Dimensioning of clearances and creepage distances

European standard EN 61984 Ed. 1.0 (22001-11) was recently published for safety prescriptions for multipole connectors for industrial uses and for the relevant tests. This standard assimilates, without any modifications, the corresponding international standard IEC 61984 Ed.1.0 (2001-06).
It is applicable to connectors with rated voltage values of over 50V, and up to 1000V, and rated currents values of up to 125A per pole, for which no dedicated standard exists, or to which the particular specifications or the manufacturer refer as regards the safety aspects.
For determining the minimum through-air and surface insulation distances, i.e. creepage distances, for connectors, this standard makes use (with some modifications) of the concepts of standard IEC 60664-1 Ed. 1.0 (1992-10) [1].
NOTE - For connectors with rated voltage values of up to 50V - excluded from the field of application of Low Voltage Directive 73/23/EEC - standard EN 61984 may be used as a guide. For surface and through-air insulation distances, refer to standard IEC 60664-1 Ed. (1992-10).
We are illustrating below the method of standard EN 61984 for determining minimum insulation values in connectors. The rated characteristics for each ILME connector family are provided on pages 14 and 15.
The following are now obsolete: the insulation group concept, and the distinction of rated voltage values into d.c. and a.c. voltage values 220V and 380V were adapted to standardised values 230V and 400V according to IEC 60038[2] and some concepts were taken from the regulations for LV electrical systems of the IEC 60364[3] series, as follows:
- The overvoltage categories (I, II, III, IV), according to the use of the equipment [4]. They are correlated to the transient overvoltages taken as a basis for determining the rated impulse withstand voltage
- The degrees of pollution
- The classification of insulating materials according to their resistance to tracking
- The conditions of the electrical field (homogenous or inhomogenous).

Overvoltage categories (or impulse withstand)

The overvoltage categories of a circuit or of an electrical system are identified by a conventional number (from I to IV) based on the limit or the control of the assumed transient overvoltage values obtained on a circuit or electrical system and depends on the means used to reduce the overvoltages.

TABLE 1
The rated impulse withstand voltage for equipment energised directly from the low-voltage mains (IEC 60664-1 Edition 1.0 1992-10)

Nominal voltage of the supply system based on IEC 60038 (CENELEC HD 472 S1, CEI 8-6)		Voltage line to neutral derived from nominal voltages a.c. or d.c.	Rated impulse withstand voltage [b]			
V	V		Overvoltage category			
Three phase [a]	Single phase	≤ V	V			
			I	II	III	IV
		50	330	500	800	1500
		100	500	800	1500	2500
	120-240	150	800	1500	2500	4000
230/400 } 277/480 }		300	1500	2500	4000	6000
400 / 690		600	2500	4000	6000	8000
1000		1000	4000	6000	8000	12000

a) The "/" symbol indicates a four-wire three phase distribution system (star distribution). The lower value is the voltage between phase and neutral (phase voltage), whereas the higher value is the voltage between the phases (mains voltage).
Where only one value is indicated, it refers to three-wire, three-phase systems (delta distribution) and specifies the line-to-line value.
b) Equipment with these rated impulse withstand values can be used in installations in accordance with standard IEC 60364-4-443 (Italian standard CEI 64-8/4 Section 443, German standard DIN VDE 0100-443).

Table 1 supplies the rated impulse withstand voltage for equipment energised directly from the low voltage mains in function of the rated voltage of the power supply system, the relative voltage line-to-neutral and the overvoltage category.
Industrial machinery and installations with fixed connection to the low voltage supply system and consequently the relative components including multipole connectors, constitute an example of the equipment that belongs to the overvoltage category III.
Examples of general equipment that comes under overvoltage category II are electrical household appliances, portable tools and other household equipment or similar.
For distribution networks with rated voltage of **230/400V** (star distribution with earthed neutral), and over-voltage category III (category **III**: impulse withstanding), the demanded rated impulse withstanding voltage is **4kV**.
For distribution networks with rated voltage of **400** or **500V** (star distribution without neutral or with insulated neutral, or delta distribution, insulated or corner-earthed), and over-voltage category III (category **III**: impulse withstanding), the demanded rated impulse withstanding voltage is **6kV**.

(1) Assimilated with modifications as European Harmonisation Document HD 625.1 S1:1996 and published by the CENELEC member countries as a national standard: Italian standard CEI 28-6 (1997-11), German standard DIN VDE 0110-1 (VDE 0110 Teil 1):1997-04.
(2) Harminisation Document CENELEC HD 472 S1, Italian standard CEI 8-6, German standard DIN IEC 38:1987-05.
(3) Italian standard CEI 64-8, German standard DIN VDE 0100.
(4) HD 625.1 S1 modifies the definition to "impulse withstanding categories".

Degrees of pollution

Pollution indicates the presence of any kind of foreign matter, whether solid, liquid or gaseous (ionised gas) that can have a negative influence on the dielectric strength or on the surface resistivity of the insulating material.
The standard establishes four degrees of pollution. The categories are identified by conventional numbers based on the quantity of polluting agents or on the frequency of the phenomenon which determines the reduction of the dielectric strength and/or of the surface resistivity.

Pollution degree 1:
No pollution or only dry, non-conductive pollution.
The pollution has no influence.
Pollution degree 2:
Only non-conductive pollution except that occasionally a temporary conductivity caused by condensation may occur.
Pollution degree 3:
Conductive pollution or dry, non-conductive pollution which becomes conductive due to condensation which may occur.
Pollution degree 4:
The pollution generates persistent conductivity caused by conductive dust or by rain or snow.

Pollution degree 3 is typical of an industrial environment or similar, while pollution degree 2 is typical of a household environment or similar.

Standard EN 61984 permits the sizing of surface insulation distances of connectors installed in enclosures in protection class ≥IP54 for the degree of pollution immediately below that of the application environment (e.g.: 2 instead of 3).

Extract from standard EN 61984
6.19.2.2 For a connector in protection class IP54 or higher, according to Publication IEC 60529, the insulating parts inside the enclosure may be sized for a lower degree of pollution.
This applies also to coupled connectors, closure of which is ensured by the connector enclosure, and which may be uncoupled for test and maintenance purposes only.
One may therefore use connectors installed in enclosures or containers in protection class ≥IP54, at the rated data referring to degree pollution 2 in industrial applications with degree of pollution 3, if, in compliance with the standard, the coupling of the connectors is opened only occasionally for tests or maintenance. In the event of temporary or limited duration in uncoupled state, a closing cover is, however, necessary, guaranteeing at least protection class IP54. However, this does not apply to connectors which remain uncoupled and exposed to an industrial atmosphere for an indefinite period. It should be noted, however, that pollution could penetrate inside coupled connectors, also when it comes from remote parts of the electrical system (e.g. through conduits providing cable entry to the connectors enclosure).
Moreover, connector enclosures are usually supplied without cable entry devices, with the installer fitting such devices according to need. The degree of protection marked on the enclosures is guaranteed only for connectors coupled through the use of cable entry devices in equal or higher IP protection class and expertly installed.

Examples of application for the selection of degree of pollution 2 for a connector
- connector on an electric motor controller, which is uncoupled only to replace a faulty motor, also in cases where degree of pollution 3 is instead specified for the system;
- connector on a module-constructed machine, which is opened only for transport purposes and which is used only for faster installation and for safer putting into service. One must make sure that the connector has not been polluted during transport. To ensure this has not occurred, protective covers or adequate packing must be used;
- connector inside a panel in protection class ≥IP54. In this case one may even renounce equipping the connector with an IP54 enclosure.

Insulating material

Insulating material influences the determination of the minimum creepage distance. It is characterised according to the damage it suffers from the concentrated release of energy during scintillations when a surface leakage current is interrupted due to the drying of the contaminated surface.
The CTI (comparative tracking index), (index of resistance to surface currents) is assumed as index of the resistance to creep currents of the insulating materials in the presence of atmospheric contaminating agents.
The CTI constitutes the numeric value of the maximum voltage at which a material can resist against 50 drops of an electrolytic test solution without tracking, i.e. without a progressive formation of conductive paths on the surface of the solid insulating material (and permanent electric arc between the electrodes of the test equipment) due to the combined effect of electrical stress and electrolytic contamination.
The solid insulating materials are classified into four groups:

Group I	600 ≤ CTI
Group II	400 ≤ CTI < 600
Group IIIa	175 ≤ CTI < 400
Group IIIb	100 ≤ CTI < 175

The values for groups IIIa/IIIb (Table 6, EN 61984) are identical for the purpose of determining the creepage distance values.
The insulating materials used to manufacture the ILME multipole connectors belong to groups IIIa / IIIb.