CONFIDENTIAL

FOR USE OF G-E EMPLOYEES ONLY

GENERAL ELECTRIC

GENERAL ENGINEERING AND CONSULTING LABORATORY

TECHNICAL INFORMATION SERIES

Title Page

AUTHOR	SUBJECT CLASSIFICATION	NO.
Shepard, B.R.	Under Water Object Locator	R50GL167
		DATE August 11, 1950

TITLE

MULTI-ELEMENT RADIAL BEAM SCANNING TUBE FOR UNDERWATER OBJECT LOCATOR

ABSTRACT

The construction, operation, and desired characteristics of a MERB scanning tube are described. The program followed in developing a satisfactory scanning tube is reviewed. Comparative results of the different steps in the development are summarized in Chart 1, page 12. The tubes were supplied by the National Union Radio Corporation.

G.E. CLASS	REPRODUCIBLE COPY FILED AT	NO. PAGES
IV	General Engineering and Consulting Laboratory Library, Schenectady, N.Y.	51
GOV. CLASS. CONFIDENTIAL		

CONCLUSIONS

The present tube represents a compromise between performance, time, effort, and money available. The major improvement in noise level was accomplished by reducing the operating voltages to lower the beam current, and the introduction of shield rings on the headers to improve the stability. The noise level was reduced to the point where the tube could be used with only one preamplifier on each grid. The noise level of the tube finally adopted was 50μv operating at a frequency of 350 kc, band-pass 50 kc, and scanning at a rate of 10,000 elements per second.

For list of contents—drawings, photos, etc. and for distribution see next page (FN-610-2).

INFORMATION PREPARED FOR General Engineering and Consulting Laboratory

TESTS MADE BY F.Hale, H.C.Maulshagen, R.W.McFall, B.R.Shepard, T.E.Thuma, D.E.Wood, C.Zobie

AUTHOR B.R.Shepard B.R. Shepard Sept. 7, 1950

COUNTERSIGNED W.H.Janssen W.H. Janssen Sept. 7, 1950

DIVISIONS Electro-Mechanical Division LOCATION Schenectady, New York

GO-1876-B (1-50)

TABLE OF CONTENTS

SUMMARY

The high picture rate and high resolution requirements of the Mark III and Mark IV U.O.L. equipments made a high scanning rate absolutely essential. It was felt that the scanning rate, 50,000 elements per second, was above the practical upper limit of the Mark II capacity scanner. To accomplish the high scanning rate, the Multi-Element Radial Beam tube was adapted for use with the U.O.L. The tubes are supplied by National Union Radio Corporation. In the course of the initial development, five changes were made in the tube structure before a reasonably satisfactory tube was developed for our application. The resultant tube, now in use, does not represent the ultimate design for this application. The noise level is high and the electrode voltages are somewhat critical. The present tube represents a compromise between performance and time, effort, and money available.

INTRODUCTION

The general method of obtaining target position and/or size information in sonar systems is to insonify the field with sound energy and receive the reflected energy from targets with as highly directional a receiver as possible. The field of view is covered by pointing the receiver beam successively toward different parts of the field.

The U.O.L. systems use the same basic techniques except that, effectively, a large number of very directional receivers are used so that information can be received from a larger field all at one time. The necessity for absorbing this information and presenting it in usable form on the face of a cathode ray tube creates the problem of "scanning" or successively and rapidly reading the signal being received on each of the large number of receivers.

The Mark II U.O.L. utilized a capacity type scanner (see report No. 33206). The capacity scanner was basically a series of small capacitors, one plate (stator) of each capacitor being connected to each receiving element. The other capacitor plate was rotated with a small motor so that it coupled energy successively from the receivers as it moved over each stator plate. In this way, the output of each receiver element was read with each motor revolution.

Because of the physical construction and mechanical drive, it is felt that a practical maximum scanning rate of about five or six thousand elements per second can be obtained with the capacity scanner.

The Mark III U.O.L., because of the picture rate resolution, and number of receiver elements, required a scanning rate of 50,000 elements per second. This scanning rate requirement led to the adoption of the MERB tube (Multi-element radial beam tube). This tube is supplied by the National Union Radio Corporation.

GENERAL DESCRIPTION

Photograph No. 1084814 shows the MERB tube. The physical construction and relative location of elements is similar to a standard pentode. A cut-away view tube structure is shown in photograph 1084817. The MERB tube has a common heater and cathode at the center as an electron source. The next element out from the center is the inner grid or accelerating grid, common to all elements. Next the screen, also common to all elements; then the signal grids, and finally the plate.

The signal grids are located between the screen and plate in what is normally the suppressor grid position. Each signal grid is separated from the adjacent signal grid by a post. The tube has 25 separate signal grids.

In operation, the tube is placed in a strong, uniform magnetic field so that the electron stream from the cathode is focused into a beam which flows through one of the signal grid elements to the plate. By varying the voltage on this signal grid, the current to the plate can be varied. By rotating the field, the electron stream can be focused successively on each signal grid. Practically, the rotating field can be obtained from a standard two or three phase two-pole motor stator. The speed of field rotation, and, consequently, the scanning rate, is determined by the frequency at which the motor stator is excited. The strength of the rotating field, and, hence, the focusing, is controlled by the amount of voltage exciting the field.

The focusing action of the field produces a double ended electron stream as indicated in Figure 2. Since there are an odd number of signal grid elements, when one end of the beam is centered on an element, the other end of the beam is between two elements and is centered on a post. Thus, as the electron beam is rotated, the elements are scanned, first on one end and then on the other, in numerical order as shown in Figure 2, and all the elements are scanned twice with each revolution of the beam. The scanning rate is, then, 2NF elements per second. Where:

N = number of elements in the tube

F = frequency of field excitation (CPS)

In order to scan 50,000 elements per second, it is necessary to use 1,000 cps field excitation.

DESIRABLE ELECTRICAL CHARACTERISTICS OF A SCANNER

There are four important features or characteristics of a scanner which determine its usefullness:

1. Signal to Noise Ratio and Gain
2. Discrimination
3. Stability and Interchangeability
4. Output Wave Shape

The best compromise between these characteristics is the most desirable design.

1. Signal to Noise Ratio and Gain

One of the most important scanner characteristics is the inherent noise level of the scanner referred to the input circuit. The lower the inherent noise level, the fewer the number of stages of preamplification required ahead of the scanner. Any reduction in noise level is effectively multiplied by the number of input elements as far as its effect on input circuit complexity is concerned. The inherent noise level limits the minimum signal which can be detected.

The inherent noise level of the MERB tube is determined by the changes in tube output current as the field rotates. The actual noise level observed in operation is that portion of the output current frequency spectrum which is accepted by the circuits following the MERB tube. High scanning rates, better discrimination, and lower operating frequencies all tend to increase the amount of noise accepted by the circuits following the scanner. All design changes and adjustments in focusing of the tube beam aim at reducing the output current variations as the field rotates without the same reduction in signal gain through the tube, and without changing the discrimination. Any reduction in scanning output variation without a proportional reduction in gain results in an improvement in signal to noise ratio. This is true only as long as the noise level is not limited by the input or output impedance levels. The object is to reduce the scanning noise below the input impedance "Johnson" noise. If this cannot be done, the input circuit noise must be raised above the scanner noise by preamplification.

The gain or loss through the scanner is not in itself too important except for its effect on the overall signal to noise ratio and discrimination. The gain must also be high enough so that any stray coupling between input and output is small in comparison to the wanted signals.

2. Discrimination

The ability of the scanner to separate signals on the input grids is called the "discrimination". The discrimination can be measured by exciting two elements separated by one unexcited element (in order of scanning) and observing the output waveshape on an "A" scope. The amount of "dip" between the two signal peaks is a sensitive indication of discrimination.

The discrimination of the MERB tube is limited by the focusing action in the tube, coupling between input circuits, and coupling between input and output circuits.

With careful design of the associated circuits, the coupling between input circuits and input and output circuits will be limited by the direct interelectrode capacities of the tube. To get the best results the effects of the interelectrode capacities should be reduced to a minimum so that the focusing action will be the prime factor controlling discrimination.

The input grid to grid capacities will limit the maximum impedance which can be used on the input circuits at any operating frequency. The input to output capacity imposes similar limitations on the output impedance. In the present MERB tube, the input to output coupling is kept to a minimum by using the cathode as the output element and by bringing the output out the top of the tube as far as possible from the input leads. The effect of input to output coupling can be reduced by operating the tube as a converter and tuning the output to the sum or difference frequencies. This method of operation reduces the signal to noise ratio because of the conversion loss.

The focusing action of the tube is limited by the construction and the action of the rotating field and electrode voltages. The best focus adjustment is that which gives highest signal to noise ratio with adequate discrimination.

3. Stability and Interchangeability

Ultimately, it is desirable not to have to make adjustments. If adjustments are necessary, they should not be critical (precise) and should not have to be readjusted periodically. Adjustments should be the same on all scanning tubes so that the scanning tubes can be interchanged without circuit readjustment.

4. Output Waveshape

The output waveshape is the envelope produced by scanning a single excited element. This waveshape should be controlled primarily by the discrimination requirements. The object is to keep the high frequency components generated by the scanner to the minimum required to give the discrimination. Waveshape control is important in applications like the type C U.O.L. where more than one signal channel is fed through the tube. If excessive high frequency components are generated in the wave shape, the adjacent signal channels must be separated farther in frequency to prevent the high frequency components from causing adjacent channel interference.

MERB TUBE DEVELOPMENT PROGRAM

The program described here was carried on with the National Union Radio Corporation, Research Division, supplying the tubes. No formal development program was set up, but improvements were requested on each new tube order, based on tests made on the previous tubes. The original order was for a tube whose scanning characteristic would present a flat field of view. An output wave-shape approximating a cosine function with adjacent elements overlapping at the 0.707 voltage point was requested. This initial order was made to determine the applicability of the MERB tube to the scanner problem.

Credit for the changes made in the tube design is primarily due to Dr. A.M.Skellett and H.J.Koch of National Union Radio Corporation. Our aim was to modify the tube originally developed by Dr. Skellett* so that it could be used as a scanner in the Underwater Object Locator. The test results were obtained by personnel of the General Engineering and Consulting Laboratory of the General Electric Company at Schenectady.

The general manufacturer's designation for the MERB tube is RB2070-25. To this number has been added a suffix type 1, type 2, etc., to separate the different stages of development. The following lists the differences in construction of each of the tubes:

---

* A.M.Skellett, "Magnetically Focused Radial Beam Vacuum Tube", Journal of Applied Physics, October, 1944, Volume 15, pages 704-709.

1. RB2070-25 type 1.

   Original tube, element arrangement as shown in Figure 1.

   No mica shield rings.

   No grid laterals.

2. RB2070-25 type 2.

   Same as type 1 except for the addition of a shield ring between inner grid and screen on the mica headers and 20 laterals per inch wound on the grid posts.

3. RB2070-25 type 3.

   Same as type 2 but with 2 times as many grid laterals per inch. By mistake, this tube had 27 elements instead of 25.

4. RB2070-25 type 4.

   Same as type 2 but with the relative position and alignment of the screen, posts, and signal grids altered to give a minimum number of beam interruptions with rotation. Figure 2 shows new element arrangement. Signal grids have 40 laterals per inch. The length of the cathode has been reduced from 1 inch to 1/2 inch, and an additional mica shield ring located between plate and signal grids.

5. RB2070-25 type 5.

   Same as type 4 but with "ruggedized" construction. Cathode brought out the top of the tube; a dummy lead is supplied in place of the original cathode lead.

Side rods on grids made of non-magnetic chrome copper.

For rapid comparison purposes, the noise levels on the above tubes are summarized on Chart 1. The results have been normalized to, as nearly as possible, the same operating conditions of scanning rates, output frequency, band pass, etc.

It should be remembered that optinum operating conditions vary between tubes of any one type. Near optinum operation can be obtained with several variations in relative tube element voltages. A trial and error method is used to select the best operating conditions for any one tube.

The following is a list of the MERB tube's more important circuit design characteristics when operated under low noise level conditions:

Outline drawing and pin connections - M9660621
Adjacent input grid to grid capacity - .4 - .5 μμfd
Input to output capacity - Plate output - .1 μμfd
cathode output - less than .01μμfd
Focusing field intensity - 150 gauss (approximately)
Input capacity - 3.5 μμfd
Output capacity
Plate output - 12 μμfd
Cathode output - 9 μμfd
Filament - 6.3 volts, 0.35 amperes

Type	Average Noise Level*	Gain	Construction	Remarks
1	10,000-20,000µv (estimated)		Original tube manufacturers recommended operating condition.	Too noisy.
2	1,000µv (estimated)		Original tube with reduced electrode voltage.	Unstable, not usable.
2	150µv		Shield rings on each header between inner grid and screen. 20 laterals per inch on signal grids.	Shield ring helps the stability but needs to be improved. Tube must be used as a mixer because of high signal grid to plate capacity
3	150µv		40 laterals per inch on signal grids to raise gain. This tube had 27 elements by mistake	Change in grid laterals did not improve gain or change operating characteristics when adjusted for best signal to noise level.
4	100µv		Relative radius of elements changed. Angular position set to give minimum beam interruptions. Cathode length reduced to ½ inch from 1 inch. Additional shield ring added on headers between signal grids and plate.	Operation satisfactory except for coupling to cathode from near-by grid leads.
5(early)	100µv		Ruggedized construction. Cathode brought out top of tube.	Tube used in UOL equipments.
5(later)	50µv		Ruggedized construction. Cathode brought out top of tube.	No explanation for lower noise level.
5(die stamped headers)	50µv		Used die-stamped headers to try to improve uniformity of tube operating characteristics.	No improvement in uniformity from tube to tube

*Normalized
Scanning rate 10,000 elements/second
Frequency 350 kc Discrimination 80% (See page 6)
Band pass 50 kc

Type 1 Tube

1. Initial recommended operating conditions:

Heater	6.3	volts
Field strength	225	gauss (approximately)
Inner grid	22.5	volts
Screen	100	volts
Anode	240	volts
Signal grid	- 4	volts
Posts	- 4	volts
Anode current	2	milliamps
Inner grid current	2	milliamps

When operated in the above manner, the noise level was too high to be usable. Very little data was recorded on this tube. When adjusted for reasonably low noise levels, the instability was such that the tube would break into an apparent oscillation or noise at the slightest provication. Very careful adjustment of the operating voltages was necessary to get any operation at low noise levels. Static field tests could not be made because of the instability. The lowest noise level measured was 300μ v scanning at 1500 elements per second and operating at a frequency of 750 kc.

Discussions with Dr. A.M.Skellett and H.J.Koch at National Union brought out the possibility of electron charges being built up gradually on the mica headers and suddenly discharging at a critical potential. This possibility was also verified in talking with Dr. Blewett and Dr. Pollock of the Research Laboratory. The solution suggested was to coat the header with a conducting material to prevent the charges from building up on the headers.

The type 2 tube was constructed with a metal ring on each header between inner grid screen and in the same plane as the header.

Type 2 Tube

The type 2 tube was identical to the type 1 tube except for the addition of a shielding ring on each mica header to improve the stability and the addition of signal grid laterals to increase the amplification of the tube.

The best operating conditions for maximum signal to noise ratio (minimum noise level) are with very low plate and screen voltages. The following is a typical set of conditions:

Field	200 gauss
Screen	14 volts
Inner grid	0 volts
Shield ring	0 volts
Posts	-3 volts
Heater	8 volts
Plate	16 volts
Signal grid	0 volts

$\mu = 7$

rp = 1/2 meg.

Signal grid to plate capacity .1µµf (average)

Noise level	30µvolts
Scanning rate	10,000 elements/sec. (400~ field)
Output frequency	750 kc
Band pass	22 kc
Mixing signal level (inner grid)	3. volts

The high grid to plate capacity makes the tube unsatisfactory as originally intended; that is, as an amplifier. The tube is used as a converter by applying oscillator voltage to the inner grid.

Element voltages are still very critical although the stability is much better than the type 1 tube. The effectiveness of the shield rings on the headers was apparent but still needed to be improved.

In an effort to check the effectiveness of the shield ring, Mr. Koch at National Union built a special tube with fluorescent material on the plate. His tests indicated that the shield ring was not doing a complete job of repelling the beam from the mica headers.

Type 3 tube

The aim of the type 3 tube was to increase the gain in the tube. The tube is the same as the type 2 except that the number of grid laterals has been doubled.

Operational results with the type 3 tube were the same as the type 2. There was no improvement in gain which was not covered by the measurement errors in the test setup.

Type 4 Tube

As a result of the type 2 and 3 tube tests and Mr. Koch's tests, the type 4 tube was built with an additional shield ring on each header between the grids and plate, a cathode with only 1/2 inch length of emitting surface instead of 1 inch, and a readjustment of the relative position of the elements to give a minimum number of beam interruptions as the beam rotates. Fairly extensive tests were made on this tube type to determine its best method of operation. Initial tubes suffered from rapid emission deterioration. Later tubes proved to be quite stable although the adjustments are still somewhat critical.

A summary of the test results follows:

1. Types of operation
    - a. Straight amplifier -- the tube is not suitable for this type of operation using high carrier frequencies and with element voltages adjusted for minimum noise factor. The tube has too much loss and too much signal grid to plate capacity.
    - b. Mixer, plate output -- usable operation, loss in noise factor due to mixing.
    - c. Cathode output -- best noise factor, signal gain through tube about the same as with plate output, low signal grid to cathode capacity.

d. Mixer, cathode output -- results about the same as with plate output.

2. Typical operating conditions for best noise factor consistent with good discrimination:

	E_p	40 volts		
	E_s	80 volts		
	Inner grid	1.5 volts		
	Posts	22 volts		
	Rings	20 volts		
	Signal grid	2.1		
	Field	140 gauss	400 ~	1000 ~
	Carrier	1500 kc		
(mixer)	Noise level		100 μ v.	420 μ v.
(amp)	Noise level			120 μ v.

3. Static Characteristics

The static characteristics were taken with a fixed focusing field supplied by a General Electric one pole, DC, 1/8 HP, 1725 rpm, motor stator. Graph 1 shows the field strength versus excitation voltage. Tests indicate that the field intensity was uniform in the central region of the field. High intensity flux concentration was found at the ends of the pole pieces, but these regions were outside the MERB tube envelope, and did not affect the focusing. The total variation in flux density along the MERB tube axis was approximately 20%. This variation is probably greater than that present in the a-c field and accounts for some of the differences noted in the static and dynamic scanning characteristics. The static current characteristics do not indicate the true scanning characteristic because the gain through the tube element falls off faster than the tube current. The variation noted in the static characteristics are similar to those which occur in the dynamic characteristics. The values of voltages used for the curves are approximately the same as those which give good performance with a 400~ a-c field.

Graphs 2 and 3 show the effect of field strength on the beam focus as evidenced by the plate current scanning characteristic. All grids except one were biased off. As is expected, higher field intensities result in sharper beam focus up to limit imposed by the cathode diameter. Graph 4 shows the plate current scanning characteristic with two grids separated by one.

The effect of post voltage is also indicated. Graph 5 shows the scanning characteristic for two adjacent grids, separately and together.

Curves 6, 7, and 8 show the plate characteristics with three values of field density. The best operating point for low noise level is in the low plate voltage region.

Curve 9 shows the effect of inner grid voltage on the gm of the signal grid. Although the higher gm values can be obtained, these result in excessive noise levels which actually yield a poorer signal to noise ratio.

Rotating AC Field Characteristics

The dynamic scanning characteristics roughly agree with the results obtained with the fixed field. Generally, better discrimination is obtained because the gain falls off faster than the plate current as the focused beam is rotated away from the element.

With a static field the signal to noise ratios of the elements compare favorably with ordinary tubes. When the beam is rotated noise components are generated which limit the signal which can be detected to relatively high values. Typical values are shown on curve 10.

Because of the high plate to signal grid capacity, the MERB tube was operated as a mixer. Tests were made with output frequencies of 150 kc, 450 kc, and 1500 kc. The noise level referred to the signal grid as a function of field strength at these three output frequencies is shown in curve 10. The noise level is lower at the higher operating frequencies because these frequencies are farther removed from the fundamental scanning noise frequency. High flux density results in high peak noise values due to the sharper focus obtained. Low flux density results in an effectively higher noise level due to lower gain; the discrimination also suffers at low flux densities.

To keep the coupling between physically adjacent elements down, it is necessary to use an input impedance of 15,000 ohms at 1,500 kc. Higher input impedances can be used at the lower frequencies.

Operating tests were made with the output at the cathode of the MERB tube. This connection enabled the tube to be operated with input and output at the same frequency. The noise level was slightly higher when compared with the same operation with the output in the plate. Practically about a 3/1 improvement in noise level was obtained since about 3/1 loss in S/N was caused by the necessity for mixer operation with the output in the plate circuit. The results in the following table are only comparative, since adequate field strength for good discrimination could not be obtained with 1000 ~ cps excitation on the 400 cycle field. The data shown with the 1000 ~ field was taken at a later date.

Mode of Operation	Signal Frequency	Scanning Rate	Noise** Level	Output
Mixer	1500 kc	20,000 el./sec (400 cycles)	100μv	Plate
Mixer	1500 kc	*50,000 el./sec (1000 cycles) 40 gauss	420μv	Plate
Cathode Follower	1500 kc	*50,000 el./sec (1000 cycles) 40 gauss	120μv	Cathode
Cathode Follower	400 kc	*50,000 el./sec (1000 cycles) 40 gauss	1000μv	Cathode
Mixer	1500 kc	*50,000 el./sec (1000 cycles) 110 gauss	525μv	Plate

* 1000~ applied to 400~ motor field resulted in approximately 40 gauss field. With a properly designed field, a flux density of approximately 110 gauss was obtained.

** band pass 60 kc.

Type 5 Data

The type 5 tube is, for all practical purposes, the same as the type 4 tube. The construction has been "ruggedized" to withstand shock, and the cathode connection has been brought out the top of the bulb to eliminate capacity coupling to nearby input leads. The appearance of this tube is shown in photograph No. 1084816. Photograph 1084817 is a cut-away view showing the internal construction.

Noise level varied from 100-300μv from tube to tube under optinum conditions. Variation in gain from grid to grid on the same tube is usually held to ± 15%. Fixed voltages of 40 v on plate and rings and 0 on posts were adopted for practical reasons, since these voltages enabled all available tubes to be adjusted to near optimum conditions. Higher noise level tubes could usually be adjusted to give lower noise levels by changing these fixed voltages.

M9660621 shows the limiting overall dimensions of the MERB tube for design considerations.

Later shipments of these tubes showed more uniform characteristics and lower average noise levels with slightly higher gain. The manufacturer knew of no changes in these tubes except the possibility of closer tolerances in punching the headers. Based on this experience, an order was placed for a set of tubes made from die punched headers. These tubes should have shown even better uniformity; however, this was not found to be true. Apparently, with the present status of manufacturing technique, precision headers do not have much effect on uniformity.

The typical performance of these tubes (average) is summarized in the following chart:

	Early	Later
Plate voltage	40	40
Ring voltage	40	40
Post voltage	0	0
Signal grid* voltage	1-3	1-3
Control grid*voltage	1-3	1-3
Screen* voltage	3-9	3-9

	Early	Later
Noise level	200μv (100-300)	100 (50-150)
Discrimination	80-90% dip between poles	80-90%
Gain	.1	.12
Field frequency	400 ∿	400 ∿
IF frequency	300 kc	350 kc
Band pass	60 kc	50 kc

* Adjust for best operating conditions.

CONCLUSIONS

The major improvement in noise level was accomplished by reducing the operating voltages to lower the beam current, and the introduction of shield rings on the headers to improve the stability. Further changes produced only relatively small reductions in noise level. The noise level was reduced to the point where the tube could be used with only one preamplifier on each grid. The noise level of the tube finally adopted was 50μv operating at a frequency of 350 kc, bandpass 50 kc, and scanning at a rate of 10,000 elements per second.

The test procedure and equipment used for testing MERB tubes is described in Appendix I.

Appendix I

MERB Tube Test Equipment

Most of the earlier MERB tube tests were made on temporary breadboard setups which were assembled from equipment available at the time the test was made. Probably due to the transient and intermittent character of the program, this practice was continued until after the final design was determined. When the UOL Mark III equipment design was fairly well settled and tubes were being ordered in sufficient quantity, the test equipment shown in photograph No. 1084816 was built so that each scanning tube could be pretested under the same operating conditions. The prime object of the test was to insure reliability of replacement tubes supplied with the equipment.

The MERB tube is essentially a hand built tube with the result that there is considerable variation in physical as well as electrical characteristics. For this reason each tube is checked for overall physical dimensions, electrical performance, and shock stability. The electrical tests consists of operation of the tube under conditions similar to those in the UOL equipments. A circuit diagram of the test equipment is shown on CPH9765084.

The equipment consists of a MERB tube socket, 400 cycle field, and controls for the element voltages; a mixer following the MERB tube,and a fixed tuned 450 kc bandpass amplifier and detector.

The tuned amplifier has a center frequency of 1400 kc; the bandpass of the amplifier determines the noise band accepted by the test equipment. The MERB tube is operated at 350 kc; this frequency is converted to the tuned amplifier frequency in the mixer. The MERB tube output is displayed as an "A scope" presentation on a cathode ray oscillograph screen. The gain in the tuned amplifier is sufficient to allow the detector to feed the vertical deflections plates of the cathode ray tube directly.

D-C power is supplied by an external 300 volt regulated supply; 400 cycle power is provided by a three phase motor-generator set with wye connected variacs for controlling the focusing field voltages. Local oscillator voltage for the mixer is obtained from a laboratory signal generator. The oscillator amplifier included on the bandpass amplifier chassis is not used.

A copy of the test procedure and a sample set of test data is included. All tubes are tested with 40 volts on the rings and plate and zero on the posts; these three voltages are fixed in the UOL equipments. The other three element voltages and field voltages are varied to get the best signal to noise ratio and proper discrimination.

Shock sensitivity is checked by tapping the tube, while operating, with a light rubber tipped pencil or mallet. This test will show up bad welds and loose elements which might cause noisy operation. The critical physical dimensions are shown in drawing M9660921. Average values for the tube's electrical characteristics are shown on the sample test sheet.

Test Procedure for the MERB Tube

The purpose of testing MERB tubes is to determine first, if all the elements are functioning properly, and also to determine the optinum operating conditions for the tube. Due to the complex structure of these tubes, each tube is slightly different. It is necessary, therefore, to obtain the optimum d-c operating voltages experimentally for each individual tube. There are several different combinations of element voltages that will result in an optimum output signal. The problem in testing MERB tubes is, therefore, to determine one set of operating conditions that result in optimum output.

Optimum Operating Conditions

The two conditions for optimum operation are:

1. Maximum signal to noise ratio.
2. Specified discrimination between signals on adjacent grids.

The noise level referred to the MERB grids should be about 100 microvolts. The discrimination between two physically adjacent grids should be an 80 to 90 percent drop between peaks. (Fig. 1)

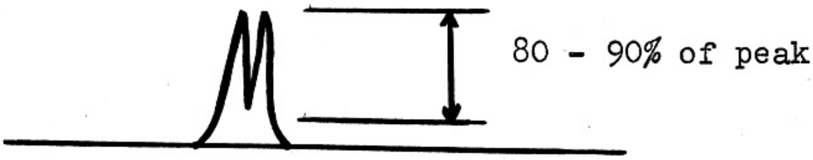

Fig. 1

Test Procedure

Apply a signal of 350 kc to a signal grid of the MERB tube.

Connect the cathode of the MERB tube to the input of the mixer amplifier and connect the output of the I-F amplifier detector to the vertical deflecting terminals of the cathode ray oscillograph. (It should not be necessary to use the amplifier in the oscillograph if the sensitivity with direct connection is about 50 volts per inch or better). The local oscillator amplitude should be adjusted for maximum output voltage on the oscilloscope. The d-c voltages on the various tube elements must be varied until the output pip is clearly visible on the oscilloscope. (The signal output can best be distinguished from noise by varying the amplitude of the input signal and observing which pip on the CRO varies in amplitude.) When the output pip is clearly visible the input signal can be reduced and the final adjustments made.

1. Set ring and plate voltages at 40 volts and MERB field voltage at 90 v rms.
2. Adjust signal grid for maximum gain. (Keep peak output less than 75 volts to prevent saturation in the amplifier).
3. Adjust screen for minimum noise.
4. Adjust inner (control) grid voltage for largest signal to noise ratio.
5. Repeat 2 to 4 as necessary to obtain best signal to noise ratio.
6. Apply signal to two grids separated by one (i.e. two physically adjacent grids). The discrimination between the two signals

should be 80 to 90%. (Fig.1) The screen grid voltage is critical in the adjustment for maximum discrimination and should be adjusted for as high a discrimination as possible while still maintaining a low noise level.

7. Check the gain of individual elements around the tube to be sure that all are approximately the same.
8. The reduction of signal level in passing through the MERB tube varies from 3:1 to 10:1. It should be remembered that the final adjustment must be a compromise between signal to noise ratio and good discrimination.

The following data should be recorded for each tube:

1. Optimum Operating Voltages
2. Noise Level
3. Input Signal Amplitude
4. Deflection in inches of CRO oscillograph beam
5. Discrimination between two physically adjacent grids
6. Reduction of signal amplitude in passing through MERB tube (Gain)
7. Field voltage and frequency
8. Relative gain of signal grids

To obtain the noise level, adjust the input voltage so that the output pip is the same height on the CRO as the noise. The noise level is then the magnitude of the input voltage.

Gain is measured by taking the ratio of the amplitude of a signal applied to a control grid to the amplitude of a signal applied to the cathode of the MERB tube when the deflection on the CRO is the same in both cases.

The relative gain of signal grids is obtained by putting a signal of constant amplitude and frequency on each signal grid and recording the deflection on the CRO.

MERB TUBE TEST SHEET

Tube No. _______

	Probable Value	Test
Plate Voltage	40 volts d-c	40 volts d-c
Rings	40 "	40 "
Posts	0 "	0 "
Signal Grid	2.3 "	___ "
Control Grid	3 "	___ "
Screen	6 "	___ "
Field Voltage	90 " rms	___ " rms
Noise Level	50-100 micro volts	_______ micro volts
Input required for 50 volts output	500 " "	_______ " "
Discrimination	80-90 %	_______ %
Gain thru MERB	.15	___
Signal Frequency	350 kc	___ kc

Relative gain of signal grid measured CCW from "K" terminal

(read down)

Grid No.	Gain	Grid No.	Gain