

Silicone Grease for Outdoor Gas-insulated Switchgear (GIS) Application

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Abstract. Silicone grease are widely applied in flange connections of gas-insulated switchgear (GIS) providing protection against flange and sealing O-ring corrosion and subsequent SF₆ gas leakage. During GIS operation, grease bleeding phenomenon was frequently observed, which not only result in a poor appearance of flange surface but a potential SF₆ leakage in the long-term application. In this paper, the possible reasons for this phenomenon is briefly discussed. In addition, the key parameters and outdoor performance of several commercial grease products were verified for a better understanding of its temperature resistance. It is shown that some grease products can have a better control on bleeding performance and should be more suitable for the outdoor GIS application.

1. Introduction

Flange corrosion in outdoor gas-insulated switchgear (GIS) often leads to SF₆ gas leakage which in severe cases could necessitate a shutdown. To avoid the corrosion and eliminate the gas leakage, flange connections are normally treated in the factory or during installation on site by injection of silicon grease into the flange connection via an injection nipple provided in the flange [1]. With this treatment the flange connections can be protected against corrosion that caused when in contact with the air or moisture, as illustrated in Figure 1[2]. In the meantime, silicone grease are also applied on assembled O-rings in order to protect it from damage by abrasion. It helps seat the O-ring properly, speeds up assembly operations, and makes automated assembly line procedures possible.

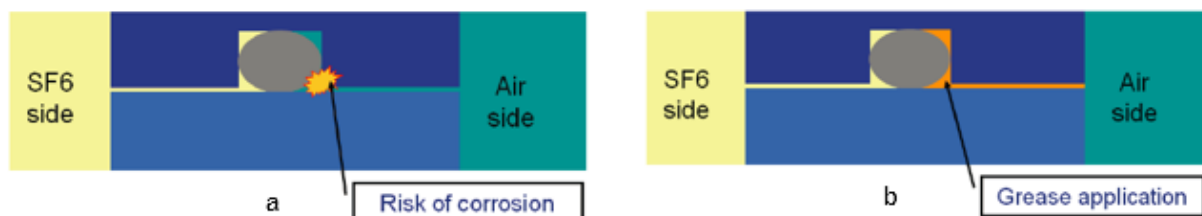


Figure 1. a. Risk of corrosion on sealing; b. Risk mitigating using silicone grease

Generally, silicone grease is a solid to semifluid product that consists of a dispersion of thickening agent in a liquid lubricant [3]. In an application, a silicone grease gradually releases oil into the working areas

of the machine surfaces in order to lubricate them. This oil release phenomenon is normally named ‘oil bleed’, one possible reason of which is related to the grease formulation. As the base oil content is increased and the amount of thickener system is decreased, the forces of attraction also decrease, thus resulting in the base oil being loosely held in the thickener system matrix and easily separated. Therefore, it is important for a grease to have the proper balance of base oil and thickener system content to function properly. Another possible reason may relate with the storage or even the transport conditions, such as high temperature, high moisture, long duration and vibration etc. The severe outdoor environment can probably speed up the bleeding phenomenon and extent. In this paper, several key parameters of some commercial grease products were firstly compared to screen candidate grease products with proper formulation. A subsequent environmental tests such as neutral salt spray, high-low temperature cycle and long-term outdoor test were then conducted with selected grease to verify their applicability in outdoor GIS.

2. Experimental

2.1. Material

The commercial silicone grease and O-rings (NBR and EPDM) were provided by varied suppliers, separately.

2.2. Neutral Salt Spray Test

The neutral salt spray (NSS) test was performed with a duration of 720h at $35^{\circ}\text{C} \pm 2^{\circ}\text{C}$ and a pH of (6.5~7.2) in accordance with ISO 9227 [4]. After NSS test, the flange modules were disassembled accordingly and the grease samples were further characterized for possible structure change.

2.3. High-low Temperature Cycle

The high-low temperature cycle test was performed with GIS modules filled with SF₆ gas [5]. The temperature range is selected as -40°C to 120°C in accordance with GB/T 11022 [6]. The gas tightness was tested before and during the temperature cycles. The module surface and groove were then checked if any grease bleeding or missing after completing the thermal cycle test.

2.4. Outdoor Aging Test

The GIS products assembled with selected grease were placed in actual outdoor conditions for more than 6 months and the flange surfaces were visually checked in a certain time interval as well as the gas tightness.

3. Results and Discussion

As mentioned previously, a grease releases its base oils from the thickener system when it is squeezed or stressed, just like a sponge that release water when it is squeezed. The stresses a grease encounters can be generated thermally during application or storage. Therefore, the thermal resistance is of importance in selecting proper grease. Here, some key parameters of several silicone grease samples were tested and summarized in Table 1. It is to be noted that oil separation represents colloidal stability, which is the resistant ability of separating oil in the long-term storage and use. The less the oil separation value, the less possibility of bleeding phenomenon. From Table 1, it can be seen that Grease 4 and Grease 5 show a better comprehensive performance as compare to other grease samples. Therefore, Grease 4 and Grease 5 were chosen for the following tests.

Table 1. Key parameters of silicone grease

Test item	Dropping point [$^{\circ}\text{C}$]	Oil separation, steel mesh, ($120^{\circ}\text{C} \times 30\text{h}$) [%]	Evaporation loss ($120^{\circ}\text{C} \times 22\text{h}$) [%]
Test method	GB/T 4929	SH/T 0324	GB/T 7325
Grease 1	205	4.4	0.18

Grease 2	>260	0	0.63
Grease 3	187	0.18	0.16
Grease 4	>260	0	0.36
Grease 5	>260	0	0.37

The aluminum flanges were prepared and further assembled with different combinations of grease and O-rings. The size of the flange is about 215mm in diameter. The assembled aluminum flanges were carefully checked and marked then put into salt spray chamber, as shown in Figure 2.

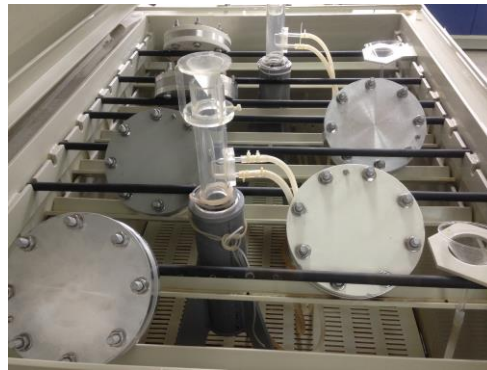


Figure 2. Layout of flange samples in salt spray chamber

A visual inspection was carried out on the surface of aluminum flanges at a certain time. Figure 3 illustrated an example of flange module assembled with Grease 5 and NBR O-ring after NSS test for 720h. As can be seen in Figure 3, the silicone grease were leaked out from the screw thread and partially from the interface of the flange. Similar phenomenon can also be found in other assembled flanges.



Figure 3. Assembled flange with Grease 5 and NBR O-ring after NSS test for 720h

All flanges were taken out of the chamber and then disassembled to check the inner surface. It turns out that no clear stain or contamination was found on inner surface but only partial of silicone grease were left over as a result of the leakage, as displayed in Figure 4. To verify the potential influence of NSS on the grease, the chemical structure were further analyzed by FTIR [7].

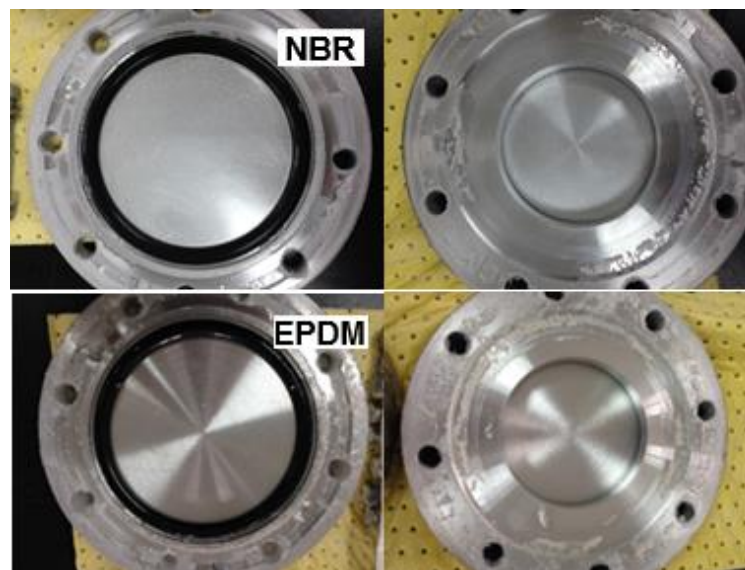


Figure 4. Inspection on disassembled flanges (Grease 5 and NBR/EPDM O-ring)

Figure 5 displays the FTIR spectrums of Grease 4 and Grease 5 before and after 720h NSS test. It can be seen that there is no obvious change in main characteristic peak position while only a very small change in peak intensity, indicating no structure alter as a result of the NSS test.

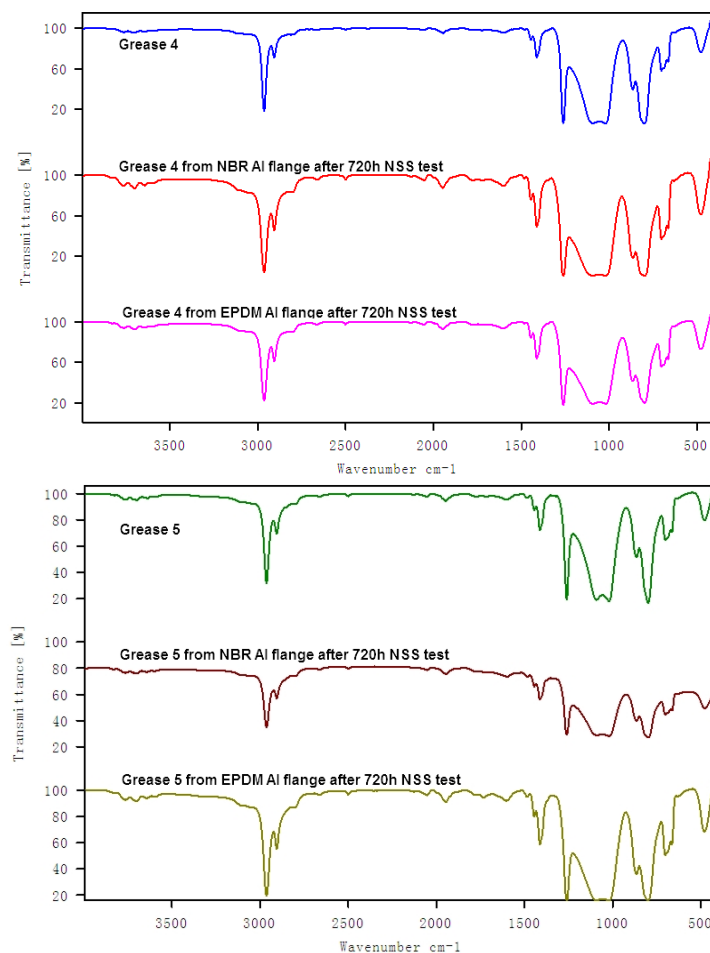


Figure 5. FTIR spectrum of Grease 4 and Grease 5 before and after NSS test

The high-low temperature cycle test was performed with GIS modules to further check the temperature resistance performance of grease. The temperature range is selected from -40°C to 120°C according to GB11022-2011. Figure 6a shows the drawing of the module with a total size of approximate $400\text{ mm}\times 400\text{ mm}$. Before test, both flange ends were assembled with cover plate to form a closed shell, as displayed in Figure 6b. After thermal cycle test, the module was disassembled to check the grease status. Figure 5c shows an example of GIS module with Grease 4, from which it can be seen that the grease was distributed evenly with little grease loss in the groove.

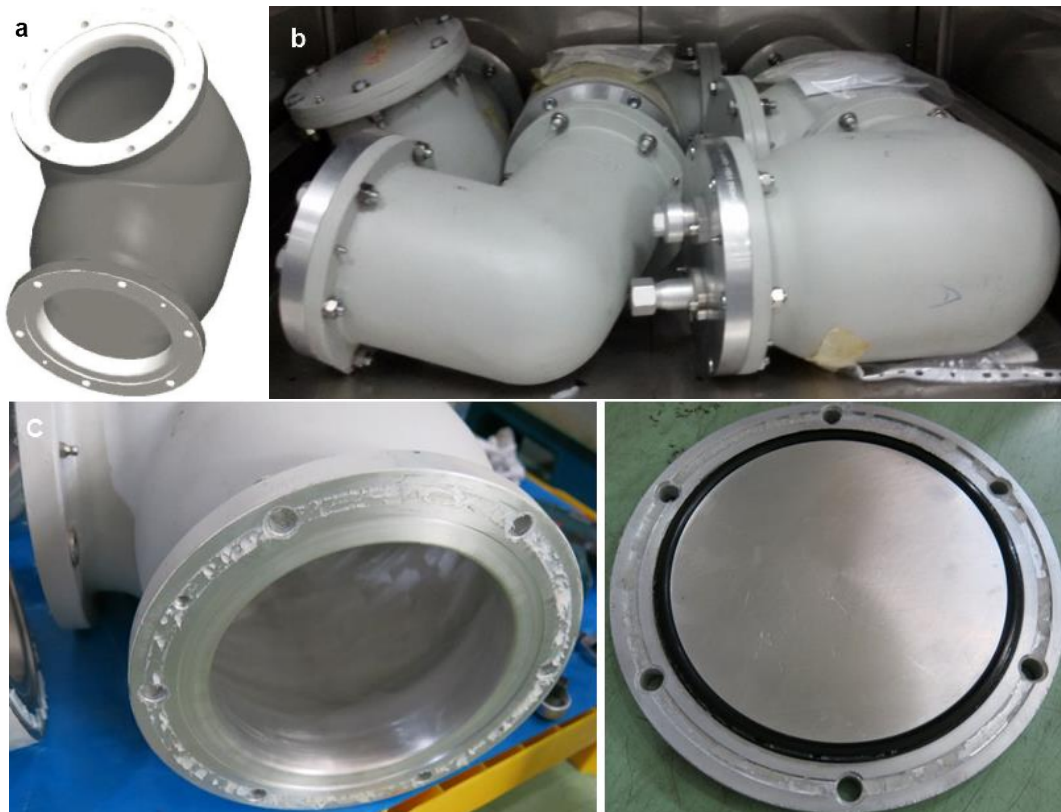


Figure 6. a) Drawing of module; b) Actual modules for the thermal cycle test; c) Example of disassembled flange to check the status of Grease 4

To better understand the long-term stability of the grease, an actual outdoor environment test was also conducted with GIS busduct, as shown in Figure 7. Two kinds of grease were injected into the flange groove by manual glue guns, respectively. The modules were then filled with SF₆ gas. All GIS modules were placed outside for more than 8 months. For every 2 weeks, the status of module surface was recorded and the gas tightness was tested to see if any leakage happened. Results showed that the gas pressure was very stable and almost no loss after the test. Meanwhile, the disassembled module illustrated that the grease were well kept in their original state without any loss or contaminant.

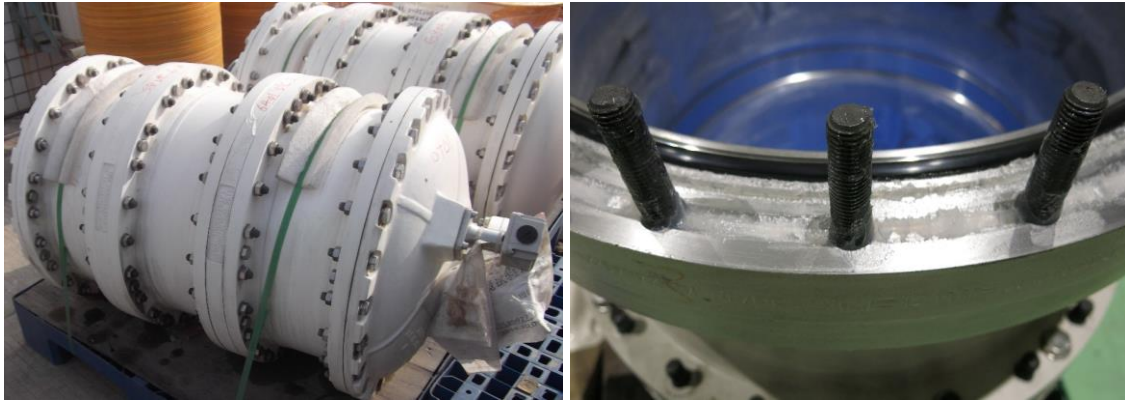


Figure 7. Outdoor verification test for GIS busduct

4. Summary

Silicone grease has been applied in outdoor GIS to avoid flange and sealing O-ring corrosion and lower the possibility of SF₆ leakage. One problem during the application of silicone grease is oil bleeding, which may lead to serious loss of grease under severe environment and subsequently give rise to flange corrosion. With accumulated experience of GIS solutions, ABB has been in position to perform a detailed analysis on aging of grease products and to select the optimum grease materials to guarantee the long-term tightness of outdoor GIS application.

5. References

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