TRENDS IN VACUUM SWITCHING TECHNOLOGY

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INTRODUCTION

Vacuum switching technology has seen continuous progress since the first commercial vacuum switches were produced during the 1950's and 1960's. From the very beginning GEC ALSTHOM and its predecessors have made significant contributions to the development of the technology, both with regard to vacuum switches and vacuum interrupters. This article reviews this evolution to date with examples from the Company, and describes recent work carried out suggesting scope for significant future developments.

DISCUSSION

The world's first 3.3kV vacuum contactor was launched by AEI in Rugby in 1965 (Fig.1), and utilised vacuum switches which represented the state of the art in vacuum technology at that time which was developed originally for the valve industry.

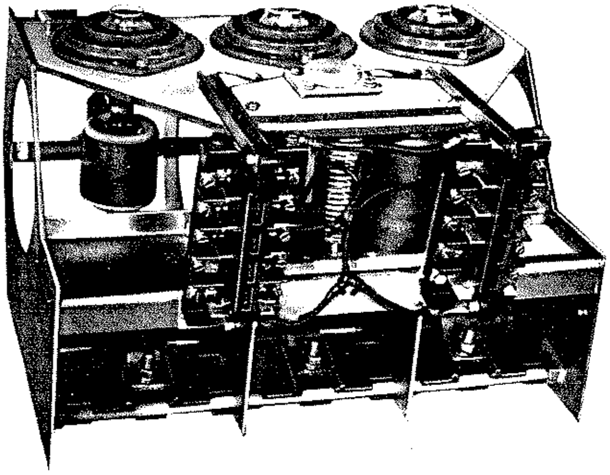

Fig.1 The World's first 3.3kV Vacuum Contactor

The vacuum switches were constructed using a glass body with a metal flange embedded in each end of the glass tube. These flanges were then welded to steel endplates which formed subassemblies carrying the contacts and a bellows to allow movement. (Fig.2).

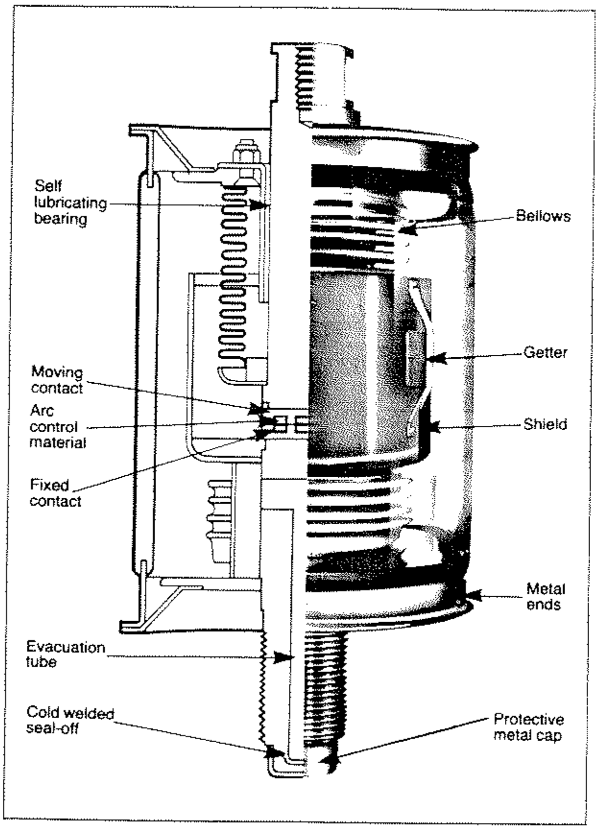

Fig.2 Glass Vacuum Switch

As vacuum switches do not normally have any special arc control system and use plain butt contacts, the devices rely solely on the properties of the contact material to give the correct characteristics on arc extinction at current zero. The special contact material developed by AEI at this time was made from Antimony and Bismuth in a Molybdenum base. The vacuum switches themselves were manufactured as subassemblies which were brazed together in Hydrogen furnaces, and then evacuated using a pump tube which was connected via a manifold to the vacuum pump system. In order to aid evacuation, and to drive off volatile contamination, the switches were heated during pumping in a small oven. Seal off was accomplished when the switches were cold by pinching the copper pumping tube using a special clamp which squeezed the pipe and caused the walls to cold weld thereby providing a vacuum tight seal.

The development of vacuum interrupters mirrored that of the vacuum switches, with the original vacuum interrupters being made using a glass bodied, welded construction, with manifold pumping and seal off. Again special contact materials had to be developed, in this case Copper Chromium, (CLR) which was developed by English Electric at their Nelson Research Laboratories. Because vacuum interrupters had a much higher interruption requirement than vacuum switches, special arc control systems had also to be developed in order to control the very high energies and assist the vacuum interrupter in switching at the first available current zero. The inclusion of these special contact geometries in turn meant that the vacuum interrupters were considerably larger than vacuum switches, but the seal off and construction technology was effectively the same. (Ref.1).

The vacuum interrupters then moved on to use a Glass ceramic insulator (Fig.3), where the vacuum interrupters were still of welded construction but were sealed off in a vacuum furnace using a series of holes known as a pumping port which was sealed by the melting of braze material.

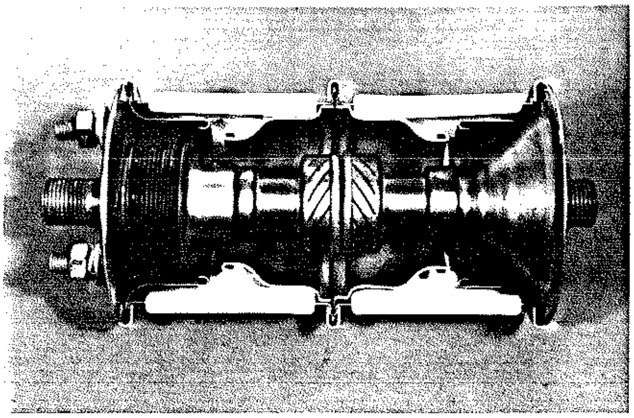

Fig.3 Glass Ceramic Interrupter

This technology remained fairly constant until the late 1970's when the application of metallized ceramics was widely introduced for these type of vacuum devices. In ceramic bodied designs the construction is quite different, with the body insulator being made from an Alumina ceramic. This is a strong material, with the grains of Alumina being fused at high temperatures. It is not possible to make embedded seals as were used with the glass insulators, but it is possible to metallize parts of the surface of the ceramic by means of a Molybdenum paste. This grips the ceramic, and provides a base for a layer of Nickel. Once the Nickel is applied, then that part of the ceramic can be brazed to metallic parts with a very great strength. This together with the fact that the Alumina ceramic is much more temperature resistant than the glass allowed a radical change to the manufacturing methods. Rather than simply replacing the glass or glass ceramic insulator with an Alumina one, advantage was taken of the different properties of the Alumina ceramic, particularly the elimination of welding, and the high temperature capability. The entire device including ceramic could be placed in a vacuum furnace and sealed using commercially available brazing materials.

This in turn led to the development of the "One Shot Seal off" technique for vacuum switches whereby all the components for the vacuum switch are assembled and then loaded into a vacuum furnace where the outgassing, brazing together, evacuation and sealing are all performed in one operation. (Fig.4), (Ref.2).

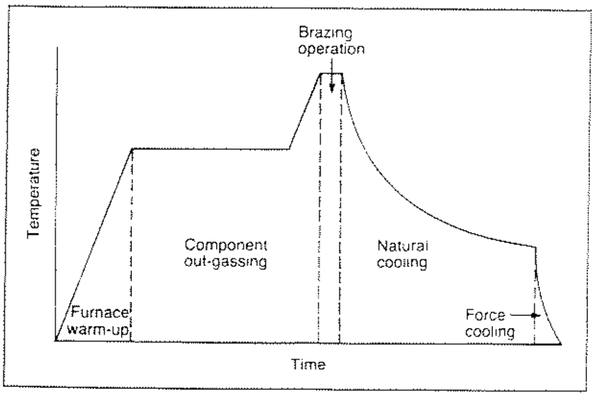

Fig.4 "One Shot Seal Off" Cycle

Alumina ceramics were also used in vacuum interrupters to allow brazed construction, although most vacuum interrupters do not use "One Shot Seal off" due to the complex contact geometries and shielding required for the control of high currents during fault interruption, and voltage requirements, which necessitates multiple brazing and assembly operations. In these cases the vacuum interrupters are usually brazed as subassemblies in a vacuum furnace, then finally assembled and returned to the vacuum furnace for evacuation and seal off, requiring two or three furnace runs for each device. The switch design is shown, (Fig.5).

The introduction of Alumina ceramics eliminated the need for welded flanges and allowed smaller vacuum devices to be made more easily. As these vacuum interrupters and vacuum switches were further developed, investigations concentrated primarily on the arc control systems for interrupters. Initially the goal was higher interrupting ratings, but once these had been achieved, the work turned to further reductions in size and cost. (Ref.3)

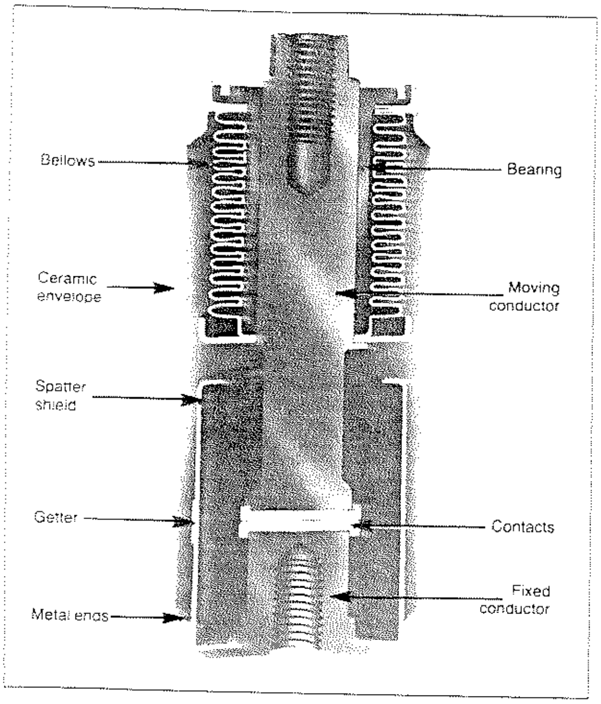

Fig.5 Alumina Vacuum Switch

Vacuum switch and vacuum interrupter development then continued to follow the pattern of smaller size/higher rating, with the size of a power vacuum interrupter rated at 12kV;20kA falling from 161mm outside diameter in 1970, to 125mm by 1978, to 85mm by 1984. (Ref.4).

As discussed, the size of a power interrupter depends both on the construction technique used and on the method of arc control. In order to establish the minimum size possible, an experiment was recently conducted by GEC ALSTHOM in Rugby where devices were made with very small bodies. These were then extensively tested using our in-house synthetic short circuit test plant. This work progressively reduced the required diameter for a 12kV;20kA device to 60mm, and then to 50mm. Although these are experimental devices the results clearly indicate that the current size of vacuum interrupter could still be substantially reduced.

For the vacuum interrupter and vacuum switch manufacturer there are further advantages in this size reduction if the "One Shot Seal off" technique is used. The devices are brazed and sealed off in large vacuum furnaces which have a high capital cost. However as the size of the vacuum devices reduces so the number which can be loaded and brazed at one time increases. Thus using the example of the 20kA vacuum interrupter development, an existing furnace could hold 30 of the 161mm diameter devices, 50 of the 125mm diameter, 90 of the 85mm diameter, and an estimated 200 of the 60mm diameter, and 250 of the 50mm diameter. In the latter case giving an eight fold increase in output capacity for the same equipment !

As a result of this work on vacuum interrupters it has become clear that the current generation of vacuum switches are also larger than they could be, and there is therefore the possibility of a significant size reduction.

CONCLUSIONS

As has been briefly shown, the history of vacuum interrupter and vacuum switch development has been one of continuous reduction in size and increase in capability. This trend is by no means over and further significant reductions in the size of these devices are predicted for the future.

Although considerations such as insulation requirements, and interphase distances must be taken into account, we believe that the substantial reductions in size and, to some extent, cost, of vacuum interrupters and vacuum switches to date, and also the further possible reductions in the future provide an opportunity for switchgear designers to take advantage of this in a new generation of significantly smaller switchgear with its inherent advantages of size and cost, both of the switchgear itself and of the installation.

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