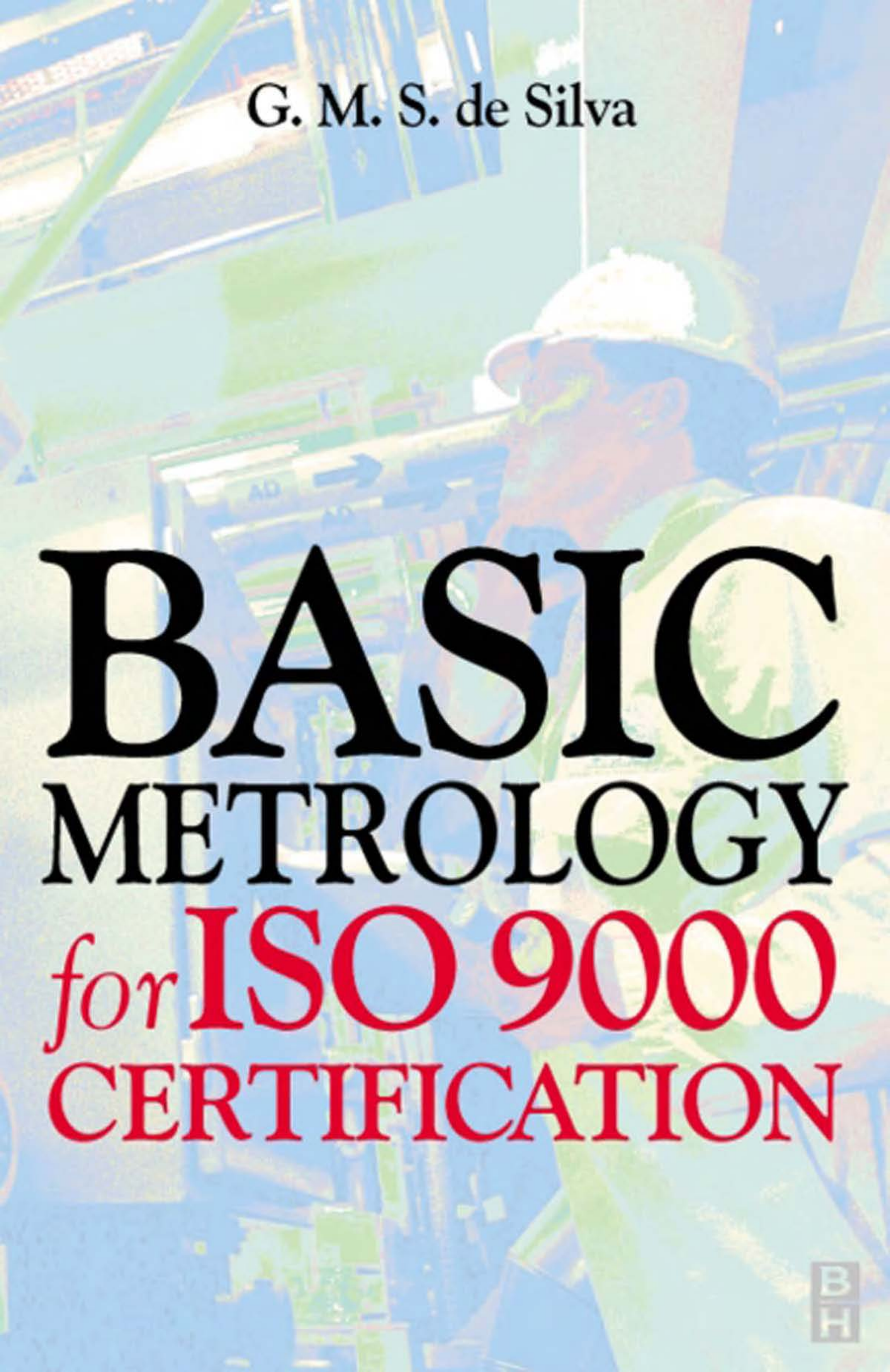

G. M. S. de Silva

BASIC METROLOGY *for* ISO 9000 CERTIFICATION

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Foreword

Metrology is often considered to be simply a field of science and technology concentrating on the measurement and accuracy of things we make. However, much of the historical development of technology suggests this chicken and egg situation is reversed, in that evolving the ability to measure qualities more accurately allows us to develop more reliable ways of manufacturing things, as we now have a means of controlling quality.

The recent rise in nano-technological advances is a beacon to this premise, which was recognized in an earlier era of technological development, that might be called the micro-technology phase associated with the industrial revolution. In particular by prominent people of that era, such as one of the founders of modern metrology, Joseph Whitworth, who in his Presidential Address to The Institution of Mechanical Engineers, in London in 1856, said the following;

"*I would next call your attention to the vast importance of attending to the two great elements of constructive mechanics, namely, the true plane and the power of measurement*",

and

"I hope the members of this institution will join me in doing what we can with reference to these two important subjects – correct measurement and its corollary proper graduation of size. The want for more correct measurement seems to pervade everything."

Little has changed in our needs in this respect, and the importance of metrology to the advancement of science and technology remains, albeit on improved levels of accuracy.

The author, Swinton de Silva, has worked for the majority of his working life, a period covering several decades, in this field, and the impressive breadth of his metrology knowledge is reflected in the very broad ranging contents of this book. As well as representing an extremely valuable contribution to the literature in the metrology field, this book also represents an essential guide to those involved with ISO 9000 Certification.

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Preface

Test and measuring instruments are used extensively in the modern manufacturing and processing organizations. The accuracy of the measurements made by these instruments has a direct impact on the quality of the product or service provided by the organization. The recent developments in the field of certified quality and environmental management systems, namely registration to ISO 9000 and ISO 14000 standards, require that test and measurement equipment be periodically calibrated using measurement standards traceable to the international measurement system. In addition there is also the necessity for test and calibration laboratories to be accredited by a third party certification body in accordance with the international standard ISO/IEC 17025 (previously ISO/IEC Guide 25).

Although a number of books are available describing specific measurement fields such as temperature and pressure, books covering a number of important measurement fields are few. This book intends to fill this gap. The book is primarily aimed at persons working in industry whose duties are related to calibration and maintenance of test and measurement equipment. Students reading for bachelor's degrees or diplomas in the fields of electrical, mechanical and production engineering and related technology-based courses can also use it as an introduction to metrology.

The book is an introduction to fundamental measurement principles and practical techniques used in the calibration of test and measuring equipment belonging to seven measurement fields, namely length, angle, mass, temperature, pressure, force and electrical metrology. Fundamental concepts of measurement and calculation of measurement uncertainties are also dealt with.

G M S de Silva

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Figures 3.3, 3.4, 3.5 and Table 3.1 (Critical characteristics of gauge blocks taken from ISO 3650: 1998), Table 6.5 (Classification of force proving instruments from ISO 376: 1987) and Table 6.7 (Classes of testing machines from ISO 7500-1: 1999) have been reproduced with the permission of the International Organization for Standardization, ISO. These standards can be obtained from any ISO member body or directly from the Central Secretariat, ISO, Case Postal 56, 1211 Geneva 20, Switzerland. Copyright remains with ISO.

The author thanks the International Electrotechnical Commission (IEC) for permission to reproduce extracts from IEC publications IEC 60751 (1983-01) entitled ‘Industrial platinum resistance thermometer sensors’ and IEC 60584-2 (1982-01) entitled ‘Thermocouples. Part 2: Tolerances’. All extracts are the copyright of IEC, Geneva, Switzerland. All rights reserved. Further information on the IEC, its publications and its activities is available from www.iec.ch. IEC has no responsibility for the placement and context in which the extracts and contents are reproduced in this publication; nor is IEC in any way responsible for any of the other content or accuracy of this publication.

1 Requirements of ISO 9000 standards for test and measuring equipment

1.1 Introduction

Certification to ISO 9000 standards has become a primary requirement for both manufacturing and service-oriented organizations. Calibration and control of test, measurement and inspection equipment is one of the more important requirements given in the standard. A company that wants to obtain ISO 9000 certification therefore has to look into this vital aspect of their operations.

Test or calibration laboratories wishing to obtain independent third party certification should be guided by the requirements of ISO/IEC 17025: 1999 (formerly ISO/IEC Guide 25). A brief outline of the requirements of ISO 9001 standards is given in this chapter.

1.2 Evolution of ISO 9000 standards

The origin of the ISO 9000 series of quality management standards can be traced to the United States (US) military standards. The US military specifications MIL-I-Q9858 and MIL-I-45208 for quality inspection are the first standards to have specified requirements for quality assurance systems in the supplier's organization. Subsequently these standards were published as Allied Quality Assurance Publications (AQAP) 1, 4 and 9.

In 1972, the United Kingdom established UK Defence Standards 05/21, 05/24 and 05/29 based on the AQAP documents 1, 4 and 9. The famous British Standard BS 5750: 1979, parts 1, 2 and 3, were based on the presently obsolete UK Defence Standards 05/21, 05/24 and 05/29.

In 1985 the International Organization for Standardization through its Technical Committee on Quality Management and Assurance (ISO/TC 176) undertook the preparation of a series of international standards for quality management and BS 5750, which had been used successfully by the British Standards Institution for quality system certification, became the natural choice for basing the new international standard. After much deliberation and arguments ISO 9001, ISO 9002 and ISO 9003 were published in 1987. These standards were then adopted by a significant number of national standards bodies, including the United Kingdom, and were published as their national standards. The ISO 9000 series was also published as a European Standard series EN 29000 by the European Committee on Standardization (CEN).

In 1994 a revision of the series was undertaken, and an updated and revised set of standards was published. In the mean time a large number of organizations obtained certification against ISO 9001 and ISO 9002 standards. The usefulness of the standards for quality assurance of products and services was beginning to be accepted worldwide, though there were some organizations that were not entirely convinced by the necessity of a documented quality system as required by the standards.

A further revision of the standards was undertaken during 1996 to 2000, and a revised and improved set of standards known as ISO 9000: 2000 has been published. In the new standard certification can be obtained only against the ISO 9001 standard. ISO 9002 and ISO 9003 standards have been withdrawn. ISO 9004 has been published as a complementary guidance document.

1.3 Requirements of ISO 9001: 2000

The requirements of the ISO 9001: 2000 standard in respect of test, inspection and measuring equipment are summarized below:

(a) The organization shall identify the measurements to be made and the measuring and monitoring devices required to assure conformity of product to specified requirements.
(b) Measuring and monitoring devices shall be used and controlled to ensure that measurement capability is consistent with the measurement requirements.
(c) Measurement and monitoring shall be calibrated and adjusted periodically or prior to use, against devices traceable to international or national standards; where no such standards exist the basis used for calibration shall be recorded.
(d) Where applicable measuring and monitoring devices shall:
    (i) be safeguarded from adjustments that would invalidate the calibration;
    (ii) be protected from damage and deterioration during handling, maintenance and storage;
    (iii) have the results of their calibration recorded; and
    (iv) have the validity of previous results reassessed if they are subsequently found to be out of calibration, and corrective action taken.

Some guidelines for achieving these requirements are given. The international standard ISO 10012 – Part 1 is also a useful source of information for quality assurance of measuring equipment.

1.3.1 Identification of measurement parameters

This is the most important requirement from the point of view of product or service quality. This clause requires that the organization identifies the parameters of the product(s) for which tests or measurements should be carried out and that it equips itself adequately to carry out these tests and measurements. For most products the identification of the test parameters is relatively easy, as they are given in the product specification, national/international standard or specified by the customer.

However, equipping the organization to carry out the tests or measurements to the required level of accuracy is not straightforward as it may cost a relatively large sum of money to acquire the test equipment and for training of monitoring staff. To minimize costs it is necessary to obtain specialist advice as to the type of equipment that should be acquired. Training of the staff in the operation of the equipment and analysis of test data is also very important.

1.3.2 Measurement capability

The capability of the measuring instrument and procedure should not be less than the measurement requirement. Measurement requirements and capabilities are defined in terms of accuracy and uncertainty (see Chapter 2 for explanations of the term *accuracy* and *uncertainty*) of the measurement process, e.g. if a thickness measurement to an accuracy of ±0.1 mm is required, the instrument and the measurement procedure used for the purpose must be able to attain the same or slightly higher level of accuracy. In this instance the cheapest method would be to use a calibrated micrometer (with known corrections) with not more than ±0.02 mm calibration uncertainty.

1.3.3 Calibration of measurement and test equipment

Adjustment of a measuring instrument is an integral part of calibration. However, not all measuring instruments or artefacts are adjustable. Most length measuring instruments such as rulers, tapes and calipers are not adjustable. Also precision weights are not adjustable. For instruments that are non-adjustable, corrections are determined when they are calibrated. Thus when measurements are made using a non-adjustable instrument the correct procedure is to use the corrections given in the calibration certificate. The correction could be neglected, if it is smaller than the required accuracy by at least one order of magnitude. For example, if in the previous example the corrections of the micrometer are of the order of ±0.01 mm or less, then these corrections could be neglected as the required accuracy is only ±0.1 mm.

Traceability to international standards (see Chapter 2 for a discussion of *traceability*) is achieved by careful selection of the calibrating agency, making sure that their standards maintain traceability to international measurement standards. This is where laboratory accreditation comes into the picture as accreditation against ISO/IEC 17025 cannot be obtained without having established traceability to international measurement standards. Calibration laboratories to be used for ISO 9001 purposes should therefore have accreditation in terms of ISO/IEC 17025 standard.

National accreditation systems that accredit test and calibration laboratories are operated in many countries. The oldest accreditation body is found in Australia and is known as the National Accreditation and Testing Authority (NATA). The United Kingdom equivalent body is the United Kingdom Accreditation Service (UKAS) and in the United States there are at least two accrediting bodies, the American Association for Laboratory Accreditation (A2LA) and the National Voluntary Laboratory Accreditation Program (NVLAP).

Although not explicitly stated in ISO 9001, it is generally advisable to obtain calibration services from a laboratory accredited by the national accreditation service of the country, if such a system is available. Also international accreditation is available from bodies such as NATA and UKAS but these would be expensive for many organizations.

1.3.4 Recalibration interval

How is the period of recalibration to be determined? This depends on a number of factors, the most important of which are: the accuracy level, type of instrument and the frequency and conditions of use of the instrument (factory or laboratory). The organization should determine and document the recalibration intervals by analysing the past calibration records of the instrument and the drift observed. The manufacturer's recommendation in this regard is a useful guideline to follow. In the case of electrical measuring instruments the accuracies of instruments are usually given for a specific time period, e.g. 90 days, one year, etc. This means that the specified accuracy may be exceeded after the indicated time period. In such an event a recalibration may be required. Some statistical techniques have been developed to estimate recalibration intervals. The references to these are given in the Bibliography.

1.3.5 Sealing of adjusting mechanisms

Very often the calibration of an instrument is lost because someone had inadvertently adjusted the instrument. This often happens in the course of a minor repair, particularly in electrical measuring instruments where potentiometers are made available for adjustment purposes. It is a good practice to seal adjusting screws with security stickers or other appropriate means so that the instrument cannot be adjusted inadvertently. Generally all good calibration laboratories carry out such practices.

1.3.6 Handling and storage of test and measurement equipment

It is very important to handle test and measurement equipment with due care as their functioning and accuracy can deteriorate rapidly due to rough handling and inappropriate storage conditions, e.g. gauge blocks, micrometers, calipers and other length measuring instruments should be cleaned and returned to their boxes after use as ingress of dust can rapidly wear off their mating surfaces. Similarly precision weights should never be handled with bare hands. Cast iron weights should be cleaned and stored in a dust-free environment as dust particles act as nucleation centres for corrosion to take place thereby changing the value of the weight. Electrical measuring instruments are very susceptible to deterioration due to high temperature and humidity. In many countries with high humidity levels corrosion is a major problem. Due care such as applying a thin layer of oil or other protective material should be considered for long-term storage.

1.3.7 Documentation of calibration results

All calibrations carried out internally or by external laboratories should be documented in the form of a report. Essential details to be recorded are: date of calibration, item calibrated, reference standard used and its traceability, environmental conditions (temperature, humidity, etc.), a brief description of the calibration procedure or reference to the calibration procedure, details of results and uncertainties. A typical format of a calibration report is given in Appendix 1.

1.3.8 Discovery of out-of-calibration status

This very important aspect is often neglected by many organizations. If critical test equipment is found to be out of calibration, then the test results obtained using this piece of equipment for a considerable period of time prior to the discovery may have been inaccurate. It is necessary to launch an investigation to find out how this condition affected the product and the customer's requirements, and to take corrective action.

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