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# Fire performance of Electric Cables

# White Paper

| | |
|---|---|
| Flame Retardance | explained |
| Smoke Obscuration | explained |
| Fire load & Heat of combustion | explained |
| Halogens and Toxicity | explained |
| Aging and Life Span | explained |

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**By Richard Hosier**

## Chapters:



# Synopsis

The common understanding amongst most specifiers, sellers, installers and users of fire performance electrical cables which are manufactured to meet the requirements of common fire Performance tests like: Flame retardance tests: Smoke obscuration tests, Halogen and acid gas emission tests is that the cables they subsequently specify, buy and use will provide a similar performance under real fire scenarios that the test methods suggest. Unless the cables are exposed exactly to the same conditions as documented in the test, which is unlikely, this may not be the case.

*IEC 60695-1-10 states that fire tests are developed to assess functional properties of a product or system under specified fire, heat or temperature conditions over a period of time and that to relate the findings of such tests to any real fire scenarios will require very careful consideration due to the effect of any uncontrolled variables such as the environment in which the product is used.*

It is not commonly known that electric cables constitute one of the biggest fire loads in many modern buildings, nor of the potential risks this might present. There are also many common misconceptions in the market concerning what constitutes fire safety especially as it relates to Halogens and Toxicity, Flame retardance, Smoke generation, Fire loads and associated oxygen depletion on combustion.

This White Paper takes a closer look at the standards, the cables and the conditions in which many electric cables might be exposed to fire. It explains and raises some serious concerns about common cable fire test methods and our understanding of these standards as they might relate to real fire scenarios.

**About the author:**

Richard Hosier represents the TRM & MICC Group and is based in Singapore. He has been working in the electrical cable industry for over 30 years in technical and senior management positions. Mr. Hosier has lectured at institutions and universities and published several technical papers on advanced and fire safe cable design. He previously served on 3 Australian and New Zealand technical standards committees for fire safe wiring systems and cables.

# Electrical Cables:
# Flame Propagation & Flame Retardance

Electrical cables are frequently blamed by the media and fire authorities as the cause of many building fires which regardless if true or not, may not be a complete explanation. Often it is not the cable which starts a fire but the misuse of the cable by frayed or damaged insulation, overloading due to incorrect or insufficient circuit protection, short circuit or over voltage. Today with so many switch-mode power supplies 3$^{rd}$ order harmonic currents at higher frequencies can also cause overloading, including in neutral conductors. These situations can cause high temperatures in the cable conductors or electrical arcing which in turn heats the cable insulation and surrounding combustible materials to initiate a fire.

Irrespective of the root cause, cable manufacturers endeavor to manufacture electric cables which under the above situations or in cases where a fire is started by another unrelated cause, will not burn or at least will not propagate the fire through the building.

In UK and around the world there are now many cable flame retardance standards written by BS, IEC or others which propose test methods to determine if the cables are self-extinguishing, or as we like to say in the industry: “Flame Retardant”.

This article takes a new look at these tests and questions if the test methods employed and their subsequent adoption into BS, IEC and other standards, building codes and authority specifications do in fact provide the implied level of flame retardance performance when installed and used in buildings.

**Making flexible electric cables:**

Most common flexible cables are made from hydrocarbon based polymers. These base polymers are not usually flame retardant and have a high calorific value so chemicals are added to modify the polymers to make them more suited to electrical cable use. Halogens like Chlorine, Bromine, Fluorine are particularly good fillers which help retard flame propagation and don’t significantly impact the dielectric properties of the polymer so Halogens can be used in both cable insulations and in cable sheaths. These halogenated polymers (like in PVC or CSP) also have a negative effect in that during fire they release the halogens as halides which are extremely toxic and irritant.

For cables which need to be Halogen Free and Flame Retardant other non-halogen flame retarding elements such as alumina trihydrate (ATH) can be used instead of Halogens, but while effective in retarding flame propagation these fillers negatively affect the polymer in other ways such as reducing dielectric performance and affecting mechanical, chemical and water resistance. For this reason additives like ATH are mostly used only for cable jackets. Halogen Free Flame Retardant cables will most often use a more pure polymer like PE/XLPE or EPR for the insulation which has good dielectric and mechanical properties but are not very flame retardant.

**Electric Cables: Propagation performance in Fire**

Understanding the above we quickly realize that the best flame retardant cables often are halogenated because both the insulation and outer Jacket are flame retardant but when we need Halogen Free cables we find it is often only the outer jacket which is flame retardant and the inner insulation is not.

This has significance because while cables with a flame retardant outer jacket will often pass flame retardance tests when cables are subjected to an external flame, the same cables when subjected to high overload or prolonged short circuits have proved in university tests to be highly flammable and can even start a fire.

Whilst this effect is well known and published (8th International Conference on Insulated Power Cables - Jicable'11 – 19 – 23 June 2011, Versailles – France) it is perhaps surprising that not one international test method or standard exists for testing cables in such a seemingly common event as current overload and one cited by authorities and the media as a primary cause of building fires.

On evaluating the common flame propagation test methods, such as IEC60332 pt.1 & pt 3 BS 4066 pt. 1 and pt. 3 which employ an external flame source on a sample or samples of cable, it is further concerning that the test samples undergoing these tests are not pre-conditioned to operating temperature but tested at room temperature. This oversight is important because the temperature index of the cable (the temperature at which the cable material will self-support combustion in normal air) will be significantly affected by its starting temperature i.e: The hotter the cable is, the more easily it will propagate fire.

Certainly it would seem that Standards organizations and Authorities need to re-evaluate the current flame retardance test methods and standards which are commonly understood by Consultants and consumers alike to provide a reliable indication of a cables ability to retard the propagation of fire.

**If we can't trust the Standards what do we do ?**

Clearly where we have electricity with its inherent properties of voltage & current and cable conductors with their inherent property of resistance the result will be some heat. It is imperative that both cable insulations and jacket materials must be flame retardant to protect from external fire and protect from internal fire such as current overload or arcing.

In USA it is interesting to note that many building standards do not require halogen free cables. Certainly this is not because Americans are not wisely informed of the dangers, rather the approach taken is that: "It is better to have highly flame retardant cables which do not propagate fire than minimally flame retardant cables which may spread a fire". i.e. a small fire with some halogen is better than a large fire without halogens. One of the best ways to make a cable insulation and cable jacket highly flame retardant is by using halogens.

In Europe and as adopted in many countries around the world they adopt a different mentality: Halogen Free and Flame Retardant. Whilst this is an admirable mandate the reality is rather different: Flame propagation tests for cables as adopted in UK and Europe can arguably be said to be less stringent than some of the flame propagation tests for cables in USA leading to the reasonable conclusion that common tests in UK and Europe may simply be tests the cables can pass rather than tests the cables should pass.

Of course simply adopting UL and ASTM flame propagation tests instead will result in difficulties for many cable manufacturers to supply cable meeting these tests which are also Halogen Free. On the face of it a dilemma with no easy solution.

**Conclusion**

For most flexible polymeric or plastic cables the choice remains today between high flame propagation performance with Halogens and reduced flame propagation performance without halogens.

Whilst enclosing cables in steel conduit will reduce propagation at the point of fire, hydrocarbon based combustion gasses will propagate through the conduit to switchboards, distribution boards and junctions. Any spark such as the opening or closing of circuit breakers, or contactors is very likely to ignite the combustible gasses in the switchboard leading to explosion and spreading the fire to another location.

There is no one right or wrong answer for every installation or application so designers will need to evaluate the required performance on a "project-by-project" basis to decide which technology is optimal.

For today's large and complex buildings where large numbers of people are confined, restricted, incapacitated or with long egress periods there is one complete solution. It is one which has been used for over 80 years with 100% reliability and is still in use today.

MICC cable being a copper sheathed cable with inert magnesium oxide insulation and copper conductors is in fact 100% flame retardant. It has no fuel element to fuel a fire so it simply cannot propagate fire. As it is metallic with mineral inorganic insulation it is not only Halogen free but free of any and all toxic gasses when burned, including CO and $CO_2$.

No other cable design today can guarantee this performance, or provide the same level of overall fire safety and integrity security throughout the life of the building. MICC cables are also water and oil proof, have a greater current ratings and have smaller diameters compared to other cable deigns. They require no conduit for mechanical, vermin or insect protection, need fewer fittings, are 100% UV, ozone and sunlight resistant as well as radiation resistant, are non-ageing and will operate in cryogenic environments. They are also mechanically stronger than any other cable design in all operating and emergency conditions.

MICC Ltd manufactures Mineral Insulated Cables with copper or special metal alloys capable of meeting all known Fire propagation, Flame and Oven tests. The company provides a guaranteed Fire Proof wiring system which not only is 100% flame retardant but 100% Halogen free, 100% smoke free, 100% toxic emission free with zero organic content. Because MICC has no fuel element it contributes no heat of combustion, creates no oxygen depletion and no contribution to temperature rise.

--------------------------- **MICC cables are for life** -------------------------------

# Electric cables:
# The primary importance of fire load

When choosing electrical cables for a project or application the choice made is often simple: For non-essential wiring we choose PVC/PVC or XLPE/PVC sometimes with additional mechanical or rodent protection like Steel Wire Armor or in metal conduit. These common, cheap and available cables, when made according to relevant standards and quality systems provide adequate electrical and mechanical properties and are generally easily installed.

In some applications where public safety is important we require electric cables to have added safety features such as flame retardance to ensure the cables do not easily spread fire and circuit integrity during fire so that essential fire-fighting and life safety equipment keep working. Sometimes we may recognize that the combustion of electric cables produces smoke and this can be toxic so we call for cables to be Low Smoke and Halogen Free.

Logically and intuitively we think that by requesting these special properties the cable we buy and install will be safer, especially when we insist that the cables used should conform to some common international standards addressing these properties like IEC, BS VDE or AS/NZS. As with many things in life a little knowledge can be a dangerous thing so in this article I like to dig deeper into the subject of smoke generation, toxicity, halogens and fire safety especially as they relate to electric cables.

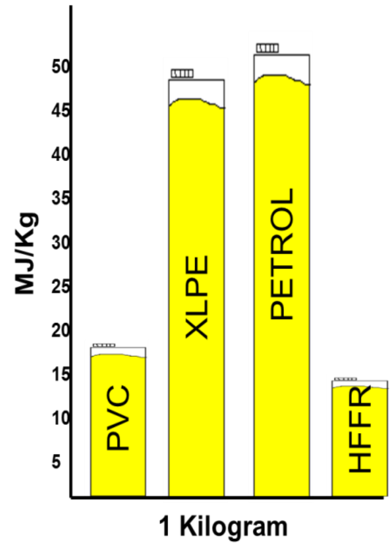
Inside all buildings and projects electric cables provide the connectivity which keeps lights on, air-conditioning working and the lifts running. It powers our computers and office equipment and provides the connection for our telephone and computer systems to communicate with the outside world. Even our mobile phones need to connect with a wireless or GSM antenna which is also connected to the telecom network by fiber optic or copper cables. In addition, cables ensure our safety by connecting fire alarms, emergency voice communication, CCTV, smoke shutters, air pressurization fans, emergency lighting, fire sprinkler pumps, smoke and heat detectors, fire door closers and so many other features of a modern Building Management System.

Whilst we know all of the above, we seldom think much about it because electric cables are mostly hidden and embedded in our constructions. Because cables are installed by many different trades for different applications, what is not often realized is that the many miles of cables and many tons of plastic polymers which make up the cable insulation and jacketing represent one of the biggest fire loads (fuel source) in the building. This point is certainly worth thinking more about.

PVC (polyvinyl chloride), XLPE (cross-linked polyethylene), EPR (ethylene propylene rubber), CSP (chlorosulphonated polyethylene) and even HFFR (Halogen Free Flame Retardant) cable materials are all based on hydrocarbon polymers. These base materials are not flame retardant and naturally have a high fire load. Cable manufacturers make them flame retardant by adding compounds and chemicals. Certainly this can improve the volatility of burning but the fuel content of the base polymers fillers and additives remains.

The following table compares the fire load in MJ/Kg for common cable insulating materials against some common fuels: Petrol / Gas, Coal and Wood. The Heat Release Rate and volatility in air for these materials will differ but the fuel added to a fire per kg and the consequential volume of heat generated and oxygen consumed is relative.

| common name | description | MJ/Kg |
|---|---|---|
| Petrol | | 48 |
| XLPE | **Polyethylene** | **46** |
| PP | **Polypropylene** | **46** |
| Nylon 66 | **Polyamide** | **33** |
| EPR | **Ethylene propylene rubber** | **28.5** |
| CSP | **Chlorosulphonated polyethylene** | **28** |
| Coal | | 25 |
| PCP | **Polychloroprene rubber** | **24** |
| Wood | | 18.5 |
| PVC | **Polyvinyl chloride** | **18** |
| SIR | **Silicone Rubber** | **15.5** |
| ETFE | **Ethylene tetrafluoroethylene** | **13.8** |
| HFFR | **Halogen Free Flame Retardant** | **13** |
| PTFE | **Polytetrafluoroethylene** | **5** |
| MICC | **Bare Mineral Insulated Metal Sheathed** | **0** |




When we consider the volume in kilometers and tons of cable insulations which we install in our buildings and projects, the fire load of electric cables becomes very considerable. This is particularly important in projects with long egress times such as high rise, in tunnels or underground environments, in public buildings, theaters, airports, hospitals etc..

In considering fire safety we must first understand what are the real and most important dangers. When we talk to the fire experts they tell us most fire deaths in buildings are caused by smoke inhalation, temperature rise and oxygen depletion or by the trauma caused by jumping or falling in trying to escape these effects. So let’s take a closer look at each of these:

**SMOKE:**
The first and most important aspect of smoke is how much smoke? Typically the larger the fire the more smoke is generated so anything we can do to reduce the spread of fire will also correspondingly reduce the amount of smoke.

Smoke from building fires will contain particulates of carbon (soot) ash as well as other solids, liquids and gasses, many are toxic and combustible. In particular fires in buildings, tunnels and in underground or confined areas cause oxygen levels to drop, this contributes to incomplete burning and smoldering which is known to produce significantly increased amounts of smoke along with large volumes of toxic byproducts including carbon dioxide and carbon monoxide. Presence of halogenated materials will also produce toxic Halides like Hydrogen Chloride which combine with the many other toxic and flammable substances and gasses in the smoke.

It is for this reason common smoke tests conducted on cable insulation materials in large 3 meter$^3$ chambers with plenty of air can provide very misleading smoke generation figures because the complete burning will usually release significantly less smoke than the partial incomplete burning or smoldering which is likely to be experienced in practice. Simply specifying IEC 61034-1/2 with a defined obscuration value then thinking this will provide a low smoke environment during a real building or underground fire may provide the specifying engineer or authority with a comfort factor but may be little help for the people involved in the fire.

**Halogens, Toxicity, Fuel Element, Oxygen depletion and Temperature Rise**

It is genuinely concerning that the electrical cable industry in Europe and in many other countries around the world have adopted the concept of halogen free materials without properly addressing the subject of toxicity. Halogens when released during combustion as halides are extremely toxic but so too is carbon monoxide and this is not a halogen gas. It is very common for engineers and authorities to call for halogen free cable insulations and then use Polyethylene because it is halogen free. Burning a Polyethylene cable (which can be seen from the table above has the highest fuel content per Kg of all insulations), generates almost 3 times more heat than an equivalent halogenated PVC cable. What this means is that on burning polyethylene it not only generates 3 times more heat but also consumes 3 times more oxygen and produces significantly more carbon monoxide than burning an equivalent PVC cable. Given carbon monoxide is responsible for most toxicity deaths in fires this situation is at best alarming!

You might then ask if using halogen free materials is a safer option? In America it is not so common for halogen free cables to be specified. The reason is not because Americans are not fully aware of toxicity dangers, they simply have the opinion that by using highly flame retardant materials (even if they contain halogens), the likelihood of a fire spreading is less and therefore any fire is likely to be smaller. A small fire with halogens may be better than a large fire without. The authors opinion is that it is better to use halogen free materials but certainly not if simply replaced by more flammable and high fuel content materials which are arguably much worse and on more levels.

The fuel elements shown in the table above indicates the amount of heat which will be generated by burning 1kg of the common cable insulations tabled. Certainly this heat will accelerate the burning of other adjacent materials and help spread the fire in a building but importantly, in order to generate the heat energy, oxygen needs to be consumed. The higher the heat of combustion the more oxygen is needed, so by choosing insulations with high fuel elements is adding significantly to at least three of the primary dangers of fires: Temperature rise, Oxygen depletion, and Flame spread.

Perhaps the best we can do is install polymeric cables inside metal conduits. This will certainly help flame spread and minimize smoke because inside the conduit oxygen is limited; however this is not a solution. Many of the gasses from the decomposing polymeric insulations inside the conduits are highly flammable. These gases can migrate along the conduits to junction boxes, switch panels, distribution boards, motor control centers, lamps, switches, fire alarm panels and the like. On entering these, the gases can be ignited by any arcing such as the make/break of a circuit breaker, contactor, switch or relay. The gasses can ignite or even explode causing the fire to spread to another location.

## Conclusion

If we have learnt anything over the years it is that fires in buildings, tunnels or underground maybe inevitable and that smoke, heat, toxic by-products of combustion and flame spread may be unavoidable. The popularity of “Halogen Free” while ignoring the other toxic elements of fire is a clear admission we do not understand the subject well nor can we define the dangers of combined toxic elements or human physiological response to them.

It is, however important that we do not continue to design with only half an understanding of the problem. While no perfect solution exists for organic based cables, we can certainly minimize these critically important effects of fire:

One option maybe to choose cable insulations and jacket materials which are halogen free and have a low fuel element, then install them in steel conduit. Maybe the American approach is better: to use highly halogenated insulations so that in case of fire any flame spread is minimized.

For most power, control, communication and data circuits we do have one complete solution available. It is a solution which has been used for over 80 years reliably and without fail. MICC cables provide a total & complete answer to all the problems associated with the fire safety of organic polymer cables.

With a copper jacket, magnesium oxide insulation and copper conductors MICC cables are effectively fire proof. Neither the copper jacket or Magnesium oxide or copper conductors have any organic content so simply cannot generate any halogen or toxic gasses at all. They cannot propagate flame and cannot generate any smoke. They have a zero fuel element so cannot contribute any heat to a fire nor can they consume any oxygen in fire.

No other cable design today can guarantee the overall electrical, mechanical and environmental performance of MICC or provide the same level of overall fire safety, integrity and security throughout the whole design life of the project. MICC cables are both water and oil proof, have a greater current ratings with smaller diameters and need fewer fittings compared to other cable deigns. They are radiation resistant, do not permit toxic radiation or biohazard propagation along the cable cores and are ideal for use in nuclear, bio-hazard, chem-hazard and cryogenic environments.

MICC cables are mechanically stronger than any other cable design in all operating and emergency conditions. They do not soften when exposed to high temperatures, are crush, impact and cut through resistant They require no conduit for mechanical protection and termites or rodents cannot eat through the outer sheath of bare MICC cables as they do for served Steel Wire Armored cables.

MICC cables are often used in critical and essential applications, for high rise, public buildings, hospitals with long egress times, for tunnels, metros and underground shopping centers, airports, government buildings, embassies. They are perfect where high or continuous current loading is required and approved for use in all Hazardous locations. The cables are often used for projects with long design lives of 50 years or more and are used frequently in many historic buildings as they are non-aging hence never need replacing and are architecturally compatible in visible locations.

So why is it that MICC cables are not used as often today as they were in the past? The reason is that 30 years ago when flame retardant, halogen free polymeric cables came to the market the cable standards at that time never considered a holistic approach to fire safety. In fact even today they still don’t.

Often with contribution from the polymeric cable manufacturers themselves, individual test methods have been created for cable tests to be conducted under carefully prescribed conditions for smoke, flame propagation, circuit integrity, halogen and corrosive emissions and more recently toxicity, often with a mind to repeatability rather than fire reality. These test methodologies have been subsequently and individually adopted by application standards accepted by various authorities and embedded in building regulations.

Unfortunately many of these test methods and the application standards adopting them today mislead users and authorities into believing the cable products they subsequently specify, buy and install will perform as expected in a real fire. As outlined in this paper, sadly this may not be correct.

Today it is better understood that electrical cable insulations represent a very considerable fire load in buildings. It is realized that adopting and specifying simple laboratory tests conducted on cables under specific conditions, which themselves often bear little relevance to real fire environments and with little or no context qualification provided in the standards, may not provide the real fire performance that the test method suggests unless under exposed exactly the same conditions.

**Specifically it might be better if:**

| | |
|---|---|
| Flame retardance: | Tests should be conducted on cables preconditioned to operating temperature. Tests for flame propagation under sever current overload should be developed. |
| Smoke Obscuration: | Tests should be conducted on insulations and jackets at high temperature without flame, when smoldering and when enveloped by flame. |
| Halogen & Acid gas: | Tests standards must qualify they are not tests determining toxicity and do not test for CO, $CO_2$ HCN or any other toxic by-product of combustion. |
| Fire circuit integrity: | Tests should be conducted according to the protocol of the international fire time temperature standard: ISO834-1 |
| Current Ratings: | Standards should clearly identify the life expectancy of cables when operated at the conductor temperatures indicated and give de-rating information for continuous loading. |

It would not be fair to blame installing contractors for buying and installing polymeric cables where fire safety is paramount because they are driven by specification, regulation and competitive economics. It is fair to say that standards organizations and regulatory authorities should re-evaluate many of the current test methodologies for fire performance testing of electric cables with a view to holistic and overall fire safety. Specifically the test standards must qualify the methodology used and results obtained with a clear explanation or disclaimer stating that:

**"The test method described may not represent actual performance in any given fire event and that the users of the standard should make their own assessments of suitability and relevance of the standard for the intended application"**.

It is important for consulting and specifying engineers to understand the real performance provided by different cable technologies in order to provide their clients with a system design which has the best possible chance of delivering the overall performance required.

MICC Ltd manufactures Mineral Insulated cables and cable systems with copper or special metal alloys capable of surpassing all known Fire propagation, Flame and Oven circuit integrity tests. The company provides a guaranteed fire proof and inherently fire safe wiring system.

-------------------------- MICC cables are for life ------------------------------

# Electrical cables - Life Span
## ( It's not what you might think )

Almost everything, be it mobile phones, cars, trains, airplanes, buildings, tunnels, bridges have a design life. I have often been dismayed by the apparent design life of my mobile phone but I am never more amazed when I drive over Sydney Harbor Bridge, now over 80 years old, or fly in a 30 year old commercial airplane. How long something is required to provide effective and reliable service in its anticipated environment is a key design criterion which will dictate the choice of design and materials used.

Electric cables are no different and have a useful design life span under specific conditions but unlike many other components, electric cables remain the fundamental arteries or nerve connections that enable every other active component to work. Because electric cables are 'embedded' often it is difficult and expensive to replace them, as such electric cables should ideally provide a reliable service life equal to or better than the equipment connected and often aligned with the project or equipment design life.

Many people think of electric cables as passive electrical components but nothing is further from the truth. On activation, electric cables need to transmit voltage and current over a range of frequencies. Due to the fundamental limitations of conductors and insulations, secondary effects such as resistance, reactance, impedance, capacitance etc. all create unwanted conflicts which need to be both understood and designed out or at least minimized as far as practicable. Connected equipment can also induce unfavorable influences in electrical cables but one very important conflict be it inherent or induced is the effect of conductor resistance on current flow because this creates heat.

Heat in the presence of air is a primary enemy of all polymer insulations but light, some acids, alkalines, salts and gases like Ozone will accelerate degradation. Heat or Thermal degradation is a molecular deterioration caused by the long chain molecules breaking (scission) and reacting with one another to change the properties. These changes typically include reduced flexibility, embrittlement (cracking) chalking, color changes and reduced elongation. In addition to the physical changes of aging performance, operational properties may also be affected and these might include insulation resistance, flame retardance, oil / water resistance etc..

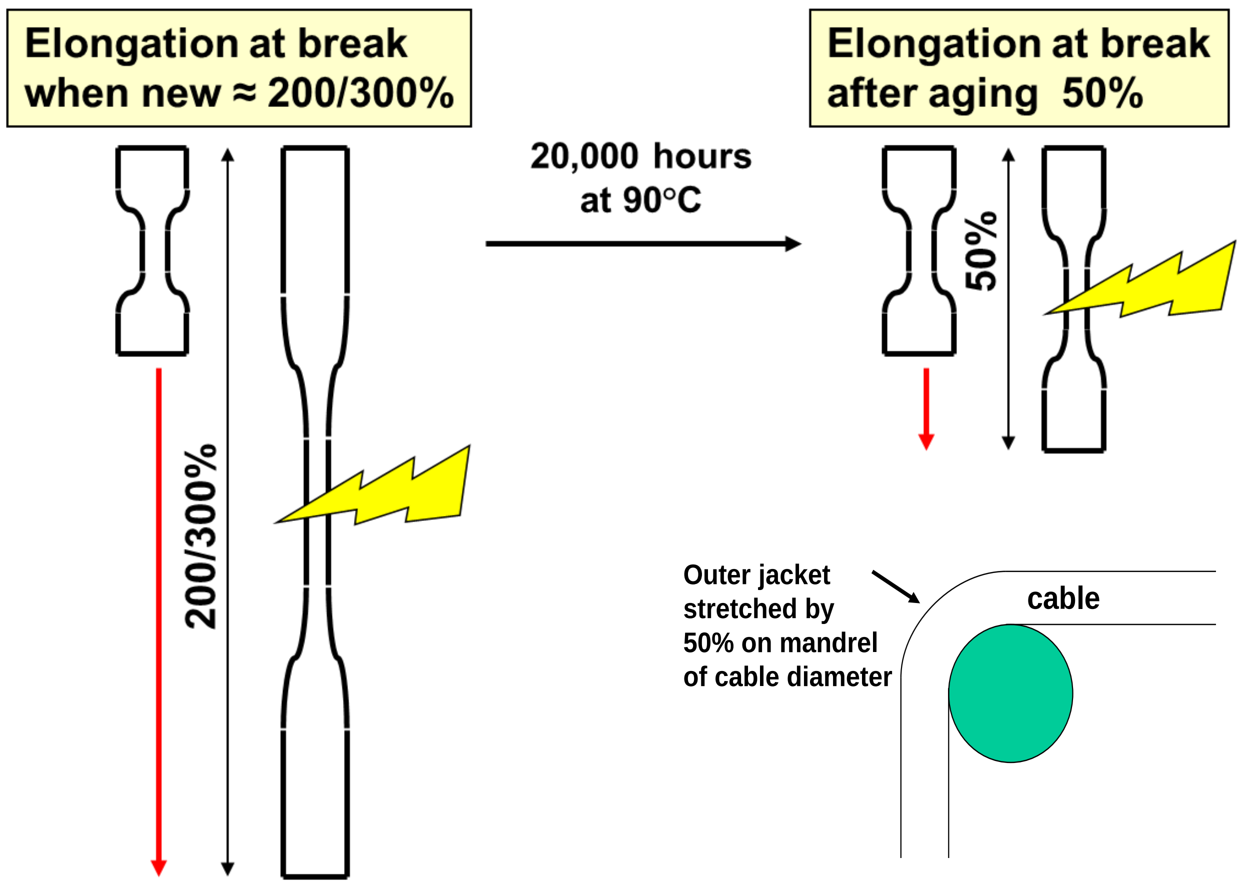
Stabilizers as used in many cable insulations are designed to slow the process by 'mopping up' free radicals but the internationally accepted test method to determine aging performance for electrical insulations is defined by IEC60216 which employs accelerated heat aging of test samples, comparing the aged elongation at break performance against un-aged samples, tabulating the results on an Arrhenius plot and extrapolating to predict extended life performance.

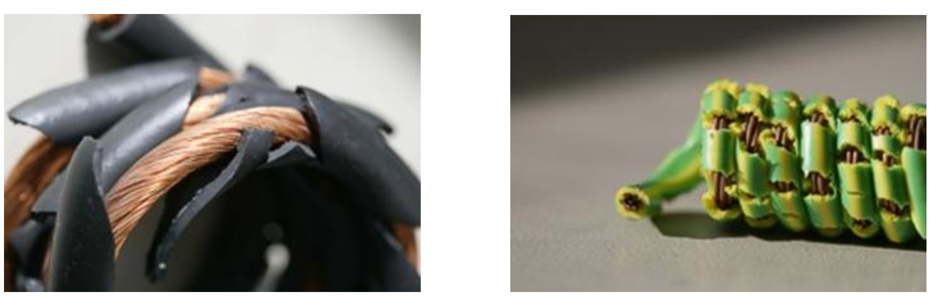
This standard is adopted widely around the world and specifies the calculation and test procedures to be used for deriving thermal endurance characteristics from experimental data obtained in accordance with the instructions of IEC 60216-1 and IEC 60216-2, using fixed ageing temperatures and variable ageing times.

**In essence:** The temperature rating given to an insulation material is: “That temperature which degrades / reduces the material’s elongation at break (EB) to 50% absolute in a period of 20,000 hours exposure” (20,000 hours = 2.3 years ).

**Common cable insulating materials operating temperature defined by IEC60216 test method:**

- PVC = 70°C
- XLPE = 90°C
- EPR / CPE / CSP rubber = 90°C
- Silicon Rubber = 180°C
- Teflon PTFE = 260°C



**Cable insulation degradation caused by thermal aging**

Understanding why PVC is rated at 70°C and why XLPE is rated at 90°C we can now better understand why the current rating standards we use calculate current ratings for PVC based on a 70°C conductor temperature and for XLPE/EPR based on a 90°C conductor temperature:

- **UK IEE wiring regulations 17th Edition,**
- **IEC 60364-5-52**
- **AS/NZS3008-1**

Perhaps what is not highlighted by these standards is that the elongation reduction to 50% absolute is calculated on 20,000 hours exposure time at this temperature - which is only 2.3 years. In fact these standards do not really expect engineers to use the cables at (PVC) 70°C or (XLPE) 90°C continuously or the cable lifespan will be exceptionally short. They assume usage will be on a basis of discontinuous loading where it is not anticipated the cables will be fully loaded 100% of the time. This pragmatic approach is the only way polymeric cable insulations can be economically viable.

A common 'rule of thumb' for cable polymer insulation aging is that a reduction of 10°C in the average cable operating temperature across its life span will double the insulation life time to the 50%EB (Elongation at Break) point: i.e:

PVC operated continuously at 70°C will degrade to 50%EB in 20,000 hours (2.3 yrs)
operated continuously at 60°C will degrade to 50%EB in 40,000 hours (4.6 yrs)
operated continuously at 50°C will degrade to 50%EB in 80,000 hours (9.2 yrs)
operated continuously at 40°C will degrade to 50%EB in 160,000 hours (18.4 yrs)

XLPE operated continuously at 90°C will degrade to 50%EB in 20,000 hours (2.3 yrs)
EPR operated continuously at 80°C will degrade to 50%EB in 40,000 hours (4.6 yrs)
operated continuously at 70°C will degrade to 50%EB in 80,000 hours (9.2 yrs)
operated continuously at 60°C will degrade to 50%EB in 160,000 hours (18.4 yrs)

Conversely increasing the continuous exposure temperature by 10°C will half the time to 50%EB. In reviewing the above it must be remembered that any additional chemical, ozone, light radiation exposure, overload or short circuit events will serve to shorten the anticipated cable lifespan.

It is not commonly realized just how quickly common polymeric cable insulations will degrade with time and temperature when operated continuously in air at their rated temperatures:

| *Insulation Material* | *Temperature Rating* | *Continuous exposure for 20,000 hours (2.3 yrs) at rated temp.* | *Expected reduction in elongation at break* |
|---|---|---|---|
| PVC | 70°C | 70°C | 80% |
| PE and XLPE | 90°C | 90°C | 85% |
| EPR, CSP, | 90°C | 90°C | 85% |

In practice, the use of IEC60216 for determining polymeric insulation temperature ratings by heat aging and elongation at break measurements with the subsequent calculations for determining cable current ratings is pragmatic but only because circuits are not often sized exactly to current demand. Full load current loading of cables circuits can be infrequent and the "averaged' operating temperature of cables over their lifetime may well be rather less than the maximum conductor temperature ratings quoted in the standards thus extending the cable life span to a reasonable time.

In defense of the mentioned standards, to calculate polymeric cable current ratings based on any more conservative usage would require significantly larger conductor sizes having significant economic impact. Environmental issues might also need to be considered, (although for power circuits corresponding reduction in Watt losses might well compensate for the additional cost over the cable installation life time).

It is critical that electrical design engineers understand the ageing characteristics of polymeric insulations when selecting cables for use in applications where long life is needed and/or where high continuous or for near continuous loading, especially in high ambient temperatures, in sunlight or where higher than normal levels of ozone is expected. Examples may include: Conventional or Nuclear Power Stations, generators, high temperature industrial facilities, transformers, continuous ventilation fans, continuous pumps etc.. In these cases “continuous use” de-rating factors should be applied or the use of cables with a correspondingly higher continuous temperature rating.

There is one cable technology that has been available and widely used for over 80 years and which is simply not affected by aging. MICC cable with its copper outer jacket, inorganic magnesium oxide insulation and copper conductors does not age regardless of heat. It will withstand repeated overload and short circuit events without any degradation. It is unaffected by sunlight, UV, Ozone and resists many chemicals.

For this reason MICC cables are often used in critical applications, for high or continuous loading and for essential safety circuits. MICC cables are often used for projects with long design lives of 50 years or more and are used frequently in many historic buildings as they are non-aging, never need replacing and are architecturally compatible in visible locations. The cable is also approved for use in all Hazardous locations.

Being inorganic MICC cables are totally flame retardant because they have no fuel element to propagate a fire so simply cannot spread flame. For the same reason MICC cannot generate halogen, corrosive or any other toxic gasses when subjected to high heating or fire, including CO and CO2.

MICC cables are also mechanically stronger than any other cable design and in all operating or emergency conditions. They do not soften when exposed to high temperatures, are crush, impact and cut through resistant They require no conduit for mechanical protection and termites or rodents cannot eat through the outer sheath of bare MICC cables as they do for served Steel Wire Armored cables.

No other cable design today can guarantee the electrical, mechanical and environmental performance of MICC cable or provide the same level of overall fire safety, integrity and security throughout the full design life of the project. MICC cables are both water and oil proof, have greater current ratings with smaller diameters and need fewer fittings compared to other cable deigns. They are radiation resistant, do not permit radiation or biohazard propagation along the cable cores and are ideal for use in nuclear, bio-hazard, chem-hazard and in cryogenic environments.

MICC Ltd manufactures Mineral Insulated Cables with copper or special metal alloys capable of meeting all known Fire propagation, Flame and Oven tests. The company provides a guaranteed Fire Proof wiring system which is not only 100% flame retardant but 100% Halogen free, 100% smoke free, 100% toxic emission free with zero organic content. Because MICC has no fuel element it contributes no heat of combustion, causes no oxygen depletion and no contribution to temperature rise. They are also non-aging.

--------------------------- **MICC cables are for life** -------------------------------

MICC Ltd
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MICC GROUP
cables for life

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