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IMPULSE ELECTRIC BREAKDOWN OF AIR AND WATER VAPOR AT INCREASED PRESSURE

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Foreign Technology Division
Wright-Patterson Air Force Base, Ohio

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13. ABSTRACT

The results of an investigation of the volt-second characteristics of the electric breakdown of air and water vapor in a non-homogeneous electric field at pressures of up to 40 tech. atm. for a surge voltage effect time of from $2\cdot10^{-7}$ to $2\cdot10^{-6}$ s are presented. A special chamber was constructed with a working volume of 7.5 l with an electric heater and a high-voltage input of 200 kV for the investigation of the volt-second characteristics under pressure. From a comparative investigation of the volt-second characteristics of compressed vapor and air in a non-homogeneous electric field in a time interval of $0.2\cdot10^{-6}$ - $3\cdot10^{-6}$ s it was found that the impulse strength of water vapor at increased pressure exceeds the strength of air. The anomalous phenomenon of the reduction in the impulse discharge voltages, occurring in the breakdown of air, was not detected for water vapor.

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О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

* <u>ye</u> initially, after vowels, and after ъ, ь; <u>e</u> elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

IMPULSE ELECTRIC BREAKDOWN OF AIR AND WATER VAPOR AT INCREASED PRESSURES

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The use of compressed gases for the purpose of insulation in high-voltage apparatuses and devices is finding ever greater application. In a number of cases the insulation of high-voltage devices operates under specific conditions and the impulse discharge occurs in a gaseous medium with increased humidity and temperature. In contemporary impulse and gas-discharge technology the breakdown processes frequently play a basic role and are the working processes in a number of instruments and devices. At the present time the deficiency of experimental data concerning the dielectric strength of air and water vapor under increased pressures and under the effect of surge voltages with a duration of 10^{-6}-10^{-7} s is being perceived.

In connection with what has been stated, the investigation of the characteristics of the impulse breakdown of compressed air and water vapor have aroused scientific and practical interest. In the present article the results of an investigation of the volt-second characteristics of the electric breakdown of air and water vapor in a non-homogeneous electric field at pressures of up to 40 tech. atm. for a surge voltage effect time of from $2 \cdot 10^{-7}$ to $2 \cdot 10^{-6}$ s are presented.

EXPERIMENTAL METHOD

For the investigation of the volt-second characteristics of water vapor under pressure a special chamber was constructed with a working volume of 7.5 l with an electric heater and a high-voltage input of 200 kV.

The device made it possible to obtain dry saturated vapor under a pressure of up to 20 kgf/cm^2 and a temperature of up to 205°C. The pressure measurement was accomplished with a manometer. The construction of the experimental chamber is shown in Fig. 1.

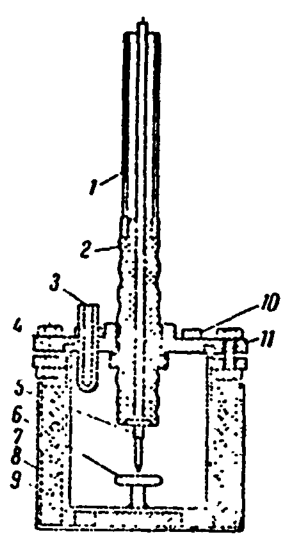

Fig. 1. Chamber for the investigation of the volt-second characteristics of water vapor under pressure.

1 - textolite cylinder; 2 - straight-through porcelain insulator; 3 - insert-slot for the thermometer; 4 - chamber cover; 5 - high-voltage point-electrode; 6 - electrode base; 7 - electrode-heater; 8 - protective metal casing; 9 - thermal insulation; 10 - nozzle for mounting the manometer; 11 - chamber.

The investigation of the volt-second characteristics of air under pressure was also carried out in a special chamber. This chamber had a working volume of 1 l and was rated for a maximum pressure of 50 kgf/cm^2 and a voltage of 200 kV. The compressed air was fed into the chamber through a reduction valve from a high-pressure cylinder.

A rod-base electrode system was employed to the work. Impulses of positive and negative polarity were supplied to the rod, and the base was grounded. The distance between the electrodes was established with an accuracy of up to 0.1 mm and varied from 4 up to 20 mm. During the investigation of the volt-second characteristics of the water vapor the variation in the inter-electrode distance due to the heating of the electrode system was 0.1-0.2 mm, which at working distances of up to 15 mm was within the limits of measurement accuracy.

A surge-voltage generator was employed as the source of the surge voltage.

The generator had a capacitance "in shock" of 0.0135×10^{-6} F and made it possible to obtain impulses of high voltages of positive and negative polarity with an amplitude of up to 400 kV and a front length of $\tau_{\Phi} = 0.3$ μs. The regulation of the front length of the impulse from 0.3 up to 10 μs was accomplished by including capacitance or inductance in the discharge circuit.

The amplitude and the impulse shape were recorded with an OK-19M oscillograph with an ohmic voltage divider, having a resistance of 3,000 ohms. The breakdown of the air and the vapor at all pressures was accomplished on a a single aperiodic impulse front. Each experimental point corresponded to the mean arithmetic value of the breakdown voltages, obtained on the basis of the processing of 20 and more oscillograms. In this case the maximum variance of the breakdown voltages was 15% of the mean values. In the process of carrying out the present work approximately 2,500 oscillograms were made and processed.

impulse discharge voltage value of the water vapor at atmospheric pressure (curves 5 and 6) on the voltage effect time in the time interval $3 \cdot 10^{-7}$–$3 \cdot 10^{-6}$ s; in this case the impulse coefficient practically does not differ from unity. The absence of a discharge lag in the water-vapor breakdown under atmospheric pressure or in the indicated time range, probably, is connected with the egress of initiating electrons from the water droplets situated in the region of the greatest electric field strength, i.e., on the point during its various polarities.

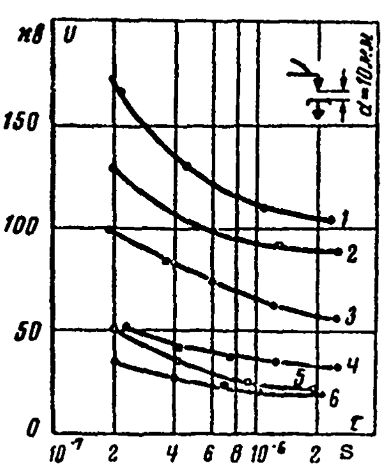

Fig. 3. Volt-second characteristics of compressed water vapor for different impulse polarities. Curves 1, 2 and 5 - negative polarity impulses, pressures respectively of 12 kgf/cm^2, 8 kgf/cm^2 and atmospheric pressure. Curves 3, 4 and 6 - positive polarity impulses for the same pressures.

Figure 4 gives the dependence of the discharge-voltage impulses of air and water vapor on the magnitude of pressure. The discharge is accomplished in a non-homogeneous electric field for a point-base gap with a length of 10 mm at different point polarities. The voltage effect time remained constant and was $0.6 \cdot 10^{-6}$ s.

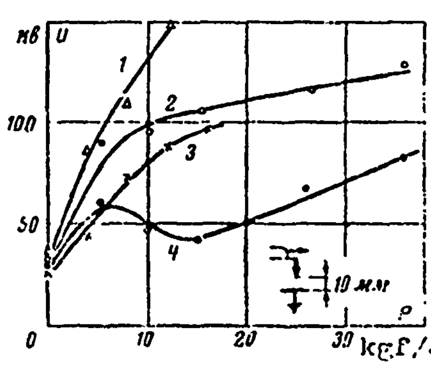

Fig. 4. The dependence of the impulse breakdown voltage of air and water vapor of pressure for positive and negative polarity impulses with a duration of $0.6 \cdot 10^{-6}$ s.
1 - negative polarity water vapor; 2 - negative polarity air; 3 - positive polarity water vapor; 4 - positive polarity air.

As is evident from Fig. 4, in the investigated pressure range the impulse discharge voltage of the water vapor exceeds the discharge voltage of the air at the corresponding point polarities. The impulse strength of the water vapor with an increase in pressure increases more significantly than for air. For example, with an increase in pressure of up to 12 kgf/cm^2 the discharge voltage of the water vapor at negative point polarity increased from 30 up to 150 kV, i.e., by 5 times, whereas the discharge voltage of air increased by only 3.3 times (curves 1 and 2). The increased impulse electric strength of water vapor, apparently, is connected with the fact, that the particles of moisture, present in the water vapor, trap electrons, producing ionization, thereby impeding particle cascades and total discharge. During the breakdown of compressed air at positive point polarity (curve 4) in the value region pd = 4,000-5,000 mm Hg column·cm a certain anomalous reduction in the discharge voltages was detected. Analogous anomalous phenomena were not observed in the breakdown of water vapor.

Figure 5 gives the dependence of the impulse breakdown voltage of air on pressure for various voltage time effects. With a decrease in the voltage time effect the pressure range of the corresponding anomalous phenomena is somewhat reduced, and the minimum values of the discharge voltage are shifted into the region of higher pressures.

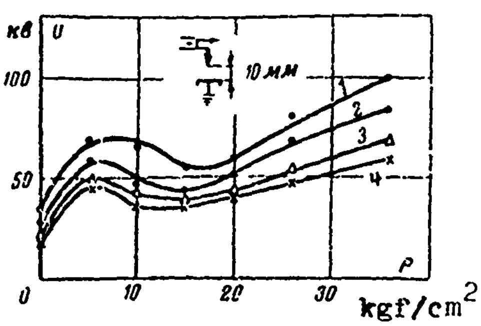

Fig. 5. The dependence of the impulse breakdown voltage of air on pressure at various voltage effect times.
1 - $\tau_\phi = 0.3 \cdot 10^{-6}$ s;
2 - $\tau_\phi = 0.5 \cdot 10^{-6}$ s;
3 - $\tau_\phi = 1.2 \cdot 10^{-6}$ s;
4 - $\tau_\phi = 2.5 \cdot 10^{-6}$ s.

Conclusions

In the present work a comparative investigation of the volt-second characteristics of compressed vapor and air was first carried out in a non-homogeneous electric field in a time interval of $0.2 \cdot 10^{-6}$–$3 \cdot 10^{-6}$ s. It was established that the impulse strength of the water vapor at increased pressures exceeds the strength of the air.

The anomalous phenomenon of the reduction in the impulse discharge voltages, occurring in the breakdown of air, was not detected for water vapor.