Revision of IEC 60282-2 - High-voltage fuses - Part 2: Expulsion Fuses

A suggestion to IEC - SC32A to include the "extension of the validity of type test reports"

http://www.cognitor.com.br/IEC602822Suggestion4Revion2021.pdf   10 minutes video resuming

In this article we show a complete suggestion addressed to the IEC – Sub Committee SC32 A (High Voltage Fuses) for the next revision of IEC 60282-2. The main change is to consider the new concept of extension of the validity of test reports based on the principles in IEC 62271-307. Sergio Feitoza is co-author of IEC 62271-307 (2015) and coauthor of the 1989 revision of IEC60282-2.

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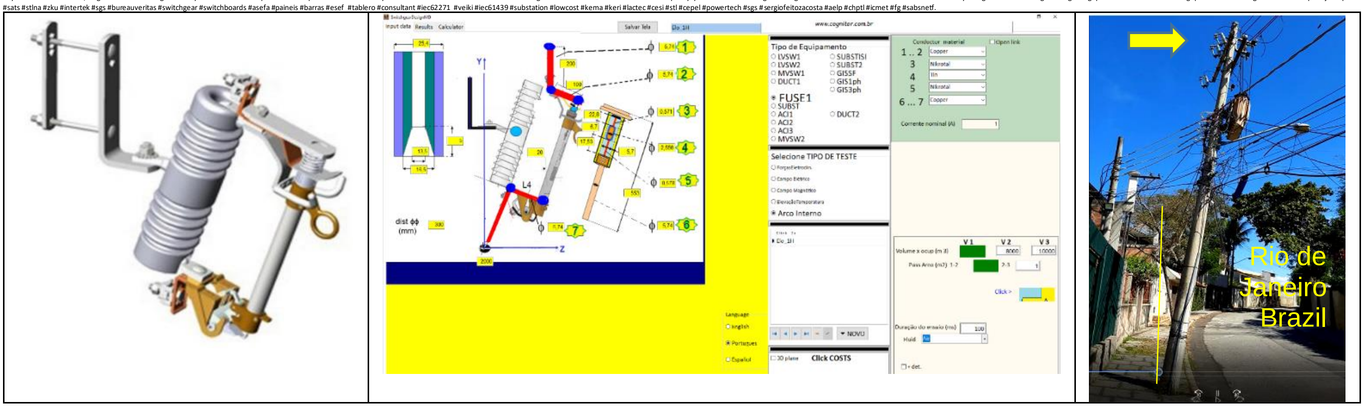

1. INTRODUCTION

Expulsion-type fuses are widely used mainly in developing countries, where they are even installed in the city center, near windows. In these countries, things like aesthetics still have a low level of priority. Technical errors, such as in the upper right corner of the page, are very common. Although taxes are among the highest and underutilized in the world, public services are of a much lower quality than in developed countries. Only a very large investment in education like 10% of GDP over 10 years could start to change things. The 570,000 deaths by Covid (August 2021) were not for lack of money or resources. They came from the same kind of neglect that caused these abandoned broken wires. If you complain to the City Hall or the electricity company, nothing happens.

IEC 60282-2:2008 is a very competent document and address well the mechanical and electrical aspects of expulsion fuses. Although seemingly simple, such fuses are very creative and efficient devices, ugly to look at , and dangerous, when they are less than 3 meters from a city apartment window. Just watch movies of small transformer failures in the street. Search the Web about related litigation in courts.

Sergio Feitoza has a long history in the development, testing, and standardization of fuses. He worked and managed, along 25 years, the CEPEL's testing laboratories. Coordinated the preparation of Brazilian standards. In IEC he worked in the revision 1989 of the IEC 60282-2 and was the Chairman of Technical Committee 32 (Fuses) by the end of 90's. Is co-author of IEC 62271-307 (2015). Manoel and Talita and Tecfuse bring with them 40 years of experience in manufacturing, testing, and writing technical standards about fuses.

Many of the concepts of IEC 60282-2 are like the ones in IEC 62271 series. The best example are the breaking tests and temperature rise tests. The main change proposed for a next revision is to bring a more up-to-date view of laboratory tests and their test reports. The focus is to consider the new concept of extension of the validity of test reports based on the principles in IEC 62271-307 (2015).

In this article we do suggestions for a new revision, in the format used in IEC WG meetings. In Section 2 we resume how to use the concepts of extension of the validity of type tests. In Section 3 we list in a table the main points to revise. In Section 4 we propose the text of the new Annexe describing the methodology for the "Extension of the validity of type tests already carried out on expulsion fuses, fuse holders and fuse links".

2. APPLYING THE CONCEPTS OF EXTENSION OF THE VALIDITY OF TYPE TESTS FOR EXPULSION FUSES ?

The principles of IEC 62271-307 (2015) show how to avoid unnecessary repetition of tests, which consume resources and increase the cost of equipment. This is done through the new concept of extending the validity of type test reports. The idea is to carefully select a certain product that will be tested like a "head of family". After approved in type tests this test report will be used to avoid testing other equipment which are of the same family, but with some differences. To be possible to do this, a series of rules described in tables are used. They cover all design parameters. The suggestion is to use in IEC 60282-2, the same approach of IEC 62271-307. Medium voltage fuses and switchgear have, within their functions, interrupting electric power circuits. Check test principles and rules as in the tables below.

The aim of the extension of validity, in this suggestion, is not to repeat individual type tests in situations such as:

• in changes of constructive details where, it can be demonstrated that the change does not influence the result of the individual type test;.

• for a change to the installation instructions, provided that the test conditions are not invalidated;

• to cover other nominal values for the same equipment, if these new values are covered by the tests already done.

• *To demonstrate that a certain type of fuse link would perform satisfactorily if used in fuse-bases and fuse holders from different manufacturers and vice versa.*

3. A TABLE WITH THE PROPOSED MODIFICATIONS

Comment #	Item of IEC 60282-2	The suggestion
1	Item1 (Add a new paragraph after the 4th)	**<u>Insert the following paragraph after the current 4th paragraph</u>** It should be recognized that the prevailing situation in the market is to find companies that manufacture (only) the fuse base and the fuse-holder but do not manufacture the fuse links and vice versa. This situation is identical to the case of IEC62271-200 products, where there are manufacturers of the metallic enclosures and manufacturers that assemble the complete panel (enclosure + the internal components like busbars, circuit breakers, etc...). There are separate prescriptions and tests to avoid that enclosure manufacturers need to do tests not related to their product. However, in IEC 60282-2 this separation is not clearly defined, and this is easy to improve. This situation is now contemplated in this revision of the Standard, considering that, in all tests where possible, it must be possible to separate the tests that apply to those who manufacture fuse-bases and fuse-holders from those who only manufacture the fuse links. The most important reference is the breaking test sequence 1. It only makes sense to the manufacturers of fuse-bases and fuse-holders . To support the "number of tests" (shots) specified in Table 6, the most important factors are the consumption of the vulcanized fiber (or equivalent material that produce gases in contact with the arc) of the fuse holder and the mechanical strength of the fuse-base. A high-quality fuse- link may perform well in the first of the shots and perform poorly in the next because all the internal fuse holder material was consumed and did not withstand the conditions as it should. It is a fuse -base failure and has nothing to do with the fuse link performance. Therefore, in a situation of this type, it makes no sense for a fuse link manufacturer to have to fulfil all the applications made to the switch. Only one is needed, as the link itself is replaced after operating. Furthermore, this separation of requirements is now facilitated by the principles in IEC 62271-307 (2015) "High-voltage switchgear and controlgear - Part 307: Guidance for the extension of validity of type tests of AC metal and solid-insulation enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV". The principles shown in this document apply to any type of equipment. There is also the possibility of using test calculations and simulations to allow extrapolating the results of a test performed on a certain product to an untested one that has some differences but is of the same family. Note: Some recent Cigré brochures give orientation in this theme. They are Brochure CIGRE 602 (2014) Simulation of Internal Arc Effects, Brochure Cigrè 740 (2018) - Low-Cost Substations in Developing Countries and Cigrè 830 (2021) Simulations for Calculating Temperature Rises "

Comment #	Item of IEC 60282-2	The suggestion
2	Item 1 (add a Note 5)	**Add the following Note 5:** Note 5) The way to ensure that a fuse with a fuse base, fuse holder and fuse link performs well is to test the combination. This is impractical due to the huge number of possible combinations. Situations like this are the fundament behind the creation of the recent IEC 62271-307 (2015) . This T.R. present objective rules, based on known technical principles, to avoid unnecessary repetition of tests. Similar practices and rules, but focused on the fuses of IEC60282-2 are detailed in the (new) **Annexe D.**
3	3.3.6 (remove or change the Note)	3.3.6 Interchangeability of the fuse links **Remove or change the Note to read as:** Note: The protection performance provided by the combination of the selected fuse link and the selected fuse holder can only be ensured by testing the specific combination of the fuse holder or by using the principles of extending the validity of type tests **(Annexe D)**
4	6.3.5 and 7.3	**Improve the text to clarify which manufacturer** is talking about (fuse base and fuse holder OR fuse link ?)
5	7.2.b	**Improve the sentence** to clarify that the fuse holder (internal material to produce gasses) must withstand the "number of tests" (shots) interruption test. A suggested sentence is: "After the operation of the (complete) fuse, its components, except those foreseen to be replaced after each operation, must be in substantially the same initial conditions, except for the internal erosion of the tube, considering the number of tests before replacing the fuse holder, which must withstand according to Table 6."
6	7.4	**Maintain only the first sentence** and remove the two others that do not add useful information and may bring doubts. "The fuse base, fuse holder and fuse link shall be capable of continuously carrying their rated current without exceeding the temperature and temperature rise limits specified in Table 12. "
	Table 12 for Temperature rise	Temperature rises depend on materials and conditions of touching enclosures and parts, among others. What is valid for a medium voltage switchgear is valid also for a fuse. The more updated table about temperature rise in IEC standards is the Table of IEC 62271-1. It is time to IEC to avoid several copies of the same table spread in different standards in different ways . For example, in IEC 61439 series is impossible to know objectively what the single temperature rise is permitted for a copper silvered connection. So **, it is proposed to maintain only the title of Table 12 and replace all its body by the single sentence:** **"The table 14 of IEC 62271-1 (2017 or the more recent edition) applies to IEC 60282-2 "**
7	8.2.2 Test Reports	**Add the following sentence:** "The test reports shall include the necessary information to do the verifications for the tables of the **(new) Annexe D** for the extension of the validity of test reports
8	Include a new section 8.2.3	**Add Section 8.2.3 to call the new Annexe D** 8.2.3 - Extension of validity of type tests Information regarding the extent of validity of the type tests is given in **Annexe D.**
9	Include the new **Annexe D**	**Include the new Annexe D** ANNEXE D (informative) - EXTENSION OF THE VALIDITY OF TYPE TESTS ALREADY CARRIED OUT ON FUSE BASES, FUSE HOLDERS AND FUSE LINKS **(Read below the text proposed for the Annexe D in Section 4 of this article)**

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4. TEXT PROPOSED FOR A NEW ANNEXE D: "EXTENSION OF THE VALIDITY OF TYPE TESTS ALREADY CARRIED OUT ON EXPULSION FUSES, FUSE HOLDERS AND FUSE LINKS "

D.1 of Annexe D of the proposed revision - General

The principles of IEC 62271-307 (2015) show how to avoid unnecessary repetition of tests, which consume resources and increase the cost of equipment. This is done through the new concept of extending the validity of type test reports. The idea is to carefully select a certain product that will be tested like a "head of family". After approved in type tests this test report will be used to avoid testing other equipment which are of the same family, but with some differences. To be possible to do this a series of rules, described in tables, are used. These rules cover the well-defined design parameters. The idea is to use in IEC 60282-2, the same approach of IEC 62271-307. Medium voltage fuses and switchgear have, within their functions, interrupting electrical circuits. The rules as in the tables below.

The aim of the extension of validity is not to repeat individual type tests in situations such as:
• for an alteration of constructive details, it can be demonstrated that this alteration does not influence the result of the individual type test;.
• for a change to the installation instructions, provided that the test conditions are not invalidated by the new instructions;
• to cover other nominal values for the same equipment, if these new nominal values are covered by the tests already carried out.
• To demonstrate that a certain type of fuse link would perform satisfactorily if used in fuse-bases and fuse holders from different manufacturers and vice versa.

This Annex is used to extend the validity of type tests performed on a fuse with a defined set of ratings to another fuse of the same family with a different set of ratings or different component arrangements *(Comment: to list here some examples with extenders, links , buttons, etc...).* It concerns the selection of functionally representative test objects from a fuse family to optimize type testing using a consistent conformity assessment.

This Annex uses a combination of sound technical and physical principles, manufacturer and user experience, and test calculations /simulations to guide the extent of validity of type tests. It is applicable in different cases such as:
a) when the validity of a type test performed on a test object is extended to other functional units of the same fuse family.
b) when, for a fuse family, test objects are selected for each characteristic, whose results validate the complete family with a minimum number of test objects and type tests.
c) when for an untested test object, an analysis is performed using test reports of available types from the same fuse family to determine if the test results validate the test object for the specified characteristics.
d) when the validity of the type test of a previously tested item is extended to a design modification

The extension of validity is based on the use of parameters and design conditions clearly established in the specific tables below, for each type of test. To make it clear that the conditions are met, the use of calculations and simulations is allowed and widely used. This has become possible and validated over the last 20 years. The bibliographical references that are in { .... } cover these themes.

For the use of the tables, it should be considered that:
• Each design parameter to be evaluated must be compared with the design parameter already tested by applying the acceptance criteria in the table itself.
• The assertion of all extension criteria allows a test performed on a specific test object to be applied to another one of the same family, with different characteristics.
• If any of the extension criteria cannot be asserted, additional evidence is needed and can be demonstrated, for example, by technical arguments, calculations, testing simulations or special tests.

As for the use of calculations and simulations, they can only be applied in a comparative sense using calculation results available for a tested test object and results obtained for the other test object under investigation. The comparison is always based on the design parameters and acceptance criteria in the tables. For example, suppose you calculate a temperature rise in a tested equipment using a validated method (validated means equal test and simulation results within a known tolerance). If the results of the temperature rise, by the same method, applied to an untested object of the same family, are lower or equal, it is confirmed that the untested object would pass the test.

Validation of software tools and calculation methods are outside the scope of this standard. However, there are in Section D.2 some rules to serve as a reference for agreements between users and manufacturers, which aim to use a method or tool to assist in the extension of validity

The tests for which the extension criteria can be used are:

- Temperature rise test
- Short time withstand current test, where applicable.
- Ability to breaking and making
- Internal arc supportability (about operation during interruption and overpressure calculations inside fuse holders and fuse link tubes)
- Dielectric withstand tests
- Mechanical endurance tests

Tables D1 to D6 show the rules for extending the validity of each test. Each of them was based on the tables of IEC 62271-307. The modifications made to adapt them to this IEC 60282-2 are highlighted in each table.:

Table D-1 - Temperature Rise (Extension Criteria)

The temperature rises of the conductors, fuse-link and, where they touch, insulating materials, at the specific points measured are the parameters to be compared. If necessary, the temperature rise of the air inside the fuse holder may help in the assessment.

Item	Design parameter	Acceptance criterion	Condition
1	Centre distance between phases	≥	
2	Phase to earth distance	≥	
3	Dimensions and volume of the fuse holder and fuse link small tube	≥	The fuse holder and fuse link small tube have same construction
4	Materials	The same or that attend the Requirements in other parts of the standard	
5	Temperature class of insulating materials in contact with conductors	≥	

Table D-2 – Short-time and peak withstand current tests (extension criteria)

Item	Design parameter	Acceptance criterion	Condition
1	Centre distance between phases	≥	
2	Electro-dynamic forces due to current path	≤	The conductors have approximately the same physical arrangement and current path.
3	Mechanical strength of insulating conductor supports	≥	
4	Length of unsupported sections of conductors	≤	

5	Cross-section of conductors	≥	Connections of the conductors are scaled and have the same or greater clamping force and contact area.
6	Material of conductors	Same	
7	Temperature class of insulating material in contact with conductors	≥	
8	Mechanical strength of the enclosure /partitions/ bushings	≥	
9	Contacts of removable part	Same	Consider complete design of contact sub-assembly and the fixing / mounting of the removable part.

Table D-3 – Breaking and making capacity (extension criteria)

The effects that influence the performance are the mechanical forces due to the short circuit, the overpressure inside the fuse holder and/or fuse link tube that gives rise to the blowing and expulsion of arc products, possibility of flashovers, speed with which the link – fuse is pulled due to the spring, after it breaks, and the thickness of the vulcanized fiber layer (which produces the gases in contact with the arc) .

Item	Design parameter	Acceptance criterion	Condition
1	Clearance between phases	≥	
2	Clearance to earth	≥	
3	Volume of fuse-holder and small tube of the fuse-link	≥	
4	~~Pressure of insulating gas~~	~~≥~~	
5	Cross-section of conductors	≥	
6	Electro-dynamic forces due to the current in the connection paths to the switching device	≤	
7	Mechanical strength of insulating supports	≥	
8	Mechanical strength of fuse-base, fuse-holder, fuse-link, extenders, buttons, and bushings	≥	
9	Length of unsupported section of conductors	≤	
10	Speed with which the fuse link is pulled after it breaks	≥	
11	Thickness of the vulcanized fiber layer (which produces gases in contact with the arc)	≥	

Table D-4 - Internal arc withstand - (regarding to performance during interruption and overpressure calculations inside fuse holders and fuse link tubes (extension criteria)

Item	Design parameter	Acceptance criterion	Condition
1	Clearance between phases	≤	
2	Clearance to earth	Same	
3	Net volume of fuse-holder and small tube of fuse-link	≥	

4	~~Rated Pressure of insulating gas~~	≤	
5	Cross-section of conductors	≥	Amount of vaporized material
6	Materials of conductor and fuse-link	Same	
7	Point of arc initiation (at the fuse link)	Same	
8	Insulating material exposed to arc	Same	
9	Exhaust opening pressure, if applicable	≥	The position of the exhaust gas outlet and the gas flow path are the same. Larger cross-sectional areas should be analyzed for gas escape velocity.
10	Mechanical strength of elements to let open the relief area, if applicable	≤	Relevant only if sealed
11	Mechanical strength of elements which may block the flux of hot gasses	≤	Relevant only if sealed
12	Mechanical strength of fuse base, fuse holder, fuse link	≥	
13	Thickness of the walls of the fuse holder and small tube of fuse-link including the thickness of the vulcanized fiber layer	≥	Same material
14	Mechanical strength of insulators , bushings, and related parts	≥	

Table D-5 – Dielectric tests performance (extension criteria)

Item	Design parameter	Acceptance criterion	Condition
1	Clearance between phases	≥	
2	Clearance to earth	≥	
3	Creepage distance	≥	
4	Electrical properties of Insulating material	≥	A comparative result between two materials might be required (e.g. Comparative Tracking Index according to IEC 60112 [7])
5	Surface roughness of live parts	≤	
6	Radius of conductive parts	≥	Not only the radius of live parts, but also the radius of all other conductive parts facing live parts (e.g. earthing devices, enclosure, LV wiring, supporting structures) shall be considered
7	Open contact gap	≥	If influenced by the fuse assembly
8	Isolating distance	≥	If influenced by the fuse assembly
9	Minimum functional pressure for insulation (if applicable)	≥	Same fluid

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Tabela D-6 – Mechanical strength performance and tests (extension criteria)

Item	Design parameter	Acceptance criterion	Condition
1	To prepare based on IEC 62271-307 concepts	≥	

D.2 of Annexe D of the proposed revision - Reference rules for using calculations and test simulations, for agreements between users and manufacturers, to the extent of validity of type tests.,

Type tests made in testing laboratories, are the most used way to verify whether a given product meets the specification of the relevant technical standard. Tests of high electrical power such as internal arc, temperature rise, and short duration withstand currents and crest are costly and require long preparation time. There are few testing laboratories in the world capable of carrying them out.

Test calculation and simulation techniques are increasingly used to predict the results of some types of tests. Some recent Cigré brochures are the state of the art and give orientation in this theme. They are Brochure CIGRE 602 (2014) Simulation of Internal Arc Effects, Brochure Cigrè 740 (2018) - Low-Cost Substations in Developing Countries and Cigrè 830 (2021) Simulations for Calculating Temperature Rises "

Calculations and simulations allow obtaining more complete information than the information that could be obtained in laboratory testing. Simulations can be applied in situations, such as:
(a) to avoid tests on a certain equipment with characteristics close to another already tested
(b) to avoid the repetition of tests in product certification processes when modifications are made to an already certified product.
(c) to replace SF6 with air in internal arc tests with environmental benefits.

Calculations and simulations can be used to extrapolate the results of a laboratory test already carried out on certain equipment to other equipment, with similarities, which has not been tested. This can be done more easily or more complex depending on the type of test.
For temperature rise tests, the use of simulation to replace a real test is simpler to perform and to validate, being possible to obtain the values at the points of interest of the standards very close to the values obtained during the real tests.

For internal arc tests, like in IEC 62271-200, or even breaking tests, the task is more complex, but possible. What must be verified during the tests are things like the effects of the overpressures that occur in chambers, during the arc, and the possibility of people in the vicinity of the equipment being hit by hot gases or solid particles. The overpressure x time curve is the determining agent for the good or bad result. This type of calculation is of direct interest for expulsion-type fusible devices. In these, the interruption process inside the fuse holders and fuse links depend on calculations like those of internal arc tests.

In short time current and crest withstand current tests, the objective is to verify the withstandability of insulators and conductors to the effects of electrodynamic forces that occur during a short-circuit. Calculating mechanical forces and stresses is not such a complex task but measuring them is very difficult and costly. However, calculation methods have been used for many decades and are well accepted in the technical world. There are documents such as IEC 61117 – "A method for assessing the short circuit with stand strength of partially type-tested assemblies" that have several classic cases that allow validating calculations and simulations of real tests.

Difficulties in validating simulation methods occur when certain measurements of relevant parameters, during testing, are not specified in technical standards. The difficulty is just the lack of reliable information for comparison.

However, the existence of IEC 62271-307 corrected these difficulties because, to use it and avoid testing, the mentioned measurements need to be made in the testing of the original equipment of a family.

The purpose of this Section D.2 is to provide guidelines for the systematization of the use of simulations and calculations, within the scope of IEC 60282-2, for the extension of the validity of tests. This may avoid test repetitions in situations where common sense shows it to be reasonable to do so. The main parameters to be recorded in the test reports, aiming at the extension of validity are in the Tables of this Annex . With them it is possible to validate calculations and simulations.

In the text below, typical values of acceptable tolerances are given for the calculated values when compared with the results of the laboratory test. The most frequent case of the use of simulations is the extrapolation of test results carried out in the laboratory, in a certain equipment, to predict the results of the same test in equipment with characteristics like the one already tested, but which has not been tested.

It is not the purpose of this Annex to present calculation methods for test simulations. A model or method is considered acceptable when it produces results that can be validated within acceptable tolerances and, in addition, validation can be demonstrated objectively and transparently to users.

D.2.1 - Definitions

D.2.1.1 – Simulation or calculation to replace a test and acceptable tolerances.
A calculation method used to predict, within a certain tolerance, the results of a laboratory test. In Table D.2.1 are presented typical values of acceptable tolerances of the results obtained in the simulations, when compared with the results of the laboratory test.

Table D.2.1 - Typical values of acceptable tolerances to validate calculations and test simulations

Type of test	Parameter to compare	Acceptable tolerances
Temperature rise test	Temperature rises in solids and fluids	1% to 5%
Internal arc tests and breaking tests	Overpressure within a defined compartment or chamber volume	5% to 10%
Short time current withstand tests	Electrodynamical forces in supports and mechanical stresses in spans of conductors	5% a 15%

D.2.1.2 - Product standard
Standard covering a specific product or a group of related products.

E.2.1.3 – Reproducibility of a simulation or calculation method or a test
The ability to obtain, for a given set of input data, the same test or simulation results on two different occasions or in two different laboratories.

E.2.1.4 – Validation of a simulation or calculation method.
A method of comparing the results shown in a well-documented test report issued by a testing laboratory and the results of the simulation method. A simulation method is generally acceptable, from the users' point of view, when it is reproducible and presents a difference from laboratory test results not exceeding a certain acceptable tolerance.

3.5 – Minimum input data to be recorded in temperature rise test reports.
These are the main values of the parameters needed to be registered in test reports to verify compliance with Table D.1:
- The circulating electric current,
- The total power dissipation within a fluid compartment
- The materials used in conductors and insulating parts
- Contact resistances (total per phase and those of individual parts, such as circuit breakers, fuses, insulators)

- The types of coatings for contacts, connections and conductors including paint.
- The fluid surrounding the components in a compartment and its temperature (at least at the bottom, at the top and at 50% of the height of the enclosure),
- The fluid circulation speed
- The position and spatial geometry of conductors
- The net volume of fluid inside the compartments
- The entrance and exit areas for ventilation as well as the existence of devices that close them during an internal arc
- The number of horizontal partitions inside the compartment, if applicable.
- The relative position of the equipment in relation to the walls, ceiling, and neighboring equipment (as in IEC 60890)

For reasons of test reproducibility, the measurement of the total resistance per phase and the main resistances that compose it, for example, those of circuit breakers and disconnectors contacts, must be measured, before and after the test, and recorded in the test report of laboratory.
Data values that affect the test result, such as those above, must be clearly recorded in the test report through photographs and/or drawings.

3.6 - Data to be recorded in <u>internal arc test reports</u> issued by laboratories
These are the parameter values which shall be registered to verify the compliance with Table D.4 with emphasis on the overpressure vs. time curve. Data affecting test and simulation results are

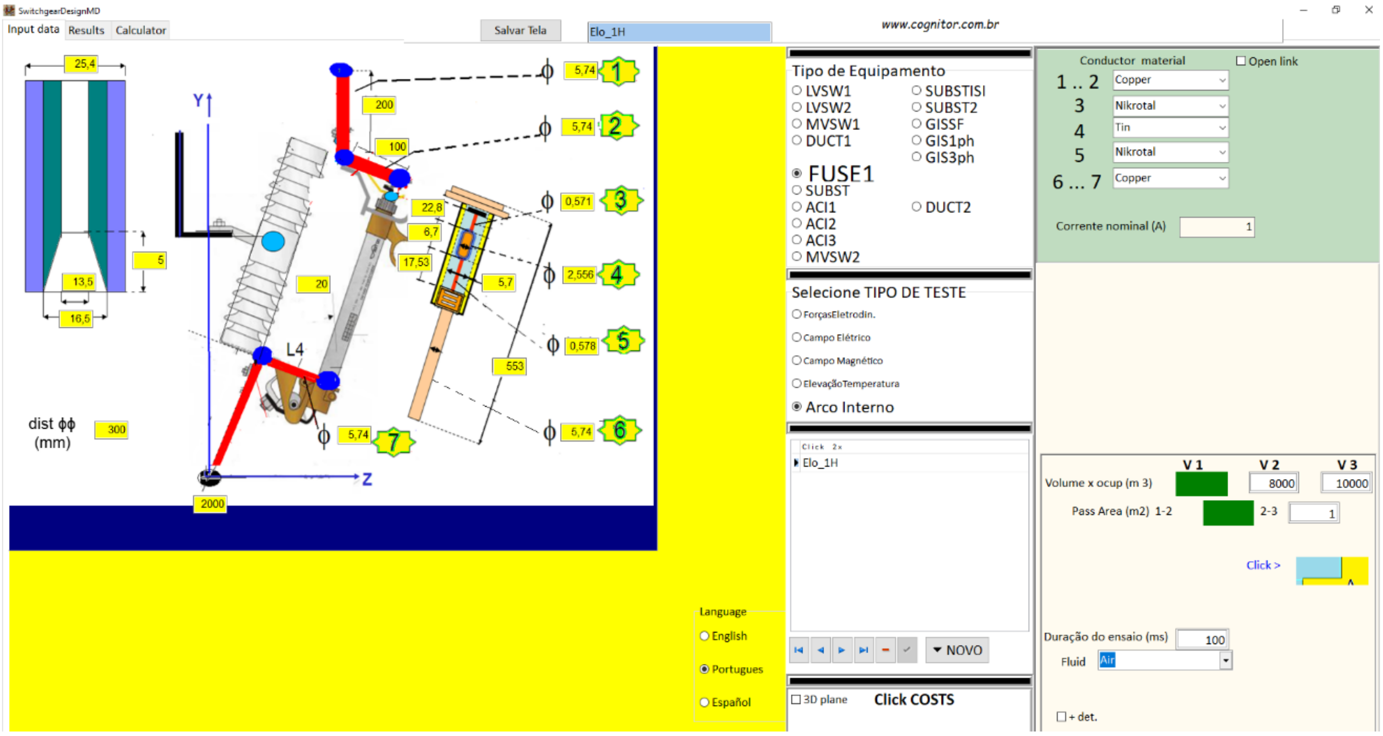
- Pressure vs. time curve with pressure transducers, when possible to measure them or values obtained by calculation. For fuses the second case apply
- The circulating electric current,
- The materials used in conductors and insulating parts
- The fluid that surrounds equipment within a compartment.
- The position and spatial geometry of conductors
- The volume of fluid inside the compartments
- The area of the overpressure relief devices and their opening speed.
- The entrance and exit areas for ventilation as well as the existence of devices that close them during an internal arc
- The relative position of the equipment in relation to the walls and ceiling.

3.7 – Data to be recorded in <u>short time current withstand current and crest test reports</u>.
These are the parameter values from verifying compliance with Table D.2. The purpose of the test is to verify the withstandability to the effects of electrodynamic forces on insulators and conductors that occur during an arc-free short circuit. Verification is done by visual inspection and by measuring the electrical resistances per phase. Data affecting test and simulation results are

- The circulating electric current,
- The materials used in conductors and insulating parts
- Mechanical resistance to traction, compression and bending efforts of support insulators and the like
- The position and spatial geometry of conductors

For reasons of test reproducibility, the measurement of the total resistance per phase and the main resistances that compose it, for example, those of circuit breakers and disconnectors contacts, must be measured, before and after the test, and recorded in the test report of laboratory. If permanent deformations of dams and other parts are identified, these must be registered by photos and their estimated maximum dimensions and recorded in the test reports.

Figure D.1 – Input and geometry data for calculations and simulations of tests in an expulsion fuse.



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