Radiative Aspects of the Ablation-Stabilized Arc in Polyethylene Tube

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Abstract—**The arcs burning through polyethylene tubes are observed photographically and spectroscopically. The arc currents are 5 ~ 15A dc. The tubes are of 2 ~ 6 mm inner diameter and 15 mm in length. Color photographs of the arc reveal that the arc column consists of three emission regions: a red-colored core and blue-colored and orange-colored layers. The spectral intensity of the arc column is surveyed for the wavelength from 300 to 900 nm, and then the radial distributions of specific spectral intensities are measured for various arc currents and tube diameters. The results indicate that the spectra from the above three emission regions are of hydrogen atom, carbon molecule, and continuum, respectively. The radial temperature distributions of the arcs are estimated from the spectral intensities of the hydrogen atom and the carbon molecule. The results show that the polyethylene arc takes a typical temperature distribution of ablation-controlled arc.**

I Introduction

CROSS-linked, polyethylene, vinyl-sheathed (CV) cables have been widely used for underground distribution systems. When an arc fault happens through the CV cable, the polyethylene (PE) insulator is quickly ablated by the arc heat. As a result, the arc space is occupied by PE ablation gas. The nature of such arc is evidently different from those of pure gas arcs and metallic vapor contaminated arcs which have been investigated intensively so far.

The ablation arcs occur also in industrial devices such as circuit breakers, expulsion fuses, and high-intensity flash lamps. A number of researchers have attempted to understand the physical behavior of such arcs [1]–[10]. They have revealed that the arc is stabilized by an axial flow of ablation gas from a tube wall [1], [2], and a nonconductive layer of low temperature, which is called a sheath, is formed near the wall [4].

Theoretical or mathematical models of the ablation arcs have been also developed [3]–[7] and compared with experimental results for high current arcs ignited in various tube materials: polyvinylchloride C_2H_3Cl [2], yttrium oxide Y_2O_3 [2], and polymethylmethacrylate $C_5H_8O_2$ [6]. Recently, the ablation arc in a polytetrafluoroethylene C_2F_4 (PTFE) nozzle has been studied to explain the phenomenon of nozzle clogging in circuit breakers [8], [9], and the thermodynamic properties of ablation gases of nylon and boric acid have been reported [10].

We have studied the basic characteristics of the ablation-stabilized dc arc in the PE tube (it is called a PE arc in this paper). The experimental results have showed that the electrical field strength of the PE arc is several times as high as that of an air arc, and the radiation power of the PE arc is more than two orders of magnitude compared with that of the air arc [11]. We consider that the main mechanism of energy loss of the PE arc is its strong radiation as well as axial gas flow. In this paper the radiative aspect of the PE arc is investigated photographically and spectroscopically and the radial temperature distributions are estimated. The arcs are operated with dc currents of 5 ~ 15A through inner diameters of 2 ~ 6 mm of PE tube.

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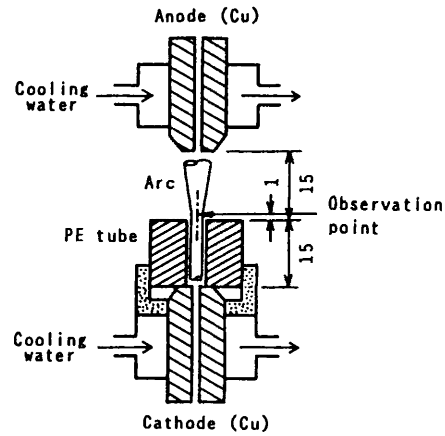

Fig. 1. Electrodes and polyethylene tube geometry.

II. Photographic Observation

The experimental setup for operating the PE arc is schematically shown in Fig. 1. The copper anode and cathode are cooled with flowing water. The PE tube is fixed on the cathode surface. The electrode separation is 30 mm, including the PE tube length of 15 mm. The arc is initiated by drawing a thin piano wire from the cathode through narrow holes drilled along the anode and the cathode axis.

The appearance of the PE arc was observed with an ordinary framing camera. The camera was set 30-mm away from the arc and color film of ASA 100 was used. It is essential to ensure operation on the sensitive part of the light intensity [12]. Therefore we took a number of color photographs of the arc ignited under same condition with various exposures. The following exposure parameters were best in this experiment: the exposure time of 1 ms and the f-number of f/22. In