R.F. Book

R.F. Note #60

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Normal Operation of the Transmitter

For the past two years or so the RF group has, like Michelangelo releasing the beautiful form from within the block of marble, been wrestling with various rf problems to create a transmitter to fulfill our hopes and dreams. At this point in time, we believe that the design of the transmitter is sufficiently "frozen" so as to allow us to ascertain the "normal operating conditions" of the transmitter. The ideal (albeit nearly impossible) case would be that the operating conditions of the transmitter (i.e. various dc and rf voltages and currents required for a given output power) would be the same for all frequencies in its range. One would also desire to have the various voltage monitors flat throughout the frequency range. This understandably is not the case. On this point it seems that Michelangelo was far more adept than we are at bringing to reality the ideas we have in our minds. Howsoever, the transmitter does perform well, when operated properly. Thus it behooves me to document the operating procedure for the transmitter along with monitor calibrations and normal operating conditions so that those persons not initiated in the use of the transmitter will be able to operate it perfectly.

THis note, then, must consist of three parts: 1) Operating procedure for the transmitter, 2) Voltage monitor calibrations, 3) Normal operating conditions.

Operating Procedure

There are four tunable elements in the transmitter, associated with the driver grids, final grid, final anode, and output capacitor. The driver grid capacities are parallel resonated with a variable inductor controlled by the electric motor-servo labeled D. Grid. The driver anode and final grid capacities are jointly resonated by a variable coil controlled by the F. Grid servo. The final anode circuit (the transmitter stem) is tuned by the position of the stem sliding short, servo labeled Trans. Stem. The purpose of the output capacity is to resonate out the leakage inductance associated with our output coupling loop to obtain the desired output amplitude and phase with repeat to the final anode rf and is controlled by the Output C. servo.

Before turning on the tube filaments and applying d.c. voltages to the transmitter, one satisfies oneself that all water circuits have sufficient flow and appropriate interlocks are satisfied. This being the case, one then selects the mode that is desired to run the transmitter in, these being 1)Driver only, 2) Trans. only, 3) Trans. Dee. In the Driver only mode, no final grid, plate, or screen d.c. voltages are applied, and one can operate the driver alone (obviously). In the other two modes, all d.c. voltages appear and the entire transmitter is operational, the main difference being that the interlocks associated with the Dee stem cooling are effective in the Trans-Dee mode.

Having selected the desired mode, and making sure that all required power supplies have A.C. power on, H.V. ready, etc., flip the "Control Power" switch to "On". This applies grid bias, starts the tube filaments, and initiates a four minute delay enabling the filaments to heat sufficiently. During this time it is convenient to set the four servos at the settings appropriate to the selected frequency. Having already read this note before attempting to operate the transmitter you know that it is necessary to connect the 100 pf. vacuum capacitor in parallel with the final anode capacity in order to operate at the frequencies 9-11 MHz. If you didn't connect this capacity (or disconnect it) as required by the frequency of operation, you may as well turn the control power switch to "Off", make the change and turn the control power on again, as opening the final anode box door drops the air interlock which in turn turns off the filaments, requireing another four minute delay anyway. (Sorry!).

Now that everything is approximately tuned and the four minute delay expired, all d.c. voltages should come on. The presence of the voltages is indicated by LED's on the control panel. If all d.c. voltages are not on (after the 4 minute delay), then flip the momentary toggle switch Reset/D.C. Off to "Reset". If this doesn't remedy the situation, then you've got trouble and better figure out what it is! (Some help huh!). If for some reason, the operator wishes to leave the area around the control panel and all d.c. is on, the operator should switch the Reset/DC Off switch to DC Off. This removes both anode and screen voltages from the transmitter but leaves the filaments and grid bias on, so that when the operator returns, it is only necessary to "Reset" the d.c. and another four minute delay is not required.

Assuming all d.c. is on, we are ready to apply a modest r.f. voltages to the driver grid. This is done by turning the knob on the amplitude regulator servo clockwise providing of course that one has the signal generator connected to the r.f. input (at a level of .6 Vms), the "r.f. out" output connected to the 50 W broad band amplifier and the output of the amp into the feed thru BNC labeled "RF Drive". The output of the amplitude servo is defeated by various fault conditions, such as sparks in various places, (through the spark detector box) excessive anode r.f. or reflected power etc. But since CW operation of the transmitter into the SOKW 75r waterload rarely causes these faults I won't belabor this point. I will present a block diagram of the amplitude regulation system later, however, in the event that the amplitude regulator refuses to give an output.

Now that we have some r.f. on the driver grids (10 volts peak), we move on to the fine tuning of the transmitter. Using two of the four 5 ft. cables on the H.P. scope, look at the signals available on bulkhead feedthru type BNC's (on the BNC panel on the NIM rack) labeled Driver Grid volts, and Driver Grid current (the actual labels are somewhat abbreviated). These two signals should be in phase if the driver grid is properly tuned. If they are not in phase, then adjust the driver grid servo to get them in phase. Now, on the scope look at the four signals, driver grid volts, driver anode volts, final anode volts and output volts available at feedthrus of similar names. Then finish tuning the transmitter as follows. The driver grid and anode should be 180^o out of phase; tuning the final grid servo will accomplish this. Since the final grid is 180^o out of phase with the driver anode, we then know the phase (and amplitude) of the final grid voltage. If the transmitter stem is tuned properly, the final anode voltage will be 180^o out of phase with the final grid, hence in phase with the driver anode voltage. Also, if the output capacitor is properly tuned, then the output voltage is in phase with the final anode. If these 3 signals (namely driver anode, final anode and output) are not in phase then an iterative procedure is required to get them there. First, tune the transmitter stem to get the two anode voltages in phase. Then tune the output capacity to get the final anode and output voltages in phase. Since this will slightly de-tune the stem, one must re-tune the stem. After a few iterations the tuning is accomplished.

Now that the transmitter is purring along, we're ready to deliver some power to the dee or dummy load. In order to measure this delivered power one measures the signal from the directional coupler found on the feedthru labeled "D.C.+". If the transmission line that the directional coupler is in was perfectly terminated, there would be no reflected power, VSWR = 1.000, and the voltage in the transmission line, $V_{t.r.}$, is related to the directional coupler signal, $V_{D.C.+}$, by the equation $V_{D.C.} = K_1 \text{x } V_{T.L.} \text{ x } f$, where f is the frequency of operation in MHz and K is a constant, approximately equal to 8.875×10^{-5}. The delivered power may be calculated by $P = (V_{T.L.}2)/150$ (with $V_{T.L.}$ expressed in peak volts), or $P = (V_{D.C.+})^2/\ 150\ (K_1 f)^2 = K_2\ (V_{D.C.+}/f)^2$, where $K_2 = (150\ K_1{}^2)^{-1} \approx 8.464 \times 10^5$. Oft times it is more convenient to know what monitor voltage corresponds to a particular delivered power. In this form we have the relation $V_{D.C.+} = \sqrt{Px150} \text{ x } K_1 \text{x } f = \sqrt{P} \text{ x } K_3 \text{ x} f$, where $K_3 = \sqrt{150} \text{x } K \approx (920)^{-1}$. Hence the directional coupler voltage required for a 50 KW output at 30 MHz is $V_{D.C.+} = \text{ Px } K_3 \text{x } f = \sqrt{5 \times 10^4} \text{ x}30/920 = 7.29$ Volts peak. Here P is in watts, f in MHz. This discussion now leads us to the second part of this note, namely monitor calibrations.

Voltage Monitor Calibrations

I present here the calibration curves for the Driver grid, Driver anode, Final grid and Final anode voltage monitors, along with a graph of the Directional Coupler calibration. Just a word or two about each monitor first.

The Driver grid voltage (and input current) monitors are 10:1 current transformers designed to work into 50Ω. The actual ratio of grid drive to monitor voltage is a function of frequency which I have approximated with a linear dependence, for simplicity. This ratio ranges from 10.6:1 to 11.7:1, a change of about 10%.

The Driver anode, Final grid and Final anode monitors are essentially just capacitive voltage dividers. Since the shunt capacity of 1200 pf. has a reactance of $1/\omega C = 13\Omega$ at 10 MHz, the 50 Ω cable represents a significant load at this frequency resulting in a phase e.ror of the signal of $\tan^{-1} 13/50 \simeq 14^{\circ}$. To compensate for this, we put a parallel combination of 40 Ω and 2.2 μH in series with the cable. This cuts the voltage in the cable approximately in half, but keeps the phase accurate to within 5°.

All calibration curves are presented in the form of ratio V actual/V monitor, hence one needs only to multiply the monitor voltage by the calibration ratio V act/ V mon. to obtain the voltage in question. The graphs can be found at the end of this note.

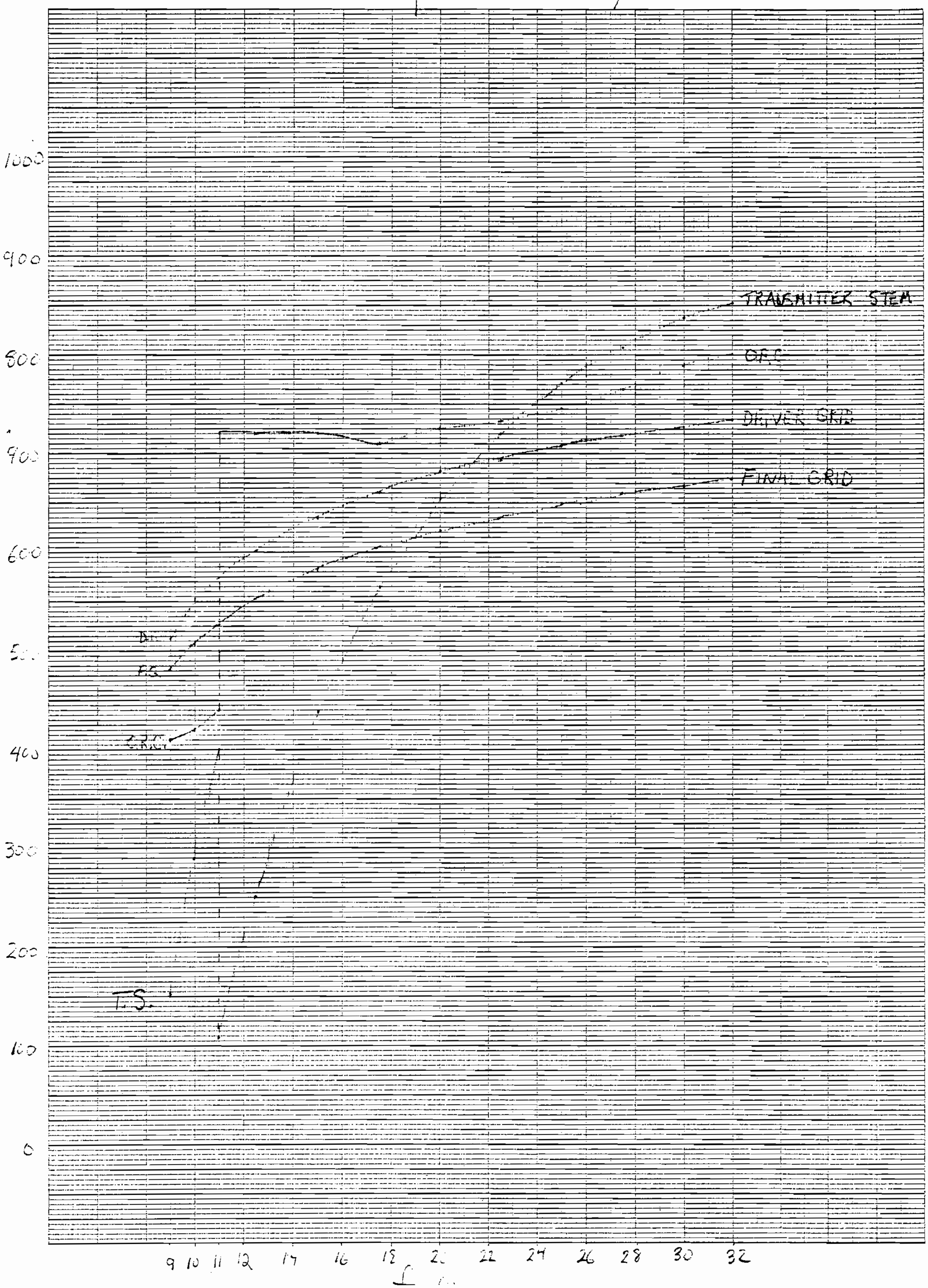
Normal Operating Conditions

I also present tables and graphs of the various parameters of the transmitter as it delivers 50 KW into the 75r water load over the range of 10 to 32 MHz. Two parameters (besides both grid, screen, and Driver anode d.c. voltages) are constant over this range; one being the delivered power (obviously), the second being the final screen current. At each frequency the final anode supply voltage was adjusted to give a final screen current of 250 mA, as this gives good transmitter efficiency. In addition to the table of NOC's, there is a graph comparing the final anode r.f. level to the B+ voltage (revealing a constant $E_{min} \simeq 5.5$ KV and a graph comparing the Driver grid, Final grid and Final anode voltages.

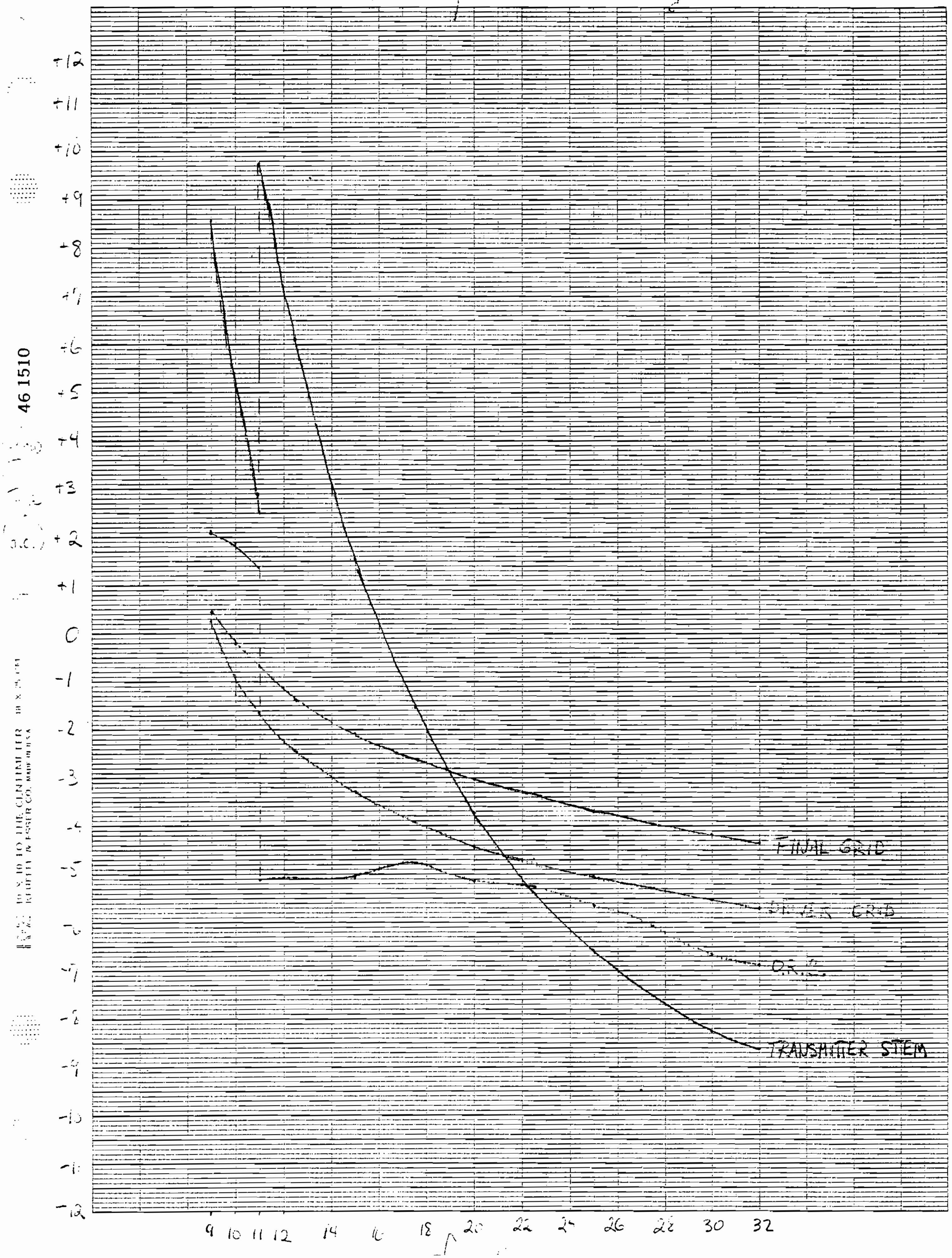
There is another water load dissipating power in the transmitter a 350 Ω waterload attached to the output of the transmitter at the beginning of the transmission line. The connection is made by means of a strap simulating a 300 r line. Since there is some reactance in the line (it not being terminated too well), this load dissipates more power at some frequencies that at others. By measuring the water flow, it was possible to calculate this power ($P=.263$ KW/$^{\circ}$C-gpm). I include this information in Table 1. Also, by measureing the water flow and temperature rise in the 50 KW, 75Ω water load, I calculated a dissipation of 49.4 KW at all frequencies, giving a good check on the delivered power.

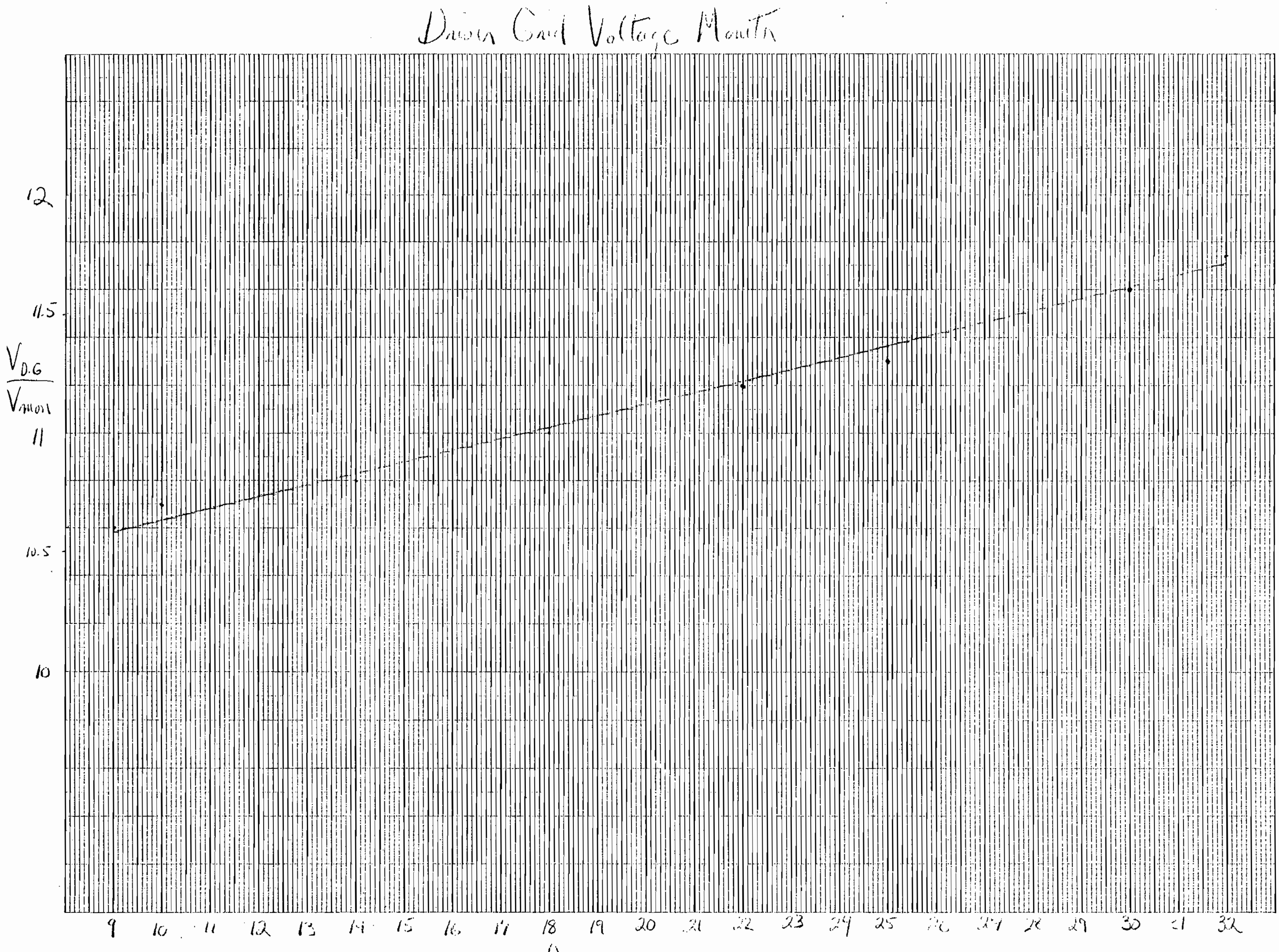
All monitor calibrations and operating parameters are for C.W. operation into the 75 Ω water load, and may be subject to change as the transmitter evolves, or if it is driving any load other than the water load. However, they should remain reasonably good for the remainder of the final r.f. tests.

Transmitter Tuning - Knob Settings 1-28-80



Transmitter Tuning - Follower Voltages 1-28-80





Drain Grid Voltage Month
12
11.5
V D.G / V nom
11
10.5
10
9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
f

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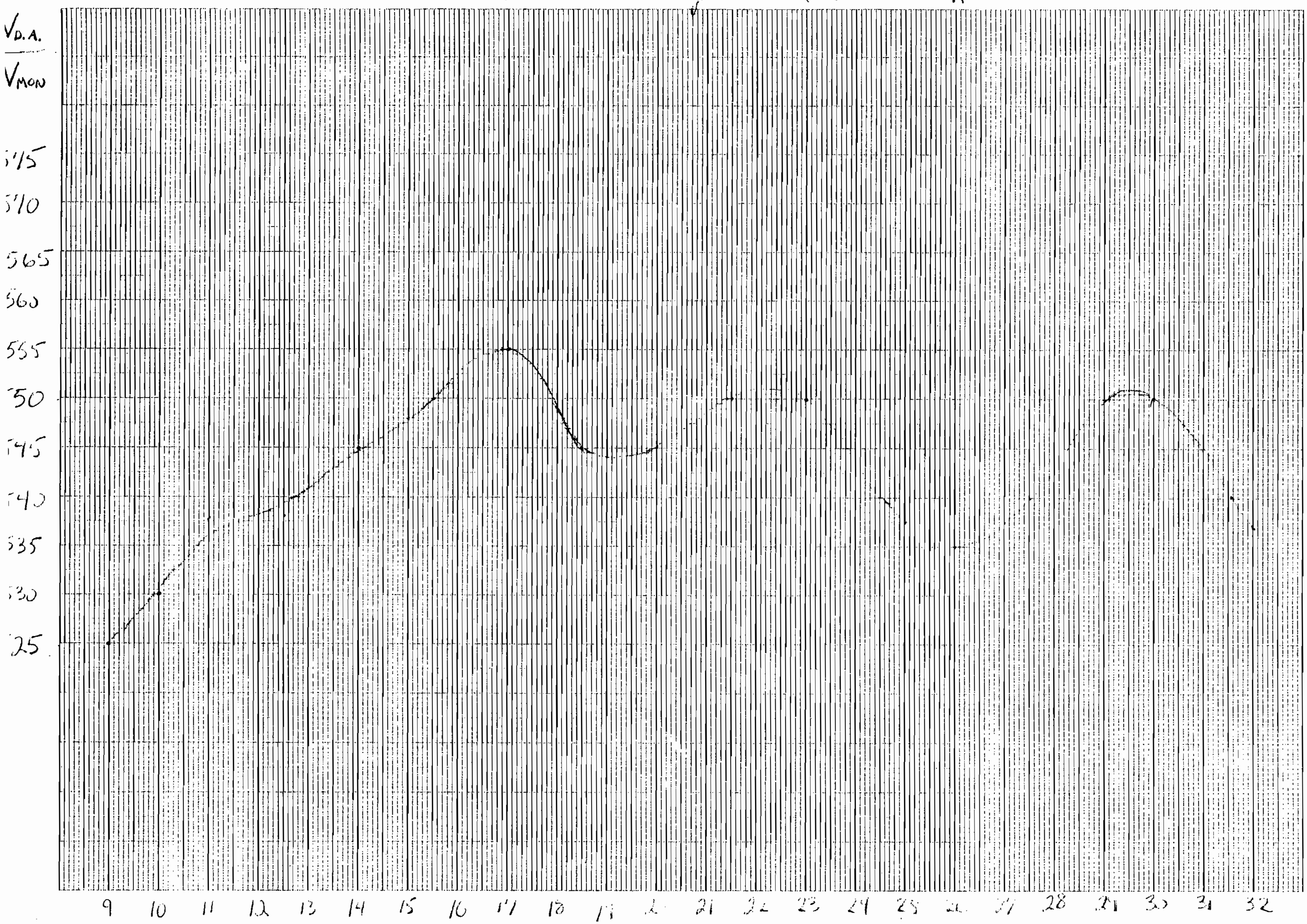
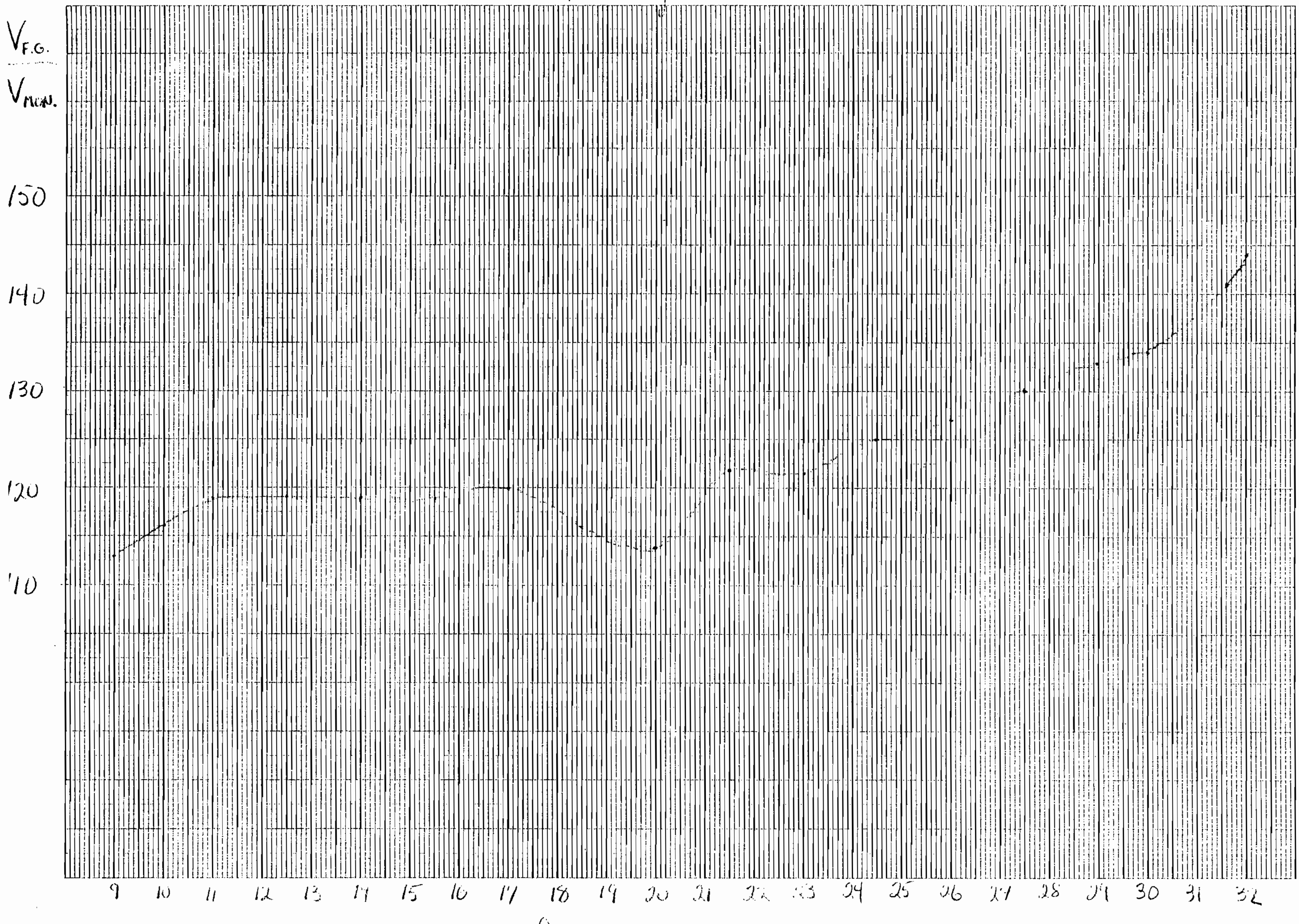
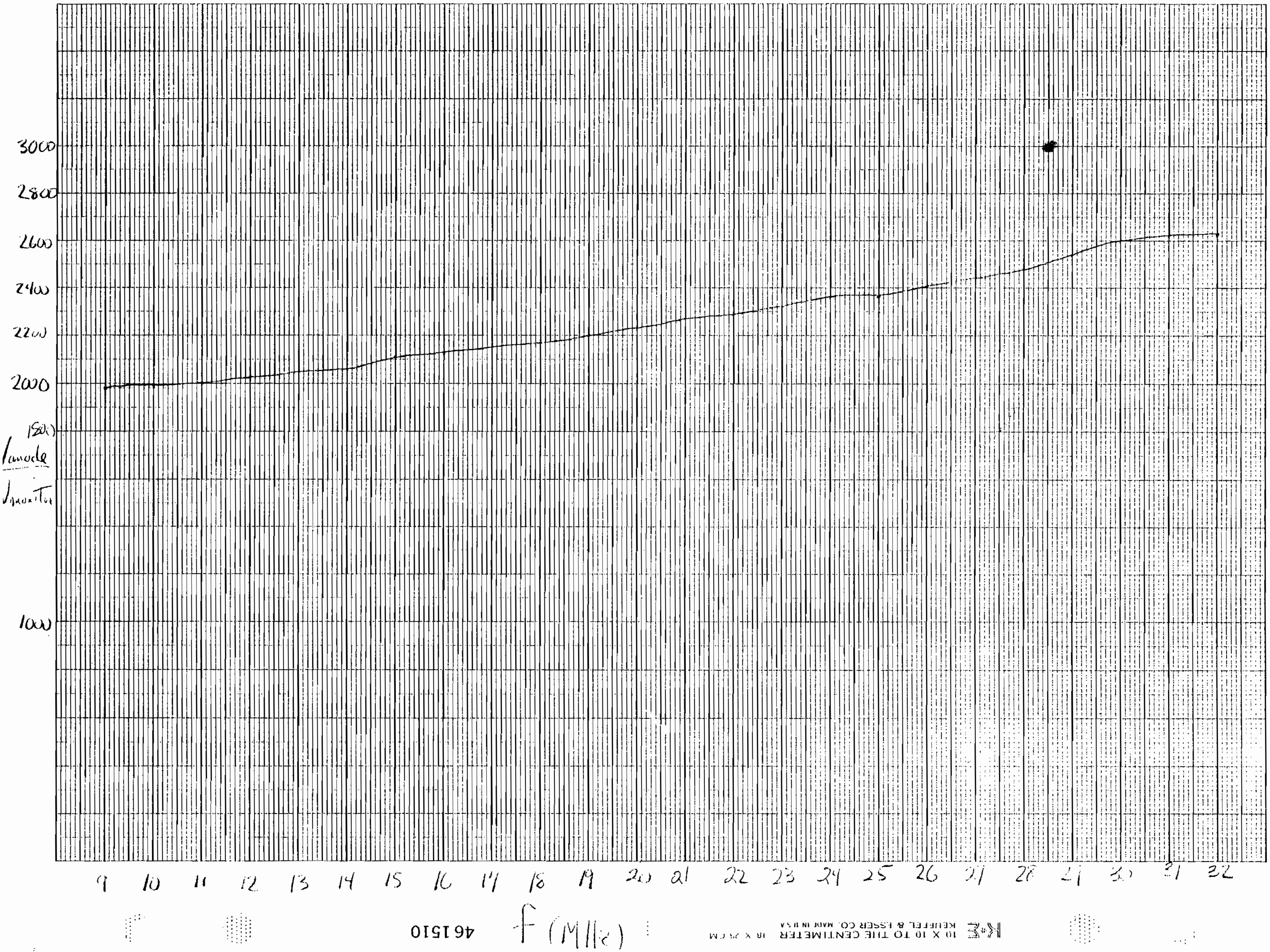
Drift Anode Voltage Monitor Calibration 1-25-00



Final Grid Voltage Monitor Calibration 1-25-80



Final Anode RF Monitor Calibration 12-21-79



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K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM
KEUFFEL & ESSER CO. MADE IN U.S.A.

Directional Coupler C10

V2+ Calibration

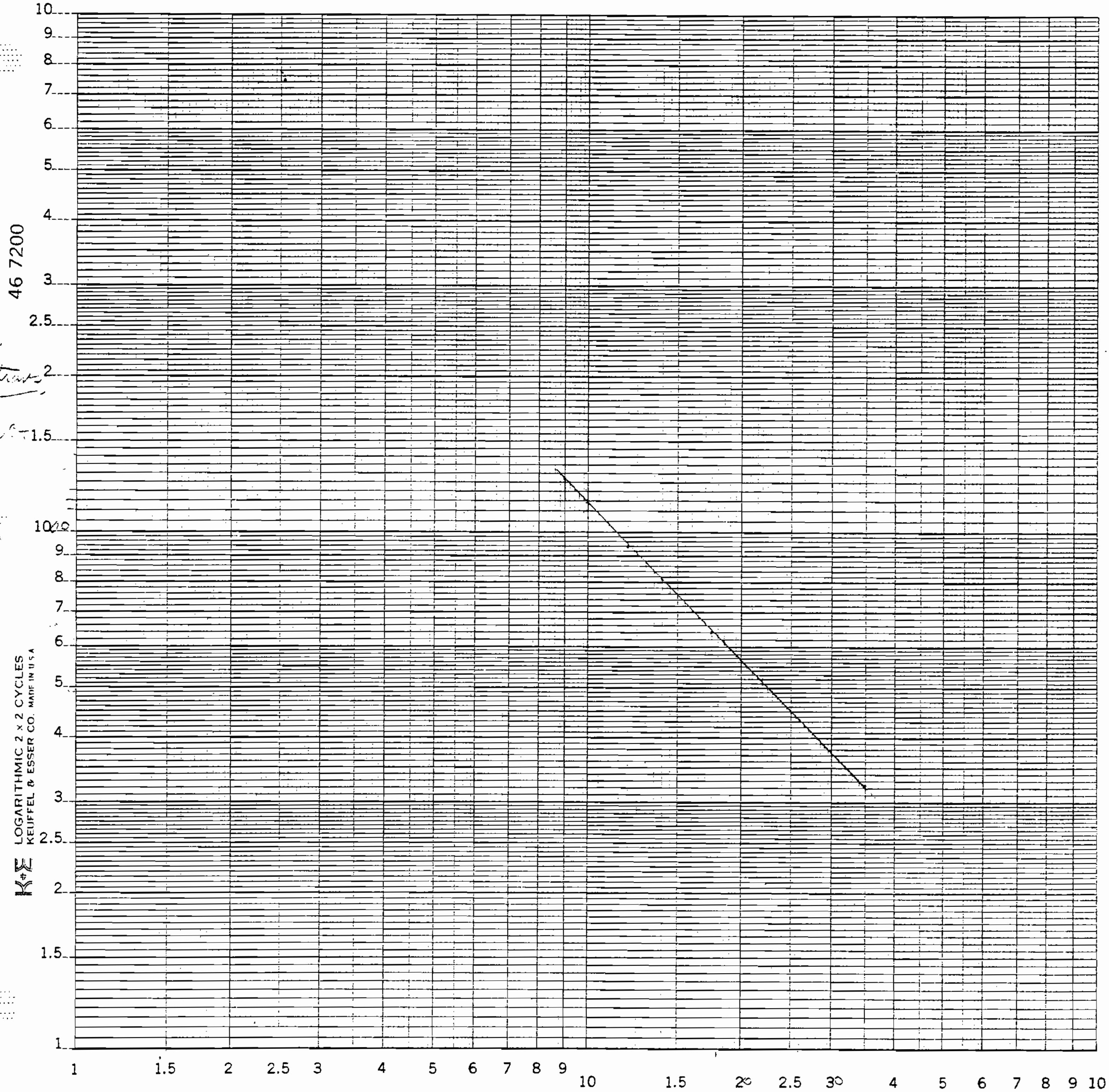


Table 1

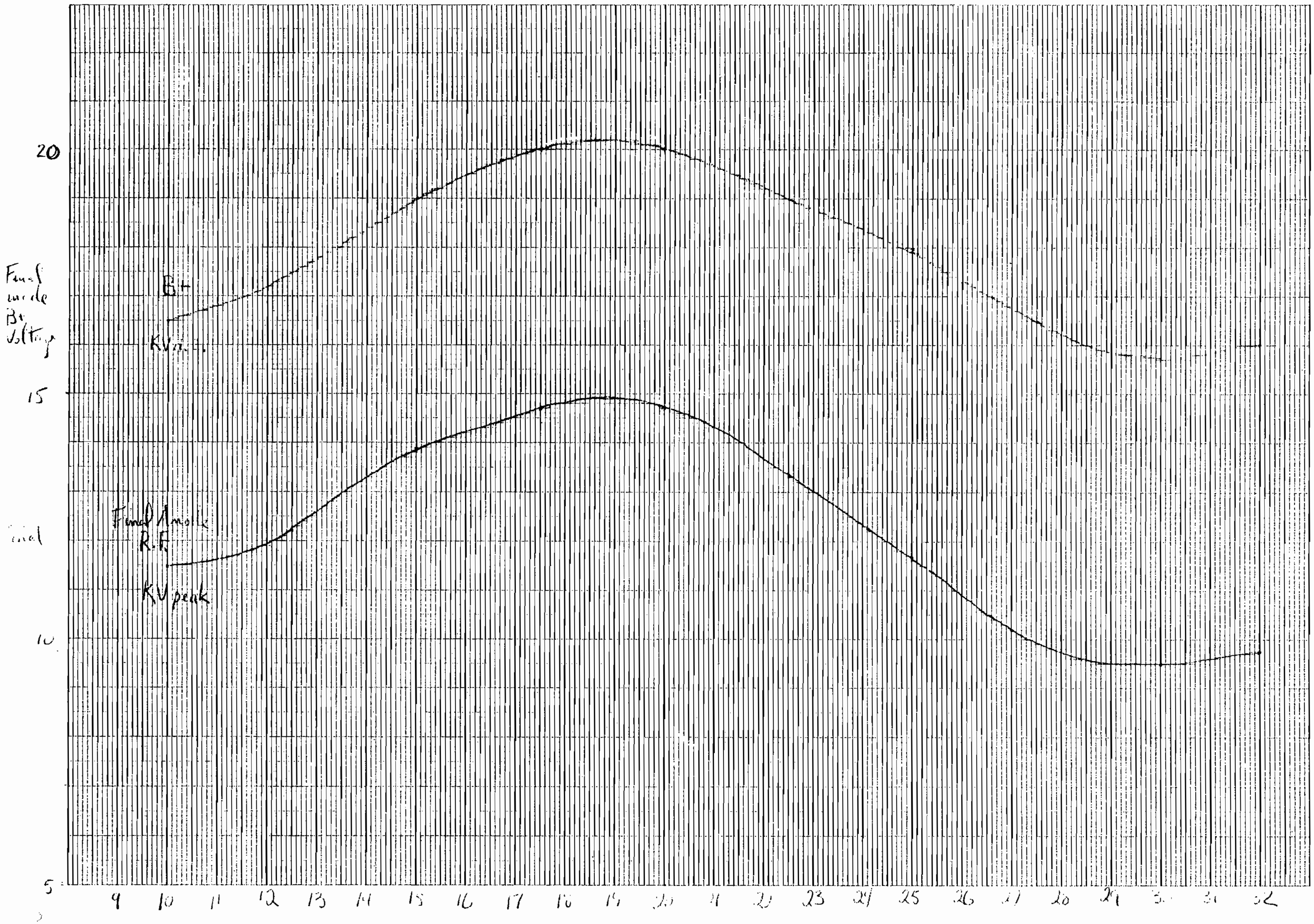
Normal Operating Conditions

f	I_{da}	I_{ds}	$V_{f.a}$	$I_{f.a.}$	V_{dg}	$V_{da.}$	V_{fg}	$V_{f.a.}$	$P_{(350\Omega)}$	Eff.
Hz	Adc.	mAdc	KVd.c.	Ad.c.	Vpk	Vpk	Vpk	KVpk	KW	%
2.0	.75	-45	16.5	7.0	29.8	1165	225	11.5	12.2	43%
[illegible]	.82	-55	17.5	7.0	33.0	1160	256	12.2	14.6	41%
5.0	.92	-65	19.0	7.0	35.8	1200	268	13.9	18.3	38%
7.5	.95	-75	20.0	7.0	36.3	1165	262	14.7	19.5	36%
10.0	.97	-75	20.0	6.8	34.7	1145	245	14.7	19.5	37%
12.5	1.03	-90	19.0	7.0	38.2	1130	261	13.3	17.0	38%
15.0	1.05	-85	18.0	7.0	36.4	1050	264	11.7	12.2	40%
[illegible]	1.12	-90	16.5	7.4	37.0	1110	277	10.2	9.7	41%
20.0	1.10	-90	15.7	7.5	35.4	1075	275	9.5	9.7	42%
22.0	1.20	-95	16.0	8.2	35.2	1075	310	9.7	12.2	38%

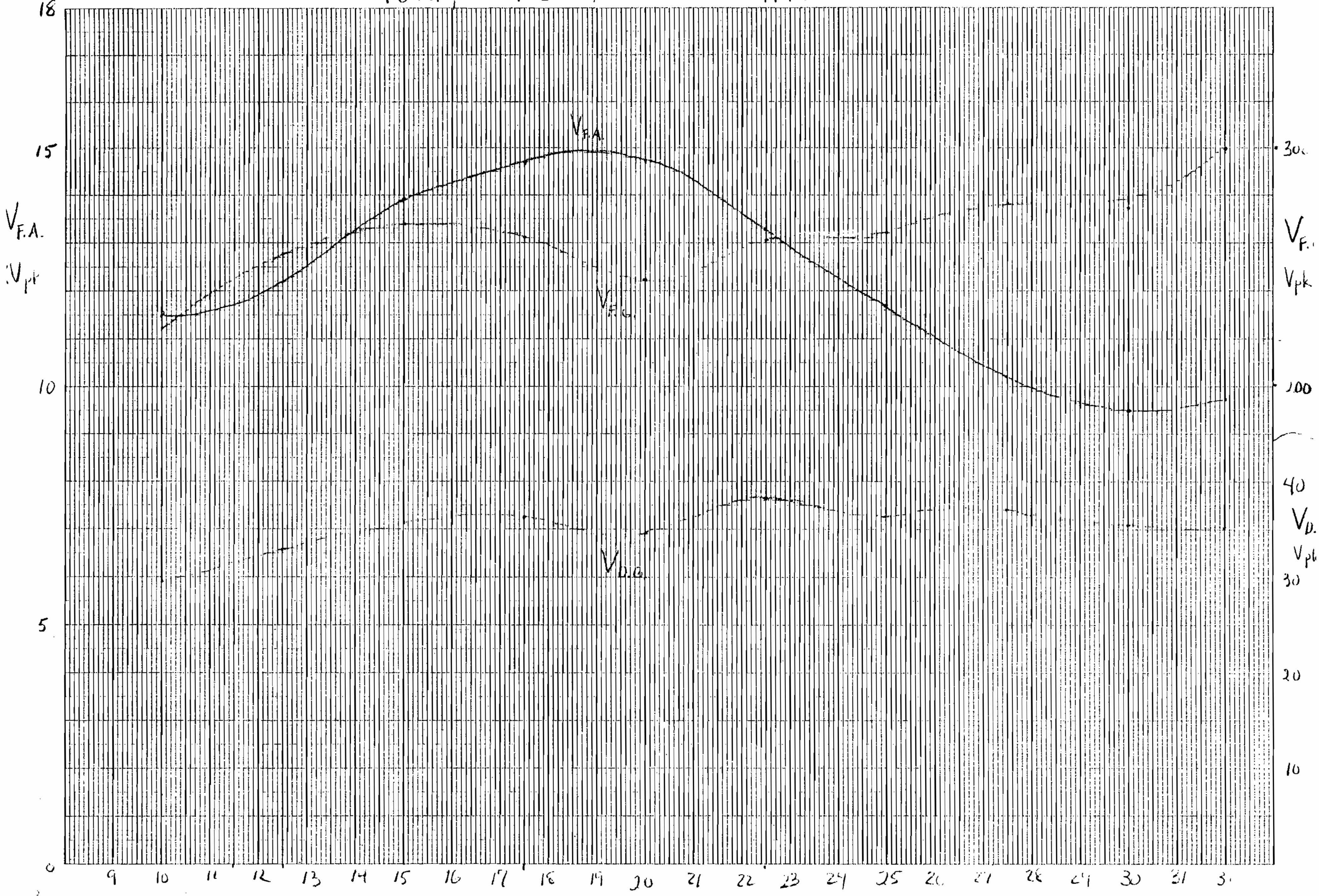
Constant over the frequency range are

Driver grid bias = -70 V d.c.
Driver screen bias = -335 V d.c.
Driver average B+ = 2.7 KV dc
Final grid bias = -200 V dc.
Final screen bias = +500 V dc.
Final screen current = 250 ma d.c.
Transmission line voltage = 2740 V pk

Final Anode D.C and R.F. Levels; 50 KW



Driver Grid, Final Grid, Final Anode R.F. levels - 50KW 1-29-80



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