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COMPARING CONSIDERATIONS ABOUT THE ENERGY-BASED EVALUATION OF THE ARC RESISTANCE OF PROTECTIVE TEXTILES ACCORDING TO THE STANDARD COMPLEX IEC 61482

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ABSTRACT

The standard complex IEC 61482 was developed to provide a base for the protection workers against the thermal hazards of electric fault arcs by protective clothing. There are two parts. Part 2 is the product standard prescribing the requirements to be met by fabrics and the clothing. Part 1 is divided into 2 test methods resulting from different development in Northern America (ATPV test) and Europe (Box test).
Being absolutely different in test procedure, set-up, parameters and results, a theoretical comparison is not possible. Based on longer experience of testing and knowledge about the fabrics responses an empirical approach is presented, enabling a principle correlation between the results of both tests.

Index Terms – Electic power installations, low-voltage, arc flash protection, personal protection equipment, testing, live working

1. INTRODUCTION

Electric fault arcs are of potential risk for the injury of persons working in or at electrical power installations, particularly when there is the danger of a direct exposure as in case of live working or working in the vicinity of live parts.

Personal Protective Equipment (PPE) may and must essentially contribute to the necessary protection. Protective clothing is to protect large areas of the human body against the occurrence of serious skin burns. It is a protection means against the thermal hazards of electric arc flash, the thermal arc resistance and protection effect of the material and garments of such clothing has to be tested and assessed.

In the USA, Canada and Europe different test methods have been developed for the determination of the arc resistance of protective textiles and partially harmonized in international standards in the last years. The test results are used to evaluate the protection performance of textile materials for the application in personal protective equipment (PPE) against the thermal hazards of electric fault arcs. The test methods show significant differences in its technical characteristics. The measurement principle in form of incident energy transmission measurement is however widely identical particularly in the standardized methods [1,2].

Theoretical and experimental investigations of the comparability of the incident energy transfer values of textile materials according to IEC 61482-1-1/ASTM F 1959/1959M-04 (ATPV test) on the one hand, and IEC 61482-1-2 (box test) on the other hand, have been carried out and assessed.

2. INCIDENT ENERGY CONDITIONS

The physical parameter characterizing the thermal arc exposures is the heat energy received at the surface, the incident energy. According to the different test procedures there are the following special conditions in the two cases of testing.

2.1. Box Test

In the box test the electric arc energy level W_{LB} (according to the test class 1 or 2) is adjusted, causing the incident energy E_{i0} in the exposure distance a = 300 mm. The transferred incident energy E_{it} at the back of the test sample does not exceed the Stoll limit for the onset of second degree skin burns in case of passing the test:

$$E_{it} \leq E_{iSTOLL} = 50,204 \cdot t_{max}^{0,2901} \frac{kJ}{m^2}$$
$$= 1,1991 \cdot t_{max}^{0,2901} \frac{cal}{cm^2}$$

In the borderline case of the test sample minimum protection effect (in the according test class) the transferred incident energy is identical to the Stoll limit. The larger the deviation between the transferred incident energy measured and the Stoll limit is, the higher is the specimen protective effect.
The instant of reaching the incident energy t_{max} that determines the Stoll limit has big values for materials of high protection effect; it is displaced to smaller values with lower protection effects. For t_{max} = 25 s the limit is E_{iSTOLL} = 128 kJ/m^2.

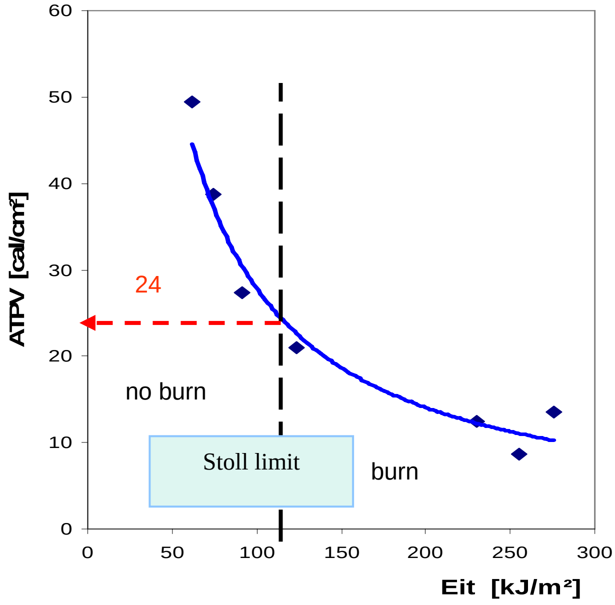

Figure 1: Empirical correlation between the ATPV and the transferred incident energy (example)

2.2. ATPV Test

In the ATPV test the electric arc energy is changes by adjusting the arc duration t_P in several consecutive test shots as long as the transferred incident energy behind the specimen (in a distance of a = 300 mm to the arc) has reached the Stoll limit:

$E_{it} = E_{iStoll}$.

The matching direct exposure incident energy value (on the specimen front side) is the ATPV indicated as the test result. This is the borderline case of the box test.

Based on the incident energies, although the principle technical differences of the test methods, empirical transformations and rough estimations may be made for the ATPV ranges correlating to the box test classes. Particularly the minimum ATPV of a material meeting box test class 2 conditions may be determined.

3. EMPIRICAL CORRELATION APPROACHES

There is no mathematical-physical transformation of the results of the both test methods because of the technical differences in the procedures, a correlation may only be made empirically. Two ways were considered for this.

3.1. Approach 1

First, correlation considerations were made regarding the direct exposure incident energy E_{i0} and the transferred one E_{it}. The higher the difference between Stoll limit and incident energy in the box test is, the larger is the ATPV. With the simplest approximation a indirect proportionality may be assumed: .

$$ATPV = \frac{E_{iSTOLL}}{E_{it} / E_{i0}} = K_1 \cdot E_{it}^{-1}$$

The factor is K_1 = 21150…56682 (for ATPV in cal/cm^2 and E_{it} in kJ/m^2).

Taking into account the dependence of the transmission conditions on the material area weight m, then is

$$E_{it} = E_{i0} \cdot e^{-\mu \cdot m}$$

according to the Lambert-Beer transmission law. The regression functions derived from the evaluation of different tests by means of each of the both methods provide, for identical area weight, the wanted correlation ATPV = f(E_{it}). For very different fabrics (FR cotton, aramides etc.) the relation

$$ATPV = K_2 \cdot E_{it}^{-2,62}$$

was found with K_2 = 8598415 (for ATPV in cal/cm^2 and E_{it} in kJ/m^2).

3.2. Approach 2

Furthermore, a pure empirical correlation of test result was made with fabrics which were tested both, by box method and ATPV one. Fig. 1 shows as an example the special correlation found for a certain fabric type (for different area weights and/or number of material layers). This material type has the protection properties of box test class 2 if its ATPV is larger than about 24. Generalizing it can be pointed out that protection class 2 is often safely just given for ATPV > 30. Class 1 means about ATPV = 6…30. The box test classes cover a wide ATPV range. The ATPV classification can be used for additionally differentiating the protection properties within a protection class.

4. SUMMARY

The empirical correlation between the results of both standardized test methods of protective clothing may only be seen as a rough possibility for classifying and estimation.

They can generally not replace real tests. Because of the very different material and fibre types, compositions and properties found empirical correlations always can only characterize similar textiles.

5. REFERENCES

[1] IEC 61482-1-1: Live working – Protective clothing against the thermal hazards of an electric arc.
Part 1: Test methods – Method 1 – Determination of the arc thermal performance (ATPV or EBt) of flame resistant material for clothing (ATPV test) – under maintenance (at present: FDIS)

[2] IEC 61482-1-2 (DIN EN 61482-1-2: 2007) : Live working –Protective clothing against the thermal hazards of an electric arc.
Part 1: Test methods – Method 2 – Determination of the arc protection class of material and clothing using a constrained and directed arc (box test)