CHARACTERISTICS OF MAGNESIUM FLUORIDE AND P7 PHOSPHORS FOR RADAR PPI APPLICATIONS

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Technical Development Report No 211

CIVIL AERONAUTICS ADMINISTRATION
TECHNICAL DEVELOPMENT AND
EVALUATION CENTER
INDIANAPOLIS, INDIANA
June 1953

U S DEPARTMENT OF COMMERCE

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CIVIL AERONAUTICS ADMINISTRATION

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SUMMARY

This report describes the results of comparative tests on three cathode-ray tubes of the types used for radar plan position indicator applications Two of the tubes tested had magnesium fluoride screen phosphors, and the third tube, a 12DP7, was used as a reference standard because of its use in current equipment The objective of these tests was to determine whether the magnesium fluoride tubes offer sufficient advantages over the currently used P7 types to warrant retrofitting of the existing radar indicators The scope of the data obtained was limited to that which would permit a preliminary evaluation of performance based on operational requirements Chief among these objectives were the factors of display persistence and brightness

Results indicate that the persistence of the PAC magnesium fluoride tubes is approximately four times that of a P7 tube operating under similar conditions The PAC magnesium fluoride tube, which was an experimental tube developed by DuMont Laboratories, provides about the same display brightness as the P7 tube The tests further indicate that although the magnesium fluoride tubes have a shorter useful life than the P7 type, the operational advantages probably outweigh this disadvantage by providing longer aircraft signal trails and thereby permitting more accurate tracking and vectoring of aircraft The PAC tube is expected to have a probable minimum useful life of at least 600 hours when MTI video is displayed and approximately 300 hours when ground clutter video is continuously displayed Extended operation in typical installations will be required to establish the life expectancy.

Suitable protective circuits are required to cut off the electron beam when either yoke rotation or radial deflection is stopped

INTRODUCTION

The function of cathode-ray tubes used in radar plan position indicators (PPI) is to convert electrical information into visual information for the benefit of the human eye It is essential that the radar display aid the operator in every possible way in the detection and resolution of the target data available from the radar receiver This requirement of radar indicating systems is, in some respects, more exacting and difficult than that of other types of displays For example, one of the principal efforts expended in any radar or communication system is in obtaining the maximum signal-to-noise ratio The problem of maintaining this ratio in the final display of a radar system is, in part, a function of the material composition of the screen coating Excluding the effects and problems of ambient light conditions, it is essential that the display tube have the highest possible conversion efficiency, that is, it should provide the maximum possible light output from the smallest electrical data signal From an operational point of view, it is also desirable that the aircraft target signal be retained for long periods of time to permit operators to detect and determine more accurately the degree of change in aircraft heading as well as to facilitate other operational requirements such as the determination of heading and rate of closure

Essentially all of the surveillance radar plan position indicators in use today utilize P7 screens composed of zinc sulphide and cadmium Although the persistence provided by these tubes is adequate, it is marginal for some types of traffic control work where short-range scales and relatively high-speed aircraft are involved This is particularly true when the radar sweep range is less than 20 miles. It is desirable from the standpoint of increased safety to provide longer persistence and therefore longer signal trails, thus enabling the operator to determine changes in heading more easily and accurately

The recent development of cathode-ray tubes having magnesium fluoride screens and long phosphor decay characteristics led to the investigation of their suitability for radar applications Two tubes were tested (1) a conventional two-anode tube manufactured by the Vacuum Tube Products Company, (2) a post-deflection acceleration type of tube manufactured by the Allen B DuMont Laboratories

TESTS, METHODS, AND OPERATION

The tests conducted on each of the tubes were divided into two groups The first group embraces the static characteristics, phosphor decay, and brightness. The second group includes visual observations of relative brightness, target signal trails, resolution, and eye fatigue. The performance of each tube is compared with that of a standard 12DP7 tube.

The relative phosphor decay characteristics were measured in a dark room using a Weston Model 856 Photronic cell with a visual correction filter. This cell was taped to the face of the tube being tested. The cell was terminated by a resistance of proper value to provide adequate sensitivity and good linearity over the required range of light levels. The output signal from the cell was amplified by a high-gain, linear, direct-current (d-c) amplifier and applied to the vertical deflection plates of an oscilloscope. A linear 30-second sweep was applied to the horizontal deflection plates.

In this manner, an accurate plot of the light output versus time was obtained during the first thirty seconds after removal of the excitation. The cathode-ray tube under test was scanned with a raster approximately seven centimeters square. The raster was continuously scanned at a television rate for a period of not less than five seconds prior to decay measurements. Switching was provided to start the oscilloscope sweep coincident with removal of screen excitation. The resulting decay measurements, taken directly from photographs of the oscilloscope, were recorded and compared with the manufacturers' data. The decay curves for the P7 and the DuMont PAC tubes are shown in Fig 1. During these tests it was found that the tube of the Vacuum Tube Products Company, hereafter identified as VTP, did not provide sufficient light output to permit accurate measurements. In view of the fact that the light output was very low compared to the P7 and the DuMont PAC tubes, no decay curve for this tube is shown. The decay is, for all practical purposes, linear after approximately three seconds. The relative brightness of each of the tubes at any given time is also indicated in this figure. Each tube was operated at the voltages and the conditions recommended by the manufacturer.

The second group of tests consisted of installing the tubes in a radar PPI and of observing the performance under typical operating conditions. Each of the three tubes was operated at the manufacturer's recommended values, adjusted for visual extinction in the absence of any signal, and adjusted for optimum focus with normal signals. Observations were based on the normal range of signal levels with the maximum level just below the blooming or defocusing point. The antenna scan rate employed was 15 revolutions

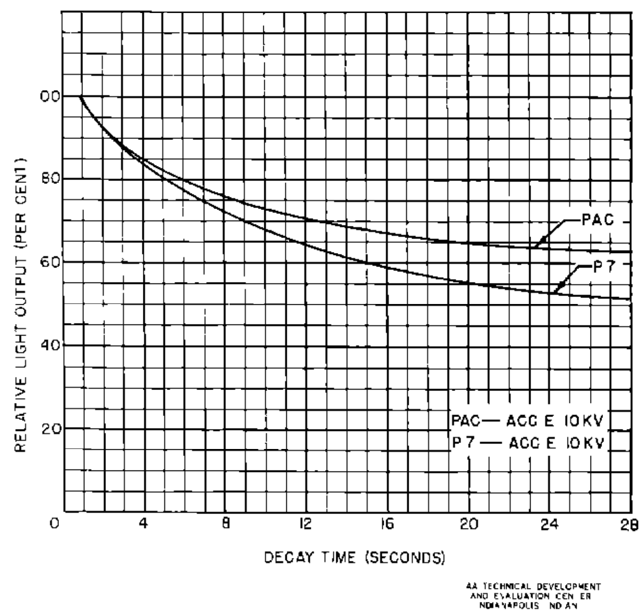

Fig 1 Decay Curves After Continuous Pulsing

per minute (rpm). A fair cross section of aircraft speeds and maneuvers was observed by several who are familiar with both radar PPI displays and operational requirements. The nature of these observations was such that the resultant information is largely subjective. For example, the response of the average human eye to the color response of the magnesium fluoride tubes is less than it is to the predominantly yellow color of the 12DP7 tube, when the absolute light levels are the same. The peak color response of the three tubes is indicated in Fig 2 on the

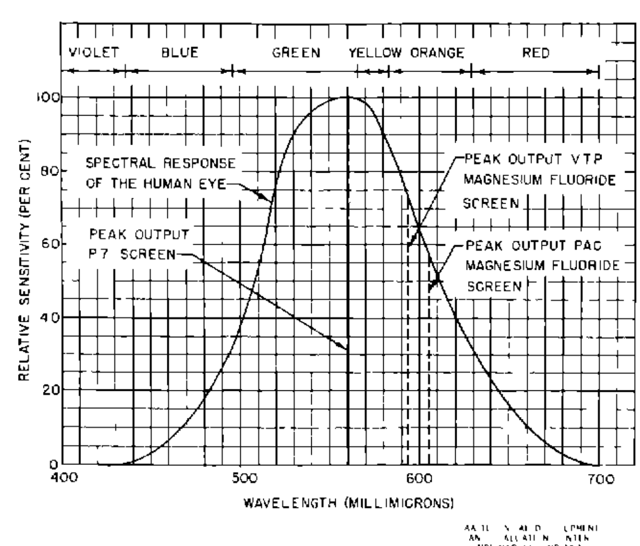

Fig 2 Spectral Response of Screen Phosphor

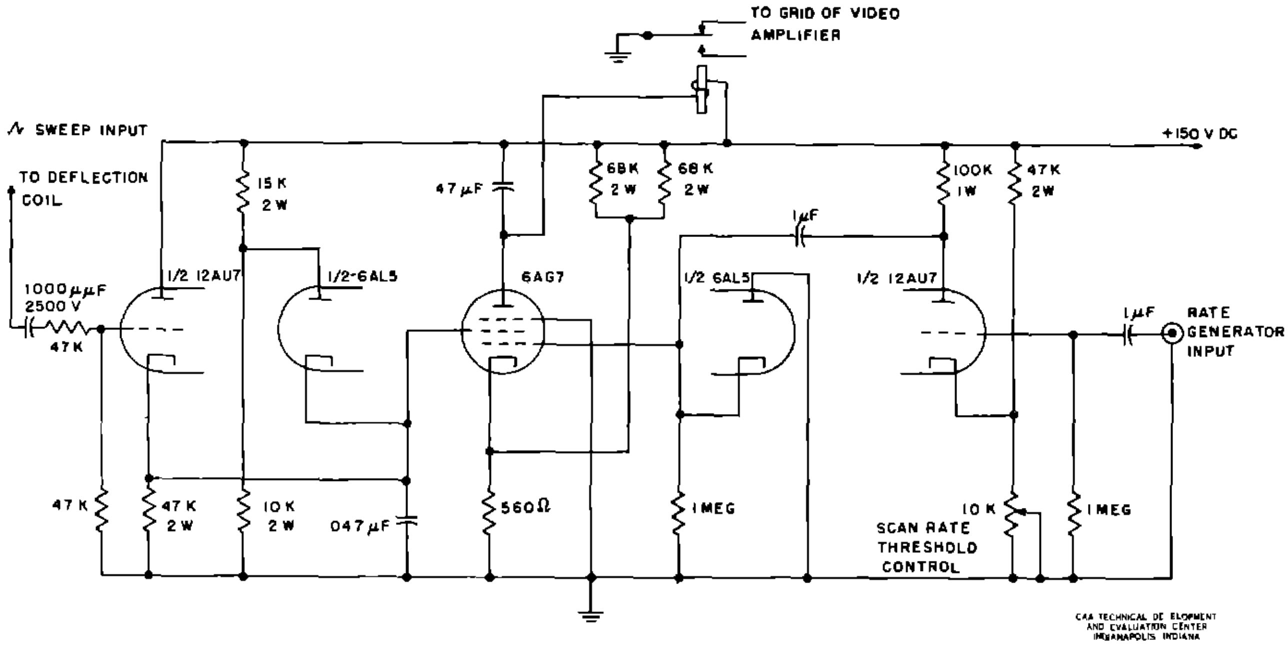

Fig 3 Circuitry for Protection of Magnesium Fluoride Tubes

curve of the relative spectral sensitivity of the human eye

The chemical composition of the screen coating of the magnesium fluoride tubes is such that it will deteriorate rapidly if the exciting electron beam is not continuously in motion or if it is allowed to scan a radial line for more than a few seconds This condition exists on radar PPI displays when the radar antenna stops or when deflection of the beam is lost because of failure of the trigger pulse This disadvantage may be eliminated by providing suitable protection circuits in the PPI, such as the circuit shown in Fig 3 The circuit is essentially fail-safe since failure of the protection circuit itself will prevent operation of the display tube The circuit was incorporated in the PPI used for these tests It is simple in nature and may be easily added to most PPI displays currently in use No evidence of deterioration due to writing such repetitive signals as range marks has been observed in approximately 300 hours of operation

TEST RESULTS

In Fig 1 it will be noted that these curves do not indicate the relative light output of the P7 and PAC tubes at or immediately following removal of excitation The slope of the decay curves during the first three seconds after removal of excitation is primarily dependent on the acceleration voltage and the degree of excitation Fig 2 indicates that the average human eye has approximately 56 per cent as much response to the peak wavelength of the DuMont PAC tube as it has to the peak of the 12DP7 output Similarly, the eye is approximately 70 per cent as sensitive to the peak output of the VTP tube as it is to the 12DP7 The effective light output of the magnesium phosphors may be raised somewhat by increasing the excitation by additional drive and acceleration voltage, thus partially equalizing the loss of eye sensitivity to the higher wavelength It should further be noted that no filter is required over the face of the magnesium phosphor tubes to filter out the initial flash, as is required with the P7 tubes The use of a yellow or amber filter over the face of a P7 tube reduces the yellow light reaching the observer's eye by an attenuation factor of approximately two to three depending on the passband of the filter and its thickness Observation of the display on the DuMont PAC tube without a filter and the P7 tube with a yellow filter under the indicated operating conditions indicates that the PAC tube provides a slightly brighter display

During the testing of the VTP tube, it was found that the light output appeared exceptionally low during the decay interval This condition may be due to the wavelength of the light during the decay period Raising the anode voltage from 10 to approximately 14 kilovolts did not appreciably increase the

TABLE I

RELATIVE PERFORMANCE OF CATHODE-RAY TUBES

	12DP7	PAC	VTP
Relative brightness (filter on P7 only)	Good	Good	Poor
Target trail length (60-mile sweep, 15-rpm scan, prf 1400 pps, 1 0-microsecond pulse)	8 scans	30 scans	4 scans
Apparent contrast	Good	Very good	Poor
Resolution	Good	Good	Good
Eye fatigue	Low	Very low	High

apparent light output and required a large increase in deflection power to deflect the beam to the edge of the tube face The design of the PAC tube is such that postdeflection acceleration techniques are utilized, thus permitting the application of higher acceleration voltages without requiring an increase in deflection power over that required by 12DP7 tubes operated at approximately 10 kilovolts

The DuMont PAC tube, when operated in a PPI with normal radar signals, provided approximately four times the target trail length attainable from the P7 tube The VTP tube displayed trails only about one-half the length of those of the P7 tube There was no great difference in the performance of any of the tubes with respect to contrast or resolution, largely because of the mode of operation A theoretical advantage exists in the PAC tube over the P7 type, in that the magnesium fluoride tube has a single-layer screen coating while the P7 type has a cascaded screen The cascaded screen is much more susceptible to halation effects on strong signals than a single-layer screen It is doubtful if this is of great significance in PPI applications because a radar with a one-microsecond pulse is not capable of providing better range resolution than that provided by the diameter of the display-tube spot, except at target ranges of less than approximately 13 miles with a 20-mile sweep range and then only after careful adjustment of focus and other operating conditions Some advantage might be realized in the case of PPI approaches where very strong signals are encountered

The relative performance of the three tubes is summarized in Table I The adjectives which are used indicate relative performance between tubes and do not imply satisfactory or unsatisfactory performance in reference to other tubes or operational requirements

The eye-fatigue factor is based on prolonged viewing in a reasonably well-darkened room, which is an operational requirement for a PPI installation Consideration was given to the effort required to determine target track, heading, and other operational viewing requirements Target trail length is based on saturating video signals at random target velocities and headings Switching of sweep ranges during the tests revealed that target trails displayed prior to switching were retained for about two minutes under certain conditions, and under conditions of heavy traffic, they cluttered the display rather badly This condition exists to a lesser degree with P7 tubes but becomes more objectionable with longer persistence of target trails

Although the PAC tube has been operated for approximately 300 hours under normal operating conditions, it is suspected that its useful life will be somewhat less than that of a P7 type of tube because of its susceptibility to burning, however, no burning or evidence of deterioration has been detected on the tube during the testing period Operation of several of these tubes over an extended period will be required to establish the useful life

CONCLUSIONS

It is believed that the PAC tube offers several operational advantages over the P7 tube if the operational requirement for longer pers.stence is valid If higher anode voltages are available for the PAC tube, a slight gain in display brightness may be realized over that obtained from a P7 tube with a yellow or amber filter In addition, an apparent improvement in visual contrast exists because of the difference in color The PAC tube will operate satisfactorily with maximum anode potentials of approximately ten kilovolts without any modification of ASR-1 and ASR-2 radar indicator circuits, except for the addition of suitable protective circuits which are essential to reasonable tube life

It is recommended that the tube be installed in a PPI at several commissioned radar facilities and given a more thorough operational evaluation to determine whether the long persistence of trails after range switching is a serious disadvantage Valuable information relative to the tube life would be obtained simultaneously The advisability of replacing all currently used 12DP7 and 10KP7 display tubes with the PAC tubes is not justified until an operational evaluation under typical and practical operating conditions is completed

GPO 81-105789