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FROM ETC-F CODE TO EPR FLAMANVILLE FIRE PROTECTION IMPLEMENTATION

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ABSTRACT

Because fire is one of the main hazard in a nuclear power plant, EPR (European Pressurized Reactor) in France and China are designed to prevent fire safety issues accordingly to the ETC-F code (EPR Technical Code for fire protection). ETC-F defines generic guidelines such as that fire compartmenting is mandatory and set fire resistance requirements for each fire compartment but leaves open how this requirement must be fulfilled. Consequently, it makes it easy to be adapted to any local regulations. At Flamanville 3 site (France), only European standards are allowed For fire-resistant penetration e.g, materials must comply with EN 1366-3 standard, meaning the sealing materials have to be fully qualified under the EN umbrella to obtain a certification (CE marking for example).

However, on-site configurations are usually out of the direct field of application which is given by the EN standards to any fire certified product. Consequently, for fire resistant penetration, a lot of field data must be collected and analysed prior any implementation of material. NUVIA PROTECTION has developed a computer aided tool on a tablet to collect and process the data and generate a report pointing out the issues about the fire certification. If needed, a list of adaptations or modifications of the site configuration is proposed. Once the best proposal is agreed, installation of materials can take place.

FIRE CODE AND EUROPEAN STANDARDS

The role of internal hazards in the safety of Nuclear Plants has been managed for years and is still in an ongoing improvement process. Among them, fire hazard is one of the major issue since both damages and consequences may be huge in case of fire. The design of nuclear power plants in France has been guiding by codes for decades using RCC-I code on 900 MW to 1450 MW former NPP, ETC-F code for currently built EPR and RCC-F for future plants. Initially written by EDF fire experts, ETC-F and RCC-F have been produced by a dedicated working group within the AFCEN organization (French Society for design, construction and in-service inspection rules for nuclear island component). More than 650 experts from the nuclear market are part of the AFCEN to work out the guideline codes on electrical, mechanical, civil engineering and fire issues. Last release of RCC-F fire code was published in 2017 but a new release is expected for 2020.

The fire protection is based on the defence in-depth approach following the 3 main next principles:

- ✓ Prevention of fire (use of materials with low reaction to fire, limitation of fire loads, use of cable with low fire propagation. …);
- ✓ Mitigation of ignited fires (fire detection, fire extinguishing system, manual means of firefighting);

- ✓ Limitation of damage and propagation of fire (fire protection to suppress fire loads, fire compartmenting, prevention of common mode failures by routing or by the use of functional fire protection or containment of non-friendly environmental substances).

However, the code gives only general principles and requirements (see table 1) but does not prescribe the technical solutions, products, materials, systems which allow these principles and requirements to be fulfilled. It makes the code very easy to be adapted to local regulations. For example, in Europe, fire issues are regulated with the Construction Product Regulation (CPR). Twenty years ago, the European Union gave a mandate to CEN (European Committee for Standardization) to published new standards. Technical committee 127 was charged with the fire safety in building topic with the goal to withdraw any conflicting national standards by May 2005. Right now, 78 standards concerning fire safety have been published and regularly updated. These standards are divided in 2 main categories:

- ✓ Standards for fire classification
- ✓ Standards for fire testing

Fire classification concerns reaction to fire and resistance to fire.

EN 13501-1 standard deals with reaction to fire and defines the property of the material to burn, to produce smoke and droplets. Classification is made with 3 group of letters:

- ✓ First group: A1, A2, B to F for burnability (from non-burnable to easy burnable)
- ✓ Second group: S + a number from 1 to 3 (from low to heavy smoke emission)
- ✓ Third group: D + a number from 0 to 2 (from low to high droplet)

EN 13501-2 to 6 standards deal with the fire resistance and define the expected performance and associated duration in case of fire. The principle classification is an association of letters and a number for the time in minutes. The most common types of classification are:

- ✓ R: loadbearing capability (no loss of structural stability)
- ✓ E: Integrity (no crack or opening, no sustained flame, no ignition of cotton pad)
- ✓ I: Insulation (limited raise in temperature)
- ✓ P: functionality (can be operated during fire)

The classification time range is 15, 20, 30, 45, 60, 90, 120, 180, 240, 360 minutes.

Table 1: Fire resistance requirements (ETC-F 2013).

	SFC	SFE	SFS	SFA *	SFI **
Structure	R 120	R 60	R 120	R 60	R 60
Loadbearing walls	REI 120	REI 60	REI1 20	REI 60	REI 60
Non-loadbearing walls	EI 120	EI 60	EI 120	EI 60	EI 60
Doors	EI1 120 Sm C5	EI1 60 Sm C5	EI1 120 Sm C5	EI1 60 Sm C5	EI1 60 C5
Penetration	EI 120	EI 60	EI 120	EI 60	EI 60
Fire dampers	EI 120S	EI 60S	EI 120S	EI 60S	EI 60S
Joints	EI 120	EI 60	EI 120	EI 60	EI 60
Functional enclosures – cases	P 120	P 120	P 120	N/A	N/A

FIRE RESISTANT PENETRATIONS TEST METHOD AND CONSTRAINTS

According to table 1, there are 2 requirements for fire resistant penetrations (EI 60 and EI 120) depending on the classification of the room. The test method for fire resistant penetration is described in EN 1366-3 standard. EN 1366-3 is a very opened standard since it doesn't impose the specimen to be tested. The test specimen must be designed to cover a given field of direct application but the field of direct application must be chosen to fit on-site configurations. It is a key process for product certification but not an easy one because certification is quite often required before having a full picture of on-site configurations.

All Penetrations

The primary input data for designing any penetration test specimen are:

- ✓ Orientation (wall, floor)
- ✓ Type of wall/floor (rigid, flexible)
- ✓ Thickness of wall/floor
- ✓ Size of the opening
- ✓ Distance between service support and wall/floor

Test results are only applicable to the orientation in which the penetration seals were tested. So, test specimen must be tested in both floor and wall orientations.

Since walls and floors of EPR are made of reinforced concrete, it is considered by EN 1366-3 standard as a rigid supporting construction. Thus, the following rule of direct field of application is the following: "Test results obtained with rigid standard supporting constructions may be applied to concrete or masonry separating elements of a thickness and density equal to or greater than that of the supporting construction used in the test" (EN 1366-3 standard). Supporting constructions of the test specimen were made of reinforced concrete with the minimum thickness needed to install the sealing material.

Concerning the size of the penetration, the field of direct application allows to have smaller linear dimensions than that tested but not larger ones. There is only one exception to this rule: "for floor constructions, results from tests with a penetration seal length of minimum 1 000 mm apply to any length as long as the perimeter length to seal area ratio is not smaller than that of the tested penetration seal." (EN 1366-3 standard)

In general, test specimen shall be designed with the maximum size encountered on site. By experience, it is an input data which is not easy to get at an early design stage of the buildings.

The last input data is even more difficult to get because the distance between the surface of the wall/floor and the first supporting device of the services is set at a very late stage during design or construction of the building. Except if design rules were defined at a very early stage of the project, seismic resistance purpose or lack of free space can make this distance unpredictable. However, as stated by the direct field of application, the distance from the surface of the wall/floor to the nearest support position for services shall be as the one tested or less.

As a conclusion, size of the opening and distance between first service support and wall/floor were the 2 key parameters the more difficult to get.

The field of direct application is also linked to the type of services in the penetration (pipes, cables…) as described below.

Pipe Penetrations

The primary input data for designing pipe penetration test specimen are:

- ✓ Material of the pipe
- ✓ Wall thickness of the pipe
- ✓ Diameter of the pipe
- ✓ Pipes arrangement
- ✓ Distance between pipes
- ✓ Distance between pipes and edge of the penetration

In case of a metal pipes, a pipe material covers pipe materials with a thermal conductivity lower than that tested, subject to the material having a melting point at least equal to that of the material tested or greater than the furnace temperature achieved at the required classification period.

In EPR referential, material of metal pipe can be steel, stainless steel and copper. Stainless steel can be covered by steel according to the above field of direct application but copper doesn't. Copper may cover steel and stainless steel but the range of diameter and thickness existing of copper pipes makes difficult to use only copper pipes in the test specimen. So, both copper and steel pipes were chosen.

In case of plastic pipes, no field of direct application exist so you get what you test so all materials (PVC, PE, reinforced glass fibre composite…) must be tested.

Thickness and diameter and linked data. In case of metal pipes and in order to cover a range of diameters and thicknesses, three pipes must be included in the test specimen (see Figure 1). Thickness and diameter may be interpolated for pipes with diameters and wall thicknesses between those tested (A, B and C).

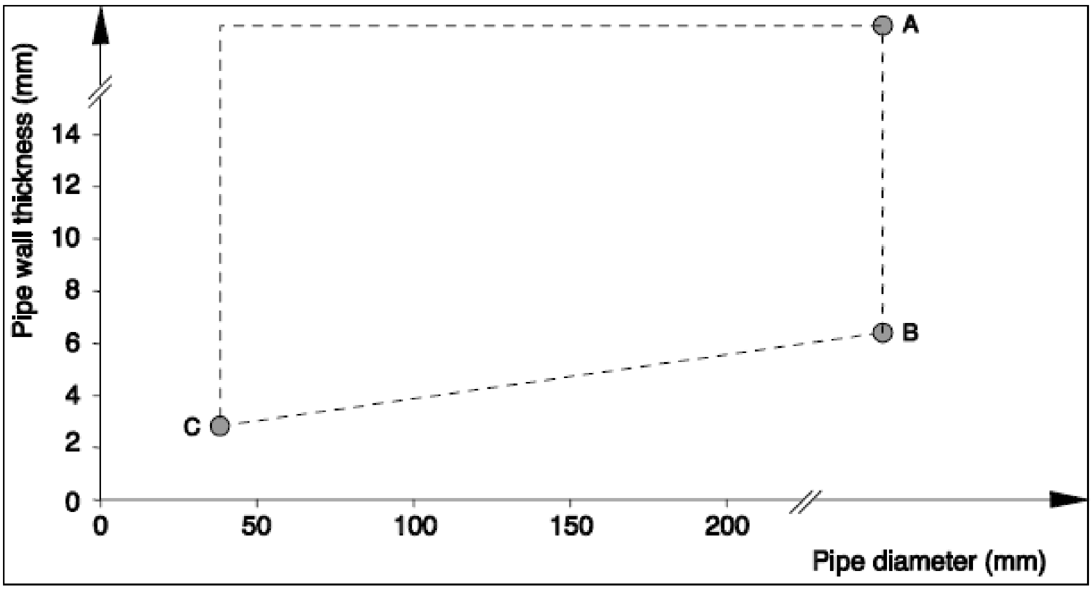

Figure 1: pipes A, B and C (EN 1366-3 standard)

In case of plastic pipes, the same kind of rules applies except that pipe C may be omitted in some specific cases.

Distances and pipe arrangements are other key parameters. Arrangement of pipes may be aligned (as option 1) or cluster (as option 2). The field of direct application of option 2 covers option 1 so it was retained option 2 for the test specimen.

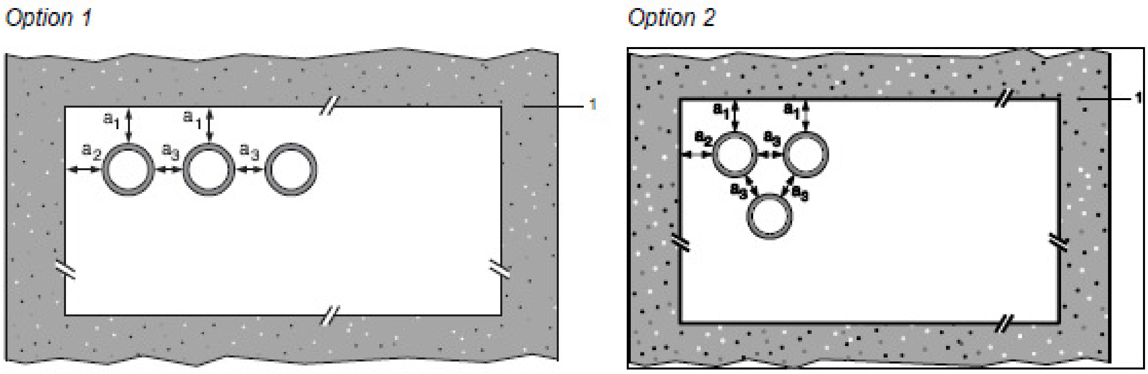

Figure 2: pipes arrangement and distances (EN 1366-3 standard)

Distances a1 to a3 are considered as minimum clearance so, the field of direct application allows to increase the distances but distances cannot be smaller than the minimum working clearances used in the test. However, it is not so much difficult to set these distances to almost 0 mm in the test specimen.

As a conclusion, material, wall thickness and diameter of the pipes were the 3 key parameters the more difficult to get.

Cable Penetrations

The primary input data for designing any cable penetration test specimen are:

- ✓ Type of cables
- ✓ Size of cables
- ✓ Type of cable support
- ✓ Distance between cable and cable support
- ✓ Distance between cable supports
- ✓ Distance between cable and edge of the penetration
- ✓ Distance between cable support and edge of the penetration

For the first 2 parameters, EN 1366-3 standard recommends either to use a standard test specimen configuration or a non-standard one. For EPR referential, the non-standard configuration (Figure 3) was chosen because of the specific type of cables (material of sheath, large diameter) and arrangement of cables on their supports (power cables not mixed with I&C cables…).

Concerning the type of supports, the field of direct application states that results obtained from tests where the supports pass through the seal are applicable to those situations where the support does not.

Like for pipes, distances are the other key parameters. Distances are considered as minimum clearance so, the field of direct application allows to increase the distances but distances cannot be smaller than the minimum working clearances used in the test.

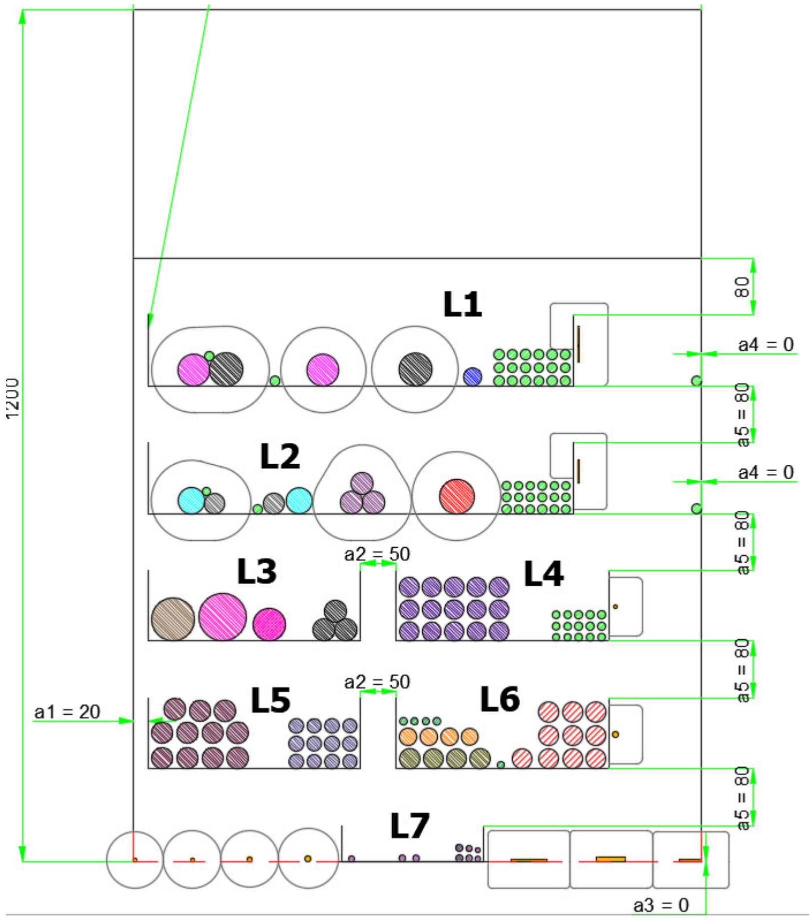

Figure 3: cable arrangement for electric test specimen

As a conclusion, since a test specification was published for EPR referential associated with design rules for electric layout, the design of the test specimen was not an issue.

Other Services Penetrations

Since bus bars or cable box systems were not concerned with fire rated penetration, the main remaining issue was with the mixed penetration. We will not enter in detail the standard but as a basic assumption, the field of direct application is a mix of pipe and cable penetration rules.

ON SITE EXPERTISE TOOL FOR FIRE RESISTANT PENETRATION

Fire certification is based on a field of direct application given by the EN standards according to the design of the test specimen. So, the major issue is to checked if the field of direct application is respected otherwise, the certification is meaningless. This expertise must be done for all the penetrations which number is about dozens of thousands in an EPR. Furthermore, for a single penetration, more than 10 parameters must be registered and controlled. Achieving this task manually would have required a huge amount of man power and time, not only to visit the penetrations but to find a solution in case of problem

For this purpose, NUVIA PROTECTION has developed and computer-aided software on a tablet. Basically, the detailed field of direct application and the associated rules have been entered in a database for all the NUVIA PROTECTION sealing materials. This work was performed under the engineering department control. Once approved, this database was loaded on the tablet.

To help collecting the important data, a graphical user interface was developed. Once all the data collected, a first conformance analysis is performed at the end of the expertise. A predefined sealing material has been chosen based on the fire-resistant penetration requirements (water or air tightness, resistance to chemicals, radiation shielding…). If the field of direct application of the pre-defined material presents an issue, another material can be proposed. For example, is one of the distances is not line with the field of direct application of mortar type sealing material, a foam type material may be selected for a more suitable use. This is only possible if both materials fulfil the penetration requirement equally. If no other material can be proposed or if other materials have also issues with their field of direct application, the next step is to make a bunch of proposals of modification. These proposals are registered in the tablet. Finally, an expertise report including the chosen sealing material properties, the checked data and eventually in case of issues, the proposals is automatically published using a template and given to our customer.

After analysis of the report, either proposals of modification are approved by our customer or they are not approved. In the first case, once modifications are done, implementation of the sealing can be done. In the other hand, a modification of the field of direct application may be done case by case by a specific fire assessment. These assessments are made by a third-party body based on the actual site configuration and dedicated to this configuration only. If an assessment is not possible, the field of direct application must be enlarged by a new test specimen.

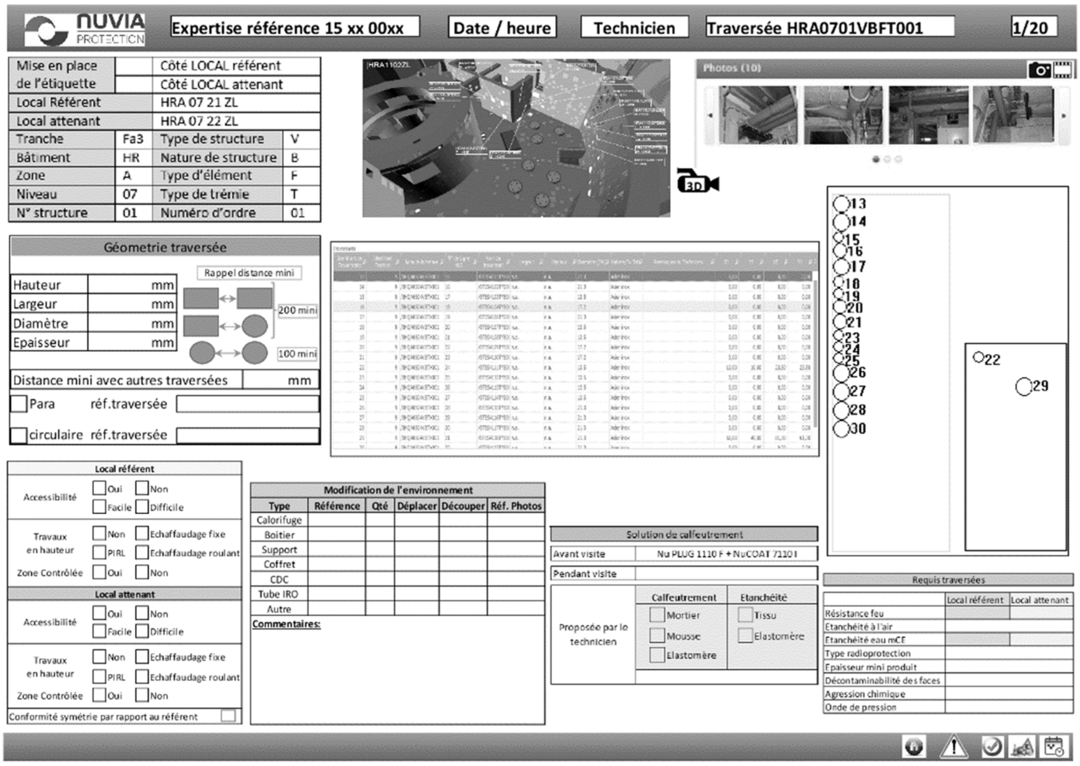

Figure 4. Overview of the collected data.

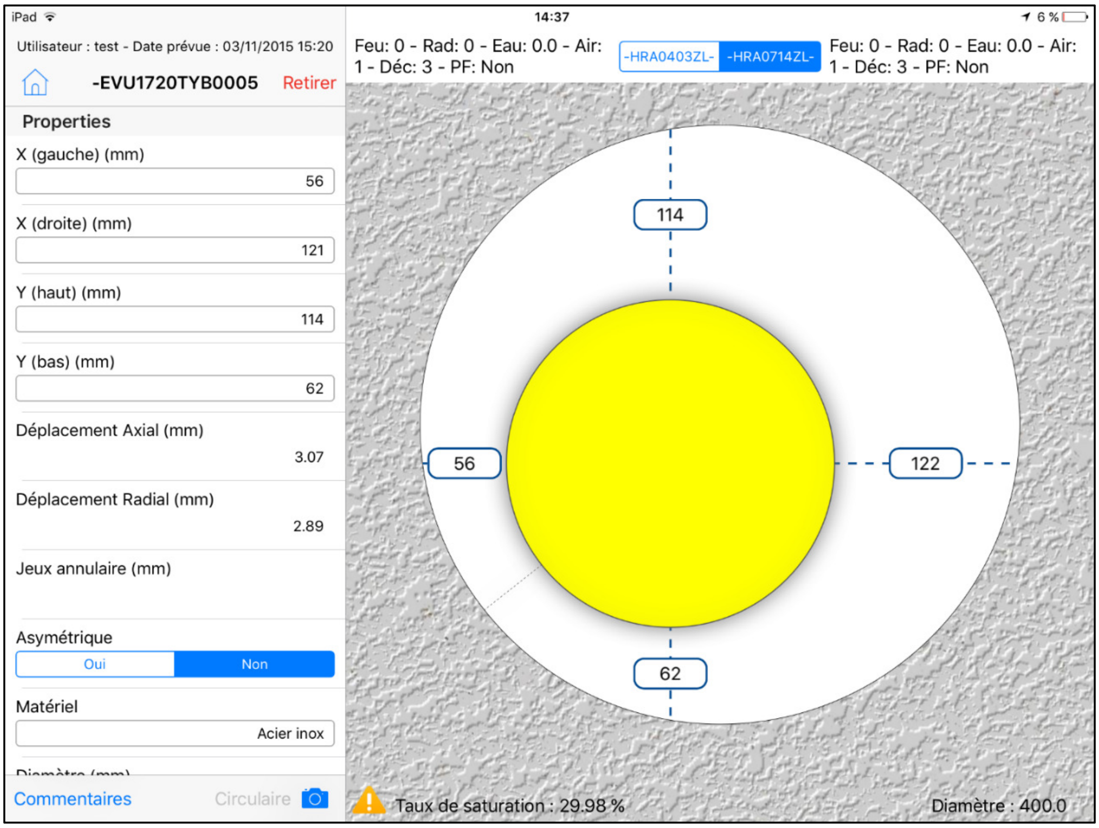

Figure 5: example of distance between pipe and edge of penetration input data

CONCLUSION

ETC-F is a generic design code for the fire safety of nuclear power plants (PWR reactor). It gives the fire protection requirements but leaves the door opened to any country or operator to choose which standard or specification will allow to demonstrate or certify the required fire rating. Then, the field of direct application must be in accordance with on-site configurations, otherwise, the certification of the materials or systems are not valid. As an example, for fire rated penetrations, NUVIA PROTECTION has developed a computer aided tool to guaranty the conformity of the on-site configurations according the European certification of its products. If an issue is detected during the expertise of the penetration, it can be solved by choosing another material, asking for modification, obtaining a fire assessment of performing a new fire test.

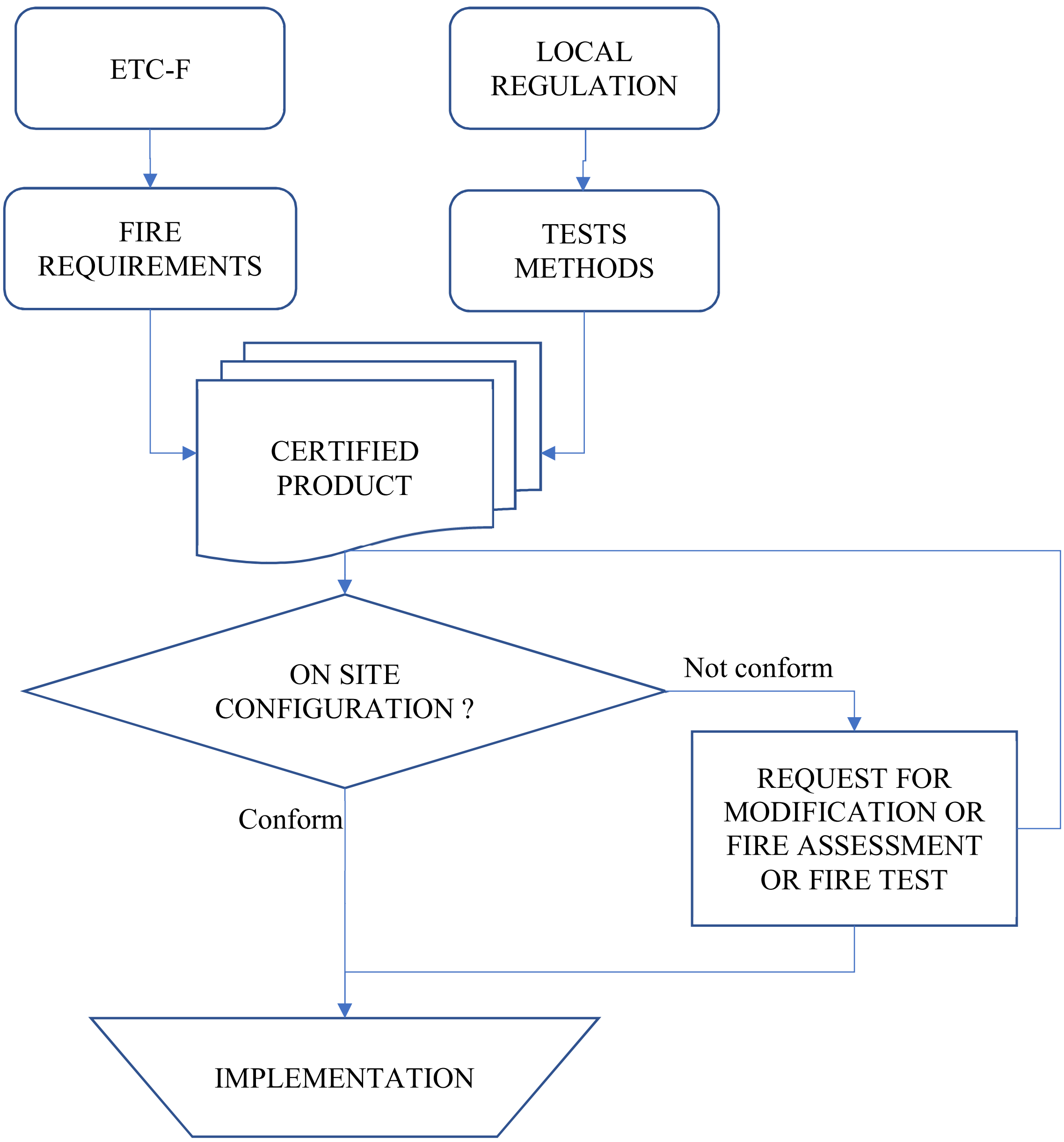

Figure 6: overall process from ETC-F code to on site implementation

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