WELMEC 2.1
(Issue 4)

WELMEC

European cooperation in legal metrology

Guide for Testing Indicators
(Non-automatic Weighing Instruments)

August 2001

WELMEC

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WELMEC is a cooperation between the legal metrology authorities of the Member States of the European Union and EFTA. This document is one of a number of Guides published by WELMEC to provide guidance to manufacturers of measuring instruments and to notified bodies responsible for conformity assessment of their products. The Guides are purely advisory and do not themselves impose any restrictions or additional technical requirements beyond those contained in relevant EC Directives. Alternative approaches may be acceptable, but the guidance provided in this document represents the considered view of WELMEC as to the best practice to be followed.

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Guide for Testing Indicators
(NAWI)

1 INTRODUCTION

1.1 General remarks

The European Standard on non-automatic weighing instruments EN 45501 contains the metrological and technical requirements for non-automatic weighing instruments subject to legal metrological control that provide presumption of conformity to the essential requirements of EC Directive 90/384/EEC. The requirements of the Standard apply to all devices performing the relevant functions, whether incorporated as a module in an instrument or manufactured as a separate module.

Subject to agreement with the approving authority, the manufacturer may define and submit modules to be examined separately. This is particularly relevant in the following cases:

- testing of the instrument as a whole is difficult or impossible;
- the module is manufactured and/or placed on the market as a separate unit to be incorporated in a complete instrument;
- the applicant wants to have a variety of modules included in the approved pattern. (See 8.1 of EN 45501).

A problem with the testing of modules is that the Standard - with the exception of load cells - does not describe which tests must be performed on these modules and how the outcome of the tests is certified.

This guide fills this gap as far as indicators are concerned.

1.2 Scope

The guide describes the procedures suitable to be used when testing indicators.

It was agreed that the guide would cover the testing of an indicator as a module for 6-wire systems and 4-wire systems.

The guide may play the following role:

- It describes the terms and aspects that are important when indicators are tested as a module;
- It describes test procedures that are clear and acceptable by other notified bodies;
- It functions as a reference in the description of the tests that have been carried out and of which the outcome is laid down in a test certificate.

The document is based on the European Standard EN 45501 on NAWIs as far as possible.

It is beyond the scope to formulate possible deviations from the Standard.

1.3 Purpose of the tests on indicators

The tests are performed to determine the relevant properties of the indicator and the conditions under which a non-automatic weighing instrument can be approved using the indicator in question.

2 WRITTEN DECLARATION

A written declaration shall be given including:

- Manufacturer's name and address and also the authorized representative if applicable;
- That the standard EN 45501:1992/AC:1993 has been adopted;
- That the indicator cannot be disturbed or fraudulently manipulated via the protective interfaces;
- Whether the test certificate number can or can not be quoted in an EC Type-approval certificate.

3 DOCUMENTATION

The documentation supplied by the manufacturer shall include the following:

- General description of type, explanations to understand the functioning.
- List of descriptions and characteristics data of all devices incorporated.
- Conceptual designs, drawings and plans of components, sub-assemblies, electric circuits etc.
- Specifications see Annex 1.

4 TEST SET-UP

It is important that the indicator is tested under normal conditions of use. To limit the number of tests the indicator should, as far as possible, be tested under conditions which cover the maximum range of applications.

A number of tests can be performed with either a load cell or a simulator but both have to fulfil the requirements of A.4.1.7 of EN 45501. However the disturbance tests should be performed with a load cell.

4.1 Load cell impedance

The disturbance tests (see 5.4.3 of EN 45501) shall be performed with a load cell and not with a simulator and with the highest practical value of the impedance (at least $^1/_3$ of the specified highest impedance) for the load cell(s) to be connected as specified by the applicant. For the "Immunity to radiated electromagnetic fields" test the load cell(s) should be inside the anechoic chamber.

The influence tests (see 5.4.3 of EN 45501) can either be performed with a load cell or a simulator. The influence tests shall be performed with the lowest impedance for the load cell(s) to be connected as specified by the applicant.

The table in Chapter 5 indicates which test has to be performed with the lowest impedance (low) and with the highest practical value of the impedance (high).

The impedance of the load cell referred to in this guide is the input impedance of the load cell, which is the impedance that is connected between the excitation lines.

4.2 Simulated dead load

The simulated dead load should be the minimum value the manufacturer has specified. The main reason for this is that the condition to cover the maximum range of applications for linearity and other significant properties is a low input signal of the indicator. The possibility of a larger zero-drift with a larger dead load is regarded as a less significant problem. However possible problems with the maximum value of the dead load (e.g. saturation of the input amplifier) have to be considered.

4.3 Peripheral equipment

With respect to peripheral equipment that can be connected to the indicator, the following requirements must be taken into account:

- Peripheral equipment shall be connected to all different interfaces;
- Peripheral equipment shall be supplied by the applicant to demonstrate correct functioning of the system or sub-system and the non-corruption of weighing results;
- Cables shall be connected to all input/output and communication lines;
- Cable types and lengths shall be as specified in the manufacturer's authorized manual or as specified in the test certificate. If cable lengths longer than 3 metres are specified, testing with lengths of 3 metres is regarded as sufficient.

4.4 Adjustment and weighing test

The adjustment has to be performed as described by the manufacturer. Weighing tests must be performed with at least five different (simulated) loads reaching from zero to the maximum number of verification scale intervals (VSI) with the minimum input voltage per VSI (for high sensitive indicators possibly also with the maximum input voltage per VSI, see Annex 3). It is preferable to choose points close to the changeover points in the tolerance-envelope.

4.5 High resolution

Normally an indicator is tested in high-resolution mode or tested in service mode where the AD-counts are given. Prior to the tests it is good practice to verify that this indicating mode is suitable for establishing the measuring errors. If this indicating mode does not fulfil this demand, a load cell, weights and small additional weights shall be used to determine the change-over points (interval = VSI * pi / 5 see A.4.4.4 of EN 45501).

4.6 Simulator

The simulator should be suitable for the indicator. The simulator shall be calibrated for the used excitation voltage of the indicator (AC excitation voltage means also AC calibration).

4.7 Fractions and set-up

The tests where pi has a range of 0.3.. 0.8 the manufacturer defines one value for these tests.

No value for the fraction pi is given with respect to repeatability. It is expected that the indicator will normally not cause a lack in repeatability. In the rare cases it does, special attention has to be paid to the reasons and the consequences.

5 REQUIREMENTS

5.1 General requirements

Article number EN45501	Article concerning	Fraction p_i =	Impedance	µV / VSI
A.4.4	Weighing performance	0.3 .. 0.8	low	min
A.4.5	Multiple indicating device			
	Analogue	1	low	min
	Digital	0	low	min
A.4.6.1	Weighing accuracy with tare		low	min
A.4.10	Repeatability		low	min/max **
A.5.2	Warm-up time test	0.3 .. 0.8	low	min/max **
A.5.3.1	Temperature (effect on amplification)	0.3 .. 0.8	low	min/max **
A.5.3.2	Temperature (effect on no load)	0.3 .. 0.8	low	min
A.5.4	Power voltage variation	1	low	min
3.9.5	Other influences			
B.2.2	Damp heat steady state	0.3 .. 0.8	low	min/max **
B.3.1	Short time power reduction	1	high*	min
B.3.2	Bursts	1	high*	min
B.3.3	Electrostatic discharge	1	high*	min
B.3.4	Electromagnetic susceptibility	1	high*	min
B.4	Span stability	1	low	min

VSI = Verification Scale Interval

* Test has to be performed with load cell.
** See Annex 3

The tests where pi has a range of 0.3.. 0.8 the manufacturer defines one value for these tests.

The following refer to EN 45501:

EN45501: 3.1.1 Accuracy classes

The manufacturer has to specify the accuracy class of the instrument in which the indicator may be used. An indicator tested according to the error fractions of this accuracy class cannot be used for an instrument of a higher accuracy class if no additional tests are performed.

EN45501: 3.1.2 Minimum value of the verification scale interval

The manufacturer shall specify the minimum value of the VSI. For an indicator using strain gauge measurement this value is given in µV/VSI.

The reasons for fixing this value are given in Annex 2.

EN45501: 3.2 Classification of instruments

The manufacturer has to specify the maximum number of VSIs (nmax) in which the indicator measuring range can be divided. The number of VSIs shall be within the limits fixed in Table 3 given in EN 45501.

EN45501: 3.3 Additional requirements for a multi-interval and a multiple range instrument

If the indicator is meant to be used in a multi-interval or a multiple range instrument it has to comply with the relevant requirements.

EN45501: 3.4 Auxiliary indicating devices

If the instrument has an auxiliary indicating device it has to comply with the requirements concerning these devices.

EN45501: 3.5 Maximum permissible errors

The error limits applicable to a module Mi that is examined separately are equal to a fraction pi of the maximum permissible errors or the allowed variations of the indication of the complete instrument.

The fractions for any module have to be taken from the maximum permissible error for the accuracy class and the number of verification scale intervals of the complete instrument incorporating the module. The fraction pi shall not exceed 0.8 and shall not be less than 0.3 if more than one module will contribute to the effect in question.

The indicator should comply with the requirements mentioned below if appropriate.

5.2 Technical requirements for a semi-self or self-indicating instrument.

EN 45501: 4.1	General requirements
EN 45501: 4.1.1	Suitability
EN 45501: 4.1.2	Security
EN 45501: 4.2	Indication of weighing results
EN 45501: 4.3	Analogue indicating device
EN 45501: 4.4	Digital indicating device
EN 45501: 4.5	Zero-setting and zero-tracking devices
EN 45501: 4.6	Tare device
EN 45501: 4.7	Preset-tare device
EN 45501: 4.9	Auxiliary verification devices
EN 45501: 4.10	Selection of weighing ranges on a multiple range instrument
EN 45501: 4.11	Devices for selection (or switching) between various load receptors - load transmitting devices and various load measuring devices in use.
EN 45501: 4.13	Plus and minus comparator instrument
EN 45501: 4.14	Instrument for direct sales to public
EN 45501: 4.15	Additional requirements for an instrument for direct sales to the public with price indication
EN 45501: 4.17	Price-labelling instrument

5.3 Requirements for electronic instruments.

EN 45501: 5.1	General requirements
EN 45501: 5.2	Acting upon significant faults
EN 45501: 5.3	Functional requirements
EN 45501: 5.4	Performance and span stability test

5.4 Computer used as indicator

See Annex 6 for Table showing necessary testing and documentation for a PC (computer) used as the indicator for a weighing system.

6 TESTS

The relevant parts of the test report and checklist of OIML R76-2 shall be used for an indicator. The non-relevant parts of the OIML R76-2 checklist are (requirements):

7.1.5.1
3.9.1.1
4.12.1
4.12.2
4.12.3
4.18.1
4.18.2
4.14.10

Other parts may be not relevant depending on the indicator.

6.1 Tare

The influence of tare on the weighing performance is depending exclusively on the linearity of the error-curve. The linearity will be found when the normal weighing performance tests are carried out. If the error curve shows a significant non-linearity, the error envelope has to be shifted along the curve, to see if the indicator meets the demands for the tare value corresponding with the steepest part of the error curve.

6.2 Temperature

In principle, the temperature effect on the amplification is tested by the following procedure:

- Carry out the prescribed adjustment-procedure at 20 °C;
- Change the temperature and verify that the measuring points are inside the error envelope after correction for a possible zero-shift.

This procedure has only to be carried out at the highest amplification and the lowest impedance to which the indicator can be adjusted if under those conditions the measurement can be carried out with such an accuracy that it is sufficiently certain that non-linearity's found in the error-curve are not caused by the test equipment used.

In case this accuracy cannot be reached (which will probably be the case for high sensitive indicators) the procedure has to be carried out twice. The first measurement has to be carried out with the lowest amplification, using at least 5 measuring points. The second measurement is carried out with the highest amplification, using two measuring points, one at the low end and one at the high end of the measuring range. The change in amplification due to temperature is acceptable if a line of the same form found at the first measurement, drawn between the two points and corrected for a zero-shift, is inside the relevant error-envelope. See Annex 3 for further clarification.

The temperature effect on no load indication is the influence of temperature variation on the zero-point expressed in changes of the input signal in µV. The zero-drift is calculated with the help of a straight line through the indications at two adjacent temperatures. The zero-drift should be less than pi VSI / 5K

The temperature influence can be subdivided in two parts:

- The temperature influence on the indicator;
- The temperature influence on the connecting cables to the load cell(s).

For 6-wire systems the temperature effect on the connecting cables is, in most cases, eliminated sufficiently. This should however be checked either by performing the tests with the maximum cable length as specified by the manufacturer or with the method given in Annex 5. For the 4-wire systems the indicator can be tested either with the specified cable length connected to the indicator or with the method described in Annex 5.

The method described in Annex 5 may not be applicable for indicators with AC excitation voltage.

6.3 Other influences

Other influences and restraints should be taken into consideration for the complete instrument and not for the modules.

7 TEST CERTIFICATE

The possibility of other Notified Bodies using the test results would be greatly enhanced if a test certificate for the indicator is issued. An example of the layout is given in Annex 4.

ANNEX 1
REQUIRED SPECIFICATIONS

Applicant

Manufacturer

Type

Intended use in Classes

Maximum number of verification scale intervals n

Load cell excitation power supply (V AC or DC)

Form (and frequency (Hz)) of the power supply

Maximum signal voltage for dead load (mV)
Minimum signal voltage for dead load (mV)

Minimum input-voltage per
Verification scale interval (µV)

Measuring range minimum voltage (mV)
Measuring range maximum voltage (mV)

Minimum load cell impedance (Ohm)
Maximum load cell impedance (Ohm)

Operating temperature range (°C)

Power supply requirements (V AC)

Value of the fractional error pi

Sense systems available

Specification of the load cell cable	type length cross section impedance
Specification interfaces/peripherals	cables interface types protective or not (see 5.3.6.1, 5.3.6.3 and 5.3.6.2 of EN 45501)

ANNEX 2
SPECIFICATION OF SENSITIVITY

The value of the verification scale interval is expressed in µV per verification scale interval in the case of strain gauge measurement.

The reasons for fixing this value are the following:

- It specifies the maximum sensitivity of the indicator, which is a very important parameter, in the correct way.

- By specifying the maximum sensitivity of the indicator the maximum amplification is fixed, which is very important for the signal/noise ratio.

- The drift in offset-voltage of the amplifier can be seen as zero-drift. The smaller the input voltage per VSI, the larger the influence of that drift. For a certain small value of the input signal per VSI, the indicator will no longer comply with 3.9.2.3 of EN 45501.

- The VSI cannot be expressed in units of mass because generally it is not known what capacity load cell will be connected to the indicator.

Furthermore it is an easy parameter to evaluate the proper combination with a load cell. The following example elucidates this.

The indicator is tested under the following conditions with a load cell:

1 the sensitivity of the load cell is 2 mV/V;
2 the excitation power supply is 10 V;
3 the load cell weighing range is 30% of maximum capacity;
4 the number of verification scale intervals is 6000 VSI;
5 therefore the unit per verification scale interval expressed in microvolts is:

(2 [mV/V] 10 [V] 30%) / 6000 VSI = 1 µV/VSI.

The test is carried out and, if the indicator performs within the MPE allowance with respect to the value calculated under 5, a test certificate is issued.

If the manufacturer of a weighing instrument combines the indicator with a tested load cell that does not have a sensitivity of 2 mV/V but 1 mV/V while the other parameters described above remain the same, then the indicator will have a unit per verification scale interval of 0.5 µV/VSI instead of 1 µV/VSI. In this case the instrument will possibly not comply with the requirements for the temperature effect on no load indication (3.9.2.3 of EN 45501).

ANNEX 3
TEMPERATURE INFLUENCE ON AMPLIFICATION

The absolute accuracy of the value of an amplification factor (VSI/µV) of an indicator is depending on many parameters, such as:

- the length of the cable to the load cell or the simulator;
- the impedance of the indicator;
- the value of the excitation power supply;
- the form of the excitation power supply;
- thermo-emf in the connecting points;
- the uncertainty of the voltage measuring device;
- the uncertainty of the excitation power supply;
- the small value of the input signal (µV);
- traceability, repeatability, stability;
- set-up parameters of the voltage ratio of the load cell simulator (if used).

Example:

If the minimum input-voltage per VSI is very low, i.e. less than or equal to 1 µV/VSI, it is very hard to find a suitable simulator or load cell to measure the linearity. If the value of the fraction pi is 0.5 for an indicator with 1 µV/VSI then the maximum permissible error in the lower envelope is 0.25 µV/VSI. The simulator should have an error better than 0.05 µV/VSI or at least the repeatability should be better than 0.05 µV/VSI.

Measurement at two amplifications

(a) The linearity of the indicator is tested over the complete input range, i.e. a typical indicator with a load cell excitation power supply of 12 V has a measuring range of 24 mV. If the indicator is specified for 6000 VSI's the linearity can be tested with 24 mV/6000 VSI = 4 µV/VSI.

(b) With the same set-up the temperature effect on the amplification shall be measured, during the static temperature test and during the damp heat steady state test.

(c) After that the indicator is set-up with the minimum dead load specified and with the minimum input voltage/VSI. Suppose this value is 1 µV/VSI, which means that only 25% of the input range is used.

(d) The indicator will now be tested with an input voltage close to 0 mV and close to 6 mV. The indication at both input voltages is registered at 20, 40, -10, 5 and 20 °C. The difference between the indication at 6 mV (corrected for the indication at 0 mV) at 20 °C and the corrected indications at the other temperatures are introduced in a graph. The points found are connected to the zero point by means of curves of an equal form as those found (a) and (b). The curves drawn must be within the error-envelope for 6000 VSIs.

(e) During this test the temperature-effect on no load indication can also be measured to see if the effect is less than pi × 1VSI/5 K.

(f) If the indicator fulfils the above-mentioned requirements it also complies with 3.9.2.1, 3.9.2.2, 3.9.2.3 of EN 45501 and it complies with the requirements for the static temperature test and damp heat steady state test.

Conclusion

For indicators with a very high input sensitivity two separate tests are made. In this way it is possible to test indicators with an input voltage between 2 μV/VSI and 1 μV/VSI. Below this value a simulator is very difficult to be used. If a manufacturer wants a lower value than 1 μV/VSI he has to supply an acceptable procedure and suitable testing equipment.

ANNEX 4
LAYOUT OF THE TEST CERTIFICATE OF THE INDICATOR

Test Certificate Number

Issued by:	Notified Body ABCD Street City Country Notified body number
In accordance with:	Paragraph 8.1 of the European Standard on metrological aspects of non-automatic weighing instruments EN 45501:1992/AC:1993 and WELMEC 2.1. The applied error fraction p_i with reference to paragraph 3.5.4 of this standard is 0.5.[1)]
Applicant:	Name of the applicant Street City Country
In respect of:	The model of an indicator, tested as a part of a weighing instrument. Manufacturer: Type:
Characteristics:	Suitable for a non-automatic weighing instrument with the following characteristics: Class [I, II, III or IIII], [single range, multiple-range, multi-interval or multi-indicating], [plus-minus comparator instrument, direct sales to public with or without price indication, price labelling instrument, industrial or instrument similar to one normally used for direct sales to public] The maximum number of verification scale intervals is: xxxxx In the description no further characteristics are described
Description and documentation:	The indicator is described in the description number No and in the documentation folder number No.
Remarks:	Summary of tests involved: see description number No. (This test certificate cannot be quoted in an EC Type-approval certificate without permission of the applicant quoted above)[2)]

City:

Notified Body's name:

Name and status of signatory:

The annex comprises x pages (if necessary)

This test certificate does not have the meaning of a type approval document as mentioned in Directive 90/384/EEC.

1) The error fraction p_i mentioned under "In accordance with" must be regarded as the decisive value for the application of the test certificate.

2) This sentence, under "Remarks", is mentioned only on request of the applicant.

ANNEX 4 (continued)

Descriptive Annex to Test Certificate Number

1 Name and type of instrument

2 Functional description of the instrument (including photographs, schematic views, exploded views, a list of devices etc.)

3 Technical data (including: maximum cable length [m/mm^2])

4 Interfaces

5 Conditions for use (for example: special inscriptions)

6 Location of seals

Tests carried out

The indicator is tested according to the Procedure on Testing Indicators with the following important deviations:

(Here the necessary information must be given, to make it clear which tests will have to be carried out on the complete instrument).

Content of documentation to be held by the Notified Body

1 Product specification

Contents: Description
Drawings
Block diagrams
Flow charts
Circuit diagrams

2 Examination report

(including an explanation of how the essential requirements are to be met)

3 Test results

ANNEX 5
TESTING OF LOAD CELL INTERFACES

CONTENTS

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1 MEASURING EQUIPMENT AND TEST SET-UP

The measuring equipment illustrated on the following figure serves as an example.

The cable resistance simulator is equipped with an 8-position switch for simulation of different cable resistances. Four equal resistances are in operation at each position. In addition to that, there are two switches for disconnecting the sense wires one by one, if any.

The excitation load simulator is used for simulation of more load cells, in this case for simulation of a multiple of 350 ohm cells together with a 350 ohm load cell simulator.

In case of another load cell impedance, this can be simulated using Rex.

MEASURING EQUIPMENT FOR EXAMINATION OF LOAD CELL INTERFACES OF WEIGHING INDICATORS

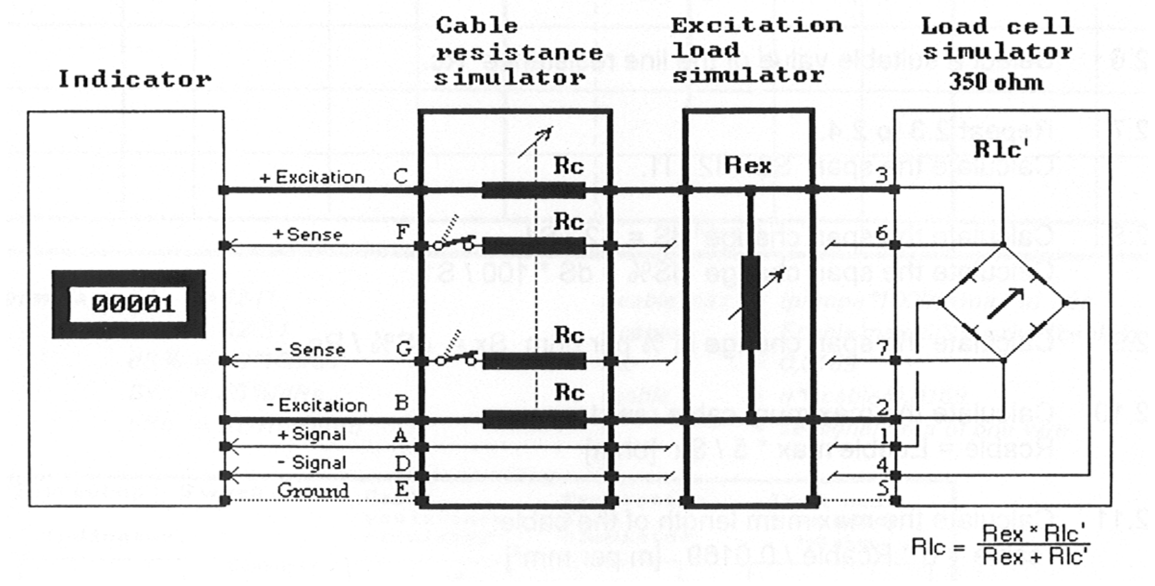
REFERENCE: WELMEC 2.1 Guide to testing of indicators

EQUIPMENT:

1. **Weighing indicator subject to examination**
   - measuring principle: Unconditional, with or without remote sense
2. **Cable resistance simulator**
   - resistances: 0 - 50.3 ohm
   - remote sense: Two switches for interruption of the sense wires
3. **Excitation load simulator**
   - equivalent loads: 1 - 12 load cells of 350 ohm
4. **Load cell simulator or load cell**
   - impedance: 350 ohm

Uncertainty of Measurement: To be specified

TEST SET-UP:



Resistance values :

Position	Rc (ohm)
0	0
1	0.34
2	1.13
3	1.93
4	5.26
5	10
6	20
7	33.3
8	50.3

Pos.	Rex (ohm)	Rlc (ohm)	Number of load cells
1	Open	350	1
2	350	175	2
3	117	87.5	4
4	73	60	6
5	51	44	8
6	39	35	10
7	32	29	12

2 TEST METHOD

Preparation
The measuring equipment and test set-up appear from Section 1.
The wiring should be done according to the illustrated example.
Adjust the indicator for high resolution, if possible for d = e/10.
The indicator shall be adjusted to the specified minimum µV/e.
Allow the equipment to warm up until stable indication.

Calculate Ecable'max from the result of the temperature testing of the instrument.
Enter the value in a suitable form as shown on the following pages.

One load cell :

2.1 Select : Rex = Infinite

2.2 Select : Rc = 0 ohm.

2.3 Apply minimum load on the load cell simulator (or the load cell).
Note the indication I1. Enter the value in the form.

2.4 Apply maximum load. Note the Indication I2.

2.5 Calculate the span S1 = I2 - I1.

2.6 Select a suitable value of the line resistance Rc.

2.7 Repeat 2.3 to 2.4.
Calculate the span S2 = I2 - I1.

2.8 Calculate the span change dS = S2 - S1.
Calculate the span change dS% = dS * 100 / S1.

2.9 Calculate the span change in % per ohm Sx = dS% / Rc.

2.10 Calculate the maximum cable resistance:
Rcable = Ecable'max * 5 / Sx [ohm]

2.11 Calculate the maximum length of the cable:
l'cable = q * Rcable / 0.0169 [m per mm²]

2.12 Select a new Rc and repeat 2.7 to 2.11.
Select again a new Rc and repeat 2.7 to 2.11.

2.13 Calculate the mean value of the observations. Apply this result.

More load cells :

2.14 Select Rex = Maximum number of load cells, if any.

2.15 Repeat 2.2 to 2.13.

2.16 Enter all the measuring results in the following spreadsheet form and let a PC program do the calculation work.

Testing of the load cell interface of the weighing indicator

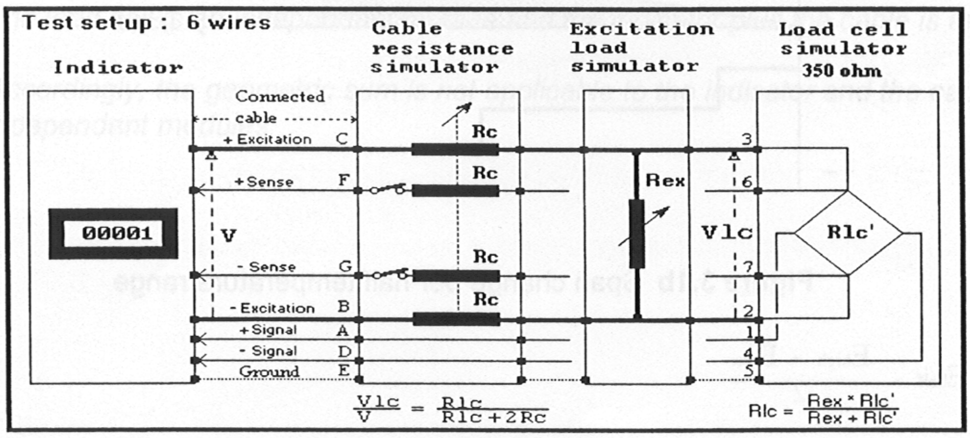
Reference : *WELMEC 2.1 Guide for testing of indicators*

Indicator type	:		e		count
Accuracy class	:		mpe		*e
Application No.	:		n'max		count
Remote sense	:		pi (p'indicator)		*mpe
Sensitivity (span)	:		Es (type test)		% per 25K
Simulator range	:		Ecable'max		% per 25K
Connected cable	:		Rlc'		ohm
Equivalent load	:		Rex		ohm

Impedance of load	**Measurements**				**Span calculations**					**Maximum cable**	
	Line	Load	Indication		Span		Span change			Resistance	Length
Rlc	Rc		I1	I2	S1	S2	dS	dS%	Sx	Rcable	l'cable
ohm	ohm	% of range	count	count	count	count	count	%	%/ohm	ohm	m/mm^2
							Mean:				

Formulae:

S1	*= I2-I1*	*Ecable'max*	*= (pi*mpe*100)/(n'max*e)-Es*
ds	*= S2-S1*	*Rcable*	*= Ecable'max*5/Sx=rho*l'cable/q*
ds%	*= dS*100/S1*	*rho*	*= 0,0169*
Sx	*= dS%/dRc*	*l'cable*	*= q*Rcable/0,0169*
dRc	*= Rc-Rc(short)*	*q*	*= sectional area of one wire*



Remarks :
Observer :
Date :

3 BACKGROUND TO THE TEST METHOD

The basis of the whole theory is the application of the result of a temperature testing of the weighing instrument.

3.1 Span change (or variation), Es, per half temperature range

This can be illustrated as follows :

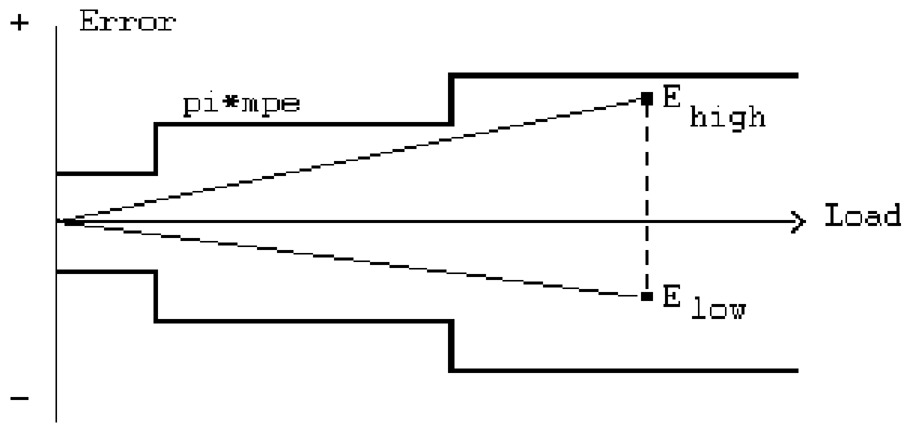


Figure 3.1a Span change

E_{high}: Span error at high temperature, T_{high}

E_{low}: Span error at low temperature, T_{low}

The span change per half temperature range E_{half} is as follows:

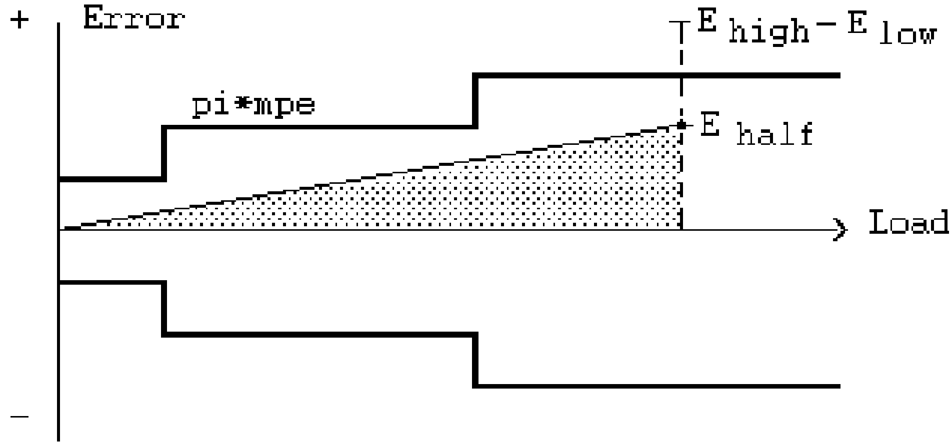


Figure 3.1b Span change per half temperature range

$$E_{half} = \frac{E_{high} - E_{low}}{2}$$

If the temperature range is 50 K, the span change per half temperature range is:

$$E_{25} = \frac{E_{high} - E_{low}}{T_{high} - T_{low}} * 25$$ (span change per 25K)

Expressed in % the following applies:

$$E_{half}\% = \frac{E_{half} * 100}{load}\%$$

$$E_{25}\% = \frac{E_{25} * 100}{load}\%$$

Hereafter, for the sake of convenience, $E_{half}\%$ and $E_{25}\%$ will be regarded in common under the term E_S.

3.2 Maximum error, E_{max}, for the indicator including the cable to the junction box for the load cells

As the span change is regarded as a numeric value, only the numerical part of the error envelope needs to be drawn.

$$E_{max} = \frac{p_i * mpe * 100}{Load_{max}}\% = \frac{p_i * mpe * 100}{n_{max} * e}\% \qquad [3.2]$$

3.3 Maximum error, E_{cable}, allocated to the cable to be connected between the indicator and the junction box for load cells

There are two possibilities of calculating E_{cable}. Either by using the algebraic sum (worst case) or the geometric sum (the square root of the sum of the squares).

In this method the algebraic sum is applied, as shown in Figure 3.3 due to the following reason:

The cable cannot be an independent module according to the term T.2.2 of OIML R76 as it does not perform a specific function which can be verified separately. Therefore, no partial error limits should be applied separately to a cable. The reason is that the cable is a vital part of the indicator and part of the measuring chain, which is terminated by another module, the load cell.

The load cell is an independent module and the indicator plus the cable is another module.

Accordingly, the geometric sum is not applicable to the indicator and the cable as independent modules.

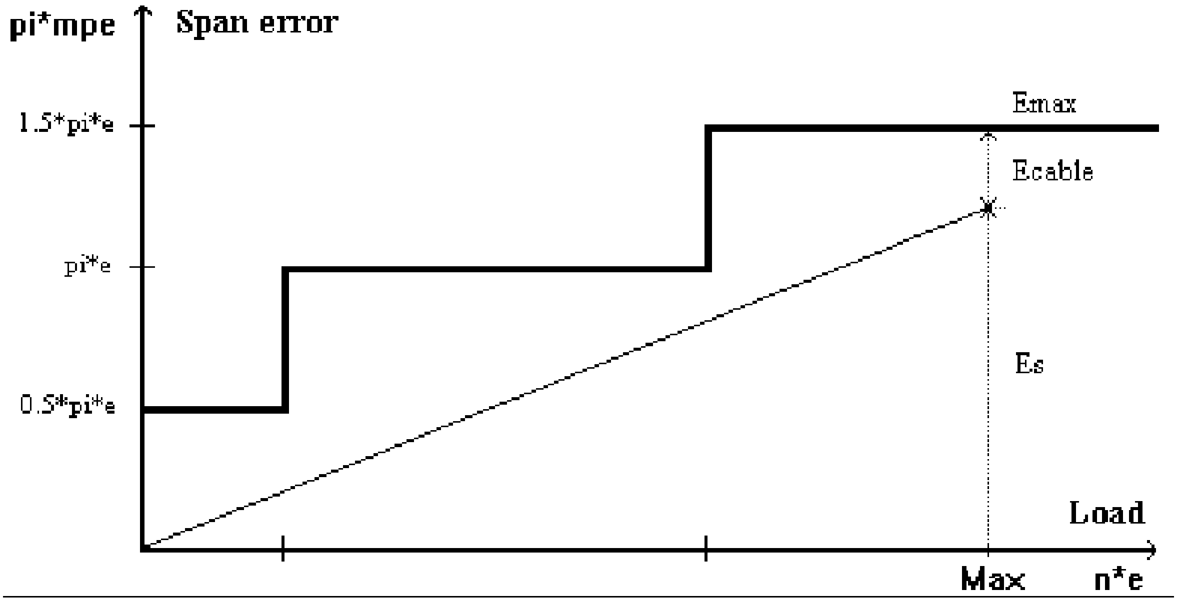


Figure 3.3 Ecable

$$E_s + E_{cable} \leq E_{max}$$

$$E_{cable} \leq \frac{pi * mpe * 100}{n * e} - E_s$$

$$E_{cable'max} = \frac{pi * mpe * 100}{n_{max} * e} - E_s [\%]$$ **[3.3]**

It should be noted that the fractional error pi applies to the indicator together with the cable.

3.4 Formulae for reducing of n_{max}, if needed

If

$$E_s = \frac{pi * mpe * 100}{n_{max} * e}$$

then it could be necessary to reduce n_{max} to make room for E_{cable}.

When reducing n_{max}, problems will sometimes arise, because of the steps of the error envelope curve and because the span change curve 'Es' is a straight line, as to principles.

A method to overcome this problem is illustrated by Figure 3.4 for accuracy class III.

On this principle, the other accuracy classes can also be considered, if the occasion requires so.

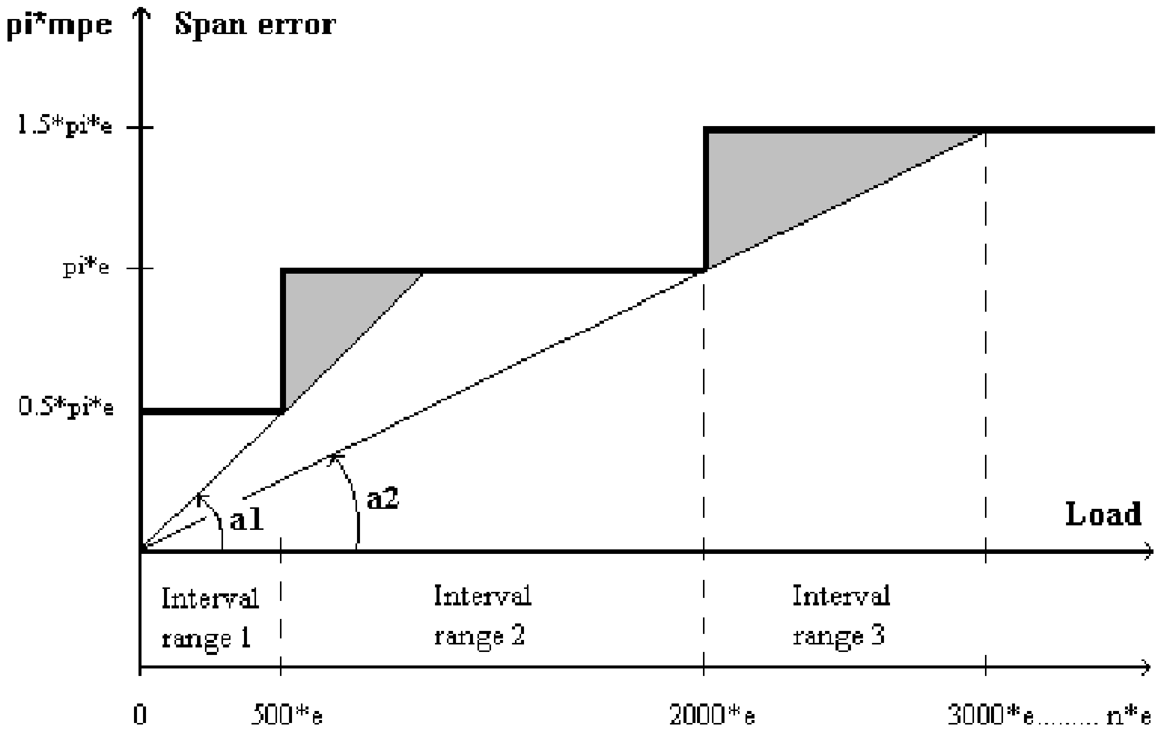


Figure 3.4 Reducing of n_{max} for accuracy class III

$E_S + E_{cable}$ can be expressed as the equation of a straight line in this way:

$$tg\angle a = \frac{pi * mpe}{load} * 100\% = E_s + E_{cable}$$

By doing so, the conditions of $E_S + E_{cable}$ can be found by the formulae below, in which the hatched areas in Figure 3.4 are excluded. This is due to the nature of the span change which is normally like a straight line.

Interval 1:

$$tg\angle a1 = \frac{0.5 * pi * e}{500 * e} * 100\% = pi * 0.1 [\%]$$

$$\text{If} \quad tg\angle a \quad \geq \quad tg\angle a1 \quad \text{then,} \quad n_{max\,1} = \frac{50 * pi}{E_s + E_{cable}}$$

Interval 2:

$$tg\angle a2 = \frac{pi * e}{2000 * e} * 100\% = pi * 0.05 \quad [\%]$$

$$\text{If } tg\angle a1 \quad > \quad tg\angle a2 \quad \text{then,} \quad n_{max\,2} = \frac{100 * pi}{E_s + E_{cable}}$$

Interval 3:

$$\text{If } tg\angle a \quad < \quad tg\angle a2 \quad \text{then,} \quad n_{max\,3} = \frac{150 * pi}{E_s + E_{cable}}$$

3.5 Resistance conditions in a linear circuit

The measuring circuit from the indicator to the load cell can be expressed as follows:

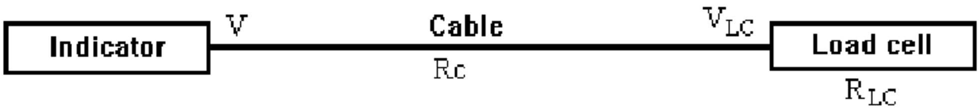


Figure 3.5.1 Principle of the linear circuit

V	:	Excitation voltage
V_{LC}	:	Excitation voltage at the load cell
R_C	:	Resistance of one wire [ohm] in the cable
l	:	Cable length [m]
q	:	Sectional area of one wire [mm²] in the cable

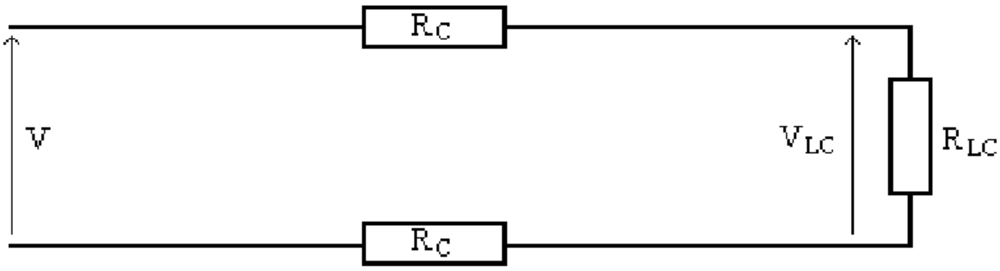


Figure 3.5.2 Voltage and resistance relations

$$\frac{V_{LC}}{V} = \frac{R_{LC}}{R_{LC} + 2 * R_C}$$

The resistance of one wire is: $R_C = \frac{\rho * l}{q}$

The resistivity of copper at 20°C is: $\rho_{20} = 0.0169\,[\Omega * mm_2 * m^{-1}]$

The variation of the resistance with temperature is:

$R_t = R_{20}\ (1 + \alpha\ (t - 20))$, of which α is about $4 * 10^{-3}$

If the indicator is placed indoors and the load cell is outdoors, the outdoor cable is exposed to temperature variations which influence the resistance of the wires in the cable.

In OIML R76, paragraph 3.9.2.1 the following is specified:

"If no particular working temperature is stated in the descriptive markings of the instrument, the instrument shall maintain its metrological properties within a temperature difference of 50 K".

As the cable is considered an essential part of the instrument, this requirement also applies to the cable which for practical reasons can be stated as follows :

Temperature range : 20 °C ± 25 °C as illustrated in Figure 3.5.3 below.

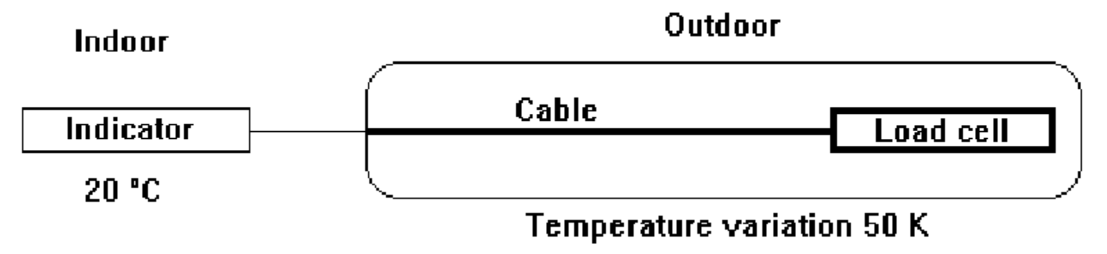


Figure 3.5.3 Indoor / outdoor relations

The change of resistance per 25 K approximated:

$$R\Delta = R_{20}(1 \pm 4 * 10^{-3} * 25)$$

$$R\Delta = R_{20}(1 \pm 0.1) \qquad [3.5.1]$$

The change of $\frac{V_{LC}}{V}$ per 25 K is:

$$(\frac{V_{LC}}{V})25 = \frac{R_{LC}}{R_{LC} + 2 * R_C(1 \pm 0.1)}$$

The relative change of $\frac{V_{LC}}{V}$ per 25 K is:

$$/V_C/ = \frac{\frac{V_{LC}}{V} - (\frac{V_{LC}}{V})25}{\frac{V_{LC}}{V}} * 100 \quad [\%]$$

Inserting $V_c = E_{cable'max}$, (see [3.3]), the value of the maximum resistance of one wire in the cable can be found :

$$R_C = R_{LC} * \frac{E_{cable'max}}{20 - E_{cable'max}(2 \pm 0.2)} \quad [\Omega] \qquad [3.5.2]$$

The ± value in the formula corresponds to either increasing or decreasing variation of the temperature.

As $R_C = \frac{\rho * l}{q}$,

the upper limit of the cable length between the indicator and the junction box can be found as follows:

$$l_{cable} = q * \frac{R_{LC} * E_{cable'max}}{\rho(20 - E_{cable'max}(2 \pm 0.2))} \quad [\text{m per mm}^2] \qquad [3.5.3]$$

3.6 Maximum resistance of each wire in the cable

The worst case of the formula [3.5.2] can be expressed as follows :

$$R_{c'max} = \frac{R_{LC} * E_{cable'max}}{20 - (1.8 * E_{cable'max})} \quad [\Omega] \qquad [3.6]$$

3.7 Maximum length of the load cell cable

The maximum length of the cable between the weighing indicator and a connection box for one or more load cells can be expressed as follows :

$$l_{cable'max} = q * \frac{R_{LC} * E_{cable'max}}{\rho(20 - (1.8 * E_{cable'max}))} \quad [\text{m per mm}^2] \qquad [3.7]$$

3.8 Formulae applicable to the test method

3.8.1 Span S1

The test method is based on the measurement of the indication I1 at minimum load and the indication I2 at maximum load.

These measurements are taken with Rc=0.

The span S1 = I2 - I1 is then calculated	[3.8.1]

3.8.2 Span S2

After this, a new set of measurements is taken with a cable resistance Rc = dRc

The span S2 = I2 - I1 is again calculated.	[3.8.2]

3.8.3 Span change dS and dS%

The span change dS = S2 - S1 is then calculated.

The span change dS% = 100 * dS/S1 is then calculated.	[3.8.3]

3.8.4 Span change Sx stated in % per ohm

The span change stated in % per ohm of the simulated cable resistance is then calculated as follows :

Sx = dS% / dRc [% per ohm]. This is a measure of the indicator's sensitivity to the cable resistance.	[3.8.4]

3.8.5 Maximum cable resistance R_{cable}

From [3.5.1] it appears that the resistance in the cable will vary about 10% per 25 K.

Sx will vary proportionally, which can be stated as follows :

$$S_{X25} \approx S_X * 0.1 \quad [\% \text{ per } \Omega \text{ per } 25\,K]$$

As a variation of the wire resistance in a linear circuit is expected to give a proportional variation of the span, this can be stated as follows:

$$S_{X25} * R_{cable}$$

This is equivalent to E_{cable}.

E_{cable} can be determined as specified in Section 3.3.

After this, the following can be stated :

$$E_{cable'max} = S_{X25} * 2 * R_C$$

$$R_{cable} = E_{cable'max} * \frac{1}{2 * S_{X25}}$$

$$R_{cable} \approx E_{cable'max} * \frac{1}{2 * 0.1 * S_X} \quad [\Omega]$$

Maximum cable resistance	$R_{cable} \approx E_{cable'max} * \frac{5}{S_X} \quad [\Omega]$	[3.8.5]

3.8.6 Maximum cable length l'_{cable}

As $R_{cable} = \frac{\rho * l}{q}$ and $\rho \approx 0.0169$ the following can be stated

Maximum cable length $l'_{cable} \approx q * \frac{R_{cable}}{0.0169} \quad [\text{m per mm}^2]$ [3.8.6]

3.8.7 Field of application

This test method is suitable for electronic weighing instruments equipped with remote sense circuit as well as instruments without a remote sense circuit.

ANNEX 6
COMPUTER USED AS INDICATOR

Table showing necessary testing and documentation for a PC (computer) used as the indicator for a weighing system.

Category No		Tests	Ref.	Documentation	Ref.	Remarks
1	PC as module -Primary indication on the monitor -ADC on PC-board without shielding (open device) -Power supply from PC	ADC and PC as unit: -according to WELMEC 2.1 -PC equipped for maximum power consumption	WELMEC 2.5 No 5.2 par 1	ADC: detailed PC: detailed	WELMEC 2.1 WELMEC 2.5 No 5.2 par 7	Influences on the ADC from the PC possible (temperature, EMI).
2	PC as module -Primary indication on the monitor -ADC on PC-board with shielding (closed device) -Power supply from PC	ADC and PC as unit: -according to WELMEC 2.1 -PC equipped for maximum power consumption	WELMEC 2.5 No 5.2 par 1	ADC: detailed PC power supply: detailed PC other parts: general	WELMEC 2.1 WELMEC 2.5 No 5.2 par 7	Influences on the ADC from the PC possible (temperature, EMI). New EMI tests in accordance with WELMEC 2.5 No 3.3 on PC only if power supply has changed, otherwise CE marking sufficient.
3	PC as purely digital module -Primary indication on the monitor -ADC outside PC in separate housing -Power supply from PC	ADC: -according to WELMEC 2.1 PC: -according to WELMEC 2.5 No 3.3	WELMEC 2.5 No 5.2 par 2	ADC: detailed PC power supply: detailed PC other parts: general	WELMEC 2.1 WELMEC 2.5 No 5.2 par 7	Influences on the ADC from the PC possible (EMI). New EMI tests in accordance with WELMEC 2.5 No 3.3 on PC only if power supply has changed, otherwise CE marking sufficient.
4	PC as purely digital module -Primary indication on the monitor -ADC outside PC in separate housing -Separate power supply for ADC	ADC: -according to WELMEC 2.1 PC: -none, CE marking is sufficient	WELMEC 2.5 No 5.2 par 2	ADC: detailed PC: none	WELMEC 2.1 WELMEC 2.5 No 5.2 par 7	Influences on the ADC from the PC not possible. CE marking is sufficient.
5	PC as purely digital peripheral	PC: -none, CE marking is sufficient	WELMEC 2.5 No 5.1	PC: none	WELMEC 2.5 No 5.1	PC: none, CE marking is sufficient.

ADC = Analogue to digital converter
Documentation: Detailed = housing, block diagram, circuit diagram, layouts, descriptions etc.
General = housing, description.

Revisions of this guide

(Changes to Issues 1 and 2 not listed)

Issue	Date	Significant changes
3	February 2001	Addition of Annex 6 table “Computer used as Indicator”. Addition of reference to maximum cable length in Annex 4 section “Descriptive Annex to Test Certificate Number”, “Technical data”.
4	August 2001	Addition of sentence in Annex 5 Part 2 “Preparation” regarding specified minimum µV/e. Paragraph deleted from Section 5.1, as duplicated in Section 4.7. Reference to “calibration” removed from Section 4.4. Equation for V_{LC}/V corrected in Annex 5 Section 3.5. Addition of this Revisions section.