Notes on visits to admiralty signal establishment extension: Bristol, Birmingham University and General Electric Company

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NOTES ON VISITS TO ADMIRALTY SIGNAL ESTABLISHMENT EXTENSION BRISTOL, BIRMINGHAM UNIVERSITY AND GENERAL ELECTRIC COMPANY

OTTAWA

JANUARY, 1944

NOTES ON VISITS TO: ADMIRALTY SIGNAL ESTABLISHMENT EXTENSION, BRISTOL, BIRMINGHAM UNIVERSITY, AND GENERAL ELECTRIC COMPANY.

-- J. G. Retallack --

I. ADMIRALTY SIGNAL ESTABLISHMENT EXTENSION

(1) Power Klystrons - Beck

9PK5 (CV-109)

This tube is for beacon use.

Input: 8 kv., 2-1/2 kw. peaks.

Maximum mean dissipation: 120 watts

Output: 1/4 to 1/2 kw. peaks

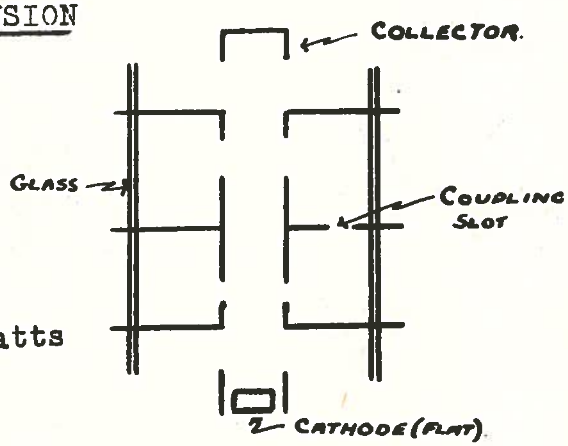


Figure 1

9PK2

This tube is to be used in early models of OBOE. Annular beams and resonators, as described in my "Notes on a Visit to E.M.I." are being tried because the beam is easy to produce, and the coupling between the beam and the resonator is much greater than for the usual cylindrical beam.

Input: 12 kv. peak. Output: 1 to 2 kw. peak.

(2) C.W. Klystron

This tube is for use in communications and laboratories.

Input: 2 kv., 80 watts.

Output: 10 watts

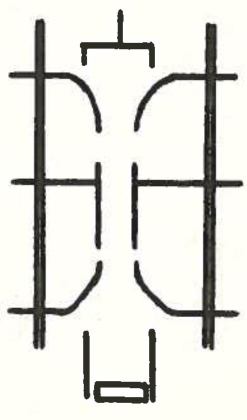


Figure 2

(3) VL-4

This is a local oscillator from 5 cm. to 10 cm. for use in a searching set. The resonant line used with this tube is shown in Dwg. No. B0146. The non-contact tuning plunger is driven through the tuning range by hand. In the VL-5, all the seals will be made with copper plated nickel-iron discs. These are strong enough to give a plug-in tube. The drive is coupled to a linear potentiometer which drives a triode controlling the reflector voltage. This voltage is -50 volts at the 10 cm. end, and -450 volts at 5 cm. The mixer tuner is also coupled to this drive.

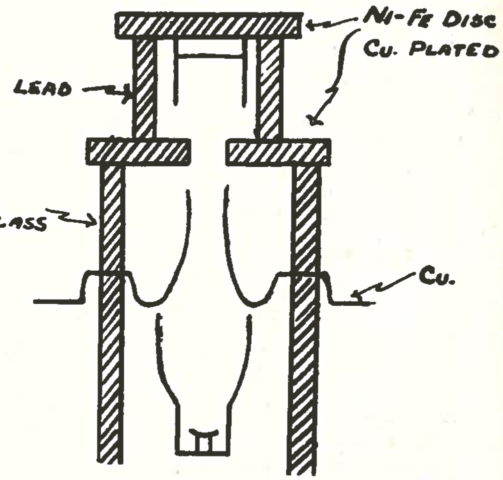
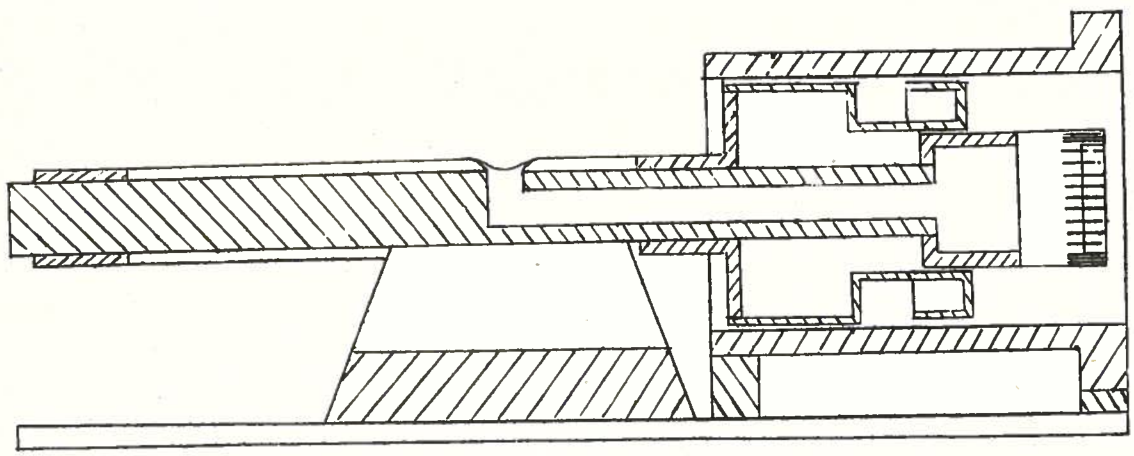


Figure 3



DRAWING No. B0146

(4) Coupling of Co-axial line to Wave-Guides and Horns

To get a broad band antenna system for the search set, the centre conductor of a co-axial line is extended in a triangle of copper which is soldered down at its end to the wide side of a wave-guide or a horn. Use of a co-axial transmission system permits a rotating joint for search in all polarizations.

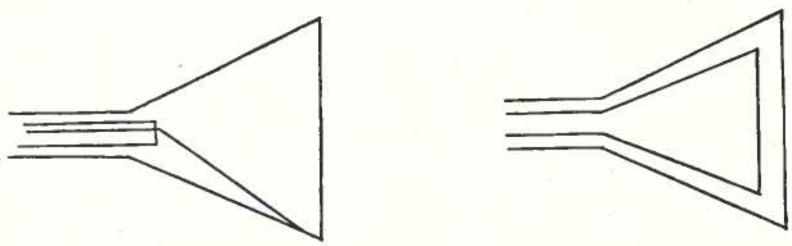


Figure 4

II. BIRMINGHAM UNIVERSITY

(1) Warning Set for use on Anti-Aircraft Gun Sites (Kumpfner)

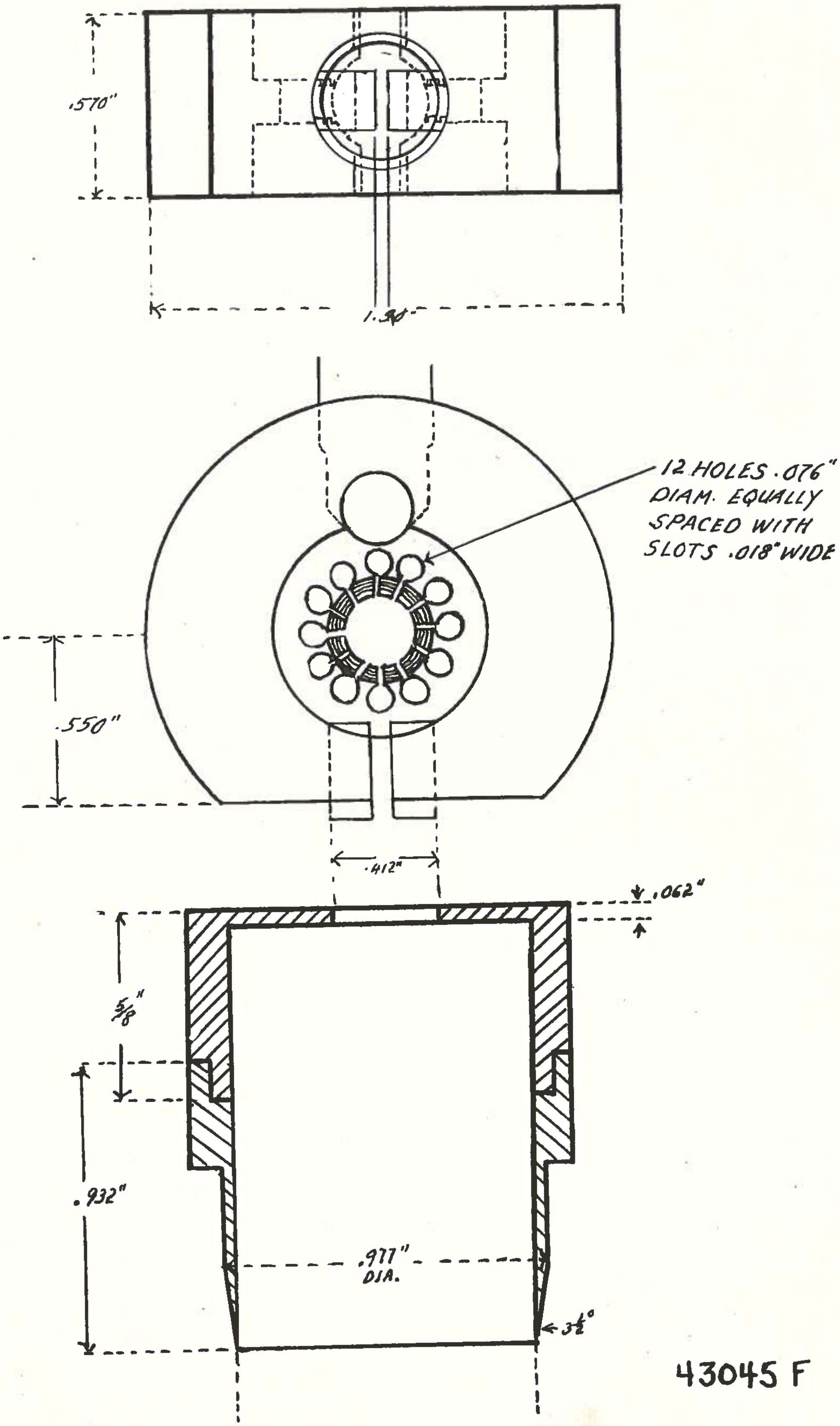
This set uses a 3 cm. local oscillator for a transmitter. The ground return, target reflection, and power from a second oscillator are mixed in the same receiver to produce an audible note to warn of moving targets near the set, and to give some idea of direction. In practice, the antenna will be continually searching. Ranges of two to three miles are expected.

(2) 3-Cm. Magnetron (Sayers, Sexmith and Watt)

The MX52 is a 12 segment, strapped, hole and slot magnetron which is comparable with the American 725-A. Dwg. 43045F shows some of the details. The output is a wave-guide opening into one of the holes and feeding a 15/16" I.D. round guide. Input is 150 kw., 1 microsecond, 1200 cycles. Output is 60 kw. Magnetic field is about 5000 gauss. Frequency pulling is + 6 mc. for a standing wave ration of 1.5:1 in voltage in the wave guide. Drawing 43045F appears on the following page.

(3) BM-728 Megawatt Magnetron (Bort)

This is a large 10 cm. magnetron for Naval use. 2 megawatt, 5 microseconds, 500 cycles output is planned.


.570"
12 HOLES .076" DIAM. EQUALLY SPACED WITH SLOTS .018" WIDE
.550"
.412"
.062"
5/8"
.932"
.977" DIA.
3½°

43045 F

2 megawatts, 1 microsecond, 500 cycles has been obtained for 47 kV. 1040 gauss, 90 amperes input. Filament leads are shielded as shown in Figure 5 to prevent breakdown. An output similar to that used in the MX52 is being tried. The usual spike with a 1/2" ball on the end in a wave-guide with carbon-tetrachloride vapour works satisfactorily.

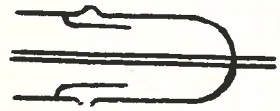


Figure 5

III. GENERAL ELECTRIC COMPANY

(1) CV-76 (Figure 6)

In a set with a long wave-guide transmission system, so that the reflected pulse reaches the magnetron while the pulse is being emitted, mode jumping becomes a serious problem. To reduce this mode jumping, a method of raising the Q of the system is being tried. A $\lambda/2$ resonant line is coupled to one of the magnetron cavities by a $\lambda/2$ line. With the top end of the resonator open, the coupling line is adjusted to reduce the Q of the magnetron well below the usual value of 30. When the resonator is adjusted, the Q can be raised to about 3000 or 4000. The 10.0 cm. mode was accompanied by a 10.7 cm. mode in the first tube tried. The efficiency was reduced to about two thirds of its former value. A 1% frequency pull is normal, --1/5th of 1% is aimed at.

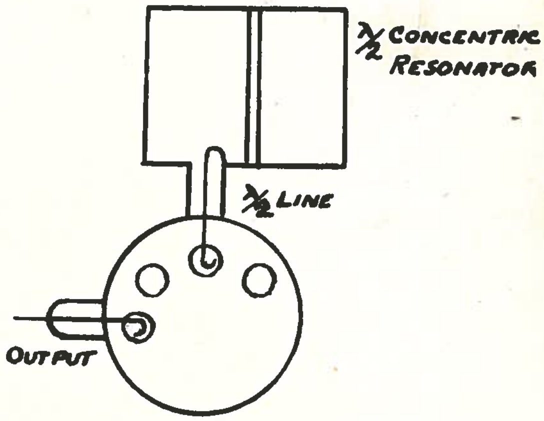


Figure 6

A magnetron for 5 megawatts input, 5 microsecond pulse, 500 cycle recurrence is being worked on. This is a strapped 10-segment tube. This tube will take 50 kv., 100 amperes and 1500 to 1700 gauss.

A copper sleeve is placed over the tungsten rod in seals as shown in Figure 7 to prevent flash-over.

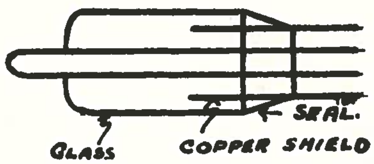


Figure 7

(2) High Power Water Load - for 5 Megawatt Tube

A 3-3/4" E guide is filled with medicinal paraffin to prevent flashing. Not more than 5% of the power is lost in the paraffin. Temperdax (k = 13) is used to match to the water load.

(3) CV-90 (James) (Fig. 8)

This is a local oscillator to be used for 10 cm. to 50 cm. It gives 100 mw. for 10 watts in, at 10 cm.

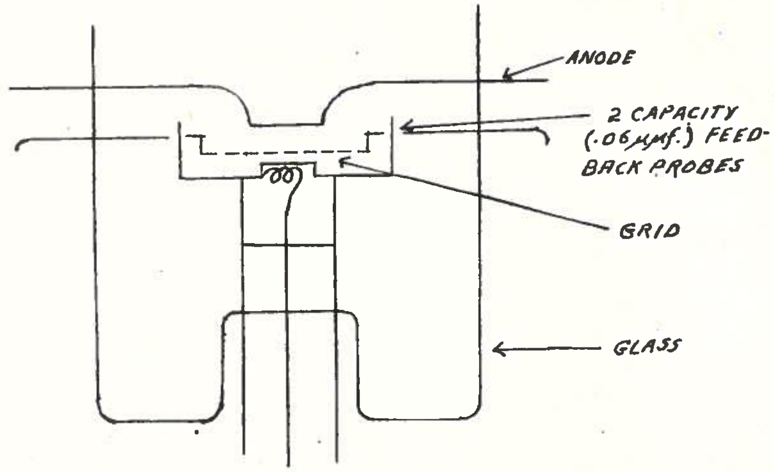


Figure 8

(4) CV-154

A similar tube, with larger cathode area and more feedback (0.24 μμF). It gives 1.5 kw. to 2 kw. in 2 microsecond pulses at 30 cm.; and 1 kw. at 10 cm. It is about three inches long and one inch in diameter.

(5) CV-153

In this tube the capacity feedback is left out, and the tube used as an amplifier and mixer. At 30 cm. it is 3.5 db. better than a crystal on signal-to-noise.

(6) Crystals (Ryde)

About 70% of the crystals being produced here are red-green. Those which do not pass the "green spot" test are used as ordinary red spots.

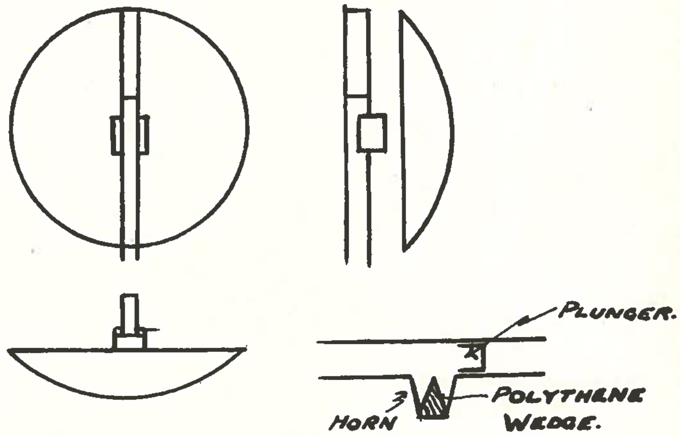
It was pointed out that it is not the shape of the point which gives the high burnout characteristic, but the boundary layer of high dielectric strength. It is voltage that causes the burnout and not power. This boundary layer is produced by first purifying the silicon very carefully, and adding proper amounts of aluminum and beryllium. If one arranged crystals in order of robustness with the usual point and changed point shape or material, the same order of robustness would be again obtained with small changes in the magnitude of the burnout voltage. For example, a round point is not quite so robust as a wedge point, and molybdenum is not so good as tungsten.

NOTES ON A VISIT TO E.M.I.

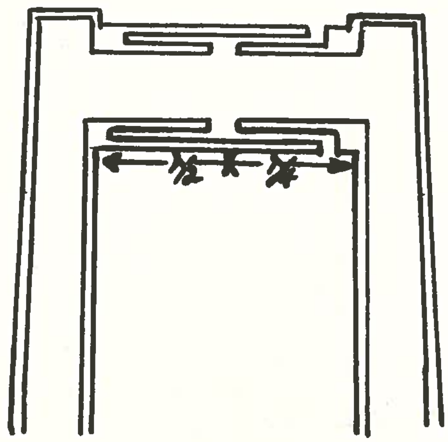
262 set. - Cork

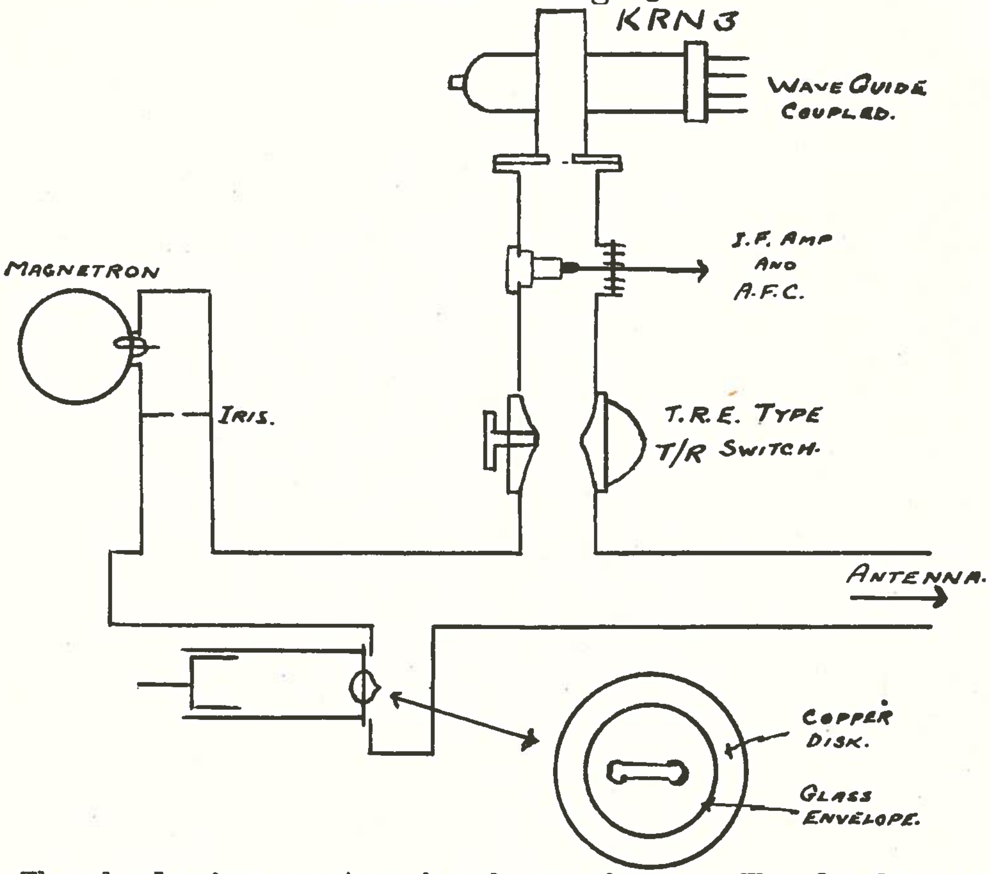
The 262 is a 3 cm gunnery set for naval use. The antenna is continuously "wobulated" with the beam 1-1/2° off the axis. Until a target is found the antenna scans about 15°. Then the set is locked on the target in range and bearing.

The reflector is a paraboloid about 30° in diameter. This is fed by a special horn which is designed to give the same pattern in both planes and to be matched. The beam width is 5° at half voltage in both planes. Lobes are less than 5%. This is obtained by using a horn shaped somewhat as shown. The guide is tapered down in the wide plane to a width below cutoff and unchanged in the narrow plane. It is then filled with a polythene plug which is wedge shaped in both planes. The polythene achieves the match and brings the horn above cutoff. This horn is very frequency insensitive. A method of calculating the reflector pattern from the radiation pattern of the horn was used successfully in the design of the horn. The method has not been written up in England but the idea was taken from an American report on the subject.



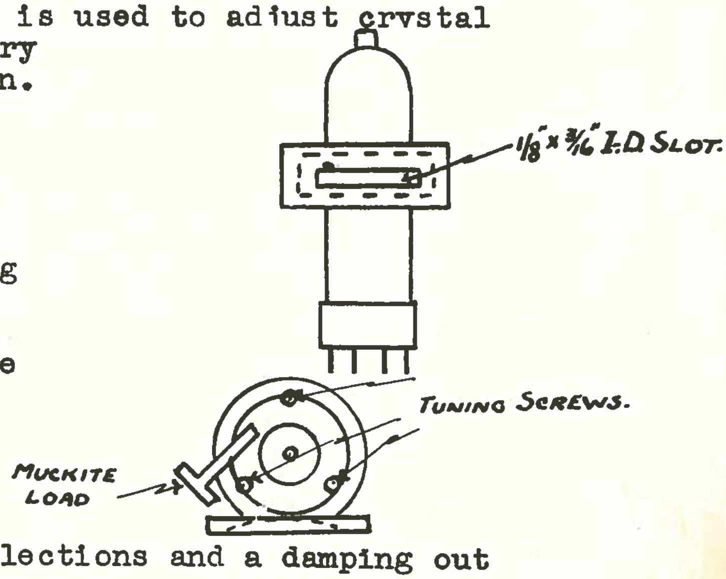
The rotating joints are a T.R.E. design as shown. The taper in the rectangular guide and the short length beyond the round guide effect a match and reduce the H_1 component in the round guide. This joint is very frequency insensitive. Since it is mechanically not very good, a new joint is being worked on which consists of two pieces of rectangular wave guide placed close together with circular coupling holes.





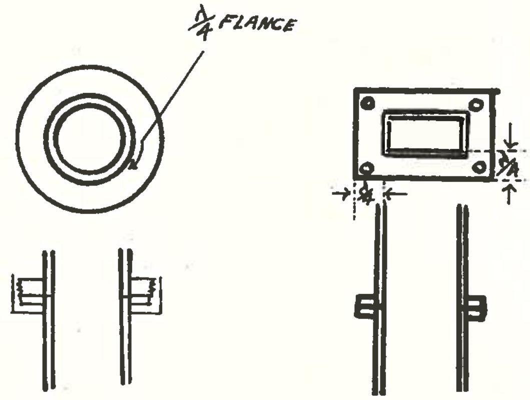
The duplexing system is shown above. The loading on the magnetron is adjusted by means of a movable iris. The R/T switch is a resonant slit in the side of a branch in the waveguide. Behind the resonant slit is a section of circular wave guide terminated by a movable plunger. The T/R switch is similar to the T.R.E. design with a wide gap and 3% tuning range - 3.15 cm. to 3.25 cm.

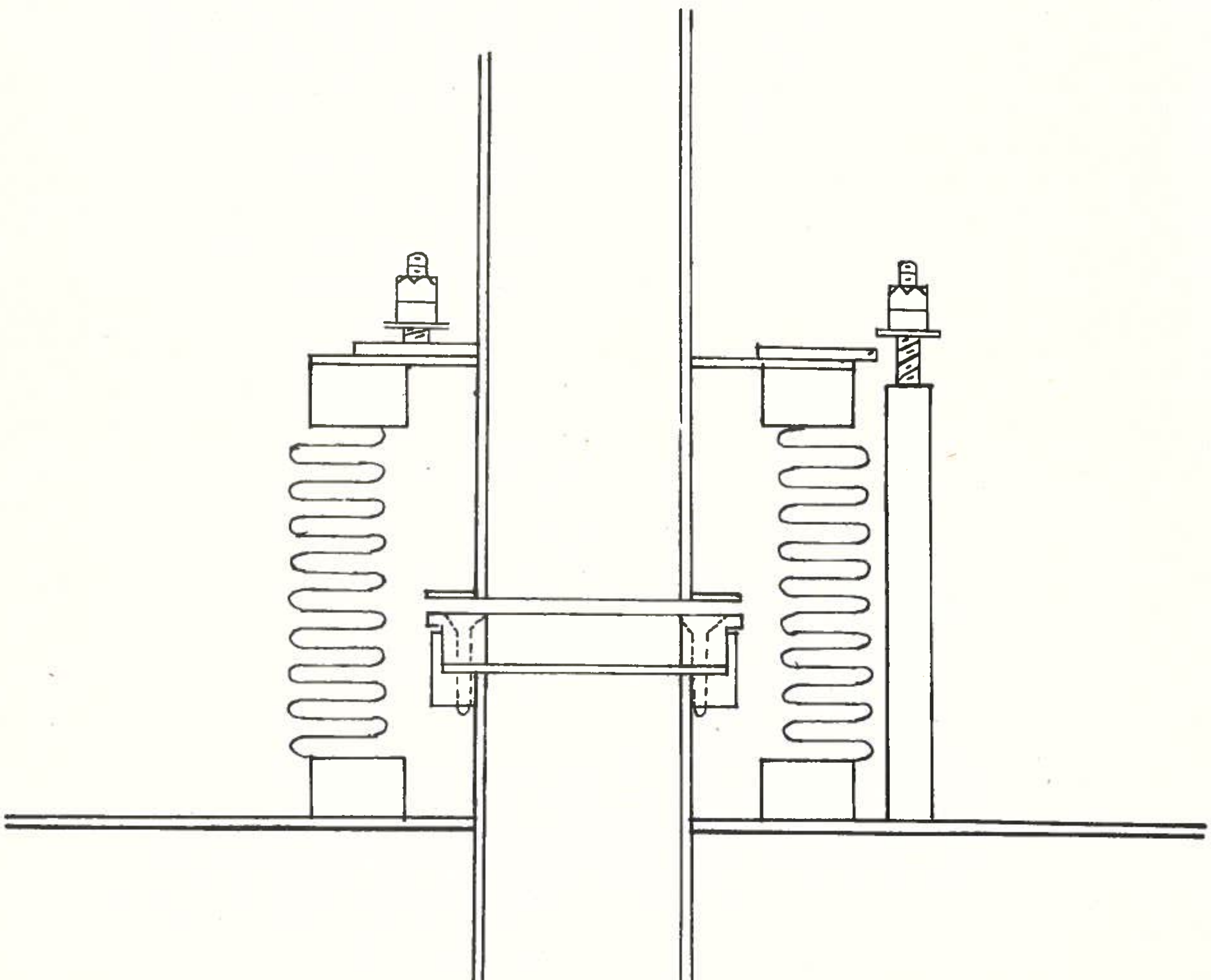
The local oscillator is a KRN3 - an A.F.C. tube with wave guide output. The muckite load absorbs about 80% of the power output of the tube and is used to adjust crystal current. The loading is necessary for satisfactory A.F.C. operation. The muckite is 20% graphite and 20% sawdust in bakelite in the form of a rod about 1/8" in diameter and 1/2" long. A small paddle wheel is placed in front of the output to trim the loading on the tube.



The right angle bends in the rectangular wave guide are made with a mean radius of 3.94 cms. in 1" x 1/2" I.D. guide so that the length of arc is $\frac{3\lambda}{2}$. This results in a cancellation of reflections and a damping out of higher modes.

For couplings no choke is used. A flange of proper diameter is soldered on the wave guide ends and the two are pulled together tightly with a threaded collar. Losses cannot be measured. A blue print of a flexible joint is included in this report. Here a $\lambda/4$ flange is soldered to the ends of the guide.





WAVE GUIDE FLEXIBLE JOINT

TUBES - CAIRNS

CV. 87 or KRN.2

This is the tube we have been using - a 3 cm. oscillator with double differential tuning and not suitable for A.F.C. use. The output is a loop and concentric line.

CV. 129

This has the same insides as the CV. 87. The envelope is shorter, the tuning is single differential leaf spring tuning, the output concentric, and not an A.F.C. tube.

CV.130

This is the same as the CV. 129 except that there is wave guide output and the tube is for A.F.C. use. The A.F.C. is made possible by a reflector of different design.

CV.150 or 9.PK - Mago

This is a 9.6 cm. klystron which will give 20 KW in 1 μs pulses at 700 cycles per second for 150 KW input. It is fitted with a wave guide output so that it can be directly coupled to a wave guide circuit.

CV.116 - Atherton

This is an 8.5 cm. A.F.C. oscillator. It is about half the physical size of the 707A. It will tune from 8.3 to 8.9 cms.

Resonator volts.	200 to 250
Reflector volts.	-125
Power output	100 mw for 6 watts in.
Cathode Screen	0.

Temperature coefficient: not more than 5 megacycles drift on warming up in 20 minutes.
20 megacycles electrical tuning range between half-power points for 35 volts change on the reflector.

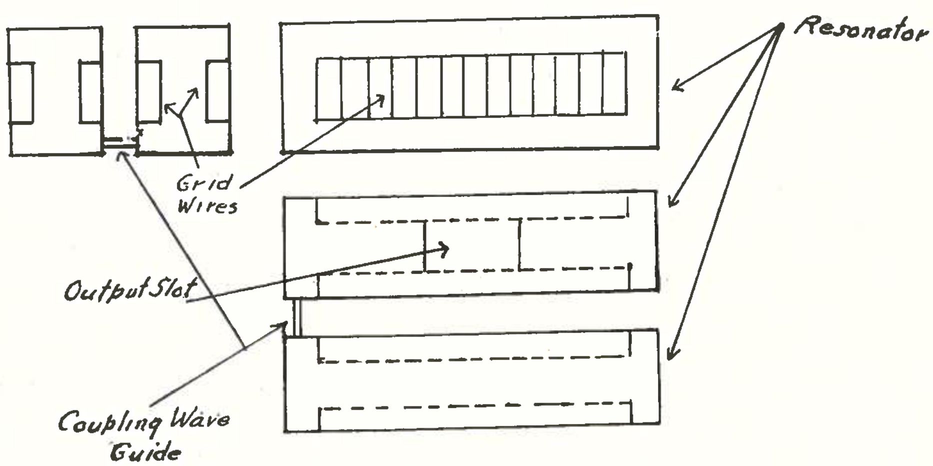
Hysteresis is greater in this mode than is liked, on a lower mode with 40 mw output and a 35 megacycle tuning range there is no appreciable hysteresis.

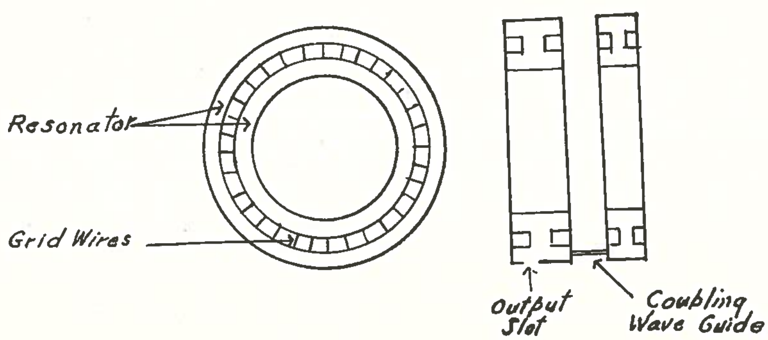
Until the tube reaches the pre-production stage a usual Sutton type tube with modified reflector design is being made as a stop gap. This tube requires voltages of the order of 1350 volts.

It was pointed out that the reflector wants to be more positive as the wavelength is increased. The reflector starts to draw current at -50 volts. Thus the extent to which wavelength can be changed by changing the cavity is limited.

__3 PK. - Pierce__

The 3 PK corresponds to the 9 PK at a wavelength of 3 cms. The resonators are coupled by means of a thin wave guide. Coupling to the wave guide load is done by means of a slot in one of the resonators. In one type the resonator is rectangular with a line electron beam. In another that was being tried this resonator is rolled up into a circle and an annular beam is used. 1 KW peaks had been obtained.





Grid Modulated 9.PK - Bull

Grid modulation has been obtained with the 9 PK with a cup shaped grid that fitted the cathode shape. The problem is to obtain a grid construction that will maintain its shape and with low grid emission. Grids made by punching holes in a formed sheet do not hold their shape while mesh grids have too much emission.

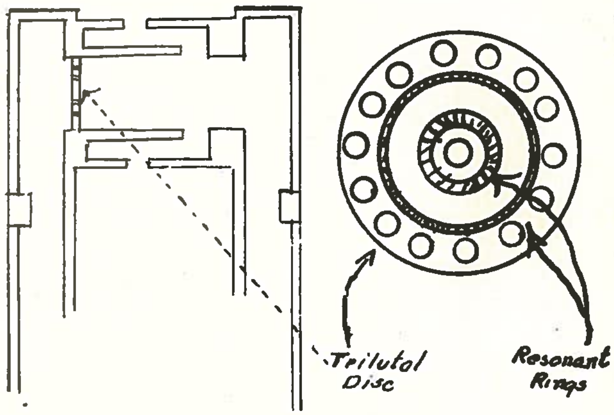
1.25 cms. Oscillator - Hill

This tube looks much like a 3 cm. oscillator. Many of the pieces are those used for 3 cm. tubes. About 30 mw of output have been obtained, or a few milliamps of crystal current. 2000 volts is required to operate it. The output is a slot for coupling to a wave guide.

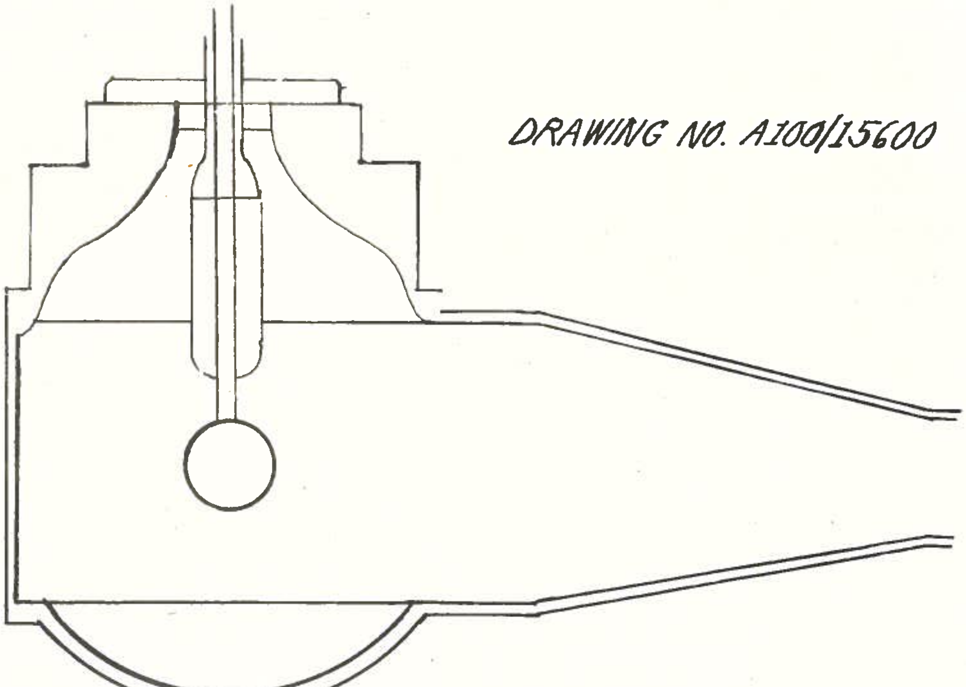
NOTES ON A VISIT TO T.R.E.

Wave-guide rotating joint.

The rotating joint used for 3 cm. is as shown. The insert in the wave-guide wall is approximately 3/8" x 1/16" and is for matching. To damp out H_1 and higher harmonics two resonant rings fixed in trilutol are placed near one transformer. As much of the trilutol as possible is drilled out. This rotator gives a S.W.R. greater than .85 over the 3% band of the magnetrons. By careful choice of the length of the round guide and the spacing between the rotators, two rotators can be made very broad.



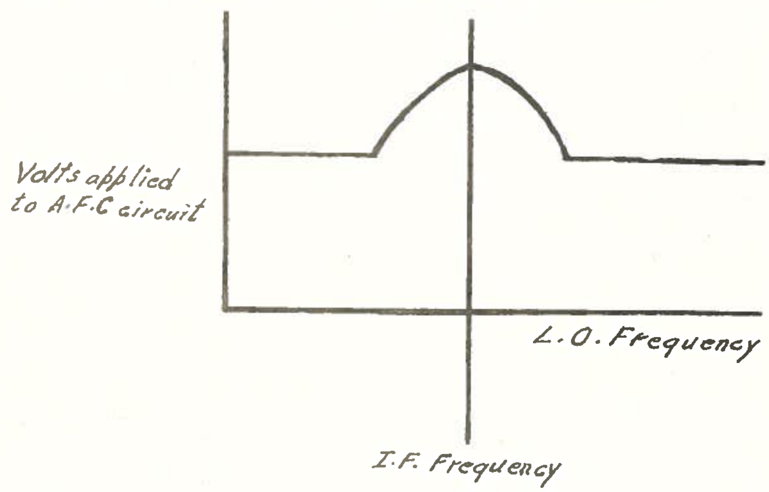
DRAWING NO. A100/15600



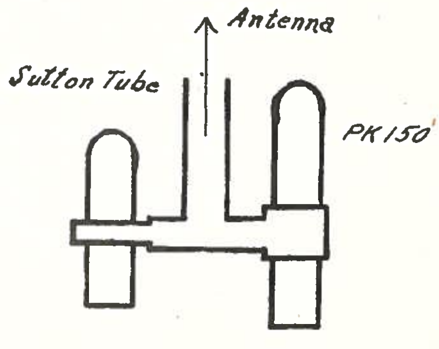
The magnetron output circuit used in the high power (200 KW) 10 cm. box is shown in Drg. No. A100/15600. The adjustment of this circuit is quite noncritical. One half inch of motion of the ball on the output spike gives a 5% variation in efficiency. The same variation in efficiency is produced by 2 mm. of motion of the wave guide termination.

In the pressurized high power 10 cm. box the magnetron is fitted with a small solid brass block which is pressed tightly against another heavy block leading through the wall of the pressurized chamber into fins which are blown. By painting the contact with aquadag for a good thermal contact, the magnetron temperature is reduced by 10°F.

A.F.C. is planned for this box but it has been found that there are two parts to the voltage applied to the A.F.C. circuit from the leakage pulse. One part tunes with local oscillator tuning. The other does not. The part that does not tune is much larger than the tuneable part. It is thought that this might be due to rectification of the large leakage pulse by the crystal or to stray pulses.

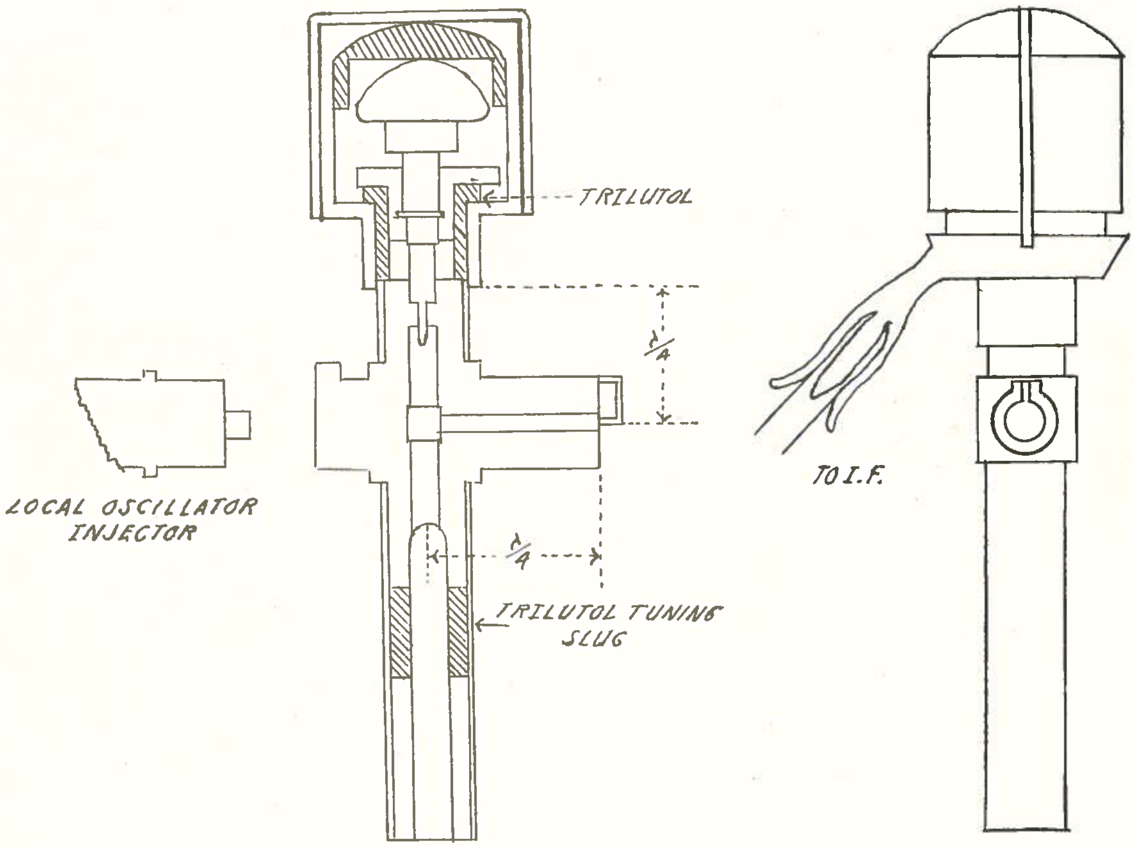


For high stabilization of the frequency of the PK150 20 KW transmitting klystron a side arm on the wave-guide with a Sutton tube is being tried. The Sutton tube is used merely as a high Q resonator. For a 2:1 S.W.R. moved along the wave-guide the pulling is 8 Mc. for 1 db loss. Another way to reduce the pulling to 3 cm. is to reduce the window coupling the PK150 to the wave-guide; but the loss becomes about 4 db.



10 cm. Mixer.

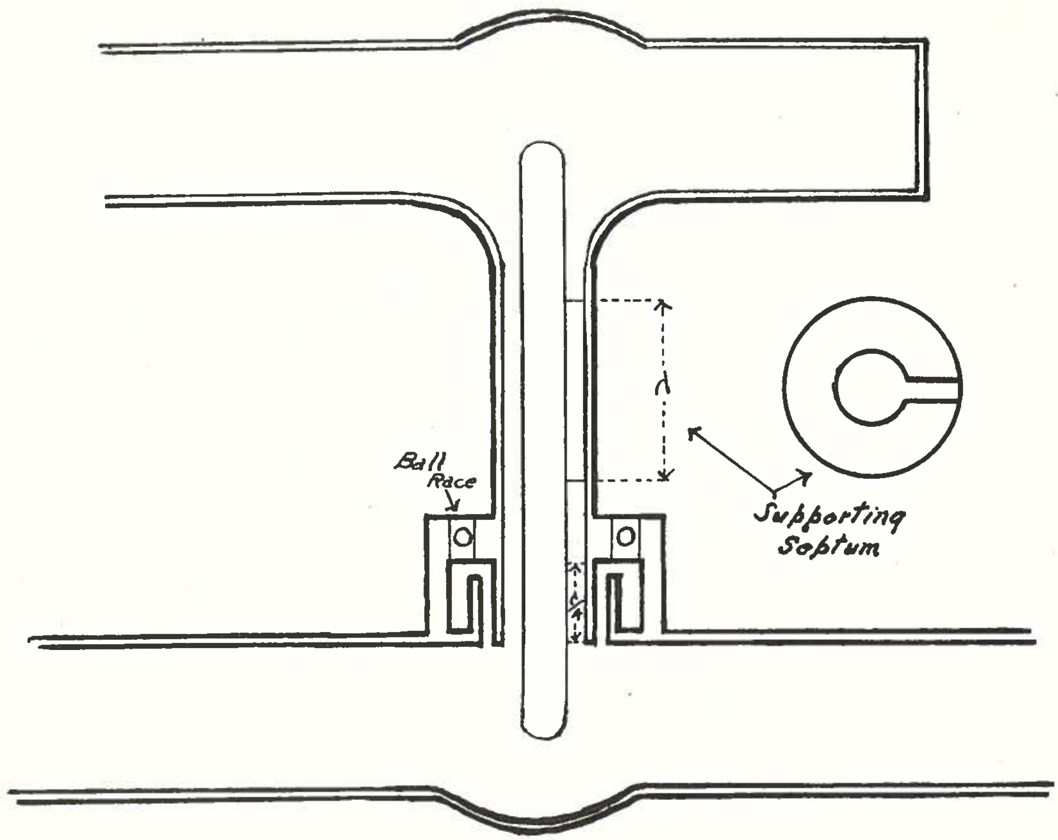
A sketch of a new 10 cm. mixer is included in the report. Measurements of the impedance of yellow spot crystals at the spot give R = 0.46 to 0.6 of 75 ohms and X = -0.4 to +1.2 of 75 ohms. By making the line to the crystal flat on reception, and the line length λ/2 from crystals to the loop for coupling to the T/R the maximum of protection on transmission is obtained. The trilotal or polythene slug in the third branch is for trimming the match into the crystal and into the mixer at the base of the loop when crystals are changed.



ESSENTIAL FEATURES OF
CRYSTAL MIXER FOR OBOE T-R BOX

10 cm. Rotating Joint.

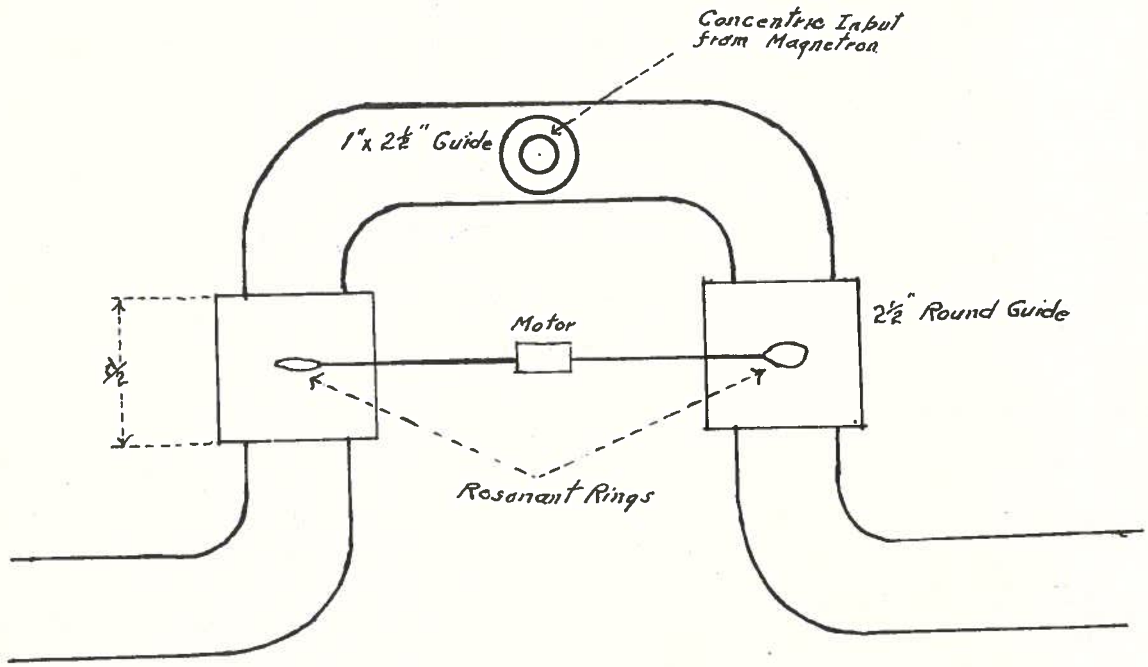
Used in A.S.V. and similar applications.

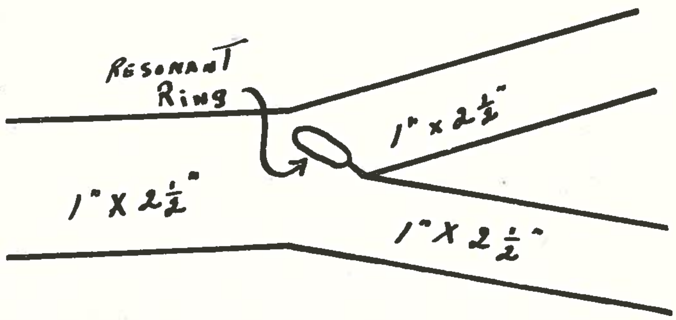


Wave-guide Switches.

This switch turns through 90° in 5-8 milliseconds once every 1/30 seconds. This is done by a clockwork motor which is continuously wound by an electric motor.

Sketches of this switch appear on the following page.



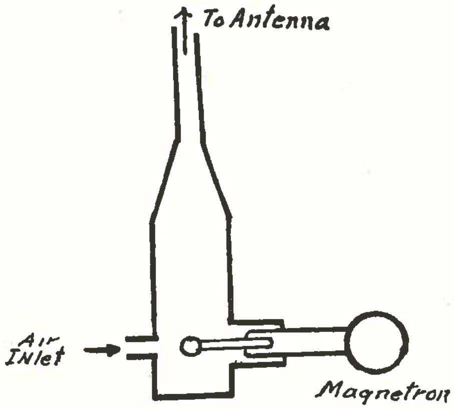


This is a mechanically stronger switch.

BRIEF NOTES ON SOME MICROWAVE EQUIPMENT SEEN AT A.S.E.E. WITLEY

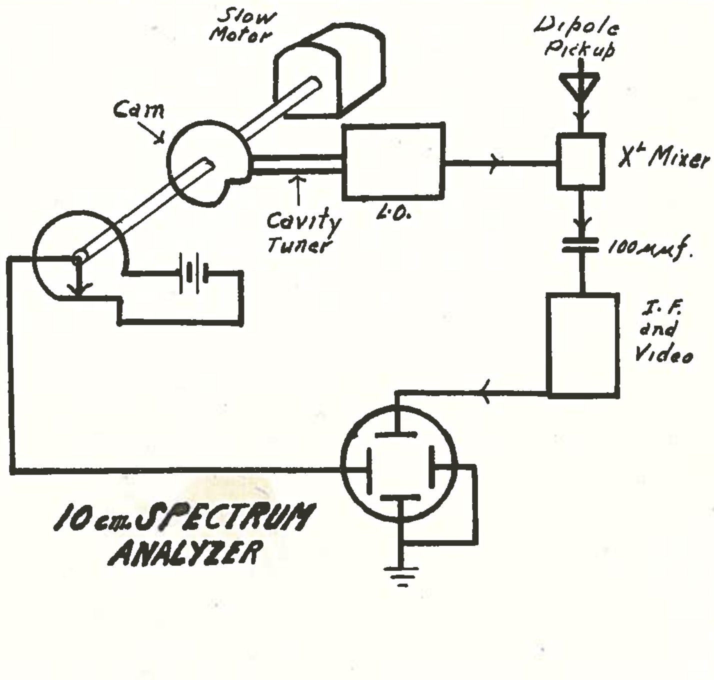
Magnetron Output Circuit in High Power Sets.

A ball about 1/2 inch in diameter is placed on the end of the output spike of the magnetron and this ball is placed at about the middle of a wave-guide 1-3/4" x 3" O.D. Opposite the input to the wave-guide there is provision for blowing air over the seal on the magnetron to cool it. The output power of the set is about 500 KW. A few inches from the input, the wave-guide is tapered down to the standard 1" x 2-1/2". These sets are designed with the aid of the spectrum analyzer described below. 10 cm. magnetrons are seriously affected by loading especially if the wave-guide line is long. If the line is long enough that the pulse reflected from the load reaches the magnetron while the pulse is being emitted, the tube sees a different impedance for different parts of the pulse. Pulses on three or four different wavelengths are seen with such arrangements. In designing a set, the output circuit is adjusted to give the best compromise between power output in the useful pulse and spectrum. It is found that usually about 15% of the power is lost in the side lobes of the spectrum.



Spectrum Analyzers.

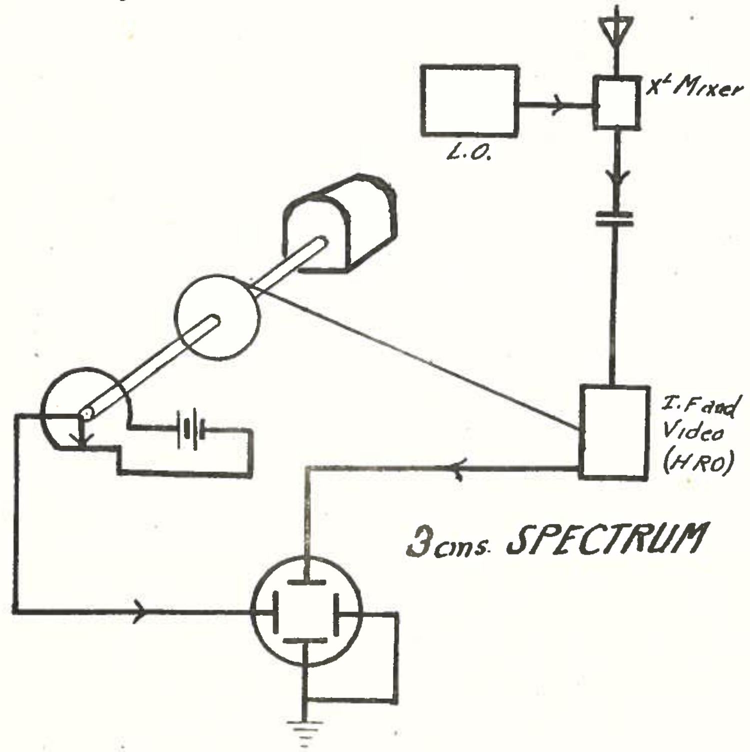
In the 10 cm. spectrum analyzer, the oscillator is a Sutton tube which is swept mechanically by a rod pushed in and out of the Sutton tube cavity with a frequency of about once every 3 or 4 seconds. (Varying reflector bias instead gives too much output variation). The sweep range is about 6 megacycles per second. Different parts of the spectrum are examined by adjusting the other tuning slugs in the Sutton tube cavity. As will be seen from the diagram, the electrostatic time base is provided by a



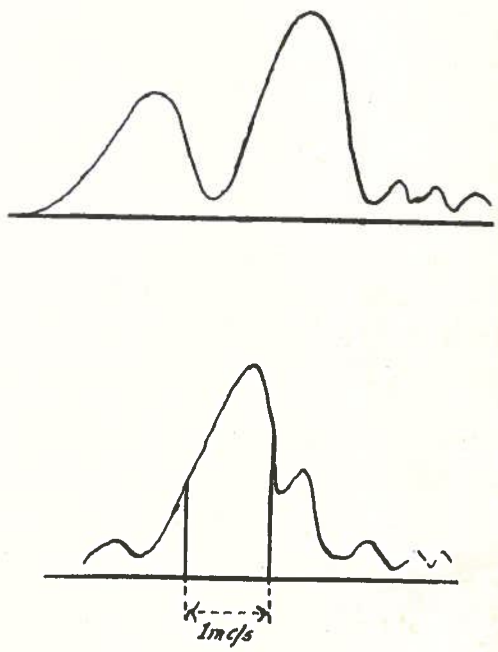
10 cm. SPECTRUM ANALYZER

potentiometer, ganged with the oscillator frequency control. The I.F. channel is very narrow, being of the order of a few kilocycles bandwidth. The C.R. Tube used has a long persistent screen.

In the 3 cm. spectrum analyzer is a fixed tuned E.M.I. tube, and the frequency of the beat oscillator in the commercial receiver is varied. This control is ganged with a pencil recorder or the sweep of a long persistence C.R.T. 3 cm. magnetrons have been found to be very sensitive to loading.



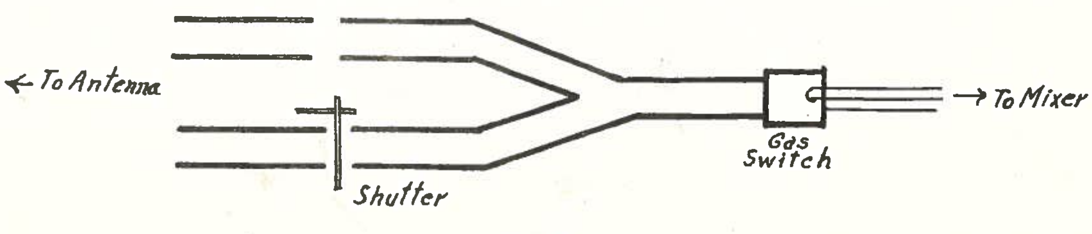
3cms. SPECTRUM



Spectra of Magnetron with different output circuits

The 274 Set

In the receiver wave-guide line is placed a Soft Sutton tube. This protects the crystal from the power which leaks into the receiving antenna from the transmitting horn. The mixer used here is the same as that used in the 271 set -- a cavity mixer.



Low Voltage Sutton Tube

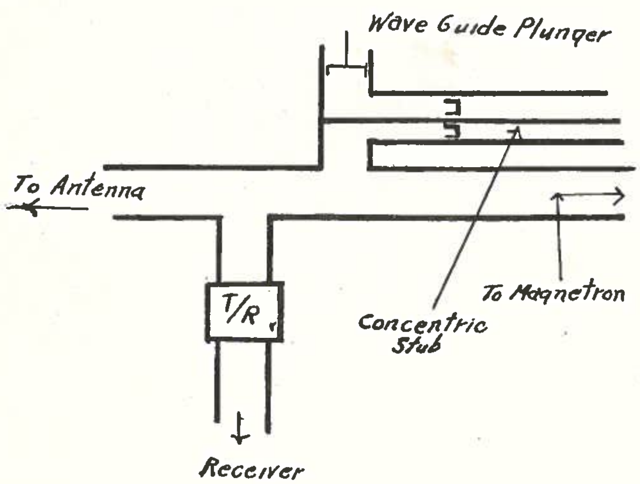
This tube looks much like the 707a. The diameter of the cavity is smaller than that of the 707a and there is more capacity in the gap. In the curve which I saw of a high negative mode there was a range of 8 megacycles which could be used for a swept oscillator. Loading is necessary for good electrical tuning. The following data are given:-

Cathode volts --	-300
Reflector volts --	-350 to -380
Plate current --	20 ma.
Power output --	50 mw.
Tuning --	About 2 mc/volt on the reflector.

The antenna system has already been described elsewhere by K.C. Mann.

The 3 Cm. Duplexing System

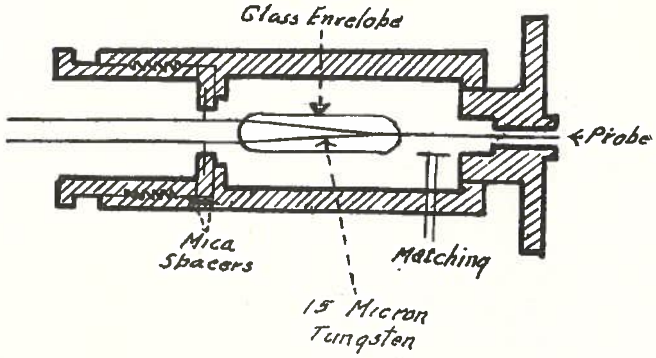
The T.R.E. T/R switch had a very wide gap. The tuning range was about 10%. The insertion loss was estimated to be about 3 db. It was pointed out that when speaking of the insertion loss of a T/R switch one should specify the type of crystal which is used in measuring the loss. With a crystal which requires more protection than the average, the insertion loss is naturally greater than with one that can stand up to more leakage power. However, receiver sensitivity is generally greater with the low burnout crystal.



To keep the signal power out of the magnetron, an R/T system which consists of a waveguide arm, terminated with a plunger and with a concentric stub branching out of it, is used and found to be satisfactory. The wave-guide plunger is adjusted for reception, and the concentric stub for transmission.

Standing Wave Probe

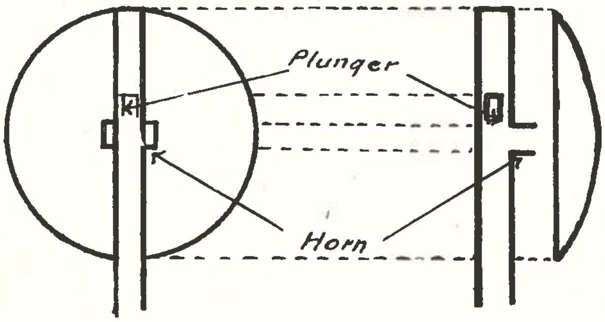
The V-shaped bolometer wire forms the center conductor of a concentric line. The wires connecting with the ends of

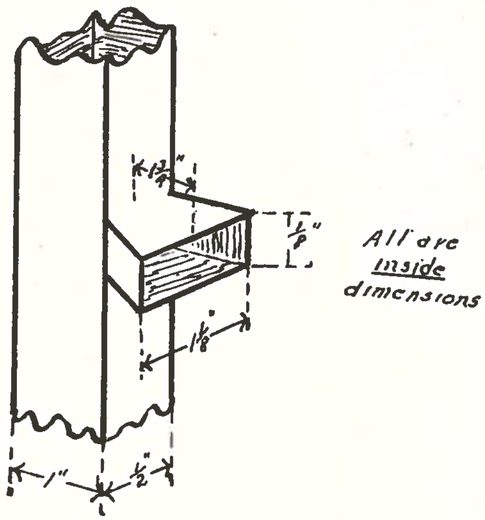


the bolometer wire are soldered to the two parts of a disc which form one plate of a condenser. The wire from the other end of the bolometer tube is continued to form the probe. Some matching is provided at this end of the unit.

Wave Guide Feed to Paraboloids

The wave-guide is carried all the way across the paraboloid and supported at the far end. In the middle of the paraboloid a small horn is brought out of the narrow side of the wave-guide with its mouth in the focus of the reflector. Dimensions are shown for one set observed at A.S.E.E. Witley.





JGR:HFH
OTTAWA
January 17, 1944.

J. G. Retallack