No. 148.

THE INSTITUTION OF
POST OFFICE ELECTRICAL ENGINEERS

Stores Specifications and Acceptance Testing.

BY

Capt. J. LEGG, B.Sc., A.M.Inst.C.E.

A PAPER

Read before the Eastern Centre on February 28th, 1933, and at the London Centre on March 14th, 1933.

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STORES SPECIFICATIONS AND ACCEPTANCE TESTING.

(1) INTRODUCTION.

Two of the indispensable requirements for economical purchase of stores are accurately drawn specifications so as to leave no doubt of what is required, and efficient acceptance testing so as to ensure that what is wanted is supplied. However perfect the actual technique of purchase, failure to meet the foregoing two requirements must result in loss to the purchaser. As the Post Office purchases engineering stores from contractors to an amount of about £4,000,000 per annum, and as the Engineering Department is responsible for the specifications for these, and for the testing of the stores when supplied, it is thought that some notes on this part of the Engineering Department's work should be of general interest. In what follows it is proposed to deal only with *stores* specifications and not with *works* specifications. The word specification is used to include drawings and patterns which may be referred to in the specification.

(2) STORES SPECIFICATIONS—GENERAL.

The purchase of engineering stores is governed by regulations designed to obtain effective competition from firms tendering, and it is important, therefore, as far as possible, to define in detail what is required, as otherwise the offers received will not be for the same thing, and there will be no effective competition. A general type of specification where few details are included, and where considerable latitude is given to manufacturers in minor points, though it may be used on occasion when stores are not yet standardised and competition is limited to manufacturers known to be experienced, is not suitable generally in the case of a public department where competition on the broadest possible basis is required, and where the lowest offer which comes within the specification must normally be accepted. What is to be aimed at, therefore, is to produce a series of specifications setting forth the requirements in such detail that all persons honestly tendering to any of these specifications will be offering the same thing, and the prices will be a true measure of the value of the offer to the Department. The possibility of preparing such a specification depends upon the possession of definite knowledge of composition and properties of materials, and of the limitations and capabilities of manufacturing methods. During the early stages of development of any product this knowledge is not available. The producer is feeling his way by investigation and trial towards a satisfactory article. The purchaser is naturally cautious about using a product which has not been proved, and of which he may doubt the usefulness. It is only as the product comes gradually into wider use that knowledge, of its characteristics and of the effects of change of composition, design, and manufacturing methods, becomes available for the preparation of a specification by which the product may be controlled. Thus a detailed specification is the result of the gradual accumulation of knowledge by both producers and purchasers until the latter have found out exactly what they want and the former have found out all about the means of meeting that want. An attempt to control by specification any factors (composition, design, manufacturing methods, etc.) about which full knowledge is not available, is either useless or misleading. On the other hand—where the necessary knowledge is available—an omission to control by specification any factors which affect the results obtained in the use of the product is a source of weakness, and may result in the supply of a product which is not the best or most economical for the purpose required.

Assuming that the necessary knowledge is available to make a detailed specification possible, it is proposed now to consider some of the points to be borne in mind when it is being prepared. The specification is the source from which persons tendering obtain their information of the work they will be called upon to do if the tender is accepted. Precision of language and absolute clearness of details are, of course, a primary essential. Indefiniteness or ambiguity will involve uncertainties and will lead to the person tendering making an addition to the price for self-protection, or will lead to disputes.

The standard of performance and quality required must be high enough to satisfy the requirements in service, but not so high as to be impossible of attainment by a good commercial product. For example, the minimum limits of a specified test may be fixed at, or near, the average of test results from the best of similar material. Such severe requirements are frequently impossible of fulfilment in bulk supplies and also lead to enhanced prices and disputes. If the safety given by the high standard is really necessary in service in any particular case it should, if possible, be obtained by other means, *e.g.*, improved design.

Where a standard item in general production would meet the requirements, the specification should not be drawn to exclude this. Unusual characteristics or modifications of standard designs should be specified only when it can be shown that the characteristics or modifications are really needed and that the better results to be obtained are proportional to the additional expense involved. In the case of supplies which are not primarily telephone stores and of which the Post Office is not the only or the largest user, a requirement for an unusual characteristic may result—apart from the question of expense—in delay in receipt of supplies or even in inability to obtain supplies at all.

The specification, in addition to being the source from which persons tendering obtain their information of the work they undertake to do, is also the source from which the acceptance testing staff obtain their knowledge of what requirements they are bound to enforce. The precise definition of the standard of quality or performance should therefore, where possible, include a statement of the means by which the standard will be estimated and (in the case of quantitative measurements) the limits which will be regarded as satisfactory.

It follows from the foregoing that a detailed specification pre-supposes the existence of a considerable amount of knowledge of the article dealt with. In writing such a specification a preliminary investigation and tabulation of this information is an aid to clearness and order in the resulting specification. For example, in the case of a material, a preliminary study might be made to include some or all of the following:—

(1) Occurrence.
(2) Properties.
(3) Uses and application.
(4) Manufacturers and process of manufacture.
(5) Current prices.

It is not intended, of course, to embody all this information in the specification, but, with this information available, consideration can be given to the special requirements for which the material is being obtained and those factors selected which influence the suitability of the material for the purpose for which it is to be used. It is important not only to include all requirements necessary in order to obtain the article desired, but also to omit any unnecessary requirements or restrictions.

Having decided on the necessary requirements, the method by which these requirements will be checked should be considered, *i.e.*, the testing officer is given any necessary guidance to avoid disputes and misunderstandings with contractors. He may check the requirements by visual inspection, or by chemical analysis, or by tests directed to ascertain any of the physical or electrical properties of the article. Appearance, finish, and workmanship as well as uniformity and the absence of flaws are checked by visual inspection, consequently any information possible to make known the standard required should be embodied in the specification. If there is an accepted trade standard of finish which will suit, this should be quoted, or reference may be made to a selected standard or pattern which the contractor would be required to imitate. The use of a pattern to show the standard of appearance and workmanship is common practice in the Post Office. Failing any guidance in the specification the inspecting officer is left to use his own experience and judgment in deciding whether the standard offered is satisfactory, having regard to the prevailing commercial standard and the work for which it is required. Chemical analysis is directed to ascertain the composition or purity of the material. Where it is known that a specified composition will give the desired results no tests of properties are needed. Generally, however, there are other factors, such as manipulation and methods of manufacture, which affect the attainment of the desired result and thus the attainment of this result is checked by tests of physical or electrical properties, *e.g.*, specific gravity, water absorption, hardness, elasticity, strength (tension, compression torsion, shear or impact), melting, boiling, or softening points, calorific value, viscosity, electrical conductivity and surface resistivity, resistance to reagents, self-extinguishing properties, etc. In the case of some of these tests, well recognised standard methods are in existence and it is merely necessary to specify the limits which will be regarded as satisfactory. In many cases, however, it is necessary, in order to avoid disputes with suppliers, to describe the method of test to be used or, at any rate, to define some of the conditions of test. Water absorption, for instance, is usually expressed as a percentage increase in weight after a piece of the material has been soaked in water for a stated time. The result is, however, affected by a number of factors on which there is nothing that could be called a well recognised standard practice, and if disputes are to be avoided they must be covered by the specification. Such factors are size and shape of specimen, treatment before immersion, temperature of water in which specimen is immersed and method of removal of surface moisture after immersion and before final weighing.

Again, the ultimate tensile strength of (say) mild steel can be specified without needing any special qualification, but if the material happens to be cotton, detailed particulars of treatment before test, rate of application of the load, etc., must be included to obtain definiteness and to avoid disputes.

In the case of manufactured goods the specification passes through the same process of growth, commencing perhaps with a general specification where it is proposed to purchase either a manufacturer's standard design or a tentative design by the Post Office, and leading up to the point of Departmental standardisation, with a specification laying down in full detail the dimensions of every part of the item to be provided and the material from which each part is to be made. In specifying the material, regard should be had to the possibility of applying the tests to the completed article as delivered. For example, synthetic resin-varnished paper board is now being used in small pieces for insulating purposes, and is specified to be to Post Office Specification 483 which requires tests to be made on comparatively large samples. In such cases provision should be made for the supply by the manufacturer of samples of sufficient size for testing, or the inspecting officer should be empowered to take samples at the appropriate stage during manufacture. Generally, the possibility or otherwise of finding out by inspection or test of the complete article whether each requirement has been met should always be considered when the specification is being framed, and if a proper check cannot be made on the completed article, provision should be made for samples of the necessary size for testing.

It emerges clearly from the foregoing that a specification is not a static thing. It is linked, on the one hand, with manufacturing and production methods and, on the other hand, with the purchaser's needs, and it must progress with both. As the purchaser frames the specification there is not much difficulty in keeping it abreast of his needs, but it is not so easy to keep it in harmony with up-to-date production methods. To this end a systematic overhaul of all specifications at fixed intervals in time seems to be indicated. The interval need not be the same for all items, but would be greater for old-established and long-standardised products, and less for products where further development is in progress. During the interval between overhauls, notes would be kept of any points of difficulty which required investigation, and this investigation would be made at the time of overhaul of the specification. The collection of information on manufacturing developments, which might affect the specification, is linked with the work of acceptance testing and further reference to this will be made later.

British Standards Institution.

The British Standards Institution exists to assist British industry by preparing British Standard Specifications. The preparation of these is undertaken by the Institution when there is a generally recognised want and the producers and users are prepared to co-operate. These specifications are based on what is considered to be best in current practice, and aim at providing a generally suitable standard of performance, quantity, or dimension, and an equitable basis for tendering. In the case of goods of which the Post Office Engineering Department is a user, that Department is represented on the Committee or Sub-Committee of the B.S.I. entrusted with the actual preparation or review of the standard specifications, and these specifications are used where possible in obtaining supplies for the Department. They cover, in the main, only articles in general use and do not touch the main body of the Department's purchases which consists, of course, of items special to communication engineering.

Inter-departmental Government Committee.

In the case of goods which are in common use by a number of Government Departments, but where the necessary conditions do not exist for a British Standard Specification to be prepared, Government Sub-Committees, on which the

Departments concerned are represented, draw up an inter-departmental specification for common use. This prevents overlapping and eliminates redundant qualities and sizes. Inter-departmental specifications are sent in draft form to the British Standards Institution for circulation to other large users and industry generally for comment, and the preparation of a British Standard Specification frequently follows. Inter-departmental specifications again do not touch the main body of the Department's purchases.

(3) ACCEPTANCE TESTING—GENERAL.

All stores, after delivery and before being put to stock, are examined and (if necessary) tested to see that they comply with the conditions of the contract. This is what is meant by acceptance testing. It covers not only new stores purchased from contractors, but apparatus repaired in the Post Office factories, and apparatus presented by the Post Office Stores Department for test before re-issue. In the case of new stores the inspection is based on the order issued, either by the Controller, Stores Department (Contract or Depot Orders), or by the Engineer-in-Chief (Engineer's Order) to the manufacturers for the supply of the goods.

This order includes reference to the necessary specification which furnishes details of what is required, and goods are approved or not approved according as they comply or do not comply with the specification. If they are not approved the reason must be stated clearly with reference to some part or parts of the specification, so that the supplier may see by reference thereto in what respect he has failed.

It may happen that the goods in question fail to comply with the specification in some minor points, but would be satisfactory in use. In these cases rejection may not be insisted upon, but a warning given to the contractor to rectify the defects in future deliveries. If, for example, urgent work is being held up for delivery of the goods, it may be worth while to accept them in spite of minor defects. Acceptance on grounds of urgency of goods *which would otherwise be rejected* is, however, strongly to be deprecated, as it tends to open a way to unscrupulous suppliers to get goods of low quality accepted, and may even result in a supplier who gets behindhand with deliveries being rewarded by having goods accepted which would otherwise be rejected. In the case also of defects which are not material, but which would entail an expense to put right quite out of proportion to their importance, the fair course is to give a warning instead of to reject. Generally, every effort is made not to penalise suppliers unduly for minor defects. It must be remembered, however, that any relaxation (however slight) at the time of acceptance testing, of the standard defined when tenders were invited, may entail unfairness to scrupulous tenderers whose prices, while higher, may have covered a better article.

In the case of stores repaired in the Post Office factories the examination is directed to find out whether the goods as repaired are fit to be passed to stock. The inspecting officer has a copy of the repair specification (major or minor) detailing the work which the factory has been required to do. He also has the Post Office standard specification for the new item and records of any decisions of allowances which may be made on specified dimensions, electrical performance or other features of repaired apparatus compared with new items. With few exceptions the electrical performance of repaired apparatus is equal to that of new, but allowances are made on certain dimensions for wear, and minor differences in design are ignored.

In the case of apparatus presented for test before reissue the examination is again directed to find out whether the goods as returned by the engineer are fit to be passed to stock. The Post Office specifications are employed as a guide, the performance tests for new goods being applied. Discretion is exercised regarding minor differences in design, finish, etc.

If it were unnecessary to take any account of economy of time or labour, acceptance testing would consist of taking each item and subjecting it to a series of tests to ascertain whether or not it complies with every individual requirement of the specification. This is, of course, not possible in practice. For instance, the specification for a telephone relay may require the apparatus to pass a series of seven or eight electrical tests as well as a protracted heating test, and, in addition, there will be the requirements for contact pressure, contact clearance, and " follow " of springs to check, involving a number of careful measurements. Consideration of economy in time or labour make it impossible to do all these tests where large numbers are concerned. Acceptance testing thus resolves itself into the problem of making reasonably sure, with the least possible number of tests, that supplies are up to standard, and making these tests as simply applied as possible. If the performance of unnecessary work is to be avoided on the one hand, and the issue of defective goods is to be avoided on the other, constant vigilance and the exercise of judgment are necessary. The number of tests applied is reduced to a minimum according to the foregoing principles, thus :—

(*a*) *Priority examinations.* The first delivery under the contract or (where the first delivery consists of a large number of units) six samples taken haphazard from the bulk, are subjected to a searching examination and test, covering all points in the specification. Dimensions are carefully checked to drawing, materials used in the make-up are tested for quality, and complete electrical performance tests are made. This is known as the "Priority" examination. During this examination a careful report is prepared in which are noted all deviations from the pattern or specification, and in which attention is called to any details that may require special checking in the routine test. When the priority samples have been approved, the priority report is associated with the contract for the guidance of the inspecting officers who will do the routine examination and tests.

If the priority examination shows the goods to be of good quality and in accordance with the specification, the remainder of the bulk may safely be subjected to a shortened examination and test. As an example of the extent of a priority examination the following list shows the points to be checked and the tests to be made during the priority examination of a "Cord, Instrument, No. 362, waterproof":—

1. *Lengths.*
   (*a*) Effective length of cord.
   (*b*) Length of conductors.
   (*c*) Lengths of main and conductor bindings.
2. *Diameters.*
   (*a*) Diameter of loops.
   (*b*) Overall diameter of cord.
   (*c*) Diameter of binding wire.
3. *10 lb. pull.* Strain cord and tags subjected to 10 lb. pull.
4. *Colours.* Colours of outer braiding and conductor coverings checked against standard.

5. *Continuity.* Buzzed through, colour to colour.

6. *Insulation Resistance.* Tested with 500 volts after immersion in water for one hour.

7. *Lay.* Length of conductors checked. Cord dismantled.

8. *Outer braiding.* Kind of cotton checked, number of ends, number of spindles counted. Tested for breaking strength and percentage elongation.

9. *Outer cotton lapping.* Kind of cotton and colour checked, number of ends counted. Tested for breaking strength and percentage elongation.

10. *Rubber lapping.* Lay and overlap checked. Radial thickness measured.

11. *Inner cotton lapping.* Kind of cotton checked, number of ends counted. Tested for breaking strength and percentage elongation.

12. *Conductor.* Electrical resistance measured. Visually examined for uniformity of stranding and freedom from any tendency to kink, spring, or untwist. Overall diameter measured. Tested for breaking strength. Tinsel threads examined for smoothness and uniformity of copper tape, and evenness of spiralling.

Conductor tested for durability by being gripped in chucks $\frac{7}{8}''$ apart, the chucks being made to approach each other to a distance of $\frac{3}{8}''$ apart and then recede to their original positions. The speed is 500 reciprocations per minute and each test consists of 50,000 reciprocations. After the test the tinsel threads are separately tested for continuity. The number of broken threads must not exceed 5% of the total number of threads subjected to the test.

13. *General.*

Direction of consecutive strandings, lappings or twists checked to see that they alternate in direction. Cottons chemically tested for neutrality and loading material.

Coloured cotton submitted to six hours dry heating at 230° to check the constancy of colour.

The priority examination in this as in many other cases involves the destruction of at least one sample to enable the materials to be tested.

The priority examination also enables the contractor's attention to be drawn early to any serious departure from the terms of the contract and thus prevents as far as possible the discrepancy being continued in supplies that may be in process of manufacture. For this reason priority reports are prepared and dealt with as expeditiously as possible and preference given to them over the normal work.

(*b*) *Shortened tests.* When the priority examination has been made with satisfactory results, bulk supplies are subjected only to those tests which are considered necessary to make reasonably sure that faulty goods will not get into stock. These tests are normally directed to ascertain whether the item will function satisfactorily when put into use. The extent of these tests is determined by supervising or controlling testing officers who, for this purpose, require a knowledge of the use to which the item is put, and exercise their judgment accordingly. For instance, a telephone relay will have a large number of requirements enumerated in its specification, *e.g.*, resistance, operating, non-operating, saturation and releasing currents, heating test, contact pressures, contact clearances, etc. For well manufactured bulk supplies, however, it may be quite sufficient merely to see that each relay operates satisfactorily at the specified current and releases after saturation.

(*c*) *Percentage Testing.* A further step in reducing the number of tests is made by testing a percentage only of the delivery instead of each article. This would be done only in the case of supplies from a manufacturer of good reputation where a uniformly high standard could be relied on. There is always some risk here of putting to stock an article which will not function when issued. Consideration must therefore be given, before deciding on percentage testing, not only to the intrinsic value of the article but also to the consequences to the Post Office, of the issue of a faulty article. If, for example, there is a chance of a faulty article being undetected until expense has been incurred in wiring or other work on it, or if a fault may give rise to an expensive maintenance journey, or expose other plant to risk of damage, it is worth while spending more money on testing than the intrinsic value of the article would warrant. If, however, in the case of a low-priced article a fault would be likely to be detected at once by the fitter and the article discarded, it is wasteful to spend money weeding out *a few* faulty items from a delivery. In other words, the risk of overlooking a few faults must be taken for the sake of economy, provided always that the risk is slight and that the saving on testing is a true economy and is not rendered of no effect by a possible loss subsequently.

In the case of large works where systematic factory and engineering inspection is carried out by manufacturers, the necessity for routine testing by the Post Office staff of bulk supplies may be avoided by relying on the manufacturer's tests for routine check of individual items, the Post Office inspecting officer being supplied with details of the firm's testing instructions and being permitted to watch the tests and satisfy himself that the necessary tests are being properly applied. If it is necessary the inspecting officer may make a snap check of any of the items passing through. This method relieves the testing staff of the necessity of undertaking a mass of routine tests such as conductor resistance, insulation resistance, impedance and impedance balance, figure of merit of relays, gauge of material, contact pressures, contact clearances, etc., and enables the Department to employ a smaller staff and at the same time to be satisfied that the specifications are being followed and the workmanship reaches a satisfactory standard. When this method is employed Post Office inspection is also applied at two other points during manufacture, (1) at the raw material and small parts stage, and (2) final inspection of the finished article prior to despatch.

Under (1) samples of raw materials and small parts may be taken by the inspecting officer for test and examination to see that they are of satisfactory quality and suitable for the purpose required. Where metallurgical or chemical tests are required the samples are sent to one of the Post Office Engineering Department's laboratories at London or Birmingham for test. By this means a check is kept on such items as insulating materials, contact metals, wire for coil-winding, etc., which either could not be checked at all at a later stage or only by destroying the finished item.

Under (2) one or more of each type of finished article supplied is subjected to a thorough check inspection similar to the priority examination described above, during which every detail is checked to the Post Office specification and drawings. Care is taken especially to see that all apparatus is of the latest approved type, that markings are correct, and that no novel or obsolescent apparatus has been included without authority.

The system of inspection described above has been applied in practice on a large scale, mainly to exchange equipment orders. These orders differ from ordinary stores contracts in two ways which bear on the present discussion:—

(1) The contractor is responsible for installing the apparatus, and making it work at the exchange, and it will not be accepted until it does work, whereas, in the case of stores contracts, the contractor's responsibility ceases when the goods are accepted and passed to stock.

(2) Exchange equipment contracts are confined to large firms which provide systematic factory and engineering inspection as a matter of routine.

As regards (1) there is nothing in this point to prevent the Department relying on the manufacturer's tests for routine check of bulk supplies, provided his system proves efficient enough on inspection and by experience. In practice, for example, a considerable economy in routine testing is effected by accepting the manufacturer's test figure for a large proportion of the capacity out-of-balance tests made on trunk cables bought under stores contracts, and for a large proportion of the impedance, effective resistance, out-of-balance, and cross-talk tests made on loading coils supplied under stores contracts. Porcelain insulators too are tested by the makers and distributed from works, snap checks only being made by the Post Office staff.

As regards (2), however, orders for goods generally cannot be restricted to manufacturers possessing an approved inspection routine of their own, as this would restrict competition, or—in the case of a number of minor items not generally manufactured by large concerns—make it impossible to get the article at all. This appears to form under present conditions a real bar to any substantial extension of the inspection system under consideration to other items obtained under ordinary stores contracts. If, however, the present tendency of manufacturing industry to become organised into big units continues, an extension of the system of combining, so far as routine testing is concerned, the purchasers' tests and the manufacturers' tests is to be expected, and in the author's opinion opportunities to do this should be watched for and taken where practicable.

When the tests to be applied have been decided on, the next step is to arrange matters so that these tests can be applied in the most convenient manner possible, delay being avoided in connecting up apparatus for test and setting up for various testing conditions. For this purpose, when there is more than a small number to be tested, special jigs or clips are provided for rapidly connecting up apparatus for test, and the various testing conditions are applied by means of change- over keys suitably wired, by plugs and jacks, etc. Arrangements are made for feeding the goods to the testing position (after unboxing and any other necessary preparation) at the right rate and removing them afterwards. The extent to which arrangements like this are made depends on the number of the same or similar items to be dealt with. For a steady job likely to last some time, permanent or semi-permanent positions are set up, while, for a smaller number, temporary sets are constructed with apparatus obtained on loan.

The testing work may be done either at the contractor's works or at the Post Office Engineering Department's Testing Branches. In the case of large orders tested at a works, where smooth and uniform production is taking place, the acceptance test is interposed at the end of the assembly " line " after the firm's final examination, and before the goods are boxed or packed. Provided the factory production proceeds without hitch, this arrangement is an extremely satisfactory one. The testing involves the least possible additional handling, storing, packing and unpacking, and introduces the least possible delay in the issue of supplies. The goods can also pass into the test room partially dismantled, as may be required, for easy examination or test. Rejections do not have to be packed but are just handed back to the firm. On the other hand, any hitch in production quickly results in the testing staff being without work and perhaps having to be withdrawn, with consequent expense in fares, travelling time, etc. Allowances are payable to testing staff at contractors' works, which, of course, involve the Post Office in additional expense; but against this must be set off a considerable saving in transport, handling, packing and unpacking. There may also be advantages in storage at, and distribution from, contractors' works instead of from a Post Office main depot, but this is a matter for the Controller, Stores Department, and cannot be discussed here. In any case there is no doubt in the author's mind that where goods are being produced in quantities by modern production methods, the point at which routine acceptance testing of bulk supplies can best be carried out from the point of view of speed, convenience, economy in handling and the minimum of interference with the normal course of supply, is at the factory. The foregoing only applies fully when the production is continuous, as is the case usually in up-to-date assembly shops. Where production takes place spasmodically in batches, a great part of the advantage is lost. If the testing work is done at the Department's Testing Branches arrangements are made in cases when many items are involved, for permanent testing positions to be set up and for the goods to be passed steadily to the testing positions at the right rate. The work does not come in continuously, but in batches; some storage accommodation is needed for the work waiting test; some delay due to testing is introduced; and the goods have to be unpacked for test.

The testing work which comes in sufficiently steadily and in sufficiently large quantities to enable what may be called " mass production " methods to be applied to acceptance testing, forms only a small proportion of the whole. The bulk of the work still consists of a large number of comparatively short jobs, rather than a few large steady ones, and, moreover, the rate of flow of work, so far from being steady, fluctuates within wide limits from week to week. For example, the average amount of work represented by each " Test Report "* received at the London Testing Branch is only 1 to 1½ man-days, while the weekly inputs vary up to 16% above or below the long-period average. To cope with the widely varied work, testing positions equipped with sets designed for a multiplicity of tests are necessary, the Combination Testing Set described in Technical Instruction VIII being an example. This set provides by means of dial switches for the ordinary electrical tests of simple apparatus items, such as relays, indicators, generators, bells, etc. The uneven rate of input involves the provision of temporary storage accommodation in association with the test rooms, and also involves a definite delay while goods wait their turn. These are evils which cannot be avoided under existing conditions, but can be mitigated by careful planning to allow of an easy flow of goods through the test rooms and by keeping

* *Note.* Some of these represent the same or similar items which can, of course, be grouped, but the effect of this is not sufficient to alter the general statement in the first part of the preceding sentence.

entirely separate space (*a*) for receiving goods for test, storing them while they wait test, unpacking them and laying them out in a form convenient for feeding to the testing officer as he requires them, repacking them and passing them out, and (*b*) for test benches, testing plant and accommodation for officers actually engaged on testing. By this means the dust and litter necessarily associated with packing and unpacking is not allowed to affect the testing apparatus. The only stores in the actual testing space are those in process of test and no packing material is in this space.

Ancillary functions of the acceptance testing organisation.

Acceptance testing serves the purpose not only of securing that unsatisfactory goods do not get into stock or use, but also:—

(1) Of acquiring information for the checking and overhaul of stores specifications referred to in an earlier part of this paper.

(2) Of watching especially the progress of orders placed with firms who are new to Post Office work (or of orders for goods which a firm has not supplied to the Post Office before) so that a decision can be taken whether the firm shall continue to be invited to tender for the item concerned.

As regards (1), the tests made on new stores supplied by contractors automatically bring to light, by rejection or threatened rejection of the goods, cases where the standard is such that general difficulty is found in attaining it in commercial supplies. In such cases it is generally worth while to make an investigation to decide whether the supplier's difficulty is a genuine one and if so, to consider whether the standard can safely be lowered, or the matter adjusted by other means such as a modification in design.

Cases where the specified test requirements are such that they can be met with a very large margin are also disclosed by the acceptance tests and such cases should be studied to determine whether the tests should be made more stringent or alternatively—if the original standard is high enough—whether a cheaper material or design should be substituted. It is unsatisfactory, generally, to have a standard specified which can be too easily reached, as it is an incentive to unscrupulous suppliers to introduce cheaper or adulterated material or to make unauthorised modifications in design, relying on the lower price to get them the order and on the need for the goods and the fact that they will pass the test, to get the goods accepted. The effect is to nullify genuine competitive tenders.

As time passes, also, manufacturers change their methods, new or improved processes are introduced, fresh materials are employed, trade descriptions fall into disuse or change their meaning. All these things have some bearing on the specification and information about them acquired by contact between the manufacturer and purchaser during the acceptance testing work will be valuable when the specification is next reviewed. It thus forms an important part of the function of the acceptance testing organisation to use its necessary contact with suppliers to help to keep the specification up to date.

As regards (2), orders placed with contractors new to Post Office work, or orders placed for goods of a class which the firm concerned has not supplied to the Post Office before, are usually placed as trial contracts and a special report on each of these contracts (based on the experience acquired from testing the goods) is furnished. This report, in addition to giving particulars of deliveries, quantities rejected (if any), and reasons for rejection, deals specially with the question whether the supplies have proved to be up to the Post Office usual standard of workmanship and finish. Where the early supplies under a trial contract show that the Post Office requirements have been imperfectly understood, special pains are taken by the testing staff, by personal explanation or demonstration, to make the requirements clear and to help to overcome the difficulty. This policy helps to bring along new sources of supply and thus promotes competition.

Testing samples submitted with tenders.

In the case of certain goods it has been found advisable—in order to make sure that suppliers understand quite clearly exactly what is required and to avoid misunderstandings and possible disputes later—to require samples showing the goods or materials offered to be submitted with the tender. These samples are then examined by the testing staff in order of price, commencing with the cheapest and carrying on until sufficient satisfactory samples have been found to meet the requirements. The regulations require that a sound reason be given for passing over any sample which is as cheap as, or cheaper than, the recommended sample or samples. Samples with tender are usually required in the case of electric light fittings, tools, oils, paints, varnishes, rubber goods, hemp and manilla ropes, and a large number of miscellaneous materials, compounds, and small stores.

(4) TESTS IN USE AND TESTING METHODS.

In the following section it is proposed to deal with the work of acceptance testing as carried out in accordance with the general principles outlined in the earlier part of this paper. Instructions on the testing of the main classes of engineering stores have been or will shortly be issued under the title "Acceptance tests," as part of the new loose-leaf series of Post Office Engineering Department Technical Instructions. Reference should be made to these for detailed information of the tests and examination of various classes of stores. It is proposed here to indicate briefly the classes of tests which are made, and to discuss those which possess special features of interest or importance. Where possible, standard or commonly known and accepted methods of test are employed, and no description of these will be necessary here.

The chief classes of tests which are made as part of the normal work of acceptance testing of engineering stores are as follows:—

(1) *Physical tests.*

Size and dimensions. Standard methods of measurement are employed to correspond to the accuracy required. Limit gauges are obtained and used wherever the amount of work justifies it. Optical comparators are now much used for checking dimensions where close limits are required and large numbers of parts have to be dealt with. Their application lies rather in factory than in acceptance testing, but they are useful for checking such dimensions as receiver diaphragm thickness, etc.

Specific gravity. This is often of considerable importance, *e.g.*, in oils, turpentine, ebonite, etc., and is estimated by the usual methods—S.G. bottle, hydrometer, etc.

Porosity. The porosity or water absorbing tendency of many materials has to be checked as an indication of the quality. Examples are the porcelain of which insulators are made, the stoneware of which ducts are made, synthetic resin-varnished paper board, etc. There is no generally accepted method of test and particulars must be given in the specification for each case. These particulars should lay down the form of the specimen to be tested, the treatment before initial weighing, the period of immersion and temperature of the water, and the treatment after removal from the water before final weighing. Testing is done according to the methods specified.

Viscosity. Viscosity is an important characteristic in a number of oils, varnishes, etc. As regards oils the viscosities are generally expressed and specified as a stated number of seconds by Redwood Viscometer. This is an arbitrary standard which has come into general use throughout the petroleum industry. The stated number of seconds represents the time occupied for a brass oil cup, of carefully defined dimensions and filled to a specified level, to empty itself through an agate jet of stated size in the bottom of the cup. The temperature must be carefully controlled and a water bath and stirring arrangements are included. A full description of the instrument and details of the precautions to be observed in its use are given in B.S.S. No. 148, Appendix V. Each instrument used for testing supplies is submitted to the National Physical Laboratory and checked for dimensions, etc., as well as being subjected to a flow test in comparison with a standard reference viscometer at the Laboratory.

Although the Redwood and other types of efflux viscometers have given good service commercially in checking viscosities of liquids—especially oils—they suffer from the disadvantage that they do not give the viscosities in fundamental (*i.e.*, length, mass, time) units without the employment of conversion tables or formulæ. Thus, results from different types of efflux viscometers cannot be compared directly, and discrepancies in the results, when calculated to fundamental units, are not uncommon. Accordingly, particulars have been standardised and published as B.S.S. No. 188, of a tube and a falling sphere viscometer by means of which the coefficient of viscosity of a wide range of liquids can be determined in C.G.S. units. In the tube viscometer, which is suitable for liquids the viscosity of which does not exceed 1500 centipoises,* the viscosity coefficient is deduced from the time taken for a measured quantity of liquid to flow through a tube. In the falling sphere viscometer the viscosity is deduced from the rate of fall in the liquid of a sphere of known diameter and density. Both types are fully described in the B.S. Specification referred to above. In the newer specifications viscosities are quoted in poises or centipoises and reference made to B.S.S. No. 188 for the method of measurements.

Hardness. The hardness of materials is often required to be checked, *e.g.*, tools, stamping machine parts, jack springs, etc. Hardness is usually specified by the Brinell hardness number. This number is arrived at by pressing a hardened steel ball on the surface to be measured. A ball of specified diameter and a stipulated suitable load are used. and the diameter of the impression made is measured. The Brinell hardness number is defined as the quotient of the applied load divided by the spherical area of the impression, and is obtained readily from tables published in B.S.S. No. 240, which also contains details of the precautions required in testing to obtain concordant results.

Refractive index. This is an important characteristic in the case of certain liquids such as turpentine, varnishes, oils, etc., where the refractive index measurement is used as an indication of the purity, as a means of analysis, or as a means of detecting a change of quality in supplies. For acceptance testing purposes the refractive index is checked by means of one of the usual types of refractometer, *e.g.*, the Abbè refractometer.

Melting and boiling points. These again are of importance in the case of a number of solids and liquids, *e.g.*, compounds, waxes, petroleum jelly, petroleum, turpentine, etc. Recognised methods are used for their determination. For lubricating oils which become jelly-like at low temperatures a special " pour " test is used to ensure that the oil will not freeze up completely in cold weather. A $\frac{3}{4}''$ test tube is half filled with oil and cooled to a specified temperature ($-10°C$ or $-5°C$ generally) for half an hour. The oil is required to flow when the tube is laid horizontally.

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* The centipoise = 0.01 poise, the poise being the fundamental unit of viscosity in C.G.S. (centimetre-gram-second) units. A detailed definition is given in B.S.S. No. 188, referred to above.

Flash point. The flash point, or the temperature at which a liquid commences to give off inflammable vapour, is frequently specified in the case of oils, etc. The flash point is determined by heating a specimen of the oil in a brass cup provided with a stirrer and a lid furnished with orifices which can be opened and closed by means of a shutter. A test flame consisting of a small gas jet is arranged so that it can be lowered and applied to the orifices at will. As the oil heats up, application of the test flame is made at stated intervals of temperature until a distinct flash is seen in the interior of the cup. The reading of the thermometer when this flash is seen is taken as the flash point. In order to obtain concordant results every detail of the apparatus must be standardised, and the procedure in using it carefully laid down. Details such as the size of the test flame, the time of application of the flame to the orifice, the rate of temperature rise of the oil, etc., all have an effect on the result. The apparatus commonly used is the Pensky-Martens closed tester which conforms to constructional details laid down by the Institution of Petroleum Technologists and carried into various B.S. Specifications, in which also the procedure for making a test is carefully laid down.

Calorific value. This is an important feature in the case of fuel oils, and a minimum value is specified. Samples are tested in one of the well-known bomb type calorimeters in which combustion in oxygen takes place in a closed steel "bomb," the mixture being ignited by an electric spark, and the heat evolved being computed from the rise in temperature of the surrounding water, in accordance with the usual methods.

Tensile tests. The ultimate tensile strength and elongation at breaking point are specified for a large number of materials, *e.g.*, iron and steel for various line stores and tools, iron, copper and bronze wire, cotton and silk for wire covering, rubber, etc. The tensile tests of iron, steel and line wire present no special features and need not be further discussed here. In the case of cotton and silk threads, however, concordant results can only be obtained if the specimens are tested in a stated condition of humidity, and if the testing length and speed of traverse of the machine are stated. It is desirable also for the material to be clamped in position in the machine under a fixed initial tension. It is necessary, therefore, for these points to be defined in the specification and to be given attention in testing.

For conditioning specimens for test, it is usual to subject them to a controlled atmosphere of a known relative humidity, within a stated temperature range for a stated minimum period of time. One way of doing this is to use a cubical box with sides about 24 inches long. The floor of the box is nearly covered by a tray containing lumps of common salt which are kept moist. The samples of material to be conditioned are placed on a shelf, or suspended over a shelf half way up the box. Air is circulated by means of a small fan over the tray, up through holes cut at two corners of the shelf, over the samples and down through holes at the opposite corners of the shelf. This arrangement gives a relative humidity of about 75% over a fairly wide temperature range. For more precise work, arrangements may be made for thermostatic temperature control and the relative humidity may be maintained by means of a dish of sulphuric acid of the appropriate concentration.

In the case of tensile tests of rubber, no conditioning is necessary, but the rubber is required to be kept at between 65° and 75°F. for 12 hours preceding the test. The rate of traverse of the machine must be laid down, and is usually 10-20 inches per minute. To hold the specimen special jaws with eccentric grips must be used. In addition to specifying the minimum elongation at break, a maximum limit is placed on the *residual* elongation six hours after break, as this is an indication of the material's power of recovery after stretching. Rubber is also required to comply with certain tensile and stretch tests after exposure to a dry heat of 270°F. for two hours, or to a moist of 320°F. for three hours.

In the case of hemp ropes the breaking load of the rope is dependent on its condition as regards humidity. Instead, however, of including in the specification detailed instructions for conditioning the rope, it has been found sufficient to specify not the breaking weight of the rope but a figure (K) which is the quotient of the breaking weight divided by the weight per fathom. This allows in a rough and ready way for small variations in the water content of the rope, and has worked well in practice. Some discretion has to be used as it was found some years ago that, if ropes were allowed to get too dry before test, they might fail where they would have passed in a slightly more moist condition. Hemp rope is bought by weight, not by length, so that the system of testing described above has a useful effect in preventing the delivery of ropes unduly loaded with moisture, and so saving the Post Office from paying hemp prices for water.

Compression tests are made on cement concrete cubes, bricks, etc. In the case of concrete cubes cast on work in the Districts and sent in for test, the date of casting must be stated so that the cubes can be tested after appropriate periods of ageing.

Photometry. Tungsten filament lamps are purchased to B.S.S. No. 161, which lays down among other things limits for the total light flux in lumens and for the efficiency in lumens per watt of each type of lamp. The total light flux from a lamp can, of course, be computed from a number of measurements of candle-power taken in different directions round the lamp. This method is very cumbersome, however, for commercial or routine testing, and in the days of the straight filament vacuum lamp a quantity called the mean horizontal candle-power was specified. This quantity could be obtained by one reading on an ordinary photometer bench, the lamp being continuously turned about a vertical axis during the test. The advent of the gas-filled lamp rendered the mean horizontal candle-power meaningless, and the use of an integrating sphere or cube in association with the photometer is now general. The integrator consists of a sphere or cube painted white inside and furnished with a small ground glass window. The photometer head and bench are arranged outside the integrator as for measuring the luminous intensity of the window. If now a photometric balance against a reference lamp is obtained (a) with a lamp of known total flux in the integrator and (*b*) with the lamp to be checked in the integrator, a direct comparison of the luminous intensities of the window in each case is obtained. Experiment has shown that if certain precautions are observed the ratio of the luminous intensities of the window is a true measure of the ratio of the total light fluxes of the lamps. By this means, therefore, batches of lamps of similar type can be rapidly checked for total light flux and, (if the electrical input is measured at the same time), for efficiency. The integrating cube must be large in comparison with the source of light, a metre cube being used for lamps and a two-metre cube for larger sources such as various fittings. The window must be shielded from direct rays from the source under test. Particulars of the internal surface coating of the integrator and other details will be found in B.S.S. No. 354—Photometric Integrators.

The integrating cube is also used for efficiency tests on illumination fittings. By making two tests, one with a bare lamp and one with the lamp inside the fitting, an idea of the total loss of light flux due to the introduction of the fitting can rapidly be obtained. In making these tests the fitting must be in the integrator during the bare lamp test, the lamp and fitting must be placed symmetrically with respect to the window during the bare lamp test, and, during the test with the lamp inside the fitting, the position occupied by the lamp for the bare lamp test must be occupied by another similar lamp—not burning, of course.

(2) *Chemical tests.*

Chemical analysis or chemical examination is made as part of the acceptance tests of a very large number of materials. The tests include:—

(*a*) Qualitative tests for the presence or absence of ingredients or impurities in compounds and mixtures, *e.g.*, chlorides and sulphates in distilled water, copper and cadmium in tinsel, platinum and gold-silver contacts, lead in enamel of signs, etc.

(*b*) Estimation of percentage of constituents or impurities in materials. For example, analyses are made of tool steels involving the estimation of the various impurities which affect the use of the steel for the purpose required; the tin is estimated in supplies of solder; the antimony or cadmium is estimated in samples of alloy sheaths; impurities such as iron are estimated in supplies of zincs for Leclanché cells. The estimations are made by gravimetric or volumetric methods, according to the particular item and the circumstances.

(*c*) Examination of various organic mixtures and compounds for identification of ingredients and/or impurities or adulterants and estimation of quantities present. Turpentine, for example, is tested for adulteration by petroleum spirit, etc., the various compounds and mixtures stocked by the Post Office (*e.g.*, "Compounds," Nos. 5, 6 and 7, "Mixture," No. 2, etc.), are tested to see that the specified ingredients are there and in the right proportions.

(*d*) *Tests for chemical neutrality of textile fibres.* Apart from the fact that natural fibres may be appreciably acid or alkaline, many manufacturing processes make use of comparatively strong acids or alkalis. Although a washing process usually follows it is not always easy to make the material quite neutral and it is necessary to check this point in the case of cotton and silk for telephone cords, etc. Acidity or alkalinity in this case is objectionable, partly on account of the decrease it brings about in strength and resistance to wear, and partly on account of the danger of setting up corrosion in the conductor where the fibre is in contact therewith. The specification for cords requires the cotton and silk to show no acid or alkaline reaction on litmus paper moistened with distilled water. This is an extremely sensitive test and a strict enforcement would result in heavy rejections and (probably) increased prices for cords. Further, there does not seem any necessity for insisting on absolute neutrality to moistened litmus, as numbers of cords in which the cotton or silk showed a *faintly* acid reaction to moistened litmus have been put into use at various times without complaint. The question of permitting up to a certain stated degree of acidity is accordingly being considered. The accurate determination of small amounts of acids in textiles is, however, not an easy matter technically, and the quantitative definition required, once the firm ground of strict neutrality is abandoned, is not easy. It seems clear, however, that it is the intensity of acidity or the hydrogen ion concentration, rather than the total acid, that is a measure of the corroding and deteriorating effect. A determination, by means of one of the modern comparator methods, of the pH (hydrogen ion concentration) value of an extract of the fibre, made under carefully defined conditions, seems a possible solution.

(*e*) *Tests of vulcanised india rubber for cables, etc.* These tests include extraction with acetone to estimate the rubber resins present and hence the quality of the caoutchoue used; estimation of the free and combined sulphur to see that the rubber is correctly vulcanised; and estimation of the loading material to see that this corresponds to the grade of rubber ordered. Until recent years V.I.R. was produced only by the addition of about 5% sulphur to the raw rubber and subsequent vulcanisation. The value of the V.I.R.

could then be accurately appraised by the chemical tests. Now, however, organic compounds termed accelerators and anti-oxidants are being added, the former to reduce the time occupied in vulcanisation and the amount of sulphur needed, and the latter to increase the life of the finished product. Well vulcanised I.R. is produced in a shorter time and with less combined sulphur, and further, each accelerator, and probably each different amount of accelerator, has a different amount of combined sulphur for the "optimum cure." It is thus becoming difficult to draw firm deductions from the sulphur estimations. Further, both accelerators and anti-oxidants may come out in the acetone extract and give a false idea of the quality of the caoutchone used. In appraising a V.I.R., therefore, the chemical analysis results must be considered in conjunction with the physical tests (breaking load, elongation, and heat tests).

(3) *Electrical tests.*

Insulation resistance. The insulation resistance of most apparatus is specified at 250 or 500 volts, and it is usually checked by means of a megger or megohm-meter, *i.e.*, a megger with the generator replaced by a 250 or 500-volt supply from outside. A motor drive is used for the megger when it is in use for long periods, but this is noisy and inefficient, and a voltage supply from outside is arranged wherever possible. A great disadvantage of this test, when large numbers of things have to be dealt with, is the absence of an audible signal to indicate low insulation. What is wanted is an apparatus which will give a buzzer or bell signal when the insulation resistance connected across its test terminal falls below the value to which it is desired to test as a minimum. The apparatus should be capable of being easily set to indicate minima of from (say) 5 megohms up to 1000 megohms. A test has been tried in which the leakage current in the dielectric is made to flow through a high resistance connected between the grid and filament of a thermionic valve, thus altering the grid bias, and (when the leakage current reaches the limiting value) causing a relay to operate by reason of the change in the plate current. If an adjustable potentiometer is also included in the filament grid circuit, this can be set to give different initial grid bias, and thus cause the relay to operate at different values of dielectric current corresponding to different insulation resistances.

The potentiometer scale can then be graduated in megohms. The method proved fairly successful in trial, but there were several disadvantages, *e.g.*, the need for frequent checking of the scale, and for providing grid, filament, and plate supply for the valve. The method has not therefore been used in practice. Rapid checking of the scale could, of course, be arranged for by providing a key to bring in a known high resistance for test. No doubt also a set could be developed with a " mains " valve so that with further work a set quite useful to the Post Office may be produced.

Where a rapid check is required and it can be fairly assumed that the insulation resistance is satisfactory, apart from actual faults, a ringing generator and a 1000-ohm magneto bell in series are used. This, of course, gives an audible signal, but only with a fault resistance of about 50,000 ohms or less.

For condensers and cables, where electrification is an important factor and has to be watched, a battery and mirror galvanometer are still used in acceptance testing.

Telephone plugs are tested as a special case with a P.D. of 500 volts alternating, applied between tip and ring, tip and sleeve, and ring and sleeve. This test discloses incipient faults due to the presence of brass dust inside the plug. This is in the nature of a proof test and not a measurement of insulation resistance. Proof tests are also made on other articles, *e.g.*, india rubber gauntlets and transformer oils, the former being required to withstand an alternating voltage of 13,000 for 15 minutes without breakdown, and the latter an alternating voltage of 30,000 for one minute between electrodes 13 m.m. in diameter and 4 m.m. apart.

Conductor resistance. For routine check of conductor resistance direct reading ohm-meters are employed. The Wheatstone bridge is much slower and is used only where greater accuracy is required and especially for tests of line wire and conductor resistance of cables. For cables where a maximum conductor resistance out-of-balance is specified, the testing circuit is arranged so that the unbalance can be read directly from a graduated scale as a percentage of the loop resistance.

Capacity. The capacity of condensers is checked by a D.C. discharge method in the case of the metal-cased condensers for ordinary telephone work. For mica condensers and certain types of paper condensers, a maximum power factor or minimum impedance angle is specified, and in these cases supplies are tested at 800 p.p.s. on a suitable A.C. bridge. The mutual capacity of pairs in telephone cables is now specified and measured at 800 p.p.s. Trunk cables are also tested at the works for capacity unbalance as part of the works' acceptance tests. This, and the whole subject of telephone cable testing, has, however, been dealt with thoroughly in recent papers before this Institution.*

A rather special case of capacity measurement arises in the case of thermionic valves when a maximum permissible inter-electrode capacity is specified. These capacities are very small and supplies are tested in a specially designed set.

The set contains a radio-frequency valve oscillator with a tuned grid circuit to which is coupled a second oscillator circuit. In this second circuit, valve-holders, connected for the three inter-electrode capacity measurements, are permanently wired in parallel with the tuning condensers. If the natural frequencies of the two tuned circuits are about the same, adjustment over a small range of the tuning condensers in the second circuit will result in this circuit being brought into or thrown out of oscillation. Either event will alter the loading of the oscillating valve, alter the amplitude of the oscillations, and produce a click in a telephone receiver in the anode circuit of the oscillating valve. The test is made by a substitution method, the position of the tuning condensers, when clicks occur in the receiver, being noted, (*a*) before inserting the valve under test in the holder and (*b*) after insertion of the valve. The difference gives the inter-electrode capacity which is of the order of 6-10 m.m.f. The clicks can be brought closer together on the condenser scale by altering the coupling, though this decreases the loudness of the clicks. In practice, they can be brought within 1 m.m.f. on the condenser scale. The difference between reading (*a*) and reading (*b*) is obtained directly by having two variable tuning condensers. One is set to a maximum value and the second is adjusted for reading (*a*) to a point midway between the two clicks. For reading (*b*) the one which was set to the maxi-

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* I.P.O.E.E. Paper No. 138. "Telephone Cable Testing." W. T. Palmer, B.Sc., Wh.Ex., A.M.I.E.E., and E. H. Jolley, A.M.I.E.E.

I.P.O.E.E. Paper No. 144. "Some Notes on the Design and Manufacture of Telephone Cables." F. H. Buckland and R. H. Franklin, B.Sc.

mum value is reduced until the clicks re-appear, the reading being taken at the mid-point again. This condenser can thus be made to read directly the required valve capacity.

Inductance and effective resistance. Limits for inductance and effective resistance (or alternatively for impedance modulus and angle) are specified in many cases, *e.g.*, loading coils, retardation coils, transformers, etc., and supplies are checked in this respect. The specification lays down the testing frequency and the testing current. Most of the testing is done at 800 p.p.s. though in the case of some coils tests down to 50 p.p.s. are required. Tests are made by means of standard A.C. bridge methods which have been dealt with in other papers before this Institution. For the lower frequencies a Westinghouse metal rectifier with a D.C. measuring instrument, such as a Tinsley portable reflecting galvanometer, gives very good results as an indicator, and there is no need for acceptance testing purposes in checking inductance to have recourse to a vibration galvanometer where the telephone receiver cannot be used. Testing at 300 p.p.s. is required for some of the apparatus in connection with the teleprinter exchange service. The effective resistance of loading coils is also checked at 1800 p.p.s, and (in the case of music coils) at 7000 p.p.s., the tests being made at the contractors' works.

Sometimes the impedance is specified by polar co-ordinates (modulus and angle) and sometimes by rectangular co-ordinates (inductance and effective resistance). Wherever possible, bridges which give a direct comparison in terms of the specification are used for checking supplies. Where this cannot be done, means of conversion must be provided. For this purpose the Davis-Grinsted slide rule is in use and proves very convenient.

Efficiency of telephone transformers and repeating coils. It is necessary to specify (and check on acceptance) the efficiency of telephone transformers and repeating coils at speech frequencies and also at ringing frequency, if they are to be used to carry ordinary ringing current. In the past, the efficiencies of these coils have been specified as minimum percentages of output to input at a stated load, and supplies were checked generally by comparison with a " standard " coil. Specifications are now framed to permit (so far as speech frequencies are concerned) a certain maximum decibel loss, to be measured on an approved transmission measuring set. Sets are in use for acceptance testing provided with a 600-ohm attenuator and suitable closing resistance for all the commonly used ratios of transformation. Terminals are also provided for inserting resistance for any new ratio. Thus coils can be rapidly and easily checked for transmission loss before acceptance. Ringing loss is checked generally by specifying a maximum current which will be permitted to pass when a defined ringing voltage is applied to the primary of the coil.

Characteristics of thermionic valves. The internal impedance and voltage amplification factors of valves are usually specified at a fixed operating point. The allowable alteration in impedance due to a stated variation in either the grid bias or the filament volts from the specified operating point is also commonly specified. The mutual impedance and voltage amplification factor are measured by an adaptation of the " Appleton " tests, a small A.C. source at 800 p.p.s. being used instead of the battery, and a telephone receiver instead of the galvanometer. For dealing rapidly with large supplies, a test set is provided which gives facilities for inter-electrode capacity measurements, for the two Appleton tests for impedance, and also for measurements of total emission, reverse grid current, etc. As most specifications give limits for impedance variation at two points of grid bias above and below the normal operating point, the set provides for three values of grid bias to be set and obtained as required by means of keys. While one valve is being tested, the one to follow is under current in a separate " heater " holder so as to get properly warmed up for the test. Keying arrangements for giving the connections for the three inter-electrode capacity tests have been found unsatisfactory owing to the stray capacities introduced, and it has proved necessary to provide three valve holders permanently wired with well separated wiring to give the required conditions.

Volume efficiency of transmitters and receivers. Every transmitter and receiver is checked for volume efficiency before it goes to stock. Volume efficiency for the purpose of acceptance testing means in the case of transmitters the ratio of electrical output to acoustic pressure input, under stated conditions of electrical loading and using a carefully defined " mixed " acoustic pressure input. The electrical conditions are those under which the transmitter is normally used in practice. The acoustic pressure input (obtained from a loudspeaker fed with a special mixed frequency electrical input) is designed to give about the same effect as a human voice. The result is that what is checked is, broadly speaking, the loudness of the transmitter in use as it will appear to subscribers. In the case of receivers, the volume efficiency must be checked under suitable and carefully defined conditions of acoustic loading. For this purpose a " dummy ear " is used and the receiver associated with this is tested in the same way as a transmitter.

A description and diagram of the testing set have appeared in the P.O.E.E. Journal* and P.O. Technical Instructions, and need not be given again here. The check in each case is by comparison with a transmitter or receiver of known volume capacity, the set being calibrated at the commencement of testing each day by means of such a transmitter or receiver.

The method of testing outlined above has only been in use for a few years. It has proved a very great improvement on the older test of speaking on a circuit containing the transmitter or receiver under test. Testing is now speedier and very much more uniform in application. Human listeners were liable to tire and thus become affected in judgment of volume.

Frying tests for telephones and transmitters. Up to a short while ago specifications for telephone transmitters merely required them to be not worse than the standard transmitter as regards frying, no quantitative test being specified. It has now been specified in the case of the " Inset, No. 10," that the maximum permissible dissipation of energy in the receiver associated with the transmitter—due to the frying of the transmitter—shall not exceed 0.00015 microwatt. This test is made with the transmitter in the standard circuit with a local line of 35 ohms only. The dissipation of energy due to frying is measured by the voltage across a non-inductive resistance of approximately the same impedance as the receiver at 800 p.p.s., the resistance replacing the receiver for the test. The transmitter may be stabilised by being spoken into before the test and is usually kept under

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* *P.O.E.E. Journal*, Volume 24, Part 1. " The Telephone Instrument Efficiency Tester." A. Hudson, B.Sc., A.M.I.E.E.

P.O.E. Dept. Technical Instructions—Tests and Inspections—Acceptance Tests E1002.

observation for 3-5 minutes. A few "bursts of fry" in excess of the specified maximum are not taken as cause for rejection if each has a duration of less than 3 seconds.

The test is a very slow one and can only be applied to the "Priority" samples and to occasional samples during the progress of the order. The transmitter under test must be in a really quiet place, free from vibration. A specially made box with double walls, the space between being filled with slag wool, and the whole box suspended on an anti-vibration stand, such as is used for mirror galvanometers, is in use for holding the transmitter. Reasonably satisfactory results are obtained with this.

A special valve voltmeter is used to indicate the voltage due to frying. This voltmeter is arranged to have a high input impedance (over 200 ohms) and must be such that sensitivity variations between frequencies of 250 and 2500 p.p.s. are kept to a minimum. Before being used to measure the "frying" voltage due to the transmitter under test, the voltmeter is calibrated in a special circuit in which minute transient currents are produced to simulate the currents due to "frying." In this circuit a wheel about 10″ in diameter and running at about 15 r.p.m. carries 14 three-inch lengths of piano wire fixed to its circumference. The wires rub on a medium file as the wheel revolves and cause an imitation of "frying" currents to be produced. These currents are taken through a transformer to a 0.05-ohm resistance, the current as read on a thermo-ammeter being made 6 m.a. The resulting P.D. across the resistance of 0.3 milli-volt is used to calibrate the voltmeter.

(4) *Endurance or "life" tests.*

Certain classes of stores are subjected to an endurance or "life" test as part of the acceptance routine. These tests are generally included in the specification but they usually take too long to make it possible to detain consignments until the result of the test is known. The procedure, therefore, is to ascertain, by actual test of production samples, that the endurance test is met before the manufacturer is permitted to commence delivery. After this deliveries are not held up for endurance tests, but specimens are systematically submitted to the test during the progress of the order to see that the standard is being maintained. The following are the chief tests under this heading:—

Uniselectors. The specification lays it down that each switch must be capable of operating :—

(*a*) 100,000 half-revolutions of the wipers without any failure or need for readjustment.

(*b*) 1,000,000 half-revolutions without any excessive wear of parts.

Accordingly, samples from supplies of these switches are tested for durability in a special testing circuit where they are put through a constantly repeated cycle of operations consisting of (*a*) hunting to a selected change-over contact on the bank, (*b*) homing from there. The point of change-over from hunting to homing is arranged to be the 5th, 12th, or 20th bank contact, the point being moved systematically during the progress of the durability test, according to a prearranged schedule. Selecting relays, with a special key control, are provided to select the change-over point and enable the alteration of the point to be made easily without the bank wiring having to be touched.

The bank contacts Nos. 5, 12, 20 of the positive and negative arcs of the switches under test are used as testing positions. The same contacts as the " M " arcs are used for making the change-over from hunting to homing. The private arcs are used for the hunting circuit, and also (in the case of non-homing type uniselectors) for homing. Switches are tested in pairs, the sequence of operations, commencing with both switches in the " home " position, being as follows :—

(*a*) Switch 2 hunts to the selected change-over contact.

(*b*) When it arrives there its own driving magnet circuit is broken and relay operations transfer the start earth to switch 1.

(*c*) Switch 1 hunts to the selected change-over contact.

(*d*) When it arrives there its own driving magnet circuit is broken and homing conditions are applied to switch 2 which homes.

(*e*) When switch 2 arrives at the home position homing conditions are applied to switch 1 which also homes.

The sequence of operations is then re-commenced.

In the event of a switch overstepping or failing to reach the selected contact, earth and battery are cut off from the particular pair of switches involved, and an alarm is given. A meter is arranged to operate at every "change-over," *i.e.*, twice per half-revolution of the switches.

Each switch is carefully checked for adjustment before being put on circuit. Subsequently the switches are inspected and, if necessary, cleaned and lubricated after every 100,000 half-revolutions.

At the start of the durability test and at intervals during the run the following tests are made:—

(1) Resistance of positive and negative bank contacts, wipers and wiper feed brushes in series.

(2) Resistance of private bank contacts and wipers.

(3) Microphonic noise test of positive and negative bank contacts, wipers and wiper feed brushes in series.

Tests (1) and (2) are made by the ammeter voltmeter method with the usual precaution for dealing with low resistances. Measurements are taken with 50 m.a. flowing and at each of the change-over points, *i.e.*, the fifth, twelfth and twentieth bank contact.

In test (3) for microphonic noise, the wipers and contacts under test are included in a zero local line connecting a subscriber's instrument (Telephone No. 121) with one end of a double-ended "Stone" transmission bridge. One uniselector of each pair is joined in the telephone line and the adjacent one made to hunt continuously, the observer listening at the receiver of the instrument in the local of which the wipers and contacts under test are included. During listening the transmitters at both ends of the circuit are substituted by 50-ohm resistances.

Facilities are provided for short circuiting the test leads when microphonic noise is heard, and thus for locating the noise either in the wipers and contacts under test or in another part of the circuit. Quantitative estimation of the noise is not possible in this particular method of test, aural estimates —"slight," "medium," "loud"—being given.

Primary cells. In order to make sure that deliveries of Leclanché type cells are capable of giving the required watt-hour output, samples from each delivery are discharged at constant current for 30 hours per week (with not more than six hours continuous discharge per day) until the P.D. between the terminals, measured at the end of a day's run, with the test current flowing, has fallen to 0.90 volts per cell. At this point the useful life is considered to have ended. The P.D. is measured at the beginning and end of each 30-hour period of discharge. The average of these two readings is used for computing the watt-hour output for the 30-hour period. The useful watt-hour output is taken as the sum of the outputs for the 30-hour periods during the useful life as defined above. The discharge rate is fixed for each type of cell, and is of the same order as the normal working discharge current. The test is therefore not an accelerated one, but represents average working conditions. It takes a long time, therefore, to get a result. If this result is below the specified minimum output, a clause in the specification provides for a proportionate allowance to be made in the price of the cells in the particular delivery represented by the samples.

Switchboard lamps. These lamps are required to be capable of withstanding a life test of from 250 to 1000 hours (according to type) continuous burning at normal voltage without decreasing in candle-power more than 25%. Samples from deliveries are subjected to this test to see that the durability standard is being maintained.

Tungsten filament electric lamps. There is a very carefully defined life performance standard laid down in the specification for these, and sample batches are regularly tested to this standard. Each lamp is run throughout the life test in the position specified, and at the voltage which makes the initial lumens per watt equal to the rated value for the class of lamp. The lamps are run until one of three things happens, either (*a*) the average life reaches the value quoted in the specification (1000 hours for most classes of lamps), or (*b*) the lumen maintenance (*i.e.*, the average lumens throughout life expressed as a percentage of the initial lumens) falls below the specified value, or (*c*) the average efficiency throughout life in lumens per watt falls below the specified value. It will be seen that (*a*) concerns the durability of the filament, (*b*) its capacity to continue to give a reasonable amount of light during life, and (*c*) its capacity to refrain from becoming unduly expensive in current during its life. If the average life, lumen maintenance, or average efficiency during life fails to reach the specified standard, the lamps are considered to have failed in the life test. Each lamp in life test is measured for lumens and watts at the test voltage at the commencement and (where the specified life is 1000 hours) at intervals of 100, 200, 300, 500 and 750 hours from the commencement. Thereafter each lamp is tested at intervals of about 250 hours from the last test until it fails. Great care is taken to keep the test voltage constant during life tests, the specification laying it down that the momentary fluctuations must not exceed plus or minus one per cent. Lamps are switched off twice daily for short periods (not less than 15 minutes).

Tinsel for cords. The conductors of switchboard cords are made of special tinsel threads stranded together. The tinsel thread consists of a flat ribbon of cadmium copper evenly spiralled round a soft cotton core. As the conductors of cords are subjected to very hard wear mechanically, a durability test intended to simulate the effect of long use is applied to the conductor, a specimen of which is gripped in chucks $\frac{7}{8}''$ apart, which are arranged to approach each other to a distance of $\frac{3}{8}''$ apart and then recede to their original positions. The speed is 500 reciprocations per minute. The test is applied as a part of all "Priority" tests. It is sufficiently short to enable the result to be known before the consignment is approved or rejected. The test is a very stringent one and only tinsel manufactured with great care will stand it. Up to a year or so back the specification required the conductor to stand 10,000 reciprocations only at a rate of 250 per minute, but it is now possible to get satisfactory supplies of tinsel to stand 50,000 reciprocations at 500 per minute. At this speed great care must be taken with the testing machine to avoid jerk or back-lash, and in order to obtain concordant results it is desirable that each specimen should be inserted in the grips $\frac{7}{8}''$ apart at the same tension or rather with the same (very small) amount of slack to ensure there is no jerk during the test. A good practice is to draw the tinsel finger tight between grips set at $\frac{7}{8}''$ plus 15 mils apart, to clamp up the grips, and then to reset them exactly $\frac{7}{8}''$ apart before commencing the test. At the end of the test each tinsel thread is separated and tested for continuity with a battery and buzzer, a maximum of 5% of broken threads being permitted. As it is possible for the copper ribbon to break without showing electrical discontinuity, due to the ends springing together, the threads are also examined visually under a glass, and any additional breaks found are added to the total.

Paints and Varnishes. The value of paints and varnishes used as protective coatings on external work is checked and compared by means of endurance tests in which the coating is exposed to the weather and examined from time to time in order to trace the progress of breakdown. Tests of this kind are not included in the specification, but are made for the purpose of collecting information on the relative value as protective coatings of different types of paints and varnishes, or on the relative values of different qualities of the same paint. For example, in connection with the protection of fire alarm posts and pillar boxes we are offered various alternatives to the present practice of covering a flat coat of P.O. red paint with a well run coat of good oil gum varnish. These alternatives include various glossy " enamel " paints, and cellulose enamels. A number of these alternatives have been given practical weathering tests. So far only one enamel (which was ruled out for general use by other consideration) and none of the cellulose paints have proved equal to the P.O. red paint and varnish. A large number of cellulose paints have been tested, with, in the majority of cases, very disappointing results, the life being only a fraction of that of the present protective coating.

The results of similar tests carried out on black paint for ironwork (used in the P.O. Engineering Department as well as for the bases of letter boxes) show that good quality bituminous paint is better and more economical than other varieties based on coal tar and petroleum pitch, although the latter varieties are lower in first cost.

Weathering tests by actual exposure are so tedious that accelerated tests have been designed to get a result in a shorter time. One such test which has been applied to exterior varnish films consists of a 24-hour cycle as follows :—

2 hours—panels exposed in refrigerator at temperature of 21°F.

21 hours—exposed to light from two plain carbon arcs enclosed in vita glass. Air temperature .110°F., humidity 50% approximately. During this period the panels are sprayed with water for 2 minutes in every 20 minutes.

1 hour—inspection, changing carbons, etc.

The varnish is brushed on to monel metal panels and is allowed to dry five days before exposure to the accelerated weathering conditions. The panels are inspected daily under a microscope (× 60) during test. The time of appearance of cracking of varnish is noted and thereafter notes are made of the condition from time to time. A definite order of merit for a series of varnishes can be obtained at any time between about 600 and 1000 hours, so that results can be obtained much more quickly than by actual exposure to weather. The order of merit varies rather according to the time at which it is observed. Partly for this reason, and partly because of doubt whether the order of breakdown shown by these accelerated tests is really the same as that which would occur in practice, the accelerated weathering tests—although they clearly pick out good varnishes from poor ones—do not enable a definite choice to be made of the most economical of a number of good varnishes offered at varying prices. If they did this they would prove very useful in dealing with tenders for the supply of varnish, etc., as results of tests on samples could be obtained before the order was placed—an impossibility with a natural weathering test.

(5) *Some special items and tests.*

In the following section it is proposed to discuss a few items and tests which are important or illustrative.

Alloy cable sheaths. Many cable sheaths are required to be made of a lead-antimony alloy instead of pure lead. It has been customary when the cable comes up for test at the works to take a small sample of the sheath and subject it to chemical analysis to estimate the antimony. This involves a delay which in the case of an urgent cable might be serious. As a result of the demand for a quicker test, a method of quantitative spectrographic analysis introduced a few years ago was developed at the P.O. Research Station, Dollis Hill, and adapted to this particular case, and is now used as a check on the composition of lead-antimony alloys supplied as cable sheaths to the Department. The method depends on the discovery recently that, given a standard method for exciting the spectrum, the intensity of a spectral line due to a minor constituent (such as antimony in a lead-antimony cable sheath) increases in a regular manner as the percentage of the minor constituent increases. If, therefore, we can compare the intensities of the antimony lines in different alloys we can compare the antimony contents, and thus by comparison with alloys of known composition measure the antimony content of an unknown sample.

In order to compare the intensities of the lines a disc with an edge cut in a logarithmic spiral is rotated in front of the spectrograph slit. The effect of this is to vary the exposure of each line logarithmically along its length, and to make the spectral lines appear as narrow wedges instead of parallel-sided bars. Since the effect on a photographic plate is also related logarithmically to the intensity of light producing the effect, the lengths of the narrow wedges give a measure of the intensities of the lines producing them, and hence a measure of the antimony concentration of the alloy. If then, a series of alloys having an accurately known antimony content were prepared and photographs of the spectra obtained under precisely similar conditions, a curve could be drawn showing the variation in length of a particular antimony line with the antimony content of the alloy. Actually, the experimental conditions cannot be reproduced sufficiently closely to make such a curve reliable.

In practice, therefore, what is measured is the difference in length between a selected lead and a selected antimony line, this difference being sensibly independent of slight changes in the experimental conditions. If these differences are measured for each of a series of alloys of known composition, a curve can be drawn connecting these differences with the composition. This curve can be used for checking unknown samples.

The method outlined above is used for checking the composition of sheath samples taken from cables offered for test. Confirmatory chemical tests are taken from time to time, but cables are not now held up pending the result of the chemical test.

Telephones No. 162 (Hand microtelephone). During the past two years these have been bought in very large quantities and some description of the routine acceptance testing arrangements may be interesting. The testing is done at the manufacturer's works at the end of his assembly work and before packing. The test room is placed at the end of the final assembly shop and the telephones pass into the test room on a moving band conveyer. Each telephone comes in minus base, inset transmitter, mouthpiece and earcap, and with the green conductor disconnected from terminal R of transmitter connections. From the band the telephones pass to the test position where an insulation test is applied and the instruments are examined by the P.O. testing officer for mechanical faults. From this position the telephone passes to an adjoining position where electrical tests are applied by means of a special testing set to check the following:—

(1) Sequence of gravity switch make and break.

(2) Direction of winding of anti-side tone coil.

(3) Resistance of anti-side tone coil windings; resistance of receiver.

Satisfactory telephones then pass to a bench where the assembly is completed by a member of the manufacturer's staff. The inset, and mouthpiece are fitted, the green conductor is joined to terminal R of the transmitter connections, and the diaphragm and earcap are fitted. The telephones, still minus bases, are then passed forward for testing for volume efficiency of transmitter and receiver, and for transmitter resistance. This is done by means of the Telephone Instrument Tester referred to earlier in the paper under transmitters and receivers. Connection to the telephone for this test is made by standing the instrument on a special testing base where spring plungers make the connection on the terminal plates underneath. After passing the test the base is screwed on the telephone and the official approval mark put on one of the rubber feet. The instrument then leaves the test room on another band or chute to the packing bench, where the key for removing the mouthpiece is associated.

As regards rejections, the principal causes have been allotted numbers according to an arranged code. When a fault is discovered a brass label bearing the appropriate number is attached to the instrument and it goes back to the assembly shop. This scheme has the advantage of standardising description of faults and avoiding misunderstandings, as well as saving the writing out of numbers of fault labels. Further, if the brass labels are taken from a board hung in the test room, the number of rejections for each fault can be obtained readily from the number of labels used. Mistakes are avoided and the keeping of records is simplified.

It should be mentioned that the anti-side tone coil is tested separately before assembly for impedance.

Teleprinters 7A. About 500 of these machines have now been inspected and tested at the manufacturer's works and passed into service. The machine, as is well known, is an assembly of 13 separate units, each of which is provided with fitting abutments adjusted to functional gauges which render them interchangeable. Each unit is adjusted and tested by the manufacturer on assembly, and the completed instrument is given a continuous working run of 7 hours, followed by a final mechanical inspection before being handed to the P.O. staff for acceptance tests. Each machine is subjected to a careful mechanical examination and check of adjustments; to an electrical test; and to a working test under which two machines send to and receive from one another.

Adjustments are checked by a number of feeler gauge and auto-plex measurements, among the features so dealt with being the tension of the pawls and the detent lever; the pressure required to depress the keys; the pressure of the transmitter selecting levers on the keyboard combination bars; the tension of the contact operating lever spring; the gap between transmitting contact tongue and gate of contact operating link; the pressure on the transmitter contact tongue.

The reliable performance of the relay is ensured by:—

(1) Close limits on distance of armature travel.

(2) A specified strength of magnetic field (*i.e.*, due to the permanent magnet—no current in coils) tested by means of autoplex measurements of magnetic pull on armature; limits being given with the trip shaft link disconnected and connected, *i.e.*, with the relay in a " free " condition and in a connected condition, mechanically.

(3) Figure of merit test with trip shaft link connected and disconnected.

(4) A test for residual magnetism by the application of a polarising current of four times the operating current, but with only a 10% allowance on the operating current when applied immediately following.

All the above points are checked by test.

The motor, in addition to general normal requirements in regard to sparking, vibration, noise, efficiency and temperature rise, has to meet speed control requirements under conditions including variations from the normal supply voltage and with the governor at the extremes of short circuit and "open" contacts.

An examination is made for the usual mechanical faults to be met with in instruments. A schedule has been prepared covering 86 fault conditions which have come under notice during inspection and these are systematically searched for in each machine. Some are tests laid down directly in the specification, and some are mechanical faults common to all apparatus, but a large number are peculiar to the machine faults common to all apparatus, but a large number are peculiar to the machine and come to light as the result of experience with a number of machines. Of the first 470 machines examined 80% had one or more of the 86 types of faults and had attention before being approved; 12% had faults which necessitated further factory attention, and 8% passed through without remark. These figures are not given as a reflection on the maker's standard of production, for the mere fact that a machine of so complex a nature can be successfully installed and used at subscribers' premises is in itself a tribute to the general standard of workmanship. The figures do indicate, however, the real difficulty of keeping everything up to the mark on a machine such as this, and the need for careful scrutiny of all points.

(5) CONCLUSION.

In the foregoing pages a general survey has been attempted of the dual problem of laying down standards for the purchase of engineering stores and of seeing that these standards are maintained in supplies. As in the case of practically all engineering problems the solution involves a compromise between conflicting requirements. The desirable object, for example, of reducing delay in acceptance testing to a minimum cannot be pursued too far without coming into conflict with another desirable object, viz., economy in testing plant and staff. Specification writing, too, is an almost continuous compromise among what we want, what we can afford, and what we can get. The test of success in the solution of the problem, is the kind of service the stores give in use. Here the need for assistance from those who actually use the stores for construction or maintenance purposes is apparent. By calling attention to cases where stores issued appear either too good or not good enough for the job, and by noticing the behaviour of stores in service and especially in what way failure occurs after service, the user can render real assistance to those on specification and testing work. For example, cases where subscribers' apparatus wiring or P.B.X. switchboards have to be changed owing to low insulation developing; cases where cords wear out quickly at one point which could perhaps be reinforced at practically no extra cost, and thus save expensive maintenance visits; cases where disconnections occur which may be due to corrosion, *e.g.*, wires in contact with fibre, empire cloth, etc.—all these and many others are worth following up to decide whether the quality or design needs altering, and in most cases it is only from the user, *i.e.*, the engineering staff in the Districts, that the information can come to set the investigation in train. Actually, opportunities of direct contact between District staffs and Headquarters officers are being provided at Sectional Engineers' meetings in order to facilitate the passage of this important information, and it is greatly to be hoped that full use will be made of these opportunities.

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BIRCH & WHITTINGTON, 10, Station Road, Epsom.