TENTATIVE DATA

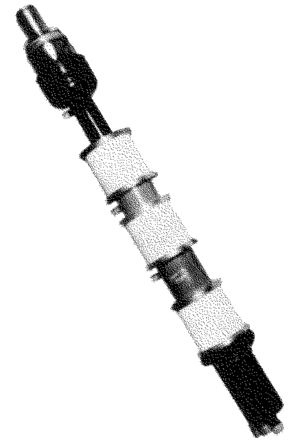
EITEL-McCULLOUGH, INC.
SAN BRUNO, CALIFORNIA

3K20,000LA
3K20,000LF
3K20,000LK

KLYSTRONS

●

L-BAND AMPLIFIERS



The Eimac 3K20,000LA, 3K20,000LF and 3K20,000LK klystrons are three cavity, magnetically focused power amplifiers intended primarily for UHF television broadcast service. Each klystron type, operating as a television visual r-f amplifier, will deliver 5.5 kW of peak synchronizing power output with a power gain of approximately 20 db. The cavities of the Eimac UHF television klystrons have ceramic windows and are completed by tuning boxes external to the tubes.

NOMINAL TUNING RANGE

The UHF television band (470-890 Mc) is covered by the three tube types as follows:

TUBE TYPE NUMBER	MC.	CHANNEL
3K20,000LA	470-580	14-32
3K20,000LF	580-720	33-55
3K20,000LK	720-890	56-83

GENERAL CHARACTERISTICS

MECHANICAL

Mounting (See Outline Drawing)	Support from Mounting Flange
Mounting Position	Axis Vertical
Cooling	Water & Forced Air
Connections:	
Filament	Flexible Leads
Cathode	Cylindrical Strap
Focus Electrode	Cylindrical Strap
Cavities	Multiple Contact Fingers
Collector	Cylindrical Strap

Klystron Type	"A"	"F"	"K"	
Maximum Overall Dimensions:				
Length	50	45	41	inches
Diameter	5⅛	5⅛	5⅛	inches
Net Weight	42	37	35	pounds
Shipping Weight	160	150	145	pounds

ELECTRICAL

Filament: Pure Tungsten		
Voltage	9.0	volts
Current (with cathode cold)	42	amperes
Current (with cathode at operating temperature)	39	amperes
Maximum Allowable Short Circuit Current of Filament Current Source	84	amperes

Cathode: Unipotential; heated by electron bombardment

MAXIMUM CATHODE RATINGS		
DC VOLTAGE	2300	MAX. VOLTS
DC CURRENT	.75	MAX. AMPERES
DC POWER	1600	MAX. WATTS

Focus Electrode
*Voltage (with respect to cathode) - 0 to —500 volts
Magnetic Field: Axial (See Magnetic Circuit Schematic)
Field Strength (approximately) - 120 gauss

*May be varied over a range of 0 to —500 volts if beam current control is desired.

ULTRA HIGH FREQUENCY POWER AMPLIFIER

MAXIMUM RATINGS

DC BEAM VOLTAGE	14.0	MAX. KILOVOLTS
DC BEAM CURRENT	1.7	MAX. AMPERES
COLLECTOR DISSIPATION	20.0	MAX. KILOWATTS

Note: Maximum beam voltage and beam current should not be applied without r-f excitation.

TYPICAL OPERATION

RF Linear Amplifier—Television Visual Service (In accordance with United States Federal Communications Commission Standards)

DC Cathode Bombarding Power	1400	watts
DC Cathode Bombarding Voltage (approximately)	2100	volts
DC Cathode Bombarding Current (approximately)	.66	amperes
DC Focus Electrode Voltage	0	volts
DC Beam Voltage	13	kilovolts
DC Beam Current	1.4	amperes
DC Collector Current (approximately)[1]	1.2	amperes
Peak Synchronizing Level (80% of saturation power)		
Driving Power (approximately)[2]	55	watts
Power Output	5.5	kilowatts
Efficiency	30	percent
Black Level		
Collector Dissipation (approximately)[1]	12.5	kilowatts
Driving Power (approximately)[2]	33	watts
Power Output	3.3	kilowatts
Efficiency	18	percent

RF Amplifier—Television Aural Service

DC Cathode Bombarding Power	1400	watts
DC Cathode Bombarding Voltage	2100	volts
DC Cathode Bombarding Current	.66	amperes
DC Focus Electrode Voltage	0	volts
DC Beam Voltage	10.0	kilovolts
DC Beam Current	.95	amperes
DC Collector Current[1]	.8	amperes
Driving Power[3]	20	watts
Collector Dissipation (approximately)[1]	5.8	kilowatts
Power Output	2.75	kilowatts
Efficiency	29	percent

[1] Minor tube-to-tube variations may be expected.

[2] Total driving power includes losses inserted for broadband operation. The output power is useful power measured in a load circuit.

[3] The driving power is the total power required by the tube and a resonant circuit.

Supersedes 3K20,000LK Data Sheet with Effective Date of 3-10-53.

APPLICATION

Mounting—The klystrons are provided with a mounting flange (See Outline Drawing) which may be used to support the tubes with either end up.

Filament Operation—For maximum tube life, the pure tungsten filament should be operated just above the emission limiting temperature. This temperature will be obtained with a filament voltage, as measured directly at the terminals, of approximately 9 volts.

Cathode Heating Power—The cathode is unipotential and heated by electron bombardment. A dc potential of approximately 2100 volts is applied between the filament and the cathode; and the recommended cathode heating power of 1400 watts is obtained with approximately .66 amperes. The filament is designed to operate under space-charge limited conditions. Cathode temperature is varied by changing the bombarding potential between the filament and the cathode.

Cooling—Forced air is used to cool the Electron Gun Structure and the Middle and Output Cavities. Only clean, well filtered air should be blown on the tube to avoid voltage breakdown due to dust accumulation. The temperature of the metal in the region of the metal-to-glass seals should not exceed 150°C. Tube temperatures may be measured with a temperature-sensitive paint, such as "Tempilaq", manufactured by the Tempil Corporation, 132 West 22nd Street, New York 11, N. Y.

Water is used to cool the Drift Tubes and the Collector Assembly. The cooling water should be of sufficient purity to prevent liming of the water system, and the use of a heat exchanger is recommended. The inlet water pressure of the Drift Tubes and the Collector Assembly should not exceed 40 pounds per square inch. The outlet water temperature must not exceed a maximum of 70°C. under any condition.

Air and water flow should be started before the filament and cathode power are applied and maintained for at least two minutes after the filament and cathode power have been removed.

Klystron Cooling Requirements for Typical Operating Conditions and Correct Magnetic Field Adjustment:

	Cooling Medium	Volume	Pressure Drop	Remarks
Input Drift Tube - -	*Water	1 gpm	1 psi	Total pressure drop if series connected with 5/16" tubing= 4 psi.
Short Drift Tube Jacket	*Water	1 gpm	1 psi	
Long Drift Tube Jacket	*Water	1 gpm	1 psi	
Output Drift Tube -	Water	1 gpm	1 psi	
Collector Assembly -	*Water	6 gpm	3 psi	

Electron Gun Structure	Filament Stem -	Air	1-2 cfm	See Cooling Diagram
	Cathode Terminal -	Air	90 cfm	
	Focus Electrode and Anode Seals -	Air	90 cfm	
Input Cavity - - - -		None		
Center Cavity - - - -		Air	15 cfm	
Output Cavity - - - -		Air	50 cfm	

*Cooling water connections should be made as noted on Cooling Diagram.

RF Contact Surfaces—The means by which contact is made between the cavities and the tuning boxes is of great importance. Two requirements which must be met to ensure proper electrical connections are as follows:

(1) Contact to the tube cavities must be made only on the peripheral surface of the 1/4" cavity flanges as shown on the outline drawing.

(2) Each individual finger of the collet or spring stock material must make positive contact to the cavity flange to prevent arcing.

Magnetic Field—An adjustable magnetic field is necessary to control and direct the beam throughout the length of the drift tube. The magnetic field should be capable of variation around the recommended field strength of 120 gauss. Typical magnetic circuit requirements for a 3K20,000LK are shown in the Magnetic Circuit Schematic. The current and adjustsment of the pre-focusing coil are optimized under low beam voltage conditions and will require minor readjustment with changes in beam voltage. The current and location of the focusing coils should be capable of independent adjustment. Readjustment of the current of the focusing coils is necessary with changes in beam voltage. Beam transmission (collector current divided by the beam current as measured in the cathode return to beam power supply) will vary from 75% to 95%. Improper adjustment or misalignment of the magnetic field, as indicated by too low a value of beam transmission, may cause the beam to strike and overheat the drift tube walls.

MAGNETIC FIELD COIL REQUIREMENTS

Number of Coils Required for Field Strength of Approximately 120 Gauss.

	Pre-focusing Coil	Focusing Coils	
Tube Type	375-750 ampere-turns per coil	1600-4800 ampere-turns per coil	0-1600 ampere-turns per coil
3K20,000LA -	1	3	1
3K20,000LF -	1	3	1
3K20,000LK -	1	2	1

CAUTION—It is convenient to operate the r-f and collector portions of the tube at ground potential. Since the cathode and filament are operated at high negative potentials with respect to ground, filament and cathode power supplies and voltmeters must be adequately insulated for these high voltages. Protection must also be afforded to operating personnel.

Protection—It is recommended that the following protective devices be used:

(1) Interlocks in air and water supplies.

(2) Interlocks in magnetic field supply circuits.

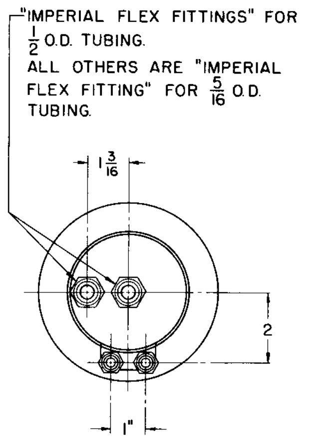
(3) Current overload in cathode bombardment supply circuit.

(4) Current overload in beam current supply circuit.

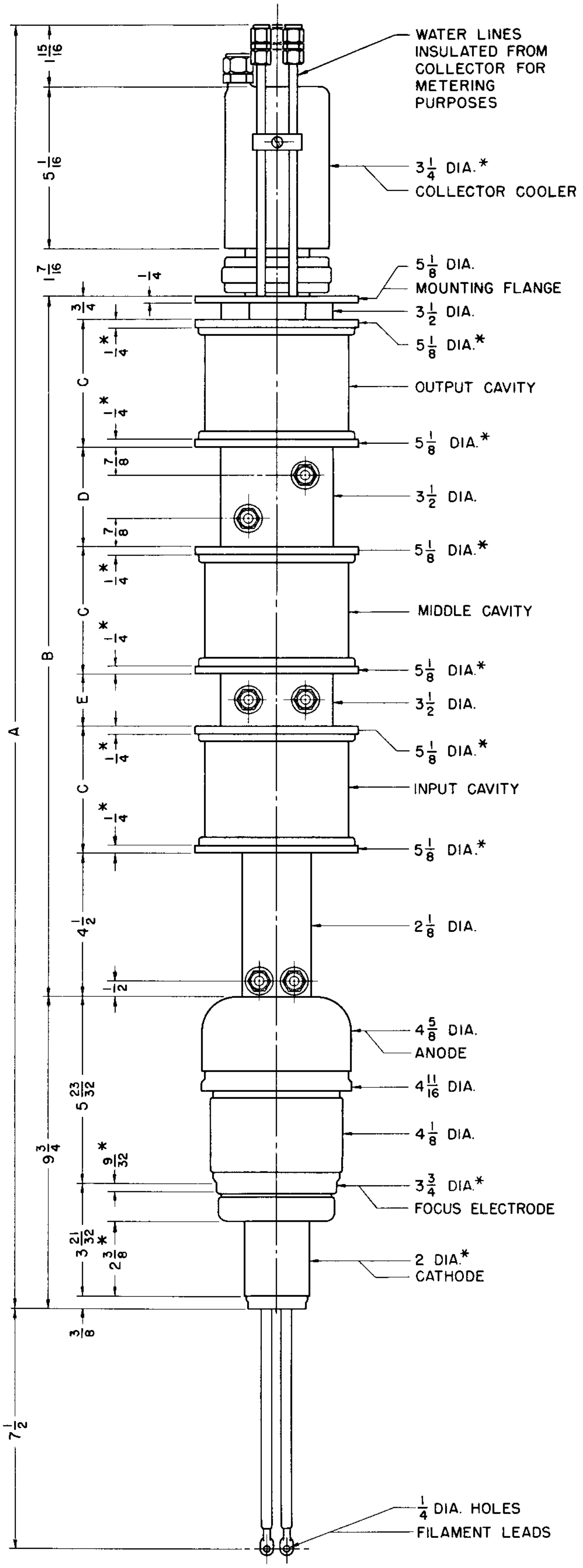
(5) Current overload in cavity current circuit.

(6) Current limiting resistor of approximately 100 ohms in series with beam power supply to isolate tube from final capacitor of supply.

The filament and cathode bombardment voltages will normally be applied before the beam voltage. Cavity tuning or magnetic field adjustment should be made with reduced beam voltage (1/2 to 2/3 normal). Slight retuning and readjustment will be necessary when beam voltage is raised to full value.



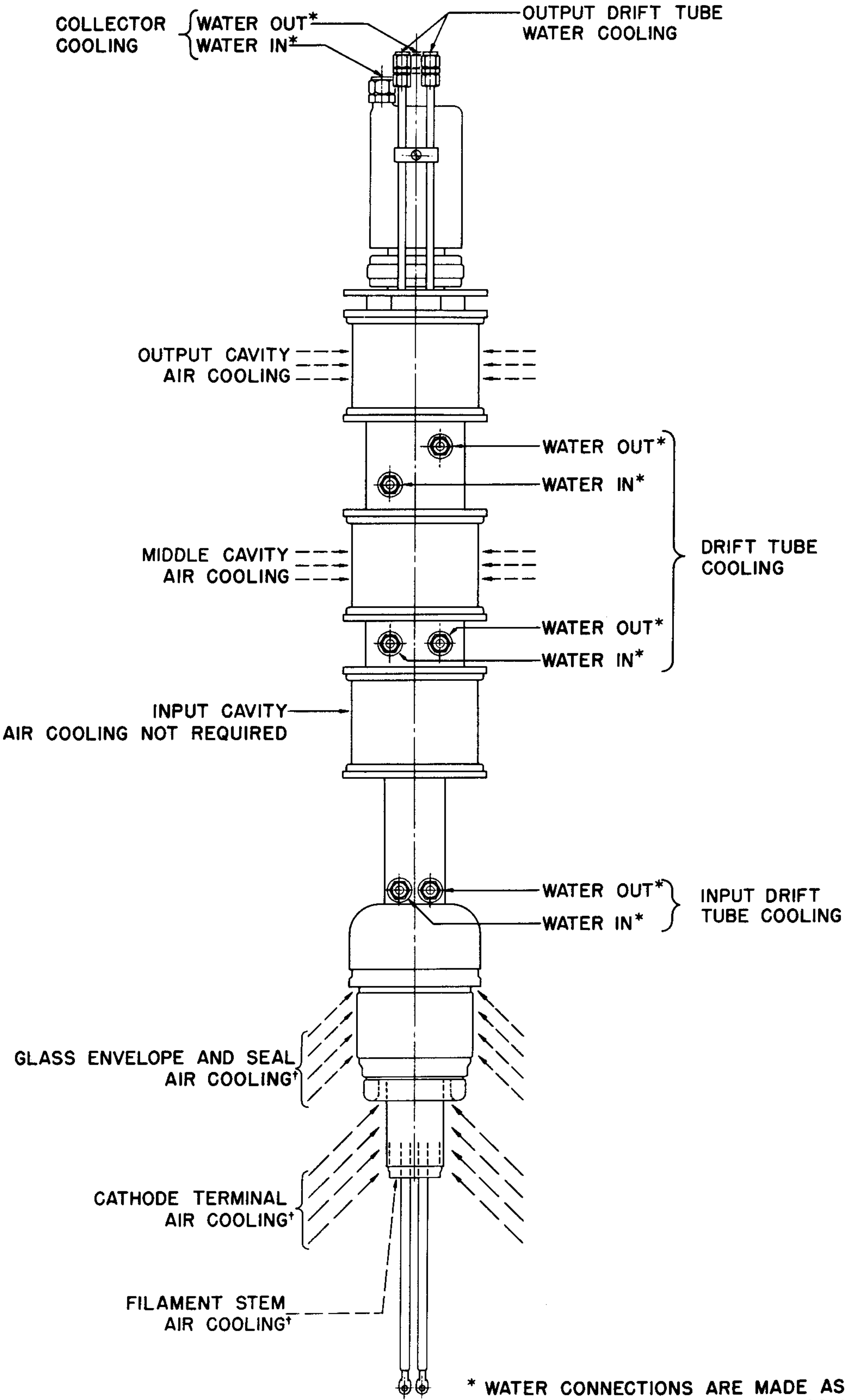
OUTPUT END VIEW



		A	B	C	D	E
3K20,000	LA	48 11/16	30 1/2	6	4 7/8	2 3/8
	LF	44 3/16	26	5	3 3/4	2
	LK	40 3/16	22	4	3 1/8	1 5/8

DIMENSIONS IN INCHES

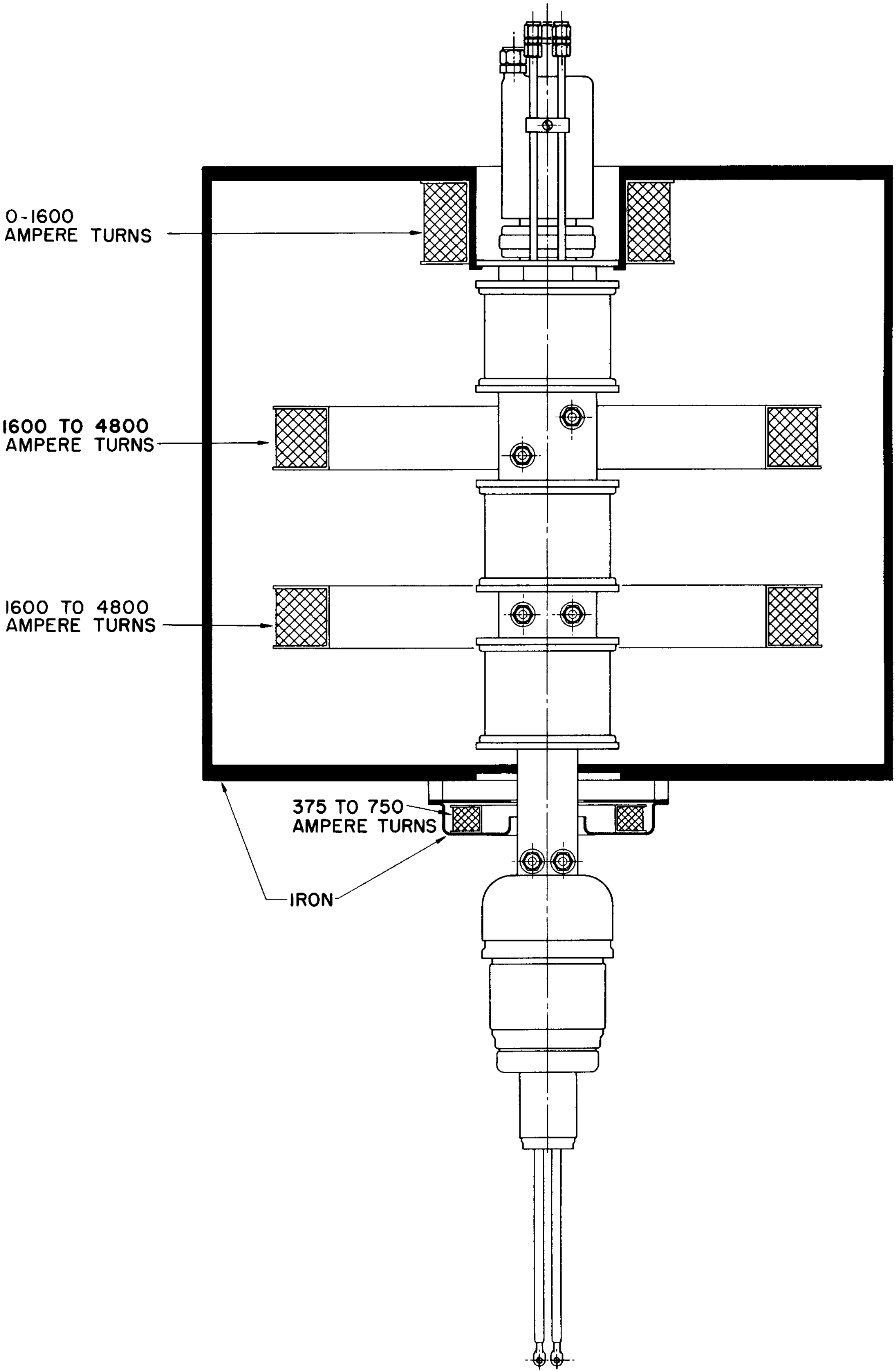
*CONTACT SURFACE



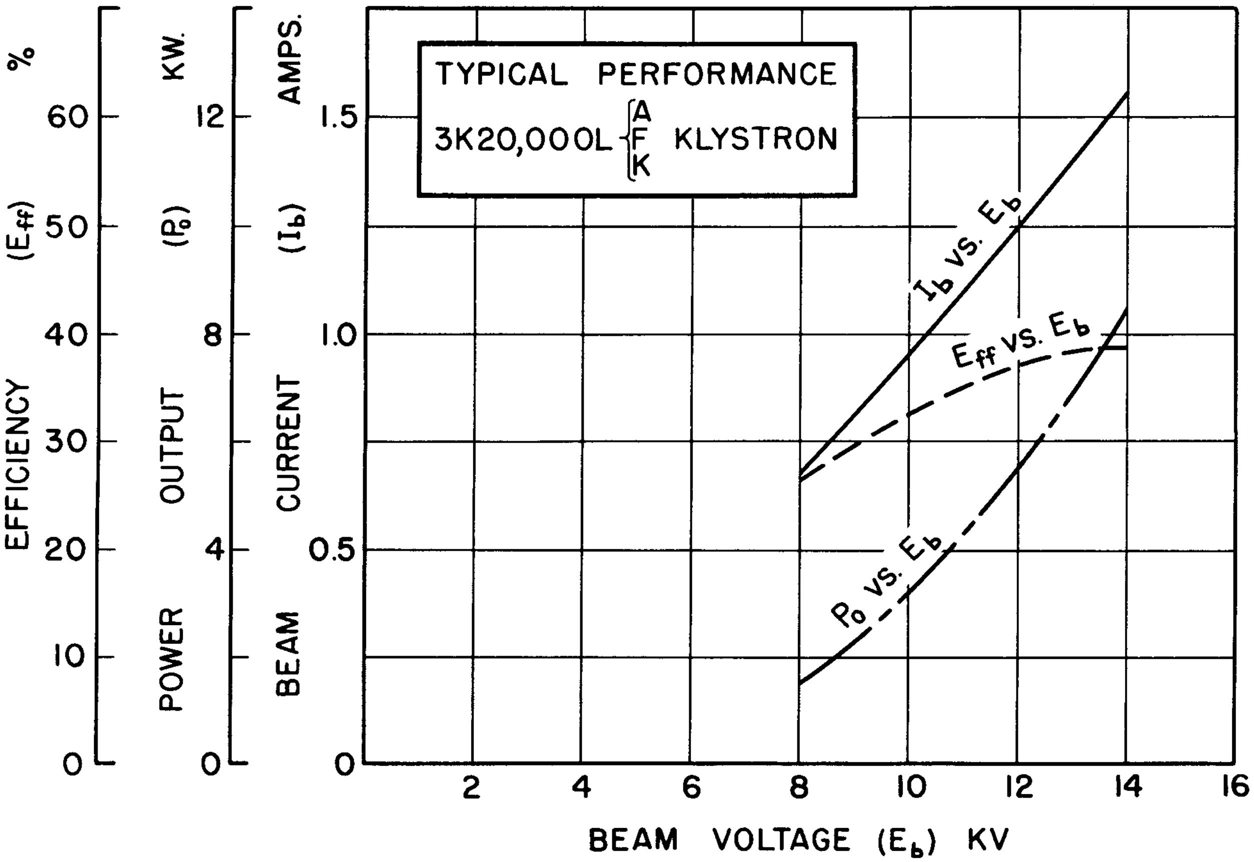
† THIS COOLING MAY BE SUPPLIED BY A SINGLE BLOWER THROUGH SUITABLE MANIFOLD & BAFFLES

* WATER CONNECTIONS ARE MADE AS SHOWN WHEN TUBE IS MOUNTED WITH COLLECTOR UP. WHEN TUBE IS MOUNTED WITH ANODE UP THE WATER CONNECTIONS MUST BE REVERSED.

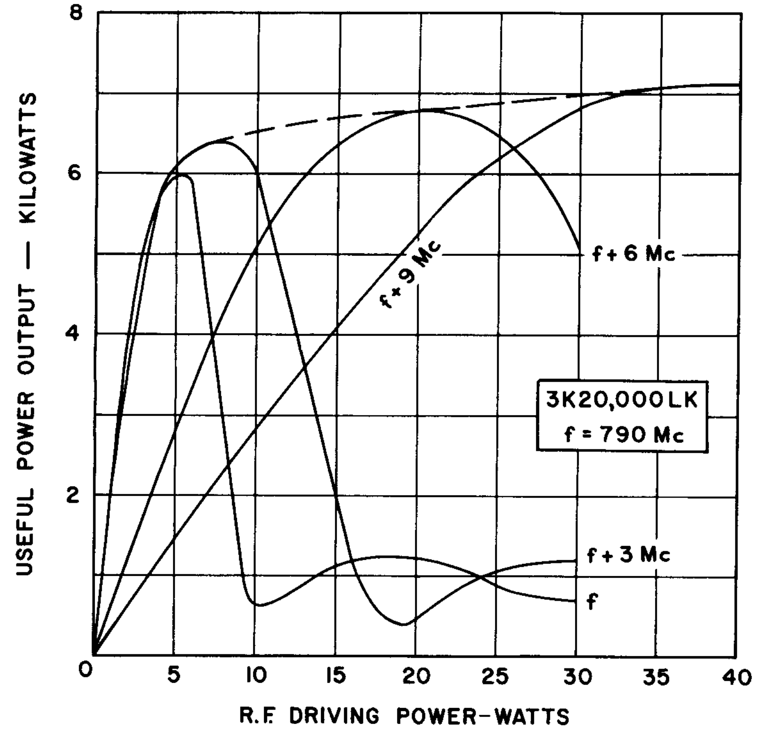
COOLING DIAGRAM



MAGNETIC CIRCUIT SCHEMATIC FOR 3K20,000LK



BEAM CURRENT, POWER OUTPUT AND EFFICIENCY VERSUS BEAM VOLTAGE



USEFUL POWER OUTPUT VS. R.F DRIVING POWER

(MIDDLE CAVITY DETUNED; INPUT & OUTPUT CAVITIES TUNED TO DRIVE FREQUENCY)

2-G3-71963

High-Power Klystrons at UHF*

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Summary—**A brief history of high-power cw klystron development and a classification of types of klystron are followed by a description of the three-cavity, gridless klystron amplifier with magnetic focusing, in general terms, and the Eimac 5-kw klystron for UHF-TV in more detail. This tube has cavities which are partly outside the vacuum system and contain ceramic "windows." The advantages of the klystron over the conventional negative-grid type of tube are reviewed from the standpoint of performance, and the main operational features are noted.**

INTRODUCTION

IN VIEW OF the increasing activity above 450 mc for such purposes as television, it may be of value to review the means of generating transmitter power presently available.

Of outstanding interest in this field is the post-World War II development of power amplifier klystrons. Although the klystron principle was discovered as far back as 1939,[1] its application to high-power generation was delayed, largely because of the 1939–1945 war and the need to concentrate on those lines of development which appeared the most promising for military purposes. The ultimate possibilities of the klystron were appreciated by few, and although a great deal of fundamental research on electron beams was carried on in various places, development in the field of high-power cw tubes was confined mainly to one group in California,[2,3] and one group in France.[4,5] As a result of this work the basic principles have been extended, and much progress has been made in techniques of construction, culminating in the recent appearance of high-power klystrons for commercial purposes in the United States,[2,6] and an increasing awareness of the great advantages of this type of tube for stable amplification at high-power levels.

The object of this paper is to review, briefly, from the point of view of the potential user, the performance of a modern high-power klystron, and to describe the special peculiarities and methods of operation of this type of tube. A brief survey will also be made of the factors limiting the performance of a klystron, compared with the factors limiting the performance of conventional negative-grid tubes.

KLYSTRON TYPES

Present-day klystrons fall into three categories:

1. *Reflex Klystron Oscillators*
   Most of these have low efficiency (of the order of 1 per cent) and generate relatively low power, and are suitable for receivers, local oscillators, test equipment, and the like.
2. *2-Cavity Klystrons*
   These may be used as amplifiers, oscillators, or frequency multipliers; as amplifiers they are capable of power gains of about 13 db and efficiencies of about 20 per cent, at frequencies of the order of 1,000 mc.
3. *3-Cavity Klystrons*
   These are useful, principally, as amplifiers, and are capable of power gains of about 20 to 30 db, and efficiencies of 30 to 40 per cent, together with bandwidths of several mc, at frequencies of the order of 1,000 mc. Because of the superior amplifier performance given by this type of klystron, the other two types will not be dealt with further in this paper.

3-CAVITY GRIDLESS KLYSTRON AMPLIFIER WITH MAGNETIC FOCUSSING

A. Description

This type of tube, sometimes called a "cascade amplifier," is illustrated schematically in Fig. 1. It will be seen to consist of four essential parts:

1. *The Electron Gun*
   This has a source of electrons (the cathode), a means of accelerating the electrons to a high energy level (the anode), and a means of focussing the electrons into a parallel beam of high electron density emerging from the hole in the anode.

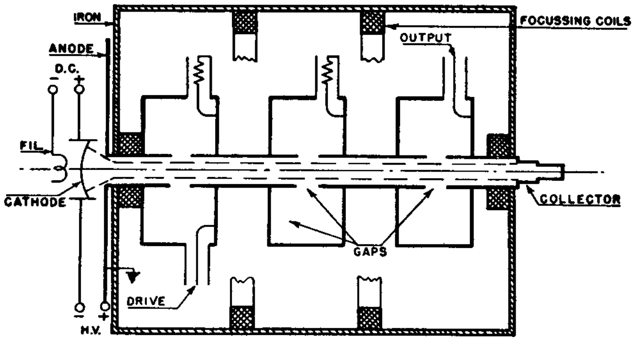

Fig. 1—Schematic diagram of 3-cavity klystron with magnetic focusing.

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* Decimal classification: R339.2×R583.6. Original manuscript received by the Institute, November 3, 1952.

† Eitel-McCullough, Inc., San Bruno, Calif.

[1] R. H. Varian and S. F. Varian, "A high frequency oscillator and amplifier," *Jour. Appl. Phys.*, vol. 10, p. 321; 1939.

[2] "High Power UHF Klystron," *Tele-Tech*, p. 60; October, 1952.

[3] W. C. Abraham, F. L. Salisbury, S. F. Varian, and M. Chodorow, "Transmitting Tube Suitable for UHF TV," paper presented at IRE National Convention; 1951.

[4] P. Guénard, B. Epsztein, and P. Cahour, "Klystron Amplificateur de 5 KW à large bande passante," *Ann. Radioelect.*, vol. VI, p. 24; 1951.

[5] R. Warnecke and P. Guénard, "Tubes à Modulation de Vitesse," Gauthier-Villards, Paris; 1951.

[6] J. J. Woerner, "A High Power UHF Klystron for TV Service," paper presented at IRE National Convention; 1952.

2. *The RF Resonant Cavities and Drift Tubes*
   The first cavity is fed with RF energy from a driving source at low level. The second cavity is tuned to resonance, or near resonance, but is not fed with energy from outside. The function of these two cavities, in conjunction with the drift tubes, is to velocity-modulate the electron beam so as to produce "bunches" of electrons at the output cavity. The latter is tuned to resonance and coupled to the antenna, or other load, and serves to extract as much RF energy as possible from the "bunched" electron beam. Its function and operation are closely similar to those of the output circuit of a Class "C" amplifier using triodes or tetrodes.
3. *The "Collector" Electrode*
   This collects the electrons after they have passed through the output cavity, and have given up part of their energy to the RF field, and thus to the load; because only about 30 per cent of the energy in the beam is converted to RF energy, this collector has to be capable of dissipating the remaining percentage, that is to say, 70 per cent of the product of the anode-cathode voltage and cathode current, when fully driven. (In practice the collector current is very slightly less than this because some electrons inevitably strike the anode and the drift-tube walls.) If the tube is used as a linear modulated amplifier, the collector will be required to dissipate 100 per cent of the input power under conditions of zero drive and zero output.
4. *External Magnetic Circuit*
   This consists of suitably disposed electromagnets producing an axial magnetic field of controllable strength which tends to keep the beam parallel as it passes along the tube. Without this field the beam would expand because of the mutual repulsion of the electrons. The optimum field strength is fairly critical, and is not necessarily uniform along the length of the tube. It is usually prevented from penetrating the cathode, either by a metallic magnetic shield or by the use of a "bucking" coil, or by a combination of both.

B. Performance and Operational Features of This Type of Klystron

The 3-cavity klystron is a tube capable of generating a much larger power output at uhf than the conventional negative-grid tube. The deterioration of performance as the frequency is raised is slight. The power gain of the klystron is very much larger than that of a tetrode. It may be worthwhile to review briefly the reasons for this.

Considering the factors limiting the power output of a triode or tetrode, aside from external circuit losses, one finds that basically they are the total cathode emission, the anode voltage, the interelectrode spacing, and the RF loss in the materials used to make the electrodes and the envelope. Now the total cathode emission, assuming the best material is used and that a given life is required, depends on its area. This area is limited at uhf because the tube forms part of a resonant transmission line in which large changes of electric and magnetic field occur over distances which are small compared with the wavelength. Since nonuniform potentials between electrodes cause loss of efficiency, it is necessary to keep the electrode dimensions small compared with the wavelength; thus, the cathode area is limited, and has to be reduced as the wavelength is decreased. The anode voltage is limited by internal flash-arcs between electrodes. The electrode spacing must, however, be small enough to give small electron transit times, and must be decreased with the wavelength. The applied voltage must, therefore, be reduced also with the wavelength. Lastly, the RF losses in the tube materials increase as the wavelength decreases. All these factors added together give the well-known result that triodes and tetrodes get rapidly smaller as the wavelength decreases, and so does the power they will generate and the efficiency. In addition, the problem of manufacture becomes more and more serious, and ultimately becomes prohibitive. The two worst problems are caused by the small spacing between electrodes, of the order of 0.001 inch, and the mechanical weakness of the fine wire grids.

Considering now the power gain, this becomes less as the wavelength decreases because the tube requires more and more driving power to overcome the increasing electron transit-time effects, losses in materials, grid current, and (usually) inherent negative feedback.

In a klystron, on the other hand, some of these limitations do not occur at all, and others are less significant. The cathode area is not limited by the wavelength because it is outside the RF field. The anode-to-cathode spacing being of the order of 1 inch, extremely high anode voltages may be applied without internal flash-arcs; also, the cavity gap spacings may be about $\frac{1}{2}$ inch in a 5-kw tube at 1,000 mc. Again, because gridless gaps may be used without serious loss of coupling between the beam and the resonant cavities, there are no problems of fabrication or heating of grid wires. Furthermore, because the collector is outside the RF field, it may be designed solely for the purpose of dissipating heat, and this becomes a minor problem in practice. The losses in the conductive tube materials are small because all the metal parts carrying RF current may be made of high-conductivity metal. (There is no loss comparable to the RF losses in a triode due to RF current flowing through lossy cathode material or fine resistive grid wires.) Therefore, the only limiting factor approached in klystrons giving adequate power for present commercial applications is the loss in the dielectrics. Some dielectrics are inevitable either in the form of windows in the cavities, as in the Eimac tube, or in the other type of tube with integral cavities, the window between the output cavity and the load. If the power level is raised high enough, these dielectrics will ultimately break down, either by cracking due to heat or by flashing over the outside surface which is at atmospheric pressure; however, this does not occur in a well-designed tube at power levels that are presently interesting.

Considering the power gain of a klystron, this is governed almost entirely by the geometry and is limited only by the small RF losses in the input cavity and the beam loading of the cavity, which is small. The transit-time loading experienced with a triode becomes a factor of minor importance, and the negative feedback disappears since there is no coupling between the input and output cavities.

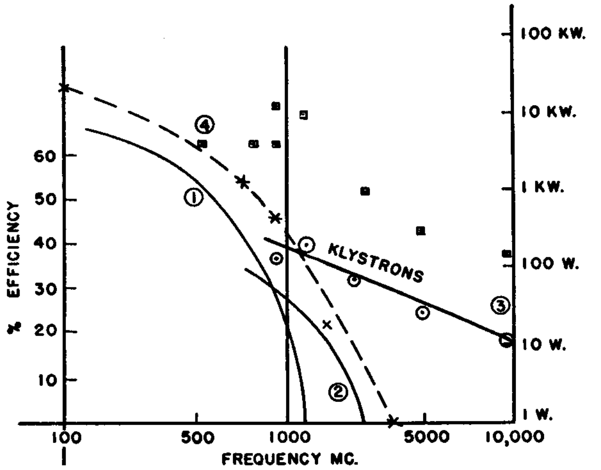

Fig. 2—Curve (1): Efficiency versus frequency for typical uhf tetrode —4X150G. (Plate dissipation 150 watts.)
Curve (2): Efficiency versus frequency for typical uhf triode —2C39. (Plate dissipation 100 watts.)
Curve (3): Typical efficiency of klystrons versus frequency (independent of output power). This is the efficiency at the optimum frequency for each tube.
Curve (4) (dotted): Maximum power output of the largest commercially available negative-grid tube at various frequencies.
Points ☐ cw power output of various klystrons (not the largest possible).

It is, therefore, apparent that the efficiency and power gain of a klystron will fall off relatively slowly, compared with a triode or tetrode, as the wavelength is reduced. This is illustrated by the curves in Fig. 2. It is also clear that the maximum size and power output of a klystron are not determined by the wavelength. It follows that the klystron is ideally suited to high-power generation at uhf and microwave frequencies, and outclasses the conventional type of tube in every respect, including ease of manufacture.

Turning now to a typical performance obtainable from a 3-cavity klystron, the results given by the Eimac tube may be taken as representative of this type of tube. This tube will generate 5 kw of RF power in the uhf television band with an efficiency of more than 30 per cent when fully driven. The over-all bandwidth is about 5 mc and the power gain, under television conditions, is about 20 db. Salient features of operation are these:

The tuning of each of the 3 cavities is independent of the others since there is no feedback present. This makes for very simple lining-up procedure.

The output cavity is tuned to resonance at the mid-band frequency, and loaded for optimum performance by means of some variable coupling device external to the tube.

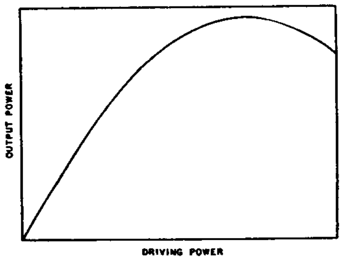

Fig. 3—Output power versus driving power for klystron.

A curve of power output against power input for this type of tube is a Bessel function of the first order and the first kind, and the first part of such a curve is very nearly linear. (See Fig. 3.) In television service, assuming that sync stretching is used in the driving stages, the klystron may be operated in such a way that the sync pulses drive the tube very nearly to the peak of the Bessel curve, so that the efficiency at sync pulse levels is nearly the fully driven efficiency.

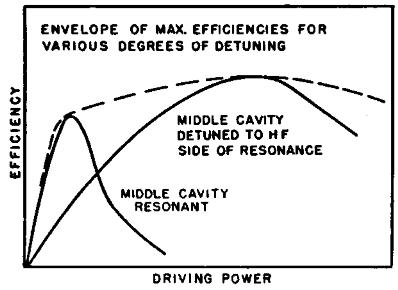

Fig. 4—Efficiency versus driving power, showing the effect of detuning the middle cavity.

The center cavity is detuned to a frequency slightly higher than the midband frequency, since this gives greater efficiency than resonant operation, and helps to broaden the pass band. This cavity may be loaded externally by resistance in some cases. This detuned operation requires greater driving power to the first cavity than resonant operation. (See Fig. 4.)

The input cavity may be either detuned on the low-frequency side of resonance or it may be tuned to resonance and loaded with external resistance in order to achieve the necessary bandwidth.

The relation between efficiency, power output, and anode voltage for a given tube is shown at Fig. 5. There is an optimum voltage for best efficiency because the voltage determines the speed of the electrons along the tube. Now a certain time is required for electron bunching to take place; this depends mainly on the frequency and determines the distance between the cavities. But this distance will be optimum for only one electron speed, and therefore only one voltage. Conversely, for a given voltage the relation between efficiency and frequency will also show a broad peak at a given frequency, and this fall-off at higher and lower frequencies will limit the useful frequency range of a given tube, even if the cavities are tunable over an indefinitely wide range.

The power input from the dc power supply feeding the anode of the tube is constant (about 1.5 amps at 13 kv), and independent of the drive voltage; therefore, the regulation of this power supply may be quite poor without adverse effects. Also, only simple circuits are necessary to reduce the hum to a low level. The filament may be heated by ac.

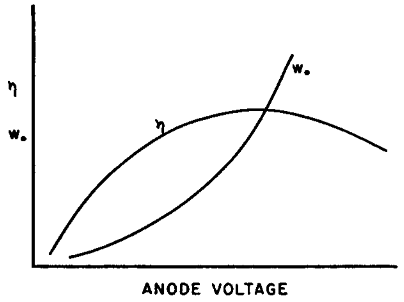

Fig. 5—Power output and efficiency versus anode voltage.

The magnetic field used for focussing the beam is simple to arrange, and relatively low in intensity, and consumes only a small amount of dc power in the coils. It must be made variable since the efficiency of the tube varies fairly rapidly with the field strength and reaches a maximum for an optimum setting of the magnetic field. The RF cavities, the drift tubes, and the anode are all in metallic contact and may be grounded. Thus, there is no problem of by-passing and dc isolation in the output circuit compared to the by-passing problem with a triode or tetrode amplifier. The collector is usually insulated from the main part of the tube in order to facilitate monitoring of the current division between the collector and the drift tubes. The anode voltage supply is grounded on the positive side, and the negative side is connected to the cathode of the tube.

Considering now the over-all problem of design, construction, installation, and operation of a high-power uhf amplifier, and the difference between the problem with a conventional type of tube and with a klystron, it is evident that the klystron scores heavily in all respects. The burden imposed on the transmitter designer is lessened because the klystron with its cavities forms a complete amplifier stage in itself. Because of the absence of feedback in the klystron, the circuit design is greatly simplified, compared with the conventional amplifier design. Also, when using a conventional tube at uhf, the designer is usually faced with the very difficult problem of obtaining the maximum efficiency from a stage in which the tube is run to its limit, and only by very careful design can the desired performance be obtained from it. With klystrons, on the other hand, the problem is easier because there is usually a greater margin of performance, both in respect to output and power gain. Also, the construction of a klystron stage is simpler than the conventional stage, and, as we have seen, the operation is also simpler.

Fig. 1 shows the more or less conventional type of klystron construction involving integral cavities, namely, cavities which are an integral part of the vacuum system. A unique feature of the Eimac tube, hereinafter described, is that part of the cavities are external to the tube envelope so that simple mechanical tuning of the cavities over a wider band of frequencies is possible. The tube itself is also simplified.

C. A Practical Example: Eimac UHF Klystron for TV

The photograph in Fig. 6 shows the Eimac uhf klystron, an example of a 3-cavity klystron in a form suitable for commercial manufacture, and now in produc-

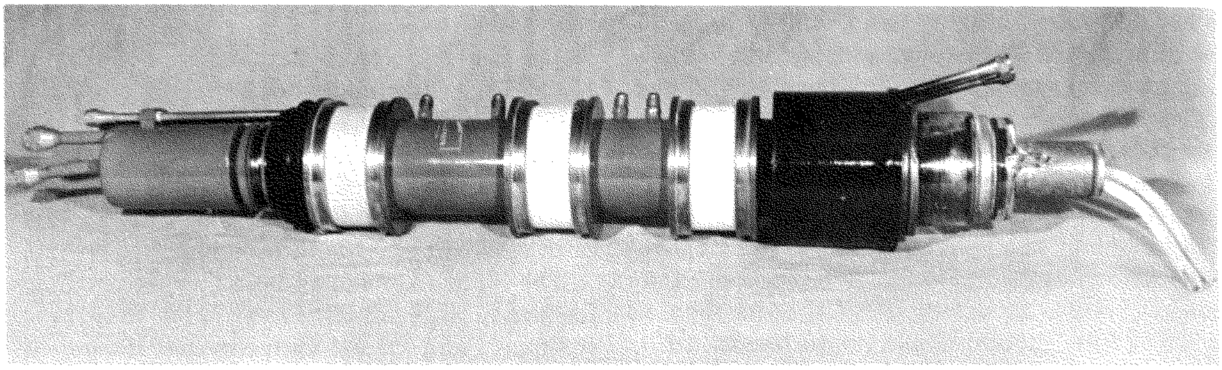

Fig. 6—The Eimac 5-kw uhf klystron for TV.

tion. Tube-cavity parts and drift-tube sections are shown in Fig. 7. Fig. 8 shows the tube and external cavities in a test setup.

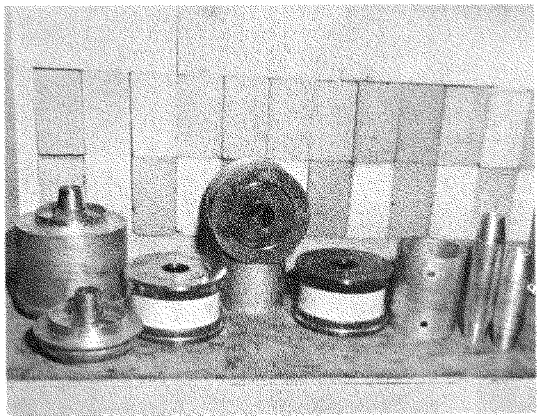

Fig. 7—Tube cavity parts and drift tube sections.

Fig. 8—The 5-kw klystron on test.

A feature of interest is the use of cavities which are tunable by means external to the vacuum system. This is made possible by use of ceramic "windows" which, if designed and fabricated correctly, will produce only a minor deterioration in the over-all performance of the tube because of their finite dielectric loss and high dielectric constant.

This means that part of each cavity is in vacuo and part is in air. The convenience of operating a tube of this type, compared with a tube in which the cavities are entirely in vacuo, is considerable. In the first place, the mechanism for varying the resonant frequency is simple and may involve straightforward shorting bars with sliding contacts with negligible losses. These slidable devices are outside the vacuum system, as shown in Fig. 8. The tuning range of such a cavity is large. With a totally evacuated cavity it has not yet been found possible to use such a means of tuning, because sliding contacts in vacuo are generally unsatisfactory. Therefore, tuning has to be done by distortion of some flexible metallic membrane. Such a membrane introduces mechanical weaknesses into the tube structure which then has to be stiffened by an external frame. Also, the range of tuning is relatively small, and usually the tuning is done by varying the gap spacing, and therefore, its capacitance. This can be done only to a limited extent. If the gap is made too wide, the electron transit time will become an appreciable fraction of 1 RF cycle, causing inefficiency; on the other hand, if the gap is too small, the bandwidth will suffer (bandwidth varies roughly as 1/c). With a ceramic window cavity the tuning is done by varying the inductance of the cavity, the capacitance across the gap is fixed, and the gap can be set for optimum performance over the frequency band.

Another point of difference is that the mechanical forces required to tune a cavity by means external to the vacuum system are small, being determined only by friction, whereas with the other type of cavity the tuning mechanism has to withstand the forces caused by the operation of atmospheric pressure against the flexible metallic membrane.

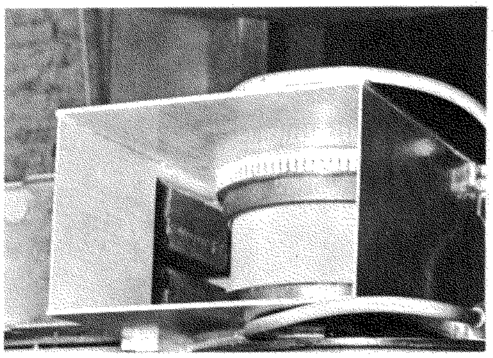

Fig. 9—Output cavity with one tuning plunger removed, showing ceramic and output coupling device.

Another desirable feature obtained with the ceramic windows is that the loading of the cavity may be accomplished outside the vacuum system, either by loops or a waveguide-to-cavity loading device, such as a quarter-wave transformer made from ridge waveguide. (See photograph of output cavity, Fig. 9.) The coupling may, therefore, be varied with ease. With a totally evacuated cavity it is very inconvenient to build in a variable load coupling, and it is common practice to use a fixed loop; thus the benefit of variable coupling is lost.

Lastly, because of the relatively large frequency band that can be covered by a given klystron with ceramic windows, a smaller number of tube designs is required to cover a given frequency band, such as the uhf TV band. This simplifies the manufacturing problem and reduces the cost of the tube.

Another feature of interest is the use of a tantalum cathode heated by electron bombardment from a tungsten filament of relatively small size by means of a dc power supply (0.6 amps. at 2,000 volts) between the cathode and the filament. This constitutes a flexible system, and is much simpler to design and construct than a radiation-heated cathode.

CONCLUSIONS

The 3-cavity externally tunable klystron is excellently suited to high-power generation at uhf (and also at higher frequencies) because

1. it is relatively simple to manufacture,
2. it is easy to use and adjust,
3. the transmitter design and construction is simplified by its use,
4. its performance as an amplifier is greatly superior to other tube types.

It is likely that the future will see more and more such tubes in commercial service for an increasing variety of applications.

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NOTE

The appended reprint from the PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS describes early experimental klystron structures.