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IEEE Guide for Cable Connections for Gas-Insulated Substations

Sponsor

Insulated Conductors Committee
of the
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Abstract: The coordination of design, material supply, installation, and test procedures required for the connection of a gas-insulated substation (GIS) is described. Preferred dimensions for mechanical and electrical interchangeability for voltage classes of 69 kV and above are established.
Keywords: cable connection, gas-insulated substation (GIS)

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Introduction

(This introduction is not a part of IEEE Std 1300-1996, IEEE Guide for Cable Connections for Gas-Insulated Substations.)

This guide serves to explain detailed requirements for cable connections for gas-insulated substations. The guide was prepared as Project 10-52 of the Accessories Subcommittee No. 10 of the Insulated Conductors Committee of the IEEE Power Engineering Society. It is based on IEC Publication 859 (1986), Cable Connections for Gas-Insulated Metal Enclosed Switchgear for Rated Voltages of 72.5 kV and above.

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When the IEEE Standards Board approved this standard on 1 August 1996, it had the following membership:

Contents

IEEE Guide for Cable Connections for Gas-Insulated Substations

1. Overview

Connection of a gas-insulated substation (GIS) to cables typically requires the coordination of design, material supply, installation, and test procedures of several different parties. This guide provides detailed directions for such coordination and establishes preferred dimensions for mechanical and electrical interchangeability for voltage classes of 69 kV and above. The general principles are applicable at all voltage levels.

2. References

The following publications should be used in conjunction with this guide:

IEC Publication 859 (1986), Cable Connections for Gas-Insulated Metal-Enclosed Switchgear for Rated Voltages 72.5 kV and Above.[1]

IEEE Std 48-1990, IEEE Standard Test Procedures and Requirements for High-Voltage Alternating-Current Cable Terminations (ANSI).[2]

IEEE Std 575-1988, IEEE Guide for the Application of Sheath-Bonding Methods for Single-Conductor Cables and the Calculation of Induced Voltages and Currents in Cable Sheaths (ANSI).

IEEE Std C37.122-1993, IEEE Standard for Gas-Insulated Substations (ANSI).

IEEE Std C37.122.1-1993, IEEE Guide for Gas-Insulated Substations (ANSI).

3. Definitions

The definitions in this clause are applicable only to the subject treated in this guide. Figure 1 illustrates the parts of a cable connection assembly for gas-insulated substations that are defined in this clause.

3.1 cable connection assembly: The combination of the cable termination with the cable connection enclosure, GIS conductor end, and removable conductor link.

3.2 cable connection enclosure: The part of the GIS that surrounds the cable termination

[1]IEC publications are available from IEC Sales Department, Case Postale 131, 3, rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse. IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

[2]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

3.3 cable termination: Parts assembled onto the end of the cable to provide the electrical and mechanical interface into the gas-insulated environment. Typically this includes a solid insulation barrier between the cable/cable fluid and the gas insulation of the GIS.

3.4 conductor current connection interface: The connection for transfer of conductor current from the GIS conductor to the cable termination

3.5 GIS conductor end: The end of the GIS high-voltage conductor inside the cable connection enclosure.

3.6 removable conductor link: A removable connector between the GIS conductor and the end of the cable termination.

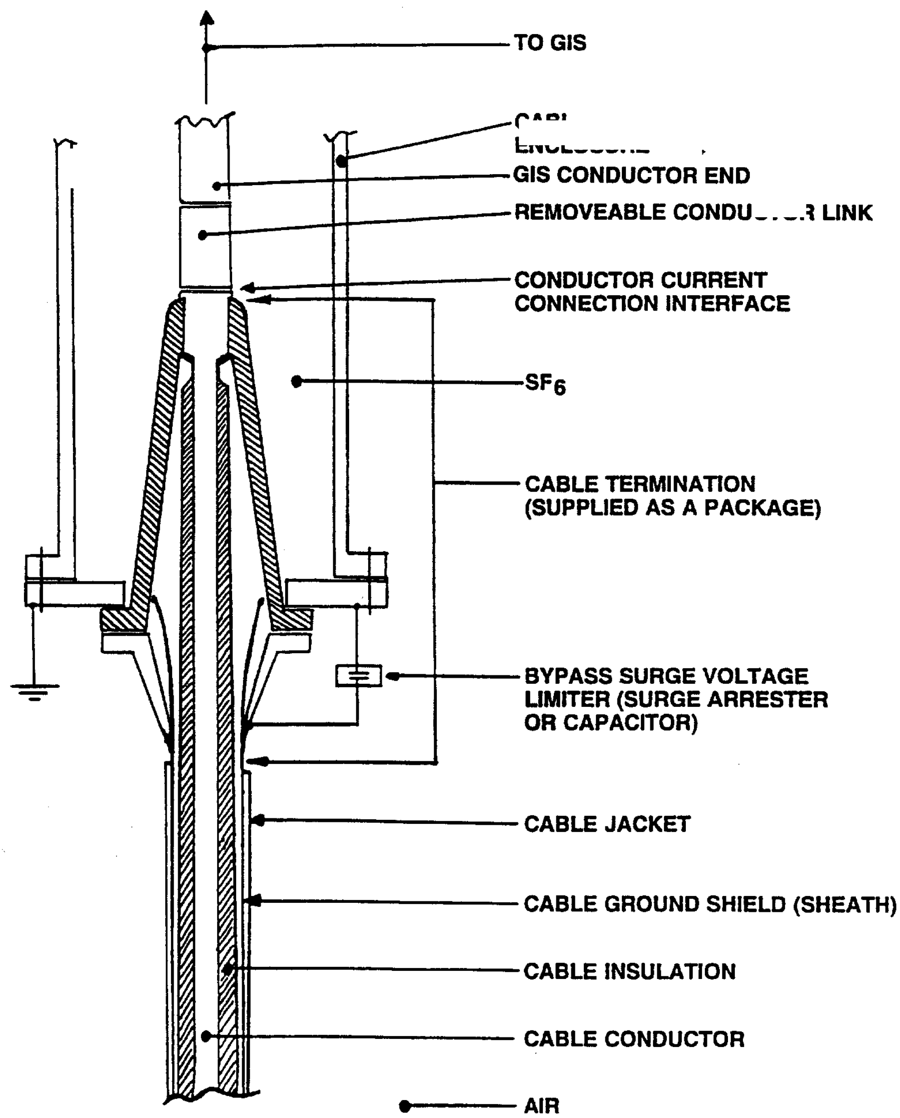
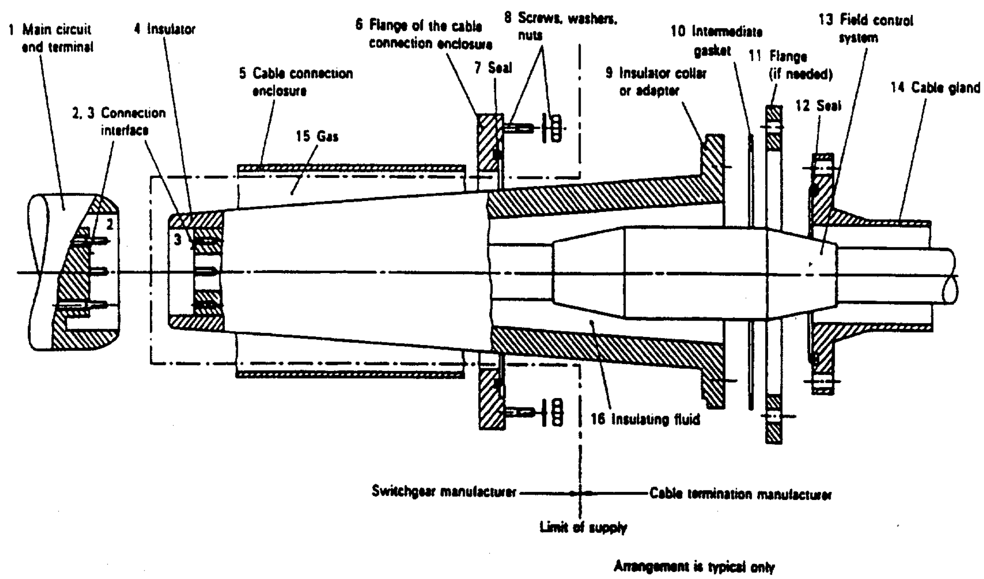


Figure 1—Parts of a cable connection assembly for gas-insulated substations

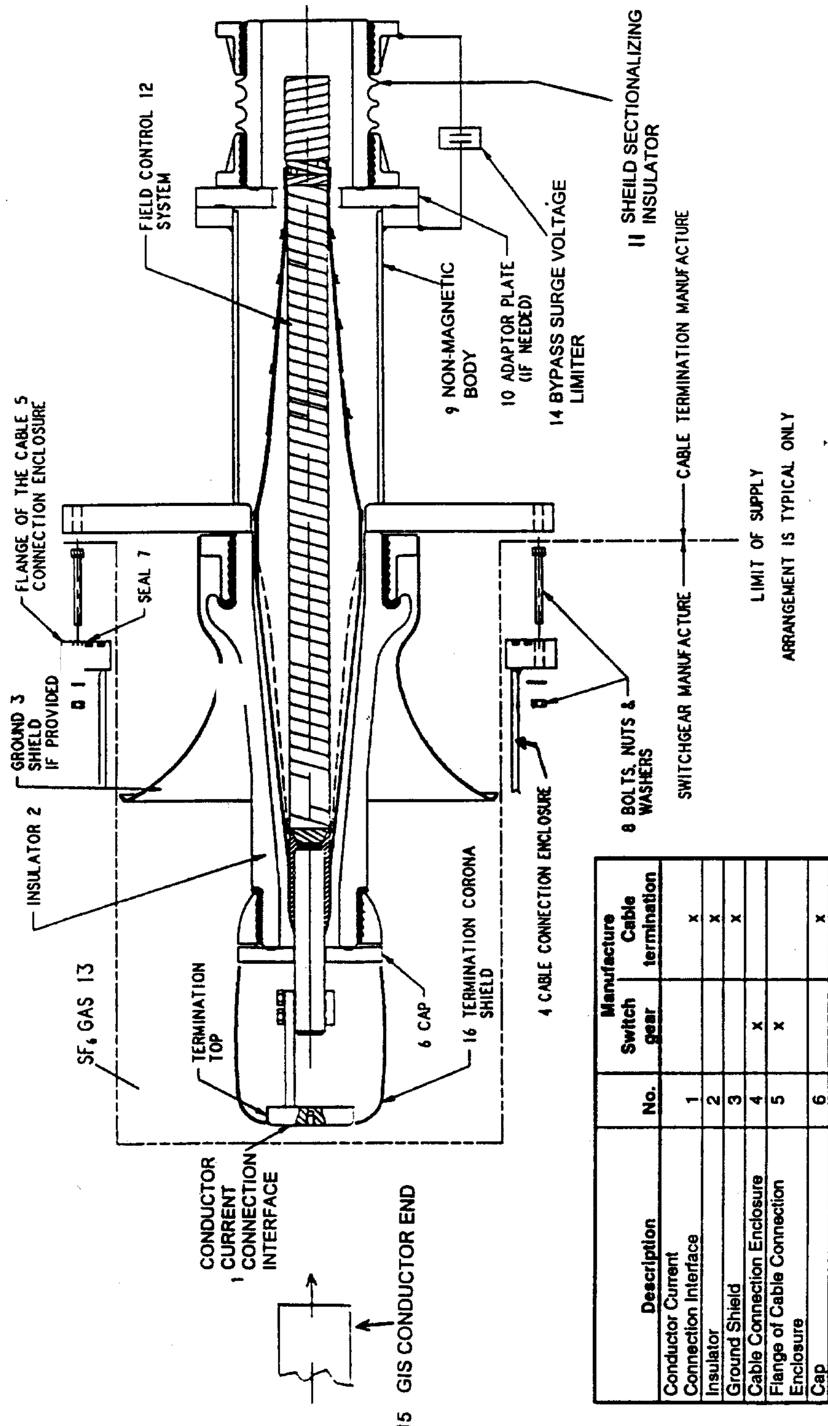
4. Limits of supply

The usual limits of supply for each party are shown in figure 2 for one type of construction frequently used for extruded dielectric cables, and in figure 3 for a type of construction frequently used for high-pressure fluid filled cables (HPFF). Similar limits of supply apply to self-contained fluid filled (SCFF) and low-pressure fluid filled (LPFF) cables.



Description	No.	Manufacturer: Switch gear	Manufacturer: Cable termination
Main circuit end terminal	1	x	
Connection interface	2	x	
Connection interface	3		x
Insulator	4		x
Cable connection enclosure	5	x	
Flange	6	x	
Seal	7	x	
Screws, washers, nuts	8	x	
Adapter	9		x (if needed)
Gasket	10		x (if needed)
Flange	11		x (if needed)
Seal	12		x
Field control system	13		x
Cable gland	14		x
Gas	15	x	
Insulating fluid	16		x

Figure 2—Typical cable connection assembly for gas-insulated, metal-enclosed switchgear for rated voltages of 72.5 kV and above

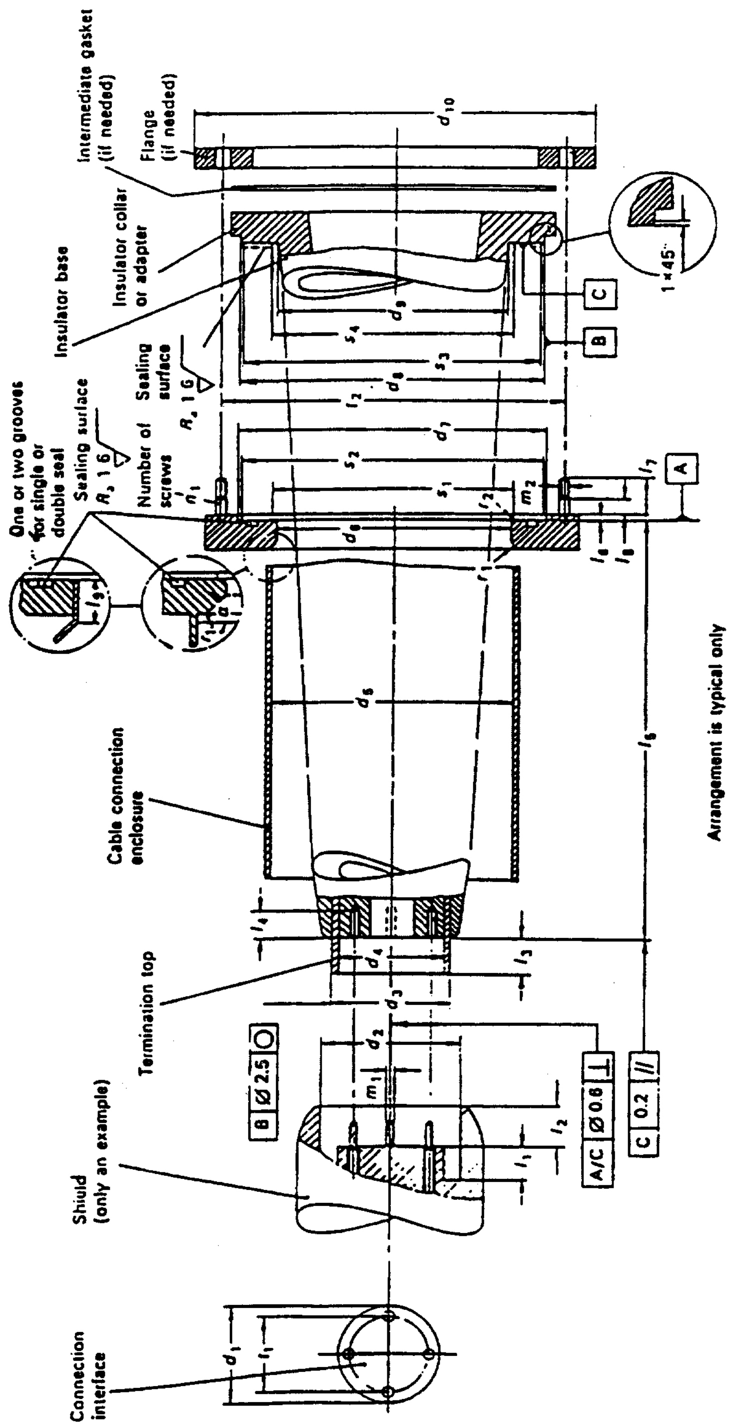


Description	No.	Manufacture: Switch gear	Manufacture: Cable termination
Conductor Current Connection Interface	1		x
Insulator	2		x
Ground Shield	3		x
Cable Connection Enclosure	4	x	
Flange of Cable Connection Enclosure	5	x	
Cap	6		x
Seal	7	x	
Bolts, Nuts & Washers	8	x	
Non-Magnetic Body	9		x (if needed)
Adaptor Plate	10		x (if needed)
Shield Sectionalizing Insulator	11		x
Field Control System	12		x
Gas	13	x	
Bypass Surge Voltage Limiter	14		x (if needed)
GIS Conductor End	15	x	

Figure 3—Limits of supply for specialized cable connection construction used for pipe-type HPFF cable

5. Typical dimensions

Typical dimensions for cable connections are given in figure 4 for a type of construction frequently used for extruded dielectric cables, and in figure 5 for a type of construction frequently used for HPFF.

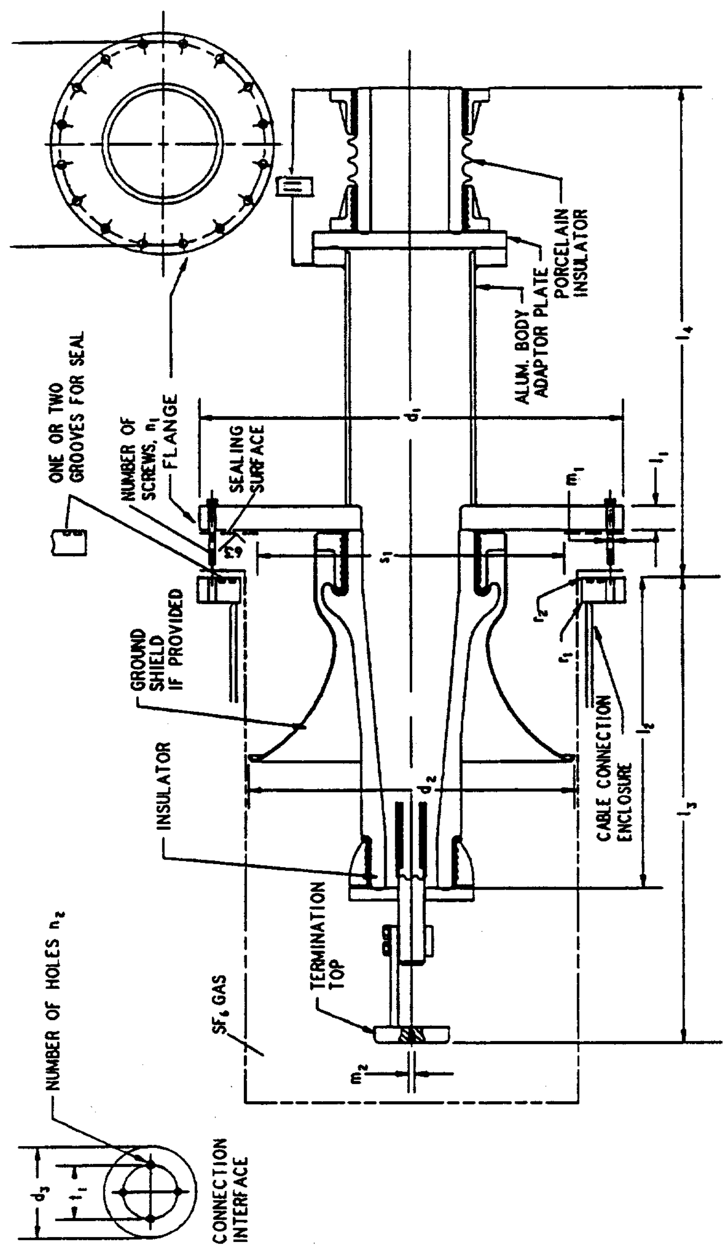


STANDARD DIMENSIONS

kV \ N°	d_1 max.	d_2 min.	d_3 max.	d_4 min.	d_5 min.	d_6	d_7	d_8	d_9 3) max.	d_{10} max.	l_1 min.	l_2 max.	l_3 max.	l_4 min.	l_5	l_6 max.	l_7 min.	l_8 max.	l_9 max.	m_1	m_2	n_1	r_1 min.	r_2 min.	s_1 min.	s_2 max.	s_3 min.	s_4 max.	t_1	t_2	$a°$
72.5 1)	99.5	112	110	100	300	200^{+5}_{0}	$246^{+0.5}_{0}$	245 ± 0.3	196	300	16	50	15	18	583 ± 1	5.5	85	40	50	M10	M10	8	10	1	205	241	242	206	80 ± 0.3	270 ± 0.5	0...45°
123 to 170	99.5	112	110	100	300	220^{+5}_{0}	$299^{+0.5}_{0}$	298 ± 0.3	215	350	16	50	15	18	757 ± 1	5.5	85	40	50	M10	M12	12	10	2.5	230	294	295	231	80 ± 0.3	320 ± 0.5	0...45°
245 to 300	139	202	200	140	480	480^{+5}_{0}	$560^{+0.5}_{0}$	559 ± 0.3	440	620	50	100	49	21	960 ± 2	6	90	40	70	M12	M16	16	10 2)	2.5	490	554	555	491	110 ± 0.3	582 ± 0.5	0...90
362 to 420	139	252	250	140	540	540^{+5}_{0}	$618^{+0.5}_{0}$	617 ± 0.3	500	690	50	100	49	21	1400 ± 2	6	90	40	70	M12	M16	20	10 2)	2.5	550	612	613	551	110 ± 0.3	640 ± 0.5	0...90

1) Values only tentative 2) If $d_5 > d_6$ 3) d_9 and corner radius shall not interfere with d_8 and r_2

Figure 4—Typical cable connection assembly for gas-insulated metal-enclosed switchgear for rated voltages of 72.5 kV and above



kV	d_1 max	d_2 max	d_3 max	l_1 max	l_2 max	l_3 max	l_4 max	n_1	n_2	m_1	m_2	r_1 min	r_2 min	s_1 max	t_1 (±.015)	t_2 (±.015)
69 to 138	470 (18.500)	368,3 (14.50)	90,5 (3.562)	38,1 (1.50)	614,3 (24.187)	938,2 (36.937)	970 (38.187)	16	4	1/2"-13	3/8"-16	9,98 (.393)	2,49 (.098)	330,2 (13)	(1.937)	(17.000)
230	724,7 (28.531)	574,6 (22.625)	155,6 (6.125)	5u,8 (2.00)	766,7 (30.187)	1098,5 (43.250)	1098,5 (43.250)	24	6	5/8"-11	1/2"-13	9,98 (.393)	2,49 (.098)	533,4 (21)	(3.625)	(26.968)
345	892,2 (35.125)	698,5 (27.50)	155,6 (6.125)	50,8 (2.00)	768,4 (30.250)	1100,1 (43.312)	1098,5 (43.250)	24	6	5/8-11	1/2"-13	9,98 (.393)	2,49 (.098)	660,4 (26)	(3.625)	(33.000)

Figure 5—Representative cable connection dimensions for specialized cable connection construction used for pipe-type HPFF cables

6. Ratings

The following should be specified and considered in design of the cable connection, and values should be chosen from IEEE Std 48-1990,[3] with due consideration being given to gas-insulated switchgear (GIS) ratings from IEEE Std C37.122-1993.

- Voltage—kV rms phase-to-phase
- Basic insulation level—kV peak
- Continuous current—A rms
- Short-time current—kA rms for 1 s or 3 s
- Peak short circuit current—kA peak
- Maximum dielectric fluid pressure for cable system—kPa
- Power frequency factory withstand voltage—kV rms phase-to-ground
- GIS power frequency field withstand voltage—kV rms phase-to-ground
- DC (or ac) cable test voltage—kV dc (or ac) phase-to-ground
- Field test voltage for cable or pipe coverings (cable jacket or corrosion protective pipe covering)

Of the preceding list items, *continuous current, short-time current, peak short circuit current, and maximum dielectric fluid pressure for cable system* are system dependent and should be referred to the cable termination manufacturer.

7. Temperature rise and conductor contact surfaces

The connection interface shown in figures 2 and 3 should be designed so that the conductor contact interface temperature shall not exceed 70 °C at the rated current of the cable. There should be no dependence on heat transfer from the GIS-conductor end to the cable.

Conductor contact interface surfaces, if aluminum, should be treated with a conductive plating or coating to ensure long term stability of current transfer. In all cases care should be taken to ensure a reliable contact and field measurement of resistance after assembly is recommended.

8. Gas pressure

For cable connections where the gas is SF_6, the design pressure should not exceed 0.85 MPa absolute (108 lbf/in^2). Dielectric-type tests should be done at the minimum operating pressure of the SF_6 gas as specified by table 1. Note that the GIS does not itself have to satisfy the minimum operating pressure applicable to the cable termination.

Table 1—Gas-pressure limits for dielectric type test of cable terminations

Range of rated voltages *U* kV rms phase-to-phase	Minimum SF_6 gas pressure (absolute) at 20 °C MPa	Minimum SF_6 gas pressure at 20 °C lbf/in^2
72.5	0.10	0
100–170	0.30	29
245–300	0.35	36
362–550	0.40	43

NOTE—The gas pressures are intended as a test guideline for the manufacturer of the cable termination. Higher values are permissible, but should not exceed 0.85 MPa (108 lbf/in^2). If a gas other than SF_6 is used, the minimum gas pressure should be chosen to give the same dielectric strength.

[3]Information on references can be found in clause 2.

9. Dielectric type test

9.1 Cable termination dielectric type test

The cable termination should be able to pass a dielectric-type test to the levels of IEEE Std 48-1990, with due consideration being given to GIS ratings from IEEE Std C37.122-1993. The tests may be done with simulated enclosures consisting of metal cylinders as appropriate for symmetrical single-phase or asymmetrical three-phases in one enclosure, as shown in figure 6.

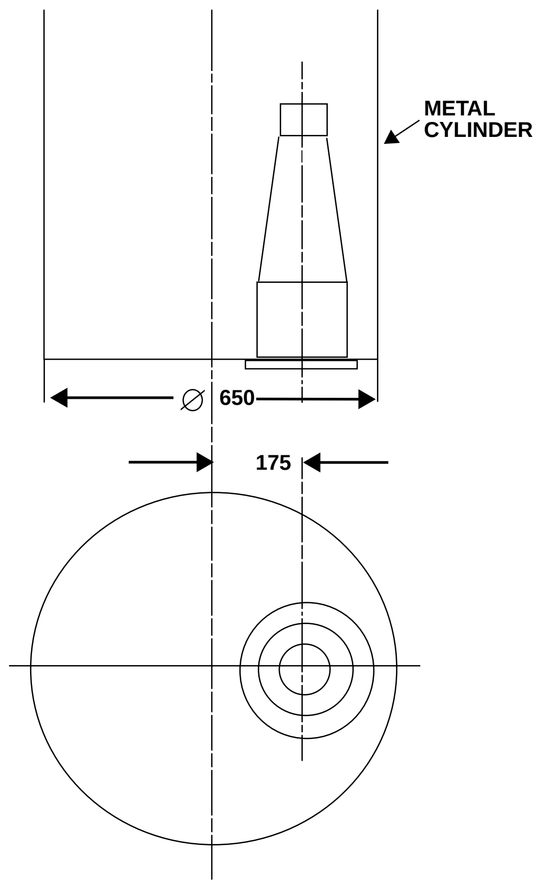


Figure 6—Nonsymmetrical arrangement for dielectric tests of cable terminations of three-phase enclosure type, not recommended for pipe type cable systems

An additional test shield may be added to shield the end of the cable termination if it does not electrically overlap the termination end in a way that would alter the electric field distribution of the cable termination itself.

9.2 Cable connection enclosure dielectric type test

The cable connection enclosure may be dielectric-type tested without the cable termination using an additional test shield on the GIS conductor end, but this shield should not alter the electric field distribution that will exist on the GIS parts with the cable termination in place.

9.3 Isolating gap

An isolating gap is needed between the GIS conductor end and the cable termination end to allow separate testing of the GIS and cable. This gap is usually provided by a removable conductor link and, if necessary, shields on the ends of the GIS conductor and/or the cable termination end. No special dielectric-type tests are considered necessary for this condition since it is only present during field tests, and separate dielectric-type tests of the cable termination and cable termination enclosure demonstrate adequate withstands with suitable shields.

10. Mechanical force (short circuit and other)

For three phases in one enclosure, the design should recognize the short-circuit transverse forces between conductors. In this case the maximum additional transverse force to be accommodated by the cable termination end should not exceed 5 kN. For single-phase cable connections, the transverse force applied to the cable termination end should not exceed 2 kN.

The GIS manufacturer should be responsible to ensure that specified forces are not exceeded, and that thermal expansion and alignment movement of the cable connection assembly does not exceed acceptable limits.

The cable termination manufacturer should be responsible for proper restraint of cable forces acting on the cable terminations.

11. Cable connection support structures

The GIS manufacturer should be responsible for proper support of the cable termination enclosure and the cable termination itself, taking into account the forces expected to be transferred from the cable to the cable termination and hence to the cable termination enclosure. The GIS manufacturer should be responsible for coordination with the cable termination manufacturer to assure proper separation and proper orientation between the two supports and adequate clearances below the lower support (if required).

12. Grounding

The cable connection enclosure should be electrically connected to the GIS enclosure for grounding. The cable termination should include an electrically insulating shield sectionalizing insulator between the parts electrically connected to the cable termination enclosure and the cable's metallic ground shield and/or pipe. Typical locations for this are shown physically in figure 7 and schematically in figure 8**.** This shield sectionalizing insulator allows separate grounding and cathodic protection of the cable's ground shields and/or pipe and a cable jacket integrity test. It can also be used to limit circulating currents in the cable's metallic shield and/or pipe.

In some cases the shield sectionalizing insulator may not be needed, or may be needed for test only, in which case the cable termination manufacturer should supply the shorting provisions.

GIS switching transients with very fast rise times may cause short duration overvoltages between cable connection parts that are separately grounded. Adequate electrical insulation must be provided between such parts both internally and externally. Bypass surge voltage limiters (metal-oxide surge arresters or capacitors) are required if a shield sectionalizing insulator exists. Since the transients have very short rise times (in the nanosecond range), the bypass surge voltage limiters need to be mounted very close to the gap to be protected and connected by short, low-impedance leads. Shield sectionalizing insulators are subjected to overvoltages for several reasons as described in IEEE C27.122.1-1993 and in IEEE Std 575-1988, and as in [B4], [B2], and [B3].[4]

NOTE—GIS manufacturer should participate in specifying bypass surge voltage limiter, but they should be supplied by the cable termination manufacturer.

[4]The numbers in brackets preceded by the letter B correspond to those of the bibliography in clause 17.

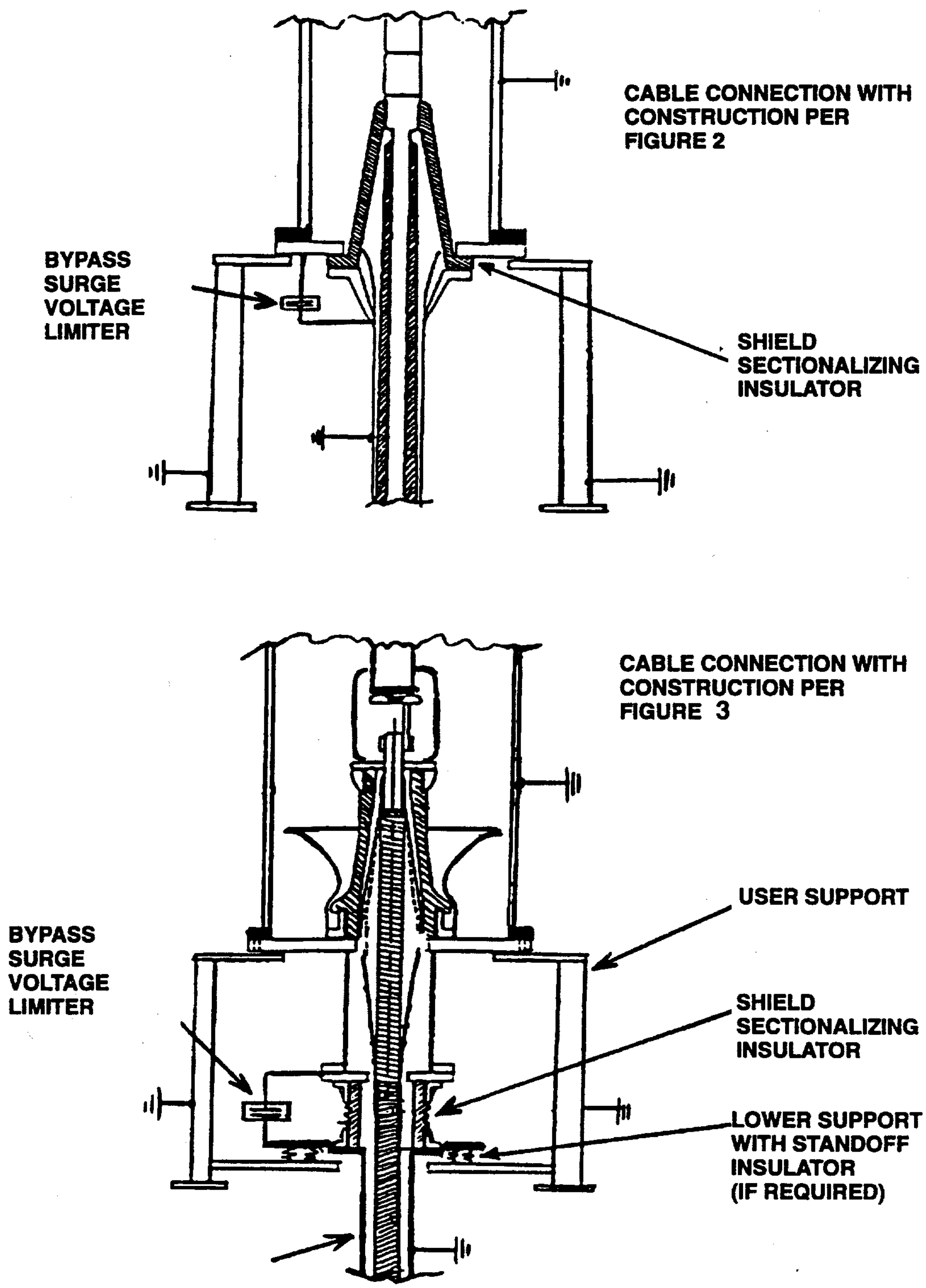


Figure 7—Typical physical locations of shield sectionalizing insulator between GIS and cable shield, sheath, or pipe—grounding and bypass surge voltage limiter

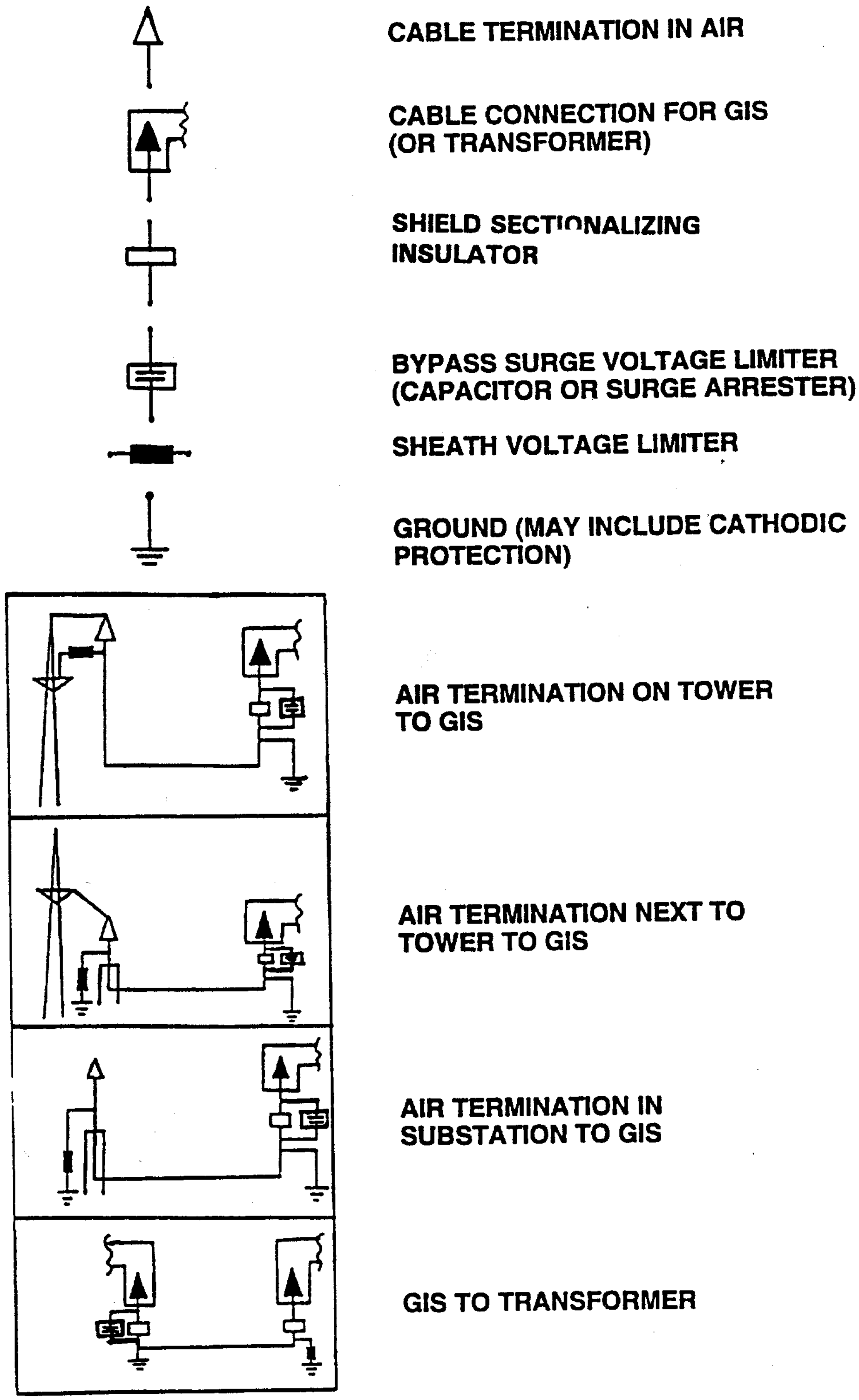


Figure 8—Typical schematic locations of shield sectionalizing insulator between GIS and cable shield, sheath, or pipe—grounding and bypass surge voltage limiter

13. Installation

The GIS manufacturer should be responsible for coordinating access provisions and for ensuring that fit is achieved within the usual design tolerances and adjustments of the various parts. This will require review of the cable installation procedure and is especially critical if the cable (or a rigid pipe) is installed prior to the GIS.

Unless otherwise specified, the GIS manufacturer and/or GIS installer is not responsible for installing the cable termination on the cable. Normally, the GIS is installed and tested prior to the cable termination being installed. In this case the GIS manufacturer should supply a suitable permanent cap for the opening in the cable connection enclosure that will later be used for the cable termination. This cap should allow complete GIS testing. The cable connection enclosure may have to be removed to accommodate installation of the cable termination.

14. Field tests

14.1 Dielectric field tests

To allow separate testing of GIS and cable, the cable connection should include the following:

a) Removable conductor link—removable connector between cable termination end and GIS conductor end, of suitable length, and shielded so that voltage may be independently applied to either the GIS or the cable. The end of the part not being tested should be grounded.

b) Any special tools (e.g., shields, grounding connectors for use inside the cable termination enclosure) needed for setting up a suitable condition for test, provided by the GIS manufacturer.

c) Test bushing—when the field test voltage must be applied at the cable connection, the GIS manufacturer should supply suitable test bushing or bushings. This may be the case when the GIS has no SF_6-air bushings and the cable is terminated at its other end in an enclosed manner.

d) Detailed instructions for removal and replacement of the conductor link, including a checklist of steps and detailed descriptions of any tools needed, provided by the GIS manufacturer.

14.2 Other field tests

Other tests as appropriate for either the GIS or the cable may be performed.

15. Operation and maintenance

The practice of reclosing should be avoided when attempting to locate faults internal to the GIS, cable connection enclosure, or cable. To facilitate fault location, current transformers may be required at the cable connections.

The gas pressure (density) is monitored as a part of the GIS alarms and controls. The cable fluids (if any) are monitored per cable and/or cable termination according to the manufacturer’s requirements.

Other devices (high-voltage surge arrester, voltage transformer, ground switch, current transformers, etc.) are sometimes installed in the same GIS enclosure as the cable termination. If any of these devices need to be removed for access or test, the GIS manufacturer should provide suitable secure covers for the openings left by removal of the device.

16. Special accessories

16.1 Vent and sample valve for fluid filled cables

The user may specify vent and sample valve at the high voltage end of the cable termination.

16.2 Detection of cable fluid leaks inside cable termination enclosure

For high-pressure fluid filled cables it may be appropriate to provide for an alarm if a significant amount of cable fluid leaks into the cable termination enclosure. The fluid will collect at the bottom of the cable termination enclosure where a sensor can detect the presence of the cable fluid.

16.3 Viewports

For especially critical applications or difficult working site conditions, a viewport on the cable termination enclosure may be specified to allow visual inspection of the internal connection.

17. Bibliography

[B1] Arkell, C. A., Galloway, S. J., and Gregory, B., "Supertension Cable Terminations For Metalclad SF_6 Insulated Substations," IEEE PES 1981 Transmission and Distribution Conference and Exposition, Minneapolis, MN, Apr. 1, 1981, Paper no. 81 TD 689-9; *Transactions on Power Apparatus and Systems*, vol. PAS-101, no. 5, pp. 1021-1029, May 1982.

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