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**National Measurement
Institute**

NMI R 14 Self-indicating Polarimetric Saccharimeters Graduated in Accordance with the ICUMSA International Sugar Scale

(OIML R 14: 1995(E), NEQ)

The English version of international standard OIML R 14: *Polarimetric Saccharimeters Graduated in Accordance with the ICUMSA International Sugar Scale* has been adapted to become the non-equivalent national standard with the reference number NMI R 14

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ABBREVIATIONS

EM	electromagnetic
EMC	electromagnetic compatibility
ESD	electrostatic discharge
ICUMSA	International Commission for Uniform Methods of Sugar Analysis
IEC	International Electrotechnical Committee
ISO	International Organization for Standardization
MPD	maximum permissible difference
MPE	maximum permissible error
OIML	International Organization of Legal Metrology

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INTRODUCTION

Polarimetric saccharimeters (subsequently referred to as saccharimeters) measure the relationship between the angular degree ($^{\circ}$) optical rotation caused by an aqueous solution of a sample and that caused by a pure sucrose solution of prescribed concentration, using linear polarised light with the same wavelength characteristics. The pure sucrose solution with properties specified by the International Commission for Uniform Methods of Sugar Analysis (ICUMSA) in SPS – 1 (2007) [2] is called the 'normal sugar solution'. The angular degree optical rotation caused by the normal sugar solution or equivalent quartz plate standard has been published for several wavelengths and is equivalent to 100 $^{\circ}$ Z units on the ICUMSA International Sugar Scale. Refer to Annex B for details.

The optical rotation of sugar-based solutions, including cane juice is factored into the determination of the 'polarisation' (Pol). In theoretical solutions containing only pure sucrose in water, Pol is a measure of sucrose concentration. For solutions of sugar mill products containing sucrose and other optically active substances, Pol represents the algebraic sum of the rotations of the constituents present. In sugar solutions and cane juice, the contribution of sucrose to this sum far exceeds that of other constituents. Therefore for commercial purposes, Pol is an adequate estimate of sucrose concentration.

Note: The convention in parts of the sugar industry to refer to the measurement result from a polarimeter as the 'polarisation' is not adopted in this document.

The Pol of raw or refined sugar in aqueous solution is equivalent to the optical rotation measured by a saccharimeter. Cane juice contains dissolved solids other than sucrose therefore calculation of 'Pol in juice' considers the optical rotation of the filtrate and the mass of solid constituents from the solution density, Brix. Commercial Cane Sugar (CCS) is a typical formula used to estimate the recoverable sucrose in cane. CCS takes into account the Pol in juice, the Brix in juice and the fibre content of the cane. The formula used to estimate the recoverable sucrose in cane may vary slightly between mills; however, a common element is the estimation of sucrose in a test sample by polarimetry.

1. SCOPE

NMI R 14 specifies the metrological and technical requirements for the pattern approval of self-indicating saccharimeters that are subject to legal metrological control. The required tests during pattern evaluation are indicated in Annex A. National Instrument Test Procedures for verification of saccharimeters is in NITP 15.2.

Note: Provisions for the polarimeter tubes are in General Certificate of Approval 1/4/0.

Manual application of a scale correction to the indicated result (in order to compensate for a bias at zero) is not permitted. Sample temperature monitoring and correction can be conducted automatically by the instrument or manually by the operator.

ICUMSA has endorsed the use of quartz plates with certified optical rotation values in place of pure sucrose solution standards. Requirements for quartz control plates used in calibration and verification of legally controlled saccharimeters are specified in clause 7.

As manually balanced, visual saccharimeters have been phased out in commercial applications, this standard is limited to saccharimeters balanced automatically.

All methods of illumination and balancing are otherwise applicable, for example:

- (a) saccharimeters with a rotating polariser or analyser where the angle of rotation can be measured, and which are illuminated by a monochromatic light source of known wavelength (must be between 540 nm and 900 nm);
- (b) saccharimeters with quartz wedge compensation that are illuminated either by a monochromatic light source of known wavelength (must be between 540 nm and 900 nm); or by the light of an incandescent lamp filtered so that the distribution of the spectral energy from the lamp arising from the degree of spectral filtration by the filter and the spectral sensitivity of the detector (e.g. photo-multiplier or photodiode) permits the use of radiation of effective wavelength 587 nm;
- (c) saccharimeters which operate according to a principle of measurement other than those given in (a) and (b).

2. TERMINOLOGY

The terms and definitions used in this document, where possible, are consistent with the OIML V 2 International Vocabulary Metrology – Basic and General Concepts and Associated Terms (VIM: 2012) [3], and OIML D

11 General Requirements for Electronic Measuring Instruments [4]. This section also defines terms applicable to the sugar industry and saccharimetry as they apply to this document.

2.1 Metrological Definitions

2.1.1 Checking Facility

Facility that is incorporated in a measuring instrument and enables significant faults to be detected and acted upon. 'Acted upon' refers to any adequate response by the measuring instrument (luminous signal, acoustic signal, prevention of the measurement process etc.)

2.1.2 Correction; Compensation (further information in VIM, 2.53)

Compensation for an estimated systematic effect.

Note: The temperature of a sample affects the rotation of linear polarised light transmitted through it. Therefore, the ICUMSA International Sugar Scale is defined at a sample reference temperature of 20 °C.

On instruments without automatic compensation, the displayed value may exhibit a significant error if the sample temperature is not manually corrected to 20 °C as required for application of the International Sugar Scale and its unit °Z. Manual corrections are in the form of negative or positive addends to the displayed value.

2.1.3 Error; Measurement Error (further information in VIM, 2.16)

Measured quantity value minus a reference quantity value.

2.1.4 Disturbance (OIML D 11, 3.13.2)

Influence quantity having a value within the limits specified in clause A.4.3, but outside the specified rated operating conditions of a measuring instrument.

Note: An influence quantity is a disturbance if the rated operating conditions for that influence quantity are not specified.

2.1.5 Displayed Value; Instrument Reading; Indication

A value shown on the display of a self-indicating instrument at the end of a measurement cycle.

Note: The displayed value on saccharimeters that cannot account for the sample temperature may require manual correction in order to minimise the error on the measured value for optical rotation.

2.1.6 Fault (adapted from OIML D 11, 3.9)

The difference between the error of measurement (during exposure to a disturbance) and the mean intrinsic error of the measuring instrument. Principally, a fault is the result of an undesired change of data contained in, or flowing through, an electronic measuring instrument.

2.1.7 Influence Quantity; Influence Factor (further information in VIM, 2.52)

Quantity that, in a direct measurement, does not affect the quantity that is actually measured, but affects the relation between the indication and the measurement result.

2.1.8 Intrinsic Error (OIML D 11, 3.7)

Error of a measuring instrument, determined under reference conditions.

2.1.9 Maximum Permissible Error (MPE); Limit of Error (further information in VIM, 4.26)

Extreme value of measurement error, with respect to a known reference quantity value, permitted by specifications or regulations for a given measurement, measuring instrument, or measuring system.

Note: For the performance tests in this standard, MPEs for various classes of saccharimeters are listed in clause 4.

2.1.10 Measured Value; Measured Quantity Value (further information in VIM, 2.10)

Quantity value representing a measurement result. For a measurement involving replicate indications, each indication can be used to provide a corresponding measured quantity value. This set of individual measured quantity values can be used to calculate a resulting measured quantity value, such as an average or median usually with a decreased associated measurement uncertainty.

2.1.11 Measurement Result (further information in VIM, 2.9)

Set of quantity values being attributed to a measurand together with any other available relevant information.

Note: A measurement result is generally expressed as a single measured quantity value and a measurement uncertainty. If the measurement uncertainty is considered to be negligible for some purpose, the measurement result may be expressed as a single measured quantity value. In many fields, this is the common way of expressing a measurement result.

2.1.12 Rated Operating Condition (VIM, 4.9)

Operating condition that must be fulfilled during measurement in order that a measuring

instrument or measuring system performs as designed.

Note: Rated operating conditions generally specify intervals of values for a quantity being measured and for any influence quantity.

2.1.13 Reference Condition (further information in VIM, 4.11)

Operating condition prescribed for evaluating the performance of a measuring instrument or measuring system or for comparison of measurement results.

Note: Reference operating conditions specify intervals of values of the measurand and of the influence quantities.

2.1.14 Reference Quantity Value (further information in VIM, 5.18)

Quantity value used as a basis for comparison with values of quantities of the same kind.

Note: For the majority of performance tests in this standard, the reference quantity value is the certified optical rotation of a quartz plate standard.

2.1.15 Self-indicating

Instrument in which the position of equilibrium and the displayed value are obtained without the intervention of an operator.

2.1.16 Significant Fault

A fault exhibited by the submitted instrument that is greater than the values in Table 4.

Note: The following faults are not considered to be a significant fault, even when they exceed the maximum limit:

- faults arising from simultaneous and mutually independent causes (e.g. EM fields and discharges) originating in a measuring instrument or in its checking facilities;
- faults implying the impossibility to perform any measurement; and
- transitory faults being momentary transitions in the indication, which cannot be interpreted, memorised or transmitted as a measurement result.

2.2 Sugar Industry and Polarimetry Definitions

2.2.1 Angular Degree Optical Rotation

Regarding plane-polarised light: the measured rotation of the plane of polarisation during transmission through an aqueous solution in angular degrees ($^{\circ}$).

2.2.2 Cane Juice

The juice assessed for cane payment purposes (e.g. first expressed juice, or the juice obtained

from the first crushing mill). A test sample of cane juice may contain clarification agents.

2.2.3 Certified Optical Rotation; Sugar Value

The optical rotation value ($^{\circ}\text{Z}$) of a quartz plate with reference to the indicated wavelength and temperature (20°C) on the measurement report that is associated with the Regulation 13 or Regulation 21 certificate.

2.2.4 Optical Rotation

The angular degree optical rotation normalised to the ICUMSA International Sugar Scale which has the unit $^{\circ}\text{Z}$. As this scale is defined at a sample reference temperature of 20°C , measurements on samples that are not 20°C shall be corrected automatically by instrument or manually by the operator.

Note: An optical rotation equivalent to that caused by the 'normal sugar solution' (a pure sucrose solution defined by ICUMSA) signifies 100°Z on the International Sugar Scale. An optical rotation equivalent to that caused by pure water signifies 0°Z .

2.2.5 Pol (Unrecommended: Sucrose Concentration; Polarisation)

An estimate of the sucrose concentration using the single measurement result, sometimes combined with a mass factor if solids are present. Depending on the mill or refinery product under assessment, the calculated Pol may take into account density meter results and other measurements (e.g. Brix, mass %).

2.2.6 (Polarimetric) Saccharimeter; Instrument; Measuring Device

A device that transmits linear polarised light through a sample, typical of which are solutions of sugars such as sucrose, and measures the resulting optical rotation in $^{\circ}\text{Z}$.

2.2.7 Polarimeter Tube, Pol Tube

A receptacle in the form of a tube closed at two ends that fixes the path length through the test sample.

2.2.8 Sample; Substance to be Analysed

Optically active substance (e.g. quartz plate, sugar solution, mixture based on mill products), at the reference temperature, that causes the plane of polarisation of transmitted plane-polarised light to be rotated. If the substance to be analysed is not at the 20°C reference temperature, correction is required to prevent error due to systematic effects.

2.2.9 Sugar Solution

Raw or refined sugar in aqueous solution. A test sample may contain clarification agents.

2.2.10 Test Solution; Test Sample

Sample with properties representative of the product being traded at the reference temperature. Correction is required if the test solution is not at the 20°C reference temperature to prevent error due to systematic effects. Clarification agents may be present.

3. UNITS OF MEASUREMENT

3.1 Degree Z ($^{\circ}\text{Z}$)

The conventional reference scale for measuring the optical rotation of sugar solutions is the International Sugar Scale defined by ICUMSA (see Annex B). The unit for optical rotation that shall be displayed on the saccharimeter is $^{\circ}\text{Z}$.

3.2 Temperature Correction

The International Sugar Scale is defined at 20°C . The magnitude of the error due to deviation from the reference temperature increases proportionally with the magnitude of optical rotation. To minimise the error, measurements on samples that are outside the reference temperature shall be compensated automatically by the instrument or manually corrected using a procedure that is in accordance with Appendix 3 Method 2 of ICUMSA GS 1/2/3/9-1 (2007) [5].

Note: According to [2], the correction for a quartz sample analysed using NIR wavelengths differs slightly from shorter wavelengths.

Measurement error due to sample temperature deviation from the reference 20°C is not tolerable during instrument performance assessment (e.g. verification or routine performance monitoring) and in high accuracy applications such as sugar solution analysis. There may be negligible benefit in correcting the error from temperature deviations in applications that require less accuracy such as cane juice analysis.

3.3 Traceability of other Reporting Units

If digital data processing device allows the result to be automatically expressed in units of other quantities that are related to the optical rotation value, e.g. 'Pol mass %' or 'Commercial Cane Sugar' (CCS), the result shall be traceable to the original measured value of the optical rotation in $^{\circ}\text{Z}$.

4. METROLOGICAL REQUIREMENTS

4.1 Scale

4.1.1 The scale on saccharimeters must be graduated in international sugar degrees ($^{\circ}\text{Z}$) or the scale interval of the display shall be in the form 1×10^k , 2×10^k or 5×10^k $^{\circ}\text{Z}$, the index k, being a negative whole number or equal to zero.

4.1.1.1 The scale must be linear; the range of measurement evaluated for approval may be from -30 $^{\circ}\text{Z}$ to $+105$ $^{\circ}\text{Z}$ or only a part of this range; the reference temperature must be 20 $^{\circ}\text{C}$.

Note: A linear scale is sufficient in practice although the optical rotation is not strictly proportional to the sugar concentration; in fact, the deviation from the proportionality does not exceed 0.003 $^{\circ}\text{Z}$.

4.1.1.2 Whatever the length of the specific polarimeter tube of a saccharimeter, the scale of which is graduated up to 100 $^{\circ}\text{Z}$, this scale must be such that a normal sugar solution (see Annex B) gives an indication of 100 $^{\circ}\text{Z}$ in this tube.

4.1.1.3 In all cases, saccharimeters must be graduated so that 100 $^{\circ}\text{Z}$ on the scale corresponds to a normal sugar solution (26 g/ 100 cm^3).

If the sample to be studied is not completely soluble in water, there may be variations in volume which, with different samples, may result in deviations. Details for certain products are given in the methods of operation.

4.1.2 In all cases, it must be possible to calibrate the saccharimeters. It must be possible to test and calibrate the scale by means of quartz plates for saccharimetric control, or by means of other suitable standards.

Note: Standards will be considered to be suitable if their characteristics are such that their value remains constant to 0.02% for 5 years.

4.2 Classes of Accuracy

According to the uncertainty affecting the measurements, saccharimeters for commercial purposes are divided into the following classes of accuracy: class 0.1, class 0.05 and class 0.02.

Note: Certain manufacturers have declared that some state-of-the-art instruments well exceed the requirements of class 0.05, and should be designated as class 0.02.

4.2.1 Maximum Permissible Error (MPE) for Verification

Table 1 lists the overall MPE applicable to any measurement over the scale. In-field conditions are represented by the rated operating conditions specified in clause A.4.2. Saccharimeters shall be designed and manufactured so that during initial verification and reverification tests, the error does not exceed the MPE shown in Table 1.

Table 1. MPE for in-field tests under rated operating conditions

Class of instrument	MPE at verification or in-service inspection ($^{\circ}\text{Z}$)
0.02	± 0.02
0.05	± 0.05
0.1	± 0.1

4.2.2 Repeatability

The difference between the highest and lowest value for a certified quartz plate in a set of measurements taken under repeatability conditions shall not exceed the values listed in Table 2.

Table 2. Allowable difference between any two determinations of a certified quartz plate under repeatability conditions

Class of instrument	Maximum difference ($^{\circ}\text{Z}$)
0.02	0.02
0.05	0.03
0.1	0.05

4.3 Error due to Influence Factor Variations

4.3.1 Variation of Select Influence Factor(s) within the Rated Operating Ranges

Saccharimeters shall be designed and manufactured so that all functions continue to operate as designed and that they do not exceed the MPE shown in Table 3 when select influence factor(s) are varied within the rated operating ranges specified in clause A.4.2.

Table 3. MPE within rated operating ranges during pattern evaluation

Class of instrument	MPE during influence factor variation within rated operating conditions ($^{\circ}\text{Z}$)
0.02	± 0.01
0.05	± 0.03
0.1	± 0.05

4.3.2 Effect of Disturbances on Electronic Instruments

In the event of disturbances of severities specified in clause A.4.3, significant faults as

defined in clause 2.1.16 shall either not occur or shall be detected and acted upon by means of checking facilities.

Note: Faults calculated to be within the limits in Table 4 are considered as insignificant and acceptable.

Table 4. Limit on a faults that can be classified as insignificant during pattern evaluation tests

Class of instrument	Limit on (insignificant) fault (°Z)
0.02	±0.01
0.05	±0.03
0.1	±0.05

4.4 Other Sources of Error

4.4.1 Error Due to Sample Temperature Variation

The International Sugar Scale defines the sample temperature as 20 °C. Regardless of the correction method, the measurement error shall not exceed the MPE in Table 3 on samples within the temperature range specified in clause A.4.1.

4.4.2 Error Due to Changes in the Instrument over Time

Changes within the instrument over time shall not compromise the accuracy of the instrument. The error on measurements taken immediately after the instrument is switched on shall be within the MPE in Table 3 where no warm-up time is specified. If a warm-up time is specified, the error on measurements taken after this warm-up time shall be within the MPE.

Any error due to instrumental drift over a period of at least four weeks shall remain stable (i.e. not exceed the limit shown in Table 3).

5. TECHNICAL REQUIREMENTS

5.1 Materials

5.1.1 Saccharimeters must be made of materials resistant to the chemical agents which may be used in the preparation of samples for measurement.

5.1.2 Ferro-magnetic materials can be used, provided that they do not influence the optical rotation.

5.1.3 The quartz in saccharimeters with a quartz compensator must be sufficiently free from homogeneity faults, twinning, striae and inclusions, so that the indicated accuracy of measurement is not affected.

5.1.4 The lenses and glass plates through which the light rays pass (between the polariser and the analyser) must be sufficiently free from internal strain so that variations in the indications of the saccharimeter, for all normal

positions of the polarimeter tube or of the control standard, do not exceed 0.01 °Z at any point of the measuring range.

5.1.5 Calcite polarisers with inclined faces are not authorised.

5.2 Construction

5.2.1 The frame and the mounting of saccharimeters must be sufficiently stable so that the measurements are not affected by vibrations and shaking that may occur normally in the working premises.

The construction must permit the optical parts of the saccharimeter to be cleaned easily, particularly with regard to any spillage or accidental fouling which may occur from liquid samples during the measurement process.

5.2.2 The internal optical parts must be inaccessible to unauthorised persons. The path of the light rays must be such that they are not masked once the polarimeter tube is put into place, and that they are not reflected by the internal wall of this tube.

That part of the path of the rays in which the polarimeter tube lies must be limited at both ends, unless the path of the light rays is established in such a way that it is limited in a parallel manner in the polarimeter tube [6].

5.2.3 The setting-up or the methods of adjusting the support of the polarimeter tube and the quartz plates or control standards must be such that the angle formed by the optical axis of the saccharimeter and the axis of the tube or the mounts of the plates or standards is (or can be adjusted to be) less than 0.5°.

5.2.4 A zero resetting device must be provided on the indicator.

5.2.5 The operation of the saccharimeter must not cause the temperature of the polarimeter tube to increase by more than 1 °C.

5.2.6 The illumination of saccharimeters must be such that, during the measurement of coloured solutions, whose optical density per centimetre does not exceed the values indicated below, any variation in the effective wavelength of the light, caused by the solution, cannot affect the results of the measurements by more than 0.02%.

5.2.7 The wavelength of the light source must be chosen by considering:

- the optical rotation of the sugar solutions;
- the optical density/absorbance of the sugar solutions (see clause 5.2.9); and
- the spectral sensitivity of the detector.

5.2.8 The noise level in photo-electric saccharimeters and the sensitivity of visual saccharimeters must be such that the

measurement accuracy specified in clause 4.2.1 is assured for all measurements to be made by the saccharimeters.

5.2.9 As far as photo-electric saccharimeters are concerned, the intensity of the light source must be such that, for the chosen wavelength, the optical rotation produced by a solution, with an optical density per centimetre (or absorbance per mm) less than or equal to the ordinate value at the point corresponding to the chosen wavelength on the curve given in Figure 1, can be measured by the saccharimeter without reducing the accuracy of measurement specified in clause 4.2.1.

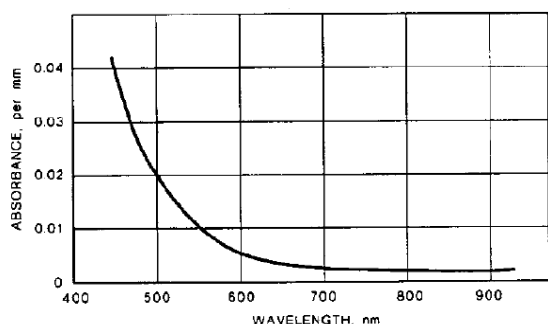


Figure 1. Effect of illumination wavelength on the optical density or absorbance per unit thickness [7]

5.2.10 After the first half-hour of operation, the systematic error due to drift of photo-electric saccharimeters must not exceed the MPE specified in Table 3 over four weeks.

5.2.11 The definitive indication of automatic saccharimeters must be obtained within a maximum of 30 seconds, whatever the value of this indication.

5.2.12 Electrically-powered saccharimeters must satisfy the specifications of this national standard despite variations of the electric power supply of -15% and $+10\%$ in voltage and $\pm 2\%$ in frequency in relation to their nominal values.

5.3 Sealing

Provision shall be made for sealing any adjustment or control device which could affect the measurement.

For adjustment or control electronic means (e.g. computer software) a password or access code (e.g. a four digit code), and recording of alter-protected parameters will suffice.

5.4 Instrument Markings

5.4.1 Inscriptions

Saccharimeters must bear the following inscriptions, in a clearly legible and indelible manner:

(a) name of the manufacturer (or the approval submittor) and their mark;

- (b) serial number;
- (c) for saccharimeters where the display value is not shown in scale unit $^{\circ}\text{Z}$: legend 'ICUMSA International Sugar Scale';
- (d) class of accuracy;
- (e) for saccharimeters without automatic tube recognition: length of the polarimeter tube or tubes which must be used;
- (f) reference temperature of 20°C and the wavelength for which the saccharimetric scale is valid (if this is not shown in the display).

5.4.2 Provisions for Stamping

The instrument shall be provided with a stamping plate or other suitable facility to affix the relevant pattern approval mark(s) and verification mark(s).

5.5 Presentation of the Displayed Value

Saccharimeters shall be equipped with a digital indicating element.

For class 0.02 and class 0.05 the display shall permit determination of the optical rotation to 0.01°Z resolution. The resolution for class 0.1 is 0.1°Z in-service but should allow for 0.01°Z resolution during pattern evaluation. Subdivisions of the unit $^{\circ}\text{Z}$ shall be in terms of decimal subdivisions (not fractions).

5.6 Manufacturer's Manual

The manufacturer shall provide with each saccharimeter, a manual that describes the installation, operation, and routine maintenance of the instrument and its accessories.

In addition, the manual must include the following information:

- (a) name and address of the manufacturer;
- (b) date of issue;
- (c) the limitations of use, including, but not confined to the following:
 - operating instructions;
 - maximum and minimum storage temperatures;
 - rated operating conditions;
 - warm-up time after switching on the electrical power;
 - details on the correction for effect of temperature (where this is necessary);
 - all other relevant mechanical and electromagnetic environmental conditions;
 - for instruments powered by an external power converter: specifications of this power converter;
 - details about compatibility with ancillary equipment (e.g. automatic temperature measurement devices, polarimeter tubes and quartz plates);

- instructions for installation, maintenance, repairs, permissible adjustments (this can be in a separate document, not meant for the user/owner); and
- conditions for compatibility with interfaces or other measuring instruments, e.g. printer, mill supervisory control and data acquisition (SCADA) system or a brixometer.

This manual shall be easily understandable and shall be supplied to the owner/user of the instrument in English.

6. POLARIMETER TUBES

Refer to General Certificate of Approval 1/4/0 for the requirements for polarimeter tubes and conditions for the test to verify the tube length.

7. QUARTZ PLATES

7.1 General

The calibration of the saccharimetric scale with a sugar solution is easily affected by errors due, for example, to the evaporation of the solution, to its instability, and to the considerable effect of temperature on optical rotation. It is therefore recommended that quartz plates be used for the calibration and control of saccharimeters.

7.2 Sugar Values of Quartz Control Plates

7.2.1 A quartz control plate is called normal when it produces the same optical rotation as the normal sugar solution, in the reference conditions set out in Annex B. Such a plate has a sugar value of 100 °Z at 20 °C for $\lambda = 546.227\ 1\ \text{nm}$.

7.2.2 A quartz control plate, for monochromatic light of wavelength λ other than 546.227 1 nm, will have a sugar value of 100 °Z, if the rotation which it produces is the one resulting from the definitions given in Annex B (the spectral region used being limited to the interval from 540 nm to 900 nm).

7.2.3 A quartz control plate for a quartz wedge saccharimeter illuminated through a filter by the non-monochromatic light of an incandescent lamp (effective wavelength 587 nm) will have a sugar value of 100 °Z, if the values of optical rotation which it produces are [2]:

for mercury:	$\alpha_{546.227\ 1\ \text{nm}} = 40.704^\circ$
for sodium:	$\alpha_{589.440\ 0\ \text{nm}} = 34.629^\circ$
for He-Ne laser:	$\alpha_{632.991\ 4\ \text{nm}} = 29.792^\circ$
for near infrared:	$\alpha_{882.60\ \text{nm}} = 14.863^\circ$
	$\alpha_{880.00\ \text{nm}} = 14.955^\circ$

The sugar value of quartz control plates for saccharimeters with quartz wedge compensation in non-monochromatic light is easily and accurately determined by measuring

the optical rotation in monochromatic light ([9] and [10]).

7.3 Quality of the Quartz

The quality of the quartz plates used must be such that:

- when placed between crossed polarisers, this quartz allows one to obtain total extinction in intense white light with the aid of a quartz compensator;
- when observed visually, this quartz is optically homogeneous and free from twinning, striae and inclusions; and
- the sugar value of the plate does not vary by more than 0.005° when the plate is rotated in its plane.

7.4 Form and Dimensions

7.4.1 The quartz plates must be in the form of a right circular cylinder with a diameter of 16.0 mm \pm 1.0 mm. They must have plane, parallel faces, cut perpendicular to the optic axis of the quartz. The circular edges must be chamfered to a maximum of 0.2 mm.

7.4.2 Quartz plates where the optical rotation for $\lambda = 546\ \text{nm}$ is less than 24° must consist of a plate of right-handed quartz and a plate of left-handed quartz. The thickness of each plate must not be less than 0.4 mm and the sum of the thicknesses must not exceed 1.6 mm.

7.5 Tolerances on Form and Dimensions

7.5.1 Flatness of the Faces

It must be possible to contain each face between two imaginary parallel planes 0.5 μm apart, at the maximum.

7.5.2 Parallelism of the Faces

If the length of the tube is not less than 20 mm, the thickness of the plate must not vary by more than 0.3 μm over its whole area. For the tube lengths less than 20 mm, this variation must not exceed 0.15 μm .

7.5.3 Optic Axis Error

The angle formed by the optic axis of the quartz and the perpendicular to one of the faces must be less than 10'.

7.6 Mounting of the Quartz Plates

7.6.1 The single or double quartz plates must be mounted, free from strain, in a tubular mount with circular flanges at the ends.

7.6.2 The free internal diameter of the tubular mount must be at least equal to 10 mm.

7.6.3 The diameter of the end flanges must be suitable for supporting the polarimeter tubes in order to allow coincidence of the optic axis of the saccharimeter and the axis of the mounting.

The permitted machining tolerances on these diameters must be such that the possible difference between the diameters cannot produce an angle error of more than 10' between the above mentioned axes.

7.6.4 The angle formed by the axis of the mount and the perpendicular to one of the faces of the plate must not exceed 10'.

7.6.5 The play of the plate within its mount must be less than or equal to 0.2 mm in the direction of the plane of the faces and contained within 5 μm and 30 μm in the direction of the axis. For lengths less than 20 mm, the play must be contained between 5 μm and 20 μm in the direction of the axis.

7.7 Metrological Control of Quartz Plates

7.7.1 Inscriptions

One of the faces of the mount or its tubular part must bear the following inscriptions, in a clearly legible and indelible manner:

- name and address of the manufacturer or their mark;
- sugar value(s), in $^{\circ}\text{Z}$, of the quartz control plate for a tube length of 200 mm;
- wavelength(s) at which this plate must be used, given to five significant figures;
- serial number corresponding to the information on the calibration certificate.

7.7.2 Certificate

Each quartz plate must have a current Regulation 13 or Regulation 21 certificate which specifies:

- (a) name and address of the manufacturer or their mark;
- (b) serial number;
- (c) production date;
- (d) wavelength(s) at which the plate must be used to five significant figures;
- (e) for each wavelength: the sugar value, in $^{\circ}\text{Z}$ for a tube length of 200 mm, and the optical rotation (α) in angular degrees at 20 $^{\circ}\text{C}$; and
- (f) accuracy of the plate for each wavelength (i.e. estimation of the measurement uncertainty).

8. PATTERN APPROVAL

8.1 General

Each pattern of a polarimetric saccharimeter used for trade from each submitter is subjected to the pattern approval procedure.

Without special authorisation, no modification may be made to an approved pattern.

8.2 Application

General application requirements are given in NMI P 106 Approval and Certification Procedures for Measuring Instruments for Trade Use [8]. The application for pattern approval shall be accompanied by:

- (a) at least one sample saccharimeter representative of the submitted pattern; and
- (b) descriptive documents and drawings.

The submitter may also provide data and other information that support a determination of whether the performance of the instrument meets requirements according to this national standard

8.3 Sample Instrument

The sample saccharimeter shall be in full working order and shall include all functions to be examined for pattern approval.

It is possible to accelerate the test program with a second saccharimeter as the testing laboratory may carry out different tests simultaneously on different units.

8.4 Documentation

The documentation submitted with the application for pattern approval shall include:

- (a) accuracy class (least error);
- (b) description of its general principle of measurement;
- (c) lists of the essential sub-assemblies, components (e.g. electronics) with their essential characteristics;
- (d) mechanical drawings, electric/electronic diagrams, containing principle layouts and block diagrams
- (e) installation requirements;
- (f) panel layout;
- (g) software documentation;
- (h) test outputs, their use, and their relationships to the parameters being measured;
- (i) operating instructions that shall be provided to the user; and
- (j) documents or other evidence that supports the assumption that the design and characteristics of the measuring instrument comply with the requirements of this national standard.

8.5 Performance Tests

The instrument shall be tested in accordance with the test procedures of Annex A. The pattern of instrument is presumed to comply with the metrological requirements if it passes the following performance tests:

Requirements	Test(s) required to pass to demonstrate compliance
Repeatability (4.2.2)	A.5.1 and A.5.2, A.6.1 – A.6.4
Error due to Influence Factor Variations: Variation of Select Influence Factor(s) within the Rated Operating Ranges (4.3.1)	Influence Factor Variations within Rated Operating Ranges: Cold (A.6.1) Dry Heat (A.6.2) Damp Heat (A.6.3) AC Mains Voltage Variation (A.6.4)
Error due to Influence Factor Variations: Effect of Disturbances on Electronic Instruments (4.3.2)	Disturbance Tests AC Mains Voltage Dips, Short Interruptions and Voltage Variations (A.7.1) Power Frequency Magnetic Field (A.7.2) Surges on AC Mains, Signal, Data and Control Lines (A.7.3) Bursts (Transients) on AC Mains, Signal, Data and Control Lines (A.7.4) Radiated, Radio-frequency, Electromagnetic Fields (A.7.5) Conducted Radio-frequency Fields (A.7.6) Electrostatic Discharge – Direct and Indirect Application (A.7.7) Mechanical Shock (A.7.8)
Error Due to Sample Temperature Variation (4.4.1)	Basic Tests Sample Temperature Sensitivity (A.5.3)
Other Sources of Error: Error Due to Changes in the Instrument over Time (4.4.2)	Basic Tests Instrument Warm-up Time (A.5.1) Instrument Drift and Instability (A.5.2)

8.6 Examinations

The operating manual shall be reviewed for completeness and clarity of operating instructions. The instrument shall undergo visual inspection in conjunction with a review of the submitted manufacturer specifications to confirm compliance with any metrological and technical requirements that cannot be evaluated during the performance tests.

9. INITIAL VERIFICATION

9.1 Legal Status of the Instrument Submitted for Verification

Production of measuring instruments shall be in conformance with the approved pattern.

Initial verification of a measuring instrument includes a procedure to ensure that the individual measuring instruments conform to the approved pattern. But, notwithstanding this initial verification carried out by NMI or servicing licensees, the pattern approval submitter has the full responsibility that the instrument complies with all the applicable requirements according to this national standard.

9.2 Verification Examination and Tests

Before being taken into service, initial verification of each individual instrument is required. A new instrument shall undergo initial verification only after pattern approval.

The visual inspection is intended to ensure that the instrument complies with the description pattern and the conditions within the issued certificate of approval. The test verifies compliance with the limit on the overall error in Table 1.

The national instrument test procedures for the verification of saccharimeters in used for trade are in NITP 15.2.

10. PERIODIC VERIFICATIONS

10.1 Reverification Frequency

Periodic verifications (reverification) ensure that polarimetric saccharimeters in service retain their metrological properties. Reverification is mandatory after any repair, adjustment or change that affects metrological performance. Annual reverification during pre-harvest season is ideal for instruments not in continuous use during the year.

In absence of a mandatory reverification interval, the following items are subject to random audits by trade measurement inspectors:

- the presence of the correct, valid and undamaged verification marks and if applicable, seals
- evidence of regular maintenance according to the manufacturers' instructions

10.2 Reverification Examination and Tests

Reverification shall be carried out according to NITP 15.2.

While consideration of instrument design, installation and suitability was afforded at initial verification, reverification shall focus on the following:

- (a) instrument and calibration integrity;
- (b) appropriateness of use;
- (c) compliance with the manufacturer's instructions; and
- (d) adequacy of maintenance.

After successful reverification, pre-existing marks must be removed or obliterated and replaced.

10.3 Control Procedures

The user of the saccharimeter shall carry out a performance check with a quartz plate before and after a testing series of test solution measurements in use for trade. The results of these checks shall be within the limits of the laboratory procedure. Such limits shall be less than or equal to the verification MPE for that instrument class (see Table 1).

Note: For some applications the laboratory procedure may require a performance check to be conducted with every batch of test solution.

For each saccharimeter subject to legal metrological control, a chronological written or electronic record of routine performance checks shall be maintained.

11. METROLOGICAL CONTROL MARKS

Metrological control marks and, if necessary, information on calibrations will be applied on a visible part (where they do not interfere with the use of the instrument) of saccharimeters, polarimeter tubes, and quartz control plate mounts.

ANNEX A. PATTERN EVALUATION PERFORMANCE TESTS (MANDATORY)

A.1 General

This mandatory annex defines the program of performance tests intended to ensure that electronic saccharimeters perform and function as intended in a specified environment and under specified conditions. Procedures under clauses A.6 and A.7 are in accordance with OIML D 11 *General requirements for electronic measuring instruments* [4]. The tests under clause A.5 confirm specific technical requirements – the procedure may be modified to suit the resources of the testing laboratory.

A.2 Initial Intrinsic Error, Instrument Preconditioning and Recovery

Prior to commencing the test program, the submitted instrument shall be adjusted so that the initial intrinsic error is as close to zero as possible.

The guidelines for preconditioning, conditioning and recovery listed in the relevant test standard shall be observed. Where there are no preconditioning guidelines, the instrument shall be stabilised according to the manufacturer's specifications.

Particularly during disturbance tests, the saccharimeter shall not be re-adjusted at any time during the test except to reset if a significant fault has been indicated.

A.3 Reference Test Conditions

Unless otherwise specified by the test procedure, the influence ranges below define the reference conditions under which the intrinsic error is determined for each influence or disturbance test.

- (a) Ambient (instrument) and sample temperature: $20\text{ °C} \pm 2.0\text{ °C}$
- (b) Relative humidity: $50\% \pm 10\%$
- (c) Power voltage: nominal mains or test voltage, V_{nom} or U_{nom}
- (d) Power frequency: nominal frequency, $f_{nom} \pm 2\%$
- (e) Instrument tilt: level at $0^\circ \pm 0.1^\circ$

During each test at reference conditions, the temperature and relative humidity shall not vary by more than 1 °C and 10% respectively within the allowable ranges.

A.4 Sample Temperature and Influence Quantities

Influence quantity values representing the rated operating conditions and potential disturbances on electronic instruments are indicated below. When the effect of the influence quantities (or disturbance) in the title of the test is being evaluated, the other influence quantities are to be held relatively constant, at values close to reference conditions.

A.4.1 Sample Temperature

- (a) Sample temperature: $15\text{ to }30\text{ °C}$
- (b) Sample and instrument temperature differential: up to 10 °C

A.4.2 Rated Operating Ranges

- (a) Ambient (instrument) temperature: $15\text{ to }30\text{ °C}$
- (b) Relative humidity: up to 85% , no condensation
- (c) Power voltage: -15% to $+10\%$ of mains or test voltage
- (d) Power frequency: nominal frequency, $f_{nom} \pm 2\%$

A.4.3 Disturbances

- (a) AC mains voltage dips, short interruptions and voltage variations:
 - reduction to 0% (0.5 cycle at 50 Hz),
 - reduction to 0% (1 cycle at 50 Hz),
 - reduction to 70% (25 cycles at 50 Hz),
 - reduction to 0% (250 cycles at 50 Hz).
- (b) Power frequency magnetic field: 30 A/m (continuous field)
- (c) Bursts (transients) on AC mains: amplitude 1 kV , repetition rate 5 kHz .
- (d) Bursts on signal, data land control lines: amplitude 0.5 kV , repetition rate 5 kHz .
- (e) Surges on AC mains: amplitude 0.5 kV (line to line) or 1 kV (line to earth) at 0° , 90° , 180° and 270° angles.
- (f) Surges on signal, data land control lines: amplitude 1 kV (line to earth) or 0.5 kV (line to line, unbalanced lines only).
- (g) Radiated radio-frequency fields, electromagnetic fields: $80\text{ MHz to }2\text{ GHz}$, 10 V/m .
- (h) Conducted radio-frequency fields: $0.15\text{ MHz} - 80\text{ MHz}$, 10 V (emf).
- (i) Electrostatic discharge – direct application: 6 kV (–) and (+) contact discharges.
- (j) Electrostatic discharge – indirect application: 8 kV (–) and (+) air discharges.
- (k) Mechanical shock: one fall up to 25 mm on a bottom edge.

A.5 Basic Tests

A.5.1 Instrument Warm-up Time

Test sample:

One plate approx $+100\text{ °Z}$

Number of measurements per series (at each test condition):

Three.

Test sequence:

1. Instrument powered off and stabilised at reference conditions.

2. Instrument powered on, take a series measurements under repeatability conditions after waiting for the specified warm-up time.
3. Take measurements again after waiting 30 min or twice the manufacturer recommended warm-up time, whichever is greater.

For an instrument where no warm-up time is specified, it is assumed that turning the instrument power on will immediately provide accurate results. The sample would therefore be tested immediately upon the instrument being powered on and then again after 1 hour.

Accuracy requirements:

The error on each measured value shall be within the applicable MPE shown in Table 3. The difference between the minimum and maximum error at each setting shall be within the applicable MPD shown in Table 2.

A.5.2 Instrument Drift and Instability

Test samples:

Two plates, one approx +100 °Z, the other can be any other sugar value.

Number of measurements per series (at each test condition)
10.

Test sequence:

1. Prior to running other tests (except of the warm-up time test), take a series of measurements under repeatability conditions on each sample on the submitted instrument.
2. After at least four weeks* and prior to any disturbance tests, take a series of measurements on the same two samples again.

*The minimum time period for assessing instrument stability shall be four weeks without any modifications, repairs, or adjustments performed on the instrument. However, the submitted instrument may be cycled through various influence factor variations (within the rated operating ranges) followed by recovery at reference conditions. In the event of an instrument modification within the four week period, the intrinsic error shall be reset to zero and the drift and instability test shall be recommenced.

Accuracy requirements:

The error on each measured value shall be within the applicable MPE shown in Table 3. The difference between the minimum and maximum error at each setting shall be within the applicable MPD shown in Table 2.

A.5.3 Sample Temperature Sensitivity

Test samples:

Two plates – one approx +100 °Z, the other can be any other sugar value.

Number of measurements per series (at each test condition):
Three.

Instrument temperature
Reference temperature (T_{ref}).

Sample temperatures
Reference temperature (T_{ref}), 15 °C (T_C), 30 °C (T_H).

Note: Prior testing, conduct an experiment to estimate ΔT , the temperature gain/loss of the cooled/heated plate over the time required to transfer the plate from the cooler/oven to the instrument. The cooler can be set at a lower temperature $T_C - \Delta T$ and the oven at a higher temperature $T_H + \Delta T$ in order to compensate for the temperature gain/loss.

Test sequence:

1. Set the temperature of the cooler to $T_C - \Delta T$ and oven to $T_H + \Delta T$ so that the sample temperature is T_C or T_H during measurement (see note above).
2. Equilibrate the instrument and samples to ambient temperature (T_{ref}). Take a series of measurements on each sample.
3. Place the samples in the cooler to equilibrate to $T_C - \Delta T$.
4. Take one sample out from the cooler, quickly transfer to the instrument and perform a measurement. Repeat on the next sample after the instrument has equilibrated to ambient temperature (T_{ref}).
5. Return the samples to equilibrate in the cooler before taking another measurement. Randomise the order in which the samples are removed from the cooler.
6. Place the samples in the oven to equilibrate to $T_H + \Delta T$.
7. Measure the heated samples in a similar fashion to the cooled samples.
8. Equilibrate the instrument and samples to ambient temperature (T_{ref}). Take a series of measurements on each sample again.

Accuracy requirements:

The error on each measured value (corrected for sample temperature) shall be within the applicable MPE shown in Table 3.

A.6 Influence Factor Variations within Rated Operating Ranges

A.6.1 Cold

Standards	IEC 60068-2-1 [11], IEC 60068-3-1 [12]
Test procedure in brief	<p>Test samples: Two plates, one approx +100 °Z, the other can be any other sugar value.</p> <p>Number of measurements per sample (at each test condition): Three.</p> <p>The test consists of exposure to the specified low temperature under 'free air' conditions for a specified time (after the instrument and sample has reached temperature stability). The change of temperature shall not exceed 1 °C/min during heating up and cooling down.</p> <p>Measurements are taken while alternating between samples under the following test conditions:</p> <ul style="list-style-type: none"> (a) at the reference temperature after conditioning; (b) at the minimum temperature, after the required exposure time; and (c) after recovery of the instrument at the reference temperature.
Test severity	Minimum temperature: 15 °C; exposure duration: 2 h; number of test cycles: 1.
Requirements	All operational functions shall operate as designed. The error on each measured value (corrected for the sample temperature) shall be within the applicable MPE shown in Table 3. The difference between the minimum and maximum error at each condition shall be within the applicable MPD shown in Table 2.

A.6.2 Dry Heat

Standards	IEC 60068-2-2 [13], IEC 60068-3-1 [12]
Test procedure in brief	<p>Test samples: Two plates, one approx +100 °Z, the other can be any other sugar value.</p> <p>Number of measurements per sample (at each test condition): Three.</p> <p>The test consists of exposure to the specified high temperature under 'free air' conditions for a specified time (after the instrument and sample has reached temperature stability). The change of temperature shall not exceed 1 °C/min during heating up and cooling down.</p> <p>Measurements are taken while alternating between samples under the following test conditions:</p> <ul style="list-style-type: none"> (a) at the reference temperature after conditioning; (b) at the maximum temperature, after the required exposure time; and (c) after recovery of the instrument at the reference temperature.
Test severity	Maximum temperature: 30 °C; exposure duration: 2 h; number of test cycles: 1
Requirements	All operational functions shall operate as designed. The error on each measured value (corrected for the sample temperature) shall be within the applicable MPE shown in Table 3. The difference between the minimum and maximum error at each condition shall be within the applicable MPD shown in Table 2.

A.6.3 Damp Heat

Standards	IEC 60068-2-78 [14], IEC 60068-3-4 [15]
Test procedure in brief	<p>Test samples: Two plates, one approx +100 °Z, the other can be any other sugar value.</p> <p>Number of measurements per sample (at each test condition): Three.</p> <p>The test consists of exposure to the specified high level temperature and the specified constant relative humidity for a specified time frame. The instrument shall be handled such that no condensation of water occurs on it. The power supply is on when the damp heat is applied. Measurements are taken while alternating between samples under the following test conditions:</p> <ul style="list-style-type: none"> (a) at the reference temperature before application of the damp heat; (b) whilst exposed to the damp heat, after the required exposure time; and (c) after recovery of the instrument at the reference temperature.
Test severity	Maximum temperature: 30 °C; humidity 85%. Exposure duration: 2 days; number of test cycles: 1.
Requirements	All operational functions shall operate as designed. The error on each measured value (corrected for the sample temperature) shall be within the applicable MPE shown in Table 3. The difference between the minimum and maximum error at each condition shall be within the applicable MPD shown in Table 2.

A.6.4 AC Mains Voltage Variation

Test procedure in brief	<p>Test samples: Two plates, one plate approx +100 °Z, the other can be any other sugar value.</p> <p>Number of measurements per sample (at each test condition): Three.</p> <p>The test consists of exposure to the specified power condition for a period sufficient for achieving temperature stability and for performing the required measurements. Measurements are taken while alternating between samples under the following test conditions:</p> <p>(a) nominal voltage;</p> <p>(b) upper limit;</p> <p>(c) lower limit; and</p> <p>(d) recovery (nominal voltage).</p> <p>If the instrument can be operated from an alternative power supply repeat the entire test with an appropriate voltage regulator.</p>
Test severity	<p>Test voltage upper limit: $U_{nom} +10\%$; test voltage lower limit: $U_{nom} -15\%$.</p> <p>Stabilising period after voltage change: 5 min.</p>
Requirements	<p>All operational functions shall operate as designed. The error on each measured value shall be within the applicable MPE shown in Table 3. The difference between the minimum and maximum error at each condition shall be within the applicable MPD shown in Table 2.</p>

A.7 Disturbance Tests

A.7.1 AC Mains Voltage Dips, Short Interruptions and Voltage Variations

Standards	IEC 61000-4-11 [16], IEC 61000-6-1 [17], IEC 61000-6-2 [18]
Test procedure in brief	<p>Test sample: One plate approx +100 °Z.</p> <p>Over four tests, the instrument shall be subjected to voltage reductions and interruptions of varying intensity and duration. A test generator suitable to reduce for a defined period of time the amplitude of the AC mains voltage is used. The performance of the test generator shall be verified before connecting to the instrument.</p> <p>The mains voltage reductions shall be repeated with a time interval less than the time required for a single measurement so that at least one voltage interruption occurs per measurement. At least 10 cycles are necessary for each test to enable the required number of measurements.</p> <p>Before each test, record the displayed value for the optical rotation. During application of voltage reductions record any change to the indication and comment on the functional performance at each test condition (a to d).</p>
Test severity	<p>Condition (a) U_{nom} to zero for a duration equal to half a cycle of frequency.</p> <p>Condition (b) U_{nom} to zero for a duration equal to one cycle of frequency.</p> <p>Condition (c) U_{nom} to 70% reduction for a duration equal to 25* cycles of frequency.</p> <p>Condition (d) U_{nom} to zero for a duration equal to 250* cycles of frequency.</p> <p>* These values are for a nominal frequency of 50 Hz.</p>
Requirement	<p>For each value obtained during a disturbance, the calculated fault shall not be significant, i.e. within the limit shown in Table 4.</p>

A.7.2 Power Frequency Magnetic Field

Standards	IEC 61000-4-8 [19]
Test procedure in brief	<p>Test sample: One plate approx +100 °Z.</p> <p>The test consists of exposure to power frequency magnetic field (50 Hz). Before exposure, record the displayed value for the optical rotation. During application of the magnetic field record any changes to the indication and comment on the functional performance.</p>
Test severity	Magnetic field strength: 30 A/m (continuous field).
Requirement	<p>For each value obtained during a disturbance, the calculated fault shall not be significant, i.e. within the limit shown in Table 4.</p>

A.7.3 Bursts (Transients) on AC Mains, Signal, Data and Control Lines

Standards	IEC 61000-4-1 [20], IEC 61000-4-4 [21]
Test procedure in	<p>Test sample: One plate approx +100 °Z.</p> <p>The test consists of subjecting the instrument to bursts of double exponential</p>

brief	<p>waveform transient voltages via each mains power supply line connection and each communication cable/interface. All bursts shall be applied during the same measurement in symmetrical mode and asymmetrical mode.</p> <p>The characteristics of the burst generator shall be verified before connecting to the instrument.</p> <p>The injection network on the mains shall contain blocking filters to prevent the burst energy being dissipated in the mains.</p> <p>For the coupling of the bursts in the I/O and communication lines, a capacitive coupling clamp as defined in the standard shall be used.</p> <p>Before each test, record the displayed value for the optical rotation. During application of bursts, record any change to the indication, and comment on the functional performance.</p>
Test severity	<p>Mains power line – amplitude (peak value): 1 kV, repetition rate: 5 kHz.</p> <p>Amplitude: 0.5 kV, repetition rate: 5 kHz.</p> <p>Number of test cycles: At least 10 positive and 10 negative randomly phased bursts shall be applied at 1000 V to each connection.</p> <p>The duration of the test shall not be less than 1 min for each amplitude and polarity.</p>
Requirement	<p>For each value obtained during a disturbance, the calculated fault shall not be significant, i.e. within the limit shown in Table 4.</p>

A.7.4 Surges on AC Mains, Signal, Data and Control Lines

Standards	IEC 61000-4-5 [20]
Test procedure in brief	<p>Test sample: One plate approx +100 °Z.</p> <p>The test consists of exposure to surges for which the rise time, pulse width, peak values of the output voltage/current on high/low impedance load and minimum time interval between two successive pulses are defined.</p> <p>The characteristics of the surge generator shall be verified before connecting to the instrument.</p> <p>On AC mains supply lines at least 3 positive and 3 negative surges shall be applied synchronously with AC supply voltage in angles 0°, 90°, 180° and 270°. The injection network on the mains shall contain blocking filters to prevent the burst energy being dissipated in the mains.</p> <p>Before each test, record the displayed value for the optical rotation. During application of surge, record any change to the indication, and comment on the functional performance.</p>
Test severity	<p>Amplitude: 1 kV (line to earth), 0.5 kV* (line to line)</p> <p>*Also applicable to unbalanced signal, data and control lines.</p> <p>Number of test cycles: At least 3 positive and 3 negative randomly phased bursts shall be applied to each connection.</p> <p>The duration of the test shall not be less than 1 min for each amplitude and polarity.</p>
Requirement	<p>For each value obtained during a disturbance, the calculated fault shall not be significant, i.e. within the limit shown in Table 4.</p>

A.7.5 Radiated, Radio-frequency, Electromagnetic Fields

Standards	IEC 61000-4-3 [23]
Test procedure in brief	<p>Test sample: One plate approx +100 °Z.</p> <p>The test procedure involves the exposure of the instrument to electromagnetic field strength as specified by the severity level and field uniformity. The specified field strength shall be established prior to the actual testing (without instrument in the field).</p> <p>The field shall be generated in two orthogonal polarisations and the frequency range shall be scanned slowly. If antennas with circular polarisation (i.e. log-spiral or helical antennas) are used to generate the electromagnetic field, a change in the position of the antennas is not required. When the test is carried out in a shielded enclosure to comply with international laws prohibiting interference on radio communications, care needs to be taken to handle reflections from the walls.</p> <p>The frequency ranges to be considered are swept with the modulated signal, pausing to adjust the RF signal level or to switch oscillators and antennas as necessary.</p> <p>Where the frequency range is swept incrementally, the step size shall not exceed 1% of the preceding frequency value. The dwell time of the amplitude modulated carrier at each frequency shall not be less than the time necessary for the instrument to be</p>

	exercised and to respond, but shall in no case be less than 0.5 s. The sensitive frequencies (e.g. clock frequencies) shall be analysed separately. Before exposure, record the displayed value for the optical rotation. During application of the radiated EM fields record any change to the indication and comment on the functional performance.
Test severity	EM frequency range: 80 MHz–2 GHz; modulation: 80 % AM, 1 kHz sine wave. Field strength: Radiated 10 V/m.
Requirement	For each value obtained during a disturbance, the calculated fault shall not be significant, i.e. within the limit shown in Table 4.

A.7.6 Conducted Radio-frequency Fields

Standards	IEC 61000-4-6 [24]
Test procedure in brief	Test sample: One plate approx +100 °Z. The test procedure involves the use of radio frequency EM current, simulating the influence of EM fields coupled or injected into the power ports and I/O ports of the EUT using coupling/decoupling devices as defined in the referred standard. The performance of the test equipment consisting of an RF generator, (de-coupling devices, attenuators, etc. before connecting to the instrument. Before each test, record the displayed value for the optical rotation. During application of the conducted EM fields record any change to the indication and comment on the functional performance.
Test severity	EM frequency range: 0.15–80 MHz. RF amplitude (50 Ω): 10 V (emf); modulation: 80 % AM, 1 kHz sine wave. Number of test cycles: One per connection cable/interface.
Requirement	For each value obtained during a disturbance, the calculated fault shall not be significant, i.e. within the limit shown in Table 4.

A.7.7 Electrostatic Discharge – Direct and Indirect Application

Standards	IEC 61000-4-2 [25]
Test procedure in brief	A capacitor of 150PF is charged by a suitable dc voltage source. The capacitor is then discharged through the instrument by connecting one terminal to ground (chassis) and the other via 330 Ω to surfaces which are normally accessible to the operator. The test includes the paint penetration method, if appropriate. For direct discharges, the air discharge shall be used where the contact discharge method cannot be applied. Before starting the tests, the performance of the ESD generator shall be verified. For instruments not equipped with a ground terminal, the instrument shall be fully discharged between discharges. Direct application – The contact discharge shall be applied on conductive surfaces, with the electrode shall be in contact with the instrument. The air discharge shall be applied on insulated surfaces or any electrically sensitive area on which contact discharge cannot be applied, i.e. the discharge occurs when the electrode approaches the EUT. Indirect application – The discharges are applied in the contact mode to coupling planes mounted in the vicinity of the instrument. Before each test, record the displayed value for the optical rotation. During application of the ESDs record any change to the indication and comment on the functional performance.
Test severity	Contact discharge voltage: 6 kV; air discharge voltage: 8 kV. Number of test cycles: At least 10 direct contact discharges and 10 direct air discharges of each polarity shall be applied on the instrument during a measurement. At least 10 indirect discharges of each polarity shall be applied to each coupling plane during a measurement. The time interval between successive discharges shall be at least 10 seconds.
Requirement	For each value obtained during a disturbance, the calculated fault shall not be significant, i.e. within the limit shown in Table 4.

A.7.8 Mechanical Shock

Standards	IEC 60068-2-31 [26]
Test procedure in brief	Test sample: One plate approx +100 °Z. The instrument, placed in its normal position of use on a rigid surface, is tilted towards one bottom edge and then is allowed to fall freely onto the test surface. The height of fall is the distance between the opposite edge and the test surface. However, the angle made by the bottom and the test surface shall not exceed 30°. Record a value for the optical rotation and comment on functional performance before and after the fall (i.e. when the instrument has been returned to the upright position).
Test severity	Height of fall: 30 mm; number of falls (on bottom edge): 1.
Requirement	For the value obtained after the disturbance, the calculated fault shall not be significant, i.e. within the limit shown in Table 4.

ANNEX B. ICUMSA INTERNATIONAL SUGAR SCALE

The ICUMSA International Sugar Scale [2] fixes the basis of a polarimetric method allowing determination of the relationship between the angular degree (°) optical rotation caused by an aqueous solution of a sample and that caused by a pure sucrose solution of prescribed concentration using the same polarised light. This scale is determined and graduated in accordance with the following requirements.

The 100 °Z point of the International Sugar Scale is fixed by the optical rotation, α , undergone by the polarised light of the green line of the mercury isotope ^{198}Hg ($\lambda = 546.2271$ nm in vacuum), when passing through a 200.000 mm length of sucrose solution in pure water, kept at a temperature of 20 °C, and containing 26.0160 g of pure sucrose weighed in vacuum per 100.000 cm³ of solution (normal sugar solution).

A mass of 26.0160 g of sucrose corresponds to 26.000 g when this sucrose is weighed in air by means of weights with a density of 8 000 kg/m³ in air, at a standard pressure of 101 325 Pa, at a temperature of 20 °C and a relative humidity of 50 %, the density of this air therefore being 1.2 kg/ m³ (see OIML R 33).

The 0 °Z point is fixed by the indication given by the saccharimeter for pure water.

In the range from 0 to 100 °Z, the scale graduation is linear because the optical rotation is practically proportional to the sucrose concentration of the solution.

In the given conditions, 100 °Z corresponds to an angle of optical rotation^{*}:

$$\alpha_{546.2271 \text{ nm}}^{20.00^\circ\text{C}} = (40.777 \pm 0.001)^\circ \quad (1)$$

For light of wavelengths other than that of the green line of the mercury isotope 198 (546.227 1 nm), the 100 °Z point is defined by the optical rotation which is given (under the same conditions as those given in above) by the formula:

$$\frac{\alpha_\lambda}{\alpha_{0.5462271\mu\text{m}}} = \frac{1}{a + b\lambda^2 + c\lambda^4 + d\lambda^6} \quad (2)$$

where:

$$\begin{aligned} a &= -0.075\ 047\ 659 \\ b &= +3.588\ 221\ 904\ 585 \\ c &= +0.051\ 946\ 178\ 3 \\ d &= -0.006\ 515\ 194\ 377 \end{aligned}$$

λ being in μm the wavelength in vacuum of the light used.

For the yellow light of spectrally purified sodium, the wavelength $\lambda_{\text{vacuum}} = 589.440$ 0 nm is taken as the mean optical centre of gravity. For 100 °Z, equations 1 and 2 give a rotation value(*) of:

$$\alpha_{589.4400 \text{ nm}}^{20.00^\circ\text{C}} = (34.626 \pm 0.001)^\circ$$

For the red light of the He-Ne laser with $\lambda_{\text{vacuum}} = 632.991$ 4 nm, the 100 °Z point from equations 1 and 2 results in a rotation value* of:

$$\alpha_{632.9914 \text{ nm}}^{20.00^\circ\text{C}} = (29.751 \pm 0.001)^\circ$$

For the near infrared wavelengths of $\lambda_{\text{vacuum}} = 880.00$ nm and 882.60 nm, the 100 °Z point from equations 1 and 2 results in respective rotation values[†] of:

- $\alpha_{880.00 \text{ nm}}^{20^\circ\text{C}} = (14.927 \pm 0.001)^\circ$; and
- $\alpha_{882.60 \text{ nm}}^{20^\circ\text{C}} = (14.836 \pm 0.001)^\circ$

* These rotation values were accepted at the 1986 ICUMSA meeting and have been valid since 1 July 1988.

† Wavelengths of light sources for instruments operating at near infrared wavelengths are not rigorously established like those of spectral lamps and need to be determined accurately.

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