Indirect Measurement of the Internal Axial Potential of Fluorescent Lamps

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Indirect Measurement of the Internal Axial Potential of Fluorescent Lamps

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In order to measure the internal axial potential of fluorescent lamps, a special lamp with internal probes had to be prepared and the potential could only be measured with this test lamp. We found that by wrapping an electrical conductive foil around the external wall of a fluorescent lamp, we could obtain the differential waveform of the internal discharge waveform as the output signal of the foil, because a kind of condenser is formed by the "discharge - phosphor • glass tube - foil". Based on this discovery. we established a new measuring method which can represent the internal axial potential of conventional fluorescent lamps. An electrical conductive foil is wrapped around the external wall of a conventional fluorescent lamp and connected to the "integral circuit" in series, and then the output signal of the integral circuit is measured.

Using this method, the internal axial potential at any point of a conventional fluorescent lamp can be measured with very simple instruments and by very easy operations without preparing a special fluorescent lamp with internal probes. Thus, this method can be used to measure the distribution of the internal axial potential, the cathode fall, the anode fall, the axial electric field of the positive column, and the potential difference between any two points of a conventional fluorescent lamp.

1. Introduction

In order to measure the distribution of internal axial potential, the cathode fall, the anode fall of fluorescent lamps, and the internal axial electric field of positive column, a special lamp with internal probes had to be prepared. We established a new measuring method which can represent the internal discharge waveform of conventional fluorescent lamps. An electrical conductive foil is wrapped around the external wall of a conventional fluorescent lamp[1] and connected to the "integral circuit" in series, and then the output signal of the integral circuit is measured. The detail of the measuring method is as follows.

2. Measurement Principle and Measurement Circuit

The structure of fluorescent lamp is shown in Fig. 1. Mercury and rare gas are contained in a discharge space which is enclosed by glass tube coated with phosphor. Therefore, if an electrical conductive foil is wrapped around the external wall of a lighting fluorescent lamp, a kind of condenser is formed by the "discharge - phosphor • glass tube - foil"[2]. So, the output signal of the foil is the differential waveform of the internal discharge waveform as shown in Fig. 2. Then, if the "integral circuit" is connected with the foil in series, the output signal of the integral circuit becomes small but it represent the internal discharge waveform of the fluorescent lamp as shown in Fig. 3.

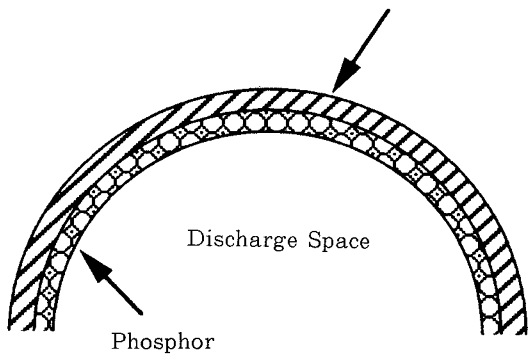

Fig. 1 Structure of Fluorescent Lamp

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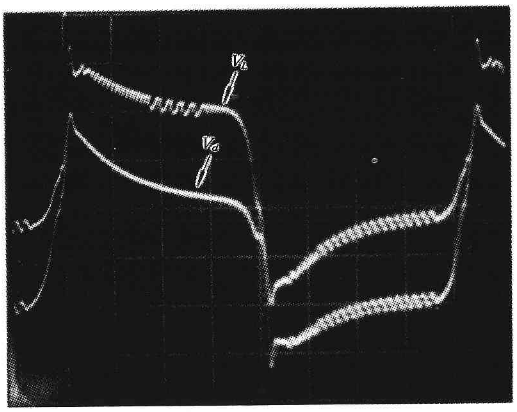

Fig. 2 Lamp Voltage Waveform and Outfput Signal of the Foil
V_L: Lamp Voltage 50V/d
V_d: Output Signal of the Foil(signal at point 76cm interval from earth) 50V/d
H: 2ms/d

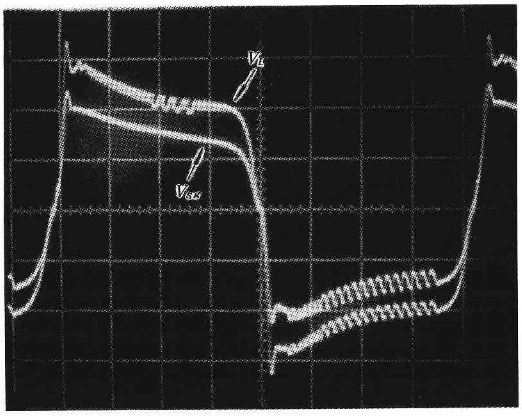

Fig. 3 Lamp Voltage Waveform and Internal Discharge Waveform
V_L: Lamp Voltage 50V/d
V_{sg}: Internal Discharge(signal at point 76cm interval from earth) 5V/d, signal ratio=0.180
H: 2ms/d

The measurement circuit is shown in Fig.4. The equivalent circuit using a oscilloscope as a measurement device is shown in Fig. 5. In this figure, the output response for the step function input is represented as follows, in case the extremely high impedance C_1, C_2 are neglect.

The circuit equations are as follows

$$E=\frac{1}{C_p}\int Idt+RinI+(R_1+R_2)I_1 \quad \cdots\cdots\cdots\cdots\cdots (1)$$

$$(R_1+R_2)I_1=\frac{1}{Cin}\int (I-I_1)dt \quad \cdots\cdots\cdots\cdots\cdots (2)$$

the output response $V_{sg}=R_2\ I_1$ for the step function input E is as follows

$$Vsg=\frac{R_2E\ \{\exp(S_1t)-\exp(S_2t)\}}{(R_1+R_2)Rin\ Cin(S_1-S_2)} \quad \cdots\cdots\cdots\cdots (3)$$

where,

$$S_1,\ S_2=\frac{-\{Rin\ Cp+(R_1+R_2)(Cp+Cin)\}\pm\sqrt{A}}{2Rin(R_1+R_2)CpCin} \quad \cdots\cdots\cdots\cdots (4)$$

and,

$$A=(Rin\ Cp)^2+2Rin(R_1+R_2)(Cp-Cin)Cp+(R_1+R_2)^2(Cp+Cin)^2 \quad \cdots\cdots\cdots\cdots (5)$$

Each notation means as follows,
E: step function input(V)
C_p: capacitance of condenser formed by "discharge - phosphor・glass - foil" (μ F)

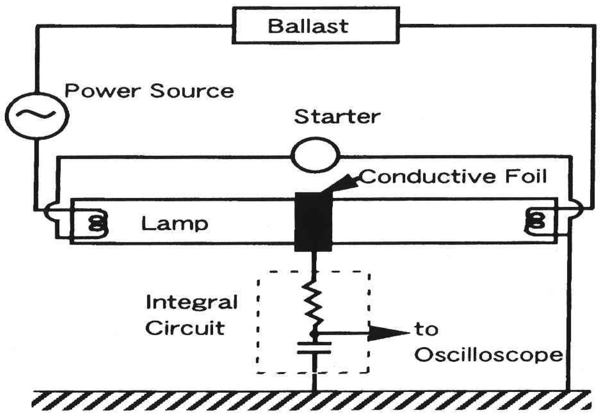

Fig. 4 Measurement Circuit

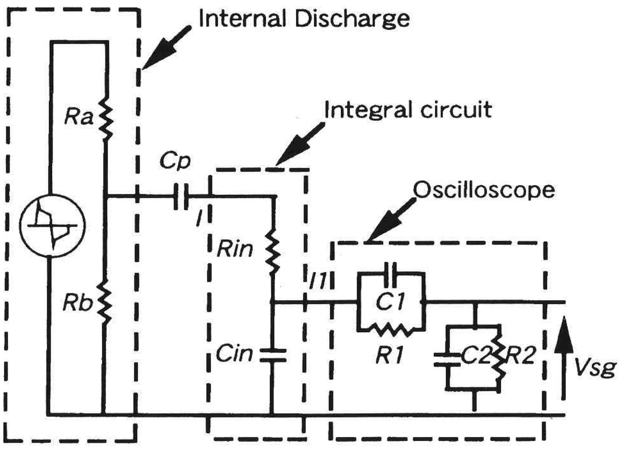

Fig. 5 Equivalent Circuit

C_{in}: capacitance of condenser of integral circuit (μF)
R_{in}: resistance of integral circuit(Ω)
R_1: resistance of probe for oscilloscope(Ω)
R_2: input resistance of oscilloscope(Ω)
I: input current to integral circuit(A)
I_1: input current to oscilloscope(A)
t: time(s)

If the condition $|S_1| \ll |S_2|$ is satisfied for S_1, S_2 of Eq.(4), the output Vsg becomes step response for the step function input E. For example, wrapping an aluminum foil 4.5cm in width around the 40W fluorescent lamp, using "10 vs 1" probe for oscilloscope and selecting the integral circuit constant Cin= 0.0018μF, Rin=10KΩ, then this condition is satisfied.

3. Measuring Method

The measuring method is as follows. The fluorescent lamp is connected to lighting circuit and turned on.

(1) An electrical conductive foil is wrapped around the external wall of near electrode of anti-earth side of lamp.
(2) The foil is connected to the integral circuit, the output terminal of the integral circuit and lamp voltage terminal are connected to the measurement instrument, as shown in Fig. 4.
(3) The ratio of the integral circuit output voltage to lamp voltage is defined as "signal ratio".
(4) The foil is moved to the measurement position of the lamp, and the integral circuit output voltage is measured.
(5) The integral circuit output voltage is divided by "signal ratio", the quotient represents the internal axial potential of measurement point of the lamp.

Through above procedure, the internal axial potential of any position of any fluorescent lamp can be obtained.

It is desirable to exclude the influence of stray capacity, connecting the earth line of integral circuit and that of measurement instrument, furthermore the wiring is as shorten as possible.

4. Comparison of Probe Method and Developed Method

The internal axial potential of a 40W size special fluorescent lamp with ten internal probes(Fig. 6) was measured directly by these probes. At the same time, the internal potential of this lamp was measured indirectly by our new measuring method. The comparison of these results is shown in Fig. 7. Aluminum foil 4.5cm in width, condenser with capacitance Cin= 0.0018μF, resister with resistance Rin=10KΩ and "10 vs 1" probe for oscilloscope are used in new indirect measuring method. Fig. 7 shows that our new measuring method is accurate. An aberration of measuring result of electric field of positive column by this new method is within 10%.

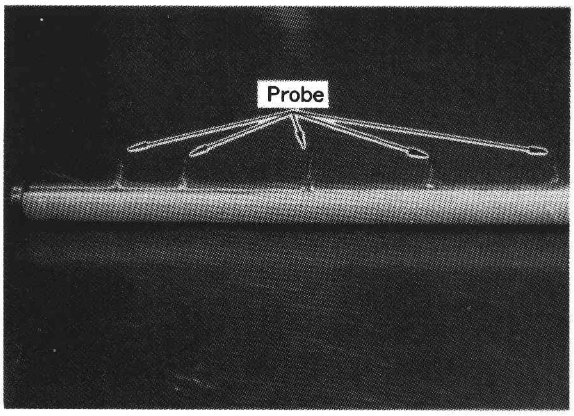

Fig. 6 Special Fluorescent Lamp with Ten Internal Probes

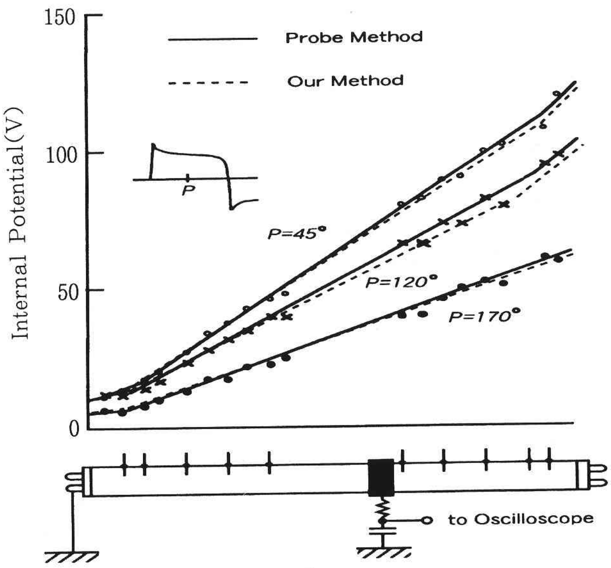

Fig. 7 Comparison of Our Method with That Using a Special Fluorescent Lamp with Interfnal Probes

5. Example of Measurement

Measurement result of internal axial potential waveform at some point of a conventional 40W size fluorescent lamp is show in Fig. 8. The cathode fall waveform and the anode fall waveform is shown in Fig. 9. The cathode fall voltage is about 11 V. A state of measurement is shown in Fig. 10.

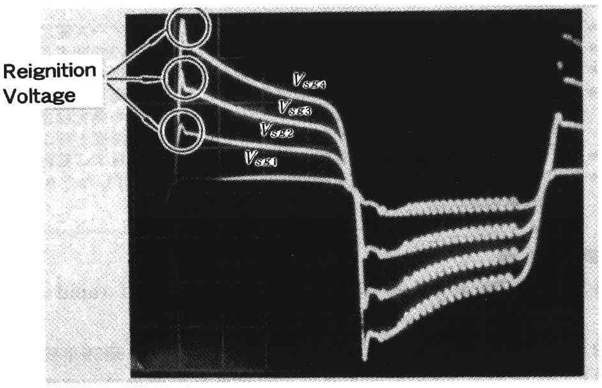

Fig. 8 Internal Axial Potential Waveform at Some Point of a Conventional Fluorescent Lamp
V_{sg1}: signal at point 16cm interval from earth 5V/d, signal ratio=0.180
V_{sg2}: signal at point 46cm interval from earth 5V/d, signal ratio=0.180
V_{sg3}: signal at point 76cm interval from earth 5V/d, signal ratio=0.180
V_{sg4}: signal at point 106cm interval from earth 5V/d, signal ratio=0.180
H: 2ms/d

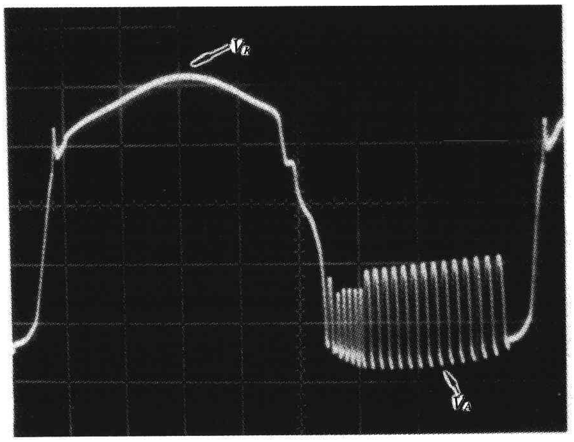

Fig. 9 Cathode Fall Waveform and Anode Fall Waveform
V_K: Cathode Fall 1V/d, signal ratio=0.180
V_A: Anode Fall 1V/d, signal ratio=0.180
H: 2ms/d

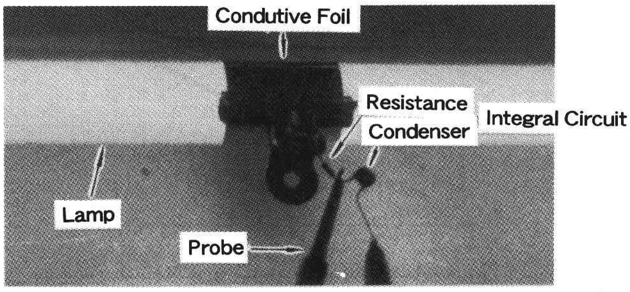

Fig. 10 State of Measurement

6. Conclusion

Using this new developed measuring method, the internal axial potential at any point of a conventional fluorescent lamp can be measured with very simple instruments and by very easy operations without preparing a special fluorescent lamp with internal probes. Thus, this method can be used to measure the distribution of the internal axial potential, the cathode fall, the anode fall, the axial electric field of the positive column. The potential difference between any two points of a conventional fluorescent lamp can be measured, using two sets of electrical conductive foil and integral circuit as shown in Fig. 11.

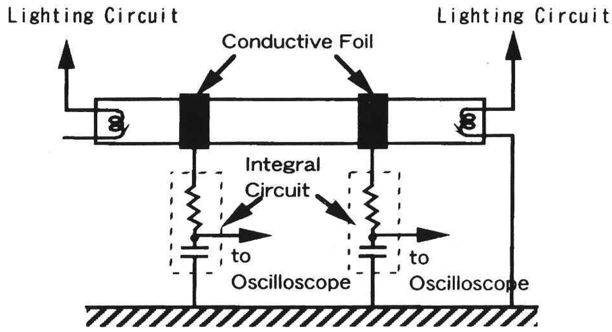

Fig. 11 Measurement Circuit for Potential Difference between Any Two Points

This method is applicable not only to the case in which a fluorescent lamp is fully operated on commercial frequency but also can be used for a fluorescent lamp operated on high frequency or using a dimmer. It is also applicable to both tubular and circular lamps. Either an oscilloscope or a digital meter can be used as the measuring device.

A DC signal cannot be detected by this method. Also, in the case of measuring a rapid-start fluorescent lamp with an internal starting aid (transparent conductive coating), the internal discharge waveform cannot be represented because the series connected condensers will be composed of "discharge - phosphor - transparent internal conductive coating" and "transparent internal conductive coating-glass tube-conductive foil".

We authors hope that this measuring method will put to practical use in many scenes.

References

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