R.F. Note

R.F. Note #45

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Transmitter Performance

The first series of tests have been completed on the transmitter, operating it into a 50 Ω resistive load over the entire frequency range from 9 to 32 MHz. Since the transmitter consists of two essentially independent sections, the "driver" and the "final" stages, it is logical and convenient to present results of the testing of these two stages separately.

Driver

The driver consist of two tubes (Eimac 4CW2000A) in parallel which are driven by a broad band 50W solid state amplifier. These tubes in turn provide the drive to the grid of the final tube. The driver has a tuned input and output, one variable inductor resonates out the parallel tube grid capacities (270 pf), and another resonates out the series combination, the driver plate and final grid capacities. Since the final grid capacity is about 5 times the driver plate capacities (570 pf/120 pf) the rf voltage that appears on the final grid is about 1/5 the voltage on the driver plates, and 180° out of phase. Actually, since the Q of this resonant circuit is quite low at the low end of our frequency range due to a 50 Ω - 1 KW dummy load on the final grid, the ratio of final grid to driver plate voltages changes from 0.24 to 0.18 as the frequency goes from 32 to 9 MHz, and the phase changes from -180° to -135°.

Considerable work was done in realizing a suitable (non inductive) screen bypass capacity in order to enable two tube operation since the driver feedback capacity would require neutralization if the screen was not a good rf ground. With this done, we agreed that the driver works "perfectly", and logged its performance at every frequency in its operating range. The driver was run at 3 different output levels at each frequency and some of the results are presented in Table I. The two graphs immediately following Table I present the driver voltage gain and driver efficiency curves for selected frequencies.

A curious observation is that the gain of the driver appears to increase with frequency. This is due, in part, to the fact that the voltage gain (the ratio of the final grid voltage to the driver and voltage) is affected by the changing Q of the driver plate-final grid circuit. Since the ratio of the final grid to driver plate voltage increases with frequency, the final grid voltage will increase with frequency, all other r.f. levels constant.

Another contributing factor in this matter is the so-called leakage inductance associated with the driver grid circuit. This inductance (about 20nH) is in series with the driver grid capacity. The grid voltage monitors read the voltage, V1 directly preceeding this series LC. The actual voltage on the grid, however is $V1/(1-\omega^2 LC)$ which at 32 MHz is 1.28 x VI. At 9mHZ, the actual grid voltage is 1.02 x V1. So as the frequency increases, so does the voltage on the driver grid increase with respect to the grid voltage monitors, hence the apparant gain of the driver increases. All this is academic, however, since V1 and V2 are in phase, and the only consequence of these effects are that we need less drive at high frequencies in order to obtain a given voltage on the final grid.

In conclusion, the driver behaves very well over the range of 9 to 35 MHz is free from paracitic or self excited oscillations, and is able to supply over 400 V peak of r.f. on the final grid, which should be sufficient to get the required power out of the final tube.

Final Stage

The final stage of the transmitter also works well when operating into a 50Ω resistive load. Testing of the transmitter has consisted of running it at two output levels, 40KW and 50KW over the operating frequency range. The 40KW and 50KW tests were conducted on two different occasions, and since all operating parameters were essentially constant over the frequency range for each run, there are no graphs to present in this case (save the stem short position and output resonating capacitor values), the graph of a constant quantity being not very interesting.

Determination of the output power was made in two ways. One was by measuring the power delivered to the dummy load using the directional coupler. The other was by measuring the water flow through the dummy load and the temperature difference between the inlet and outlet ports. At 10 G.P.M., a $1^{o}C$ temperature rise signifies a dissapation of 2.63 KW. Thus, 40 KW causes a $15.2^{o}C$ temperature rise, and 50 KW, $19.0^{o}C$. Since our temperature probe reads integral degrees, it is possible to have an error of almost $2^{o}C$ in reading the temperature difference, an error of over 10%. Agreement was good between the two measurements, however, so it is possible to feel confident that they are reasonably accurate.

One peculiarity of this transmitter is that the resonator is not long enough to resonate out at 9 MHz. In fact, the moving short is at the bottom of the stem just as it reaches the 10 MHz position. The solution to this problem is to add a discreet 100pf to the plate capacity of the tube, thereby lowering the resonant frequency of the transmitter by about 30% and enabling operation down to 9 MHz. To insure that we have sufficient overlap for these two modes of operation, the testing of the lowest 3 MHz (9, 10 and 11 MHz was done with this added plate capacity, it already has been seen that we can operate down to 10 MHz without the extra 100pf. So there is at least 1 MHz overlap between the two modes of operation, and no problem to operate the transmitter at any frequency in the range of 9 to 32 MHz. The transmitter operates quite well with the added capacity, but it causes discontinuity in the tuning curves associated with the final stage, i.e. the moving short position and output resonating capacity vs. frequency. With this in mind, the "tuning" curves presented in the back here should be self evident.

It is nice to know that the method of coupling the resonator to the transmission line works as we expected, for both operating conditions. The output resonating capacity resonates out the inductance of the coupling loop to achieve the proper phase and amplitude of the output voltage with respect to the final plate voltage. The output voltage is roughly 1/4 of the final plate voltage and of equal phase. It is, in fact, critical that the output capacitor be tuned properly, because if it is not, the transmitter stem sees a partially reactive load and one finds two degenerate modes in the transmitter stem resonator, neither of which produce the required phase and amplitude of the output voltage. Fortunately, tuning this output capacity has been no problem thus far, and may be brought under servo control fairly easily.

On 3-23-79, a test was performed to see if the transmitter is able to produce sufficiently high voltage to deliver up to 100 KW to the dees via the 75Ω transmission line. Unfortunately, our dummy load is good only up to 50 KW, and will burn up if it gets that much power. So it was necessary to disconnect the transmission line/dummy load from the coupling loop for this test. This causes the Q of the cavity to be quite large, ∿5000, and increases the effect of any feedback capacity associated with the final tube. In the process of detuning the final grid-driver plate circuit we found that the transmitter wanted to self-excite. We observed this for about 30 seconds, meanwhile a teflon spacer was burning up in the anode box due to a corona discharge from a sharp helicoil corner. The spacer has been fixed, sans helicoils, and the decision made to try to neutralize the final tube. Although this has yet to be finished, we are confident that the transmitter will behave quite well in all normal operating circumstances, it having required a large perturbation from these normal operating conditions to enable the self excited oscillations to exist. None the less, one must be careful and try to make the transmitter as "fool-proof" as possible.

To conclude, I say that the transmitter has performed very well in tests so far (perhaps with the exception of the one incident of the preceeding paragraph) but more tests have yet to be made. However, in the interests of documentation, I present these tables and graphs of the results of the tests already made. These should be fairly self explanatory. I also present calibration curves for the various voltage monitors of the transmitter. These calibrations are presented in the form of $V_{actual}/V_{monitor}$ vs. frequency.

This dimensionless ratio is then multiplied by the monitor voltage in order to obtain the actual voltage existing in the transmitter. Curves are given for monitors of the driver grid voltage, final grid voltage, final plate voltage, transmission line voltage, and the directional coupler voltage. The first four of these monitors were designed to be "flat" over the operating frequency range with the ratio of actual voltage to monitor voltage being 10:1, 60:1, 1000:1 and 300:1 respectively. In actuality, with paracitic reactances and such, these monitor ratios are a function of frequency, varying $\sim$10% over the frequency range. The directional coupler output varies as $1/\omega$, so this calibration is essentially a straight line on log-log paper with a slope of -1. Two curves appear on the final grid voltage monitor calibration graph as the two monitor outputs were significantly different.

Table 1 - Driver

Grid bias = -70 Vdc
Screen bias = 340 Vdc
Plate bias = 2.7 KVdc

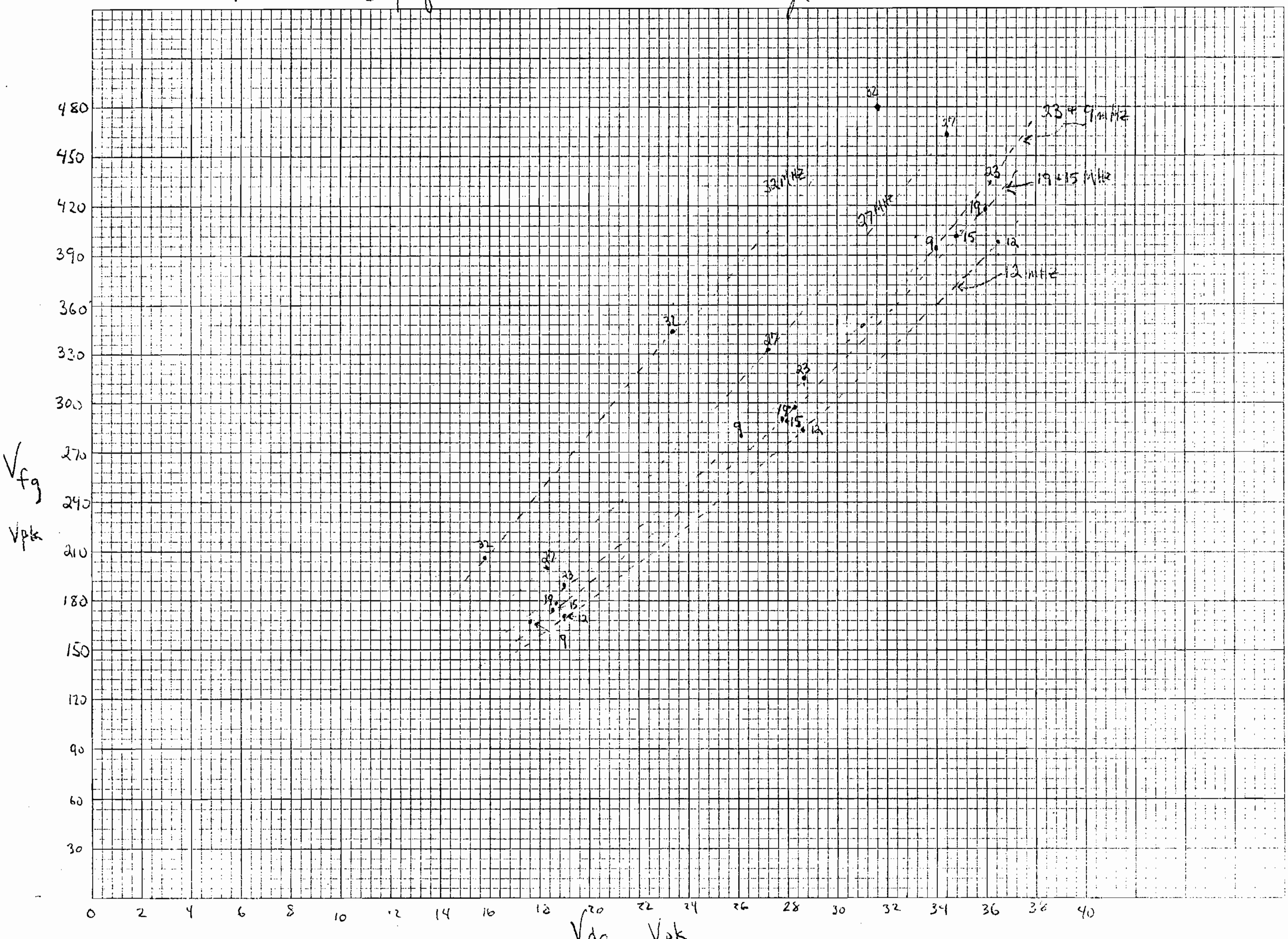
mHZ	$V_{driver\ grid}$ Vpk	$V_{final\ grid}$ Vpk	I_{plate} Adc	I_{screen} mAdc	$\frac{V_{fg}}{V_{dg}}$	Eff %
32	16	206	.63	- 45	13.0	25%
	23	343	.93	-135	14.7	47%
	32	481	1.20	-170	15.2	71%
31	16	205	.60	- 45	12.8	26%
	23	341	.90	-120	14.6	48%
	30	478	1.17	-155	16.0	72%
30	17	204	.60	- 40	12.3	26%
	24	339	.90	-120	13.9	47%
	32	475	1.19	-150	14.8	70%
29	18	202	.60	- 40	11.3	25%
	26	336	.89	-110	12.9	47%
	35	471	1.18	-150	13.6	70%
28	18	200	.61	- 35	10.9	24%
	27	334	.90	-110	12.4	46%
	35	467	1.20	-155	13.5	67%
27	18	199	.61	- 40	10.9	24%
	27	332	.92	-120	12.3	44%
	35	464	1.19	-150	13.4	67%

mHZ	$V_{driver\ grid}$ Vpk	$V_{final\ grid}$ Vpk	I_{plate} Adc	I_{screen} mAdc	$\frac{V_{fg}}{V_{dg}}$	Eff %
26	18	198	.60	- 40	11.2	24%
	27	329	.89	-115	12.8	45%
	35	460	1.16	-140	13.6	68%
25	17	196	.59	- 30	11.5	24%
	26	327	.87	-100	12.5	46%
	34	458	1.10	-135	13.7	71%
24	18	193	.59	- 30	10.7	23%
	27	322	.88	-100	11.7	44%
	35	451	1.14	-135	12.9	66%
23	19	190	.60	- 30	10.0	22%
	29	317	.89	-105	11.0	42%
	36	443	1.16	-150	12.3	63%
22	18	187	.59	- 30	10.2	22%
	27	311	.86	-105	11.4	42%
	36	435	1.15	-150	12.1	61%
21	18	183	.66	- 30	10.2	21%
	27	305	.87	-100	11.1	40%
	35	427	1.12	-140	12.4	60%
20	18	181	.58	- 30	10.0	21%
	27	301	.85	- 90	11.0	39%
	35	421	1.10	-135	12.2	60%

mHZ	$V_{driver\ grid}$ Vpk	$V_{final\ grid}$ Vpk	I_{plate} Adc	I_{screen} mAdc	$\frac{V_{fg}}{V_{dg}}$	Eff %
19	18	179	.56	- 30	9.8	21%
	28	298	.84	- 90	10.5	39%
	36	418	1.07	-140	11.6	60%
18	19	178	- 30	- 30	9.5	21%
	29	297	- 90	- 90	10.3	39%
	37	415	-140	-135	11.3	59%
17	19	177	.56	- 30	9.4	21%
	28	294	.84	- 90	10.3	38%
	37	412	1.10	-135	11.1	57%
16	18	176	.56	- 30	9.6	20%
	28	293	.84	- 90	10.7	38%
	36	410	1.08	-140	11.6	58%
15	19	175	.56	- 25	9.4	20%
	28	291	.82	- 80	10.5	38%
	35	408	1.04	-120	11.7	59%
14	18	173	.55	- 25	9.4	20%
	28	289	.80	- 75	10.3	39%
	36	404	1.00	-115	11.3	61%
13	19	172	.55	- 25	9.1	20%
	29	287	.86	- 75	9.9	38%
	37	402	1.03	-115	11.0	58%

mHZ	$V_{driver\ grid}$ Vpk	$V_{final\ grid}$ Vpk	I_{plate} Adc	I_{screen} mAdc	$\frac{V_{fg}}{V_{dg}}$	Eff %
12	19	171	.55	- 30	8.9	20%
	29	285	.80	- 75	9.9	37%
	37	398	1.04	-120	10.9	57%
11	19	170	.54	- 25	8.9	20%
	30	283	.79	- 75	9.3	38%
	39	397	1.00	-110	10.3	58%
10	18	170	.53	- 20	9.3	20%
	27	283	.75	- 70	10.6	39%
	34	396	.96	-100	11.6	60%
9	18	159	.51	- 20	9.6	21%
	26	281	.74	- 60	10.8	40%
	34	394	.92	- 90	11.6	62%

Driver alone performance - 3-1-79 - Voltage Gain



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Driver Efficiency Curve

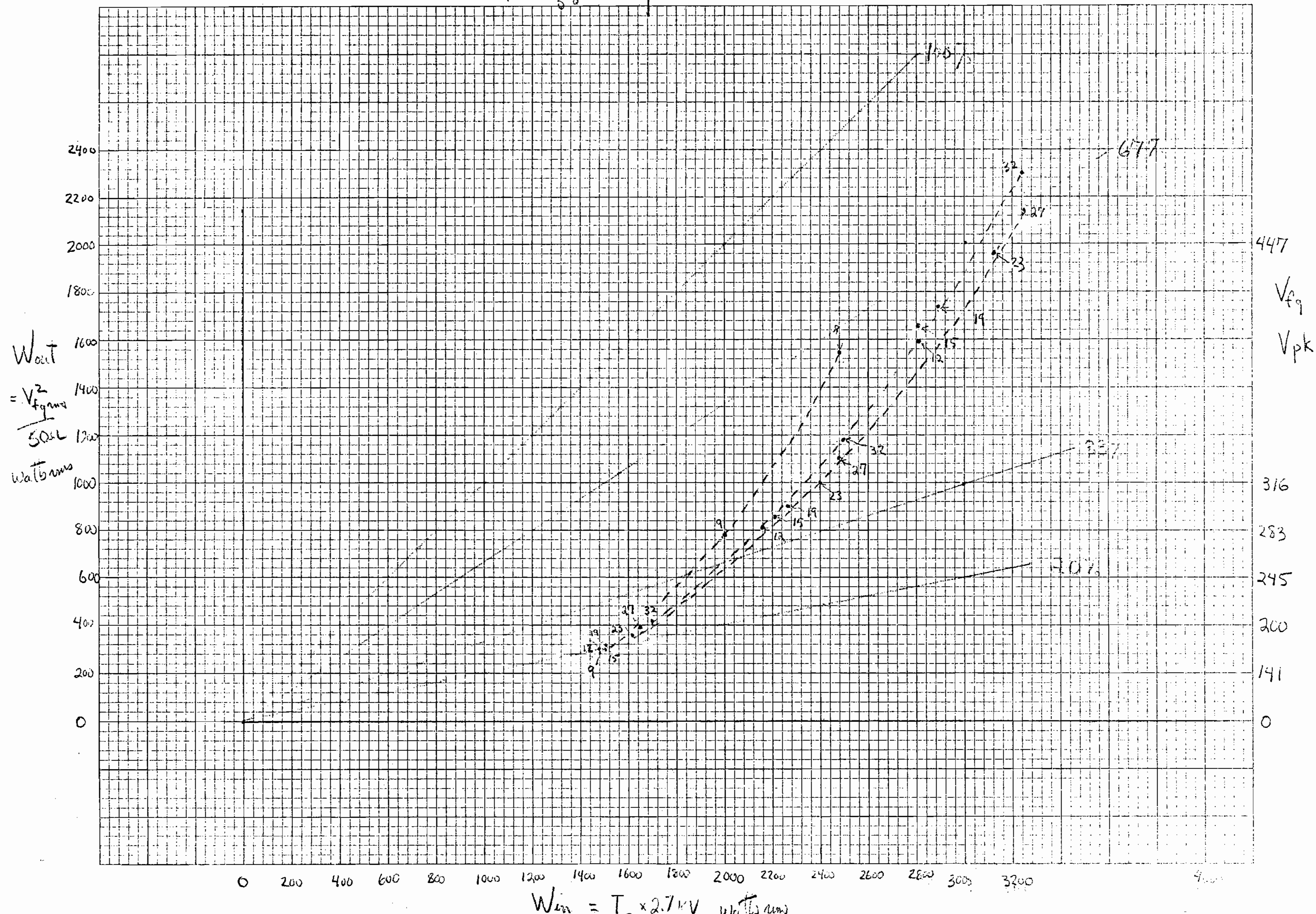


Table II - Final

Grid bias = -300 Vdc
Screen bias = 1500 Vdc
Plate bias = 12.5 KVdc

W_{out} = 40 KW/50Ω

f MHz	$V_{final\ grid}$ Vpk	$V_{final\ plate}$ KVpk	V_{out} KVpk	I_{plate} Adc	I_{screen} mAdc	W_{out} (Water) W	Eff %
32	210	7.80	1.85	5.5	310	42.0	61%
30	207	7.98	1.97	5.4	310	42.0	62%
28	204	7.89	1.97	5.5	280	42.0	61%
26	209	8.03	1.95	5.6	270	40.0	57%
24	205	7.80	2.08	5.5	250	42.0	61%
22	204	7.76	1.96	5.4	250	40.7	60%
20	199	7.73	1.95	5.4	240	39.5	59%
18	204	8.10	1.98	5.4	250	42.0	62%
16	212	7.87	1.99	5.4	250	40.0	59%
14	212	8.04	1.97	5.4	245	42.0	62%
12	203	8.27	1.94	5.4	245	39.5	59%
11*	225	7.94	2.00	5.0	240	39.5	63%
10*	216	7.80	1.96	5.0	220	39.5	63%
9*	208	8.67	2.07	5.4	270	43.7	64%

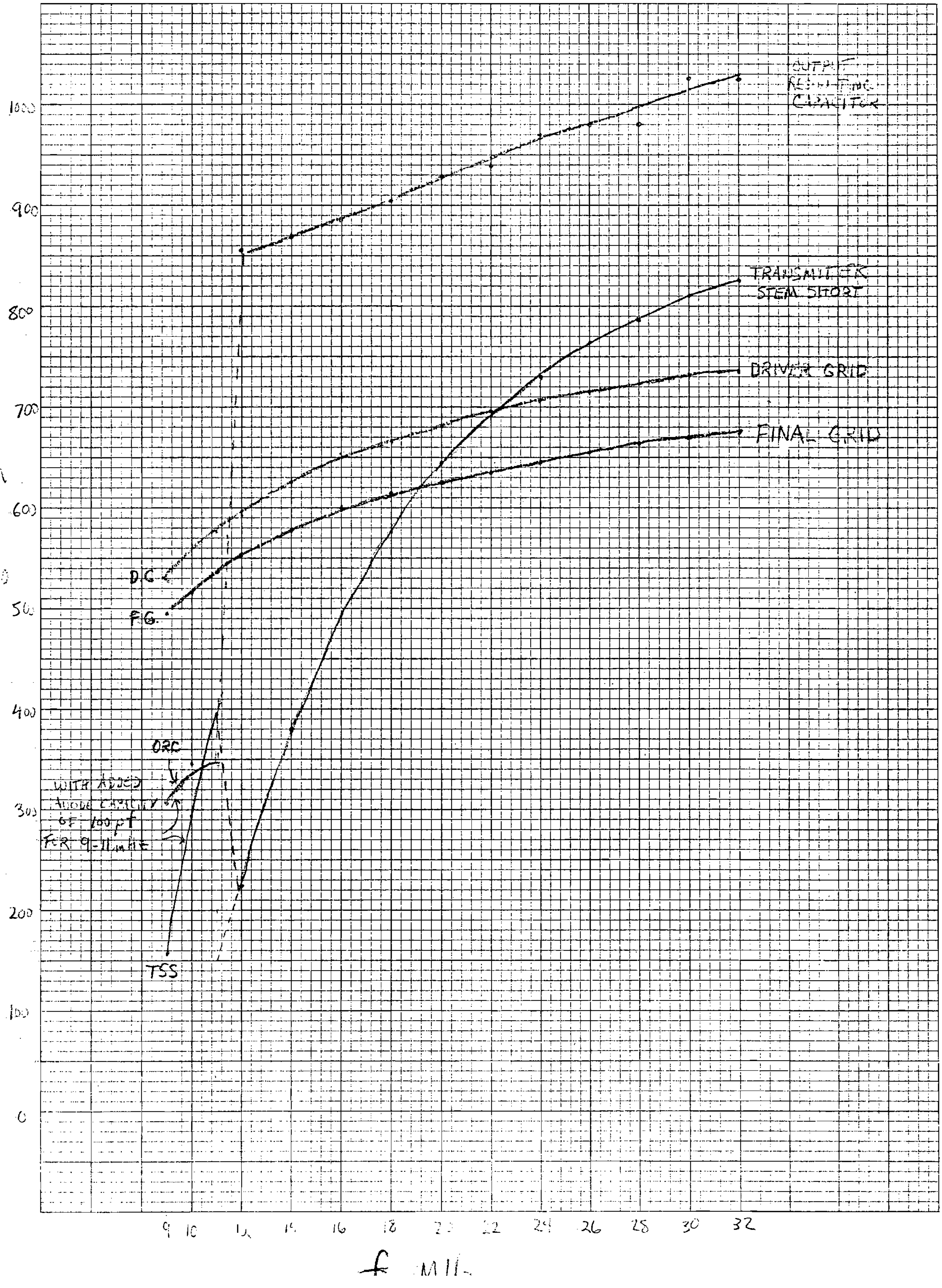
* Operation at these frequencies was with extra 100 pf plate capacity.

Table III - Final

Grid bias = -300 Vdc
Screen bias = 1500 Vdc W_{out} = 50 KW/50Ω
Plate bias = 15 KVdc

MHz	$V_{final\ grid}$ Vpk	$V_{final\ plate}$ Vpk	V_{out} KVpk	I_{plate} Adc	I_{screen} mAdc	W_{out} (Water) W	Eff %
32	210	9.60	2.24	5.1	250	50	65%
30	217	9.65	2.24	5.5	260	55	67%
28	205	8.90	2.24	5.2	210	48.7	62%
26	204	8.90	2.24	5.3	200	51.0	65%
24	206	8.90	2.24	5.5	200	50	61%
22	206	8.73	2.24	5.6	200	50	60%
20	200	8.75	2.24	5.6	180	50	60%
18	211	9.00	2.24	5.7	180	50	58%
16	208	9.00	2.24	6.0	280	65.8	73%
14	204	9.00	2.24	5.9	160	50	56%
12	202	10.00	2.24	5.6	200	50	60%

For Test on 3-5-79



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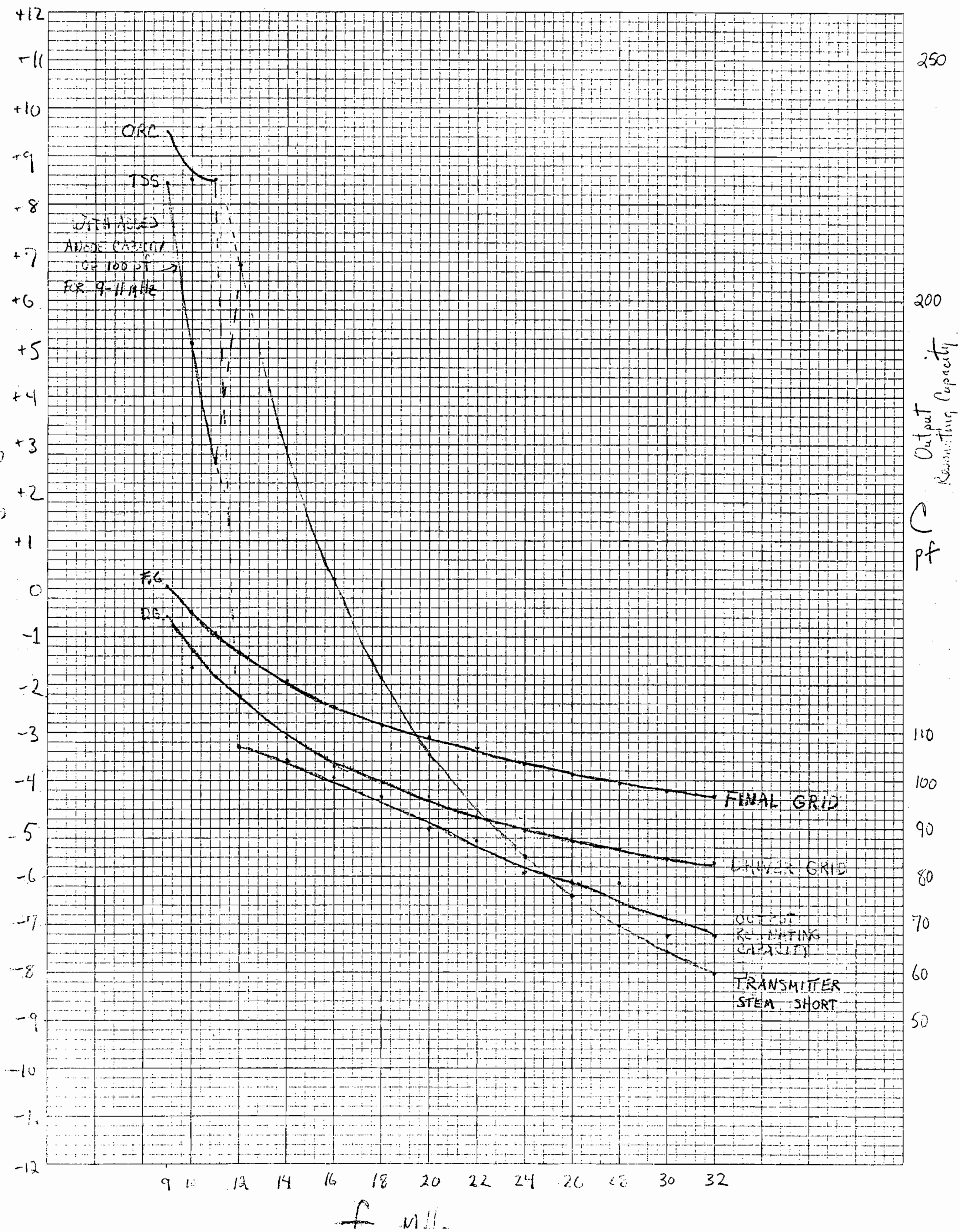
5 X 5 TO THE CENTIMETER 18 X 24 CM.
KEUFFEL & ESSER CO. MADE IN U.S.A.

For test on 3-5-79



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5 X 5 TO THE CENTIMETER 18 X 24 CM.
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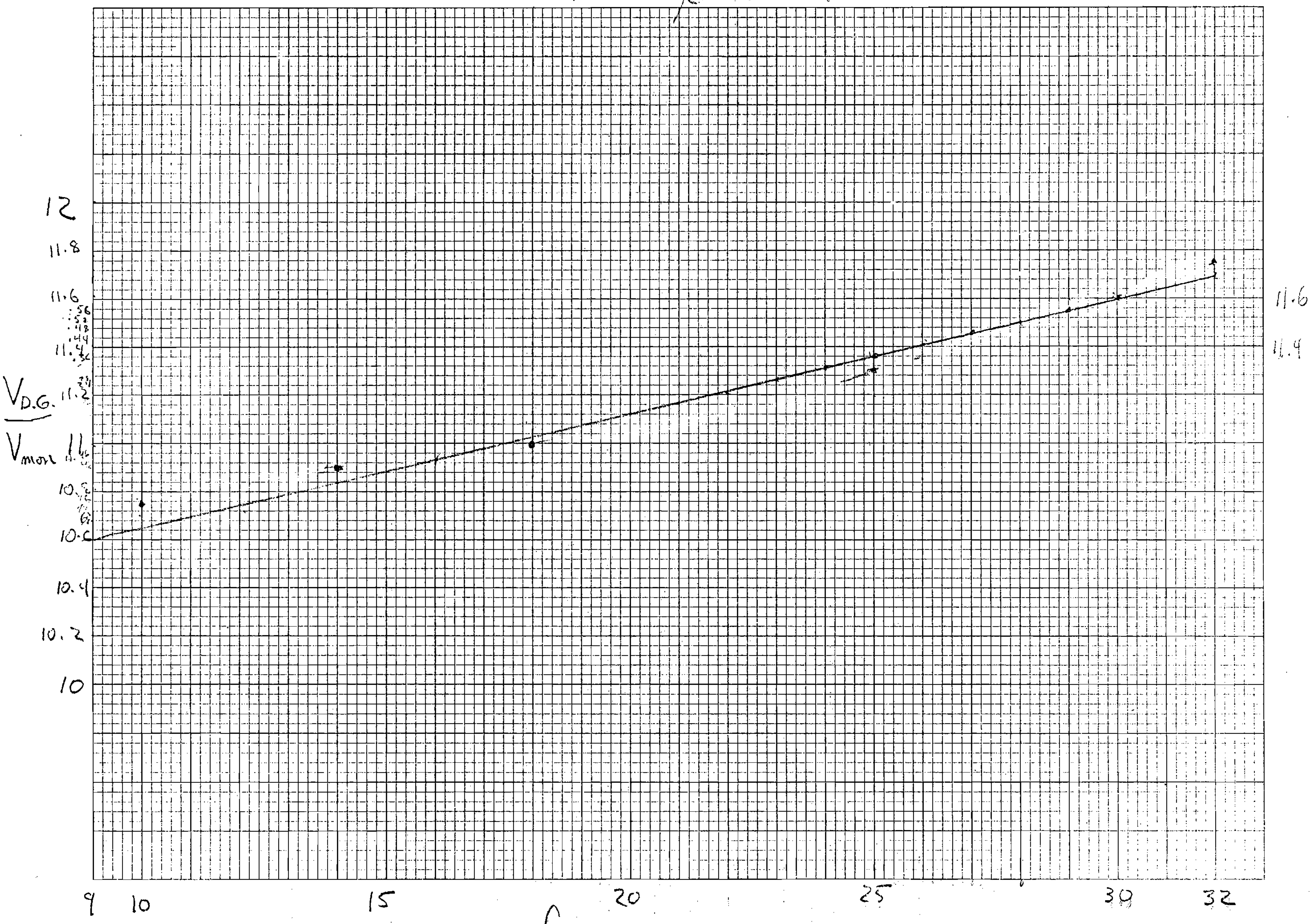
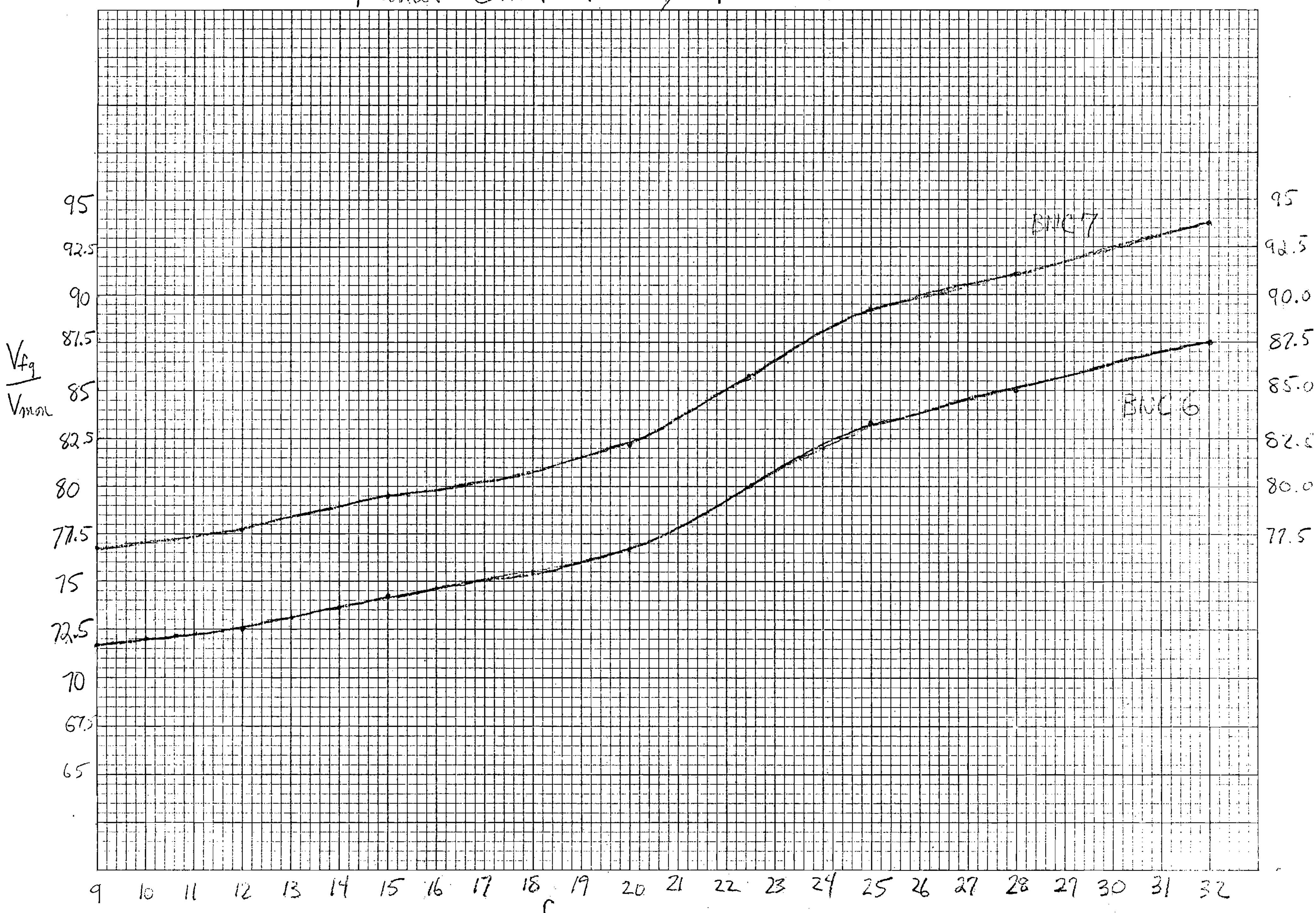
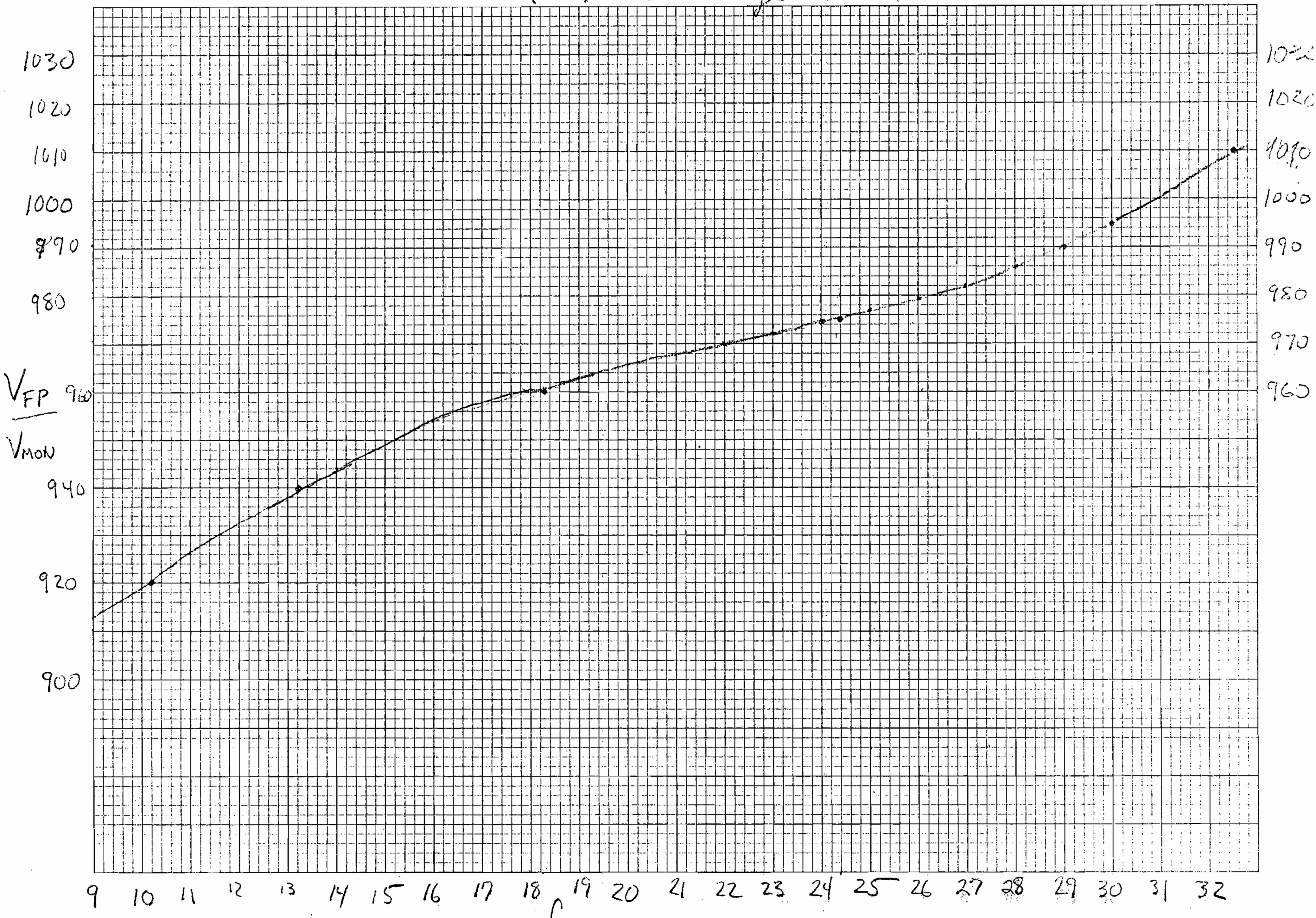
Driver Grid Voltage Monitor



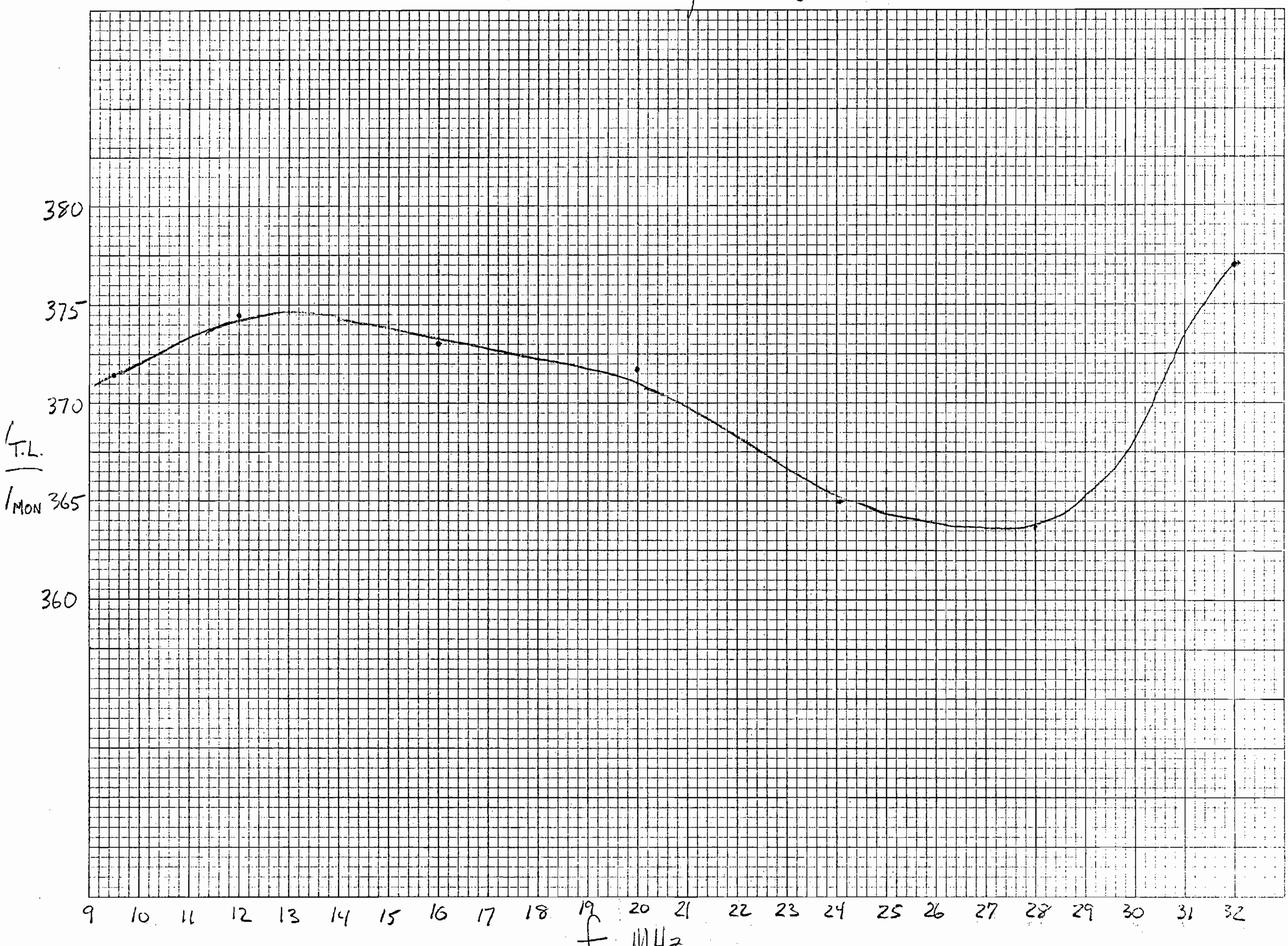
Final Grid Voltage Monitor



Final Plate Voltage Monitor



Transmission line voltage monitors



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Directional Coupler Calibration

Transmitted Wave