The Development and Operation of a Projection Oscillograph

Electrical Engineering

B. S.

1911
THE DEVELOPMENT AND OPERATION
OF A
PROJECTION OSCILLOGRAPH

BY

JOHN BESLER BASSETT

THESIS
FOR THE
DEGREE OF BACHELOR OF SCIENCE
IN
ELECTRICAL ENGINEERING

COLLEGE OF ENGINEERING
UNIVERSITY OF ILLINOIS
1911
UNIVERSITY OF ILLINOIS

May 27, 1931

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

John Besler Bassett

ENTITLED The Development and Operation of a Projection Oscillograph

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Electrical Engineering

Instructor in Charge

HEAD OF DEPARTMENT OF Electrical Engineering
INTRODUCTION

The task set before the writer of this thesis has been substantially that of finishing the work begun in 1908 by Briggs Odd Brown in his thesis on "The Design and Construction of a Projection Oscillograph".

The actual construction of the oscillograph as designed by Brown was never completed by him, and some of the parts that were finished had to be redesigned by the author, but the general principle of operation of the original design was found to be correct, and was adhered to closely. No attempt will be made, therefore, to repeat the general theory of the instrument as given in the original thesis, but the following matter will be confined to a description of the design of the new parts, and the reasons for making the changes that were found necessary.

The writer desires to acknowledge his indebtedness to Dr. Ernst J. Berg, and to Mr. J. M. Bryant, for many valuable suggestions.
REFERENCES

In addition to the references given in the original thesis by Brown, which is kept in the office of the Chief Clerk of the Library of the University of Illinois, the following reference of more recent date may be of value:—

THE VIBRATORS

The original design of the vibrators provided for a free length of vibrating strip of about three inches, and for about an inch or so more of spiral spring, making a total length of over four inches between rigid supports, and tending to make the frequency of the vibrating system very low. This construction was necessary in order that the wave could be moved up or down on the screen without moving the whole vibrator structure. In the new design provision is made for turning the whole vibrator about the strip as an axis, thus giving the desired vertical adjustment, and allowing the length of strip between bridges to be made any desired amount.

Fig. 1.

In Fig. 1 the phosphor bronze strip is shown stretched from the brass plate 1, across the ivory bridge 2, around the ivory pulley 3, and back. It is held taut by the flat spring 4, and carries the small mirror 5, midway between the bridges.
The strip is \(0.0132\) inch wide by \(0.0024\) inch thick, and its safe current carrying capacity is \(0.5\) ampere. The resistance of the strip is about \(0.03\) ohm per inch, and as the length of strip in one vibrator is 5 inches, the resistance of the vibrator is about \(0.4\) ohm. Then in order to get \(0.5\) ampere through the vibrator at 110 volts pressure, 220 ohms should be put in series with it. Taking the ultimate strength of the phosphor bronze as \(140,000\) lb. per square inch, the strength of one strip is \(4.44\) lb. and for both strips it is \(8.88\) lb.

Now the tension in the strip is increased by turning down the screw 6 in the head of the vibrator, thus elongating the frame, and the maximum pull that can be obtained from the flat spring is about \(1.25\) lb. - well within the ultimate strength of the strip. The small mirror is \(1/8\) inch square by \(0.025\) thick, and is fastened to the strip with shellac. The natural period of the vibrator is about \(0.002\) second with the spring loose, - this will permit demonstration of a fifth harmonic at 60 cycles, and higher harmonics may be followed by increasing the tension in the strip. To assemble the vibrator and holder between the poles of the electromagnet, the holder is first slipped into place and fastened with a long brass rod which passes down through the magnet cores and the hole 7 in the hard rubber back of the holder. The vibrator is then introduced into the holder, the pin 8 slipping into support 9, and the hard rubber head 10 sliding into the brass collar 11. When the vibrator has received the proper vertical adjustment, the screw 12 may be tightened to lock it in place.
THE SYNCHRONOUS MOTOR

Some experimentation was necessary before the synchronous motor could be gotten into a reliable operating condition. The starting device, or contact maker, was improved by the addition of a phosphor bronze spring with silver contacts.

The bearings of the motor were reamed out to reduce friction, and the air gap was filed out a little to insure mechanical clearance. The hard rubber fillers were taken out of the armature so that it might fan the field poles and cool them.

A new shaft for the motor was turned out of 1/2 inch cold rolled steel and threaded on one end to receive a small ball bearing. The middle of the shaft was left larger for greater rigidity. A brass flywheel 3 1/4 inches long and 1 1/4 inches in diameter was made to fit over this part of the shaft to help the motor keep constant speed. To reduce vibration a counterbalanced aluminum shutter was made to replace the old brass shutter.

After many trials it was found that the motor started most readily with a resistance of about 75 ohms in series, at 60 cycles, 110 volts, and that it then operated without hunting on full voltage.
THE SYNCHRONOUS MIRRORS

The power developed by the synchronous motor is not very great; in fact it would be entirely inadequate to drive the heavy mirror holder, weighing about 8 ounces, provided by the original design. The light mirror holder shown in Fig. 2 was therefore designed.

Fig. 2.

In Fig. 2 the main member 1 of the holder is a solid bar of aluminum with a short arm at its lower end. The bearing for the cam roller 2 is of brass and is screwed to this arm. The roller itself is of the best tool steel. The knife edges 3 are of saw blade steel, and the mirror holders 4 are of brass. These are adjustable in a vertical direction. The holder weighs less than an ounce, and most of the metal is near the axis of oscillation, so that the moment of inertia of the whole system is very small. The spring 5 is designed to hold the cam roller against the cam, and at the same time to hold the knife edges against their bearings.
THE SPIRAL CAM

An eccentric cam was provided in the original design, but it may readily be seen from the manner in which a sine wave is generated that the cam should be spiral instead of eccentric, the motion produced by the cam must be a uniform one, instead of the accelerated motion produced by an eccentric. A spiral cam was therefore designed, and the resulting shape, taken directly from the cam, is shown in Plate II. One half of the cam is a simple spiral, and the other half is a curve designed to give a harmonic, or uniformly accelerated motion to the mirror holder, so that there will be no jar or vibration. The cam is made of cold rolled steel, and was laid out and cut as accurately as possible by hand.
THE CYLINDRICAL MIRROR

The cylindrical mirror shown in the original design consisted of a flat block of glass ground out on one side to a 12 inch radius and silvered. The silvering could not be protected, as the light had to be reflected from this side, and so it quickly tarnished and came off. A new mirror was designed and was ground by the Bausch & Lomb Optical Company, of Rochester, New York. This mirror has two concentric surfaces with the silvering on the rear one, properly protected with enamel.
OPERATION

Up to the date of writing, only one test has been made on the oscillograph, but the results of this trial were satisfactory, and brought out clearly the good and bad points in the construction of the instrument.

The oscillograph was set upon a table about ten feet from a screen, with the arc lamp about a foot and a half to one side. The light from the lamp was focused on the opening in the side of the case and the final mirror adjustments were made. The synchronous motor was brought up to speed. The fields were excited by 1 ampere D.C., and about .3 ampere A.C. was sent through one of the vibrators. The resulting wave produced on the screen was about 2 feet long and 2 inches high. The field current was now increased to 2 amperes, and the wave ordinate doubled accordingly. The tension in the vibrator strip was now reduced, and the height of the wave increased to over a foot, above and below the zero axis. The card was then about two feet square, and the curve appeared to be nearly a true sine wave.
MODIFICATIONS

Several improvements and changes were suggested by the results of the test, perhaps the most desirable one being a greater maximum ordinate in the projected wave, at a lower excitation of the fields, and with a higher tension in the vibrator strip. At present there is room for about 1500 more turns on the fields and these will be added. This should raise the flux density of the air gap from 40,000 to 58,000 lines per square inch, or in the ratio of turns, neglecting the iron part of the circuit, 3334 to 4834 turns, for each gap. The length of free vibrating strip between bridges will also be increased from 1 inch to 1 1/2 inch. This may safely be done without bringing down the natural frequency of the vibrator to too low a value, and should increase the ordinate of the projected wave to 2.8 times its former value for the same strength of field, or to 4 times its former value for the stronger field when the additional turns have been wound on.

A further refinement in the form of a machine cut cam in place of the present rather rough hand made one would undoubtedly improve the form of the wave, but this would have to be cut with special machinery and at the date of writing the time is too short for this to be done.
CONCLUSION

An effort has been made to put the best possible workmanship and material into this oscillograph so that it might not only be simple to operate, but durable and proof against wear and careless treatment. The vibrators are easily removed from the holders on the magnets, and if burned out may be supplied with a new strip in a few minutes. The synchronous system runs easily, and shows no signs of wearing out at any point; there is nothing about it to break. Perhaps the most delicate, and certainly the most precious part of the instrument is the cylindrical mirror. It was ground on a special order and could not be duplicated in less than three weeks time.

It is the sincere hope of the author that this oscillograph may give good service for some time to come in fulfilling its purpose - the demonstration of the elementary theory of alternating currents in the class-room.
Plate II
Motor Shaft, Mirror Holder, and Spiral Cam for a Projection Oscillograph.

Scale Full Size

May 7, 1911.

F. B. B.