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Applicability of the Spark Coil Transformer
in Determining the Condition of Vacuum Tubes.

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SUBJECT

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BY

NAVAL RESEARCH LABORATORY

BELLEVUE, D. C.

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NAVY DEPARTMENT

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Applicability of the Spark Coil Transformer in Determining the Condition of Vacuum Tubes

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AUTHORIZATION

1. This investigation, the results of which are embodied in the subject report, was authorized by ref.(a). It concerns the "Applicability of the Spark Coil Transformer for determining the Condition of Vacuum Tubes". References (b) and (c) are informative on matters relevant to the origin of the present problem.

Reference: (a) BuEng let. S67/38(11-4-W8) of 27 Feb.1936.
(b) NRL let.S67/38/38160 of 25 July 1935.
(c) BuEng let.S67/38(11-4-W8) of 27 Dec.1935.

OBJECT OF INVESTIGATION

2. The object of this investigation was to ascertain the efficacy of the "Spark Coil Transformer" for determining the condition of vacuum tubes. With the aid of this device, a rapid shelf check of tube stock can be made, thus preventing an accumulation of defective material, and permitting of the replacement of defective material by the manufacturer wherever a tube life guarantee prevails.

ABSTRACT OF INVESTIGATION

3. Tubes, found to be in an inoperative condition due to the presence of gas, were excited electrically to permit spectroscopic analysis.

4. A series of tests at various gas pressures, one set with air, another with hydrogen, was made by introducing the gas into a Type 38160 tetrode and photographing the tube with its contents in a state of ionization.

5. Correlation of tube operating performance in the master oscillator circuit of the Model TBK radio transmitter with the above results was then made.

6. Effect of alternating versus direct current supply to the spark coil transformer was determined.

Conclusions

The conclusions reached as a result of the subject investigation are:

(a) That tubes, showing ionization within the glass envelope, no matter how faint, when excited by spark coil, are unfit for further usage.

(b) That conversely, tubes showing no ionization whatsoever within the glass envelope, indicating the absence of gas content, when excited by spark coil, will generally be found satisfactory for further usage.

(c) That air and hydrogen are the most commonly found constituents in "gassy" tubes.

(d) That with tubes showing ionization by spark coil, the approximate gas pressure can be estimated by a comparison and study of Plates 9 to 18 inclusive.

(e) That the spark coil transformer can be used equally well on an a.c. or d.c. supply, with no critical adjustments necessary to the interrupter gap.

Recommendations

(a) In the application of the spark coil transformer for determining the condition of vacuum tubes, the tests should be conducted in a dark room so as to make discernible any tube ionization existent.

(b) In future acquisitions of spark coil transformers, it is recommended that their electrical strength be increased about 50%.

DESCRIPTION OF SPARK COIL TRANSFORMER

7. The spark coil transformer, shown in Plate 1, is a device built to produce high potential damped radio frequency for the purpose, with respect to its present use, of creating ionization within the glass envelope of a tube containing traces of gas.

8. The parts comprising the electrical circuit of this device are enclosed in a bakelite cylinder eleven inches long and one and three-quarters inches in diameter, at one end of which is a brass exploring rod, and at the other a knob for contact adjustment on the interrupter gap. Plate 2 shows the wiring diagram of this device.

METHOD OF CONDUCTING INVESTIGATION

9. In ascertaining the applicability of the spark coil transformer in the determination of vacuum tube condition, selection was made of a few representative tubes from a large quantity of Type 38160 tetrodes found in an inoperative condition, for the purpose of spectroscopic analysis. The tubes so selected were photographed while being excited by the spark coil transformer with the photographs so resulting being subsequently painted to correspond to the actual appearance of the tube with its gas contents ionized.

10. An arrangement of glassware was then assembled as shown in Plate 8 to connect together the glass envelope of a Type 38160 tetrode with the essential elements of a vacuum system. With this apparatus, it was then possible to vary the gas pressure within the subject tube envelope from a large to a small value and to excite the tube simultaneously by application of potential to a tube electrode from the spark coil transformer. Ten photographic records at various pressures were then obtained, five taken with the tube filled with air and five showing similar records with hydrogen. The pressures were so regulated and photographs taken at such values thereof that the appearances of the discharges each represented distinctly different distributions of ionization from their predecessors.

11. Certain tubes classed as "borderline" tubes, viz; those producing upon excitation only a very faint localized glow, or none at all, but which from a previous test had been classified as "gassy", were given an oscillation test in the Model TBK transmitter and subjected to operating potentials to determine their behavior therein.

12. The spark coil transformer used in the subject investigation was operated both from a d.c. and a 60 cycle a.c. source and the vibrating contact manipulated for observation of differences in the tube ionization.

DATA RECORDED DURING INVESTIGATION

13. The nature of this investigation was such that most of the information recorded was in the form of photographs. These are presented in Plates 3 to 18 inclusive. The results of spectroscopic analysis of

the gas content of five representative tubes are shown in Plates 3 to 7 inclusive. The table given below indicates the correlation data found between the Model TBK transmitter operation and the spark coil transformer tests on Type 38160 tetrodes.

Tube Designation	When excited with the spark coil transformer	Operation in Master Oscillator Circuit of the Model TBK radio Transmitter	Plate Current Value 100 m.a. Full Scale
71458	No visible glow.	OK	90
71403	Faint localized glow.	Could not be operated. Blue glow.	Off scale
71541	No visible glow.	Slight blue glow, disappearing soon after potential application.	65
71503	No visible glow.	OK	90
71449	No visible glow.	OK	80
71459	Faint localized glow.	Could not be operated. Blue glow.	Off scale
71431	Faint localized glow.	Could not be operated. Blue glow.	" "
Normal tube.	No glow.	OK	70

PROBABLE ERROR IN RESULTS

14. The error in reading the mercury manometer is probable near 0.1 of 1% at pressures approximating one atmosphere. The accuracy with which this instrument can be read decreases as the pressure is reduced so that at approximately 1 millimeter of mercury the error is about 25%.

15. Readings of pressures below one millimeter of mercury were taken on the McLeod gauge and are considered accurate to within 5%.

RESULTS OF INVESTIGATION

16. The results of the subject investigation may be grouped as follows:

(a) Spectrum analysis to determine nature of gas in inoperative tetrodes.
(b) Photographic display of ionized air and hydrogen at various pressures.
(c) Operation as oscillator in the Model TBK transmitter for correlation of results with those of (b).

(d) Spark coil transformer operation on a.c. versus d.c. power supply.

(a) The results of spectrographic analysis shown on Plates 3 to 7 inclusive of a number of representative gassy type 38160 tetrodes revealed the fact that the contents of these tubes consisted in some cases of hydrogen, in other cases, air, and in still others, a mixture of these gases. The source of the hydrogen so found is principally as occluded gas from the tube elements. The air enters through defective tube seals and cracks in the glass envelope.

(b) The results of tube photography of ionized hydrogen and air at various pressures are shown in Plates 9 to 18 inclusive. Plates 9 to 13 inclusive depict the condition of ionized air within the glass envelope of the Type 38160 tetrode at various pressures, ranging from 76 centimeters of mercury to 0.01 millimeter of mercury. Plates 14 to 18 inclusive depict the condition of ionized hydrogen within the glass envelope of the Type 38160 tetrode at various pressures ranging from 3 centimeters of mercury to 0.1 millimeters of mercury. With air as the gas content of a Type 38160 tetrode, at standard atmospheric pressure, the ionized discharge within the tube set-up by means of the spark coil transformer had the appearance similar to a spark drawn from a pointed electrode. Occasionally, when conditions of electrode spacing were proper, a plurality of internal tube discharges was discernible. The appearance of the discharge remained unchanged until a pressure of 53 centimeters of mercury was approached in which vicinity the electrical discharge within the glass envelope was observed to have increased slightly in width, changed its color from blue to violet, and augmented the number of discharge paths. Again, as the pressure was gradually decreased to a value around 15 centimeters of mercury, a change in appearance occurred with the gradual development of purple streamers emanating from the corner extremities of the anode radiating fins. As the gas pressure was still further reduced, the streamers increased in number and became more intense. With decreasing pressure, approaching 7 centimeters of mercury as shown on Plate 9, the ionization present within the tube became sufficient for photographic purposes.

Plate 10 shows the tube appearance with a pressure of 2 centimeters of mercury, where the streamers became somewhat diffused. In this photograph it was observed that the grid structure frames were enveloped throughout their length in a purple sheath, and a soft purple glow more intense toward the tube base and at the center of the tube pervaded the inside of the glass envelope.

Plate 11 shows the character of the glow at a pressure of 5 millimeters where the diffusion had still further increased, producing a more nearly uniform appearance, but with the base neck of the tube having a pink discharge; the remainder of the tube envelope retaining the purple coloration.

Plates 12 and 13 of 0.5 and 0.1 millimeters pressure show almost uniform diffusion throughout the tube envelope with the tube elements assuming a pink coloration.

Below an air pressure of 0.1 millimeter, the glow did not extend throughout the entire space within the tube. It was noted that at this pressure the glass became fluorescent in places where gas particle bombardment occurred. When the pressure was still further reduced, the space ionization gradually diminished and became less in intensity until a pressure around 0.01 millimeter was approached, near where the glow abruptly became extinguished.

Similar experiments were conducted with hydrogen, a maximum pressure of 3 centimeters being used as an upper limit, as tubes seldom attain a pressure higher than this value by virtue of the quantity of occluded gas in the tube elements.

Plate 14 is a photographic record taken at a pressure of 3 centimeters, showing a blue glow surrounding one grid support member and also some glow concentrated in certain other localities and faint blue streamers emanating from the corners of the anode radiating fins, and a lighter glow, pinkish-blue in color, near the base.

As the pressure was reduced, both grid support members were surrounded by a blue sheath throughout their length; a row of short discharge paths was set up between the control grid structure and the screen grid on each grid supporting column, the bright glow near the base remained as in the previously described condition and only a very faint glow occurred within the tube outside of these areas. Plate 15 shows this condition with hydrogen at a pressure of 1.8 centimeters of mercury.

The glow at the center of the tube spread rapidly as the pressure was reduced until, at 6 millimeters of mercury, shown in Plate 16, it was uniformly diffused throughout the greater portion of the glass envelope. A further reduction in pressure, to 0.5 millimeters, shows in Plate 17, a still softer diffused appearance. At a pressure of 0.1 millimeter, shown in Plate 18, the glow had ceased to cover the entire interior of the tube and had begun perceptibly to flicker. Prior to the pressure being reduced to 0.01 millimeter, all glow had disappeared.

(c) To correlate the results obtained by the use of the spark coil transformer with tube operation in the Model TBK transmitter, eight tubes were chosen for this work. Four by spark coil, showed no glow; these gave satisfactory TBK operation. On one, by spark coil, no visible glow was evident; however, the TBK operation showed a momentary glow near the grid stem, but cleared up almost instantly, thereafter giving satisfactory circuit operation. Three tubes, by spark coil produced a feeble glow; in the TBK circuit the operation was unsatisfactory and there was a high degree of ionization prevailing during the application of potentials. The plate currents of each tube were found to be excessive.

(d) In comparison of d.c. versus a.c. supply to the spark coil transformer and on interrupter gap adjustment, only a slight difference in performance could be noted. The intensity of the glow showed little variation and did not affect the color or distribution of the space ionization.

CONCLUSIONS

17. The conclusions reached as a result of the subject investigation are:

(a) That tubes, showing ionization within the glass envelope, no matter how faint, when excited by spark coil, are unfit for further usage.

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ACKNOWLEDGMENT

18. Assistance rendered by the Division of Physical Optics is hereby acknowledged.