INSTRUCTION AND OPERATING MANUAL
FOR

Type QM1
Q - METER

CONTENTS

SECTION 0
SPECIFICATIONS

Q-RANGE

30 to 625

While the instrument is direct reading from 30 to 250, Q-values up to 625 are measured by reducing the RF current and multiplying the readings of the two meters.

ACCURACY OF Q-MEASUREMENTS

5% of reading + 2 units at all frequencies below 20 Mc. At Q-values above 250 the accuracy decreases gradually to 10% at Q = 625.

VARIABLE CAPACITOR

Range

Main Capacitor: 45 to 500 $\mu\mu$F.
Vernier Capacitor: ±5 $\mu\mu$F with divisions of 0.2 $\mu\mu$F.

Accuracy

Main capacitor: 1% or 1 $\mu\mu$F whichever is the greater.
Vernier Capacitor: 0.1 $\mu\mu$F.

RF OSCILLATOR

Frequency

50 kc to about 70 Mc in 8 ranges. (The instrument can be used down to 1 kc by means of an external signal source, which can supply 0.5 amp into 1 ohm.)

Accuracy

1% below 30 Mc.
3% above 30 Mc.

POWER SUPPLY

Voltages: 110,127,200,220 and 240 volts.
Line Frequencies: 50 to 60 cps.
Consumption: 30 watts

TUBES

1 EC81 (6R4)
1 7586 Nuvistor
2 90C1
1 EZ40

MOUNTING AND FINISH

Steel cabinet with slanting front panel provides for convenient operation, finished in grey enamel.

OVER-ALL DIMENSIONS

Height	Width	Depth	
320	475	220	mm
12 1/2	18 3/4	8 3/4	inches

WEIGHT

13 kilos net (29 lbs.).

ACCESSORIES SUPPLIED

1 type 12G13-1.5 power cord.

ACCESSORIES AVAILABLE

Shielded coils for use when measuring on capacitors. The following inductance values are standard:

0.3 - 1 - 2.5 - 3 - 5 - 10 - 25 - 30 - 50 - 100 - 250 - 300 - 500 μH.

1 - 2.5 - 3 - 5 - 10 - 25 - 30 - 50 mH.

SECTION 1
GENERAL DESCRIPTION

1.1 INTRODUCTION

The Q-Meter measures the Q of self-inductance coils. It can be also used to determine h-f resistance, h-f losses in insulating materials, and power factors of capacitors as well as measuring self-inductance and capacitance.

The Q of a coil is expressed by:

$$Q = \frac{\omega L}{r}$$

$\omega = 2\pi f$ being the angular frequency, L being the self-inductance of the coil measured in henrys, and r the h-f resistance of the coil in ohms at the frequency f.

When making certain computations it may be convenient to use the power factor d, which is expressed by the ratio of resistance to impedance. When Q is greater than 10, d is equal to the ratio of the resistance to the reactance. Thus:

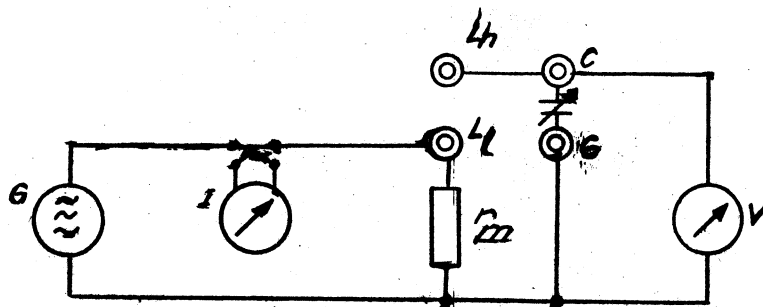$$d = \frac{r}{\omega L} = \frac{1}{Q}$$

The power factor of a capacitor is:

$$d = r \omega C$$

r being the effective series resistance in ohms, and C the capacitance in farads.

The Q-Meter contains an h-f generator, a thermocouple meter, a tuning condenser, a vacuum-tube voltmeter, and a power supply.

The operating principle of the instrument appears from the diagram below:

From the generator G an h-f current of 0.5 amp is transmitted through
the non-inductive resistor r_m of approximately $40 \cdot 10^{-3}$ ohms. The
current is measured with the thermocouple meter I. A coil connected
to the terminals L_h and L_1 and the tuning capacitor forms a circuit
in which the resistor r_m is in series with coil. When the generator
is tuned to resonance with the measuring circuit, the voltage of approx.
20 millivolts across r_m will result in a current in the measuring circuit.
This gives a voltage across C that is Q times higher than the voltage across
r_m. The vacuum-tube voltmeter is calibrated so that Q values from 30
to 250 can be read directly on the scale. If Q is higher than 250, the
current through r_m must be decreased. Then the Q is found by multiply-
ing the reading of the vacuum-tube voltmeter by the reading of the thermo-
couple meter.

1.2 THE H-F GENERATOR

Covers the frequency range from 50 kilocycles to about 73 megacycles
in 8 ranges. The change-over from the one frequency range to another
is made by a coil turret with a gear mechanism making a convenient op-
eration and a distinct marking of the positions.
The generator is able to furnish 0.5 amp to the coupling resistor in all
ranges except the highest frequency range in which the maximum cur-
rent is somewhat lower and somewhat dependent on the frequency. The
current supplied is controlled by varying the anode voltage of the oscil-
lator tube with the knob "Power". In none of the ranges does the gener-
ator furnish such a strong current that the thermocouple will burn out.
However, the instrument should only operate for a short period with more
than full deflection on the thermocouple. The frequency accuracy of the
oscillator is better than $\pm 1\%$ except on the highest frequency range where
the accuracy is about $\pm 3\%$, because the frequency varies somewhat with
the setting of the power control.
The anode voltage of the oscillator is stabilized by glow discharge tubes,
so the current that flows from the oscillator through the coupling re-
sistor is barely influenced by line voltage variation.

1.3 THE THERMOCUPLE METER

This measures the current through the non-inductive resistor r_m.
For 0.5 amp a-c it deflects to the last division designated 1, and for
0.25 amp the meter deflects to the division 2, etc. The scale is cal-
ibrated in steps of 1/10 between 1 and 2 and is also calibrated at 2.5.
A resistor of approximately 1 ohm in one of the leads to the meter pro-
vides for the adjustment of the sensitivity.

1.4 THE COUPLING RESISTOR

The coupling resistor is designed so that its self-inductance is negligble
at measurements below 30 megacycles. The resistor is located between
terminal L_1 and the cabinet and is connected to the terminal by a short
lead.

The resistor is made of gold, and its temperature coefficient of 0.4%
per degree centigrade is unimportant, because the temperature coef-
ficient of the sensitvity of the vacuum-tube voltmeter is about minus
0.4% per degree centigrade.

The exact value of the resistor at 25°C is stated in the chart at the back
of the instruction manual. As the value is very small (about $40 \cdot 10^{-3}$
ohms) it is generally unimportant when measuring Q in the frequency
range below 2 megacycles.

1.5 THE TUNING CAPACITOR

The tuning capacitor which is part of the measuring circuit is calibrated
directly in pF. A fine-tuning capacitor is in parallel with the main ca-
pacitor. The total circuit capacitance appears as the sum or difference
of the two scale readings. The main dial covers a range of 45 to ap-
proximately 530 pF, and the fine-tuning capacitor can be varied between
-5 and +5 with a reading for every 0.2 pF. So the minimum capacitance
is 40 pF. The accuracy of the calibration is about 1% ±1pF for the main
capacitor while that of the fine-tuning capacitor is about ±0.1 pF.

The series resistance of the tuning capacitor is about $8 \cdot 10^{-3}$ ohms at
1 megacycle, and it varies proportionally with the square root of the
frequency. Its exact value is stated in the chart at the end of the in-
struction manual.

1.6 THE VACUUM-TUBE VOLTMETER

is made as an infinite input-impedance detector with such low dynamic losses that they do not affect the measurements. The grid of the triode is connected directly to the terminal L_h by a short lead. The anode voltage of the tube is stabilized with glow-discharge tubes so that line voltage variations do not affect the sensitivity. However, the line voltage does affect the electrical zero to some extent.

When there is no galvanic connection between the terminals L_h (or C) and chassis, the grid of the triode is not connected to chassis. This will cause the meter to give full deflection, but a limiter circuit protects the meter against damage.

1.7 THE TERMINALS

The terminals for connecting coils and capacitors are drilled to take banana plugs. The terminals are mounted 25 mm apart and are designed so that only small losses are had. The resistance is about 10^{-3} ohms at 1 megacycle for 2 terminals, and it increases in direct proportion to the square root of the frequency.

The terminals to which coils are connected are marked L_h and L_1. L_h is the high potential end of the coil and L_1 the low potential end because the non-inductive coupling resistor is mounted between this terminal and the chassis. Terminal C is connected to terminal L_h, and terminal G is grounded to chassis.

SECTION 2

OPERATING INSTRUCTIONS

2.1 CONNECTING TO THE POWER LINE

(1) Adjust the instrument to line voltage available before turning on the power.

Use the line voltage switch located behind the plate fastened with screws on the back panel of the instrument. The switch can be set to 110, 127, 200, 220, and 240 volts.

A 0.2 or 0.4-amp fuse is mounted on the line voltage switch to pre-vent the line transformer from being damaged in case the instrument is connected to d-c by mistake.

(2) Check the mechanical zero of the meter.

(3) Switch on the instrument with the OFF-ON switch.

2.2 MEASURING COILS

(1) Connect the coil to be measured to the terminals L_h and L_1.

(2) Adjust the electrical zero with the potentiometer ZERO.

During this adjustment the generator and the measuring circuit must not be in resonance.

(3) Set the oscillator to the frequency required as follows: First choose the proper frequency range with the knob located to the lower left on the front panel. Then read the frequency from the proper scale on the frequency dial, which has 5 scales, that means from the scale beneath the part of the index with the same marking as the frequency range chosen.

The 8 ranges of the oscillator cover the frequency range from approx. 50 kilocycles to approx. 73 megacycles. With an external generator the range can be extended down to 1 kilocycle.

(4) Tune the measuring circuit to resonance with the generator. Use two built-in tuning capacitor and multiply the indication of the two meters.

The Q of the circuit is found directly if the self-capacitance is small in proportion to the tuning capacitance. The deflection of the thermo-couple meter should always be as great as possible to have the most accurate results. The measuring range of Q is 30 to 625.

The self-inductance proper of the coil is computed from the formula

$$L = \frac{1}{\omega^2 (C_1 + C_e)}$$

where C_1 is the reading of the tuning capacitor, and C_e is the self-

capacitance of the coil.

The self-capacitance C_e is determined by repeating the measurement at another frequency.

If the reading of the tuning capacitor is denoted C_1 at the frequency f_1 and C_2 at the frequency f_2, C_e can be computed from the formula:

$$C_e = \frac{f_1^2 C_1 - f_2^2 C_2}{f_2^2 - f_1^2}$$

2.3 CORRECTIONS TO BE MADE WHEN MEASURING COILS

(1) Self-capacitance

The Q-Meter indicates directly the Q value of the circuit Q_c made up by the coil and the internal circuit components of the instrument if the self-capacitance of the coil is low in proportion to the tuning capacitance. At a low tuning capacitance or high self-capacitance the value read,

$$Q_{read}$$

should be corrected for the self-capacitance according to the formula:

$$Q_c = Q_{read} \left(1 + \frac{Ce}{Cr}\right)$$

where C_e is the self-capacitance of the coil and C_r is the reading of the tuning capacitor.

(2) Internal losses

The inevitable internal losses in the Q-Meter result in Q being less than the Q of the coil,

$$Q_{coil}$$

The easiest way to include the internal losses in the computations is by allowing for the power factor:

$$d = \frac{1}{Q}$$

instead of the Q value, then we have:

$$d_{coil} = d_{circuit} - d_i$$

where d_i is the power factor of the part of the circuit made up by the tuning capacitor, the coupling resistor, the vacuum-tube voltmeter, and the terminals. On the appended chart d_i is shown as a function of the capacitance C_r and with the frequency as parameter.

At frequencies below 20 to 30 megacycles the accuracy of the corrected value of the Q of the coil is about 5%. At higher frequencies it is smaller. The accuracy also depends on the deflection of the meter needles, because the percentage of the scale error which is about 1% of full deflection is higher at small deflections.

2.4 MEASURING THE CAPACITANCE AND POWER FACTOR OF CAPACITORS BELOW 400 pF

A coil must always be connected to the terminals L_h and L_1 during any kind of measurement with the Q-Meter. When measuring capacitance, choose a coil with a circuit resonance at the frequency wanted. Turn the generator to resonance with the circuit and do not touch the generator during measurement.

(1) First measure the Q of the circuit without connecting the unknown capacitor. Note the indication Q_1 and the tuning capacitance C_1.

(2) Next connect the unknown capacitor to the terminals C and G, re-tune by decreasing the reading of the tuning capacitor and write down the indication Q_2 and the new reading C_2 on the circuit capacitor. C_1-C_2 will then indicate the value of the unknown capacitor, and the power factor is found from the formula

$$d_x = \frac{C_1}{C_1-C_2} \cdot \frac{Q_1-Q_2}{Q_1 \cdot Q_2} = \frac{C_1}{C_x}(d_2-d_1)$$

where Q_1 and Q_2 are the values read, possibly corrected for self-capacitance of the coil. However, no correction is to be made for the internal losses.

When d_x is small, the result for d_x depends on the difference between two almost equal figures. In this case the accuracy is limited and most dependent on the care with which the readings are taken.

At high frequencies it may be necessary to correct for the change in the internal losses which occur when changing the setting of the tuning capacitor, and also for the influence of the terminal resistance. The corrected value of the power factor may then be found from

$$d_x = \frac{C_1}{C_x}(d_2-d_1) + r_c\omega \ (C_1+C_2) - 2r_{K1}\omega \ C_x$$

If C_1 and Q_1 are values belonging together without C_x connected, and C_2 and Q_2 are values belonging together with C_x connected, the following applies to the above formula:

$$C_x = C_1 - C_2$$

$$d_1 = \frac{1}{Q_1'}, \quad Q_1' = Q_1 \ (1+\frac{C_e}{C_1})$$

$$d_2 = \frac{1}{Q_2'}, \quad Q_2' = Q_2' \ (1+\frac{C_e}{C_2})$$

C_e = the self-capacitance of the coil

$$2r_{KL} = \sqrt{f_{Mc} \cdot 2r_{KL}'}$$

$2r_{KL}'$ is the resistance of the terminals at 1 megacycle, which is stated in the correction chart

$$r_c = \sqrt{f_{Mc} \cdot r'_c}$$

r'_c is the series resistance in the tuning capacitor at 1 megacycle, which is stated in the correction chart.

2.5   MEASURING CAPACITORS OVER 400 pF

(1)   Connect an adequate coil to terminal L_h.

The coil must be of such a magnitude that resonance is obtained at the frequency wanted and with such a setting of the tuning capacitor that resonance can be obtained with the oscillator frequency maintained, even when the capacitor is connected.

(2)   Next connect the capacitor between one end of the coil and the terminal L_1 with leads as short as possible.

In order to make a d-c connection between the grid of the vacuum-tube and the chassis the capacitor must be shunted by a resistor of 10 to 20 megohms.

(3)   Short-circuit the capacitor with a heavy lead, and resonate the circuit to the generator. Write down the capacitance C_1 of the tuning capacitor and the $Q = Q_1$ of the circuit.

(4)   Remove the short-circuit, and re-resonate the circuit to the generator with the tuning capacitor in the circuit. Write down the new values C_2 and Q_2.

The capacitance of the capacitor is then found from

$$C_x = \frac{C_1 \cdot C_2}{C_2 - C_1}$$

If C_1 is greater than C_2, it means that the impedance of the capacitor is inductive and is

$$L_x = \frac{C_1 - C_2}{C_2} \cdot L_s$$

where L_s is the self-inductance of the coil.

The power factor of the capacitor is:

$$d_x = \frac{C_1 Q_1 - C_2 Q_2}{(C_2 - C_1) Q_1 Q_2}$$

When measuring small condensers at low frequencies, the necessary shunting of the capacitor with a high ohmic resistor will entail an error in the measurement.

If the external parallel resistance of the condenser is denoted R_c, the corrected value of the power factor is:

$$d_c = d_x - \frac{1}{\omega C_x R_c}$$

(R_c in ohms)

(C_x in farads)

eQM1
2-4b/361

Note: the value of R_c to be inserted in the formula is not the d-c value of the resistor but the value which the resistor has at the measuring frequency. This resistance may be determined separately as mentioned below.

2.6 MEASURING HIGH RESISTANCE AND H-F LEAKAGE

(1) Connect a coil to the terminals L_h and L_1.

The coil must be of such a magnitude that resonance is obtained at the frequency wanted and with such a setting of the tuning capacitor that resonance can be obtained with the oscillator frequency maintained, even when the component is connected to the terminals C and G.

If the Q of the circuit without the components is Q_1, and Q_2 when the component connected to the terminals C and G, the high frequency resistance is found from

$$R = \frac{Q_1 Q_2}{2 \pi f C_1 (Q_1 - Q_2)}$$

(R in Ohms)

(f in cycles per second)

(C in farads)

while the capacitance is found as the difference between the two readings of the tuning capacitor.

The measuring range depends on the frequency and on the Q of the circuit used. When measuring high h-f resistances, a coil with a high Q and a small tuning capacitance should be used.

2.7 MEASURING RESISTANCE OF LOW VALUES

(1) Connect an adequate coil to terminal L_h and L_1.

(2) Resonate a circuit with the generator at the frequency required and measure its Q at Q_1.

(3) Insert the resistor to be measured between the coil and the terminal L_1, and write down the new value of $Q=Q_2$ after re-resonating with the tuning. If the two readings on the tuning capacitor are C_1 and C_2, the value of the resistance is found from

$$r_s = \frac{1}{2 \pi f C_1} \cdot \frac{\frac{C_1}{C_2} Q_1 - Q_2}{Q_1 Q_2},$$

where f is the frequency in cycles and C_1 the capacitance in farads.

If C_1 is greater than C_2, the impedance of the resistor is inductive and is

$$L_r = L_1 \frac{C_1 - C_2}{C_2},$$

where L_1 is the self-inductance of the tuning coil which may be calculated from

$$L_1 = \frac{1}{\omega^2 C_1} = \frac{1}{4 \pi^2 f^2 C_1}$$

If C_1 is smaller then C_2 the resistance is capacitive, and its series capacitance is

$$C_r = \frac{C_1 C_2}{C_2 - C_1}$$

2.8 MEASURING WITH AN EXTERNAL GENERATOR

The Q-Meter has 2 jacks marked EXT. GEN. for connecting an external generator which is coupled when the coil switch is set to position EXT. GEN. In this way the frequency range can be extended downwards so that measurements can be made down to 1 kilocycle.

The generator must be able to furnish 0.5 amp in about 1 ohm, and if it can furnish more than 1 amp, necessary care should be taken when operating the instrument so as to prevent the thermocouple from burning out, if the fuse which is in series with the thermocouple should fail.

As self-inductances for the frequency range 1-50 kilocycles generally have a high self-capacitance it should be noted that it is necessary to correct the indication if the tuning capacitance is low in proportion to the self-capacitance of the coil.

The tuning capacitance can be increased by connecting an extra capacitor to the terminals C and G.

The frequency response is linear down to 10 kilocycles.

At 5 kilocycles the indication is 1% low
" 2 " " " " 2% "
" 1 " " " " 4% "
" 0.5 " " " " 10% "

The values of "Q" read should be corrected accordingly.

SECTION 3
MAINTENANCE

3.1 TUBE REPLACEMENT

(1)   Tube No.1 is a type EC81 operating as an oscillator tube.

The tube can be replaced without any precautions. If its capacitance deviates from that of the old tube it may be necessary to trim the generator a little. The trimming is made through the two holes in the back panel of the oscillator box, the upper hole being placed opposite the iron-core coil and the lower hole opposite the trimmer. The coil for the highest frequency range has neither iron core nor trimmer.

(2)   Tube No.2 is a type 7586 Nuvistor used as a voltmeter tube.

The tube should be aged and selected so that the meter gives full scale deflection for a voltage of $0.5 \, r_m \cdot 250$ and deflects to $Q = 100$ for a voltage of $0.5 \, r_m \cdot 100$.

A coarse adjustment of the sensitivity for full scale deflection can be made by changing the part of the cathode resistor of the tube located between the plus pole of the meter and the chassis. A fine adjustment can be made by changing the series resistor of the meter or by slightly shunting the meter.

(3)   Tubes No.3 and No.4 are type 90C1 glow discharge tubes and can be replaced right away.

(4)   Tube No.5 is a type EZ40 rectifier tube and can be replaced without any precautions.

3.2 TESTING THE NON-INDUCTIVE RESISTOR

The test can be made by connecting a storage battery in series with a milliammeter and a variable resistor to the terminals EXT.GEN. and making 0.5 amp flow through the resistor. The coil switch must be in position EXT.GEN. The voltage present across the terminals L_1 and G is measured with a millivoltmeter.

The value of the resistance at 25ºC is stated in the appended chart. If the measurement is made at a different temperature, corrections should be made. The temperature coefficient of the resistor is +0.4% per degree centigrade. If the value measured deviates by more than a few per cent from the value stated, the instrument should be returned to the factory for repair.

3.3 TESTING THE THERMOCOUPLE AND THE xQ METER
The test is made as follows:

(1)   Set the coil switch to EXT.GEN.

(2)   Connect the a-c generator in series with the a-c ammeter to the terminals EXT. GEN.

The meter must deflect to the x1 division for 0.5 amp a-c.

The test cannot be made by d-c current because the thermoelement of the thermocouple used is not insulated from the heating filament, so its emf depends on the direction of the current.

If the sensitivity of the thermocouple has changed because of overload, it may be corrected by changing the series resistance of the meter.

Correction chart for QM1 no _____ date _____
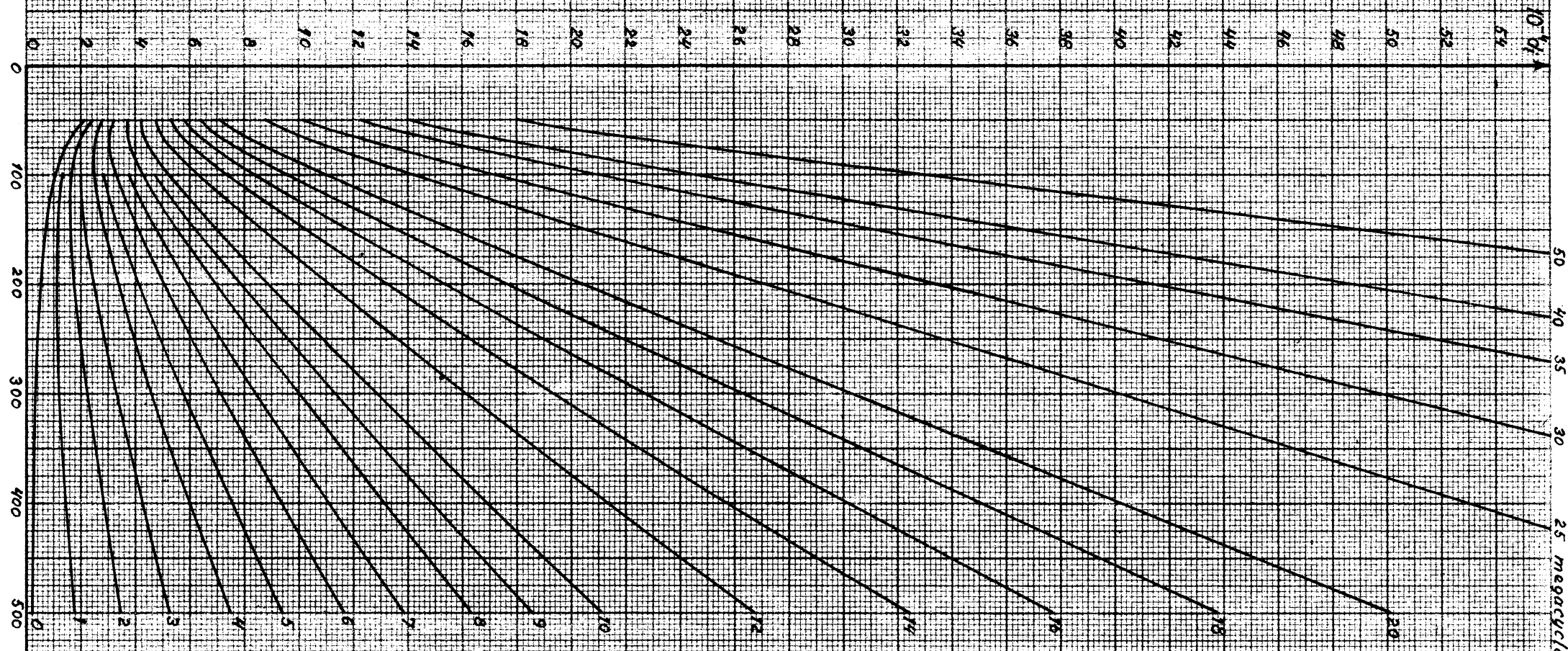
$d_{coil} = d_{circuit} - d_i$

d_i = internal losses

$Q_{coil} = \dfrac{1}{d_{coil}}$

Parallel resistance

HF-resistance of two terminals
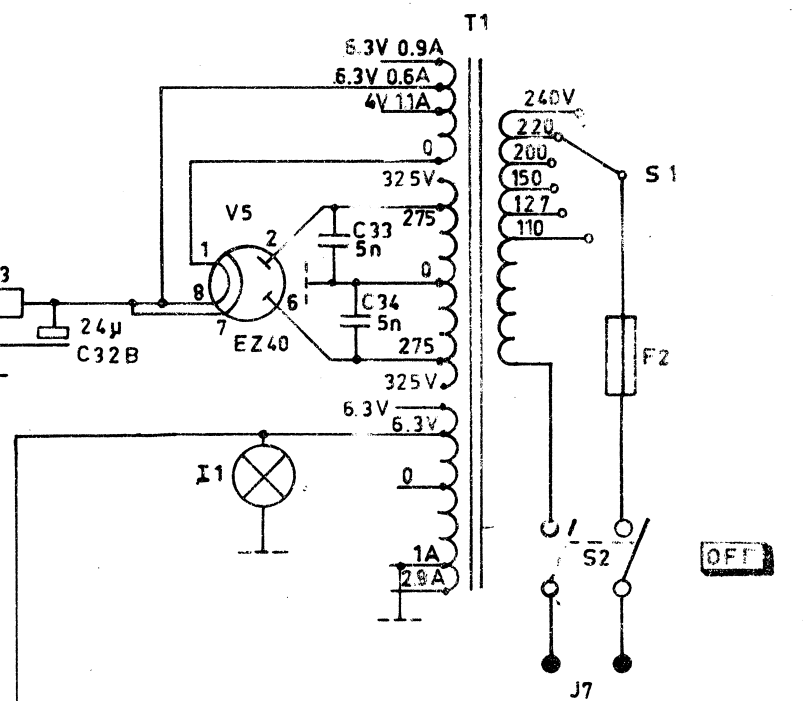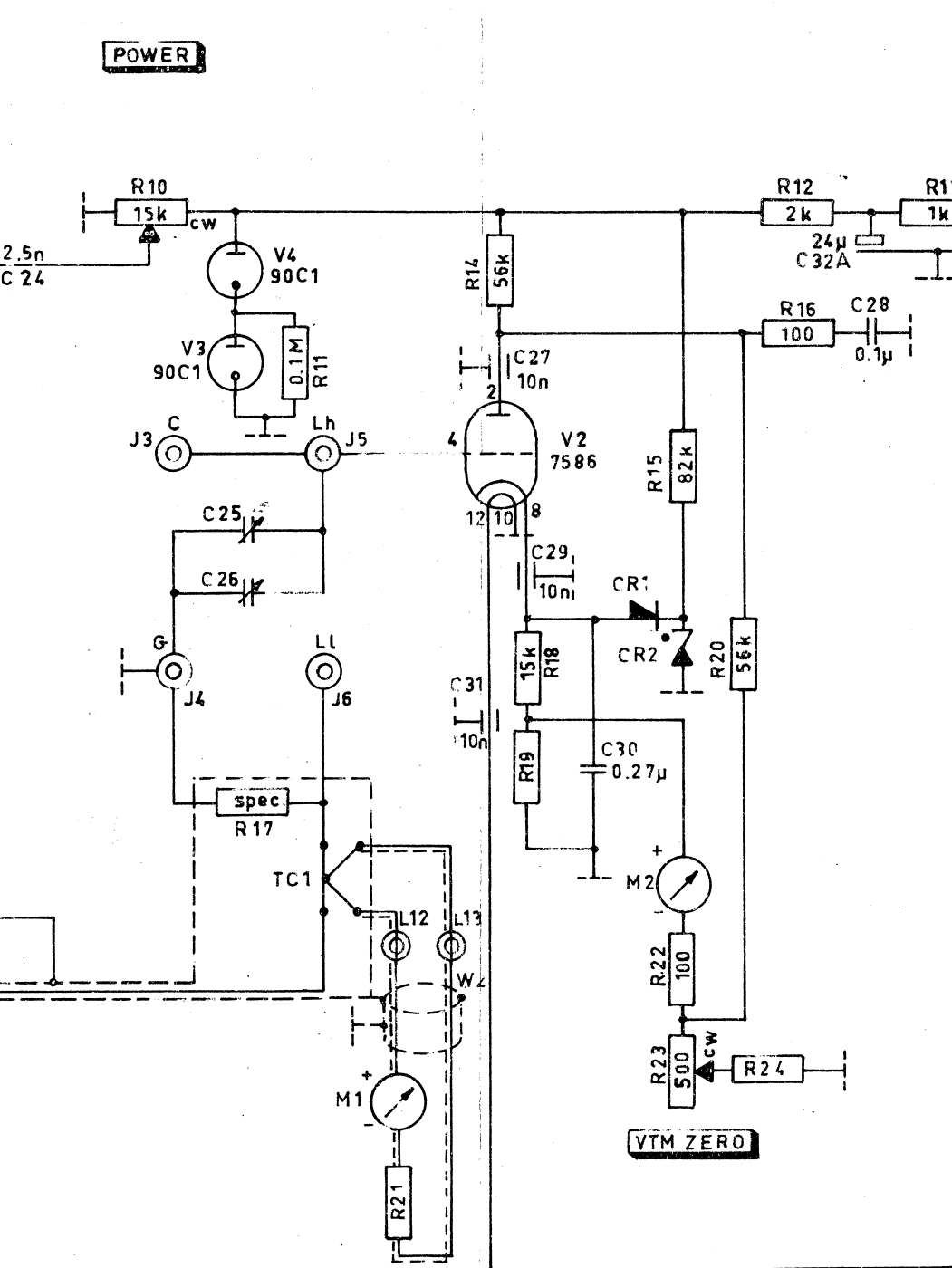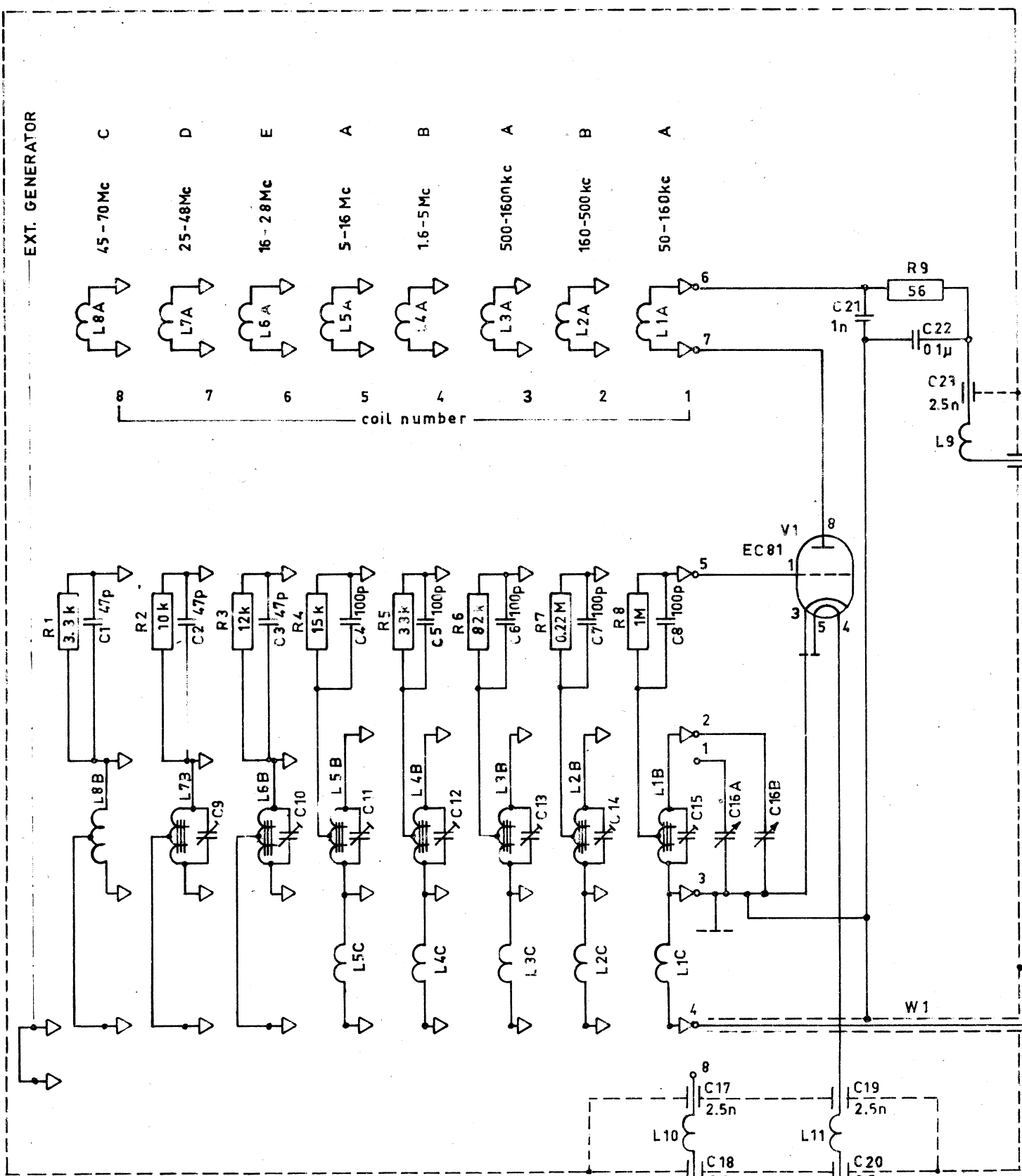
Series resistance of tuning condenser:

Coupling resistor:

R = 15 megohms at 1 megacycle

$2r_t$ = 1 milliohm at 1 megacycle

r_c = 8 milliohms at 1 megacycle

r_m = _____ milliohms.

A 4 210 x 297 m.m.

J. CHR. PETERSEN

18.15.38 B/t

EXT. GENERATOR

C	D	E	A	B	A	B	A
45-70Mc	25-48Mc	16-28Mc	5-16 Mc	1.6-5Mc	500-1600kc	160-500kc	50-160kc

L8A L7A L6A L5A L4A L3A L2A L1A

6
7
8 7 6 5 4 3 2 1
— coil number —

R9 56
C21 1n
C22 0.1μ
C23 2.5n
L9
C24 2.5n

POWER

V1 EC81

| R1 3.3 k | C1 47p | R2 10k | C2 47p | R3 12k | C3 47p | R4 15k | C4 100p | R5 3.3k | C5 100p | R6 82k | C6 100p | R7 0.22M | C7 100p | R8 1M | C8 100p |

L8B L7B L6B L5B L4B L3B L2B L1B
C9 C10 C11 C12 C13 C14 C15 C16A C16B
L5C L4C L3C L2C L1C

R10 15k cw
V4 90C1
V3 90C1
R11 0.1M
J3 C
Lh J5

C25
C26

G J4
Ll J6

spec R17
TC1
L12 L13
W2
M1

C17 2.5n
C19 2.5n
L10
C18 2.5n
L11
C20 2.5n
F1
J1
J2 EXT. GEN.
R21

R14 56k
C27 10n
V2 7586

C29 10n
C31 10n
15k R18
R19
C30 0.27μ
M2
R22 100
R23 500 cw
R24
VTM ZERO

R15 82k
CR1
CR2
R20 56k

R16 100
C28 0.1μ

R12 2k
24μ C32A
R13 1k
24μ C32B
V5 EZ40

I1

T1
6.3V 0.9A
6.3V 0.6A
4V 1.1A
0
325V
275
C33 5n
0
C34 5n
275
325V
6.3V 6.3V
0
1A
2A

240V
220
200
150
127
110
S1
F2
S2
OFF
J7

W1

2		5/12-63		
1		6/5-63		AP
Rt Nr	Fra Fab. Nr	Dato	Rt. af	Kont	Norm

Malestok | Tegn. |
Kont. | AP
Norm.

Erstatter
1496-A 3
Erstattet af