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Crimped joints for aircraft electrical cables

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FOREWORD

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Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 1966 was drawn up by Technical Committee ISO/TC 20, *Aircraft and space vehicles.*

It was approved in May 1970 by the Member Bodies of the following countries :

Belgium	India	South Africa, Rep. of
Brazil	Israel	Spain
Canada	Italy	Switzerland
Czechoslovakia	Japan	Turkey
Egypt, Arab Rep. of	Netherlands	United Kingdom
Germany	New Zealand	U.S.S.R.
Greece	Romania	

The Member Bodies of the following countries expressed disapproval of the document on technical grounds :

France
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Crimped joints for aircraft electrical cables

1 SCOPE AND FIELD OF APPLICATION

1.1 This International Standard specifies the design requirements (and tests) for the crimping of insulated and non-insulated terminations to general purpose electrical cables for aircraft, with conductors of copper, copper alloy, aluminium or aluminium alloy, in locations in which the stabilized conductor temperature does not exceed the values specified for the relevant type of cable, i.e. 105 °C, 190 °C or 260 °C. The type of cable with which the terminations are intended to be made has to be declared (see 3.1.5).

1.2 The International Standard also contains recommendations relating to the inspection of such connections and the tools used to perform the crimping operation. Since satisfactory crimping is dependent upon the maintenance and setting of tools it also contains recommendations for tests to confirm their serviceability.

1.3 Testing of crimped joints to assess their suitability for aircraft shows that certain environmental conditions, for example vibration, have no significant effect on the performance of the joints. It has therefore not been considered necessary to provide for such tests in this International Standard.

2 DEFINITIONS

2.1 termination: A permanent connection formed by the end of an electrical cable conductor with a terminal end or a pin or socket contact.

2.2 terminal end: A connecting device with barrel(s) accommodating an electrical cable conductor with or without additional provision to accommodate and secure the insulation.

2.3 pin or socket contact: A contact used in a plug or socket (receptacle) with a barrel at one end to accommodate an electrical cable conductor with or without additional provision to secure the insulation.

2.4 cable splice: A connecting device with barrel(s) each accommodating an electrical cable conductor(s) with or without additional provision to accommodate and secure the insulation.

2.5 cable splice connection: A permanent connection formed by the ends of electrical cable conductors attached to a cable splice.

2.6 crimping: A method of firmly attaching a terminal end or cable splice to a conductor by re-shaping the barrel around the conductor to establish good electrical and mechanical contact.

2.7 insulation grip: That part of a terminal barrel or cable splice barrel into which the insulation of the cable is placed, and which by reforming grips the insulation.

2.8 pre-insulated joint: A crimped connection formed with an insulated terminal end or insulated cable splice.

2.9 post-insulated joint: An uninsulated crimped connection insulated after conductor crimping.

2.10 crimping tool: A manually operated or power-operated mechanical device for making a crimp or insulation grip.

2.11 positioner: A locator, turret or other device permanently or removably attached to a crimping tool, serving correctly to locate and control the position of the crimp on the barrel.

3 DESIGN REQUIREMENTS

3.1 General

3.1.1 Terminal ends, pin or socket contacts and cable splices shall comply with the requirements of the appropriate national and international standards.

3.1.2 The protective treatment and surface finish of the terminal end, pin or socket contact or cable splice shall be of such a quality that the completed crimped connection complies with the requirements of this International Standard. The electrochemical potential difference between all conducting surfaces should not exceed 0,25 V.

3.1.3 The design of the terminal end, pin or socket contact or cable splice shall be such that adequate engagement of the cable conductor in the completed joint can be readily established by inspection.

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3.1.4 Any material used for pre- or post-insulation shall be non-corrosive, resistant to abrasion, fungus and aircraft fluids and shall not support combustion. The insulation, and internal sleeve if any, shall remain firmly fixed in its correct position before and after crimping. The insulation should be colour-coded in respect of its conductor size or sizes in accordance with the relevant national standards.

3.1.5 The manufacturer shall make the following information available :

1) terminal end, pin or socket contact or cable splice material specification;

2) protective treatment;

3) size and type of cable for which each item is available;

4) appropriate crimping tool or die references and settings;

5) the identification code of crimp marking;

6) information on the preparation of cable ends before crimping;

7) maximum overall dimensions of the completed crimp;

8) instruction sheets for the proper use of the recommended crimping tool.

3.2 Crimped joints

The completed crimped joint should take the form of a conductor crimp and insulation grip effected in one operation, using the die or dies stipulated by the tool manufacturer. All terminal ends or cable splices for size 12 cables or smaller shall have an insulation grip unless equivalent insulation support is otherwise provided.

3.3 Tools and dies

3.3.1 Tools shall be so designed that

1) they will correctly locate and control the position of the crimp;

2) they will not release the termination during normal operation until the crimp has been correctly formed;

3) they will not axially deform pin or socket contacts or increase the effective diameter along the length of the crimped section by more than the amount specified in the connector specification;

4) during the formation of the conductor crimp, they will apply the appropriate mark, where required by section 6, to indicate the die size or tool which has been used;

5) they will not adversely affect the external protective treatment or insulation during the crimping operation;

6) they will not fracture the terminal end or cause any rough or sharp edges.

3.3.2 Tools shall be marked with the manufacturer's name and serial number. Dies for a particular tool should be interchangeable with other tools of that type. If they are not interchangeable they shall be marked to identify the tool for which they are suitable.

3.3.3 The gauging method of tools and dies shall be declared, and provision may be made for the use of test gauges or test bars.

4 DIMENSIONS

The overall dimensions of the completed joints shall comply with the requirements of the appropriate national and international standards.

5 STRENGTH AND PERFORMANCE

The mechanical strength and electrical performance of the completed joints shall be such that they fulfil the requirements of this International Standard.

6 MARKING

The completed joint shall, when practicable, be marked in accordance with the declared code for the identification of the size of the crimping tool or die. Such marking, which shall be applied during the formation of the crimp, may be embossed or indented.

7 TESTS

The tests listed below should be in accordance with the relevant national specification for crimped joints for general purpose electrical cables for aircraft. Evidence should be available to the purchaser that joints covered by this International Standard have satisfactorily passed type tests conducted in accordance with section 8. In order that a consistent standard of quality be maintained, the manufacturer should conduct production control tests in accordance with section 9, and the user control tests in accordance with section 10.

8 TYPE TESTS

8.1 Test conditions

Unless otherwise specified, all tests shall be performed at a temperature of 20 ± 5 °C, at an air pressure between 930 and 1 070 mbar and a relative humidity not greater than 80 %. All joints used in the type tests should be stored under these conditions for a period of 48 h before testing.

8.2 Test sequence and specimens

8.2.1 The tests in 8.3 to 8.7 shall be applied to each and every combination of type, size, material and finish of crimped conductor barrel, crimped to the appropriate sizes of conductor of each type, material and finish, by each type of tool and each size of die, indenter or positioner.

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8.2.2 When a particular crimped conductor barrel is used on more than one item (for example on terminal ends and on pin and socket contacts, or cable splices), tests in accordance with 8.3 to 8.7 need only be carried out on one type of item.

8.2.3 When a particular crimped conductor barrel is designed to accommodate a range of conductor sizes, for a particular type of tool or type and size of die or positioner, tests need only be carried out on the smallest and largest sizes of conductors in the range.

8.2.4 When a particular tool, die or positioner is designed to accommodate a range of crimping barrels, tests need only be carried out on the largest and the smallest sizes of crimping barrels.

8.2.5 The tests shall be made in the order shown in Table 1 on sixteen specimens. If the tests in 8.5 and 8.6 are made consecutively on the same specimens, eight specimens only are necessary.

TABLE 1 — **Test sequence and number of specimens for tests in clauses 8.3 to 8.7**

Clause	Test	Number of specimens for tests
8.3	Inspection	1 to 16
8.4	Voltage drop	1 to 16
8.5	Climatic	1 to 8
8.6	Load and temperature cycling	9 to 16
8.4	Voltage drop	1 to 16
8.7	Tensile	1 to 16

8.2.6 Specimens shall consist of

1) terminal ends : a length of cable with a terminal end at each end;

2) cable splices : lengths of cable joined by an in-line connector;

3) pin or socket contacts : a length of cable with a pin or socket contact at each end.

The cables shall be 152 ± 1,3 mm (6 ± 0.05 in) long, measured before crimping between the points where the conductors enter the respective conductor crimping barrels.

Specimens shall be numbered on an area not involved in the crimping operation.

8.2.7 The number of items to be tested in accordance with 8.8 and 8.10 shall be as stated in the appropriate clause. The attached cable may be of any suitable length.

1) In preparation.

8.3 Inspection

The following shall be verified :

1) use of correct cable, tool, die and terminal end, pin and socket contact or cable splice;

2) correctness of dimensions;

3) correctness of form and location of crimp;

4) freedom from fracture, rough or sharp edges;

5) adequate insertion of conductor strands in the barrel;

6) absence of damage to the conductor or insulation;

7) correct die mark.

8.4 Voltage drop test

8.4.1 The appropriate test current stipulated in Table 2 or 3 at an open circuit voltage of not more than 30 V shall be passed through the specimen. For type tests, precision class measuring instruments shall be used.

8.4.2 For terminations other than pin or socket contacts the voltage drop shall be measured between the intersection of one palm and barrel and the corresponding point on the other terminal end, care being taken to avoid contact with the conductor strands. For pin or socket contacts the measurement shall be taken between the intersection of the shoulder and the crimped barrel of the pin or socket contacts. For cable splices, the measurement shall be between the midpoints of two consecutive connectors. (See Figure 1.)

8.4.3 For the purposes of the test, the voltage drop across each joint shall be regarded as one-half of that ascertained by subtracting from the overall drop the voltage drop attributable to the length of included cable, i.e. 152 mm (6 in), measured on not less than 3 m (10 ft) of cable taken from the same reel as that used for the test specimens.

For cables with copper or aluminium conductors the values of voltage drop so obtained shall not exceed the appropriate value listed in Table 2 or 3. For conductors other than copper or aluminium the voltage drop values should be as agreed with the approving authority.

NOTE — Care should be taken that the conductor temperature remains sensibly constant for successive readings.

8.5 Climatic test

8.5.1 The specimens shall be subjected to the tropical exposure test described in ISO . . ..[1)]

8.5.2 Upon completion of the tests the specimen shall be examined and any visible signs of corrosion or other damage shall be reported to the approving authority.

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8.5.3 The specimens shall be subjected to the voltage drop test as specified in 8.4. Any significant increase in reading shall be reported to the approving authority.

8.5.4 At the conclusion of the climatic test cycles on insulated joints, the specimens shall be removed from the chamber and allowed to recover at normal temperature and pressure. Within a period of 1 1/2 to 2 h the insulation resistance at 500 V d.c., measured between the exterior of the insulation and the palm, shall be not less than 100 MΩ.

8.6 Load and temperature cycling tests

8.6.1 The specimens shall be placed in a suitable enclosure, the ambient temperature of which shall be the upper ambient limit implied by the relevant cable specification, i.e. 65 °C, 150 °C or 220 °C. [1)]

8.6.2 The appropriate test current stated in Table 2 or 3, as applicable, shall be applied to the "heat-on" period.[2)]

The time period of the "heat-on" cycle shall be such that not less than 95 % of the maximum temperature rise above the upper ambient limit, measured at the centre of the conductor, is attained for every size and type of cable being tested.

The enclosure heat and the applied current shall then be removed from the specimens for a "heat-off" period, during which the specimens shall cool to a temperature less than 30 °C.[3)]

One cycle shall consist of a "heat-on" period followed by a "heat-off" period.

8.6.3 Voltage drop readings shall be taken, with the cables at a temperature of not more than 30 °C, at intervals throughout a test comprising not less than 1 500 cycles. Readings shall be taken every 100 cycles during the first 1 000 cycles and subsequently at every 50 cycles, provided that if instability is shown at any time during the test more frequent readings are taken. During the last 500 cycles, or as otherwise agreed with the approving authority, there shall be no significant increase in the reading.

8.6.4 Intermediate and final voltage drop readings per crimped joint shall not exceed 150 % of the relevant maximum voltage drop figure listed in Table 2 or 3.

8.6.5 Upon completion of the tests, the specimens shall be visually examined and any signs of corrosion or other damage shall be reported to the approving authority.

8.7 Tensile test

Each specimen shall be tested in a suitable tensile testing machine in which an axial pull is applied and in which the jaws separate at a steady rate of between 25 and 50 mm (1 and 2 in) per minute.

Each end of the specimen shall be tested to destruction and shall not fail below the relevant load specified in Table 2 or 3.

8.8 Insulation grip tests

Sixteen unstripped cables, of length not less than 101,6 mm (4 in), of the maximum and minimum size appropriate to each size of insulation grip, shall be fitted to the appropriate terminal ends or cable splices. The cable shall be inserted only into the insulation grip portion of the terminal end and a crimp effected in the normal manner. Using a mandrel with a diameter equal to that specified for the flexibility tests for the relevant type and size of cable, each termination shall be tested as follows. With the termination or cable splice held tangential to the mandrel, and the cable end of the barrel in contact with it, the cable shall be wound round the mandrel at least one turn. Tension shall be applied to the cable sufficient to keep it in contact with the mandrel. This test shall be made in opposite directions in planes parallel to the axis of the crimp and mutually perpendicular. The complete test shall be made twice, and the insulation shall not be punctured and shall remain in position in the insulation grip. (See Figure 2.)

8.9 Tensile tests on conductor crimp alone

For those types of terminations and cable splices having an insulation grip, sixteen specimens shall be made of each and every combination of crimped barrel, conductor, tool, die indenter or positioner required by 8.2 but using the minimum size of conductor only.

The insulation grip shall be rendered ineffective by removing the cable insulation. The specimens shall then be tested in accordance with 8.7.

8.10 Additional tests for insulated joints

8.10.1 *Samples*

For the purposes of the tests described in 8.10.2 to 8.10.5, sample crimped joints shall be made on each and every combination of barrel type and size, crimped to a minimum size of cable conductor, by each type of tool, die, indenter or positioner.

8.10.2 *Fluid resistance*

Five samples shall be immersed one in each of the following fluids for not less than 24 h at a temperature such as is likely to be experienced in service for the particular fluids :

1) aviation fuels;

2) lubricating oils (including ester-base oils);

3) hydraulic fluids (including ester-base hydraulic fluids);

4) de-icing fluids.

1) The enclosure ambient temperature may have a tolerance of ± 5 °C from the values stated.

2) The time period may vary between different batches of similar size and type of cable, and this should be established from preliminary tests on a sample of the cable being tested, to the satisfaction of the approving authority.

3) Accelerated cooling is permissible.

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Upon removal from the fluids, the terminations shall be left in the conditions specified in 8.1 for 1 h, after which time any remaining excess fluid may be wiped off. Within 90 min of removal from the fluid the terminations shall pass the dielectric strength tests, and the insulation shall show no signs, to normal vision, of splitting, cracking or other deterioration.

8.10.3 *Heat ageing*

Two samples shall be maintained at a temperature of 15 ± 2 °C above the maximum stabilized temperature of the appropriate cable for a period of 120 h.

After removal from the chamber, the samples shall be cooled to 20 ± 5 °C within a period of 1 h. When cooled, the samples shall pass the dielectric strength test and the insulation shall show no sign, to normal vision, of splitting, cracking or other deterioration. Discolouration on the insulation material shall not be considered damage.

8.10.4 *Low temperature crimping*

Two samples shall be tested. The prepared cable, terminal ends or cable splices and the crimping tools shall be maintained at a temperature of −15 ± 2 °C for 1 h; the terminals or cable splices shall then be crimped to the appropriate size of cable at a temperature of −15 ± 2 °C, maintained at that temperature for 1 h and then exposed to room temperature (20 ± 5 °C) for 1 h. After this test the samples shall pass the dielectric strength test, and the insulation shall show no signs, to normal vision, of splitting, cracking or other deterioration.

8.10.5 *Dielectric strength*

The tongue of the crimped lug shall be dipped in hot beeswax having a temperature not exceeding 154 °C, to a depth sufficient to close the open end of the lug barrel. The wax should not reach the edge of the depression resulting from the applied crimping pressure. One of the cables in a cable splice shall be cut as close to the insulating sleeve as possible, and the cable entrance end shall be sealed with beeswax as described above. When the beeswax has hardened, the samples shall be immersed in a 5 % aqueous sodium chloride solution to a depth sufficient to cover the crimped areas of the barrel and the insulation grip.

A potential of 1 500 V r.m.s. at a frequency at 50 to 60 Hz shall be applied between the conductor assembled to the crimped joint and an electrode in contact with the liquid. The voltage shall be applied for 1 min without breakdown.

9 PRODUCTION CONTROL TESTS

9.1 Terminations and cable splices

Samples of each type and size of terminal end and cable splice to be supplied shall be inspected for compliance with the requirements of 3.1.

9.2 Tools and dies

All tools and dies to be supplied shall be inspected for compliance with the requirements of 3.3.

10 USERS' CONTROL TESTS

10.1 Routine inspection of crimped joints

Every crimped joint shall be visually inspected in accordance with the requirements of 8.3.

10.2 Quality control tests

10.2.1 At the beginning of the use of any tool or die and subsequently

1) at intervals of 3 months, or at intervals of 1 000 crimps[1] per tool, whichever is the smaller; or

2) if the tool is stored without use for a period longer than 3 months, upon withdrawal from stores; or

3) as otherwise agreed with the inspecting authority,

tools and dies shall be inspected to verify that they comply with the requirements of 3.3 and with gauging in accordance with the tool manufacturer's recommendation.

10.2.2 Tensile tests in accordance with 8.7 shall be made on not less than four specimens of each and every combination of crimped barrel, conductor, tool die, indenter or positioner as required by 8.2.

10.2.3 If any specimens fail to fulfil the requirements of these tests, the cause of failure shall be investigated.

1) By agreement with the inspecting authority this frequency may be decreased progressively to a maximum of 10 000 crimps per tool in the light of experience.

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TABLE 2 — **Test currents, voltage drop values and pull-off loads for copper conductor crimps**

1	2	3	4	5	6	7	8	9	10	11
Conductor			**Test currents and voltage drop per crimped joint**							
Cross-sectional area		Size No.	ISO Recommendation references and maximum temperature of cables						Pull-off loads*	
			ISO/R 469 and ISO/R 474 (105 °C)		ISO/R 470 and ISO/R 1075 (190 °C)		ISO/R 539 and ISO/R 1490 (260 °C)			
			Test current	Voltage drop (maximum)	Test current	Voltage drop (maximum)	Test current	Voltage drop (maximum)		
mm^2	in^2		A	mV	A	mV	A	mV	N	lbf
0,347	0.000 54	22	11	8	9,5	11	9	11	62	14
0,556	0.000 86	20	14	7	12	9	11,5	9	85	19
0,966	0,001 50	18	18	7	16	9	15	9	142	32
1,17	0.001 8	16	21	7	18	9	17,5	9	169	38
2,05	0.003 2	14	31	6	27	8	26	8	254	57
3,22	0.005 0	12	43	6	38	8	36	8	400	90
5,33	0.008 3	10	61	5	54	7	50	7	600	135
8,76	0.013 6	8	87	5	77	7	72	7	850	190
13,3	0,020 6	6	115	5	100	7	95	7	1 200	270
21,5	0.033 3	4	160	5	140	7	133	7	1 870	420
33,3	0.051 7	2	200	5	175	7	165	7	2 700	608
40,7	0.063	1	220	5	195	7	180	7	3 140	705
53,0	0,082	0	240	4	210	6	200	6	3 410	767
68,3	0,106	00	270	4	240	6	220	6	3 890	875
84,2	0.131	000	300	4	260	6	250	6	4 310	970
109	0,170	0 000	350	4	305	6	290	6	7 160	1 609

* To be verified.

TABLE 3 — **Test currents, voltage drop values and pull-off loads for aluminium conductor crimps**

1	2	3	4	5	6	
Conductor			**Cable reference : ISO/R 1076**			
Cross-sectional area		Size No.	Test current*	Voltage drop* per crimped joint (maximum)	Pull-off loads**	
mm^2	in^2		A	mV	N	lbf
8,31	0.012 9	8	61	8	1 070	240
14,2	0.022 0	6	87	7	1 600	360
21,3	0.033 0	4	115	6	2 090	470
34,1	0.052 8	2	160	6	3 110	700
53,9	0.084	0	200	6	4 230	950
69,3	0.107	00	220	6	5 340	1 200
84,7	0.131	000	240	5	6 230	1 400
108,0	0.167	0 000	270	4	7 120	1 600

* The test currents and voltage drop values in columns 4 and 5 apply to cables with maximum stabilized conductor temperatures of both 105 °C and 190 °C.

** To be verified.

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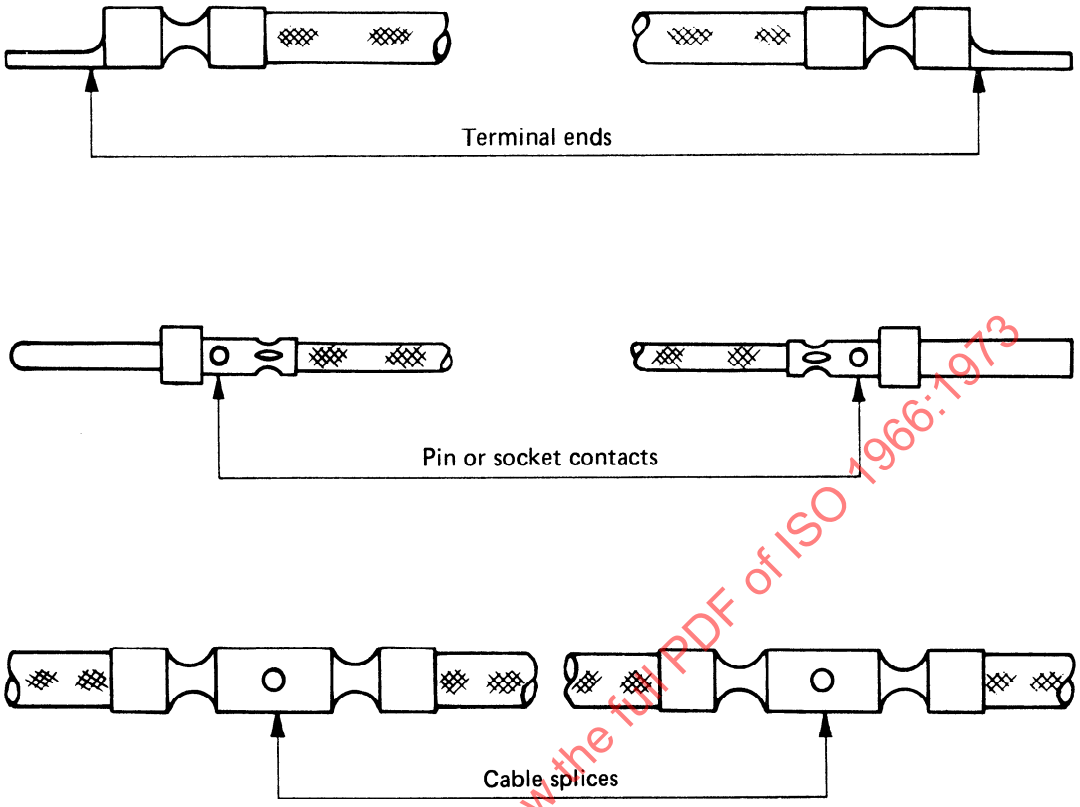

FIGURE 1 — **Measuring points for voltage drop tests**
(See 8.4)

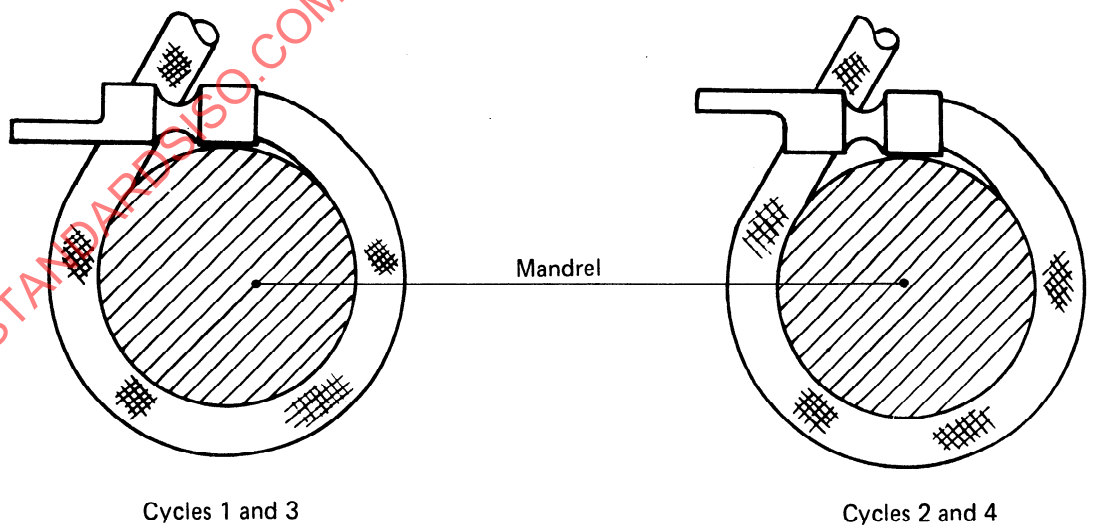

FIGURE 2 — **Method of testing for insulation grip tests**
(See 8.8)

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