Internal Pressure Rise due to Arc under Insulating Oil in a Closed Vessel
-Fundamental Examination for Oil-filled Power Equipment-

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When an arc fault occurs inside oil-filled equipment such as transformers in electric power systems, it heats the oil, thus generating flammable gas, and it causes dynamic increases in pressure, which can lead to a blowout. This paper reports a fundamental study on pressure rise due to an arc in a closed vessel containing air and oil. The pressure rises in the air and oil are measured under experimental conditions involving a 2.0-kA arc current, and 100-ms arc duration. The experimental results show that the arc decomposes surrounding oil to the flammable gas and the pressure oscillations vary in air and in oil. Our approximate pressure rise calculations considering oil flux are consistent with the experimental results.

1. Introduction

Electric power systems include oil-filled equipment such as transformers. When an arc fault occurs inside such equipment, the internal pressure increases, and this may result in blowout and other hazards. To clarify the arc fault phenomena, this paper reports a fundamental study concerning pressure rises due to an arc under insulating oil in a closed vessel.

2. Experimental conditions

Arc tests were carried out at the High-Power Testing Laboratory, CRIEPI, under the conditions listed in Table 1. The vessel used in the experiment (Fig. 1) contained the oil and a little air; the pressure rises were measured using pressure transducers located in the air and the oil. The arc was ignited by a fusing copper wire between the copper electrodes under the oil.

Table 1. Experimental conditions.

Item		Condition
Power source (Short-circuit generator)	Test frequency	50 Hz
	Voltage / Current RMS	7.2 kV / 2 kA
	Arc duration	100 ms
Closed vessel	Shape	See Fig. 1
	Air / Oil volume	1.51 / 120 x10^{-3} m^3
Electrodes	Material / form	Copper / round bar
	Diameter / Gap length	5 mm / 5 mm

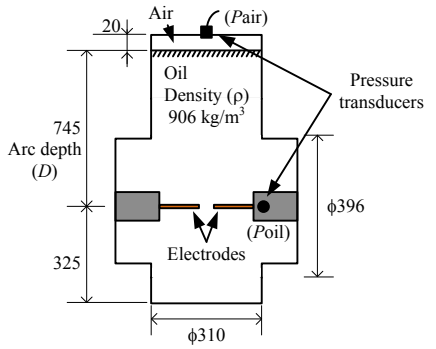

Fig. 1. Configuration of closed vessel. (Unit: mm)

3. Results and discussion

The measured waveforms shown in Fig. 2 represent the arc current, pressure rise in air (*P*air), and that in oil (*P*oil), respectively. Every pressure rise peaks to about 200 kPa for the arc duration. The pressure oscillations in air and in oil have reversed phases. To discuss the differences in pressure oscillation, we calculated the approximate pressure for an oil flux. Assuming that flammable gas surrounding the arc compresses the air volume, an acceleration of the oil flow (α) can be calculated from *P*air. Based on this assumption, the pressure rise in oil (*P*cal) is calculated from the oil density (ρ), arc depth (D), and measured *P*air as follows:

$$P\mathrm{cal} = \rho D \alpha + P\mathrm{air} \quad (1)$$

Thus, it was observed that *P*cal is roughly consistent with the measured value except for several pressure peaks, the differences of pressure oscillation in air and in oil are attributed to oil flow.

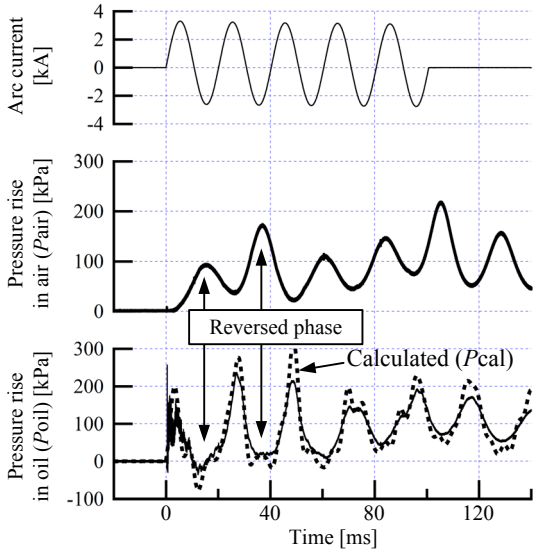

Fig. 2. Measured waveforms and calculated pressure rise in oil (*P*cal).