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THE ORGANIZATION AND SCOPE OF ACTIVITIES OF NATIONAL METROLOGY SERVICES

and

MEASUREMENT AND MEASURING INSTRUMENTS, CALIBRATION AND MAINTENANCE [1/]

by

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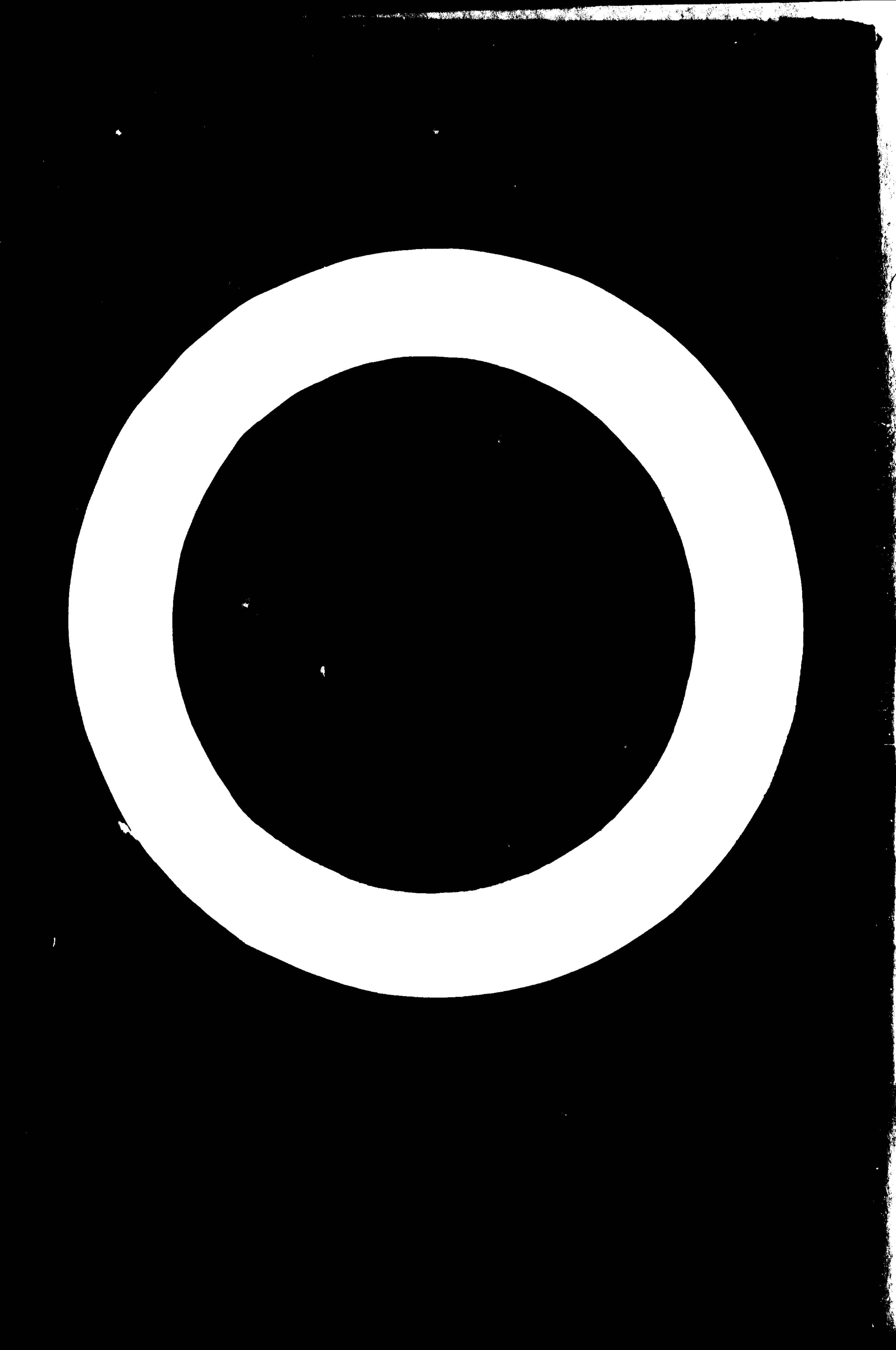

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The Background of National Metrology Services

1. The existence of a national metrology service is an essential feature of any country with any claim to being regarded as civilized by present standards. Such a feature of the social organization of a country is, however, though probably in an elementary form, one of the oldest attributes of a stable unified government, dating in essence from the beginnings of recorded history, from times of essentially personal rule and ante-dating democracy by many generations.

2. For most of recorded history the national metrology services were relatively simple in concept and limited in scope, being essentially directed towards the fixing of legally-supported standards required for purposes of trade. As the more developed countries changed from being primarily concerned with agriculture, hunting, fishing and, in general, an economy mainly based on natural resources and their simpler derivatives to an economy based more and more on technological processes, so measurements of more and more characteristics, to greater and greater exactitude, became an inevitable feature of every type of industrial activity and therefore of every day life.

3. Recognition that this is so has not, however, become part of the conscious knowledge of the average inhabitant of even the more-advanced communities; in fact appreciation of this aspect of life has been blunted by the fact that over many generations the reliability of measurements met in daily life has led

the average inhabitant to take their reliability for granted; this has bred what I like to call an unjustifiable faith in dial readings.

4. The first standards of measurement were apparently those of length and mass. Those of mass were developed when barter, the direct exchange of object for object gave way to trade, the exchange of a commodity for something both parties to a deal recognized as intrinsically valuable but for which the value could be described only in terms of its quality and its weight, no other attribute being applicable to all supplies. In many of the older civilizations the so-called 'precious metals' were available in small quantities and because of their availability and their freedom from loss and decay due to wear or corrosion, they were adopted as bases for mutually-acceptable currency. The value of any particular lot of currency depended on its weight and on recognition of its purity. Hence the adoption of standard weights on the one hand, and of the practice of coining, or stamping pieces of precious metal of approved purity with a portrait or other symbol as part of a deterrent against substitution of all or part of a precious metal by another metal of less value.

5. Because 'precious' metals were inherently scarce the quantities involved in the representation of a typical transaction in trade were relatively small so one of the earliest 'standards' of weight was the grain of cereal because such grains were found to be very uniform in size and could easily be counted up to the numbers likely to be required. So long-lived has this standard been that the unit 'grain' still forms one of the elements in the avoirdupois scale of weights still current in Britain, having the value of 1/7000 lb. or about 65 milligrams.

6. Most of the systems of weights seem to have had a working standard in the range of 115 to 230 grains (approximately 7.5 to 15 grammes). Sub-divisions seem to have been mainly by successive halving and larger units frequently decimal multiples, though multiples of 2, 3, 4 and 6 also occurred. One of the common names for units in this range was the shekel, the use of which extended into early European history. The early Roman pound or libra apparently consisted of 25 such units and was also divided into 12 unciae or ounces. The ratio of 12 ounces to one pound could still be found in the Troy pound of 12 ounces which was legal in Britain until about 100years ago. The avoirdupois pound of 16

rather different ounces was used in parallel, for different trades, and is still current though likely to give way to the metric system in the near future. Most systems of weights outside the metric system included a value fairly close to, and sometimes very close to, the pound derived from the Roman libra, as the symbol lb. implies, and even in countries already converted to the metric system the unit is often in use colloquially (e.g. the 'livre' or'pfund' used to describe half a kilogramme).

7. Units of length may possibly be of earlier origin than units of weight, though so far as I know there is no such early 'standard' still in existence. This is perhaps because the materials suitable for making early measures of length were not suitable to survive many generations, being if portable, either of wood, non-precious metal or fabric or if designed to be permanent, i.e. of stone, liable to the fate that befell most early buildings.

8. It seems likely that early standards of length were first used to describe distances or the sizes of things. The greater distances would have been described in terms of travelling time, such as the time taken to go from A to B on foot or. later, on horseback. Therefore the measures of length were related to things and people and perhaps for this reason or because of the relative uniformity of the average body characteristics of humans (and their convenient mobility as approximate measures) most of the standards of length were based on the characteristics of the average human body - inch, palm, foot, cubit,yard and fathom all being related to body characteristics or simple multiples thereof.

9. The need for recognised standards of length again probably grew out of trade, because one of the earliest activities of human society is the weaving of fabrics for protection, comfort or decoration and one of the earliest uses of standards of length must have been to describe the width and length of a piece of fabric. The continuity of this use of a standard is seen in the fact that one of the recognized widths of woven fabrics today is 54" (or its equivalent metric value) which is equal to two of one version of the mediaeval 'ell', this ell being apparently the longer version of the ancient cubit which

is traceable through the Teutonic countries for many centuries.

10. Later developments in standards of length must have arisen in connection with the earlier technologies, in particular those of building and ship-building and perhaps rather later for surveying and navigation. Manufacture as such was probably not so much involved in earlier years being based on craft practices in which absolute dimensions were not so important.

11. Measures of volume were also important very early for purposes of trade not only in liquids such as wines and oils but for cereals and many other like products which could be described by volume as conveniently as by weight. So far as I can ascertain there has never, until the metric system, been any clear pre-determined relationship between the unit dimension for length and the unit dimension for volume.

12. Length, mass and volume are the venerable standards. Time has been of equal importance throughout history but, since the rotation of the earth has provided a standard of far greater stability than could be achieved in any other direction without a standard, the measurement of time has always provided a problem of a different sort - how to divide the solar day into suitable intervals, and to indicate their passage easily and economically when the sun is not visible. This has not, in general, been a matter requiring a legal standard so government activity in this field seems to have been generally confined to providing a daily time signal and to supporting the development of a reliable timekeeper as an aid to navigation.

13. Therefore in the hierarchy of government institutions in developed countries a universally - recognised commitment ever since there have been governments has been the establishment of standards of length, mass and volume (or capacity), and the creation of a body of law requiring observance of these standards and providing penalties for infringement of the law. It has also generally been recognized that unless the operation of the law is properly supervised it will, like any other law which is not enforced, fall into disrepute, after which restoration of order and of confidence will be disproportionately difficult and expensive. Consequently most wise governments

provide and support both nationally and internationally organizations for the maintenance of standards of measurement and the supervision of the law requiring their observation. In the more far-seeing and better organized governments provision is also made, though not necessarily through the same channels, for expenditure on new standards and improved techniques of measurement to meet the requirements which continuously arise from technological development for better measurements.

14. The position outlined above developed slowly throughout the course of history and was in essence stable for long periods. Advances in measurements and standards occurred with the development of new needs or as part of the development of new technologies. Reference has already been made to the improvement in time indication which occurred in the eighteenth century to meet the needs of navigation. In the eighteenth and nineteenth centuries the industrial revolution, involving the large-scale application of power to manufacture, resulted in the replacement of craft practices by division of labour which depended essentially on better measurements in the mechanical field. The concurrent development of machine tools would not have been possible without such measurements and also required such measurements for their effective employment. Consequently many of the basic problems of good mechanical measurement were solved during the nineteenth century through the capabilities have been improved as new techniques were developed under the stimulus of new needs.

15. Probably the second major factor in the development of measurements has been the practical use of electricity, first in its power applications and later in the younger field of electronics. A hundred and fifty years ago electricity was nothing but a scientific curiosity; a hundred years ago it had been applied to telegraphy but had no effect on industry other than speeding up communications. During the last hundred years the whole of life in developed communities has been widely affected by the applications of electricity and this has given rise to a whole new range of measurement tasks, both in the measurement of electrical quantities and in the use of electrical techniques for making other measurements.

16. During the nineteenth century there were great developments in the

teaching of science and technology in universities and other academic institutions. These developments were closely interwoven with developments in technology, in scale of manufacture and in communications, both for transmission of ideas and for conveyance of manufactured products. The major international exhibitions in London (1851 and 1862) and Paris (1855 and 1867) undoubtedly added to the discussions about the need for better and more universally acceptable bases for sophisticated measurements; these led to the Convention of the Metre, the establishment of the International Committe of Weights and Measures (C.I.P.M.) and the foundation of the International Bureau of Weights and Measures (B.I.P.M.) at Sevres, on the outskirts of Paris. For nearly one hundred years these bodies have had the task of establishing agreement between the measurement standards of the participating countries but even B.I.P.M., that venerable and respected body, has for some years lacked sufficient resources to carry out its proper task of co-ordination and intercomparison in many of the more recently - developed fields of measurement.

17. The same ferment of thought which led to the establishment of B.I.P.M. led also to the recognition in the more advanced countries of the need for accessible standards of the prime quantities of measurement and so, between 1887 and 1901, four major establishments were set up for this purpose. The credit for the first goes to the Germans who set up in 1887 the Physikalische Technische Reichsanstalt (P.T.R., later to become P.T.B.); the second was apparently the Russian Mendeleev Institute (V.N.I.I.M.) in 1893; this was followed in 1900 by the National Physical Laboratory (N.P.L.) in the U.K. and in 1901 by the National Bureau of Standards in the U.S.A.

18. The only aspect of these events I feel I should mention at this time is that, as so often seems to happen, Great Britain provided its own standards organization with less capital and less guaranteed income than either Germany or the United States and I suspect that the consequences of this parsimonious attitude are still being felt in the U.K. and have contributed indirectly to the establishment of the British Calibration Service with which I was connected until retirement.

19. About forty countries belong to B.I.P.M. and contribute varying amounts to its support. Of these most, if not all, have an organization for the maintenance of traditional standards of length, mass and capacity and presumably for the control, to varying extents, of their use in trade. Probably about half the forty are actively engaged, to some extent, on development of new techniques and/or improved equipment for meeting new measurement needs; in some cases the work is done in Government laboratories and in others in universities or similar institutions but in such cases may not necessarily result from identification of particular national needs.

20. Presumably many of the other countries in U.N., particularly those which have become independent in the last twenty-five years, have inherited from the former governments of their territories some provision of standards in these fields but what is not easy to ascertain is how far national standards cover other types of measurement and how far organizations exist to ensure the maintenance of, and compliance with, such standards.

Structure and Functions of National Metrology Services

21. What can be stated without hesitation is this :-

(a) Every country needs an organization to maintain and disseminate standards of measurement, if only for purposes of trade and for protection of consumers;

(b). Every country which wishes to operate industries must have an organisation corresponding to that in (a) but covering those measurements required in its industries;

(c) Every country which hopes to export any of its products must have a similar organization to cover the measurements involved in the specifications appropriate to the exports and must in addition ensure either through achieving agreement of its standards of measurement with the corresponding international standards or by nation-to-nation co-operation with the buyers of its products that the relevant measurement standards of the buying and selling countries are compatible.

(d) The achievement and maintenance of good measurement capability is an expensive operation involving not only initial expenditure but the costs associated with continuous supervision and development; the more sophisticated the products, generally speaking, the greater the cost of adequate measurements.

(f) In order that its work and decisions may be accepted with respect and goodwill it is right and necessary that the national measurement organization be given official status with full government backing and support but it must at the same time be entirely free of administrative interference or change for political reasons; a long view must be taken of provision for its needs and of training for its staff so that it will operate in a stable atmosphere unaffected by the relatively short time-cycles of governments.

22. It is quite possible for a small country to avoid the need for expenditure on any original work in the measurements field by relying on the measurement equipment and/or calibration services of other more advanced or better-equipped countries but it has to be remembered that all measurement equipment requires periodical calibration if confidence in its indications is to be maintained; the limitations of time and cost of transport will indicate the point at which it is preferable to establish a national or local standard for any particular measurement of a quality suited to the national or local needs.

23. Traditionally in many countries the organization for the maintenance of the 'classical' standards of length, weight and capacity has grown up within, or subordinate to, a ministry of commerce or trade, whereas many of the other measurements have been treated as the concern of other ministries e.g. low-frequency electrical measurements and measurements of gas supply (volume and/or thermal value) have been treated as the responsibility of the ministry or ministries responsible for the corresponding supplies. Many of the more sophisticated measurements have not been the specific responsibilty of any single ministry, the corresponding development work having been undertaken either by a university or equivalent purely as an item of research without any commitment to ensure adequate dissemination, or by some official or semi-official body needing the technique for its own purposes.

24. I am inclined to the view that the best national organization would give

responsibility for the maintenance of the national standards of every measurement required in a country to one or more designated national standards laboratories, with power to develop new standards wherever this was agreed to be preferable to importing such development from another country or was agreed as a task to be undertaken as a contribution to international knowledge in this field. In making such an arrangement the following provisions and precautions appear necessary :-

(a) to provide the national standards laboratory or laboratories with an advisory body whose members would be knowledgeable about measurements and the fields of their application in order to give broadly-based guidance to the laboratories on their programs of work;

(b) to ensure that the national standards laboratories devote an adequate proportion of effort to maintenance of existing standards and to their dissemination by providing a comprehensive and commercially-acceptable calibration service for working calibration laboratories (and other laboratories) holding standards at one level below national standards.

(c) to ensure that the national standards laboratories would be financed by a single central department able to take the broadest possible view of future needs and to plan on a long term basis;

(d) to provide a single, central, technically-competent management unit to control the dissemination of standards throughout all the recognised calibration/measurement laboratories in the country.

To summarise this paragraph - the cost of providing and maintaining the national standard of every measurement required in the country should be a charge on central government funds but the cost of calibrating any instrument against the national standard should normally be charged at at a fair economic rate against the owner of the instrument.

25. At the other end of the scale of government interest in measurements is the supervision of measuring instruments used in the relationships between the instrument-users and the general public, which for this purpose is assumed to be non-technical or at least not in a position to check the validity of measurements made. This supervision could be carried out entirely by specialists but it is

not unusual to combine it with other aspects of consumer protection which is probably economical on geographical grounds and also as it tends to decrease apparent official supervision of traders. Therefore it is probably desirable to operate such supervision with staff belonging to the local government authority but coming for 'weights and measures' purposes under the technical direction and control of the central authority mentioned in 24 (d).

26. In between the two extremes of 'weights and measures' supervision in trade and development and maintenance of national standards comes the whole range of laboratories required to ensure confidence in measurements made in industry, in research, in inspection, in education and in the development and production of measuring equipment itself. For all these purposes confidence in each measurement is, to varying degrees, essential. This confidence depends on two factors, confidence in the design of the instrument used and confidence in its calibration. These two factors are considered separately.

27. Taking first the question of calibration. What the user needs is confidence that the instrument has been properly calibrated and that it was done sufficiently recently, having regard to its type and usage, to be operating within the performance limits stated in its specification. Confidence in the adequacy of calibration can be established by official approval and supervision of the calibration laboratory, provided such approval and supervision are carried out by qualified specialists of recognized competence and independence. The date of calibration, or the date by which recalibration is recommended, should be indicated on the calibration certificate and/or on the instrument itself.

28. There seems to be no reason why any competent laboratory should not, if it so wishes and meets all reasonable requirements, be approved to operate as part of the national measurement service. The employment of competent laboratories which participate on a voluntary basis not only makes available the facilities of laboratories already experienced in the business but it does so more quickly than could possibly be achieved by setting up new laboratories to meet ascertained needs; it also avoids the considerable expense which new laboratories would involve and in most cases improves the utilization of

expensive equipment needed by a laboratory for its own purposes but not fully employed.

29. This approach to the problem of providing calibration facilities was followed in setting up the British Calibration Service - a reprint of a fairly recent article describing the Service is attached for information. The number of approved laboratories has now reached fifty and is increasing. It needs to be emphasized that the essence of such a system lies in two main aspects :-

(a) the recognized professional competence and integrity of the assessors who inspect a laboratory to determine its compliance or otherwise with published criteria;

(b) the thoroughness of supervision which consists of periodic visits of re-assessment combined with a system of audit measurements which is mentioned in the paper and has proved a very powerful tool for this purpose.

30. The operations of the professional staff of the British Calibration Service H/Q organization are helped and guided by a separate panel of experts for each field of measurement so that the expertise brought to bear on each stated requirement and each new problem represents the collective wisdom of a selection of the country's best practising experts in each field though the staff of B.C.S. H/Q is quite small.

31. The second aspect of confidence in a measurement is that of confidence in the design and quality of the instrument used because the better these are the greater is the likelihood that the instrument will continue to perform within its specification during the interval between successive calibrations. Confidence in design and quality may result from previous experience of the type or in the case of a new instrument may result from consideration of a report on the evaluation of one or more prototypes or samples. In classical 'weights and measures' operations the evaluation and approval of prototype instruments is usually a function of the national measurement service. In the general field of instruments such evaluation is sometimes undertaken by users of large numbers, before purchase of a new type, or by specialist research organizations on commission. In the U.K., at least, the instrument industry has not taken kindly

to a proposal that all new instruments be independently evaluated (as a sort of quality - mark operation).

32. In some countries it is a legal requirement that all instruments intended to be used for measurements called up by law be officially evaluated and approved before they may be used for this purpose. This seems to be a reasonable compromise between protecting the consumer or the user on the one hand and limiting too far the freedom of the instrument producer to sell his products to any willing buyer. But the principle of 'caveat emptor' can really only equitably apply if the purchaser is reasonably able to satisfy himself that what he buys will meet his needs. Otherwise he needs help and as it is not reasonable to expect him either to conduct or pay for evaluation when he may need only a very few instruments there is a case for a public evaluation service to meet the needs of the user of small numbers of expensive instruments. Such provision might be considered to be a proper function for a national measurement service.

33. A country dependent on imports for most of its instruments might well feel the need for evaluation before purchase and might prefer to buy instruments from a country offering a suitably - authenticated evaluation service. This is in line with the principle, already widely adopted in various countries, of using some kind of special mark to indicate that a particular product complies with the governing specification. Most of these 'quality marks' are based on approval of prototypes followed by checking of samples taken from production. So far as calibration certificates are concerned, however, B.C.S. insists that each applies to an individual instrument (identified) and the same rule could be applied to certificates of compliance with type approval where thought desirable.

34. To summarize, I see a national measurement service as being the national organization to ensure :-

(a) that any measurement made in the country may be trusted to be true within the limits appropriate to the equipment used for making the measurement;

(b) that any instrument calibrated in the country may be expected, up to the recommended date for recalibration, to indicate true values within the limits indicated by its specification subject, of course, to reasonable use and treatment since the last calibration;

(c) that measurements made for legal reasons are made with equipment approved for the purpose and, in appropriate cases, by persons approved for the purpose;

and, as a possible extension of the foregoing,

(d) that any measuring instrument offered for export sale performs in accordance with its specification.

Planning of Development of National Measurement Service

35. To do this it is first necessary to decide the objectives and their relative priorities. Among those which fall to be considered are:

(a) protection of general body of consumers against unfair trading;

(b) establishment of equity of measurements in trade as between buyer and seller;

(c) improvement of measurements to assist industry, particularly to ensure common standards of measurement between manufacturers as an aid to sub-contracting and to interchangeability in general;

(d) assistance to research and to technological development by making measurements in the country compatible with those made in other countries;

(e) assistance to exports by general support of quality control activities (which depend on accurate measurements);

(f) support of education and research by ensuring internationally-acceptable measurement capability in teaching and research establishments.

36. Some of these activities, e.g. 35(a), form part of the general cost of good government; the cost of providing adequate national standards cannot in this sense be offset against increased national income. Some other activities, e.g. 35(e), are likely to improve the international trading position of a country but could not be embarked on without also meeting the requirements of 35 (a) and (b) and probably (c). The possible gain cannot be quantified in advance - so making an appropriate provision becomes an act of faith based to some extent on experience in other countries.

37. It is possible to estimate fairly closely the cost of meeting some of the

separate objectives, subject to the existence of a supply of suitable manpower with ability and background training appropriate to receiving the necessary specialist training, at least some of which might have to be sought in other countries.

38. Having selected the objectives and estimated costs as far as possible it then becomes a political or administrative decision on whether and to what extent a suitable program is to be adopted as part of an overall national plan for development (assuming there is one). It is, of course, fair to add that, given a suitable opportunity and climate of opinion, enthusiastic presentation of a well-documented and adequately-costed plan has a better chance of success than a proposal in general terms.

Financial and Physical Requirements for N.M.S.

39. These can be developed from the objectives set out in para.35. Having settled the objectives, either in toto or phased in time, the next operation is to ascertain the available resources so as to determine which items are altogether missing and which exist but may have to be mobilized for the public service. To avoid the need to work absolutely from scratch it would be worth while to refer to documents published by the various measurement organizations in other countries showing the measurement facilities available in those laboratories. Having selected the parameters in repect of which a service is required, and the best uncertainty required in each case, it becomes necessary to choose the location(s) for the national standards laboratories and the tasks to be assigned to each. It also has to be decided whether, particularly in the early stages, the national laboratories are to be used only for custody and dissemination of national standards or whether they are also to be used as working calibration laboratories at lower levels. This must depend in part on the ability to mobilize existing working laboratories to provide a public service and partly on the expected initial load of calibration of sub-standards from such working laboratories.

40. Where there not sufficient national standards laboratories or working calibration laboratories available to provide the desired facilities it may be

necessary to start from nothing and build new ones. Whatever new facilities are required can be estimated in terms of floor space and/or bench space for different types of measurement activity. For each type varying accommodation criteria have been found desirable, partly to reduce external perturbations and partly to establish stability of conditions. These include :-

(a) freedom from vibration - choice of location not liable to earth tremors, use of basement or ground floor, special pillars, anti-vibration mountings etc

(b) freedom from temperature variation, both general and local - design of building to reduce received solar radiation and/or protect from heat loss, double glazing (or absence of windows), control of internal air flow;

(c) control of humidity and dust as sources of electrical leakage and general deterioration of switches and equipment - dust-free construction of buildings, easily cleaned surfaces, use of air filters, sticky mats and general attention to housekeeping;

(d) freedom from electro-magnetic radiation - screened rooms and screened cages for R.F. operators;

(e) freedom from noise.

Also necessary are facilities for proper storage of handbooks and relevant literature, provision for documentation and retention of copies of results and records of calibrations of standards ; facilities for refreshment away from working areas; accommodation for storage of instruments not in use and of transitory instruments waiting for calibration or despatch, for protective clothing and for sanitary purposes.

41. All those requirements have already been documented and perhaps the main decision to be made is whether the working temperature in those laboratories which require temperature control is to be one of the standard temperatures, normally 20°C, 23°C or 25°C or some other value which is likely to arise only if the cost of keeping the general temperature down to these levels throughout the year is likely to be excessively high. If it is, consideration may have to be given to doing selected operations in small specially-controlled enclosures or

in glove boxes, or to providing facilities for relating results at the selected working temperature to those at the more normal international standard temperatures.

42. For the various types of accommodation costs are available in various countries which can be converted into costs for the country in question. Capital costs of necessary equipment can be obtained from suppliers or from catalogues, it also needs to be ascertained whether any agreed expenditure is to be funded by outright Government grant or by some loan scheme operated internationally and, if so, at what rate of interest. Maintenance of buildings, running costs for heat, light, power and consumable supplies can all be assessed. Staff costs must depend on the tasks to be undertaken and allowance should be made for initial training before operations are commenced, for further training as new equipments come into use and for training of replacement staff from time to time. Some amount of administrative overheads will be inevitable. From all these can be estimated

(a) the capital costs of the project

(b) the running costs " " "

(c) the overhead charges which will have to be levied on each man-hour of actual calibration or measurement work done.

This assessment should make it possible to produce a realistic scale of charges for services to be provided by the laboratory.

<u>Types of laboratories and facilities</u>

43. The types of laboratories required will be determined by the objectives selected under para.35. Present experience seems to confirm as convenient and practicable grouping of laboratories by fields of measurement which typically include the items shown :-

(a) Mechanical, covering acceleration, angle, capacity, circular division, diameter (internal and external), displacement transducers, force, gauges (various), gears, hardness, length (including division), levels, load cells, mass, measuring machines, profile, roundness, screws, slip gauges, straightness, surface plates, surface texture, tapers, testing machines, weights and weighing machines.

(b) Low-frequency electrical, covering A.C./D.C. transfer, bridges, capacitance, conductance, current, frequency (up to say 100 kHz), impedance, inductance, magnetic materials, potentiometers, power, power-factor, reactance, resistance and voltage.

(c) High-frequency electrical, covering items as in (b) for frequencies above those covered by (b), also admittance, dissipation factor, frequency deviation and modulation, susceptance, voltage reflection coefficient, and voltage standing-wave ratio.

(d) Fluids, covering flow-rate, pressure, quantity, viscosity and volume, all for air, gases, vapours and various liquids.

(e) Optical, covering brightness, colorimetry, diffraction gratings, geometry of surfaces, photometry, reflection, refractive index, spectral power, transmission and transfer function.

(f) Thermal, covering latent heat, reflectivity, specific heat, temperature (pyrometers, thermocouples, thermometers) and thermal conductivity.

(g) Acoustic, covering absorption, frequency response characteristics, insulation, hearing aids, noise, sound levels, transmission and ultrasonics.

(h) Ionizing radiations, covering health physics, radiation levels, sources and protection.

44. The facilities required for a standards/calibration laboratory are those required to cope with the objectives of the laboratory and the size of its maximum load and must be designed to meet the criteria set out in para.40. Additional facilities which should be considered at the planning stage, the need for each depending on the foreseen tasks of the laboratory, include :

(a) blinds or sunshades for occasional use to prevent solar radiation from impinging on particular instruments, particularly those sensitive to temperature variations;

(b) power supply or supplies of good wave form (if A.C.), stable in voltage and as free as possible from interruptions or switching surges. It may be necessary to provide local independent or stand-by supplies when local control of voltage, frequency or phase is necessary or to safeguard particular installations against unintentional shut-down;

(c) supplies of distilled water, if the local supply is not good enough, and of clean oil-free compressed air;

(d) special storage facilities for equipment or instruments needing to be maintained at a constant temperature, either for conditioning prior to calibration, or for maintenance in a state of readiness for use. This requirement may extend to the provision of a vehicle either thermally-insulated or provided with body heating or with local power points, for the carriage of instruments of standards which require protection or separate heating in order to ensure either stability of characteristics or immediate availability for use when standards are to be taken to a remote site for use there;

(e) workshop accommodation outside the standards/calibration laboratory for the repair or adjustment of instruments in use or under calibration or for the construction of new devices to assist work in the laboratory. Typical of this sort of activity is the construction of rigs or jigs to faciliate the rapid calibration of several instruments of one type using a layout made up or maintained specially for that purpose.

45. In designing a laboratory it is probably necessary to adopt a technique somewhere between the two following alternatives :-

(a) an attempt is made to assess the future load of the laboratory, divided between types of work as outlined above and it is provided with facilities appropriate in size and scope to each foreseen element of load.

(b) an attempt is made to assess the total load, probably in terms of the maximum number of staff to be employed, and a modular form of construction is adopted, providing each module with every facility required for any task but without internal divisions of the building except, perhaps, for the segregation of office space from laboratory space, so that the building, when completed, will be completely flexible in use and by use of movable partitions can be divided up to meet needs for current tasks without destroying flexibility for the future.

46. Of these alternative approaches, method (a) will normally produce a cheaper building but on the other hand it is not so likely to meet requirements when ready because from the consideration of requirements to occupation of the finished building is likely to be at least four years and there are very few single tasks in the technology field which remain wholly stable in nature, size and requirements over such a period so that any building designed for a foreseen load is likely to be unsuitable in some respect or other when finally occupied.

47. This disadvantage is not so marked for a function of a stable type, with well-developed techniques and equipment, such as a power station, water-pumping station or telephone exchange. In such fields the usual change is one of increase of load without rapid change of technique. The same is likely to be true of the load of a calibration laboratory. The disadvantage of method (b) is although it undoubtedly achieves long-term flexibility it does so at the price of the increased cost of providing facilities which may never be used in particular areas. For example, the approach might well result in general provision of certain facilities such as chemical drains, stabilized power supplies or close temperture control which were needed only in a limited part of the building.

48. For the foregoing reasons the best compromise in the case of a projected standards or calibration laboratory seems to be to make an effort to determine the base load and probable growth of each type of calibration work and then provide purpose-equipped accommodation for each type within a shell meeting the basic requirements for all types of work, allowing for growth up to say twenty years if the building is to be a 'permanent' one or up to perhaps ten years if a suitable form of prefabricated (unit) construction is employed. Space for the development of new standards or techniques would preferably be provided in advance with all facilities likely to be required so that it could be employed for different tasks as the needs changed.

49. To provide the maximum stability of environment for measurement laboratories and at the same time the maximum amenity for laboratory staff it seems to be a sound arrangement to use the core of a building for the measurements most in

need of temperature stability and the outward-looking parts either for offices or for workshops etc. not needing temperature stability. This should substantially reduce the amount of temperature-conditioning plant required. Also since the ratio of volume to surface area is greatest with a cube, a design of approximately cubic form is likely to prove most economical from this point of view. With modern lighting such an arrangement can be made acceptable but it needs to be remembered that the radiation from high-intensity lighting installations can affect the stability of some measuring equipment so either the lights must be kept on always or the intensity must be reduced in particular areas or the equipment must be screened from such radiation.

The National Measurement Service and Quality Marking

50. Quality marking is a system used by individual or grouped manufacturers or providers of services to encourage customer confidence in their products by showing that they have received some sort of allegedly-independent approval. The basic idea is undoubtedly sound but some forms have tended to bring such systems into disrepute because the methods of application were inadequately controlled or because the standards set were too low or because a scheme which started well was eroded for a variety of reasons.

51. Quality marking can in fact be divided into types, relating respectively to products and to services. As applied to products, the award of a quality mark means either

(a) the product is, in the opinion of the assessors, up to some standard which they consider adequate but which may not be known, or not fully known, to the potential purchaser,

or(b) the product meets some standard which is clearly stated and known, at least in principle, to the potential purchaser.

Customer confidence depends on experience of such marked products, of belief in the ability and willingness of the mark-awarding organization to apply effective sanctions to offenders in the event of a marked product being found below standard and on the effectiveness of the arrangements for publicising the scheme.

52. Such schemes fall into two groups in another way - those in which the general approval mark is associated with each item treated individually and those in which the approval is based on assessment of typical items and is subsequently maintained by sampling of the product. The second approach - control by sampling - is not so secure as the former but is probably adequate in those areas in which the product is made in considerable quantities and the whole nature of the product and the method of production is likely to be stable and a sample is likely to be representative of the whole. It is also really only applicable to products in which likely variations between one and the next are well within the limits tolerable for the product as a whole.

53. A good example of the former type of quality mark is the hall-mark as applied to articles made of precious metals. The mark in such cases applies to the individual item and serves only to indicate that the purity of the metal is up to the required standard. An example of the second kind in the U.K. is the 'kite mark' used by the British Standards Institution to indicate that a product e.g. a crash helmet or plumbimg fitting, complies with the corresponding British Standard Specification.

54. The application of approval marks to services takes various forms. One example is the grading of hotels, restaurants, etc. in the publications of various motoring associations or in private-venture publications such as the Michelin guides to various countries. The success or failure of such schemes depends on whether the interested public is made aware of the criteria applied and whether it is satisfied, in the light of its own experience, that the standards are realistic, meet its needs, are applied with integrity and enforced by effective sanctions if the standards are not sustained.

55. Another example of approval services is that of approval of laboratories to function as part of the British Calibration Service. Here the attempt to secure public confidence in the scheme is approached by :-

(a) setting high standards for approval;

(b) publishing the requirements in detail so that all interested parties may be fully aware of them;

(c) arranging assessment prior to approval and supervision after approval by professional staff acceptable as experts in the field of work of each laboratory;

(d) applying thorough supervision after approval by three distinct methods, one of which represents a frequent practical test;

(e) giving help as far as possible to approved laboratories in the way of advice and the provision of facilities for training;

(f) charging for services rendered so that approval is sought only by those organizations which really value membership and so have an interest in maintaining high standards of work.

It is perhaps early to say whether the scheme meets all the objectives but the future is viewed with confidence in this respect though one of the problems is undoubtedly that of making the existence of the service known to all potential users.

56. The relation between any national measurement service and any quality mark system has two aspects :-

(a) for a product to be assigned a quality mark the controlling body should ensure that any measurements significantly involved in the product are themselves subjected to a quality standard and are therefore authenticated as appropriate by the N.M.S.

(b) if the product is itself a measuring instrument a quality mark indicating type approval may be attached permanently to the instrument but a quality mark indicating approval of its measurements must be of such a nature (e.g. a calibration certificate or calibration seal) as to indicate as appropriate when or in what circumstances recalibration is required.

II. Measurement and Measuring Instruments, Calibration and Maintenance.

Testing and Calibration of New and Imported Instruments

57. Every buyer of an instrument wishes to be sure that it will fulfil the purpose for which it was obtained. To achieve this he usually

(a) tests it fully himself to ascertain whether it complies with the governing specification in all respects - this is usually possible only for buyers in organizations with extensive measurement laboratories;

or(b) buys on the strength of type-approval tests carried out by some trade association to which he contributes or by some consultative body for a fee, supplementing these by spot checks against a rogue instrument or damage in transit;

or(c) buys it with a certificate from an independent organisation in the country of supply or his own country showing that the instrument has been calibrated in accordance with its specification;

or(d) buys it on the strength of the supplier's recommendation and/or implied warranty.

58. One of the problems associated with buying a complex or sophisticated instrument is sometimes that the buyer wishes to use it in a role involving only part of the performance specification; it may be a long time before he wishes to use it for some other role within the specification and only then finds out that the instrument does not meet the specification, by which time any formal guarantee has long expired.

59. It is therefore in the interests of every buyer to assure himself, so far as he can, that any instrument he buys will actually meet its specification. Unfortunately not all instrument specifications are comprehensive and some are probably optimistic, reflecting the triumph of imaginative salesmanship over facts supplied by development or evaluation teams. Undoubtedly, therefore, a wise buyer will benefit by obtaining independent authentication of performance,

particularly when the instrument is of a new type or one which he cannot fully check himself.

60. This is particularly true when the buyer is in another country from the seller. Even with the utmost goodwill between buyer and seller the cost of transport, the additional risks of damage in transit, difficulties with import and export regulations, customs dues, international payments and postal delays, coupled with the loss of time in which the faulty instrument is not available for use all tend to emphasize the desirability of ensuring, as far as possible, that the instrument supplied is fit for its intended purpose.

61. The position for the buyer is easier if the supplier has a local agent who is competent, staffed and equipped with instruments and spares to provide a repair or recalibration service. Such facilities are however rare and therefore it is as well for the buyer to obtain an independent certificate for the instrument from the supplying country or to be able to refer the instrument to a suitable organization of the national measurement service in his own country.

62. Since almost every instrument in use in a country is likely to be in need of repair or recalibration at some time it is very much in the interests of any country which both uses sophisticated instruments and is remote from its sources of supply to equip itself with adequate laboratories for calibration and preferably with facilities for repair. This involves training or recruiting from other countries staff to operate such facilities. Staff required for such purposes are likely to be similar in background and training, only probably more expert than those who will operate the instruments but consideration of any proposals for a national measurement service should not omit the question of recruitment and/or training of plenty of suitable staff.

Periodical Testing and Calibration of Measuring Instruments

63. Reference was made earlier to 'justifiable faith in dial readings'. The extent to which this matters necessarily depends on the complexity of the instrument and the purpose for which it is used. Neither a foot rule nor a clinical thermometer, if correctly calibrated originally, is likely to give

trouble in use through incorrect markings except as a result of catastrophic damage which is obvious. With more sophisticated instruments, however, the possibilities of faults developing are greater and while outright failures will probably be obvious, slow drifts as a result of wear or changes in components are not likely to be noticed, at least in the early stages. The results of such changes will be errors which will almost certainly be embarrassing and may be extremely expensive.

64. Any user of measuring instruments is therefore well advised to ensure against errors of this type by making arrangements for the regular inspection and re-calibration of all his measuring equipment. This is obviously best organized by making it a formal task for suitably qualified persons to undertake. It can be controlled by a diary which indicates when each instrument should be called in for checking and by a sticker or other firmly-secured label on each instrument indicating when it should no longer be used without recalibration. It should be noted that the existence of such a label does not excuse the user from returning an instrument earlier for examination if he has any doubt about its performance or thinks it may have been exposed to a risk of damage or misuse.

65. The appropriate periodicity for recalibration for each type of instrument can be fixed by a combination of intelligent estimation and experience, being modified in the light of the results of successive calibrations. In this field an experienced calibration organization can guide instrument users. Too -frequent calibration costs money and decreases instrument availability; too infrequent calibration may mean that results recently obtained are suspect and expensive waste may result.

66. In instruments used for trade or for supplies to the general public - balances, electricity meters, taximeters etc,-the periodicity for recalibration is sometimes covered by statute; even in such cases intelligent supervision of results can lead to adjustment of periodicities to achieve maximum economy consistent with confidence in indicated values. In this type of field, also, intelligent analysis of results of recalibration should lead to elimination

of those types of instrument which are the most unstable.

67. Considerable economies can be achieved by checking subscribers' meters in situ, though this is , so far as is known, applied at present only to electricity meters.

68. Many, if not most, electricity supply authorities are organized and equipped not only to check new meters supplied by contractors but also to repair and recalibrate meters withdrawn from service, either on change of subscriber or a periodic basis. In some cases new supply meters are checked both by manufacturer and supply authority and perhaps also by government and some economy could result by co-operation to make only one check, suitably supervised, serve all purposes. Some amendment of legislation might be required in particular cases.

69. Economies in recalibration can be achieved for certain types of instrument in widespread use, either by arranging special rigs, possibly partly or fully automatic, for the calibration of particular types or by grouping like instruments, on a calendar basis, so that like instruments are dealt with together.

70. As a long-term project, calibration results could be fed into a computer which could be programmed to draw attention to particular trends, drifts of standards or weaknesses of particular types of instrument or to watch trends in the performance of particular calibration laboratories.

Documentation of Instruments and of Calibrations

71. Each laboratory will normally maintain an inventory of its own equipment and instruments to which additions will be made as new instruments are obtained. For each measuring instrument a record should be maintained, identifying the instrument by make, type, serial number and relevant specification and showing details of the periodic calibrations against an appropriate better standard, either within the laboratory or elsewhere, with the particulars of adjustments required to bring the instrument within the specification limits or of repairs or replacement of components. The correspnding calibration certificates should be filed with the record of the instrument.

72. Each calibration of a customer's instrument done within the laboratory should be recorded on a certificate of standard form, either as used within the particular laboratory or as used for the measurement service as a whole. It should also be recorded briefly in a day-book or log, from which the laboratory copy of the certificate appropriate to any particular calibration can easily be traced in one or more files in which copies are held in order of certificate numbers. The log entry should also show who made the calibration if not the person signing the certificate.

73. It is fundamental to confidence in the national measurement service that no certificate may be issued in circumstances likely to reduce confidence in the integrity of the service or in the correctness of the results reported.

74. The following requirements will be found suitable for observance in most working calibration (or measurement) laboratories :-

(a) A standard size of certificate should be adopted - international sizes A4 and A5 serve most purposes. If fold-out sheets are required, e.g. for extensive tables, they should normally be multiples of the A4 size less an allowance of 2 - 3 cms to allow a margin for filing. Paper should be white or nearly so, tough and durable.

(b) Printing or writing may be used so long as it is clear and unambiguous, durable in storage or when exposed to artificial light or sunlight and does not involve washable ink. Durability for at least five years is desirable.

(c) The text shall show :-

- the name, address and telephone number of the laboratory;
- the identification of its status within the N.M.S., including approval number, if any;
- the words 'Certificate of Calibration' or 'of Measurement', as appropriate;
- the serial number of the certificate (serial numbers shall be issued in chronological order) which shall appear on each page;
- the date of issue, expressed in order day, month (word not figures), year;
- the number of pages in the certificate, counting each printed side

as one page;

- a suitable statement about the correctness of the measurements reported and claiming copyright in the certificate;
- the signature of the person in the laboratory responsible for the correctness of the information presented; this shall be legible on each copy,
- details of the instrument calibrated, including make, type, serial number, details of accessories where relevant to the calibration, together with a cross-reference to any known preceding calibration certificate for the same item;
- details of the specification (source, number, issue, date) or handbook to which the calibration is related;
- an estimate of the uncertainty associated with any measurement reported

(d) If the certificate reports compliance with a specification but does not report actual measurements, the particular clauses of the specification must be clearly identified and it must also be clear that the measurement results obtained lie within the relevant specification limits narrowed by the estimated uncertainty of measurement.

(e) Any special precautions taken regarding environment or preliminary conditioning, or any variation in environment which might have affected results must be noted in the certificate. Similarly any adjustment made before, during, or after calibration must be recorded.

(f) Should any instability be observed it should be recorded. In a serious case the laboratory would normally refuse to issue a certificate.

(g) No supplementary information affecting the validity of a certificate shall be reported by any other means (e.g.letter) - any correction or addition must be reported by the issue of a further certificate clearly marked as 'Supplement to certificate number.......' and complying with the foregoing requirements.

74.10.2