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EXPERT GROUP ON MAINTENANCE AND REPAIR
OF INDUSTRIAL EQUIPMENT IN DEVELOPING
COUNTRIES
28 November-9 December 1966
New York

REPORT OF THE GROUP OF EXPERTS ON MAINTENANCE AND REPAIR OF INDUSTRIAL EQUIPMENT IN DEVELOPING COUNTRIES

Submitted to the United Nations Commissioner
for Industrial Development*

* The United Nations Industrial Development Organization (UNIDO), established by the General Assembly of the United Nations, took over the functions of the Centre for Industrial Development in January 1967.

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1/ An annex containing charts and instructions in the "Organisation and maintenance of repair workshops", as contained in the report submitted to the Commissioner, is being elaborated and prepared for later publication.

Letter of transmittal to the Commissioner for Industrial Development

We have the honour to submit herewith the Report of the Group of Experts on Maintenance and Repair of Industrial Equipment in Developing Countries. It was prepared during our meeting at the United Nations Headquarters in New York from 28 November to 9 December 1966. The Group elected Mr. Fouad Hussein, Director-General, Industrial Design Administration, General Organization for Industrialization, United Arab Republic, as its Chairman.

The other members of the Group were:

Algon, Enver	Manager, Metallurji Fabrikasi, Izmer, Turkey;
Ali, Raza	Chief of Operations, Pakistan Industrial Technical Assistance, Lahore, Pakistan;
Chigbo, G.O.	Principal Research Officer, National Institute of Industrial Research, Lagos, Nigeria;
Coppini, Edgard J.	Head of Engineering Division, Grafa S.A. Textile Mill, Buenos Aires, Argentina;
Farmer, Richard N.	Professor, Graduate School of Business, Indiana University, Bloomington, Indiana, United States of America;
Henry, Pierre	Engineer, A/M, Chief Division, Entretien Kodak-Pathé; President, Association Française des Ingenieurs et Chefs d'Entretien, Paris, France;
Mulla, D.S.	Consulting Engineer, Express Building, Churchgate, Bombay, India;
Pinnington, T.	General Superintendent of Maintenance Monsanto Chemicals Ltd., Ruabon, Wrexham, United Kingdom;
Pronikov, A.S.	Rector, Moscow Technological Institute, Moscow, USSR;
Riha, Frantisek	Chief Engineer, Power Department, CKD Prague, Czechoslovakia.

Mr. I.D. Radović, staff member of the Centre for Industrial Development, was assigned to the Group to assist in its work.

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The terms of reference given us by Mr. I.H. Abdel-Rahman, Commissioner for Industrial Development, in his opening address were to study and analyse in depth:

1. The current conditions of maintenance and repair of industrial equipment in developing countries.
2. The organizational characteristics of the maintenance and repair function best suited to the needs of developing countries.
3. The economic implications of the maintenance and repair function in the industrialization of developing countries.
4. The significance of industrial attitudes and related labour problems in the performance of maintenance and repair of industrial equipment in developing countries.

More specifically, because of the particular relevance to the subject matter, we were also requested to examine in more detail the problems of:

5. Training for maintenance and repair in developing countries, and
6. Replacement parts.

On the basis of the above, we were asked to reach conclusions and make recommendations for appropriate national action by advanced and developing countries and international action by the United Nations system.

Our report, based on the preliminary report submitted to us by the Centre for Industrial Development, follows these guidelines.

We recommend that the attention of Member Governments of the United Nations be drawn to this report, and their comments on the same be invited. We also recommend that the report, with the comments received, be presented at the International Symposium to be organized at the end of 1967 by the United Nations Industrial Development Organization.

In submitting this report, we have acted in our personal capacity and not as official representatives of the organization or Governments to which we have the honour to belong.

We wish to express our gratitude to the following people who, by participating in our discussions, have contributed valuable data and insight into the special problems in this area:

Mr. James M. Boyle	Senior Engineer, Installations and Service Engineering, General Electric Company;
Mr. T.P. Creamer	Service Administrator, Euclid Products, Foreign Distribution Division of General Motors Corporation;

Mr. Richard G. Hermann	Manager, Installations and Service Engineering, General Electric Company;
Mr. Egon L. Jensen	Manager, International Regional Engineering and Service, Worthington Corporation;
Mr. William F. Knop	Chairman, Foreign Affairs Committee, American Institute of Plant Engineering;
Mr. F.E. Peltier	General Manager, Regional Engineering and Service Division, Worthington Corporation;
Mr. Alfred W. Sitarski	State Government Relations Representative, Humble Oil and Refining Company;
Mr. Henry P. Steier	Director, Technical Writing Division, Employee Development Services;
Mr. Otto Teitler	Vice-President and General Manager, Machine Tools International, Incorporated.

We thank the management of the Humble Oil and Refining Company for the informative visit to their refinery in Linden, New Jersey. We also wish to acknowledge our appreciation to the Technological Division of the Centre for Industrial Development for collecting and contributing papers that formed an indispensable background for our discussions. In particular, we would like to express our thanks to Mr. I.D. Radović for preparing the preliminary report, and to Mr. R.C. Desai in his efforts in preparing for this meeting. Finally, our thanks for all other help that made this Report possible.

Signed: Fouad Hussein
Edgard J. Coppini
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Introduction

In developing countries, where with few exceptions, scarcity of capital is a major obstacle to industrialization, the maintenance and repair of industrial equipment assumes particular importance. Investment in equipment, usually imported, represents a considerably larger share of resources than is the case in industrially advanced countries. For this reason, good maintenance and repair practices, assuring more effective use and longer life of equipment are of the first importance.

The maintenance and repair function has a variety of aspects in developing and developed countries alike, and these are described in annex I. Conditions in developing countries, however, rarely correspond to these countries' needs. In many cases equipment is operated at only a fraction of capacity, equipment downtime is excessive, and machinery is sometimes damaged beyond repair. The reason is not only insufficient care on the part of operators, but indifference on the part of management: maintenance is considered an unnecessary burden since it does not yield immediate results. This attitude, together with lack of skilled labour, spare parts and adequate facilities leads to comparative over-investment in equipment and high capital-output ratios in countries which can ill afford it. The over-all result of inadequate maintenance and repair is lost income for the enterprise, slower growth for the country and excess capital investment.

The principal objectives of maintenance and repair policies in modern industry are:

(a) To ensure that all available machinery and equipment are being used for production;

(b) To preserve the value of machinery, equipment and plant by keeping deterioration to a minimum;

(c) To accomplish the above objectives as economically as possible for as long as possible;

(d) To protect the safety of all employees.

These objectives can be best achieved, broadly speaking, by ensuring:

(a) Proper selection of machinery and equipment for long, useful life;

(b) Availability of replacement parts for trouble-free performance during normal life of machinery and equipment;

(c) Availability of qualified maintenance and repair personnel and operators to obtain reasonable life expectancy for machinery and equipment;

(d) Correct choice and adaptation of most suitable maintenance and repair systems and techniques.

The evaluation of maintenance and repair performance is not easy, since it is impossible to select a single criterion that provides a meaningful measure of performance for the wide array of industrial enterprises in a national economy. The over-all objectives of the maintenance and repair function in developing countries, however, are among the most significant aspects of their long-range industrialization. Certainly, considerable improvements are possible. Comprehensive studies made in industrially advanced countries indicate that even there the useful working time for maintenance labour is between 35 per cent and 50 per cent.

The characteristics of the maintenance and repair function in developing countries undergo important changes with the process of industrialization. In addition to the growing stock of machinery and equipment, requiring an ever larger maintenance force, the increased use of specialized and precision types of equipment demand and bring about constant qualitative change.

Conclusions and recommendations

Examination of various aspects of maintenance and repair of industrial equipment in developing countries leads to the following conclusions:

(a) In both industry and government there is not sufficient realization of the need for more effective maintenance management and for the recognition of maintenance and repair as a function in its own right;

(b) The major obstacle to efficient maintenance and repair is the lack of adequately trained personnel, at both the managerial and supervisory levels;

(c) Poor maintenance and repair leads to poor utilization of industrial equipment, excess capital investments, and high production costs;

(d) Local attitudes are often in conflict with the application of effective maintenance and repair practices;

(e) Preventive maintenance of industrial equipment is particularly neglected;

(f) Local manufacture of spare parts raises serious problems of quality in terms of engineering technology, quality control, and supply of raw materials of correct specifications.

On the basis of careful examination of the subject-matter of this report and of the conclusions made, the Group of Experts makes the following recommendations for action to be undertaken by developing countries, by industrially advanced countries and by the United Nations:

A. Developing countries

1. Organization of centralized and diversified or specialized workshops to carry out maintenance and repair work and initiate local production of replacement parts for smaller enterprises incapable of setting up their own effective workshops. Such workshops can be established on either a regional, country, or industry basis;

2. Establishment and development of ancillary sectors to the engineering industries so that supplies of raw materials of correct specifications are made available for the manufacture of replacement parts;

3. Establishment of design centres for designing original equipment and spare parts especially for developing countries; and for adapting to local needs existing designs originating in industrially advanced countries;

4. Provision by the Government of financial, fiscal and other incentives to industry, for the purpose of inducing rational maintenance and repair policies in industry at large and the establishment of in-plant training programmes;

5. Formulation of a rational policy on imported replacement parts, more efficient customs clearance procedures and, whenever applicable, the establishment of duty-free zones where spare parts may be stocked for use in the region without undue cost to users;

6. Organization of a bureau to collect and disseminate information on maintenance and repair and inventory problems and practices, and to answer queries from industry on this subject; collaboration of such bureaux with other existing regional and national industrial information centres; encouragement of the formation of a maintenance technical association;

7. Standardization, and a reduction of unnecessary variety in makes and models of industrial equipment, by co-operative action of Government and industry;

8. Provision of incentives for trained maintenance people to remain within their specialized occupations;

9. Establishment of more trade training centres and technical colleges, where practical craft training and specialized training would be provided under the direction of qualified instructors. Modern training techniques such as visual aids should be acquired by those responsible and existing training centres and educational institutions reorganized with the same requirements in mind. Proven student and trainee selection techniques should be introduced;

10. Promotion of closer contact between industry and educational institutions to ensure that curricula and practical training meet the needs of industry; for instance, establishment of management courses in organization, planning and scheduling, costing, inventory control, report writing, job analysis and objective setting, human relations, and so on;

11. Provision of incentives for larger firms and directives to government enterprises to give practical training to a sufficient number of workers to meet their own requirements, as well as the needs of firms too small to run their own training centres;

12. Establishment of a planning organization for the formation of a maintenance and repair and spare parts production system commensurate with the level and nature of industrial development of the country concerned;

13. Promotion of training for supervisory and middle management levels, first to develop their potential as managers and second, to assist them in carrying out their specific responsibilities. Such a programme needs a planned follow-up over a number of years;

14. Establishment of a broad educational programme to promote industrial attitudes that would facilitate the industrialization process.

B. Industrially advanced countries

1. Preparation by equipment manufacturers of detailed operating and maintenance manuals and spare parts lists, where necessary in local languages, and making these available upon delivery of equipment;

2. Provision of pre-delivery training of local personnel by equipment suppliers, where needed and requested;

3. Selection and establishment of local agents of foreign manufacturers who have sufficient technical competence to give practical assistance in maintenance and repair; and adequate facilities for this purpose;

4. Use of designs for especially sturdy equipment with a minimum of gadgetry and better tropicalisation to reduce need for maintenance and repair;

5. Establishment of closer contacts with design centres in developing countries for the purpose of promoting local designs for equipment and spare parts;

6. Use of international standards for basic forms and sizes of maintenance instruction sheets and manuals;

7. Making available to Governments, firms, and other relevant institutions of developing countries all available books, pamphlets, and other documents on maintenance and maintenance management produced for public use by various government departments;

8. Manufacture of spare parts for equipment sold in developing countries so that they remain available for periods longer than is the practice based only on the needs and experience of industrially advanced countries; or, alternatively, the filing of production drawings and specifications for parts no longer manufactured and making same available, upon request from developing countries, at cost.

C. The United Nations

1. Rendering of assistance in establishing centralized and diversified or specialized workshops for maintenance and repair and production of replacement

parts. Assistance would be given in planning such workshops, in providing qualified experts where needed, and in financing the acquisition of equipment;

2. Rendering of similar assistance in establishing and developing ancillary sectors to the manufacturing industries so that supplies of raw materials of correct specifications for the manufacture of replacement parts are assured;

3. Continuation of the high priority accorded to the study of maintenance and repair problems in the Secretariat work programme in the field of engineering industries. The future work programme may further consist of exchange of information such as accounts of studies, and professional meetings, in this field. The United Nations may also consider convening periodic meetings at both governmental and expert levels to continue exchange experience between developing and advanced countries;

4. Rendering of assistance in establishing training centres and technical colleges where emphasis is on practical training, and the quality of teaching is maintained at a high level. Assistance would be given in the planning of curricula, in providing qualified teaching personnel and in financing for equipment, teaching aids, and school facilities; and in reorganizing and expanding existing training centres and technical educational institutions;

5. Establishment of scholarships and fellowships for training key maintenance and repair personnel abroad;

6. Rendering of assistance to selected industries and firms by organizing permanent maintenance staff departments and training managers for these; and installing maintenance planning and control systems;

7. Compilation of manuals on the organization and management of (a) maintenance facilities; (b) maintenance staff departments; (c) day-to-day operations in a maintenance shop;

8. Dissemination of the report and similar United Nations reports as widely as possible to all management and engineering institutions, technical institutions, and to industry.

I. MAINTENANCE AND REPAIR OF INDUSTRIAL EQUIPMENT IN DEVELOPING COUNTRIES: A SUMMARY SURVEY OF CURRENT CONDITIONS

1. In early 1966, the Centre for Industrial Development of the United Nations (UNIDO) prepared a comprehensive questionnaire concerning the current condition of maintenance and repair of industrial equipment in developing countries of which a copy is shown in annex II. About 140 copies of this questionnaire containing 30 questions were distributed to 34 developing countries through United Nations resident representatives, experts and private companies; 61 responses were received. This chapter is a summary of the findings obtained through an analysis of these responses. Because of the limited number of replies received from individual industry groups, the analysis was not made on an industry-by-industry basis; nevertheless, wherever indisputable conclusions can be drawn concerning particular industry patterns and problems, these have been pointed out.

2. Responding to the questionnaire were eighteen United Nations and other experts; nineteen private firms; ten public enterprises; and fourteen government ministries or agencies. A variety of relevant points of view is thus reflected in the information received. Of the 34 countries contacted, replies were received from 20 countries: from Asia and the Far East, 9 countries; from Latin America, 5 countries; from Europe, 2 countries; from the middle East, 1 country.

3. Responses came from the following industry groups: food processing, chemicals, mining, electrical equipment, power, metal working, textiles, construction, and various types of light manufacturing. A number of answers were also received from training institutes, laboratories, and unspecified government authorities. The principal findings are shown below.

Shortage of maintenance and repair personnel

4. More than three quarters of the replies reported shortages of personnel for maintenance and repair. The pattern of responses indicated that the more industrially advanced countries were short of highly specialized personnel; while countries in earlier stages of industrialization needed both specialists and personnel capable of routine maintenance. Supervisory personnel is in short supply in all developing countries.

Training for maintenance and repair

5. About two-thirds of the responses acknowledged that some kind of specialized training for maintenance and repair personnel was available in their countries. However, the comments also indicated that vocational training in schools is generally very limited, and that which exists is not sufficiently specialized for maintenance and repair. The practical content of the curricula in vocational schools is generally considered meager and the equipment insufficient and outdated. Both instructors and students, it is felt, should undergo better screening.

6. In-plant training is provided by most large enterprises and government agencies, but it must start from basics, since mechanical awareness is normally lacking in new employees. Effective training programmes, therefore, must continue for several years. Protracted courses and seminars are considered of limited value except as stimuli for developing more interest in maintenance problems.

Shortage of equipment for maintenance and repair

7. Less than half of the replies reported shortages in equipment; and these were mostly in (a) special purpose implements and precision machine tools, which are expensive for a single small or medium-sized establishment; (b) testing and calibration equipment; (c) mobile service equipment; and (d) simple tools and auxiliary materials handling devices such as cranes. In general, public sector enterprises are considered better equipped than all but the largest private enterprises.

Condition of maintenance and repair by industry and type of equipment

8. The light engineering industries, especially those producing comparatively simple products, appear to experience fewer difficulties with maintenance and repair than industries requiring the use of complicated control and measuring devices to assure quality. Small enterprises in remote areas and industries depending on imported parts have more acute repair and maintenance problems because of the lack of facilities and timely replacements. Large processing industries (sugar, oil, rubber) are generally among those industries with the most satisfactory repair and maintenance conditions.

Centralized maintenance and repair shops

9. Slightly more than half of the responses reported that centralized workshops for maintenance and repair existed, although the majority also commented that such workshops existed as exceptions rather than as a rule. The workshops reported were mainly run by the government in the transportation (aviation, railway, shipping, motor vehicles) industries or were available within the major industrial establishments. Over three quarters of the centralized shops were general purpose, and almost all manufactured parts were of a limited or emergency replacement nature. There was scarcely any provision for specialized training.

In-plant maintenance and repair facilities

10. Answers indicated that large enterprises in every country had established sizable in-plant maintenance facilities, while smaller companies, short of capital, had concentrated on productive facilities and depended on outside repairs for anything more serious than routine work.

Preventive maintenance

11. Only about a quarter of the replies received disclosed that preventive maintenance was a generally accepted procedure in these countries. Most enterprises reporting such practices as regular lubrication, cleaning, and resharpening, were large industrial enterprises which were either subsidiaries of foreign companies or government establishments.

Safety

12. In a little over a quarter of responses, poorly maintained equipment was considered to have contributed to unsafe conditions for industrial workers. A good number of replies specified inadequate or faulty braking and steering systems as major causes of motor vehicle accidents. Train derailments were also felt to have been due in part to poor repairs to tract and rolling stock.

Replacement parts

13. Over 90 per cent of responses from enterprises or individuals indicated that some locally produced replacement parts were available in their countries, either for equipment used in their particular industries, or in others.

However, in only three of the more advanced developing countries (India, Taiwan, and Yugoslavia) were significant quantities reported. The quality, durability, accuracy, surface finish, and other such features of these parts were in most instances less than fully satisfactory. The reasons generally given for this were shortages of basic materials and inadequate foundry and heat treatment facilities.

Maintenance and repair shops as nuclei of manufacturing plants

14. Only about a third of the responses provided information on this subject. Only four cases were cited where a successful transition was made from maintenance and repair shops to manufacturing plants: these concerned electrical appliances, automobile assembly, machine tools, and military equipment. While this method of industrialization had been rarely tried out, the opinion was expressed that it had been successful in some countries and had made a significant contribution to the rapid development of manufacturing units, both large and small.

Imports of replacement parts

15. Some countries reported no import restrictions, or minor ones, while the remainder indicated that import restrictions existed. There are no regional patterns for this: tariffs are imposed in various countries for one kind of equipment or another depending on whether a particular type is thought vital or whether it is locally produced. Restrictions are often imposed not only to protect local industries and markets, but also to save foreign exchange.

Servicing by foreign manufacturers

16. Less than a third of the responses indicated satisfaction with present conditions. It appears that with the exception of a few highly reputable firms in each country, most of the foreign distributors do not have after-sales service facilities, or if they do they are limited to sales for which they are poorly stocked. The best servicing conditions seem to be those for motor vehicles, but this is not universally so.

17. In some instances, assistance is given during a period of guarantee; thereafter it is discontinued. The technical ineptitude or disinterest of

company agents was repeatedly commented on, both in the matter of rendering practical assistance in making repairs and in obtaining out-of-stock parts quickly. Detailed operation and service manuals are scarce, particularly in local languages.

Obstacles to efficient maintenance and repair

18. The pattern of response rating the importance of various factors that obstruct efficient maintenance and repair is almost identical in all regions and appears to be: first, shortage of skilled personnel for maintenance and repair; second, lack of readily available replacement parts; third, the negative attitude of users due to their lack of awareness of the need for effective maintenance management of industrial equipment; fourth, inadequate equipment and facilities.

Standardization in maintenance and repair.

19. Over 20 per cent of all replies agreed that maintenance and repair were made considerably more difficult because of the large variety of industrial equipment, and absence of standardization at all levels. However, no strong opinions were expressed about curbs either on local manufactures or imports. The reasons for this appears to be the fear that compulsory standardization would act as a barrier to progress in design or to imports of latest models of equipment.

Special equipment designs for developing countries

20. About three-fourths of those answering agreed that special equipment designs for developing countries could facilitate maintenance and repair problems in these countries. The points most commonly suggested were: (a) simplified construction eliminating excess gadgetry; (b) more rugged construction enabling equipment to withstand overloads; and (c) better tropicalization and special protection for dusty conditions. Those not in favour of special designs (a) viewed them as forms of technical stagnancy; (b) were wary of whether foreign producers would design special equipment for such small markets; and (c) doubted whether users would be willing to pay higher prices for such innovations.

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Productive life of industrial equipment

21. From the information obtained, no industry patterns are discernible. The variety of industrial equipment and differing conditions of use do not permit a meaningful aggregation.

22. It appears, however, from the responses given, that the "production life" of equipment, when used in the same sense as in the industrialized developed countries, in the majority of cases is shorter in the developing countries. The reasons most often suggested for this condition are: (a) improper initial installations; (b) overloading and negligence; (c) extended use while equipment requiring repairs is awaiting arrival of spares; and (d) poor repairs.

Downtime

23. The same pattern was found in the answers of all countries. The waiting period for industrial equipment to be repaired was said to depend on the availability of replacement parts. Once spares have been obtained, repair progresses normally.

24. Typical cases reported that the time lag in ordering ran from a few days, if parts were available within the country, up to a year if replacements had to be obtained by sea freight from abroad. Exchange controls, customs complications, excessive paper work, in-country transit time, and a general lack of co-ordination may further delay receipt of an order; consequently, waiting times of three to six months are common. Cases were reported in which idle equipment had been broken down and cannibalized in order to make repairs on other similar pieces of equipment. The problem seems to be general, with no one region or industry appreciably better off than another. The majority of the responses indicated that history cards were not kept on equipment and that no data on maintenance and repairs were available.

Main causes of equipment breakdown

25. The lack of adequate maintenance and operating skills are widely recognized as the main causes of equipment failure. Climate or other physical conditions peculiar to the locality were third in order of importance.

Replacement

26. Only one response indicated that history cards on equipment operation and maintenance expenses were kept and used as the basis of cost projection for replacement purposes. Some few establishments for example (railways, motor vehicles) stated that equipment was expected to last a set number of years. More typically the policy seems to be to make replacements after a major breakdown or when equipment is unserviceable. Some Governments have depreciation policies (normally ten years amortization), but specific use of these tax regulations in forming prevalent industrial replacement practices is reported as slight.

Other problems of maintenance and repair

27. Other factors contributing to the difficulties of maintenance and repair were reported as humidity and dust, poorly equipped and staffed workshops in the interior, the wide variety of models of industrial equipment, small internal markets which make it impossible to produce replacement parts cheaply and lack of special materials, of documentation, and of interest in maintenance and repair problems.

Maintenance and repair services provided by the Government

28. The organization of government services for the maintenance and repair of industrial equipment is generally similar in all regions. Individual countries may omit one or more of the functions described below.

29. Typically, a Department of Industry acts as liaison with industry and gives general advice. Practical assistance is provided on request to small-scale private firms by a small-scale industrial corporation (as in India), a technical co-operation service (as in Chile), or other agency or public establishment, for example, a railway. Management and technical training institutes and productivity centers run training courses, hold seminars, prepare manuals and may even give workshop assistance on a contract basis (as in Taiwan). Government inspectors also visit plants and give advice on accident prevention and workmen safety.

30. Replies mention that although such bodies as are mentioned above deal with maintenance and repair problems, in most cases they do so only peripherally, or

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they provide limited services such as general advice, films, and short seminars. When actual workshop assistance is needed, the situation generally is that the government departments are concerned only with their own maintenance problems, and few co-ordinated efforts are made, in the event of equipment failures, to offer practical assistance even to other national agencies. Consequently, as one response stated, "small private firms are at the mercy of the large companies for practical assistance (for example, major overhauls requiring specialized tools) and must pay whatever price is asked".

Programmes for improving maintenance and repair

31. Special programmes for the improvement of maintenance and repair of industrial equipment are not extensive, although responses indicate that some individual establishments are attacking maintenance and repair problems by means of inventory control of spare parts, centralized workshops and better training. The extent to which the national Governments participate in these special efforts (in addition to their normal training and plant inspection activities) is not known, since if such programmes do exist, approximately half of the replies fail to disclose knowledge of them, private or public.

Foreign assistance and assistance by the United Nations

32. Although considerable technical aid has been received for particular manufacturing or public works projects, foreign assistance specifically for improving repair and maintenance practices is not reported as substantial. Most significant has been aid in training technical personnel. Only about a quarter of the responses indicated experience or knowledge of United Nations assistance programmes available for this purpose.

Measures recommended for improving maintenance and repair of industrial equipment

33. The measures recommended included both general and specific actions. Those most frequently mentioned involved activities required of national Governments, equipment manufacturers and equipment users, and appeared as follows:

Functions of Governments:

(a) Most technical and managerial training comes under government control. Present specialized courses for maintenance and repair are few. This training

needs to be expanded and facilities brought up to date, to allow more concentration on practical work and special techniques. Poor teachers should be shifted out to make way for instructors with industrial or workshop experience. Evening classes should be held so that workers can attend, and roving vans showing films on aspects of maintenance employed to stimulate interest. "White collar" engineers should not be encouraged, and more work of practical nature should be introduced into university courses;

(b) Standardization and a reduction in the variety of make and models should be encouraged by the Government.

Functions of equipment manufacturers:

(a) Detailed operating and maintenance manuals in local languages should be prepared by equipment manufacturers and these should be made available, together with spare parts lists on delivery of equipment;

(b) Pre-delivery training should be provided by equipment suppliers if desired;

(c) Local agents of foreign manufacturers should have sufficient technical competence to give practical assistance in repairs, and adequate facilities should be set up for this purpose;

(d) Special sturdy designs with a minimum of gadgetry should be made available and better tropicalization provided.

Functions of equipment users:

(a) Satisfactory organization and structure must be given to the maintenance activity, and budgets should be established for the maintenance and replacement of equipment. This will require the preparation and use of equipment record cards. Introduction of simple inventory controls, and good accounting practices should also be developed;

(b) Preventive maintenance programmes need to be established and given initial support by government agencies, training institutes and industry associations. Simple rules, clearly set forth, are needed.

II. THE MAINTENANCE MANAGEMENT PROBLEM

Introduction

34. Maintenance problems are crucial within manufacturing organizations of all types, and emphasis should be largely on such organizations. A basic concern is why maintenance problems have become so serious in recent years in many types of organizations in many different countries. One may begin with an analysis of specific problems in the developing nations which bear directly on maintenance and maintenance management.

35. To accomplish this task, it is first necessary to construct a framework for an analysis. This chapter will be focused on this question, and the following chapters will indicate the nature of specific problems identified here and potential solutions. The focus here is on management, since the persons able to influence maintenance practice most directly are managers of enterprises who are in the position to exercise authority, in order to bring about necessary changes in maintenance organizations. This point of view does not, however, omit the importance of technical skill and craft training necessary to proper maintenance practice. All dimensions of the maintenance process are like links in a chain - no single one is uniquely important, since all links must be in place at the same time.

The nature of management progress

36. Modern productive enterprises in developed countries everywhere share many common characteristics. These organizations are complex interrelationships between people and machines, organized in a hierarchical fashion. Figure 1 in annex III indicates the general pattern. Generally speaking, there are approximately six levels of personnel in such organizations:

I. Top management: these are the well educated, highly trained presidents, vice-presidents, general managers, and other executives who formulate basic organizational plans and strategies. Rarely are such persons concerned with day-to-day activities in their organizations.

II. Top level staff: here are found such highly skilled individuals as lawyers, personnel specialists, market analysts, research and development scientists,

economists, and similar personnel. Such men assist the top management in planning the over-all strategies of the corporation. They are also rarely involved in day-to-day operations of the organization.

III. Functions management: marketing managers, plant managers, engineering managers, maintenance managers, financial managers, and similar persons belong in this group, their major task being to manage the actual operations of the concern. Often they are directly concerned with routine operations and frequently work directly with those who are actually performing work tasks. They are responsible for getting assigned jobs done.

IV. First level management: here are found foremen who actually supervise workers in various sectors of the work task.

V. Skilled machinists, electronics technicians, pattern-makers, plumbers, and similar highly trained craftsmen are at this level.

VI. Workers: the large group of unskilled and semi-skilled workers who actually perform routine work tasks.

37. In presently developed countries this type of hierarchical organization has evolved slowly over centuries. The main reason why it has endured is that it works well in most industrial situations. By means of this organizational method, it is possible to assign responsibility and authority in a highly specialized manner, allowing for the proper and efficient development of all types of skilled men. It is impossible for any modern man to know everything - but with this type of organization, a man does not have to know everything. He can specialize in the activity most suited to his natural talents, and higher level personnel need only check occasionally to determine that things are going well.

Conditions in developing countries

38. Now that technology is being transferred from the developed countries to developing nations, this sort of organization becomes requisite. Thus, a developing country that imports large and complicated lifting cranes needs skilled craftsmen to maintain this equipment properly. These men require a foreman to instruct them in their duties. The foreman requires a middle manager to guide him in planning his work - and so on. As more complex equipment and capital is imported, the need for a structure of productive organization similar to that employed in developed countries increases.

39. A basic difficulty in most developing countries is that the trained managerial and technical manpower necessary to staff such an organization does not as yet exist. As a result, firms tend to appear as in figure 2, annex III. Levels II, IV, and V within the managerial hierarchy are understaffed or badly staffed, since not enough trained men are on hand to do the job. In most countries a few very competent men at all levels will be found, but there never are enough of them.

40. The lack of such middle level personnel shows up very strongly in maintenance operations, since most maintenance management and activity takes place on these levels. Thus, the typical firm may have a superintendent of maintenance, who normally would be a level III manager. He would supervise level IV foremen, who in turn would direct level V craftsmen and technicians in actual work. But all too often there is no adequate candidate to fill this level III position, and as a result maintenance management is poor. The fact that level IV and V personnel are often insufficient only makes the problem more difficult. A number of studies in human resource development stress the seriousness of the problems in finding and training adequate personnel on all of these levels of skill; and where such men do exist, the quality of their work is not always up to the best world standards.

41. Thus maintenance in developing countries suffers from two major shortages: first, of middle level managers and technicians to plan and organize maintenance: second, of the necessary craftsmen and technicians who actually do the work. Any proposed solutions to maintenance problems must take into account these difficulties.

Attitude of top management in developing countries

42. The lack of level II through V personnel in developing countries creates many problems for top management. Without adequate staff to perform lower level tasks, and their supporting staff being non-existent or untrained, their organizations are in frequent danger of getting out of control.

43. The result often is that shown in figure 3 in annex III. Top management here is literally forced to do not only the top management job, but also the jobs of their non-existent subordinates. The difficulty here is that no group, however talented, has time to accomplish all of these jobs well. Top management must

necessarily in such cases ignore or overlook many crucial tasks. If the question of a critical bank loan comes up at the same time that an urgent parts order must be made, top managers will almost always attend to their banker first and parts second, if at all. Note that in more developed countries, this parts order would be handled by a competent level II or IV man. But in a developing country, these men do not exist.

44. Evidence to support this argument is voluminous. The usual maintenance results are poor, because maintenance problems, unless they reach the total crisis level, simply cannot compete with other top and middle management functions for top management time.

45. The shortage of trained craftsmen and technicians is serious, but it is equally important that such skilled men be managed properly. Where maintenance programmes can be planned well in advance by capable maintenance managers, trained men are most efficiently utilized. But where trained maintenance managers are extremely scarce, this management function is not performed well, if at all. Good craftsmen are wasted if most of their work is unsystematically planned.

Impediments to maintenance solutions in developing countries

46. With regard specifically to maintenance, a large number of local owners and managers in developing countries appear to view maintenance expense as something that must be reduced, since it adds nothing to immediate revenue. Maintenance is a subtle type of operation, and it is not always immediately obvious that spending now can save much more later. Unless the managers or owners of an enterprise become interested in maintenance, it will be done poorly, no matter how good the maintenance crew.

47. It appears that preventive maintenance in particular tends to be neglected in developing countries. Where no visible problems affect the equipment, it seems surely good for one more day of service: but days drift into weeks, and eventually avoidable major damage occurs. A simple and effective corrective action cited in an example from a Middle Eastern country was, when major breakdowns occurred, to make a quick check of preventive maintenance records. If the given piece of equipment had been neglected, the operations supervisor was responsible. After a few such instances, the operations supervisor realized that the question of his competence was at stake, and preventive maintenance was much more efficiently carried out.

48. To a great extent, planning determines how well and how efficiently maintenance is performed, but in developing countries planning is often a comparatively new notion. It implies some future time orientation for both managers and workers, and relatively few in these countries have been trained to think in this manner. The common attitude is that today is today and tomorrow is something unconnected with it. Planning also involves the firm belief in causation, and this, too, may not be much in evidence.

49. At the bottom of many difficulties in developing countries is the notion that an educated (that is, literate) person should not perform manual labour. Such a man will choose to work as a clerk, a government official or entrepreneur or in a similar position. That a craftsman should be educated is indeed alien to some cultures, and accompanying this attitude is the notion that any mechanical work is easy: a broken part is replaced, a malfunction repaired and what could be easier? One result of this is the inability of maintenance and repair personnel to communicate with those who have no experience with this field. This has quite serious consequences on operational efficiency, because the attitude of owners and managers toward maintenance personnel is as important as the qualifications of the maintenance craftsmen.

50. The above remarks are not meant to imply that education and personnel are all-important. Various local limitations are also present. For example, in the absence of a bureau of industrial standards, much time is wasted by firms trying to work out difficult standards problems on their own. But the usual reason why such bureaux do not exist is that the personnel needed to operate them administratively and technically does not yet exist. Government bureaucracies typically suffer from many of the administrative problems noted above. Or it may be that because local spare parts manufacturing operations are not yet created, the firm must laboriously manufacture many of its own spares. Again, the reason why such operations are lacking is due at least in part to the lack of personnel to staff them properly.

51. Capital shortages, foreign exchange shortages, political questions, lack of raw materials of correct specifications, and many similar circumstances may also be deterrents to good maintenance practice. But many developed countries suffer from such problems (or have so suffered in the past), and they have been able to resolve their difficulties the more easily because they have had skilled men to help. Later, some of these institutional problems will be explained in more detail; still, many of them have as an underlying cause the shortage of skilled men.

52. Perhaps the most critical impediment of all to good maintenance management in developing countries is the attitude of top management and government officials. Good maintenance is very much a matter of proper state of mind among the responsible persons. Simple failure to appreciate the value of good maintenance practice weighs more than many of the institutional or educational constraints.

53. The legal limitations placed on the number of foreign skilled technical personnel that can be employed locally in developing countries is definitely an incentive to train native workers and craftsmen. But such regulations must be applied circumspectly lest they seriously impede certain industry functions, such as maintenance and repair, and unnecessarily increase the costs involved.

54. Another personnel problem in many developing countries is the difficulty of communication among persons of different cultures, in particular between local personnel and foreign specialists. The barrier is not only that of language, but also - and often more so - of different patterns of thought and action. Certainly, the local population must learn to adjust to the demands of life in an industrialized society; but there is also a definite need for foreign personnel to make adjustments too, and thus increase the effectiveness of their contribution to the industrialization process.

55. Realistically, it must be recognized that managerial attitudes are extremely important in determining how well maintenance management and activities are practised. Top managers must be convinced of the value of good maintenance before effective measures can be taken, as must key government officials, and until many old habits and thought patterns are changed, improvement may be difficult.

56. Also important here are worker attitudes toward industrial discipline, education, work and planning. Workers often come from pre-industrial environmental patterns, and such patterns must be modified if technical training is to be successful.

57. No less important than the acquisition of technical skills is the reorientation of old attitudes or formation of new ones compatible with an industrialized society. In most of the developing countries the existing attitudes are often in sharp conflict with the purposes of the maintenance and repair function, and changes of attitude, more often than not, come about only over a longer period of time.

58. The adjustment of a worker with a predominantly agricultural background to industrial life is often difficult. In the old order, seniority had precedence, but in industry it is technical ability, not seniority, that has precedence.

59. Safety, like maintenance, appears expensive in the short run, but it indubitably pays in the long run. Safety conditions depend very much on how serious the top management of a given enterprise is about accident prevention. If the subject is constantly stressed and if supervisors are rated in part on how successful they are in minimizing accidents, it is possible to make considerable headway in cutting down the accident rate. Most accidents can be prevented - if management cares enough.

60. In developing countries, where the discipline imposed by industrialization is still largely lacking among local workers as well as among many supervisors, follow-up is necessary. Every programme, including maintenance programmes, requires constant checking until its implementation continues without consistent pressure.

61. Such worker problems are decidedly not insurmountable. In many instances, firms have successfully trained to high standards men from pre-industrial backgrounds. But it is important, if such training and development programmes are to be successful, that top management recognize the difficulties of training in such circumstances, and that they make every effort to gain insight into the workers' background so that training can be focused properly for the men involved. Failure to recognize this can lead to failure, and such failures are common in many countries. Training and education should be tailored to specific country requirements, not imported from another country without thought as to applicability.

The source of maintenance problems

62. Although good maintenance management is practised by the middle levels of a firm and actual maintenance work is ordinarily performed by craftsmen at still lower levels, responsibility for good maintenance practice is with the top. In any environment those in the best position to create the necessary climate, policies and plans for good maintenance practice are senior managers and owners of productive firms and senior government officials. These persons, if they are aware of the problems created by poor maintenance and see clearly the economic advantage of good maintenance practices, are able to press for basic reforms, involving improvements in education and training, in organization, in institutions, and in existing maintenance management and practice. But these changes cannot occur as the result of hard work and thinking by maintenance managers or workers. Such men can, with directives, rapidly improve maintenance performance in almost any country or firm; but they must be given full support and approval from the top.

Short range and long range solutions

63. The development of the organization hierarchy shown in figure 1 of annex III took centuries in developed countries. Time and effort are needed to develop and train good men on all levels, and countries which began their development process early have had this time. Developing countries, however, do not have centuries in which to evolve such manpower, and every possible shortcut must be devised to help them to their goal. The crucial short range problem is to find a way to develop middle level personnel in the shortest possible time. Maintenance managers and skilled workers must be included in any meaningful training programme.

64. We are speaking here only of maintenance management, and of maintenance craftsmen and technicians - but finding personnel of levels II through V is a problem in other areas of production and distribution as well. If one is to discuss ways of improving manpower, it is necessary to know what this manpower must do. The training of maintenance craftsmen, while complex, is usually understood clearly. Such skills as welding, machine-shop work and so on, are relatively clearly defined.

65. However, maintenance management is not understood so well. Essentially, a maintenance manager is the person who attempts to achieve maximum continuity of production so that the firm can operate most efficiently, and he must do this at the minimum possible maintenance cost. This balance between minimum maintenance cost and continued production can only be achieved by vigorous application of scientific thinking in organization, planning, training, engineering design and cost accounting. Persons capable of performing well in all of these demanding spheres are scarce everywhere, and the developing countries have great difficulty in finding and training such men. But unless they are found and trained quickly, and unless skilled craftsmen are trained to work under them, maintenance problems will continue. This is the essence of the short range maintenance question for developing countries.

66. The long range maintenance problem is somewhat easier to solve though less relevant at the present time. In general, developing countries will continue to follow the lines already set in more developed countries, where in the course of time, more and better middle level personnel has been developed. Eventually, all countries will be better developed in this sense, since they will have had enough time to develop their human resources more fully. But every possible acceleration of manpower training on all levels now is a critical part of any maintenance improvement suggestions.

Nature of solutions

67. The above analysis affirms that virtually all solutions to maintenance problems directly involve the rapid improvement of personnel at all levels. Of particular importance here is the need to move lower level personnel up to higher levels through various forms of training. Figure 4 of annex III indicates the nature of the proposed strategy. Managers must select the best of their lower level employees, pass them through intensive training, both inside and outside the firm, and move them back into the firm at progressively higher levels. Thus the semi-skilled production worker may become a skilled worker; the skilled worker a foreman or supervisor; and the foreman a maintenance manager. Clearly not all of this work can be done within the firm, and a later chapter will deal extensively with training at various levels. However, it is important for firm managers to recognize the critical necessity of training on all levels, and to encourage the maximum participation of their people in training programmes of all sorts. They must also co-operate with government and supra-national authorities to develop still more and better training programmes of every sort.

68. The result of such intensive training efforts, if successful, is also shown in figure 4. Here the top management pyramid steadily tends to grow with time, and more and more competent and trained persons are educated and brought back to the firm to operate in positions of increased responsibility. The end of this process will occur when the pyramid resembles those in more developed countries - in short, when the supply of truly competent and well trained persons approximates the level in the more advanced economies. At that point, top management can operate as top management, leaving the critical level II, III and IV functions to their own qualified personnel. Not until this process is completed will such difficult problems as maintenance be resolved. It is crucial that top management recognize this human resource development problem, and that they take every possible step to ensure that the supply of highly trained manpower is adequate. It is equally important that various responsible senior government officials recognize the importance of the role they must play in this co-operative education and training effort.

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Conclusion

69. This chapter has attempted to indicate, in a brief and perhaps over-simplified manner, the nature of management problems in developing countries as these problems apply to maintenance practice. The following chapters of this report deal with specific problems and suggestions for solutions. It is felt that in most countries much can be done quickly to improve maintenance practices, but that it is crucial, if such programmes are to be effective, that full support be forthcoming from the top. Many programmes fail, training plans are thwarted, and good maintenance practices decline, because the necessary pressure from the top is not present.

70. The world's industrial countries have a vast pool of unutilised knowledge about good maintenance practice and management, which is available to developing countries for the asking. Many of the developing countries have themselves evolved sound and useful maintenance programmes which might be applied in other developing nations. This report is an effort to outline the essence of good practice from every source, in order that any country really wanting to improve this sector can do so.

III. ORGANIZATION FOR MAINTENANCE AND REPAIR

71. The purchase of replacement parts typically involves maintenance, production, and purchasing. It is necessary in every operation to make sure that all three of these functions are welded into an homogeneous whole. This is more easily said than done. The production or operations supervisor is usually under pressure to get goods made or services rendered; the warehouse is under pressure to avoid excess inventories; the maintenance supervisor wants the equipment to be in perfect order and operating. Each manager, in trying to optimize his own area, is in conflict with the other two. Co-ordination of various functions is therefore essential: all areas have to be integrated into a harmonious whole by top management if maintenance is to be efficient. This is particularly difficult to achieve in a developing country where there are shortages in every sort of skilled labour.

72. In organizing maintenance and repair of industrial equipment in developing countries alternative methods may be described. The first is when the supplier of the industrial machinery and equipment provides proper maintenance and repairs, adjusts complex units and provides spare parts.

73. The advantages of this method are ease of maintenance and high quality of the work. It does not, however, provide uniform maintenance for all production equipment in the plant, keeping it in first-class condition, because normally in any plant the equipment and machinery are supplied by a number of different manufacturers. Furthermore, it does not help to train local maintenance personnel for the machine building industry of the country concerned. Maintenance personnel have also to follow a larger number of different instructions and service manuals; and too often, units have to be delivered and maintenance personnel sent from afar, requiring an expenditure of foreign currency.

74. The other alternative in maintenance work is the provision of a special maintenance and repairs work system capable of keeping all production equipment in the best working condition at the least cost in the shortest time. Usually this system does not depend on suppliers, and spare parts do not have to be imported.

75. Such a system helps to create the nucleus of a future machine-building industry, and to familiarize local personnel with production equipment. It also makes possible the unprejudiced evaluation of all equipment, and favours the

development of ways to improve the reliability and durability of the equipment according to the specific conditions of the country. Such systems, worked out for each country and taking into account local conditions, would contribute to the specialization and centralization of repair work.

76. Specialization and centralization of maintenance work may result in a 25-30 per cent reduction of expenses in equipment maintenance, cutting down idle time five or six times and supplying industrial enterprise with all kinds of spare parts for maintenance work, thus contributing to high quality repairs.

77. When repairing production equipment at a specialized plant, it is advisable for production equipment maintenance work to be carried out together with modernization.

78. Whether maintenance and repair shops will be centralized or decentralized, specialized or not, will depend on the size of the enterprise and on the type of product made or service rendered. But, in all cases organizational principles will be the same:

(a) Determination of responsibilities;
(b) Cost controls;
(c) Preventive maintenance;
(d) Planning and scheduling;
(e) Work measurement;
(f) Methods and standards;
(g) Consumable and non-production materials;
(h) Maintenance budget;
(i) Training;
(j) Reports to management;
(k) Tools, equipment and facilities.

These items are briefly commented upon below.

79. While the determination of responsibilities must never result in a rigid system, the maintenance activity should have a written organization chart showing clearly and logically how the total work-load is divided, and how the divided parts are properly co-ordinated. Functions must be spelled out in detail so that the responsibilities of various positions are known. Experience indicates that for the best operation of the maintenance activity, the person having over-all

responsibility for maintenance functions - this is usually the plant engineer - should report to the person having over-all responsibility for the entire plant. In cases where the plant engineer reports to the production superintendent or production manager, there is danger that maintenance problems will be subordinated to production problems and will not receive the unbiased attention they deserve. Examples of organization charts are given in annex IV.

80. In order to control maintenance and repair costs, it is necessary that the person responsible for maintenance and repair be kept constantly advised of the breakdown of his expenditures and that he take prompt action to analyse and to correct variations in his budget performance. He must also establish an authorized cost limit on maintenance and repair operations. Maintenance repairs which exceed the authorized cost limit, or which are not strictly classified as repair work should be approved by the plant engineer.

81. Accurate and complete reporting and recording of the downtime of production machines is essential to the evaluation of maintenance performance and control of costs. Machine downtime, expressed as a percentage of scheduled machine production time, is a direct and objective answer to the question, "To what degree is the maintenance department succeeding in its goal of maximizing the availibility of machinery and equipment for production or service?" Historical trends shown graphically on a machine downtime chart are of great value in relating past performance to the present position and, even more important, for setting up realistic goals for future improvement. Downtime records on an individual machines alert management to design weaknesses and other maintenance problems and should guide future purchases. Analysis of the cause of downtime on a particular piece of equipment provides excellent guidance for the solution of design problems. Eliminating the need for repeated repairs is a most effective way of reducing both manufacturing and maintenance and repair costs.

82. One of the most successful techniques for reducing equipment downtime is to put into effect a carefully designed preventive maintenance programme tailored to the specific requirements of the plant. The essence of preventive maintenance is anticipation - ideally, anticipation of the adjustments and repairs of machines as gauged by scheduled inspection and analysis of past maintenance records.

83. In this way, adjustment and replacements are accomplished before major damage occurs necessitating costly repairs. In many developing countries, written maintenance records may be incomplete or absent. In such cases, it is possible for managers to reconstruct them partially by communicating orally with low-level personnel (who may not be literate) about their knowledge of similar equipment in the past. Often such men are very knowledgeable, although they may be unable to communicate their knowledge unless they are questioned on specific points.

84. Another major source of maintenance information for planning purposes is the handbooks, parts manuals, and service information provided by manufacturers of the equipment. Managers should always attempt to obtain as much of this material as possible.

85. Essential to efficient and effective maintenance performance is proper planning and scheduling of the work-load. The magnitude and complexity of the typical maintenance and repair operation in any larger manufacturing and many service enterprises require that a formal and systematic procedure is followed. The potential for successful planning and scheduling is greatly increased when the following steps are taken:

(a) Establishment of control units with responsibility for all planning and scheduling, headed by one qualified individual;

(b) Use of a maintenance and repair backlog report showing estimated hours for each individual job, by trade, and total backlog by trade. Estimated completion date for each job must be shown on the report;

(c) Use of written requests for all maintenance and repair work beyond routinely scheduled work;

(d) The detailed planning and estimating of labour hours and materials costs for all maintenance jobs except crisis maintenance;

(e) Development of daily work assignments for each craftsman, planned one day in advance by his maintenance foreman;

(f) Assignment of priority rating to each maintenance job:

Crisis - Breakdown or safety

Scheduled - Important or routine.

86. Detailed time studies of repetitive maintenance tasks can be very effective in improving maintenance performance in a given plant. To be successful, a work

measurement programme must provide the basis for improved maintenance performance by establishing how long it should take to complete each assignment, not how long it has been taking to get the job done. It is then possible to:

(a) Establish the approximate time required for each task so that effective planning and scheduling can be accomplished;

(b) Replace the foreman's job estimates with more accurate and better-founded job-time data;

(c) Provide a more accurate basis for staffing maintenance crews;

(d) Provide a means for measuring the effectiveness of maintenance forces;

(e) Furnish yardsticks to measure departmental and group performance.

87. The methods and standards developed and used by maintenance and repair operations can exert a considerable influence upon the performance of maintenance and repair tasks. With the development of power-operated portable tools and equipment which has occurred over the past two decades, and which appears to be continuing at the same high rate, many cases are found where better tool, material, or method selection would have resulted in lower total job cost. Training of the maintenance personnel in the use of this equipment is crucial. Evaluation of maintenance and repair performance must be made in terms of the most modern materials, methods, tools and equipment available.

88. Good judgement and careful administrative control are required to achieve the best compromise between the conflicting demands of adequate parts availability and minimum investment of funds in the maintenance and repair inventory. Inadequate stocking of repair parts increases machine downtime and often results in reduced maintenance labour efficiency. On the other hand, over-insurance, in which every possible needed repair part is stocked in the plant, can be very costly. One of the characteristics which many manufacturing plants have in common is the constant change in machinery and equipment employed by the plant; this is another reason for continuous analysis of the spare parts position. The evaluation of material and supply inventories must be tempered by an understanding of a vast difference in requirements in a highly automated steel plant compared, for example, to an automative trim manufacturing plant.

89. The budget performance by the maintenance and repair department is only one of several yardsticks in evaluating performance. Excellent budget performance may be achieved while excessive deterioration of plant and machinery is allowed to

occur. Likewise, budget performance in the maintenance accounts gives no indicatio of production machinery availability or of machine downtime due to maintenance deficiency. Once these limitations of budget performance as an indicator in evaluating maintenance performance are realized, budget can be a useful tool not only for comparing week-to-week operations, but also for comparing trends for a period of several years. It is important that maintenance cost standards are regularly reviewed and revised to take into account any improvements in equipment, materials, tools or methods.

90. A well-trained crew is critically important to good repair and maintenance performance. To assure a qualified work-force on a continuing long-term basis, many larger enterprises will find they must establish and operate employee training programmes, both at supervisory and operator levels. In addition to these continuing training programmes, it is often necessary also to give specialized technical training courses on new machinery and equipment design and such operational features which require new, specialized maintenance and repair procedures.

91. Reports to management must be compiled to provide a continuing picture of plant maintenance and repair costs, and to show the position, progress and effectiveness of the repair and maintenance programme. Graphical presentations can be very useful for this purpose.

92. Insufficient durability and reliability of machine tools involves a considerable increase in expenditure for their maintenance and repair because of constant use of equipment and unfavourable climatic conditions.

93. In a number of developing countries unsatisfactory conditions of utilization of technological equipment are typical. This is due to high humidity and temperature, the lack of opportunity to produce machine tools or tools for their repair, or spare parts, and the necessity of employing workers with inadequate qualifications. Therefore, in the case of developing countries it is especially important to pay attention to all the main aspects of the problem of durability and reliability of service of machines and machine tools, as it is the only way to minimize expenditure of time and other inputs involved in breakdowns.

94. Planning and wide-scale implementation of measures aimed at raising the durability and reliability of service of machines of different types, development of scientific research work in this field, theoretical elaboration of the problem, analysis and summing up of data on the utilization of machines will lead to sound means and a variety of methods for raising the working capacity of machines.

95. Methods and apparatus for testing the technological reliability of machinery are important. The technological reliability of machinery is its capacity to retain the qualitative parameters of the technological process during a given period of time. When a machine is used, its qualitative parameters are affected by different processes and gradually change. It is essential that a new machine should not only retain its precision but should also retain it in the required limits during the inter-repair period. To attain this, tests of technological reliability of machinery should be carried out. Tests should first assess the reserve in the precision of machining in a given machine tool, and second, give some prognosis as to the period of time during which the reserve will be present.

96. Methods and instruments for testing and investigating separate parameters of machine tools as well as standard rates have been developed in industrialized countries. The technological reliability test for modern machine tools is an indispensable part of complex tests, which allow the assessment of the main technological parameters of a machine tool and provide the data for the most effective perfection of its design and methods of maintenance.

97. In cases where a plant does not have sufficient use of specialized equipment to justify its acquisition, serious consideration should be given to purchasing maintenance and repair services from a well-equipped contractor, where such services are available. Control over the activities of such concerns should be vested in a staff member of the maintenance department.

98. While variable maintenance and repair work may fluctuate in direct proportion with production, a great opportunity is presented to maintenance during periods of low production to accomplish all the repairs which have had to be deferred during normal or above-normal volume periods when machines are not available for repairs. Provision must be made to reserve, and not to cancel maintenance work which accumulates during periods of high production. Still, to control maintenance manpower and thereby keep down maintenance costs, the backlog of work should normally be kept relatively constant, so far as this is possible.

IV. ECONOMIC AND COST CONSIDERATIONS OF MAINTENANCE AND REPAIR

99. There are two distinct types of cost savings which may be realized through improved maintenance and repair operations. The first, and the more difficult to measure, is the type of saving made through reduction in downtime, reduction in scrap and re-work, increased efficiency and improved quality of product. The second is the saving realized through increase in work efficiency. As an example, a large company in the United States, using a technique known as "work sampling", estimates 40 per cent as the effective working time of its maintenance work force. By increasing the level of effective working time (the time a craftsman spends in actually using the tools of his trade) from 40 per cent to 70 per cent, the time utilization of maintenance labour is improved by 75 per cent. Relating this improvement to a maintenance crew of 100, one can see that a crew of 57 craftsmen would be sufficient. It is entirely possible, however, that while reduced machinery and equipment downtime may result in savings, maintenance costs could actually rise. It is the responsibility of maintenance management to secure the correct balance between maintenance and repair costs and the cost of plant downtime, and so achieve a minimum total cost.

100. Too often the effort will be made to reduce maintenance costs by arbitrarily cutting the maintenance labour and material budgets. Very frequently this method of cost reduction and management attitude results in the "spending" of the plant worth. Deferred maintenance, with premature failure and replacement of equipment, inevitably results in increased costs in the long run.

101. Another practice usually associated with this type of management approach to maintenance and repair is that of reducing the maintenance labour force during seasonal slack periods or scheduled downtime. During these periods, the maintenance force should be sustained at a strength sufficient to perform essential work which cannot be accomplished during production periods. Major overhauls can be performed at such times with minimum cost and with little or no interference with production.

102. In order to keep maintenance and repair costs down, it is essential to establish cost controls, such as:

(a) A cost classification and a breakdown and segregation of costs in order to keep management informed of expenditures;

(b) Written maintenance and repair requests;

(c) An authorization limit for maintenance and repair requests for the purpose of controlling the type and cost of maintenance and repair work requested;

(d) Work orders for authorizing, identifying, estimating and scheduling all maintenance work involving sums which exceed the authorization limit of the maintenance and repair request;

(e) Material requisitions as a basis for controlling and compiling material costs;

(f) A management committee to scrutinize all work orders involving certain types of work and funds over a designated amount;

(g) Purchasing of items and services which cannot be economically fabricated or performed by plant forces;

(h) A maintenance and repair budget.

103. The purpose of the maintenance and repair budget is to provide all levels of management with a review of proposed expense levels and to maintain effective control of costs. Budgets should not be based solely on past performance, but should also reflect planned future operations and their effect on maintenance and repair costs. A warning should also be made that the maintenance and repair budget must be used carefully in the evaluation of the maintenance and repair functions; good budget performance may be achieved by allowing equipment to deteriorate beyond a reasonable point. Also, budget performance does not indicate production equipment availability or machine downtime attributable to quality of maintenance.

104. The cost of efficient maintenance and repair is high, even in industrially advanced countries. In the USSR, research has shown that in the machine building industry every year approximately 10 per cent of the stock of equipment undergoes major overhaul, 20-25 per cent intermediate overhaul, and 90-100 per cent minor overhaul. In an average or small size enterprise, the cost of major overhaul alone is normally up to 60 per cent of the cost of a new machine in the case of medium-sized turning lathes; up to 40 per cent in the case of universal milling machines; and up to 75 per cent in the case of capstan lathes. Also, before the major overhaul, a machine tool undergoes two intermediate overhauls, each of which takes about half as much labour as a major overhaul, and six minor overhauls,

each of which takes about a quarter as much labour as a major overhaul. In addition, machine tools are periodically checked for accuracy, lubricated and given preventive treatment.

105. Thus, the cost of maintaining and servicing a machine tool during one maintenance cycle (that is, up to and including the major overhaul) is greater than the cost of a new machine; and if maintenance and repair is badly organized, it can be several times greater.

106. No less important in the economics of maintenance and repair is evaluating the idle time of equipment while it is out of production during various kinds of overhaul. The maintenance downtime per maintenance cycle for screw-cutting lathes of average size and complexity will be taken as an illustrative example. The figures given below (also from the experience in the USSR), are for maintenance teams working a single shift; they indicate how many days a screw-cutting lathe must remain idle for the given type of maintenance.

Type of maintenance	Lathe downtime
Major overhaul	10 calendar days
Intermediate overhaul	6 " "
Minor overhaul	2.5 " "
Accuracy checks	1 " "

107. As indicated earlier, a machine tool normally undergoes two intermediate and six minor overhauls before its major overhaul. Accordingly, the number of days for which the lathe will be idle for maintenance over the period of the maintenance cycle will be $10 + (6 \times 2) + (2.5 \times 6) = 37$ days.

108. A machine's operating life before major overhaul, and similarly between intermediate overhauls, depends to a large extent on the methods of operation. If the screw-cutting lathe runs for eight years before major overhaul, the time lost for maintenance will amount to an average of five days a year. But if, because of insufficient attention to operating and maintenance methods (and this is common in many developing countries), the maintenance cycle is four years, the volume of maintenance work will be twice as great. This clearly indicates that great attention must be given to methods of maintaining and operating equipment. The maintenance cycle pattern and the interval between overhauls must be such that, through fuller utilization of the service life of the equipment parts and

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sub-assemblies, the equipment is idle for overhaul for the shortest possible time, and expenditure on its overhaul is kept to the minimum.

109. In most developing countries the maintenance and repair of equipment will normally cost more, often considerably more than in industrially advanced countries. Trucking companies in a Middle Eastern country are reported to have maintenance and repair costs five to ten times as high as similar firms in the West. Enterprises in developing countries must often have more capital-intensive operations than analagous developed countries. One of the reasons for this over-investment in equipment is that much of it will be idle for repairs at any given time. As an example, American trucking companies engaging in a given type of operation will have 20 to 30 per cent of their annual revenues in capital investment. A firm in the Middle East engaged in the same type of operations (and under outstanding management) was cited as having 70 per cent of its annual revenues in capital investment, and virtually all of the excess was in shop and maintenance facilities. This was not because managers were incompetent; it was because many of the ancillary facilities available in developed countries were non-existent in the country. In developed countries, much of the maintenance work can be sub-contracted to specialists. In developing countries, this is usually impossible. The few maintenance and repair facilities that exist often do sub-standard work, and the few really competent shops are so crowded as to be frequently unavailable at critical times. In the circumstances described, where in order to assure continuity of operations, an enterprise must achieve a great degree of self-sufficiency, the use of cheaper hand equipment in jobs where under-utilisation is fairly certain or where absolute continuous reliability is not so important, can prove economical and advisable.

110. Closely connected to the higher cost of maintenance and repair in developing countries is the unavailability of skills for testing or rebuilding defective parts taken off equipment. For instance, the skilled manpower necessary to check out a complex part or sub-assembly like a carburettor or transmission, diagnose the difficulty, replace minor components which are defective and restore to an almost new condition is often totally lacking. As a result, an example was cited, again for a Middle Eastern country, where instead of $1.50 carburettor repair kits, $23 complete replacement units were ordered. Instead of $8 replacement gears or $2 bearings, $140 transmissions were obtained. This type of aggregate parts replacement, instead of minor replacement, is a way of making up for unavailable skilled labour, but the price is far higher.

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111. Closely related to the above is the practice of throwing away perfectly good parts or only partially used items. In the Middle Eastern country already mentioned, thousands of discarded truck tires, each costing about $200 new, had served on the average about 30 per cent of their usable life (based on western experience) before failing, due to improper tire maintenance and lack of re-building facilities.

112. The practices described above are usually even more injurious for developing countries than they would be for industrially advanced countries. In the latter, because of the rising wage levels relative to material costs, the trend has been towards decreasing the use of labour in maintenance. In developing countries, where labour costs are lower and material costs higher, greater use should be made of labourin order to save on spare parts, other things being equal. Calculations also show that, because of lower costs and for the same interest rates, optimum lifetime for equipment is longer in developing than developed countries; and this again calls for additional attention to be given to maintenance and repair.

113. In developing countries, the reason for a smaller share of investment funds normally being allocated for equipment replacement is that rates of new investments generally exceed those of replacement needs. Resources are devoted as much as possible to new investment and new capacity, in order to accelerate economic growth. The normal course of action for governments of developing countries is, therefore, to seek to reduce equipment replacement as much as possible and to encourage installation of new capacity. In this context, there may be a divergence of opinion between private and public interests. From the private point of view, reduction of costs is equally satisfactory whether it applies to labour, material or other costs. But from the point of view of the national economy, if labour is the abundant factor, its replacement by capital in order to reduce labour costs may not be justified. On the other hand, replacement of old equipment should be encouraged by the government if the installation of new equipment provides substantial reductions in costs, especially in importing materials, or in investment costs elsewhere in the production process. A maintenance and replacement programme in developing economies should be closely connected with the national investment plans.

V. TRAINING

114. About half a century ago H.G. Wells wrote that human history has become "more and more a race between education and catastrophe". This certainly is evident in the problems of maintaining and repairing industrial equipment in developing countries. The shortage of qualified maintenance and repair personnel is one of the most serious obstacles in the industrialization of these countries where often no more than the rudiments of formal education exist.

Craft training for maintenance

115. It can be stated with no reservation that the educational level of both production and maintenance personnel directly affects their understanding of the methods to be followed in operating and maintaining equipment to which they are assigned. Unless the worker has a minimum educational background, it is useless to train him for work on an intricate machine. It must be understood that, before undertaking any sort of technical training, a minimum educational level is an absolute prerequisite for the trainee. An illiterate trainee cannot progress beyond a relatively low level of acquiring skills, since he is unable to perform any of the routine duties of a good mechanic, such as reading measuring instruments, noting part numbers, or reading simple written instructions.

116. General primary education is not a function that can or should be performed by industry. It is the responsibility of the state to provide for it. Educational programmes, both technical and non-technical, take time to mature and often begin to bear fruit only after several years. Any educational plans should therefore be drawn on the basis of several years, with provisions for these plans to be reviewed and adjusted annually in the light of past experience.

117. To a much greater degree than in industrially advanced countries, on-the-job training is the way maintenance skills are learned in developing countries. A young man might begin work as an unskilled labourer in a maintenance operation; he would learn and gradually progress by being a mechanic's helper, or a greaseman, or by performing some other similar job. This sort of training should not be underestimated, because many competent mechanics have acquired very significant skills in this way. An important advantage here is that men work on equipment

which is in operation under normal working conditions. Moreover, in practical work of this kind, the job has to be done correctly, and one quickly learns how important it is to work to high standards. One disadvantage of on-the-job training is that it is too practical. The man working in this way sees only what is being done. He never sees and rarely thinks about the reason for its being done. Thus, in electrical repair work, a man may learn, by rote, to put 126 turns of a certain kind of copper wire on a relay. But he will never learn why. The next relay may require 270 turns of a smaller diameter wire, and on-the-job trainees can also learn this. But each item is different, and a new and unknown type of relay cannot be fixed by such a man. A relatively simple course in electrical theory would correct this situation, but no one can teach him this on the job. Lacking fundamental theory, the mechanic could only fumble on a trial-and-error basis to get the job done. Underlying much of maintenance work is a sophisticated physical, chemical or other natural science theory, and few really good technicians can be created by trial-and-error procedures. Theory is important.

118. If training on the job can be supplemented by some form of classroom experience, the training programme can be both improved and accelerated. Industry often takes the view that this more formalized classroom training is the responsibility of the government. Although industry may initiate and operate formal technical training courses, its ultimate objective very often is that the teaching of the skills with which its schools are concerned should be integrated as soon as practicable into the national system of education. There have been both failures and successes with more formalized training, but the greatest successes have occurred where much thought has been given to tailoring the programmes to local needs.

119. In evaluating the training programmes, one should seek answers to the following questions:

(a) Has provision been made to select qualified men for training and for determining standards of performance of trainees?

(b) Has provision been made to measure performance of trainees against a given standard of performance?

(c) Have the programme content and level of instruction been designed to meet the specific training needs of the enterprise?

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(d) Has the responsibility for the training programme been delegated to a qualified individual so that the details of the training programmes will be effectively administered?

120. Very often, candidates for training programmes are not properly selected, with costly results, such as training failures, high labour turnover and unsatisfactory industrial relations. Aptitude testing can usually help avoid pitfalls of inadequate selection, with many resulting advantages: to the enterprise, less wastage, shorter training time, and greater uniformity of output; to the employee, more satisfaction in his work; to the country, greater productivity and optimum utilization of its manpower. The comparison between the unknown performance of industrial workers and their aptitude test scores shows a high correlation.

121. The need for training maintenance and repair personnel for developing countries is not limited to the craftsman. More acute shortages often exist at the middle and higher supervisory levels, for technicians and for instructors.

122. For all training, it cannot be too strongly emphasized that what is right for the young European or American is not always right for the young man from a developing country. Training programmes must always be tailor-made. The higher the rank of the employee, the more acute this problem becomes. A particular point which should also be brought up is the training of counterparts and craftsmen by foreign technical personnel employed in a developing country. Foreign personnel and overseas representatives should be responsible for training of local employees in how to operate and maintain newly installed equipment properly. Drawings, equipment specifications and other relevant operating and maintenance information necessary for the efficient operation and maintenance of the plant, should also be handed over to the customer prior to makers' representatives leaving site after plant start-up.

123. In addition to the initial training for maintenance and repair personnel, training is continually necessary in order to improve performances, to increase efficiency, and to apply new developments. Up-grading training must also be considered.

124. Effective training for maintenance and repair, as for other subjects, depends upon effective instructors. These, however, are in very short supply in developing countries, and they must also be trained. Their curriculum of instruction must

cover a wide range: instruction and practice in techniques of training; discussion of the requirements of a training man's job in order to give him a good understanding of a teacher's role and instil in him the necessary self-confidence for the meeting of his future teaching responsibilities; imparting to him flexibility, an intelligent and adaptable approach to any training problem that may be encountered.

125. In many developing countries the biggest gap in the national educational system is often not at the bottom or top of the scale, but in secondary education, particularly technical secondary education. This is a serious drawback for any enterprise which depends for its existence on technology: for every technical university graduate that an oil company employs it may need five technicians with a secondary education. Yet, so much is involved in developing one of these technicians that there is a limit to what can be done within the enterprise; the foundation for company training must first be laid in technical colleges and other similar educational institutions.

Management training for maintenance

126. For many decades and until rather recently, the maintenance function, as an important part of an enterprise, has been overlooked in many of the developed nations. Maintenance schemes were often introduced on a ad hoc basis, to be abandoned soon afterwards. Very seldom did a permanent maintenance function exist as part of the organization.

127. During the last decades this situation has drastically changed. Today permanent maintenance functions have been set up within the organization of the enterprises, and they have carefully planned and established maintenance schemes, for the execution of which it has become necessary to train an appropriate number of engineers, foremen and supervisors.

128. In the developed economies it was found, by bitter and costly experience, that the maintenance function, as such, could not be fully decentralized and placed under the direct authority of the heads of the separate departments; nor could the function be fully delegated to supervisors and foremen. As time passed, it became clear that a centralized maintenance department, as a staff unit attached to the line organization, had to be installed.

129. This department develops the over-all maintenance policies of the enterprise and, subsequently, detailed schemes; these in turn are adjusted to such considerations as the importance and value of existing equipment, production methods and whether or not spare parts are immediately accessible. The maintenance department also controls these schemes or systems. Responsibility for the daily execution and control of established maintenance schemes, may be divided or not between the maintenance department and the line organizations. The department is also responsible for the training of all personnel involved in the maintenance schemes.

130. This installation of functional staff maintenance departments into existing organizations has, however, not been an easy task. To begin with, there were objections by the heads of production departments and by their foremen and supervisors. This negative attitude was understandable, but it has gradually been overcome, mainly as a result of changes of thought among top executives.

131. The above-mentioned experiences in developed countries should be kept in mind when attempts are made by industries in developing nations to improve their organization of maintenance.

132. Based on the experience of various developed countries, on the present situation with regard to maintenance in the developing nations, on reports received from United Nations experts in the field, and on research papers prepared, internationally, for the United Nations Centre for Industrial Development, the Centre has developed a programme which facilitates the introduction of permanent and efficient maintenance schemes in the developing countries. It includes:

(a) A short and intensive orientation round table on the principles of modern industrial organization and the role of the maintenance department within it. Top executives and department heads should participate in this seminar as well as the specialists who will be in charge of the maintenance department;

(b) In-plant training schemes for maintenance specialists. The theoretical and practical part of this includes: (i) formulation of maintenance policies, (ii) development and installation of maintenance systems, and (iii) maintenance performance analysis;

(c) Preparation of a manual on the organization and management of a maintenance department;

(d) Preparation of a manual on training of maintenance personnel;

(e) National, regional and international seminars to discuss the findings of studies and propose recommendations.

133. Additional information relevant to training for maintenance and repair is found in annex V.

VI. REPLACEMENT PARTS

134. Replacement parts, without which no industrial plant can operate efficiently, are often both scarce and expensive in developing countries. Management and Government may not be aware of the importance of an adequate supply of parts, or else the total equipment inventory is so heterogeneous in terms of age, type and country of origin, that effective procurement of parts becomes a complex and often impossible task. However, careful study and application of modern inventory and purchasing methods can, in many cases, result in some improvement in parts supply. Of particular importance is the need to keep accurate records of use, in order that future orders of spare parts can be based on relevant local experience. To add to these difficulties, transportation delays and foreign exchange problems make the problem of spare parts even more complicated. There are several solutions.

1. Establishment of workshops

135. Transportation delays and foreign exchange problems alone are excellent reasons for initiating local production of replacement parts in developing countries. An efficient and versatile workshop makes possible a significant reduction of the inventory of parts carried (many of which may never be needed), and it can carry out, besides, emergency repairs without loss of time due to delayed delivery. The cost of operation of such workshops may be considerably higher than that of workshops in industrially advanced countries, but this drawback is usually outweighed in the long run by the advantages mentioned.

136. Where individual enterprises are too small to establish their own workshops, one or more workshops can be organized on a co-operative basis. A number of examples of such co-operative efforts already exist in developing countries, but often there is a lack of sufficient technological and engineering experience and of the required high precision machine tools needed for the manufacture of more complicated or precision parts.

137. Governments in developing countries can be very helpful in setting up such groups of workshops, one of which should be given assistance in installing the more expensive precision machine tools; and also in seeing that all the workshops are provided with fully qualified technical personnel and highly skilled workers.

2. Standardization

138. The Government can also help reduce the level of inventories of imported spare parts by encouraging standardization and reduction of unnecessary variety of equipment. But, because of small demand and purchases of equipment in small quantity, adequate stocking of parts may be uneconomical by the standards of highly industrialized countries.

139. One frequent complaint in developing countries is that revenue duties on replacement parts are excessive, and that this makes unnecessarily expensive the repair and maintenance of industrial equipment. Here, the desire to promote the local manufacture of replacement parts and save on foreign exchange must be tempered by the clear realization that the industrial plant must also be kept running at all times.

140. Equipment manufacturers usually have available recommended parts purchases, but these are usually based on the experience of industrially advanced countries, and alterations must be made for local conditions based on previous experience. For instance, king-pin bushings rarely wear out in the United States so the recommended supply by manufacturers is small. But in one example reported, trucks working in the sand in Saudi Arabia often wear out a set in a few months. Governmental influence can also be used to good effect in providing more efficient arrangements for the allocation of import licences and foreign exchange, and for the simplification and speed-up of customs procedures.

3. Inventories

141. The planning of parts inventories in developing countries is difficult for more reasons than in developed countries. One reason is the long lead time for orders, which may require planning up to several months in advance; no one can really predict so far in advance what difficulties may arise. Other problems are involved in obtaining skilled personnel to process orders, which involves not only foreign ordering, but also clearance through local ports and customs. The principal difficulty seems to be, however, in training men to realize that each part has a different use rate. The tendency, in early stages, is to order a set number of everything; the result is an accumulation of slow moving items and shortages of critical parts. The only planning which is meaningful in such a situation is

detailed and time consuming. One effective procedure reported was to bring maintenance operators and inventory personnel together to consider a large number, or even most parts, item by item with the maintenance people and to decide what kinds of use experience has been typical in the past. Of course, this is tedious and time-consuming, but time can be saved by ignoring cheap parts costing under a certain pre-determined level, and by focusing on more expensive items: careful attention to detail pays off here. An example was given of a trucking company in the Middle East showing that, in five years, through the practice of the above, inventory value fell from 50 per cent of the cost of the vehicles to under 10 per cent. These points are equally important for parts ordered from abroad and for those manufactured locally. Effective inventory control, of course, requires good projections, usually based on past experience of future parts demand. These projections, however, need not be exact, and good estimates will still yield results near the minimum cost point.

4. Economic aspects

142. An economic factor which must be considered carefully in the problem of making spare parts locally is the cost of equipment downtime in terms of revenue. If the earning power of a piece of equipment down for repair is high, very high local manufacturing costs for parts of inferior quality may still prove economical if they reduce downtime considerably. The cost of carrying inventory also advocates local production of parts, particularly the slow moving ones. For instance, in one case reported concerning a Middle Eastern country, carrying inventory costs about 25 per cent of its landed cost per year, and a part costing $5, used four years later, really cost over $10. In many cases, local substitutes could be made for perhaps $8 or $9.

5. Rebuilding of spare parts

143. An important part in the economics of maintenance and repair is the rebuilding of worn-out parts. Two of the more common methods of rebuilding are metal spraying and welding. In a large number of cases, such as sliding surfaces and shafts which have become worn or damaged, parts can be resurfaced, and after the appropriate machining or grinding they can be rehabilitated, sometimes even giving the same

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long service as the original parts. Wear-resistant surfaces can in the same way be built on parts of earth-moving machinery, which would otherwise have to be discarded. While the work of such rebuilding needs a certain technological experience, it is not outside the scope of the developing countries to acquire these techniques.

6. Redesign of spare parts

144. One other possibility which developing countries can usefully explore is the redesign and further development of spare parts. Many parts designed in industrial countries are not necessarily suited to economical manufacture in developing countries. Thus, a certain bushing which, because of the cost of labour in the developed country, may be made of nylon. The developing country's workshop may be able to devise a brass substitute bushing that will work equally well. Many such substitutes and redesigns may be feasible in a variety of situations. A central design engineering group could be established in a developing country to co-ordinate such work, and local Governments can assist in establishing them.

145. One possible solution to the difficult and complicated problem of replacement parts might be attained by co-operation of the manufacturer and consumer country in the classification of spares in two respects: by the manufacturer, according to the technological difficulties encountered in producing them; by the consumer Government or concern, according to the figures representing the magnitude of demand resulting from the statistical analysis made for local requirements. It will then be left to the developing country to choose the items best suited for economical production within its installed manufacturing means and according to the technological documentation supplied by the manufacturer.

146. A pronounced advantage of this procedure is the amount of in-factory training this would provide for the personnel of the advancing country; in other words, it would be another way for sowing the seed for a bigger and more advanced stage of industrialization.

ANNEX I

TYPES OF MAINTENANCE

	Controlled by production supervision	*Breakdown*	*Scheduled*	*Planned*	*Preventive*
1. *Methods of control*	(*a*) Skilled craftsmen operating machine tools or similar engineering equipment carry out their own maintenance. (*b*) The production department has skilled craftsmen specifically allocated to machine maintenance; these men are called to machines by operatives or production supervision as necessary. (*c*) A small maintenance gang is carried in each plant or area, under the supervision of a skilled foreman responsible to the production manager of the area.	Maintenance is organized as a separate section, but regarded merely as a service to be brought in by the production department when failures impede, limit or prevent the desired rate of production.	The maintenance staff produce an inventory of major items of plant and suggest to the production department items likely to require attention during the following year. In general, the production programme determines the approximate times at which individual items will be made available for maintenance. Scheduled maintenance is the first step, both in time and principle, towards preventive maintenance and is the natural system to use where plant does not run continuously or is subject to periods of idleness, due to change of product or completion of orders. It is usually readily applicable to service plant, such as boilers, compressed air stations and the like.	This system presupposes the establishment of scheduling for at least the major items of plant, the schedule forming the framework of a more detailed analysis leading to the planning of the work to be done on these items. From records of the conditions found and work done under scheduled maintenance, tentative estimates are made of the work content of jobs, and labour and material are provisionally allocated. Analysis of performance against estimate, and strict application of the lessons learned, improve forecasting to an extent which experience has shown to be unexpectedly large, indirect advantages being considerable.	This system is a development of planned maintenance, the prior establishment of which it presumes. At this stage previous records become inadequate by themselves, and scheduling and planning are extended to more detailed items of production and service plants. Work of an inspection, maintenance, replacement or modification nature, which it will be necessary to carry out during the lifetime of the items, is broken down into elements, and these are studied to improve methods and to obtain more accurate work contents. Maintenance policy is aiming at the abolition of "repair" as generally understood and is concerned with upkeep, replacement and modification.
2. *System may be suitable*	Where: (*a*) The production staff are qualified engineers; (*b*) The operating personnel are skilled craftsmen; (*c*) The corrosion factor is negligible; (*d*) The machinery employed in production is straightforward in its engineering aspect; (*e*) Production is to satisfy specific orders, which can be programmed individually.	Where: (*a*) There is temporary urgency for a limited and definable period; (*b*) Plant capacity exceeds the current market demand; (*c*) Storage capacity for the final product is large; (*d*) The process is obsolescent and more modern equipment is under consideration; (*e*) Many standardized and interchangeable units are concerned, a short life is economically justified and replacement is easy.	Where: (*a*) Plant does not operate continuously on three shifts, seven days a week, and maintenance in the idle periods does not necessitate excessive overtime; (*b*) Continuously operating plant has either fixed idle periods in the year, such as an annual holiday, re-tooling or revising of [illegible] for new product, seasonal falling off in demand or statutory examination, for example, of boiler plant; (*c*) Plant is operating at or below its capacity.	Where scheduled maintenance is said to be inadequate, that is, where: (*a*) Demand exceeds the rated capacity of continuously operating plant; (*b*) There is no general annual holiday or other accepted break in production.	Where: (*a*) Continuity of production is essential because of inadequate storage for finished product or of perishable nature of the product; (*b*) Building space for extension is restricted or excessively costly; (*c*) There is a shortage of labour either for production or for maintenance; (*d*) Limitations are imposed on capital expenditure; (*e*) Delivery of materials is slow; (*f*) Maintenance costs form a high proportion of the indirect charges against production.

3. *Advantages*	(*a*) The absence of any clerical or paper work; (*b*) No need to employ highly qualified maintenance staff who might be more directly used on production; (*c*) The unity of control obtained by a single vertical organization; (*d*) Economy of labour in small plants.	(*a*) The absence of any clerical or paper work; (*b*) No need to employ highly qualified maintenance staff; (*c*) The cheaper initial capital cost of plant, if the system is combined with a capital replacement policy.	(*a*) It enables the maintenance staff to make better long-term forecasts of labour requirements; (*b*) A large measure of flexibility in the use of any item is retained until a date close to the scheduled date; (*c*) The approximate date at which particular replacement items may be required is known.	(*a*) Better utilization of maintenance labour and material; (*b*) Provision of data whereby alternative production programmes can be compared from the maintenance aspect; (*c*) More reliable and consistent production during normal running period.	(*a*) Flexibility arising from accurate advance knowledge in easily interpreted form; (*b*) Accuracy of production forecasts not only as to quantity but as to time; (*c*) The lowest possible depreciation for a given installation; (*d*) Low capital charges for installed spares and storage; (*e*) Better working conditions for all employees; (*f*) Lowest costs for a satisfactory standard of plant condition.
4. *Disadvantages*	(*a*) The inability to obtain separate maintenance costs and records; (*b*) The lack of continuity in maintenance techniques as operating personnel change; (*c*) The difficulty of organizing an adequately trained squad for a major emergency, or a complete overhaul; (*d*) The risk of neglecting essential maintenance due to concentration on immediate production.	(*a*) Heavy depreciation; (*b*) Increased cost of plant spares, particularly installed spares, due to the need for greater "insurance" cover; (*c*) Lower machine availability and therefore incomplete utilization; (*d*) Lower labour utilization in both production and maintenance, and erratic nature of demand; (*e*) Unreliable production forecasts, with unheralded repercussions on associated departments; (*f*) Wide fluctuations in cost over standard reference periods; (*g*) Poor working conditions for maintenance labour and probably for operating labour, due to less reliable nature of plant; (*h*) Greater losses in production, at breakdowns, due to lack of warning of failure.	(*a*) The idle production period may be inadequate for the work found desirable on a particular item; (*b*) The maintenance staff, owing to lack of data, cannot make an accurate forecast of maintenance work and can therefore make little contribution to that aspect of the original production programme; (*c*) Some clerical work is necessary in preparing and following up the programmes; (*d*) There is a tendency for production staff to release items at short notice; this mainly arises from (*b*) above.	(*a*) There may be some loss of flexibility in production programmes as last-minute alterations to planned shut-down work become too expensive; (*b*) Clerical work may be increased—it will at least have to be rationalized; (*c*) High-quality supervision is essential if the benefits are to be obtained.	(*a*) The main potential disadvantage is a tendency towards keeping in production plant which is technically out of date, but which is in such good condition that there is reluctance to spend money on known technical improvements; (*b*) A substantial amount of clerical and additional engineers' paper work is necessary.
5. *Conclusion*	This method is an elementary type of maintenance of strictly limited application and one which may put a heavy and divided responsibility on the production staff. They must be able to give equal weight to arguments for and against short-term overloading of plant at the eventual expense of efficiency or total annual output. The method also tends to disguise from top management the real size of the maintenance problem with which it may be faced.	Maintenance of this type appears to involve the acceptance of a lower state of mechanical efficiency, which may not result in a very high percentage of lost production time, but will continuously restrict production below that obtainable from the same machinery and plant, maintained at a higher (and attainable) level.	Where the normal idle time of production plant is adequate for total necessary maintenance, scheduling increases the efficient use of that idle time. With continuously operating plant, it is a very necessary first step towards reduction in "down time" due to mechanical failures of running plant and equipment.	Planned maintenance sets a standard which may be economically justified only in plants operating continuously at high rates of output. In these conditions, experience indicates that it will reduce both maintenance and production costs and the incidence of emergencies.	There is no generally applicable formula for preventive maintenance. It can be applied successfully only through the efforts of efficient maintenance staff who have that outlook. Its administration must be at a sufficiently high level to ensure integration with production policy. Technical methods for both production and maintenance must be under constant (and related) review and allocation of functions must be clearly defined, so that a simple mechanism exists for applying policy at the operating level in both departments.

Source: Anglo-American Council on Productivity, *Plant Maintenance* (London, 1952), pages 10 to 23.

Annex II

QUESTIONNAIRE ON REPAIR AND MAINTENANCE OF INDUSTRIAL EQUIPMENT IN DEVELOPING COUNTRIES

Explanatory notes

1. The purpose of the attached questionnaire is to provide sufficient data on repair and maintenance of industrial equipment in developing countries, to make possible necessary steps for the improvement of this important industry function in such countries.

2. Answers should be as detailed as practicable, with illustrative examples and statistical data, when these are available.

3. When an estimate is given this should be so stated.

4. The questionnaire has been prepared with a broad spectrum of industry and government correspondents in mind. Consequently, all questions do not apply for every individual case. Please disregard them when not applicable.

5. The classification of industrial equipment suggested for consideration in filling this questionnaire (for purposes of uniformity) is the following:

(a) Mechanical equipment (including metal-working equipment)

(b) Electrical equipment

(c) Process equipment

(d) Transportation equipment

(e) Service equipment (power plant, air-conditioning, heating, ventilating, valves, piping, etc.).

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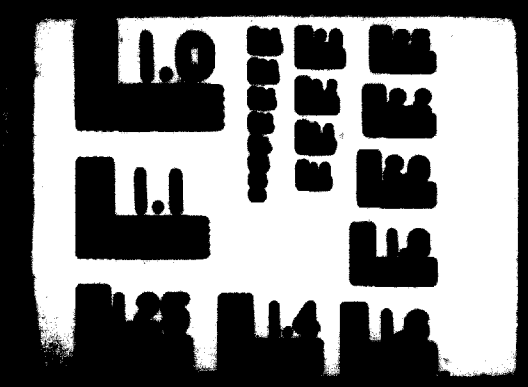

QUESTIONNAIRE

REPAIR AND MAINTENANCE OF INDUSTRIAL EQUIPMENT IN DEVELOPING COUNTRIES

1. Is there a shortage of repair and maintenance personnel? If so, in what areas in particular?
2. Are there any specialized training courses for repair and maintenance personnel (vocational schools, in-plant training etc.)? If yes, give relevant particulars.
3. Is there a shortage of equipment necessary for repair and maintenance? If so, what equipment in particular?
4. In which industries, or with what types of industrial equipment are conditions of repair and maintenance especially acute? Where are the conditions best?
5. Do centralized repair and maintenance shops exist? If yes,
   (a) Are they specialized or general-purpose?
   (b) Do they manufacture parts?
   (c) Do they provide any training?
6. Are industrial plants equipped as a rule with satisfactory in-plant repair and maintenance facilities?
7. Is preventive maintenance an accepted and established industrial practice?
8. Can a significant number of accidents be attributed to poor repair and maintenance of industrial equipment? Give statistical data, if available.
9. Are replacement parts manufactured locally? If yes, to what extent? Is their quality satisfactory?
10. What has been the local experience with repair and maintenance shops as nuclei of manufacturing plants?
11. Are there any restrictions on the importation of replacement parts? If yes, give particulars.
12. Is servicing by foreign manufactures of imported industrial equipment satisfactory?
13. What is the main obstacle to satisfactory repair and maintenance of industrial equipment: shortage of repair and maintenance personnel; inadequate equipment and facilities for repair and maintenance; lack of replacement parts; negative attitude or lack of awareness among users of industrial equipment?
14. Do the absence of standardization and the unnecessary variety of industrial equipment (either imported or manufactured locally) contribute significantly to the difficulties of repair and maintenance?

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15. Do you believe equipment designs specially adapted to the needs of developing countries could significantly facilitate repair and maintenance?

16. Give estimates of average expected productive life of industrial equipment, by type of equipment.

17. Give estimates of the average age of industrial equipment currently in use, by type of equipment.

18. Give typical examples for waiting periods for industrial equipment to be repaired.

19. Are there estimates of the percentage of the time industrial equipment is idle because of repair and maintenance? By type of equipment.

20. What are the main causes of equipment breakdown: equipment age, lack of preventive maintenance, lack of operator skill, climatic conditions, or other causes? Give statistical data if available.

21. What are the prevailing industrial equipment replacement policies and practices, and what are government regulations concerning equipment replacement?

22. Describe other relevant industry policies and practices affecting repair and maintenance of industrial equipment.

23. Describe special local problems, needs and characteristics of repair and maintenance of industrial equipment, if any.

24. What governmental organization (or organizations) is dealing with problems of repair and maintenance of industrial equipment, and what are its functions related to this subject?

25. Are there any programmes considered or already under way with the purpose of improving the repair and maintenance of industrial equipment? If so, give particulars.

26. What kind of assistance, if any, is being (or was) received from abroad with respect to repair and maintenance of industrial equipment?

27. Do you know of the assistance available through the United Nations system with respect to problems of repair and maintenance of industrial equipment?

28. Give any other information which you consider important and relevant to the repair and maintenance of industrial equipment.

29. What are, in your opinion, the necessary measures for the improvement of the repair and maintenance of industrial equipment?

30. What is your opinion of the merits of a possible interregional conference, to be organized by the United Nations, to consider problems of repair and maintenance of industrial equipment and develop a programme for action for the benefit of developing countries. Would your country be interested in participating in such conference?

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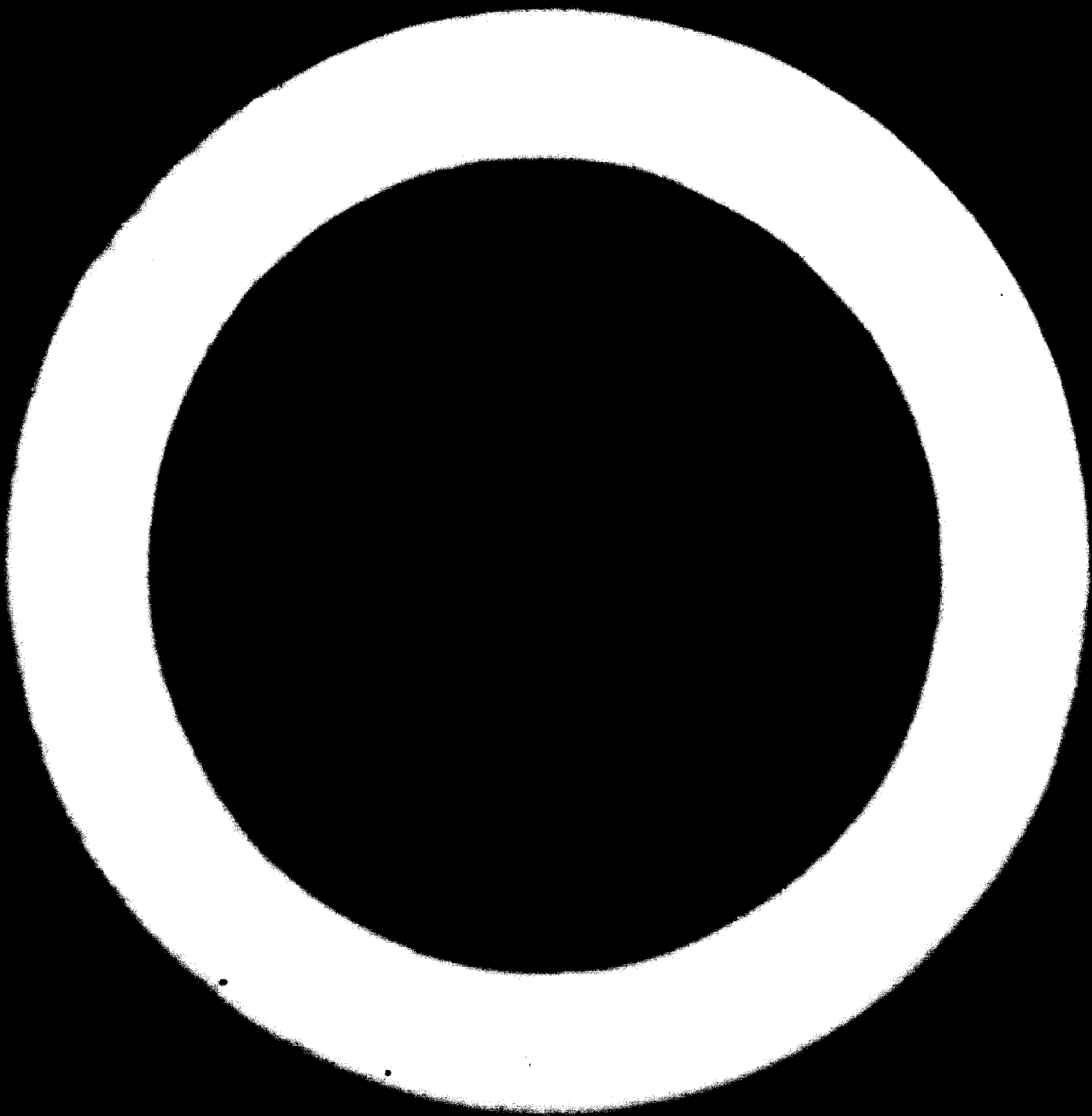
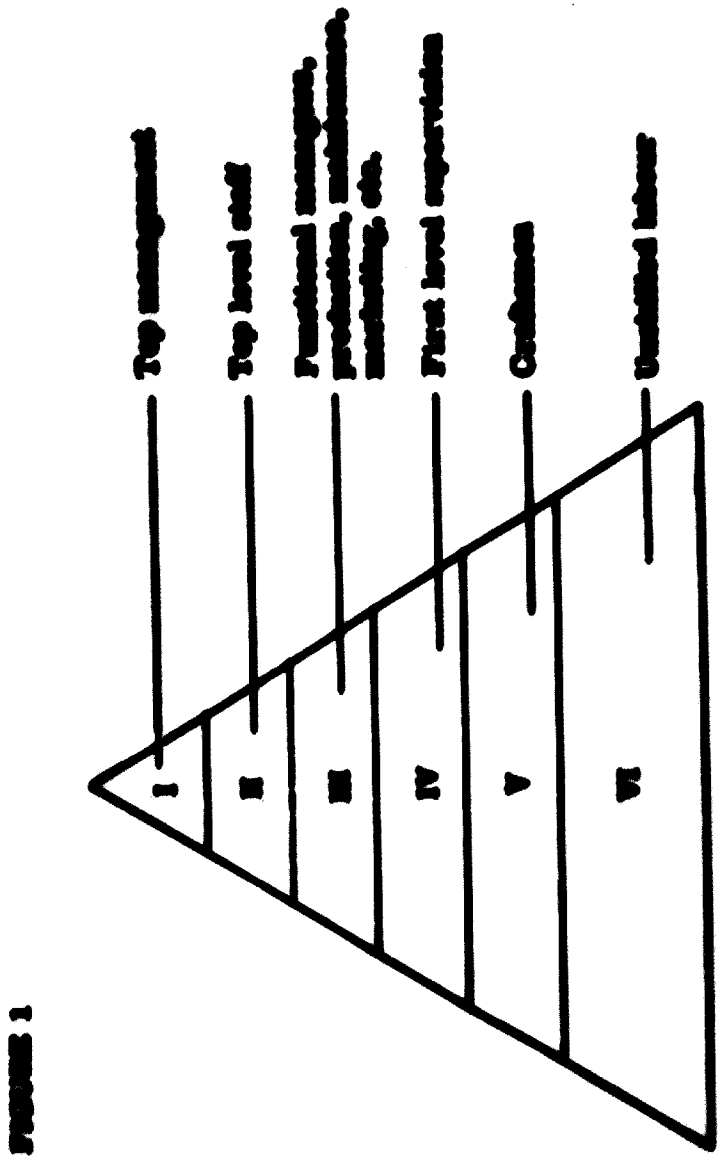
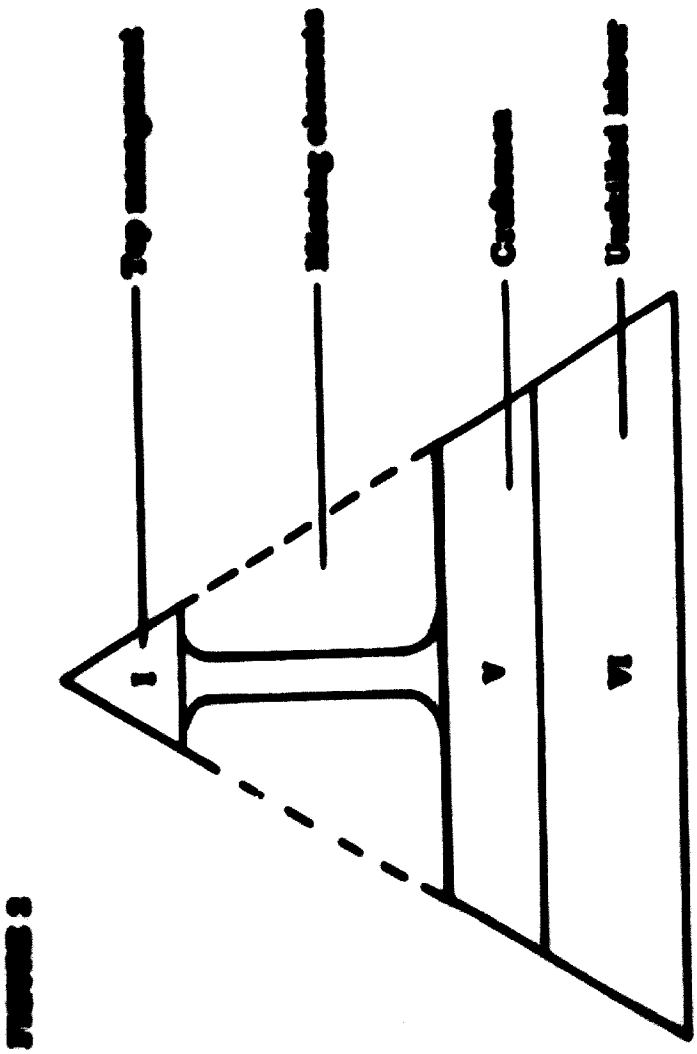
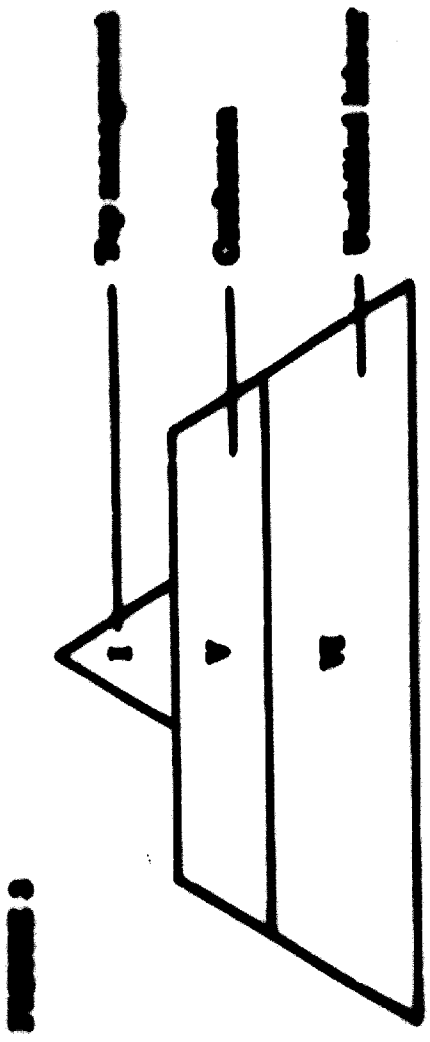


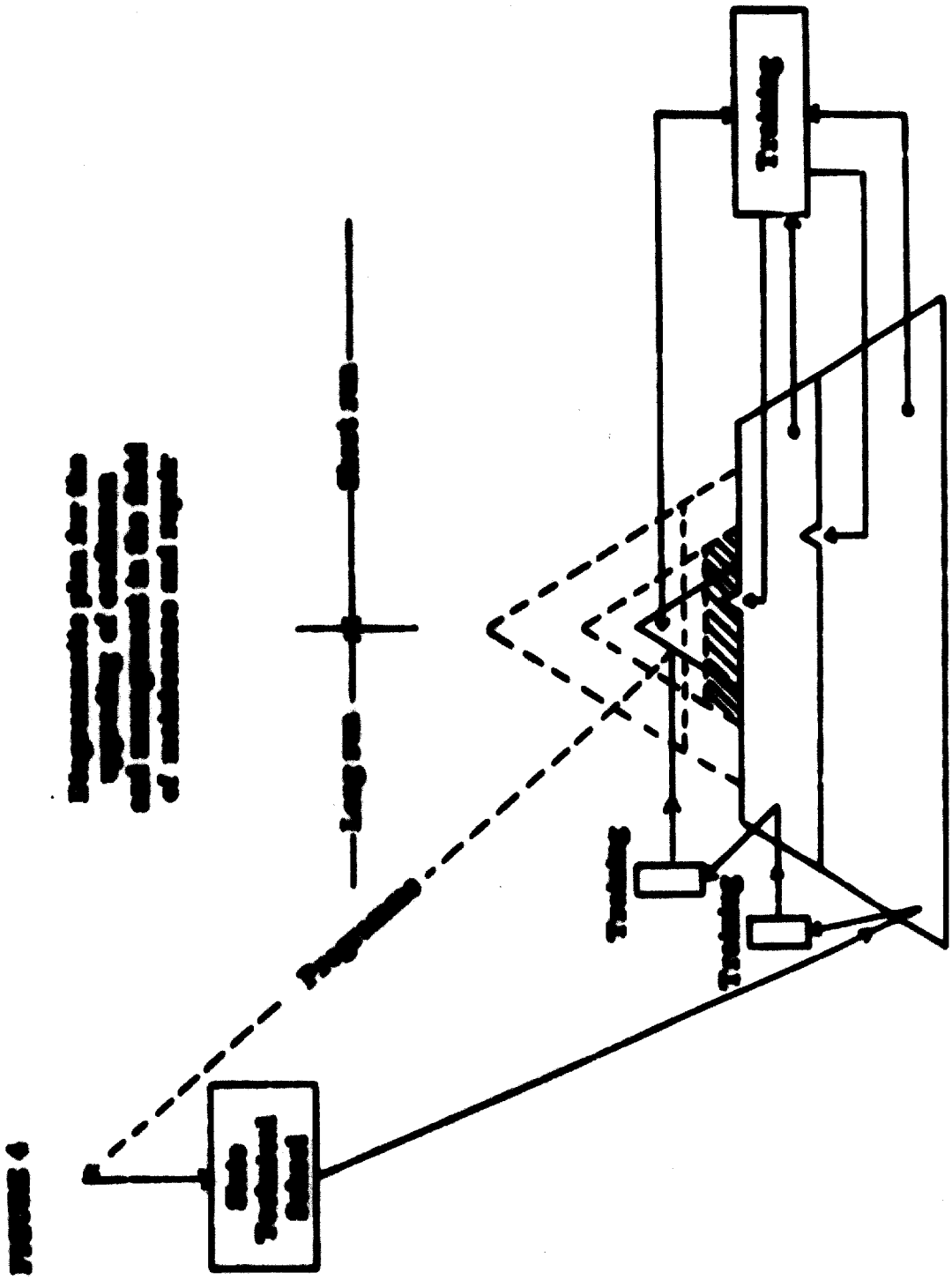
Annex III

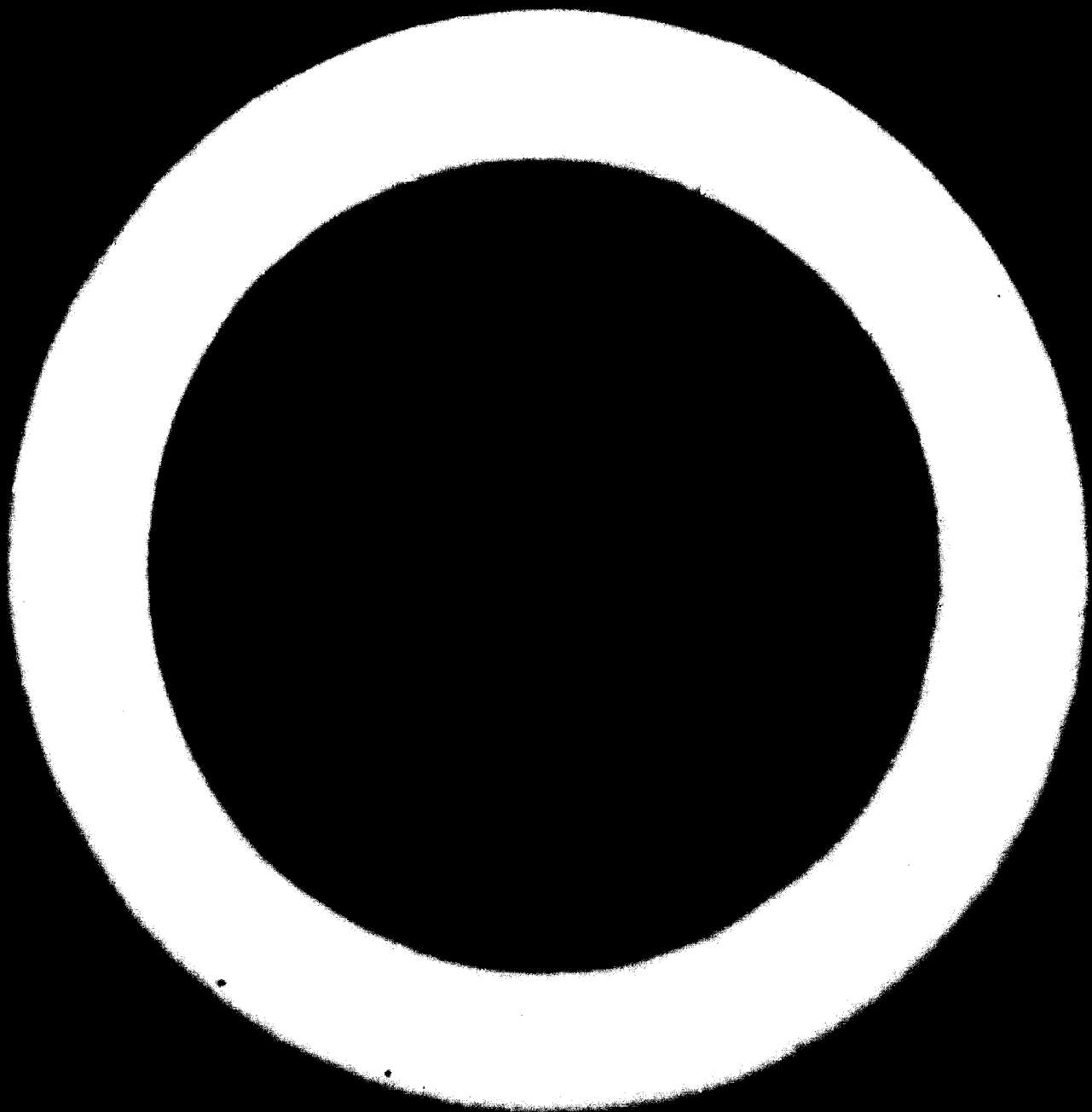
[illegible] STRUCTURE DIAGRAMS











Annex IV

ORGANIZATION CHARTS

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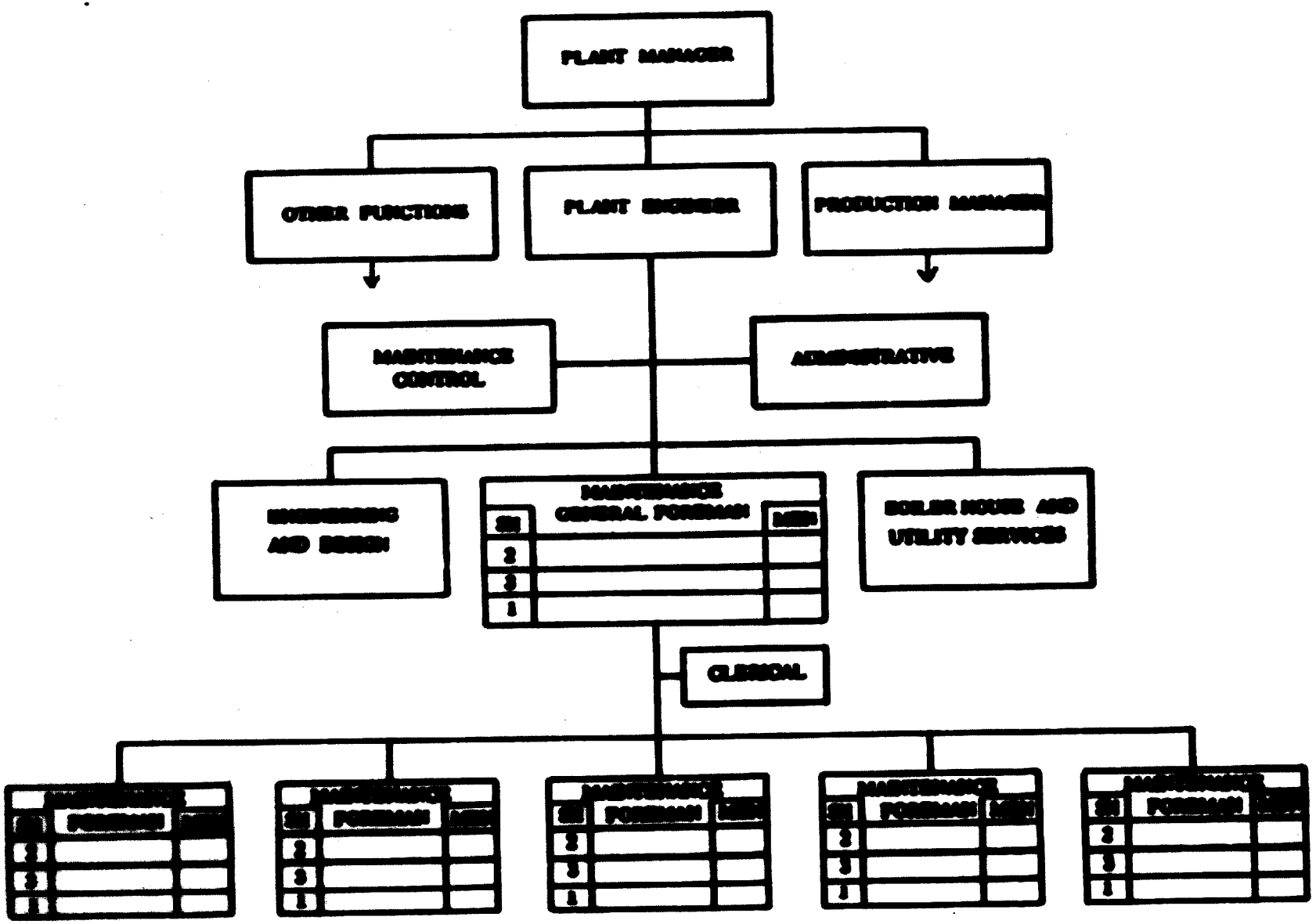
TYPICAL PLANT ENGINEERING ORGANIZATION

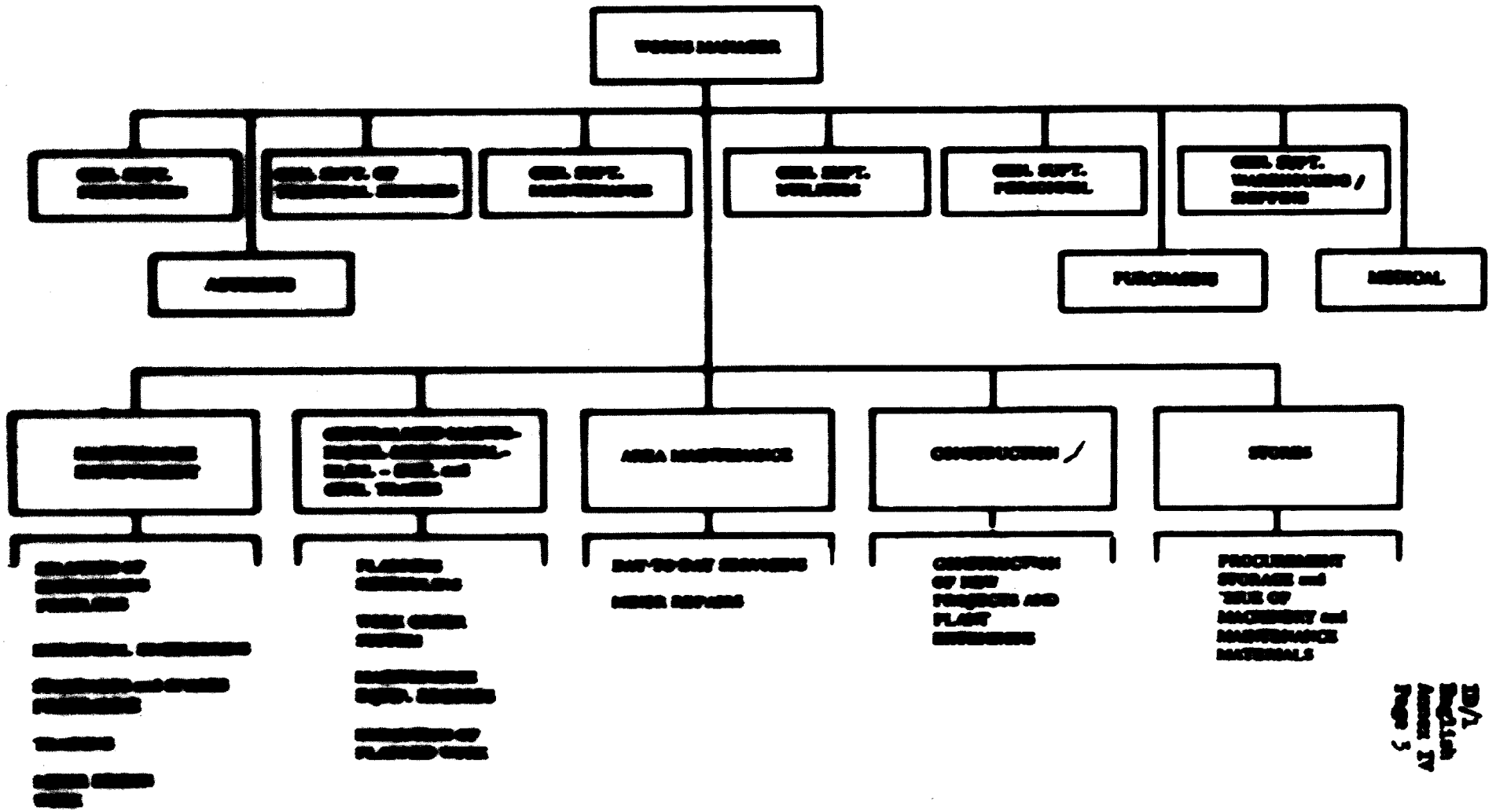
MEDIUM UNIT

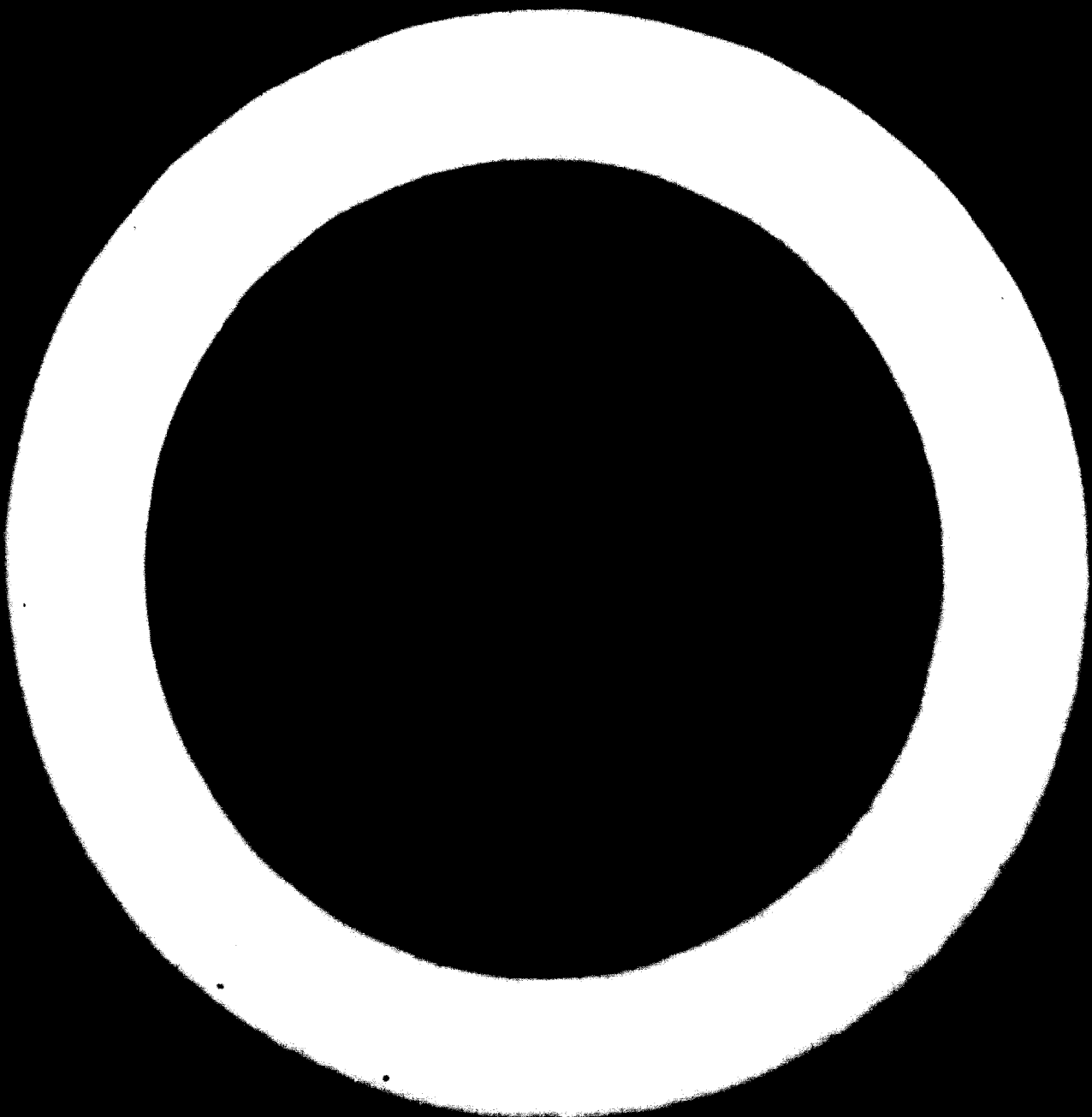
25 TO 125 HOURLY MAINTENANCE EMPLOYEES ON LARGEST SHIFT (EXCLUSIVE OF BOILER HOUSE PERSONNEL)



CHEMICAL PLANT IN U K

PRESENT ORGANISATION CHART WITH PARTICULAR REFERENCE TO MAINTENANCE DEPARTMENT ORGANIZATION





Annex V

TRAINING FOR REPAIR AND MAINTENANCE

A. A possible approach to training for consideration by developing countries

Assistance in training may be developed as follows:

1. Typical and suitable plants in developed countries are selected to provide in-plant training.
2. Similar industrial units in developing countries are selected as pilot plants for application of maintenance training.
3. Training proceeds in two phases: in developed countries, by providing general knowledge and experience; and in developing countries, by actual application.
4. Instructors are selected in two categories:
   (a) Engineers with five or more years' experience in maintenance organization and management;
   (b) Craftsmen with ten or more years' experience in maintenance work.
5. Trainees should be selected from among engineers and technicians of the developing countries, preferably in the electrical, mechanical or industrial branches, with at least five or more years' experience in a production or maintenance department and with a fair knowledge of the language of the selected developed country.
6. Training will start in a developed country with six weeks of general theoretical training and twelve weeks of actual maintenance shop work under the instructor's supervision. Following this, the trainee will have three months or more of applied work in the plant of his own country, under the supervision of the expert instructor, preferably the instructor responsible for his earlier training.
7. This project should be followed continuously every year, selecting different countries and different subjects.
8. If maintenance equipment and facilities are lacking in the developing countries, centralised maintenance shops may be established in the industrial areas.

9. The following curricula are suggested for training specialists at a technical college or university level:

(a) Basic mechanics and electrical engineering courses:

(i) Drawing;
(ii) Strength of materials;
(iii) Design of machine parts;
(iv) Production technology;
(v) Mechanics;
(vi) Electrical engineering;
(vii) Statistics.

(b) Special maintenance and repair courses:

(i) Metal cutting technology and equipment;
(ii) Forging and foundry technology and equipment;
(iii) Welding technology and equipment;
(iv) Principle of work and design of hydraulic equipment, pneumatic equipment and electrical equipment;
(v) Design of cutting tools, metal cutting machine tools and metal cutting technology;
(vi) Theory of interchangeability and tolerance;
(vii) Technology of assembly, testing and setting up of machinery and industrial equipment.

(c) General courses:

(i) Material handling equipment;
(ii) Accounting;
(iii) Motion and time study and work study;
(iv) Safety.

3. [illegible] minimum qualifications for trainees [illegible]

	Qualifications/Attainment of Trainee			Qualifications of Trainer		
	Education	Training	Experience	Education	Training	Experience
Worker	Primary	-	-	Training to be organised by particular country concerned		
Craftsman	1. Primary 2. Technical if possible	Basic craft training Minimum - 1 year Technical training - 2 years	-	1. Primary 2. Technical 3. Language of country to be visited	1. Practical craft 2. Instructor training	Practical craft experience Minimum - 5 years
Foreman	1. Primary 2. Technical if possible	As above plus management training	Craft experience Minimum-3 yrs. Leadership qualities	1. Primary 2. Technical University degree or equivalent qualification	As above plus management principles e.g. organisation industrial engineering economics personnel policies objective setting	Practical - 10 yrs. Technical - 5 yrs. Foremanship-2 yrs.
Management	1. Primary 2. Technical/ University degree or acceptable level of achievement	Practical training Management training Minimum - 1 year	In maintenance or production engineering as engineer or foreman Preferably some design experience 2 years Application of basic management techniques	1. Primary 2. University graduate or equivalent qualification	As above	All round knowledge of all facets of maintenance, including experience as a senior manager Minimum - 10 years

C. An apprentice training scheme

The importance of training

Craftsmen represent the skilled labour of the manufacturing industry and account for more than one third of its manpower. In a country such as the United Kingdom where we rely for our very existence upon the products of our workshops and factories, it is essential that we train our apprentices in every facet of their craft.

Up to recent years the accepted method of craft training was to put a trainee to work with a craftsman who acted as an instructor. This system, known as "training by exposure" is now being superseded in the more advanced industrial organizations by a better and more systematic approach to training.

Our competitors are also making great strides in this field. Germany and France in particular have many ideas worth noting.

Chief aims of the apprenticeship scheme

(a) To develop manual skill and dexterity at as early an age as possible;

(b) To encourage pride in craft;

(c) To produce a reliable craftsman brought up to meet the needs of the company;

(d) To develop good working, social and safety habits.

Apprenticeship committee

The scheme will be supervised by a representative committee of management who may modify such details as they consider necessary.

Age of entry and duration of training

Boys between the age of fifteen and sixteen years, six months, will normally be accepted as candidates for an apprenticeship course which will terminate at the age of twenty-one years, or after five years, whichever is the shorter.

The committee reserves the right to admit older boys to the scheme, if in their opinion, the applicant has the ability to complete the course satisfactorily.

Progress and aptitude will be reviewed quarterly, and the continued participation in the scheme of any apprentice will be subject to satisfactory reports.

Numbers accepted for entry

The number of apprentices to be accepted for training will be determined by the committee according to the requirements of the various craft groups.

Method of enrolment

Boys desirous of entering the scheme will be required to complete and submit an application form, copies of which, together with any further information about the training scheme, may be obtained from the Personnel Department.

Suitable applicants will be called for interview and the successful candidates notified. Parents or guardians will be asked to sign a declaration form agreeing to the terms of the appointment. Following the satisfactory completion of the six months' probationary period the appropriate indentures for apprenticeship will be signed.

Rates of pay

No fees or premiums are required to be paid by a trainee. The rates of pay for apprentices are those agreed between the Engineering Employers' Federation and the appropriate Trade Unions. These form a sliding scale with increases according to age.

Hours of work

These will be governed by the hours applicable to the Engineering Department and will conform to the requirements of the Factory Act, where this governs the working hours of youths.

Record of progress

A composite record will be kept of each boy's progress throughout his apprenticeship.

Progress prizes in the form of books, tools or instruments will be awarded annually. Any such award will be made by the committee on the basis of progress shown by the reports covering the past year.

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Selection of craft apprentices

Selection will be based on a combination of the following considerations:

(a) School reports;

(b) Written tests including such subjects as English, Arithmetic, General Knowledge and Science;

(c) Interview by members of the apprenticeship committee;

(d) Existing family connexions with company, all other considerations being equal;

(e) Medical report.

Induction and probationary course

New entrants will be required to undertake a six-month probationary course in the Works Training Centre. Initially they will receive practical training on the bench, thereby acquiring some knowledge of basic hand tools, metals and measuring instruments. Subsequent training will incorporate simple electrical work, instrumentation, welding, forging, sheet metal work and machine work.

Throughout the induction period and subsequent training programme, instruction will be given in safety and health principles to establish and develop a sensible attitude to safety. The syllabus will also include a general introductory course covering such items as, company history, products, welfare and social amenities.

Apprenticeship indentures

On satisfactory completion of the six months' probationary period, or earlier if practicable, the progress and particular aptitude of each boy will be reviewed and an indentured apprenticeship offered in the trade for which the apprenticeship committee consider him most suited.

Should the personal choice of the trainee conflict violently with that of the company, the company would reserve the right to terminate further service.

In this respect our experience and that of other companies indicates that such a situation seldom if ever arises since the trainees are usually only too willing to be guided on such matters.

It does, however, emphasize the need, where a trainee is a complete "misfit", for a decision to be taken regarding his future prospects with the company as soon as possible during the probationary period.

Parents will be invited to sign indentures for apprenticeship on the apprentices' "Open Day" when the Central Workshops and the Training Centre will be open to visitors.

Further training

Irrespective of their chosen craft all apprentices will continue to receive instruction and training in the Training Centre for a further six months.

On completion of the first year's training, electrical, instrument and welder apprentices will be assigned to their respective craft workshops to receive specific training relative to their particular trade.

During the last three years each apprentice will receive extensive plant experience in his appropriate trade, including Drawing Office practice in the case of the more promising students.

Endorsement of indentures

At the conclusion of the apprenticeship the indentures will be endorsed and signed by an executive of the company before being handed over to the apprentice as a permanent record of a completed apprenticeship.

Technical education

Apprentices will be expected to attend Day Continuation or Technical School on one full day per week and two evenings a week where this is considered necessary. Apprentices will also be allowed to complete the college session during which apprenticeship expires. This ensures that apprentices starting on a particular course will not have their studies interrupted.

Wages will be paid for the time spent at day classes. School fees and examination fees will be paid by the company dependent upon the boy showing satisfactory progress.

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Those wishing to enrol for further studies at the college after completion of apprenticeship may be allowed time off by arrangement with the department head concerned.

Apprentices showing outstanding progress in their studies will be considered eligible for a company scholarship to enable them to pursue their technical studies at a university.

Note: The company reserves the right to make any alteration it may deem necessary to the training scheme as set out herein.

Suggestions for the training of craft apprentices

Introductory courses

A short introductory course is suggested as an essential opening to a planned scheme of training. In the majority of cases a one- or two-day course should be adequate.

The course should be attended at the outset of employment, or as soon after as possible. The boys should be welcomed by a responsible member of management who will give them a description of the purposes of the course.

The syllabus of a general introductory course should attempt to cover most of the following items:

(a) The amenities provided by the company, including canteen arrangements, cloakroom and toilet facilities, welfare and social activities;

(b) The history of the company, its products, customers and sources of raw materials. Films could be shown during the course to provide a good background to the activities of the whole industry;

(c) A brief explanation of the various processes carried out in the works. Talks on these processes could be interspersed with visits to the various departments;

(d) The pay packet; how it is made up; the deductions; P.A.Y.E. arrangements; how and when wages are paid;

(e) Educational facilities provided by the company; day release; courses available and arrangements for enrolling at day and evening classes;

(f) Accident prevention should be stressed from the beginning of the apprenticeship course.

An explanation of dangers and precautions to be taken are a vital part of an introductory course. It is advisable to continue safety training during the whole apprenticeship period.

Films and filmstrips will be shown from time to time to help build up a sensible attitude to safety.

Technical courses

In the case of a boy who has entered an apprenticeship from the Secondary Modern School at fifteen, it is advisable to find a course which gives him instruction in the basic technical subjects.

It is customary to grant day release facilities without any ties. Experience has shown that the wastage rate at day classes is far lower than that encountered at evening shools.

The majority of craft apprentices would be advised to take the City and Guilds Machine Shop Technology Course or a new course for less academic boys - Mechanical Engineering Craft Practice. Outstanding boys should be given the opportunity of sitting for the National Certificate in Mechanical Engineering.

Preparing a syllabus of training

Practical instruction is of paramount importance, not only for the skills that are taught but for the attitudes and habits that can be created in the early months of work. It therefore follows that the craftsmen who are to give this instruction must be carefully chosen. This is especially so when a company does not possess a training workshop with specialist instructors.

A further factor of vital importance in the training of apprentices on the shop floor is the role of the departmental foreman, who ordinarily has the responsibility of seeing that the boys work with competent craftsmen who have the ability to impart their knowledge. He must assess the apprentices' progress and make sure that they are given experience in the various skills of the craft. He must never lose sight of the variations in the learning ability of individuals.

It is essential that the departmental foreman is conversant with the needs and aims of the training scheme and that his full co-operation is enlisted.

In companies where size does not allow the establishment of a training centre, it is often possible to allocate a small part of the tool room or machine shop for the purpose of training. A few basic machine tools, such as a milling machine, a lathe, a drilling machine and a bench for primary training in the use of hand tools, would prove a great asset.

A skilled craftsman might be made instructor either on a full or part time basis. This is particularly valuable in the first six to twelve months of a boy's apprenticeship for it is the means of establishing good working habits and a satisfactory attitude towards work. It is possible, by carefully graded work exercises, to keep the apprentices at full stretch and still allow development of their individual abilities.

Subsequent training should include a period in the central workshops doing maintenance and construction work, followed by general works experience in the production and engineering services departments. A planned itinerary should be prepared in order that each apprentice may gain as wide experience as possible.

Other aspects of training worthy of consideration include apprentice exchange schemes, inter-company or otherwise, and such extra-mural activities as participation in Apprentice Societies and Outward Bound Schools.

Equipment for training scheme

The training centre is situated in the Central Fitting and Machine Shop and is equipped with the necessary basic machine and hand tools to cope with the primary training requirements of eight or ten apprentices. Drawing facilities and a small technical library are also available in the adjacent Fitting Shop Office.

Workshop equipment

(a) Machine section

1 - 4" S.S. and S.C. lathe
1 - 6" S.S. and S.C. lathe
1 - 18" shaping machine
1 - milling machine
1 - bench model sensitive drill
1 - marking table
1 - oxy-acetylene welding and cutting set
Set of blacksmith's stoples, etc.

Use is made of main workshop equipment such as the radial drilling machine, machine saw, centre grinding machine, forge, as dictated by work requirements.

(b) Bench section

2 - benches and 8 vices
1 - bench for sheet-metal work, soldering and brazing. Electric arc facilities for training purposes are available in the welding sheet-metal workshop
4 - wiring boards for instrumentation and electrical exercise

(c) Tools kept in training centre, to be withdrawn as required

Stocks and dies
Taps and wrenches
Reamers
Drills
Selection of files
Selection of spanners and Allen keys
14" Stilson wrenches
Hacksaws
2" ball pein hammers
Sheet-metal working tools
3" and 6" inside and outside spring callipers
Feeler gauges
Screw cutting gauge
Dial gauge
Scribing blocks
Machine cutters and tools
6-foot steel tape

(d) Tools issued to apprentice on loan whilst receiving instruction in the training centre

8" F.J. outside callipers
8" F.J. inside callipers
6" spring dividers
5" odd leg callipers
5" engineers square
12" rule
Scriber
Centre punch

(Subsequently apprentice is required to provide a similar range of tools of his own.)

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(e) Tools on loan to apprentice - to be returned on leaving company

1 1/2 pound hammer
Set of spanners: 3/8"-7/8"
Flat chisel
Cross cut chisel
Diamond point chisel
Round nose chisel
8" flat file second cut and bastard
12" flat file second cut and bastard

Instruction in training centre

Fitting: series of test pieces and small hand tools; items for works and model making.

Machining and turning - a limited number of test pieces are made, as well as items mainly produced for works, and charge is made accordingly.

All items produced are subject to rigid checking: marks are allocated and records are maintained. Each apprentice is interviewed weekly by the apprentice instructor and the fitting shop foreman for a review of work and conduct. All assessments are read out to apprentice before being recorded. Strict discipline is maintained. No smoking permitted.

Staff

A craftsman acts as an apprentice instructor with direction from fitting shop foreman and workshop engineer, as necessary.

Other craftsmen and foremen act as part-time instructors in the training centre and specialist workshops, as considered necessary.

Annex VI

LIST OF BACKGROUND STUDIES AND DOCUMENTS SUBMITTED TO THE EXPERT GROUP ON REPAIR AND MAINTENANCE OF INDUSTRIAL EQUIPMENT IN DEVELOPING COUNTRIES

A. Studies prepared or commissioned by the Centre for Industrial Development:

1. "Repair and maintenance of industrial equipment in developing countries - Nigeria"; by Mr. G.O. Chigbo, Principal Research Officer, National Institute of Industrial Research.
2. "Repair and maintenance of industrial equipment in developing countries - United Arab Republic"; by Mr. Fouad Hussein, Director-General, Industrial Design Administration, General Organization for Industrialization, United Arab Republic.
3. "Repair and maintenance of industrial equipment in developing countries - a case study based on the experience in Saudi Arabia"; by Professor Richard N. Farmer, Graduate School of Business, Indiana University, United States.
4. "Repair and maintenance of machine tools in developing countries"; by Professor A.S. Pronikov, Rector of Moscow Technological Institute, USSR.
5. "Organization of facilities for repair and maintenance of industrial machinery and equipment in developing countries"; by Professor M.O. Yacobson, Experimental Scientific Research Institute for Machine Tools, USSR.
6. "Analysis of answers to a questionnaire on repair and maintenance of industrial equipment in developing countries"; by the Industries Section, Technological Division, Centre for Industrial Development.
7. "Use of industrial equipment in Underdeveloped Countries"; Industrialization and Productivity, Bulletin No. 4. United Nations.

B. Other studies and documentation:

1. A Survey of Training, Shell International Company, Ltd., 1961.
2. "Nuts, Bolts and Economic Progress", Forum, March 1966: by Professor Richard N. Farmer, Graduate School of Business, Indiana University, United States.

3. Various articles and unpublished documentation on the subject of repair and maintenance, submitted by the Ford Motor Company, the General Motors Corporation and the General Electric Corporation of the United States; by Mobil Fabbé and l'Association Française des Ingenieurs et Chefs d'Entretien of France; and by Monsanto Chemicals, Ltd., of the United Kingdom

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