DESIGN AND CONSTRUCTION OF A THYRATRON STROBOSCOPE

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AND

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PREFACE

The object of this thesis was to construct a thyratron stroboscope to be used in the Virginia Polytechnic Institute Electrical Laboratory and to study the use of the thyratron tube as a stroboscope. The writers of this thesis know that nine months is a short time to spend on such a broad subject, but an honest effort has been made and we feel as though much has been accomplished from our experimenting and study.

The authors wish to express their appreciation for the constructive criticism and assistance given them by Professor Claudius Lee, Professor C. W. Hoilman, and Professor B. M. Widener, of the electrical department, Professor F. B. Haynes of the physics department, and S. R. Prichard, Jr.

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I. INTRODUCTION

Ever since the advent of high speed motors, a need has been felt for an instrument to note the operation of these machines while running at full speed. The first stroboscopic instrument was an arc lamp. This was very crude device but showed that such an apparatus was possible.

A stroboscope usually consists of a disk rotating with the shaft of the motor under consideration and is provided with some device which allows it to be seen by the eye only at certain regular intervals. The operation depends upon the property of the eye to retain an image. For example, if a moving object attains a certain position twenty times or more a second and is allowed to be seen by the observer only when in the stated position, it appears to be stationary. There are a variety of stroboscopes designed to meet specific problems. The latest type is one using the thyratron tube.

II. REVIEW OF LITERATURE

A. Types of Stroboscopes

One form of stroboscope makes use of a slotted disk, back of which is located a small neon lamp. The neon lamp is selected because of its nominally instantaneous responsiveness to applied voltage and its low thermal capacity which prevents it from continuing as a light source while the voltage wave crosses the zero axis. When the disk revolves, it interrupts the passage of light between the neon lamp and the observer. In this connection there is described also an ingenious method of reading high voltage values of induction motor slip by means of two disks and a system of pulleys.

Another stroboscope is that designed by Dr. D. Robertson in which light interruption is obtained by means of an electrically driven tuning fork placed between a segmented disk and the observer. The prongs of the forks have slotted aluminum wings. With the fork vibrating, light reaches the observer's eye when the slots are opposite and is cut off when they are not opposite. Thus the number of interruptions per second depends on the fork frequency.

Dr. C. V. Drysdale also makes use of the tuning fork, an induction coil, and a neon tube. The tuning fork, which is electrically driven makes and breaks the primary current of the induction coil. The secondary of the coil is connected to the neon tube. Thus the number of interruptions recorded by the vibrating fork causes the neon tube to flash, producing the usual stroboscopic results.

B. The New Neon Electric Stroboscope

The new neon electric stroboscope consists of four parts: a transformer, a condenser, a neon lamp, and a disk. All this apparatus is enclosed in a case for protecting the lamp against breakage and the operator against high voltage. The only connections to the case are those leading to the primary of the transformer. This stroboscope works on practically the same principle as the older types of neon lamp stroboscopes without all the extra connections.

C. The Thyratron Tube as a Stroboscope

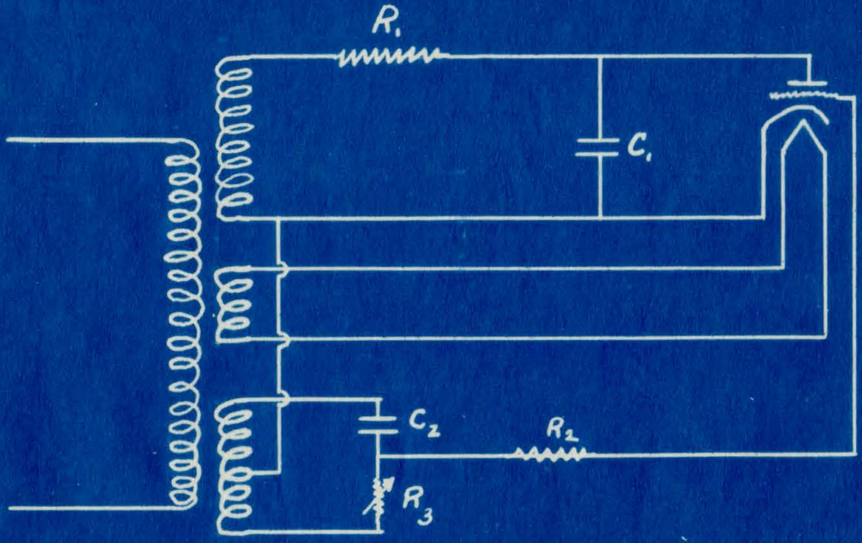
The latest type of stroboscope is that using a thyratron tube for the source of illumination. It consists of a multi-circuit transformer, two condensers, three resistances, a disk, and a FG-33 thyratron tube.

IV. INVESTIGATION

A. Object of Investigation

The thyratron tube has been used for many purposes but it has only been recently experimented with as a stroboscope. These first tests have succeeded beyond the hopes of the investigators. With this in view, the writers have constructed a stroboscope using the thyratron tube, the completed instrument to be left in the Virginia Polytechnic Institute Electrical Laboratory.

B. Design and Construction of the Apparatus



THYRATRON TUBE STROBOSCOPE CIRCUIT

Fig. 1.

A design or plan of the stroboscope was first made (Fig. 1), and then an investigation of laboratory supplies for available equipment. Only the thyratron tube and a variable resistance were acquired from outside sources.

The multi-circuit transformer to provide the voltages to the tube was the first part to be constructed. It is a core type with a 110 volt primary and secondary windings to provide 660 volts across the plate, 50 volts (with center tap) across the grid circuit, and 5 volts across the filament circuit. The following calculations were made:

General formula $E = 4.44 \times f \times N \times \phi \times 10^{8}$

E = primary voltage

f = frequency

N = number of turns on the primary

ϕ = total number of lines of flux

A = cross-section area of the core

$$A = 1.5 \times 1.5 \times 0.9 = 2.13 \text{ square inches}$$

$$\phi = 65000 \times 2.03 = 132000 \text{ lines of flux}$$

By substituting these values of A and ϕ in the general equation,

$$N = \frac{110 \times 10^{8}}{4.44 \times 60 \times 132000} = 300 \text{ turns on the primary}$$

The equation giving the relation of the required voltage to the number of turns was then used to determine the secondary windings.

$$E_1 : E_2 :: N_1 : N_2$$

$$N_2 = \frac{300 \times 660}{110} = 1800 \text{ turns to provide plate voltage}$$

$$N_2^1 = \frac{300 \times 50}{110} = 140 \text{ turns to provide grid voltage}$$

$$N_2^2 = \frac{300 \times 5}{110} = 14 \text{ turns to provide filament voltage}$$

Using the fundamental equation of electricity, $E = RI$, the currents in the various secondary circuits were calculated.

$$I_{plate} = \frac{1000}{5000} = 0.20 \text{ amperes}$$

$$I_{filament} = \frac{5}{1} = 5.00 \text{ amperes}$$

$$I_{grid} = 0.05 \text{ amperes}$$

From these values of current, the volt-amperes were calculated which permitted the current necessary on the primary to be obtained.

0.2 x 660 = 132 va.

5.0 x 5 = 25 va.

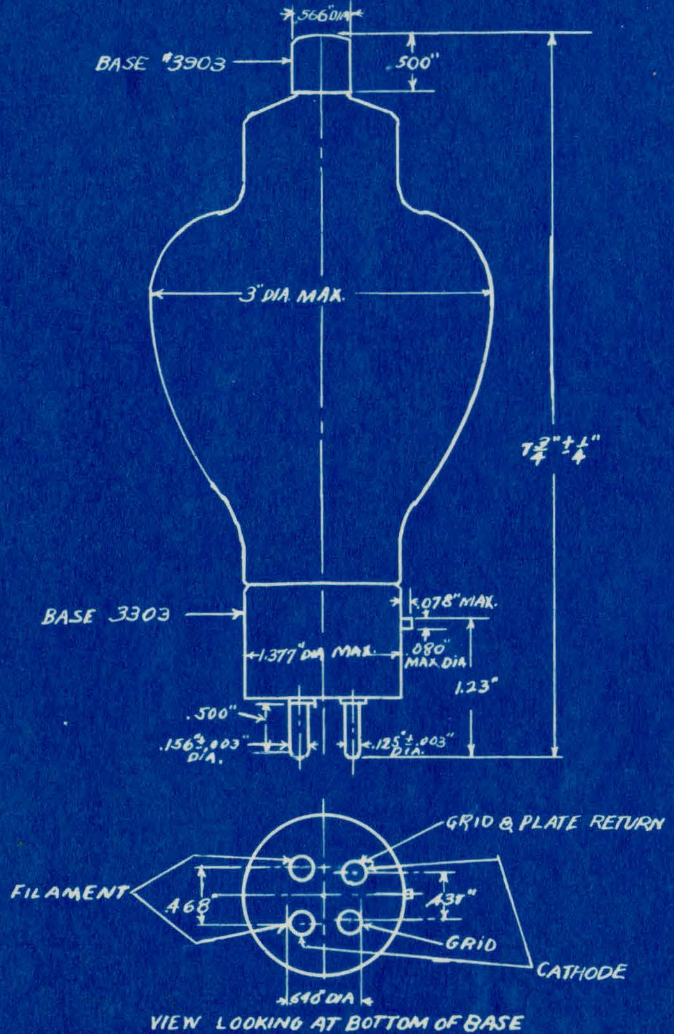
0.05 x 50 = 2.5 va.

Total va. on secondary = 159.5

$$\text{Current in primary} = \frac{159.5}{110} = 1.5 \text{ amperes}$$

The wire size necessary to carry the required currents in each coil was taken from the wire tables and were as follows; No. 18 for the primary, No. 26 for the plate circuit, No. 14 for the filament, and No. 32 for the grid circuit.

The transformer was then assembled, insulated, shellacked, and dried. The circuits were first tested for shorts and grounds. The terminals of the primary were then hooked across a 110 volt, 60 cycle circuit and voltmeters placed across the secondary circuits of the transformer. The readings of the voltmeters verified the calculated voltages of the secondary, 660 volts, 5vvolts, and 50 volts. Loads were then added to the secondary circuits to see if the voltages would drop below our required values. The potentials still remained the same so the transformer was deemed ready for use.



OUTLINE DIMENSIONS OF THYRATRON FG-33

Fig. 2

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Referring again to Fig. 1, the following values of the constants were found to give the most satisfactory results.

R_1 = 5000 ohms

C_1 = 0.5 micro-farads

R_2 = 200 ohms

C_2 = 1 micro-farad

R_3 = 25000 ohms (variable)

An eight inch disk was made of sheet iron, constructed in such a way that it could be fastened to the end of the shaft of the machine to be tested. The flat surface of the disk was laid off in eight equal sections, alternately black and white. The number of sections vary as the number of poles of the machine to be tested.

A case made of one-half inch, well-finished oak, was built to hold the assembled apparatus. The inside dimensions are fifteen inches long, eight inches wide, and twelve inches deep. A hole, three inches in diameter, was bored in one end of the case to permit the illumination of the lamp to reflect on the disk. The variable resistance control and the transformer primary terminals were placed on top of the case where they could be easily handled by the operator.

The assembled apparatus was placed in the case and well secured, which would prevent injury to the individual parts and danger to the operator from the high voltage on the secondary of the transformer.

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C. The Thyratron Tube

The tube used (Fig. 2) is the FG-33 Thyratron produced by the General Electric Company. It is a hot-cathode, mercury vapor, grid controlled rectifier requiring a definitely positive grid voltage for operation. It is an electron discharge device in which the emission is obtained from a cylindrical cathode with an enclosed tungsten heater. The cathode is so constructed as to reduce heat radiation.

The mercury in the tube produces a vapor pressure depending upon the temperature of the coolest part of the tube. Electrons emitted by the cathode collide with the mercury vapor atoms and produce ionization. Positive mercury ions are attracted toward the cathode and neutralize the normally negative space-charge around the cathode. This action results in a relatively low voltage drop between the anode and the cathode, with consequent low loss in the tube.

The function of the grid is to control the starting of the anode current. A grid potential, more negative than a given positive value with respect to the cathode, will prevent the occurrence of a discharge. Once the discharge is started the grid potential, except for very low plate currents, has no appreciable effect on the anode current; control is restored to the grid only when the discharge ceases long enough for the mercury to deionize.

When an alternating voltage is applied to the plate, the grid has an opportunity to regain control during the negative half of each cycle and to retain this control for as long a period during the extent of the cycle as its potential is sufficiently negative. By thus controlling the time of starting of the plate current in each positive half cycle, the average plate current is controlled.

The ratings and data of the FG-33 thyratron are:

Cathode

Volts..................................	5.0
Amperes............................	4.5 (approx.)
Type..........................	Indirectly Heated
Typical Heating Time (min.)...............	5.0

Maximum Peak Voltage

Inverse..................................	1000
Forward..................................	1000

Maximum Plate Current (amperes)

Instantaneous..............................	15
Average..................................	2.5

Maximum Time of Average Plate Current (seconds) 15

Maximum Grid Current (amperes)

Instantaneous..............................	15
Average..................................	.25

Tube Voltage Drop

Maximum..................................	24
Minimum..................................	10

Approximate Starting Characteristic

Plate Voltage	Grid Voltage
100	10
1000	10

Overall Dimensions

Maximum Length........................ 8 inches

Minimum Length.. .... $7\frac{1}{2}$ inches

Maximum Diameter...................... 3 inches

Temperature Limits Ambient (C)............. 20-50

Type of Cooling............................ Air

Deionization Time (micro-seconds).......... 1000 (approx.)

The tube is fitted with a four prong base for the cathode and grid connections and with a cap for the plate connections. It was mounted in a socket fastened in the bottom of the case so as to operate in a vertical position.

D. Results

The disk was attached to the shaft of a four pole, 110 volt induction motor and the primary of the stroboscope was placed across two of the supply terminals. The control was adjusted for maximum illumination but no reflection was obtained from the disk. Inspection showed mercury vapor on the exposed side of the tube. It was reversed and again placed in operation. This time the reflection was clearly definable to the observer's eye. The tube did not give off as much light as was expected and we had to get the best results possible without the benefit of a dark room.

IV. DISCUSSION OF RESULTS

The results obtained were not as favorable as expected and lack of time prevented further experimenting. The chief drawback was the lack of illumination from the tube. This could probably be remedied by applying normal filament voltage for at least fifteen minutes with no plate voltage applied to the tube so as to remove the splattered mercury from the bulb. It was also found that by shielding out other light from the disk, the definition of the reflection was much plainer. The writers suggest that a cone be made of heavy paper extending from the tube to the disk with a telescopic arrangement whereby the operator can view results. Other advantages noted of this type of stroboscope were simplicity of operation, compactness, portability, absence of moving parts, and low cost.

V. CONCLUSION

1. A multi-circuit transformer was constructed with material available in the laboratory.
2. The constants found for the circuit proved satisfactory.
3. The use of a thyratron tube as a stroboscope proved desirable.
4. The design used for the construction of the stroboscope was correct in all details.
5. Addition of shield for light would improve reflection of light from the disk.
6. This type of stroboscope has the advantages of simplicity of operation, compactness, portability, absence of moving parts, and low cost.

VII. SUMMARY

The thyratron stroboscope was designed using a multi-circuit transformer, condensers, resistances, a thyratron tube, and a disk. Most of the material was personally constructed in the laboratory and the whole assembled according to Figure 1 and placed in a case. Tests were made with the instrument and although it displayed some flaws, results were generally satisfactory. The chief disadvantage found was lack of illumination from the tube. Some of the advantages are simplicity of operation, compactness, portability, absence of moving parts, and low cost.

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