IMPROVED INVERTED DC GUN INSULATOR ASSEMBLY*

M. Neubauer, R. Sah, A. Dudas, Muons, Inc.

Abstract

High gradient DC guns are currently being developed with inverted ceramic insulators in order to avoid failure of the insulators from field emission and charge build-up. Our goal is to increase the DC voltages from 250 kV to 500 kV in these inverted ceramic DC Gun insulator assemblies. To achieve reliability, the arc-path gradient along the length of the insulator ceramic at the interface with the dielectric material should be lower than 500 kV/m (13 V/mil). In order to achieve this low arc-path gradient, a novel extended inverted insulator ceramic is being developed. Novel assembly processes are being developed for the high voltage connector, so that the interface between the connector dielectric and the surface of the extended inverted ceramic insulator will be void free. A complete DC Gun Inverted Ceramic Insulator Assembly will be designed and fabricated for reliable 500 kV DC operation.

INTRODUCTION

High gradient DC guns are currently being developed with inverted ceramic insulators in order to avoid failure of the insulators from field emission and charge build-up. The technical challenge we address here is how to increase the DC voltages from 250 kV to 500 kV in these inverted ceramic DC Gun insulator assemblies. To achieve reliability, the arc-path gradient along the length of the insulator ceramic at the interface with the dielectric material should be less than 500 kV/m (13 V/mil). In order to achieve an arc-path gradient of less than 500 kV/m, a novel extended inverted insulator ceramic will be developed. Novel assembly processes will be developed for the high voltage connector, so that the interface between the connector dielectric and the surface of the extended inverted ceramic insulator will be void free. Later, a complete DC Gun Inverted Ceramic Insulator Assembly with connections to the power supply will be designed and fabricated for reliable 500 kV DC operation. A computer model will be used to determine the optimum extended inverted ceramic and connector design, for use with and without SF6. The two designs will be compared and a mechanical design will be completed for brazing the extended inverted ceramic assembly. New processes based on industry-standard, room-temperature vulcanizing (RTV), silicone-rubber coatings will be optimized to insure that the assembly of the connector dielectric to the extended inverted ceramic surface will be free of voids and trapped air.

* work supported in part by USDOE Contract No. DE-AC05-84-ER-40150.
mike@muonsinc.com

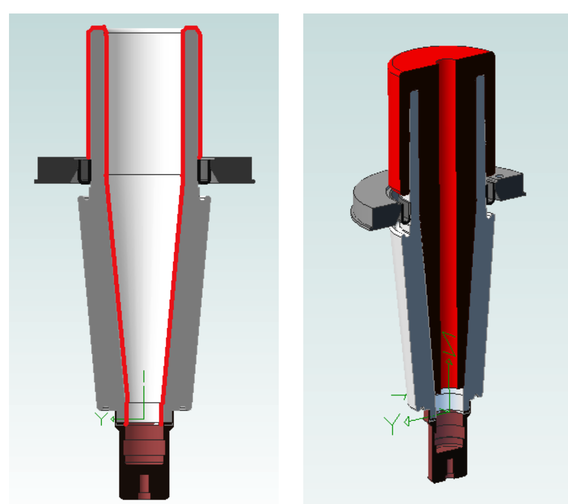
TECHNICAL APPROACH

In this R&D program we shall be exploring designs and process techniques for making the connection to an inverted ceramic DC Gun. The main problem areas to be addressed are the following:

- The arc-path gradient should be less than 0.5 MV/m (13 V/mil)
- The surface of the interface between the hard ceramic and the silicone rubber surface of the connector must be uncontaminated and free of trapped air voids
- The electrostatic design of the ground plane region around the connector needs to be designed to minimize gradients.
- There needs to be a means for protecting against particulate contamination in the region where SF6 is used.

Extended Inverted Ceramic

To reduce the arc-path gradient to acceptable levels, the design of the inverted ceramic will feature some novel concepts, as shown in Figure 1. This design has an *extended* inverted ceramic insulator (i.e., the insulator is very tall). This extension is required to make the arc-path gradient less than 0.5MV/m (13 V/mil).



(a) (b)

Figure 1: A conceptual drawing of the inverted ceramic whose length extends beyond the mounting flange. (a) With a dielectric coating along the surface and (b) with a silicone boot that may be part of the connector assembly.

The profile of the extended inverted ceramic may include other features as well. These features will be explored in detail. Most likely, the extended inverted ceramic will look quite different for a system using SF6 as compared to a system without SF6. For example, the silicone rubber boot requires smooth surfaces so the connector can be removed, while in an SF6 system the extended inverted ceramic may have ridges on it to increase the arc-path gradient more efficiently.

RTV

The surface of the extended inverted ceramic can also be coated with an RTV silicone rubber similar to what is already being done for high voltage transmission line insulators as shown schematically in Figure 1(a). Coating transmission line insulators with RTVs has been in use for some time. Primarily, this alleviates problems associated with contamination from dust and salt air. The technique of coating the insulators with an even coating has been experimented with, and the optimum thicknesses have been found [1]. Our Phase I program will explore these processes to determine the best system for bonding RTV to an extended inverted ceramic. It should be noted that many RTVs are capable of operating for long periods of time at temperatures above 250C. This means that, if an extended inverted ceramic is coated with RTV, the assembly can still be baked out with the DC gun.

For the connection without SF6 an RTV silicone rubber boot could be molded to the end of the cable termination as shown schematically in Figure 1(b). The molded boot was a technique used in microwave tubes with arc-path gradients in excess of 0.7 MV/m (18 V/mil). This would allow for easily connecting and re-connecting a HV cable termination to the extended inverted ceramic. But the problem with this approach would be the difficulty in maintaining clean surfaces over large areas.

An optimum configuration may be a combination of the two approaches: coating the extended inverted ceramic with less than one mm of RTV to protect it, and a then a final, thicker layer of RTV - either a boot at the end of a cable, or a boot in conjunction with an SF6 containment vessel.

Mechanical Design

A mechanical design issue with the extended inverted ceramics is the braze joint between the ceramic and the mounting flange. The "U" shaped seal flange needs to be rigid enough to minimize undue stresses during connecting and reconnecting the cable and flexible enough to provide a nearly stress-free joint to the ceramic. In this program, we shall create a computer model of this joint and investigate various designs, metals, and thicknesses of materials. This joint will be made from copper-plated 70/30 CuNi or a similar material of the appropriate thickness and length.

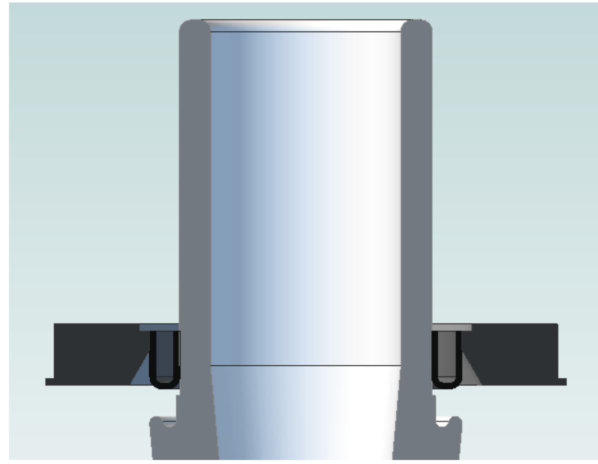


Figure 2: Braze joint between the extended inverted ceramic and the mounting flange by the "U" seal.

Insulator Design for Use with SF6

There are two fundamental contamination issues that need to be addressed in 500 kV high voltage connections. The first is contamination of the surface of the inverted ceramic insulator, and the second is contamination by microscopic metal particles in the regions filled with SF6 gas.

In this development program, we shall design fixtures and processes to minimize handling issues with the extended inverted ceramic. This may include a means for applying a protective coating on the non-vacuum side of the ceramic after it has been brazed into a sub-assembly. The protective coating could be the first layer of an RTV applied in such a way as to guarantee the absence of air trapped in voids, such as a vacuum-potting system.

The problem with microscopic particles in the regions filled with SF6 gas has been studied in high voltage transmission systems [2, 3]. As it turns out, one of the solutions was to coat the inside surface of the SF6 containment vessel walls with an epoxy. The thickness and types of epoxy were investigated in reference [3], while the flashover characteristics along the connector bushing were investigated in reference [2]. In our Phase I program, we will use these prior results in guiding the design of SF6 containment vessels.

Process Design

When working with RTVs and ceramics, there are many handling issues that need to be resolved either by strict guidelines or by handling fixtures. In this R&D program, we shall develop concepts and fixture designs that can be used to protect the vacuum side of the extended inverted ceramic while applying RTV to the air side. We contemplate these fixtures being simple and easy to use. One idea would simply be a stainless steel pressurization vessel that would attach to the mounting flange of the brazed extended inverted ceramic assembly. The pressurization vessel would have an atmosphere or two of nitrogen to prevent contamination and could be used during various processing steps to prevent the vacuum side contamination of the ceramic.

REFERENCES

[1] H. Deng and R. Hackam, "Electrical Performance of RTV Silicone Rubber Coating of Different Thicknesses on Porcelain", IEEE Transactions on Power Delivery, Vol. 12, No. 2, April 1997.

[2] K. Watanabe, "Flashover Mechanism of SF6-Gas Type Termination of DC Power Cable," IEEE Transactions on Power Delivery, VOL. 15, NO.3, JULY 2000.

[3] M. Marcos, et. Al., "Insulation integrity of GIS/GITL systems and management of particle contamination" Electrical Insulation Magazine, IEEE, Sept.-Oct. 2000, Volume: 16 Issue: 5.