Product Safety - Physical and Mechanical Considerations.

In this article we shall provide a general explanation to some of the physical and mechanical design considerations. This article does not attempt a total solution for any specific safety standard but will help the designer eliminate some of the most common causes of non-compliances.

In an attempt to simplify the issues involved we will first consider the product safety implications for an idealised enclosure. Our idealised enclosure is all metal and has no doors or openings, it is permanently fixed to a surface - and hence stable. We will then consider how practical items (such as openings, plastic components and doors) will impose design constraints upon us.

Definitions

A fire enclosure is part of the equipment that is designed to minimise the spread of fire. Fire emanating from a point source, is usually assumed to fall vertically within a 5° cone whose apex is that point. A chimney can fulfil the requirements of a Fire Enclosure.
A mechanical enclosure is part of the equipment intended to prevent injury to an operator or service engineer due to mechanical or other physical hazards.

An electrical enclosure is any part of the equipment that prevents contact with parts at hazardous voltage, current or energy levels.

There is no need for any of these items needs to enclose the entire product - sometime a rectangular metal plate is all that is required to eliminate, or to contain the hazard.

The 'Perfect Enclosure' - Fixed

This all-metal enclosure will provide a 'perfect' *mechanical*, *electrical* and *fire* enclosure. Therefore our most important considerations are the amount of fuel that it contains, temperature, electrical contact between internal sources and the outer surface, and whether its surface is hazardous.

We limit fuel by ensuring that no plastic part inside the enclosure has a flammability rating worse than UL 94-V2.

We carry out the "Steel-Ball" and a variety of force tests to confirm that creepage and clearance distances are compliant, even when the "250N Force" or the "800N Step" tests distort the outer surface of the enclosure.

Check that external edges of the enclosure will neither cut nor scratch skin, nor damage electrical insulation.

Finally confirm that external temperatures are within the maximums given for contact.

The 'Perfect' Enclosure - Free Standing

The enclosure is now free to move but must not topple (during transit, when someone leans against it, or steps upon it). We check compliance by testing that the equipment does not topple if subjected to the 10 ° tilt, a force of 20% of its mass (up to 250 N) and the 800 N step test.

The Non-Metallic Fire Enclosure

Up until now we have been able to ignore the detailed requirements for Fire Enclosures: for equipment that is fixed, **or** weighs more than 18kg, the Fire Enclosure must be UL 94-5V; for equipment that is not fixed **and** weighs less than 18kg the flammability rating of the Fire Enclosure may be only UL 94-V1.

Incorporating a Mains Inlet Socket into the enclosure

Provided that the inlet sock (or similar component) has an appropriate IEC component approval we can usually assume that the component will maintain the integrity of the fire enclosure, we may need to consider the mechanical strength of the component and to conduct an impact test on the component.
We will also apply a Steady Force Test (30 N is a typical force) to ensure that components do not yield under pressure to expose hazardous live or moving parts. Where plastic parts are involved, this test is repeated at the relevant maximum temperature defined by this Standard.(Some materials become flexible at elevated temperatures and it is not uncommon for plastic parts to fail this test at elevated temperatures).

Incorporating a Cathode Ray Tube into the enclosure

Select a CRT that has appropriate European approval and complies with IEC 65.

Adding Holes, Apertures and Openings

Holes should not be located above hazardous bare parts (because a short circuit could occur if something conductive was dropped in), or under components that require a fire enclosure (because fire could escape). If holes are permitted, the maximum hole sizes are contained within the relevant standard.
Next we must check access using the *test finger*, *test pin*, *test chain*, or whatever else is identified by the standard to verify that we cannot access any hazardous voltage, current, energy, moving part, or anything else that could inflict injury.
Note that if the hazardous moving part is required for the function of the equipment and the process, (e.g. removing the hazardous moving part would destroy the functionality of the equipment) and where the hazard is obvious to an operator then a warning in the local language or international signs may be considered acceptable by the standard.
Note: if fingers, jewellery, clothing can be drawn into moving parts then there must be a suitable means to stop the equipment.
When we add an aperture, or a plastic window, we have the potential to destroy the *fire enclosure* or the *electrical enclosure* properties of our enclosure. Impact testing with a *steel ball* or an *impact hammer* will verify that, during "reasonably foreseeable" use there should be no breach of the enclosure.

Ensure that the flammability of the plastic the same as, or better than, that required by the fire enclosure to ensure that internal fire hazards are contained.
There may be strict rules for openings for ventilation and cable entries - check the relevant standard for the detailed requirements: do consider combining requirements for a number of standards to improve the safety of the product. (e.g. many computer monitors designed to met EN 60950 also comply with the "Test Chain" test in EN 60065.)

Cable Entry into a Fire Enclosure

Conduit Entry - if the conduit and fixing hardware are all-metal then the fire enclosure should be preserved. ***Question*** *what will prevent the customer fitting a plastic conduit or conduit blanking-plugs of the wrong flammability rating?*

Cable Entry Strain Relief Grommet - some standards will accept flammability ratings as low as UL 94-HB: whilst this rating is acceptable if the gland is mounted outside of the fire enclosure it may be better to specify glands with the (highest) UL 94-5V flammability rating. These glands will be suitable for all enclosures: and will reduce the likelihood of the wrong part being fitted.
Labyrinth Entry - this comprises a system of gaps with baffle plates designed to ensure that molten or burning material is contained within the fire enclosure.
Sockets with appropriate agency approvals are discussed above.

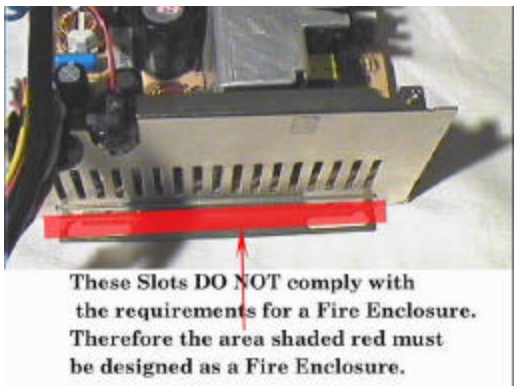
Adding Doors and Panels

If the door (or panel) has a lock which requires a key or a 'tool' then internal parts are "Service Accessible". We open the door to the worst possible position and repeat the toppling tests (250N and 800N), because the extra leverage provided by the door, or racks, may cause the equipment to topple.
If the equipment has racks on sliders then these are pulled out (as many as possible) and the tests repeated.
If stabilisers are necessary they can be physically installed by "Service" personnel - they MUST operate automatically if the "Operator" can access these parts.
If the "Operator" can remove a panel (using any tool provided or required by "Operator Actions") then the internal parts exposed are "Operator Accessible". Some standards allow us to use the "Lightening Flash" symbol ISO 3864, Number 5036 to warn "Operators" not to remove the panel.
If a door can be opened by the "Operator" then we must repeat the "Operator" accessibility tests using the *test finger*, *test pin*, *test chain*, etc. inside the enclosure to show that there are no "Operator Hazards".
It is usually permitted to add interlocks so that hazards are automatically rendered safe when a door is opened. All safety interlock switches should be the *Positive Displacement Type* (please note that a common failure-mode for a micro-switch is a welded contact) the safety switch should also have an appropriate safety mark or approval.

Any interlock, emergency stop, safety or warning label is a safety critical item and should be controlled accordingly.

Components that require a Fire Enclosure

These include all wound components, open contacts of relays and switches, certain types of wiring, resistors, semiconductor devices, fuses and other over-current protection or current limiting devices.



These components should be mounted 'above' a fire enclosure: we may assume that molten or burning material emitted from these components will fall under gravity, but most of the standards allow for them to fall up to 5° from the vertical. So we need to make a vertical projection of the component and where this 5° shadow strikes we must place a *fire enclosure*.

At this point we will ignore the complexities of fire enclosure design and simply place a sheet of metal, - or plastic of flammability rating UL 94-V1 (for movable equipment less than 18kg) or UL 94-5V (for equipment that is fixed or weighs more than 18kg) - under the potential fire-source. For electronic components a UL 94-V1 PCB can provide a Fire Enclosure.

It may be helpful to group these potential fire sources together in ac effort to reduce the overall size of the Fire Enclosure that will be required.

Internal Components

Before we add components and sub-assemblies we need to investigate the circuits to discover which of the components can become hot during normal use and also under single-fault conditions. (Abnormal testing, under single fault conditions is vital to our understanding of potential fire, and other, hazards. This analysis and testing will make-up a significant portion of product safety test plan.)

It is important to note that few of our standards provide a useful definition of what constitutes 'hot'. This is partially due to the fact that the ignition-point of materials differ. Therefore the designer may first need to employ *due diligence* in determining a strategy for this analysis and investigation.

As a general rule locate things that get 'hot', or which emit molten or burning material at least 13 mm clear of the sides of enclosures and the more flammable parts. (Parts with flammability ratings of less than UL94-V1 should be separated from potential ignition sources by a distance of at least 13 mm.)

Adding Non-Flammable Liquids

The design must accommodate overfilling. In particular we must ensure that any spillage does not create an electrical or any other hazard. A typical overfilling test would comprise pouring an additional 15% of the total capacity over a period of one minute. Make sure that the system cannot build-up excessive pressure.

Adding Flammable Liquids

Minimise the volume; and select a liquid with a high flash-point. (Typically no more than 5 litres or an 8 hour supply; hydraulic, or lubricant should have a flash-point greater than 149 °C, other liquids will generally have a flash-point greater than 60 °C. Do not allow the liquid to be pressurised so that it could become 'atomised' (and potentially explosive).
Seal the reservoir and test the internal atmosphere (typical limits are less than 25% of the explosive limit).

Labels

Now is a good time to start considering labelling. Rating and safety information must be clear and placed on parts that cannot be removed, interchanged or assembled so the warning is hidden or confused. Ensure there is a suitable surface to which labels can be affixed.

Components that do not require a Fire Enclosure

Our enclosure may, under certain conditions, not need to meet the requirements of a *Fire Enclosure*. These circumstances usually rely upon a *Limited Lower Source* - typically this will require that the maximum current, supplied by a Safety Extra Low Voltage (SELV) source, will be limited to 200 mA.
Whilst a *Limited Lower Source* can provide a useful technique to avoid the need for an (expensive) Fire Enclosures; we must note that even 200 mA can provide up to 12 Watts of power. Even this relatively low power can produce a significant temperature rise within small components. As a result of these potentially 'high' temperatures we must be careful, seek expert help and conduct a thorough investigation.