MACHLETT LABORATORIES

INCORPORATED

SPRINGDALE, CONNECTICUT

April 19, 1950

Mr. Grote Reber
National Bureau of Standards
Washington, D. C.

Dear Mr. Reber:

As you requested recently, we are sending herewith technical data on the ML-281 ceramic-insulated planar tetrode. In addition is included a copy of the Spring Issue of the Cathode Press with an article discussing more fully the design features and applications of the ML-281.

We are also sending herewith technical information on the ML-280 ceramic "lighthouse" triode which may be of interest to you.

Since ML-2C39A data sheets are not yet available, we are enclosing technical information on the ML-2C39 and JAN specifications on the ML-2C39A which is now the standard for this type tube. As you probably know, the ML-2C39A is made to closer transconductance and other limits and is tested to considerably higher frequencies than was the 2C39.

Please feel free to call upon us for further information regarding the foregoing.

Very truly yours,

R E Nelson

R. E. Nelson,
Field Engineer

REN:oad
Encls.

MACHLETT LABORATORIES, INCORPORATED

ML-281

Tentative Technical Data

The ML-281 is a ceramic-insulated, planar tetrode designed for use as a VHF and UHF power amplifier or oscillator in radio transmitting service. Features include low cathode heating and input driving power requirements with relatively high power gain and plate dissipation. Compact, rugged construction with ring-type silver-solder seals, which minimize the lead inductance and r.f. skin-effect losses, makes the tube ideally adapted to use in coaxial circuits. The use of ceramic insulation greatly reduces dielectric heating losses at ultra high frequencies. The cathode is an indirectly-heated, oxide-coated disc. The anode is forced-air cooled and is capable of dissipating 100 watts. Maximum ratings of 1600 volts plate voltage and 100 watts plate input apply at frequencies up to 500 mc/sec; operation at frequencies up to 2500 mc/sec can be achieved with reduced plate efficiency using lower heater voltage.

GENERAL CHARACTERISTICS

ELECTRICAL

Heater Voltage	6.3 volts
Heater Current at 6.3 volts	1.0 Amp
Amplification Factor, G1-G2	50
Transconductance	14000 umhos
Ib = 60 mA; Ec1 = -1 volt; Ec2 = 300 volts; Eb = 600 volts	
Interelectrode Capacitances	
Cathode - Grid #1	8.0 uuf
Grid #1 - Grid #2	11.0 uuf
Grid #2 - Plate	4.5 uuf

MECHANICAL

Mounting Position	Optional
Type of Cooling	Forced Air*
Maximum Incoming Air Temperature	45 °C
Required Air Flow on Anode	12.5 cfm
Maximum Anode Temperature	175 °C
Net Weight	6 oz.

* For maximum plate dissipation of 100 watts, recommended air flow is 12.5 cfm with cowling shown in the attached drawing. Cooling must be sufficient to limit anode seal temperature to 175°C. Cavity should be ventilated and an air flow provided, when necessary, to limit cathode and grid seal temperatures to 175°C maximum.

Maximum Ratings and Typical Operating Conditions

Class C CW Amplifier - Grounded Cathode Circuit

	Typical Operation		Max. Ratings	
D-C Plate Voltage	1300	1600	1600	volts
D-C Screen Voltage	200	300	300	volts
D-C Grid Voltage (Note 1)	-15	-20	-20	volts
D-C Cathode Current	47.4	56	125	MA
D-C Grid No. 1 Current	6.7	5	40	MA
D-C Grid No. 2 Current	6.1	7.7	8	MA
D-C Plate Current	34.6	43.3	100	MA
Plate Input	45.0	70	150	watts
Grid Dissipation	0.06	0.05	2	watts
Screen Dissipation	1.2	2.3	2.5	watts
Plate Dissipation (Note 2)	15	25	100	watts
RF Grid Swing (peak)	25	30	40	volts
RF Plate Swing (peak)(Note 3)	1000	1200	1500	volts
RF Input Power, Pg	0.16	0.15	2	watts
RF Output Power, Po	30	45	50	watts
RF Power Gain, Po/Pg	187	300		
Frequency	500	500	500	mc/sec.

Note 1: Recommended minimum grid-leak resistance is 400 ohms.

Note 2: Up to 150 watts plate dissipation allowable with forced-air cooling sufficient to limit seal temperature to 175°C. Recommended air flow is 15 cubic feet per minute. Convention cooling is normally sufficient up to 20 watts dissipation.

Note 3: Maximum rating 2600 volts for high voltage breakdown tubes.

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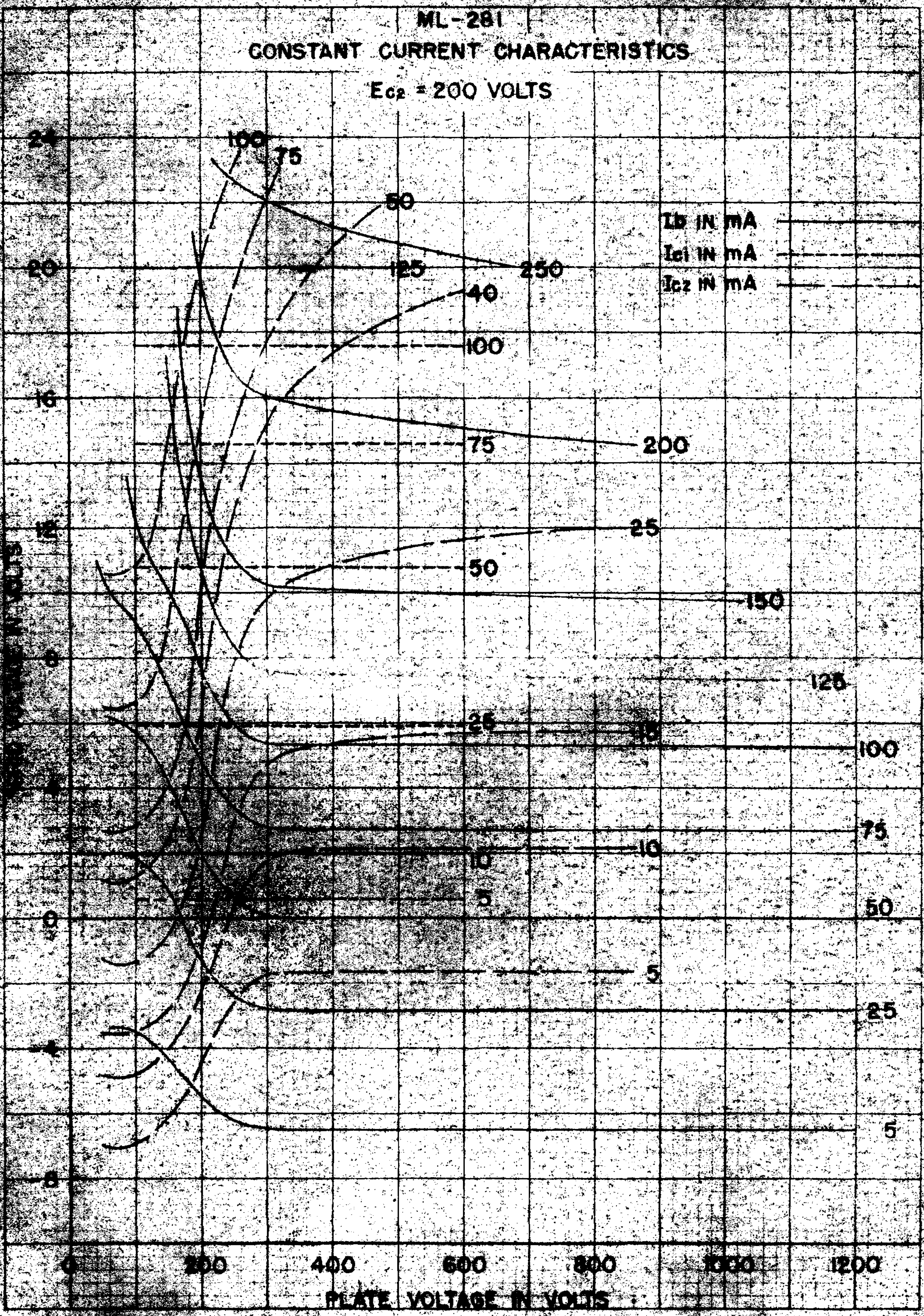

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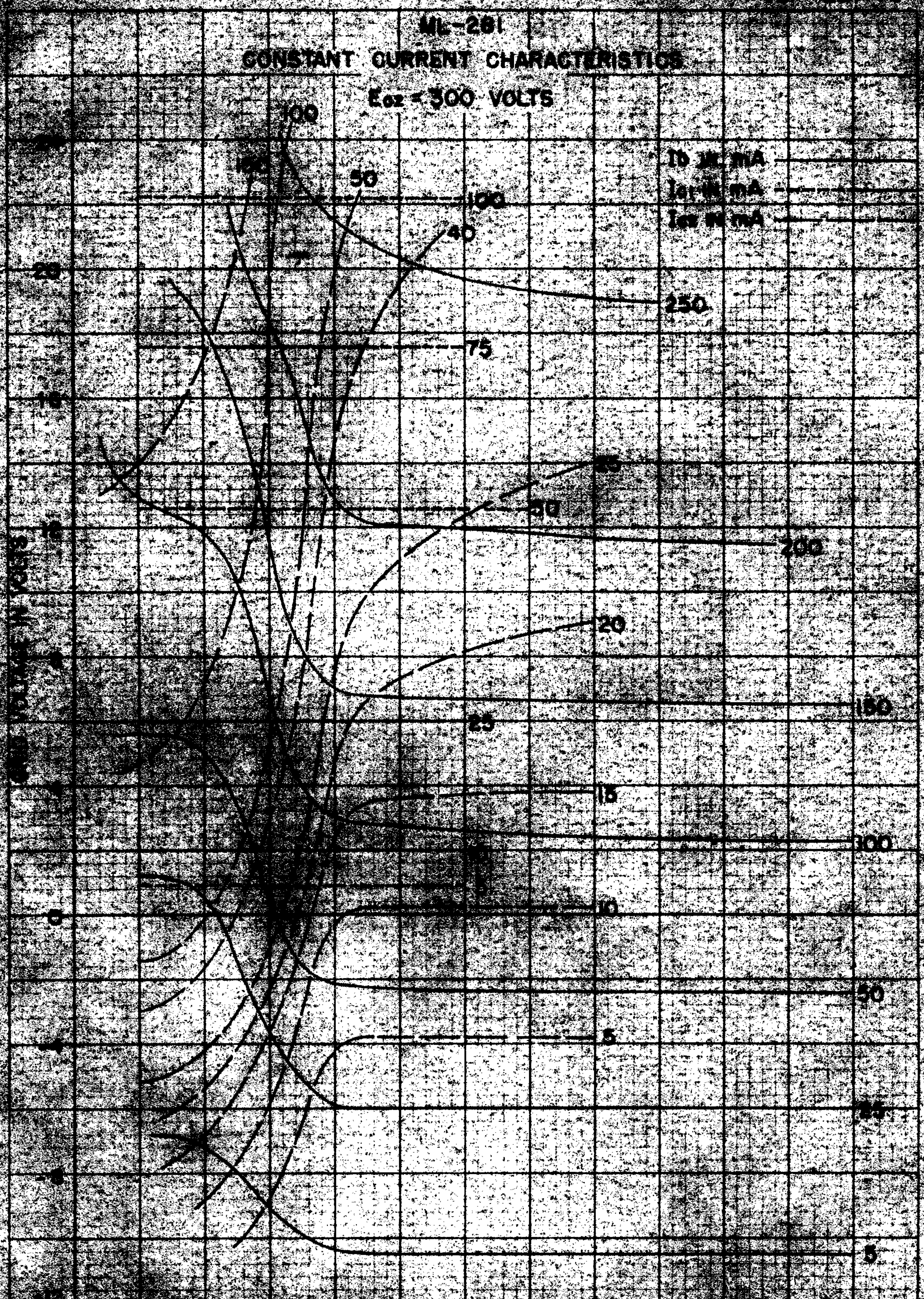
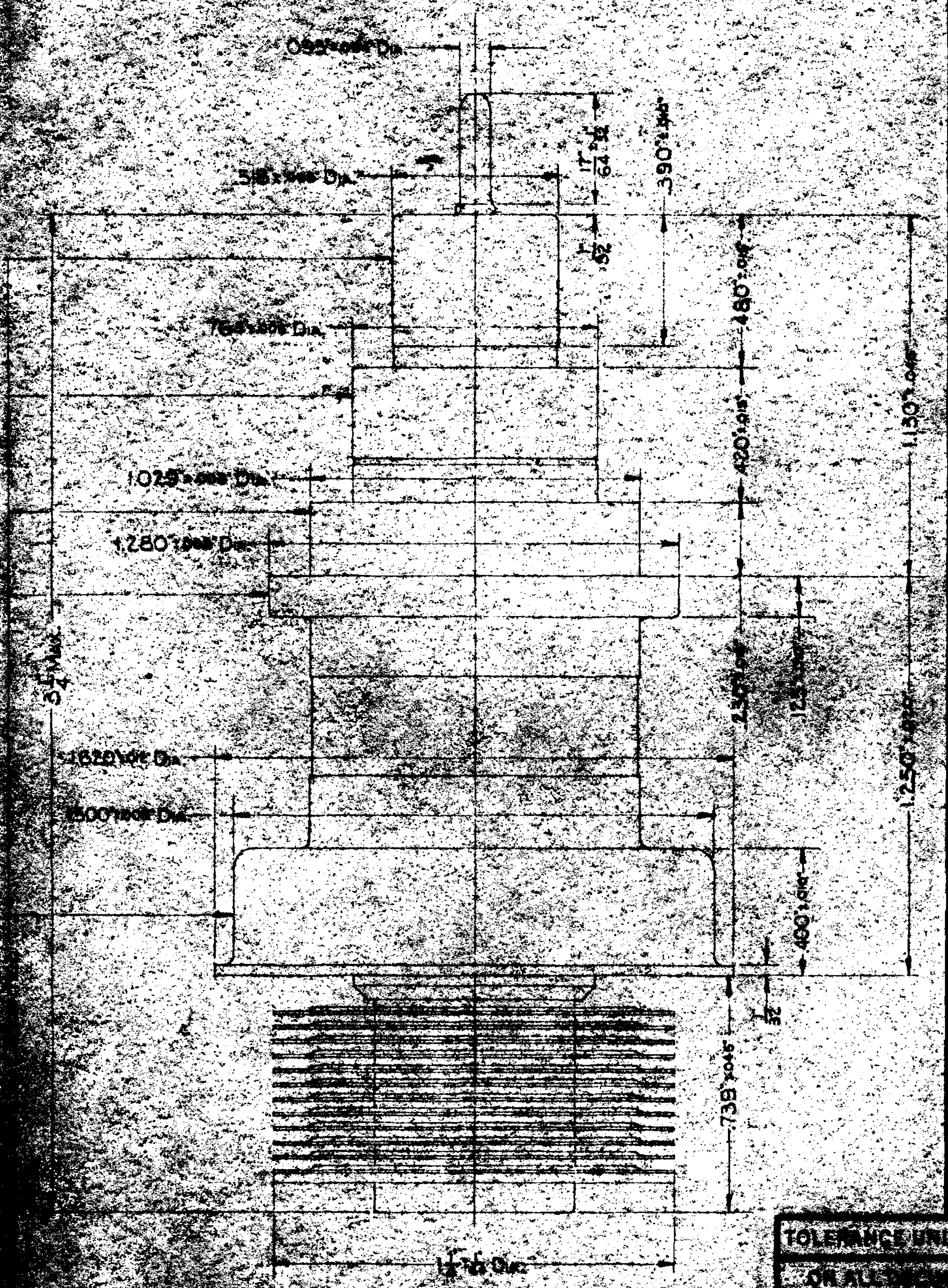

ML-281
CONSTANT CURRENT CHARACTERISTICS
Eoz = 300 VOLTS
100
150
50
100
40
250
75
25
50
200
20
150
25
15
100
10
50
5
25
5
200
400
600
800
1000
1200
PLATE VOLTAGE IN VOLTS

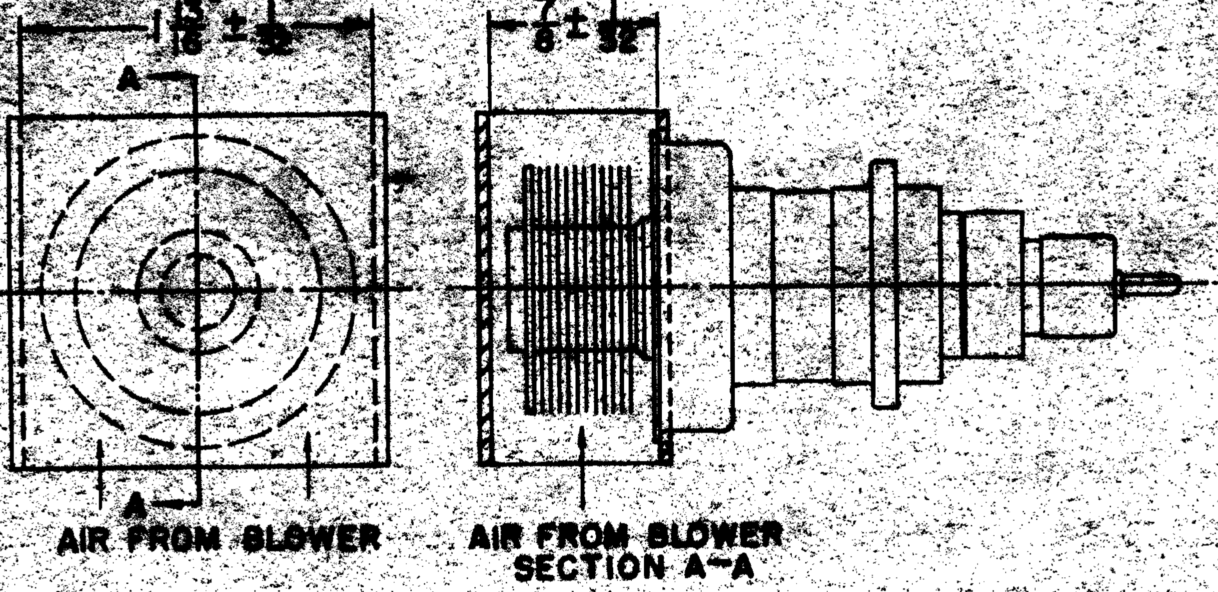
ITEM Outline of ML-281 Tetrode

REVISIONS



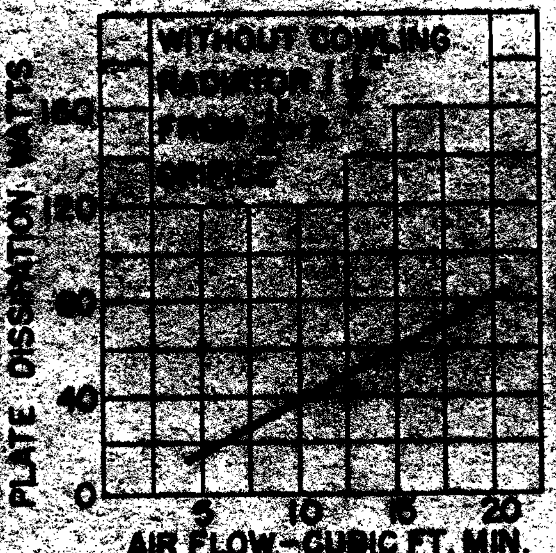
TOLERANCE UNLESS OTHERWISE SPECIFIED

DATE



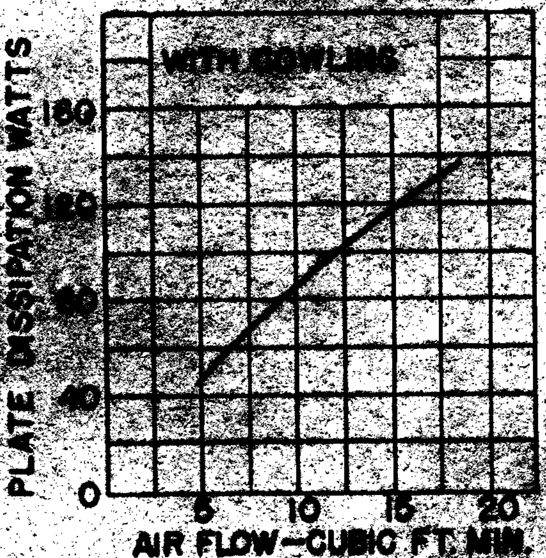
SECTION A—A

AIR FLOW VS DISSIPATION



AIR FLOW—CUBIC FT. MIN.
TEMPERATURE RISE 70°C
MAXIMUM SEAL TEMPERATURE 140°C

AIR FLOW VS DISSIPATION

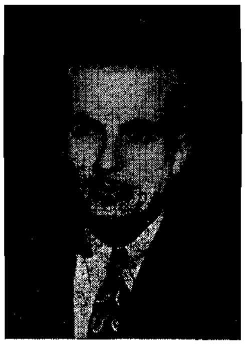


AIR FLOW—CUBIC FT. MIN.
TEMPERATURE RISE 70°C
MAXIMUM SEAL TEMPERATURE 175°C

MAXIMUM AMBIENT TEMPERATURE 70°C

THE ML-281 TETRODE ... in which ceramic insulation replaces glass ... provides higher power gain than the 2C39 with comparable power output at the lower frequencies. At the higher frequencies the increased gain is accompanied by comparably higher power output.

A CERAMIC PLANAR POWER TETRODE



By R. H. RHEAUME

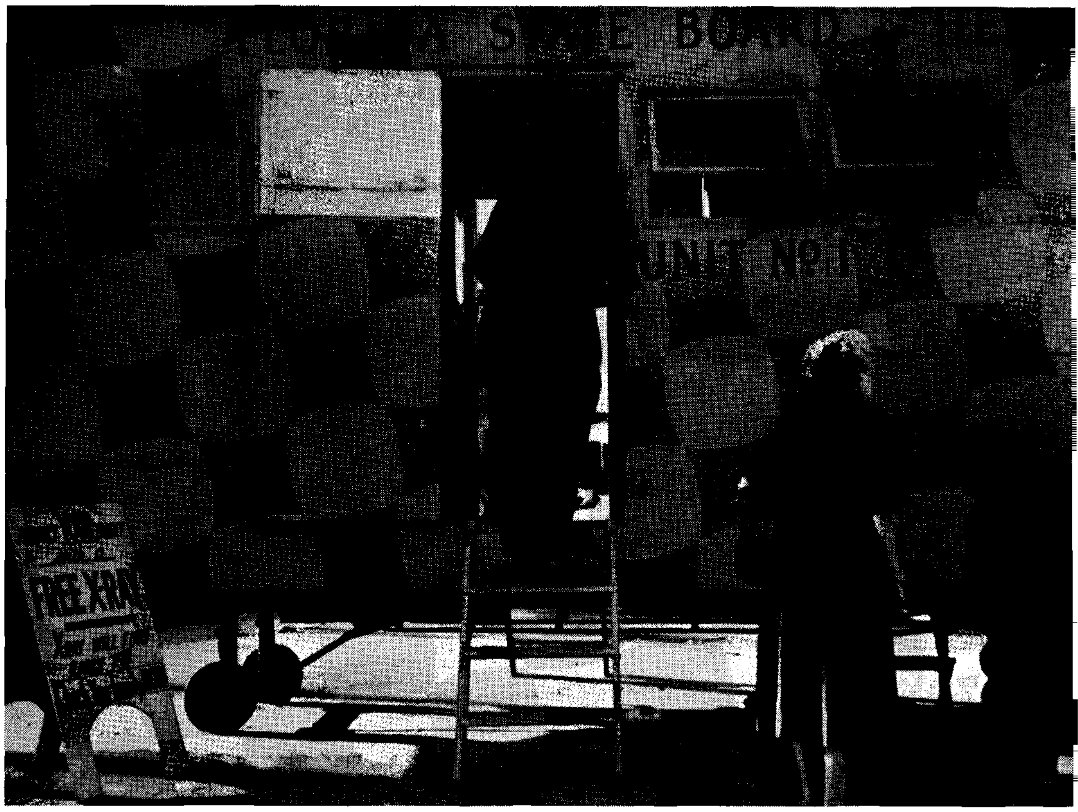
Design Engineer, Machlett Laboratories, Inc.

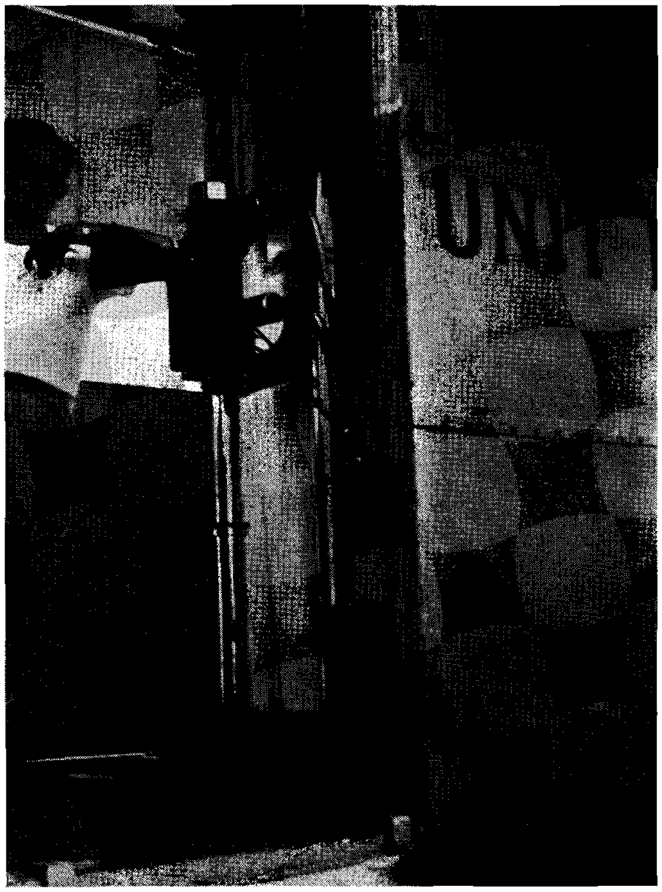
Introduction

The problem of triode stability in grounded cathode circuits becomes increasingly acute, as operating frequencies rise toward the 100 mc/s region. When triodes are employed at these, and higher frequencies, it is customary to resort to grid separation circuitry, which minimizes stabilization difficulties, but cuts down the power gain per stage. The power required to drive a grounded grid amplifier stage to a desired value of output power is several times that needed for a corresponding grounded cathode stage. It follows, that if an attempt is made to construct light weight, high gain, very high frequency amplifiers by the process of cascading grounded grid stages, the designer is confronted with the difficulties of numerous tubes and bulky power supplies. Moreover, in the operation of most triodes, electron transit time losses will have made their appearance before 100 mc/s, while at 1000 mc/s even the 2C39 planar triode is noticeably diminished in performance for this reason.

Pre-war radio experience with transmitting triodes and tetrodes in grounded cathode circuits furnished some interesting comparisons between these two types of tubes. While tetrode power outputs were limited to the order of a few kilowatts, by the second grid's inability to drain off bombardment heating rapidly enough to avoid primary emission at higher powers, still, within their scope, tetrodes gave notably better power gains, maximum operating frequencies, and stability than triodes did. The introduction of the second grid not only provided better isolation of output and input circuits; its position and high d-c potential served also to improve the transconductance and to minimize losses from electron debunching and long interaction time in the anode region. The usefulness of the high gain, grounded cathode type of circuit was accordingly extended consider-

YOU CAN'T GET AWAY FROM THE DYNAMAX





Tom Rogers, our Manager of Engineering, while vacationing in Florida recently, happened to see a Florida State Board of Health mobile x-ray unit parked off the street in Daytona Beach, displaying a sign inviting all comers to step in for a free chest x-ray. Assuming, naturally, that the unit would be equipped with a Dynamax tube, (it was) he stepped in for a chat with the technicians regarding Dynamax performance. He found them most accommodating and willing to discuss their work with the tube. "This is a relatively new tube," one of them remarked. "We've had it only 5 or 6 months. Our previous Dynamax tube went gassy after we had over 102,000 exposures on it. We put through 1200 cases in 6 hours that day. Must have gotten the tube too hot."

Tom observed the unit in operation for some time, and took the pictures shown here. This was part of a state-wide mass chest survey program then in progress. The method of handling the survey was interesting. No appointments were required; all passers-by were urged to participate in the survey, and local publicity in newspapers and on bill boards called the local inhabitants' attention to the fact that the unit would be available at the given location and urged them to pay it a visit at any time. The equipment, of up-to-date photofluorographic design, was mounted in the trailer-bus shown in the picture. This arrangement is typical of a great many such units used throughout the country for tuberculosis case-finding surveys.

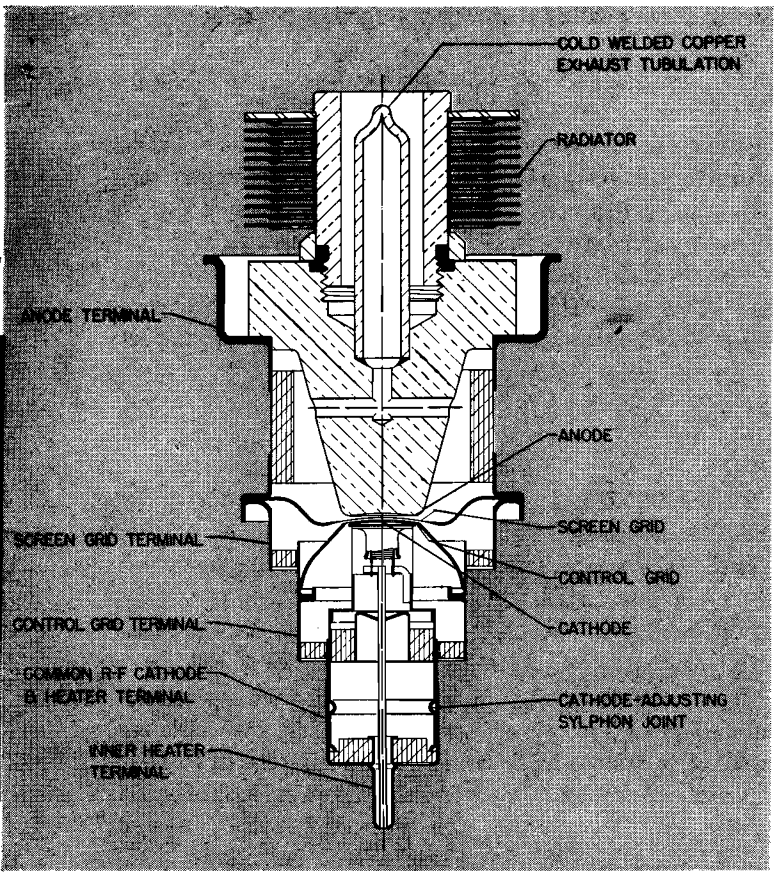


Figure 2

ably further into the very high frequency spectrum. Since less driving power was required than with triodes, appreciable economies were effected in number and cost of driver circuit components.

The subsequent development of ring seal planar power triodes led logically to a consideration of the possibilities of ring seal planar power tetrodes.

Metallized Ceramic Hard Solder Seals

The steady trend of power tube design toward larger outputs and higher frequencies has uncovered certain limitations of glass-to-metal vacuum seals. Feather edge copper vacuum seals with glass are structurally weak, while kovar-glass seals heat excessively when subjected to high circulating current densities at u-h-f frequencies. Moreover, the heating of glass itself due to dielectric loss becomes increasingly severe as frequencies continue to ascend.

It remained for German engineers, who were working on decimeter tubes for military purposes during the period of hostilities, to make an important contribution to the art of high frequency vacuum tube insulation. They developed a powdered molybdenum-iron-nickel sintering technique for applying metallized bands to special high thermal expansion coefficient ceramic bodies.[1] Nickel and silver plated sleeves of 42%-46% nickel iron alloy could then be hard soldered to the metallized ceramic, forming the desired vacuum seals. When American scientific teams arrived in Germany along with the advance guard of our occupation forces, they found that various types of ceramic insulated tubes had been fabricated there on an experimental basis. However, all productive effort was at a standstill. Fortunately, some sample tubes were available, and it was possible to reconstruct the details of the German process. It was also ascertained that a tendency to vacuum seal leakage had not been entirely overcome.

Through the foresight and initiative of Mr. R. W. Grantham, Code 836, the Bureau of Ships Tube Development Group became interested in procuring some improved ceramic insulated tubes in the United States, with immediate interest in a ring seal planar power tetrode of general form factor and power output similar to the 2C39 planar triode. Machlett Laboratories undertook a Bureau of Ships development contract[2] for the purpose of designing and fabricating the appropriate sample tubes, and the ML-281 ceramic planar tetrode is the outgrowth of that development. A photograph of this tube is shown in Figure 1.

Remembering the tendency to vacuum leakage previously noted by the Germans, Machlett Laboratories have carefully worked out optimum percentages of nickel and iron required for matching the thermal expansion rates of the sealing alloys with that of the ceramic. All sintering and brazing techniques have also been subjected to detailed revision. In this way, a procedure has been evolved for fabricating completely vacuum tight ceramic tubes; the method has important potential advantages for large scale manufacturing of many different kinds of electron tubes.

Advantages of Ceramic Insulation

Ceramic insulation in vacuum tubes offers several improvements. First of all, its high melting point is advantageous for several reasons; it permits higher outgassing temperatures when pumping the tubes, it offers possibilities of higher temperature tube operation, and it permits installation of cleaner hydrogen-fired tube parts. The latter is so because the ceramic, contrary to glass, will not soften at silver brazing temperatures. Another advantage is improved electrical characteristics. I^2R losses from electrode charging currents (r. f. tank currents) flow only in silver metal, and the dielectric losses of the ceramic are less than 10% of those encountered in the best glass available for glass-metal seals. A third advantage is the feasibility of accurately jigging parts for brazing, so that a more uniform product is made.

[1] U. S. Department of Commerce Report PB-52343, "German Metal-Ceramic Technique and Metal-Ceramic Decimeter Tube Series."

[2] Bureau of Ships Contract No. NObsr-30150.

ML-281 Structural Details

Referring to Figure 2, which is a longitudinal section view of the ML-281 tetrode, it will be observed that coaxial ring seal terminals are used for all electrodes, with cathode, control grid, screen grid, and anode terminals sequentially arranged in order of increasing diameter. This "oilcan" form factor permits quick insertion of tubes in equipments, leaving anodes exposed for most efficient cooling. The ring seal terminals minimize lead inductances, at the same time helping to achieve closer parallelism among the active electrode surfaces. Slightly convex shaping of the cathode, and of all electrode surfaces to correspond, ensures that any thermal movements of electrodes will occur axially in the same sense, thereby keeping spacings constant even under heavy loading.

ML-281 oxide coated cathodes are found to have good thermal efficiency, drawing only one ampere of heating current at 6.3 volts. A single-loop sylphon joint, incorporated within the cathode supporting structure, allows the emitter surface to be advanced toward the control grid after the tube is pumped and sealed off, thereby permitting an adjustment to be made for optimum transconductance under static electrical conditions equivalent to those encountered in service, later on.

The screen grid is beamed optically into the shadow of the control grid and then hard soldered in that position, for the purpose of minimizing screen electron bombardment with its attendant heating and loss of otherwise useful electrons from the anode region.

The copper anode of the ML-281 tetrode is similar, in general, to that of the 2C39 triode, though more massive; the sealing-off operation is likewise performed at the anode end of the tube, although directly in the copper tubulation by means of a cold welding technique rather than through the conventional kovar-glass seal normally employed. In this way, all risk of gas contamination of tubes from overheated glass is entirely eliminated.

ML-281 Electrical Characteristics

1. Cathode-Return Circuits

The majority of 2C39 triodes are used in grounded grid coaxial circuits in the frequency region up to 2500 mc/s. Power gain per stage is of the order of 5. However, below about 500 mc/s beam tetrodes with ring seal terminals can be made to give much better power gains, with satisfactory stability, in properly designed grounded cathode circuits. W. G. Wagener has discussed this advantage of beam tetrodes over triodes in "500-Mc. Transmitting Tetrode Design Considerations," Proc. I.R.E., May 1948. After reviewing their favorable power gain characteristics, he finds that neutralization requirements are only one-quarter as severe as for triodes in grounded cathode circuits. The following expression is developed for feedback voltage in a tetrode:

$$\Delta e = E_p\left[\frac{C_{gp}}{C_{gs}} - \omega^2 C_{ps} L\right] \quad (1)$$

where Δe is the feedback component of plate voltage E_p appearing between grid and cathode requiring neutralization, C_{gp} is capacitance between grid and plate, C_{ps} is capacitance between plate and screen, and L is effective screen-to-cathode lead inductance. An expression for the rate of change of feedback component, as the circuit is tuned, may be obtained by differentiating (1) with respect to frequency:

$$\frac{d\,(\Delta e)}{df} = -8\,\pi^2 f\, E_p\, C_{ps} L \quad (2)$$

In the ML-281 design, C_{gp}, C_{ps}, and L are unusually small, and consequently it follows from equation (1) that a higher self neutralizing frequency will be obtained, and from equation (2) that neutralization will tend to remain more stable with changes of frequency for ML-281's in grounded cathode circuits than for other kinds of tetrodes.

It is believed feasible to build coaxial circuitry for the ML-281, such that an enclosed relationship will exist between screen and cathode terminals, reducing L still further, and suppressing stray radiation of r-f power. It is thought

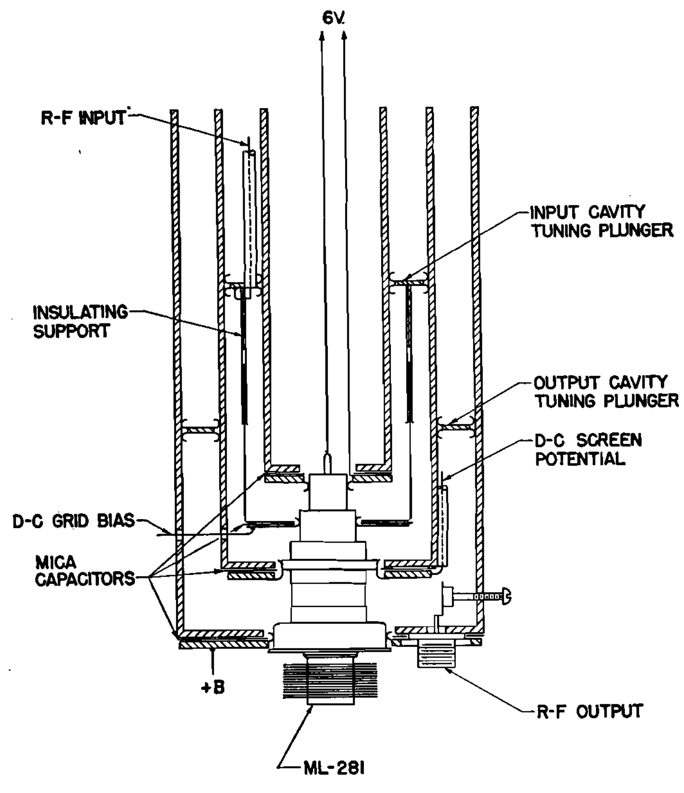


Figure 3

that high gain grounded cathode operation may be extended, in this manner, to even higher frequencies. Figure 3 is a proposal for such a circuit, suggested by Dr. H. D. Doolittle of Machlett Laboratories. The principle of operation is to maintain cathode and screen always at r-f ground potential by means of the properties of quarter-wavelength coaxial lines, while the grid is made to alternate in r-f potential with respect to them. Since there need be no restrictions as to d-c electrode biases, other than the conventional ones, this circuit will retain the characteristically high power gain of a grounded cathode tetrode circuit.

Average ML-281 static characteristic curves, with calculated grounded cathode class C CW amplifier ratings, appear in the ML-281 tentative data sheet at the end of this article. The basic observational data were obtained from pulsed measurements per Figure 5 on page 30. These pulsed measurements also indicated that, for optimum performance, tube parameters should be maintained as follows:

(a) Control grid bias voltage for maximum power gain should be made only slightly more negative than cut-off; further negative biasing improves plate efficiency, but reduces power gain severely. Biases less negative than cut-off permit space current to flow at undesirable times.

(b) Screen potential for optimum power gain must be held as high as possible without incurring excessive heating from electron bombardment. The electron stream originating at the cathode will then be deflected past the control grid and accelerated into the screen-anode space at high velocity; electron debunching and interaction time are minimized, and plate efficiency is improved. Transconductance is also enhanced, and grid drive is reduced, for a specified power output; power gain is thereby increased. +300 volts seems to be the optimum d-c screen bias for ML-281 tetrodes.

(c) The minimum instantaneous anode potential for ML-281 tetrodes should be not less than a hundred volts more positive than the screen, for optimum power gain and low screen dissipation.

(d) The ample dissipation rating of the anode permits the use of higher plate voltages than the 2C39, without overheating.

The foregoing observations are consonant with the following ML-281 electrode design premises:

(a) Cathodes must be placed very near control grids, for good transconductance; for that same reason, and to avoid losses due to remote cut-off-effects, extreme parallelism of electrode surfaces is also essential.

(b) The screen must be carefully beamed into the electrical shadow of the control grid, and located close to it, in order to achieve maximum transconductance, optimum power gain, and minimum screen dissipation.

(c) The anode surface must be set as near as possible to the screen commensurate with breakdown restrictions and maximum permissible output capacitance limitations.

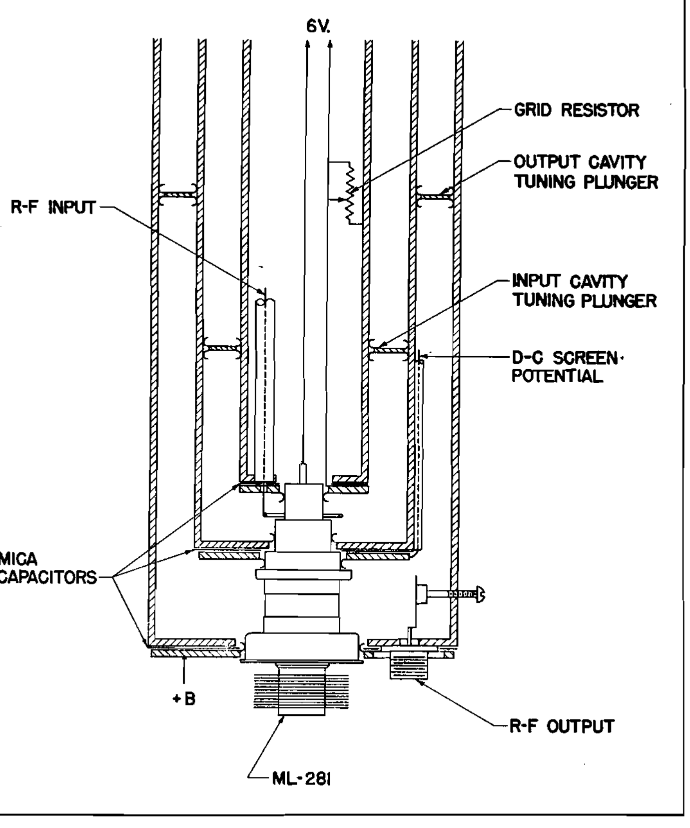


Figure 4

2. *Grid-Return Circuits*

The ML-281 tetrode, like the 2C39 triode, may be very successfully employed in grid separation coaxial circuitry, as shown in figure 4. Grid and screen are both held at r-f ground potential by means of a 100 uuf mica capacitor, and the customary d-c electrode biasing potentials may be applied, as in grounded cathode service. The source of driving power causes the cathode to alternate in r-f potential with respect to the grounded grid and screen electrodes; that portion of the driving power which is not dissipated in the biasing resistor or in electron bombardment of the grid reappears in the output circuit, just as with conventional grounded grid triodes. Under these conditions, power gains of 8 to 10 can be achieved with the ML-281 tetrode.

The higher gain and output, when compared with grounded grid triodes such as the 2C39A, are expected to be better sustained in the ultra high frequency spectrum above 1000 mc/s with ML-281 tubes, because the high-potential screen

Continued on page 30

DYNAMAX MOTOR CONTROLS

An important adjunct contributing to the outstanding performance of the Dynamax rotating anode tubes, which has not been pointed out in previous articles[1, 3, 4] on this subject, is the "Motor Control Equipment" which accompanies each tube. This equipment, when properly installed and inter-connected with the tube and the control of the x-ray machine, permits loading of the Dynamax tube only under proper conditions of rotation with no more thought or attention required on the part of the operators than in the case of a simple stationary anode tube. The purpose of this article is to discuss the evolution of the Dynamax Motor Control Equipment, describe how it functions and how it helps the user obtain better service from his tube, and assist the service personnel installing and maintaining this equipment in correlating its circuitry with the remainder of the installation.

When rotating anode tubes were first introduced commercially, the provision for controlling the rotation consisted merely of a simple switch to be turned on manually before an exposure was made and turned off afterward. This procedure was objectionable for several reasons; the danger of the operator forgetting to start the rotor before making an exposure or making the exposure before the rotor is up to full speed, the likelihood of the motor being turned on considerably longer than necessary before and after each exposure, and the undesirability of the technician having still another thing to worry about at the time of making an exposure. To avoid these objections, when the Dynamax was introduced an auxiliary "Motor Control Equipment" was developed to be supplied with it so that the operator could proceed in exactly the same manner in making exposures as with conventional (stationary anode) tubes, with nothing new to learn. This device thus had to be actuated by the conventional exposure initiating push-button switch, whereupon it would automatically apply power to the tube motor and after a proper, precisely determined interval, automatically give the signal to the timer or other exposure controlling device to proceed with making the exposure in the normal manner. Other requirements were that the push-button should retain complete control over the timer input circuit, so that this circuit would be opened instantly upon release of the push-button, and that the control unit would provide protection against accidental disconnection or reversal of the leads to the tube motor resulting in exposure without rotation. Later on, other protective features became desirable and were provided by modifications introduced from time to time.

Basic Design Considerations

Before the development of a device to accomplish these results could proceed, it became necessary to decide upon the most desirable means of providing the exact amount of time delay required between initiation of rotation and initiation of exposure. Inasmuch as the device, as one of its major functions, supplies power to the motor field (the rotor in the tube acting like the armature of a conventional induction motor), a logical approach might appear to be to utilize the difference between starting and running current of the motor to actuate a differential relay when the motor reaches normal speed. Actually, however, this difference turns out to be very slight because this kind of motor, with its large "air gap," has relatively high inductance and low "back-e.m.f.", and is less than the difference in current drawn when the tube unit is cold and when it is warm from normal operation. Hence, no consistent time delay interval could be obtained on this basis.

It was decided to depend on a definite time interval provided by an accurate timing circuit. This approach appeared to be entirely feasible in view of the basic qualities[1] of the

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[1] ROGERS, T. H.: Fundamental Factors Underlying Rotating Anode Performance, *Cathode Press*, Spring 1947.

A Ceramic Planar Power Tetrode — continued from page 9

eliminates the debunching tendency of the triode, and minimizes interaction time in the screen-plate space, by accelerating all electrons uniformly at high velocity into that region.

3. *Miscellaneous*

The screen of the ML-281 tetrode will control off-cathode potential gradients, which would otherwise be imposed upon the cathode by the plate, to such an extent that higher plate d-c voltages can be applied without danger of cathode deterioration, than with 2C39A triodes. ML-281's are rated at 1600 volts for typical operation in continuous service, and at 3500 volts in pulsed operation. Because of this greater cathode shielding, it may be possible to use grid pulsing in pulsed amplifier circuits.

ML-281 TENTATIVE DATA

GENERAL CHARACTERISTICS

Heater Characteristics

Filament Voltage	6.3 volts
Filament Current (approx.)	1.0 amps
Required heating time	60 seconds

Amplification Factor

Screen Grid	50

Transconductance

Approximately 14,000 umhos at Ib = 60 ma; E_{c1} = —1 volt; E_{c2} = 300 volts; E_b = 600 volts.

Direct Interelectrode Capacitances

Cathode to Grid No. 1	8.0 uuf max.
Grid No. 1 to Grid No. 2	13 uuf max.
Grid No. 2 to Plate	4.5 uuf max.

MAXIMUM RATINGS AND TYPICAL OPERATING CONDITIONS

Class C CW Amplifier — Grounded Cathode Circuit

	Typical Operation		*Maximum Ratings*	
D-C Plate Voltage	1300	1600	1600	volts
D-C Screen Voltage	200	300	300	volts
D-C Grid Voltage	—15	—20	—150	volts
D-C Cathode Current	47.4	56	125	MA
D-C Grid No. 1 Current	6.7	5.0	40	MA
D-C Grid No. 2 Current	6.1	7.7	8	MA
D-C Plate Current	34.6	43.3	100	MA
Plate Input	45.0	70	100	watts
Grid Dissipation	0.06	0.05	2.0	watts
Screen Dissipation	1.2	2.3	2.5	watts
Plate Dissipation (Note 2)	15.0	25	150	watts
R-F Grid Swing (peak)	25	30	40	volts
R-F Plate Swing (peak)	1000	1200		volts
R-F Input Power, Pg	0.16	0.15	2.0	watts
RF Output Power, Po	30.0	45	50	watts
RF Power Gain, Po/Pg	187	300		
Frequency	500	500	2500	mc/sec.

NOTE 1: Recommended minimum grid-leak resistance is 400 ohms.

NOTE 2: Up to 150 watts plate dissipation allowable with forced-air cooling sufficient to limit seal temperature to 175°C. Recommended air flow is 15 cubic feet per minute. Convection cooling is normally sufficient up to 20 watts dissipation.

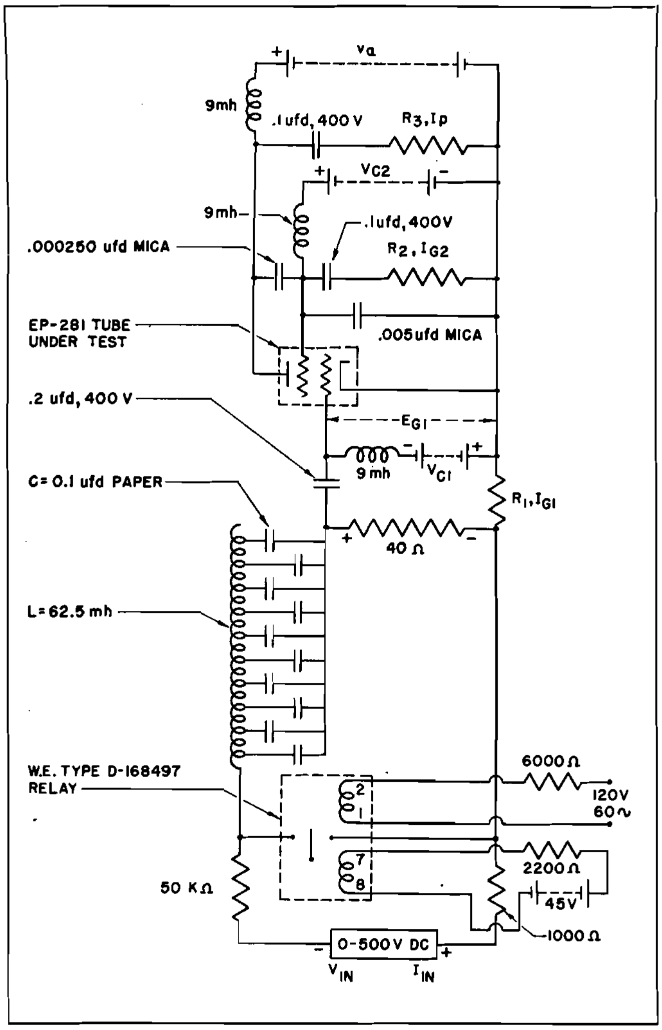

Figure 5

1. ***R=8.9Ω, R²=9.0Ω, R₃=9.0Ω. All Sprague Kool Ohm 5W non-inductive resistors.***
2. ***All 400 V capacitors are Sprague Hypass, non-inductive.***
3. ***Pulse voltage drops across R_1, R_2, R_3 are measured with Tektronix type 511 Cathode Ray Oscilloscope.***

Longer Life Industrial Tubes . . .

Continued from page 21

ment Machlett heat radiating filament and grid connectors, sketched in Figure 5, have also been installed to improve electrical contact to filament and grid terminals and to provide adequate finned cooling area to keep terminal and seal temperatures within reasonable limits. The grid connectors are joined to a single strap by means of a jumper in such a manner that r.f. grid currents will be split evenly between the two grid terminals of the ML-5668. It is not necessary, however, to replace existing 892 connectors with these just discussed, since filament and grid terminal dimensions of the two tubes are identical; the ML-5668 can be operated with one grid terminal connected in the same manner as the 892 being replaced.

There has been a misconception that electron tubes built to withstand the severe needs of r.f. heating service could be manufactured only at prohibitive costs. This is not so, Machlett industrial tubes being priced equivalent to or only slightly higher than the broadcast counterparts which they replace. Actually, lower average costs are gained with tubes made specifically for r.f. heating, since industrial tubes are designed to achieve full filament life, with minimum possibility of premature failures due to other causes.

In the case of the 892 user who has been averaging 3000 hours or less even within rated filament voltage, an ML-5668 conversion can be expected to pay more than for itself within its own life. Although accurate field information among industrial users is not readily obtained, limited data indicate 6000-7000 hours life at rated filament voltage can be expected with the ML-5668. Under these circumstances two Type-892 tubes might be purchased for a single-tube installation during a period when a similar unit in the same production line converted to an ML-5668 required but one tube. Besides the advantages gained in performance and reliability, there would be an appreciable net saving of over $100.00 in favor of the ML-5668 in spite of the conversion costs. Equipment maintenance costs after the original installation of industrial tubes are cut appreciably more.

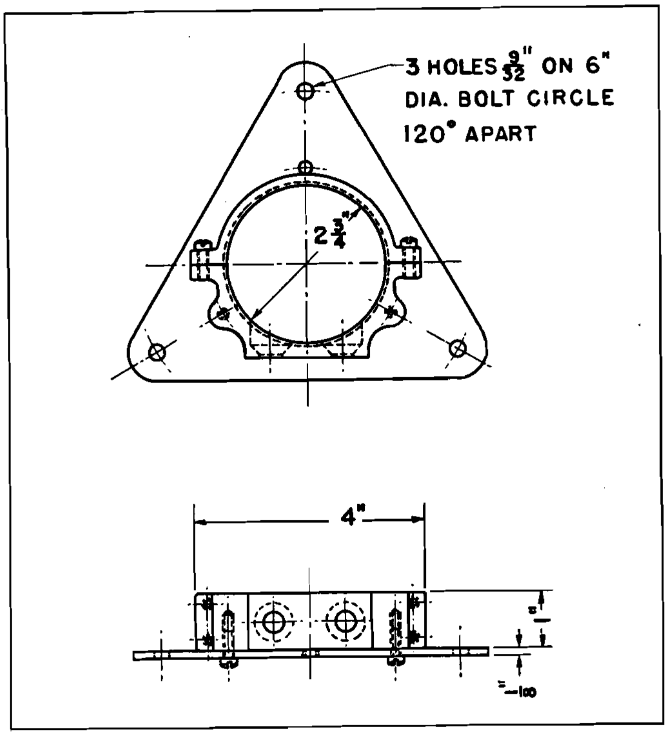

Figure 4

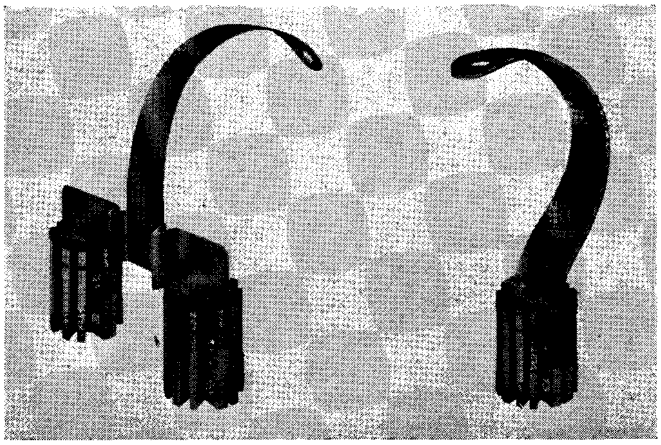

Figure 5 — Extruded brass connectors help dissipate heat . . . are easily attached or removed with small socket wrench.

ML-5669 Industrial Electron Tube

The ML-5669 is the forced-air-cooled version of the water-cooled ML-5668, just as Type-892R is the radiator version of the 892. It incorporates all the industrially designed considerations of the ML-5668 and offers similar advantages over Type-892R. The ML-5669 replaces directly Type-892R in industrial applications without any equipment modifications and permits 10 kilowatts plate dissipation, compared to 4 kilowatts for the 892R, providing additional safety factor against overloading, gassiness, flash-arcing, and short life. Again, the advantages gained with this industrial tube are available at but a token premium.

Tubes Built for R. F. Heating Service

Machlett Laboratories is intent on making the best possible tubes for industrial applications and has a specific program directed to that end. ML-5668 water-cooled tube and ML-5669 forced-air-cooled tube, obsoleting Type-892 and Type-892R, respectively, for r.f. heating service, are included in the line which brings older, widely used types of tubes up-to-date, taking advantage of improvements in materials and methods in vacuum tube manufacturing. This line makes it possible to have rugged industrial tubes in all r.f. heating equipments in the 5 to 50 kilowatt range.

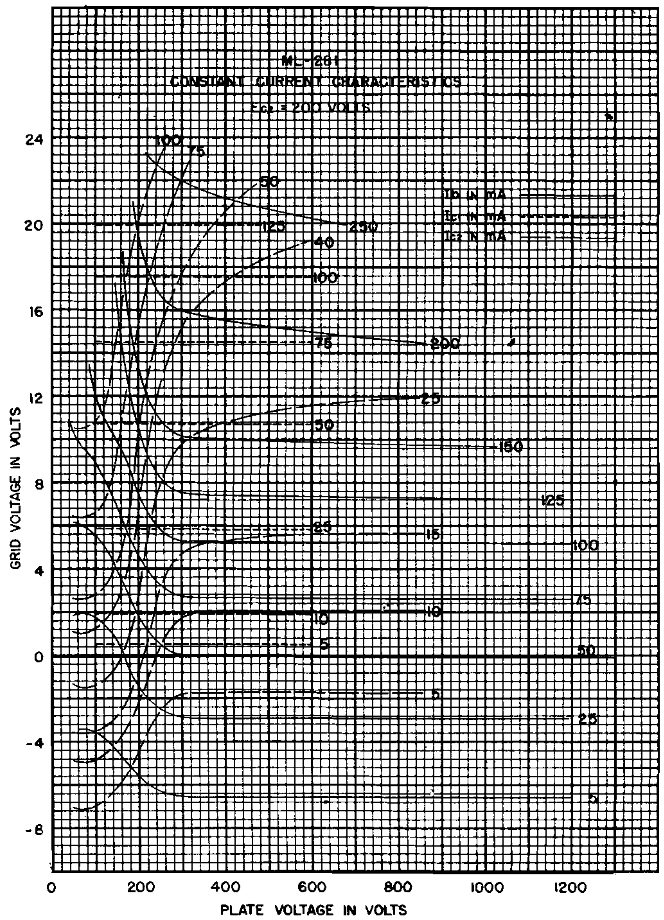

Figure 6

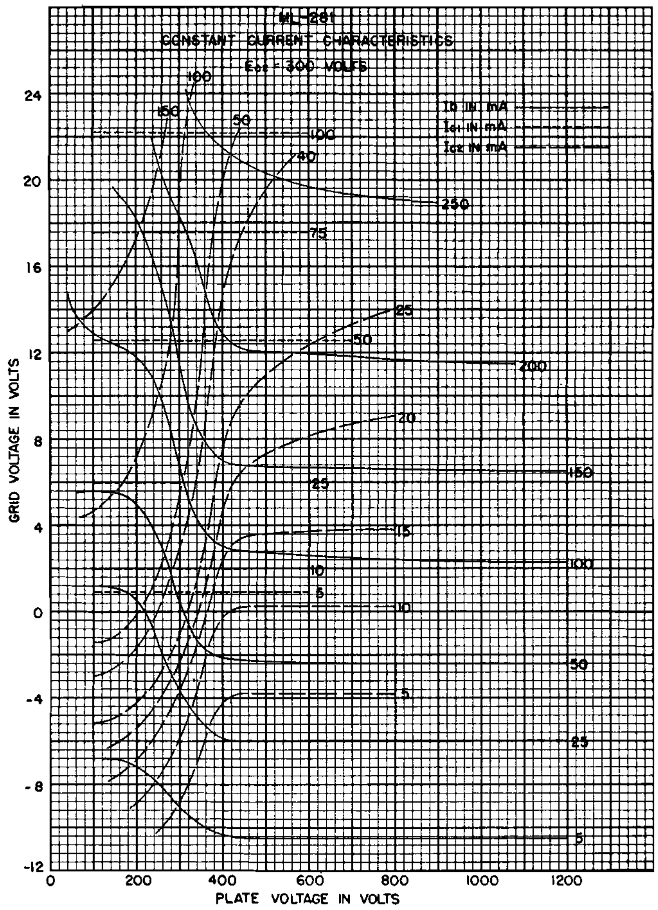

Figure 7

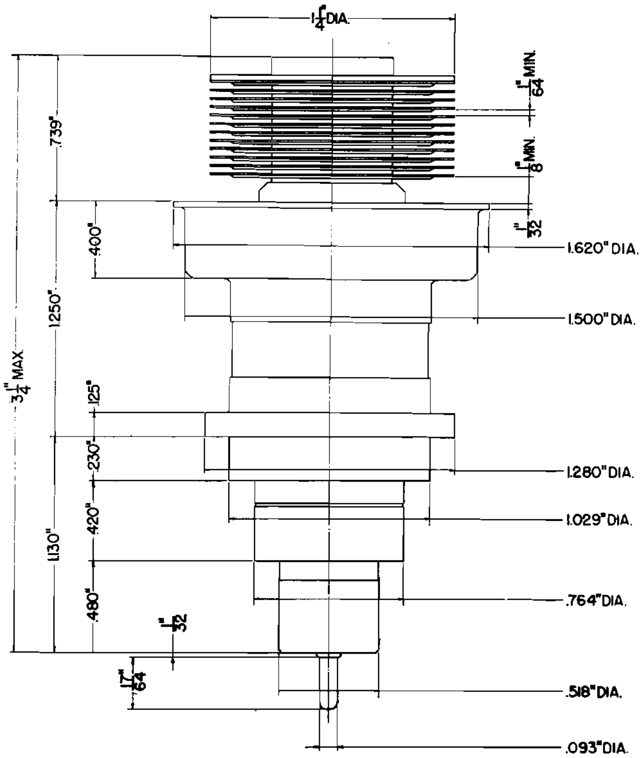

Figure 8

The Dollar Sign In Radio Frequency Heating
Continued from page 17

where formerly such hardening was impractical. Result: longer life, less distortion of lathe-bed ways, making for a far superior lathe, and one which commands a better, wider market. Here, as illustrated in the photo, the entire lathe-bed casting of about 18 tons is moved progressively under the specially designed inductor coils at ½ foot per minute. A depth of case of 1/32" of hardened steel on the surfaces of the ways is thus produced, and instant quenching after heating eliminates distortion, and assures uniform depth of hardened surfaces. Induction heating costs here are not important compared to the great improvement of this high grade lathe-bed.

6. The Proof of the Profit is in the Heating

The Charles A. Richardson, Inc., West Mansfield, Massachusetts, heat treated several million shuttle tips each year by oil-fired pot furnaces for the textile industry. Rejects were high because the hardened area could not properly be controlled. They turned to radio frequency heating using a 20 KW electronic oscillator of approximately 450 KC.

This installation brought the following results:

(a) Production increased to 3,000 tips per man-hour from 1,000 formerly.
(b) Unskilled labor replaced skilled labor.
(c) Actual factory cost per tip was slashed by 53%.
(d) A far superior product is produced because of the elimination of any chance of error. The new radio frequency operation is entirely automatic.

Case after case of well engineered applications prove that industrial heating with this new tool can not only increase production very materially, but also can accomplish this increase with notable reductions in the cost of the final product.

Space limitations make a discussion of dielectric heating in this article impractical, and the data presented here is merely typical of the enormous strides being made in the field of induction heating of metals alone. High frequency heating is not a cure-all, of course, for every industrial heating problem, however; and because of the higher investment in Btu's per hour for this type of equipment, the financial hazards in its selection are obviously greater. Despite this handicap, the use of induction and dielectric heating is rapidly expanding. The controlled depth and area of heated metal is unsurpassed, in induction heating.

In dielectric heating, the uniform, rapid heating accomplished throughout the mass of product is a phenomenon not present in any other heating method. The rapid heating of non-conducting materials by conventional means — convection ovens, flame, etc. — has always presented difficulties due to the fact that critical surface temperatures cannot be exceeded. Moreover, most electrical non-conductors are also thermal insulators. Therefore, with the advent of high frequency industrial oscillator tubes in the megacycle range of frequencies, a new field of heating these products developed resulting in uniform heating throughout the mass, with notable savings in unit cost.

There is now an installed capacity of nearly a half million kilowatts in the induction and dielectric heating field. Each four-year period since the beginning of the industry thirty years ago has seen the dollar value of these installed equipments doubled in industrial use. Improved techniques in tube design have been largely responsible for this growth. Outstanding among the many contributors to tube design and manufacture are the Machlett Laboratories of Springdale, Connecticut. Their long experience in the x-ray tube development, with the accompanying design and manufacturing techniques of this specialized industry, give them an excellent background for the manufacture of long-life, ruggedly built radio frequency heating tubes for industry, which will aid materially in expanding the use of this new heating tool still more.

A typical Machlett industrial tube incorporating the design features and manufacturing techniques referred to above, is discussed in the article on Page 19 of this issue:

Dynamax Motor Controls
Continued from page 13

the voltage supply of the filament transformer to suitable taps on an auto-transformer or resistor voltage divider. A simple arrangement is to install an auxiliary resistor of proper value and characteristics in series with the primary of the filament supply transformer and to connect terminals 10 and 11 across this resistor so that it is short-circuited during the "boost" period. With this arrangement, the filament circuit adjustments can be made in the normal manner prior to the insertion of the resistor, which can then be added to reduce the filament current to a suitable "stand-by" value.

A "suitable stand-by value" is the filament current corresponding to a value of anode current in the range usually employed for fluoroscopy, namely, 3 to 5 milliamperes. A 100-ohm, 100-or 200-watt, adjustable wire-wound resistor is generally satisfactory for use in the manner described above to reduce the current to such a standby value. An exact adjustment of the stand-by value is not necessary, unless it is desired to employ this setting for actual fluoroscopy in connection with spot-film work. This arrangement affords a convenient means for boosting the filament current from the fluoroscopic to radiographic setting in spot-film applications, simultaneously with switching on the rotor. Hence, in such cases, the spot-film switch-over contacts may be used to actuate the Dynamax Motor Control Equipment, which will then take care of both boosting the filament and energizing the stator.