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MAINTENANCE AND REPAIR OF SELECTED ELECTRO-MECHANICAL DEVICES AND INSTRUMENTS

by

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Organised in co-operation with the German Foundation for Developing Countries and the German Association of Machinery Manufacturers (VDMA).

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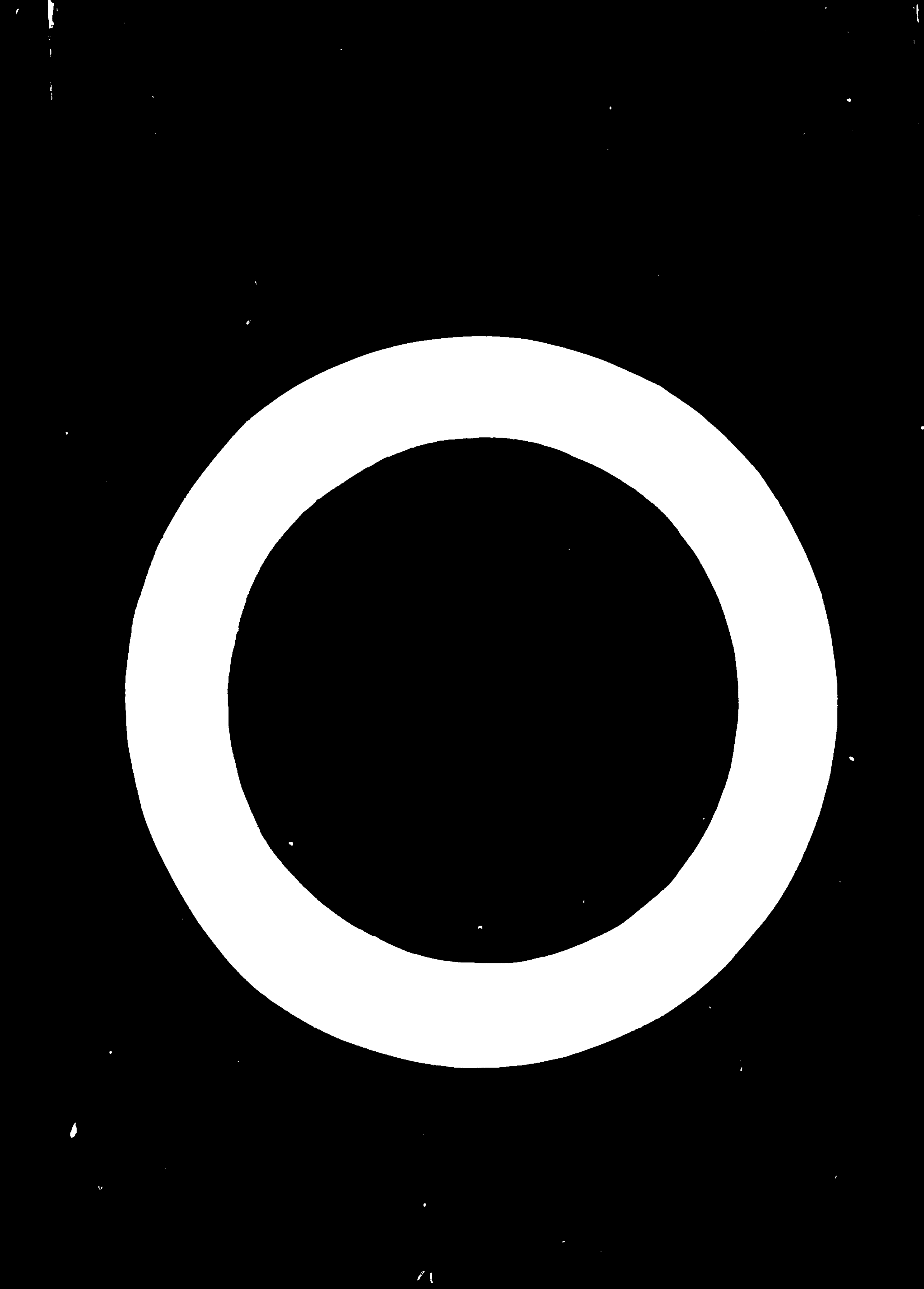

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GENERAL PRINCIPLES AND ORGANIZATION OF MAINTENANCE DEPARTMENT

In this chapter an effort will be made to point out the major services which a maintenance department is expected to perform, along with the methods that may be used in selecting and training maintenance personnel.

A particular emphasis will be given to the instrument maintenance department and staff.

1.1. Functions and Objectives

A maintenance department is expected to ensure the availability of the equipment and buildings needed by other departments for the performance of their operations at optimum return of investment. In general, the functions of a maintenance department can be divided into two classes:

(a) Primary Functions, such as:

- Continuous maintenance of the existing equipment and buildings, along with additional alterations and installation of new equipment
- Regular supply of power, air, heat and water;
- Control of maintenance cost.

(b) Secondary Functions, such as:

- Complete plant protection and property supervision;
- Salvage and waste disposal;
- Any other services delegated by the management, for which there is no specific section within the plant.

Respectively to the above, the main objectives of maintenance are:

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(1) To maintain equipment at maximum operating efficiency, so as to provide freedom from breakdowns and reduce to a minimum the 'down-time' resulting from breakdowns and planned stops;

(2) To maintain a high level of engineering practice in the performance of the maintenance works;

(3) To reduce to a minimum the costs of the maintenance work.

Attaining these objectives necessitates the following:

- A competent engineering group, which would keep abreast of industrial practice, modern methods, equipment and materials;
- A planned maintenance programme for both preventive and corrective maintenance, including the maintenance control;
- Continuous analyses and investigations into the causes of and efficient remedies for emergency breakdowns;
- Close co-operation with operating and production supervision.

All the above must be done in an economical and expeditious manner, at the convenience of production schedules and consistent with a high level of engineering practice and safety practice.

1.2. Organizational Principles

Although there is no universal organizational scheme applicable to all types of maintenance, there are some basic factors and practical rules to be considered in establishing an effective maintenance department, such as:

(a) Type of Factory. The importance and shape of maintenance differs from factory to factory. For instance, in precision mechanical and instrument factories, the maintenance covers their vital research and development facilities as well, so that, since here the invest-

Contd. 5.

ment in precision test equipment and tools is the largest expenditure, the responsibility for maintenance is placed on the highest level.

(b) Size of Factory. A large factory needs more maintenance staff, so that the supervision density may be increased considerably on the lower level to provide for a higher degree of specialization. A smaller factory may employ fewer but more versatile staff, increasing the supervisor's respopsibility to cover more specialities.

(c) Equipment. If machines of the same type are placed all over the factory, a centralised organization may be better than a decentralized one. If, howevr, the same type of machine is concentrated in one department, a decentralized maintenance may be better.

(d) Personnel Training. In areas where skilled workers are scarce, better training facilities and more supervision must be provided than in areas where skilled workmen are not scarce.

(e) Continuity of Operation. A factory working continuously requires continuous maintenance supervision and overall planning, particularly concerning preventive maintenance. In a single-shift working factory the problems are different.

(f) Location. A dispersed factory must have decentralized groups or parallel organizations, while a compact factory can be maintained from one centralized shop or office.

Having once the maintenance organization chosen, the maintenance work can be organized so as to be divided into three basic groups: preventive maintenance, corrective maintenance and maintenance control, along with the administartion.

3. Preventive Maintenance

Briefly, preventive maintenance means the activities aiming at keeping

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the equipment in satisfactory condition for safe operation, preventing unforseen stops caused by breakdowns and reducing wear.

Preventive maintenance is applicable to all factories, regardless of size. The major effects produced by preventive maintenance are:

(1) Shorter down-time for planned stops instead of unplanned breakdowns, and lower cost for planned repairs before a breakdown;

(2) Longer life and better conservation of equipment, reducing and/or postponing the replacement;

(3) Better safety and improved protection of factory;

(4) Better work control, less rejects and higher quality product;

(5) Better spare parts control, with minimum inventory requirements;

(6) Lower maintenance and production costs.

Preventive maintenance must be integrated with other maintenance functions as well as with production planning, work measurement and studies, administration and personnel education. This is essential, since the preventive maintenance plan must be based on correct information concerning the production plans, the investment policy, the quality of equipment and product, and the plans for discarding and refurnishing. Based on this information, the annual time to be spent on preventive maintenance is calculated for each item separately. This result may now be used to calculate the personnel needed as well as the time the production has to be stopped. Although it is possible and some managers prefer to define the dates for major preventive maintenance operations, it appears that the method of including predeterminated operations but varying time intervals is more flexible and more convenient, particularly for the instrument manufacturers, as changes may be made during the period without futher complications. In any case, the administrator of a preventive maintenance programme must let economic considerations guide his general activities and, sometimes, even let overrule his engineering sence. Beside the technical possibilities and needs,

Contd. 7.

what should really be examined is the influence of preventive maintenance programme on the manufacturing cost. The programme and its development, therefore, must be outlined in close co-operation with other managemant sections.

The main point of a preventive maintenance programme are periodic inspections, ranging from observations to complete tests, and meant not only to reveal the condition of a particular device, but also to adjust and correct it. Such an inspection system consists of five maintenance levels:

- 'First-Level Maintenance'. This includes non-scheduled daily observations, carried out by the operator. It includes visual observing the function of the equipment in its normal working cycle. Sometimes, special instruction may be given to the operator. No written form is used for reporting failures, but only verbally to the foreman.

- 'Second-Level Maintenance'. This includes scheduled and non-scheduled observation and inspection, carried out by a serviceman, primarily of the items reported by the operator. Report is required only in case of some serious failure.

- 'Third-Level Maintenance'. This includes scheduled and non-scheduled performance tests, carried out by a specially trained maintenance man. It can be completed without stopping the production, so that there is no need to notify the production-plannig staff. The interval between these inspections is from two to six months; the time for the next check is usually set according to the results on the report.

- 'Fourth-Level Maintenance'. This includes checking, replacement and re-calibration, if required. It can be accomplished by providing a board of checking, testing and calibrating means. If a replacement must be made, a brief shut-down is requested. This inspection is usually carried out once a year, or every second year, depending on the item, and gives a good information on the equipment condition and

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dependability. In case of incorrect condition, it is recommended that the fifth-level maintenance be done at once.

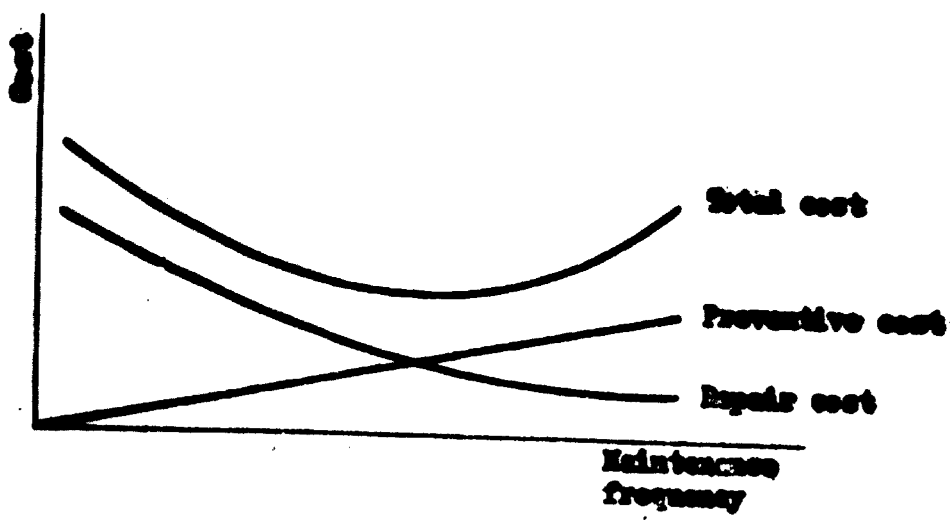
- 'Fifth-Level Maintenance'. This takes place either on the request made in the fourth level or, normally, every third year. It involves the repair, when necessary. The production must be stopped, so that it must be planned. This inspection will be fully described below, concerning particular instruments.

Another important aspect of the above is the cost.

1.3.1. Preventive Maintenance Costs

Preventive maintenance has a considerable influence on the production stop cost, which consists of three parts: direct repair cost, investment cost (depriciation and interest) and losses in production. The point, therefore, is to obtain an economic balance between the actual prventive maintenance cost and the cost of 'not applying preventive maintenance'.

Empirically speaking, repair cost (as a function of maintenance frequency) decreases parabolically, while the maintenance cost increases as a straight line, so that, at a certain value of the preventive cost, there will be a minimum total maintenance cost (Fig.1).



Adding the cost for the production stops will give another curve (Fig. 2), showing that the preventive maintenance cost is small compared with the stops cost, which increases the total cost parabolically.

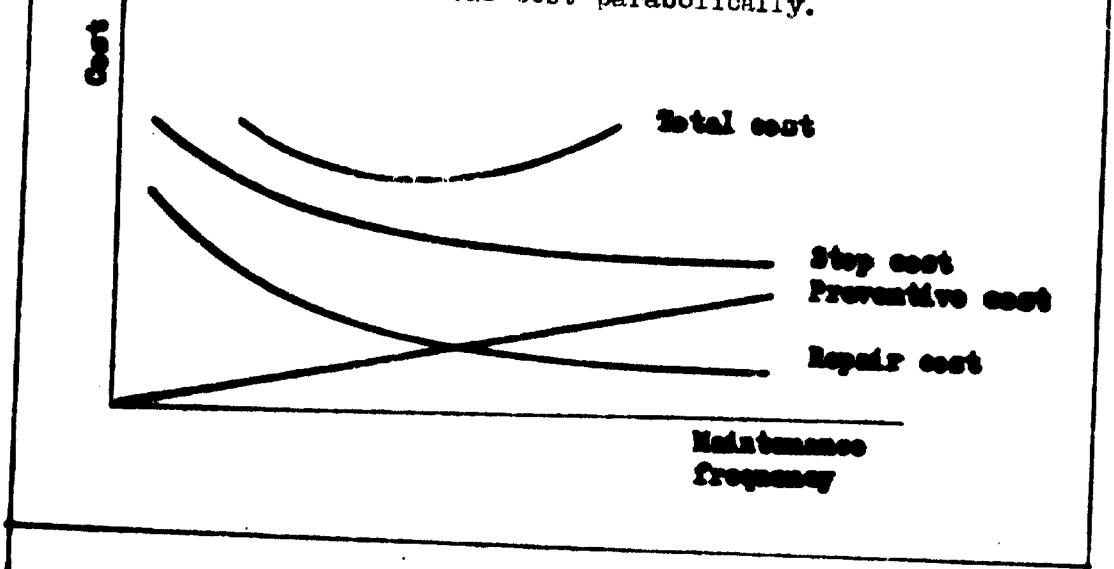


Fig. 2

With the repair costs further reduced (applicable for planned repairs), the total maintenance cost will also be reduced (dotted line in Fig. 3), proving that a properly organized preventive maintenance results in considerable savings. Practically, small amounts spent on increasing the preventive maintenance will save large amounts on repairs lowering, thus, the total production cost.

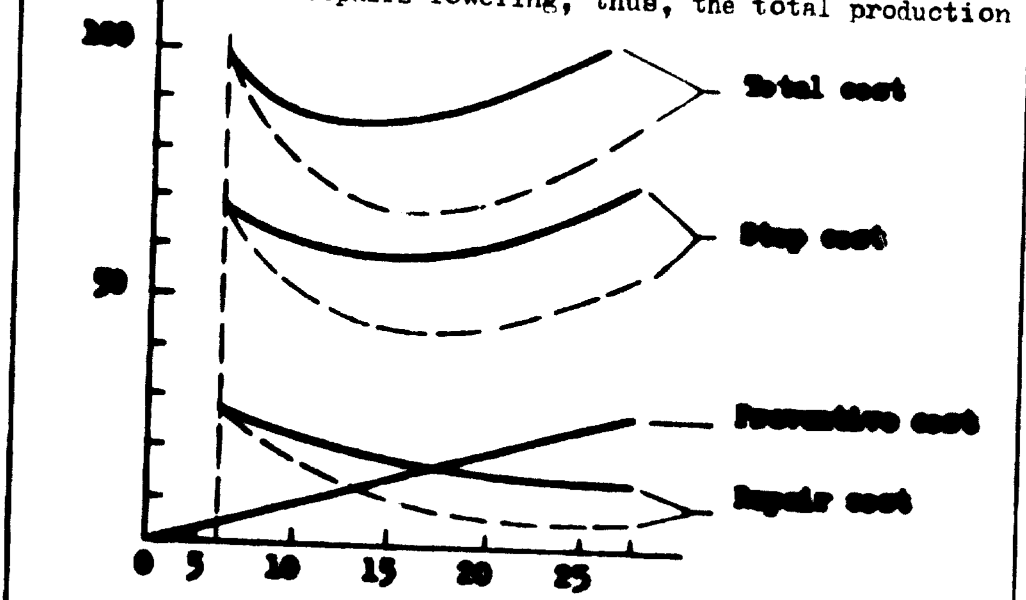


Fig. 3

As a matter of fact, it is difficult to find out the optimum value or minimum cost, since it is hardly measurable over short periods. Therefore, the check must be continuous, often over the years. One simple way to record the

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the checks is a form (Fig. 4), in which each square represents one job, and the worked time on each job is noted in.

Prod. line No.							Maintenance hours									Week No.			
Job No.	Prev. maintenance						Repairs						Overhauls						Total
	M	T	W	T	F	Tot.	M	T	W	T	F	Tot.	M	T	W	T	F	Tot.	
Total jobs																			
Total hours																			
Average hours																			

Fig. 4

The form may be used for a week or a month, depending on the needs and system. A subsequent detailed analysis of the form will give valuable information, such as:

- Number of preventive maintenance jobs (should be fairly constant);
- Average time per job (should be gradually decreasing);
- The number of planned and unplanned repairs (if it increases, something is wrong somewhere);
- Average time per repair (if it increases, it may mean overload);
- Total preventive maintenance time per period (should be fairly smooth).

As far as the instrument preventive maintenance is concerned, the costs are basically determined by the following:

(a) The amount of testing and calibration equipment that is required for maintaining a particular group of instruments;

(b) The amount of replacement parts and/or assemblies;

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(c) The level of maintenance know-how and how much training the plant must provide or is required of instrument technicians to perform the maintenance job.

(d) The amount of maintenance consideration given the instrument by both the designer and manufacturer.

The last point (d) is particularly important when the instruments are in question. Since a technological process depends primarily on the instruments (measurements and control) the instruments must be designed from a maintenance stand-point too, in order to reduce the maintenance cost for numerous instruments in a modern plant, aiming at preventing the necessity of everyday maintenance. This has been recognised fairly recently (already known as 'maintenance prevention') by the instrumentation engineers in both the instrument-using and the instrument-manufacturing factories, so that, consequently, it is now becoming a criterion for a good instrument. The benefits are numerous, including lower maintenance and production costs, safer operation and higher production output.

1.4. Corrective Maintenance

Corrective maintenance means correcting of the failures caused by break-downs and overhauling of equipment to restore the operating condition. It can can be centralised or de-centralised, depending on circumstances.

The fact that repairs caused by breakdowns should be started without delay, implies that a simple and quick planning routine must be worked out. To be efficient enough, such a routine should be set up in co-operation with production and planning departments. For this purpose, the repair work should be described by use of standard terms, and the description must be sufficient to allow the assignment of a predetermined time. This is then calculated by a specially trained time-calculator or estimator, and noted in the planning form. The form is then forwarded to the repair foreman, who chooses the man and gives the instructions. For easier handling, these instructions should be classified and

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stored with a list of special tools, so that the job could be started quickly. Such an organisation is profitable, since quick repairs mean shorter production stops, resulting in considerable savings.

When planning overhauls, it is normal to be more accurate, since planning commences a year before the actual date of starting work, and, besides, has as a basis the report on the previous inspection. When the time and cost are calculated, the time for production stop is to be set with the production-planning department, along with the decision about measures to keep production moving. When this has been worked out, the load on the maintenance department is calculated, along with the cost. All this should be done as precisely as possible, since overhauling can be regarded as a realistic alternative to buying a new equipment, and vice versa. Therefore, the decision which course to take must be founded on a sound techno-economic analysis, especially if a costly equipment is question; in case of less expensive items, the cost per annum may be calculated for all overhauls for a longer period, e.g. five years. When all the above has been worked out, a chronological plan of operations is made and each work station loaded accordingly.

Many modern companies today use an investment calculation system, such as American "API-system. It certainly is beyond this brief manual to describe that system, but, in all cases, the total overhaul cost consists of:

- Work time cost;
- Spare parts and material cost;
- Cost for production losses during overhauls;
- Overheads and extras.

Procedure and sequence of operations for overhauling depend entirely on the item concerned, and should not be changed, especially if they are prescribed by the manufacturer of the equipment in question.

Applicable to both repairs and overhauling, a very valuable aid for

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fault-finding and what caused the fault are the trouble shooting charts. Although many manufacturers - the good ones - provide the trouble shooting charts (usually as a part of their servicing manuals), one must be aware of the fact that no trouble shooting chart can be entirely exhaustive, especially for the electrical devices and equipment. Therefore, the best trouble shooting charts are those made by the maintenance department for its internal use, prepared on the basis of long-term observation and analyses. Therefore and for the same reason, the maintenance staff should be well and methodically trained in logical fault-finding methods, besides the other subjects for maintenance job. The maintenance management is expected to pay utmost attention to this and to encourage it, especially since practice has proved that such training is feasible within the department and gives good results.

For a quick fault-finding (when the trouble shooting charts are not available) it is absolutely necessary to have access to another data, such as: a) function diagram, b) circuit diagram, and c) layout drawings; besides these, a list of statistical probabilities of some faults and causes (usually made by the maintenance department on the basis of long-term records and statistics), may be of valuable assistance as well. These facilities must be used simultaneously, since as separate items are not sufficient enough. It is a fact that the circuit diagrams only - without the other aids - can not be sufficient, since, as the first, in one circuit diagram no more than one system can be shown (e.g. either the electric or pneumatic system, but not how these two are inter-connected, as the case is, for instance, in an electro-pneumatic recorder, etc.); besides, the circuit diagrams show the different components and sub-assemblies or complete assemblies in one position only, usually the start position. Therefore, as a complement to this, the function diagram (also called "sequence diagram") must be used, since it shows the sequence of movements of all components and assemblies (electrical, mechanical, pneumatic and/or hydraulic) in one single diagram, relating to one cycle of operation. In order to get a complete picture, the layout drawings must be added to those two aids. Unfortuna-

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tely, although they are very useful aid, the function diagrams are extremely seldom - or almost never - included into the servicing manuals supplied by the manufacturers, probably because the function diagram is a fairly new idea. For this reason, they also have to be made by the maintenance engineer, and, for the same reason, all the maintenance technical staff should be trained in that direction as well. [illegible] very difficult to make this diagram, and it is recommended that this should be done for every piece of equipment, since it will considerably shorter the time needed for fault-finding. Having all these aids available and using them simultaneously, the maintenance technician will certainly be able, by thinking in a technically logical manner, to divide the entire system into as many circuits as he needs, and check each circuit in the correct way. Of course, it is supposed and expected that one preparing himself for this work, must have sufficient theoretical background concerning the technology of the field concerned, and then to be trained to read and use properly these diagrams and charts. In a normal training course, a programme for making function diagrams and circuit diagrams should start with exercises on simple devices, such as: exercise with a contactor, exercise with motor starter, exercise with three-phase motor and starter, exercise with a three-phase motor connected for two-way running, exercise with hydraulic cylinder and valves, exercise with hydraulic and electric circuit diagrams, etc. Many of the exercises [illegible] accomplished on drawings and diagrams in the classroom, without having real equipment for practice. The aim of such a training is to find faults in a logical way.

1.5. Maintenance Control

The effect of good maintenance on the total factory economy makes it necessary to establish and maintain close control over and checking of all maintenance activities. Therefore, the purpose of the maintenance quality control is to find out and to state what changes have taken or should take place, and how they affect the function and the acquired tolerances in work pieces. This

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finding must be objective and in detail. Briefly, the maintenance quality control assists to:

(a) find the errors while they are small enough not to affect the quality of the product, and before a breakdown has occured;

(b) state the time for overhauling or replacement in time, so as to prevent the need for eventual improvisation in production.

The quality control inspections can be either periodical or at request, usually from production department. Instructions for these inspections are the national or international standards.

1.6. Administration

Maintenance work demands good administartion. The maintenance forms and routines should be critically worked out, using a critical analysis technique as applied in work study. For this purpose, it is necessary to have employed an office organizer. If, however, such a man is not available, than the maintenance executive must be with a good knowledge of work study methods and a good degree of administrative abilities.

For the purpose of controlling, it is necessary to have good statistics. Therefore, the data for statistics should be collected, processed and stored in a form easy for use, whenever required.

Registration of all documentation is also essential. Starting from the purchase, all the papers should be classified and stored conveniently. A useful practice is that the technical data are separated and recorded on a special card of which copies are given to the production department, production-planning and the tool-design office, while the original is stored in the maintenance office. This card is known as "Technical Data Card", and it should be available for both standard and special equipment. Besides this card, there are three more cards, so that all four cards are usually arranged and used as a horisontal-slide card

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system (e.g. Remington Cardex). The other three cards are:

(1) "Economical Statistical Card", recording the purchase price, installation cost, insurance, replacement value, depreciation, operation cost and the annual maintenance cost.

(2) "Collecting Card", recording the production stop times, nature of repairs and the reason.

(3) "Inspection Card", recording the inspection intervals, the maintenance done and the quality.

Instead of the above cards, the punched ones may be used as well, but they are more convenient for larger factories.

The spare parts stock must be controlled as well. A simple method is a system of cards, used both as stock record and purchase card.

1.7. Automatic Data Processing in Maintenance

The maintenance operations data have started, during recent years, to be recorded and processed on automatic data processing machines, since it has great advantages over the manual processing. This, however, requests that the number system, along with all the maintenance forms and routines, should be redesigned, so that as much as possible data are in digit form.

For maintenance work, a five-digit numbering system appears to be sufficient: the first digit for the type of equipment, the second and third for description and the size, the last two as the identification number within the group. Part code can be done with a code of two digits, while for the fault code one digit is sufficient.

However, a disadvantage is that the automatic data processing machines must have a considerable capacity, so that they are more suitable for larger maintenance organizations, i.e. in larger factories.

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1.8. Personnel

The claims on personnel in a maintenance department appear to be, to some extent, greater than in other departments. The possibilities of appointing well qualified staff are not great, because maintenance techniques have not so far been fully taught in schools, so that, at present, there is no formal qualification for maintenance as a profession. Consequently, the problem is not only on selecting personnel, but on qualifying as well.

To qualify as an instrument-maintenance engineer requires more time and effort than many other phases of engineering. A person wishing to become such an engineer, must take his formal education either in mechanical or electrical engineering, and then, as he works, to educate himself in other branches. Basically, instrument maintenance requires a working knowledge of bot electrical and mechanical engineering, including pneumatics and hydraulics, with a good grounding in physics. After the education has been completed, then come the years of actual work with the instruments, along with broadening of other subjects of engineering, either by attending evening courses (if available) or by home study. Besides the instrument production, a profitable progression for accumulating the necessary experience would be to spend also some time in the instrument research and development, after which come instrument designing (drafting room is not very necessary). The next step should be the test laboratory and instrument calibration. After having completed al these, the engineer will be ready to enter the instrument maintenance department, with a good theoretical and practical background, and to qualify as a competent instrument-maintenance engineer.

If there is no practical possibility for passing all the above phases and stages of preparation, there are two periods which may be eliminated eventually. these are the research and development, while the rest of the outlined programme should be accomplished. Of course, the best results will be achieved if followed as outlined, without eliminating anything.

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During the preparation, the engineer will have the opportunity to see many failures of instruments, and how the production behaves under normal and abnormal conditions. Very likely, he will also see some errors commited by the production people, and how they affect both the maintenance and the economics of the Company. In this way - if he applies himself alert and studying - he will learn a lot of things 'not-to-do', and this is the main point which every maintenance man must reach; he must know these equally well as the things 'to-do', and then why and how to do?

Selecting the personnel for instrument maintenance is not very easy, especially if the applicant is experienced in some other instrument work, but the maintenance. In this case, the choice should be base mainly on the nature of his personality. Empirically speaking, the abjective nature is less desirable for the instrument maintenance staff, than the objective one. For, an instrument maintenance man must be able to see the slightest imperfection and to object accordingly. Thus, the applicants in objective class are preferred over those in the abjective class. This criterion may well be applied to the inexperienced applicants as well. Of course, there is no fullproof method which can classify applicants correctly, but by various additional test a reasonable separation can be made.

When distributing personnel for preventive or corrective maintenance, another criterion should be observed, since their profiles differ conciderably. Briefly, to qualify for preventive maintenance work, the candidate should, before all, have a keen sense of observation and be satisfied to follow a monotonous routine; the preventive maintenance supervisor should, in addition, have a good degree of administrative ability, as well as the ability to recognize and attend in detail. On the other hand, the corrective maintenance personnel should be able to analyze the faults and the job, to be well familiar with the work study techniques, and to have a multi-side technical knowledge, especially if the supervisor is in question. Common for both corrective and preventive maintenance personnel is a high degree of responsibility.

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The greatest attention should be paid to the selection of the maintenance manager. He must be something of a 'jack-of-all-trades', since he must be in contact practically with every other function in the Company. Besides a good theoretical background of many different fields, he must also have wide and varied experience, combined with an ability to co-operate. Besides the management training usually required for the other managers, he should, in particular, be well trained in maintenance principles and techniques, application of work study to maintenance work, and education and training of maintenance personnel. Even if a well educated and experienced engineer is chosen as a maintenance manager, he must be given all opportunities to develop his capacities further, especially concerning the teaching and training methods.

1.8.1. Personnel Training

The technical training of maintenance personnel is of the utmost importance. As already stated, most of the training should and can be done within the department itself, in addition to the training in other departments within the same factory.

A full maintenance training course normally covers a period of four years for unqualified and inexperienced workers, used as follows:

- The first year: The apprentice learn to use mechanical hand tools, simple machine tools and measuring instruments. The practical work is combined with theoretical lectures on basic mathematics, physics, materials technology, work safety and drawing techniques.

- The second year: The apprentices work in the maintenance shop itself, assisting in dismantling and assembling of simpler instruments and equipment. They may also take some part in overhauling, as assistants to a skilled worker. Theoretical lectures now include the basic principles of mechanical and electrical engineering.

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- **The third year:** The apprentices are by now skilled enough to carry out some repair works independently, so that during the last six months they may be placed as formal assistants to a skilled worker. Theoretical lectures include electrical circuitry, basic electronics, hydraulics and pneumatics.

- **The fourth year:** The work in overhauling shop (or group), until he is capable of making a complete overhaul independently. Theoretical lectures are continued in a form of short courses on printed circuits, cacontrol systems, solid-state devices, trouble shooting techniques, calibration methods, etc., condluding with maintenence principles and organization. Important to note: since the development of industrial measuring and control instruments is very rapid, the courses have to be repated from time to time in revised versions, dealing with newly developed instruments and techniques.

It is a good practice to arrange special training courses for maintenance supervisors and engineers, concerning the general aspects of maintenance techniques, work study on maintenance work, time standards for maintenance and maintenance controls. It is also advisable to arrange study groups, with the most experienced engineer as a leader.

The foreman and instructors should be trained particularly in teaching and instructing methods to be used in the daily work. The most popular and used instruction method is co-called TWI-Method ("Training Within Industry").

Training of personnel is always profitable, especially in rapidly developing fields, as the maintenance undoubtfully is. The maintenance manager must be well aware of this, and to encourage and support the training of his staff.

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- Chapter II -

MAINTENANCE OF SELECTED INSTRUMENTS

The material in this chapter is prepared in step-by-step form. First, the functional description and materials are given, then the methods to be used in servicing, maintaining and trouble shooting, along with detailed calibration instructions. Preparing the text in this manner, enables the paper not only to meet the need of the maintenance engineers and technicians dealing with these instruments, but also - or even more - to bring to the attention of the application and maintenance engineers a proper method of preparing a practical manual, since it is their duty to prepare such manuals, as explained in Chapter I.

The space alloted for this paper did not allow to elaborate more than two groups of instruments. It has been, therefore, decided to focus on the instruments which are mostly in use, such as kWh-meters and moving coil instruments.

2.1. POLYPHASE (SINGLE DISC) kWh-METERS

2.1.1. Construction Details and Materials

Case, Frame, Cover and Terminals. The case is formed from phenolic resin moulding. An O-ring ensures a damp- and dust-proof joint, when the cover is fitted. The cover-window is made of toughened glass, sealed in with a butyl rubber containing no solvents, so that no corosion gasses can be produced. The frame is a silicon-aluminium diecast, supporting all assemblies in a correct alignment. The terminal block is a phenolic moulding, and the terminal chamber is barriered to provide anti-creeping surface.

Electromagnets. Each electromagnet is provided with temperature compensation, low load compensation, torque balance and phase-angle adjuster, and a magnetic shield, all being secured to a steel frame, which itself gives further

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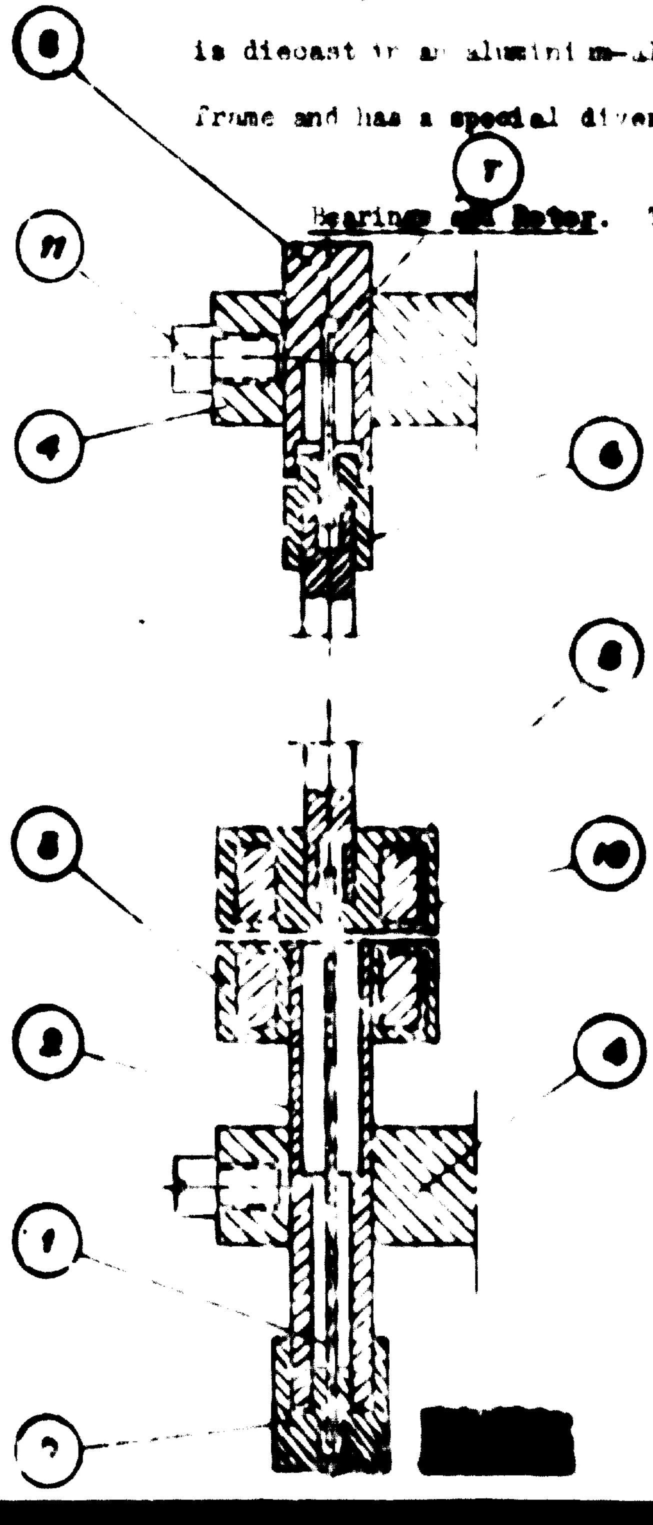
magnetic shielding. Current and voltage coils are encapsulated in polypropylene with an insulation level of 10 kV to earth. Permanent protection against corrosion is given to the assembled laminations by lacquer coating.

Brake Magnet. The brake magnet system (UNIX is in possession of the patent rights of it) comprises two Alcomax magnets, producing a bi-polar vertical braking field, which is symetrical about its centre and minimises the effect of the rotor disc height variations, as well as partial cancellation of forces due to the alternating eddy currents induced in the disc. High permeability stainless iron pole pieces, together with a nickel-alloy temperature compensating shunt, are bonded with an epoxy resin to the magnets, and the complete unit is diecast in an aluminium-alloy housing. The magnet assembly is secured to the frame and has a special divert screw for calibration adjustments.

Bearings and Rotor. The lower bearing is a magnetic repulsion type (Fig. 5), with barium-ferrite magnets. The rotor rotates around a stainless guide pin (1) fitted through a tubular brass housing (2), on which the bottom magnet (3) is assembled. When the housing (2) is set at the correct height in the meter frame (4), the rotor is supported constantly at the same height by mutual repulsion between the two magnets (3 and 5).



[redacted]

The top bearing consists of a moulded cap (6), rotating around a stainless steel pin (7), mounted in a housing (8) in the upper part of the frame (4).

The both magnets are encapsulated so as to provide an integral guide bearing in the upper magnet assembly, and to pro

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vide protection against damage. It is also taken for moulding the guide pin bottom bush (9). These are the most modern bearings.

A cheaper version of the lower bearing (Fig. 6) consists of a carbon-chromium steel ball (1), rotating between two sapphire jewels (2 and 3). The rotating jewel is carried in a mount (4), fitted into the end of the rotor shaft (5). The lower fixed jewel is located in a recessed mount, secured on the frame by a screw (6). To prevent undue lateral movements, the bearing is surrounded by a moulded nylon shroud.

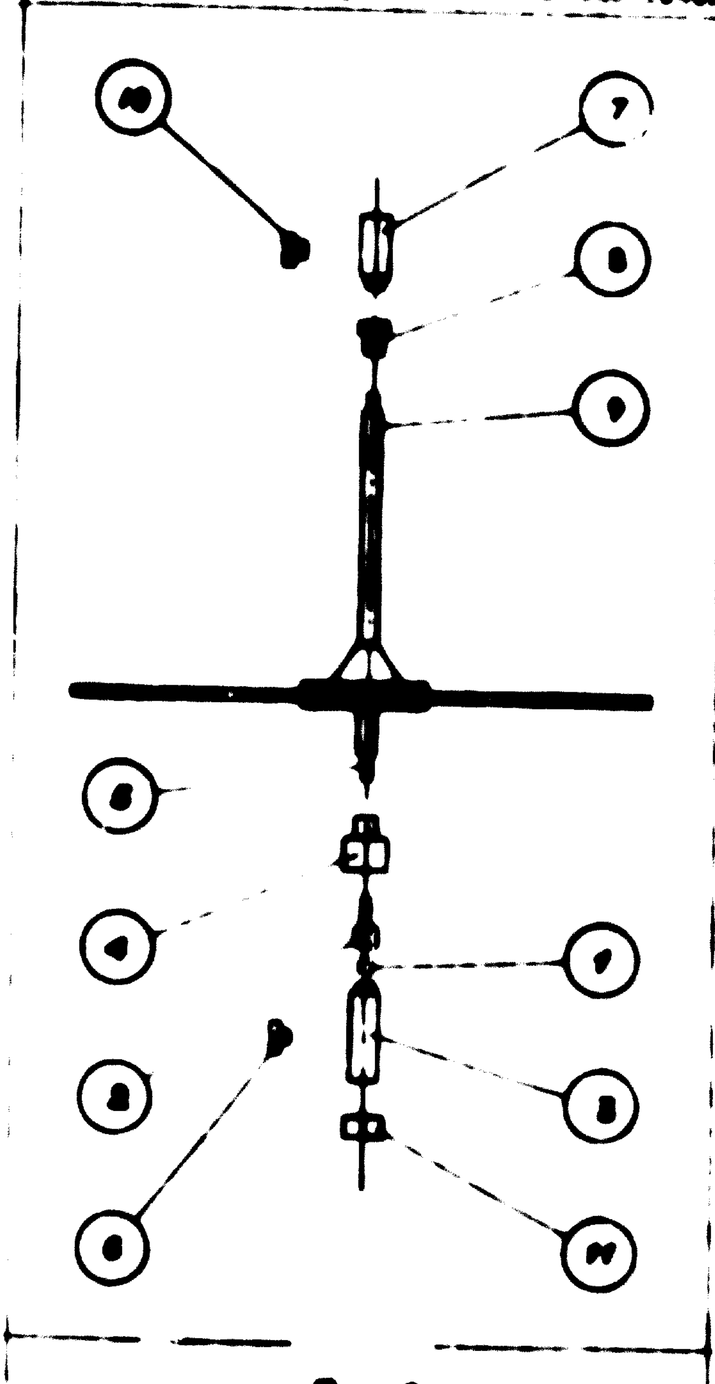


Fig. 6

Magnet Temperature Compensator. On the lower magnet, the moulding encapsulates a nickel-iron temperature compensating band (10 in Fig. 5), clipped around the element. Since it has opposite temperature characteristics to the barium-ferrite, the nickel-iron compensates for magnetic flux variations, due to changes in ambient temperatures.

Rotor assembly. The central area of the rotor disc is isolated from the area under the poles, so as to isolate and confine the eddy currents to the outer part of the disc, as well as to reduce the interaction between the field produced by the electromagnets. The disc is laminated, consisting of two layers of high-purity aluminium, bonded by epoxy resin and glass cloth. Each disc is concentrically slotted, so as to isolate the central area and restrict the eddy currents to the outer ring area. The disc is diecast to the aluminium-alloy rotor

Contd. 24.

shaft. A cut worm gear is provided on the shaft to drive the energy register. For stroboscopic calibration, 400 serations are cut in the edge of the disc, and, for testing, the disc has divisions of 100 and 200 marked around its upper surface.

Energy Registers. All register gear wheels and pinions are precision individual mouldings. The mouldings extend along hard-drawn stainless steel shafts, providing low-friction thrust surface against the metal support plates.

The single-rate register has an impulsing action. It comprises five number wheels and a final-figure pointer dial, besides an additional pointer dial provided to facilitate testing and showing the truw reading corresponding to the first number wheel. This duplicates the indication of the first number wheel, but advances continuously to indicate a gain or loss on the first wheel due to the impulsing. The first number wheel is coupled through a gravity operated impulse mechanism, which causes the second wheel and the others to advance suddenly from 9 to 0. A disengaging device is provided for resseting to zero.

The two-rate register has two sets of number wheels and a final-figure pointer dial. The sets are driven through a differential gear, either train being locked in a stationary position, as required, by energising an electromagnetic actuator. A flag indicator on the locking shaft shows the register in operation. This register is also provided with a disengaging device for resetting to zero.

Maximum Demand Indicator. The maximum demand indicator is driven by the energy register gearing. Its scale is surrounding the register dials. At the end of each integration period (5, 10, 15, 30 or 60 minutes), a synchronous time switch de-energises the electromagnet, which disengages the gearing, and the detent mechanism returns the driving pointer to zero. The demand indicator pointer is held at its reading by a ratchet and pawl, and can be reset to zero by actuating a spiral spring. Maximum demand indicator is an interchangeable

Contd. 25.

unit, which can be removed without disturbing the register.

Timer for Maximum Demand Indicator. A synchronous motor drives a single-step cam making one revolution per demand interval. Two contact springs ride on the cam. The lower spring falls a short time before the upper one, and the contacts are open during that interval; this contact-open time (detent time) is usually set to 1/50th of the total demand interval. An unidirectional pawl provides an impulse for driving the motor in correct direction, if the rotor swings bacwards on energisation.

2.1.2. Meter Adjustments

Full Load Adjustment. Full load adjustment is obtained (approximately 5% to 6%) by rotating the divert screw of the brake magnet assembly, without releasing the magnet. If further adjustment is required, the magnet must be released and re-positioned.

Low Load Adjustment. Low load adjustment is made by turning a screw located on the side of each elemnt, which moves a conducting vane over the surface of the voltage pole. One turn of the screw gives approximately 5% adjustment.

Torque Balance Adjustment. Torque balance is adjusted on each element, by turning a screw which raises or lowers auxiliary magnetic pole, varying the the proportion of useful flux cutting the rotor disc.

Load Power Factor Adjustment. This adjuster is in the form of a linear sliding resistor, provided on each element.

2.1.3. Dismantling for Maintenance and/or Repair

Follow strictly the sequence of procedure, as given:

(1) Remove the nameplate from the energy register, and, then, the regis-

Contd. 26.

tor from the meter frame.

(2) Remove the whole magnet assembly, by unscrewing the dowel screw holding the assembly to the frame.

(3) Place the meter upright. Loose the set screw (6, Fig. 6) holding the lower bearing mount ( ), and remove the lower bearing. Note: Take care to collect the bearing ball, using special "ball tweezers"!

(4) Remove the top bearing (7), together with the rotor shaft.

(5) Remove the top bearing cap (8), by drawing it gently from the rotor shaft. Note: Take good care not to bend the shaft!

(6) Holding the rotor assembly upside down, pull gently the rotor shaft out of the bearing shroud, to remove the lower jewel bearing (2).

Inspect the above dismantled components and assemblies. If necessary to dismantle further, proceed as follows:

(7) Disconnect the leads from the terminal block.

(8) Unscrew the main frame fixing screws, and pull out the complete frame from the base.

(9) Unsolder the voltage coil.

(10) Unscrew the electromagnet frames from the main meter frame, and remove the magnetic shield and low load vane from each frame.

(11) Unscrew the fixing screws and remove the current and voltage electromagnets. Note: Do not remove the quadrature compensating loop from the voltage electromagnets, since it is not interchangeable!

When dismantling the magnetic bearings, follow only the points (1) and (2) from the above, and then proceed as follows:

Contd. 27.

(3') Release the top bearing set screw (11, Fig. 5).

(4') Raise gently the top bearing housing (8), until its pin clears the mulded cap (6).

(5') Unscrew the bottom brass housing cap (2), and, then, gently withdraw the guide pin (1).

(6') Pull out the whole rotor assembly.

For replacement of cover glass, proceed as follows:

(1) Remove window clips, and scrape off the sealing compound from the window frame. Note: Make sure the surface is clean!

(2) Apply fresh sealing compound around the rim of the frame. Leave for for a few minutes (but not too long), till the compound has become tacky.

(3) Clean the perimeter of the glass with methylated spirit.

(4) Press the clean glass down onto compound, and hold for a few seconds, until good adhesion is made.

(5) Replace the window clips, using special "winow clip tool".

2.1.4. Cleaning and Lubrication

The worm and top cap cavity of the rotor (9, Fig. 6) are to be cleaned with a little petrol or trichlorethylene, using a fine soft brush. After cleaning, hold in a jet of clean air to remove surplus solvent.

Wash in trichlorethylene the top cap (8) and the top pin bearing (7). After cleaning, examine the bore of the top cap and the bearing surface of the pin. Note: Replace if faulty, since no repair possible!

Contd. 28.

Clean the bearing jewels (2 and 3) only by using a jet of dry steam. After cleaning, examine under microscope. Note: Replace if faulty, since no repair possible!

Wash the new ball bearings in petrol, to remove the protective oil. After washing, roll gently between several layers of superfine linen cloth. Warning: On NO account should the ball be touched with fingers! Special "ball tweezers" must be used! The ball should not be left in petrol for any length of time!. The petrol must be clean, and no other degreasing agents are recommended!

The magnetic bearings are maintenance free, and they do not need cleaning or lubrication.

Lubricate the lower jewel bearing (3) with a thin film of a special Meter Oil No. 2.

The top pin bearing need not be lubricated.

2.1.5. Assembling

Before assembling check that all components are perfectly clean.

The first to be assembled are the driving elements. Proceed as follows:

(1) Insert the torque adjuster between the voltage coil and the voltage lamination of each electromagnet, and fit the moulded half-nut to the upper end of the adjuster (Fig. 7).

(2) Secure the guide screw through the quadrature compensating loop.

(3) Assemble the voltage electromagnet to the sub-frame, by screwing the two steel screws into the lower fixing holes. Note: Do not tighten at this stage!

Contd. 29.

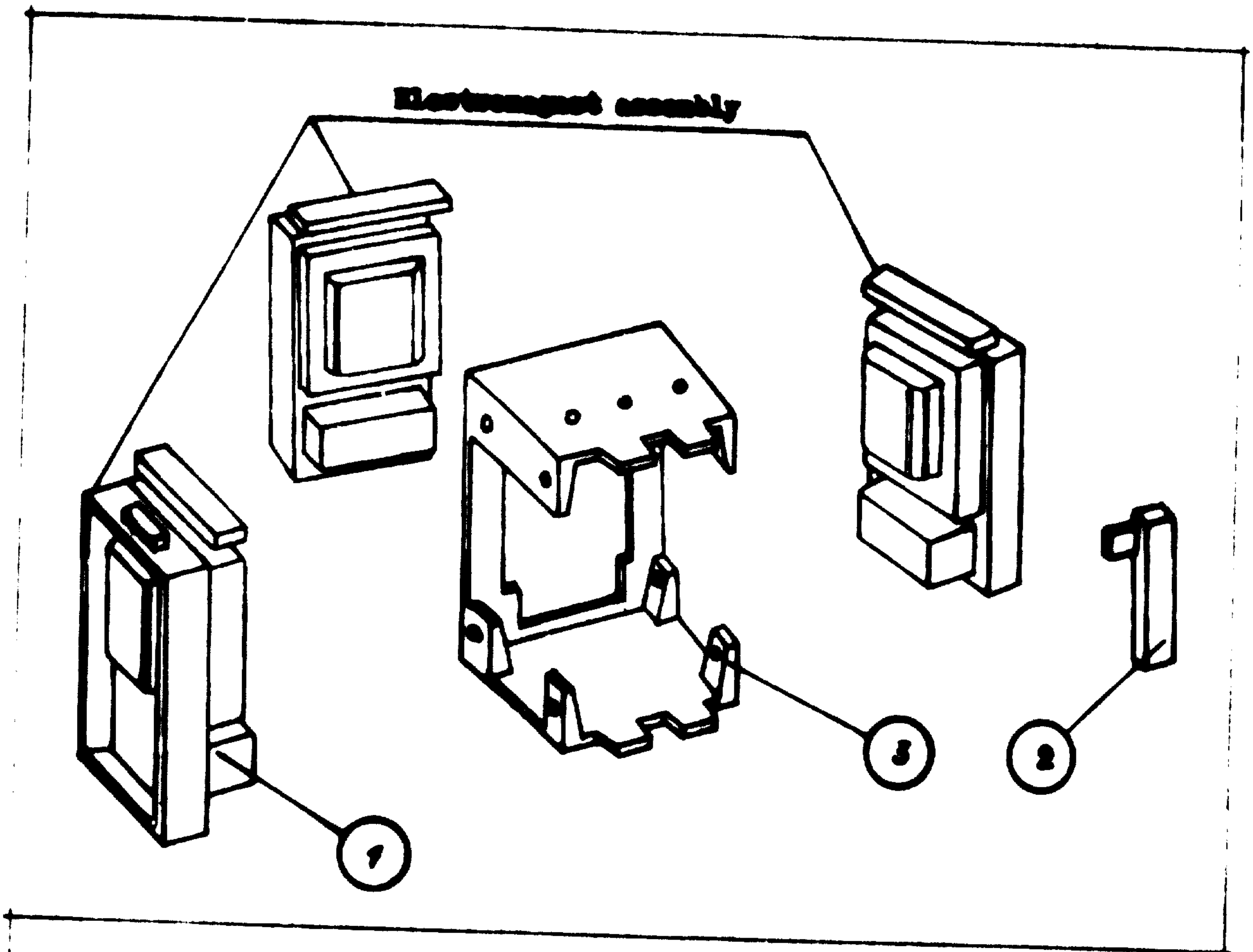


Fig. 7

(4) Thread the inductive load adjuster and the current electromagnet leads through the opening on the lower part of its sub-frame. Position with the fixing screws the electromagnet on the frame. Note: Do not tighten at this stage!

(5) Use special "electromagnet gap gauge" and set the electromagnet gap as precisely as possible. Now, tighten the screws fixing the electromagnet to its frame.

(6) Use special "poles distance gauge", and check that the distance between the outer voltage poles and current poles is correct.

(7) Fit the moulded half-nut to the low load vane, and place it loosely over the adjuster shaft (1). Note: Do not tighten at this stage!

Contd. 30.

(8) Assemble the magnetic shield, and check that the half nut of the low load vane is correctly engaged in the slot at the rear of the shield.

(9) Secure the magnetic shield with its screws. Check that the outer legs and the central tongue of the shield are in level with the current poles; correct, if necessary.

For assembling the main frame, proceed as follows:

(1) Assemble all the assembly sub-frames to the main meter frame, using their brass screws.

(2) Fit the inductive load adjusters (2, Fig. 7) to the sub-frames.

(3) Solder the voltage coil to the voltage terminals.

(4) Place the meter upright, and put the rotor assembly in the frame, approximately in its correct position. Note: Do not drop it!

(5) Very carefully, slide the top bearing pin (7, Fig. 6) through the frame into the top cap (8). Note: Do not tighten the set screw (10) at this stage!

(6) Insert the lower jewel bearing and the ball into the frame bush, and adjust the rotor disc height, so that the disc is centrally positioned in the electromagnet gaps. Now, tighten the lower jewel bearing set screw (6), and slide the locating collar (11) up to the frame.

(7) Use special "rotor endshake gauge" and set the gap between the top cap and the top guide pin bearing.

(8) Spin the rotor gently by hand, and see that it runs true. If an electromagnet is out of alignment, raise or lower it by slackening the fixing screws and adjusting the jacking screws (3) in the bottom face of the main frame. Check again that the rotor runs true.

Contd. 31.

(9) Position the brake magnet assembly, and secure with the dowel screws. Carefully adjust the magnet vertically, so that the rotor disc runs in the centre of the magnets gap; if necessary, move up or down the clamping plate. Note: If the meter has to be re-calibrated, the brake magnet should be fitted and adjusted during full load unity factor adjustment.

(10) Place the meter in the base, and secure with the fixing screws. Note: Do not place the meter manually, but use special "meter insertion fixture".

(11) Connect the current and voltage leads to their terminals.

(12) Fit the energy register, and lightly secure with its fixing screws. Note: Do not tighten at this stage!

(13) Use special "periscope for worm meshing adjustment" and check that the wormwheel is correctly meshed with the rotor worm. The teeth should engage to a depth of between 50% and 70% of the tooth height. If the meshing is satisfactory, tighten the register to the frame. If it is not satisfactory, release the two screws holding the locating plate, and correct the meshing. When satisfactory, press the locating plate (1, Fig 8) against the front face of the frame and tighten the screws (2).

2.1.6. Servicing the Energy Registers

2.1.6.1. Single-Rate Cyclometer Register

For zero resetting, proceed as follows:

(1) Slacken the two fixing screws (3, Fig. 8), and remove the register from the frame, by sliding it forward. Note: Do not force it!

Contd. 32.

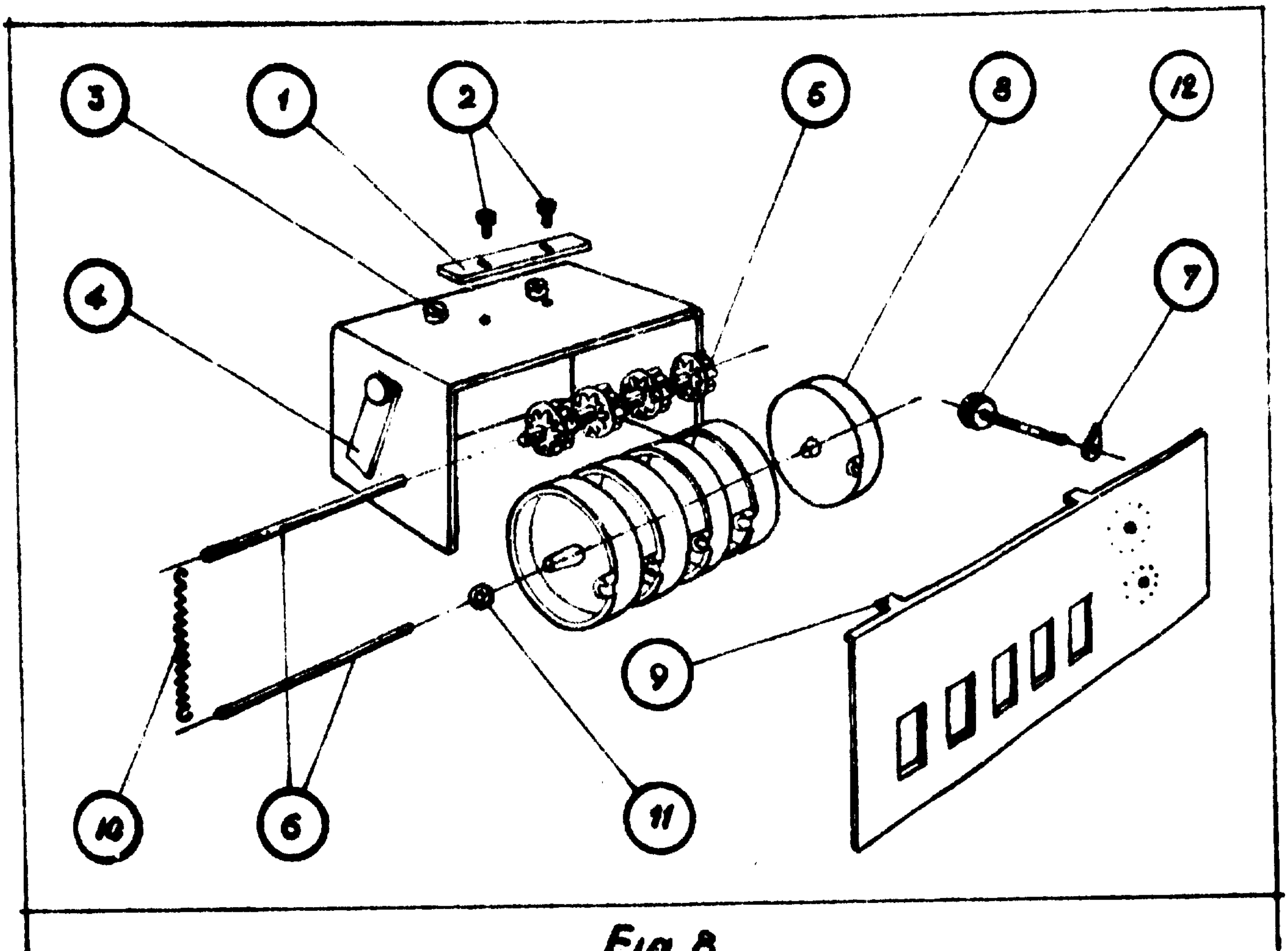


Fig. 8

(2) Move the locking plate (4) towards the rear of the register.

(3) Place the register face downwards, with the plate (4) to the **right**, and, then, gently push the three right-hand number wheels out of engagement with their pinions (5), and rotate them until a reading of 444xx appears above the register cross-member.

(4) Allow the number wheels to re-engage the pinions, and check that a reading of 999xx appears exactly in the centre of the dial aperture. <u>Note:</u> The wheels and pinions should be now free to move on their shafts.

(5) Move the plate (4) towards the dial so that it covers the ends of the spindles (6) and clicks into correct position. <u>Note:</u> A click must be heard!

Contd. 33.

(6) Turn gently the two lowest value number wheels forward, to reach zero. Hold the register upright, and check that all numbers change positively from 99999 to 00000.

(7) Check that the test pointers (7) are set correctly, in relation to the first number wheel (8). Adjust if necessary.

(8) Place the register on the meter, and secure with its fixing screws (3). Use special "periscope for worm meshing adjustment" and check the meshing, as instructed above in 2.1.5.

For dismantling the register, proceed as follows:

(1) Remove the test pointers (7, Fig. 8), by pulling them off the shafts. <u>Note</u>: Do not force them!

(2) Bend up the two retaining clips (9), and remove the dial plate.

(3) Unscrew the screws from the changewheels bracket, and remove it.

(4) Move the shaft locking plate to the rear of the register, and unlock the number wheek and pinion shafts (6).

(5) Remove the retaining springs (10) and both shafts, so as to release all the number wheels and pinions.

For cleaning the register, there are two possible ways, depending on the equipment. If an ultrasonic cleaning equipment is available, the complete register is to be cleared by immersion in perclorethylene, without dismantling; after washing, shake off free liquid, and dry in clean air at maximum temperature of 80°C. Alternatively, if such a modern equipment is not avilable, dismantle the register and wash all the parts in trichlorethylene or perchlorethylene; after washing, gently clean the bearing holes with sharpened pegwood. After washing and drying, brush lightly the gear teeth with a soft brush.

Contd. 34.

Lubrication is not required.

For assembling, proceed as follows:

(1) Place the register frame on a flat surface, with the bracing strap downwards and the test pointer on the right hand side. Move the locking plate (4) towards the rear of the register.

(2) Insert the plain end of the number wheel shaft (6) from the left hand side, and thread on the shimwashers (11) and four number wheels.

(3) Assemble the first number wheel (1, Fig. 9) and impulse weight (2). The impulse weight has a bore to match the number wheel boss, and it

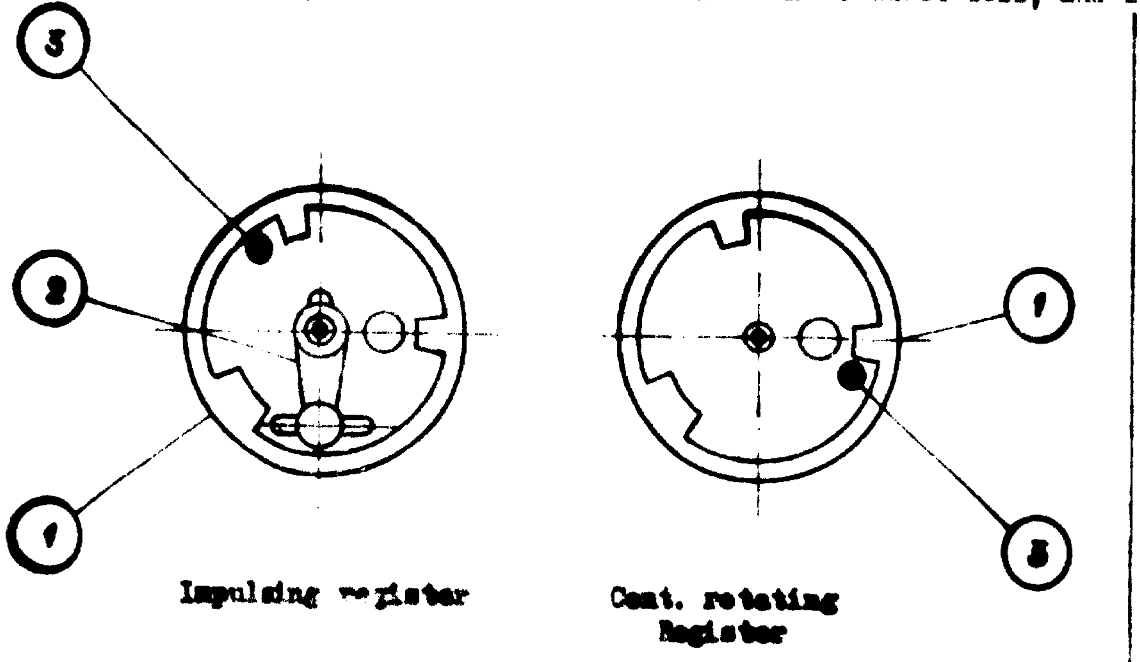


Fig. 9

must be assembled correct side uppermost with the weight located in the number wheel sector, between the numerals 4 and 7. The counterbalance weight (3) on the gear wheel is located as shown. Place the complete assembly on the number wheel shaft.

(4) Check endplay of the number wheels, and remove or add the shimwashers (11, Fig. 8) at the left hand. Note: The number of the shimwashers depends on the endplay!

Contd. 35.

(5) Insert the plain end of the pinion shaft (6) from the left hand side, and thread on four pinions (5), the long boss pointing to the left.

(6) Fit the retaining spring (10) between the number wheel shaft and pinion shaft, making certain that the springs' loops are engaged in their groves.

(7) Locate the register frame so that the dial plate is uppermost, and the test shaft side to the right. Position the first test shaft (12) and the second shaft in the changewheel bracket.

(8) Fit the dial plate, locating the two test shafts in the correct holes and, then, press down the reatining clips and deflect them, but not more than 45°.

(9) Replace the bracket and changewheels, and tighten the screws.

(10) Set all number wheels to zero, as instructed above in 2.1.5., and return the locking plate to the operating position.

2.1.6.2. Two-Rate Cyclometer Register

For zero resetting, proceed as follows:

(1) Pull off the connection clips at the actuator (1, Fig. 10), and disconnect the operating coil leads.

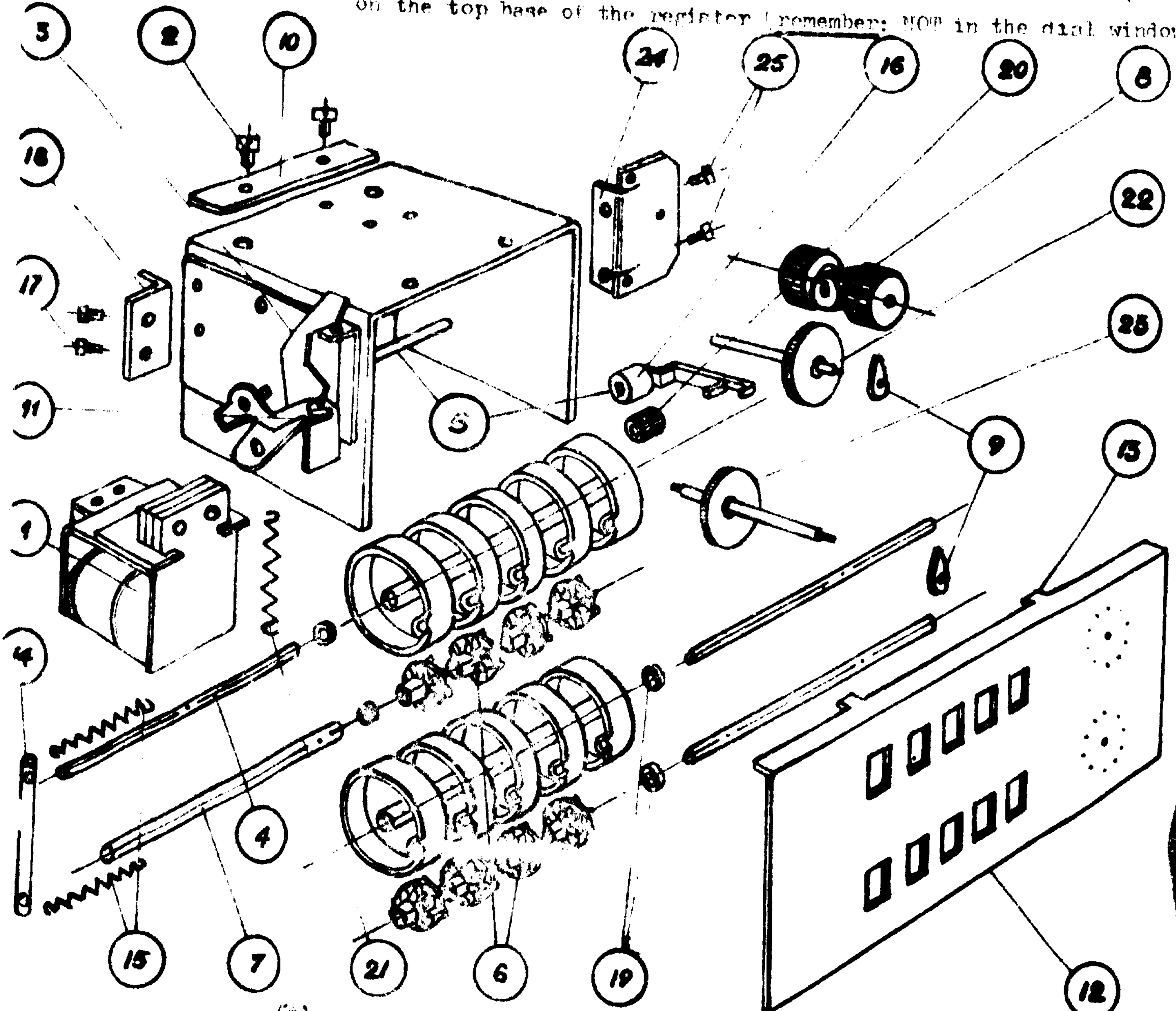
(2) Slacken the two screws (2), slide the register forward and remove it from the meter.

(3) Place the register upwards, and move the pinion shaft locking lever (3) towards the dial.

(4) Depress the left hand end of the upper dial pinion shaft (4), by in-

Contd. 36.

serting a special tool "reset finger for two-rate register" between the locking lever (3) and the actuator changeover arm (5), and turn the three highest reading number wheels to show a reading of 777xx on the top base of the register (remember: NOT in the dial windows).



(5) Allow the pinions (6) to re-engage and check that none of the four highest reading wheels shows half numbers.

Fig. 10

(6) Turn the register over, and place it uppermost.

(7) Lift the left hand end of the lower dial pinion shaft (7) so as to disengage the pinions (6), and rotate the number wheels to show a reading of 333xx above the pinions (remember: NOT in the dial window

Contd. 37.

(8) Allow the pinions to re-engage, and check correct engagement.

(9) Move the lever (3) away from the dial until it clicks into its correct position. Note: A click must be heard!

(10) By rotating the differential shaft (8), turn the two lowest number wheels forward on the dial, to reach zero. Hold the actuator (1) in the energized position, and repeat for the other dial.

(11) Check that all parts move now freely, and that the test pointers (9) have correct relation to the first number wheel.

(12) Place the register on the frame, and secure with the two fixing screws. Recheck the meshing as instructed above in 2.1.5., and reset the locating plate (10).

(13) Retighten the fixing screws, and re-connect the actuator.

For dismantling proceed as follows:

(1) Remove the test pointers (9), by pulling them off the shafts. Note: Pull gently, with no force!

(2) Bend up two retaining clips (13), and lift off the dial plate (12).

(3) Unscrew the fixing screws from the wormwheel bracket, and remove it.

(4) Remove the shaft retainer (14) to unlock the number wheel shaft, and move the locking lever forward to unlock the pinion shafts.

(5) Remove the retaining sleeves and springs (15) from the pinion shafts.

(6) Loosen the stop lever boss (16) and spacer collar on the flag arm assembly, and slide out flag arm shaft.

(7) Unscrew the screws (17), and lift off the retaining plate (18).

Contd. 38.

(8) Withdraw slowly two number wheel shafts and two pinion shafts, to release the gearwheels, number wheels and pinions.

For cleaning there are two alternatives, depending on equipment. If the ultrasonic cleaning equipment is available, remove only the actuator (1), and wash the register ultrasonically in perchlorethylene, as instructed in ...5.1. above. Alternatively, if that equipment is not available, dismantle the whole register and clean as instructed in ...1.5.1.

Lubrication is not required.

For assembling, proceed as follows:

(1) Assemble number wheels to their shafts, and press the spacer collars (19, Fig. 10) onto shafts to the correct distance. Check the endplay and remove or add shimwashers at the left hand side, as necessary.

(2) For each shaft, place the gear (20) on to its sun gears, and slide stop wheel unit into position.

(3) Fit assemblies into register frame, and assemble the dial plate, bending retaining clips (13) over, at not more than 45°.

(4) Place register on the bench face downwards, and assemble four number pinions on each pinion shaft, with long bosses towards the space collars (19), and place in position. Thread on retaining plate (18), and secure with one screw. Note: During this operation, the locking lever (3) should be in unlocked position.

(5) Assemble springs (15), and fit retaining plastic sleeves to the ends of both pinion shafts. Check that all pinions are free.

(6) Assemble electromagnet bracket, and secure with screws and spring washers.

(7) Thread the flag arm assembly (5) through the plate (18) and the

Contd. 39.

register frame.

(8) Assemble spacer collar (19) and stop lever (16) onto flag arm, so that the boss on the stop lever projects towards the flag arm side of the register. Position the stop lever so that the claws engage the teeth on the stop wheels, and lightly secure with one screw. Check that indicating flag arrows appear in the dial window, and adjust if incorrect. Tighten both stop lever screws.

(9) Fit flag arm spring (21). Caution: Flag arm and spring as shown in Fig. 10 are for the 'enrgise for upper dial' form of register, while in 'energise for lower dial' registers, the spring is above the flag.

(10) Check flag arm spring force.

(11) Assemble shaft retainer (14) and actuator (1), and secure them with screws and spring washers. Note: Do not tighten the screws before adjusting the actuator on its bracket to centre its operating arm in the slot of the flag arm (5); recheck and tighten the screws.

(12) Adjust the setting of the operating arm so that, when the armature is attracted to the core, the arm is clear of the claw on the flag arm, and, when the armature is released, the armature backstop is just clear of the actuator electromagnet yoke. This will ensure full travel of the locking arm - check it!

(13) Check that stop wheels are locked against a steady turning force, in each direction. If they are not locked, check the spring forces, and, if necessary, correct the shape of the stop lever tips. Note: The wheels must be locked!

(14) Assemble pointer shafts (22 and 23) and the differential shaft (8). Fit test shaft bracket (24), and secure with screws (25).

Contd. 40.

(15) Gently push the pointers onto the shafts, so that the pointer bosses do not touch the dial plate. Note: Do not bend the pointers or shafts

If the electromagnetic actuator has been dismantled as well, proceed as follows:

(1) Assemble together the coil (1), core (2) and yoke (3) of the actuator (Fig. 11). Note: Take good care and check that mating surfaces of the magnetic circuit are clean!

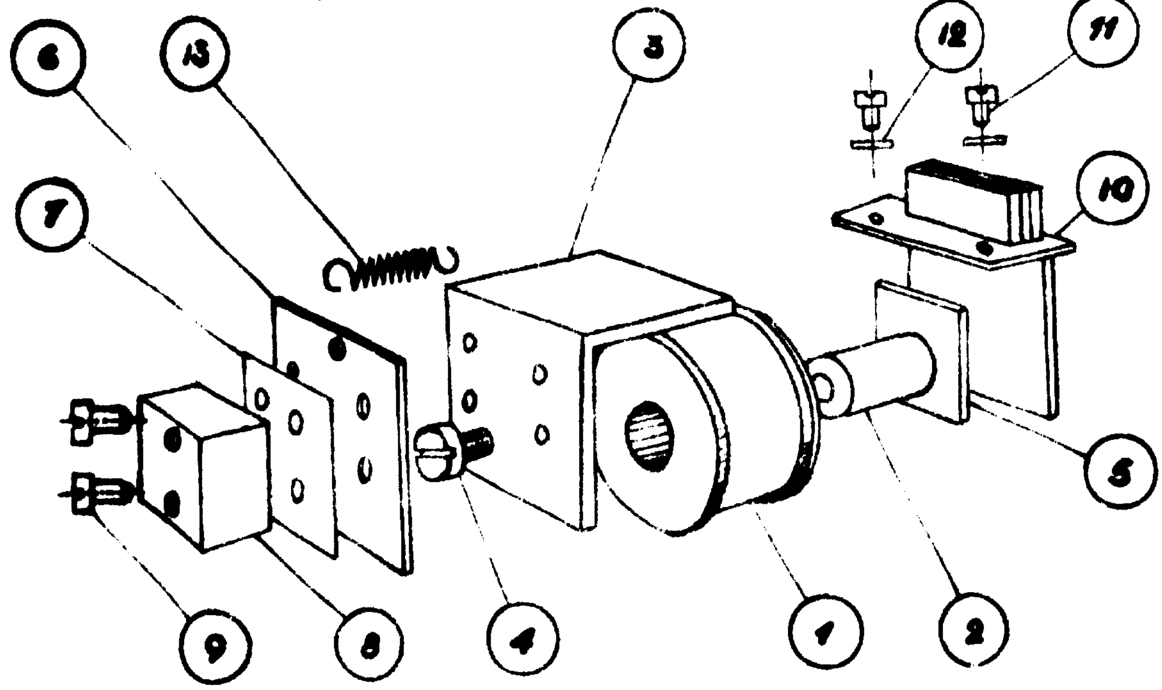


Fig. 11

(2) Secure with screw (4), and, while tightening, hold the quad-loop square (5) with the yoke.

(3) Place the armature in position, and check that it seats properly along the face of the yoke, and that its tip is in contact with the core face. Note: Do not secure at this stage!

(4) Check that the coil surface is aligned with the ground end of the yoke. Note: These parts are ground in pairs, and must not be mixed!

(5) Fit spring plate (6), insulation (7) and terminal block (8), and

Contd. 41.

secure with two screws (9).

(6) Thread the armature retaining plate (10) over the armature assembly, and place in correct position on the yoke. Insert two screws (11) and lock-washers (12). Note: Do not tighten at this stage!

(7) Slide special "armature feeler gauge" between the armature and the yoke, and press the armature against it. Press home the retaining plate, and tighten the fixing screws.

(8) Withdraw the feeler gauge, and fit the spring (13).

(9) Check the clearance between the backstop and the yoke, as well as the sideways movement of the operating lever fixed to the armature. Adjust, if necessary.

(10) Test the coil insulation between leads and frame, and/or measure the insulation resistance.

(11) Fit the assembled actuator onto the register, as instructed above.

2.1.6.3. Pointer Dial Register

Basic layout is given in Fig. 12. Five pointers are in-line, while the one with the lowest value is ofset.

Cleaning procedure is the same as for the single-rate cyclometer register, described above in 2.1.6.1.

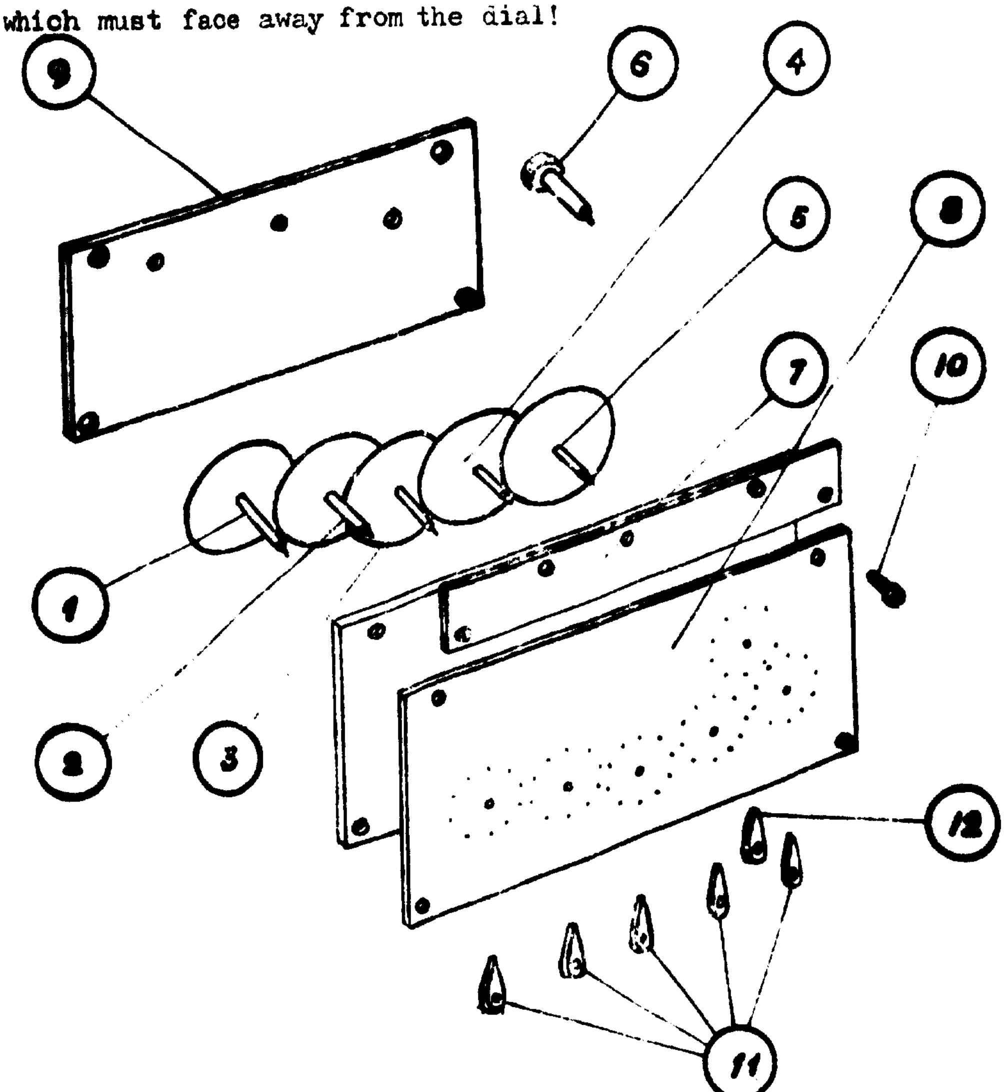
No lubrication is required.

For assembling, proceed as follows:

(1) Insert at first the highest reading pointer shaft (1, Fig. 12), and then the other shafts (2, 3, 4, 5, and 6) into their holes in the

Contd. 42.

backplate. <u>Note:</u> The lowest reading pointer shaft has a bevel gear, which must face away from the dial!



(2) Assemble the front gearing plate (7) and dial plate (8) to the base plate (9) and secure with four screws (10).

Fig. 12

(3) Position the first five pointers (11) into their in-line holes, and use the sixth red one (12) for the dial printed in red. <u>Note:</u> The spindles should project through pointers, but pointer bosses must not touch the front plate; check this!

(4) Assemble gear train and bracket. Check correct meshing.

(5) After assembling, turn all six pointers to zero, and check shafts for correct endplay. Adjust, if necessary.

Contd. 43.

2.1.7. Servicing the Maximum Demand Indicator

For removing the maximum demand indicator from the meter, proceed as follows:

(1) Switch off supply before opening meter case.

(2) Remove meter nameplate, by slackening the fixing screws and sliding the nameplate upwards.

(3) Disconnect the leads to demand indicator operating coil as well as timing unit.

(4) Loosen the screws on each side of the indicator, and the captive screw in the damand dial.

(5) Lift the retaining latch at the top of the indicator, and draw indicator gently forwards, leaving the energy register on the main meter frame. Note: Take care not to damage the register!

For dismantling, proceed as follows:

(1) Detach the energy register and timer.

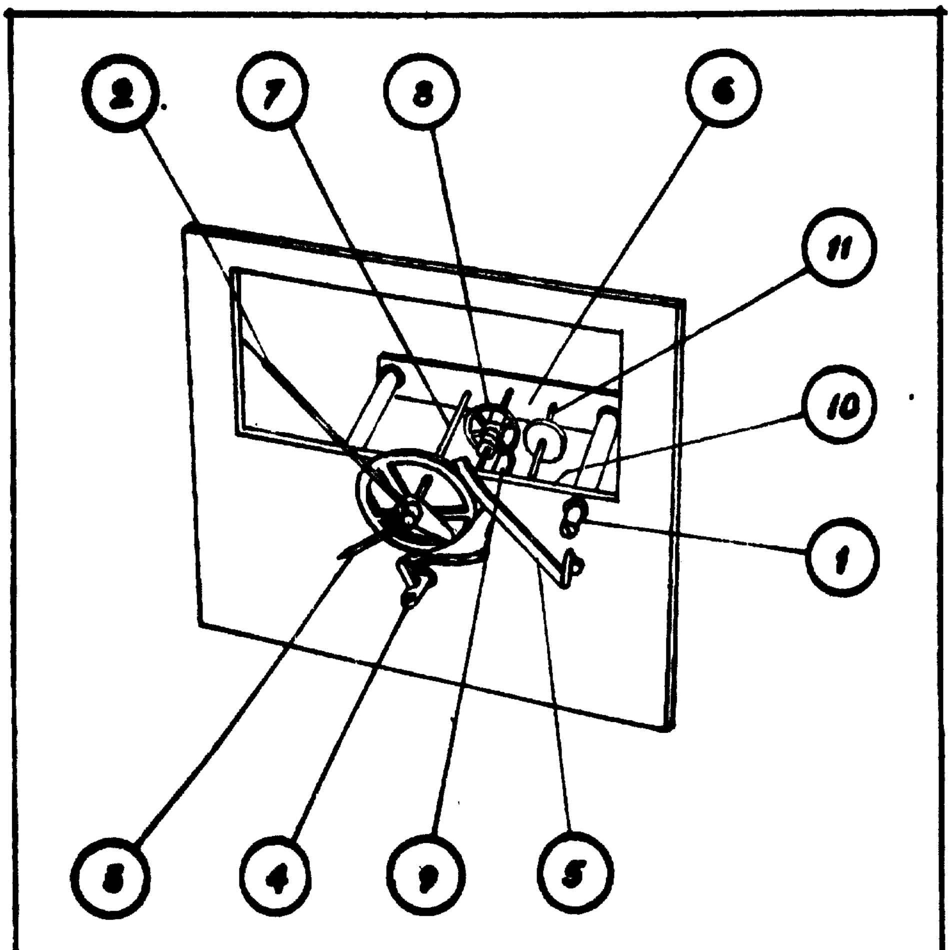
(2) Remove the electromagnetic actuator.

(3) Remove the screws holding dial and nameplate, and also the captive screw (1, Fig. 13), which is to be pulled out and unscrewed.

(4) Position the pointers (2 and 3) at half-scale reading, lift lower edge of dial over zero stop (4), and slide very carefully dial over the pointers. Alternatively, rotate dial clockwise through 90° after lifting over the zero stop, so as to permit one edge of dial to drop between the upper fixing pilllars.

Now, inspect and examine the whole mechanism. If it is necessary to dis-

Contd. 44.



mantle further proceed as follows:

Fig. 13

(5) **Remove the alarm device.**

(6) Remove tapered pin securing maximum pointer spring, **then remove the** ratchet spring (5), zero stop (4), driving pointer (3) **and maximum pointer** (2). Note: Take care not to damage them!

(7) **Remove** tapered pin securing the driving pointer spring, **and disconnect** the tension spring from the detent mechanism.

(8) **Remove the two** screws holding the back plate (6), **and take gently out all the** moving parts.

Cleaning procedure depends on the equipment available, as for the energy registers. In general, procedure is the same as given in 2.1.6.1. above.

After cleaning, take care not to handle the demand indicator ratchet teeth, but use the tweezers.

Contd. 45.

No lubrication is required.

For assembling, proceed as follows:

(1) Examine the spring on driving pointer shaft (7) for concentricity and squarness. If it is satisfactory, assemble and check that end of spring is aligned with spring post. Fit with taper peg and square up.

(2) Check the slipping torque of clutch assembly (8). If it is satisfactory, place the shaft assembly in position with the set screw at 10 o'clock, viewed from the back of mechanism.

(3) Assemble detent lever (9) and detent spring (10), bevel gear shaft (11) and backplate (6), and tighten the two screws. Check endplay of shaft and detent spindle; if it is satisfactory, square up pusher pointer spring.

(4) Fit demand indicator pointer, and examine setting of the spring. If correctly aligned with the spring post, fit with taper peg and square up.. With spring pegged, pointer should lie at 2.30 o'clock, viewed from the front of mechanism (Fig. 14). Check the torque both at zero and at full scale, as prescribed.

(5) Position driving pointer, and secure with set screw on to the flat side of spindle. Check that pointer lies above maximum indicating pointer at 3.30 o'clock, with spring at zero deflection. Check the torque at zero and at full scale, as prescribed.

(6) Engage transfer lever with detent lever, and check proper operation. Adjust stops to give necessary meshing depth and clearance.

(7) Place mechanism it its normal operating position, and tap it gently to check eventual movement of the pointers for zero spring torque. If astisfactory, then, now without tapping, deflect maximum pointer

Contd. 46.

clockwise, and release slowly. If the pointer stops before position of 5 o'clock, friction is excessive and it must be corrected.

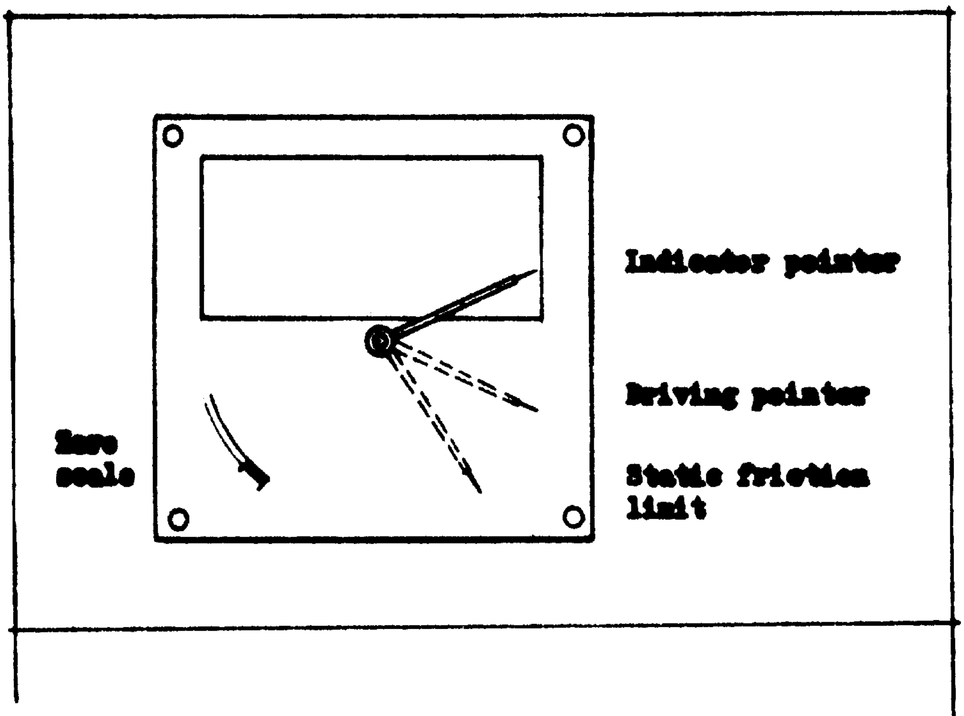


Fig. 14.

(8) Deflect driving pointer clockwise, holding maximum pointer out of the way and detent out of mesh. Release slowly, and see that the push pointer reaches position of 5 o'clock, otherwise friction is again excessive and it must be corrected.

(9) Deflect both pointers clockwise beyond zero scale, fit the zero stop, and tighten the screw.

(10) Fit ratchet spring, and secure with a screw and lock-washer. Check that it engages the wheel correctly.

(11) Check action of reset slide.

(12) Place the electromagnetic actuator over the end of the transfer lever so that this lies between the yoke and the armature stop. Fit the

Contd. 47.

lock-washers, and tighten the screws.

(13) Place dial plate with pointers at half scale position, insert screws, and, if the adjustment is necessary, centralise scale on maximum demand pointer, before tightening screws.

(14) Check that pointers do not foul the dial or each other.

(15) Check that ratchet spring is clear of dial.

(16) Set pointers to zero, and check that head of screw in clutch boss is in position between 2 and 4 o'clock, viewed from the rear.

(17) Fit internal timer, and tighten captive screw.

2.1.7.1. Timer for Maximum Demand Indicator

For dismantling, proceed as follows:

(1) Release worm (1, Fig. 15) and worm gear (2), and gently slide out spindle (3) Note: Take care not to bend it!

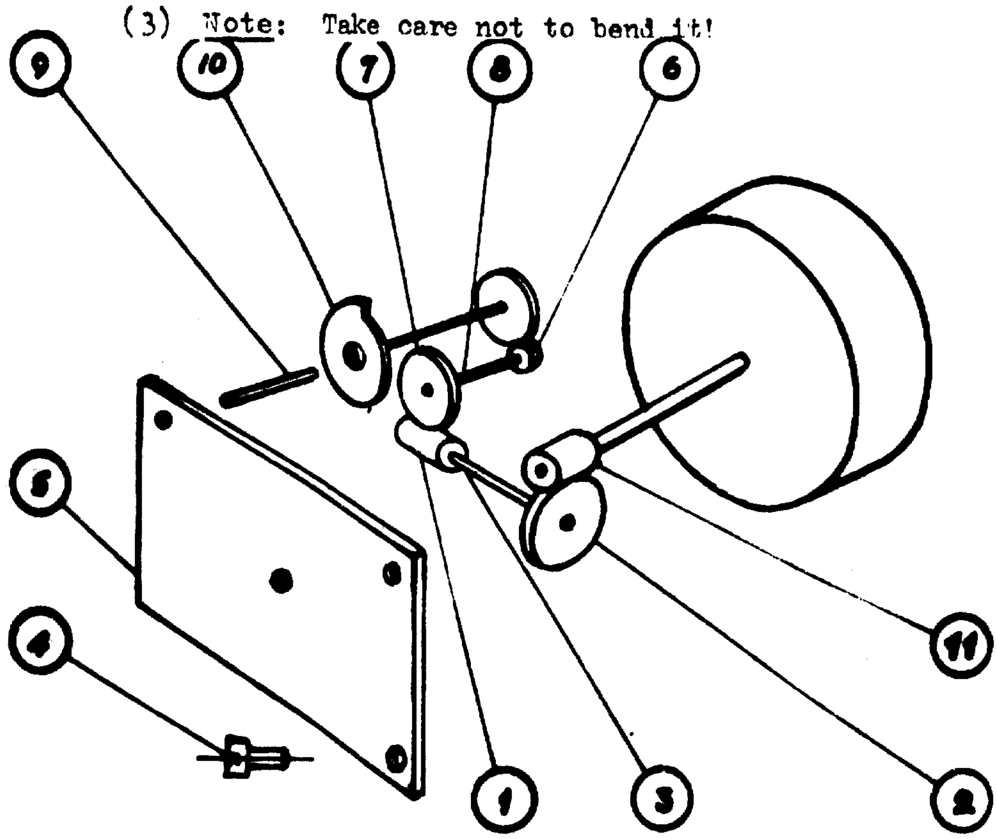


Fig. 15

Contd. 48.

(2) Remove screw (4) holding topplate (5), and lift it off to remove shaft assembly with gears (6,7, and 8).

(3) Release screws in hub at front end of cam shaft (9) only, and slide off complete clutch assembly (10).

(4) Remove motor worm (11)

(5) Remove screws from the motor rear plate, and witdraw this with the rotor. Note: Commencing with this point, further dismantling relates to the motor only, and it may be continued only if necessary to inspect the motor. In this case, proceed as follows:

(6) Using a non-magnetic spanner, hold the rotor sleeve by two flats below the magnet, and unscrew the cap and magnet. Note: Take good care not to touch the magnet with magnetic tools!

(7) Unscrew the nut, and withdraw the thrust washer and rotor sleeve.

Under normal conditions, the motor bearings would not require attention. However, they should be replaced only if the motor does not start properly at approximately 80% of the lowest marked voltage, or if the unidirectional pawl operates sluggishly.

For cleaning the timer, dismantle it completely and wash all the moving parts (with the exception of the motor) in perchlotethylene or trichlorethylene, and dry them. Carefully clean the silver contacts with a burnishing tool, but do not use abrasives. Clean out bearing holes with sharpened pegwood or nylon.

Lubricate the motor sleeve and cap and the motor unidirectional pawl with Meter Oil No. 2, gear train pivots with Rocol Mt 380 Grease, worms and worm gears with Rocol Moly 300 Oil. Other parts do not need lubrication.

For assembling the motor, proceed as follows:

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(1) Before assembling, lubricate the unidirectional pawl and the recess inside the motor sleeve bearing with Meter Oil No. 2. Note: Take care not to get oil on the screw threads!

(2) Assemble sleeve to shaft, and fit thrust washer and nut.

(3) Hold the rotor cap open and upwards, assemble magnet, and drop the ball into recess. Carefully put one or two small drops of Meter Oil No. 2 in recess. Note: Take good care not to oil the threads!

(4) Hold the sleeve with non-magnetic spanner, and screw the cap onto the sleeve. Before tightening, turn the cap backwards and forwards, to get out the entrapped air.

(5) Insert the rotor into the stator, and screw on the two fixing screws. Note: Do not tighten, at this stage!

(6) Hold the motor with the spindle horizontal, and the unidirectional pawl at the left. Turn the rotor backwards, and check that it does not remain against the pawl.

(7) Repeat the above, with the pawl to the right. If necessary, rotate the stator frame between its clamping plates for about 3°, and check again. Remember that the best starting performance is obtained when the rotor comes to rest well clear of the unidirectional pawl in each position, and this must be obtained. When this is acheved, tighten the fixing screws.

For assembling, proceed as follows:

(1) Re-assemble the gear train, and apply graphited grease (Rocol MT 380) to the pivots. Insert into the bearing holes. Note: Check that all are greased before inserting.

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(2) Set all worms and gears on their spindles, and check that gears mesh correctly under all conditions of endplay.

(3) Take a clean brush, and apply oil (Rocol Moly 300) to worms and worm gears, but not excessively.

(4) Check the torque of clutch slipping. Adjust, if necessary.

(5) Take a feeler gauge, and carefully check the clearance between the anti-backlash spring and the boss of the clutch. If necessary to adjust, proceed in the following manner: rotate slowly the clutch boss and ensure that the domed rivet contacts the anti-backlash spring when the contact fingers are just slightly overlapping the tripping cam face.

For contact setting, proceed as follows:

(1) Set the inner contact spring so as to drop off the cam, when the indicating arrow is vertical (Fig. 16). Check the pressing force on the cam after drop-off.

(2) Set the outer contact spring so as to give correct detent times in seconds for demand intervals of 5, 10, 15, 20, 30, 60 and 120 minutes as quoted below in Table I "Correct Detent Times".

(3) Using a feeler gauge, fix the moulded support blocks so as to maintain correct contact distances.

(4) After setting, check that the contact springs are properly aligned on the centre of the cam.

(5) Using one feeler gauge, check the clearance between the contacts when open, and with another feeler gauge check the clearance betwwen the contact spring tips when closed. Adjust, if necessary.

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Table I. CORRECT DETENT TIMES

Demand Intervals (Minutes)	5	10	15	20	30	60	120
Demand Times (Seconds)	2	4	6	8	12	24	48

CAUTION: The values quoted for the demand times in Table I are applicable to one meter, developed by an expert of the United Nations. For any other make, the values may slightly vary. Therefore, the Table is given more as a pattern to the application engineers, since they will be expected and requested to make their own servicing manuals, as already emphasised in the introduction of this chapter.

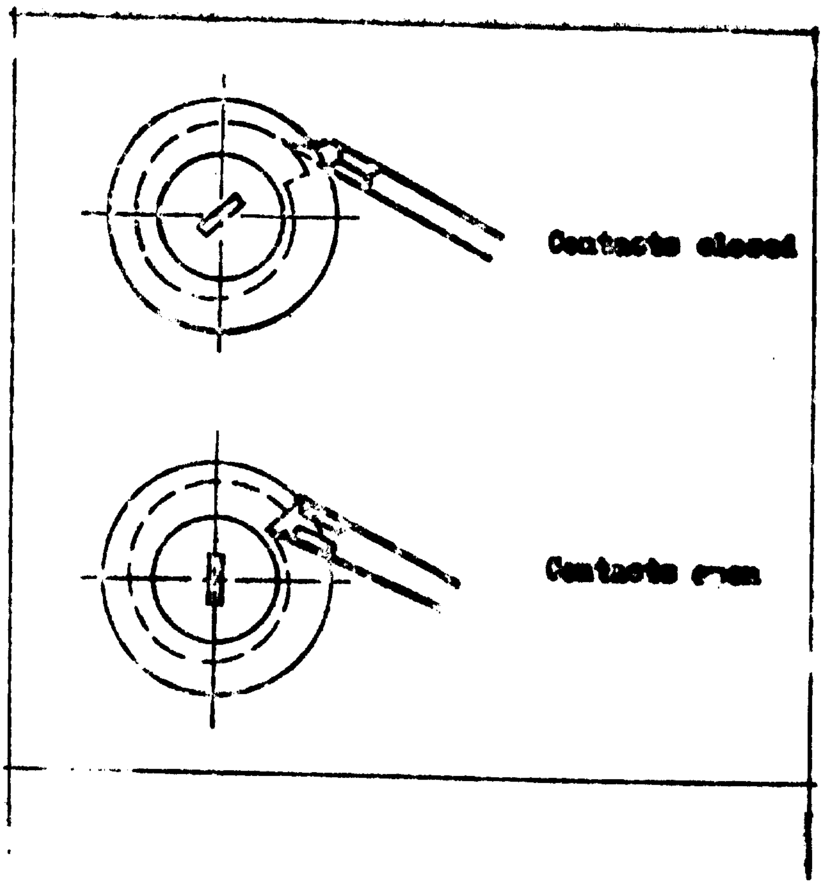

Fig. 16.

After contact setting, perform the following tests:

(1) Check that the motor starts and runs satisfactorily at 80% of the lowest rated voltage.

(2) By using a synchronous clock, check the demand intervals, i.e. times between closing the contacts and the detent times, or contacts open time. Note: Synchronous clock must operate from the same supply.

2.1.8. Instructions for Calibrating

After overhauling, the meter must be re-calibrated, particularly if some of the components or sub-assemblies have been replaced, and/or the electromag-

Contd. 52.

net gaps have been disturbed. In addition, it may be necessary or requested to re-calibrate the meter to suit some S.T. and V.T. ratios different from those originally used.

Calibration is to be done with regard to the following points:

(a) Test Constant. Work out the test constant for the meter from the revolutions per unit of the energy register, by using the following formula:

$$\text{Time for one revolution} = \frac{3600}{W \times R} \text{ seconds.}$$

Where: W = Power in kW (simulated by the test circuit);

R = Revolutions per unit (nameplate data)

Using this formula, calculate the time in seconds for required number of revolutions, i.e. 20 or 30 revolutions for full load tests.

If the revolutions per unit are not given, to find the value use the following formulas:

$$R/kWh = \frac{660 \times 10^3}{V \times I} \quad \text{or} \quad R/MWh = \frac{660 \times 10^6}{V \times I}$$

Where: V = Line Voltage

I = Current rating.

(b) Shunt Balance. Apply the rated voltage to each element in turn, and, with the current circuit open, slacken the low load locking screw, and set the low load adjuster so as to give a balance of forward and reverse creep, i.e. zero creep. If this operation is to be done more rapidly, remove the brake magnet.

Contd. 53.

(c) Torque Balance. Energise the meter so as it will be used (e.g. for a three-phase three-wire circuit apply three-phase voltage in the correct phase sequence), and apply nominal full load at unity power factor to each element in turn. Measure the time of each element, and compare the figures: if the figures show that the elements are appreciably unbalanced, adjust the torque balance by operating the torque balance adjuster (one turn in a clockwise direction will increase the torque by approx. 0.7%).

(d) Full Load Unity Power Factor. Fit the brake magnet as instructed in 2.1.5. above. Apply load to all elements, and adjust, i.e. position the brake magnet so as to give the desired speed. For this adjustment, proceed as follows:

1.) Using special "full load adjuster gauge", set the divert screw so as to give correct distance from the underside of the head to the magnet casting.

2.) Slacken one magnet clamping screw, and calibrate the meter to ± 1% of correct speed by rotating the magnet (use special "brake magnet coarse adjusting tool"). Clockwise rotation will increase the meter speed, while anti-clockwise direction will slow the meter down.

Now, tighten the clamping screw, and check that the rotor disc is central in the magnet gap. Then, by turning the divert screw, calibrate the meter to the required speed (clockwise turning increases the meter speed, and anti-clockwise rotation decreases the speed). Check again - as above in (1) - the correct position of the divert screw, and adjust if necessary.

(e) Inductive Load. Apply full load at 0.5 power factor lagging to each

Contd. 54.

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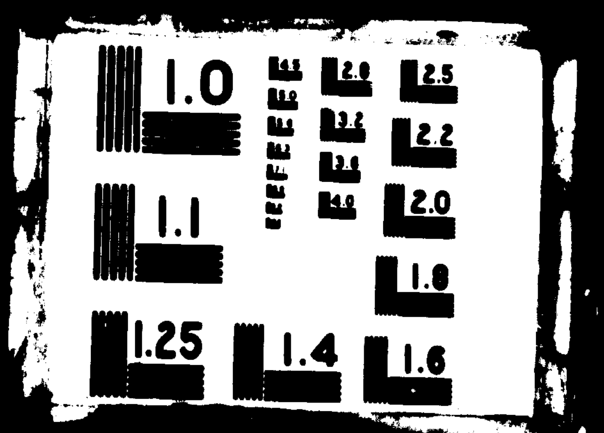

element, and set the inductive load adjuster (by moving the shorting clamp) to give the correct registration. To increase speed, slide the shorting clamp to the left, while movement to the right will slow the meter down; observe that the effect on the speed is approximately linear. Now, apply balanced load at 0.5 power factor lagging, and check that the combined error is within limits. If some adjustment is necessary, repeat the above procedure and move all inductive load adjusters by the same amount.

(f) Low Load. The low load test point is 1/20th of the marked current rating at unity power factor. Apply this load to all elements simultaneously, and, using special tool "angled screwdriver for meter calibration", adjust the low load adjusters so as to obtain the required speed. Movement in a clockwise direction increases the speed, while in anticlockwise direction decreases the speed. After adjustment, tighten the locking screws and relock the adjusters.

(g) Final Test. Energise the meter at the marked voltage and frequency for a period of at least two hours before testing. Check that the voltage and current of the test supply have sinusoidal wave-form and correct frequency. For revolution testing, use the 100 divisions printed on the upper surface of the disc, and compare with a substandard. For stroboscopic testing, use either 400 slots machined on the outer edge of the disc, or, alternatively, use the 200 divisions printed at the smaller diameter; do not use 100 divisions.

(h) Meter Characteristics. When calibrating the meters as a routine job, compare the readings with the values of certified meter characteristics given in the form of curves, with the percent error as a function of: 1) rated load current, 2) rated voltage, 3) frequency and 4) temperature variation. (These characteristic curves are to be prepared

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by the maintenance and test engineers, and kept as a certified standard reference).

2.1.9. Special Servicing Tools

For servicing and overhauling the meters, as instructed above, use the special gauges and tools as follows:

- Rotor endshake gauge;
- Full load adjuster gauge;
- Electromagnet gap gauge;
- Poles distance gauge;
- Set of feeler gauges;
- Reset finger for single-rate register;
- Reset finger for two-rate register;
- Brake magnet coarse adjuster;
- Periscope for worm meshing adjustment;
- Angled screwdriver for calibration;
- Set of Watchmaker's screwdrivers;
- Set of non-magnetic spanners;
- Insertion tool for base unit;
- Window clip tool;
- Ball tweezers;
- Pivot tweezers;
- Rivet pliers;
- Set of small hand tools in wallet.

Before using any of the above special tools, check their accuracy and cleanliness. After using the tools, repeat the check for accuracy and clean them, if necessary. Remember: the tools must always be accurate and clean!

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2.1.10. Storage Instructions

If the original packing is not available, prepare the following:

(a) Packing for Temperate Zones:

1) Oven dried silica gel;
2) A polythene bag (to contain the meter together with the silica gel), the opening of which must be heat sealed;
3) A rubberished hair mould (to enclose the meter in its polythene bag);
4) A cardboard box (to contain the hair mould);
5) A gummed paper strip (to seal the cardboard box);
6) A label to be affixed to the box, giving the basic information.

(b) Packing for Tropical Zones:

1) Water resistant paper (to completely enwrap the meter). Then proceed as in (a) above, (1) to (3).
2) A polythene bag (to hold the rubberished hair mould). Then, heat seal the bag, and proceed with a cardboard box and a gummed paper strip, as in (a) above, (4) and (5).
3) A wooden box (to enclose the cardboard box). Secure it and affix a label, as in (a, 6).

If the original packing is available, use it and affix the label.

For a long-term storage, observe the following:

1) Meters must be stored under conditions where humidity does not exceed 90%, and the temperature is within a range -20°C to +50°C.
2) The storage limiting period is five years.
3) Meters which have been in store for five years, must be subjected to the calibration check.

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2.1.11. Trouble Shooting Chart

Symptoms	Probable cause	Remedy
Driving torque erratic.	Incorrect magnitudes of the fluxes.	Check the line voltage and load current; if considerably increased, this may be the cause. If O.K., check the frequency; if unstable, this may be the reason. If O.K., check the resistance of the potential coils, and adjust as instructed in Calibration.
	Incorrect phase relation of the fluxes.	Check the frequency; if abnormal, this may be the cause. If O.K., check the lagging; if disturbed, correct by operating the adjusters on each element in turn. If O.K., check the speed on non-inductive loads: the higher speed indicates an increased internal temperature, so that the temperature compensators are to be checked.
	Lack of symmetry in the magnetic structure.	Check the position of each element in turn, as well as their screenings; if out of alignment, re-position them and screen. If O.K., check the resistance of the compensating loop on the

Contd. 58.

		potential coils, and adjust.
	Changes in the eddy-current paths in the disc.	Check the disc, and ensure that the central area is isolated from the area under the poles.
Retarding torque erratic.	Changes in the line voltage.	Check the line voltage; if considerably increased, this may be the cause.
	Changes in the load.	Check for excessive overload; if exists, this may be the cause.
	Changes in the strength of the brake magnets.	Check the strength of the brake magnets; if weak, re-magnetise, re-age and stabilise the magnets.
	Changes in the resistance of the disc.	Check the resistance of the disc; if changed, check for the internal temperature of the meter, and, if increased, check the temperature compensators.
	Abnormal friction of the moving parts.	Check the both bearings, guide pins, pin housings and steel ball; if damaged, replace them.
Distorted wave forms.	Presence of an additional harmonic in both the voltage and current wave form.	Re-calibrate the meter, as instructed in Calibration.

Contd. 59.

Meter can not be brought up to the speed.	Disc out of position, or does not run true.	Check the alignment of the elements and the height of the disc. Re-position the disc, brake magnets and elements.
	Lint or magnetic particles between brake magnets and disc.	Check and clean thoroughly, using the air stream.
	Guide pin(s) worn.	Check and replace.
	Dirt in jewel.	Check and clean, as instructed in 2.1.4.
	Jewel cracked or rough.	Check and replace.
	Upper guide bearing pressed down on shoulder of spindle.	Release and re-adjust the height
	Undue friction in the worm and the registering train.	Release and re-position the register.
Meter over-registers.	Weak brake magnets.	Re-magnetise and re-age the brake magnets.
	Short circuit on the customer's premises.	Check for short circuit.
Registration incorrect on an unbalanced load.	The elements unbalanced.	Re-balance the elements, each in turn. With the voltage coils connected in parallel and current coils in series opposition, there will be no rotation.

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2.2. MOVING COIL AMMETER AND VOLTMETER

2.2.1. Construction Details and Materials

General Information. This instrument is basically a d.c. permanent magnet moving coil indicator, with application as: a) low-range voltmeter, b) ammeter (with or without an external shunt, depending on the range), c) millivoltmeter and d) milliammeter.

Case, Cover and Terminals. The complete instrument is accomodated in a waterproof, insulation lined, steel case (1, Fig. 17), and bears on the seating

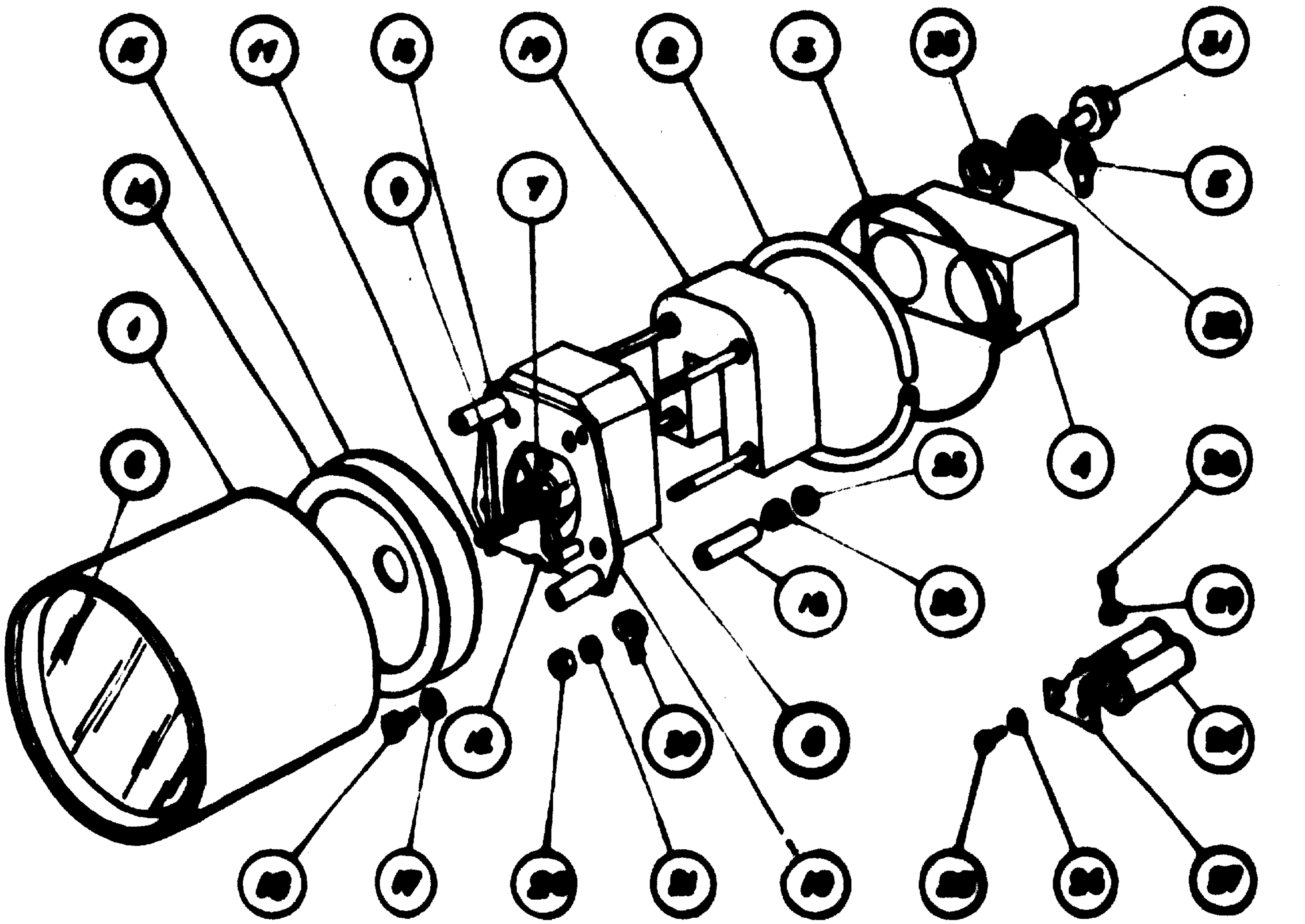

Fig. 17

Contd. 61.

spring steel ring (2). The assembly is retained by a soft-metal sealing wire (3), which is soldered into correct position to maintain a sealed condition. A two-way terminal block (4), with earthing tag (5), connects the instrument to a wiring system. The terminal block is a phenolic moulding, resistant to atmospheric corrosion, while the terminals are made from brass, and are tin-zinc plated. The cover window (6) is made of heavy gauge toughened glass.

The Movement and Moving Elements. The complete movement assembly consists of a moving element (7) and an Alnico IV permanent magnet (8). The moving element is a coil of a fine gauge copper wire, wound on a light aluminum frame. An aluminium-tube pointer (9), silver-steel pivots and phosphor bronze control springs complete the moving element. The moving element assembly is pivoted between the two spring loaded adjustable jewel bearings, which are inset in the top and bottom bridges of the movement housing. The coil of the moving element swings in a gap formed by a soft-iron core and pole pieces, which partially surround the core. One end of the permanent magnet fits into a recess in the core, while the other end fits into a recess in the yoke, which also encloses the core and pole piece.

The complete movement assembly is secured to the top mounting plate (10), which also carries the top bearing bridge, while the bottom bearing bridge is secured to pillars projecting from the lower ends of the mounting plate. Two pointer stops (11) and (12) are secured to the top bridge.

Indicating Scales. The two indicating scales are mounted on pillars (13), carried on the top mounting plate (10). A clip on the underside of the top scale (14) engages in a groove on one of the pillars, so that the lower scale (15) is securely held in position, when both scales are fitted. The both scales are pre-printed thin aluminium plates. Two screws (16), with their lockwashers (17), passing through both scales, secure them to the pillars, projecting from the mounting plate.

Contd. 62.

Mounting Parts. The complete movement assembly is mounted on four spacers (18), fitted to the four pillars projecting from the moulded support (19), and is secured by the nuts (20) and lockwashers (21). The moulded support is secured to the end plate and terminal block by special safety nuts (22) and lockwashers (23).

Spools. The spools (24) are secured by screws (25) and lockwashers (26) to the spool mounting bracket (27), which is secured to the pole piece by spool bracket retaining screws (28) and spring washers (29).

2.1.2. Dismantling for Maintenance and/or Repair

Before dismantling, observe absolute cleanliness of work bench and tools to be used, and check whether the instrument has been delivered with a history sheet or some record, which may indicate any part or point requiring particular attention. Then, proceed as follows:

(1) Hold the indicator firmly, and, using special wire-pliers, remove the sealing wire (3. Fig. 17).

(2) Release and withdraw gently the complete assembly until it is possible (Note: Do not exersise an excessive force!), to take out the seating ring (2) from the case (1). Now, gently withdraw the main main assembly complete.

(3) Remove scale retaining screws (16) and their lockwashers (17), two off each item.

(4) Remove the upper scale (14) and the lower scale (15), taking good care not to damage the pointer (9).

(5) Remove the safety nuts (20), along with thier lockwashers (21), and the terminal tag (30).

Contd. 63.

(6) Remove the spool retaining screws (25), along with their lockwashers (26), and detach the spools (24).

(7) Remove the spol bracket screws (28) and lockwashers (29), to remove spool mounting bracket (27).

Inspect the above dismantled components and assemblies. Further dismantling depends on the extent of the necessary repair, and it is to be done on a special order. The reason for this is the following WARNING:

Operators and servicemen are warned against dismantling the movement assembly down to the moving element, as the indicator is fitted with a pre-printed scale, which requests a special technique in determing the relative positions of the core, magnet and pole liece to establish the required accuracy of indication. If the movement is faulty, it must be returned to the manufacturer for replacement, since the movements are dispatched with a saturated magnet, so that the ageing must be carried out during adjustment.

If the special order for further dismantling is given, proceed as follows:

(8) Raise the movement assembly gently on the pillars until it is possible to have access to unsolder the connection to the bottom bridge terminal tag (30). Note: Take care not to damage the control spring! Now, remove four spacers (18).

(9) Remove the safety nuts (22) and lockwashers (23), and remove gently the moulded support (19).

(10) Remove terminal screw and washer assembly (31), along with slotted nuts (32) and lockwashers (33), two off each item, from terminal block. Now, remove the terminal block.

(11) To remove end plate, unsolder connections.

Inspect the above dismantled components and assemblies.

Contd. 64.

2.2.3. Cleaning and Lubrication

For cleaning, proceed as follows:

(1) Before cleaning, examine all metal parts for corrosion.

(2) Use acetone to remove all Bostic adhering to threads of screws and nuts. Note: Ensure that the acetone does not come into contact with varnished surfaces or insulation! After cleaning, hold in a jet of clean air to remove surplus solvent.

(3) Remove all dust and particles from the case, using a soft brush.

(4) Blow out the magnet gap with a fine jet of clean dry air.

(5) For cleaning the jewel bearings, proceed as in 2.1.4. above.

No lubrication is required.

2.2.4. Inspection and Repairs

Glass Cover. If the glass cover is damaged, it must be replaced. When the glass is an integral part of the case and if damaged, the complete case must be replaced.

Case and End Plate. If either part is damaged or defective in any way, it must be replaced.

Movement Complete. If any part of the movement is defective, the complete movement assembly must be replaced, for the reason as outlined in 'warning', 2.2.2. above.

Pointer Adjuster. If the pointer adjuster is damaged or defective in any way, the complete end plate assembly must be replaced, since the adjuster forms an integral part of the seal for the end plate.

Contd. 65.

Jewel Bearings. If the jewels are cracked or rough, the whole jewel bearing assembly must be replaced.

Control Springs. If defective or damaged, they must be replaced.

Other Parts of this instrument can be repared, providing that the damage is not excessive.

For general inspection, proceed as follows:

(1) Examine all metal parts for corrosion.

(2) Check all threads for serviceability, and all screws, nust and bolts for good condition.

(3) Examine for obstruction and dirt the gap in which the moving coil swings, using a strong magnifying glass. If any small particles adhere to the core or the pole piece, remove them using a sharped piece of pegwood or celluloid. Caution: Never use a metalic needle for this purpose! Take a good care to avoid damage to the control springs!

(4) Examine the instrument case for damage, distortion, scoring. etc.

(5) Examine the window glass cover for cracked or broken glass.

(6) Examine the terminal block for bent terminals or pins.

(7) Check that the pointer is not bent or damaged, and that the moving coil assembly moves freely.

(8) Check the insulation of the moving coil, and that its resistance is within the given limits.

(9) Check that all the supporting pillars are securely attached to the base and not bent.

Contd. 66.

2.2.5. Assembling

Before starting assembling, observe absolute cleanliness of both work-bench and tools to be used, and prepare Bostic No. 772 (thinned with acetone to a brushable consistency), for applying during assembly a spot to all threaded holes, nuts and screwheads, to lock them against vibration.

For assembling, proceed as follows (referring to Fig. 17):

(1) Place the moulded support (19) on the mounting pillars, and secure tightly with lockwashers (21) and safety nuts (20).

(2) Inspect again the gap in which the moving coil swings and ensure that it is free from any dirt or small particles. If necessary, clean as outline above in 2.2.3.

(3) Adjust the jewel bearings to centralise longitudinally the position of the moving coil in the pole piece.

(4) Ensure that the moving coil is centered evenly. If necessary, turn the jewel screws clockwise in several increments of approx. 1/10th of a turn, until 'pointer flop' is just eliminated (i.e. the movement of the pointer due to the pivots being able to move laterally in the jewel bearings).

(5) Now, back off the jewel screws by approx. 1/10th but no more than 1/8th of a turn, until 'pointer flop' is just perceptible.

(6) Check and ensure that there is no angular displacement between the moving coil and the pointer.

(7) Place the spacers (18) on the pillars of the moulded support (19).

(8) Assemble spool mounting bracket (27) to the complete movement, and secure tightly with lockwashers ([illegible]) and screws ([illegible]).

Contd. 67.

(9) Fix spools (24) on bracket (27), and secure tightly with lockwashers (26) and screws (25).

(10) Assemble the complete movement to the pillars of the moulded support (19), and secure with lockwashers (21) and nuts (20)

(11) Resolder the connections to the tags.

(12) Slide the lower scale (15) under the pointer (9), and position it on the supporting pillars on the top mounting plate (10). Note: Do not bend the pointer!

(13) Place the upper scale (14) over the lower scale (15), so that the clip on the underside of the upper scale engages securely in the groove of the pillar. Now, secure both scales in correct position by tightening the screws (16) and lockwashers (17).

Before proceeding with further assembling, balance the movement as outlined below in 2.2.6. Note: If a renewal movement complete is being fitted, age and stabilize the magnet as outlined below in 2.2.7.

After balancing the movement, carry out the tests appropriate to the application, as given below, in 2.2.8.

Now, proceed with assembling as follows:

(14) Pass the seating ring (2) over the end plate, and locate it into correct position.

(15) Insert the complete instrument into its case (3), and see that it bears safely on the seating ring.

Before proceeding further, carry out the Insulation and High Voltage tests, as described below in 2.2.8. Then, proceed as follows:

Contd. 68.

(16) Cement jewel screws and coat all soldered connections with Red Thermolene Lacquer No. 185.

(17) Solder the sealing wire (3) between the end plate and the case, and carry out the Sealing Test, as outlined below in 2.2.8.

2.2.6. Balancing the Movement

Before starting balancing, check the jewel bearings for correct adjustment, and adjust if necessary.

For balancing, proceed as follows:

(1) Using a special wrench, adjust the balance weights to maintain the pointer within the balance limit of 1% of range value. Note: During the whole balancing, pointer error must not exceed 1% of range value!

(2) Using a special tool 'pointer adjuster', align the pointer to the scale zero position.

(3) Now, check the balance and see where the weights are positioned (Fig. 18): either on arms 'A' and 'B', or on arms 'C' and 'D'?

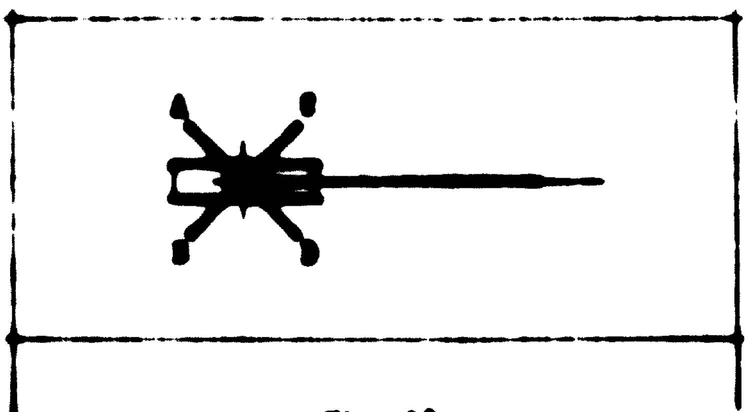

Fig. 18

(4) If the weights are positioned on arms 'A' and 'B', it means that the system is 'pointer heavy'. In this case, proceed as follows:

Contd. 69.

(a) Placing the scale face in the horizontal plane, rotate slowly the movement assembly, until arm 'A' is pointing towards the operator, pointer tip being to the left of the operator.

(b) Slowly raise the movement assembly so that the scale face is in the vertical plane and arm 'A' points vertically downwards, pointer tip being to the left of the operator. Adjust weight on arm 'B' to keep balance within the limit of 1%.

(c) Recheck balance with arm 'A', but now pointing vertically upwards.

(d) Repeat operations (a) and (b), but now with the pointer tip to the right of the operator, and arm 'B' pointing vertically downwards. Adjust weight on arm 'A' to keep balance within the specified limit of 1%.

(e) Recheck balance with arm 'B', but now pointing vertically upwards.

(5) If the weights are positioned on arms 'C' and 'D', it means that the system is 'tail heavy'. In this case, proceed as follows:

(a) Turn movement complete from the scale face in horizontal plane to the scale face in vertical plane, but now with arm 'C' pointing vertically downwards, pointer tip being to the left of operator.

(b) Adjust weight on arm 'D' to keep balance within the limit of 1%.

(c) Recheck balance with arm 'C', but now pointing vertically upwards, and adjust if necessary.

(d) Repeat operations (a) and (b), but now with arm 'D' pointing vertically downwards, pointer tip being to the right of the operator. Adjust weight on arm 'C' to keep balance within the limit of 1%.

(e) Recheck balance with arm 'D', pointing now vertically upwards.

Contd. 70.

(6) If the required balance has not been obtained, repeat the above operations (4 and 5) until the satisfactory balance is obtained.

The same procedure of balancing, [illegible] above, [illegible] as well when [illegible] balance [illegible] to have been placed [illegible] of the arms or [illegible] all four arms, with [illegible] some adjustments that have to be made to the weights during the balance checks.

[illegible] the [illegible]

In general, [illegible] accomplished either [illegible] the gradual approach and [illegible] the coil, [illegible] increasing [illegible] decreasing the current in the [illegible] coil. In [illegible] case, [illegible] continued until the [illegible] deflection [illegible] is obtained. [illegible] coil must [illegible] alternating current [illegible], and to be used [illegible] with [illegible].

[illegible], [illegible] voltmeters and ammeters, the only [illegible] the [illegible] voltmeters, or [illegible] the [illegible]. In both cases, [illegible] until the [illegible] is [illegible].

To stabilize the magnet, [illegible] after satisfactorily completing the [illegible] eight hours, [illegible] temperature of 70[illegible]. If, eventually, the [illegible] after [illegible] the magnet, proceed as above [illegible].

After satisfactorily completing the balancing, [illegible] and stabilizing process, the instrument is ready for final testing, adjustment and calibration, as [illegible] below. I [illegible] hereby certify that the above processes have been satisfactorily completed, before proceeding further

2.2.0. Final Tests and Calibration Check

For testing the instrument as a voltmeter, proceed as follows:

(1) Connect the indicator into the circuit given in Fig. 19. Note: Check and ensure that the test instrument is of a precision grade.

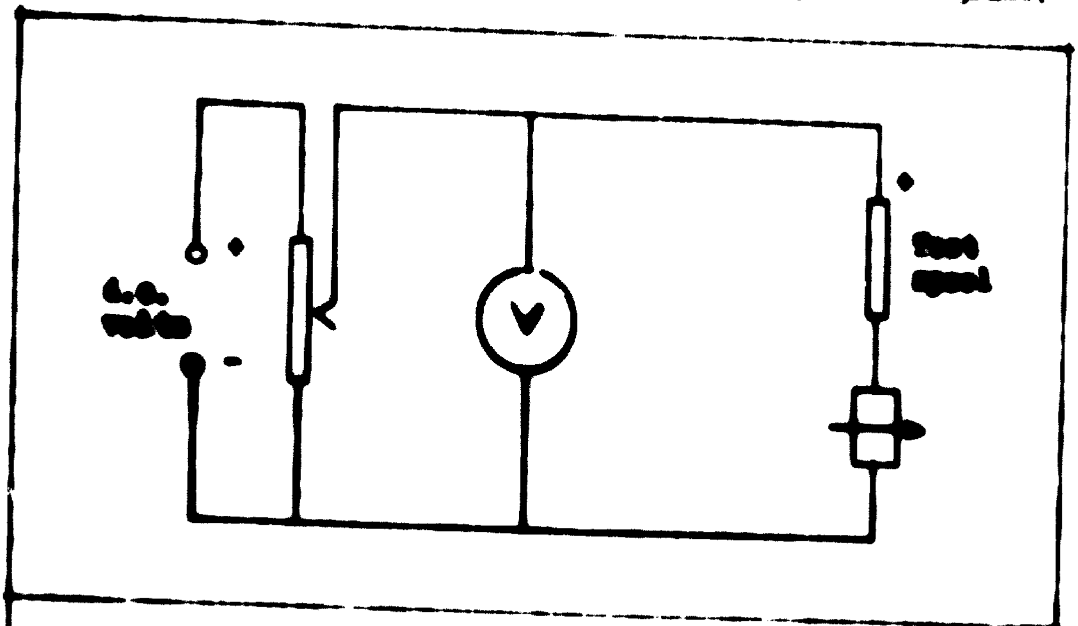

Fig. 19

(2) Apply the appropriate voltage, for a particular application.

(3) Adjust the potentiometer to vary the deflections of the voltmeter under test.

(4) Check the deflections at appropriate points on the scale of the voltmeter under test, and compare the readings with the test instrument.

(5) Since the scale is pre-printed, check the calibration of the voltmeter according to the values given for particular range.

For testing the instrument as a millivoltmeter, connect the indicator into the circuit shown in Fig. 20, and proceed in the same manner as outlined above, for the voltmeter (2 to 5). If the spool has to be changed, connect the adjusted replacement spool in series with the moving element, and age the magnet until the specified deflection of the pointer is obtained, with the correct

Contd. 72.

voltage applied to the circuit.

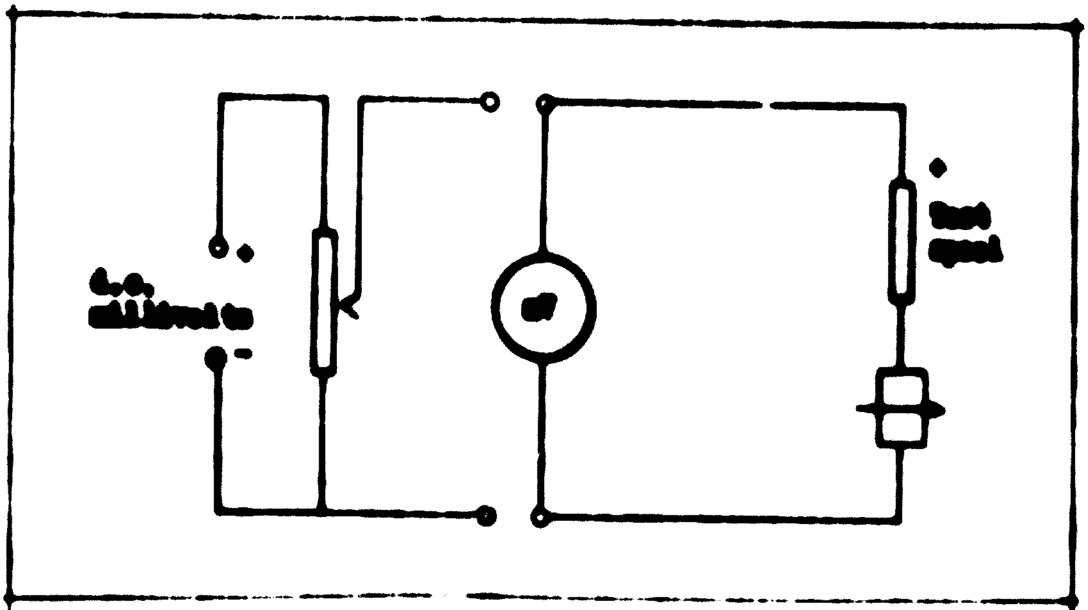

Fig. 20

For testing the instrument as an ammeter with external shunt, connect the indicator into the circuit shown in Fig. 21, and proceed as above.

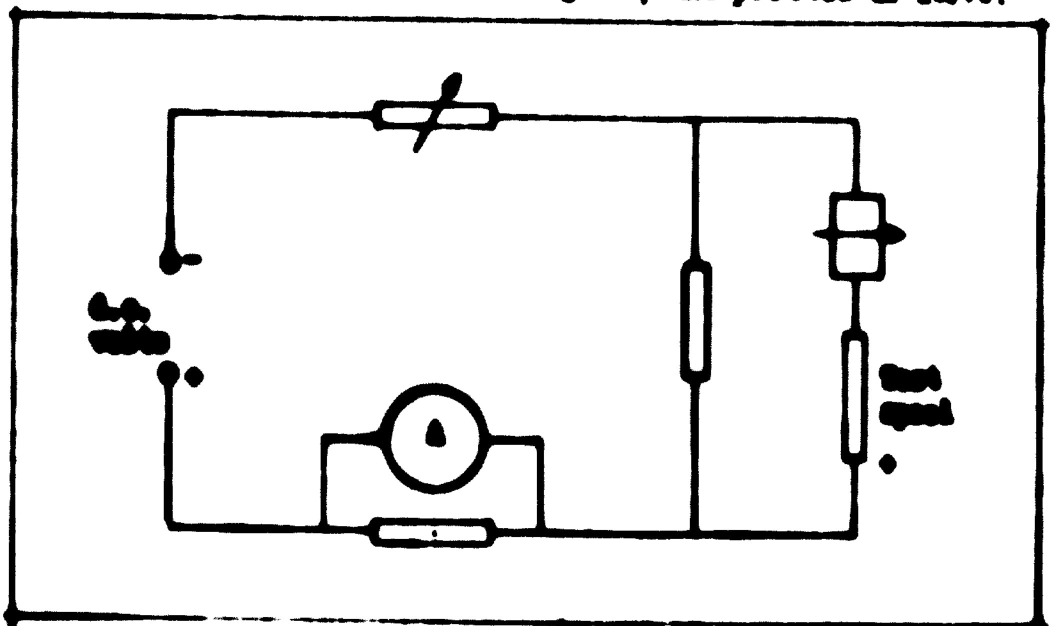

Fig. 21

For testing the instrument as a self contained ammeter, connect the indicator as shown in Fig. 22. The same diagram is to be used for testing the instrument as a milliammeter, the only difference being that the test instrument must be a precision grade milliammeter.

Basically, testing procedure and calibration check are the same as for the voltmeter, outlined above.

Contd. 73.

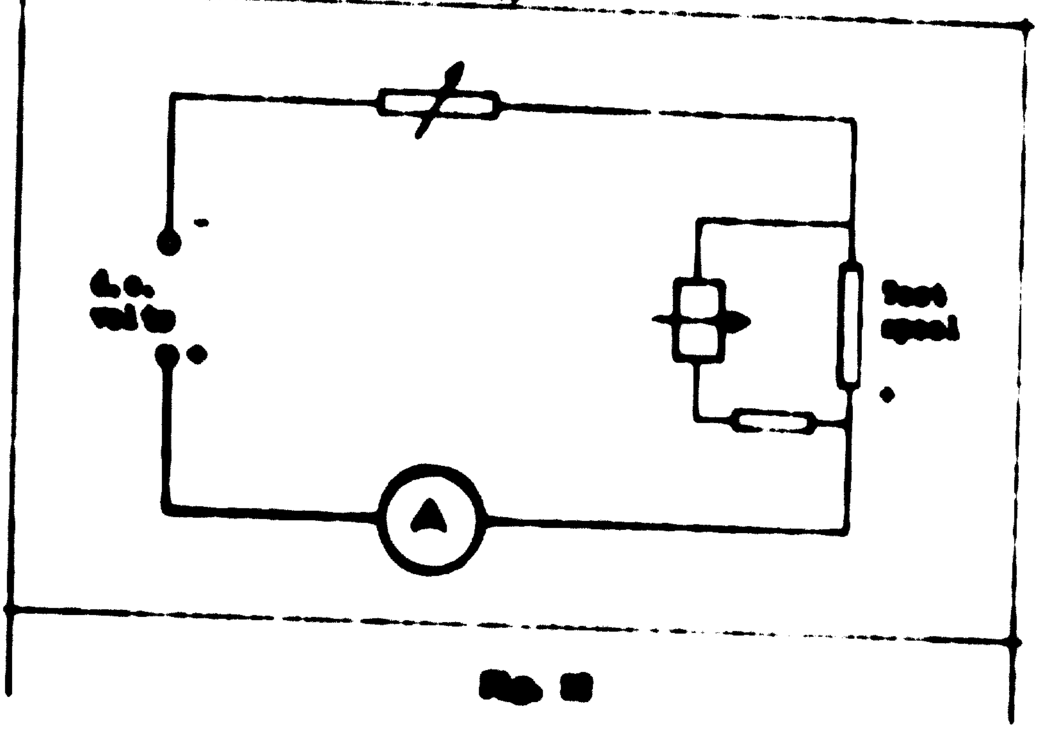

Fig. [illegible]

For the High Voltage Test, the procedure is as follows: Apply 500 volts (r.m.s.) between all the terminals, connected together, and the instrument case, and certify that there is no breakdown.

For the Insulation Test, the procedure is as follows: Apply 500 volts d.c. for a period of at least one minute, and then measure the resistance between the terminals and the instrument case; this resitance must be at least 20 Meghoms, or better.

After satisfactorily completing all the above adjustments, checks and tests, the last test to be performed is the Sealing Test. For this test, use the diagram shown in Fig. 73, and proceed as follows:

(1) Connect the exhaust stud (1) of the instrument to the manifold tap (2), and ensure that a tight seal is made. WARNING: Place the instrument in a special safety tank, to prevent possible injury to personnel, in the event of the case cover glass disintegrated!

(2) Close tightly the manifold tap (2) connected to the instrument, as well as the dry nitrogen tap (3) and admittance valve tap (4).

Contd. 74.

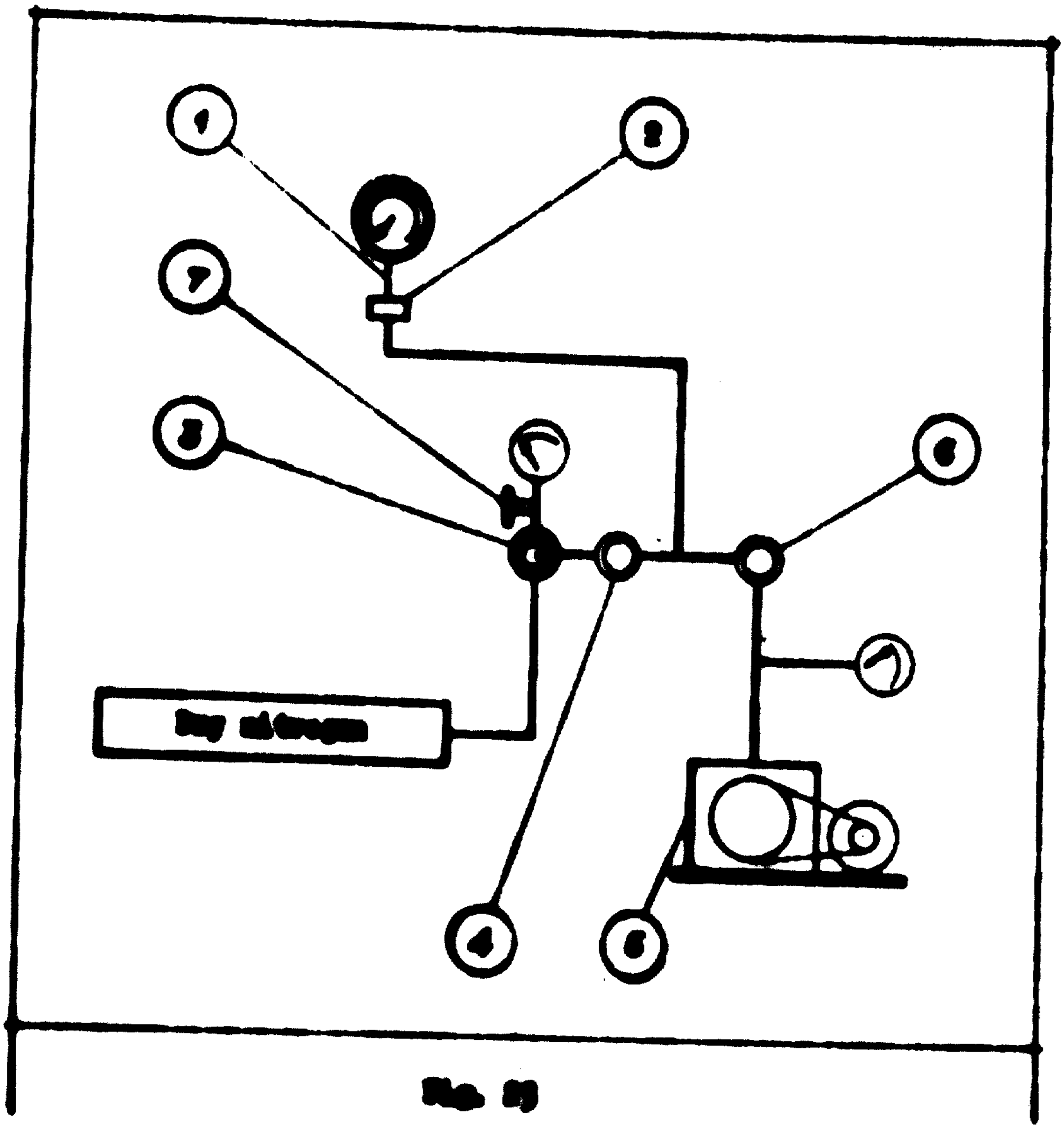

Fig. [illegible]

(3) Start the vacuum pump motor (5), and obtain the required degree of vacuum (for normal applications 0.1 mm of mercury).

(4) Open valve (6) and the manifold tap (2), and allow the system to regain the required vacuum. If it is not possible to maintain the required vacuum, proceed as follows:

(a) Close the manifold tap (2) and remove the instrument.

(b) Check the instrument for leakage, and, if necessary, reseal it.

(c) Re-connect the instrument to the pumping system again, and regain the required vacuum.

Contd. [illegible].

(5) Close valve (6) and open valve (4), to admit dry nitrogen into the instrument.

(6) Using control valve (3), adjust to obtain a pressure of 15 lb per square inch gauge.

(7) After a period of 30 seconds, operate the control valve (3) and the leakage needle valve (7), so as to reduce the pressure to 10 lb per square inch gauge.

(8) Immerse the indicator (still under pressure) into a tank containing 99.5% distilled water and 0.5% appropriate wetting agent (Shell Teepol 514, if available).

(9) Check for a period of over 5 minutes for leakage, which will be shown by small bubbles leaving the instrument case. In the event of lekage, mark the instrument as 'reject'. Note: Particularly check for leakage at the sealing joint of the case glass cover and the terminal block.

(10) By operating both control valve (3) and the leakage needle valve (7), reduce the dry nitrogen pressure to zero.

(11) Disconnect the instrument from the manifold tap, and remove it from the tank.

(12) Seal the sealing tube (ot the sealing stud) of the instrument by soldering the end. Note: This operation must be done immediately after removal of the instrument from the tank!

2.2.9. Special Servicing Equipment

For servicing and overhauling this indicator, as instructed above, use

Contd. 76.

The special instruments and equipment, as follows:

- Precision grade potentiometers;
- Precision grade milliammeter;
- Precision grade ammeter;
- Precision grade millivoltmeter;
- Precision grade voltmeter;
- Balance weight wrench;
- Pulse-ager or magnet setter;
- Sealing Test equipment.
- Cylinder of dry nitrogen gas.

2.2.10. Storage Instructions

Follow the Instructions as given above, in 2.1.10.

2.2.11. Trouble Shooting Chart

The faults may be classified into two basic groups, as follows:

(1) Electrical faults, such as:

(a) Incorrect pointer deflection for applied input (voltage or current) value;

(b) Fluctuation of indication for constant input value.

(2) Mechanical faults in moving elements, due to dirt, etc.

The faults may be traced by using trouble shooting chart, as given below. More for the sake of illustration, this trouble shooting chart is given in the form of a diagram, to differ from the chart given in 2.1.11. This is to bring to the attention of the maintenance and application engineers, that they may prepare their charts in the form and shape most convenient for their staff.

Contd. 77.

Trouble Shooting Diagram

If pointer shows :

Incorrect deflection for applied input value.

Check full scale sensitivity.

- If not O.K., check resistance of the moving element. — If out of limits, replace movement complete.
- If O.K., check for control spring convolutions touching and/or sticking. — Reset springs or if damaged, replace movement complete.
- For voltmeters and millivoltmeters, check all leads and spools. — Renew all faulty leads and spools as instructed.

Fluctuation of indication for constant input value.

- Check for correct setting of moving element between jewel bearings. — If faulty, reset and adjust, as instructed in 2.2.8.
- If O.K., check for obstructions in gap between core and magnet. — If any, remove obstructions, as instructed in 2.2.4.
- If not O.K., this indicates cracked jewels or damaged pivots. — Replace movement complete.

Contd. 78.

2.3. TEMPERATURE INDICATOR

2.3.1. Constructional Details and Materials

General Information. This indicator is basically a precision moving coil permanent magnet 0 - 1 mA d.c. milliammeter, being fitted with a scale calibrated in degrees Centigrade, indicating the medium temperatures over the range from 40°C to 800°C.

For constructional details and materials, refer to 2.2. above, since this temperature indicator is only a specific application of the already described moving coil indicator, the only difference being in the resistance of the moving element.

Thus, the procedures for dismantling, cleaning, inspection, assembling, etc., are to be performed in the same manner and sequence as for the above described moving coil indicator (2.2.).

2.3.2. Final Test and Calibration Check

Proceed as follows:

(1) Connect the indicator into the circuit shown in Fig. 24.

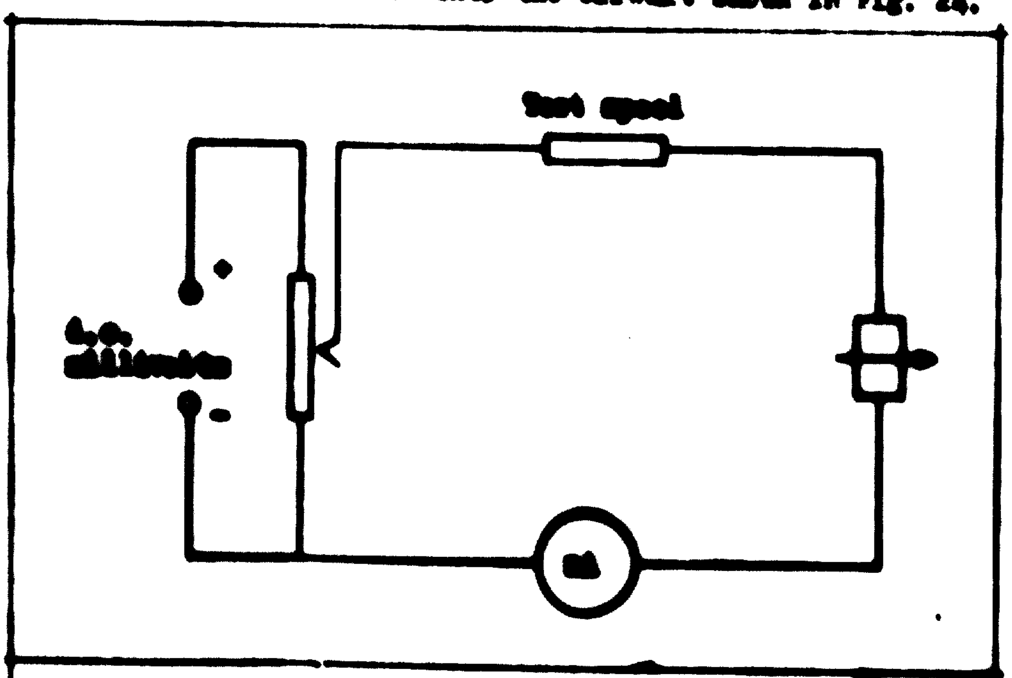

Fig. 24

(2) Using a special pointer adjuster, set the pointer approx. at a position corresponding with 400°C.

(3) Using a pulse-magnetiser or a magnet setter (whatever available), set the magnet as described above in [illegible] until the pointer aligns with the 500°C cardinal, when the circuit current is [illegible] microamperes.
Note: This value will be different for other designs, depending on the moving element resistance (including springs)!

(4) After a [illegible] set, [illegible] it as instructed in [illegible].

(5) Check for accuracy at 100°C, 200°C, 250°C, 300°C, 400°C, 500°C, 600°C, 700°C and 800°C, and, whenever necessary, adjust the pointer by means of the pointer adjuster, so as to correspond with the values given in the appropriate table, with required accuracy.

After satisfactorily completing the above, perform the High Voltage Test, Insulation Test and Sealing Test, as instructed in 2.2.9.

2.3.3. Special Servicing Equipment

Refer to the list in 2.2. .

2.3.4. Storage Instructions

Follow the instructions as given in 2.1.10.

2.3.5. Trouble Shooting Chart

Use the chart as given in 2.2.11.

74.10.16