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

Suggestions to SC32A for next revision .

About aging of fuse links, concepts of IEC62271-307 and identification of what was tested.

(Include a world comparison of prices & quality of distribution services)

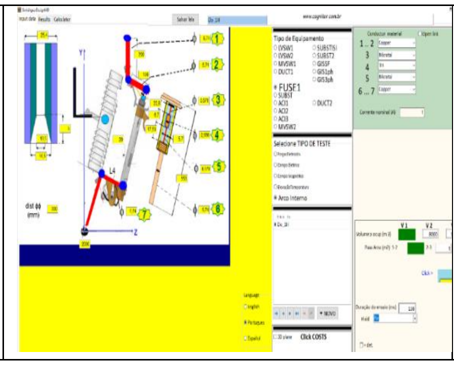
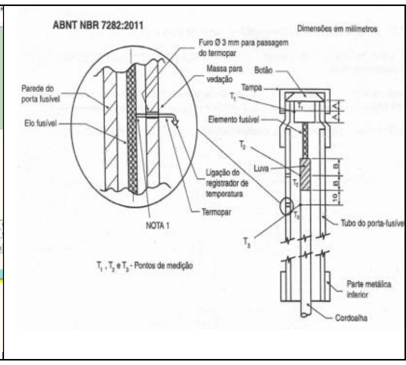
VIDEO YOUTUBE https://youtu.be/3E15-S82URs

https://www.cognitor.com.br/IEC602822sugestionstosc32afrombrazil.pdf

Authors: **Sergio Feitoza Costa (Cognitor – Consultancy, R&D, Training)** ** Manoel Esteves Sobrinho / Talita Bolandim (TECFUSE).

For contacts: e-mail: sergiofeitozacosta@gmail.com Site: www.cognitor.com.br

keywords: #iecstandards, #cigre #busbar #testinglaboratory #internalarc # overpressure #temperaturerise #electrodynamic #stresses #shorttimecurrent # emc #magneticfields #electricfield #certification #qualitysystem #newtechnologies #design #costsreduction #validation #calculation #busway #sergiofeitoza #switchgeardesign #highpower #r&d #simulation #highpowertest #testing #shortcircuit #cpri #jstc #pehla #sats #stlna #zku #intertek #sgs #bureauveritas #switchgear #switchboards #asefa #paineis #barras #esef #tablero #consultant #iec62271 #veiki #iec61439 #substation #lowcost #kema #keri #lactec #cesi #stl #cepel #powertech #sgs #sergiofeitozacosta #aelp #chptl #icmet #fg #sabsnetf.

1. REASONING FOR THE SUGGESTIONS

Most IEC standards focus on practices from developed countries for the simple reason that they are present in IEC working groups because understand the importance and invest in participating in the preparation of IEC documents. Other countries rarely participate in IEC working groups (WG). They prefer to wait for the publication of the IEC document and translate it years later. It is an obvious source of technological delay. I learned this participating in the IEC WGs which prepared IEC60282-2 (1995) and IEC 62271-307 (2015). Between 1990 and1994 I had the honor of being the chairman of IEC Technical Committee32.

IEC60282-2 (2008) does not address fuse-links aging issues. For example, by IEC60943, if you overpass the limit of temperature rise permissible for a connection, by only 10K, you may have a loss of life near the melting element of some 50%. Remember the daily overloads of fuse-links protecting distribution transformers. For the fuse-links, the points to measure in the temperature rise test are not defined. The current text, although not wrong, was prepared with a view in the fuse carrier and base. In addition, the advances derived from the IEC62271-307(2015) in Ref [1] are little known outside the TC17. Also, it is essential, to avoid to make explicit the fact that there are manufacturers of complete expulsion fuses (base + fuse carrier + fuse-link) and manufacturers of (only) fuse links. Another improvement is related to the clear identification of what was tested as described in the next paragraphs.

During the IEC work for the 1990 revision of the IEC 60282-2 the Brazilian National Committee (BNC) presented most of these suggestions which had been incorporated to the Brazilian standard. These suggestions were mainly focused on the aspects of premature aging of fuse-links and its consequences. The reasoning for those suggestions were based on the efforts of a Brazilian national program carried out to improve the quality of electricity supply, reducing failure rates in Brazilian distribution system. This successful program named PROQUIP brought very useful and measurable results. The hundreds of tests and R&D actions involved testing laboratories, most manufacturers of complete expulsion fuses, manufacturers of fuse-links and several distribution power utilities. A lot of money was invested, especially in the area of expulsion fuses and their fuse-links. The aim of the program was to identify the causes of the high taxes of failures in the whole distribution system. In the article of Ref. [2] we present objective numbers showing that the system quality indexes improved considerably in the decades that followed. Possibly the coverage of the technical analysis carried out at that time is still unique in the world today. The indexes considered were:

- SAIDI (System Average Interruption Duration Index) ,= total duration of interruptions / Number of customers

- SAIFI (System Average Interruption Frequency Index) = total amount of interruptions/ Number of customers

Expulsion fuses are very much used, even downtown, in the Brazilian cities. Most of the new points included in the NBR 7282 (1989), were suggested to SC32A for the revision of IEC60282 published in 1995. Some of the suggestions were accepted and included in the 1995 version. However , the most relevant, related to aging were not accepted at that moment, possibly because it was not still possible to demonstrate the positive effects that they would cause in the decades after. Now, 27 years after, the good results are demonstrated. The suggestions presented in the table below consider five main aspects.

The first aspect is to include the recent (2015) concept of extension of the validity of test reports brought by IEC TR 62271-307. This TR aims to avoid unnecessary repetitions of tests. It enables extending the validity of tests done in an approved type tested equipment to another's untested, of the same family.
The idea is that, if you have successfully tested an equipment whose design parameters are well identified in the test report, you can avoid tests on similar, but not identical, equipment. To do this we use tables applicable to each type of test (interruption, temperature rises , short time currents, internal arc, dielectric and mechanical). These tables describe and compare each relevant design parameter. If the rules in the lines of the table are met it is not necessary to repeat tests. If there are doubts about compliance with the rules, calculations and test simulations are permitted. Contrary to the past, today it is possible, e.g., to quickly check , for each breaking test series, where the role of the fuse link stops, and the role of the fuse carrier starts. Beyond IEC 62271-307, there are important Cigrè references about testing simulations of products for substations. They present validations and knowledge. Check Ref. [3 to 6]

The second aspect is to recognize the fact that there are manufacturers of complete expulsion fuses and manufacturers of (only) fuse links. This recognition is important because there is no "standard fuse-carrier for testing of fuse-links" in the current standards. So, if you are a fuse link (only) manufacturer, you depend on the manufacturer of complete expulsion fuses to do your test. This is an obvious market barrier for the fuse-links (only) manufacturers. The fact that it is now possible to simulate where the role of the fuse-link ends and that of the fuse-holder begins is still not taken into account in the standard, but it could be, signalizing guidelines to create a "standard fuse-carrier for testing of fuse-links". In most cases of dropout fuses the thickness of the fuse carrier inner lining defines the maximum withstandable number of breaking operations.

The third point is to minimize a weak point present in most IEC standards, in terms of clearly identifying what has been tested. Without a good identification in the test reports, it is not possible to say that a test is reproducible. If a declaration from the manufacturer that what is tested is the same as what is marketed was enough, it might not even be necessary to spend a lot of money to carry out type tests in neutral laboratories.

It is not necessary to go using techniques for product "certification" as, for example for Ex products. In these cases, every detail must be recorded to ensure that a design change will not cause worse performance. In the opposite direction, as an example, it is easy to find temperature rise test reports that do not even identify the product's conductor's cross section. An important case is the thickness of the fuse carrier inner lining. Try to identify at least one case of reporting the thickness of the inner lining. To do comparisons you need this information.

A fourth point is to improve the "Bibliography". Some IEC standards which are applicable to several Technical Committees are, unfortunately, unknow by other TCs to which could be useful. A good example is IEC TR 60943 (TC32 / SC32B) [Ref. 7] which is the world-wide more complete document about aging of electric products and their parts . It is applicable to fuses, switchgear, switchboards, power transformers but few people know it exists. The fact that IEC62271-307 was prepared by TC17 or IEC60943 was prepared by TC32 does not mean that those engineering concepts are not applicable to other products. IEC though TC17 + TC32 could create a joint work to organize these documents in a single one. Could be a kind of guide for general use in all TCs like an "IEC (TR) " Guidelines for the design of LV to HV electrical products". Ref. [12]

The fifth point is related to the movie above. It is to provide in the text of the standard some kind of alert like "expulsion fuses and the distribution transformers they protect shall not be installed at a distance lower than 6m from buildings and windows where people may stay due to the risk of life. This standard does not include tests to verify this performance."

Cell phone. 55-21-9 88874600
E-mail: sergiofeitozacosta@gmail.com Site: http://www.cognitor.com.br

In the table of Section 4 there is a set of suggestions for the next revision of IEC 60282-2.

2. SOME INDICATORS OF THE QUALITY OF ELECTRICITY DISTRIBUTION SERVICES IN SOME COUNTRIES

Here are indicators of the quality of electricity distribution services from the late 80's to recent years. I got this data in the web, just to present orders of magnitude. In the case of Brazil, they give an idea of how the distribution systems improved after the program Proquip and NBR7282. I used as indicators:

- SAIDI (System Average Interruption Duration Index) ,= total duration of interruptions / Number of customers
- SAIFI (System Average Interruption Frequency Index) = total amount of interruptions/ Number of customers
- Electricity price (USD/KWh or USD / MWh)
- Electricity price divided by the country minimum wage, to understand the difficulty to pay the electricity bill

Table 1 - ELECTRICITY QUALITY & COSTS indicators: ORDER of MAGNITUDE

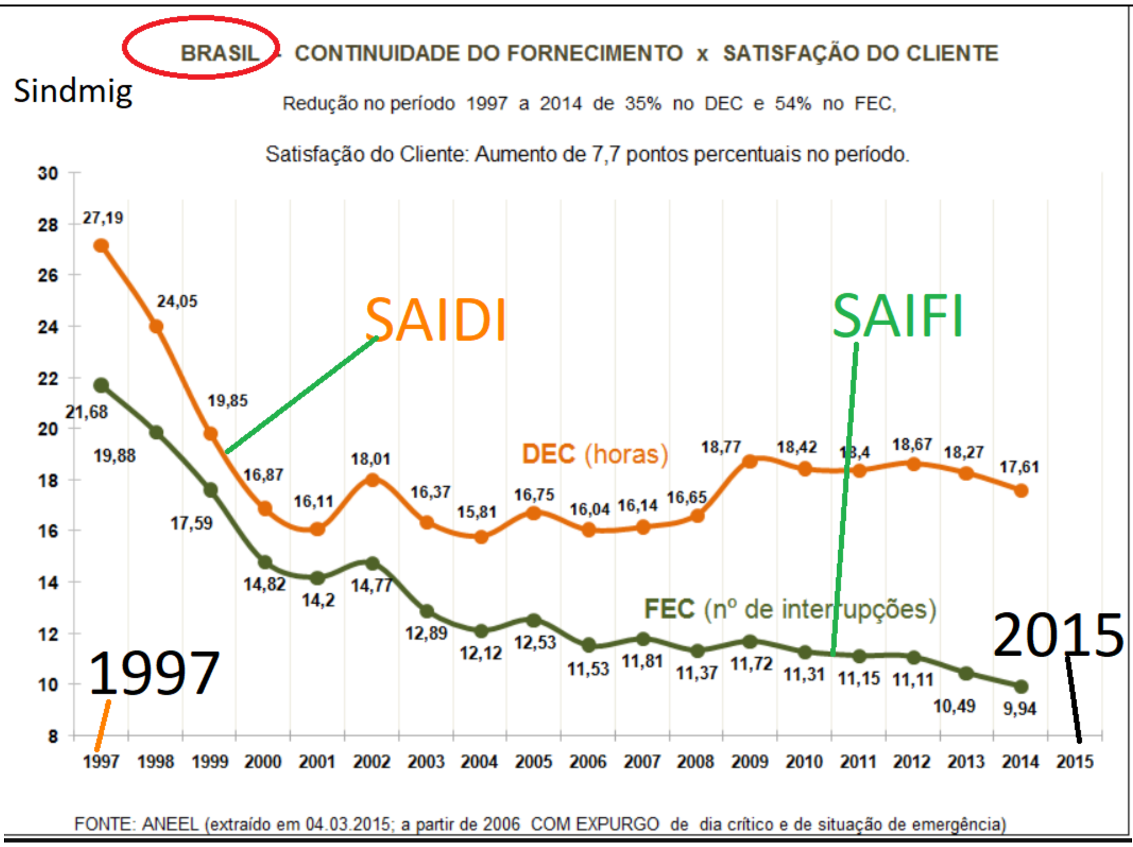
Country	SAIDI (minutes)		SAIFI		Quality of electricity supply Index (World Bank GovData360)	Price (*) of residential consumer bill (USD / MWh)	(USD / MWh) divided by minimum month wage in the country
USA/Canada	> 92 (2019) IEA		1,25 (2016) IEA		**6,2 -6,6**	140 - 170	**0,12**
France	48,0 (2002) 70,0 (2016) CEER methodology		0,11 (2002) 0,22 (2002) CEER methodology		**6,7**	267	**0,13**
Netherlands	31,5 (2012) 27,3 (2016) CEER methodology		0,33 (2012) 0,32 (2016) CEER methodology		**6,8**	259 - 316	**0,14**
Australia					**5,7**	176	**0,14**
Turkey					**4,4**	77	**0,23**
Philippines					**4,2**	150	**0,50**
South Africa					**3,9**	208-230	**0,70**
B R A Z I L	**26 (1996)** **16 (2016)** DEC - GESEL		**22 (1996)** **8 (2016)** FEC - GESEL		**4,5**	280-314 (*)	**0,85**

(*) Order of magnitude of values. In Rio de Janeiro - Brazil I paid the electricity bill in April 2022 (apartment for 3 people) ~ USD 206.00 for 654 kWh (USD 314.00/MWh). Taxes are 33% of the total bill.

(**) CEER -Table 9 - Electricity: planned and unplanned SAIDI, including exceptional events (minutes per customer)

(***) CEER - Table 17 – Electricity: planned and unplanned SAIFI, including exceptional events (interruptions per customer

*** Your help to update / correct the SAIDI / SAIFI is very welcome (write to sergiofeitozacosta@gmail.com)



SINDIMIG: http://www.sindimig.com.br/wp-content/uploads/2016/04/dec-e-fec-aneel.bmp

OTHER INTERESTING SOURCES OF INFORMATION:

Minimum Wage by Country 2022 (worldpopulationreview.com)	https://worldpopulationreview.com/country-rankings/minimum-wage-by-country OECD https://stats.oecd.org/Index.aspx?DataSetCode=RMW
Quality of electricity supply - GovData360 (worldbank.org)	https://govdata360.worldbank.org/indicators/heb130a3c?country=BRA&indicator=547&viz=line_chart&years=2007,2017
IEA - Statistics report - Key World Energy - Statistics 2021 - September 202 + EIA	https://iea.blob.core.windows.net/assets/52f66a88-0b63-4ad2-94a5-29d36e864b82/KeyWorldEnergyStatistics2021.pdf EIA methodology USA https://www.eia.gov/todayinenergy/detail.php?id=45796
MAIFI , SAID, SAIFI (Wikipedia)	https://en.wikipedia.org/wiki/MAIFI#:~:text=The%20Momentary%20Average%20Interruption%20Frequency,period%20(typically%20a%20year).
International electricity prices: How does Australia compare? (energycouncil.com.au)	https://www.energycouncil.com.au/analysis/international-electricity-prices-how-does-australia-compare/#:~:text=The%20average%20annual%20cost%20of,costs%20(down%20by%20%2467)
Energy Quality of Supply Work Stream (EQS WS) - **CEER** Benchmarking Report 6.1 on the Continuity of Electricity and Gas Supply - Data update 2015/2016	https://www.ceer.eu/documents/104400/-/-/963153e6-2f42-78eb-22a4-06f1552dd34c
ERIA Research project report 2017 Nr.12 Comparative Power Prices in the Philippines and selected Asian Countries	https://www.eria.org/research/comparative-analysis-of-power-prices-in-the-philippines-and-selected-asean-countries/
ANEEL – Indicadores coletivos de continuidade	https://www.eia.gov/todayinenergy/detail.php?id=45796
Dados Energéticos – São Paulo	https://dadosenergeticos.energia.sp.gov.br/portalcev2/intranet/Eletricidade/index.html
SINDMIG (chart above 1997 – 2015)	http://www.sindimig.com.br/wp-content/uploads/2016/04/dec-e-fec-aneel.bmp

3. REFERENCES

[1] IEC TR 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 (1 to 52 kV).

[2] : IEC 60282-2 - High-voltage fuses - Part 2: Expulsion Fuses - Suggestions to SC32A for next revision based on the Brazilian standard NBR7282 (cover aging of fuse links, concepts of IEC62271-307 and identification of what was tested) . (Include a world comparison of prices & quality of distribution services)
https://www.cognitor.com.br/IEC602822sugestionstosc32afrombrazil.pdf

[3] Brochure CIGRE 602 (2014) - Tools for the Simulation of The Effects of the Internal Arc in T&D Switchgear.

[4] Proposal to IEC about the use of simulations in technical standards:" Guidelines for the use of simulations & calculations used in IEC standards" referred in Brochure CIGRE 602.
http://www.cognitor.com.br/GUIDE_Simulations_v0_October2010.pdf

[5] Brochure CIGRE 740 (2018) - Contemporary Solutions for Low-Cost Substations.

[6] Brochure 830 (2021) Simulations for Temperature Rise Calculation.

[7] IEC/ TR 60943 - , Guidance concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals. (Produced by TC32)

[8] IEC/TR 60890, A Method of Temperature-rise Verification of Low Voltage Switchgear and Controlgear Assemblies by calculation

[9] IEC 61117, Method for assessing the short-circuit withstand strength of partially type-tested assemblies (PTTA)

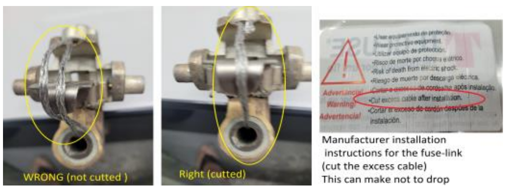
[10] IEC 60865-1, Short-circuit currents – Calculation of effects – Part 1: Definitions and calculation methods

[11] IEC TR 60865-2, Short-circuit currents – Calculation of effects – Part 2: Examples of calculation

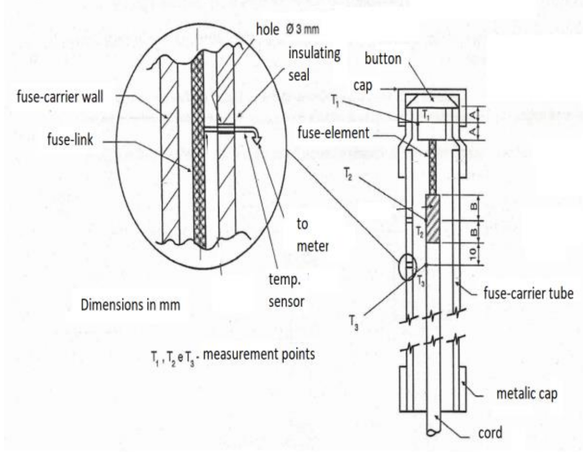
[12] Suggestions to the management of key IEC standards (at least for TC17 and TC32)

https://www.cognitor.com.br/improvementsiec.pdf

4. TABLE WITH SUGGESTIONS TO THE NEXT REVISION OF IEC 60282-2 (start in next page)

#	Item of IEC 60282-2 (2008)	PROPOSED MODIFICATION and what is in the current the text that need to be improved	REASONING / EXPLANATION ON WHY TO CHANGE
# 1	**Item1** **Add a new Paragraph after the 4th**	**Add this paragraph after the 4th paragraph** "It shall 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. It should be noted that testing a homogeneous series of fuse-links (testing a large T link and a small K link as the maximum and minimum links to be tested) aims to cover everything in between, including different types of K or T such as the type H widely used in some countries ~~Brazil~~). When it is not clear where the role of the fuse link ends and that of the fuse holder begins, test simulation techniques and the principles of extending the validity of test reports defined in the (informative) Annex D, can be used. These principles are an adaptation of the ones presented in IEC62271-307." What is written in IEC 60282-2 (2008) to be improved 4th paragraph of 2008 version states: This standard covers only the performance of fuses, each one comprising a specified combination of fuse-base, fuse-carrier and fuse-link which have been tested in accordance with this standard; successful performance of other combinations cannot be implied from this standard   	When the 4th paragraph says "ONLY" and "SUCCESSFUL PERFORMANCE OF OTHER COMBINATIONS CANNOT BE IMPLIED FROM THIS STANDARD" users and buyers are induced to ask manufacturers who produce fuse-links ONLY to do all breaking tests of sequence 1 to 5 eventually is several bases and fuse carriers of different manufacturers. It is similar to IEC62271-200 products, where there are manufacturers of metallic enclosures and manufacturers that assemble the complete panel (enclosure + internal components such as busbars, circuit breakers, etc.). However, in this case, there are separate prescriptions and tests to prevent enclosures-only manufacturers from having to do tests unrelated to their product. In IEC 60282-2 this separation is not defined, and this is what needs to be improved. Comparing the 1989 edition of IEC 60282-2 with the 2008 edition, we see that the SC32A tried to solve the problem of requiring an almost prohibitively large number of tests. Testing of a homogeneous series of fuses has changed by adopting the IEEE C37.41 approach (essentially testing a large T link and a small K link as the maximum and minimum links to be tested, covering everything in between, including different types of K or T as the type H widely used in Brazil). However, the issue of different manufacturers supplying cut-out components to a customer was not addressed. Therefore, the current wording penalizes those who manufacture only fuse-links in favor of those who produce the complete set. A fact to mention is that unlike in the past, there are now easy and cheap test simulation techniques and, after IEC 62271-307 (2015), the principles of extending the validity of test reports. When it is not clear where the role of the fuse link ends and that of the fuse holder begins, test simulation techniques and the principles of extending the validity of test reports can be used. These principles are taken up in the informative annex D. A real example, demonstrable with test reports, is when a manufacturer of – only – fuse-links invest thousands of dollars going to a 3rd partl test laboratory and performing, in addition to sequences 4 and 5, test sequence 1. In the test of TD1 , the current is interrupted, but the fuse holder does not fall. The laboratory places a negative statement, on the basis that "Any failure to interrupt and, for self-opening fusible devices, any failure to move and remain in the correct opening position, during any test in test groups 1 to 5, is a failure of the device". There is evidence that the only influence the fuse link could have on not dropping the fuse holder is if the fuse link manufacturer's written instruction for cutting the cord is not followed by the user (see photo below). After this event, when the manufacturer went to sell the fuse-link to an electric power utility, they did not accept that fuse because they identified this statement in the test report. Thus, the standard text should be improved so as not to unduly eliminate fuse-links manufacturers from the market. Therefore, in addition to the warning phrase, openings must be created so that calculation methods or simulations or the rules of IEC 62271-307 can be used.
#	**Item1**	**Add the following Note 5:**	

2	**Add** **Note 5**	NOTE 5 The <u>best</u> way to ensure that a fuse device with a base, a fuse holder and a fuse link performs well , in the real life, is to test the combination. Doing this with too many combinations is impractical. A complete technical identification of the set submitted to type tests, through drawings, photos and indication of materials, is the only way to assure that what was tested is what is regularly supplied. Extension of the validity of previous tests results performed on a certain device may be used to estimate the test result on an untested device. The principles for this are presented IEC 62271-307. These principles are detailed in Annex D, however, customized to IEC 60282-2.	Read the line above with the same reasoning Maybe the text of this note can be positioned in a part different of the “scope”, for example in the Notes of the Breaking Tests table. However, the alert about “what is tested should be equal to what is sold” is an important issue. The fact is that many IEC tests nowadays are not reproducible, at all, by lack of information in the test reports.
# 3	**Item** **3.3.6**	<u>**Remove the Note or change it to:**</u> Note: The protection performance provided by the selected fuse link and selected fuse holder combination can be verified by testing the specific fuse holder combination or using the principles of extending the validity of test reports of tested and approved products of the same family (Annex D)	<u>What is written in IEC 60282-2 (2008) to be improved</u> **3.6 - interchangeability of fuse-links** compatibility of dimensions and pre-arcing time-current characteristics between different manufacturer's expulsion fuse-links, permitting use of such fuse-links in fuse-carriers of alternative manufacturers, without significant alteration of the pre-arcing time-current characteristics NOTE It should be noted that the protective and interrupting performance provided by the combination of the selected fuse-link and the selected fuse-carrier can only be assured by performance test on the specific combination. REASONING: Read above suggestion to Section1
# 4	**Items** **6.3.5 / 7.3**	<u>**Improve the text to clarify which manufacturer**</u> is talking about (Fuse base and fuse holder OR fuse link ?) **Proposed texts:** 6.3.5 - The rated current assigned …… if applicable, within a fuse-carrier specified by the <u>manufacturer of the fuse-link</u>, at ambient temperature of ….. 7.3.1 General The time-current ….and unloaded fuse-link in a fuse-base specified by the manufacturer <u>of the fuse-link</u>	**REASONING:** 6.3.5 – This should be the manufacturer of the fuse-link. If a fuse-link that is made by someone other than the fuse-holder manufacturer does not meet the temperature rise requirements, it would not be suitable for use in the fuse-holder. 7.3.1 – again the fuse-link manufacturer, although the possible understanding is that the fuse-holder has very little influence on the time current characteristic the range specified in 8.7 (i.e., to 300/600 s).
# 5	**7.2. b**	<u>**Improve the sentence**</u> to clarify that the fuse holder (internal material to produce gasses) must withstand the “number of tests” (shots) interruption test. **The proposed sentence is:** ... After operation of the (complete) fuse device, its components, except those intended 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 to replace the fuse holder, which it must support, according to Table 6. The identification of the material used, and its dimensions must be sufficiently presented in the test report, to enable reproducibility.	<u>**Editorial improvement**</u>
# 6	**7.4**	<u>**Maintain only the 1st and 3rd sentences**</u> and remove the 2nd that do not add useful information and may bring doubts. **Proposed text** 7.4 - Temperature and temperature rise The fuse-base, fuse-carrier and fuse-link shall carry their rated currents continuously without exceeding temperature and temperature-rise limits specified in	**REASONING** 2nd sentence is superfluous

		Table 12. ~~These limits shall not be exceeded, even when the rated current of the fuse-link is equal to the rated current of the fuse-carrier intended to accommodate this fuse-link.~~ Fuse-link parts for which temperatures cannot be easily measured during tests (for example the small arc-quenching tube of distribution fuse-cutouts), shall be checked by visual examination for deterioration	
# 7	**8.2.2** **Test Reports**	**<u>Add the following sentence:</u>** "For a good identification of the tested product, it is recommended that the test reports include enough information to make the verifications of the relevant design parameters of the tables in the (informative) Annex D .	**REASONING** The principles of the extension of the validity of test reports (IEC 62271-307) are each time more used. They are based in tables listing the rules to attend associating design parameters to a higher or lower severity if they change. If all the rules of a table are attended, you do not need to retest or to do calculations to prove if the tested item was approved in the tests the untested would also pass. If it is not clear if a rule (line of the table) is attended you may use testing simulations for temperature rise tests, electrodynamic forces and even breaking tests The information of the tables can be used to do calculations, extrapolation of results and, for example, to identify where the role of the fuse link ends and that of the fuse holder begins (read the suggestion to Section 1). Testing laboratories usually include in the test report only what is required by the test payer or explicit in the technical standard. If you read an incomplete test report it is impossible to know if the test is reproducible or <u>to verify if what as tested is the same that is sold.</u> For example, fuse holders of expulsion fuses shall support 3 shots before replacement. The thickness & material of the internal tube define the result but its relevancy are not even mentioned in the standard.
# 8	**New** **Section** **8.2.3**	**<u>Include Section 8.2.3</u>** 8.2.3 - Extension of validity of type test reports Information regarding the fundaments and applicable design parameters is given, for each type of test, in the (informative) Annexe D.	This sentence is to call the new Annex D
# 9	**Section 8.5** Temperature rise	**Insert a Figure for the temperature rise test clarifying where the temperatures shall be measured to avoid premature aging.** **This is not obvious for fuse-links** **Reasoning:** Aging is a key factor but is not addressed in IEC60282-2. For example, by IEC60943, if you overpass the limit of temperature rise permissible for a connection, by only 10K, you may have a loss of life near the melting element of some 50%. Remember the daily overloads of fuse-links protecting distribution transformers. For the fuse-links, the points to measure in the temperature rise test are not defined. The current text, although not wrong, was prepared with a view in the fuse carrier and base. If you measure in the wrong point, you do not see what is relevant .Telling that the temperature rises of the table shall no be overpassed is not sufficient for fuse-links.	
# 1 0	**Table 12 for Temperature Rise**	**<u>To avoid a duplicate source of information, maintain only the title of Table 12 and replace all its body by the single sentence:</u>** **"The table 14 of IEC 62271-1 (2017) or the more recent edition applies to IEC 60282-2 .**	**REASONING** Temperature rises limits specified in all IEC standards have the same fundaments. <u>Most IEC knowledge about temperature rise limits is explained in the IEC TR 60943 - Guidance concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals. The first version was published in 1989 by TC32.</u> I knew about its existence by chance because one year after I became Chairman of IEC TC32 (1990-1994). This document is fully applicable to fuses, switchgear, power transformers, etc. because the materials and principles

<table>
<tr>
<td></td>
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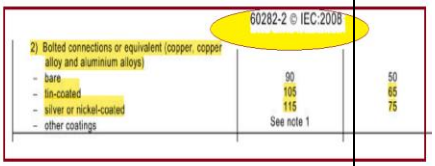
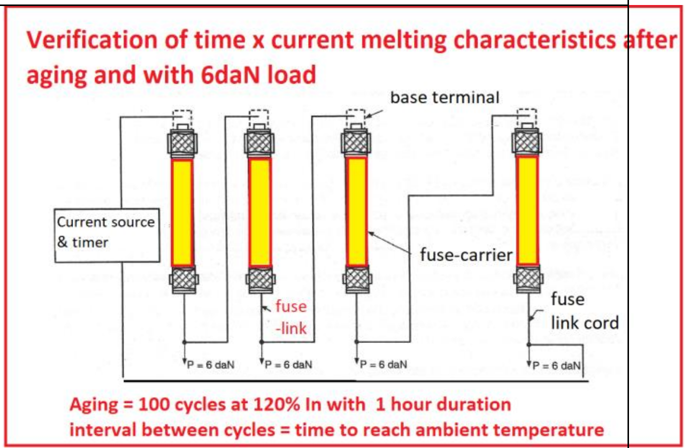
<td>The publication “IEC TR 60943 - Guidance concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals”, provides relevant information about temperature rise limits and its relationship with the aging of fuse-links and other components“</td>
<td>are the same. However, because it was published by a fuses committee and is a T.R. , very few people, even within other IEC TC’s know about its important contents.
The fact is that standards of different TCs use the same table of IEC 60943 and the copy-pastes are a source of errors.

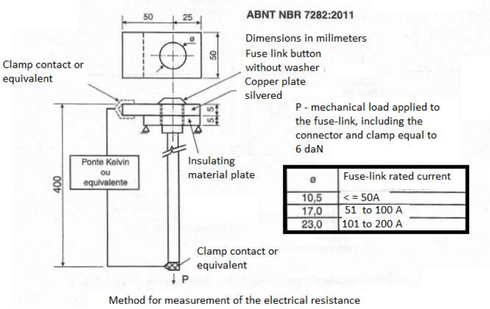
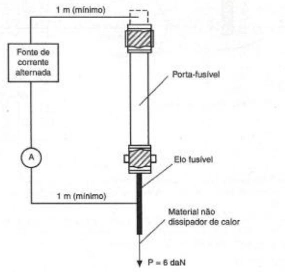
NBR 7282 (2011)
<table>
<tr><td>2) Conexões aparafusadas ou equivalentes (cobre, ligas de cobre e ligas de alumínio)</td><td></td><td></td></tr>
<tr><td>— nu</td><td>90</td><td>50</td></tr>
<tr><td>— prateado ou niquelado</td><td>105</td><td>65</td></tr>
<tr><td>— estanhado</td><td>115</td><td>75</td></tr>
<tr><td>— outros revestimentos</td><td></td><td></td></tr>
</table>


60282-2 © IEC:2008
<table>
<tr><td>2) Bolted connections or equivalent (copper, copper alloy and aluminium alloys)</td><td></td><td></td></tr>
<tr><td>- bare</td><td>90</td><td>50</td></tr>
<tr><td>- tin-coated</td><td>105</td><td>65</td></tr>
<tr><td>- silver or nickel-coated</td><td>115</td><td>75</td></tr>
<tr><td>- other coatings</td><td>See note 1</td><td></td></tr>
</table>
There are worst situations like in IEC 61439 series. When using this standard, it is impossible to a test lab to know what is the temperature rise is permitted for connections and contacts. They are generally the hot spots. Most LV switchgear tests reports do not have a conclusion (passed / not passed) due to this. Possibly, in the past, someone modified the original table and did a gross mistake that directly affect the market.
Check the article

https://www.cognitor.com.br//TemperatureRise_IEC61439Mistery.pdf</td>
</tr>
<tr>
<td># 1 1</td>
<td>9.3</td>
<td><u>Insert a special test 9.3 named “Verification of time x current melting characteristics after aging”</u>

As a preconditioning for the verification of the time x current melting characteristic curves, all sample units must be electrically connected in series and pulled by a load 6 daN, as shown in the Figure.
The units, installed as indicated …, must be subjected to 100 cycles of current rating 20% higher than the nominal. Each cycle must consist of 1 h of current application and a shutdown period required for units to reach ambient temperature. This conditioning must be accompanied by current and/or temperature records to ensure that test conditions remain unchanged throughout the test.
After conditioning, half of the samples must be submitted to verification of the curves of minimum melting characteristics time x current of 10 s, in accordance with ….. the other half of sample must be subjected to verification of the maximum melting characteristics time x current of 300 s. For the verifications of these tests, the mechanical load tension must be 6 daN . Conditioned units must meet the requirements of ….</td>
<td>
</td>
</tr>
<tr>
<td># 1 2</td>
<td>9.4</td>
<td><u>Insert a special test</u>

Measurement of ohmic resistance of contacts
The resistance of the fuse switch contacts must be measured between each terminal on the base and the part metal of the nearest accessible fuse holder after contact. The resistance value must be the arithmetic mean of three independent measurements…..</td>
<td>
This test creates a reference for the adjustments of the complete fuse. If the inclusion is accepted , we will provide the complete text of the method used in the Brazilian standard</td>
</tr>
</table>

# 1 3	**9.5**	<u>**Insert a special test**</u> **Measurement of electrical resistance of fuse links** The electrical resistance of the fuse link must not vary outside the limits of plus or minus 10% of the resistance of a standard comparator resistor to be prepared by the manufacturer for each rated current value and fuse link type.	 Method for measurement of the electrical resistance If the inclusion is accepted , we will provide the complete text of the method used in the Brazilian standard.
# 1 4	**9.i**	<u>**Insert a special test**</u> **Electromechanical test for H type fuse-links** Apply the rated current during 24 hours with a load of 6 daN Fuse-link is approved if supports the conditions for 24h	 If the inclusion is accepted , we will provide the complete text of the method used in the Brazilian standard.
1 3	**Include the new Annex D**	<u>**Include the new Annexe D**</u> 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.** **If the idea is approved the Tables shall be better adapted for expulsion fuses**

1. 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, will be used. All these rules are related to 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. There is a clear similarity of test principles and rules as in the tables presented 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

<u>The tests for which the extension criteria can be used are:</u>
• 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

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.

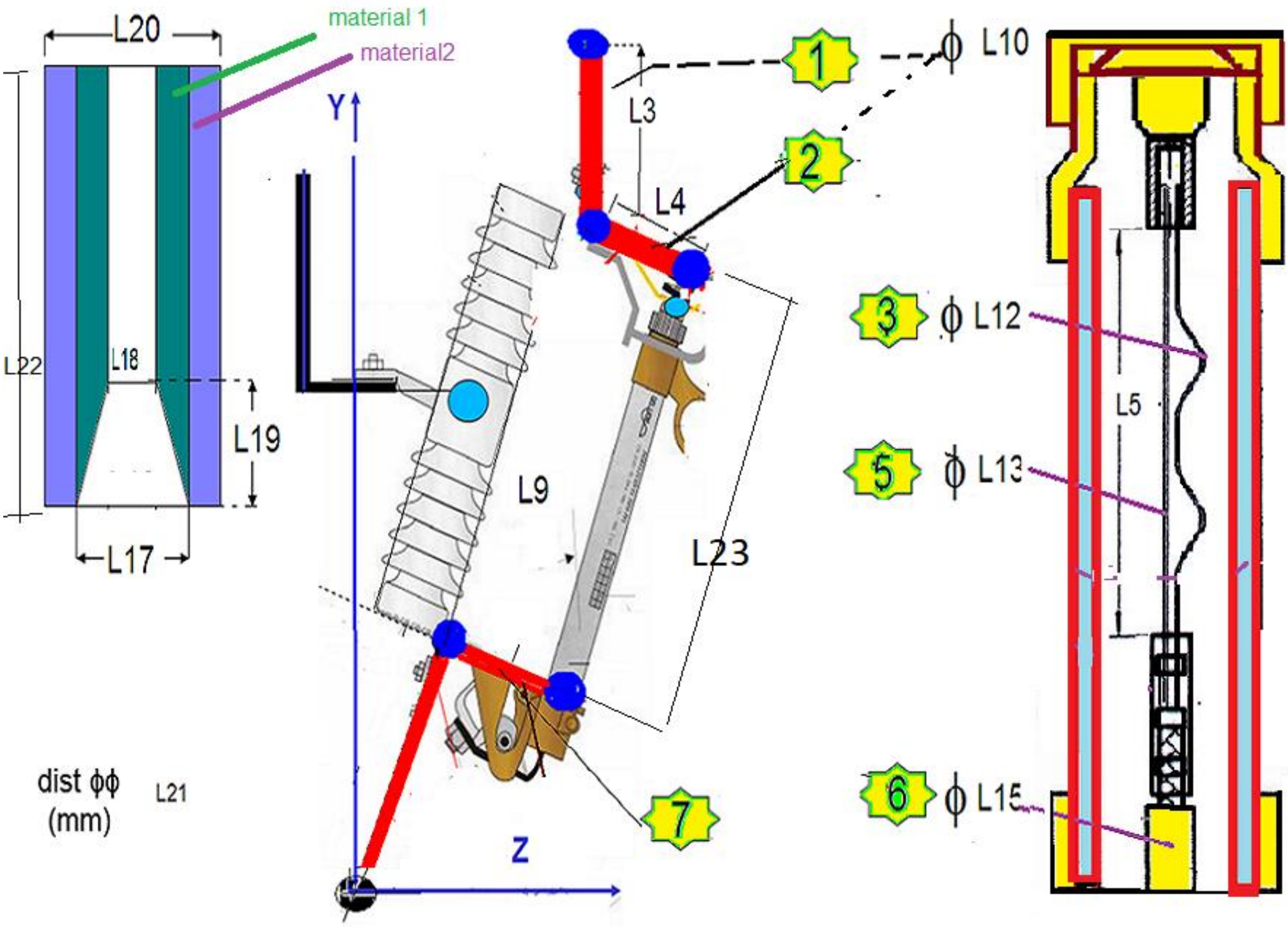
3.6 - Data to be recorded in internal arc test reports issued by laboratories
These are the parameter values which shall be registered to verify the compliance with Table D.4 with emphasis on the overpressure vs. time curve. Data affecting test and simulation results are
- Pressure vs. time curve with 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 short time current withstand current and crest test reports.
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 – Some design parameters to be considered for calculations and simulations of tests in a expulsion fuse.



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The author of this article is Eng. Sergio Feitoza Costa. Sergio is an electrical engineer, M.Sc. in power systems and director of COGNITOR. It has 40+ years of experience in the design, operation and management of high power, high voltage, and other testing laboratories. After leaving CEPEL's testing labs, Sergio gained considerable experience using lab experience + test simulations to support manufacturers and certification companies.
He is the author of SwitchgearDesign for testing simulations and DECIDIX for technical economical assessment of energy projects. Sergio was chairman of IEC Technical Committee 32 and is coauthor of IEC 62271-307 & IEC60282-2. In CIGRÈ is, coauthor of Cigrè brochures 602 (Internal Arc), 740 (Substations) and 830 (temperature rise). Sergio is also book writer, songs composer & musician.

More details, CV, free publications, training, and use of "SwitchgearDesign" in the site https://www.cognitor.com.br

CV here https://www.cognitor.com.br/Curriculum.html

Some things Sergio helped to do https://www.cognitor.com.br/HelpedToDo.pdf .

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For contacts, please write to Sergio Feitoza Costa

E-mail sergiofeitozacosta@gmail.com .

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