Testing equipment for electrical energy meters

ICS 91.140.50

National foreword

This British Standard reproduces verbatim IEC 736:1982 and implements it as the UK national standard.

The UK participation in its preparation was entrusted to Technical Committee PEL/13, Electricity meters, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

From 1 January 1997, all IEC publications have the number 60000 added to the old number. For instance, IEC 27-1 has been renumbered as IEC 60027-1. For a period of time during the change over from one numbering system to the other, publications may contain identifiers from both systems.

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Equipement d'étalonnage de compteurs d'énergie électrique

Testing equipment for electrical energy meters

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CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

TESTING EQUIPMENT FOR ELECTRICAL ENERGY METERS

FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

PREFACE

This report has been prepared by Sub-Committee 13A: Electric Energy Measuring Equipment, of IEC Technical Committee No. 13: Electrical Measuring Equipment.

Drafts were discussed at the meetings held in Warsaw in 1976 and in Florence in 1978. As a result of this meeting, a draft, Document 13A(Central Office)43, was submitted to the National Committees for approval under the Six Months' Rule in June 1979. Amendments, Document 13A(Central Office)49, were submitted to the National Committees for approval under the Two Months' Procedure in October 1980.

The National Committees of the following countries voted explicitly in favour of publication:

Austria	Ireland
Belgium	Israel
Brazil	Italy
Bulgaria	Japan
China	Netherlands
Czechoslovakia	Poland
Denmark	Romania
Egypt	South Africa (Republic of)
Finland	Sweden
France	Switzerland
Germany	Turkey
Hungary	

In view of the fact that this is the first IEC publication on meter testing equipment (MTE) and that, in various countries, there are very different ways of constructing and using an MTE, explanatory notes, additional notes and guidance to which attention should be given will be found in Appendices A, B and C.

TESTING EQUIPMENT FOR ELECTRICAL ENERGY METERS

1. Scope

This report is applicable to three-phase and/or single-phase equipment used for type and acceptance testing of electrical energy meters of Classes 0.5, 1 and 2.

2. Units and definitions

The units used in this report are those used by the International Electrotechnical Commission (IEC).

2.1 *Testing equipment for electrical energy meters; meter testing equipment (MTE)*

An assembly of apparatus to supply energy to meters under test and to measure this energy.

2.2 *Power × time measurement method (wattmeter method)*

A method by which the energy supplied to the meter(s) under test is determined by the product of a known constant power and a known interval of time.

2.3 *Energy comparison method (standard meter method)*

A method by which a known amount of energy is supplied to the meter(s) under test.

2.4 *Reference standard*

A standard with which standards of lower accuracy are compared.

2.5 *Working standard*

A standard which, calibrated against a reference standard, is intended to verify working measuring instruments of lower accuracy.

2.6 *MTE test standard*

A measuring device for the determination of the accuracy of an MTE. It always includes a reference standard. It may include other elements, for example precision instrument transformers, precision time interval generator, etc.

2.7 *Output terminals of an MTE*

The terminals from which the power, corresponding to the separate application of voltages and currents, is supplied to the terminal block(s) of the meter(s) under test.

2.8 *Maximum output of an MTE*

The output, in voltamperes, corresponding to the highest loading applied at the output terminals of an MTE, for which the limits of permissible errors (Table I) under reference conditions (Sub-clause 3.3) are not exceeded.

The output shall be defined separately for the voltage and current circuits.

3. Accuracy

3.1 *General remarks*

An MTE shall allow the user to adjust and measure the necessary quantities, voltage, current, power-factor, time, power and energy within the permissible tolerances for the relevant class of meters which will be tested with this MTE.

The error E of an MTE is the overall error of all its components under normal service conditions.

3.2 *Methods for the determination of the overall error of an MTE*

The determination of the overall error of an MTE is made according to the following methods:

- comparison of the *energy* delivered at the output terminals of the MTE indicated by the MTE test standard with the energy indicated by the working standard(s) of the MTE;
- comparison of the *power* at the output terminals of the MTE, indicated by the MTE test standard, with the power indicated by the working standard(s) of the MTE. The influence of the accuracy of the time measurement on the error of the energy shall be specified.

3.3 *Reference conditions*

The reference conditions at the input of the MTE shall be specified by the manufacturer and shall be such that, at its output, the reference conditions for the meter(s) under test are fulfilled.

Sub-clause 3.4 gives the particular requirements for the magnetic field produced by the MTE.

3.4 *Magnetic field of the MTE*

It is recommended that the magnetic flux density produced by the MTE at the position of the meter(s) under test should not exceed the following values:

for $I \leqq 10$ A $\quad$ $B \leqq 0.0025$ mT

for $I = 200$ A $\quad$ $B \leqq 0.05$ mT

The limiting values of magnetic flux density for I, between 10 A and 200 A, shall be evaluated by interpolation.

I = output current of the MTE.

B = magnetic flux density in air due to the magnetic field.

Note. – $B = \mu_0 H$, H in amperes per metre.
$\mu_0 = 4\pi \cdot 10^{-7}$ H/m (henrys per metre).

3.5 *Error determination of an MTE*

The error of a newly manufactured MTE at a certain test point shall be lower than the error E_{max} in Table I (see Clause B1 of Appendix B for the error definition).

If the result of a single measurement gives an error in excess of the permissible limits, then two additional measurements at this particular test point can be taken. The results of these two additional measurements shall be within the permissible limits of E_{max}.

An MTE is capable of being used at least for meters of the relevant class (type test or acceptance inspection) according to Table I, if the results of all test points (Table III) are within the limits of the permissible errors.

If the results of some test points are not within the limits of the permissible errors, the use of this MTE may be restricted to certain ranges, for certain classes of meters. Such a restriction shall be indicated in a suitable visible place on this MTE.

TABLE I

Limits of permissible errors in percentage

Meter class	0.5			1			2		
Power-factor	1	0.5 lagging	0.5 leading	1	0.5 lagging	0.5 leading	1	0.5 lagging	0,5 leading
E_{max}	±0.10	±0.15	±0.20	±0.20	±0.30	±0.40	±0.30	±0.45	±0.60

3.6 *Correction of the error E of an MTE*

If the error E of an MTE in service is outside the limits of Table I but within twice the relevant values of Table I then a correction for the error of the MTE shall be applied to the results of the tests on the meter(s) under test. In these cases, it is recommended that an effort should be made to reduce the error of the MTE in order to bring it within the permissible limits.

3.7 *Repeatability of the measurements (see Clause B5 of Appendix B)*

A sequence of repeated measurements is recommended for the "control point" U_c, I_c, at power-factor 1 (reference No. 1 of Table III). Not less than five measurements for each phase shall be made. Between successive measurements the controlling switches and controlling devices shall be operated.

The results of these repeated measurements are used to calculate the value s, which is the estimation of the standard deviation:

$$s = + \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (E_i - \bar{E})^2}$$

where:

E_i = error of the MTE determined by one individual measurement of a sequence of repeated measurements at a certain test point

$\bar{E}$ = mean value of the errors E_i

n = total number of individual measurements

For newly manufactured MTEs, the values of s at the control point U_c, I_c, power-factor 1 shall be within the limits of s_{max} given in Table II.

If additional measurements are made at power-factor 0.5 lagging, the corresponding values for s_{max}, given in Table II, are recommended.

For MTEs in service, twice the values of Table II are permitted.

TABLE II

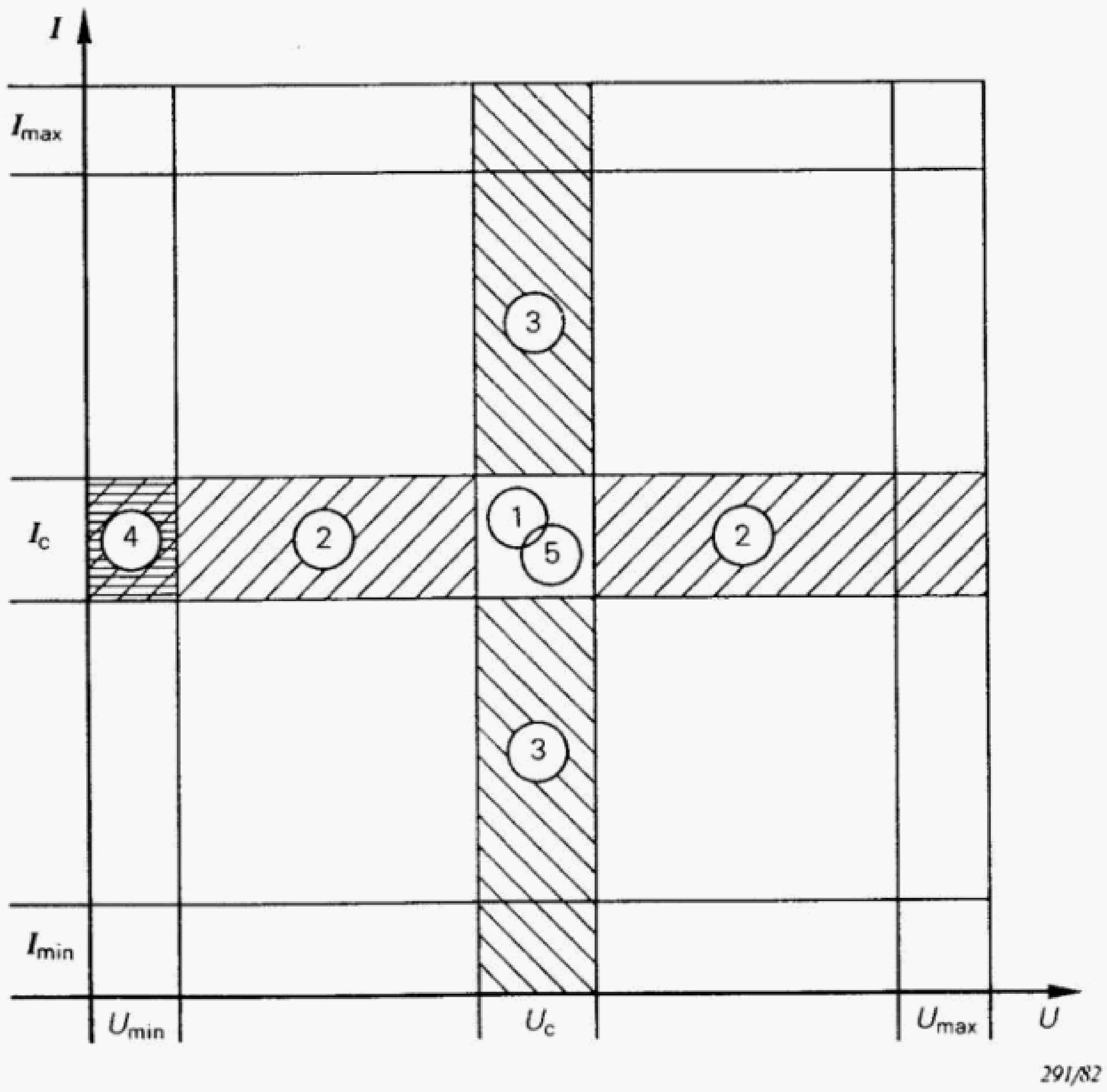
Limits of permissible values s in percentage

Meter class	0.5		1		2	
Power-factor	1	0.5 lagging	1	0.5 lagging	1	0.5 lagging
s_{max}	0.01	0.02	0.02	0.03	0.03	0.05

4. Testing procedure

4.1 *Selection of voltage and current ranges*

Of all the possible combinations of voltage and current, only those should be chosen for testing which are particularly important in practice or with which certain sources of error show up with the most effect. Figure 1 shows by means of a graph the way in which the measuring points given in Table III have been chosen.



The values U_{max}, U_{min}, I_{max}, I_{min}, U_c, *and* I_c correspond to the rated values of the relevant ranges.

① ② ③ ④ ⑤ are the reference numbers of test points in Table III.

FIGURE 1

For a sequence of repeated measurements (Sub-clause 3.7), the values for the control point U_c, I_c, can be fixed by agreement, for example according to the rated voltage and the basic current of meters which are usually tested with the MTE.

Additional test points or a reduction of the number of test points can be fixed by agreement. It is recommended, that all voltage ranges and current ranges which include the values U_{max}, U_{min}, I_{max} and I_{min} of the MTE are included when determining the error of the MTE.

Errors of voltage, current and power-factor combinations which have not been measured but calculated and derived from other measured errors shall not be used as a basis for assessing the error of an MTE. If those combinations are significant the errors shall be measured.

Note. – In order to check the extent of any capacitive interference of various origins (e.g. wiring, instrument transformers), additional measurements at U_{max}, I_{min} at a power-factor 0.5 lagging are recommended.

TABLE III

Ranges controlled

Reference No.	Voltage	Current	Power-factor	Load of the MTE		Number of tests	
				Single-phase Three-phase	Min. or Max.[3)]	Basic measurements (Sub-clause 4.2)	Control measurements (Sub-clause 4.3)
1	U_c	I_c	1 0.5 lagging 0.5 leading	Single-phase Single-phase Single-phase	Min. Min. Min.	1 1 1	1 1 1
2	$U_{min} \leq U_i \leq U_{max}$ [1)] $U_i \neq U_c$	I_c	1	Single-phase	Min.	$i = 4$ [1)]	$i = 2$ [1)]
3	U_c	$I_{min} \leq I_i \leq I_{max}$ [1)] $I_i \neq I_c$	1	Single-phase	Min.	$i = 7$ [1)]	$i = 2$ [1)]
4	U_{min}	I_c	1 0.5 lagging 0.5 leading	Single-phase Single-phase Single-phase	Max. Max. Max.	1 1 1	1
5	U_c	I_c	1	Three-phase[2)]	Min.	2	2
Total number of tests for a single-phase MTE						17	8
Total number of tests for a three-phase MTE						53	26

[1)] i is the index of a certain test point (U or I). If an MTE has less voltage or current-ranges than stated by the limits for i, then the number of tests is correspondingly reduced.

[2)] One measurement should be made in four-wire connection and a second in three-wire connection.

[3)] Minimum load corresponds to the connection of one measuring instrument (meter or wattmeter) only. Maximum load corresponds to the connection of the highest number of meters which consume the maximum output of the voltage circuit and/or the current circuit.

4.2 *Basic measurements*

The basic measurements according to Table III include the most important measurements and shall be made when a newly manufactured MTE commences service. They should also be made:

— when the general use of an MTE has been changed (e.g. change of the control point U_c, I_c);

— when components of an MTE, which are important for its accuracy, have been repaired or replaced;

— if for any reason doubt exists about the use of an MTE for a certain class of meters;

— when the result of a control measurement according to Sub-clause 4.3 gives rise to doubt.

4.3 *Control measurement and its interval frequency*

The interval frequency of control measurements of an MTE shall be adapted to the use which is made of the equipment. Thus, the greater the utilization made of the equipment and, if it is used to control large quantities of meters, the shorter the interval between two control measurements shall be.

Conversely, an MTE which is not frequently used (e.g. if it is intended exclusively for prototype tests) may be controlled at the same intervals as these tests.

Generally, the interval of time between two control measurements should be not greater than:

— two years for MTEs for meters of Class 2;

— one year for MTEs for meters of Classes 1 and 0.5.

If for any reason doubt exists, the control measurements shall be repeated.

5. Dielectric properties

The MTE shall be such that it retains adequate dielectric qualities under normal service conditions and under normal conditions of atmospheric humidity and under normal service voltages.

The insulation tests for an MTE should be made according to the requirements of the local authorities responsible for other safety requirements, such as earthing connections, protection switches, etc., and according to the requirements for the instruments and apparatus used with the MTE.

APPENDIX A

ADDITIONAL NOTES AND GUIDANCE CONCERNING TESTING EQUIPMENT FOR ELECTRICAL ENERGY METERS

A1. Laboratories

All laboratories for the testing of electrical energy meters should have facilities for carrying out the required tests in accordance with the relevant standards and corresponding requirements.

The rooms for laboratories should be:

- sufficiently large;
- clean;
- dry;
- dust-free;
- free from vibration;
- sufficiently illuminated;
- protected against solar-radiation.

A2. Supply to the MTE

The supply to the MTE shall be such that the relevant values at the output terminals of the MTE (voltage, current, frequency, waveform, phase sequence, balance of voltage and current) are in accordance with the relevant standards for the meter(s) under test.

The supply voltage shall be constant in such a way that the accuracy of all measuring devices used and necessary for measuring a certain class of meter can be utilized. If the MTE is connected to the mains network, the voltage may not be stable enough for the wattmeter method to be used. However, if the wattmeter method is used, some action should be taken in order to meet the requirements of this report (e.g. voltage stabilizer).

In order to avoid different voltage drops in the event of output changes of the MTE, the cross-section of the feed wire to the MTE must be sufficient.

A3. Meter test bench

The meter test bench is a bench including the necessary constructional requirements and the requisite connections designed to enable meters to be tested under reference conditions specified in the relevant documents. The wiring shall be such as to minimize the effects of magnetic induction, capacitive interference and voltage drop.

A4. Output terminals

By agreement, the terminals from which the meter test bench is supplied may be defined as the output terminals of the MTE.

A5. Magnetic fields

In a laboratory the meters under test and the MTE may be influenced by magnetic fields of different origin:

- magnetic field of a generator or a mains-voltage regulator;
- magnetic field of the wiring from the voltage supply to the MTE;
- magnetic field of the wiring or of a component of the MTE;
- magnetic field of the wiring or of an apparatus in the measuring circuit outside the MTE, especially the field of the wiring from the MTE to the meter(s) under test or between the meters under test;
- magnetic field of the meter-bench (illumination, auxiliary circuit, etc.);
- other external magnetic fields in a laboratory.

A6. Running with no-load of meters under test

It shall be possible to open the current circuits in order to prevent any current being produced by induction in these circuits by the voltage circuits.

A7. Adjusting devices*

A7.1 *Voltage adjusting device*

The voltage adjusting device shall permit the adjustment of the rated voltage within the tolerances given by the reference conditions for the relevant class of meters.

A7.2 *Current adjusting device*

The current adjusting device shall permit the adjustment of the necessary testing current within the entire load range for which the MTE is provided, and within the tolerances given in the reference conditions for the relevant class of meters.

A7.3 *Phase shifting device*

The phase shifting device shall permit the adjustment of the phase angle and of the voltage and current balances within the entire load range for which the MTE is provided, and within the tolerances given for the relevant class of meters.

A8. Voltage transformers*

Voltage transformers shall allow compliance with the permissible limits of Table I as regards percentage errors and of Table II as regards standard deviation values.

A9. Current transformers*

Current transformers shall allow compliance with the permissible limits of Table I as regards percentage errors and of Table II as regards standard deviation values.

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* By agreement between the parties, special requirements may be laid down regarding adjusting ranges, accuracy, etc.

A10. Measuring instruments*

A10.1 *Voltmeters*

Voltmeters shall permit the adjustment of the rated voltage within the tolerances given in the reference conditions for the relevant class of meters. The tolerance refers to the indication of the voltmeter, the errors of series resistances and/or voltage transformers included.

A10.2 *Ammeters*

Ammeters shall permit the adjustment of the rated current within the tolerances given in the reference conditions for the relevant class of meters. The tolerance refers to the indication of the ammeter, the errors of parallel resistances or current transformers included.

A10.3 *Wattmeters*

The wattmeters shall permit the adjustment of the power between the permissible limits for the class of meters considered, depending also on the required value of the power-factor, and have an accuracy which allows compliance with the permissible limits of Table I as regards percentage errors and of Table II as regards standard deviation values.

A10.4 *Voltage balance*

In order to obtain the necessary voltage balance according to the reference conditions of the relevant class of meters, voltage balance adjusting devices and voltage balance indicators may be used. Voltmeters used for indication shall have an appropriate accuracy.

A10.5 *Current balance*

In addition to phase shifting devices, current balance devices may be used.

A10.6 *Frequency meter*

A frequency meter should be used if the frequency of the supply mains is not sufficiently regulated, or if the frequency of the MTE output is not identical with the mains frequency.

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* By agreement between the parties, special requirements may be laid down regarding adjusting ranges, accuracy, etc.

APPENDIX B

NOTES CONCERNING ERROR DEFINITIONS, BASIC QUANTITIES, ACCURACY AND ERROR DETERMINATION

B1. Error definitions

The absolute error of an MTE is "indicated value – true value". The term "*true value*" is often used when the "*conventional true value*" is meant. Since the true value cannot be determined by measurement (because it would be necessary to have a measuring process which introduces no error), it is approximated by the *conventional true value*, a value corrected for systematic errors and with stated uncertainty, that can be traced to national standards or to standards agreed upon by manufacturer and user.

The errors are expressed as relative errors:

E_0 = theoretical true error of the MTE test standard after applying any known correction corresponding to its known part

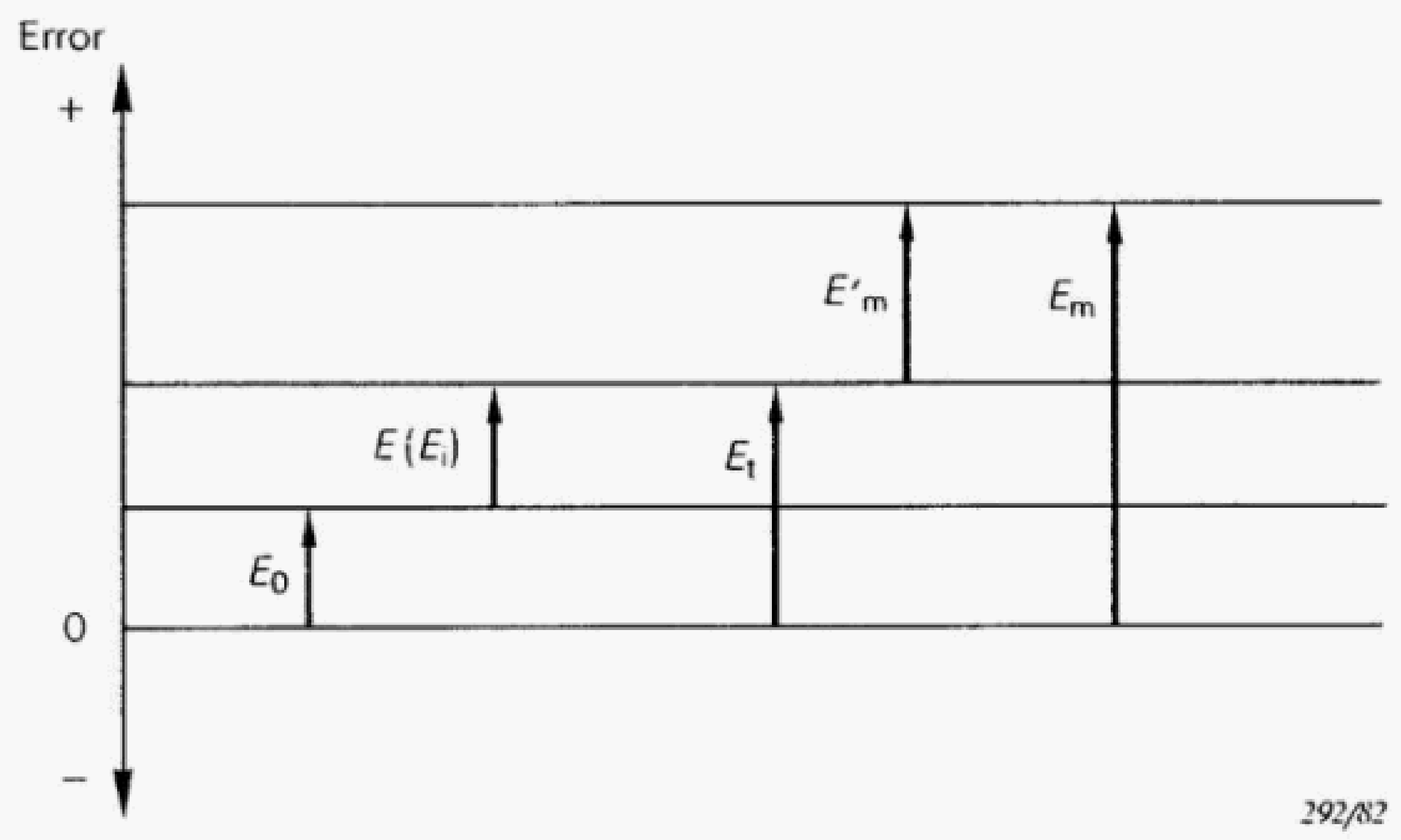
E_t = theoretical true error of an MTE

E = error of an MTE

E_i = error E of an MTE determined by one individual measurement at a certain test point

E'_m = error of a meter under test measured with the MTE

E_m = theoretical true error of a meter under test



$$E_m = E_t + E'_m = E_0 + E + E'_m$$

Note. – An error E of an MTE causes an error of the meter under test equal to E but of opposite sign.

$$E_t\,\% = \frac{\text{indicated value} - \text{true value}}{\text{true value}} \cdot 100$$

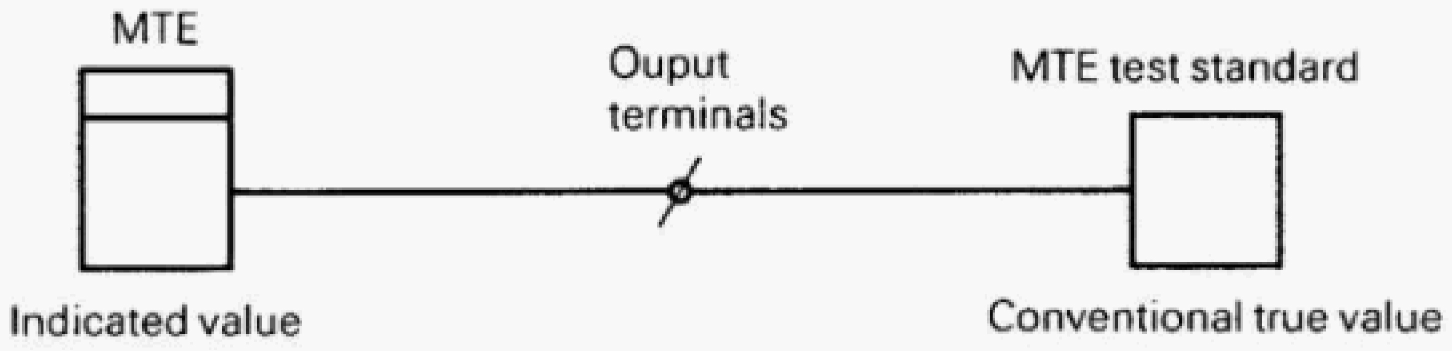
$$E\,\% = \frac{\text{indicated value} - \text{conventional true value}}{\text{conventional true value}} \cdot 100$$

$$E_i \% = \frac{W_i - W_o}{W_o} \cdot 100$$

where:

W_i = value of the energy indicated by the MTE
W_o = conventional true value of the energy (corrected indicated value of the MTE test-standard)

Note. – Instead of the energy *W*, the power can be the basis for this measurement, taking into account the influence of the accuracy of the time measurement.



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B2. Basic quantities

The energy measurement is derived from the standard cell, the standard resistor (power) and the time measurement with a quartz oscillator (energy). The uncertainties of national standards for the standard cell and the standard resistor are given by the national standard laboratories in the range of 10^{-5} to 10^{-6}. D.C. potentiometers are capable of measuring d.c. voltages with an uncertainty of about 10^{-5}.

The accuracy of the time measurement is 2 to $3 \cdot 10^{-11}$ for an atomic clock, $5 \cdot 10^{-9}$ for a quartz clock in most national standard laboratories. Portable quartz generators have an uncertainty between $1 \cdot 10^{-4}$ and $5 \cdot 10^{-5}$.

To relate the measurement of a.c. quantities to equivalent d.c. quantities transfer standards shall be used. The most suitable of these devices which, at present, permit the highest attainable accuracy and which are used by national standard laboratories, enable measurement of a.c. energy with an uncertainty in the order of $2 \cdot 10^{-4}$ (power-factor = 1.0).

Examples of such transfer devices are:

- electrodynamic comparator;
- thermo-electrical comparator;
- static multiplier circuit.

B3. Lowest possible uncertainty of the elements of an MTE test standard

The overall uncertainty of an MTE test standard depends on the uncertainty of each of the elements used.

These different uncertainties are directly related to the quality of the elements used and the calibration possibilities offered by national standard laboratories of the highest order (see Clause B2).

The overall uncertainty of an MTE test standard should be estimated preferably by the root mean square (r.m.s.) value of the uncertainties of the elements used.

Typical values of uncertainty of the lowest, at present, possible uncertainty for these elements are given below:

a) Static wattmeter *b) Static standard meter* *c) Double and triple scale wattmeter*	$2 \cdot 10^{-4}$ (power-factor = 1.0) $4 \cdot 10^{-4}$ (power-factor = 0.5)
d) Single-scale Class 0.1 wattmeter	$5 \cdot 10^{-4}$ (power-factor = 1.0) $10 \cdot 10^{-4}$ (power-factor = 0.5)
e) Current or voltage transformers	$1 \cdot 10^{-4}$ and 0.2 min

Taking into account the fact that a phase difference of 1 min gives an additional error for either instrument transformer of about 0.05% at a power-factor 0.5, the resultant uncertainties are:

$1 \cdot 10^{-4}$ (power-factor = 1.0)
$1.5 \cdot 10^{-4}$ (power-factor = 0.5)

When using current and voltage transformers, the most probable values for the uncertainty may be given by the r.m.s. summation of the above-mentioned values:

$1.5 \cdot 10^{-4}$ (power-factor = 1.0)
$2 \cdot 10^{-4}$ (power-factor = 0.5)

B4. Interval frequency for the control measurement of the accuracy of an MTE

The interval frequency for the control of the accuracy of an MTE depends on:

- the type of equipment;
- the history of the MTE;
- the number of meters tested with the MTE in a period;
- the maintenance of the MTE;
- the accuracy class of meters being tested with the MTE;
- the quality of the components of an MTE;
- the possible error fluctuations stated when operating an MTE.

B5. Mean value and repeatability of the measurements

(Explanation of Sub-clause 3.7)

- An MTE with the mean value of error $\bar{E} = 0$, but a high value for the estimation s of the standard deviation does not ensure the repeatability of measurements.
- An MTE with a high mean value of error $\bar{E}$, but a low value for s may be used for measurements of high accuracy, when a correction is used or the mean value $\bar{E}$ is corrected by a correction transformer.

From a statistical point of view, the number of measurements to be carried out at each test point depends on the metrological result required. However, taking into account the fact that tests have to be made for:

- different current ranges;
- different voltage ranges;
- different power-factors;

- maximum load;
- minimum load;

and for:

- single-phase meters;
- three-phase meters;
- different measuring methods (three-phase three- and four-wire systems),

it is evident that the method for ascertaining the error E of an MTE has to take into consideration not only metrological, but also economic facts.

As a low number of measurements usually does not give a statistical basis, a correct determination of the error of an MTE on a statistical basis is not possible. Therefore, Table II gives the permissible limits for the estimation s of the standard deviation. A good compromise is to carry out five measurements as indicated in Sub-clause 3.7.

APPENDIX C

GUIDELINES FOR THE INITIAL CHECKING OF A NEW METER TESTING EQUIPMENT

C1. **Mechanical construction**

C2. **Wiring** and **connections** especially those of parts which can be moved (e.g. phase shifting device)

C3. Stated **accuracy** of all measuring instruments

C4. **Dielectric properties**

C5. **Phase sequence**

C6. **Voltage circuit — Control of the components**

C6.1 Measuring range switch.

C6.2 Voltage adjusting devices. Regulating capacity at various loads.

C6.3 Voltage balance adjusting devices and balance indicators.

C7. **Current circuit — Control of the components**

C7.1 Measuring range switch.

C7.2 Current adjusting devices. Regulating capacity at various loads.

C7.3 Current balance adjusting devices.

C8. **Measuring circuits**

C8.1 Wattmeters and meters used as working standards: Measuring ranges, measuring methods. Checking of phase displacement (lagging-leading).

C8.2 Polarity changing of wattmeters.

C8.3 Accuracy measurements (see Clauses 3 and 4).

C9. **Distortion factor control**

C9.1 Input terminals of the MTE.

C9.2 Output terminals of the MTE:

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Voltage circuit (power-factor = 1.0 and 0.5 at maximum/minimum load).

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