Australian Government
National Measurement Institute

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NMI V 1

Uniform Test Procedures for the Verification, Certification and In-service Inspection of Non-automatic Weighing Instruments

Learners Manual

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1 INTRODUCTION

The integrity of any legal metrology system requires a number of factors, none of which are more important than having highly skilled and experienced personnel. Consequently this training program has been developed to enable participants to acquire the skills necessary to competently conduct verification, certification or in-service inspections of non-automatic weighing instruments being used for trade.

This learner's manual relates to non-automatic weighing instruments and will be used as part of the non-automatic weighing instrument training module, which includes both classroom and on the job training. While the learning material covered in this manual has been developed in consultation between the National Measurement Institute and Queensland Trade Measurement, it can be used by any organisation involved in legal metrology including interstate or international Trade Measurement Authorities and Servicing Licensees.

The non-automatic weighing instruments training module has been developed using a competency-based model for workplace training, which allows learners to develop the required skills and knowledge at their own pace. Learners will be required to complete a number of assessment activities based on the units of competency in either classroom and/or on-the-job situations.

This student's manual only relates to non-automatic weighing instruments and provides material relevant to the following learning outcomes:

Apply enabling legislation to measuring instruments:

- Access and use current information relating to the legislation.

Describe the design and application of basic components:

- Identify the fundamental operating features of non-automatic weighing instruments.
- Describe the purpose of major components within non-automatic weighing instruments.

Determine the type of inspection required:

- Assess measuring instruments to determine whether a verification, certification or in-service inspection is to be undertaken.
- Explain the processes required for verification, certification and in-service of a non-automatic weighing instrument.
- Identify the appropriate tolerances for the determined inspection.

Perform inspection to determine compliance.

- Analyse the instruments' operating environment to determine how it could impact on its performance.
- Identify sources of any possible operational error in the use of measuring instruments.
- Select and use specialised equipment in the prescribed manner for the inspection.
- Conduct inspection of measuring instruments in accordance with appropriate test procedures and workplace, health and safety guidelines.

This training module is designed to be used in conjunction with *NMI V 1 Uniform Test Procedures for the Verification, Certification and In-service Inspection of Non-automatic Weighing Instruments.* These procedures were developed to ensure that test procedures used by State and Territory trade measurement inspectors and licensed certifiers in Australia are nationally uniform.

During this training module there are a number of incidences where photographs of non-automatic weighing instruments are used to demonstrate a particular problem. In these cases the problems have been simulated for training purposes only.

1.1 WORKPLACE REQUIREMENTS

To gain the best results from this training module, you will need to follow the instructions given throughout this learning material.

Completing the learning activities

You will work through the information contained in this *Learners Manual* with your workplace trainer during the classroom component of your training.

Assessment

The assessment for this training module is made up of a number of **Assessment Activities** and **Structured Observation Checklists** of your work performance. These assessment activities and observation checklists are found in the Assessment Manual.

1.2 COURSE OUTLINE

Day 1

- Overview of the course
- Australia's National Measurement System
- Construction of non-automatic weighing instruments
- Overview of NSC V 1
- Equipment required for testing a non-automatic weighing instrument
- Standard Procedures for testing a non-automatic weighing instrument
- Visual inspection of a non-automatic weighing instrument
- Testing a non-automatic weighing instrument
- Suggested sequence for testing
- Question and answer session.

2 AUSTRALIA'S NATIONAL MEASUREMENT SYSTEM

The national measurement system is a coherent formal system, which ensures that measurements can be made on a consistent basis throughout the country. It ensures practical measurements made by industry and the community are linked to the international system of units (SI). When first established the national measurement system focused on "physical measurements" such as length, mass, time and temperature. The development of chemical and biological measurement capabilities and widespread testing means that the national system now must also cover these measurements. Chemical and biological measurements are critical to decision-making on many aspects of our social and economic life – environmental issues, public health, law enforcement and trade.

Under the Australian Constitution, the Federal Government is responsible for weights and measures. The *National Measurement Act 1960* is the basis for Australia's measurement system. This Act establishes Australia's units and standards of measurement; the National Measurement Institute (NMI) and the Chief Metrologist as the reference points for the national measurement system; and Australia's link into international measurement infrastructure. A copy of the National Measurement Act can be viewed at http://scaleplus.law.gov.au/html/pasteact/browse/TOCNA.htm.

Australia's national measurement system is made up of four national organisations, which are complemented by trade measurement authorities and verifying authorities. The national organisations are Standards Australia International (SAI), the National Association of Testing Authorities, Australia (NATA), the Joint Accreditation System of Australia and New Zealand (JAS-ANZ) and the National Measurement Institute (NMI). Figure 1 shows the main areas of responsibility of these organisations.

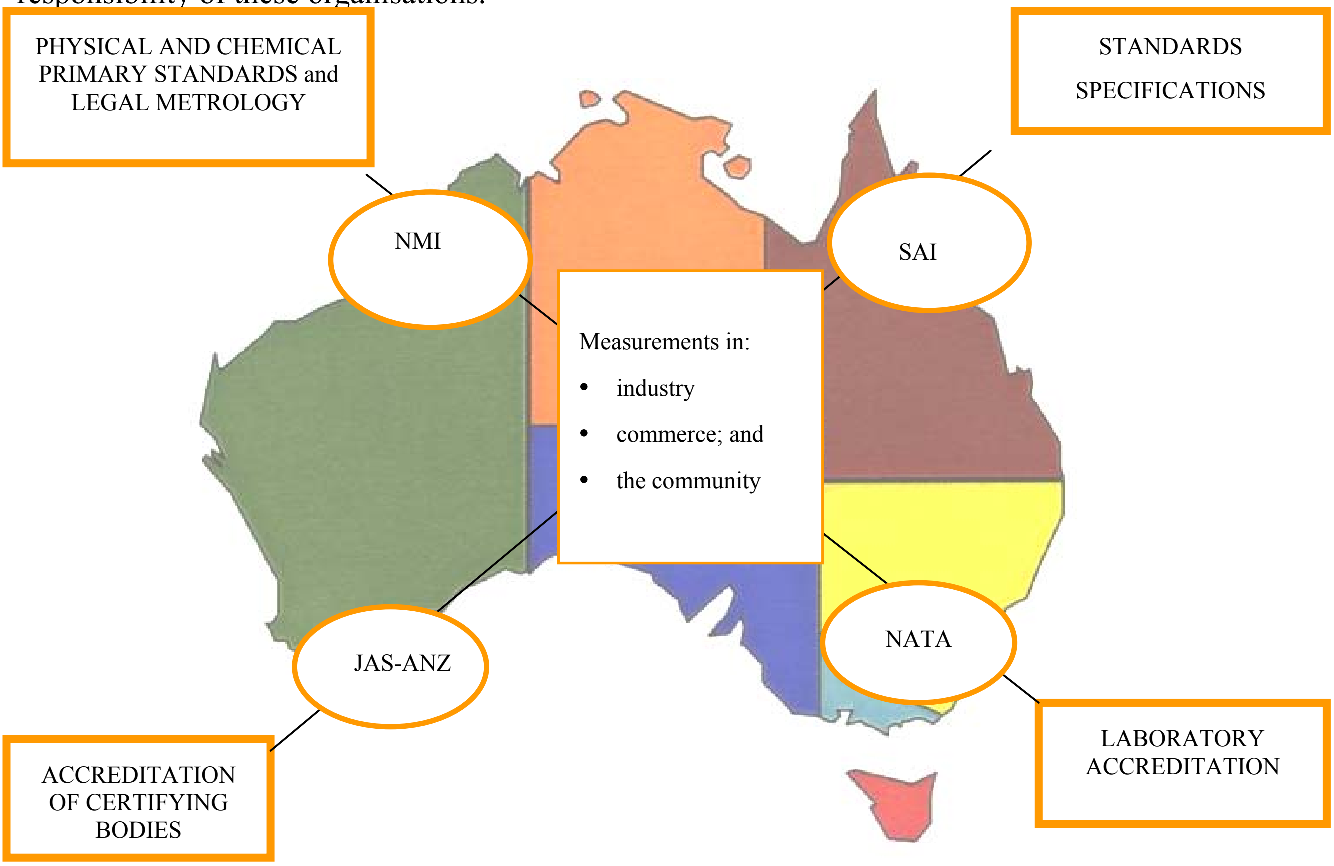


Figure 1 –The main areas of responsibility of SAI, NATA, JAS-ANZ, and NMI.

2.1 THE NATIONAL MEASUREMENT INSTITUTE

The National Measurement Institute is Australia's premier source of advice and services to the Government on physical, chemical and biological measurement. It:

- Maintains the national standards of measurement across the spectrums of physical, chemical and biological measurement. It will ensure national standards, where appropriate, conform with and are traceable to international standards.
- Performs pattern approval testing of measuring instruments used for trade to ensure they comply with national and international standards.
- Provides services to industry and government clients to ensure measuring instruments used by them are calibrated to national standards or otherwise traceable to them.
- Provides training and assistance with technology transfer to industry in support of their take-up of leading edge measurement standards and techniques.
- Undertakes research and development work to ensure Australia's measurement standards and techniques across the spectrums of physical, chemical and biological measurement lead the way in technological advances in measurement.
- Coordinates and implement Australia's legal metrology framework as set out in Commonwealth legislation.
- Contributes to the further development of and adherence to international standards; the removal of technical barriers to trade principally through negotiating mutual recognition arrangements; and to the international harmonisation of legal metrology standards.

Services provided by the National Measurement Institute include the provision of; both primary and secondary standards of physical, chemical and biological measurement; specialist chemical and biological measurement in areas of forensic science, drugs in sport, food safety and the environment; testing and calibrating measuring instruments; and training - both internationally and nationally. The institute collaborates closely with industry clients to ensure its science base, its skills, its expertise and its services are responding to industry needs in the fields of physical, chemical and biological measurement and are providing leadership in making technologically advanced standards and techniques available to industry. The driving goal of the institute will be to keep Australia at the leading edge of innovation in all fields of measurement in support of national industry development and expansion of international markets for our goods and services. For more detail visit: http://www.measurement.gov.au

2.2 NATIONAL ASSOCIATION OF TESTING AUTHORITIES, AUSTRALIA

NATA was established in 1946 to coordinate testing, measurement and calibration facilities throughout Australia and was the first such comprehensive national organisation in the world. Almost all of the second-level and routine calibration work in Australia is carried out in laboratory establishments accredited by NATA. The governing body of NATA is its Council, which consists of elected representatives of accredited laboratories, nominees of the Commonwealth and State governments, members of the Confederation of Australian Industry and Standards Australia together with representatives of Australia's leading professional institutes. The Council is supported by committees and panels of independent technical advisers who advise it on suitable criteria for the accreditation of laboratories, and who conduct peer group assessment of compliance with those criteria.

NATA defines criteria for all areas of laboratory quality assurance, i.e. personnel, accommodation, facilities, calibration, management and laboratory practices. All accredited laboratories must demonstrate compliance with the required criteria at regular intervals.

NATA plays a major role in the International Laboratory Accreditation Conference (ILAC) and has mutual recognition agreements with corresponding organisations in many other countries. For more detail visit: http://www.nata.asn.au/

2.3 STANDARDS AUSTRALIA

Standards Australia is an independent body formed in 1922 and incorporated by Royal Charter. Standards Australia enjoys the full cooperation of the Commonwealth and State governments and of Australian industry and commerce. Its main function is to facilitate the preparation, publishing and updating of Australian standard specifications and related documents.

The affairs of Standards Australia are managed by a Council comprising nominees from the Commonwealth and State governments together with representatives from manufacturing associations, commercial interests, professional institutes and a diversity of community interests. Responsibility for supervision of standards documentation work within particular spheres of interest is devolved by the Council to a number of specialised standards boards. In addition there are a substantial number of technical committees and sub-committees comprised of users, purchasing bodies, manufacturers, suppliers, regulatory authorities, research and testing organisations, professional and technical bodies and consumer organisations. Australian standards take the form of a document containing a concise set of requirements including, where appropriate, procedures for determining that the requirements are satisfied. Standards Australia also issues the AS mark which is a third-party certification, registered under the Trade Marks Act, that an article or product complies with a specified Australian standard.

Standards Australia represents Australia on the International Organisation for Standardisation (ISO) and the International Electro-technical Commission (IEC) and through these organisations maintains communication with its counterparts in other countries such as the British Standards Institution (BSI) and the American National Standards Institute (ANSI). For more detail visit: http://www.standards.org.au/

2.4 JAS-ANZ

JAS-ANZ is a not for profit, self funding international organisation established under a Treaty between the Governments of Australia and New Zealand on 30 October 1991 to act as the joint accreditation body for Australia and New Zealand for certification of management systems, products and personnel. On 28 March 1996 a regulation was made under the Australian International Organizations (Privileges and Immunities) Act 1963 declaring JAS-ANZ to be an international organisation to which the Act applies. New Regulations re-affirming JAS-ANZ's status, were made on 18 June 1998.

JAS-ANZ is non-discriminatory, in that it will accept applications from Certification Bodies operating anywhere in the world. The JAS-ANZ Board has placed no geographic limitations on the organisation’s operations. JAS-ANZ accreditation programmes are accessible to all Certification Bodies, irrespective of size, location or affiliations, whose operations include activities for which accreditation programmes are currently available.

JAS-ANZ s mission is to:

- strengthen trade;
- be the joint accreditation body for Australia and New Zealand for certification of management systems, products and personnel;
- develop mutual recognition in overseas markets for Australian and New Zealand producers, exports and personnel;

- establish strong links with counterpart bodies; and
- establish mutual recognition agreements with other accreditation bodies and relevant organisations with national or regional coverage on a bilateral and multilateral basis as appropriate.

For more detail visit: http://www.jas-anz.com.au/showpage.php

2.5 TRACEABILITY

The Australian measurement system links the SI units through a chain of measurement standards to the practical measurements made in industry and the community. A practical measurement that is linked to the SI units in this way is called a traceable measurement (i.e., traceable to internationally recognised measurement standards and units). Figure 2 shows the essential features of Australia's metrological pyramid.

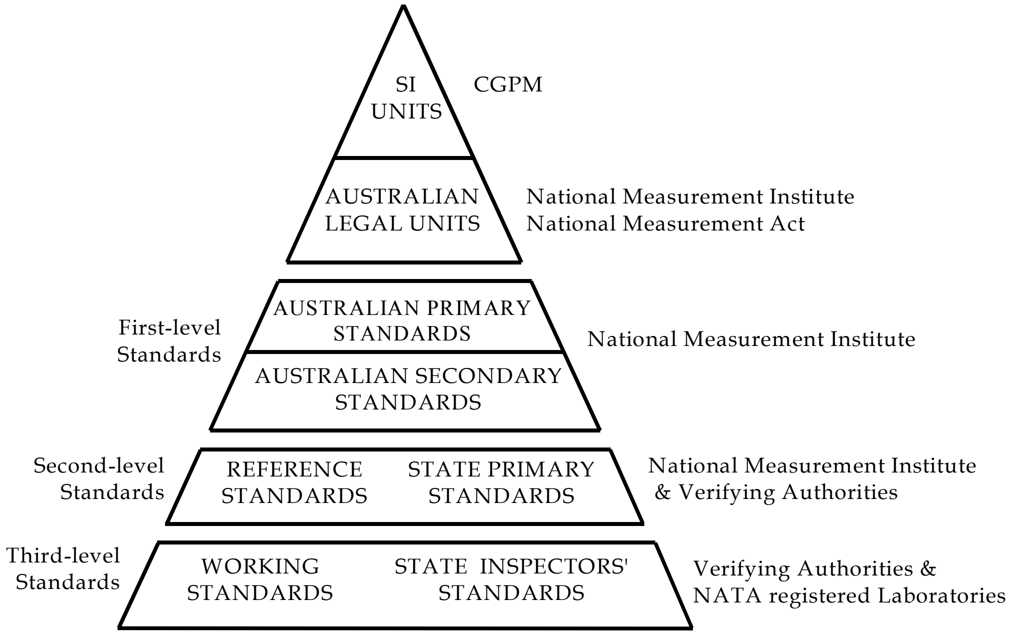


Figure 2. – Australia's hierarchy of physical units and standards

2.5.1 Australian legal units

At the top of the pyramid is the international system of units (SI units). The international system of units was adopted by international agreement at the General Conference of Weights and Measures (CGWM) in 1960. SI units are adopted as Australian legal units of measurement by incorporating reference to them in the *National Measurement Act 1960*. This provides the basis for legal traceability of measurements in Australia. The National Measurement Institute is responsible for maintaining the Act and for advising on its implementation. For more detail on SI units visit: http://www.bipm.org/en/si/

2.5.2 First-level standards

The units of measurement have to be realised as tangible practical standards of measurement in order to be useful. The National Measurement Institute is responsible for realising, maintaining and disseminating Australia's national physical standards. It is also responsible for the development and maintenance of chemical reference materials and methods, which underpin consistency of chemical measurements.

Responsibility for maintaining standards relating to ionising radiation has been delegated to the Australian Nuclear Science and Technology Organisation and the Australian Radiation Protection and Nuclear Safety Agency.

The National Measurement Institute maintains a national (or Australian primary) standard for each of the SI base units except the ampere (which is derived from standards of voltage and resistance) and the mole (for which no internationally-defined realisation has been developed as yet). It also maintains Australian primary standards for a wide range of derived SI units. It also holds Australian secondary standards (calibrated in terms of the primary standards), which are used when calibrating lower-level standards or instruments.

2.5.3 Second and third-level standards and measuring instruments

It would be impractical for the National Measurement Institute to handle all of the measuring standards and instruments that require calibration in order to demonstrate traceability of measurement. The National Measurement Institute calibrates higher accuracy standards held by government calibration laboratories, verifying authorities such as trade measurement authorities, and by private-sector calibration laboratories accredited by the National Association of Testing Authorities, Australia. These laboratories use these second-level standards to calibrate a wide range of lower accuracy standards and measuring instruments used in industry and commerce.

2.5.4 Traceability in chemical and biological measurement

The SI unit for measurement of chemical quantities is the mole. One of the difficulties for chemists in achieving traceability is that there is no internationally agreed realisation or "prototype" of the mole. Consequently, traceability of chemical measurements is usually achieved by the use of tools such as 'chemical reference standards' or 'reference methods'.

Other important components of this systematic approach to establishing traceability for chemists are:

- demonstration of the equivalence of national (or other high level) standards through inter-laboratory comparisons.
- links between high level standards and working level measurements established through secondary standards, calibration laboratories and working level inter-laboratory comparisons or proficiency testing
- establishment of a formal quality system and third party certification and accreditation.

The bio-measurement area provides even greater challenges in the application of a metrological approach. Bio-measurement is not only concerned with quantity and identity, but also the activity of the substance being measured. The national Measurement Institute's bio-measurement program has been established to ensure Australia's active involvement in this new and challenging area of measurement

2.6 PATTERN APPROVAL OF MEASURING INSTRUMENTS

The National Measurement Institute is responsible for examining and approving patterns of trade measuring instruments. Instruments are examined in accordance with national or international metrological specifications to determine whether or not an instrument is capable of retaining its calibration over a range of environmental and operating conditions and to ensure the instrument is not capable of facilitating fraud. Pattern approval protects measuring instrument manufacturers and importers from substandard measuring instruments that would otherwise provide unfair competition. It also means that when a measuring instrument is bought there can be confidence that the instrument will meet certain metrological standards of performance over a range of operating conditions and that the instrument will not need to be excessively recalibrated. As a result the parties to the measurement are also protected.

Where the National Measurement Institute does not have the appropriate testing facilities, Approving Authorities may be appointed to carry out pattern approval testing of measuring instruments used for trade or regulatory purposes. Test reports from Approving Authorities are submitted to the National Measurement Institute together with an application form for pattern approval.

The National Measurement Institute pattern approval laboratory is NATA registered and any bodies appointed by the National Measurement Institute for this purpose would also need to be NATA registered.

2.7 PATTERN COMPLIANCE/ASSURANCE

Pattern compliance/assurance is the process whereby a statistically significant number of production instruments are randomly checked to ensure that they comply with the approved pattern for their design. If the production instrument does not comply with the approved pattern, the community may suffer loss in two ways. Firstly the non-complying instruments might include features that facilitate fraud. Secondly the instruments might not be able to maintain calibration and the inaccurate measurements lead to disputation and significant transaction costs. Currently mutual recognition agreements are being developed between countries with similar pattern approval capabilities. This will reduce the number of times an instrument manufacturer has to get the same instrument approved. Pattern compliance will be used as a tool to protect consumers and ensure the instruments comply with the approval.

2.8 AUTHORITIES

The National Measurement Institute appoints three categories of authorities to support the needs of the national measurement system: Approving Authorities; Certifying Authorities; and Verifying Authorities. These appointments are autonomous and are subject to different criteria. Verifying authorities may be appointed either to verify reference standards of measurement, or utility meters. Verifying Authorities are the well-established method of disseminating traceable standards throughout the national measurement system. Approving Authorities and Certifying Authorities were introduced in 1999 as an important component of the metrological control system for utility meters and grain protein measurements.

Verifying authorities for standards comprise all trade measurement authorities, all surveyors general and some other regulatory authorities and calibration laboratories. Verifying authorities hold standards of measurement for various physical quantities for which there is a legal requirement to demonstrate the value and uncertainty of the quantity that has been measured. The standards they hold must be legally traceable to the Australian Primary Standards. The National Measurement Institute’s website contains an up-to-date list of all Verifying Authorities and the physical quantities related to their appointment.

2.9 TRADE MEASUREMENT

Each State and Territory has a trade measurement authority. Their titles vary, e.g. Trade Measurement Queensland (QLD), Trading Standards Office (ACT), Office of Fair Trading (NSW), Trade Measurement Victoria (VIC), Office of Fair Trading, Department of Public and Consumer Affairs (SA) however, they all have the same primary functions. These include:

- maintaining the State primary standards of measurement;
- ensuring traceability of the State primary standard to the Australian primary standard;

- disseminating secondary, reference and working standards from the State primary standards;
- verifying the accuracy of measuring instruments used for trade in their State or Territory;
- checking pre-packaged articles and trading practices; and
- licensing and auditing servicing licensees.

State and territory governments require that all goods sold by measurement of weight, length, volume, area or count are accurately measured, labelled and the correct price calculated. This includes petrol pumps, shop scales, weighbridges, pre-packed articles, machines for measuring length etc.

States and Territories have their own weights and measures legislation. In the case of all states except WA this is based on uniform trade measurement legislation. Currently, major efforts are being made to ensure that there is uniformity of trade measurement requirements between all the States and Territories.

Trade measurement plays an important part in the metrological control of measuring instruments used for trade, and is an important contact with the general community in maintaining consumer and trader confidence in the many areas that are legally controlled by measurement. One of the roles of a trade measurement inspector is to ensure that the community understands the requirements of these laws and that they are effectively enforced.

Trade Measurement legislation, exists to:

- promote commercial certainty;
- reduce business costs;
- improve the efficiency of the trade measurement industry; and
- maintain consumer confidence through suitable protection provisions.

The trade measurement inspector's role is to enforce the requirement of this legislation. Servicing licensees are appointed by Trade Measurement jurisdictions to support this work. They certify and in-service inspect instruments in the field using the Uniform Test Procedures. This work should be carried out in a professional, non-threatening and informative manner. Upon arrival at a service station the inspector or certifier must always:

- inform the service station manager they are on the premises;
- identify themselves using their official identification card;
- explain the purpose of the visit; and
- provide opportunities for the service station manager to ask questions to clarify any concerns.

2.9.1 Verification or Certification of Trade Measurement Instruments

Verification or certification is the process whereby instruments are:

- inspected to ensure that they comply with the approved pattern;
- tested using uniform test procedures to ensure that they are operating within the maximum permissible errors; and
- marked with the inspectors or certifiers approved identification mark to testify that they have verified or certified the instrument in accordance with the appropriate uniform test procedures.

If a government inspector carries out the above procedures it is referred to as verification. If it is carried out by a private organisation licensed to do this work then it is called a certification. When this process is carried out for the first time it is referred to as initial verification or initial certification. Initial verification/certification is conducted prior to delivery from the factory or at installation in the field. Subsequent verification/certification is conducted on an instrument that has been in service and for some reason is required to be tested again. This could be because the instrument has been repaired or adjusted; the verification/certification period has expired, or at the request of the user. Subsequent verification follows the same procedures as initial verification. The National Measurement Institute in conjunction with Trade Measurement Authorities, industry and other stakeholders develops the uniform test procedures and requirements for verification/certification. These documents are available on National Measurement Institute website. http://www.measurement.gov.au.

2.9.2 In-service Inspection

In-service inspection is a test of the accuracy of measuring instruments that have been in use for some time. Trade Measurement inspectors carry out in-service inspections as part of their regulatory responsibility. Certifiers appointed by the States and Territories Trade Measurement Authorities perform this work on behalf of traders who wish to ensure their equipment is working as required. When an inspector carries out an in-service inspection it is sometimes referred to as a re-verification.

2.10 OIML

The International Organization of Legal Metrology (OIML) was established in 1955 in order to promote the global harmonization of legal metrology procedures. Since that time, OIML has developed a worldwide technical structure that provides its Members with metrological guidelines for the elaboration of national and regional requirements concerning the manufacture and use of measuring instruments for legal metrology applications.

OIML is an intergovernmental treaty organisation whose membership includes *Member States* and *Corresponding Members*. *Member States* are countries, which participate actively in technical activities while *Corresponding Members* are countries, which join OIML as observers. For more information visit www.oiml.org. The National Measurement Institute represents Australia as a member state of OIML. For more detail visit: http://www.oiml.org.

2.11 METROLOGICAL CONTROL OF MEASURING INSTRUMENTS

An efficient metrological control system is essential to provide control of measuring instruments in the many areas legally controlled by measurements such as environmental monitoring, traffic control, health and safety, and trade.

This requires a uniform approach to the pattern approval, verification/certification and in-service inspection/certification of measuring instruments. An efficient pattern approval process is essential to determine the integrity of the measuring instrument. Assurance that production instruments conform to their pattern and do not drift outside acceptable tolerances in the field is also an important aspect of metrological control.

3 THE CONSTRUCTION OF WEIGHING INSTRUMENTS

A weighing instrument, as defined in OIML R 76, is a measuring instrument that serves to determine the mass of a body by using the action of gravity on this body. This is achieved using mechanical and/or electronic devices as described below and illustrated in Figure 3.

Mechanical weighing instruments are principally designed as lever magnifying systems, where the relatively small deflection to the load receptor is magnified to a large deflection of a pointer on a dial or chart. This change in deflection is achieved mostly by using levers of the first or second order. The final resistance or effort to balance the load is either by steelyard, spring or cam and pendulum mechanisms.

Hybrid instruments are usually mechanical weighing instruments in which the analogue indicating device has been replaced by a digital indicator. A load cell is used to change the mechanical force into an electronic force. The levers in the base still carry the load cell installed in the connecting rod, which previously went to the analogue indicator. Hence the term 'hybrid weighbridge'.

Electronic weighing instruments are those in which the load cell/s carry the load via a load receptor and a digital indicator displays the load. No mechanical levers are used. Hence the term 'full load cell weighbridge

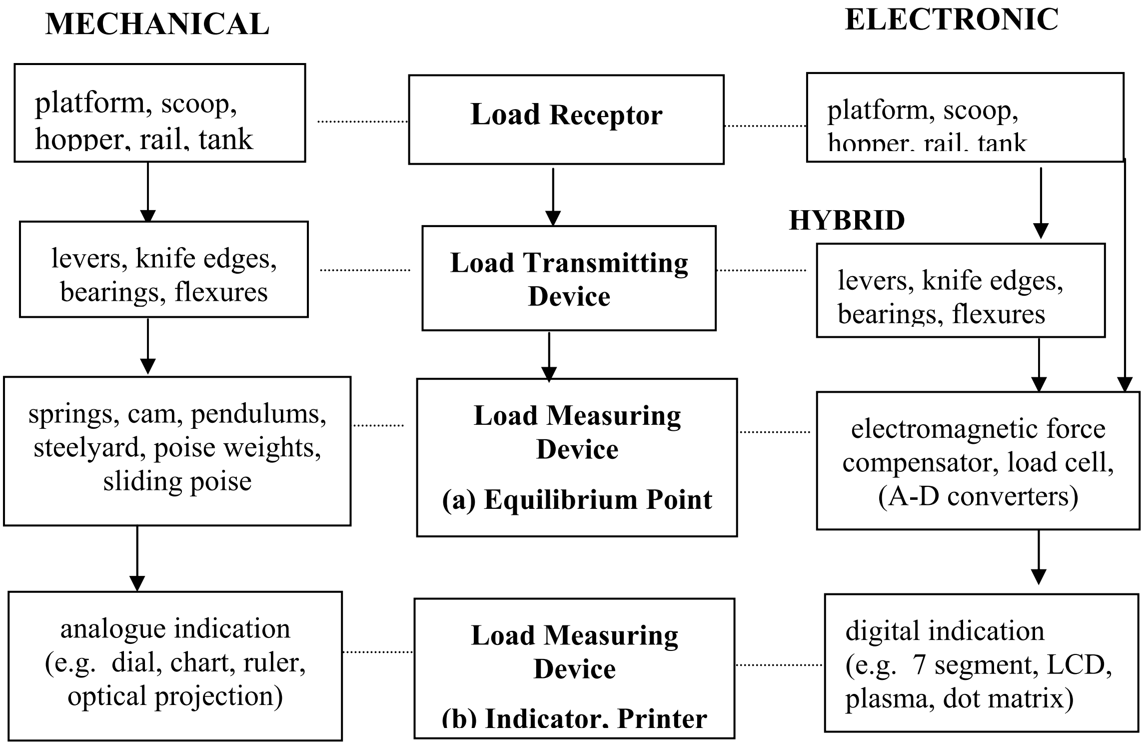


Figure 3 – Basic components of a weighing instrument

3.1 MECHANICAL WEIGHING INSTRUMENTS

3.1.1 Levers

The most common mechanism used in the construction of mechanical weighing instruments is the lever. This can be defined as a rigid bar, which can turn about a fixed axis called the fulcrum. The fulcrum is usually a knife-edge, which is able to pivot in a bearing. The shape of the lever may vary, as may the forces and the direction in which they act on the lever.

In general engineering practice a lever in used to overcome a weight or load by applying a force usually called the effort. In this way work is usually done, but in weighing instruments, levers are brought to a state of equilibrium or rest, the effort being merely sufficient to balance the load. The effort resists the force due to the load, and for this reason it is termed the resistant in weighing. The value of the resistant force is used to measure the weight of the load when a state of equilibrium is reached.

The lever is used for a number of different purposes in a weighing instrument. This includes:

- obtaining a mechanical advantage or disadvantage between the resistant and the load;
- transferring a force from one point to another;
- changing the of direction of a force; and
- adding loads so that their efforts may be transferred to one common lever.

In all of these purposes the resistant (effort) required to reach equilibrium is controlled by the relationship between length of the lever arm and the position of the fulcrum.

It is usual to classify levers under three groups, as follows:

First Order Levers – The fulcrum is between the load and the resistant (see Figure 4a). The resistant is usually either equal to the load or is less. In the latter case the lever has a mechanical advantage.

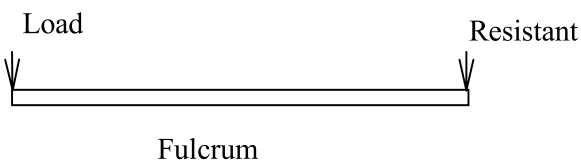


Figure 4a

There is also a modification of the first order lever, the cranked lever, where the two arms, fulcrum-load and fulcrum-resistant, are at an angle to one another (see Figure 4b).

A simple beam balance and the short lever in a platform scale are examples of first order levers.

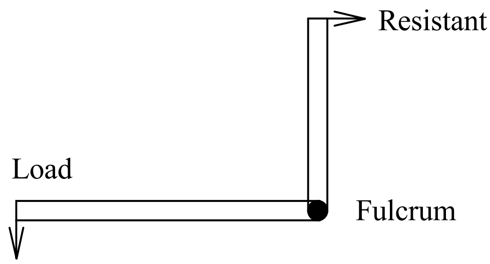


Figure 4b

Second Order Levers – The fulcrum is at one end of the lever and the resistant is at the other (see Figure 4c). The lever has a mechanical advantage. A weighbridge transfer lever and the long lever in a platform scale are examples of second order levers.

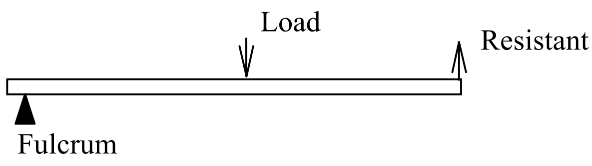


Figure 4c

Third Order Levers – The fulcrum is at one end and the resistant is between the fulcrum and the load (see Figure 4d). The lever has a mechanical disadvantage.

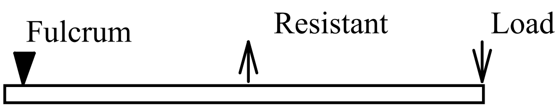


Figure 4d

This order of lever is not commonly used in weighing instruments, however the intermediate lever of all Berenger models is an example.

3.1.2 Single Lever Weighing Instruments

Weighing instruments using a single first order lever have been used since ancient times (see Figure 5). They are the simplest and the most accurate to use (see Figure 6).

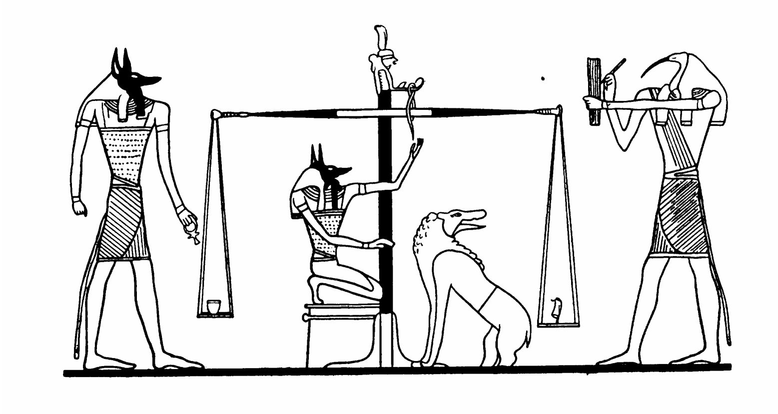


Figure 5 – Early Egyptian equal arm balance

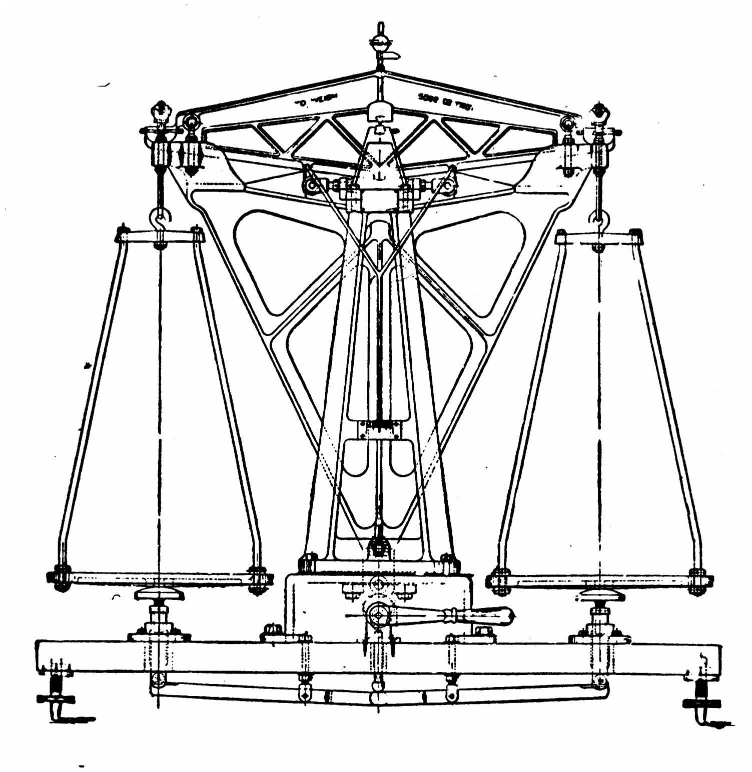


Figure 6 – A modern high precision equal arm balance

3.1.3 Compound Lever Weighing Instr

In theory a single lever-weighing instrument can be used to weigh considerable loads. In practice this is difficult to achieve because of increased friction, bending or flexing of the long arm used as the resistant and damage due to material fatigue. However if two or more levers are linked together, each providing a mechanical advantage, these problems can be overcome and a much more compact instrument is the result. These instruments are known as compound lever weighing instruments.

In this example (see Figure 7) of a platform scale, two levers, the short and the long lever are suspended from the platform casing on four knife-edges and bearings. The force of the load is transferred through the central shackle to the connecting rod. The indication of the load is achieved by bringing the steelyard into equilibrium using proportional weights (not shown) and the poise weight.

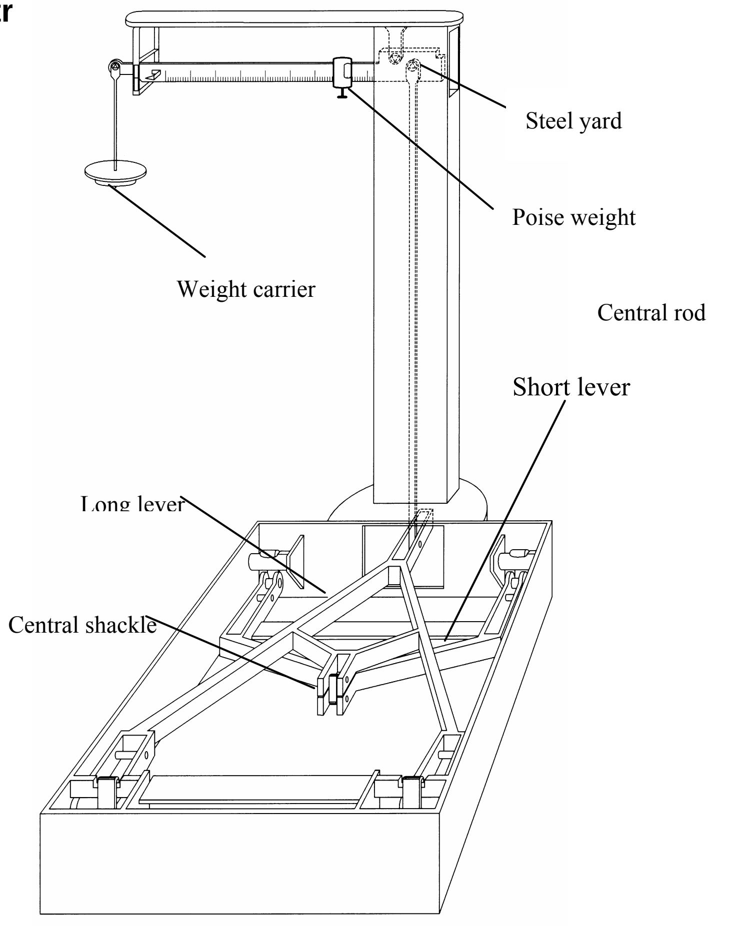


Figure 7 – Platform Scale

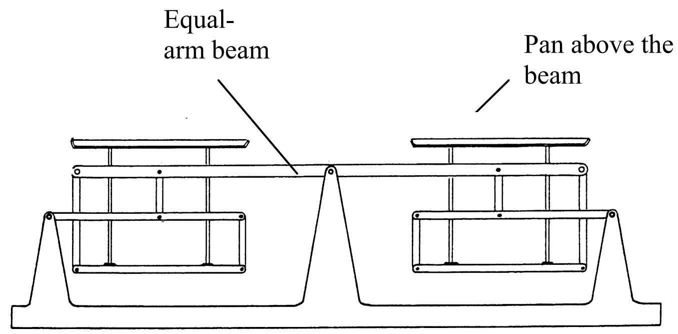


Figure 8 – Beranger Scale

In a Beranger scale the pans are mounted above an equal-arm beam using a system of levers (see Figure 8). This arrangement of the levers gives a large mechanical advantage and is quite common in large capacity mechanical instruments such as weighbridges.

The Roberval scale consists of a double beam (see Figure 8) with the pans mounted above the beam. The two beams are parallel to each other with rigid cross-members connecting them together. Although not as accurate as the equal arm balance this weighing instrument made it very easy to load and unload the pans making easier to use for trade.

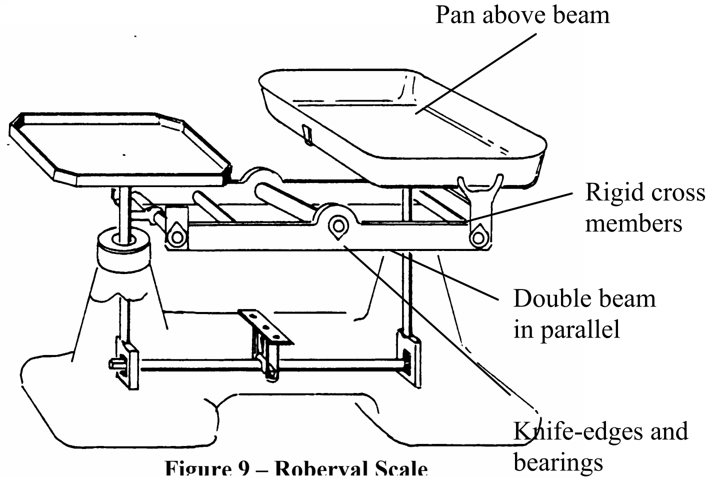


Figure 9 – Roberval Scale

3.1.4 Helical or Coiled Springs

Helical or coiled springs can also be used to determine the weight of a load. This is because a helical spring will extend in a uniform way when under the strain of a load. It will then compress and return to its original size when the load is removed.

The movement of a pointer on a dial or graduated scale indicates the regular extension or compression of the spring. The vibration of the spring is often damped to allow the indicator to settle quickly so that a reading can be taken.

The suspended spring scale shown in Figure 10 has air dash pots to dampen the vibration. A rack and pinion device moves to drive the pointer on the clock-face dial as the springs extends and compresses when under load

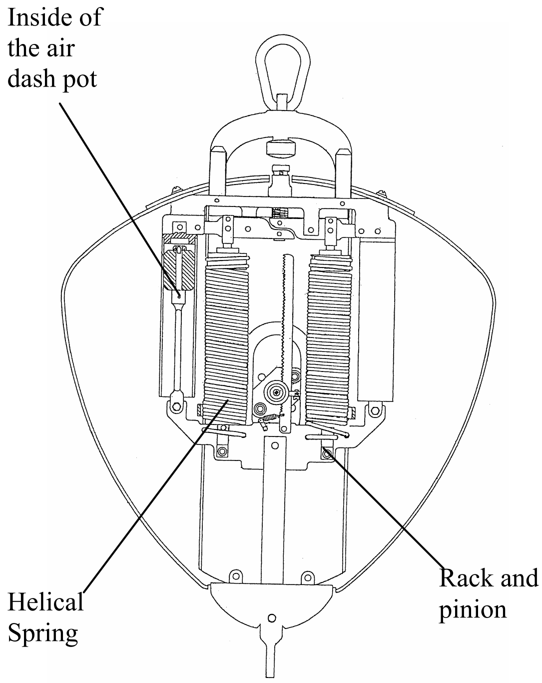


Figure 10 – A Suspended Spring Balance

3.2 ELECTRONIC WEIGHING INSTRUMENTS

The basic principle of an electronic weighing instrument is that the object to be weighed is placed on load cell transducer/s, which convert the mechanical force into an electric property, producing a change in the electrical signal output.

For example, in the small counter scale below (see Figure 11) when a load is placed on the load receptor, its mechanical force due to gravity is transferred through the cross to cause changes in the electrical signal output from the load cell. This electrical signal is converted by the analog to digital board into a form that can be read by the processor. The processor analyses this signal as well as information coming via the keyboard and then relays a signal as various outputs on the digital indicator or ticket printer.

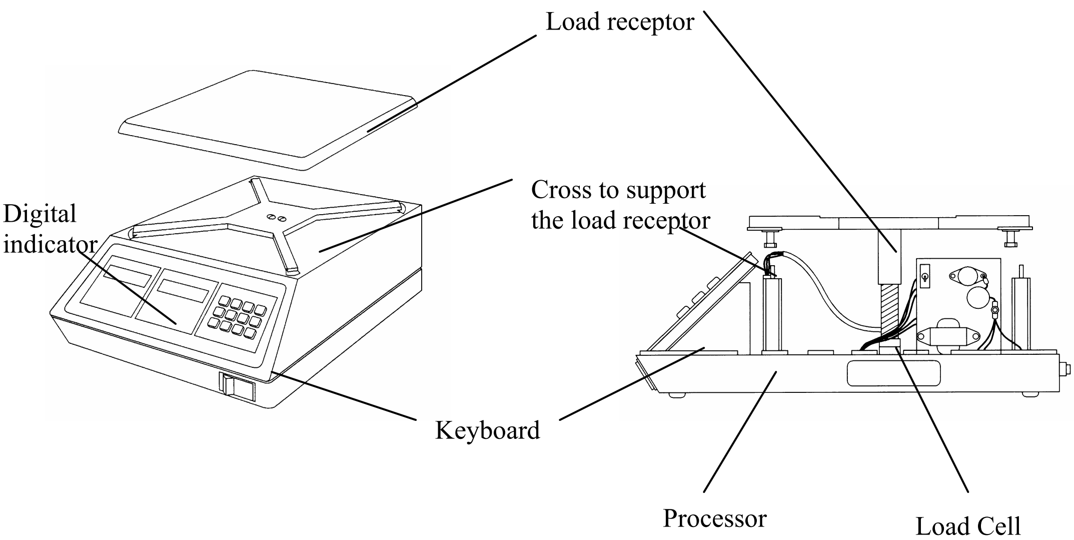


Figure 11 – Small electronic counter scale

3.2.1 Load Cell

The load cell comprises four strain gauges attached to a metal frame (see Figure 13a). It detects weight by reading the difference in the resistance values of the strain gauge when a load is applied.

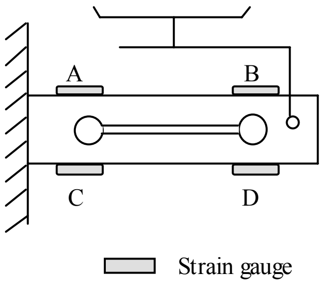


Figure 12a

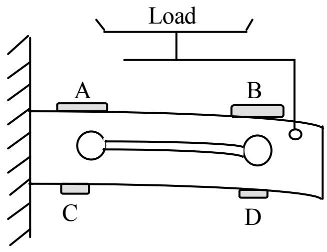


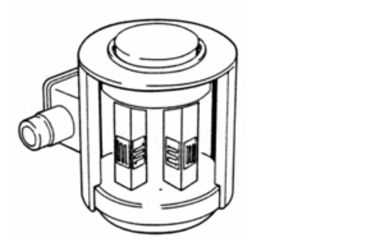
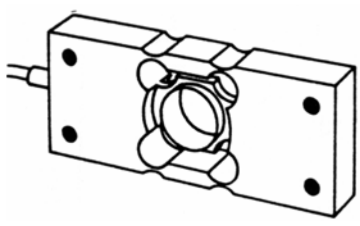
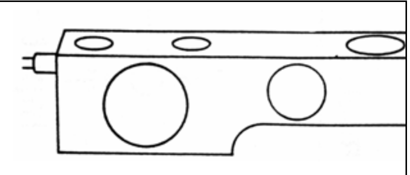
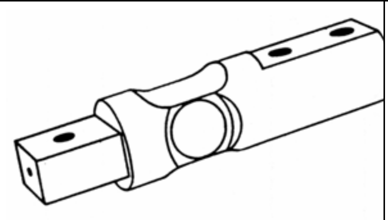
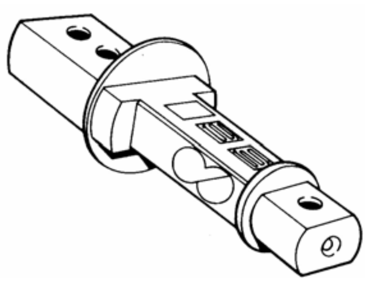
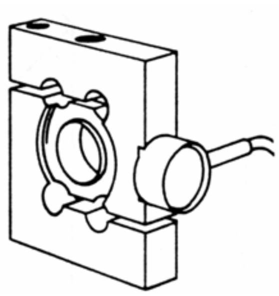
Figure 12b

When a load is applied, the metal frame is deformed in proportion to the weight of the load (see Figure 12b). At this time, the strain gauges (A) and (B) extend, resulting in an increase in their resistance value. On the other hand, strain gauges (C) and (D) compress, as a result of which their resistance value decreases. It is this change in resistance, which is proportional to the applied force on the metal frame and can be measured precisely.

3.2.2 Types of Load Cells

Strain gauge load cells fall into two categories: canister type cells; and beam cells. Although these groups can be further subdivided into many different forms there are three primary modes of operation. These are: compression/tension; bending; and shear.

For many process and platform applications the shear cell has become the industry standard. Shear cells have inherent low deflection and high rejection of side loads making them ideal for process weighing. However, shear cells can become expensive and cumbersome to mount above 20 tonne in capacity and traditional canister cells still find many applications up to several hundreds of tonnes. Some different types of load cells are shown below.

		
Traditional Canister Cell	**Hermetically Sealed packaging Sensor**	**Regular Shear Beam**
		
Round Shear Beam	**Bending Beam Cell**	**S-Beam Cell**

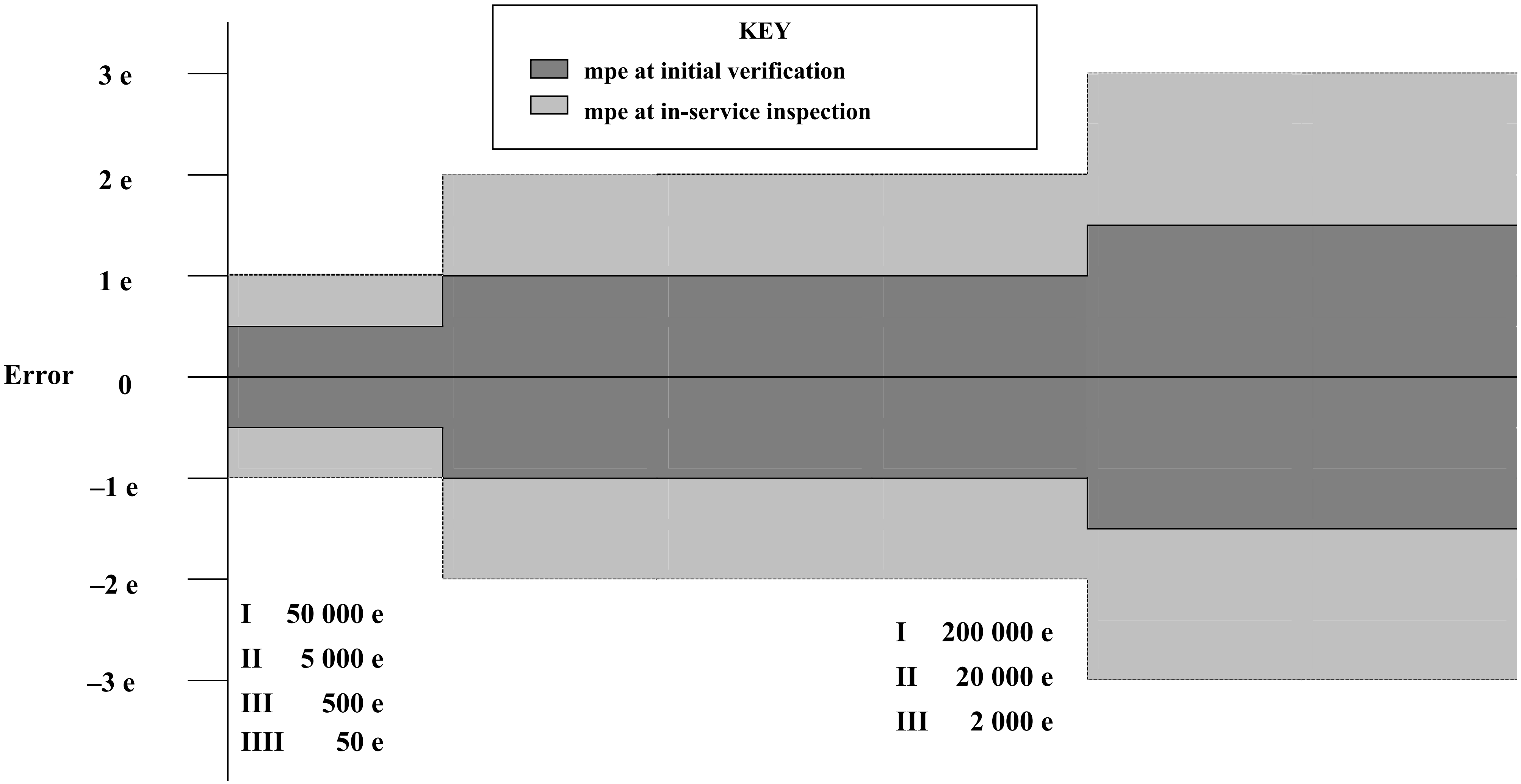
A summary of load cell type and their applications are shown in the table below.

Type	Typical capacity range	Applications
Single point cells	1 – 50 kg 0 – 500 kg	Retail scales, Postal scales, Counting scales, Fish graders, Packaging machines, Industrial scales
Bending beam cells	5 – 200 kg	Hybrid scales, Packaging machines, Hopper weighing
Bi-directional cells (tension/compression)	5 – 1 000 kg 1 – 20 t	Hybrid scales, Packaging machines, Testing machines, Mechanical scale conversions Vessel weighing
Compression cells	5 – 250 t	Weighbridges, Vessel weighing, Aircraft weighing
Shear beams	0.5 – 20 t	Industrial scales, Weighbridges, Pallet scales, Vessel weighing
Double ended/shear beams	20 – 50 t	Weighbridges, Vessel weighing

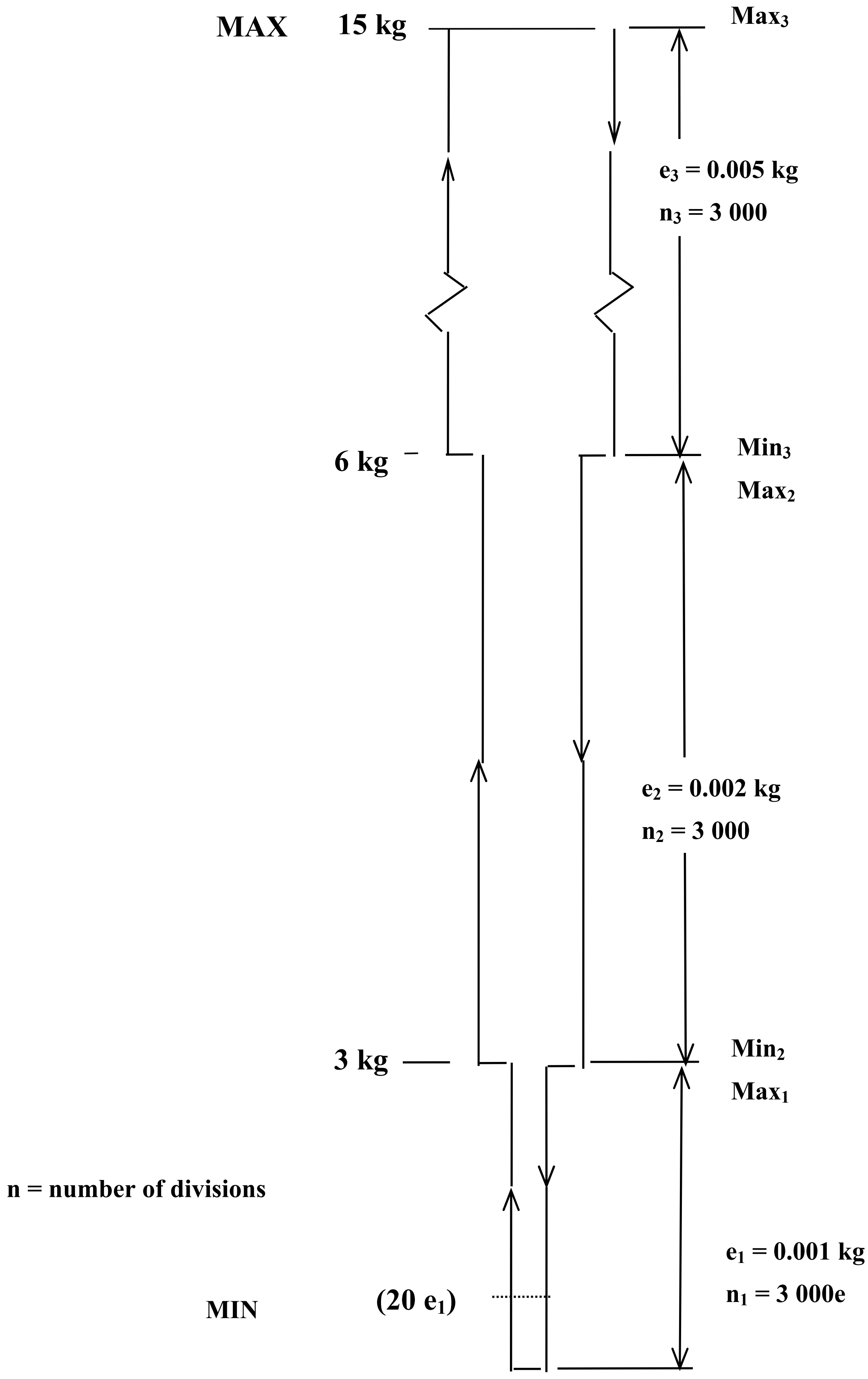
4 MAXIMUM PERMISSIBLE ERRORS

Maximum permissible errors on initial verification	For loads, m, expressed in verification scale intervals, e			
	class 1	class 2	class 3	class 4
±0.5 e	0 ≤ m ≤ 50 000	0 ≤ m ≤ 5 000	0 ≤ m ≤ 500	0 ≤ m ≤ 50
±1.0 e	50 000 < m ≤ 200 000	5 000 < m ≤ 20 000	500 < m ≤ 2 000	50 < m ≤ 200
±1.5 e	200 000 < m	20 000 < m ≤ 100 000	2 000 < m ≤ 10 000	200 < m ≤ 1 000

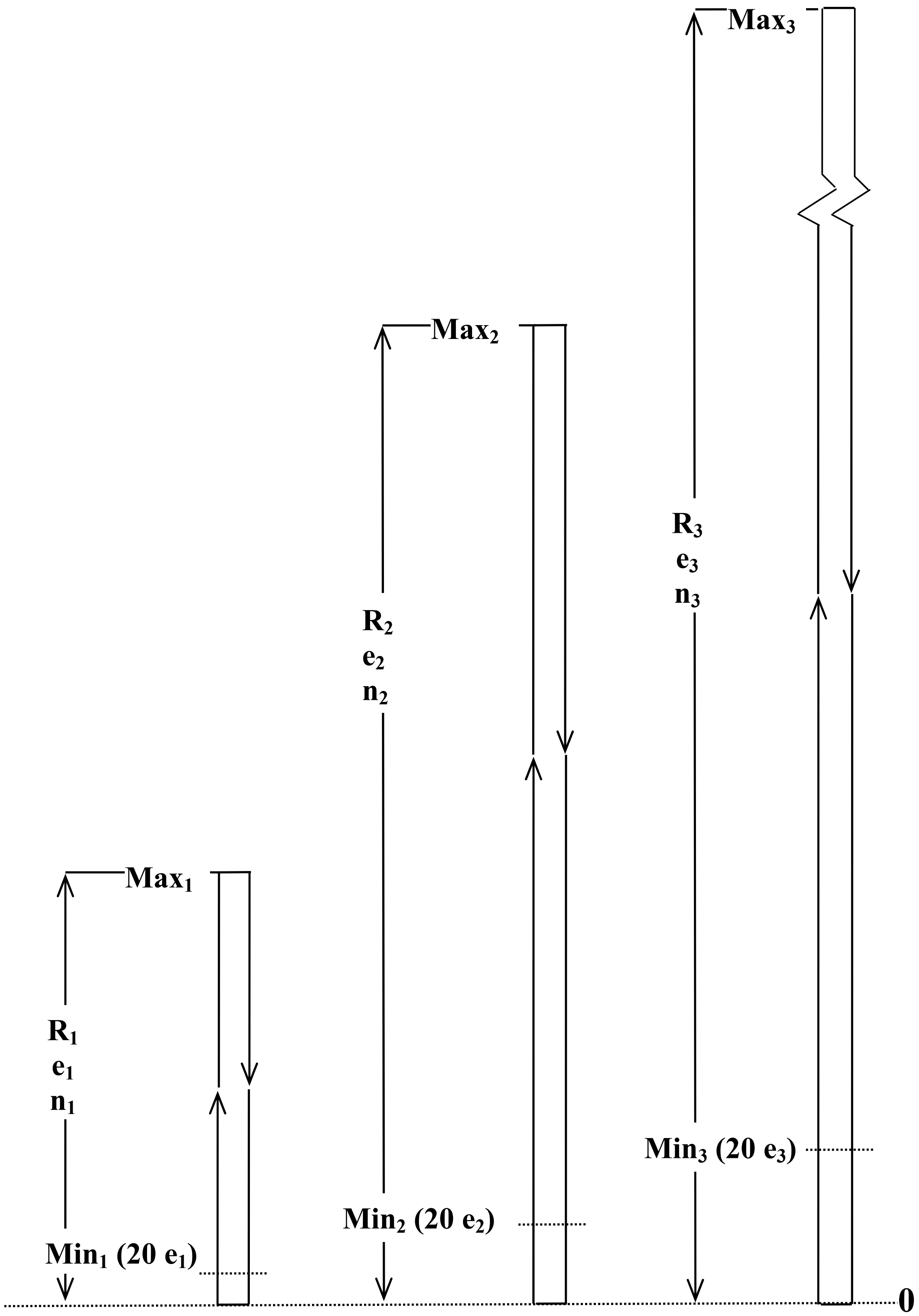
Maximum Permissible Errors



Multi-interval Instrument

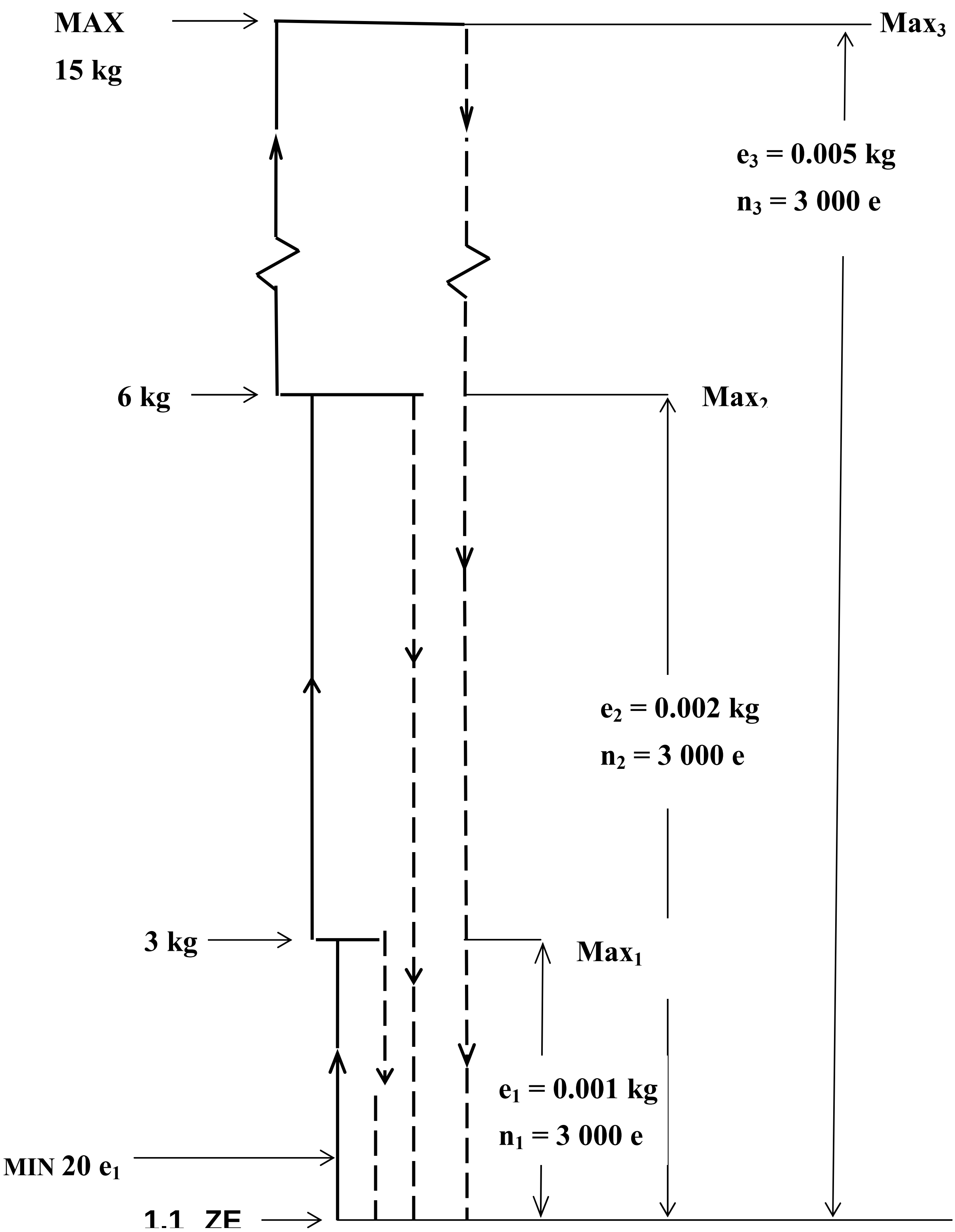


Multiple Range Instrument – Manual Change



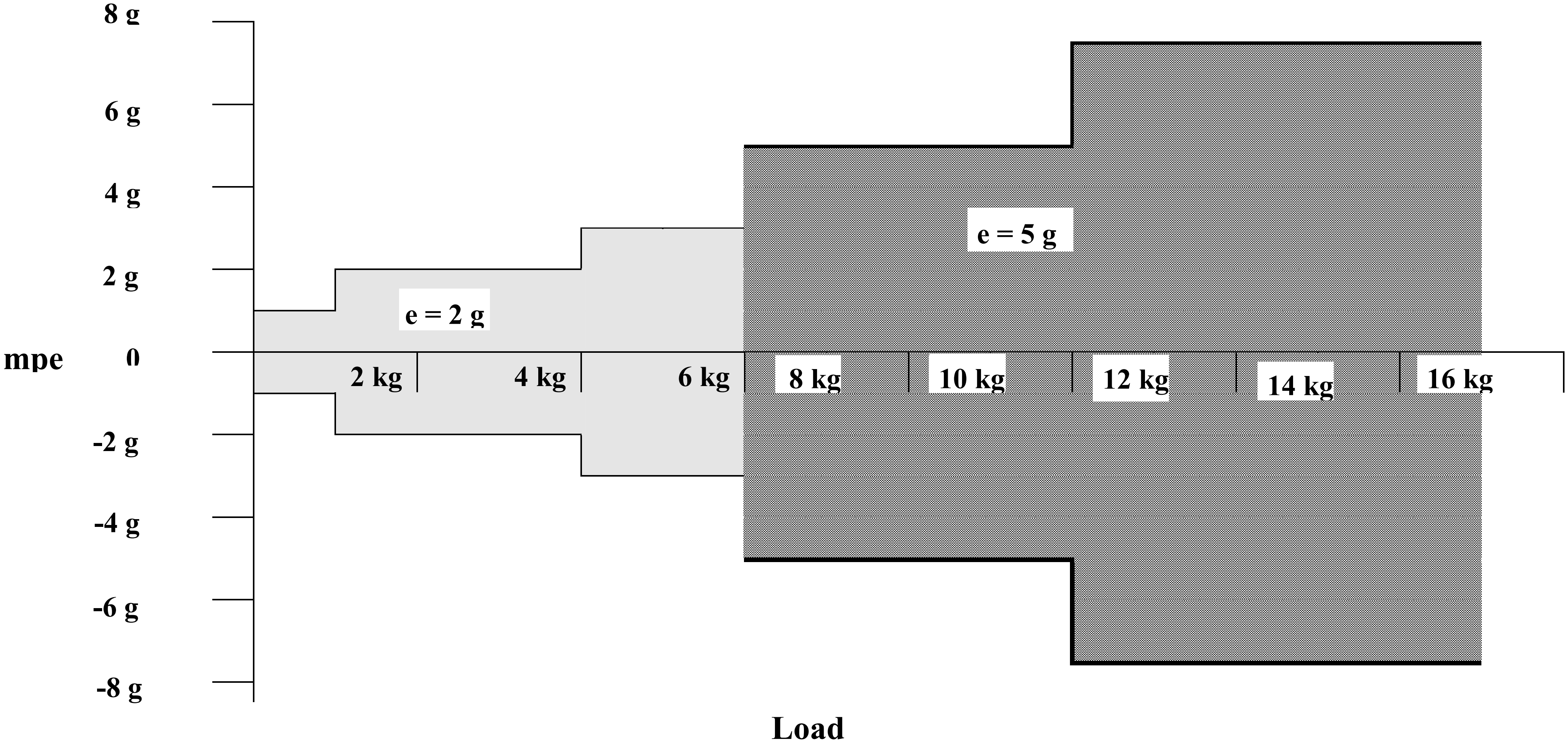
R = range (Each range is like a separate instrument)

Multiple Range Instrument – Auto Change



Maximum Permissible Errors

For a dual interval instrument class 3 with e = 2/5 g and maximum capacity 15 kg



4.1 LEARNING ACTIVITY – MPE CHANGE POINTS

1. Calculate the mpe change points for a class 3 instrument that is single range with a maximum capacity of 30 kg and an e value of 10 g.

2. Calculate the mpe change points for a class 2 instrument that is single range with a maximum capacity of 1 000 g and a e value of 10 mg.

3. Calculate the mpe change points for a class 3 instrument that is a single range with a maximum capacity of 10 kg and an e value of 20 g.

4. Calculate the mpe change points for a class 4 instrument that is a single range used to weigh luggage at an airport with a maximum capacity of 150 kg and an e value of 200 g.

5. Calculate the mpe change points for a multi-interval class 3 instrument. The e values are 2 g and 5 g. The maximum capacity for the first interval is 6 kg and 15 kg for the second interval.

6. Calculate the mpe change points for a weighbridge with a maximum capacity of 120 t. The instrument is multi-interval, class 3. The first interval has a maximum capacity of 40 t with an e value of 20 kg; the second interval has an e value of 50 kg.

7. (a) Calculate the mpe change points for a multiple range - auto change, class 3 instrument with a maximum capacity of 30 kg. The first range has a maximum capacity of 6 kg and an e value of 2 g, the second range has a maximum capacity of 15 kg and an e value of 5 g and the third has an e value of 10 g.

   (b) What is the instruments e value at a load of 2.560 kg if you have decreased the load from: (i) 25.980 kg; (ii) 9.465 kg; and (iii) 5.578 kg.

8. (a) Calculate the mpe change points for a multi-interval class 3 instrument with a maximum capacity of 60 kg. The first interval has a maximum capacity of 15 kg and an e value of 5 g, the second interval has a maximum capacity of 35 kg and an e value of 10 g and the third has an e value of 20 g.

   (b) What is the instruments e value at a load of 2.560 kg if you have decreased the load from: (i) 45.88 kg; (ii) 16.49 kg; and (iii) 5.575 kg.

4.2 LEARNING ACTIVITY – MPES VERIFICATION/CERTIFICATION

For this learning activity complete the following table assuming each inspection to be verification or certification inspection.

Instrument Class	Verification Scale Interval (e)	Applied Load	Instrument Indication	Within MPE Yes/No
III	0.200 kg	2.001 kg	2.004 kg	
II	10 mg	250 g	249.98 g	
III	0.005 kg	8.0025 kg	7.995 kg	
IIII	2 kg	301 kg	302 kg	
III	50 kg	75.025 t	75.050 t	

4.3 LEARNING ACTIVITY – MPES IN-SERVICE INSPECTION

For this learning activity complete the following table assuming each inspection to be in-service inspection.

Instrument Class	Verification Scale Interval (e)	Applied Load	Instrument Indication	Within MPE Yes/No
III	0.200 kg	2.001 kg	2.004 kg	
II	10 mg	250 g	249.98 g	
III	0.005 kg	8.0025 kg	7.995 kg	
IIII	2 kg	301 kg	302 kg	
III	50 kg	75.025 t	75.050 t	

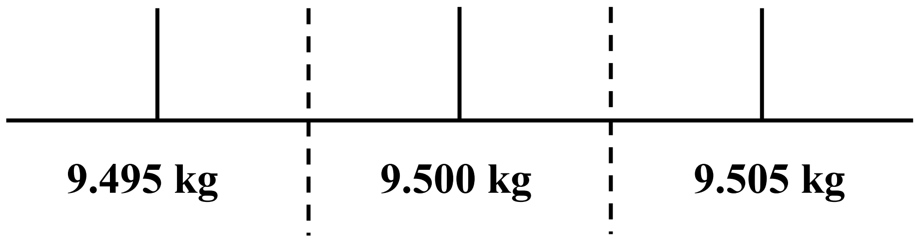
4.4 LEARNING ACTIVITY – REPEATABILITY

Your instructor will work through this exercise with you.

During a repeatability test using 9.500 kg on a single interval instrument with a maximum capacity of 15 kg and e = 5 g, the second test resulted in an indication of 9.495 kg. Consequently it was necessary to find the actual position on the scale for each test and the following results were achieved.

1	9.500 kg	Centre e
2	9.495 kg	with 3.0 g added to go to the next changeover point.
3	9.500 kg	with 4.0 g added to go to the next changeover point.

Find the actual position of each test on the indicators scale and then determine if the instrument has passed or failed.



1. During a repeatability test on a class 3 instrument with a maximum capacity of 15.000 kg and e = 5 g, a test load of 9.500 kg is used. The second test resulted in an indication of 9.505 kg. Consequently it was necessary to find the actual position on the scale of each test and the following results were achieved.

   (a) 9.500 kg Centre e

   (b) 9.505 kg with 3.0 g added to go to the next changeover point.

   (c) 9.500 kg with 1.5 g added to go to the next changeover point.

   Find the actual position of each test on the indicators scale and then determine if the instrument has passed or failed.

2. During a repeatability test on a class 3 instrument with a maximum capacity of 30.00 kg and e = 10 g a 19.50 kg test load is used. The third test resulted in an indication of 19.49 kg. It is necessary to discard the second test and find the actual position on the scale of the next two test loads. The following results were achieved.

   (a) 19.50 kg Centre e

   (b) 19.50 kg discarded

   (c) 19.49 kg with 4 g added to go to the next change over point

   (d) 19.49 kg with 1 g added to go to the next changeover point.

   Find the actual position of each test on the indicators scale and then determine if the instrument has passed or failed.

3. During a repeatability test on a multi-interval class 3 weighbridge with a maximum capacity of 100 t, e = 20 kg/50 kg with the interval changing at 60 t. A test load of 68.00 t is used. The second test resulted in an indication of 67.95 t. Consequently it was necessary to find the actual position on the scale of each test and the following results were achieved.

   (a) 68.00 t Centre e

   (b) 67.95 t with 16 kg added to go to the next changeover point

   (c) 68.00 t with 14 kg added to go to the next changeover point

   Find the actual position of each test on the indicators scale and then determine if the instrument has passed or failed.

4. During a repeatability test on a class 4 platform scale with a maximum capacity of 100 kg, e = 100 g. The second test resulted in an indication of 60.1 kg. Consequently it was necessary to find the actual position on the scale of each test and the following results were achieved.

   (a) 60.0 kg Centre e

   (b) 60.1 kg with 90 g added to go to the next changeover point

   (c) 60.1 kg with 40 g added to go to the next changeover point

   Find the actual position of each test on the indicators scale and then determine if the instrument has passed or failed.

4.5 LEARNING ACTIVITY – SUBSTITUTION

Your instructor will work through this exercise with you.

During a weighing test on a class 3 weighbridge with a maximum capacity of 100 tonnes, and an e value of 20 kg, 30 tonne of standard weights are available to be used. At an indication of 30 t the load needed to go to the next changeover point was 8 kg. At this point a substitution load is applied which shows an indication of 29.56 t before being taken to the next changeover point. Calculate the actual weight of the substitution load.

1 Calculate the actual weight for the substitution loads used in the following examples to complete the final column in the table below.

	Class	Max.	e	L	I	ΔL	I_{sub}	L_{sub}
(a)	3	60 t	20 kg	20 t	20.00 t	12 kg	19.48 t	
(b)	3	10 t	5 kg	2 t	2.000 t	2.5 kg	1.845 t	
(c)	4	2 t	2 kg	1 t	1.000 t	1.6 kg	0.964 t	
(d)	3	80/120 t	20/50 kg	30 t	29.98 t	2 kg	29.46 t	

2. During a weighing test on a class 3 weigh bridge with a maximum capacity of 40 tonnes, and an e value of 10 kg, 8 tonne of standard weights are available to be used. At an indication of 8 t the load needed to go to the next changeover point of 8.01 t is 8 kg. At this point the standard weights are removed, a substitution load is applied and brought to the next changeover point of 7.56 t.

   The standard weights are applied again to bring the indication up to 15.56 t. At this point 5 kg is required to take the indication to the next changeover point. The standard weights are removed and material is applied for a second substitution load and brought to the next changeover point at 15.37 t.

   Calculate the actual weight of both the substitution loads used.

3. During a weighing test on a class 3 weigh bridge with a maximum capacity of 5 tonnes, and an e value of 10 kg, 2 tonne of standard weights are available to be used. At 2 tonne the load needed to go to the next changeover point of 2.01 t is 7 kg. The standard weights are removed; a substitution load is applied showing an indication of 1.86 t before being taken to the next changeover point.

   The standard weights are applied again to bring the indication up to 3.86 t. At this point 5 kg is required to take the indication to the next changeover point. The standard weights are removed and a second substitution load is applied showing an indication of 3.61 t before being brought to the next changeover point.

   Calculate the actual weight of both the substitution loads used.

4.6 TEST REPORT FOR NON-AUTOMATIC WEIGHING INSTRUMENTS

Test report reference number ....Date of test.......................................

Type of test (tick one) ☐ Verification ☐ Certification ☐ In-service inspection

For in-service inspection record the verification/certification mark ....

Name of owner/user ....

Address of owner/user..

Contact name..

Address of instrument, if applicable ....

Description of instrument..

Manufacturer/s .... Model ....

Instrument serial number............................... Certificate/s of approval number.................................

Max.. Min ....

Verification scale interval (e).....................................Accuracy class ....

Does the instrument comply with its certificate/s of approval?	yes/no
Is the instrument being used in an appropriate manner?	yes/no/na
Are all mandatory descriptive markings clearly and permanently marked on the data plate?	yes/no
Is the data plate fixed on the instrument?	yes/no
Is the instrument complete?	yes/no
Is the instrument broken?	yes/no
Is the instrument clean?	yes/no
Is the instrument operational?	yes/no
Is the level-indicating device (if fitted) secured and functional?	yes/no/na
Is the instrument level?	yes/no
Are there any apparent obstructions to the operation of the instrument?	yes/no
Is the instrument mounted on a firm base?	yes/no
Does the operator (and where applicable, the customer) have a clear and unobstructed view of the indicating device and the whole weighing operation?	yes/no
Is the instrument adequately protected against abnormal dust, air movement, vibrations, atmospheric conditions and any other influence likely to affect its performance?	yes/no
If applicable, does the steelyard, tare bar or proportional weight comply with the mandatory requirements in respect to design and marking?	yes/no/na
For overhead track weighing instruments: is the weigh rail of acceptable form and correctly aligned?	yes/no/na
For suspended weighing instruments: does it hang freely and are all transparent covers in good repair?	yes/no/na
For weighbridges: does it comply with the relevant Trade Measurement (Weighbridge) Regulations and the *Code of Practice for Weighbridge Installations*?	yes/no/na
For additional indicating devices: do they exactly repeat the information on the primary indication and do any device for price computation and/or ticket/label printing comply with the requirements of the General Supplementary Certificates (see clause 3.2.18)?	yes/no/na

Test Results

<table>
<tr><td rowspan="6">Repeatability (clause 5.1)</td><td>Load</td><td colspan="3"></td></tr>
<tr><td>First reading</td><td colspan="3"></td></tr>
<tr><td>Second reading</td><td colspan="3"></td></tr>
<tr><td>Third reading</td><td colspan="3"></td></tr>
<tr><td>Difference</td><td colspan="3"></td></tr>
<tr><td colspan="4">☐ Pass ☐ Fail</td></tr>
<tr><td rowspan="9">Eccentricity (clause 5.2)</td><td colspan="4">Number of supports:</td></tr>
<tr><td colspan="4">Load used:</td></tr>
<tr><td>Position 1</td><td></td><td>Position 7</td><td></td></tr>
<tr><td>Position 2</td><td></td><td>Position 8</td><td></td></tr>
<tr><td>Position 3</td><td></td><td>Position 9</td><td></td></tr>
<tr><td>Position 4</td><td></td><td>Position 10</td><td></td></tr>
<tr><td>Position 5</td><td></td><td>Position 11</td><td></td></tr>
<tr><td>Position 6</td><td></td><td>Position 12</td><td></td></tr>
<tr><td colspan="4">☐ Pass ☐ Fail</td></tr>
<tr><td>Zero setting (clause 5.3)</td><td colspan="4">☐ Pass ☐ Fail</td></tr>
<tr><td rowspan="9">Weighing performance not using substitution load (clause 5.4.1)
Note: For weighing performance using substitution load refer to the following page</td><td colspan="2">Loads applied (minimum 5)</td><td>Up</td><td>Down</td></tr>
<tr><td colspan="2"></td><td></td><td></td></tr>
<tr><td colspan="2"></td><td></td><td></td></tr>
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<tr><td colspan="2"></td><td></td><td></td></tr>
<tr><td colspan="2"></td><td></td><td></td></tr>
<tr><td colspan="4">Over-range blanking ☐ Pass ☐ Fail</td></tr>
<tr><td colspan="4">☐ Pass ☐ Fail ☐ na</td></tr>
</table>

Discrimination (clause 5.5)	☐ Pass ☐ Fail
Sensitivity (clause 5.6)	☐ Pass ☐ Fail ☐ na
Accuracy of tare setting (clause 5.7)	☐ Pass ☐ Fail ☐ na
Price computation (clause 5.8)	☐ Pass ☐ Fail ☐ na
Overall result	☐ **Pass** ☐ **Fail**

Inspector's/certifier's name.. Identification number ....

Signature...

Comments..

Weighing performance using substitution load (clause 5.4.2)										
Method used	☐ Method A			☐ Method B						
MPE change points										
Available standard weights										
First substitution load										
Second substitution load										
Third substitution load										
Up	*L*	Makeup of load	MPE	I	½e	Δ*L*	E	L_{sub}	L_{sub} (rounded)	Pass/fail/na
Over-range blanking	☐ Pass	☐ Fail								
Down*	*L*	Makeup of load	MPE	I	Pass/fail					

*Note: Zero load must **not** indicate above 0.25e

Discrimination (clause 5.5)	☐ Pass	☐ Fail	
Sensitivity (clause 5.6)	☐ Pass	☐ Fail	☐ na
Accuracy of tare setting (clause 5.7)	☐ Pass	☐ Fail	☐ na
Price computation (clause 5.8)	☐ Pass	☐ Fail	☐ na
Overall result	☐ **Pass**	☐ **Fail**	

Inspector's/certifier's name.. Identification number......................

Signature...

Comments...

5 WORKED ANSWERS

Learning Activity – 4.1

1. **Calculate the mpe change points for a class 3 instrument which is single range with a maximum capacity of 30 kg and verification scale interval (e) of 10 g.**

   For a class 3 instrument the change points are at 500e and 2 000e. The mpe change points are worked out by multiplying the e value for the instrument by each change point.

   Here e = 10 g.

   So the mpe change points are:

   10 g x 500 = 5 000 g = 5 kg and for 2 000e   10 g x 2 000 = 20 000 g = 20 kg

   So your mpe change points are 5 kg and 20 kg.

   No need to go higher as you will pass max.

2. **Calculate the mpe change points for a class 2 instrument which is single range with a maximum capacity of 1 000 g and an e value of 10 mg.**

   Change points for class 2 instrument are at 5 000e and 20 000e. Here e = 10 mg
   So the mpe change points are:

   10 mg x 5 000 = 50 000 mg = 50 g

   10 mg x 20 000 = 200 000 mg = 200 g

3. **Calculate the mpe change points for a class 3 instrument that is single range with a maximum capacity of 10 kg and an e value of 20 g.**

   Change points for class 3 are 500e and 2 000e.

   e = 20 g

   20 g x 500 = 10 000 g = 10 kg

   As 10 kg is full capacity no mpe change points exist in this instrument.

4. **Calculate the mpe change points for a class 4 instrument that is single range used to weigh luggage at an airport with a maximum capacity of 150 kg and an e value of 200 g.**

   Change points for class 4 instruments are 50e and 200e.

   e = 200 g

   So the mpe change points are:

   200 g x 50 = 10 000 g = 10 kg

   200 g x 200 = 40 000 g = 40 kg

   200 g x 1000 = 200 000 g = 200 kg greater than the capacity of this instrument.

5 **Calculate the mpe change points for a multi-interval class 3 instrument. The e values are 2 g and 5 g. The maximum capacity for the first interval is 6 kg and 15 kg for the second interval.**

   Change points for a class 3 instrument are 500e and 2 000e.

   For the e value of 2 g and a max of 6 kg the mpe change points are:

2 g x 500 = 1 000 g = 1 kg   2 g x 2 000 = 4 000 g = 4 kg

At 6 kg the mpe also changes from 1.5e to 1e in the 5 g range.

Now we move into the higher interval where e = 5 g. The mpe change points are:

5 g x 500 = 2 500 g = 2.5 kg (covered by the lower interval)

5 g x 2 000 = 10 000 g = 10 kg

In summary the mpe change points are: 1 kg, 4 kg, 6 kg and 10 kg.

6 **Calculate the mpe change points for a weighbridge with a maximum capacity of 120 t. The instrument is multi-interval class 3. The first interval has a maximum capacity of 40 t with an e value of 20 kg, the second interval has an e value of 50 kg.**

The change points for a class 3 instrument are 500e and 2 000e.

For the e value of 20 kg and a max of 40 t the mpe change points are:

20 kg x 500 = 10 000 kg = 10 t and 20 kg x 2 000 = 40 000 kg = 40 t

Now we move into the higher range where e= 50 kg. The mpe change points are:

50 kg x 500 = 25 000 kg = 25 t (covered by the lower interval)

and 50 kg x 2 000 = 100 000 kg = 100 t.

In summary the mpe change points are: 10 t, 40 t and 100 t.

7. **(a) Calculate the mpe change points for multiple range – auto change class 3 instrument with a maximum capacity of 30 kg. The first range has a maximum capacity of 6 kg and an e value of 2 g, the second range has a maximum capacity of 15 kg and an e value of 5 g and the third has an e value of 10 g.**

Change points are: 500 e and 2 000 e. Remember a multiple range instrument does not change back when the load is decreasing.

For Max 6 kg the mpe change points are:

2 g x 500 = 1 000 g = 1 kg   2 x 2 000 = 4 000 g = 4 kg

For max 15 kg the mpe change points are:

5 g x 500 = 2 500 g = 2.5 kg (Applies when testing downwards)

5 g x 2 000 = 10 000 g = 10 kg

For max 30 kg the mpe change points are:

10 g x 500 = 5 000 g = 5 kg (Applies when testing downwards)

10 g x 2 000 = 20 000 g = 20 kg

At 6 kg and 15 kg the mpe also changes as the range changes.

In summary the mpe change points are: 1 kg, 4 kg, 6 kg, 10 kg, 15 kg, 20 kg and 2.5kg and 5 kg when testing backwards.

(b) What is the instruments e value at a load of 2.560 kg if you have decreased the load from: (i) 25.980 kg; (ii) 9.465 kg; and (iii) 5.578 kg.

Since this instrument changes its e value on the way up only.

e value coming down from 25.980 kg would be 10 g

e value coming down from 9.465 kg would be 5 g e value coming down from 5.578 kg would be 2 g

8 **(a) Calculate the mpe change points for a multi-interval class 3 instrument with a maximum capacity of 60 kg. The first interval has a maximum capacity of 15 kg and an e value of 5 g, the second interval has a maximum capacity of 35 kg and an e value of 10 g and the third has an e value of 20 g.**

For max 15 kg the mpe change points are:

5 g x 500 = 2 500 g = 2.5 kg 5 g x 2 000 = 10 000 g = 10 kg

For max 35 kg the mpe change points are:

10 g x 500 = n/a 10 g x 2 000 = 20 000 g = 20 kg

For max 60 kg the mpe change points are:

20 g x 500 = n/a 20 g x 2 000 = 40 000 g = 40 kg

At 15 kg and 35 kg the mpe also changes as the range changes.

In summary the mpe change points are: 2.5 kg, 10 kg, 15 kg, 20 kg, 35 kg 40 kg.

(b) What is the instruments e value at a load of 2.560 kg if you have decreased the load from: (i) 45.88 kg; (ii) 16.49 kg; and (iii) 5.575 kg.

5 g for all of them as the scale changes on the way down.

Learning Activity – 4.2

For this learning activity complete the following table assuming each inspection to be verification or certification inspection.

Instrument Class	Verification Scale Interval (e)	Applied Load	Instrument Indication	Within MPE Yes/No
(III)	0.200 kg	2.001 kg	2.004 kg	**No**
(II)	10 mg	250 g	249.98 g	**No**
(III)	0.005 kg	8.0025 kg	7.995 kg	**No**
(IIII)	2 kg	301 kg	302 kg	**Yes**
(III)	50 kg	75.025 t	75.050 t	**Yes**

Learning Activity – 4.3

For this learning activity complete the following table assuming each inspection to be in-service inspection.

Instrument Class	Verification Scale Interval (e)	Applied Load	Instrument Indication	Within MPE Yes/No
III	0.200 kg	2.001 kg	2.004 kg	**Yes**
II	10 mg	250 g	249.98 g	**Yes**
III	0.005 kg	8.0025 kg	7.995 kg	**No**
IIII	2 kg	301 kg	302 kg	**Yes**
III	50 kg	75.025 t	75.050 t	**Yes**

Learning Activity – 4.4

1. **During a repeatability test on a single interval class 3 instrument with a maximum capacity of 15.000 kg and e = 5 g, a test load of 9.500 kg is used. The second test resulted in an indication of 9.505 kg. It is necessary to find the actual position on the scale of the each test and the following results were achieved.**

   (a) 9.500 kg Centre e

   (b) 9.505 kg with 3.0 g added to go to the next changeover point.

   (c) 9.500 kg with 1.5 g added to go to the next changeover point.

   Find the actual position of each test on the indicators scale and then determine if the instrument has passed or failed.

   Using the formula I + ½ e – ΔL

   1 9.500

   2 9.505 + 0.0025 – 0.003 = 9.5045

   3 9.500 + 0.0025 – 0.0015 = 9.5010

   Difference between highest and lowest is:

   9.5045 –9.500 = 0.0045 kg or 4.5 g Pass as e = 5 g

2. **During a repeatability test on a single interval class 3 instrument with a maximum capacity of 30.00 kg and e = 10 g a 19.50 kg test load is used. The third test resulted in an indication of 19.49 kg. It is necessary to discard the second test and find the actual position on the scale of the next two test loads. The following results were achieved.**

   (a) 19.50 kg Centre e

   (b) 19.50 kg discarded

   (e) 19.49 kg with 4 g added to go to the next changeover point

(f) 19.49 kg with 1 g added to go to the next changeover point.

Find the actual position of each test on the indicators scale and then determine if the instrument has passed or failed.

Using the formula I + 1/2 e – ΔL

(a) 19.50

(c) 19.490 + 0.005 – 0.004 = 19.491

(d) 19.490 + 0.005 – 0.001 = 19.494

Difference between highest and lowest is:

19.500 –19.491 = 0.009 kg or 9 g Pass as e = 10 g

3. **During a repeatability test on a dual interval class 3 weighbridge with a maximum capacity of 100 t, e = 20 kg/50 kg with the interval changing at 60 t. A test load of 68.00 t is used. The second test resulted in an indication of 67.95 t. Consequently it was necessary to find the actual position on the scale of each test and the following results were achieved.**

(a) 68.00 t Centre e

(b) 67.95 t with 16 kg added to go to the next change over point

(c) 68.00 t with 14 kg added to go to the next change over point

Find the actual position of each test on the indicators scale and then determine if the instrument has passed or failed.

Using the formula I + 1/2e – ΔL

(a) 68.00

(b) 67.95 + 0.025 – 0.016 = 67.959

(c) 68.00 + 0.025 – 0.014 = 68.011 Difference between highest and lowest is:
68.011 – 67.959 = 0.052 t or 52 kg Fail as e = 50 kg

4. **During a repeatability test on a class 4 platform scale with a maximum capacity of 100 kg, e = 100 g. The second test resulted in an indication of 60.1 kg. It is necessary to find the actual position on the scale of each test and the following results were achieved.**

(a) 60.0 kg Centre e

(b) 60.1 kg with 90 g added to go to the next changeover point

(c) 60.1 kg with 40 g added to go to the next changeover point

Find the actual position of each test on the indicators scale and then determine if the instrument has passed or failed.

Using the formula I + 1/2 e – ΔL

(a) 60.00

(b) 60.1 + 0.05 – 0.09 = 60.06

(c) 60.1 + 0.05 – 0.04 = 60.11

Difference between highest and lowest is:

60.11 – 60.00 = 0.11 kg or 110 g Pass as the mpe is now 1.5e = 150 g

Learning Activity – 4.5

1. Calculate the actual weight for the substitution loads used in the following examples to complete the final column in the table below.

	Class	Max.	e	L	I	ΔL	I_{sub}	L_{sub}
(a)	3	60 t	20 kg	20 t	20.00 t	12 kg	19.48 t	19.492
(b)	3	10 t	5 kg	2 t	2.000 t	2.5 kg	1.845 t	1.8475
(c)	4	2 t	2 kg	1 t	1.000 t	1.6 kg	0.964 t	0.9656
(d)	3	80/120 t	20/50 kg	30 t	29.98t	2 kg	29.46 t	29.482

(a) max 60 t, e = 20 kg

$E = I + ½e – ΔL – L$

$E = 20.00\ t + 0.010 – 0.012 – 20.00\ t$

$= –0.002\ t$ (slow)

$L_{sub} = I_{sub} + ½e – E$

$= 19.48 + 0.010 –(–0.002) \qquad = 19.492\ t$

(b) max 10 t, e = 5 kg

$E = I + ½e – ΔL – L$

$E = 2.00\ t + 0.0025 – 0.0025 – 2.00\ t$

$= 0.00$

Now use this error to determine the true value of the substitution load.

$L_{sub} = I_{sub} + ½e – E$

$= 1.845 + 0.0025 – 0$

$= 1.8475\ t$

(c) max 2 t, e = 2 kg

$E = I + ½e – ΔL – L$

$E = 1.00\ t +0.001 – 0.0016 – 1.00\ t$

$= –0.0006\ t$ (slow)

Now use this error to determine the true value of the substitution load.

$L_{sub} = I_{sub} + ½e – E$

$= 0.964 + 0.001 –(–0.0006)$

$= 0.9656\ t$

(d) max 80/120 t, e = 20/50 kg

$E = I + ½e – ΔL – L$

$E \quad = \quad 29.98\ t + 0.010 - 0.002 - 30.00\ t$

$= \quad -0.012\ t$ (slow)

Now use this error to determine the true value of the substitution load.

$L_{sub} \quad = \quad I_{sub} + ½e - E$

$= \quad 29.46\ t + 0.010 - (-0.012)$

$= \quad 29.482\ t$

2. During a weighing test on a class 3 weighbridge with a maximum capacity of 40 tonnes, and an e value of 10 kg, 8 tonne of standard weights are available to be used. At an indication of 8 t the load needed to go to the next changeover point of 8.01 t is 8 kg. At this point the standard weights are removed, a substitution load is applied showing an indication of 7.55 t and brought to the next changeover point of 7.56 t.

The standard weights are applied again to bring the indication up to 15.56 t. At this point 5 kg is required to take the indication to the next changeover point. The standard weights are removed and material is applied for a second substitution load and brought to the next changeover point at 15.37 t. Calculate the actual weight of both the substitution loads used.

max 30 t, e = 10 kg

$E \quad = \quad I + ½e - \Delta L - L$

$E \quad = \quad 8.00\ t + 0.005 - 0.008 - 8.00\ t \quad = \quad -0.003\ t$

$L_{sub} \quad = \quad I_{sub} + ½e - E$

$= \quad 7.55\ t + 0.005 - (-0.003) \quad = \quad 7.558\ t$

$E_2 \quad = \quad I + ½\ e - \Delta L - L$

$E_2 \quad = \quad 15.56\ t + 0.005 - 0.005 - 15.558\ t\ (8 + 7.558\ L_{sub})$

$= \quad +0.002\ t$

$L_{sub2} \quad = \quad I_{sub2} + ½e - E_2$

$= \quad 15.36\ t + 0.005 - 0.002 \quad = 15.363\ t$

3. During a weighing test on a class 3 weighbridge with a maximum capacity of 5 tonnes, and an e value of 10 kg, 2 tonne of standard weights are available to be used. At 2 tonne the load needed to go to the next changeover point of 2.01 t is 7 kg. The standard weights are removed, a substitution load is applied showing an indication of 1.86 t before being taken to the next changeover point.

The standard weights are applied again to bring the indication up to 3.86 t. At this point 5 kg is required to take the indication to the next changeover point. The standard weights are removed and a second substitution load is applied showing an indication of 3.61 t before being brought to the next changeover point. Calculate the actual weight of both the substitution loads used.

$E \quad = \quad I + ½e - \Delta L - L$

$E \quad = \quad 2.00\ t + 0.005 - 0.007 - 2.00\ t \quad = \quad -0.002\ t$

$L_{sub} \quad = \quad I_{sub} + ½e - E$

$= \quad 1.86 + 0.005 + 0.002 \quad = \quad 1.867\ t$

E_2	=	$I + \frac{1}{2}e - \Delta L - L$		
E_2	=	$3.86\ t + 0.005 - 0.005 - 3.867\ t$	=	$-0.007\ t$
L_{sub2}	=	$I_{sub2} + \frac{1}{2}e - E_2$		
	=	$3.61\ t + 0.005 - (-0.007)$	=	$3.622\ t$