principle, where the aim is to obtain the maximal value of owning the equipment, i.e., the maximum discounted income plus discounted selling value by choosing the amount of preventive maintenance and the sale date. This model is no doubt a valuable development of the model of reference[2]. To be useful for the practical engineer, however, that presumption must be valid, that maintenance costs, the influence of maintenance on productivity, and as well on sale value and productivity deterioration if not maintained preventively, must be known with certain security and expressed in exact figures suitable for calculation.

The same or corresponding restriction is, of course, valid for all theoretical models. This scientific work is most welcome and promising. Before such work can yield practical solutions of more general interest for production and maintenance engineers and investment decision makers there must be more information available based on effective information collection and data processing systems to make sure that the input data in the models are appropriate. Furthermore these data, strongly influenced by local environments, will not be generally valid without restrictions for branches or types of equipment. Consequently each enterprise must have its own information collecting work done continuously. Finally when such information is available the models must be tested under different conditions and environments in different branches and on different types of equipment.

By such work it might, in due time, be possible to shorten the way for the decision maker to the goal of making sound maintenance/renewal decisions. In the meantime the traditional investment calculations will be the main help. However developed and detailed these might be done, there is no short-cut to find correct cost and income information and sound judgement about the trends of the future. There will be no witchcraft in future mathematical models by which correct information collection and data processing and the old-fashioned sound judgement and common business sense can be by-passed. The only thing we can hope to do is to give the decision maker a better support. ●●●

[3]Optimal Maintenance Policy and Sale Date of a Machine: G. L. Thomson, Carnegie-Mellow University, *Management Science*, Vol. 14, No. 9, May 1 968.

# Procurement, Storage and Distribution of Spare Parts

**EP Leiter***

**There is hardly a general applicable solution for spare parts supply problems. The objective, however, is "the right parts in the right quantity, at the right time, in the right place". Appreciation of the operating environments would aid in the procurement, storage and distribution of spare parts.**

THIS paper deals with Procurement, Storage, and Distribution of Spare Parts from the points of view of management, giving practical solution from the view of a world-wide supplying manufacturer of machines. We are producing highly qualified machines which are not manufactured as single units but as optimum series production on progressive assembly lines.

There is hardly a general applicable solution for spare parts supply problems. In a definite case of need we have firstly to ask whether the object for which these spare parts are required is a sturdy standard machine or a more sensitive special machine, whether it is a question of a product of single-part production or series production.

We have to ask whether it is a question of problems of short-sight spare parts supply or problems of long-term spare parts supply.

By means of further questions we are trying to find out what are the problems which oppose a smooth-running spare supply. There are large distances between the machine manufacturers and the user; consequently communication problems and transport problems. In addition to that there are specific geographical and climatic obstacles, not to forget economica barriers.

You can see already from this brief description how problematic the spare part supply is and which factors play a decisive role.

We don't want to see only the difficulties, but the main points are:

What does the machine user want?

What are his ideas and wishes?

and how can the machine manufacturer come up to these ideas?

With the spare parts business it is the same as with any other problem in the world. With a good co-operation from both sides there is a good solution to any complex of questions.

As I said before, we want to see the subject from the view of a world-wide manufacturing

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and world-wide supplying manufacturer of highly sophisticated special machines who supplies to all five continents. It goes without saying that such a manufacturer can rely on very comprehensive experiences.

Based on this experience there is only one motto for a good and efficient spare parts policy:

The right parts,

in the appropriate quantity,

at the right time

in the right place.

This single sentence contains the requirements and demands of the machine users as well as the tasks of the machine manufacturer.

Converting this principle into practical work means:

*The right parts*: First of all, only such parts which are subject to more or less rapid wear, and which for this reason are required at short notice and for the major part of the machines in the respective country.

*In the appropriate quantity*: Not too much and not too little.

too much—Large binding of capital

too little—Breakdown of machines, loss to the machine user, partly complete loss in value of the respective machine.

*At the right time*: Not at birthday and not at Christmas, *but always in that very moment* when the spare parts are necessary, that means at the peak of work during the time of highest stress or in case of a breakdown of a machine.

*In the right place*: The most beautiful and completely filled central depot is of no use if the machine user has to wait for days or weeks until he gets his parts.

The primary wearing parts must be available in that place where the machines are operating and where they have suffered a breakdown due to a damage.

These are the vital aspects of a quick, effective and economical spare parts conception.

All we have to do now is to speak about the ways that guarantee the realization of the motto:

The right parts,

in the appropriate quantity,

at the right time,

in the right place.

This demand applies as much to Africa as to Australia or South America and, of course, also to the European countries.

We know that more of the machines in the world run for 10 years without any repair; the higher the working value and the price of a machine the more important is it to ensure its operational reliability. That is a fact which applies to all machines, and it is at the same time the tribute we all have to pay to the technical development.

The engineers of all important manufacturers are trying hard during their designing work to obtain a far-reaching freedom of maintenance. This ideal cannot be realized to a 100%, and above all the operation under particular difficult climatic working conditions causes additional problems which can only be overcome by a good spare parts policy and an effective service.

## Procurement

An economical procurement policy which at the same time takes into account the specific requirements of the respective country is not quite easy.

These thoughts are influenced quite considerably by

the information flow,

the delay in procurement,

the way of transport,

the import licences,

various customs regulations,

the import problems,

the foreign exchange problems,

and, of course, also by the

distribution problems in the country.

These thoughts already make it clear to everybody who is somewhat familiar with this subject that from the very moment the purchase of machines is being discussed it is absolutely necessary to handle the spare parts problem with the same importance and precedence.

But it is also clear to the same extent that reasonable considerations can only be made if one can obtain necessary advice by manufacturer's experts regarding the procurement of the basic spare parts stock.

These experts know the wearing parts; they know best which parts are particularly affected by which conditions, and if the importer points out clearly the problems of his cases of requirements, i. e.,

the conditions of operation,

his special demands,

and his possibilities regarding organization,

it will always be possible to create by mutual efforts the basis for a satisfactory spare parts supply.

For the building up of such a reliable Spare Parts Supply Organisation, both parties have to clarify the following presuppositions:

(1) What are the conditions under which the machines are operating?

(2) Number of hours of operation per year?

(3) Will the machines be spread all over the country or will they be put to work only in areas of main efforts during the initial period?

(4) What number of machine will be imported during the first year?

(5) Place of central depot?

(6) Where are wearing part stores (regional depots) necessary and how many?

(7) Area of (a) the central store, (b) the regional depots?

(8) What kind of shelves are available in these stores?

(9) How many m² are: (a) the total shelve area, (b) the available shelve area for the considered parts?

(10) How are the ways and arrengement of transport?

(11) What is the situation regarding specialists: (a) in the central store, (b) in the regional depots?

(12) State of training of these collaborators?

(13) Training of the collaborators in the factory with regard to organization, investigation of requirements, and storage system.

(14) After clarification of these questions setting up of stock order for the basic spare part stock adjusted to the mentioned conditions and the number of machines.

Such check lists, should be very simple during the initial phase of co-operation, so that they are the best basis for a successful operation.

Although a part of these questions belongs to the field of spare parts storage, it is necessary and useful to have these questions clarified as far as possible even during the phase of procurement, so that the procurement of the basic spare parts stock can be adjusted to the special requirements and possibilities of the respective country.

For finding out the required quantity we use a rough calculation:

| | |
|---|---|
| 10-20 machines of same model: | 20% of the machine value for the basic spare parts stock |
| more than 20 machines: | 10% of the machine value for the basic spare parts stock. |

This quota for the basic stock has to be adjusted to the climatic conditions in the country as well as the conditions of operation, and according to the experiences of the machine manufacturer it must include not only the fast moving parts but also the normally moving parts.

To a certain extent it is also necessary to make arrangements for an accident, paying special attention to the availability of such parts which cannot be made locally by craftsmen.

When making up this order for the basic spare part stock it is, of course, necessary that besides those points already mentioned the number of the corresponding regional depots is taken into account as well as the distribution schedule indicating in which districts the machines are likely to operate.

This order has to be made up and placed so early that **the procurement time by the manufacturer, the transport and importation regulations** are settled at least two months prior to the actual requirements, leaving two months for the ordinary stocking in the central store and the distribution in the country itself as well as the regional depots.

To ensure such a working procedure, the appreciation and co-operation of the importing country and the importer respectively are also necessary to the full extent so that the whole complex of questions including timely financing can be settled carefully.

For future procurement it is of vital importance that by means of a reasonable requirement investigation the actual demand is found out and recorded so that subsequent order can be worked out in time and above all only those parts are subsequently procured which are actually required.

These aspects are often not noticed or not considered and cause increased demand of capital and foreign exchange which is completely uselessly employed by parts being re-ordered which are not frequently used; in other words the whole spare parts business in the respective importing country **must be clear after two working periods at the latest**

In the central store of my company, which manufactures special machines in series production and supplies them world-wide, are stored more than 36,000 items.

With only 2.8% of these 36,000 items, that means with only 100 items, we covered 50.9% of the total demand during the past financial year.

55.4% are so-called intermediate parts which are only required on older models or in case of major repairs, as for instance for general overhauling actions.

41.8% of these 36,000 items are available for very old or completely new models with actually no demand during the current year.

Owing to a positive attitude of the manufacturing company and for reasons of loyalty to products the parts for the very old models are stored in small numbers.

Once in the respective country this effective organisation of the spare parts business is achieved and ensured to a certain degree, a rational, early and economical procurement is not a problem any more.

This vital organisation of the spare parts policy can only be created if the spare parts supply is built up as a system from the side of the supplier as well as the machine user and operates effectively by close co-operation from both sides.

## Storage of Spare Parts

When procuring the basic spare parts stock respectively, when setting up the first order and when establishing the storage system, **very often it is economised too much and exactly on the wrong place.** To recognise the full range of this problem there is no other choice but to put the clear question and to figure it out in writing:

What does it cost, for example, to have parts for $1,000 more on stock than being needed?

In the end it will cost only the interest of the capital; and even with the interest rates today being comparatively high all over the world that is after all ten times cheaper than a situation:

where machines are stopped in one country due to spare parts shortage,

where machines cannot be used 2,3,4 weeks or longer,

where spare parts have to be reordered by costly telephone calls from continent to continent and be flown in.

Out of my own experience I would like to say: Here we are touching an essential problem of spare parts supply. At the wrong time it always is economized too much and then during the period of operation the above mentioned spare parts for $1,000 have to be flown in, **the air freight charges for these parts amounting to $1,500.**

Where is the economy and the obligation to guarantee a good service to the machine user in this case? where remains common sense?

Here is a real example that occurred just recently in Europe:

A larger combine harvester, value at about $12,000, can only be used 6 to 8 weeks every year, because the harvest period is not any longer.

If this machine comes to a standstill for only one day due to just one spare part that probably has a value of $2 or $5, the owner will suffer a loss of $ 480 to $ 600.

What difference does it make if the concerned spare part costs $5 instead of 4, **but can be supplied from the regional depot within 5 minutes;** and how enormous will be the losses if a machine for production comes to a standstill, because if the necessary spare part is not available and the whole production staff of 300, 400, 500 employees or more has to be interrupted?

Every customer will confirm to us that it is not the price of a spare part but the quickness of delivery that **is the decisive factor.**

A good spare parts service requires a lot of money from all of us.

These costs are already occurring when procuring spare parts and by using fast procurement—quick service by aeroplane in emergency cases—the graph of costs is climbing up rapidly.

For the machine user it is therefore much better and cheaper to pay one dollar more and to avoid a loss of $480 to $600 (note real example) by getting the genuine spare part that is guaranteeing him the correct functioning of the machine in a fraction of time. The interest, the storage costs, the organization and the necessary personnel can be paid for and spare parts storage becomes interesting to both partners. A really dependable spare parts service can only be obtained and guaranteed on this basis.

Apart from the questions already dealt with, the following problems too, have an importance in the storage and distribution of spare parts:

(a) a reasonably constructed building, serving as a warehouse,

(b) sufficient storage possibilities,

(c) an appropriate shelf system,

(d) a carefully planned system for storing spare parts (locater system) by which the whole spare parts policy in the country itself can be made and can be implemented.

A further presupposition for reaching this goal and for the functioning of every organisation is a minimum of orderliness and a reasonable and faultless functioning and collection of all requirement data.

To reach this aim the machine manufacturer will advise his partners in all countries and will train their personnal, so that a minimum of capital, a maximum of good organization, proper functioning, and security of procurement can be achieved.

Presupposition for this, however, also is the willingness of these partners to accept such proposals and to overcome existing problems of mentality so that the common aim can be converted into reality by joint efforts.

A simple way and a simple system are—at least in the beginning, in the run-in-period—for sure more economical and functioning more expedient than a hypermodern, complicated system for which, maybe, various presuppositions are missing.

**Distribution in the Country**

The problems discussed in connection with procurement and storage have an essential influence also on the distribution within the country. No matter what economical system is used in a country, when setting up a spare parts organization it is important that the partners who themselves are storing spare parts in regional depots or in workshops keeping ready, and supplying them quickly are willing to do this in time, carefully, and properly only **when their means of livelihood is guaranteed.** Regulations differ very much from country to country, so that a general guideline cannot be dealt with here. Considering the practices, regulations, and laws in the country concerned, both partners have to select and use the right way. The goal should be to set up spare parts bases or regional depots within a country.

The more bases there are in one country, the better the customer supply and the lighter the load on the central store will be, avoiding many small part orders, back orders, and resultant air-lifting from the machine supplier.

Furthermore this way a safety stock is built up all over the country exceeding the normal urgent need, so that a continuous, reliable supply is guaranteed.

When such a spare parts supply system exists the whole load of supplying does not only hit the central base, but the first phase of requirements is absorbed by the regional depots, the central base is not cleaned out right away, the supply base stays stable, and within two periods of operation the central base is gaining the necessary, many times already mentioned organisation for economical dispositions in the future.

This organisation is of decisive importance for procurement, storage and distribution. It is gained only by:

a sufficient stock-keeping during the starting period,

a special and adequate organizational central base,

the regional depots modified to the country's requirements, and

an exact requirement investigation and by a simple order processing.

The circle is closing itself. The organisation in **procurement**, in **storage** and in **distribution** produces the general view so that the **right parts** in the **appropriate quantity** at the **right time,** in the **right place** can be supplied.

Goodwill and understanding on both sides, of the problems of both partners, are the best guarantee and the best presupposition to solve properly even the most difficult spare parts problems. ●

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

**E Arneberg***

**Spare parts and materials are considered as a part of maintenance, and maintenance as an integral part of production. The composition and stock of spare parts are not guided merely by the cost involved but by the loss of income of being without them which is generally termed as downtime cost.**

**Inplant standardisation of production equipment is that factor which will considerably reduce the spare parts and maintenance materials stocked. For high value items, the preventive maintenance programme can result in a considerable reduction in capital tied up in spare parts. Preventive maintenance will have its impact only under norml working conditions.**

**It is better to depend on domestic manufacturers to avoid risks and it is also wise to concentrate on a wide composition of spare parts and have smaller spare parts inventory.**

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

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

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

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

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

**Main Groups of Maintenance Materials and Spare Parts**

a. *Regularly used materials:* For instance oil, grease, lamps, fuses, washers, overcoats, shoes, bolts, nuts, etc.—under special corrative atmosphere, also steel

*Expert from Norway

and metal plates, bars, pipes, fittings, etc.

For practical purpose this *consumption* can be considered as *regular.*

b. *Irregularly used materials:* For instance, steel plates and bars, metal, etc. which we suddenly need because something unforeseen happens. It might be fault in the original material, accidents, etc. The consumption is impossible to forecast and is *highly irregular.*

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

d. *Irregularly used spare parts:* These are also parts manufactured to be *identical* to one or more parts in the machine, but they are supposed to have a lifetime which in most cases is *the same*, or *longer* than the lifetime of the machine. When the machine is scrapped, the parts in the machine may be still in a satisfactory condition. Examples are a propeller in a ship, an axle in a machine, a casting, etc.

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

### Possibilities for Control

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

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

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

Unfortunately, we *do not* have any *crystal ball* to tell us which special components, of which machines are going to have a breakdown, and when will that happen. Instead, we build up a *stock of spare parts* which will enable us to meet most of the situations which might take place. When the machine is finally scrapped, a number of spare parts will have to be scrapped together with the machine. For group *b* the situation is somewhat better. The sales value of this material will, for instance, be considerably better.

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

### Factors Influencing Stock of Maintenance Materials and Spare Parts

The factors mentioned below will vary considerably from one part of the world to the other, from one country to the next, be different in different parts of the same country, be different in different branches of industry, and even vary from company to company. *In general* they have, however, an influence on the set-up of spare parts and mainteance materials which each company must make for itself.

1. *The possibility of getting a fast supply of spare parts:*

   a. From the firm's own stores
   b. From a local dealer
   c. From another enterprise which has the same machine
   d. From a nearby machine shop
   e. From the manufacturer's store-room.

2. *Influence on production and productivity:*

   a. Can production temporarily be transferred to another machine?

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

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

   The machine units can be grouped in the following categories:

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

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

3. *Standardization of production equipment and components:*

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

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

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

4. *Preventive maintenance procedures:*

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

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

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

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

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

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

6. *Location of the factory:*

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

7. *Government rules and regulations:*

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

8. *Branch of industry and degree of automation:*

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

## Total Cost of Maintenance During the Lifetime of Production Equipment

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

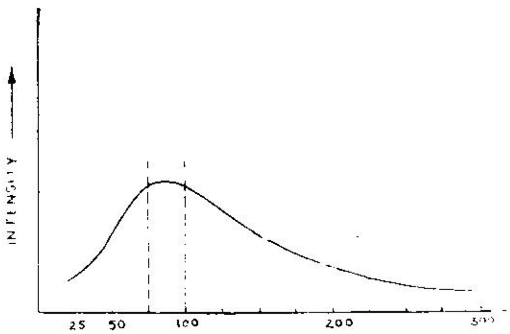



**Fig. 1**

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

The maintenance cost consists of:

— cost of different *spare parts* and *maintenance materials,*

— cost of *maintenance labour* and *maintenance management.*

If, for example, the maintenance cost of a machine during its lifetime is equal to purchase price and installation, and if 40% of this maintenance cost is labour and management and 60% spare parts and maintenance material, then we have to reckon with spare parts and maintenance material cost worth $6.00 during the lifetime of the machine for every $10.00 of the purchase and installation cost of the machine. Frequently these facts are *neglected,* both in the economic planning in the industrial enterprise and in the country as a whole.

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

From a *total cost concept,* the most expensive machine to buy might be the cheapest in the long run, as indicated in alternative II in Fig. 2, the reason being the use of better steel or other materials, bigger dimensions in design to absorb overload. In general we can thus reduce the store of spare parts and other maintenance materials, if we buy high quality production equipment, which are more expensive. This has very often been *neglected in procurement procedures* and regulations set by different corporations, companies or government agencies.

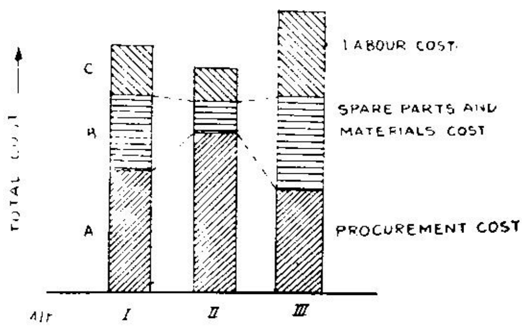



**Fig. 2**

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

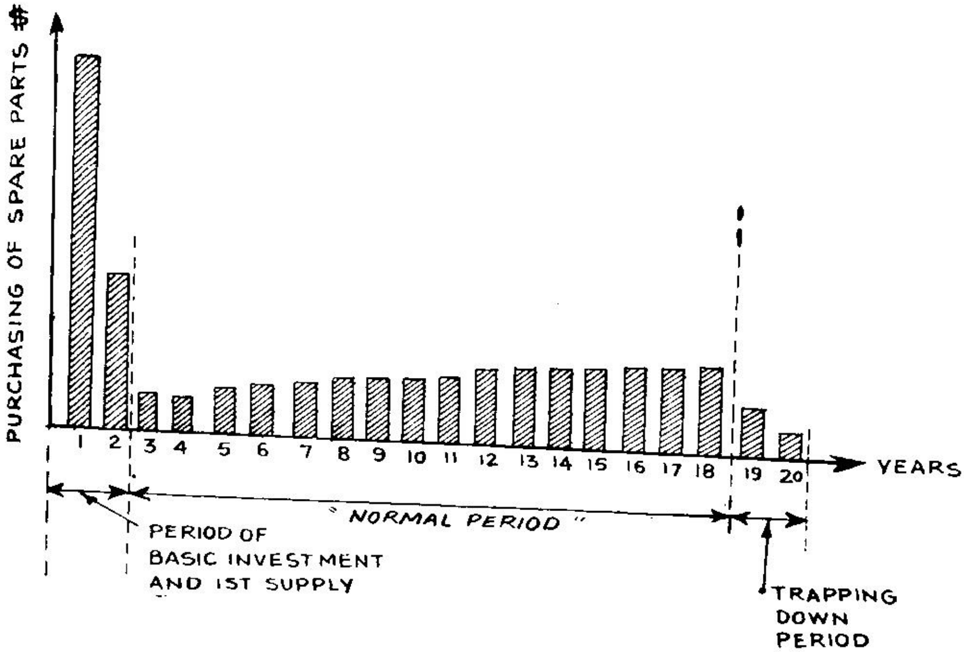



**Fig. 3**

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

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

a. *Period of basic stock and major supplement to stock:* This includes the parts we buy together with the machine. and the parts the first period to operation tells us we need.

b. *Period of "normal consumption"*, with a slight tendency to increase.

c. *"Trapping down" period:* Decision has been made to take the machine out of production in a year or two. New spare parts must only be brought under very special circumstances.

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

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

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

### Determination of the Optimum size and Composition of Stock of Spare Parts and Maintenance Materials for Machinery and Equipment of a Manufacturing Plant

Determination is for the individual industrial enterprise a very complicated and difficult matter. Only to a limited extent can it be based on theoretical economic methods and formulae.

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

Composition and size of spare parts must, first of all, be determined *when the plant is planned and layed out,* and decided at the same time as the different production units are decided. Later on, the composition will be varied with *supplementation* of spare parts in stock. At this stage the firm will have a growing experience from operation of the plant on the basis of which the stock is determined. In this situation a systematic and *complete record* of the consumption of spare parts and maintenance materials are very valuable and necessary material.

## FACTORS AFFECTING SPARE PARTS STOCK

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

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

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

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

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

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

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

a. *which spare parts to keep in stock,* and

b. *annual consumption of each of these spare parts.*

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

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

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

### Expensive and Inexpensive Spare

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

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

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

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

**Which Parts to Carry in Stock**

When a company decides which parts to carry in stock, it is important to consider their *value* (purchasing cost) in addition to their *calculated necessity* or desirability. The *low value items* represent a small investment and a relatively low figure compared to calculated cost of production downtime. For this group it is logical to apply a *very liberal policy*, especially in the determination of spare parts composition. The *high value items* represent, first of all, a much greater *financial problem*.

Secondly, the ratio between cost of parts (or units) and cost of production downtime will be quite different for this than for the other group. In some cases the most economical solution might be *not* to carry the parts in stock, but to supply them if a breakdown should take place. For this group of *high value items* a different and *much more critical policy* must be applied. Only items for which calculated risk of breakdown is comparatively high, or where the consequences of a breakdown are extensive, stocking of spare parts is justified.

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

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

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

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

**Determination of Stock Size**

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

We can classify the parts in two major groups:

1. A stock size of *two or more* (parts or units).

2. A stock size of *one* (part or unit).

Before proceeding any further, the definition of the important terms may be noted.

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

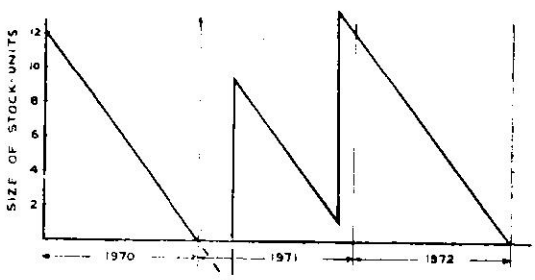



Fig. 4

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

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

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

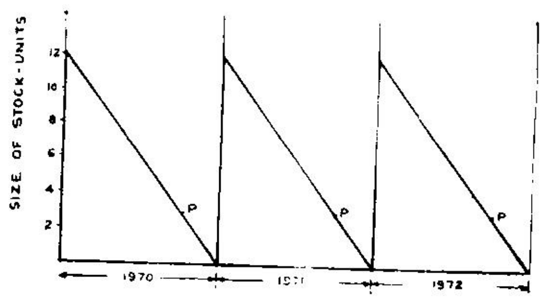



Fig. 5a

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

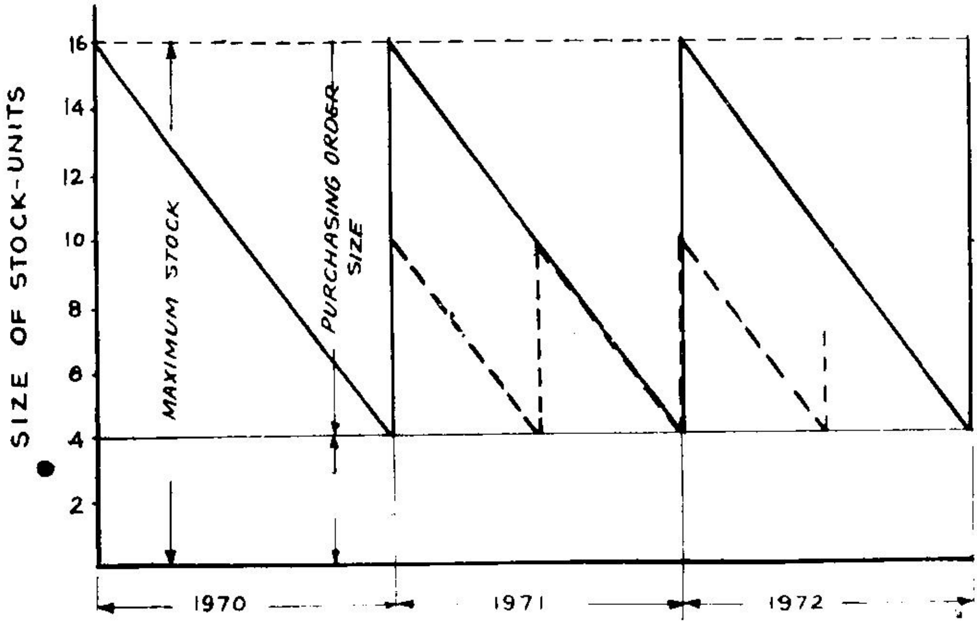



**Fig. 5b**

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

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

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

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

**Summary and Recommended Procedure**

1. *Collect all background material for the determination of composition and optimum size of spare parts stock.*

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

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

3. *Separate these desirable units in high and low value items.*
4. *Establish different policies for these two groups.*
5. *Make final decision on which parts to have in stock.*
6. *Decide which parts to have in stock in one unit, and which to store in two or more units.*
7. *Decide minimum stock size and purchasing order size for the different spare parts.*
8. *Order the spare parts to be delivered together with the machine or plant.*
9. *Review decision on spare parts stock regularly and not less than once a year.*

## FACTORS DETERMINING THE SIZE OF STOCK

### Downtime Cost due to Lack of Spare Parts, Utilisation of Capacity and Its Impact on the Need for Spare Parts

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

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

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

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

*Downtime cost is composed of:*

a. Profit lost due to lost sales resulting from lack of production.

b. Direct labour paid but not producing.

c. Spoilage of products preceding, during and following the stoppage.

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

e. Interest on idle investment.

f. Penalties for late delivery and loss of customers.

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

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

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

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

A highly *mechanized* or *automated* plant is very sensitive to breakdowns of components in production equipment. A sudden failure in one out of 10,000 parts might put the whole assembly line, or even a complete factory, out of production. Even if the *reliability of each* part is 99.9% the reliability of the whole unit is only 80%.

## Summary and Recommendations

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

Unfortunately only a *limited group* of industrial enterprises have *reliable figures for loss due to downtime* due to different reasons, waiting for spare parts for instance. This

*A highly mechanised or automated plant is very sensitive to breakdowns of components in production equipment.*

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

*General comparison* like this can be somewhat *dangerous*, as they assume that the spare parts stock in any way has *a sensible composition and size (of each unit).* This is most often *not true.* Maintenance people get the impression that the store-room has *almost anything except the part they need.*

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

1. *Develop figures for stock cost of spare parts and materials.*
2. *Record figures for downtime due to waiting for spare parts and maintenance materials.* (This recording might take several years.)
3. *Compare the figures and evaluate changes which will improve total company economy.*

4. *Evaluate at the same time the composition and size of the different elements in the stock.*

## IMPACT OF STANDARDISATION OF PRODUCTION EQUIPMENT AND COMPONENTS

### Economic influence of standardization

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

This standardization includes:

1. *Complete machine units,* as tool machinery, material handling devices, boilers, compressors, furnaces, etc.

2. *Machine components,* as electric motors, pumps, valves, bearings, fittings, pipes, etc.

3. *Regular consumed maintenance materials,* as steel bars, plates, oil, metals, etc.

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

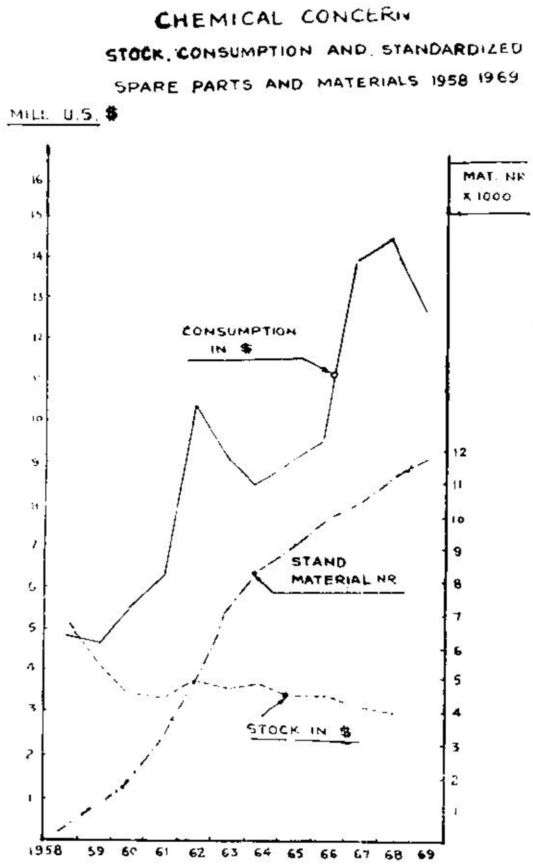



Fig. 6

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

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

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

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

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

## Organization of Standardization Background

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

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

*Use of norms:* The material collected in the book of norms will be used for:

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

2. *Purchasing* of materials and spare parts to the factory.

3. *Requisition* of materials and spare parts from the storeroom.

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

## Standardization Office/Committee

There are *two main possibilities* for organizing standardization work.

1. *A standardization committee,* consisting of people who, most of their time, are engaged in other types of work.

2. *A standardization office,* with one man or a group of people working *full time* on this subject.

In aadition the office will operate with supporting and decision-making commitees.

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

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

A small or medium-sized company will have the problem of affording a qualified man for standardization work alone. In any case the establishment of norms must work according to the "Management of Objectives" principles. *Certain goals* for the number of items standardized must be set up *for each time period*.

*Books of norms:* As mentioned earlier, the product of the standardization office is a steadily growing *book of norms*. This book will have one sheet for each type of material. In Fig. 7 is indicated a norm sheet for steel pipes of *cast iron*.

It contains the following information:

a. *Type of article*—Steel plate for boilers

b. *Blade no.*—here 002.007, which identifies the sheet. It is different from any other norm sheet.

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

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

## STOCK NORMS

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

*Example of ordering:* Steel plates for boilers 16×1250×2500 DIN 1543
H II DIN 17155, certificert

*Stock term:* Steel Plates for biolers 16×1250×2500 H II
Material nr. 002.007.09

Thickness and tolerances according to DIN 1543

| Mat. nr. | Thick-ness t | Dimension w×l | Tolerances t | Tolerances w | Tolerances l | Weight ca kg/pl | Weight ca kg/2 | on stock by R | E | G | N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | mm | mm | mm | mm | mm | kg/pl | kg/2 | R | E | G | N |
| 002.007.03 | 5 | 1250 × 2500 | —0.3 | +10 | +12.5 | 125 | 40 | | × | | |
| .04 | 6 | 1250 × 2500 | —0.3 | +10 | +12.5 | 150 | 48 | | × | | |
| .06 | 8 | 1250 × 2500 | —0.3 | +10 | +12.5 | 200 | 64 | | × | | |
| .07 | 10 | 1250 × 2500 | —0.3 | +10 | +12.5 | 250 | 80 | | × | | |
| .08 | 12 | 1250 × 2500 | —0.5 | +10 | +12.5 | 300 | 96 | | × | | |
| .09 | 16 | 1250 × 2500 | —0.5 | +10 | +12.5 | 400 | 128 | | × | × | × |

Fig. 7

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

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

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

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

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

Up to August 1970 a total of approximately 400 normblades have been worked out, which covers between 18,000-19,000 items. This also includes standardized items which are not in stock *today*, but are used in production equipment now being designed or brought, and thus will be in stock in the future. This proves that *standardization starts in the factory*—planning period, not after the factory in finished.

## Responsibility for Standardization

Standardization can be handled by:

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

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

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

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

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

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

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

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

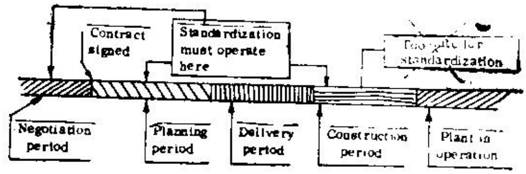



Fig. 8

### Buyer's Authority

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

The *well-organized enterprises in Europe and North America* have detailed specified *books of norms* which are used for all new installation. Furthermore, this book of norms is strictly adhered to in practice. A developing country which gets a key door factory delivered through a contract or low range loan or gifts, should have the same possibility to influence standardization. The receiving country is, however, often *short of qualified people* to take on this job. Furthermore, the technicians come into the picture at a comparatively *late stage*. When the plant is under construction, it is much too late to do anything about it.

Standardization must come into the picture at the planning stage, as indicated in Fig. 8. With the great influence *standardization and internal norms* of different materials, parts, etc. have on the *spare parts stock* and spare parts service, it is of great importance for any industrial enterprise of some size to get this function *organized and operating properly.*

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

**Impact of Preventive Maintenance and Regular Control of Machine Unit Condition**

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

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

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

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

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

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

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

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

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

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

However, a considerable *research and development* activity is going on in developing new and better *non-destructive control methods* for machine units. It seems that the methods which are most developing are the more *advanced and complex condirion control systems*. Primarily this is the condition of different tests built into the machine unit when it is designed, and connected with *automatic recording and alarm systems*.

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

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

**Summary and Conclusion**

The steadily more applied and improved systems for preventive maintenance and control of machine units condition will have a great influence on the size and composition of stock of spare parts. It is important that this composition and size is evaluated in close cooperation with the existing and planned programmes for preventive maintenance and condition control.

**Cost of Maintaining Stock of Spare Parts and Maintenance Materials**

Costs arise from the following—

a. Making the purchasing order

b. Follow-up with the vendor

c. Receive, control and put in store received material

d. Invoice cost

e. Customs and freight cost

f. Capital costs of materials in store

g. Storerooms cost (building, supplies, shelves, transportation, equipment and other facilities)

h. Cost of storeroom, labour and supervisors

i. Deterioration cost (some material will be destroyed during storage, especially in tropical climates)

j. Shrinking cost (theft, misplacing, etc.).

These costs can be grouped in:

1. *Total purchasing* cost (from point a to e above)

2. *Storage cost* (from point f to j above)

**Economic Lot Size in Purchasing**

The cost of making *one purchase order* can for practical calculations be considered as constant. It is mainly the cost of own personnel which is involved (Maintenance Dept., Purchasing Dept., storeroom, bookkeeping, etc.). Whether 10 of 100 units are ordered, and whether one order consists of 1 or 3 different items makes comparatively small difference. Companies which have made calculations of their cost of making *one purchase order* have come out with figures which vary from 5 to 15 US\$. For *inexpensive materials*, routines for procurement can be drastically simplified with a comparative reduction in cost.

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

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

*Storing cost* consists on the average of:

| | |
|---|---|
| Interest | 8% |
| Storeroom, supplies, etc. | 3% |
| Personnel | 3% |
| Shrinking, etc. | 3% |
| Insurance | 1% |
| Total | 18% |

of cost of material in stores

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

**Mathematical Equation for Economic Lot Size in Purchasing**

The minimum stock size is considered as a fixed overhead, permanently existing in stores, and thus does not affect the calculation of economic lot size. Minimum stock is not included in the calculation of total storing cost. The material passing through the stores will be in our case, equal to total purchase per year.

$c$ =cost price per unit
$o$ =purchasing cost (\$7) per order
$i$ =storing cost per year per \$ in store (18% or 0.18)

M =annual consumption in units
x =economic lot size in purchasing

Total purchasing cost per year:

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

Total storing cost per year:

$$L = \left(e + \frac{o}{x}\right) \cdot \frac{x}{2} \cdot 1$$

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

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

The *total annual cost* will be:

$$K = I + L$$

$$K = e.\ M + o.\ \frac{M}{x} + \left(e + \frac{o}{x}\right) \frac{x}{2}\ 1$$

Derivation of this question on x gives:

$$K' = + o \cdot \frac{M}{x^2} + \frac{1}{2}\ e \cdot 1$$

With minimum K'=o and we get

$$O = + o \cdot \frac{M}{x^2} + \frac{1}{2}\ e \cdot 1$$

$$x = \sqrt{\frac{2 \cdot o \cdot M}{e \cdot 1}}$$

Graphically this is shown in Fig. 9.

*Example:*

| | | |
|---|---|---|
| e | =cost per unit | =$10 |
| o | =purchasing cost | =$ 7 |
| 1 | =storing cost =18% | =0.18 |
| M | =annual consumption | =300 units |

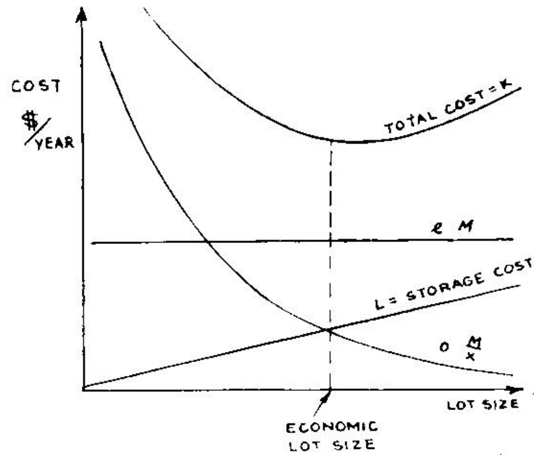



Fig. 9

Economic lot size:

$$x = \sqrt{\frac{2 \cdot o \cdot M}{e \cdot 1}} = \sqrt{\frac{2 \cdot 7 \cdot 300}{10 \cdot 0.18}}$$

$$x = 49 = 50$$

This means *it is most economical* to order 50 units every 2nd month. The *curve for total cost* will in practice be *very flat near the minimum point.*

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

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

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

+50% *and* +100% *of economic lot size.*

Purchasing lot size *outside these borders should be avoided.*

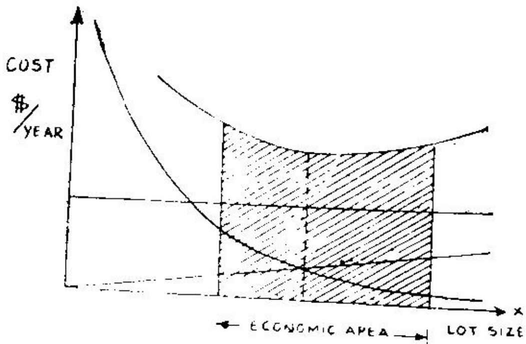



Fig. 10

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

*Use of economic lot size in purchasing:* It is only practical to use this formula for: Group of High Value materials or spare parts.

*Group a and c:* Regular consumed materials and spare parts (see page 1).

Based on the most common distribution of materials and spare parts between the different groups this means that
*less than* 10%
of the articles on stock can be calculated this way.

In total they do however represent
*between* 50 *and* 60%
of the *value* of the stored material and spare parts.

**Stock Size Depending Upon the Number of Places the Item is Used in the Manufacturing Plant**

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

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

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

**One Piece on Stock or None at All**

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

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

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

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

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

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

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

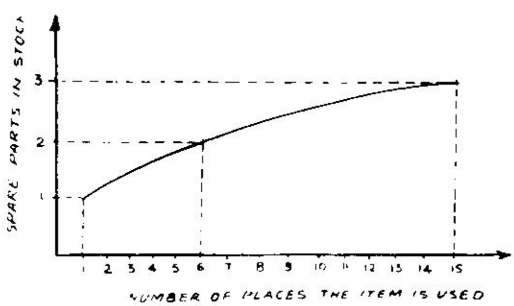



Fig. 11

These figures will, however, vary depending upon:

—frequency of consumption

—delivery time of new parts

—number of critical places where the part is used

—downtime cost.

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

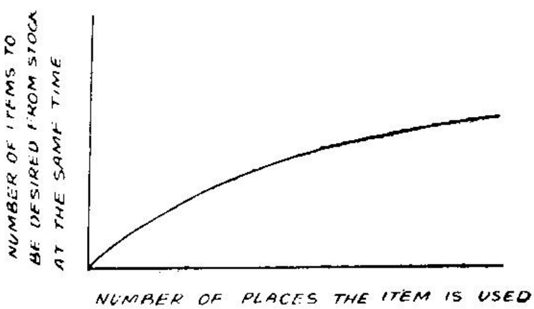



**Fig. 12**

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

It must be realized that *standardization of units used in production* equipment gives quite enormous possibilities for:

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

In one chemical factory it was found 125 *different units* (manufacture and size) of *one type of valve*. The standardization programme brought this number down to 12. It was at the same time made clear that if standardization had been done *before* the plant was designed, 8 different units would have been sufficient. It is quite obvious which reductions in spare parts stock and increase in the availability of parts, this made possible.

## IMPACT OF BRANCH OF INDUSTRY, TYPE OF MACHINERY AND DEGREE OF AUTOMATION

### Branch of Industry

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

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

However, enterprises could be divided into:

(a) 1 shift operation

(b) 2 shift operation

(c) 3 shift operation

(d) continuous production during the week

(e) continuous operation

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

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

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

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

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

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

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

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

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

## Type of Machinery

Factors of importance are:

1. The machinery *needs for spare parts* and its ability to take overload and rough treatment.

2. The possibility of *fast supply of spare parts,* from a dealers stock in the same country, or from the manufacturer.

3. *The cost of spare parts.* Some manufacturers seem to have the policy to sell the machine itself at a low price and charge very high prices for spare parts.

4. *Technical drawings,* with correct dimensions and tolerances.

*Before a machine is bought it is of great importance to investigate and evaluate its needs for spare parts.*

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

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

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

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

## Degree of Automation

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

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

*A high degree of automation requires a very good and fast maintenance service.*

Even with a *reliability of each unit* of 99.9% we can easily come out with a *total reliability* for the automatic plant of 50—80%.

A high degree of automation requires a very good and fast maintenance service in general—including an *extensive stock of spare parts, both in composition and size.*

## SUPPLY SYSTEM FOR SPARE PARTS, SPEED OF DELIVERY, RISHS, QUALITY AND ALTERNATIVE TRANSPORT COSTS

### Spare Parts Supply System

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

Such a system includes:

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

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

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

4. *Location and size of spare parts stock.* Where will stock be kept? —At the manufacturer only? —at dealers in different parts of the world? —in different countries or in different industrial areas? Which parts are kept in each of these stocks?

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

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

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

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

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

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

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

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

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

**Speed of Delivery**

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

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

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

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

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

**Risks**

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

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

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

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

**Quality**

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

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

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

**Transportation Cost**

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

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

We had so far discussed the different *types* of spare parts and maintenance materials, the "total cost concept" of procurement and maintenance and also the *different factors* influencing the issue.

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

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

### 1. Spare Parts and Procurement of a Piece of Production Equipment

a. Is the need for spare parts evaluated?

b. Is the need for spare parts surveyed through contact with other factories which have the machine in question.

c. What does the manufacturer recommend?

d. Does the vendor keep a stock of spare parts?

e. Which parts does he keep in stock?

f. What is his price?

g. How fast can the vendor get new supplies from the manufacturer?

h. Can we get technical drawings of critical parts delivered together with the machine?

i. For how many years does the manufacturer/vendor guarantee spare parts stock?

### 2. Internal Standardization Programme

a. Has the enterprise developed internal standards or is it decided to do so?

b. Is this programme being used, or is it more a "programme on paper" than a reality?

c. Is there a clear and precise top management instruction for the use of standards or normblades?

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

### 3. Internal Maintenance Workshop

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

b. What kind of work can they do?

c. To which tolerances can they work?

d. Has the workshop enough qualified craftsmen?

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

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

### 4. External Maintenance Workshops

a. Which workshops are in the same area?

b. What kind of work can they do?

c. What are their delivery time and price?

d. Are there workshops available in other manufacturing plants?

e. Are there other workshops in the country?

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

### 5. Technical Drawings

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

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

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

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

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

### 6. Types and Value of Spare Parts and Materials

a. Have we dicided all units in:
—Regular consumed materials?

—Irregular consumed materials?

—Regular consumed spare parts?

—Irregular consumed spare parts?

and in:

—low value items?

—high value items?

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

### 7. Statistical Figures

a. Which figures from production and maintenance are recorded?

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

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

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

### 8. Preventive and Protective Maintenance

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

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

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

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

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

### 9. Size of Stock

a. Is a realistic minimum stock size decided upon?

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

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

### 10. Storeroom Routines

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

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

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

d. Does somebody check changes in delivery time?

e. Are stock figures changed correspondingly?

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

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

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

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

**11. Organization**

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

b. How is authority and responsibility delegated?

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

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

## SPARE PARTS PROBLEMS IN DEVELOPING COUNTRIES

**Developing countries compared to industrially developed countries**

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

*In a developing country where it takes a long time to get a new supply of spare parts, we will find the smallest stock of spare parts, both in size and composition.*

Fig. 13 indicates the situation concerning:
—Spare parts on stock
—Possibility to get fast delivery
—Possibility to make spare parts

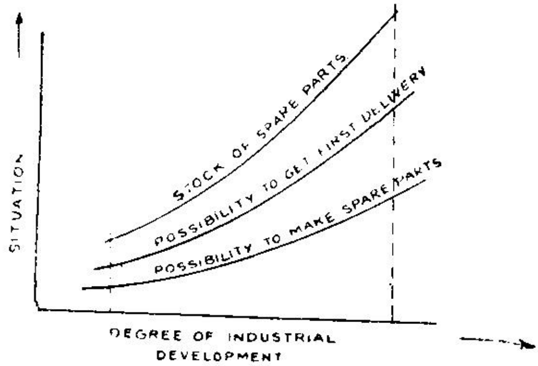



**Fig. 13**

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

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

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

**What is Wrong with the Organization of Spare Parts Service in Developing Countries?**

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

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

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

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

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

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

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

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

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

*Factories which belongs to international concerns have in general a much better stock of spare parts-*

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

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

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

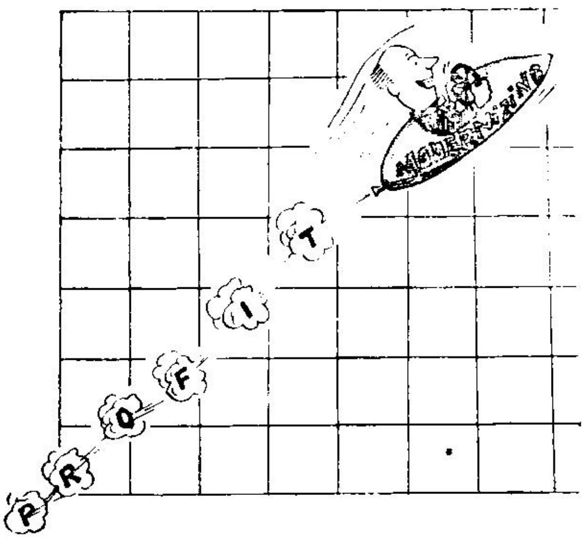
9. The utilization of available machinery and capacity inside the country could be better.

   If a maintenance workshop in one factory has specialized tool machinery, it will in most cases have an ideal capacity for making parts for other manufacturers. This is a matter of coordination, of knowledge and of company policy.

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

# Modernisation Means More Profits

Courtesy : *Industrial world*




SCENE: QUARTERLY MEETING OF THE EXECUTIVES OF THE ABC MFG. COMPANY

**Managing Director:** We shall modernise Plant No. 2 next year. All our marketing studies indicate that next year will be good for us.

**Works Manager:** But Sir, this is the fourth year in a row that you have told me this. It's always 'we'll modernise next year. For four years this Company has watched its costs rise faster than its sales. Plant No. 2 is our key manufacturing plant, and it's just too inefficient to permit a profit no matter how high sales rise.

**Managing Director:** (His face flushed with anger. He was not used to having his subordinates argue with him)—Next Year ! Next Year !

Another year passed. The Company's financial picture was just too bleak. Now he was gathering his staff together to make a sad announcement.

**Managing Director:** The Members of the Board of Directors have decided—in view of fact that the Company cannot operate profitably—to cease all operations exactly from one month now. (His hands trembling and tears in his eyes) I am sorry. I am deeply sorry.

**MORAL—At the first sign of inefficient operations, modernise. Waiting for improved profits in order to modernise is like putting the cart before the horse.**

**In fact when you modernise, you almost invariably profit...in all ways.**

# Handling and Storing of Spare Parts & Materials for Maintenance Purposes on Plant Level

WH Brown*

**Proper control of spare parts, materials and supplies can be an important factor in reducing maintenance costs. and to achieve this end, the organisational set-up to exercise this control must in itself generate a high standard of efficiency.**

THE demands of Modern Plant Management for higher productivity and cost improvement, previously applied to production processes, now equally applies to Maintenance Practices, in these modern times. Consequently the Handling and Storing of Spare Parts and Materials on the palnt level, for maintenance purpose, must now be considered as part of the Maintenance Practice.

Much has been written on effective maintenance management, and the old adage of a "necessary evil" has evaporated with the realisation that this function is an integral part of the whole function of any production or process unit—large or small.

Consequently the importance of the service organisation supporting the maintenance function in the supply of spare parts and materials, needs no further emphasis.

The proper control of spare parts, materials and supplies can be an important factor in reducing maintenance costs, and to achieve this end, the organisation set up to exercise this control must in itself generate a high standard of efficiency.

The efficiency or performance of this service can be related to an increase or decrease in plant downtimes, corresponding to increased or reduced maintenance expense, arising as a result of inferior supplies and waiting time, or reliable material promoptly delivered.

Equally, great care has to be taken not to promote stock investment levels absorbing capital which would be more usefully employed in promoting higher and more efficient production levels.

Therefore, as it is a vital essential in any effective economic industrial policy to place quality and reliability high on the list of requirements, it is equally essential to provide the service of spares and supplies on the same basis.

Modern technologies previously considered as fringe professions involving metallurgy, automation and instrumentation, although increasing the complexity of maintenance control and application, have the primary objectives

*British Steel Corporation, Newport, United Kingdom

of higher process efficiencies and cost reduction. These in conjunction with Accounting Techniques in Budgetary and Maintenance Costs Control, provide the basis for sound Maintenance Practice.

Consequently in highly sophisticated production units delays in the rectification of unforeseen stoppages, caused as a result of the premature failure of equipment or unscheduled extensions to the planned maintenance down times, must inevitably be calculated in terms of substantial financial and production losses.

Having established the background and the essential requirements in providing an effective organisation for the handling, storing and supplying of spares and materials to maintenance and process units, it will be appreciated that such an organisation must in itself be sophisticated in order to achieve the desired result.

## THE POLICY CONCEPT

Normally the organisation set up to handle spare parts and materials is located either within the Administrative or the Engineering Control structure of a Plant, for Management Control purposes. This organisation of necessity must have direct communications with all operating or functional sections of the Plant.

Essentially therefore, on medium and large plants, the Stores Control section requires to be autonomous in concept. Equally the organisation must be capable of operating procurement and supply systems which will involve Administrative, Accounting and Engineering skills, to ensure an efficient and economic service.

The proximity of the Stores Unit/s to the user Plant sections is an important economic factor, and this should be carefully considered with regard to future plant expansion or development, when determining the location.

Depending upon the type and size of the Industry involved, Stores Organisations usually fall into two categories, i.e. a Centralised single unit or serveral units closely located in one area, alternatively, a decentralised organisation having several units each located adjacent to the Maintenance Section of a major plant unit.

In the latter case each Unit would have the special function of providing the particular spare parts for a specific plant process, other than the general or common supplies required. These individual units would be controlled directly from a Central Distribution Stores, operating as the Administrative Control Section.

Either system has operational problems and inefficiencies. Largely the determination as to which system will provide the best service at minimum operating cost, will depend upon the amount of capital available to establish the organisation, coupled with the volume and investment in spares and materials to be stocked.

## TYPE OF ORGANISATINM

In general, the following aspects should be considered when deciding upon the type of Stores Organisation to be projected.

**The Centralised Organisation**

(a) The ever present possibility of insufficient storage space as a result of protracted or varying supply times necessitating increased stock holdings.

(b) The necessity to relocate stocks arising from variations in stock quantities held, to prevent multi-location problems.

(c) The tendency for Plant Maintenance or Operational Personnel to establish stocks of spares and materials on plant local to their activities, giving rise to waste or loss and involving extra expense.

(d) Operating a continuous transport service of supplies to, and recovery from the Plants. This service if inefficient and under emergency supply conditions, can extend maintenance times, thereby creating production delays and financial losses.

### The Decentralised Organisation

(a) The extension of Manning to operate the organisation.

(b) The extension of communications from the Central Control, and the involvement of sophisticated data recording techniques.

(c) The provision of central and local distribution transport, and the extension of mechanical handling facilities.

### Objectives

The evaluation of each system requires a considerable amount of study, research and fore-knowledge, resulting from which several imponderable aspects will still remain.

Consequently, joint consultation with the suppliers and the users is most essential to overcome some of the imponderables to be met in this kind of study, before eventual decision is taken.

This kind of joint consultation not only eradicates waste in effort, and money, but promotes the correct atmosphere and relationship in developing efficient material control systems.

It is too late to start thinking about material handling and storing when the material is delivered. The effort has to be made at the ordering stage. It is necessary that all control personnel directly involved in this process, should be consulted, to achieve the desired results. Equally this must be done at the inception or introduction of any Stores Development project.

Ostensibly the results to be aimed at are:-

(a) Minimum manual labour costs.

*Evaluation of each system requires a considerable amount of study, research and fore-knowledge*

(b) Flexible holding capacities when and where required.

(c) Minimum volume of material in transit.

(d) Efficient stock control and therefore minimum capital outlays on stockholdings.

(e) Efficient utilisation of service transport.

(f) Maximum volume of production.

(g) Improved Industrial Safety.

(h) An overall increase in efficiency.

The effectiveness of the policy determined will depend upon the correct functioning of the Planned Organisation supporting that policy.

This fact has been demonstrated over thousands of years of history, where there was a need for the conservation of supplies for ready use. This function has now become a science, concerning itself with Inspection and Testing of these supplies, storage conditions, protection and security, to name only a few of the many requirements to be met. Today many industries are classified by their ability or inability to operate an efficient supply and stock control organisation.

It will be obvious, therefore, that to meet the multiple of conditions and circumstances surrounding these operations, it is a fundamental requirement for Stores Management, in conjunction with all other interested parties, to lay down practical procedures or rules. In this way reasonably smooth working can be achieved in all sections, and such efficiency promoted that service costs can be maintained at sensible economic levels.

In essence the strategy recommended in establishing policy can be summated as follows:-

(a) *Service:* To provide or progressively improve the quality of the service to the process units or plant sections concerned.

(b) *Finance/Costs:* To budget and control all expenditure.

(c) *Productivity:* To increase productivity on a regular planned basis.

(d) *Development:* To develop the service given in the light of the best available knowledge, and to the advantage of the plant sections concerned.

(e) *Personnel:* To provide a well motivated efficient staff and to develop the skills an aptitudes of that staff to the best advantage.

(f) *Consultation:* To consult with associated plants and organisations on common problems.

## THE BASIC ORGANISATION

In setting up a stores organisation, the policy having been agreed, and the capital involvement having been established determination of the minimum staff required, in grades and job descriptions is the pre-requisite. Generally such employees are established in staff and works grades, covering Administrative duties on a staff basis and Manual operational duties on a works grade basis.

### Administrative Section (Clerical)

Deals with the paperwork systems adopted for the control and recording of all spares and material movements. They would also liaise with other departments, such as the Purchasing and Accounting Sections, should these functions be separate from the Stores Organisation.

### Operational Sections (Manual)

Usually supervised by staff personnel, and utilising works grade personnel, are responsible for the security, movement and protection of all spares and materials in store. They would also maintain such records as are necessary for material flow control.

### Inspection Section (Engineering)

Would deal with all incoming spares in particular, and a variety of general supplies, checking limiting dimensions to drawing, material specifications, workmanship and material condition, before such materials are passed to storage.

It will be appreciated that such a unit would only normally be introduced in large or integrated types of Plants, utilising Spares of considerable value, and unit holdings of Insurance Spares, considered critical for Plant continuity.

The integration of these sections, and their relationship with the Service and Production or Process units on the Plant, has then to be evolved by the introduction of control systems. These systems in the main should be designed to record or produce information for control purposes, or requiring action, so that the whole organisation is in effective motion, to continuously maintain the service.

The main systems to be considered are:-

(a) Inventory and stock controls.

(b) Receipts and distribution producers.

(c) Inspection control and reporting procedures.

(d) Recovery and repair systems.

(e) Budgetary and expense control systems.

*In promoting separate identifications for spares, either as component or assemblies, and general supplies termed "cousumables," separate stock or code numbers have to be introduced,*

**Inventory and Stock Controls**

In order to establish these controls, it is first necessary to promote a comprehensive inventory or catalogue of essential spares, insurance spares, and consumable or general supplies. These schedules would normally be prepared, in association with the equipment or machinery supplier, and/or upon previous experience obtained on another similar types of plant.

The evaluation of these schedules on the basis of annual usages can then, with Management approval, become the basic budgets for inventory and accounting purposes.

Subsequently as statistics are generated, modifications to the operating budgets can be introduced, including allowances for depreciation of plant, due to the normal extension of maintenance, as the result of wear becomes more effective on plant operation.

In promoting separate identifications for spares, either as components or assemblies, and general supplies termed "consumables", separate stock or code numbers have to be introduced. Differenciation requires to be made, between specific spares connected with particular equipment or machinery, and those spares which have a common application to a large variety of equipment of plant units. The remainder being dealt with in a "consumable range" of materials.

Depending upon the data collection system equipment used, in the recording and accounting system, simple or compound codes can be used. Generally these codes should follow the pattern outlined below, and contain the following information:

a) The Departmental Code Number.

b) The specific Process Unit or Plant Section Code Number.

c) The numerical sequence number of all components to be carried, as spares stock for the equipment concerned. Spares Assembly numbers should be incorporated where component spares and assemblies are both stocked.

d) Differenciation coding to distinguish between Electrical/Mechanical/Automation/Instrumentation etc.

Provided the data collection system can accommodate say ten digits then for example a stock or code number for a mechanical spare could be 6501/307/002.

In this example 65 is the plant or process section number, 01 is the equipment or machinery reference in this section, 307 is the assembly section of the equipment or machinery concerned, and 002 is the actual spare part code involved. Similarly 6502/ etc. could apply to electrical equipment on the same plant section etc.

This type of coding system is essential when considering spares inventories of 60/1,00,000 items and above, whereas simpler forms can be used for considerably smaller spares inventories.

Considering common spares coding, e.g. bearings in multiple use in any plant or process unit, it may be adequate to purely prefix a numerical series, by a single or two digit reference. to give adequate identification e.g. 40/C02041.

Similarly with general supplies, i.e. consumables, a simple two digit prefix system is adequate for control purposes, provided sensible segregation and grouping of these supplies, has been determined initially.

Inventories or catalogues mainly fall into four categories, for stock control purposes:

(a) Replenishment on a cyclic calendar basis usually arising through Contract Orders on suppliers.

(b) Safety stocks for essential supplies where uncertainty exists or usage is irregular.

(c) Anticipated requirements for stock above normal holdings, as a result of forward planning for a specific maintenance task.

(d) Insurance stocks, critical for the continuity of plant or process, and whose replacement times would be extremely protracted, or are supplied from sources outside the country requiring them.

In establishing efficient inventory programmes, certain objectives require to be considered. These are:

(a) To arrange with Management and Maintenance Control the quantitative terms of the requirements, and to ensure that the Stores Control Personnel can operate consistently within these terms.

(b) To balance the Inventory, and to operate within the Budgeted Investment level.

(c) To ensure an adequate level of service to the Plant or Process Units.

(d) To promote a high proficiency in the control procedures, and a high utilisation of the administrative and operational personnel.

(e) To adopt simple calculation techniques within the control procedures, which can be carried out on a routine basis by clerical staff.

(f) To promote limiting budget rules in quantitative terms which if exceeded will require control by management action.

(g) To provide exception reports for management decision and action.

## PLANNING MATERIALS HANDLING

Any store or warehouse should be established as a planned space area, capable of the efficient handling of spares and materials specific or variable at minimum cost.

The greater part of this function is handling, either manually or by means of mechanical aids, or a balance of both to give the best efficiency in the operation.

The cost aspect in this connection is of vital importance, in that such costs add to the oncost of a product but do nothing to increase the value of that product.

These costs can represent from 15% to 85% of the product cost, and consequently, this function offers greater scope for improvement and ingenuity than probably any other field of industry.

In these competitive times, the cost of non-productive services in any sphere of industry is all important. Essentially therefore, more sophisticated techniques are continuously being introduced to achieve better results and reduce these costs.

Consequently Materials Handling stands high on the list of functions which must be under constant review, and in particular the irrecoverable material and energy losses arising from bad practice.

It is only in recent times that greater attention has been paid by Plant Management to Stores and Materials Handling. Previously their attention generally has been focussed upon improving production process or practice, in order to sustain competitiveness in their field of industry.

Arising from this emphasis on improved equipment and tooling, and on the development of work study, value analysis, and incentive schemes it becomes obvious that without a highly effective Spares and Materials service, such objectives could be jeopardised. Therefore, unless suitable investment and consideration is injected into this function, to permit it to achive the necessary efficiency, economies in production and financial costs, will not necessarily be achieved.

There are three distinct cost centres in operating a stores organisation—labour, space and equipment. Depending upon the availability of each, and the policy adopted by Management, the whole operation can be very expensive, without the necessary efficiency being achieved.

This type of problem can be resolved by the introduction of modern techniques in space saving methods and equipment, but this usually calls for considerable capital investment.

Consequently, in adopting a philosophy which will be viable within the prescribed limits of the organisation concerned, the reasons for the function requirement must first be considered. Briefly these are:

(a) To control a variable flow of spares and materials, either as a result of Purchasing or arising from the Plant or Process production.

*There are three distinct cost centres in operating a stores organisation—labour, space and equipment.*

(b) To ensure Plant or Process availability by safeguarding any interruption of these supplies.

(c) To provide an autonomous control at an economic cost, compatible with a high level of service.

Accepting these reasons and conditions then the variation in the operating requirements have to be analysed. These are:

(a) Dealing with fast moving spares, and consumable materials.

(b) Dealing with slow moving spares, and materials.

(c) Dealing with a combination of both fast and slow moving spares and materials.

It is essential, therefore, for handling and storing purposes, that decisions have to be taken as to which of the three categories the stores or spares should be included. It is equally important to establish, in what ratio these are expected to be handled and stored.

It will be appreciated that there can be a considerable difference in the equipment, and facilities required, for the different categories to achieve the desired efficiency.

Consideration must also be given to the material and physical characteristics of the spares and stores concerned, to ensure proper handling and storing without damage or waste in energy.

All of these aspects must be given full and proper consideration, when designing the layout, *Irrespective of the way in which a store is established, space conservation within the store is of vital importance.*

and selecting the equipment necessary for the stores organisation.

In many instances planners have to adapt existing plant buildings, or part of such buildings. This generally arises as a consequence of the emphasis on capital expansion of production or process units. Under such conditions, stores are still expected to be capable of the flexibility required to meet rapid changes in the production and maintenance services, resulting from order book fluctuations.

From the foregoing it will be appreciated that, to be forward looking, under all conditions, the organisation requires not only to maintain flexibility and a high level of service, but to be continuously motivated, anticipating change at all times, but in essence dynamic.

Irrespective of the way in which a store is established either as a result of the acquisition of existing premises, or built to Specification, space conservation within the store is of vital importance. Without such intention, the essential flexibility or the dynamic control under viable conditions will be lost.

There are various systems and developments in this respect, all with the same objective in mind:—space conservation, and in general these systems can be defined as follows:—

(*a*) *Permanent or Fixed Locations:* Inferring Areas of fixed storage equipment, such as bins or racks, specifically calculated to hold predetermined capacities, and set out in stock or code number series.

(*b*) *Group or Area Locations:* Of a flexible capacity, catering for loose pallet or stillage equipment, or multiple floor loads, such as bagged materials, and capable of random storage for a reasonable time cycle.

(*c*) *Block Storage Locations*: These in essence are areas of very high density, with large holdings of similar spares of materials, usually received and issued in large quantities, and suitably arranged for mechanical handling.

## HANDLING AND STORAGE EQUIPMENT

Basically the variation of design and size capacity of the storage equipment selected, should be based upon the result of a study of the number of unit items to be held in each type of storage. This study should be related to the economics of Handling, Purchasing, and Plant usage factors over an appropriate time cycle. This will result in the establishment of "unit load" factors, for each type of Spare or Consumable item carried in stock.

These unit loads according to size and weight will automatically determine whether they can be handled manually, or by mechanical aids, but close consideration must also be given to ensure the maximum of standardisation, to achieve the greatest economies in operation.

The necessary requirement to utilize maximum space height in any building has led to many developments in handling aids, e.g. pallet trucks, fork lift trucks, stacking trucks, side-loading trucks, hoists, cranes and conveyors and each as required can be modified with suitable attachments for special applications.

The obvious advantages of these aids are flexibility, speed in operation, stacking, loading and transporting, *with one man operation.*

The only simple rule arising from their use is that spares and materials should not be placed directly onto the floor, or on fixed racking, but should be contained on a transportable pallet, or supported on timbers, to allow direct access by the lifting equipment in use.

Pallets used in conjunction with a fork truck, enables spares an materials to be handled efficiently and safely, by a smaller number of operatives.

In modern practice, Suppliers, will load the materials on pallets, to facilitate more rapid handling at the reception area. Without this facility, extensive transport delays will arise, either as a result of the necessity to resort to manual off loading of the supplies, or otherwise due to transport congestion in a busy store, where manual work will have no precedence over fork truck handling of receipts.

Unit loads in palletised form can if desired, be transported directly to the Production or Processing Unit, and so avoid double handling of such loads.

## CONTROL SYSTEMS AND PROCEDURES

The control procedures to be implemented are generally as follows:

(a) The receipt and checking, of all incoming spares and stores against prepared documentation.

(b) The controlled supply or issue of such materials to Plant and the certification of issuing documentation.

(c) The maintenance of a reliable location control system to effect a rapid service.

(d) Ensuring the security, protection and correctness of the supplies stocked.

These routine procedures require constant supervision to maintain efficiency, basically because they are routines. They are necessarily introduced to reduce possible production or financial loss, arising from errors or omissions and creating emergencies on Plant.

*Irrespective of the size, type or complexity of any store organisation, control procedures are almost as essential as the materials stored.*

Irrespective of the size, type or complexity of any stores organisation, Control Procedures are almost as essential as the materials stored, if effective economic ordering and financial controls are to be maintained.

Basically these controls should in all cases be related to essential "disciplines", affecting Management and Staff alike, in order to generate the common purpose of continuous motivation within the service.

Consequently parameters require to be set up in Capital Controls, Expense controls, limitation on varieties of supplies, and equally time control factors.

All of these requirements can be termed "Basic Budgets", against which operating performance requires to be measured on a routine if not continuous basis, to produce the best possible relationship between the cost of the whole operation and its generative effect on Plant Maintenance.

Such section budgets are part of the overall operating plan of any Plant, which consists generally of a series of separate but interlocking plans, covering all main plant operations of functions. Each plan is dependent upon the others maintaining their objectives, to ensure the successful accomplishment of the overall operating plan, and the profitability of the Plant.

The Order Control system within the stores organisation for the Purchasing of Spares and Supplies, must be aimed at the production of the minimum number of orders raised for any specific Spares or Supplies group. They must ensure a constant, but safe minimum quantity and investment level for these supplies, commensurate with Plant requirements.

This is general means that contract orders require to be set up, against which stores administrative personnel can obtain supplies, by simple communication usually on a "cyclic" or calendar period.

The important aspect in this regard is that each group of orders must be evaluated against the budgeted allowance, to ensure compliance with the operating plan.

*The order control system within the stores organisation must be aimed at production of minimum number of orders.*

Emergencies and other exigencies will arise from time to time, and consequently excessive budget conditions require to be permitted over a short period of time, provided these are eventually corrected over a given financial control period, either monthly or quarterly.

In order to ensure effective control, Management practice in this connection is simply to maintain a moving average graph against each supply group and plotted against the budget factor.

This arrangement permits a limited amount of flexibility within the purchasing programme budget to cater for unusual conditions while retaining management control of the situation.

Concerning safety stocks for essential supplies, where the usage is irregular, these also can be controlled on a budget and contract supply basis related to maximum and minimum stock controls. These are not necessarily re-ordered on a routine time cycle, but according to the minimum stock situation existing at any time. It is necessary, however, to ensure that arrangements have been made under the contract for the supplier to maintain "Buffer Stocks" thereby permitting investments to be controlled at acceptable levels.

Likewise the evaluation of the orders raised and graphed on a moving average basis, provides the basic control for management.

Where specific items and insurance spares critical for production continuity are concerned, again in a limited way contract conditions can be established provided that these items are manufactured within a reasonable distance from the Plant, or are proprietary items reasonably available.

Otherwise operation on a maximum/minimum closely controlled stock review, after each issue has been made, is the most satisfactory method of securing the right balance in stock availability and investment control.

To support and maintain this type of system, controls require to be set up to deal with delivery time variations, and to examine all the possibilities of effecting repairs to used spares, on a routine basis and, where cost savings are involved.

These controls are normally introduced or directed in conjunction with Senior Maintenance Personnel, who must satisfy themselves that the efficiency of the repaired item will be equal to that of a replacement.

There are, of course, major spares items of considerable capital cost, wherein replacement must be subject to Senior Management decision, and usually such items are catered for in capital Plant Budgets.

It will, therefore, be appreciated that control procedures to be established in the Purchasing section of the organisation and to be effective must emanate from Management. These controls will operate through the strata of the service organisations each having limiting authority, established as a discipline right down to the clerical section, who normally initiate the whole function.

Supply orders having been satisfactorily produced, progress control then takes over, which can either be as a routine function or "by exception", according to the type of supply involved.

Routine progressing would apply generally to essential spare parts, enquiries being made with suppliers in advance of the delivery date to obviate unforeseen delays. In cases where delays are indicated, this information can then be passed on to the Maintenance Control in adequate time, for alternative action to be taken as required.

"By exception" progressing would normally apply to routine deliveries, where a variation of a few days would not jeopardise Plant availability. Usually this action arises as a result of the Stores Administrative section reporting the non-delivery of material against their control schedules.

Receipts control is the next step in the system, and again a vital step in the chain of maintaining optimum service to the Plant. Errors and omissions at this stage can create interruption of supplies to the maintenance section in particular, resulting in an extension of the planned programme and involving financial and production losses.

To assist the speed and accuracy of this function it is essential that receipts documentation includes copies of the official orders, or in their absence copies of the originating paperwork for the Spares or Materials required, to ensure that the description and quantity of the items received is in accordance with the order.

Both being correct, and the condition of the material being satisfactory, then the paperwork having been completed, the materials can be removed to the stores location allocated.

In cases where an Inspection section is utilised, then normally all spares items would be processed through this unit prior to location. In such circumstances, verification of the correctness of the receipts is confirmed by Inspection certification on the Receipt documentation .

Regarding general supplies, it is essential where these are not fully checked or inspected that the location control personnel not only ensure that the storage location is accurate but that these supplies are similar to those already in stock.

Resulting from these actions the original documentation now updated requires to be registered and distributed to all sections concerned, namely:

(a) The Purchasing Department to allow closure of progressing records.

(b) The Accounts Department to update stock and investment records.

(c) The Maintenance Section to indicate availability.

(d) The Financial Section to authorise the Invoice upon receipt.

## COMMUNICATIONS AND INFORMATION HANDLING ON PLANT

The minimum information, required for the distribution section of the Central or Area Store concerned, should be contained on a summary or analysis schedule of the Spares and Materials required by the Maintenance Section concerned and indicating the Plant delivery point. i.e., maintenance location on a Date/Time basis.

This is not management information but arises as a result of forward planning on maintenance, allowing time to ascertain the availability of supplies and the co-ordination of transport. to meet the requirements of the maintenance programme.

On completion of the maintenance and the recovery of the unused supplies, the normal accounting practice of charging out the used supplies can then proceed with the minimum of paperwork and time.

Within the same time cycle arrangements including works orders/buyers requisitions can be produced. These orders or requisitions are raised for the replacement of spare parts, as necessary, and for repairs to be effected to recovered unserviceable spares, with the minimum of delay.

The close co-ordination of this process can have a major effect in reducing the stock levels, particularly of spares, and consequently the investment levels of these spares.

Recoverable Spares and other materials left lying around is gross waste and eventually, if allowed to accumulate, can become a serious safety hazard and security risk, as well as destroying the principles of good housekeeping.

## Management Techniques and Controls

As Plant and Process Development extends in any inudstry increasing the complexity, the need for a more rapid and easier flow of primary data assumes greater importance. This is particularly the case in respect of control information and to this end more sophisticated data collection techniques are being introduced continuously.

Not so long ago, in stores service units of considerable magnitude, manual recording of all movements was the accepted practice, whereas within the span of a few years, the necessity to absorb, analyse, and report information accurately and speedily for control purposes has brought into common use Electronic Data Processing Units, utilizing Computer Control.

Such equipment has many advantages over the manual systems, particularly in the speed of operation and the enormous memory or information banks which can be generated within the system. Such systems provide immediate availability of any of this information as required, without the laborious effort of searching through manual records.

The expense justification of E.D.P. Units mainly applies in large Industrial Units, where as a result of fesasibility studies, savings and better performances can be achieved relative to the mannual systems, whereas in small units it would be difficult to justify the purchase or lease of such equipment.

However, it is equally feasible for a number of small Plant units to investigate the possibility of jointly obtaining this service or of obtaining such a system through a central computer service organisation.

The relative costs of manual and E.D.P. systems can be calculated, but it should be remembered that there are many unforeseen advantages in the E.D.P. systems which usually result in significant savings. These savings in the main result from more usable information or the rapid conversion of such information for better control which in turn produces cost savings.

The greater the uses to which the computer is put, the lower the unit cost, as the equipment can account for 75% of the total cost of the E.D.P. system.

Computer systems have a very extensive application, other than informaton handling, and are being applied to Production Process Controls over a wide range of Industries. Under certain conditions they are also being applied to materials control and handling in large Stores or Warehouses, normally termed Automated Storage Handling.

The main object in establishing an Automated Store is to reduce the overall cost of the operation. This cost reduction is achieved through savings in wages, handling, investment levels and other oncosts, while increasing the service levels of such stores.

Most stores planners would, in the interests of efficiency, prefer to design the equipment and layout to meet the needs of their own problems, and the types of spares and materials with which they are concerned. In the interest of economy these desires have to be subjugated and standard equipment introduced wherever possible, to effect economies in maintenance of the installed equipment.

The basic operational requirements in an automated Store are no different to those in the conventional store, in that input is effected by fork-lift truck or conveyors onto transfer pallets operating between input and issue conveyor systems and stacker cranes.

Similarly with issues the process is reversed but the whole system is computer controlled, largely eradicating manual labour operating with manual record control systems.

As stated previously, the viability of sophisticated equipment of this nature can only be considered where capital is available, and the volume of materials handled is of a considerable magnitude. Primarily the end use will be to materially assist the supply service at a reduced cost, and that the capital outlay will be recovered over a period of about five years from the commissioning date.

These systems can be interlinked with planned maintenance programmes, where prior knowledge of the availabilities of spares and supplies is essential. Such an arrangement can have a major effect in increasing the effectiveness of the maintenance operations, thereby promoting savings in maintenance costs and improved production performance.

Feed back information is, therefore, essential in such systems to ensure that each section motivated complies with the procedure and performs at optimum efficiency.

With E.D.P. systems, information feed back is the primary objective in order to promote further activity and to maintain the whole system in motion. It is essential such reporting is continuously monitored by more than one person, to prevent the possibility of oversight and error.

With manual systems, however, it is essential to introduce Supervisors or Controllers, wherein checking routines are employed, to ensure no lapse in the system.

Usually this type of control would employ calendar control schedules, statistical updating records, and probably registers to ensure that the routine disciplines are observed.

Again with E.D.P. equipment, as with manual systems, the accuracy of all documentation is vital to the whole operation. Supervisorry control and monitoring of this documentation is essential to ensure that the "disciplines" are being rigidly observed.

Errors or omissions arising in the system as a result of malpractice on the part of operators usually mean the reproduction of all documentation and the recirculation of the paperwork, giving rise to increased cost and delays.

In cases where the receipts do not comply with the order specification or quantity, exception reports require to be raised, and the action necessary to correct the situation included on these reports.

When this action is completed and the materials are returned, or additional supplies are awaited, the system returns to the initial status of providing paperwork including the order copies to the receipts control point.

Referring now to the cost aspects arising from the fulfillment of maintenance and production requirements, unless continuous vigilance by monitoring and evaluation of these issues is maintained, all the preparatory planning and budgetting of the supply and investment aspects will be thrown into confusion.

The information generated for these controls continuously revolves, starting with the ordering condition and terminating with the supply to plant, which activates the starting point again.

Consequently, as in the case of many such activities, the diminishing effort towards the end of the sequence, equally applies in the control of this type of expense.

Realisation of this defect in performance, makes it essential that the "disciplines" to be introduced to ensure control, must be even more stringent to achieve the correct budget performance.

As will be well appreciated the volume of separate issues arising each week in any size of Plant, relative to the receipts volume is extremely high, and can reach ratios of issues to receipts of the order of up to 100 ; 1.

*Serious consideration with some ingenuity has to be given to reduce the problem of the plant personnel while maintaining the objective of expense control within the budget discipline.*

It will also be appreciated that in the case of the materials receipts aspect the function is generally being handled by a limited number of trained personnel, as a total function, whereas, requests for supplies arise from a very much larger number of Maintenance and Production personnel. It is usual for Maintenance and Production personnel to consider the need to provide request notes as a function they could well do without and has no direct part in their activity.

Herein lies the greatest danger, in that supplies if continuously overordered by plant personnel, to economise in their paperwork, can set a paittern of usage which of its own volition will destory the concept of budgetary control, and minimum investment levels. This chain rection if allowed to continue would seriously affect the overall operating plan.

Consequently, serious consideration with some ingenuity, has to be given to reduce the problem of the Plant personnel, while maintaining the objective of expense control within the budget discipline.

There are numerous systems employed and developed, as a result of such experience. It cannot be simply solved, by limiting or refusing to supply, as this creates frustration, and could result in labour discontent and reaction, resulting in reduced productivity, with consequent financial loss to the Plant.

The basic requirements must, therefore, include the following:

(a) The reduction or elimination of request documentation originated by plant personnel.

(b) Wherever possible, to arrange supplies to Plant on a regular or calendar basis.

(c) Providing, where necessary, limited storage arrangements local to the activity centre, where, with the co-operation of Plant Supervisory, Maintenance or process personnel, regular usage items of a general character can be obtained

*The frequencies of delivery will obviously depend upon the volume of any commodity group required, and the storage capacity available in any plant section.*

without further request paperwork.

(d) Prompt dealing with the exceptions to the above, if unplanned and requiring to be supplied from a store remote from the activity centre.

An analysis of the possible and preferred results to be derived from these proposals would be:

(a) The reduction or elimination of errors and omissions in the primary data arising from plant requests.

(b) Reduced handling and transport costs between Stores and Plant, and obviating the possibility of the overordering of small quautity requests.

(c) The elimination of delays in awaiting trivial supply items, but essential to maintenance productivity, and reducing or preventing additional expense, arising from material loss or waste left around the activity centre.

To establish the control system for issues and embracing the foregoing requirement, it is at first necessary, as a result of a work study, or available statistics or a measure of both, to establish the limiting budgets. In these considerations Senior Plant personnel should be involved and the results approved by Management to ensure a fair compromise all round in the initial stages.

From the usage/expense analysis obtained, supply time sequences should be established, having regard for high vehicle loadings, high transport utilisation, to give minimum cost.

The frequencies of delivery will obviously depend upon the volume of any commodity group required, and the storage capacity available on any plant section.

The routine would then follow the practice of delivering the same groups of items to all plant stores in rotation, to be followed by the different groups on a cyclic basis.

Depending upon the accounting system employed, it is possible to arrange that the receipts credits to stock, and the supply debits to Plant, can be processed through the accounts at almost the same time, thereby economising in all paperwork transactions and accounting activity.

## ACCOUNTING/COSTING

The essentials in any comprehensive system of accounting and costing, related to the control of spares and other materials, should provide a complete analysis between the actual and the budgeted costs for all control functions.

*Expense forecasting for Cost Control is today a common feature in Plant Management.*

Such an analysis would, for example, indicate over-or under-variances on the recovery of fixed expenses, resulting from changes in activity, in storage, handling, delivery, administration and maintenance functions.

This information should be processed within the period under review, highlighting those expenses under each separate control function.

Expense forecasting for cost control is today a common feature in Plant Management, the aim and effect being to reduce labour and material costs to a minimum, or to maintain these costs at an economic level, while promoting high productivity.

Consequently the stores function, in providing to costs, accurate forward information of anticipated usages and therefore expense to be coupled to the forecast of maintenance costs, over any given period based upon the regulator systems in operation is of considerable importance.

As a result of receiving this information Plant Managers are in a position to monitor the effect of their intentions before decisions are taken.

Charges to plant should stipulate the demander and the plant section to be charged, to enable Plant Management to verify such costs.

From the results of the costs information, continuously produced by the accounting costing system, performance trends can be generated, which if fully utilised by management, will promote many benefits in the improvement of maintenance costs arising as a result of:

(a) The better use and control of maintenance spares and materials.

(b) Focussing attention on high cost sections and high cost spares or materials usage.

(c) Isolating weaknesses in particular plant items, resulting in modifications and improvement in performance being obtained.

(d) Improved maintenance methods and the improvement in the supply and handling of spares and materials to plant.

**Conclusion**

The foregoing was an endeavour in short form, to cover in a narrative, some of the aspects of a Spares and Materials service on the Plant level.

The inter-relationship of much of the subject matter is such, that there is no particular or logical sequence to the practices and systems discussed.

However, it is hoped that the philosophy and principles projected will prove of consequence to those contemplating introducing such a service and organisation.

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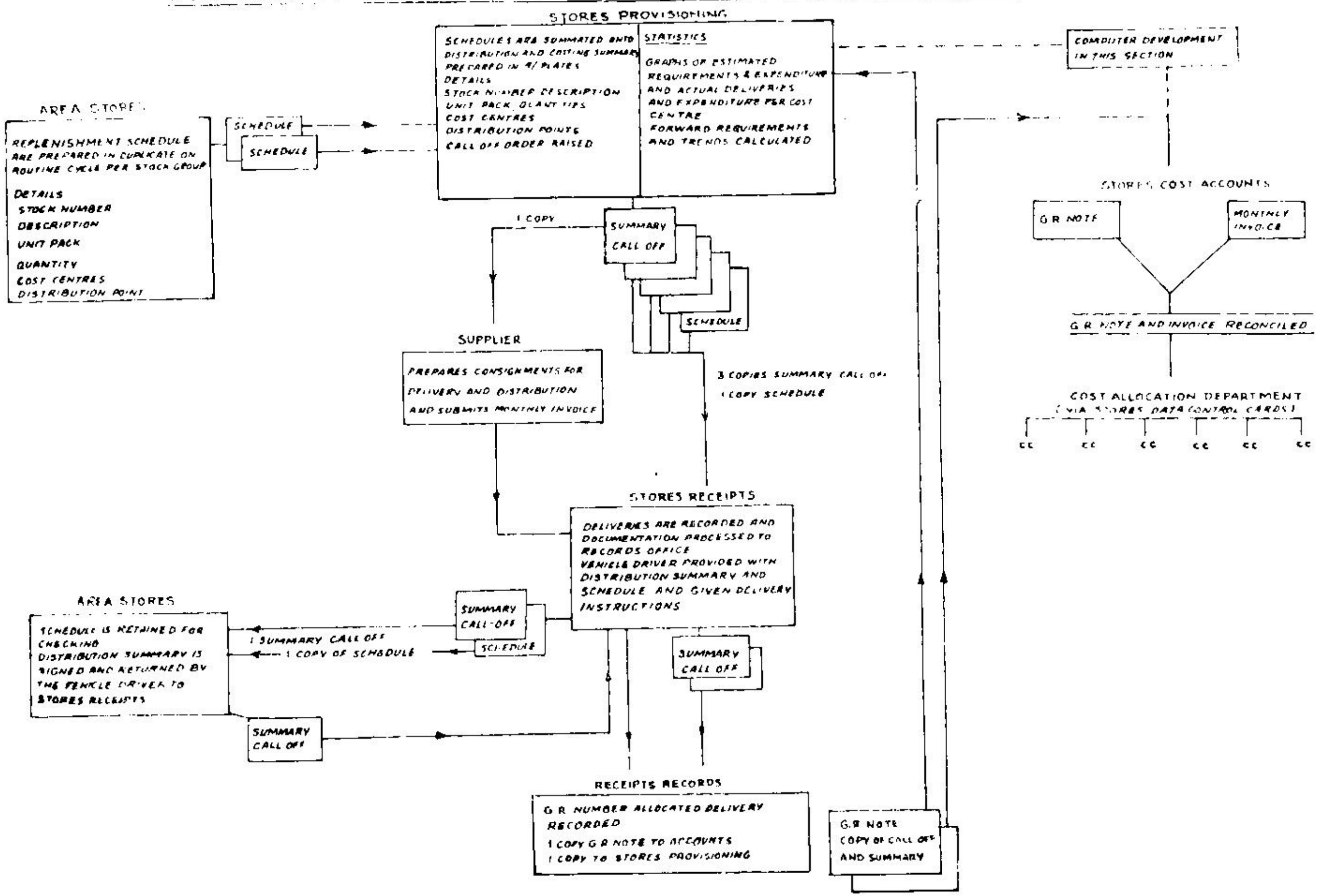
## APPENDICES

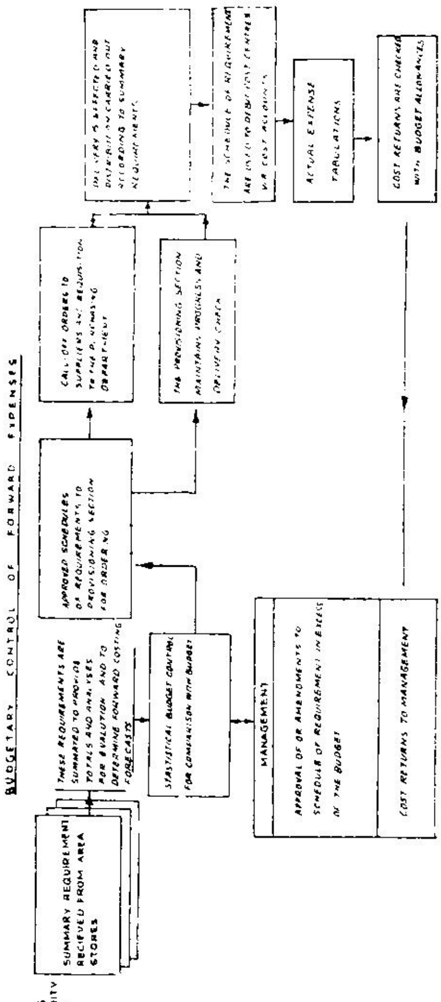
1. Order and Receipts Paperwork Flow Chart.
2. Expense and Budgetary Control Chart
3. (a) Typical Order Master and,
   (b) Summary Stock Requisition
4. Typical Inspection Report Form
5. (a) Typical Issue Notes and
   (b) Spares and Consumable Supplies.
6. Stock Record Cards
7. Work Order Form
8. Goods Received Note
9. Distribution Schedule
10. Consignment note.

# Appendix 1

DOCUMENTATION FLOW CHART IN RESPECT OF ORDERING RECEIPTS AND DISTRIBUTION PROCEDURES



# APPENDIX 2


BUDGETARY CONTROL OF FORWARD EXPENSES
VARIOUS COMMODITY GROUPS
SUMMARY REQUIREMENT RECIEVED FROM AREA STORES
THESE REQUIREMENTS ARE SUMMATED TO PROVIDE TOTALS AND ANALYSES FOR EVALUTION AND TO DETERMINE FORWARD COSTING FORECASTS
APPROVED SCHEDULES OF REQUIREMENTS TO PROVISIONING SECTION FOR ORDERING
CALL-OFF ORDERS TO SUPPLIERS AND REQUISITION TO THE PURCHASING DEPARTMENT
STASTISTICAL BUDGET CONTROL FOR COMPARISON WITH BUDGET
THE PROVISIONING SECTION MAINTAINS PROGRESS AND DELIVERY CHECK
THE SCHEDULE OF REQUIREMENT ARE USED TO DEBIT COST CENTRES VIA COST ACCOUNTS
MANAGEMENT
APPROVAL OF OR AMENDMENTS TO SCHEDULE OF REQUIREMENT IN EXCESS OF THE BUDGET
COST RETURNS TO MANAGEMENT
ACTUAL EXPENSE TABULATIONS
COST RETURNS ARE CHECKED WITH BUDGET ALLOWANCES

## APPENDIX 3 (a)

Copies to :-

ACCOUNTS DEPARTMENT
PURCHASING DEPARTMENT
SPARES DEPARTMENT
STORES

PURCHASE ORDER MASTER

| | | | |
|---|---|---|---|
| Supplier's Code Number | ORDER NUMBER<br>SN<br>DATE | G.R.N. NUMBER<br>DATE | |
| | SANCTION NUMBER | ADVICE NOTE NUMBER | |
| | REQUISITION NUMBER | INSPECTED BY | |
| | | G.R.N. CERTIFIED | |

| ITEM | QUANTITY OR WEIGHT | DESCRIPTION | STOCK NUMBER OR COST CODE NUMBER | QUANTITY RECEIVED | LOCATION |
|---|---|---|---|---|---|
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| YOUR QUOTATION | DELIVERY REQUIRED | DELIVERY QUOTED | TERMS OF PAYMENT | PACKING CASES |
|---|---|---|---|---|
| | | | | QTY |
| | | | | SERIAL NOS. |
| | | | | CHARGED |

TO COMMERCIAL DEPARTMENT

# SUMMARY STOCK REQUISITION

Date

Group/Serial Number

| Stock Number | Re-order Level | REQUIREMENT | | | Delivery Required/Remarks | Location | Progress Reference | Order No. Date | G.R. Note No. Date |
|---|---|---|---|---|---|---|---|---|---|
| | | QTY | UNIT | to be ordered as :- | | | | | |
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| Delivery to, if other than Central Stores | Prepared by : | Approved By: |
|---|---|---|
| | | |

# Appendix 4

## INSPECTION REPORT

CENTRAL STORES

SERIAL NO.

| SUPPLIER | ADVICE NOTE NO. & DATE | DATE |
|---|---|---|
| ADDRESS | | |
| | SUPPLIER'S REFERENCE | RECEIPTS REFERENCE |

| ORDER NO. | REQ'N NO. | LOCATION |
|---|---|---|

### CONSIGNMENT DETAILS

| QUANTITY | DESCRIPTION – INCLUDING PART/SERIAL NUMBERS | STOCK NUMBER |
|---|---|---|
| | | |
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### INSPECTOR'S REPORT

| SIGNED<br>INSPECTOR | SIGNED<br>SENIOR INSPECTOR |
|---|---|

### DISPOSAL REQUIREMENTS

| P.D. | TYPIST | CHECKED | DATE |
|---|---|---|---|

MEMORANDA

STORES CONTROLLER

TO: COMMERCIAL DEPARTMENT, ACCOUNTS DEPARTMENT OTHER DEPARTMENT
SPARES DEPARTMENT, INSPECTION DEPARTMENT

# APPENDIX 5 (a)

MECHANICAL

720021

## SPARES TRANSFER NOTE

| | | | | | |
|---|---|---|---|---|---|
| Description | | | QTY REQ'D / DATE REQ'D | STOCK NUMBER | |
| DEPARTMENT | | | LOCATION | QUANTITY ISSUED | |
| DELIVERY POINT | | | UNIT OF ISSUE | MAINTENANCE EMP. COST CENTRE | |
| AUTHORISED BY DATE | | | | COST CENTRE PLANT ITEM | |
| STOREKEEPER | | | DATE | TYPE OF CHARGE | |
| | | | | SPECIAL CHARGE | |
| FOR USE BY SPARES, STORES AND ACCOUNTS DEPARTMENT ONLY | | | | | |
| OLD SPARE | SCRAP | RECONDITION | ENGINEER'S INITIALS | REGISTER NUMBER | |
| AVAILABLE FOR COLLECTION AT: DATE | | | REQ'N NO. | ORDER NO. | WORKS ORDER NO. |
| DESPATCH TO | | | CARRIAGE/CHARGE TO | | DATE OF DESPATCH |
| | | | DESPATCHED PER | CONSIGNMENT NOTE NO: | |
| | | | PACKING | DESPATCHED BY | |
| SPECIAL INSTRUCTIONS | | | PACKING REF: NO. | | |

## APPENDIX 5 (b)

### MECHANICAL

### CONSUMABLE STORES WITHDRAWAL NOTE

(One Item per Withdrawal Note)

No: 92048

| | | |
|---|---|---|
| Description | | Quantity Required |
| Charge to | | Unit of Issue |
| Deliver to:- | | Loc/Bin |
| Date Required | | |
| Required By:- Engineer | Issued By:- | |

| | |
|---|---|
| Date | |
| Stock Number | |
| Quantity Issued | |
| Maintenance Employee cost Centre | |
| Cost/Centre Plant Item In which used | |
| Type of Charge | |
| Special Charge | |

# APPENDIX 6

STOCK RECORD CARD

DESCRIPTION ROL ______ ROQ ______ Supply Unit STOCK NO. ______ UCI

| ALLOCATION AREA STORES Cd e | CSB | MP | ES | CM | HM | ST.P. | INST | BF | CO | REF | AUTO | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

Consumption Rate | Period | Lead Time | Location

| Date/Ref. | Ord'd | Rec'd | Iss'd | Bal | Date/Ref. | Ord'd | Rec'd | Iss'd | Bal |
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APPENDIX 7

# WORK ORDER

NUMBER

| | |
|---|---|
| PLANT<br>INITIATED BY<br>DATE TEL: | GOODS RECEIVED NOTE<br>NUMBER<br>DATE<br>CERTIFIED BY |
| COST CENTRE | |
| RECONDITIONED OR NEW | |
| JOB CATEGORY NUMBER | |
| SANCTION NUMBER | |
| DRAWING NUMBER | |
| SPARES TRANSFER NOTE NUMBER | DELIVERY NOTE NUMBER |
| SHOP JOB NUMBER | INSPECTED AT CENTRAL STORES BY |
| DELIVER TO | |

| ITEM | QTY. ORDERED | DESCRIPTION | STOCK NUMBER | QTY. RECEIVED | LOCATION |
|---|---|---|---|---|---|
| | | | | | LOCATED BY |

| | |
|---|---|
| GENERAL INSTRUCTIONS | RECEIVED AT C.E.W. STORES<br>DATE<br>STOREKEEPER |
| | RECEIVED AT CENTRAL STORES<br>RECEIPTS REFERENCE<br>STOREKEEPER |
| | RECEIVED AT PLANT<br>DATE<br>SIGNATURE<br>SPARES TRANSFER NOTE NO. |

CIRCULATION:- STORES ACCOUNTS, SPARES DEPARTMENT COST ACCOUNTS. C.E.W.

## Appendix 8

### GOODS RECEIVED NOTE

Release Note Number

Date

Agaist

Standing Order Number

G.R.N.Number

Date

Advice Note No.

Inspected by.

Supplier's Code

G.R.N. Certified

| Quantity | Unit | to be supplied as | Description | Stock No. or Cost Code No. | Quantity Received | Location |
|---|---|---|---|---|---|---|
| | | | | | | |

# APPENDIX 9

M.E. 9842 CENTRAL STORES - RECEIPTS CONTROL SCHEDULE DATE: 6.00.Hrs. to 5.59. Hrs.

| SERIAL NUMBER | SUPPLIER | PACKAGE/ CASE NUMBERS | ORDER NUMBER | CHECKED to A/N | to ORDER | TO INSP'N | TO LOC'N | TO LOC/T CONTROL | B.1. D.A. | DELIVERY SHEET NO. | PASSED TO RECORDS | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
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# APPENDIX 10

## CONSIGNMENT - ADVICE NOTE

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| TO:- | | | | NO | | | |
| | | | | DATE | | | |
| | | | | R.T.B. CONTRACT NO. | | | |
| PLEASE RECEIVE IN GOOD ORDER THE UNDERMENTIONED MATERIAL | | CARRIAGE | | CUSTOMER'S ORDER NO. | | | |
| Wagon Number | Description | No of Articles | No of Galls | T. | C. | Q. | LB |
| | | | | | | | |
| TARE TICKET NO.<br>VEHICLE NO. | | | | | | | |
| CARRIER | | | | | | | |

NOTICE OF ANY LOSS OR DAMAGE TO THESE GOODS MUST BE GIVEN TO US AND THE CARRIER IN WRITING WITHIN THREE DAYS OF DELIVERY

NOTICE MUST BE GIVEN TO US IF THEY ARE NOT DELIVERED WITHIN TEN DAYS OF THE ABOVE DATE:

CONSIGNEES COPY

# Maintenance Guidelines at Tendering Stage

**K Sward***

**Decision about plants and machines are often made without full and complete knowledge of the future maintenance costs. Complete factories have been delivered from industrialised countries without spare parts and necessary information about the absolute minimum of maintenance activities required to keep the production at the desired capacity and quality level. It is quite possible that such proposals will be turned down if the full cost situation is revealed at the tendering stage itself.**

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

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

*Expert from Sweden

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

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

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

It is to some extent difficult to find evidence from the practical life, but a Swedish industry can provide one. It is a chemical factory and the example involves two identical plants, bought in 1954 and 1959.

*First Plant*—Chief of project: Manager of the purchase department. The design of the plant was worked out by the manufacturer. The chief of project exerted a heavy pressure on the price of the plant, but no attention was paid to the maintenance problems.

The plant was installed and started. The maintenance department had to take care of a whole lot of problems. Many modifications were required, and as the plant met all specifications when delivered, the costs were recorded as maintenance cost

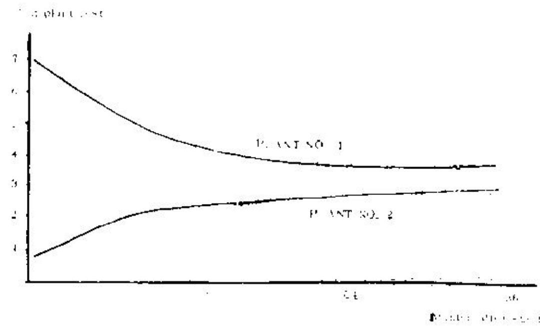
It took more than 12 months to get the plant upto full capacity.

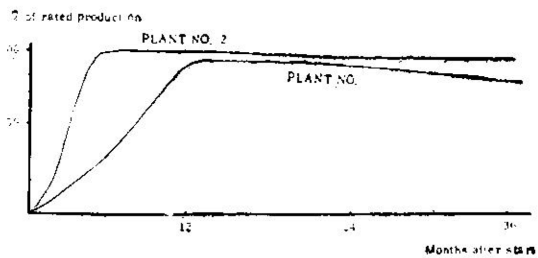
*Second Plant*—Chief of project: Maintenance Manager.

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

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

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






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

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

**Production and Maintenance**

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

—the rated capacity of the machine at a certain level of production quality and

—the available number of production hours per annum.

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

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

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

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

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

*Operation Availability:* Utilization of the Operation Availability is the responsibility of the Production Management, and to keep a predetermined level of Operation Availability is the responsibility of the Maintenance Management.

*Operation availability is determined by three factors—reliability of machine, maintainability and supply effectiveness of maintenance resources.*

**Operation Availability**

The operation availability is determined by three factors :

—the Reliability of machine or plant,

—the Maintainability,

—the Supply Effectiveness of Maintenance resources.

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

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

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

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

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

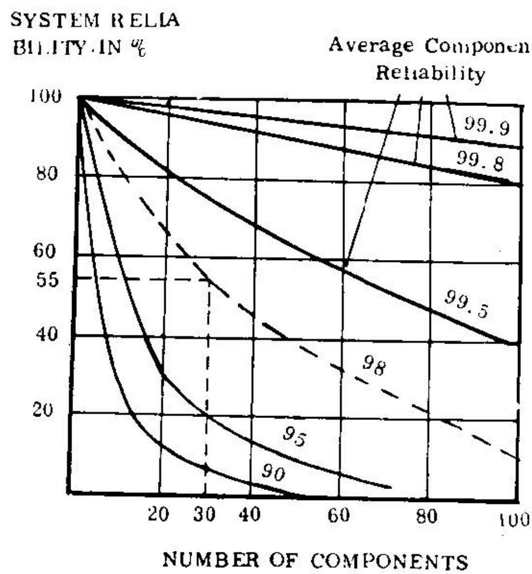
**Reliability**

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

A component with a reliability of 99.9% is likely to give one unsafe or incorrect functioning, meaning failure, in 1·000 operations, but it does not mean it fails after 1·000 operations.

*Usually the probability of safe and correct function is used as a measurement of reliability.*

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




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

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

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

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

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

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

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

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

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

**Mean Time Between Failures (MTBF)**

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

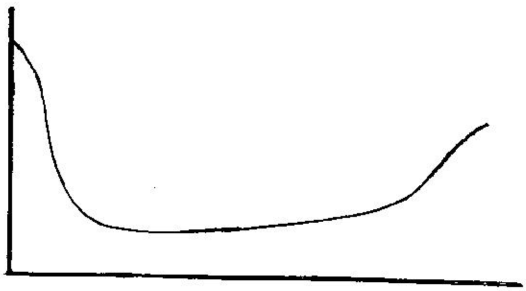
The real value may be determined or estimated as a part of the initial calculation of reliability and presumed operating conditions. This calculation is a part of the Operation Analysis programme usually applied on new machinery.

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

*The higher the total cost of a failure, the better justification for a reliable but high-priced component.*

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

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



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

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

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

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

**Maintainability**

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

One way to analyze Maintainability may be described as follows:

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

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

C. Use the collected information to:

1. establish necessary preventive actions such as lubrication, inspections, condition checks and tests;
2. estimate possible failures and breakdowns and establish necessary operations to correct;
3. estimate necessary operations to replace worn parts;

4. use a dependable time standard to calculate the time needed to perform the operaions under C1—C3 and also calculate the cost for spare parts and material.

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

D. Use Work Simplification Technique and/or Value Analysis technique to find out, if the proposed machine or plant could be changed or improved to give:

1. less requirements on maintenance operations
2. less time to perform necessary operations of preventive nature
3. less time for estimated repairs.

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

F. Use your findings as a base for your requirements to the manufacturer at the tendering stage. Remember:

—need for training courses and training material for both maintenance workers and operators

—need for special tools, instruments and aids,

—need for operators instructions, maintenance plans, disassembly and assembly instructions, drawings, spare parts catelogues

—need for spare parts and material, if possible, for the next five years, but distributed over this period.

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

In this connection it should be remembered, that a survey was made in Germany about 1960. More than 7,000 machine tools were analyzed and the total maintenance cost during their lifetime was stated. Only a very few of these machines had a total maintenance cost lower than the initial purchase price of the same machine. This fact is not well known or regarded by purchasers of machines but several manufacturers have made great efforts to improve the design of their products in order to reduce both the need for maintenance activities as well as the necessary time for performing these activities.

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

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

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

Another annoying design feature is the lack of drilled holes for pushers and threaded holes for mounting pullers for ball bearings, roller bearings, seals, flanges, gears, wheels, covers etc. Once the machine parts are assembled, it might sometimes be impossible to remove such parts

## The Maintenance Workshop

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

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

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

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

Sometimes it is found feasible to locate the spare part storeroom so near the workshop, that the personnel also can take care of the workshop's toolroom.

## The Workshop Equipment

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

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

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

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

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

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

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

### The Maintenance Records

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

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

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

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

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

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

*It is possible to use subcontractors for some types of maintenance work such as general repairs, overhauls and repairs as a result of severe breakdowns.*

### Subcontractors for Maintenance

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

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

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

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

In several developing countries such maintenance contractors have been established. If an investment is considered, where such subcontractors for maintenance will be involved, the investment project group must investigate their possibilities and take the result into the total picture. If not, the investment may be

*The normal size of spare part stock depends also on the performance of the maintenance programme and the operators' handling of the same.*

based on missstatements, causing unexpected costs and production difficulties in the future.

## Supply of Spare Parts and Material

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

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

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

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

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

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

## Local Manufacturing of Spare Parts

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

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

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

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

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

Unfortunately, the situation is not unusual. A sugar factory lost production at a value of about 250,000 US $ because it was impossible to raise some 5,000 US $ to buy rubber tyres for the tractors used to haul cane from the fields to the factory. The country has a rubber tyre factory which made tractor tyres, but not of the same dimension. It was also impossible to modify the tractor wheels to take the available dimension, because there was no supply of rims and no possibility to rework the existing rims.

Another practical situation: 10 big earthmoving machines were bought for a certain project, but no spare parts were ordered. The maintenance manager proposed that only 9 should be bought and the rest of the available money used for spare parts. The proposal was not accepted. The result was, that after only a few months 6 of these expensive machines were idle, because some worn parts could not be obtained. These parts called for a big forging press and none such was available in the country. Relining the parts with welding was possible, but the necessary welding material was not available.

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

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

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

### The Maintenance Control System

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

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

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

*Experience from many industries shows that about 20% of maintenance subjects cause about 80% of the total maintenance costs.*

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

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

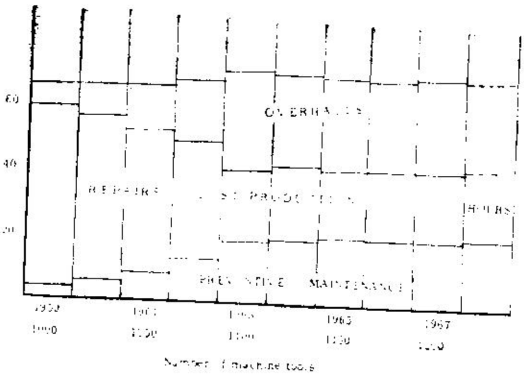
The application of a complete maintenance control system is always giving good profit. What is important in this connection is, that the maintenance cost itself is of less importance to the enterprise than the losses in production.

An example from a Swedish industry may be used to prove this. The enterprise is a fairly large industrial engineering company. The number of machine tools is between 1,000 and 1,200, as shown below.

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

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

1,000 manhours




## General Maintenance Guidelines

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

The work was done by a committee of manufacturers of machine tools and a number of well-known maintenance enginneers from the German industry. During the later part of the work a number of specialists in international and national law were taking part.

The final name of these booklets is:

*TECHNISCHE AUS FUHRUNRGS-SRICHTLINIEN FUR WERKZEUGMASCHINEN UND AHNLICHE FERTIGUNGSMITTEL*, which in a free translation means Technical

Guidelines for Machine tools and Similar Production equipment.

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

VDI 3227 GENERAL GUIDELINES AND PURCHASE PROCEDURES
- —Standards and Guidelines, official
- —Asking for a tender
- —The tender
- —The order
- —General technical guidelines for operating devices, safety devices, signs, noise levels.
- —Recommendations on delivery procedures, transportation and installations of machinery.

VDI 3228 MECHANICAL COMPONENTS
- —Guidelines for bearings, couplings, clutches, bolts and chains, plain flat surface bearings, counterweights, limit devices, packings and gaskets, screws, hoses.
- —Assembled groups of components, power packs, gear boxes, pumps and pipe for coolant, tanks and filters for coolant.
- —Lubrication systems. Lubrication plans.

VDI 3229 PNEUMATIC COMPONENTS
- —Circuit diagrams, symbols, list of components.
- —Guidelines for compressors, tanks, valves of different types, motors, cylinders, pipes and connectors.

VDI 3230 HYDRAULIC COMPONENTS
- —Circuit diagrams, symbols, list of components.
- —Guidelines for pumps, motors, cylinders, filters, strainers, valves of different types, pipes and connectors.
- —The circuit diagram.
- —Testpoints.

VDI 3231 ELECTRIC COMPONENTS
- —Circuit diagrams, symbol, list of components.
- —Guidelines for different components. (This part is not yet finished because an international standard is under work.)

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

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

**The Project Work**

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

tives were ready for the plant engineers. The plant engineering department made to survey layouts and calculated approximate prices for buildings with cranes and other transportation devices needed. The power station was analyzed and found capable to deal with the increased load.

After another 2 months the basis for a decision by the board of directors were finished. In this case the cost

1 production engineer

and as part-time members :

1 expert in transportation

1 power engineer

1 expert in adminstrative routines.

The work started with a modification of the choosen alternative. Then from this project lay-out the objectives for each one of the inderation of all facts about the plant or machine at the tendering stage.

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

phase 6. For smaller investments one group is responsible for all 6 phases.

In order to assure a continous process in the groups and that the established rules for the project work are followed, the planning officer or secretary of the group is a trained project man, who follows the project from start to finish. The project manager is always appointed by the general manager, he might be either a specialized project man or one of the



volved departments and the main contractors were formulated. In each department a subgroup was set up, mostly with part-time working members.

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

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

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

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

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

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

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

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

The mounting of the furnaces took 3 months.

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

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

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

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

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

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

**Phase 3**

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

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

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

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

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

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

### Design Checking

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

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

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

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

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

All lubrication points must be well marked for easy access.

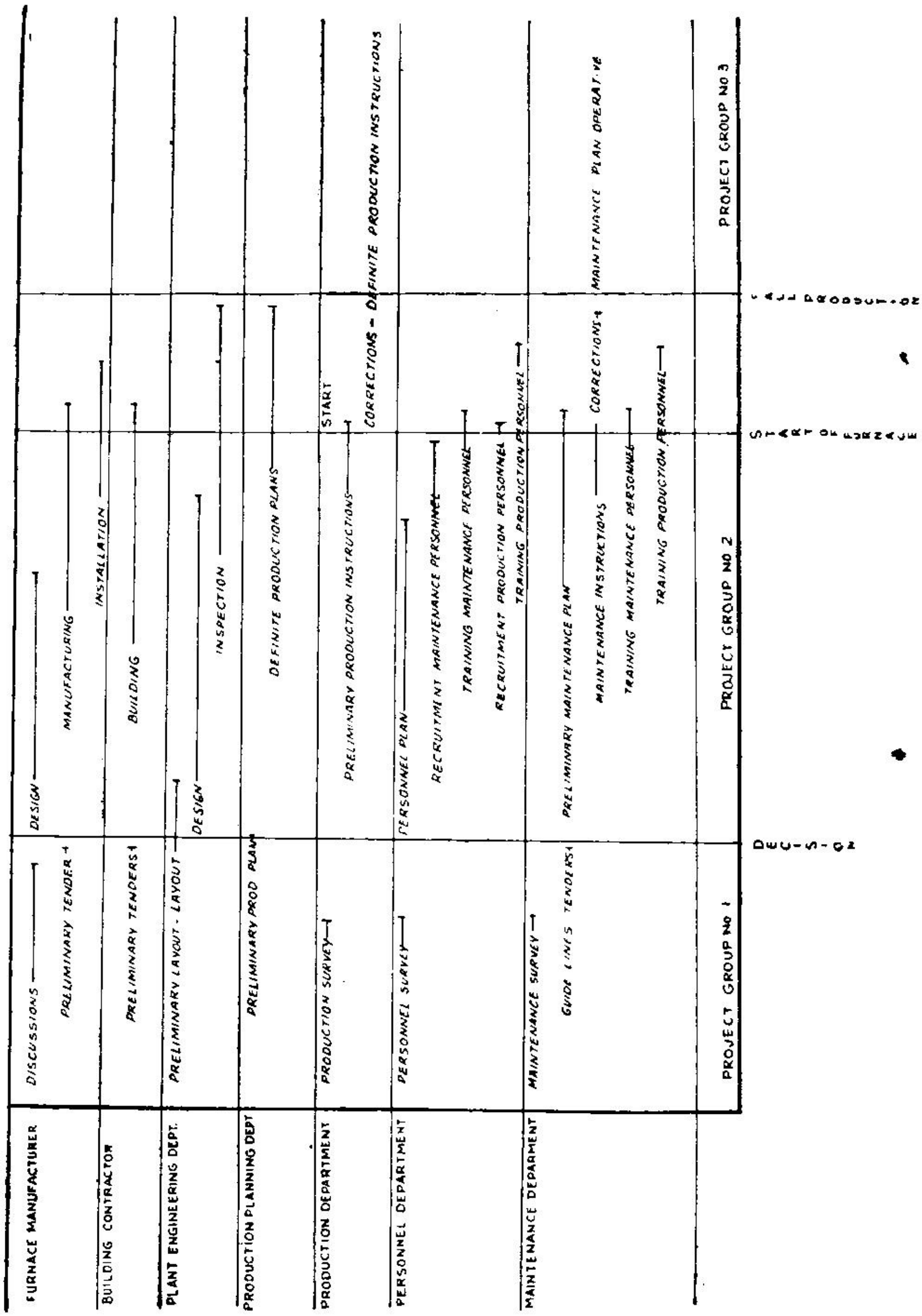
*Lifting:* Heavier machine parts should have facilities for attaching lifting ropes or hooks. Threaded holes for the application of eyebolts, hooks or lifting beams are simple to make, when the manufacturing is going on, but very difficult to add afterwards.

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

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

*Pullers:* Machine components like wheels, sleeves, gears, pulleys, covers and bushings, with a tight fit, should be provided with facilities for removing them without much labour. Threaded holes for attaching pullers is a good solution. For covers two or three equally spaced holes for pushbolts around the circum-

*Machine components like wheels, sleeves, gears, pulleys, covers and bushings should be provided with facilities for removing them without much labour.*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PRODUCTION PLANNING DEPT
PRODUCTION DEPARTMENT
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MAINTENANCE DEPARMENT
DISCUSSIONS
PRELIMINARY TENDER
PRELIMINARY TENDERS
PRELIMINARY LAYOUT - LAYOUT
PRELIMINARY PROD PLAN
PRODUCTION SURVEY
PERSONNEL SURVEY
MAINTENANCE SURVEY
GUIDE LINES TENDERS
DESIGN
MANUFACTURING
INSTALLATION
BUILDING
DESIGN
INSPECTION
DEFINITE PRODUCTION PLANS
PRELIMINARY PRODUCTION INSTRUCTIONS
START
CORRECTIONS - DEFINITE PRODUCTION INSTRUCTIONS
PERSONNEL PLAN
RECRUITMENT MAINTENANCE PERSONNEL
TRAINING MAINTENANCE PERSONNEL
RECRUITMENT PRODUCTION PERSONNEL
TRAINING PRODUCTION PERSONNEL
PRELIMINARY MAINTENANCE PLAN
MAINTENANCE INSTRUCTIONS
CORRECTIONS
TRAINING MAINTENANCE PERSONNEL
TRAINING PRODUCTION PERSONNEL
MAINTENANCE PLAN OPERATIVE
PROJECT GROUP NO 1
PROJECT GROUP NO 2
PROJECT GROUP NO 3

ference is handy. The thread dimension should preferably be the same as the fastening bolts.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

be open for the need of spare parts and the possibilities to get them.

**The Inquiry**

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

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

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

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

— which national laws, standards and rules are applied on the tender, the design, delivery, installation and guarrantee period.

— the climatic conditions

— supply of power, water, steam, gases etc.

— ground conditions

— availability of local service, machining facilities, material stock, spare parts, subcontractors for installation

— what is required included in the delivery in the form of drawings, transparent drawings for copying, operator's instructions, maintenance plans, spare parts catalogues

— how much training of operators and maintenance craftsmen is expected, local training and training abroad

— which language should be used in the written instructions.

— the Operation Availability of the machine or plant and how these informations are desired

— information about spare part supply cost, need for special tools and maintenance equipment should be included in the tender.

**The Tender**

When the tenoer has arrived it should be checked in every detail against the inquiry and the information collected in the investment project group.

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

Based on the information in the tender and his knowledge of local conditions, the maintenance engineer should make careful calculations on the maintenance situation for the next years. It has no purpose to limit the calculation time to one year only, as the enterprise probably has to live with the plant or machine for 10 to 50 years, depending on the lifetime of the equipment. On the other hand, it is practically impossible to find data of sufficient accuracy for a longer period than 5 to 7 years.

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

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

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

## Delivery and Installation of a Machine

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

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

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

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

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

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

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

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

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

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

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

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

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

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

**Manufacturer's Service**

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

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

— a suitable design of plant or machine

— good quality control of the machine or plant at the manufacturing and installation stage

— appropriate instructions for the operation and for the maintenance of the plant or machine

— assistance in training of the operators, instructors and the maintenance personnel

— a well dimensioned spare part stock with quick delivery service

— well trained servicemen.

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

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

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

The following is check list at the tendering stage, for:

Production, Actual and Future

Process Technique

Machine Design

Space, Premises, Transport

Maintenance

Delivery and Installation

What Delivery Should Include

## CHECK LIST AT THE TENDERING STAGE

| Project: | | | | Project No. | |
|---|---|---|---|---|---|
| Checked by: | Date: | Approved by: | | Date: | |
| Short description: | | | Yes | No | Remarks |

A. PRODUCTION, ACTUAL AND FUTURE

1. Are there any plans to change the actual product within the near future?
2. How long time is the product actual?
3. Can the design or material be changed to eliminate the actual operation?
4. Is it possible to increase the capacity of existing machines to cover the needed quantity?
5. Will the new machine become a key machine?
6. How much of its capacity will be utilized during the first year?
7. Is the size chosen big enough to allow new products?

B. PROCESS TECHNIQUE

1. Which is the peak value for production per hour?
2. How much time of production is required to cover the production programme for the next years?
3. Is it possible to increase the product quality level? How much?
4. Which are the required production data and does the machine have sufficient possiblities to change or adjust these data to meet future demand?
5. How long time is needed for setting up the machine for production, or to change from one product to another?
6. Is the machine design and construction correct from view of method study?
7. Does the operation of the machine comply with biotechnological rules?
8. Are information about the efficiency of the machine at various loads available?
9. Does the machine meet safety rules?

C. MACHINE DESIGN

1. Is the machine sturdy enough to meet all possible load situations?

**Check list** (*Contd.*)

| | Yes | No | Remarks |
|---|---|---|---|

Machine Design (*Contd.*)

2. Does the machine need a foundation?
3. Is a simple set-up permitted?
4. Are figures available about the total reliability of the machine?
5. Are such figures available for the most important components?
6. Do the components quality meet the company standards?
7. Is the protection against corrosion, dirt, steam, vapour etc sufficient?
8. Is the electric equipment of the right class?
9. Are special equipment outside the machine necessary?

D. SPACE, PREMISES, TRANSPORT

1. Are necessary lifting and transportation equipmen t for the installation available?
2. Is it possible to locate an.ev. fundamentation on the most suitable place in the factory?
3. Does the machine need ventilation? Air conditioning? Filters?
4. Fire protection? Explosion hazards?
5. Does the machine cause vibrations in the building, that may harm other machines?
6. Any demands on special lighting?
7. Does the machine in production increase the need for storing space around the machine?
8. Is there a demand for extra space for tools?
9. Does the machine need compressed air? Is the supply good enough?
10. Does the machine need cooling water, steam, gases? Are these available?
11. Is the power supply sufficient? Correct voltage? New cables? New switchgears?
12. How much power is needed? Power contract limits?

E. MAINTENANCE

1. Has the machine's maintainability been analysed?
2. Is the accesibility for maintenance good enough?

**Check list** (*Contd.*)

| | Yes | No | Remarks |
|---|---|---|---|

Maintenance (*Contd.*)

3. Are there extra facilities for locating faults? Instructions on fault-finding procedures?
4. Are lubrication instructions included in the delivery? Do they meet our standards? Is it possible to buy the lubricants in our country?
5. Is a maintenance plan delivered? Does it meet our standards?
6. Has the spare part supply been discussed and checked? Are spare parts ordered? For how long time?
7. Are drawings and circuit diagrams included? Is the marking of the components done?
8. Is our personnel competent to perform preventive maintenance? Repairs?
9. Are special tools or aids for maintenance and repair needed? Have these been supplied or are they ordered?
10. How is the manufacturer's service for maintenance and repair? Contracts?

F. DELIVERY AND INSTALLATION

1. Is the machine run for testing before delivery from manufacturer?
2. Are we going to send a representative to watch the tests?
3. Shall the final delivery test be done in the manufacturer's shop or after the installation in our premises?
4. Are function tests or accuracy tests arranged? Where and when? Standards?
5. Are any special production difficulties expected during the installation period?
6. How is the machine shipped? Knocked-down or assembled?
7. Are the internal transports checked? Any extra work to be done? Reinforcement of bridges? Knocking down walls?
8. Shall the machine be stored? How should it be protected during storage?
9. Who is responsible for the installation?
10. What about competent workers for installation?
11. Which requirements are expressed regarding painting and corrosion protection?

**Check list** (*Contd.*)

| | Yes | No | Remarks |
|---|---|---|---|

Delivery and Installation (*Contd.*)

12. Which changes in production are necessary because of the installation?
13. Board and lodging for foreign people needed for the installation?
14. Special craftsmen for the installation?
15. How long time for the installation? Is an installation time plan made?
16. Who is responsible for the final testing of the machine after installation?

G PURCHASE

1. Is the tender correct?
2. Any complementary information needed?
3. How with guarrantee period?
4. How with fine for delayed delivery?
5. Payment terms acceptable?
6. Have all requirements from production been met?
7. Have all requirements from maintenance been met?
8. Are all problems with shipping, storing, installation, starting, testing and checking solved?
9. Are all possible costs calculated? Transport, shipping, packing, testing, insurance, duty?
10. Have all people in the company, concerned with the purchase, had an opportunity to discuss this purchase?

H. THE DELIVERY SHOULD INCLUDE:

1. Complete installation instructions should be mailed 4 weeks or more before the machine is planned to arrive. Value of weight, external measurements of the machine should be included. Instructions for lifting and transport. 2 models in scale 1:50 for layout purposes. Fundament drawing.
2. A complete set of circuit diagrams for the electric, hydraulic and pneumatic circuits. Assembly drawings or special drawings with instructions about disassembly and assembly for repairs.
3. Spare part catalogue and/or spare part list in 3 copies. If possible a spare part stock recommendation, based on our conditions, covering......years.

**Check list** (*Contd.*)

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

## RECOMMENDED BOOKS

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

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

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

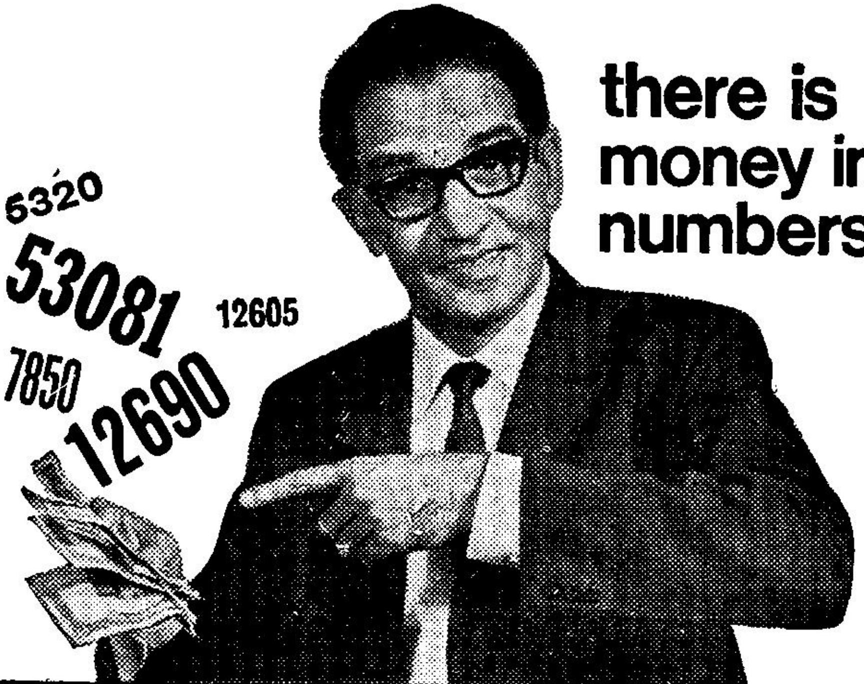
SYSTEMATIC MAINTENANCE, Lecture notes, International Centre for Advanced Technical and Vocational Training, Turin.

## RECOMMENDED MONTHLY PAPERS

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

MAINTENANCE ENGINEERING, London

# The Mysore Paper Mills Ltd.

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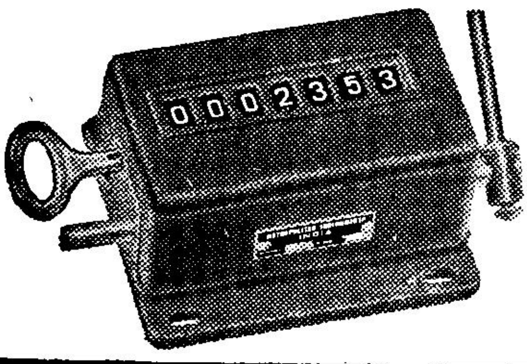


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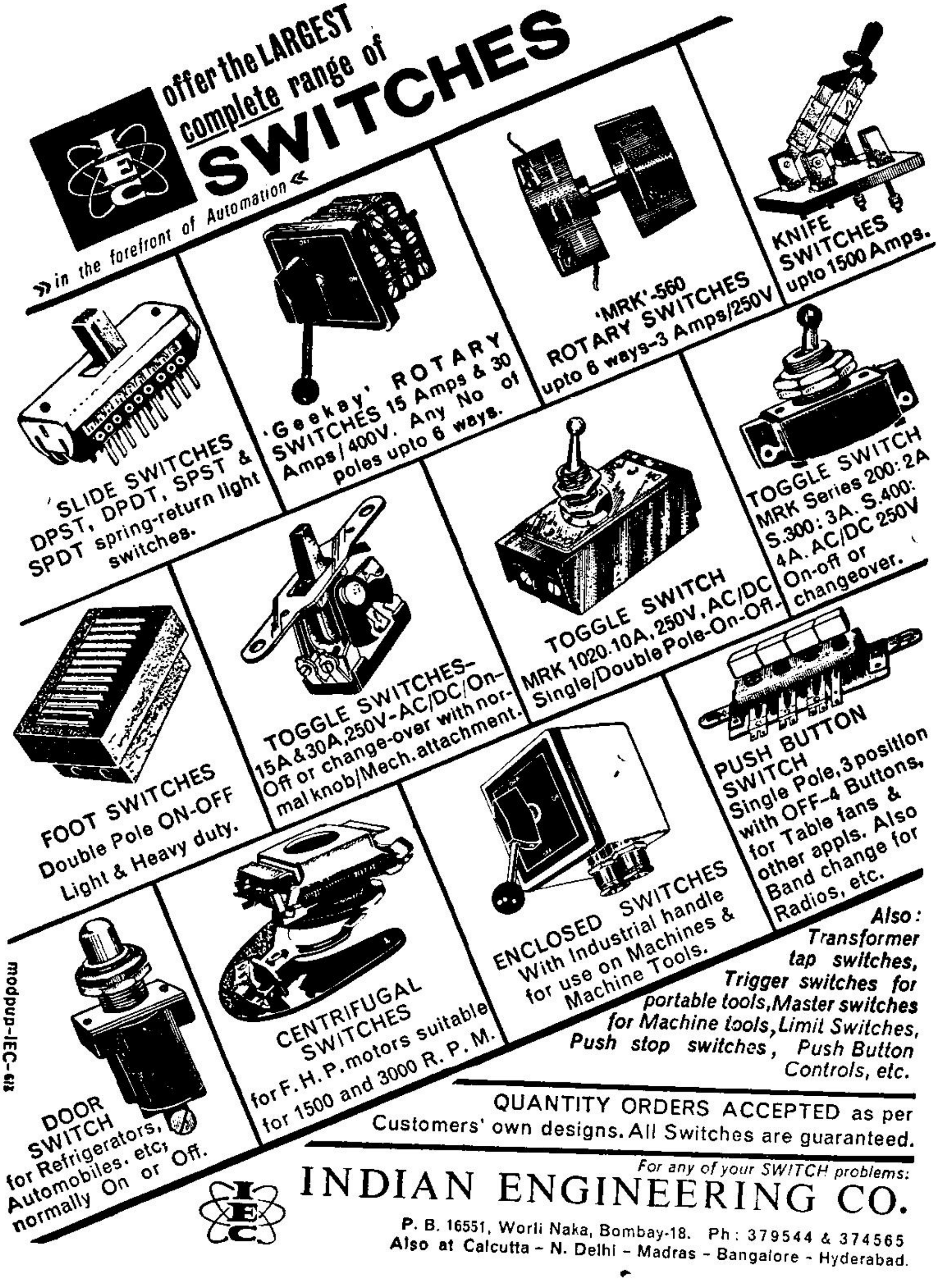
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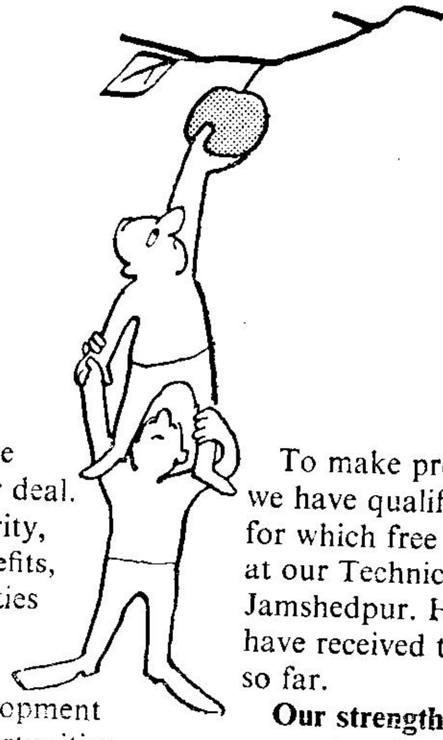

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