Questions & Answers regarding

PPE to Protect Eyes & Face against an Arc Flash

Q: When selecting PPE to Protect Eyes & Face against an Arc Flash, what is the most important selection criteria?

A: Of course the arc protection level is the most important criteria, i.e. the **arc rating** (ATPV) as per ASTM F2178 or the **arc protection class** as per GS-ET-29. However, typically the higher the protection level, the lower the luminous transmittance also called **Visible Light Transmission (VLT)**. Considering the usually poor illumination inside switching cabinets and several other typical electrician workplaces also this VLT is a deciding safety factor. Due to bad visual conditions mistakes may happen – finally even causing an arc flash accident. Note that products with a VLT between 50% and 75% (VLT Class 1) already may need additional illumination. Products with a VLT of less than 50% are supposed to be "very dark". Those products only should be used, when extreme high protection is required and provided by a particular product. For the same reason the field of view, i.e. the peripheral area one can see without moving the head, is important, e.g. when a switching hood is required.

Q: Paulson offers arc flash protective products tested to ASTM *and* or EN 166 / GS-ET-29. Why?

A: ASTM F2178 is not a listed standard as per CEN (European standards). Manufacturers selling their products in Europe MUST have a CE mark, which requires a testing as per EN 166 and GS-ET-29. Several Paulson products are tested to both standards. For Europe here the ATPV as per ASTM F2178 may provide further purchasing criteria. In case a product is tested to GS-ET-29 only, the gap between the heat flux sensors and the boundary line (Stoll Curve) may help to understand the safety buffer provided by a particular product.

Q: How about products tested to higher arc energies as defined by GS-ET-29?

A: All serious manufacturers are supposed to test their products under over load conditions to optimize the protective properties, however these results should not be used for marketing purposes as the user cannot gain objectively verifiable inputs from this data when selecting PPE to a hazard and risk analysis. The determination of additional protection classes is a matter of numerous considerations on work safety and hundreds of measurements under dozens of test conditions. Therefore Paulson does not use their over-load results for marketing purposes, despite of the impressive results.

Q: Some companies are offering so called "clear" shields, suggesting to have better color perception than tinted shields?

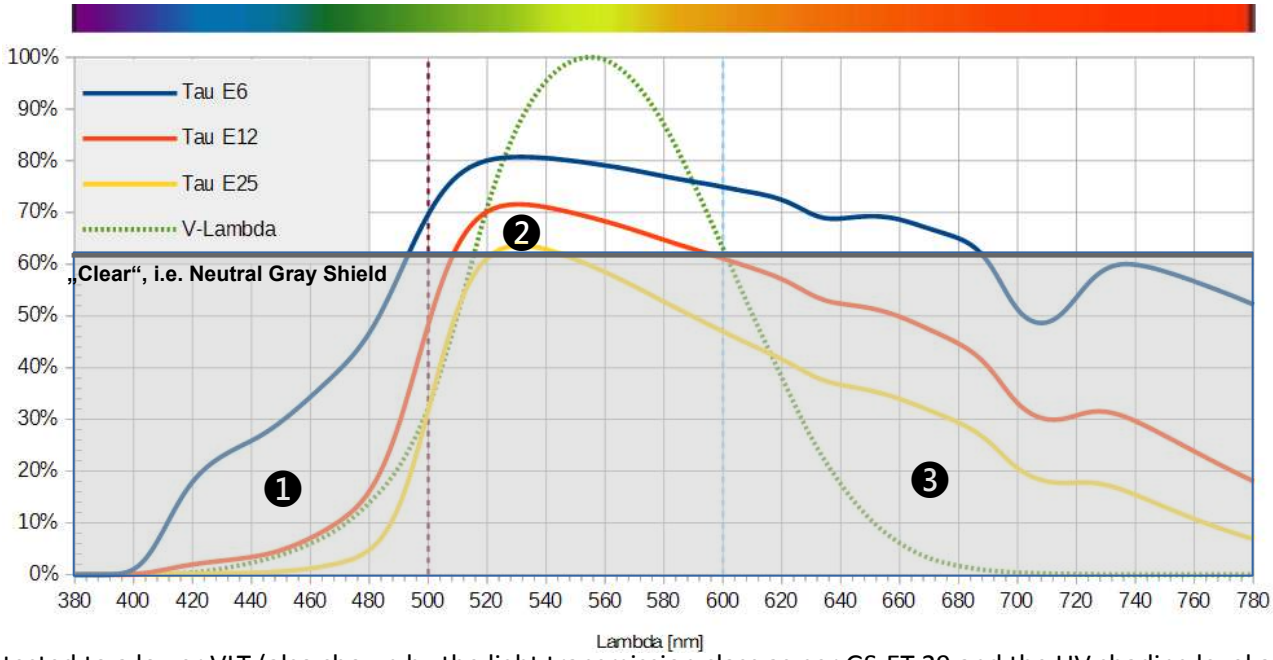
A: Indeed color perception may be important, when working with complex cable color codes. Products with a 'C' in the marking are successfully tested to "Improved Color Perception". Therefore all Paulson arc protective products certified to EN are showing this 'C' in their marking. However in practices this figure must be combined with the a.m. VLT, as human color recognition significantly decrease with dark environments. We all know, that at night humans are not able to distinguish between colors.

For higher arc protection levels the so called "clear" shields on the market are typically tinted in gray. Best case gray filters reduce all colors by the same ratio, but human eyes do not have the same color sensitivity. for all colors.

On the other hand the amount of energy, which is supposed not to harm human eyes, depends on the color. For example blue light is more aggressive than green light, while our eyes are more sensitive to green light. That is why Paulson arc protective products are made with a light greenish tinting, i.e. allowing more

light to pass through in the yellow green color range and unload face & eyes from radiation where human eyes are less sensitive. Nevertheless all Paulson arc protective products certified to EN 166 fulfill the requirements for “Improved Color Recognition” at high levels of VLT (see the 'C' in the marking).

For better understanding let have a look at the spectrogram of a PAULON ARC-E12 shield:



tested to a lower VLT (also shown by the light transmission class as per GS-ET-29 and the UV shading level as per EN 170), which means you have to shift down the gray line. Now the effect is even more significant, as zone ❷ is growing, while the zones ❶ and ❸ are shrinking.

Nevertheless, also the PAULSON ARC-E12 is certified to “Improved Color Recognition”!

Q: Are products tested to EN 410, showing a 'Color Reproduction Index' better than products tested to EN 166 only?

A: EN 166 and subordinated standards are dedicated to to eye and face protective products, where the subordinated EN 170, clause 5.3 and Annex A.1, specifically describes requirements for “Improved Color Recognition”, while EN 410 is issued to asses window properties of buildings. Now, when assessing the color mixing of a Picasso protected by a glass housing under optimal illumination the color reproduction index may be important.

Typically arc protective products are not used for these kind of tasks. Therefore Paulson prefers to give precise information based on standards dedicated to eye & face protection applied under realistic working scenarios, where optimal illumination, e.g. in a switching cabinet is typically not given. Here best possible VLT and best possible contrast perception is required.

Q: How can Paulson offer such high VLTs and at the same time high arc protection levels?

A: Typically arc protective products are a compromise, as they cannot differentiate between “normal” working and an arc flash incident, i.e. their filter characteristic is more or less the same.

Paulson arc protective products however significantly change their properties in case of an arc flash by using the arc energy. With other words the Paulson technology provides a two stage protection: Minimal protection during normal work at very high VLTs, changed to optimal protection in case of an arc flash.

Q: Some arc flash protective products on the market are advertised by absorption, some by reflection others by automatic darkening filters. Which one is the best?

A: Don't worry about these technology questions. Important is, what you can see during your normal work and how much energy can be blocked from your eyes and your face in case of an arc flash.

Products offering protection by **reflection** are typically working with very thin layers of metal alloys on their surfaces, i.e. the entire protection relays on the properties of some micrometers.

The protection of arc protective products based on **absorption** (such as Paulson products) typically comes from the whole product, i.e. the full thickness of e.g. the face shield, where damages even of the complete surface logically doesn't significantly reduce the level of protection.

Like Paulson arc protective products **automatic darkening filters** do have a two state protection, but based on electronic components. Electronic components however need a battery and my fail. Furthermore it is very difficult to produce auto-darkening filters with a large peripheral view and good optical properties at the same time. Typically such products are equipped with a relative small flat lens, which doesn't provide peripheral vision in the sides, down- and upward.

Reflective products and auto-darkening filters are known to proved a relative low VLT.

Q: What happens to the arc energy when absorbed by a Paulson arc protective product?

A: Here comes the deciding advantage: Paulson *uses* the energy to change the product properties. A part of the energy is used to dissociate the surface material by a controlled process. This process is called *ablation*. The remainder energy is used to create another protective layer on the outer surface of the transparent components of the Paulson arc protective products. This process is called *carbonization*. The surface looks like regularly distributed flakes of burned plastic. These flakes are dark, i.e. absorb heat radiation (IR) and include air for thermal insulation. By this Paulson arc protective products change their optical and thermal properties starting at the very first moment the energy exceeds a limit supposed to be normal (e.g. normal sunlight or typical environmental heat).

Q: How about product aging? Are reflective products staying longer in the field than absorbing products?

A: In general *all* products are suffering from aging. Therefore responsible manufacturers always clearly recommend product replacement periods necessarily also considering the typical usage. Finally the live time of a product depends on the product quality and the way products are used regardless to protection technology.

A poor quality reflective layer may be damaged in very short times, while a poor absorbing material may dissociate, when exposed to sun light or may melt, when exposed to an arc flash. Products tested to EN 166 must endure a comprehensive test to prove long term stability.

Unfortunately products made from pre-manufactured sheet material do not allow to design the absorbing components. This is one of the reasons why Paulson arc protective products are manufactured by injection molding. During the sophisticated manufacturing process the Paulson absorbing nano-particles are carefully distributed over the entire plastic material and reliably implemented to the plastic structure. Broadly speaking the Paulson nano-technology provides absorption at any place in the material “intelligently” capturing the energy before it can harm the plastic material.

Q: What else needs to be considered when selecting eye & face arc flash protective equipment?

Now, every selection criteria should be derived from the hazard & risk analysis. Consider **side and chin/neck protection and / or 360° protection**. When combining arc PPE make sure, that the arc rating or arc protection class of *every* component comply to the hazards and risks identified. Don't forget, even the best PPE doesn't help, if not worn, i.e. PPE must be wearable. The user must understand the merits gained from wearing proper PPE.

Q: The EN 166 is still valid. I suppose, following this standard I'm safe and in accordance with the legal rules & regulations, right?

A: Definitely NO! In regard to Arc Flash Protection EN 166 is over-aged. Publications issued by work safety organizations informing on this fact are available for everybody. In general standards & norms like the EN 166 are recommendations only advising how to follow law, as in our case the PPE Council Directive of the European Union (89/686/EEC, s. http://eur-lex.europa.eu).

A standard or norm is partly or even entirely no longer applicable, if it doesn't reflect the state of knowledge. This is the case for the EN 166 in terms of arc flash protection. Therefore, the European Notified Bodies (certification organizations) decided to request a real arc exposure test for any PPE protecting against an arc flash.

They agreed on the box test procedure as per GS-ET-29. Products certified as per the new regulations are showing two further numbers trailing the '8' (protection against arc flash) in the product marking. These two figures are providing information on the arc protection class and the visible light transmittance (VLT) class, e.g. '8-2-0'.

Q: However the EN 166 in fact does refer to arc exposure tests using significantly higher arc amperage as currently requested for a class 2 test as per GS-ET-29?

A: Following EN 166 clause 7.2.7 some eye and face protectors were visibly inspected only after having been exposed to an arc flash, i.e. no measurements were taken to confirm the protection behind the eye & face protector. A product which could stand an arc exposure test without showing significant damages was supposed also to sufficiently protect the person wearing that shield. So, EN 166 clause 7.2.7 only requests special product properties (e.g. plastic material thickness) to grant a certification for arc flash protection. No particular arc exposure test for the product to be certified was requested. Herewith the energy of the electromagnetic radiation as generated by an arc flash was neglected. Today we know that apart to several other effects, an arc flash as per Class 1 (GS-ET-29) could cause 2nd degree burns to human eyes and skin behind an arc flash protective product that fulfills the requirements as per EN 166, even in case the product doesn't show any damages.

Q: In most working scenarios an eye and face protection of class 1 as per GS-ET-29 should be sufficient, right?

A: NO, without a dedicated hazard & risk analysis it is impossible to determine the incident energy, i.e. the energy impacting on the person to be protected and to select an appropriate PPE. For eye & face PPE certified to GS-ET-29, the DGUV Information 203-078* provides a recommendable hazard & risk analysis approach.

* DGUV Information 203-078 (former BGI/GUV-I 5188 E) is issued by 'Deutsche Gesetzliche Unfallversicherung e.V.', DGUV (http://www.arbeitssicherheit.de/de/html/library/document/7050950,1); German version: DGUV Information 203-077 (former BGI/GUV-I 5188 E)

Q: May I further use PPE which is showing the '8' in the marking only?

A: Most probably a PPE showing the '8' in the marking only was never exposed to a real arc flash test. As per actual state of knowledge nobody can finally predict the protection level of such a product. As discussed in the preceding question a hazard and risk analysis need to be performed in order to select sufficiently protective products. How can I now, whether a product sufficiently protects, if no classification or rating ever has been done.

NOTE: Old certificates may nor show an expiring date, thus it seems that they are still valid, however they are based on over-aged assumptions.

Q: By selecting a Class 2 PPE as per GS-ET-29 I should always be on the safe side, right?

A: NO! Only a comprehensive hazard & risk analysis can confirm that even in worst case situations higher arc expositions can be excluded. In case the hazard & risk analysis results in incident energies above the Class 2 limit, further means should be considered to reduce the risk (s. below).

Q: I'm using ATPV rated PPE selected on the basis of a hazard and risk analysis as per IEEE 1584. Thus, I should be sufficiently protected and compliant to European laws, right?

A: NO, as in case of an arc flash accident the ATPV rating per definition tolerates a 50% probability of a 2nd degree burn. Thus, a PPE showing an ATPV Rating only, is not in compliance with the European PPE Council Directive, which does not accept any 2nd degree burn. However, if a PPE is classified to GS-ET-29, an additional ATPV Rating may provide further useful information (s. below).

Q: Now, what's to do?

A: By the DGUV Information 203-078* we have a strong tool to assess hazards & risks in our working environments. In fact the result of this analysis really shows the worst case effects in case of an arc flash accident, i.e. the maximum incident energy to be expected at the location in front of the face.

However, depending on the particular work place set-up the results of a first hazard & risk analysis may be too pessimistic. Checking the parameters involved in a 2nd run or, if possible, changing the work scenarios or work place configurations (such as increasing the work distance, using quicker or lower rated circuit breakers, disconnecting multiple power sources) may lead to better results, i.e. lower worst case incident energy levels.

In any case all those considerations and changes should be well documented. In case incident energies higher those energy level as per class 2 have to be expected, life working should not be an option anymore.

Looking for PPE promising a better protection in real live working scenarios may be a last chance, but in general a very risky approach considering that with higher incident energies the effects of an arc flash

accident drastically are getting worse. Here we also have to accept that either PPE may not really protect against all these effects (falling off caused by the pressure wave, poisonous gases, explosion bang) or a PPE configuration, which really protects may be unwearable or increase the risk of creating an arc flash accident, e.g. by working with dark face shields, clumsy gloves etc.

In case someone is searching for a “safety buffer” for arc flash protection a comparison of ATPV ratings may help. However note, the figures gained from the hazard & risk analysis as per DGUV Information 203-078 cannot be transferred, i.e. these figures only can be used to select PPE tested to GS-ET-29. Additional use of ATPV ratings require an additional hazard & risk analysis as per IEEE 1584.

Actually a new ranking method is under work determining a figure (ELIM) derived from the same test data used to calculate the ATPV, however excluding the probability of a 2nd burn. Standards describing the ELIM are under work and are supposed to be published soon. When using the ELIM for PPE selection an a (additional) hazard & risk analysis as per IEEE 1584 must be performed.

* DGUV Information 203-078 (former BGI/GUV-I 5188 E) is issued by 'Deutsche Gesetzliche Unfallversicherung e.V.', DGUV (http://www.arbeitssicherheit.de/de/html/library/document/7050950,1); German version: DGUV Information 203-077 (former BGI/GUV-I 5188 E)