

PLASTIC HIGH VOLTAGE INSULATORS BASED ON INTECH MATERIALS

S. Korenev^a, G. Bartosch^b, T. Mihov^b,

^aSTERIS Corporation, 2500 Commerce Drive, Libertyville, IL 60048, USA

^bINTECH Corporation, 250 Herbert Avenue, Chester, NJ 07624, USA

Abstract

This paper covers the concept of high voltage insulators that utilize the INTECH Power-Core™ material. They consist of a stainless steel electrode and a specially formulated plastic material (PA12G) cast in. A special technology for treatment of metal core (electrode) provides an excellent mechanical connection on the interface between these two materials. The physical properties of the plastic material allow using these insulators for the nanoseconds range, high voltage pulses. The experimental results of the study of threshold electrical properties for these materials are discussed, and the design of the insulators for the 100 kV to 1000 kV range described. Examples of insulators for pulsed electron accelerators are presented. This insulator is reliable, simple and cheaper in comparison with other types.

I. INTRODUCTION

The development of pulsed high voltage equipment lead to new technical requirements for the high voltage insulation. The insulator is the main component of high voltage devices. A careful selection of the insulator material is crucial; the specific requirements on the insulating materials are:

- * high dielectric strength;
- * good mechanical properties;
- * low level of gas emission in vacuum;
- * low cost and maintainability.

The design of high voltage insulators is guided by the knowledge of the properties of the insulating and metallic materials. The vacuum environment of insulators requires special considerations. The standard design of vacuum high voltage insulators consists of a ceramic insulator combined with a central metallic electrode. The technology of these insulators is complex, voltage being the main limiting factor. For example, an insulator for 400 kV requires a large ceramic body, which introduces a mechanical problem of size for the central electrode.

A reliable design of high voltage insulators for electron pulsed accelerators is important [1, 2]. The use of plastic materials based on caprolan and polyethylene is required in the special gasketed connection for vacuuming of the central electrode [3].

The search for new approaches to the bushing in the high voltage insulators is important and it attracted significant scientific and applied interest.

The new type of high voltage insulators based on the INTECH Power-Core material is suggested in this paper to be considered for application in the pulsed high current electron accelerators.

II. THE CONCEPT OF HIGH VOLTAGE INSULATORS

A distinguishing feature of this new type of high voltage bushing insulators based on the plastic materials from INTECH Power-Core consists of a combination of a stainless steel electrode that is cast in a specially formulated cast plastic material (PA12G). This special technology leads to good mechanical connections on the interface between these two materials and stable vacuuming.

In the manufacturing process the melted monomer, without any additives, is cast into a mold around a centrally located metal core. The mold's outside contour conforms to the insulator shape, or the shape can be easily machined from a cast, e.g. cylindrical, shape. Subsequent polymerization, which occurs in the mold under controlled external conditions, turns into crystallization before to mold cools down. The result is a dense, tension free crystalline structure, which gives the material its superior chemical, electrical and mechanical properties as well as stability over time. These include lack of moisture absorption, resistance to chemicals, oils, ionized water, and bubble free adhesion to metal core while stable in vacuum. The material retains its physical properties from -60 °F to 140 °F and is well suitable for outdoor use. The casting process allows casting large components.

The structure of these new combined materials is given in Fig.1. The picture of this material is given in Fig.2. The metal electrode has the usual (knurled) surface roughness and the plastic material (PA12G) has good adhesion to central metal electrode. The proper roughness of the metal electrode assures mechanical strength of the connection between the two materials. The central electrode has good vacuuming on the interface with plastic material in part due to the controlled surface pressure developed during crystallization. The superior adhesion on the interface of these two materials allows using this technology for bushing insulators.

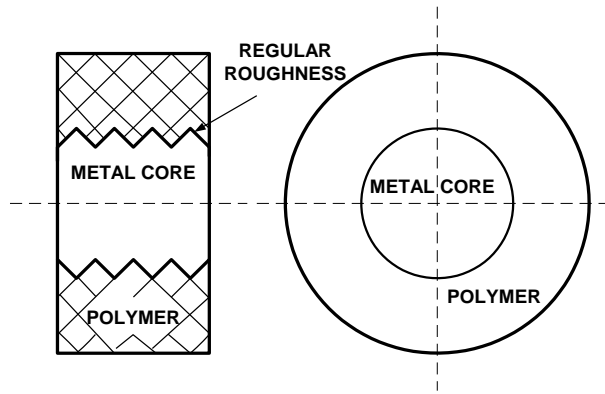


Figure 1. Structure of plastic material from INTECH Power-Core.

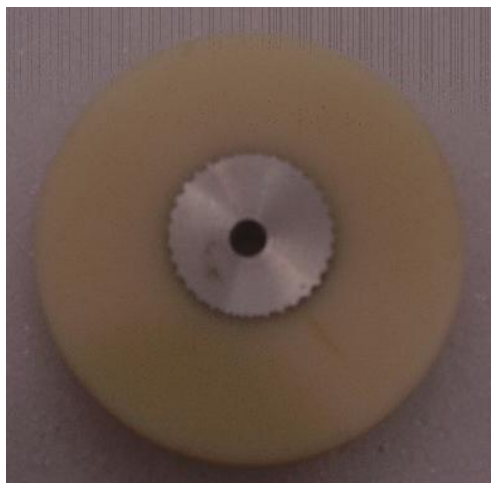


Figure 2. A sample of material for high voltage insulator.

The typical design of bushing high voltage insulators is given in Fig 3.

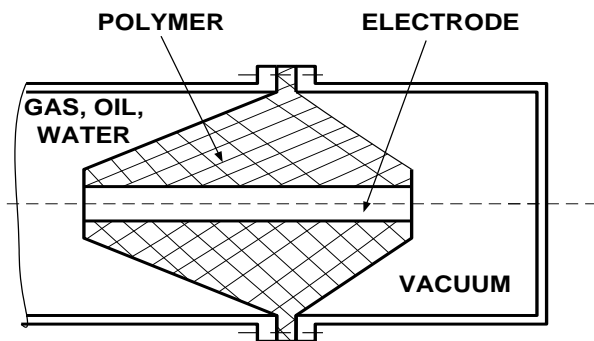


Figure 3. General concept for the bushing employed in the high voltage insulator.

The insulators have different geometry depending on technical requirements. Because of the rigidity and strength of the combined materials, the insulator becomes

also a structural, load carrying part [Fig. 6] and can be used to connect, for example, two cylinders containing two different media. As an example, one side of the insulation may face a vacuum, the other gas, air, oil, or water. The physical and chemical properties in combination with the chemical resistance to gas, oil or water enable gas and liquid separation.

III. EXPERIMENT

Experiments were performed to measure the dielectric strength of 3 types of the outside insulation:

- * vacuum insulation (10^{-5} Torr);
- * gas insulation (dry air, SF_6);
- * transformer-oil insulation.

The main goal of these experiments was to determine the threshold conditions for the forming of electrical discharge on the surface of the plastic.

The block-diagram of the experiments is presented in Fig 4,5.

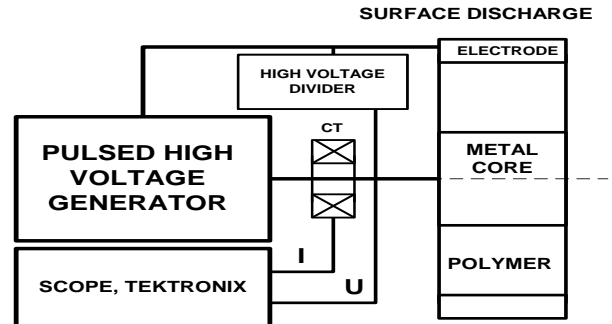


Figure 4. Block- diagram for measurements of threshold condition for surface discharge.

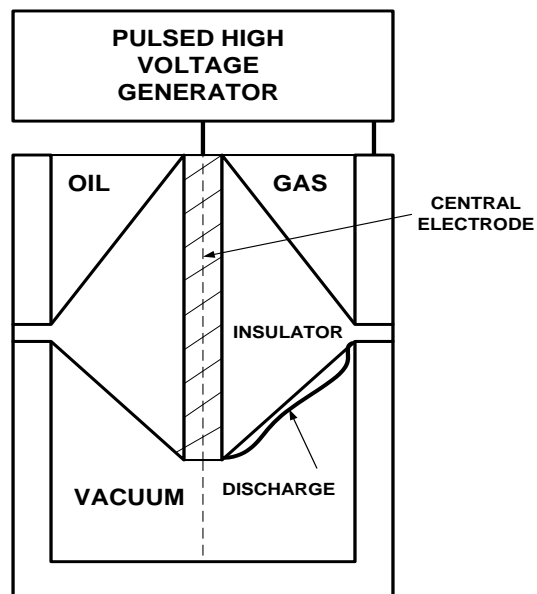


Figure 5. Block- diagram for measuring of surface discharge threshold condition with different insulation thickness.

The experiment was conducted with different types of generators that allowed testing a wide range of voltage pulse duration: 10 ns, 100 ns, 10 μ s and 10 ms. The beginning of the formation of the surface discharge was controlled by the discharge current. The gas absolute pressure (SF6 and Dry Air) was regulated from 100 kPa to 500 kPa.

The results of the threshold electrical field for the formation of the electrical discharge on the surface of the polymer are presented in Fig.6. A negative polarity of the pulsed voltage was used in the experiments. The picture of the spark on the surface of the polymer is given in Fig. 7 as an example.

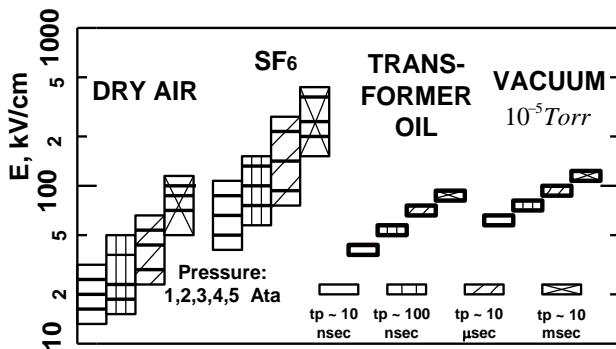


Figure 6. Threshold electrical field for these insulators.



Figure 7. The spark on the surface of the polymer between the electrodes.

These data attest to the suitability of the INTECH Power-Core composite plastic/metal materials for the design of bushings in the high voltage and power insulators. According to the experimental data, the pulsed voltage can have a range of 1 MV. Potentially, we can consider the design of the insulators for the pulsed voltage to reach 5 MV to 10 MV.

The mechanical properties and chemical resistance to liquid and gas insulators (transformer oil, gases) of these materials are very good and acceptable for practical using.

IV. EXAMPLES OF INSULATORS

Several samples of the high voltage insulators for pulsed electron sources of high current electron accelerators were designed and manufactured.

The insulators were designed for and tested in the 150 kV to 400 kV range with pulse duration from 20 ns to 300 ns.

An example of the insulator is presented in Fig. 8.

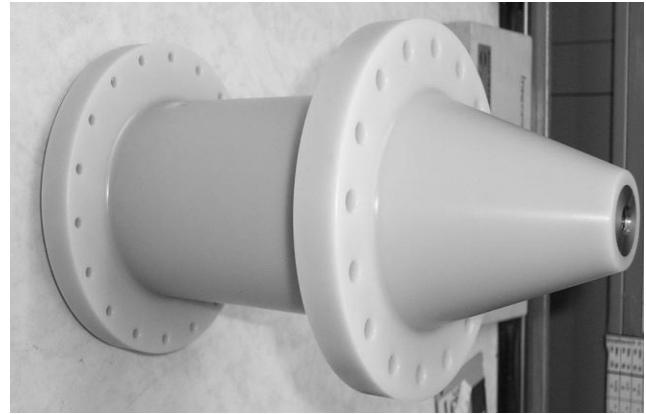


Figure 8. Example of the high voltage insulator for 400 kV.

V. CONCLUSIONS

As a result of this work we reached the following conclusions:

1. Plastic materials with metal core from INTECH Power-Core are acceptable for high voltage insulators and pulsed voltage up to 1 MV.
2. Extrapolation of the characteristics of these materials indicates their suitability for insulators for 5 MV to 10 MV.
3. These materials are acceptable for nanosecond voltage pulse duration and can be used in the pulsed high current accelerators and similar devices.
4. These materials are cheaper in comparison to ceramic materials.
5. They are easy to clean and maintain.

References

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