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V-39, V-40 KLYSTRON OSCILLATORS
DESIGN AND DEVELOPMENT PROGRAM

Progress Report for
Quarter Ending 28 February 1954



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V-39, V-40 KLYSTRON OSCILLATORS
DESIGN AND DEVELOPMENT PROGRAM

Progress Report for
Quarter Ending 28 February 1954

Prepared for: Bureau of Ships
Navy Department

On: BuShips Contract No. NObsr-52105
Index No. NE-112044

By: Robert G. Rockwell

Approved: SF Varian
Sigurd F. Varian
Vice-President for Engineering

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PURPOSE

The purpose of the program covered by BuShips Contract No. NObsr-52105 is to design and develop two wide-range klystron oscillators, V-39 and V-40, which will comply with the specifications outlined in this contract.

The two oscillators will cover the frequency band from 10 to 21 kmc. One tube will tune over the lower half of the band from 10 to 15.5 kmc, and the other will cover the band from 15 to 21 kmc. Preliminary design tubes of each type, complete with electrical test and characteristic data, will be furnished. In addition, five tubes embodying the final design of each type will be supplied, along with electrical characteristics and test data, final proposed specifications, and manufacturing drawings.

GENERAL FACTUAL DATA

At the beginning of this quarter, the cavity design of the V-40 was changed in order to reduce the excessive amount of bowing of the reflector header caused by pretuning. The tube of the new design showed adequate performance and successfully solved the bowing problem. This tube was therefore selected to be used as the model from which to scale a V-39.

The first V-39 scaled from a V-40 was only partially scaled to ascertain what part of the geometry of the tube was predominant in the positioning of the undesired modes.

Operation of this tube showed that the interfering modes which had been difficult to suppress in previous, unscaled V-39's were still present. It thus became necessary to build a completely scaled tube.

The first completely scaled V-39 successfully shifted the interfering modes as intended, so that the desired modes were undisturbed over most of the tuning range. Some slight interference was still detectable, however, at frequencies below 11 kmc. Further work will therefore be necessary to obtain the right combination of coupling hole size and position, and width and length of mode suppressor waveguide in order to eliminate this interference.

Work on the tuning shorts for the V-40 tubes was centered on the non-contacting types, since use of the V-39-type contacting shorts in the V-40 resulted in insufficient contact along the tuning cavity. The first non-contacting short built consisted of a cylindrical choke sliding in a reamed waveguide, to increase the effectiveness of the short. When operated in a tube, this short achieved an upper frequency limit of only 19.5 kmc, instead of the required 21 kmc, and dropped out of oscillation at some points.

A non-contacting short similar to the one above, but not operated in reamed waveguide, was constructed by the Hewlett-Packard Company. When this short was operated in a tube, oscillations at 21 kmc were realized, but some of the erratic performance previously experienced remained. It was determined that this was due to the short coming in contact with the waveguide.



Work then reverted back to V-39-type contacting shorts, and tests were run for comparison between these and the non-contacting shorts. A cavity incorporating a rectangular choke short with four slots appears at present to give the most power output. Further investigation into this problem will be made during the next interval.

Two standard V-39 tubes were shipped during this quarter.

DETAILED FACTUAL DATA

During this quarter, the V-40 cavity design was altered slightly to reduce the excessive amount of bowing of the reflector header necessitated by pretuning. The V-40 tube incorporating this design change (V-40 tube No. 68) showed adequate performance and successfully eliminated the bowing problem. This tube was therefore used as a basis for designing a V-39, using a scale factor of 1.4 to 1.

It was decided to build first a partially scaled V-39, and thus determine if the internal cavity dimensions were predominant in the positioning of the undesired modes, or if some other part of the geometry of the tube was. From the partially scaled tube, it would be determined if this tube would suffice or if a fully scaled V-39 would be required. The first partially scaled tube built (V-39 tube No. 29) was essentially of the same design as previous V-39's, except that a larger diameter drift tube protruded farther from the cathode headers and the headers were separated by an additional 0.005 inch. A cold test of this tube was made and showed no significant change in the tuning characteristics when compared with a previous V-39.

Tube No. 29 was operated, and performance was quite satisfactory with power output exceeding 50 mw over the 10 to 15.5 kmc range. Comparison of the data for this tube with data for an unscaled tube (tube No. 4), however, showed that the positioning of interfering modes was not noticeably affected by the change in design.

It therefore was decided that complete scaling of the V-39 would be necessary. The first completely scaled V-39 tube (No. 52) altered the position of the modes to such an extent that it truly appeared to be a scaled model of the V-40 as intended. The positioning of the modes apparently was affected predominantly by the transition between the internal and external cavities. The partial scaling had changed the internal cavity size so as to affect all the cavity modes in like amounts; however, the complete scaling had made an additional change in the transition between cavities.



Thus in the latter case, only those cavity modes which had strong fields in the region of the transition were affected. Since the full-wavelength mode has zero electric field near the region of the transition, this mode was less affected than the 1/2-wavelength and 3/2-wavelength cavity modes, which have strong electric fields near the transition region.

Figures 1 to 6 show the power output vs reflector voltage characteristics for V-39 tube No. 52, each figure corresponding to a different short position. The tube was operated without mode suppressors. Comparison of data for the completely scaled tube with data for an unscaled V-39 (tube No. 4) and the partially scaled V-39 (tube No. 29) indicates that the positioning of the interfering modes was markedly affected by the change in design of the transition.

Figures 1 to 6 do not show any mode interference on the operating side of the desired modes. Some mode interference was detected, however, and the limits of this interference are shown in Table I.

TABLE I
Mode Interference in V-39 Tube No. 52

<u>Tuning Knob Turns</u>	<u>Desired Mode Frequency</u> (kmc)	<u>Interfering Mode Frequency</u> (kmc)
17	11.00	12.65
24	10.57	12.00

It was also desirable to eliminate the 3/2-wavelength mode at 11.1 kmc when the desired mode was tuned to 10 kmc (see Figure 6). It therefore became apparent that stringent requirements would have to be placed on the size and location of the mode suppressor in order to suppress frequencies above, but not below, 11.05 kmc.

A standard V-39 (with three perpendicular mode suppressors) was tested in order to obtain a mode plot showing the effectiveness of the mode suppressors. The tube (V-39 tube No. 21) was tested and produced the results



shown in Figure 7. This figure shows that the tuning range is adequately covered in the full-wave (λ) cavity mode by use of the $4-3/4$ and $3-3/4$ reflector modes.

Completely scaled V-39 tube No. 52 was then operated in a cavity which had a mode suppressor built alongside but a coupling hole located in the same position as for an unscaled V-39. Figure 8 shows the loaded characteristics of the tube in this cavity. This figure indicates that there is no loss of power attributable to the mode suppressor. However, additional data taken of this tube showed that mode interference again occurred at 17 turns of the tuning knob, although the interference was suppressed at 22 turns. This meant that the coupling hole had to be moved towards the tube the equivalent of five turns.

An external cavity was thus constructed with the coupling hole moved five turns closer to the tube, covering this hole was a waveguide forming the mode suppressor alongside the main tuning cavity. This suppressor was of the same width as mode suppressors (alongside) used in conjunction with previous V-39's. The data taken of the tube with this suppressor are shown plotted in Figure 9. From this figure it is obvious that interference is still present, plus absorption of the desired mode in the mode suppressor. Thus, further work will be needed to obtain the right combination of coupling hole size and position, and width and length of mode suppressor waveguide.

Considerable work was done this quarter on tuning shorts for the V-40 tubes. Since the V-39 tuning shorts appeared to give relatively little trouble, it was reasonable to assume that the desirable features of these shorts should be incorporated in the V-40 tubes. However, extreme difficulty was encountered in obtaining sufficient contact when using the V-39-type contacting shorts in the V-40 tubes. It was therefore decided to design and build a non-contacting short. This short consists, first, of a cylindrical choke made up of three quarter-wavelength (at 18 kmc) sections to provide two low impedance lines separated by a high impedance, and second, of a reamed waveguide to increase the effectiveness of the short, since close



spacing (low impedance) is obtained over a greater distance than with a cylindrical short in ordinary rectangular waveguide. The upper limitation on the ream is such that the length of the close spacing is less than half the free space wavelength of the highest frequency desired, namely, 21 kmc.

The reamed waveguide external cavity and choke short were operated in conjunction with V-40 tube No. 68. The reamed section did not go all the way to the tube, as a 0.100 inch wall was left for contact with the rings. Hence the upper frequency limit was 19.5 kmc. There was no contact jitter upon tuning the tube, and it could be tuned through 15 kmc. However, there were some points at which the tube dropped out of oscillation.

Meanwhile, a non-contacting short similar to the one described above was constructed at the Hewlett-Packard Company. This short differed from the above short in that it was not located in reamed waveguide. The Hewlett-Packard short was borrowed for use with V-40 tube No. 68. When this short was inserted, oscillations at 21 kmc were realized; however, erratic operation was still present when using this short. It was determined that this was due to the shorts coming in contact with the waveguide. The external cavity had apparently been slightly collapsed during construction. This presented a possible explanation for the poor operation of the present V-39 contacting short with rubber backing. This short might have only been making contact in the very center of the waveguide.

In order to obtain good oscillations at 21 kmc, the beam voltage was raised to 800 volts, and data with different types of contacting and non-contacting shorts were taken. A comparison between power characteristics using the different types of shorts is shown in Figures 10 and 11. A cavity incorporating a rectangular choke short with four slots appears to give the most power output.

The tuning short problem will be pursued further during the next interval.



During the quarter covered by this report, two V-39 tubes (tubes No. 14 and 18) were shipped. Data for these two standard V-39 tubes are given in Tables II and III; tuning curves for the tubes are shown in Figures 12 and 13.

TABLE II
 Performance Data of V-39 Tube No. 14

Heater Voltage = 6.3 v
 Heater Current = 1.2 a

Frequency (kmc)	Beam Voltage (vdc)	Beam Current (madc)	Reflector Voltage (vdc)	Power Output Matched Load (mw)	Optimum Load (mw)	Tuning Resetability (%)
15.5	750	33	-290	57	81	0
15.0	750	33	-270	98	98	0.02
14.0	750	33	-210	73	81	0.01
13.5	750	33	-190	62	67	0.01
13.5	750	33	-390	105	105	0
13.0	750	33	-350	103	103	0.02
12.0	750	33	-275	105	122	0.005
11.0	750	33	-210	61	119	0
10.0	750	33	-140	20	63	0.01



TABLE III
Performance Data of V-39 Tube No. 18

Heater Voltage = 6.3 v
Heater Current = 1.2 a

Frequency (kmc)	Beam Voltage (vdc)	Beam Current (madc)	Reflector Voltage (vdc)	Power Output Matched Load (mw)	Optimum Load (mw)	Tuning Resetability (%)
15.5	750	32	-320	55	85	0.01
15.0	750	32	-285	80	95	0.01
14.0	750	32	-240	73	82	0.01
14.0	750	33	-420	84	87	0.005
13.0	750	33	-360	75	75	0
12.0	750	34	-290	99	122	0
11.0	750	34	-230	59	125	0.008
10.0	750	34	-160	21	73	0.02

CONCLUSIONS

Considerable work has been done on scaling a V-39 tube from a V-40. The first scaled V-39 - a partially scaled tube - showed no advantageous results over previous, unscaled V-39's. The next tube - completely scaled - exhibited a closer approach toward the desired characteristics. Further work is necessary to eliminate mode interference.

The problem of developing an adequate tuning short for the V-40 has been ardently pursued. Since the contacting shorts used with the V-39 had given relatively little trouble, it was assumed at first that these shorts could be readily adapted to the V-40. This did not prove to be the case, however, since the shorts did not obtain sufficient contact with the cavity walls to be effective. As a result, non-contacting shorts were developed. Some trouble has been experienced with these shorts, too, which may possibly be due to a slight collapse of the tuning cavity during construction. Late in this quarter several contacting and non-contacting shorts were tested for comparison. At present, a cavity incorporating a rectangular choke with four slots appears to give the most power output. During the next interval a final short design will be determined.



PROGRAM FOR NEXT INTERVAL

Work will continue on the problem of mode suppression in the completely scaled V-39. An attempt will be made to obtain the proper combination of coupling hole size and position, and width and length of mode suppressor waveguide to eliminate the prevailing mode interference.

Additional investigation will be made of tuning shorts for the V-40.

Estimated expenditures during February 1954: \$3200.00

Estimated man-hours during February 1954: 323

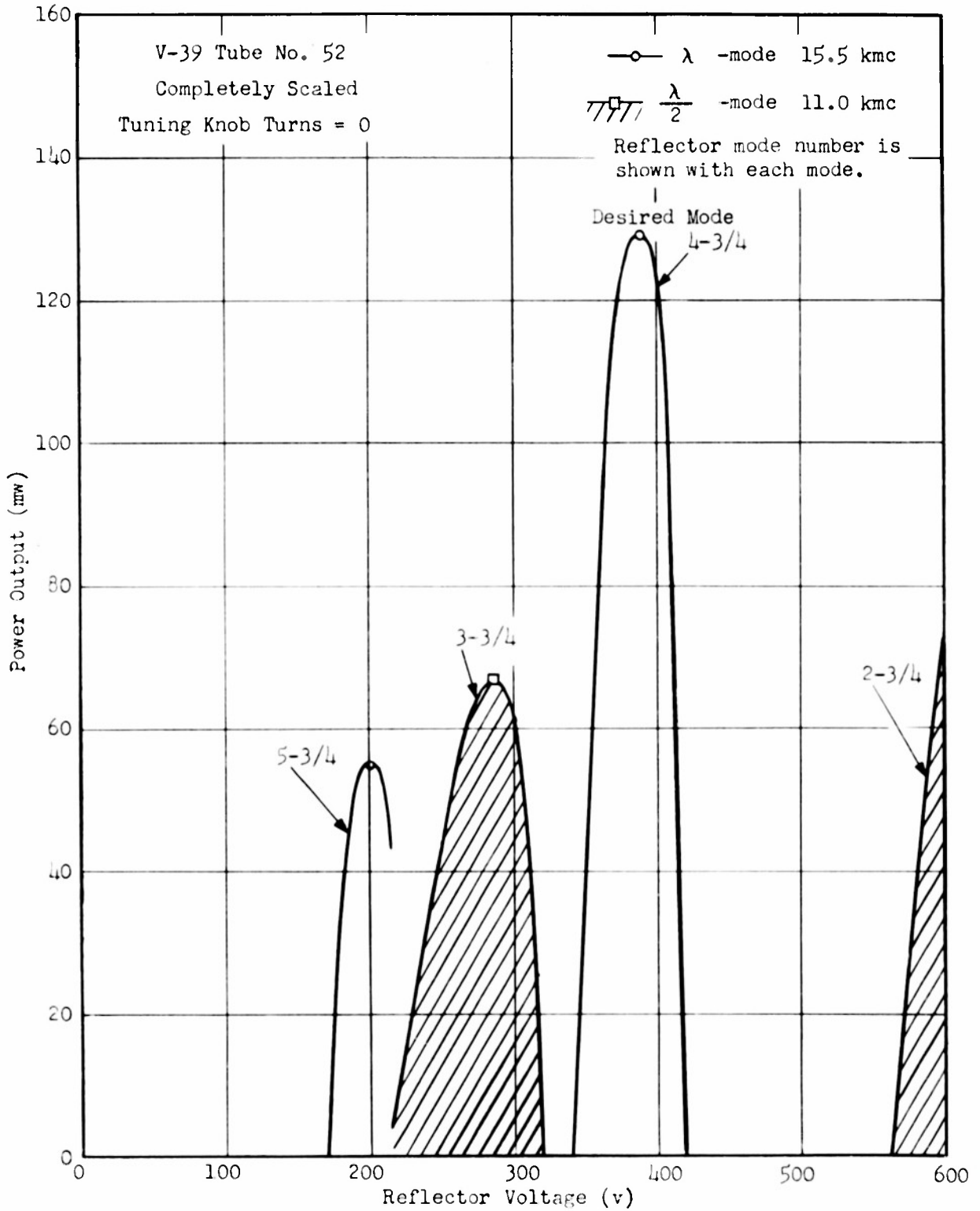


FIGURE 1
POWER OUTPUT vs REFLECTOR VOLTAGE FOR V-39 NO. 52
(TUNING KNOB TURNS = 0)

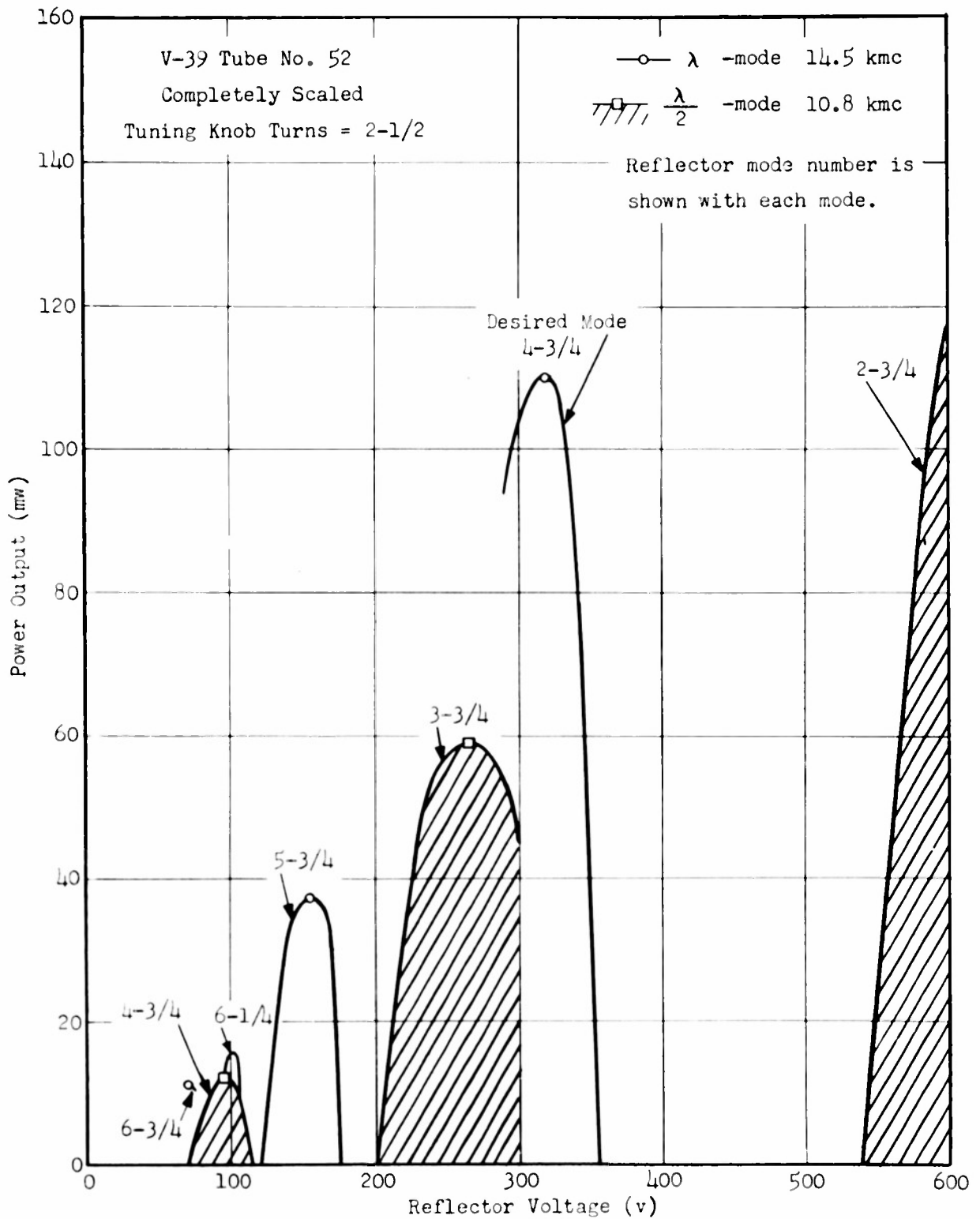


FIGURE 2
POWER OUTPUT vs REFLECTOR VOLTAGE FOR V-39 NO. 52
(TUNING KNOB TURNS = 2-1/2)

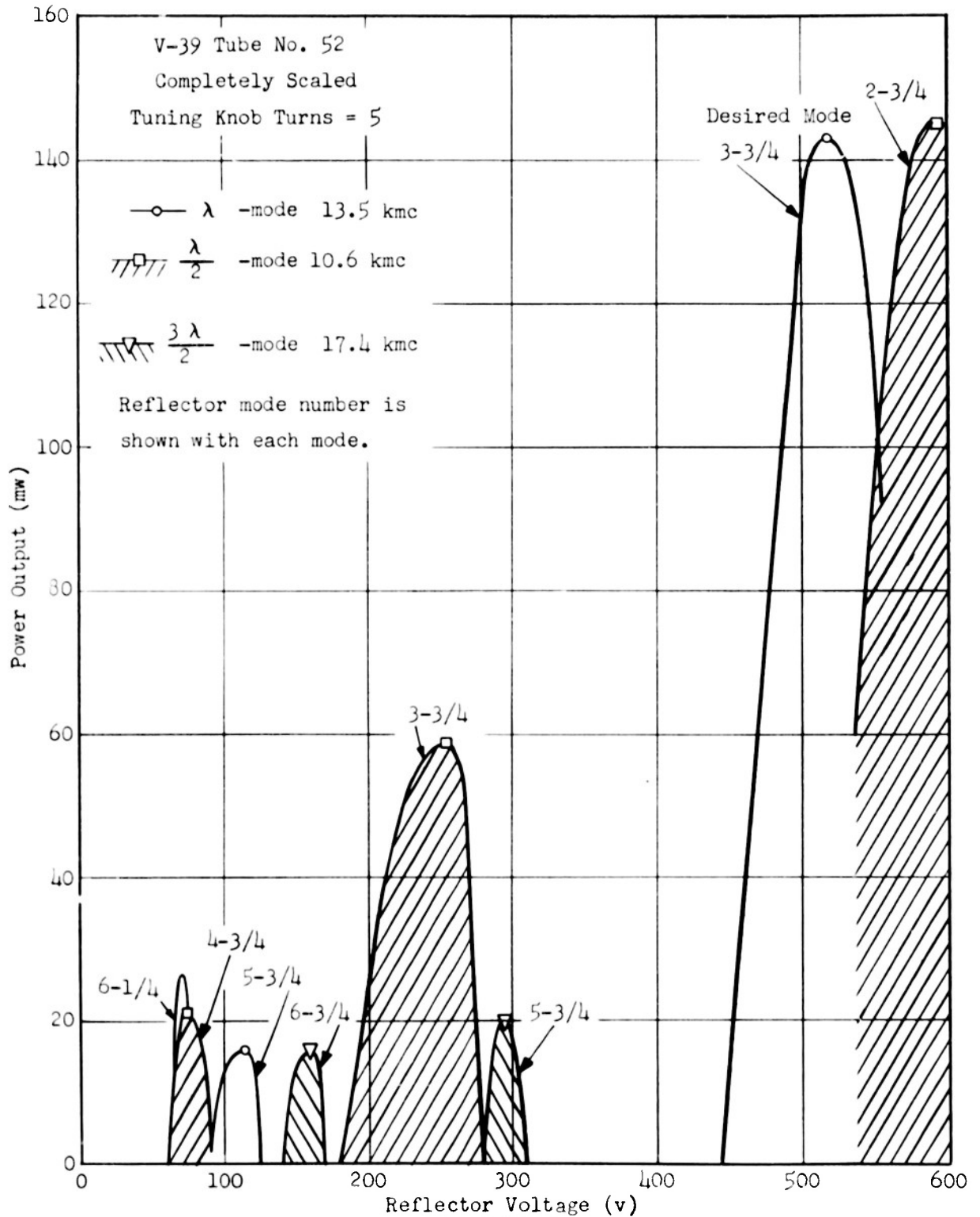


FIGURE 3
POWER OUTPUT vs REFLECTOR VOLTAGE FOR V-39 NO. 52
(TUNING KNOB TURNS = 5)

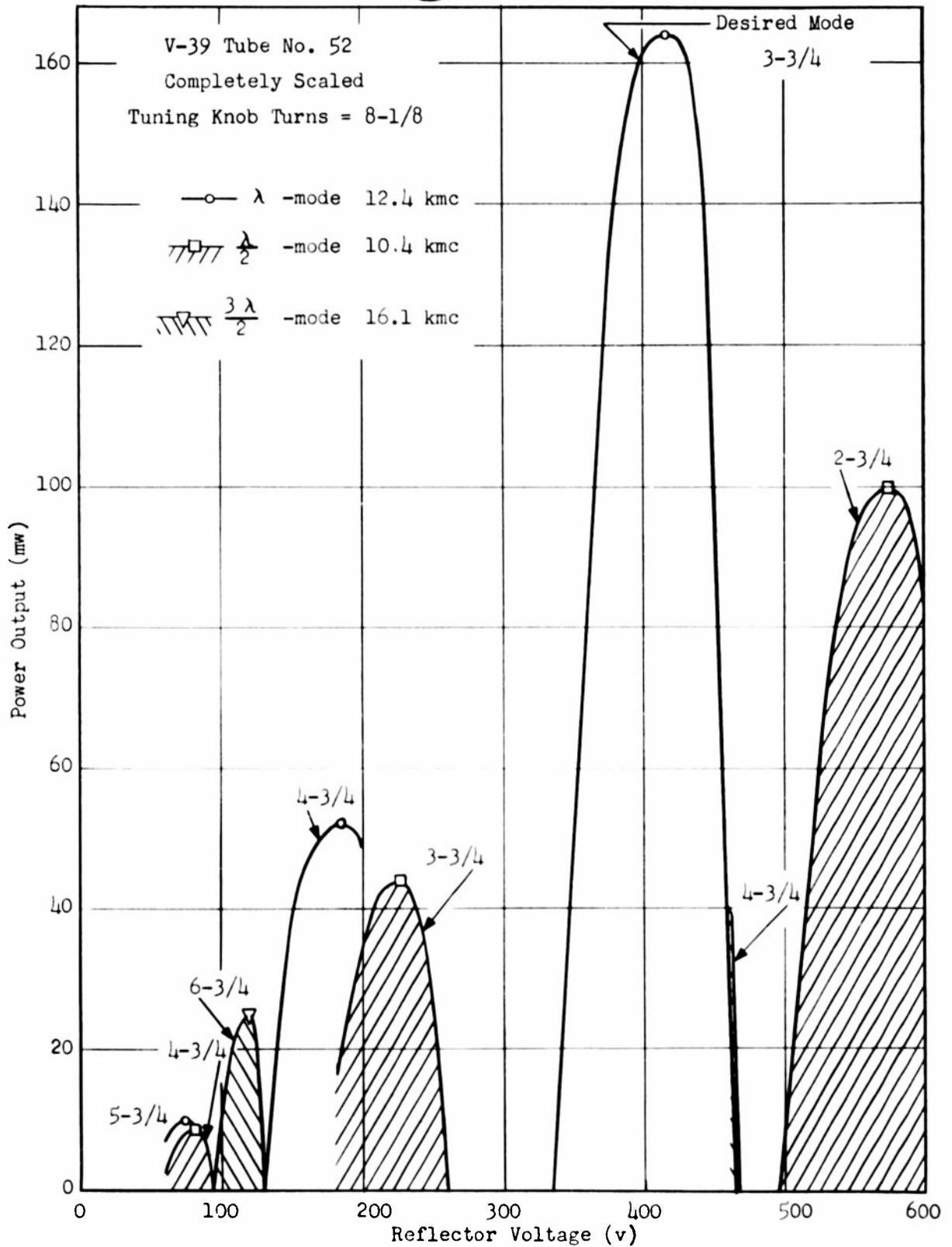


FIGURE 4

**POWER OUTPUT vs REFLECTOR VOLTAGE FOR V-39 NO. 52
 (TUNING KNOB TURNS = 8-1/8)**

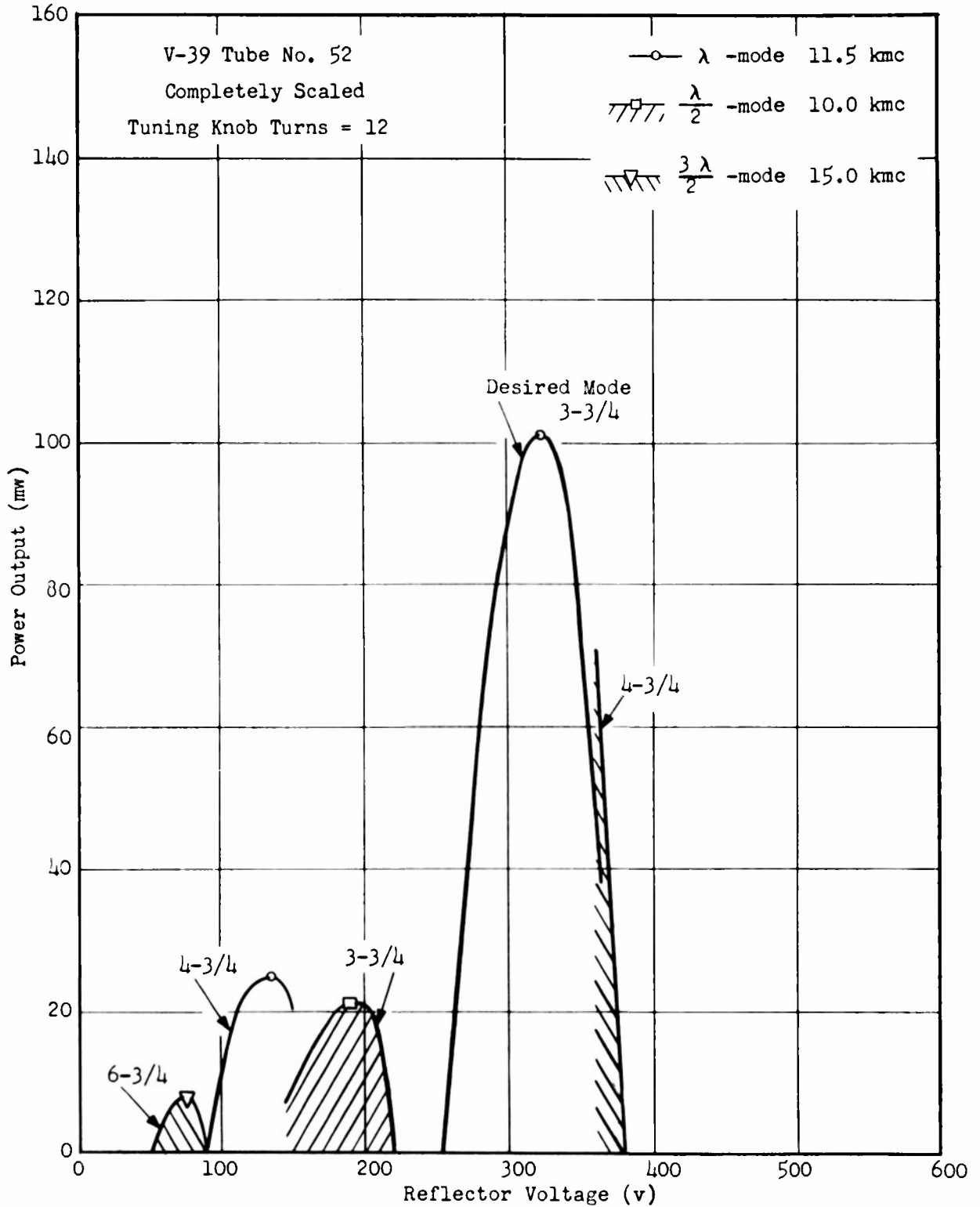


FIGURE 5
POWER OUTPUT vs REFLECTOR VOLTAGE FOR V-39 NO. 52
(TUNING KNOB TURNS = 12)

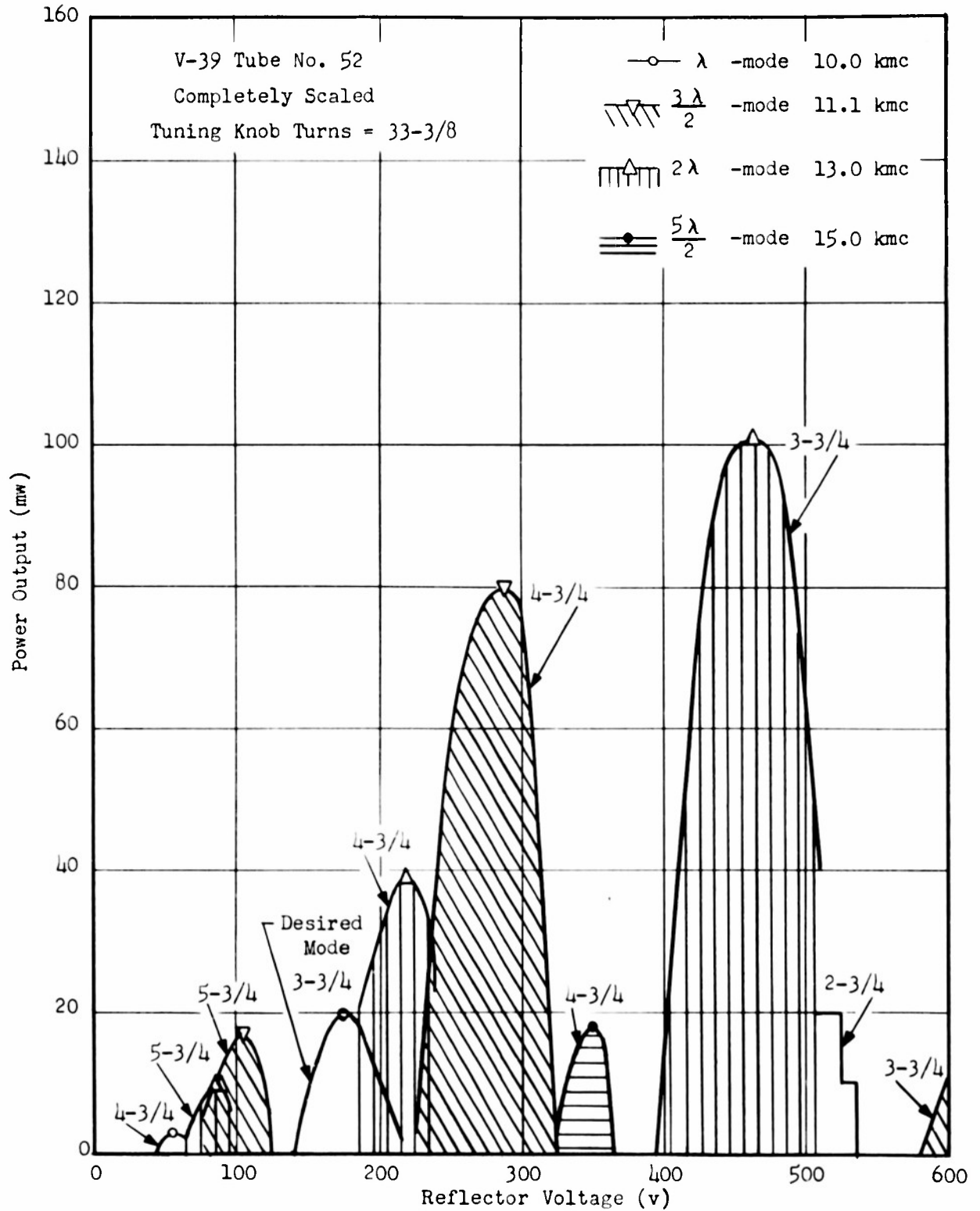


FIGURE 6
POWER OUTPUT vs REFLECTOR VOLTAGE FOR V-39 NO. 52
(TUNING KNOB TURNS = 33-3/8)

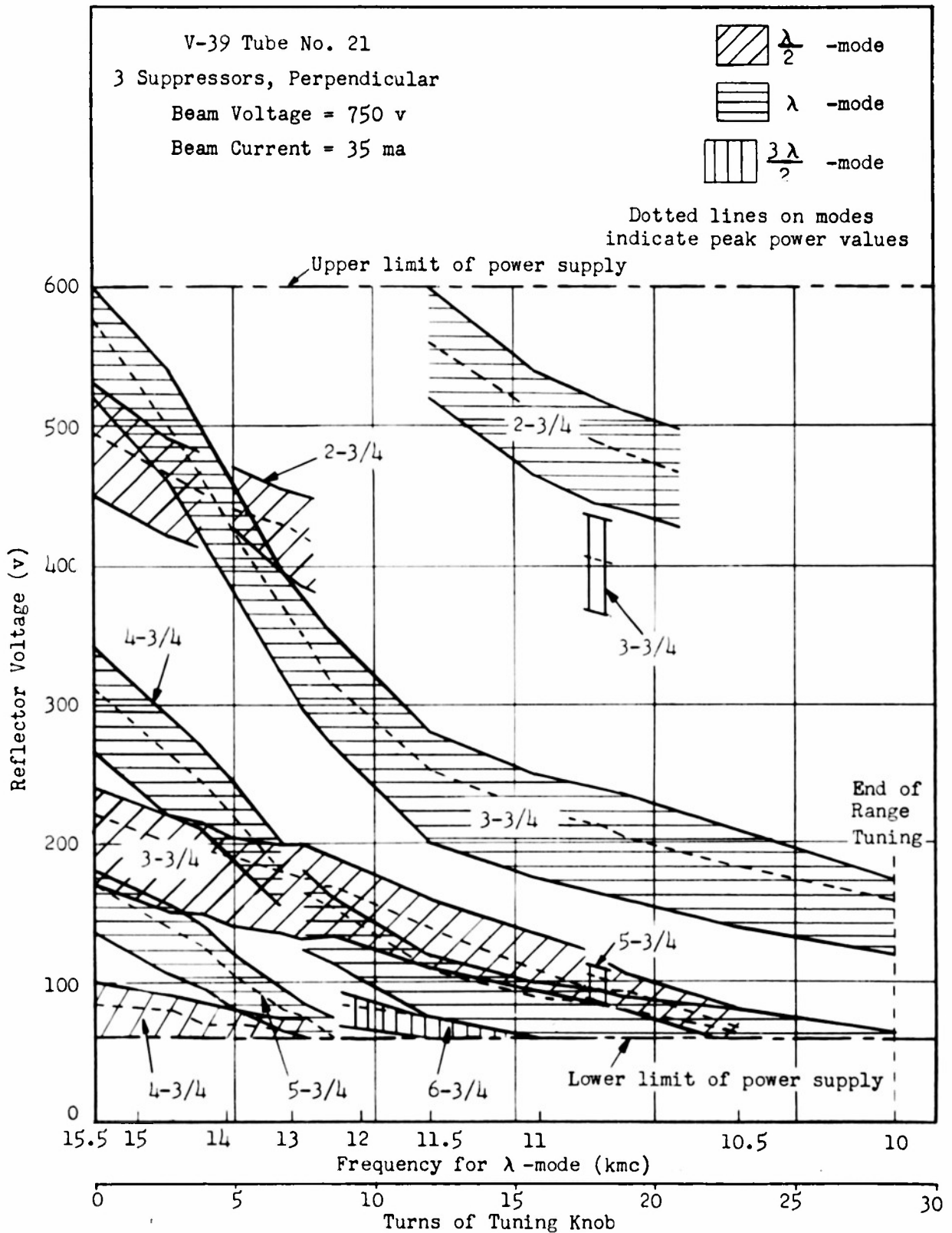


FIGURE 7
MODE PLOT FOR V-39 TUBE NO. 21

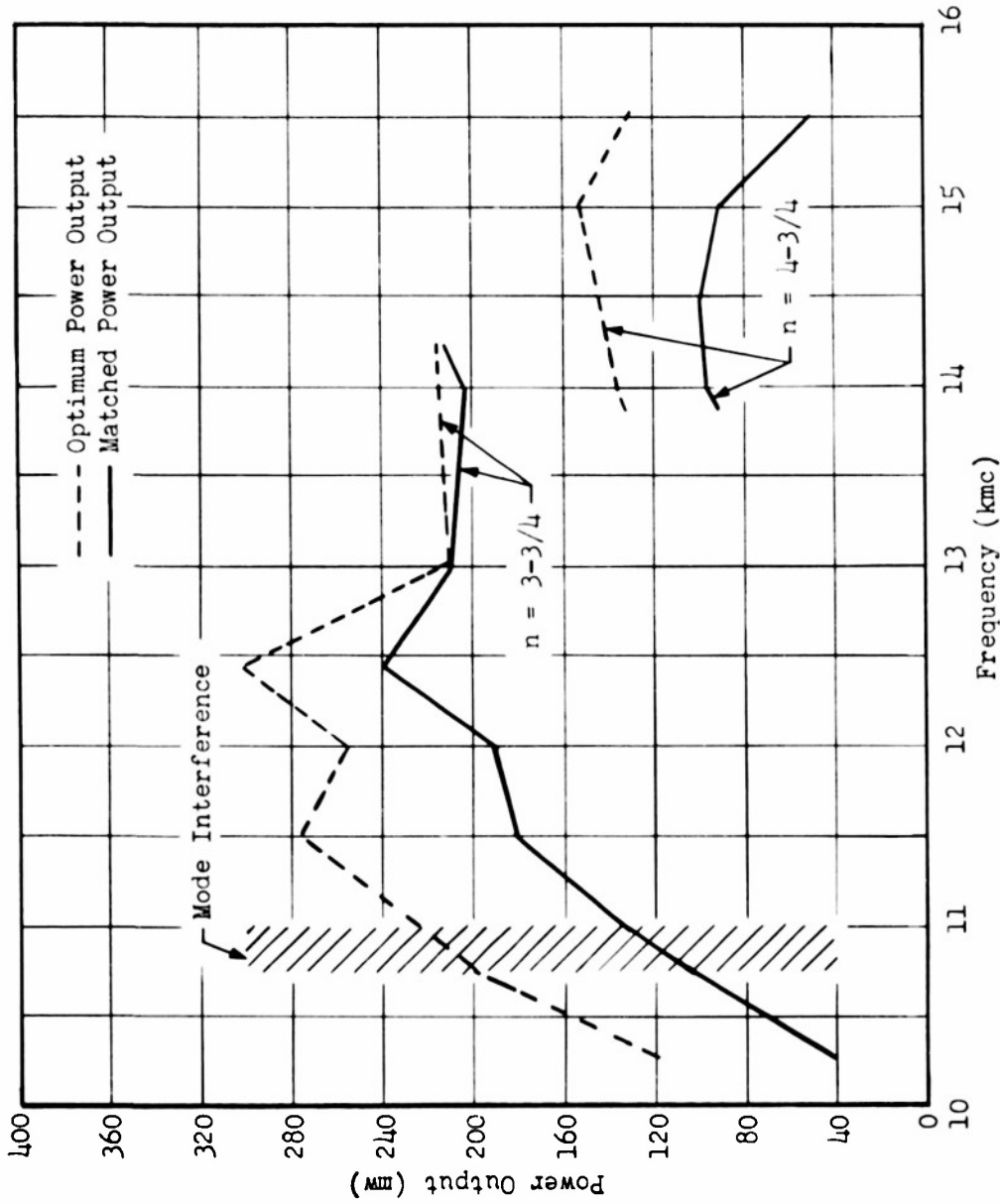


FIGURE 8
POWER CHARACTERISTICS OF COMPLETELY SCALED
V-39 TUBE NO. 52 IN A PREVIOUS V-39 CAVITY
USING ONLY THE LARGEST SUPPRESSOR ALONGSIDE

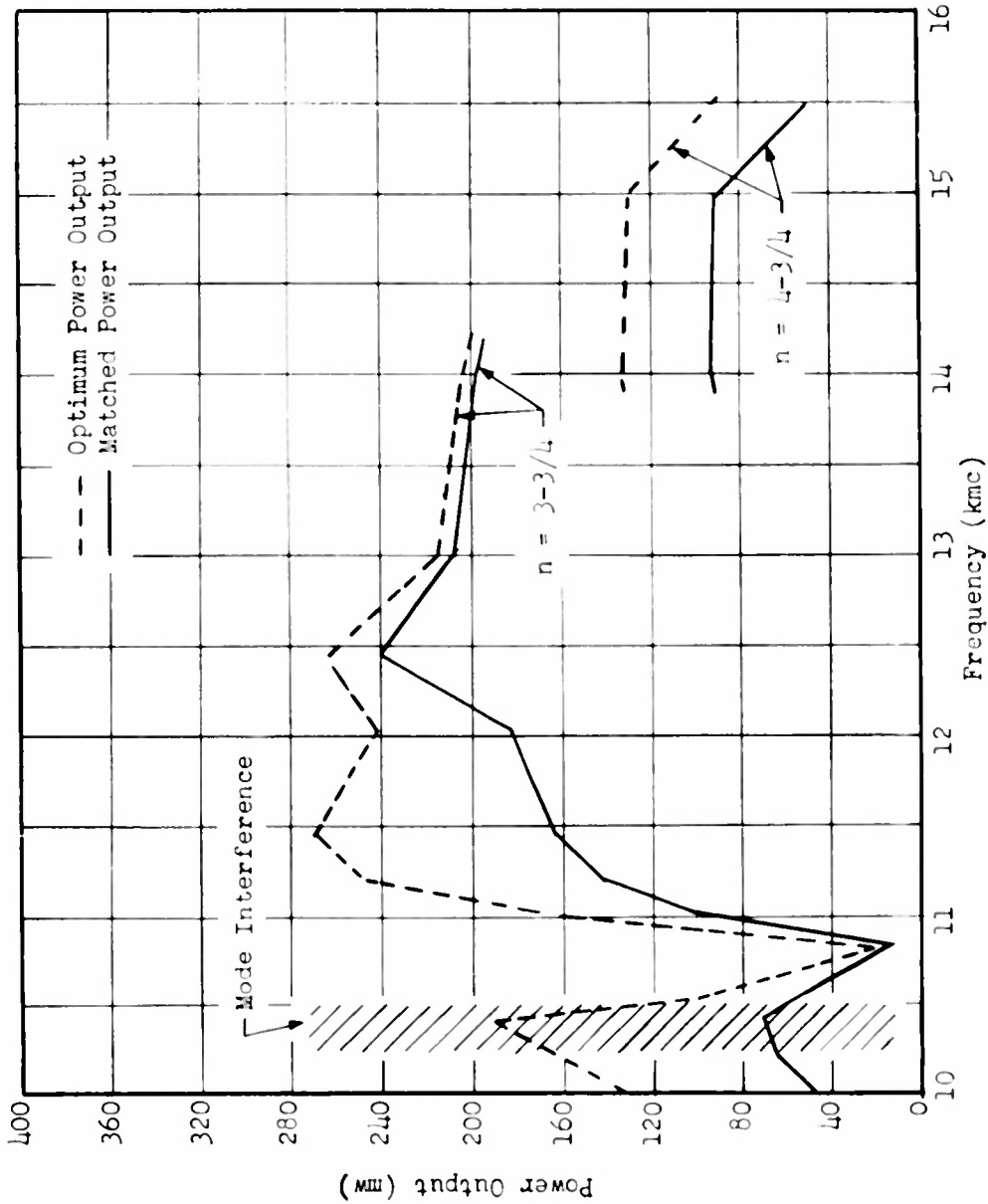


FIGURE 9
POWER CHARACTERISTICS OF COMPLETELY SCALED
V-39 TUBE NO. 52 IN A PREVIOUS V-39 CAVITY
WITH COUPLING HOLE MOVED

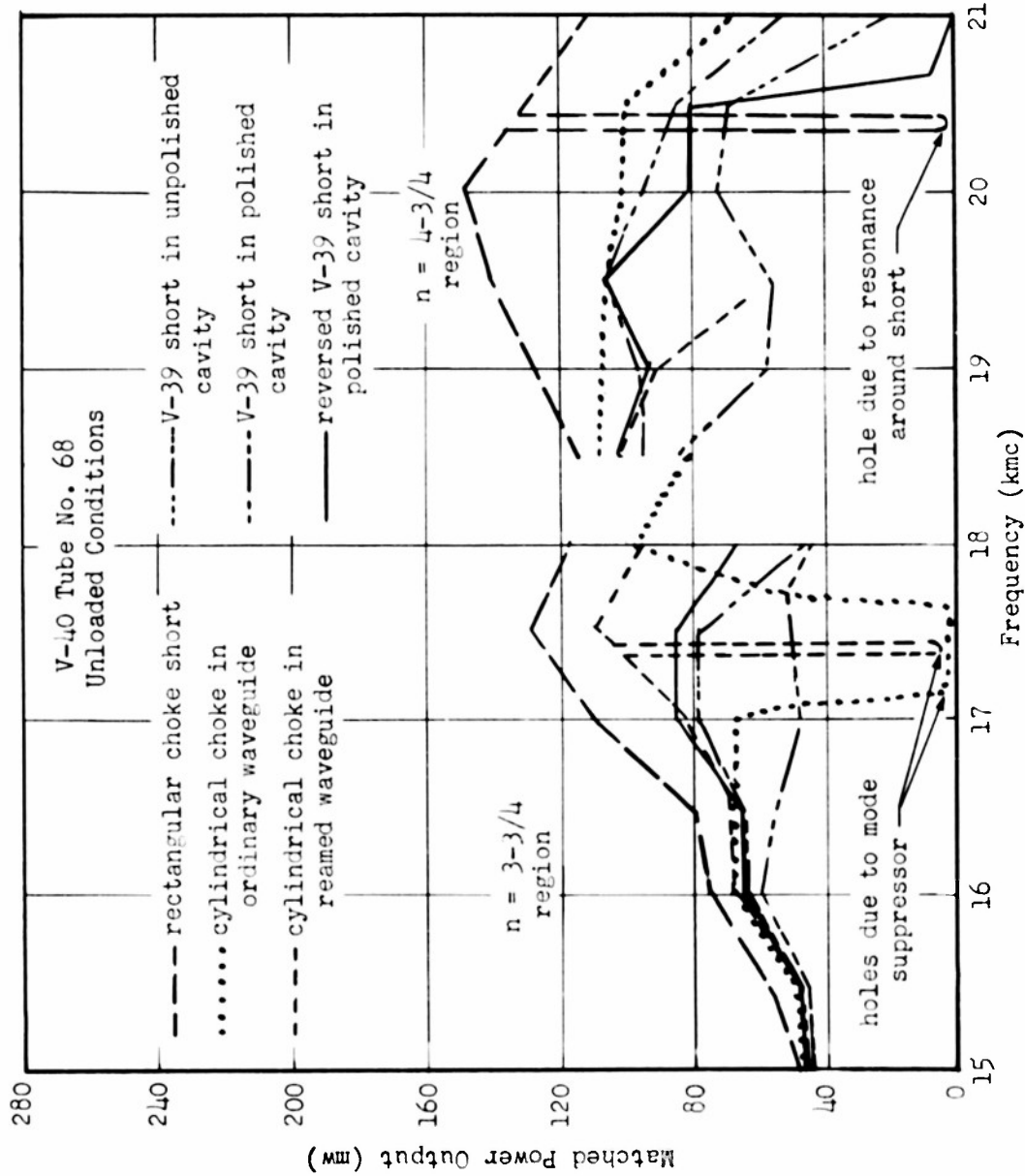


FIGURE 10
COMPARISON OF MATCHED POWER CHARACTERISTICS
USING DIFFERENT TYPE SHORTS

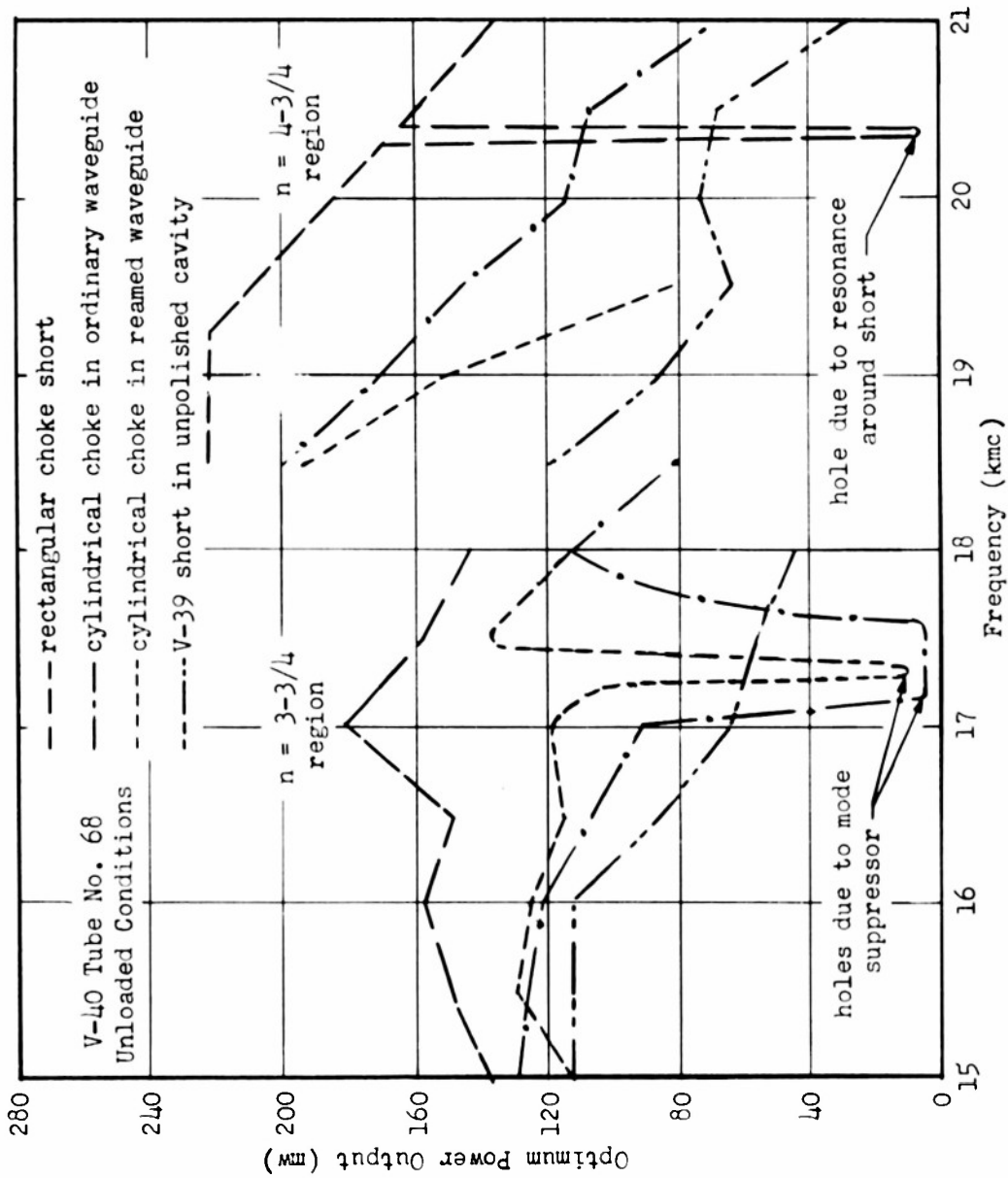
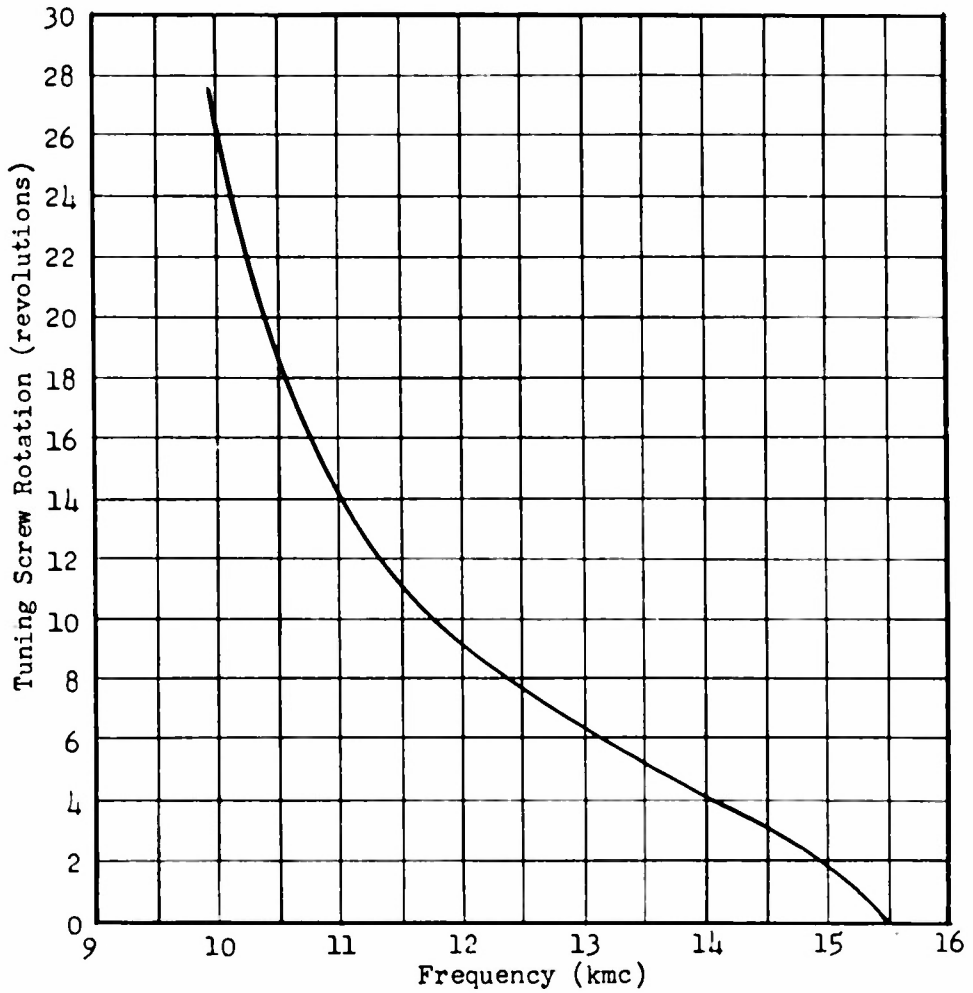
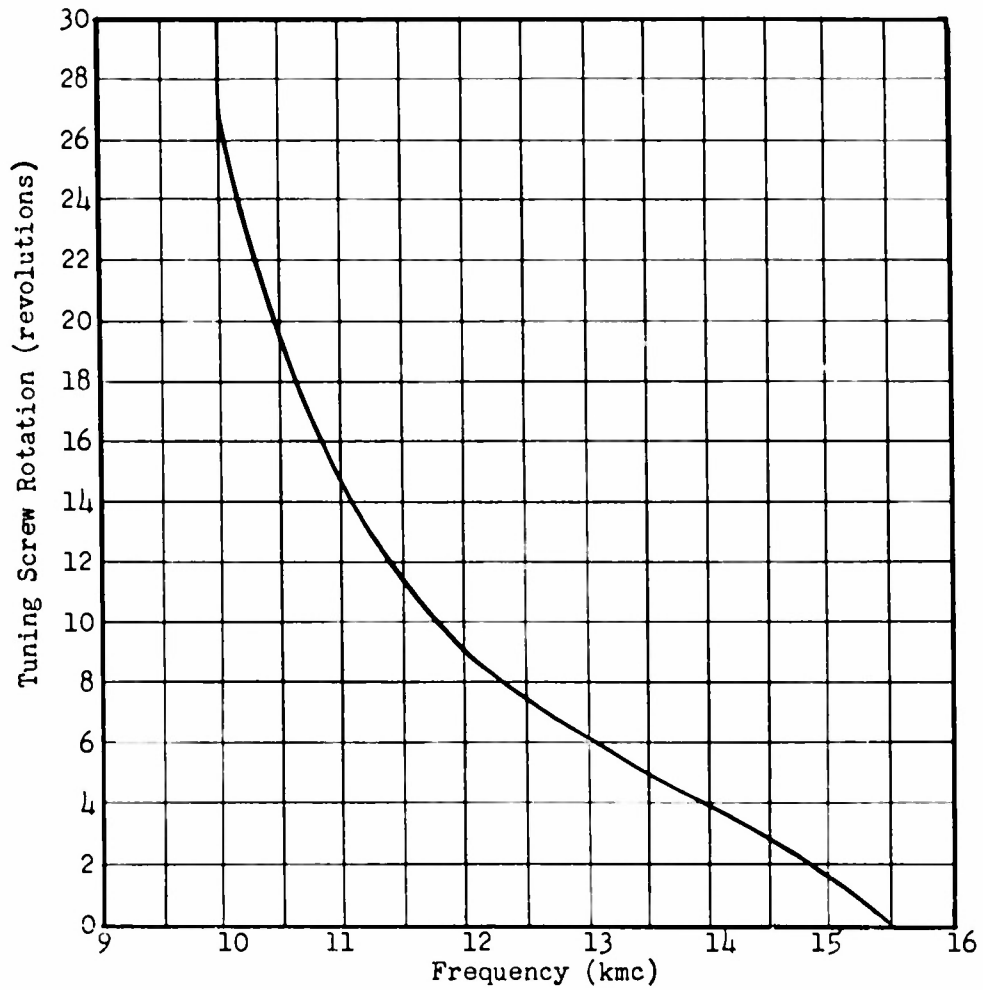


FIGURE 11
COMPARISON OF OPTIMUM POWER CHARACTERISTICS
USING DIFFERENT TYPE SHORTS



Reflector Mod. Sens. = 0.16 mc/volt at 12 kmc
FM Noise (all battery voltages on tube) = 3.0 kc
FM Noise (a-c voltage on heater) = 6.0 kc

FIGURE 12
TUNING CURVE FOR V-39 TUBE NO. 14



Reflector Mod. Sens. = 0.17 mc/volt at 12 kmc
FM Noise (all battery voltages on tube) = 2.0 kc
FM Noise (a-c voltage on heater) = 5.0 kc

FIGURE 13

TUNING CURVE FOR V-39 TUBE NO. 18

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