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Indian Standard

SPECIFICATION FOR DC BRIDGES FOR MEASURING RESISTANCE

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MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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Indian Standard

SPECIFICATION FOR DC BRIDGES FOR MEASURING RESISTANCE

Electrical Instruments Sectional Committee, ETDC 48

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Indian Standard

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0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 27 September 1983, after the draft finalized by the Electrical Measuring Equipment Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 This standard covers the requirements of dc bridges and their auxiliary equipment used in the measurement of resistance. This standard has been formulated in the light of the modern practices in the manufacture of bridges.

0.3 In the preparation of this standard considerable assistance has been derived from IEC Publication 564 (1977) 'Dc bridges for measuring resistance' issued by the International Electrotechnical Commission.

0.4 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value shauld be the same as that of the specified value in this standard.

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1. SCOPE

1.1 This standard specifies the requirements of dc bridges for measuring resistance from 0·1 to 100 000 Ohms. It also applies to auxiliary equipment which is a built-in part of the bridge.

1.2 This standard does not apply to bridge comparators nor to self-balancing bridges nor to those which emply graduations on the null detector to obtain a part of the indicated value, nor to external auxiliary equipment used with the bridge.

NOTE — A bridge comparator is a device intended to compare two resistors, for example, a two arm adjustable ratio set.

*Rules for rounding off numerical values (*revised*).

2. TERMINOLOGY

2.0 For the purpose of this standard the following definitions in addition to the relevant definitions given in IS : 1885 (Part 11)-1964* shall apply.

2.1 Dc Bridge for Measuring Resistance (Hereinafter Designated Bridge) — The assembly of at least three resistance arms which, together with a test resistor, forms a bridge network; a source of direct current and a null detector are also required for its operation: these may or may not be built in. At balance, there exists a calculable relationship between the resistance values of the resistors.

NOTE — A dc bridge for measuring resistance may be intended to measure two-terminal or four-teminal resistors each with or without a leakage current screen (circuit); it will be termed accordingly a two-terminal bridge or a four-terminal bridge with or without provision for a leakage current screen (circuit).

2.2 Test Resistor — The resistor whose resistance value is to be measured.

2.3 Two-Terminal Resistor — A resistor having a single combined current-potential terminal at each end.

2.4 Four-Terminal Resistor

2.4.1 Current Terminal — A resistor having two terminals at each end for current carrying circuit.

2.4.2 *Potential Terminal* — A resistor having two terminals for connection to a potential measuring circuit.

NOTE — The value of the resistance is defined as the quotient of the potential difference between the two potential terminals to the current entering and leaving the current terminals, provided that no current is drawnfrom the potential terminals.

2.5 Resistor with Leakage Current Screen (Circuit) — A resistor having a leakage current screen (circuit) connected to a separate terminal, which is often called the 'guard terminal'.

NOTE — A resistor with leakage current screen (circuit) may be represented as a delta network consisting of an equivalent value of resistance connected between each pair of terminals. Of these three resistances, the resistance between the two main terminals is the main equivalent resistance which is intended to be measured. The other two resistances of the delta network are usually insulation (leakage) resistances which, for very high values of the main equivalent resistance, may be of the same order to smaller than it. The main equivalent resistance may appear either as a two-terminal resistor.

*Electrotechnical vocabulary: Part 11 Electrical measurements.

2.6 Resistance Decade — A multiple resistor which, usually by means of a switching device, allows the selection of a combination of resistance values rising in equal steps, each step corresponding to an increment of a decadic resistance value such as, far example 0·1 Ω, 1 Ω or 10Ω.

NOTE — A resistance decade generally allows a selection of 10, 11 or 12 resistance values (including zero).

2.7 Range-Changing Device — A switch or similar device whereby the effective range may be multiplied by a factor (for example, 0·1) which is known as the 'range factor' or 'range multiplier'.

2.8 Measuring Dials — The dials from which, taking into account the setting of range-changing device(s), if any, the value of the test resistor is determined.

2.9 Connecting Resistance (Potential) — For a four-terminal bridge, the resistance of the conductor connecting a potential terminal of the bridge to the corresponding potential terminal of the test resistor, plus the resistance of the potential conductor inside the test resistor.

2.10 Link Resistance (Current) — For a four-terminal bridge, the resistance of the conductor connecting a current terminal of the bridge to the corresponding current terminal of the resistor, plus the resistance of the current conductor inside the test resistor.

2.11 Auxiliary Equipment — Additional equipment, which is or is not an integral part of the bridge, necessary to enable the bridge, to operate accurately and safely as specified.

2.12 Ripple Content — The ripple content of a dc supply, expressed as a percentage of the mean value of the supply is:

$$\frac{\text{rms value of the fluctuating component}}{\text{mean value of the supply}} \times 100$$

2.13 Leakage Current Screen (Circuit) — A conducting path which prevents leakage currents from affecting the results of measurements.

NOTE — The terminal of the leakage current screen (circuit) is often called the 'guard terminal'.

2.14 Electrostatic Screen — An electrically conductive enclosure or coating intended to protect the enclosed space from external electrostatic influences.

2.15 Measuring Terminals — The terminals to which the test resistor is intended to be connected.

2.16 Measuring Circuit — The internal circuit of the bridge which is (or can be) conductively connected to the measuring terminals.

2.17 Effective Range — For a specified range factor, the range between the minimum and maximum values of resistance wihch can be measured with the stated accuracy.

2.18 Overall Effective Range — Using all range factors, the overall range of resistance values which can be measured with stated accuracy.

2.19 Dial Setting — The setting of the measuring dial(s) after balancing the bridge, multiplied by the range factor, if applicable, when determining the value of a test resistor.

2.20 Resolution — For measuring dials with discrete settings only, the resistance corresponding to one step on the measuring dial of lowest value on any specified range.

For measuring dials in which one dial is continuously adjustable, the resistance corresponding to the smallest division on the measuring dial of lowest value in any region of the dial setting on any specified range.

NOTE — For continuously adjustable dials which are non-linear, the resolution may change with the dial setting.

2.21 Influence Quantity — A quantity, other than the measured quantity, which is liable to cause unwanted variation in the dial setting.

2.22 Reference Conditions — The specified conditions under which the bridge meets the requirements concerning intrinsic error(s).

2.23 Reference Value — A specified single value of an influence quantity at which, within the stated tolerance, the bridge meets the requirements concerning intrinsic error(s).

2.24 Reference Range — A specified range of values of an influence quantity within which the bridge meets the requirements concerning intrinsic error(s).

2.25 Variation with Influence Quantity — The difference between the dial settings for a constant value test resistor when an influence quantity assumes successively two different specified values.

2.26 Nominal Range of Use — A specified range of value which each influence quantity can assume without causing a variation exceeding the specified limits.

2.27 Limiting Values of an Influence Quantity — Extreme values which an influence quantity may assume without the bridge being damaged or permanently altered in such a way that it no longer satisfies the requirements of its accuracy class.

2.28 Fiducial Value — A single value for each effective range to which reference is made in order to specify the accuracy of a bridge.

Unless otherwise stated by the manufacturer, the fiducial value of effective range is the highest integral power of 10 within that range.

NOTE — For a bridge offering measurement from 1 milliohm to 11·11 Megohm with seven different range settings (·001, ·01, 0·1, 1, 10, 100 and 1 000) and having four resistance decades of (units, tens, hundred and thousand) the Fiducial Value will be 10 ohm, 100 ohm, 1 000 ohm, 100 kiloohm, 1 M and 10 megohm.

2.29 Error — The value obtained by subtracting the true value of the measured quantity from the dial setting.

NOTE 1 — Since the true value cannot be determined by measurement, a value obtained under specified test conditions and at a specified time is used. This value is derived from national measurement standards or a measurement standard agreed upon by the manufacturer and the user.

NOTE 2 — The error due to any auxiliary equipment which is not built-in to the bridge is not included in the error of the bridge.

2.30 Intrinsic Error — An error determined under reference conditions.

2.31 Accuracy — The accuracy of a bridge is defined by the limits of intrinsic error and the limits of variations due to influence quantities.

2.32 Accuracy Class — A class of bridges, the accuracy of all of which can be designated by the same number if they comply with all the requirements of this standard.

2.33 Class Index — The number which designates the accuracy class.

3. CLASSIFICATION

3.0 Bridges shall be classified as given in **3.1** and **3.2**.

3.1 According to whether they measure the values of two-terminal of four-terminal resistors with or without a leakage current screen (circuit).

NOTE — Some bridges may be capable of measuring the value of more than one type of resistor.

3.2 According to their accuracy classes as given in Table 1.

4. STABILITY

4.1 Bridges shall comply with the relevant limits of intrinsic error specified for their respective accuracy classes for the duration of one year from the date of certification associated with delivery or another date to be agreed upon by the manufacturer (or responsible supplier) and the user (or purchaser), provided that the conditions of use, transport and storage specified by the manufacturer are complied with.

NOTE — For bridges stability with regard to time is an essential characteristic. Here, it is specified only for the duration of one year, but experience has shown that the rate of change due to ageing effects generally decreases with time.

TABLE 1 ACCURACY CLASS FOR DC BRIDGES

(*Clause* 3.2)

0·C01	0·002	0·005	0·01	0·02	0·05	0·1
(10 ppm)	(20 ppm)	(50 ppm)	(100 ppm)	(200 ppm)	(500 ppm)	(1 000 ppm)
0·2	0·5	1	2	5	10	
(2 000 ppm)	(5 000 ppm)	(10 000 ppm)	(20 000 ppm)	(50 000 ppm)	(100 000 ppm)	

The class index of a bridge may be expressed either in percent or parts per million (ppm) or both.

If a bridge has several measuring ranges, each range may have its own class index.

NOTE 1 — Accuracy classes 2 to 10 (20 000 ppm to 100 000 ppm) are not intended for use except with bridges measuring very high values of resistance or very low resistance.

NOTE 2 — The accuracy test should be determined by choosing a suitable standard resistance so that balance is obtainable with a ratio of 1 : 1 and all the resistance arms are used.

5. PERMISSIBLE LIMITS OF INTRINSIC ERROR

5.1 The permissible limits of error of a bridge are composed of two parts:

a) Constant term related to the fiducial value, and

b) Variable term proportional to the dial setting.

5.1.1 The two limits are given by the positive and the negative values respectively, of the binomial formula:

$$E_{lim} = \pm \frac{c}{100}\left(\frac{R_N}{k} + X\right)$$

where

E_{lim} = permissible limit of the error, expressed in ohms;

R_N = fiducial value, expressed in ohms;

X = dial setting, expressed in ohms;

c = class index, expressed as a percentage; and

k = 10 unless the manufacturer states a higher value.

When the class index c is expressed in parts per million (ppm), the formula given below should be used:

$$E_{lim} = \pm \frac{c}{100\,000}\left(\frac{R_N}{k} + X\right)$$

NOTE 1 — Any error due to lack of perfect resolution is included in the permissible error.

NOTE 2 — If a bridge has several measuring ranges each range may have its own permissible limits of intrinsic error.

5.1.2 Bridges intended to measure values of four-terminal resistors shall comply with the requirements of **5.1.1**. If, in order to meet these requirements the connecting resistance and link resistance should have a specified value(s) or range of values, the manufacturer shall state these values for each effective range, as appropriate.

6. CONDITIONS FOR THE DETERMINATION OF INTRINSIC ERRORS

6.1 The reference values relative to each of the influence quantities are shown in Table 2.

6.2 Before any measurment, sufficient time shall elapse for the bridge to reach a stable state and to be in equilibrium with the reference values of the influence quantities.

6.3 The leakage current screen (circuit) and the electrostatic screen, if any shall be connected in accordance with the manufacturer's instructions.

6.4 The test shall be carried out in succession for both polarities of the dc supply source. If the difference between the results of the two measurements does not exceed 20 percent of the value corresponding to the class index, it is considered as negligible. When the difference exceeds this amount, the error shall be taken as equal to the mean of the errors obtained for each of the two polarities.

NOTE — The test resistor should not be a source of emf or, if it is a source of emf, this should be allowed for in determining the error of the bridge.

TABLE 2 REFERENCE CONDITIONS AND TOLERANCES OF THE INFLUENCE QUANTITIES

(*Clauses* 6.1, 7.1 *and* 9.1.1)

INFLUENCE QUANTITY	REFERENCE CONDITION*	TOLERANCE PERMITTED FOR TESTING PURPOSES†
Ambient temperature	27°C	±1°C
Relative humidity	40 to 60 percent	
Position	Any	
Bridge supply voltage or current	Rated value	±10 percent
Ripple content of bridge supply	Less than 0·1 percent	
Duration of application of bridge supply	Any	

*Unless otherwise indicated by the manufacturer.
†For a reference range, no tolerance is allowed.

7. PERMISSIBLE VARIATIONS

7.1 Limits of Variation — When the bridge is under the reference conditions given in Table 2 and a single influence quantity is varied in accordance with the requirements of **7.2**, the variation shall not exceed the values specified in Table 3.

TABLE 3 LIMITS OF THE NOMINAL RANGE OF USE AND PERMISSIBLE VARIATIONS

(*Clauses* 7.1, 7.2 *and* 9.1.1)

Influence Quantity	Class Index		Limits of Nominal Range of Use*	Permissible Variation†
	Percent	ppm		
Ambient temperature	0·001 ... 0·002	10 ... 20	Reference value ±2°C	100 percent
	0·005 ... 0·05	50 ... 500	Reference value ±5°C	
	0·1 ... 10	1 000 ... 100 000	Reference value ±10°C	
Relative humidity			25 percent and 75 percent	20 percent
Bridge supply voltage or current			Rated value $^{+15\text{ percent}}_{-75\text{ percent}}$	10 percent

*Unless otherwise indicated by the manufacturer.
†Expressed as a percentage of the permissible intrinsic error.

7.2 Conditions for the Determination of the Variations — Variations shall be determined for each influence quantity. During each test, all other influence quantities shall be maintained at their reference conditions.

The variation is assessed as follows:

a) When a reference value is assigned to the bridge, the influence quantity shall be varied between that value and any value within the limits of the nominal range of use as given in Table 3.

b) When a reference range and a nominal range of use are assigned to the bridge, the influence quantity shall be varied between each of the limits of the reference range and any value in that part of the nominal range of use adjacent to the chosen limit of the reference range.

8. ADDITIONAL ELECTRICAL AND MECHANICAL REQUIREMENTS

8.1 The requirements for the voltage test and other safety requirements are specified in IS : 9249 (Part 1)-1979*.

*Safety requirements for indicating and recording electrical measuring instruments and their accessories: Part 1 Common safety requirements for instruments.

8.2 Insulation Resistance — The manufacturer shall state the minimum value of dc insulation resistance, measured at 500 V ± 10 percent, between any accessible terminal of the bridge circuit to any other accessible point not intended to be connected to the bridge circuit. This value shall be not less than 5 Meghoms.

The measurement shall be made between 1 and 2 minutes after the application of the test voltage.

8.2.1 Except for the condition referred to in **8.2.2**, the connection of any one terminal to the case or to earth shall not produce a variation exceeding 10 percent of the permissible limits of intrinsic error. For this test, the case, if it is conductive, shall be connected to earth. If the case is made of insulating material, the bridge shall be placed on a conductive plate which shall be connected to earth.

8.2.2 If there are limitations on earthing, the manufacturer shall state which terminals may be connected to earth or to the case, and/or which terminals need to be connected to earth or to the case. He shall also state which terminals are factory-connected to the case.

8.2.3 If means are provided for avoiding leakages associated with the test resistor by connecting its screen to the leakage current screen (circuit) of the bridge, the manufacturer shall state the minimum value of leakage resistance which produces a variation of not greater than 10 percent of the permissible limits of intrinsic error. Under these conditions, the requirements of **8.2.1** do not generally apply.

8.3 Duration of the Application of a Limiting Value of an Influence Quantity — When the limiting values of an influence quantity are dependent on the duration of application, this fact, together with the length of time for which the influence quantity may be applied, shall be stated by the manufacturer.

8.4 Limiting Temperature for Storage, Transport and Use — Unless otherwise stated by the manufacturer, bridges shall be capable of withstanding, without damage, exposure to ambient temperatures within the range of —10° to 50°C. After returning to reference conditions, the bridges shall meet the requirements of this standard.

NOTE 1 — If bridges are installed in racks or test desks, care should be taken to ensure that the ventilation required for their operation is not impeded.

NOTE 2 — Bridges should be transported and stored in accordance with the manufacturer's instructions so as to prevent a change in performance by using a method which avoids shock, continued vibration and wide temperature fluctuations.

9. INFORMATION, MARKINGS AND SYMBOLS

9.1 Information

9.1.1 The following information shall be given by the manufacturer:

a) Manufacturer's name or trade-mark or that of the responsible supplier;

b) Type reference, if any, given by the manufacturer;

c) Serial number;

d) Effective range, resolution and range factor(s); alternatively, at the choice of the manufacturer, the overall effective range may be given for bridges of classes 0·5.....10 (5 000.....100 000 ppm);

e) Accuracy classes or a single accuracy class when the overall effective range is given;

f) Value of k if other than 10 (**5.1**);

g) Reference value and nominal range of use for temperature if different from those given in Tables 2 and 3;

h) Where relevant, reference position and nominal range of use for position;

j) Reference value (range) and nominal range of use for other influence quantities [*see* Item (g) and (h)] if different from those given in Tables 2 and 3;

k) Duration of application of a limiting value of an influence quantity, if necessary (**8.3**);

m) Where relevant, essential characteristics of the auxiliary equipment;

n) Test voltage;

p) Temperature limits and other requirements for transport, storage and use, if necessary (**8.4**);

q) Circuit diagram, values of components and list of replaceable parts;

r) Procedure for use of the bridge;

s) Values or range of values of the connecting resistance and link resistance (**2.8** and **2.9**), if relevant; and

t) Value of the dc insulation resistance (**8.2**).

9.1.2 If a certificate is supplied by agreement between the manufacturer or responsible supplier and the user, it shall contain the following information:

a) Certified values together with their uncertainties at specified reference condition,

b) Date of certification, and

c) Designation of certifying authority.

9.2 Marking, Symbols and Their Locations — The markings and symbols shall be legible and indelible.

The symbols specified in Table 4 shall be used where relevant.

9.2.1 The following information shall be marked on the nameplate or on the case:

a) **9.1.1**(a), (b) and (c);

b) **9.1.1**(e), using symbol E-7 or E-8;

c) **9.1.1**(h), using symbols D-1 to D-6; and

d) **9.1.1**(n), using symbols C-1 to C-3.

9.2.1.1 In addition, the following marking shall be made: 'dc resistance bridge'.

9.2.1.2 Where relevant, symbol F-33 showing that some other essential information is given in a separate document.

9.2.1.3 If a reference value or a reference range is marked, it shall be identified by underlining.

9.2.2 All terminals shall be marked to show polarity (where relevant); function and supply.

9.2.2.1 In particular, the following terminals shall be identified by a marking adjacent to the terminal:

a) Measuring terminals;

b) Terminals for connection to auxiliary equipment;

c) Earth terminal, if any (using symbol F-31);

d) Terminal(s) of the leakage current screen (circuit), if any; and

e) Terminal of the electrostatic screen, if any.

9.2.3 The following information shall be given either on the nameplate or on the case or in a separate document:

9.1.1(d), (g) and (k).

9.3 Documentation

9.3.1 Documentation shall state:

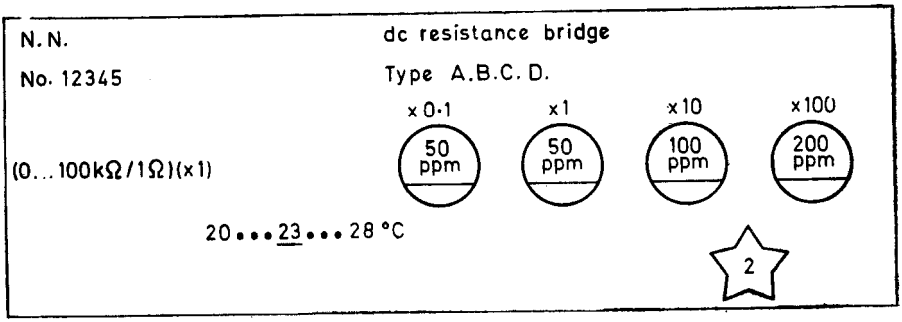
a) Information as given in 9.1.1(a), (b), (c), (f), (k), (m), (p), (q), (r), (s), (t); and

b) Following shall be stated in case these are not marked on the nameplate or on the case [*see* **9.2.3**(d), (g) and (k)].

9.3.2 The certificate referred to in **9.1.2**, when supplied, shall state, the information given in **9.1.2.**

9.4 Examples of Marking of a Bridge

9.4.1 Bridge specified in terms of the effective ranges.



In this example, the markings provide the following information:

a) DC resistance bridge, Type A.B.C.D., serial number 12345, manufactured by N.N;

b) The effective range using the × 1 range factor is from 0 to 100 kΩ with 1Ω resolution.

Range factor of ×0·1, ×1, ×10 and ×100 correspond to class indices of 50 ppm, 50 ppm, 100 ppm and 200 ppm, respectively;

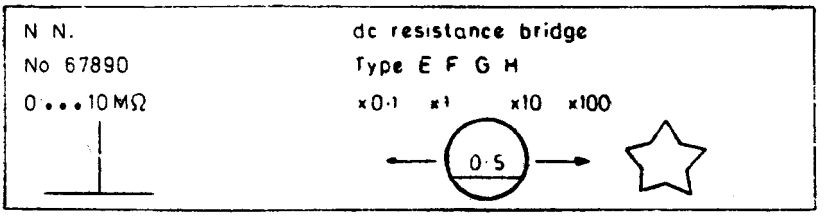
c) Reference value of temperature: 23°C.

Nominal range of use from 20° to 28°C (these values are shown because they are different from those specified in Table 1 and 2);

d) Test voltage: 2 kV; and

e) The absence of a position symbol shows that the bridge may be used in any position.

9.4.2 Bridge specified in terms of overall effective range:



In this example, the markings provide the following information:

a) DC resistance bridge. Type E.F.G.H. serial number 67890, manufactured by N.N;

b) Overall effective range from 0 to 10 MΩ: the limit of resolution is less than the permissible limit of intrinsic error. Range factors: ×0·1, ×1, ×10 and ×100. Class index on all ranges: 0·5;

c) Bridge is to be used with the supporting surface vertical; and

d) Test voltage: 500 V.

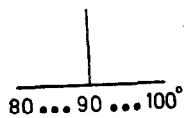
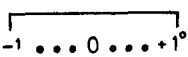
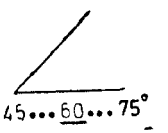
TABLE 4 SYMBOLS FOR MARKING BRIDGES

(*Clause* 9.2)

No.	Item	Symbol
C	SAFETY	
C-1	Test voltage 500 V	
C-2	Test voltage above 500 V (for example 2 kV)	
C-3	Apparatus not subjected to a voltage test	
D	POSITION OF USE	
D-1	Bridge to be used with the supporting surface vertical	

(*Continued*)

TABLE 4 SYMBOLS FOR MARKING BRIDGES—*Contd.*

No.	Item	Symbol
D-2	Bridge to be used with the supporting surface horizontal	
D-3	Bridge to be used with the supporting surface inclined (that is 60°) from the horizontal plane	
D-4	Example for bridge to be used as D-1 nominal range of use from 80° to 100°	
D-5	Example for bridge to be used as D-2 nominal range of use from −1° to +1°	
D-6	Example for bridge to be used as D-3 nominal range of use from 45° to 75°	
E	ACCURACY CLASS	
E-7	Class index with errors expressed as a percentage (for example 0·01) when the permissible error is proportional in part to the fiducial value and in part to the dial setting	
E-8	Class index with errors expressed in parts per million (for example 100 ppm) when the permissible error is proportional in part to the fiducial value and in part to the dial setting	
F	GENERAL SYMBOLS	
F-27	Electrostatic screen	
F 31	Earth terminal	
F-33	Reference to a separate document	
F-41	Leakage current screen	(Under consideration)