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DATE 7 March 1934

SUBJECT

Report on

Detector Characteristics

by

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NAVAL RESEARCH LABORATORY

[illegible] BELLEVUE, D. C.

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NAVY DEPARTMENT

BUREAU OF ENGINEERING

Report on

Detector Characteristics

NAVAL RESEARCH LABORATORY
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WASHINGTON, D. C.

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APPENDICES

I AUTHORIZATION

The work reported upon herein deals with the study of detectors and is a part of the work authorized by Bureau of Engineering letter 367/46(2-27-38) of 14 April 1933.

II OBJECT

Investigation of detection characteristics of various types of detector tubes under various operating conditions for the purpose of selecting the type best suited to the particular needs of the Naval Service. This investigation is a part of Problem R5-7 assigned by the subject authorization and having for its object, "the investigation, and design, and model construction of new shipboard radio receiving equipment to better fill the needs of the Naval Service in the light of improvements in the radio art".

This objective was not attained for the reason that the problem was cancelled. Such tests as were completed are reported herein.

III DESCRIPTION OF TESTS

Tests were conducted on type 77 triple grid detectors and on type 37 triodes only.

The tests conducted were designed to determine (a) the detection efficiency (gain), (b) the effect of the detector on the tuned input stage preceding it, and (c) to construct, if possible, a detection system having a sharp cut-off characteristic for overloads.

IV METHOD OF CONDUCTING TESTS

A radio frequency amplifier having the following specifications was constructed for operation at 600 kilocycles:

Tube: Type 78
Plate voltage: 250 V. Screen voltage: 100 V.
Cathode bias: 3.2 V.
Plate coil (untuned) 510 uh.
Output coil (tuned 640 uh (for detector input)
Mutual inductance 143 uh

The grid of the detector under test was connected to the tuned output circuit of the radio frequency amplifier. The output of the detector under test was connected to the input of an audio amplifier of the type used in the Models RAA and RAB receivers.

Determination of signal voltages existing at various points was made by the method of substitution; that is, for any given 30% 1000 cycle modulated signal applied to the grid of the radio frequency

amplifier, by a standard signal generator, the output of the audio amplifier was noted. The signal was then applied to the grid of the detector and increased in amplitude until the same audio output was obtained. The ratio of the grid signal of the detector to the grid signal of the radio frequency amplifier is the gain of the radio frequency amplifier. In the same manner, a measured 1,000 cycle signal is applied to the input of the audio amplifier and increased in amplitude until the previously noted audio output is obtained. The ratio of this detector output signal to the detector grid signal is the detector gain.

V TEST RESULTS

Plate 1 represents the test of a type 77 plate detector under the following conditions: Plate battery potential E_B = 250 volts, screen grid potential E_{sg} = 100 volts, control grid bias E_g = -4.2 volts (constant), plate load resistor R_L = 0.25 megohms, and the plate by-pass condenser C_p = 0.005 microfarad. With no input signal applied, the plate current was 0.4 milliamperes.

This plate shows that the detector characteristic is exactly expressed by $E_o = 3.2E_i^2$ and is, therefore, square law. The detector gain is $E_o/E_i = 3.2E_i$ and is, therefore, seen to increase in linear proportion to the signal voltage.

The gain of the radio frequency amplifier is constant at a value of 88. Consequently, the detector grid draws no conductive current (no positive grid current) throughout the measured range.

Plate 2 represents the test of the same tube under identical conditions except that the grid bias (same numerical value as before) is supplied by a suitably by-passed cathode resistor.

The detector characteristic is expressed by $E_o = 3.2E_i^2$ and the gain by $E_o/E_i = 3.2E_i$; expressions identical with those above. The increase of D.C. plate current with input signal is insufficient to materially change the cathode bias from its no signal value.

These tests were limited to a maximum signal of 0.5 volts on the detector grid, this value being the maximum output of the standard signal generator.

Plate 3 represents the test of the same tube under conditions identical with those of Plate 2 except that the screen grid potential was reduced to 28 volts, with a resulting plate current of 0.14 milliamperes.

The detector characteristic is still square law as before, but the gain is about 16% greater. The characteristic is expressed as $E_o = 3.7E_i^2$. The gain is $E_o/E_i = 3.7E_i$.

Plate 4 represents the test of a type 37 grid detector under the following conditions: $E_B = 250$, $E_g = 0$, $R_L = 0.1$ meg, grid leak $R_g = 1$ meg, grid capacitor $C_g = 250$ mmf.

The detector characteristic is not square law but varies between the second and first powers throughout its range. The gain characteristic likewise varies between the first and the half power.

The gain of the radio frequency amplifier is about half that obtained when using a type 77 tube as a detector. This is to be expected because of the conductance of the grid circuit of the type 37 tube when used as a grid detector. The fact that the gain of the radio frequency amplifier rises with increased signal is not understood in the light of the meager data obtained in the time allotted. This apparent rise may possibly be the result of experimental error.

Plate 5 represents the test of the same type 37 tube under conditions identical with those of Plate 4 except that the load resistance R_L has been reduced to 0.05 megohm. The results obtained are identical with those of Plate 4. Thus it may be supposed that the dynamic plate resistance of the tube as used is small compared to 50,000 ohms.

Plate 6 represents the test of the same type 37 tube under conditions identical with those of Plate 5 except that the grid bias is -0.8 volts (constant).

The radio frequency amplifier gain has increased to 60 for small input signals and drops slightly for larger signals, as would be expected as the detector grid conductance has been reduced for small signals and increases for larger signals.

The use of this additional detector grid bias has greatly reduced the detector gain, particularly at low signal levels.

Plate 7 represents the test of the same type 37 tube under conditions identical with those of Plate 6 except that the grid bias is -1.2 volts (constant).

The radio frequency amplifier gain remains in the vicinity of 60 while the detector gain is further decreased, especially for small signals.

VI CONCLUSIONS

The tests outlined in the foregoing paragraphs were of a very preliminary nature, made primarily for the purpose of determining the operating conditions which would produce a sharp cut-off characteristic for overloads of any desired amplitude. Such an operating

characteristic was not found and it is probable that such a one can not be produced without serious reduction of detector gain at points below cut-off.

Of the two types of tubes tested, the type 77 tube used as a plate detector is far superior to the type 37 tube used as a grid detector. This statement is based not only on the inherently better gain of the former, but also on its much smaller damping effect on the preceding tuned circuit.

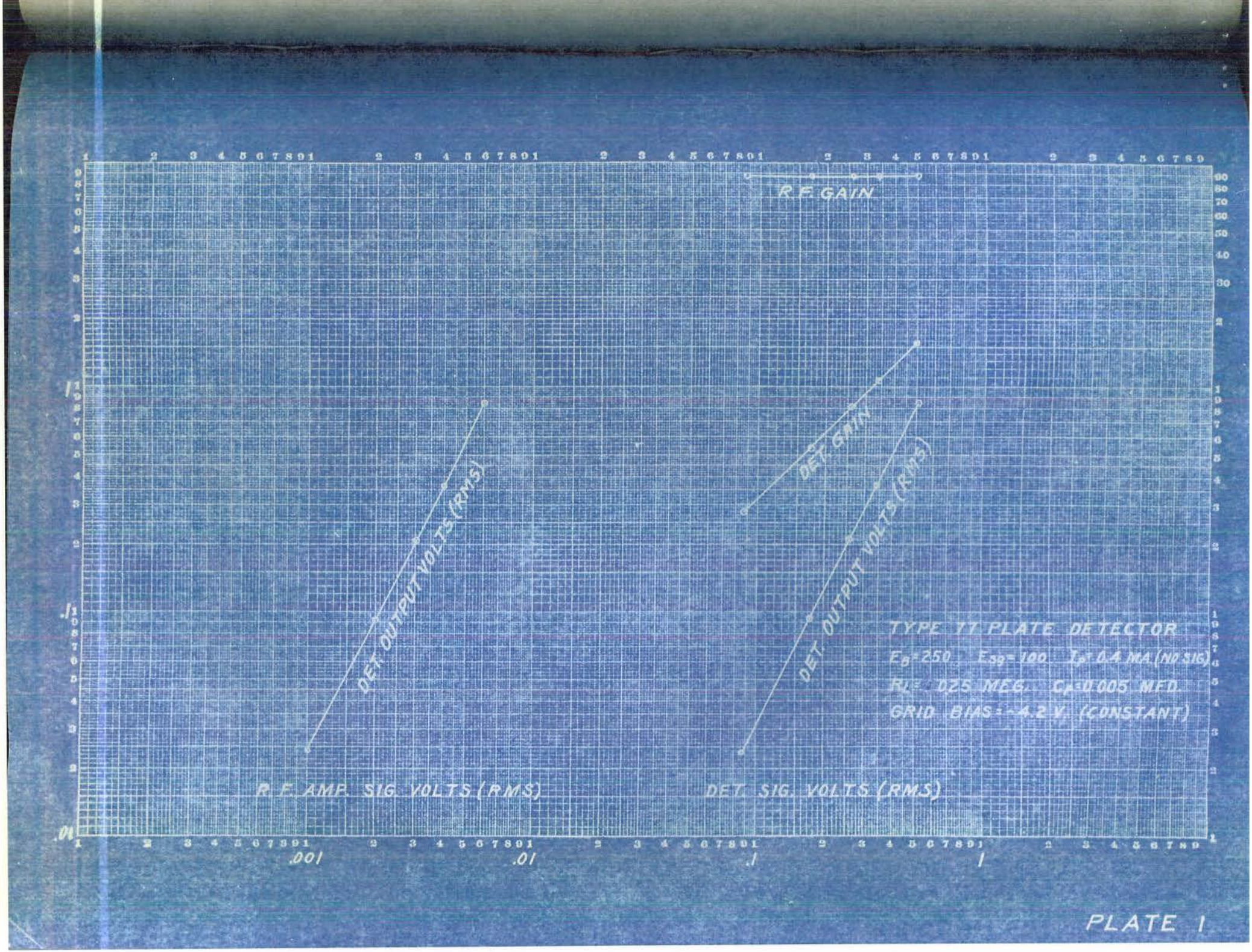
R.F. GAIN
DET. GAIN
DET. OUTPUT VOLTS (RMS)
DET. OUTPUT VOLTS (RMS)
TYPE 77 PLATE DETECTOR
E_B=250 E_{SG}=100 I_B=0.4 MA (NO SIG)
R_L=.025 MEG. C_K=0.005 MFD.
GRID BIAS = -4.2 V. (CONSTANT)
R.F. AMP. SIG. VOLTS (RMS)
DET. SIG. VOLTS (RMS)
.001
.01
.1
1

PLATE 1

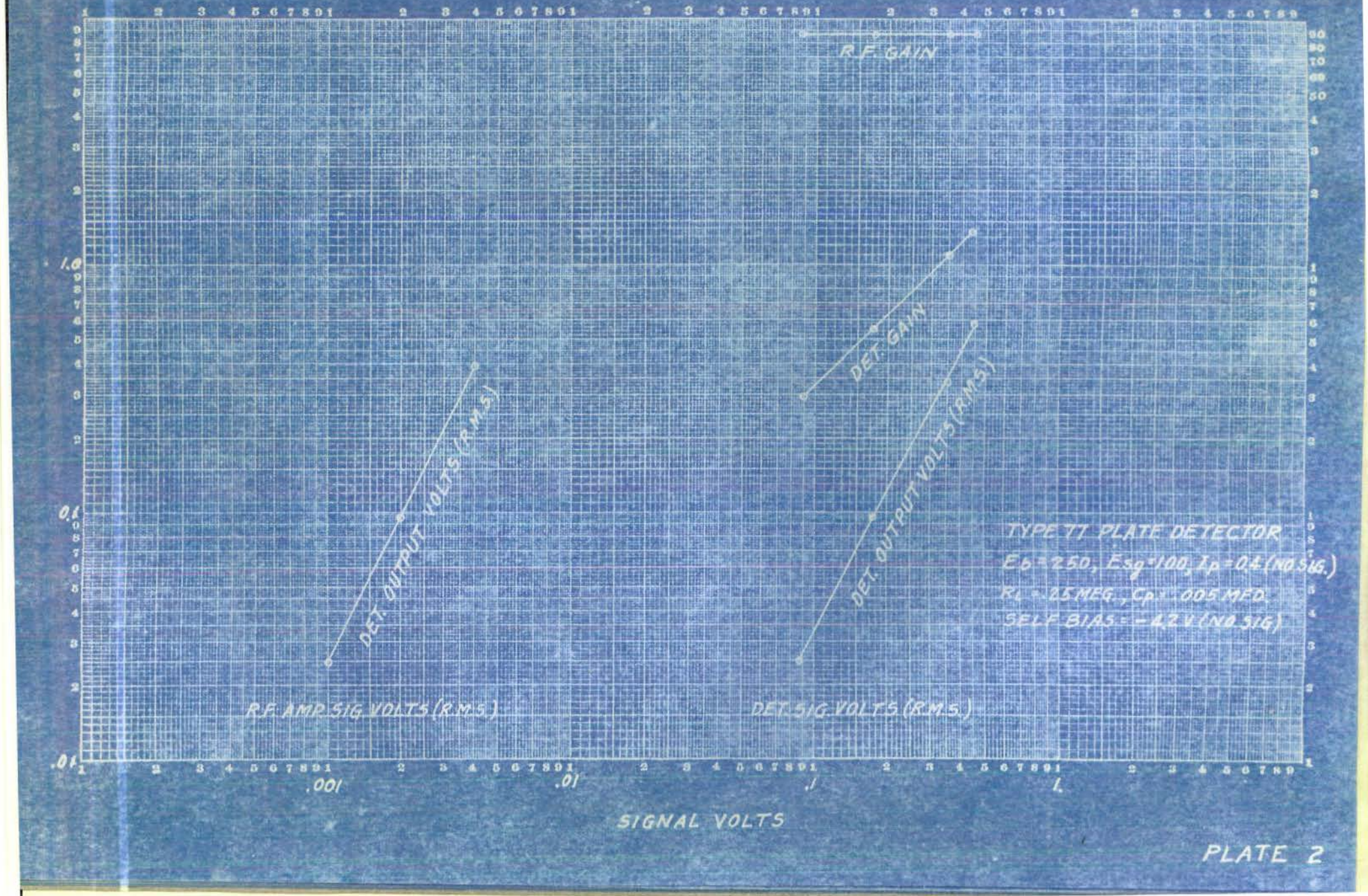
R.F. GAIN
DET. GAIN
DET. OUTPUT VOLTS (R.M.S.)
DET. OUTPUT VOLTS (R.M.S.)
TYPE 77 PLATE DETECTOR
E_b = 250, E_{sg} = 100, I_p = 0.4 (NO SIG.)
R_L = .25 MEG., C_p = .005 MFD.
SELF BIAS = −4.2 V (NO SIG.)
R.F. AMP. SIG. VOLTS (R.M.S.)
DET. SIG. VOLTS (R.M.S.)
.001
.01
.1
1.
SIGNAL VOLTS

PLATE 2

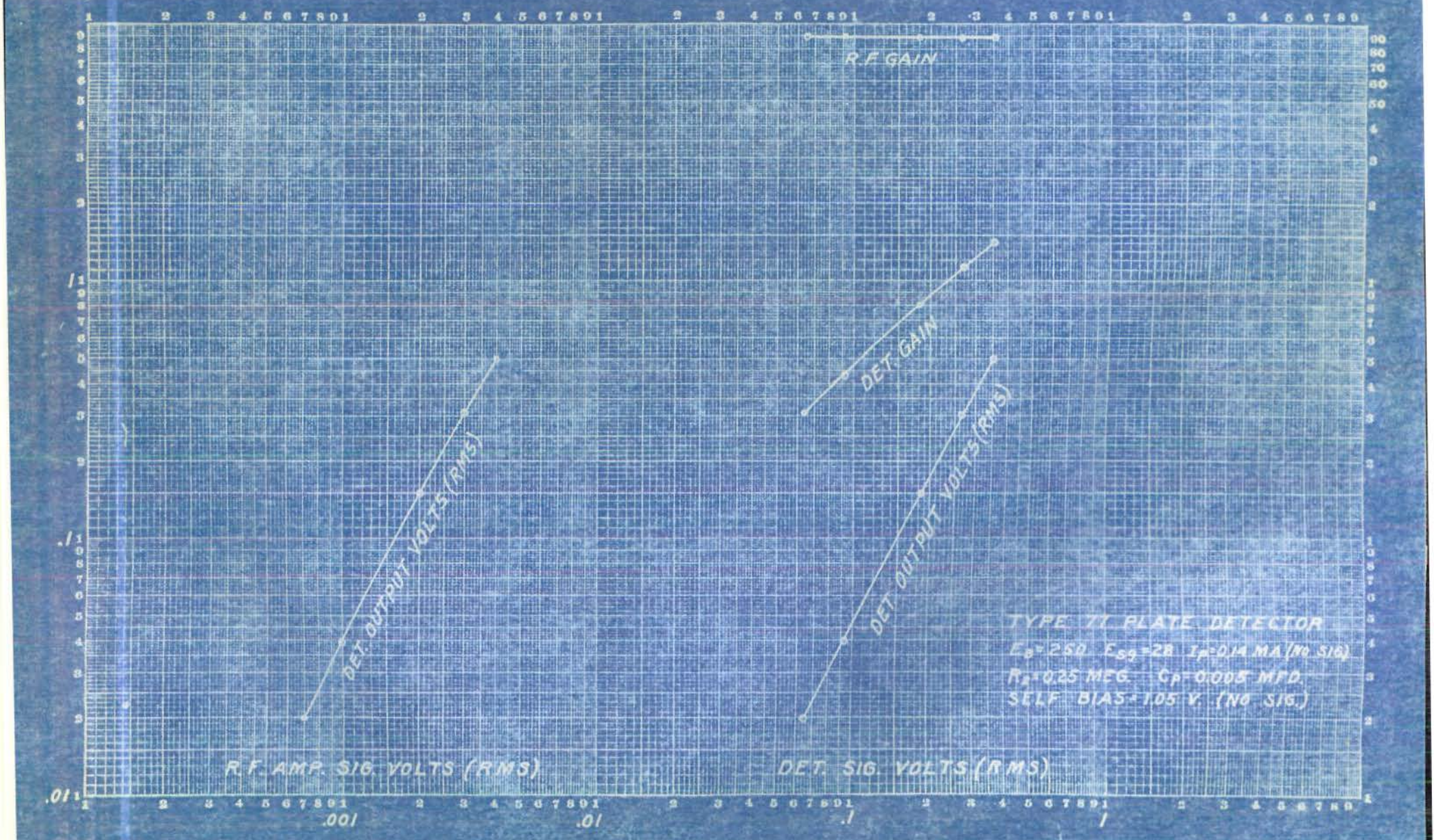
R.F GAIN
DET. GAIN
DET. OUTPUT VOLTS (RMS)
DET. OUTPUT VOLTS (RMS)
TYPE 77 PLATE DETECTOR
E_B=250 E_{SG}=28 I_P=0.14 MA (NO SIG)
R_g=0.25 MEG. C_p=0.005 MFD.
SELF BIAS=1.05 V. (NO SIG.)
R.F. AMP. SIG. VOLTS (RMS)
DET. SIG. VOLTS (RMS)
.001
.01
.1
1
.01
.1

PLATE 3

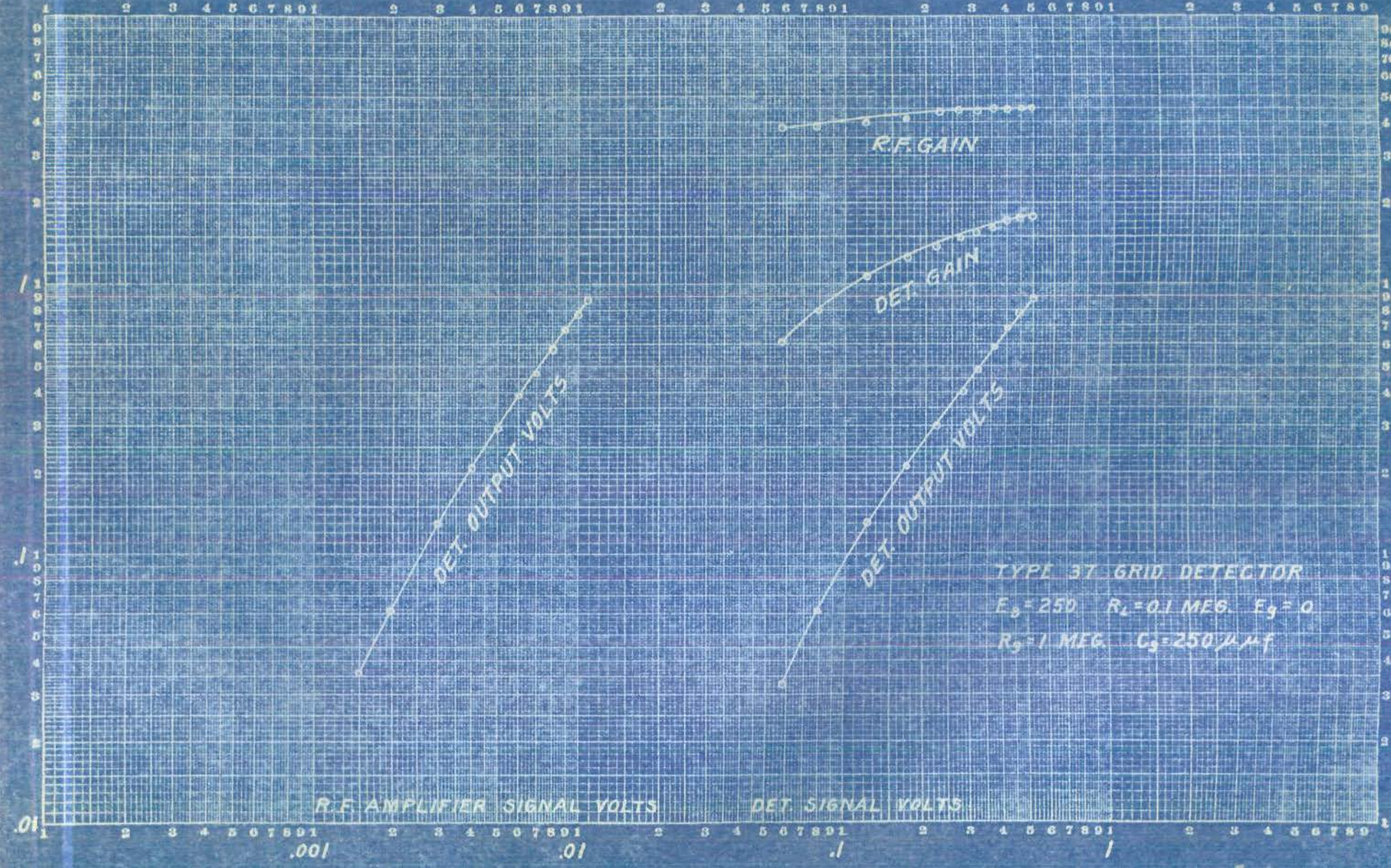
R.F. GAIN
DET. GAIN
DET. OUTPUT VOLTS
DET. OUTPUT VOLTS
TYPE 37 GRID DETECTOR
E_b = 250 R_L = 0.1 MEG. E_g = 0
R_g = 1 MEG. C_g = 250 μμf
R.F. AMPLIFIER SIGNAL VOLTS
DET. SIGNAL VOLTS
.001
.01
.1
1

PLATE 4

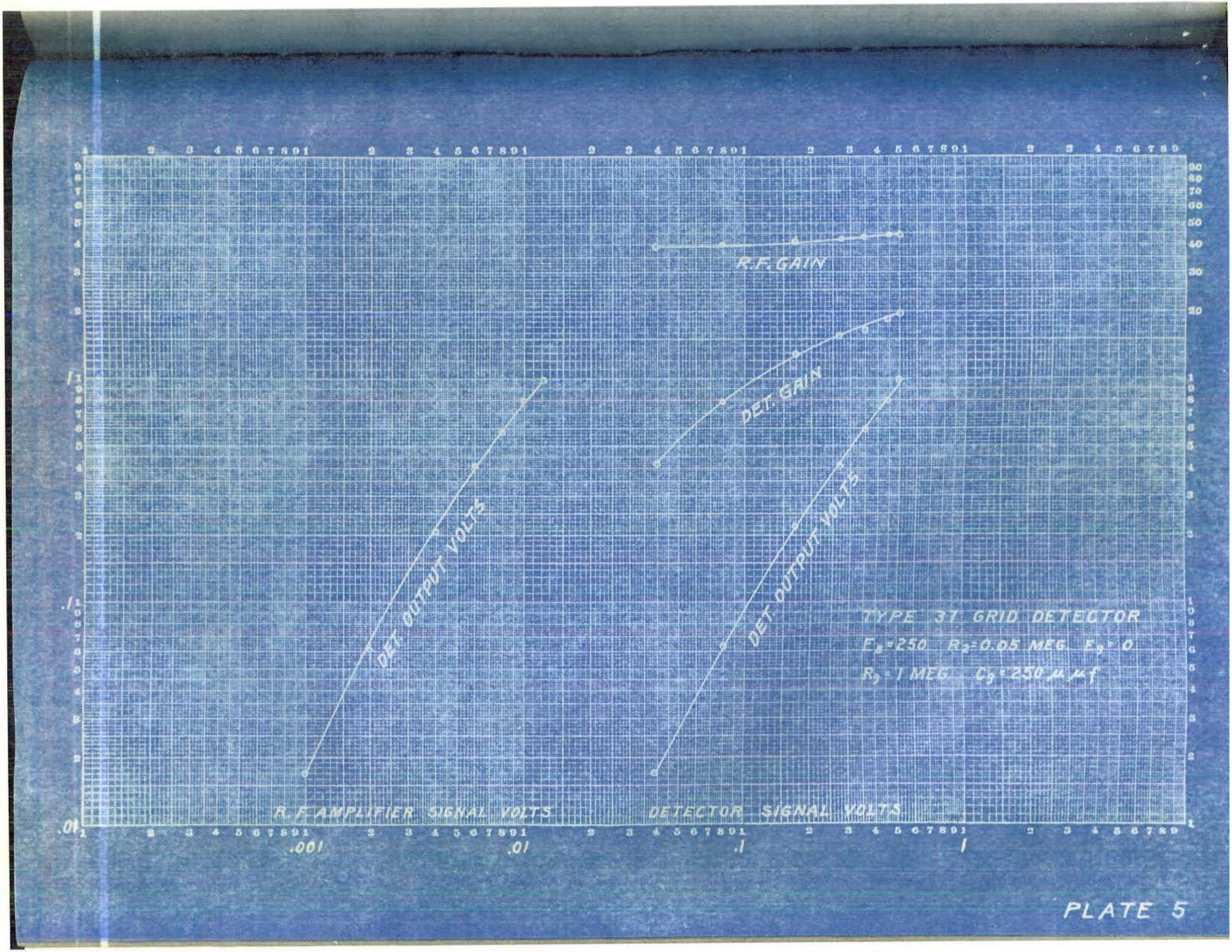
R.F. GAIN
DET. GAIN
DET. OUTPUT VOLTS
DET. OUTPUT VOLTS
TYPE 37 GRID DETECTOR
E_b=250 R_g=0.05 MEG. E_g=0
R_p=1 MEG. C_g=250 μμf
R F AMPLIFIER SIGNAL VOLTS
DETECTOR SIGNAL VOLTS
.001
.01
.1
1

PLATE 5

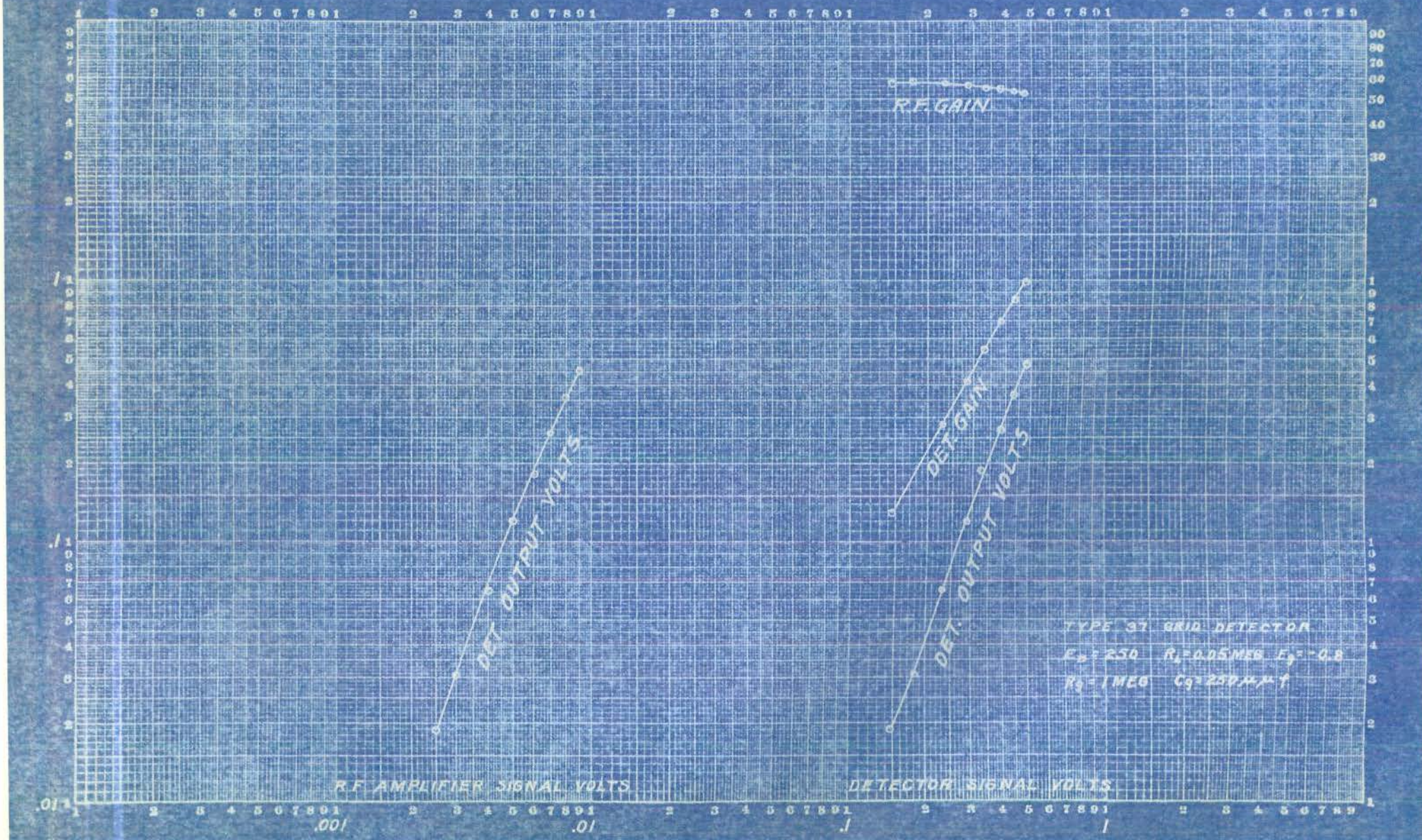
R.F. GAIN
DET. GAIN
DET. OUTPUT VOLTS
DET. OUTPUT VOLTS
TYPE 37 GRID DETECTOR
E_b = 250 R_k = 0.05 MEG E_g = -0.8
R_g = 1 MEG C_g = 250 μμf
R.F AMPLIFIER SIGNAL VOLTS
DETECTOR SIGNAL VOLTS
.001
.01
.1
1

PLATE 6

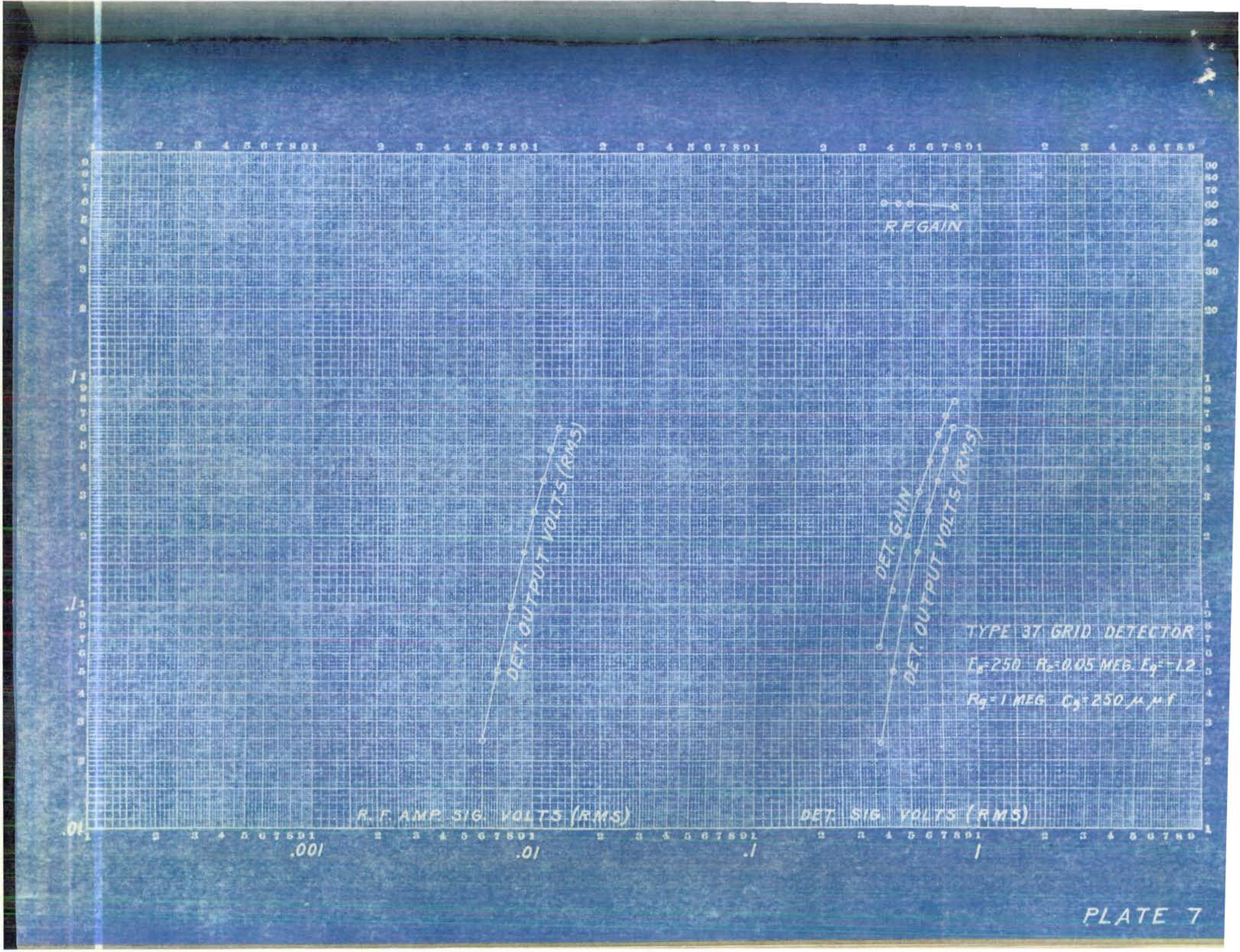
R.F GAIN
DET. GAIN
DET. OUTPUT VOLTS (RMS)
DET. OUTPUT VOLTS (RMS)
TYPE 37 GRID DETECTOR
E_b=250 R_c=0.05 MEG. E_g=-1.2
R_g=1 MEG. C_g=250 μμf
R. F. AMP. SIG. VOLTS (RMS)
DET. SIG. VOLTS (RMS)
.001
.01
.1
1

PLATE 7