Dimensional criteria for the design of ‘Ex d’ and ‘Ex e’ enclosures for panel boards suitable for Hazardous Areas with risk of explosion

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INTRODUCTION

In order to make a correct sizing of panel boards for light distribution, motive power, MOV power (motorized valves) and power-tracing systems, it’s necessary that multiple parameters are systematically taken into account and used as a calculation method for the determination of mechanical and electrical sizes.

Considering that these enclosures must be suitable for installation in hazardous areas (‘Ex d’, ‘Ex de’) and they are, therefore subject to certification by qualified entities recognized at international level, is of utmost importance that these sizing meet all the parameters set by the reference Standards, such as:

- IEC 60079-0 / EN 60079-0 / CEI EN 60079-0: Explosive atmospheres – Part 0: Equipment – General requirements;
- IEC 60079-7 / EN 60079-7 / CEI EN 60079-7: Explosive atmospheres – Part 7: Equipment protection by increased safety “e”;
- IEC 60079-14 / EN 60079-14 / CEI EN 60079-14: Explosive atmospheres – Part 17: Electrical installations design, selection and erection.

This task belongs mainly to the manufacturer of such equipment, as prescribed by the regulations listed above; however, we intend to provide our customers a wide description of the criteria that we usually take to realize the sizing.

These types of enclosures, in succession called "Panel Board", which must be suitable for installation in explosion-proof areas, industrial plant, on drilling/production plant (Off-Shore), on flotation devices used in the drilling and/or production (FPSO), are divided mainly into the following types:

- Power distribution Panel Board
- Lighting distribution Panel Board
- Motor operated valve (MOV) Panel Board
- Motor starting Panel Board
- Local control Panel Board
- Marshalling Panel Board
- Feeder electrical tracing Panel Board.

Stated that the choice of a panel has to be made in accordance with IEC 60079-14 / EN 60079-14 / IEC 60079-14 standards and that this choice depends on plant needs and a deep analysis of subsequent time and maintenance costs, construction types for these types of panel boards are two.

The examples described below, refer to II 2 GD Ex d IIB method of protection, however the same analyzes are applicable to II 2 GD Ex d IIC method of protection.

1. “Directly” cable entry, type (‘Ex d’ method of protection)
2. "Indirect" cable entry, type ('Ex de' method of protection).

The "directly" execution provides for the entry of cables directly to the Panel Board in 'Ex d' method of protection, so in compliance with IEC 60079-1/EN 60079-1/CEI EN 60079-1 standards, with the use of sealed cable glands that does not allow for a possible explosion within the Panel Board to spread outside of it. In this case, the choice of the cable or sealing fitting shall meet the requirements of the Standard, as in Graphic 1.

**Graphic 1**

- **The equipment contains an internal source of potential ignition?**
  - **Not**
  - **Yes**
    - **The ignition source requires an enclosure in IIC execution?**
      - **Yes**
      - **Not**
    - **The installation area is Zone 1?**
      - **Not**
      - **Yes**
        - **The free internal volume of the enclosure is greater than 2 dm³?**
          - **Use sealing device with Ex d containing a sealant (sealing fitting series EYD, EYS or E2S) or Ex d barrier cable gland, series F6 or FGAB**
          - **Use input device in Ex d version with sealing ring, such as our cable glands series REV and REVD**


The "indirect" execution involves the use of an increased safety "Ex e" junction box for input/output cables, so in compliance with IEC 60079-7/ EN 60079-7 / CEI EN 60079-7, within which are housed the increased safety terminal blocks. From this enclosure are derived all the links from and to the explosion-proof enclosure in "Ex d" execution. The passage between the two enclosures will be through sealed locking devices and/or sealed bushings, always in ‘Ex d’ execution. In this case, the choice of the sealing fittings and/or the sealed bushings has to comply with the requirements of standard, such as from the above Graphics 1.

THE MECHANICAL DIMENSIONING

One of the primary problems for the mechanical dimensioning is to verify that the quantities of the entries of the in/out cables from the panel are correctly dimensioned and arranged, according to the parameters of the certificate. It determines the maximum possible drilling of each wall and/or of the cover that are a focal point for this dimensioning.

Another problem is to check the quantity of devices which may be installed inside of these enclosures, the minimum respect distances, inter-distance between the various internal components and the least inter-distance of entries on the walls of passage always in accordance with the parameters of the certificate which defines the maximum thermal dissipation (Watt) at the various classes of temperature and at the various ambient temperatures.

- "Minimum respect distance" means the minimum distance of the component and/or equipment to be inserted into the enclosure, towards the wall of the housing itself and/or to the component to which it has to be joined, in order to allow the component and/or equipment a proper heat dissipation and, consequently, its proper functioning in accordance with the dimensional parameters of the constructor.
- "Inter-distance between the various internal components" means the physical distance that must be left between a component and the adjacent one, in order to allow for a proper thermal dissipation and to not reduce the power current due to the extreme proximity to another component. This distance can be checked in the manufacturer's technical documentation.
- "Least inter-distance of entries on the walls of passage" means the minimum distance provided in the technical documentation and certificate, in respect of the maximum drilling surface in accordance with the technical documentation.

First of all, it’s important to have the sizing parameters that must be provided by customer at the time of size request which are the basis for continuing the technical analysis. These parameters can be summarized as follows:

1. Method of protection
   Ex d IIB, with direct entry of cables;
   Ex d IIB+H₂, with direct entry of cables (presence of hydrogen);
   Ex d IIC, with direct entry of cables;
   Ex d IIB, with indirect entry of cables;
   Ex d IIB+H₂, with indirect entry of cables (presence of hydrogen).

2. Temperature Class
   T1, T2, T3, T4, T5, T6, in accordance with IEC 60079-1 or EN 60079-1 or CEI EN 60079-1 Standards and according to the place of installation which must be provided by customer at the time of size request.

3. Ambient temperature
   This very important parameter for a correct dimensioning must be provided by customer at the time of size request.

4. Description of the composition of the Panel Board
   The composition of the Panel Board is a dimensioning parameter that must be provided by customer at the time of size request.
5. Pre-heater of the Panel Board (low temperatures)

This is a variable function that is applied only when the ambient temperature is negative (from -20°C up to -60°C). The designers have to consider it, even if not expressly requested by the customer, but necessary for the correct operation of the equipment at this negative temperature.

In consequence of the above parameters, we can proceed to the mechanical sizing of the enclosure, analyzing the following four aspects.

**Number of holes on each walls of the enclosures**

According to the certification parameters, the designer analyzes the possibility to stay the entries (for size and quantity) required by the client.

For this test, two fundamental parameters must be taken into account:

- the maximum drilling surface of the wall;
- the minimum distance for the positioning of the entries, both towards the border of the maximum drilling and towards the adjacent entry/entries.

The maximum drilling surface of the wall is a parameter attributable to the specific size of the enclosure and, then, consequential to the quantity of components to be placed inside the enclosure. Therefore, one of the two parameters must be evaluated along with the “Verification of the equipment positioning inside the enclosure”.

The minimum distance of entries positioning is another parameter that should be carefully analyzed. Indeed, this minimum distance, defined by certificate parameters, in addition to ensuring the mechanical strength of the perforated wall, allows the installer to proceed with the proper tightening of the components into such entries (e.g., cable glands, plugs, reducers and/or adapters). Furthermore, the minimum distance to the boundaries of the maximum drilling is important to ensure non-interference with the thickness of the adjacent wall.

Have a look at the criteria which is usually adopted for such sizing.

The minimum positioning distance towards the borders of the maximum drilling can be better understood from the following illustration:
Stated as certain the dimensions "a" and "b", which are specific for each size of enclosure, the dimensions "x" will be determined according to the size of the component that you plan to place. As you can see from the drawing, it’s not necessary to comply with the dimensions marked by the hatching but it will be sufficient that the relative size of the outer diameter of the mechanical IP gasket (this only for the Metric threads which need gaskets) does not exceed (total support on the flat surface of the wall) over the drilling limit. On the other hand, for the conical threads, as it’s not necessary to lean on the surface of the wall, you can align the diameter of the hole to the edge of the drilling surface (x = ½ minimum thread).

Obviously, you have to consider the largest dimension "x ..", if the entries are of different sizes.

![Diagram](image)

**Description of the composition of the Panel Board and of the electrical features**

We assume that a customer made the following request. A lighting panel board, consisting of:

- n° 1 main incoming line 400Vac, 3Ph+N+Pe suitable for 20 kW nominal power and 10 kA breaking capacity;
- n° 10 output light branches, 230Vac, 2 Poles 2kW and related ELCB (earth leakage circuit breaker) 30mA;
- n° 1 XLPE/SWA/PVC of 4G 25sqmm feed armored cable, with outer armor diameter Ø 27,6mm and inner armor diameter Ø 20,8mm;
- n° 10 XLPE/SWA/PVC of 3G 6sqmm, outgoing feed armored cables for lighting circuits, with outer diameter Ø 16,9mm and inner diameter Ø 12mm.
- Environmental conditions: ambient temperature 45°C, height above sea level 30m.
- Temperature Class: T6.
- Method of protection: Ex d IIB.
- Incoming and outgoing cables: on the short lower side.
- Degree of mechanical protection: IP 65.

The first dimensional analysis is related to the sizes of the cable glands, depending on the diameters of the cables required.

- For the incoming feed cable, it’s necessary a double seals cable gland, type REVD3, size M32, with outer armor sealing ring range of 24 ÷ 31mm and inner armor sealing ring range of 18 ÷ 24mm.
- For the outgoing feed cables it’s necessary a double seals cable glands, type REVD2, size M25, with outer armor sealing ring range of 16÷24mm and inner armor sealing ring range of 12÷18mm.

The second dimensional analysis is the dimensioning of the circuit breakers, as the customer’s request is in value of power (kW).

- For main circuit breaker, you will have a rated current of 40A (I) at an operating voltage of 400VAC three-phase plus neutral (I = P/(V x 1,73 x μ x cosφ)).
- For outgoing lighting circuit breakers, you will have a rated current of 10A (I) at a operating voltage of 230VAC one phase plus neutral (I = P/V).

On the basis of these data, we can use our EJB series enclosure, size 5 (EJB-5), which is suitable to easily contain what is required, both in quantity of equipment to be housed inside and in compliance with the request to have input and output cables on the short lower side.
As you can see, whether adopting the "linear" or "triangle" criterion, there is the same type of capacity on the lower short side, with the possibility of a greater spacing than the minimum distance of coupling with the "triangle" disposal.

For sizing purposes, as shown in the drawing, is considered a distance that is not the maximum size of a single cable gland, but rather the minimum distance, as provided in the certificate, suitable for clamping with standards tool as a wrench.

**Number of control devices that can be placed on the lid of the enclosure**

The number of control devices that can be placed on the lid of the enclosure is a test that involves multiple issues, both mechanical and electrical. These are problems which require a correct approach in order to check that there is no interference with what will be housed inside the enclosure.

For illustrative and non-limiting purposes, we give below a short list of variables that are involved in this type of sizing:

- minimum distance \((P)\) applicable to operators on the cover, distance defined in the documentation of the certificate;
- minimum distance \((P1)\) applicable to the single component to be housed within the enclosure;
- minimum distance \((K)\) to be respected from the component to the inner wall of the enclosure;
- minimum distance \((K1)\) to keep from the terminal block to the wall of the input/output cables.

As you can well understand, consider only the minimum distance between the holes on the lid is sometimes not enough. In fact, if we consider the use of the enclosure as a signal and control panel, so without equipment to be placed inside the enclosure unless the terminal strips for input/output cables, should be sufficient to check the minimum distance between the operators and their depth, in order to not interfere with the dimensions of the terminal strip.
Maximum permissible dissipation, according to the class temperature and the ambient temperature of the project

The maximum allowable dissipation is a parameter intrinsic to the size of the enclosure which varies according to the ambient temperature and the class temperature (ambient temperature and class temperature values that must be provided by the customer at the time of the size request). Considering the quantity of equipment required and the coefficient of contemporaneity of the same in continuous operation, you can then proceed to the check, noting the dissipation of such equipment and terminal blocks. These values can be detectable in the technical documentation of the manufacturers of such equipment (values as dissipated power at a specific temperature, directly expressed in Watts, or as resistance value, expressed in Ohm). If these values are expressed in Watts, it’s enough to make the sum of these values, only for equipment working in parallel and simultaneously. If these values are expressed in Ohms, it’s necessary to convert the resistance value in power value in Watts, with a simple formula: \( P (W) = r \times I^2 \), in which “\( r \)” is the resistance value declared by the manufacturer “\( I \)” is the nominal working current under operating conditions. The sum of \( P_1 + P... n \) will provide the total value of the dissipated power (\( P_t \)) of the units operating in parallel and contemporary. This value is then compared with the value of maximum dissipation provided in the certificate, at specific ambient and class temperatures. If the "\( P_t \)" value will be less than the expected certification value, the sizing will be correct and suitable for the customer’s request. On the other hand, if the "\( P_t \)" value will be higher, we should proceed to a dimensional review with the use of an enclosure that meets the dimensional proportion.

**THE ELECTRICAL DIMENSIONING**

The problems relevant to a correct electrical dimensioning are many.

**Choice of sectioning and interruption devices.** This is the first function that the designer must perform properly because it affects the electrical sizing, both the main circuit breaker and the departures.

Notoriously, the sectioning and interruption devices are divided into three classes and more precisely: no load switch – isolator, on load switch – interrupter, thermo-magnetic circuit breakers.

**No load switch – Isolator**

These devices are suitable for the sectioning of the power line and can operate in the presence of voltage but without downstream load (defined as sectioning device -time dependent). They cannot open or close in the presence of a short circuit and they do not have a thermal resistance. The No load switch, as an incoming isolating function to the Panel board, it’s unwise, because unable to open with loads (Typical 1 in Scheme 1). However, it’s possible that the downstream circuit breaker opens without load (Typical 2 in Scheme 1), if the sectioning device is paired with an advanced auxiliary contact on the opening handle. Such contact must be returned to the circuit breaker located upstream of the feeding line, operating on the opening coil of such switch, in order to
open it in advance to the downstream isolator, by cutting off the power. In this case, there will be in addition, compared to other solutions described below: a cable, the opening coil and the advanced auxiliary contact.

**Scheme 1**

Typical 1  
\[ \text{-Q... -QG} \]  
Start-up sequence: first close-QG and then close -Q...
Sequence of isolation: first open-Q ... and then open-QG

Typical 2  
\[ \text{-Q... -QG} \]  
Start-up sequence: first close-QG and then close -Q....
Sequence of isolation: first open-Q ... and then open-QG

**On load switch - Interrupter**

These devices are suitable for the isolation of the power supply line both in presence of voltage and of nominal load (defined as sectioning device-time independent). They can open and close with the presence of load, but not in the presence of short-circuit. However, they must be able to withstand, without permanent deformation, the short-circuit current passing through.

The on load switch, as an incoming isolating function to the Panel board, it’s recommended as it can open with loads (Typical 1 in Scheme 2). The main reason for this choice is due to the concept of protections coordination. In fact, if there’s a thermo-magnetic circuit breaker upstream, placing an on load switch downstream, ensures the selectivity of action, avoiding the opening under short circuit in one of the two upstream-downstream points, in an unpredictable way (Typical 2 in Scheme 2).

**Scheme 2**

Typical 1  
\[ \text{-Q... -QG} \]  
Sequence of operation: both organs can be closed without any specific sequence
Sequence of isolation: both organs can be opened without any specific sequence
Remark: logic says that you have to open the disconnectin switch that is located closer to the load below

Typical 2  
\[ \text{-Q... -QG} \]  
Sequence of operation: both organs can be closed without any specific sequence
Sequence of isolation: both organs can be opened without any specific sequence
Remark: in this case it will not be possible to predetermine which circuit breaker will open in the presence of a short circuit

**Thermo-magnetic circuit breakers**

These devices are suitable for isolation of the power supply line in the presence of voltage, nominal load, overload and short circuit (defined as sectioning device-time independent). They meet the operating cycle O-CO (according to IEC 60947-2 standard O = open; CO = Closed-Open) and are able to open and close in case of short-circuit.

The thermo-magnetic circuit breaker, as an incoming isolating function to the Panel board, is able to open with the presence of loads and, also, in the presence of short-circuit (Typical 1 in Scheme 3).

Thermo-magnetic circuit breakers can be chosen as general protection of the panel board if it’s not installed another circuit breaker upstream but a device not able to open and interrupt the supply line in presence of over load.

**Scheme 3**

Typical 1  
\[ \text{-Q... -QG} \]  
Sequence of operation: both organs can be closed without any specific sequence
Sequence of isolation: both organs can be opened without any specific sequence
Remark: logic says that you have to open the disconnectin switch that is located closer to the load below

Typical 2  
\[ \text{-Q... -QG2} \]  
Sequence of operation: both organs can be closed without any specific sequence
Sequence of isolation: both organs can be opened without any specific sequence

Remark: The incoming cable is not protected against short circuit generated on the cable, except with the activation of the main circuit breaker -QG of the upstream switchgear.
and short circuit *(Typical 2 in Scheme 3).* In this case, the upstream main switch (-QG) will protect from over loads and short circuits. This choice is generally not recommended, *unless specifically requested by the customer.*

**The rated operating current** \((I_e)\) is the value of current (in amps) that the components absorb in operation, continuous operation 24 hours and it is the value that will be considered for a correct dimensioning of the electrical conductors inside of the enclosure. It should be considered that this value *must be communicated by client at the time of dimensioning request* and, depending on the temperature and the temperature class in which the Panel Board will operate, the designer will have to properly size the conductors and components based on these data.

- **“Thermal rated current \((I_{th})\)”** means the rated current that the component is able to withstand during a continuous service and to a reference temperature. These data can be found in the technical documentation of the manufacturer of such components.
- **“Rated current \((I_e)\)”** means the rated current that the project has provided to operate to the component (current that normally differ much from the thermal nominal current). This nominal current \((I_e)\) must obviously be compared to the temperature in which the component will operate (this temperature is NOT the temperature but is the temperature of the project but derated for use in confined space and with little or no ventilation).

*The breaking capacity \((I_{cn})\) in kA and time of intervention \((s)\) are basic values for the correct sizing and *must be communicated by client at the time of dimensioning request.* Such values determine all the electrical dimensioning and, therefore, are considered fundamental for the analysis of calculation.*

**Breaking capacity \((I_{cn})\)** means the rated short-circuit capacity of the component, in accordance with CEI EN 60947-2 standard (value expressed in kA) and the response time in seconds.

The choice of **trip curves of thermo-magnetic** or magnetic circuit-breakers is also an important part in the sizing and it’s a parameter, such as the breaking capacity \((I_{cn})\), which must be communicated by client at the time of dimensioning request.

**Tripping curve breakers** means the characteristic curve for type of use as following:

- **Curve B:** When there’s a generator able to provide only a low short-circuit current.
- **Curve C:** Standard loads.
- **Curve D:** When the starting current is of high intensity (5 to 7 times the rated current).
- **Curve K:** Protection of users with high inrush currents (motors, transformers).
- **Curve Z:** Protection of electronic circuits.
- **Curve MA:** Motor protections (circuit breakers with magnetic function only).

The sizing depending on the **environment temperature**, according to temperature class and as per the subdivision of IEC 60079-0 or EN 60079-0 standards, is a further important parameter for a correct analysis. In fact, the current capacity of the devices is strongly influenced by the variation of temperature, which in turn undergoes a reduction in function of the temperature class, class of temperature that *must be communicated by client at the time of dimensioning request.*

*“Ambient temperature”* is intended the project value that must be communicated by client at the time of dimensioning request.

*“Temperature class”* means the value, expressed in °C, to which refer for the control of the maximum surface temperature that the outer surface of the housing can reach for its correct operation in an environment, classified as:

\[
\begin{align*}
T1 &= 450°C \\
T2 &= 300°C \\
T3 &= 200°C \\
T4 &= 135°C \\
T5 &= 100°C \\
T6 &= 85°C
\end{align*}
\]
temperatures which must not be exceeded due to overheating of internal components.

The coordination of electrical/filiation and selectivity is another of the dimensional variables that must be considered for the calculation. In fact, if you opt for sizing all Thermal-magnetic circuit breakers according to the breaking capacity required, provided that it would be technically correct, you would have a overheating of components and electrical conductors, according to this value. However, the construction technologies have made that, with a proper coordination of the circuit breakers, you can get, downstream of the main circuit breaker, a lower short circuit current and, consequently, adopt downstream circuit breaker suitable for the underlying value. This, in addition to allowing a suitable dimensioning, leads to a not negligible economic saving.

The sizing according to the maximum allowable power dissipation (W) is essential for a proper sizing because it affects the electric parameters of the certificate. In fact, in order to get the certificate, a series of tests have been performed in order to verify the maximum allowable thermal dissipation in the enclosures, as a function of both the temperature class and the ambient temperature. For this test, therefore, have to be taken into account the equipment individual dissipation that will be installed inside the enclosures and their sum, which mustn’t, in any case, exceed the expected value of the certificate. Obviously these values, detectable from the technical documentation of each manufacturer, will have to be remeasured as a function of the temperature and the downgrading for installation under a prevented ventilation.

"Maximum power dissipation of the component and/or equipment, at the temperature of the project (W)" means the value of thermal dissipation of that object. This value may be found in the manufacturer’s technical documentation and downgraded or outclassed in terms of its value, to a specific temperature to bring back to the temperature value of the project. You should observe a greatest attention to this sizing, whereas normally the components and/or equipment have a value of thermal dissipation for an installation in free air at a temperature of 20°C or other temperature stated by the manufacturer.

The verification of the energy which pass through the electrical conductors (I^2t = K^2 S^2) is of great importance for the purposes of a correct dimensioning because all the currents caused by a short circuit that is present in any point of the circuit, must be interrupted in a time not greater than that which brings the wires to the allowable temperature limit. Therefore, it will be necessary to test the conductors based on that value. Such value of I^2t must be specified by the manufacturer of the protective device.

"Through energy of electrical conductors" means that the electrical conductors must be properly sized to prevent that, overheating generated during the working or during the event of over current due to a malfunction (short circuit), may be the cause of the enclosure surface temperature increase and, consequently, source of ignition the outer atmosphere. This sizing must be depending on the energy I^2t which pass through each wire in extreme short-circuit. This value can be found in the manufacturer’s technical documentation but it needs a specific next calculation, depending on the temperature class and on the temperature of the project.

The coefficient of contemporaneity is another of the parameters necessary for the correct electrical sizing. This coefficient must be communicated by the client at the time of dimensioning request. It determines, in function of the simultaneous operation of the equipment, the value of the current that must be considered for sizing the electrical conductors. For contemporary, we mean the ability to be operative in continuous parallel service.

The dimensioning of the auxiliary transformer for secondary circuits, where necessary and in the presence of auxiliary circuits generated within the Panel Board, is another of the analysis parameters. This calculation is performed by summing the loads and the contemporaneity factor that they can have, considering also the peak of maximum absorption of the biggest start-up device in addition to the sum of the total loads.

The nominal voltage (Ue) is the value of the operating voltage that defines the characteristics of the use of a specific circuit. All electrical equipment that are going to be used, shall be constructed in order to be capable of operating at this voltage value, with the tolerances set by the reference standard which in principle correspond to ± 10%, unless otherwise specified in the customer request.

The insulation voltage (Ui) is the efficient value of the insulation test voltage assigned by the manufacturer of the component and/or equipment, which determines the resilience of its isolation and surface distances (the shortest distance measured along the surface of an insulator interposed between two conductive parts).
The nominal frequency (Hz) is the frequency value at which report the operating conditions of the system. All electrical equipment that are going to be used, shall be constructed in order to be capable of operating at this frequency, with the tolerances set by the reference standard which in principle correspond to ± 5%, unless otherwise specified in the customer request.

The electromagnetic compatibility of the components and/or electrical equipment is one of the requirements in the use of electrical equipment which must be taken into consideration.

"Electromagnetic compatibility of components and/or electrical equipment" means that, in addition to the various requirements of the ATEX and IECEx Directives, all components and/or electrical equipment must also meet: the machinery Directive 2006/95/EC, the Directive on electromagnetic compatibility (EMC) (2004/108/EC), the local electrical reference such as EN 61547 or IEC 61547 (intrinsic immunity) and the protection from over-voltage transients networks, according to the values specified in the EN 61547 or IEC 61547 Standards (immunity).

Sizing the preheating is a variable function that is applied only when the ambient temperature is negative (from -20°C up to -60°C). The designers have to consider it, even if not expressly requested by the customer, but necessary for the correct operation of the equipment at this negative temperature.

All electrical and electronic equipment are built to operate at specific climatic conditions which may vary from manufacturer to manufacturer but, in practice, the range is from -20°C to +40°C.

When the temperature is positive, must be carried out, as previously described, the realignment at the design temperature, compared to the functional temperature stated by the manufacturers.

When the temperature is negative, must be carry out the verification with the values declared by the manufacturers and, if this temperature does not fall within the design value, a pre-heating must be provided in order to ensure the full functionality of the equipment.

The following parameters should be considered:

- internal dimensions of the enclosure;
- thickness of the metal;
- material of the enclosure;
- coefficient of thermal conductivity of the enclosure material;
- inside air convection (if applicable);
- outside air convection;
- internal/external surface;
- internal request temperature;
- external project temperature;
- material from external insulation (if required).

We conclude our presentation stating that the above description is intended as a brief introduction to this issue. We did not want to dwell in the deepening of each specific activity, but only highlight how many problems contribute to a correct sizing of the flameproof enclosure suitable for panel boards.

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