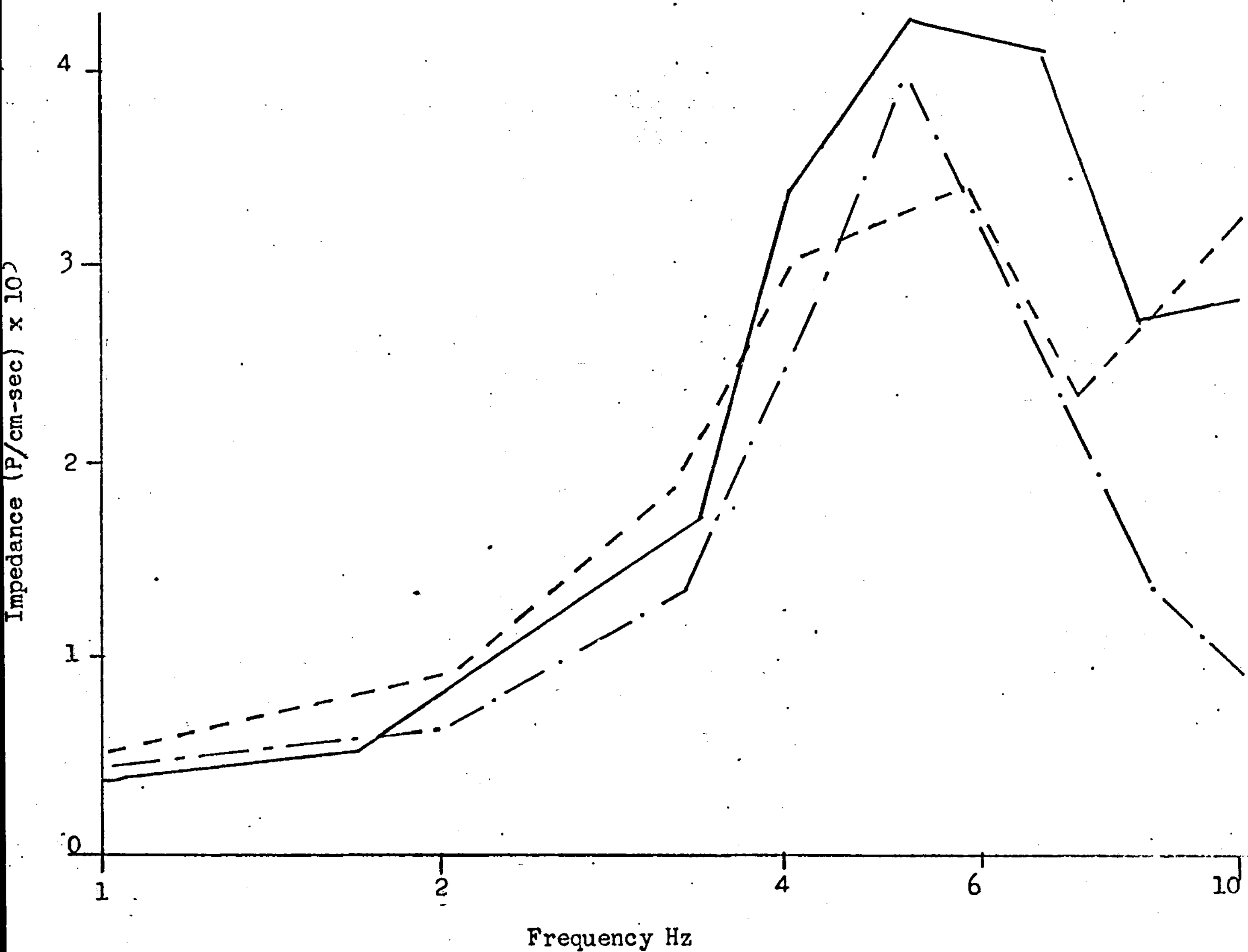
FIGURES, TABLES and PLATES

for

PART B

Dieckmann (1958)



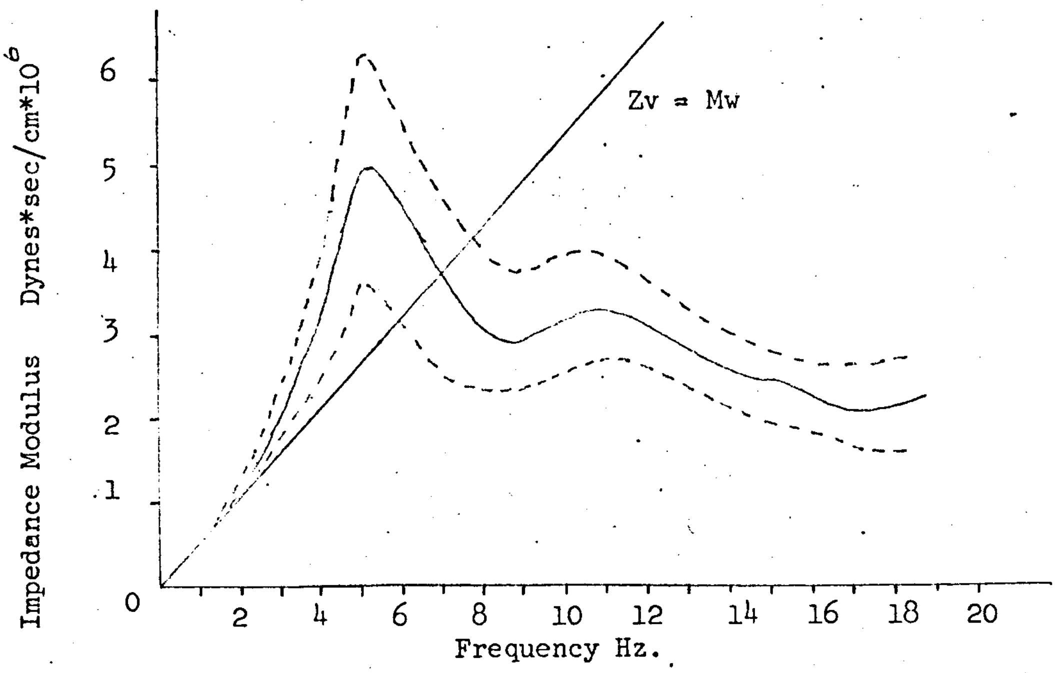
KEY ——— Direct - measurement of vibrating force

– – – Indirect - measurement of acceleration of oscillatory motion

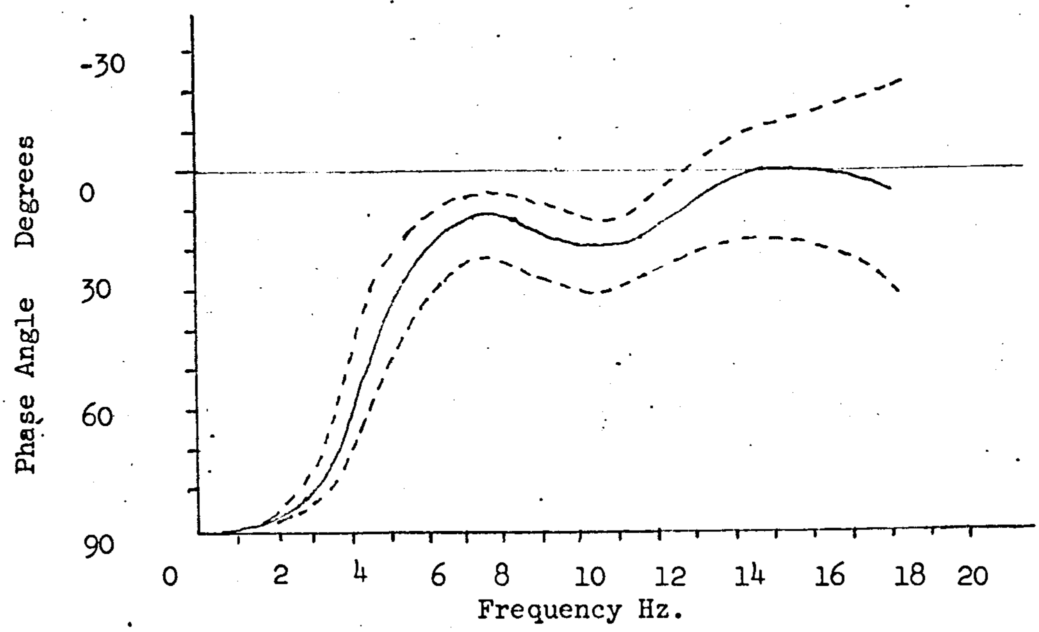
—·—·— Calculated impedance for one spring-mass system

Figure No. **26**

R.R.Coermann. (1963.)



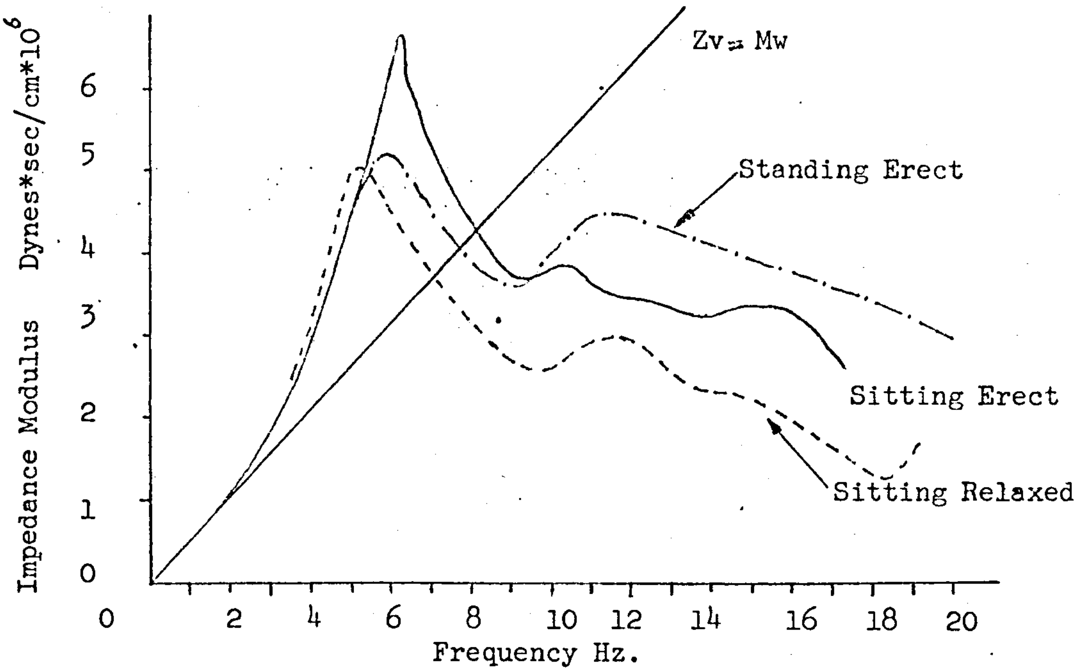
The median and the twentieth and eightieth percentile of the modulus of Impedance of 8 different subjects sitting erect, compared with the impedance of a pure mass.



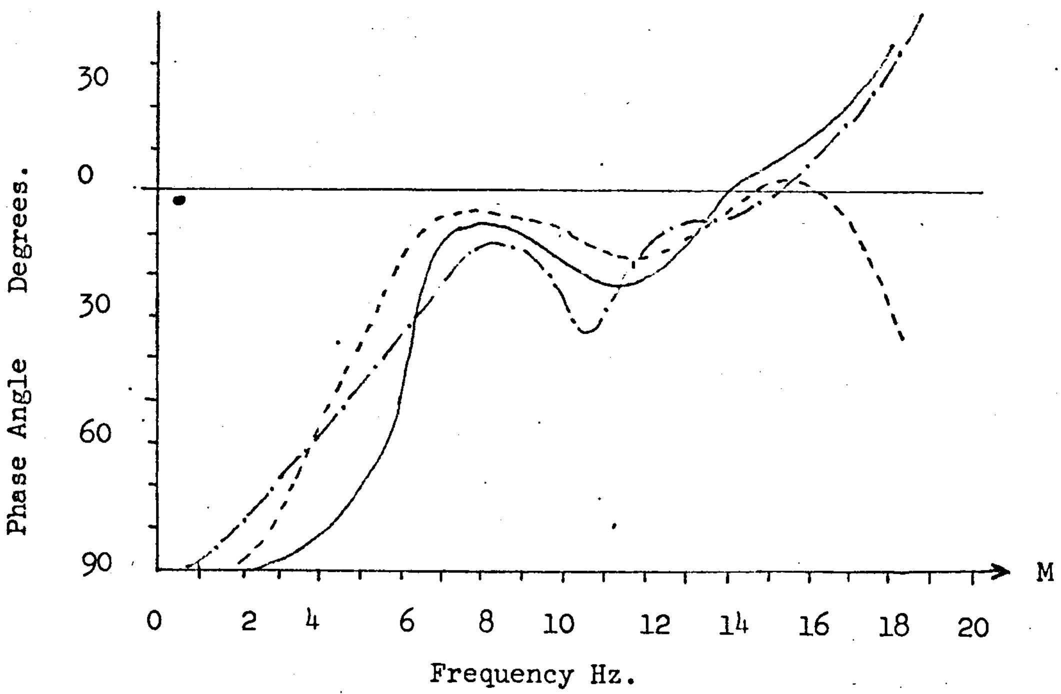
The median and the twentieth and eightieth percentile of the phase angle of the impedance measured from 8 different subjects.

Figure No. 27

R.R.Coermann. (1963.)



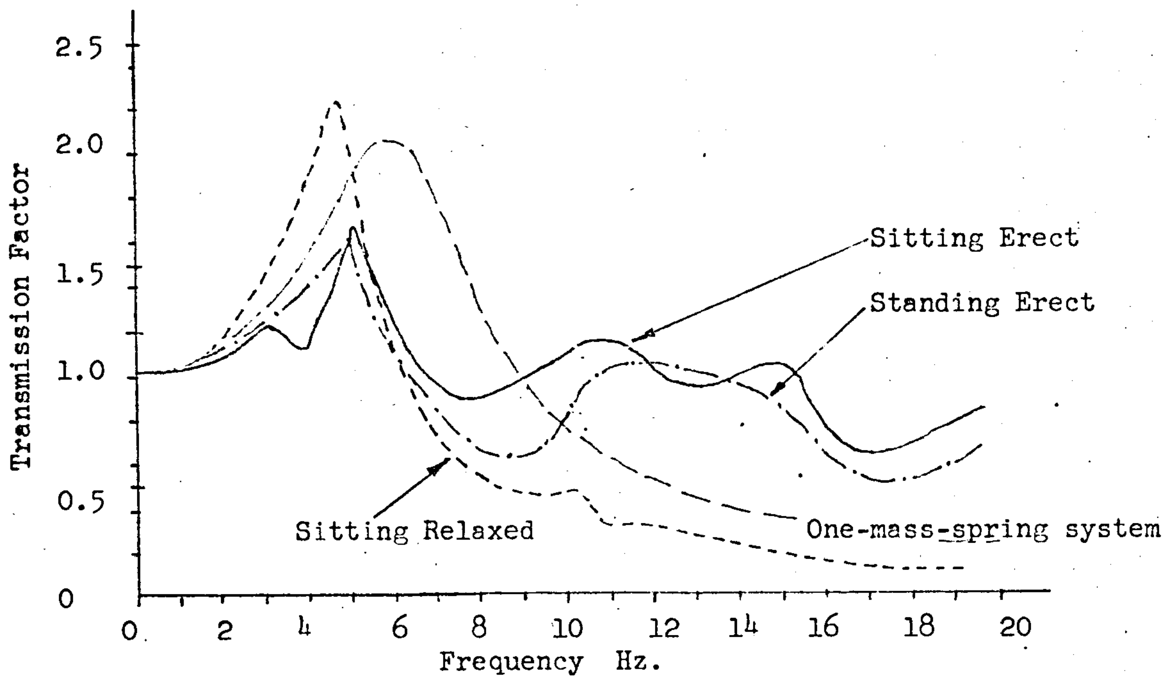
The modulus of impedance of one subject at varied body postures compared with the impedance of a pure mass (Mw).



Phase angle of the impedance for one subject at varied body postures compared with that of a pure mass.

Figure No. 28

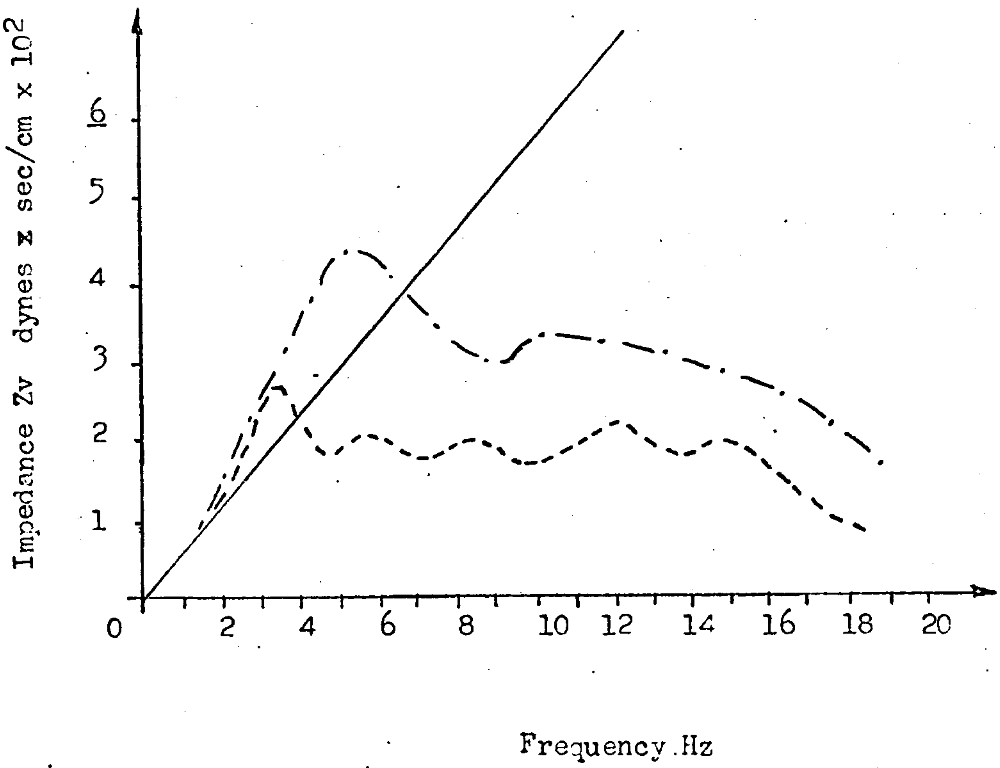
R.R.Coermann. (1963.)



The transmission of vibrations from the seat to the head on one subject at varied body postures compared with the transmission factor of a one-mass-spring system with damping.

Figure No. 29

Coermann (1963)

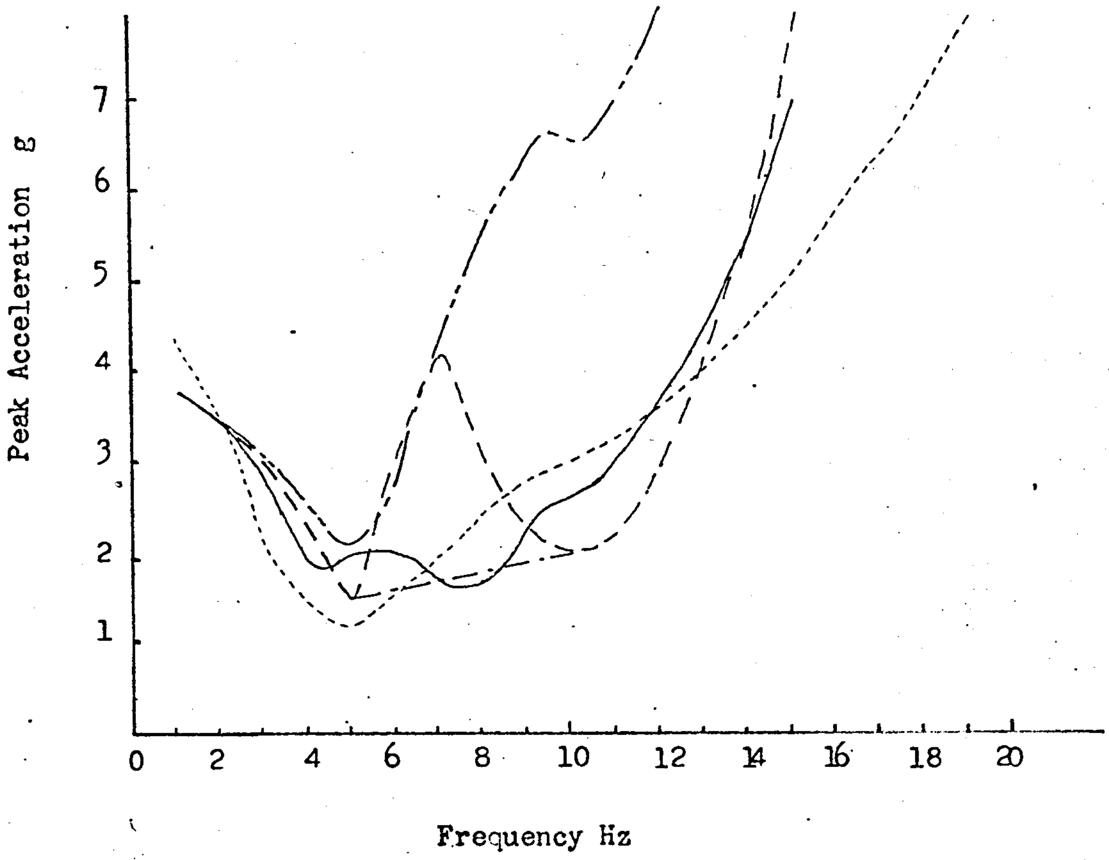


Subject W.B. mass 90,000 dynes x sec^2/cm

Sitting relaxed posture, recordings made at different times.

Figure No. 30

R.R.Coermann (1963)



Subjective Short time tolerance curve

Dissipated Energy 10K cal/min

Subjective short time tolerance curve

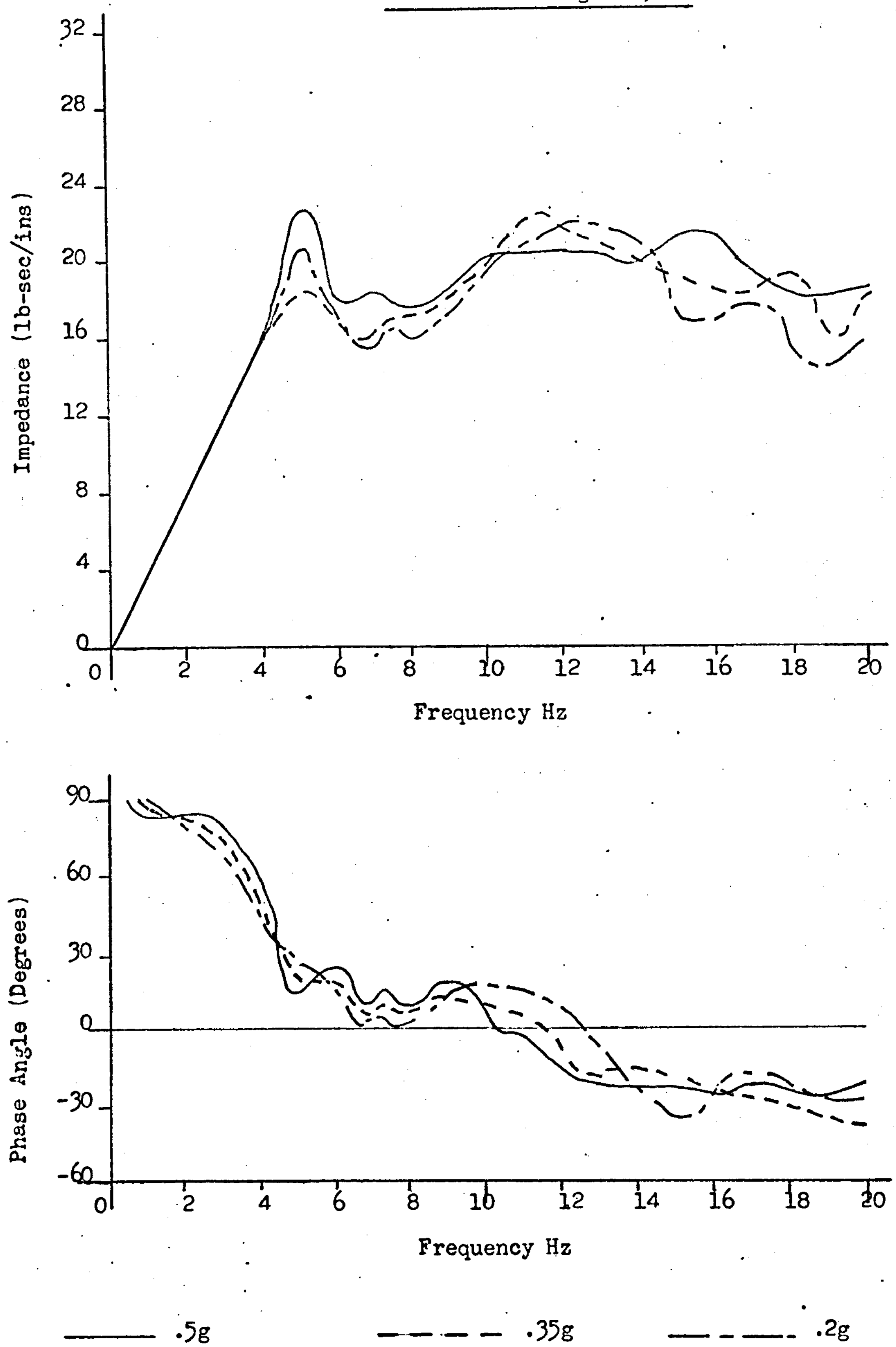
Constant relative displacement of the effective body mass

Extrapolated line

Human tolerance curve to vertical vibrations compared to curves for constant transmitted force, constant relative displacement of the effective body mass, and constant dissipated energy derived from the mechnical impedance measurements

Figure No. 31

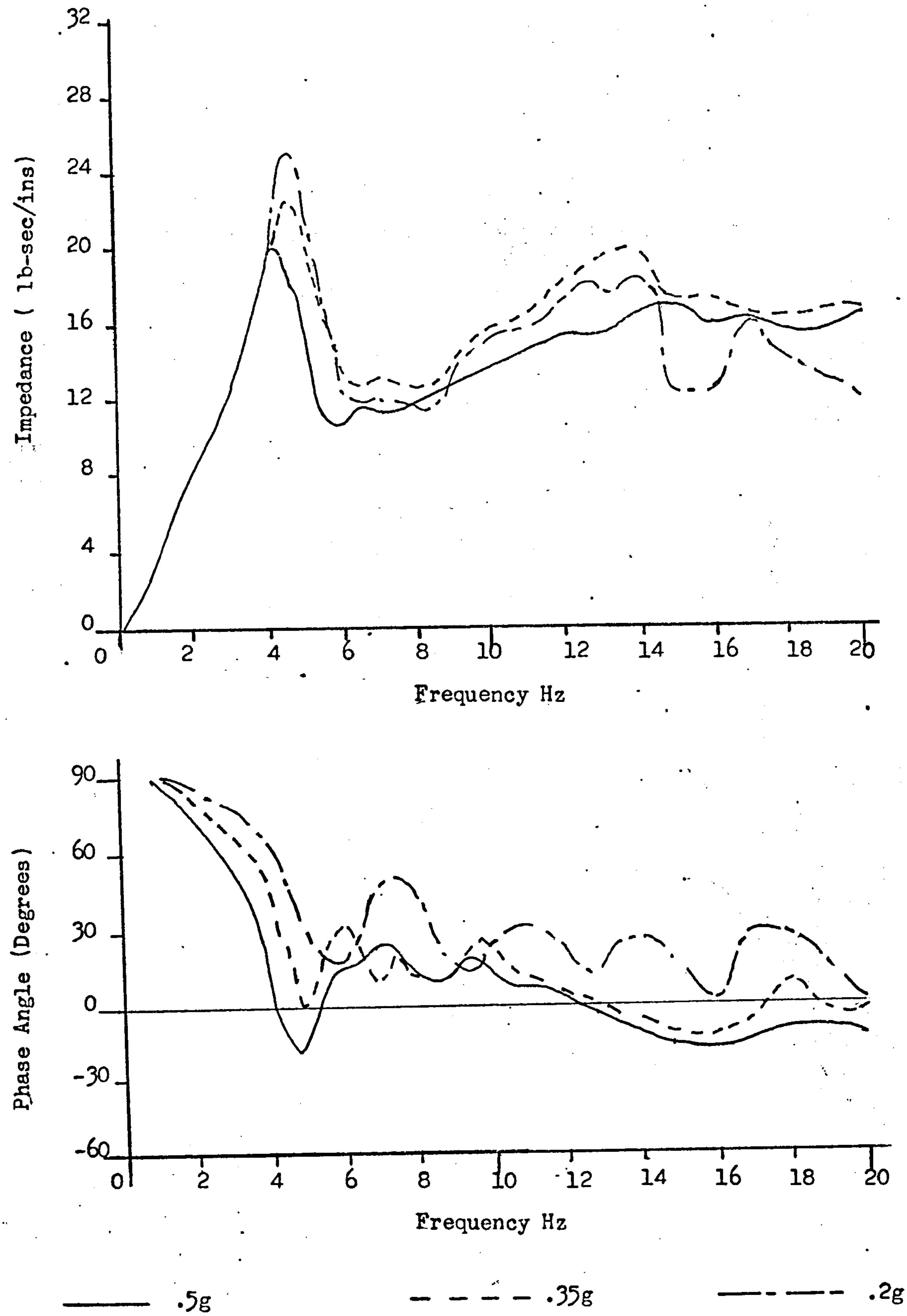
Edwards and Lange (1964)



Whole body Mechanical Impedance vs Frequency with table acceleration as a parameter. Subject A.E.F Standing Relaxed

Figure No. 32

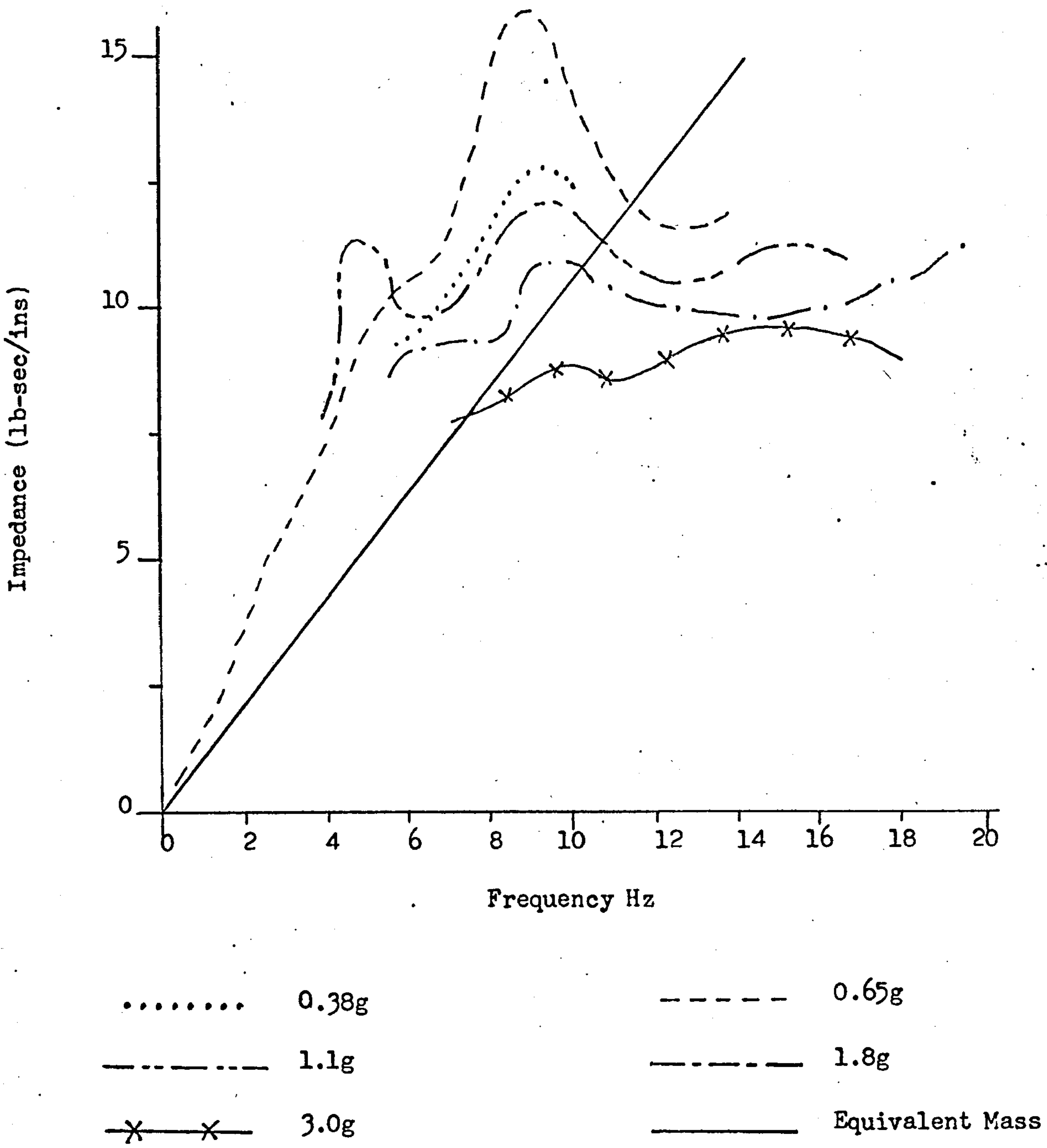
Edwards and Lange (1964)



Whole body Mechanical Impedance vs Frequency with table acceleration as a parameter. Subject R.G.E Standing Relaxed

Figure No **33**

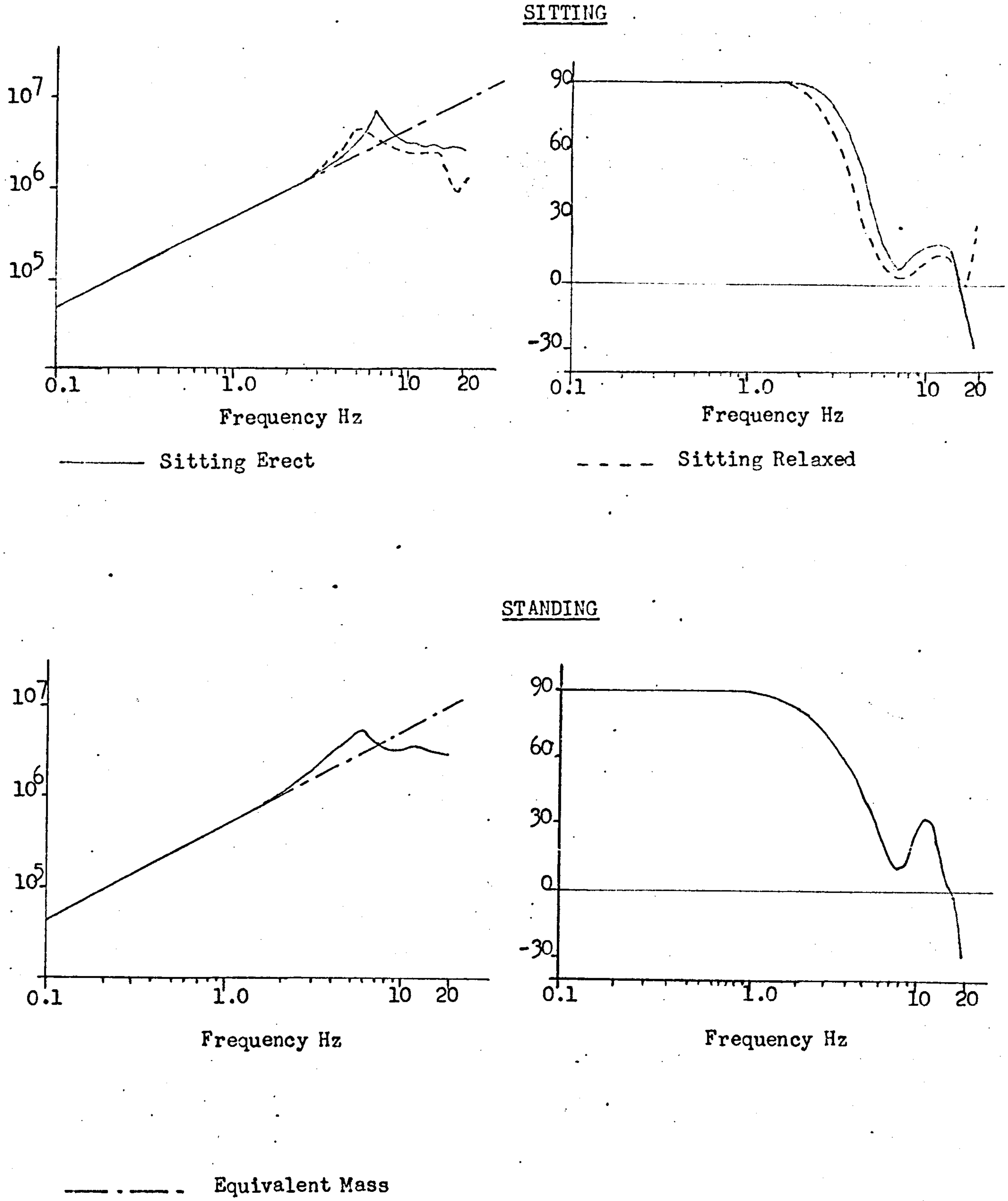
Krause and Lange (1963)



Mechanical Impedance of a 70 lb. pig at five different shake table acceleration levels.

Figure No.34

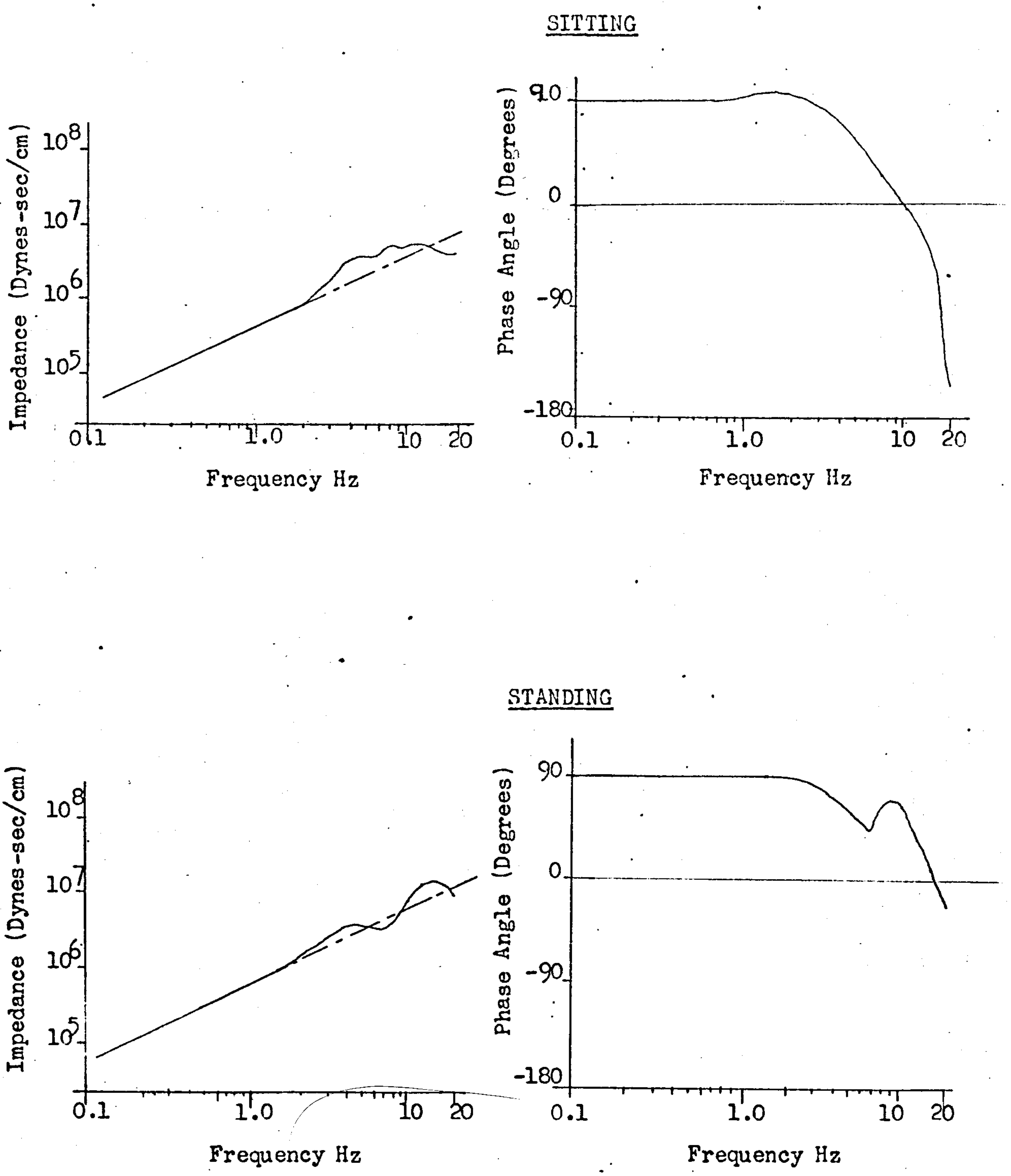
Weis, Clarke, Brinkley and Martin (1964)



Human Mechnical Driving Impedance Determined in a Steady-State Sinusoidal (Vibration) Enviroment

Figure No. 35

Weis, Clarke, Brinkley and Martin (1964)

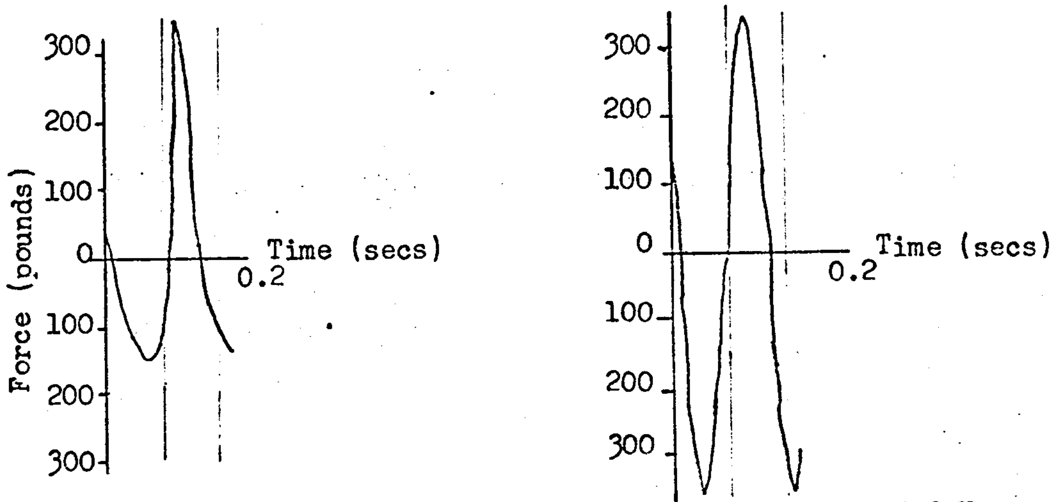


——-——-—— Equivalent Mass

Human Mechanical Driving Impedance Determined in the Transient (Impact) Environment.

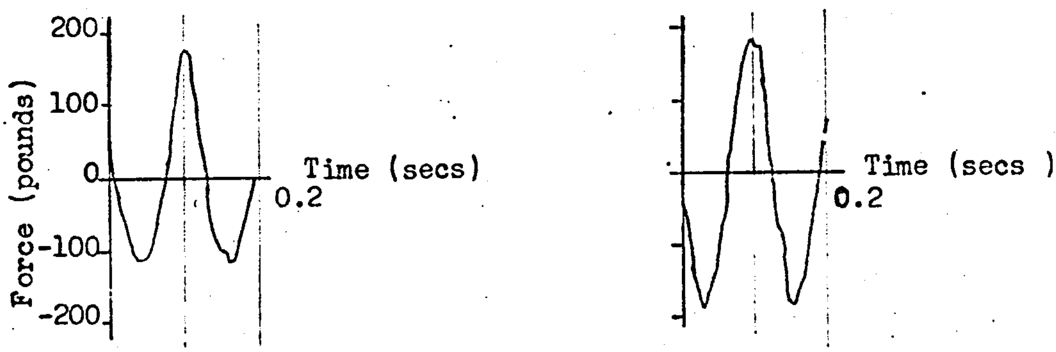
Figure No 36

Whittmann and Phillips (1969)



Nonlinear force response of seated subject at 0.9g and 3 Hz

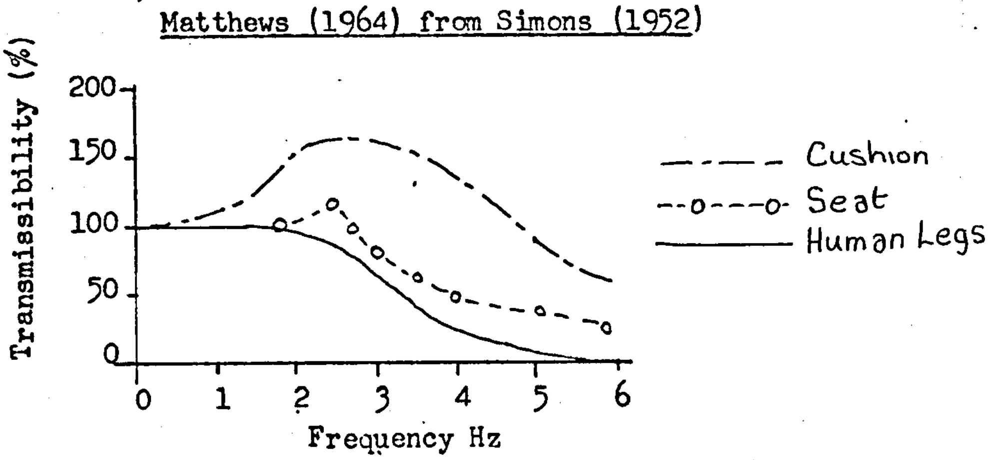
Figure No. 37



Nonlinear force response of seated subject at 0.5g and 4 Hz

Figure No. 38

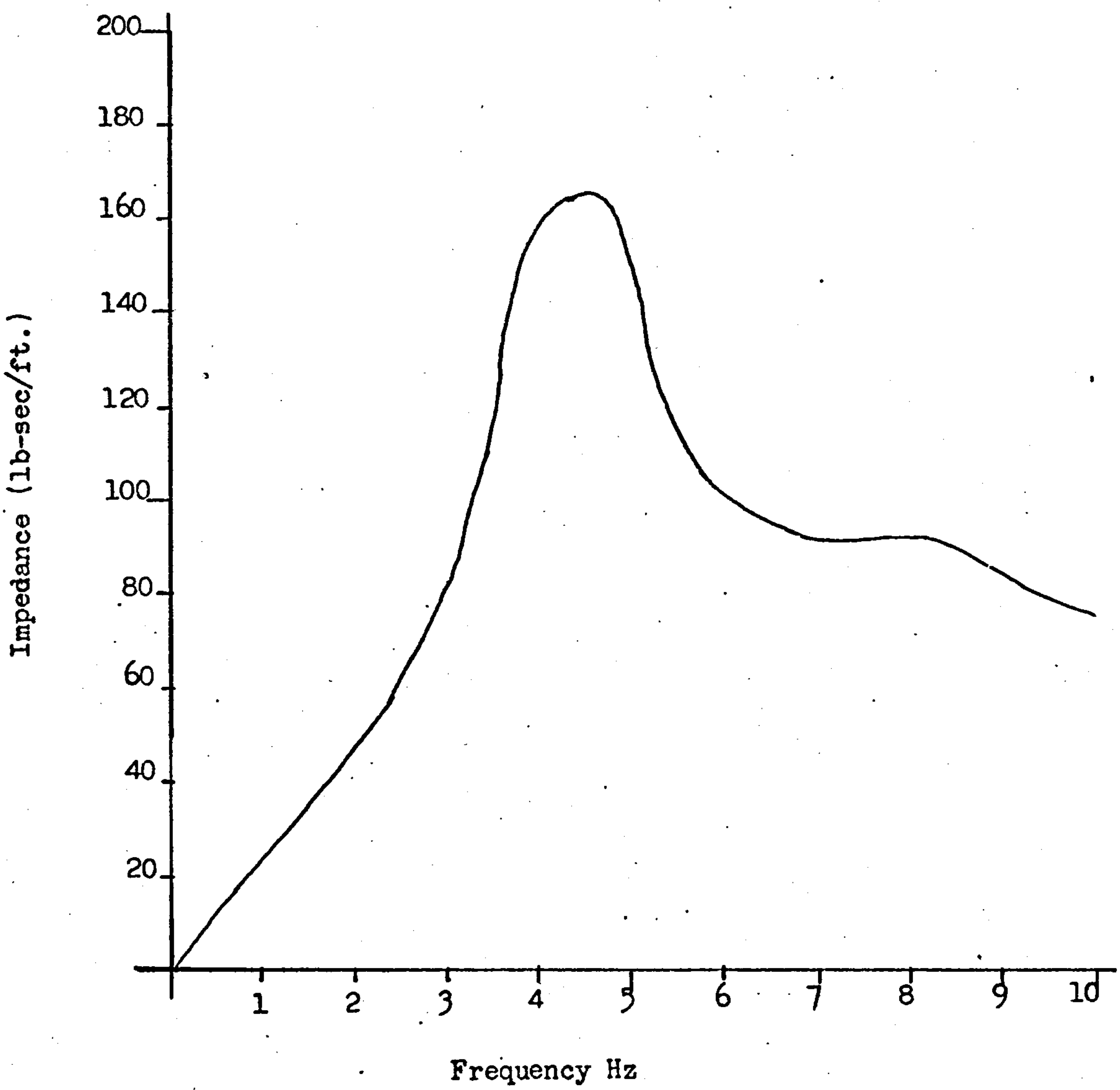
Matthews (1964) from Simons (1952)



Comparison of good seat transmissibility with human legs

Figure No. 39

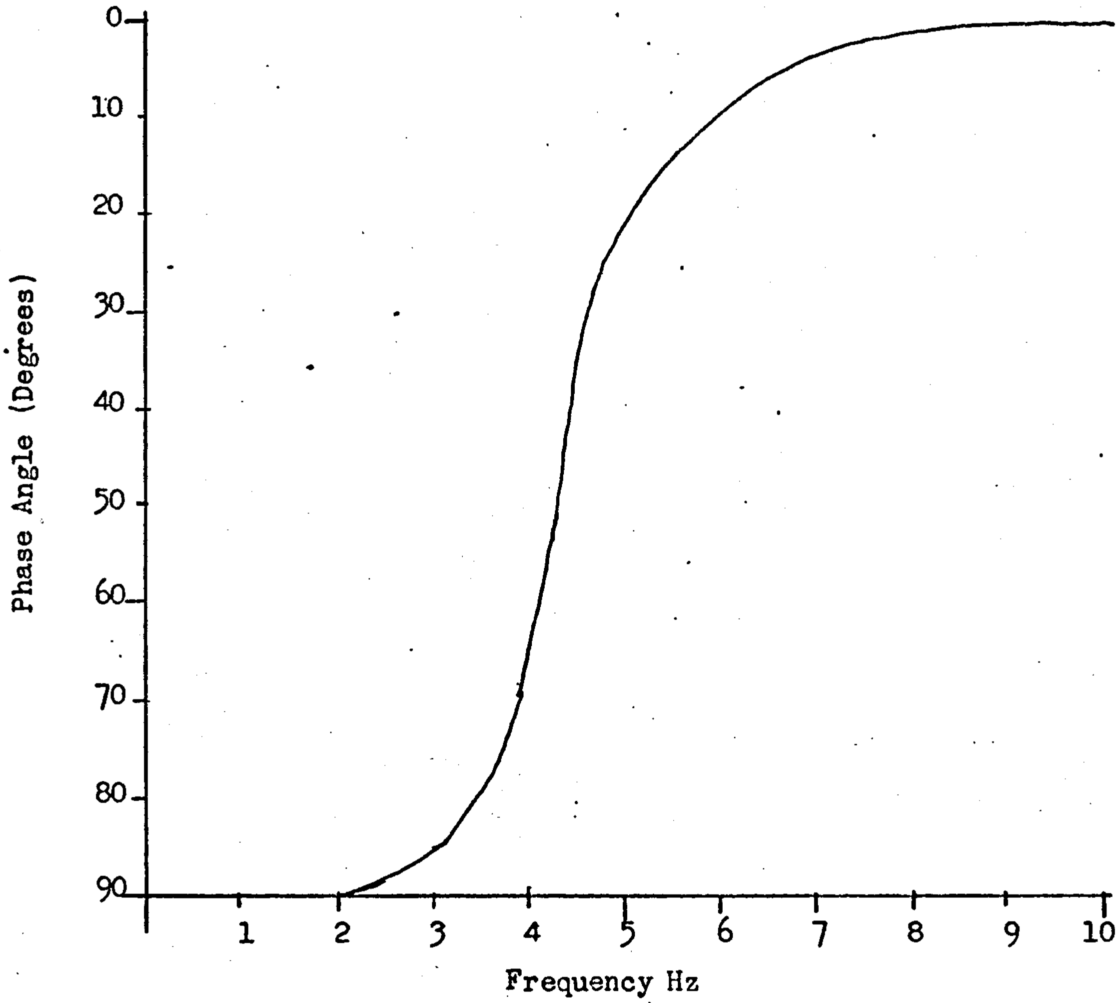
C.W. Suggs C.F. Abrams L.F. Stikeleather(1969)



Average impedance magnitude curve of 11 subjects. Note secondary resonance at about 8Hz.

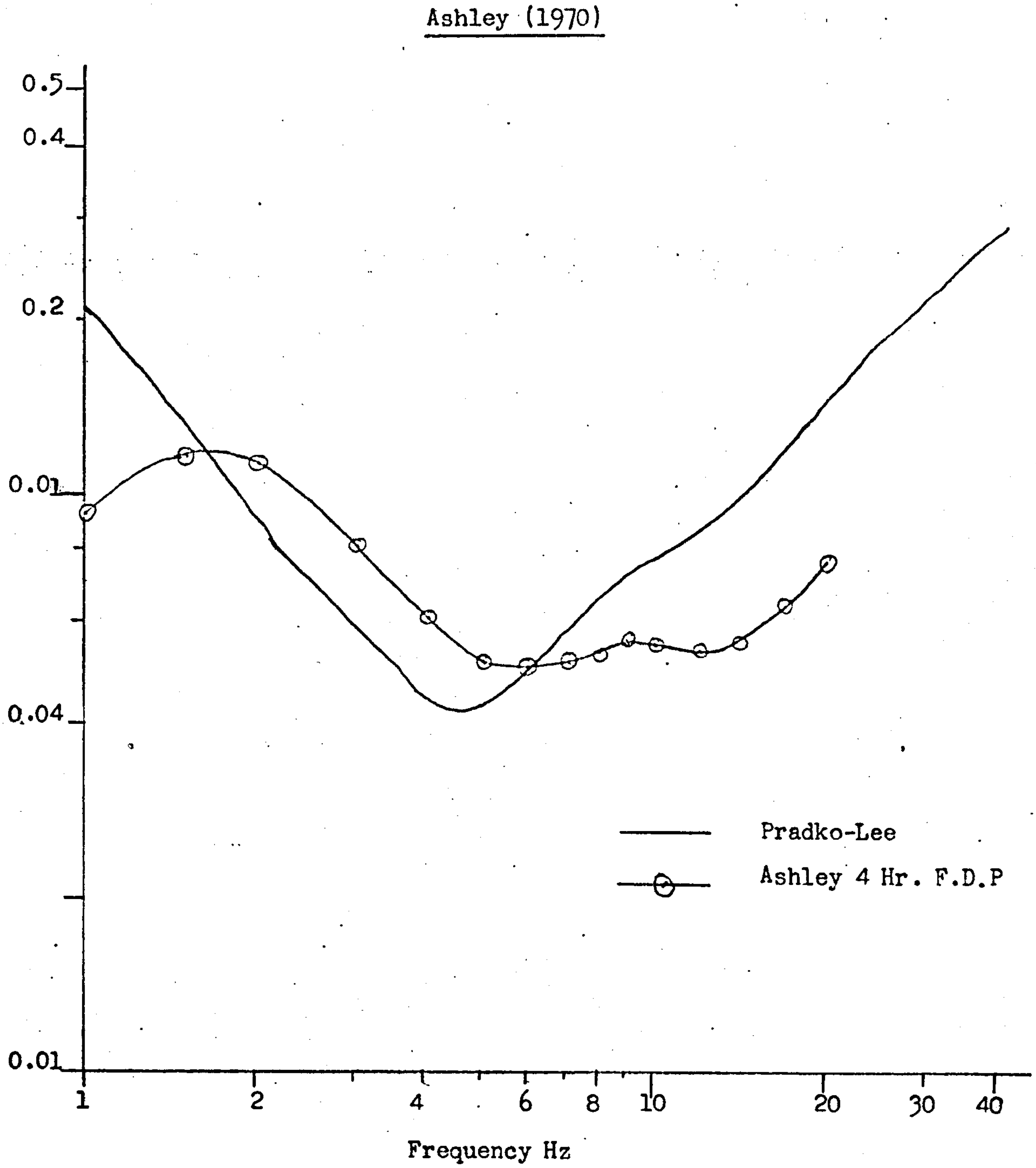
Figure No. 40

C.W. Suggs C.F. Abrams L.F. Stikeleather (1969)



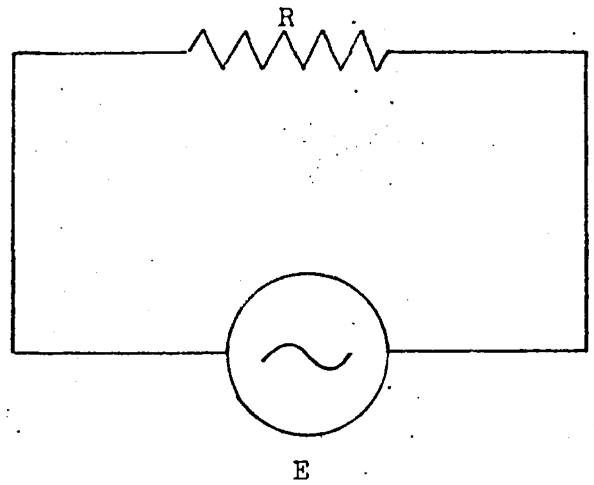
Average impedance phase angle curve of 11 subjects.

Figure No. 41



A comparison between cross matching and normalised absorbed power for the sitting position

Figure No.42



A sinusoidal voltage E applied to a resistance.

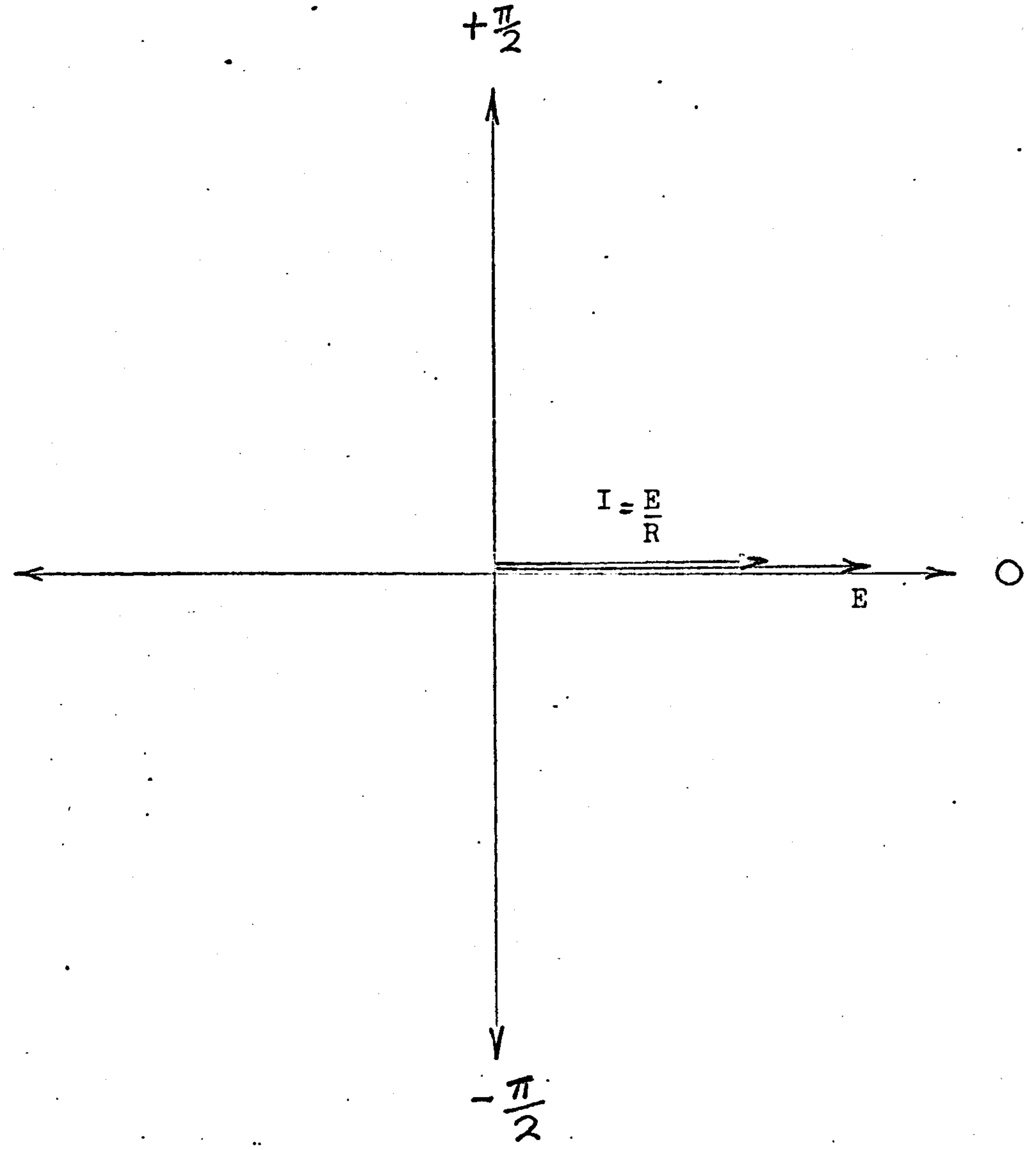
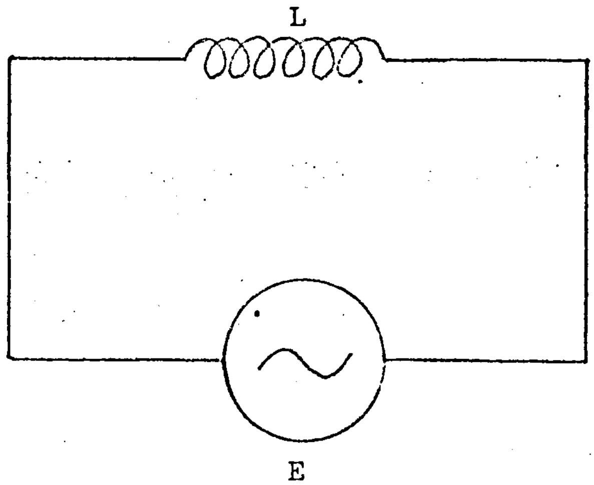


Fig. 43 Voltage and Current vectors in phase.



A sinusoidal voltage E applied to an inductance.

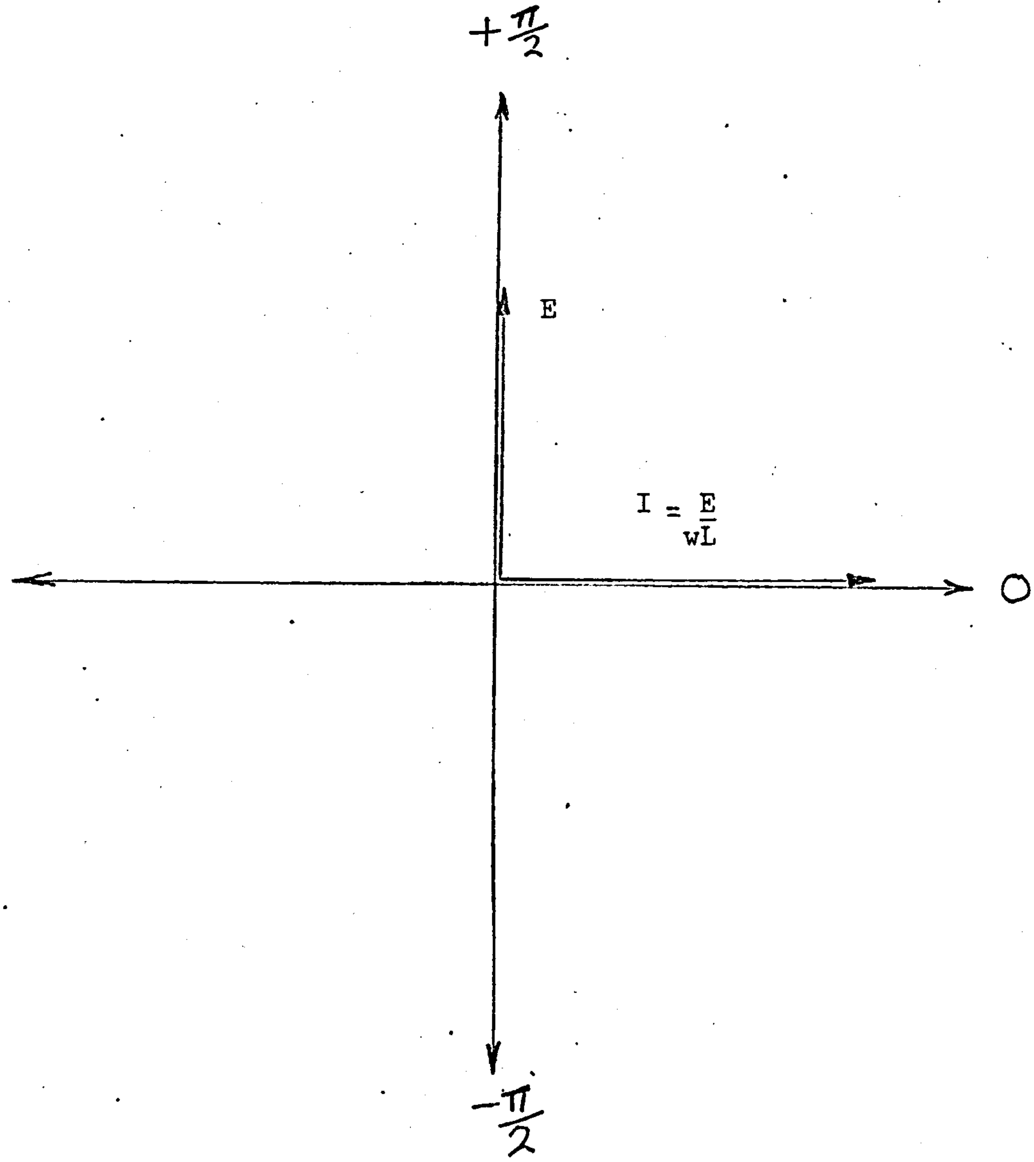
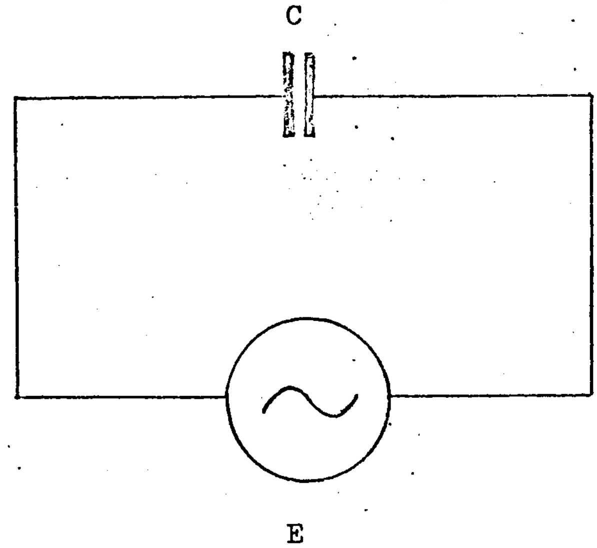


Fig 44 Voltage vector leading current vector by 90°.



A sinusoidal voltage E applied to a capacitance.

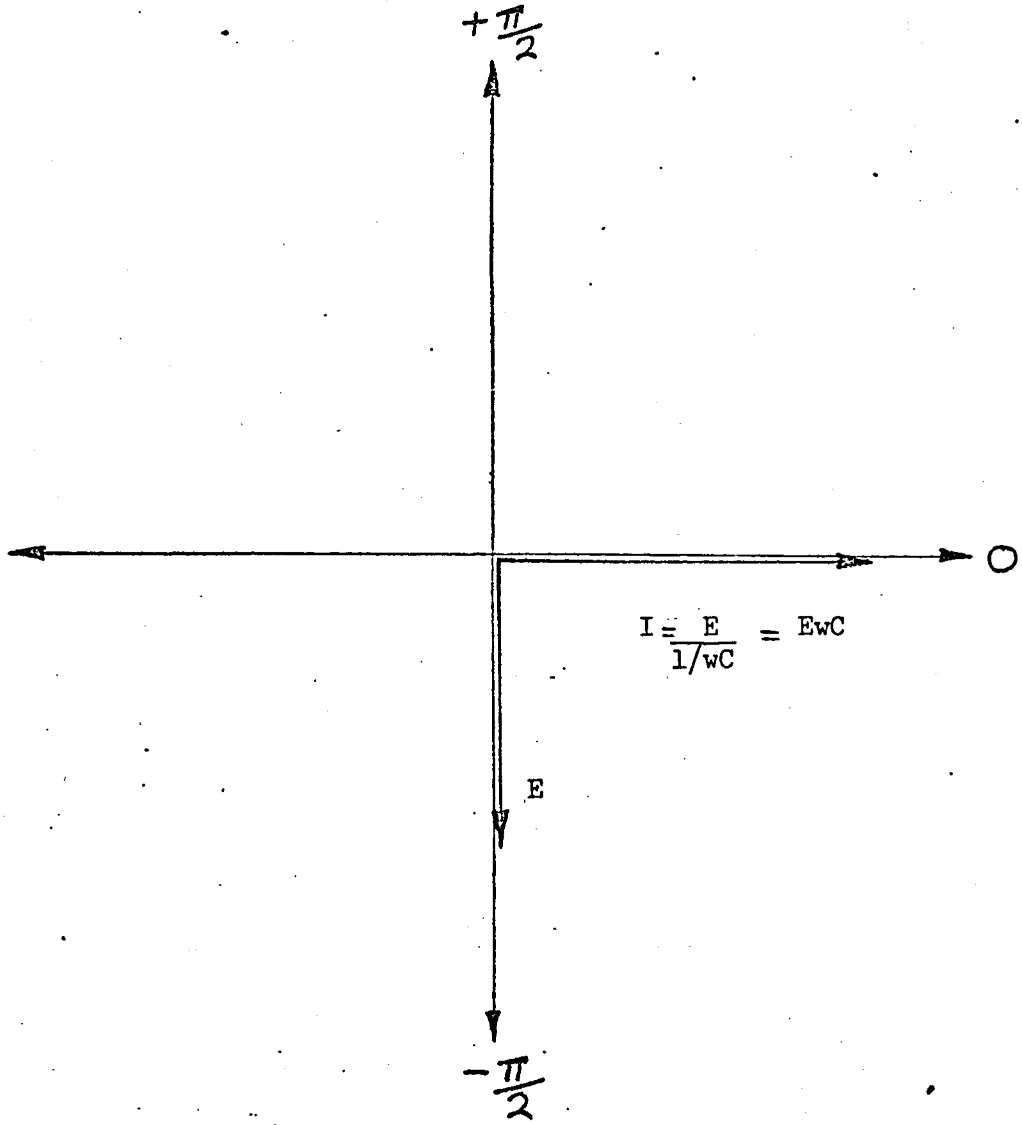


Fig.45 Voltage vector lagging current vector by 90°.

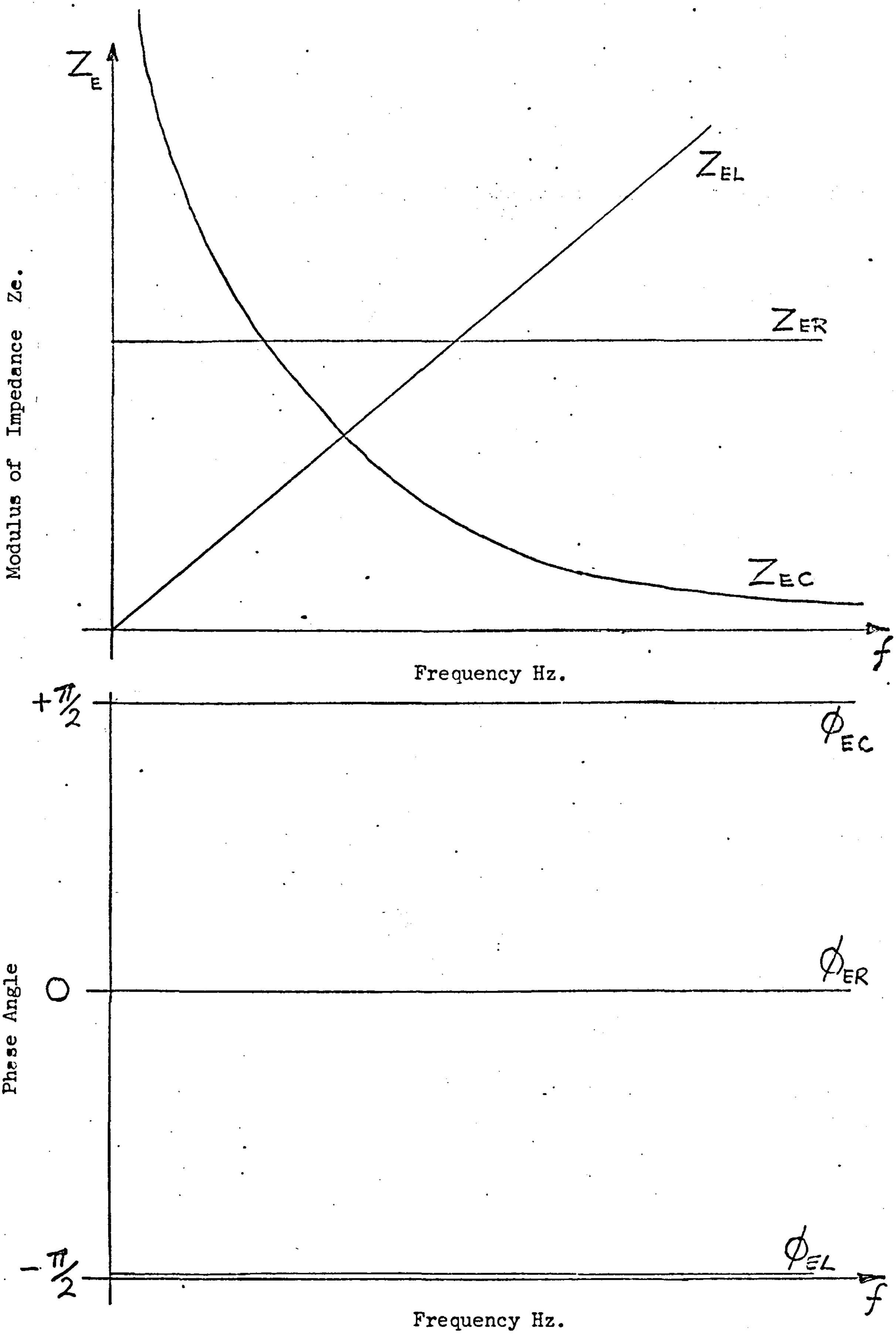


Fig. **46** Impedance plots for Electrical Elements.

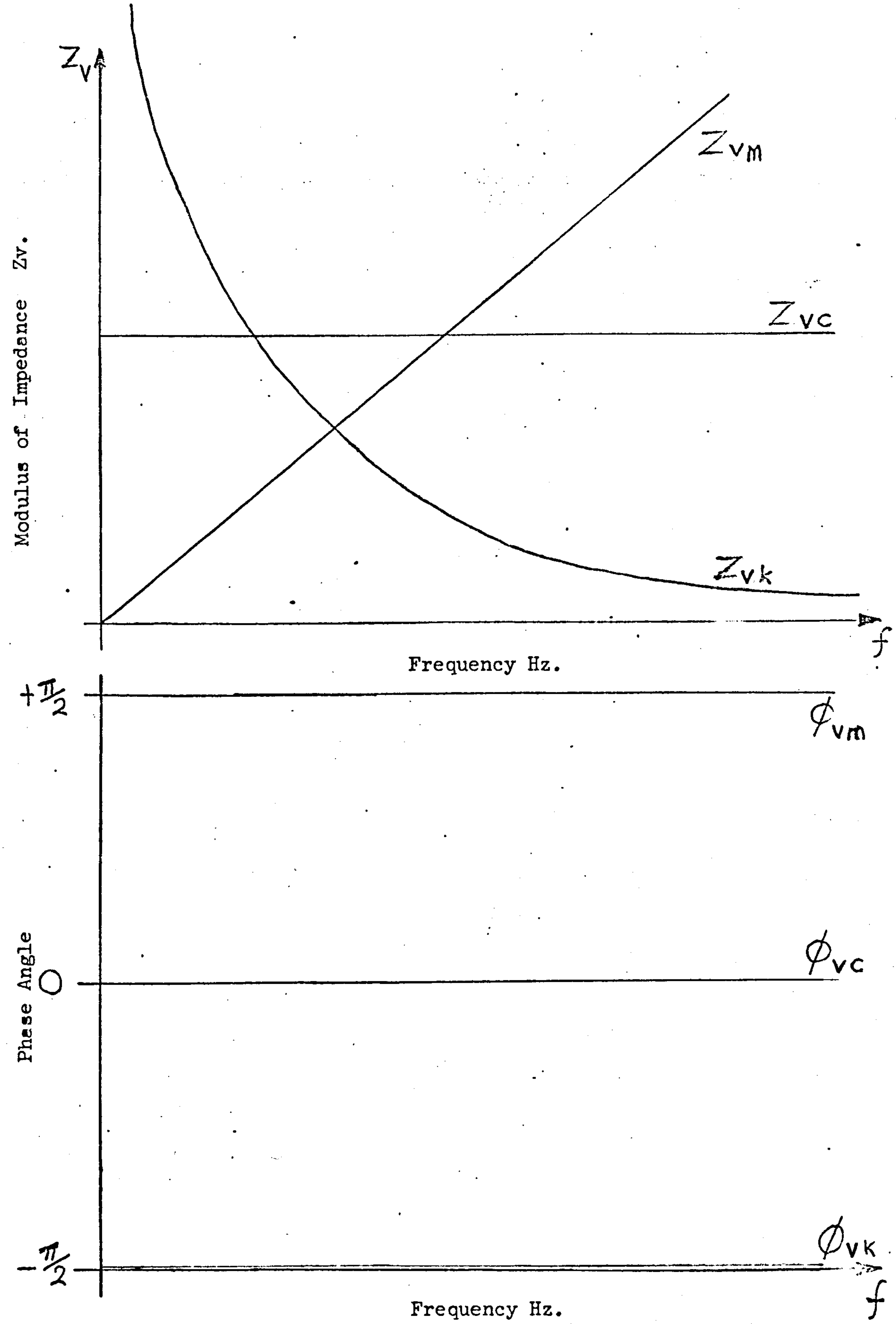


Fig. 47 Impedance Plots of Mechanical Elements. (Velocity Base.)

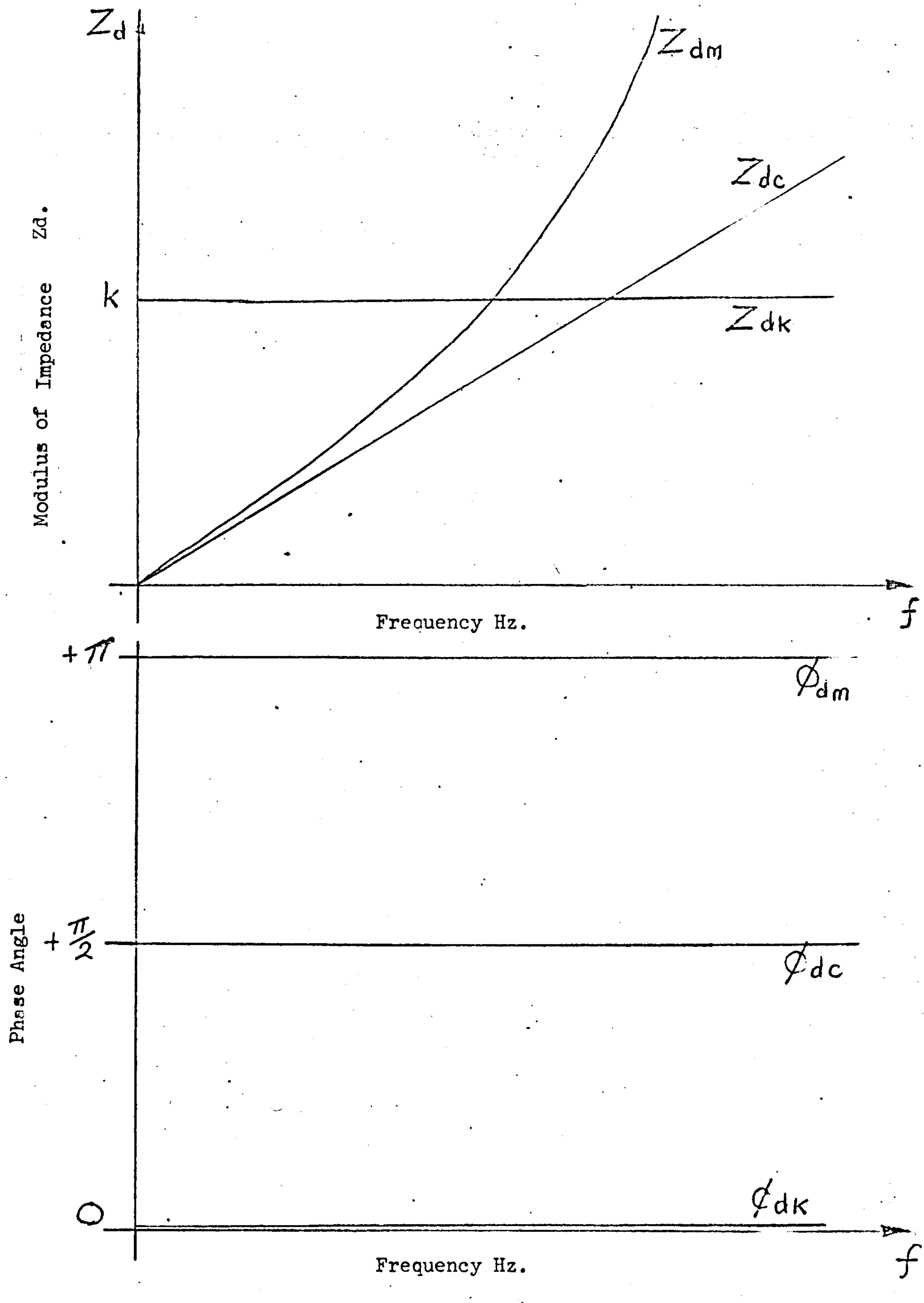


Fig. 48 Impedance Plots of Mechanical Elements. (Displacement Base.)

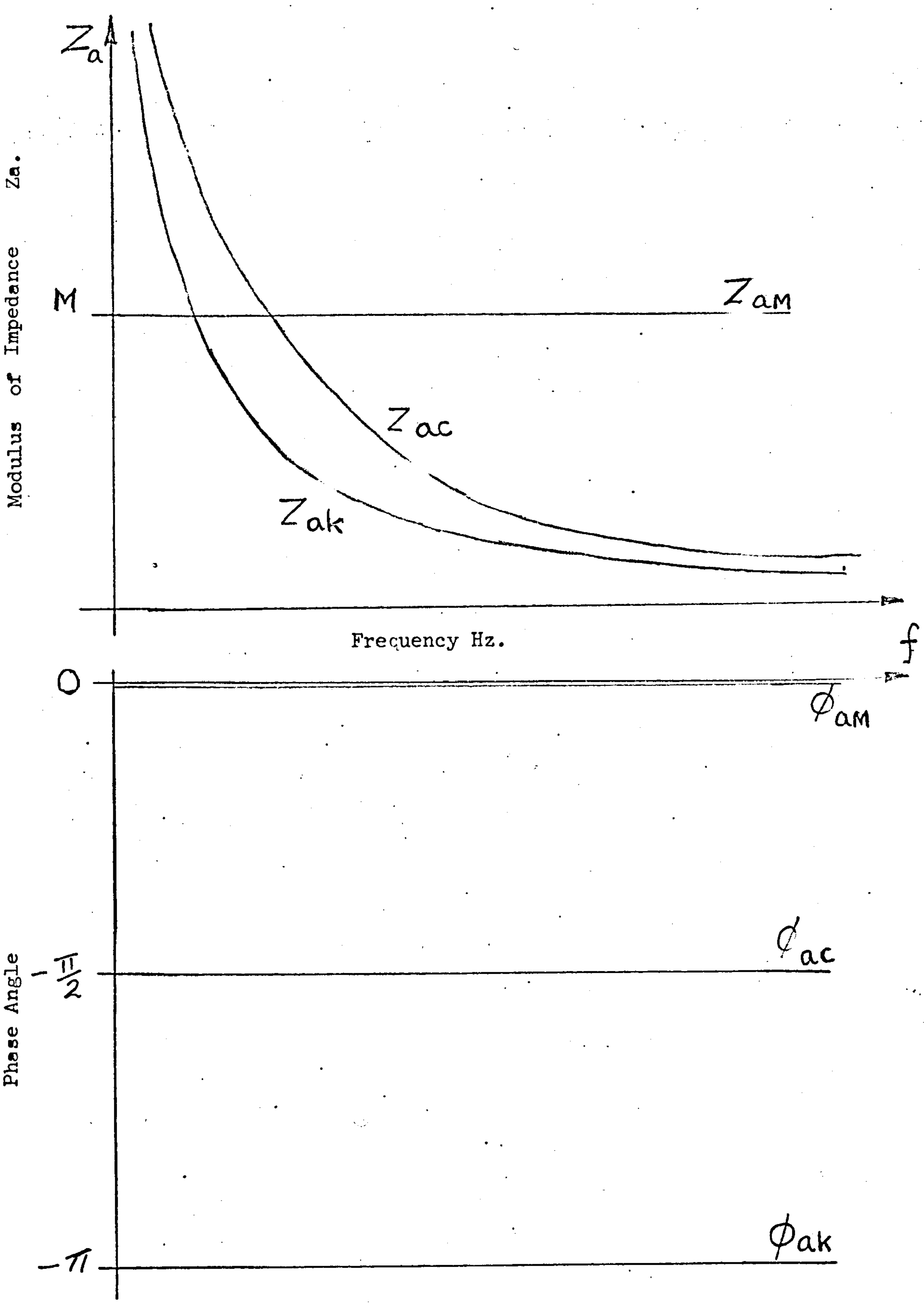
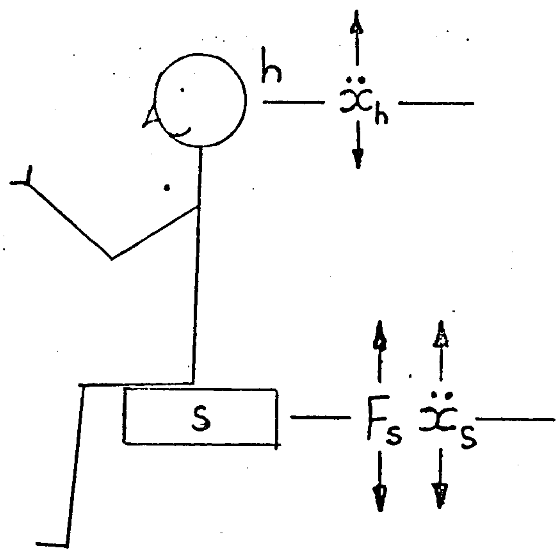


Fig. No.49 Impedance plots of Mechanical Elements (Acceleration Base)

Point - Transfer Impedance



Point Impedance (Ability to absorb/withstand Vibration).

$$Z_{ass} = \frac{F_s}{\ddot{x}_s}$$

Transfer Impedance (Ability to transmit/isolate vibration)

$$Z_{ash} = \frac{F_s}{\ddot{x}_h}$$

Figure No. 50

Mechanical System

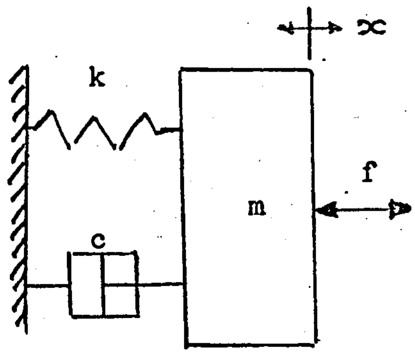


Figure No 51

Electrical System (1)   Mass-Inductance Analogy

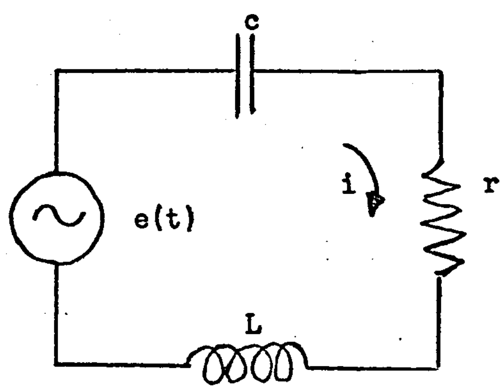


Figure No. 52

Electrical System (2)   Mass-Capacitance Analogy

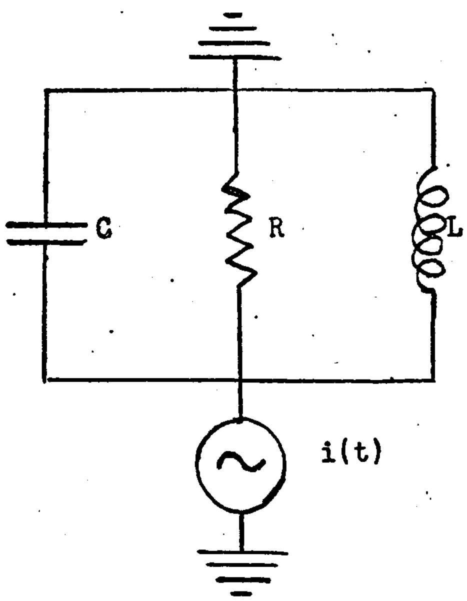


Figure No.53

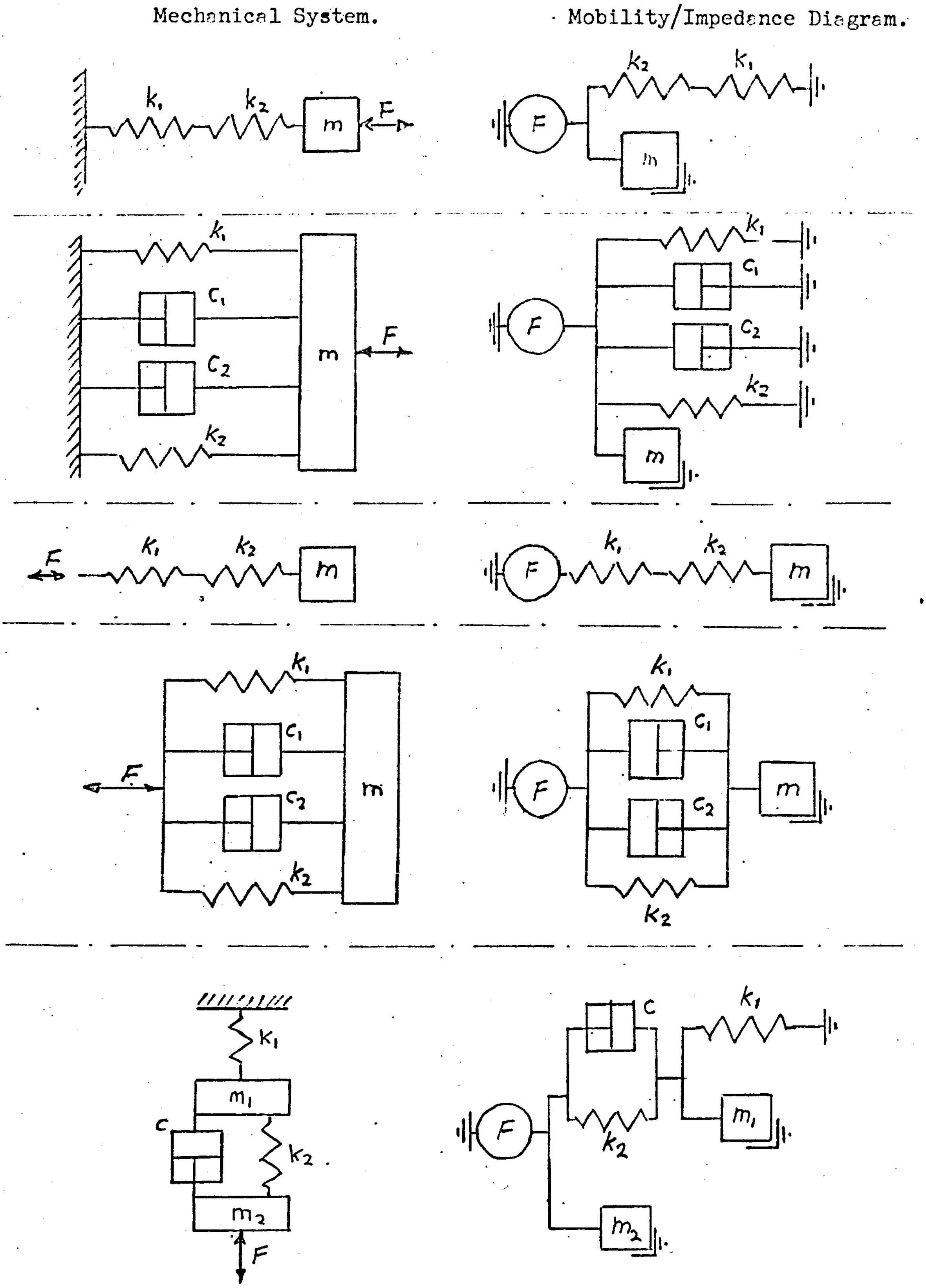


Fig. 54 Typical Mobility/Impedance Diagrams for Mass-Capacitance Analogy.

A parallel Mechanical System

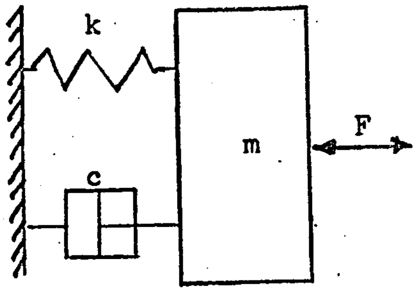


Figure No.55

A series Mechanical System.

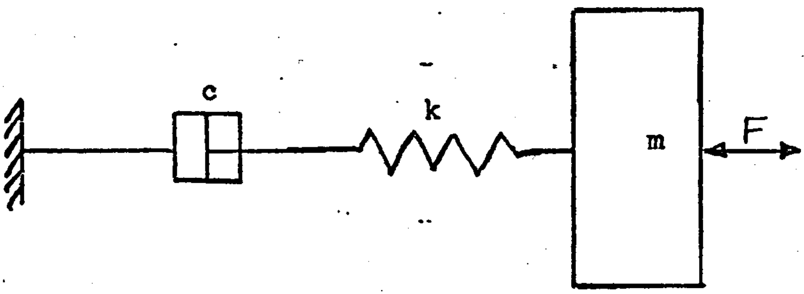
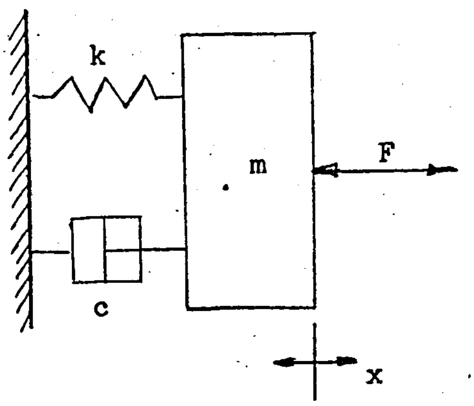
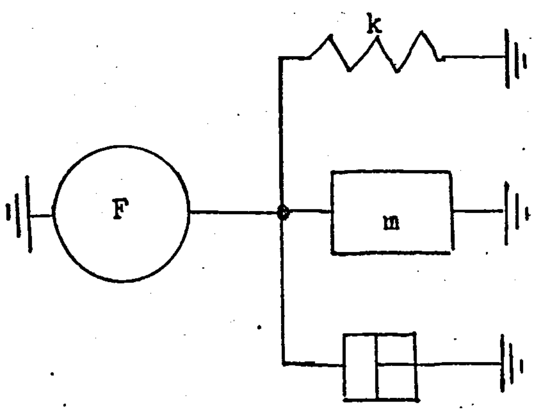


Figure No. 56

System A. Single Degree of Freedom system



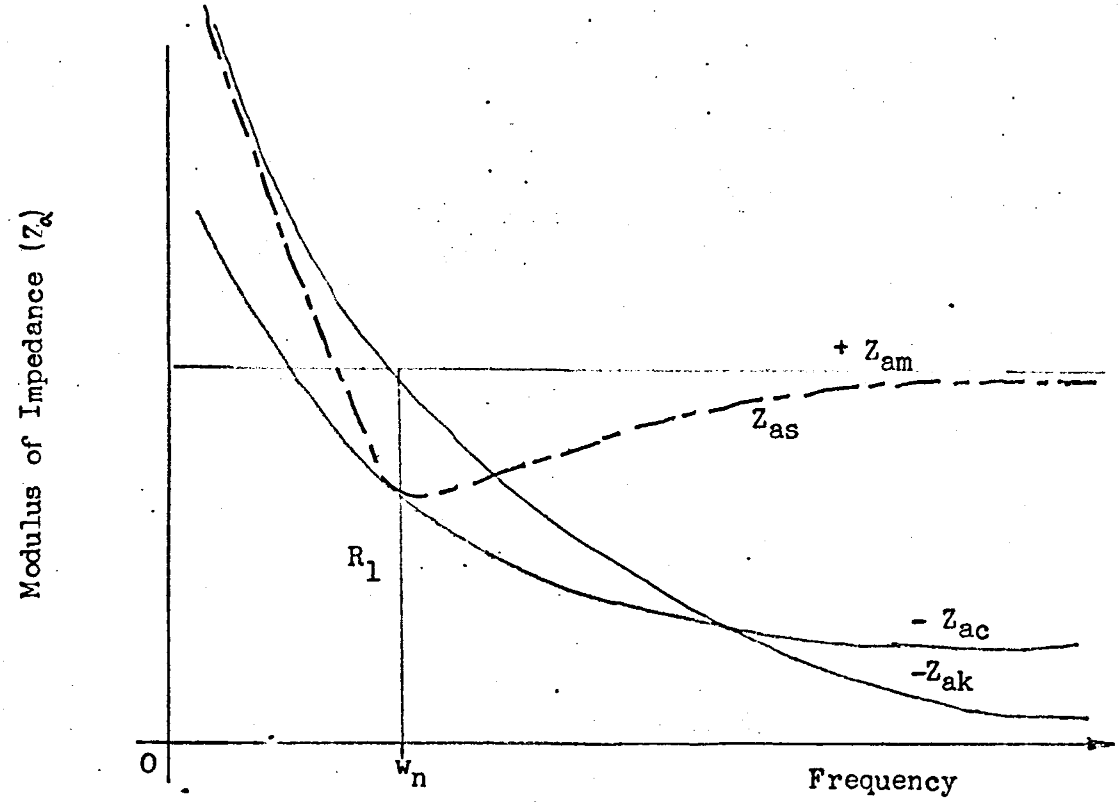
Mechanical System



Mobility/Impedance Diagram

Figure No. 57 System A.

M. of I. and Phase Angle curves for System A.



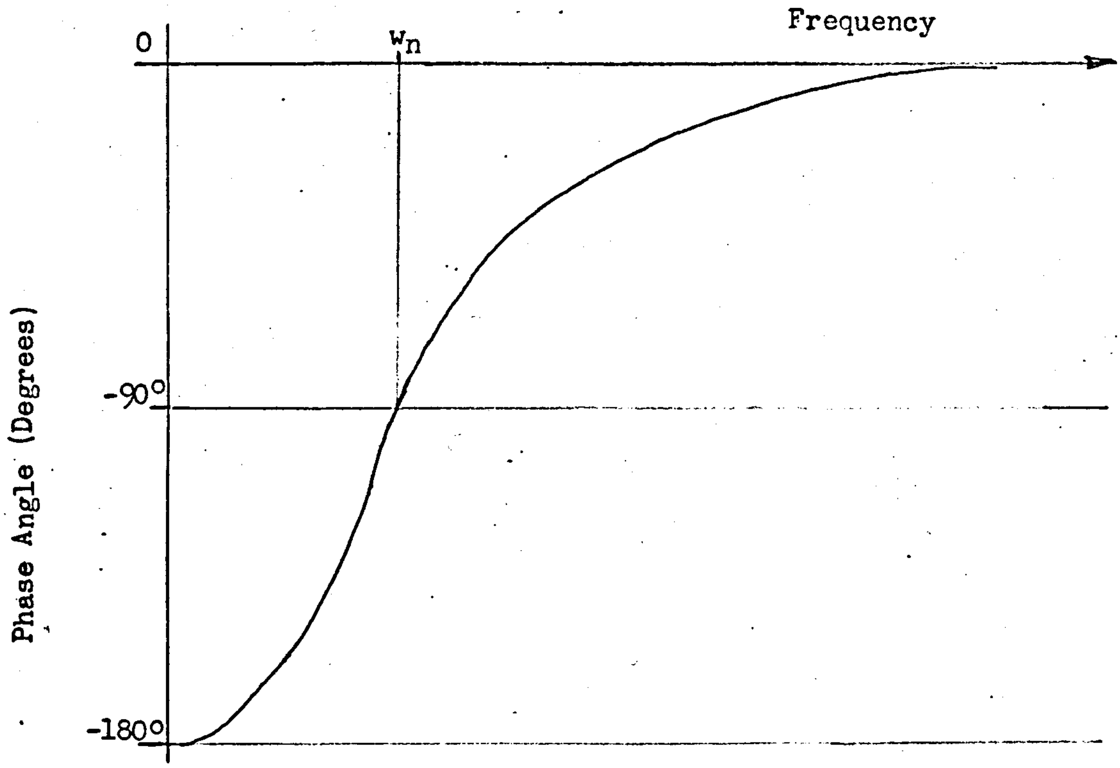
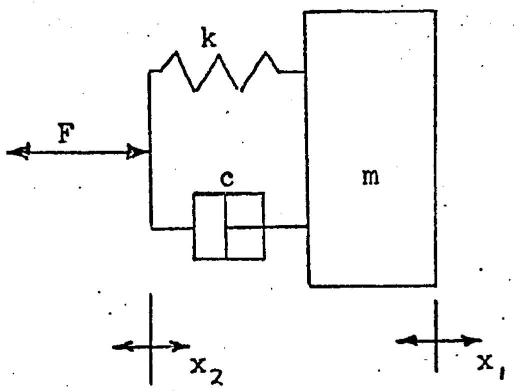
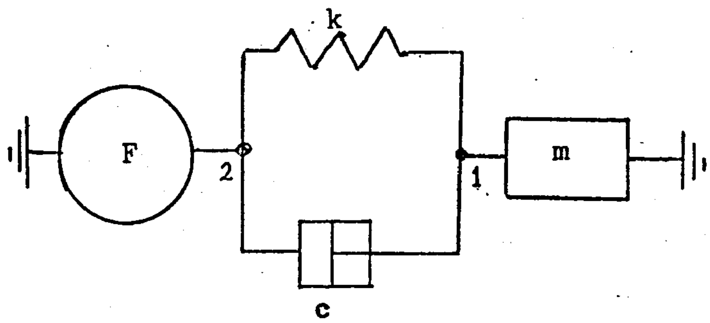


Figure No. 58 System A.

System B. Single Degree of Freedom System - with base excitation



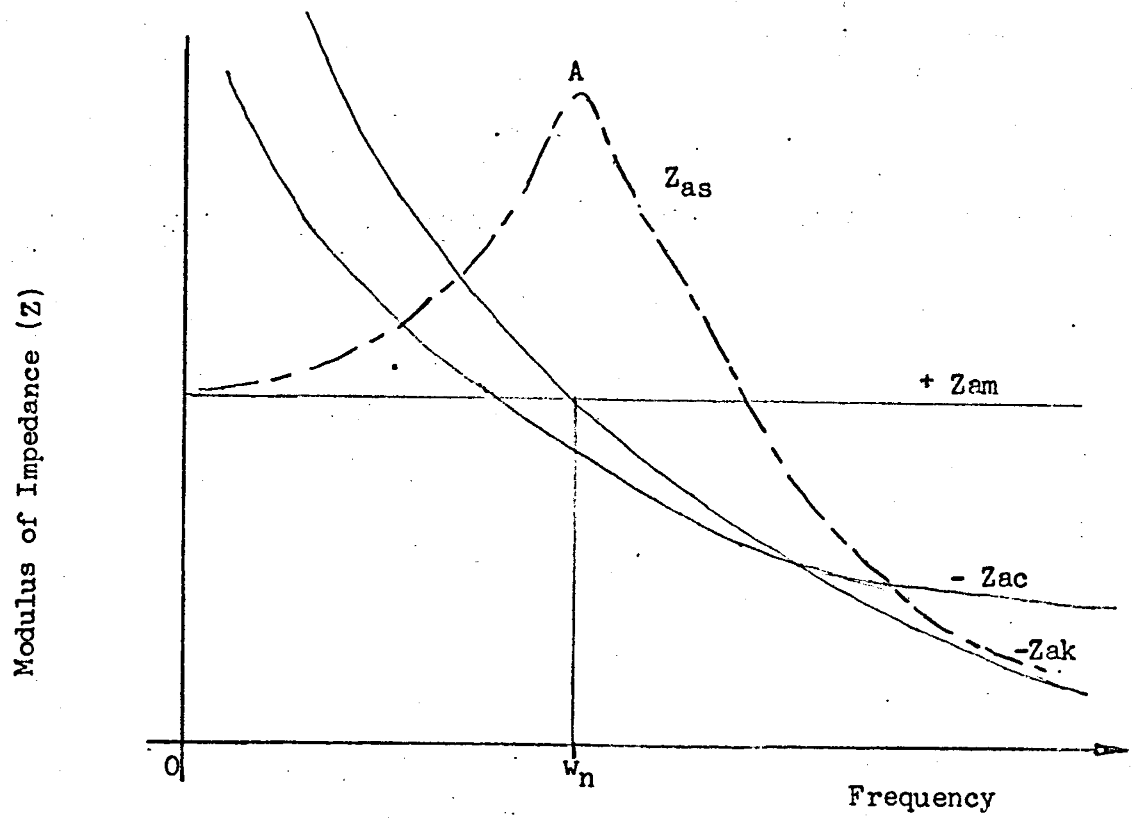
Mechanical System



Mobility/Impedance Diagram

Figure No. 59 System B.

M. of I. and Phase Angle curves for System B.



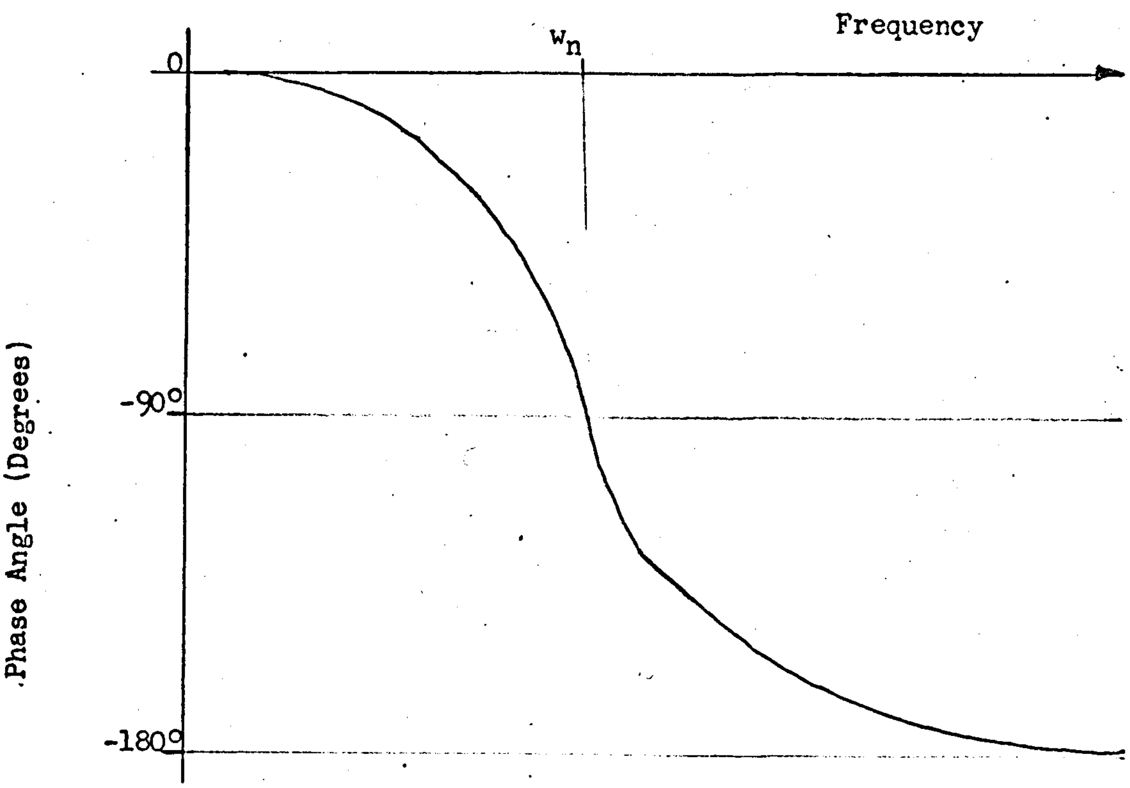
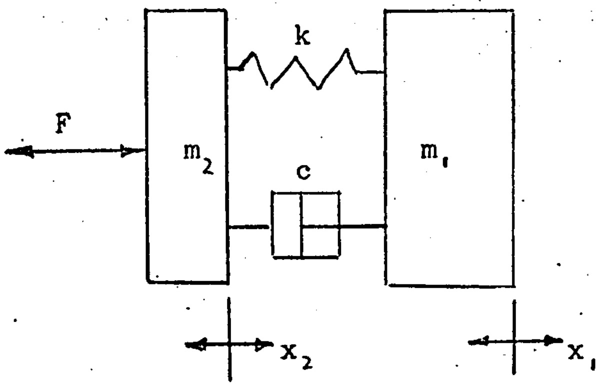
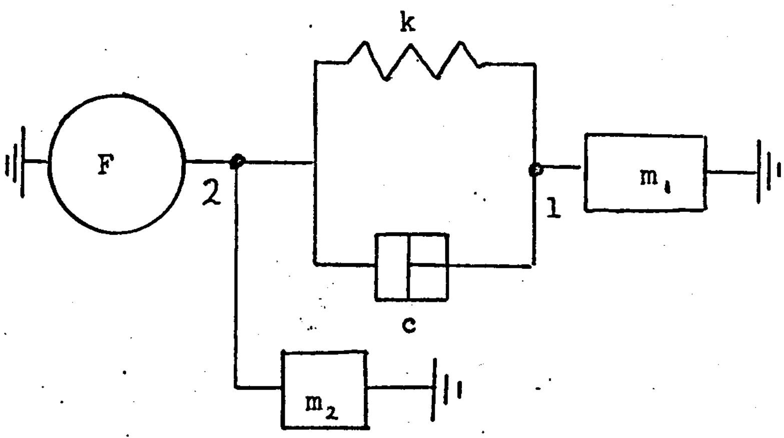


Figure No. **60** System B.

System C. Single Degree of Freedom System (Displaying resonance and anti-resonance)



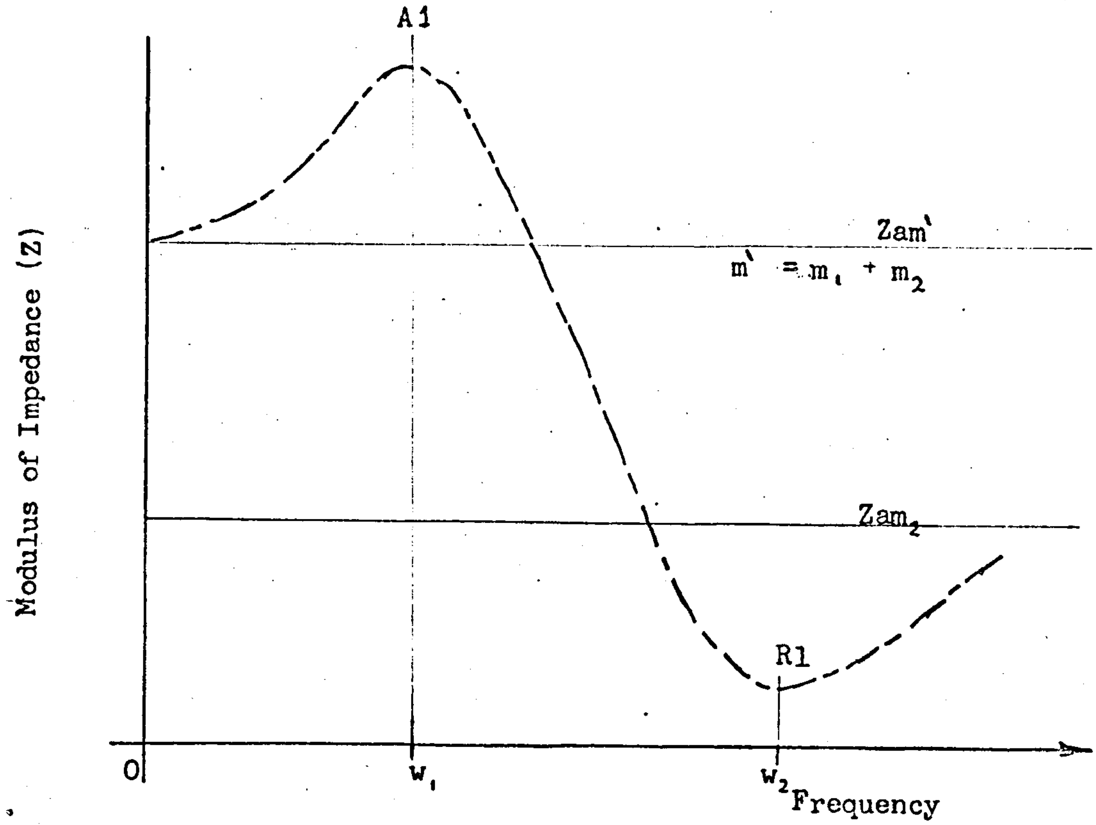
Mechanical System



Mobility/Impedance Diagram

Figure No. 61 System C.

M. of I. and Phase Angle curves for System C.



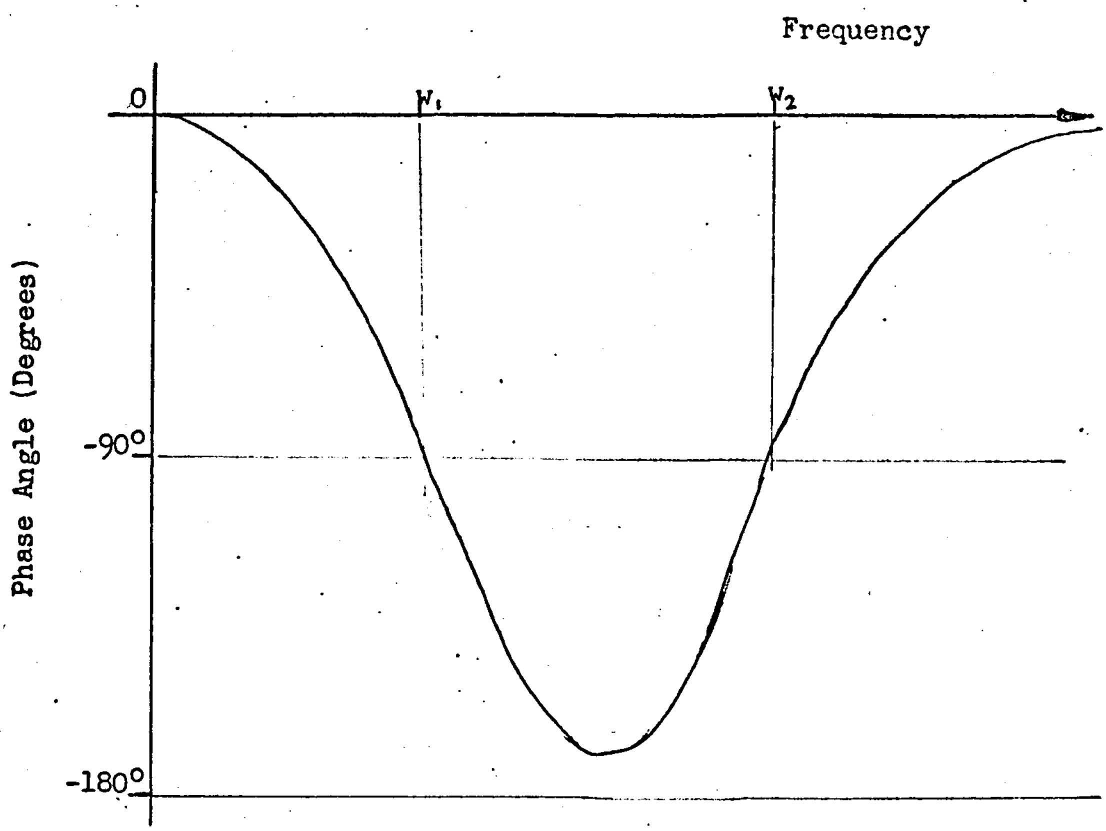
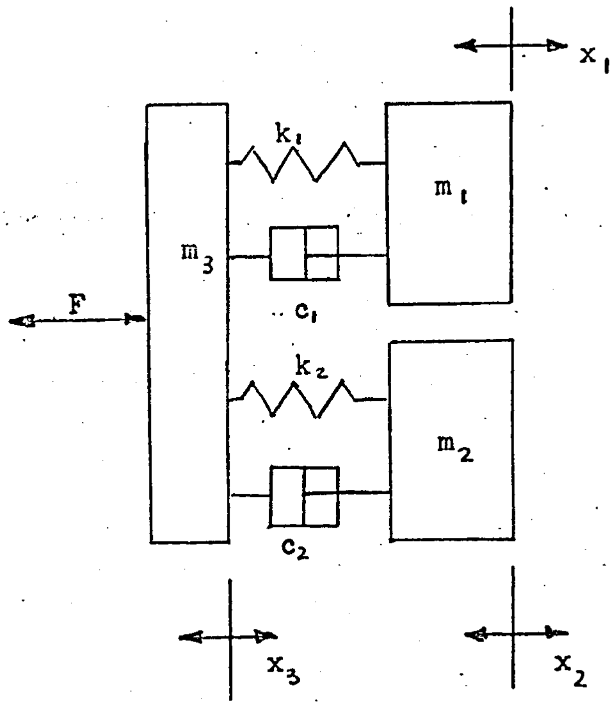
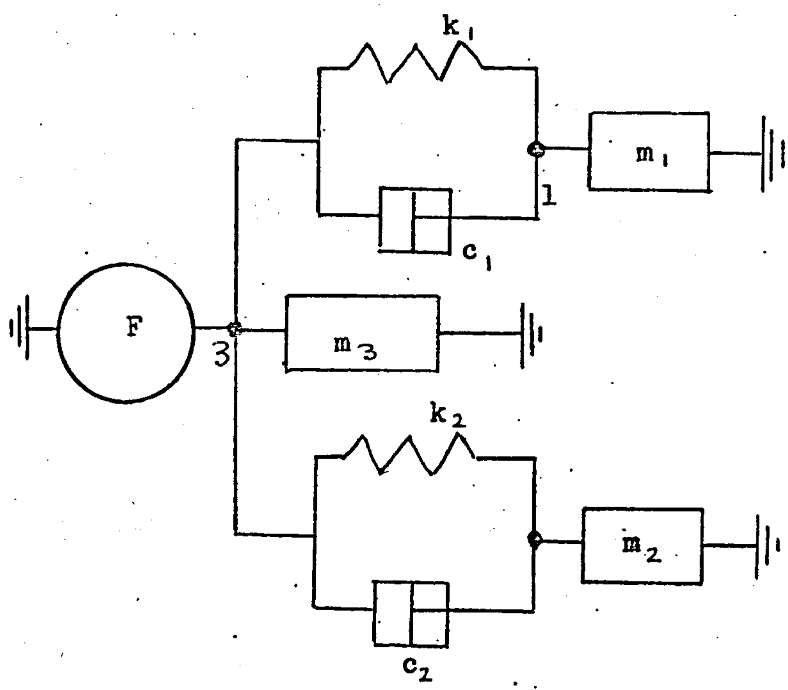


Figure No. 62 System C.

System D. Two Degrees of Freedom system (A parallel system)



Mechanical System



Mobility/Impedance Diagram

Figure No. 63 System D.

M. of I. and Phase Angle curves for System D.

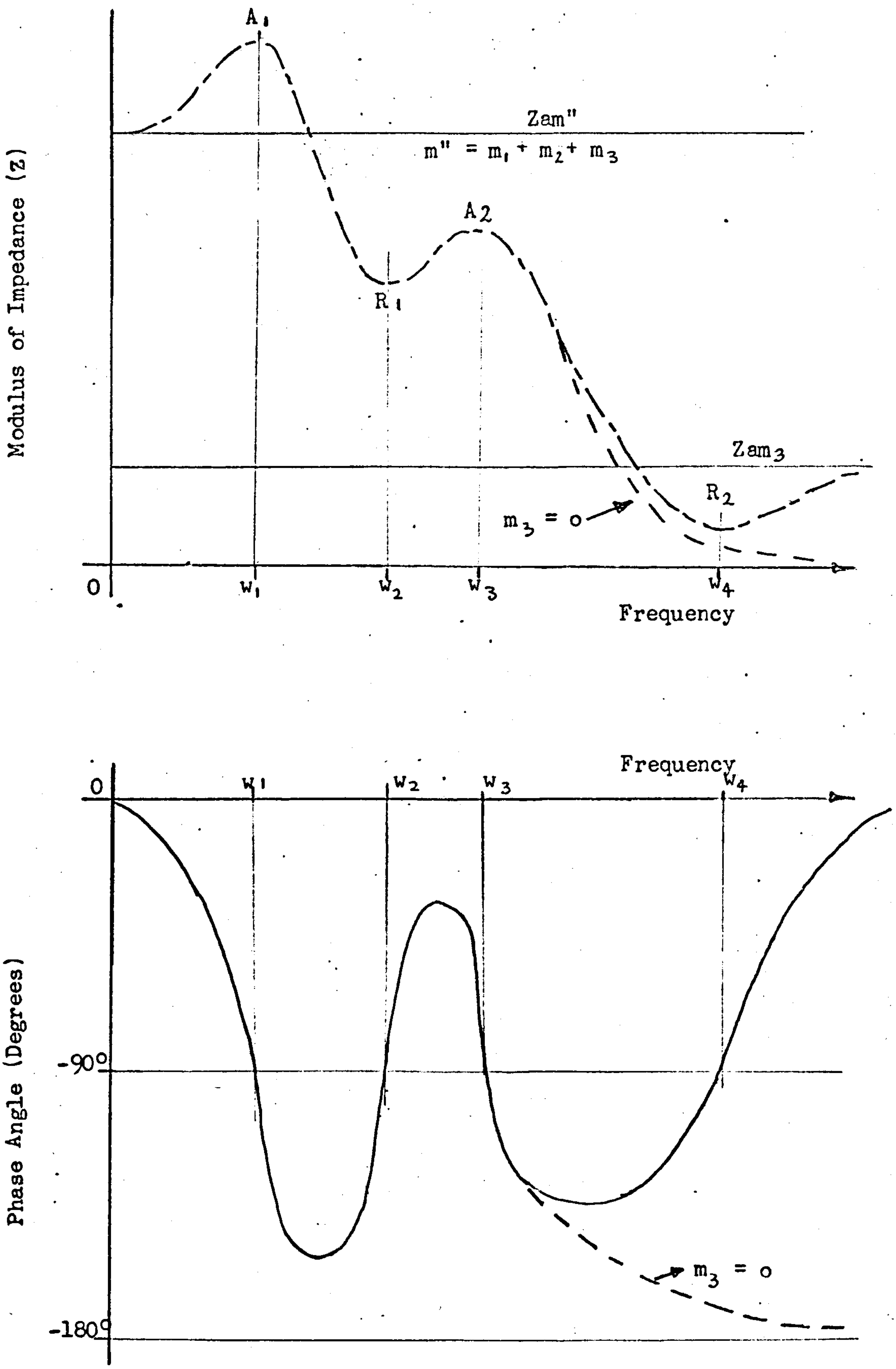
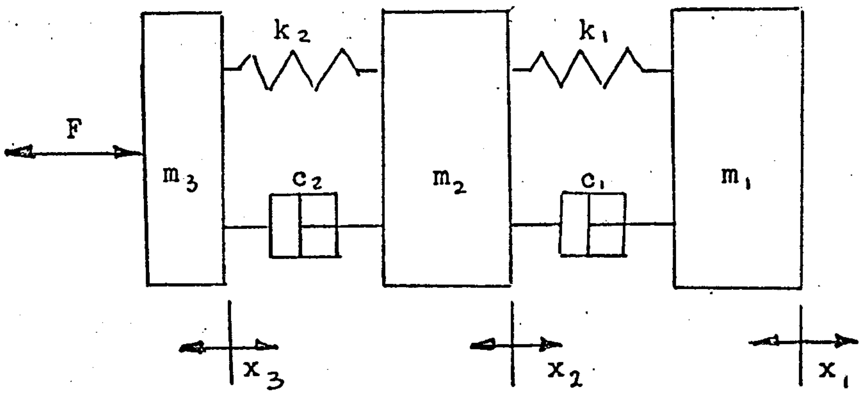
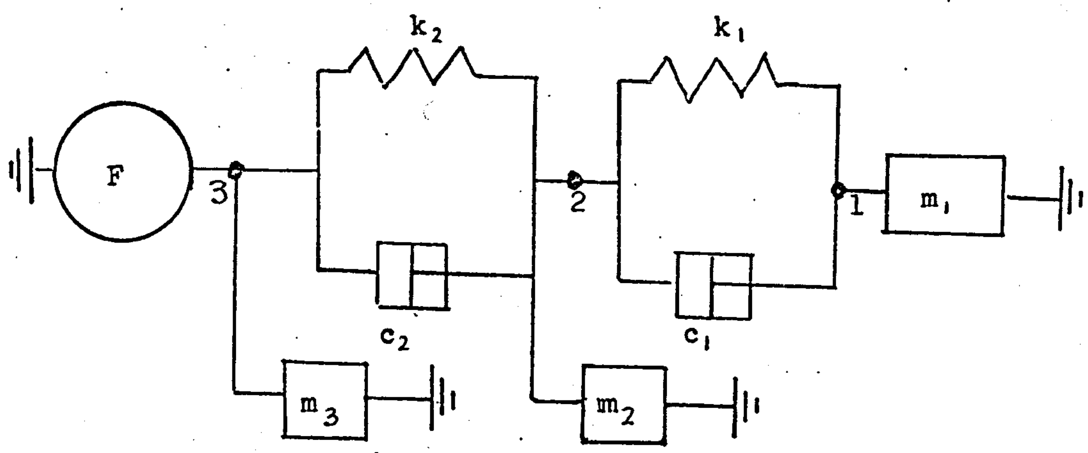


Figure No. 64 System D.

System E. Two Degrees of Freedom System (A series system)



Mechanical System



Mobility/Impedance Diagram

Figure No. 65 System E.

M of I and Phase Angle curves for System E

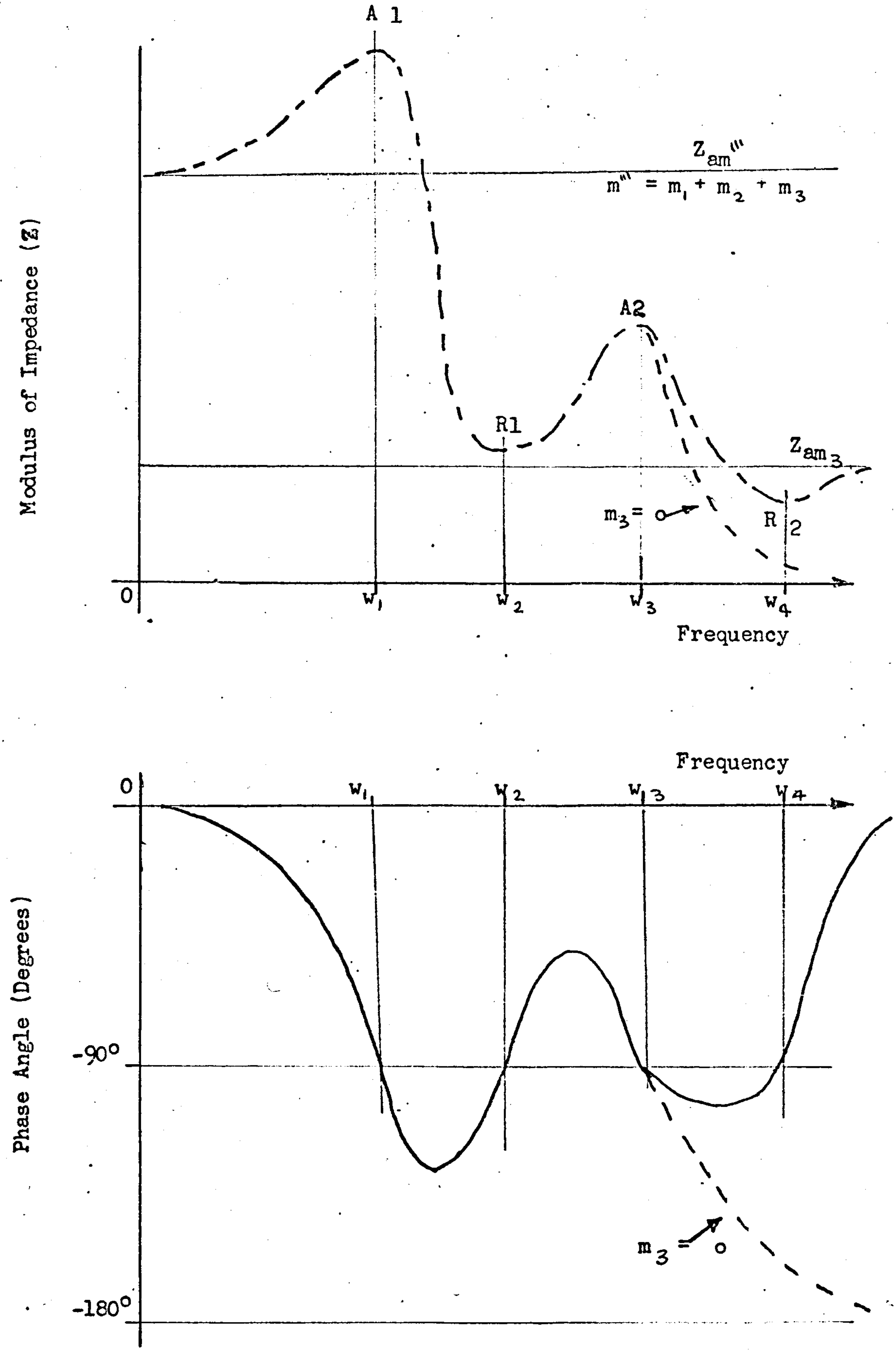


Figure No. 66 System E.

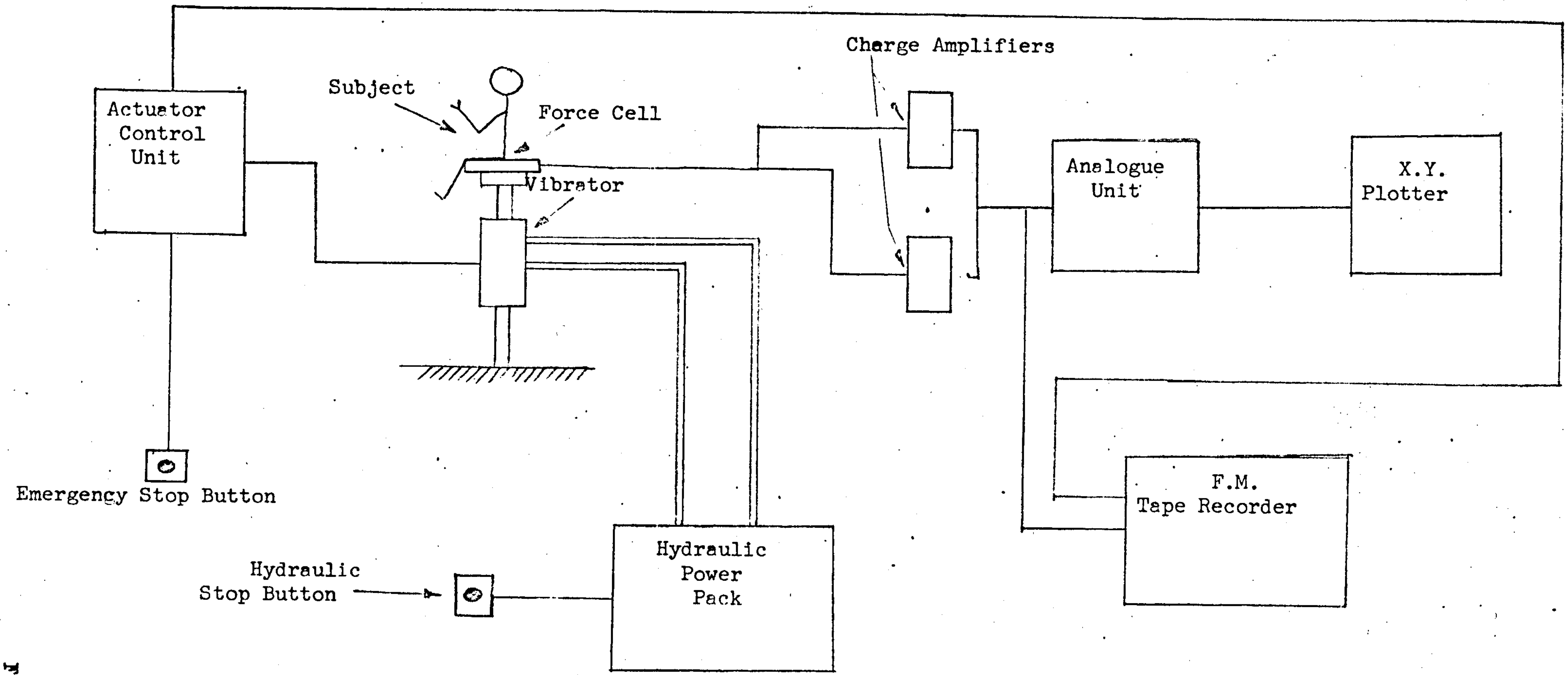

Charge Amplifiers
Subject
Force Cell
Actuator Control Unit
Vibrator
Analogue Unit
X.Y. Plotter
Emergency Stop Button
Hydraulic Stop Button
Hydraulic Power Pack
F.M. Tape Recorder

Figure No.67

Pace Analogue Computer circuit diagram -1.

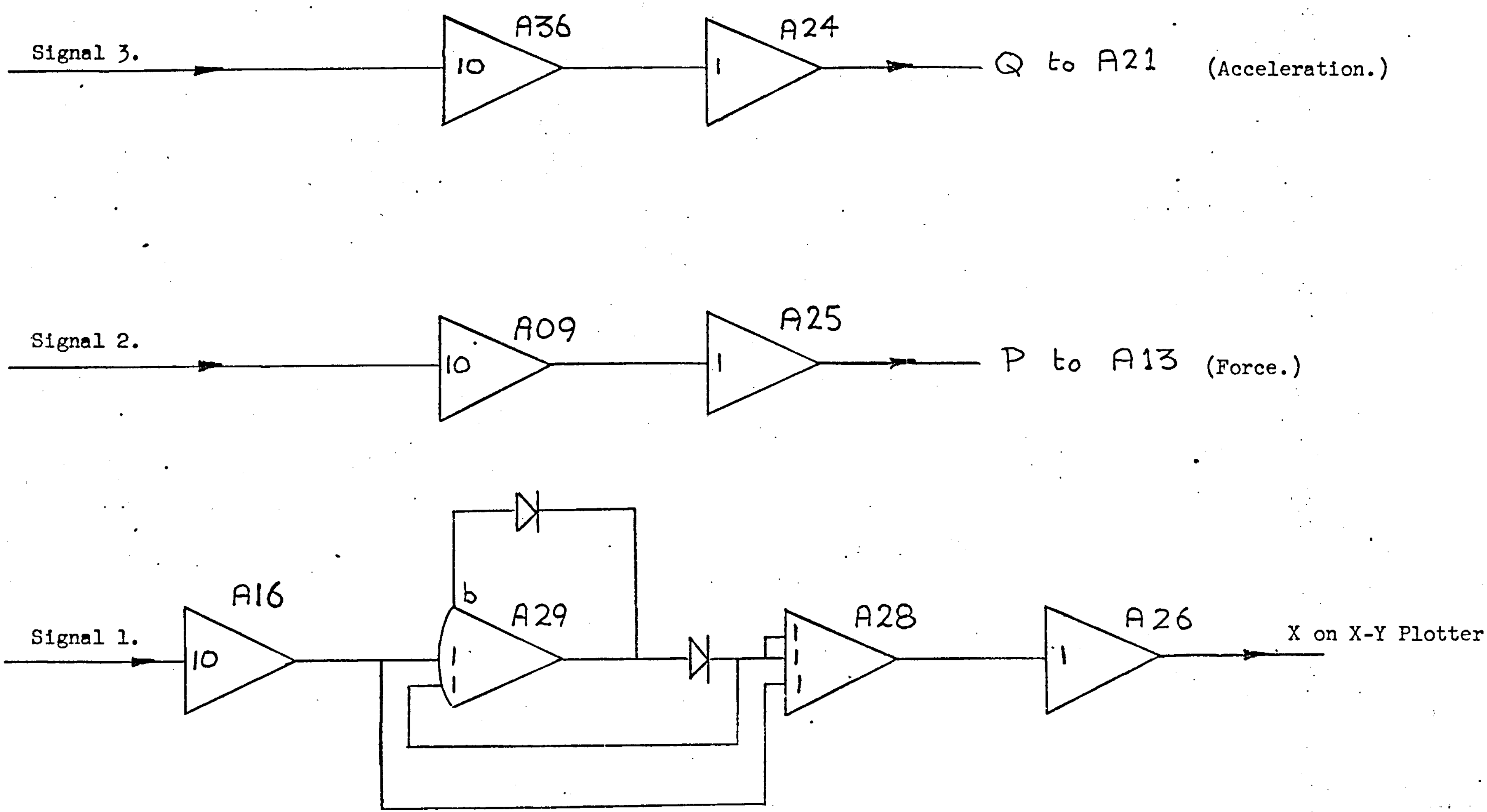
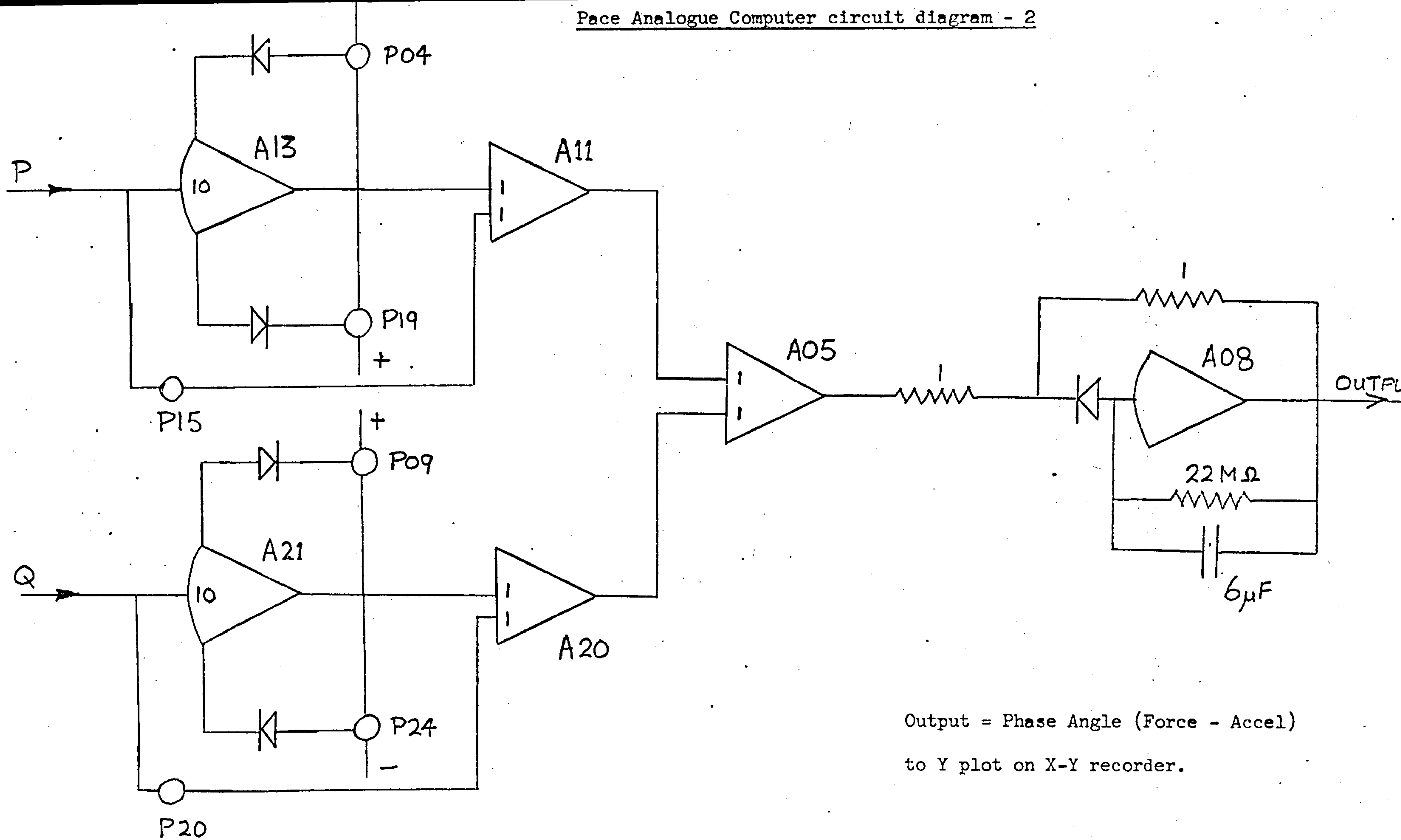


Figure No. 8

Pace Analogue Computer circuit diagram - 2

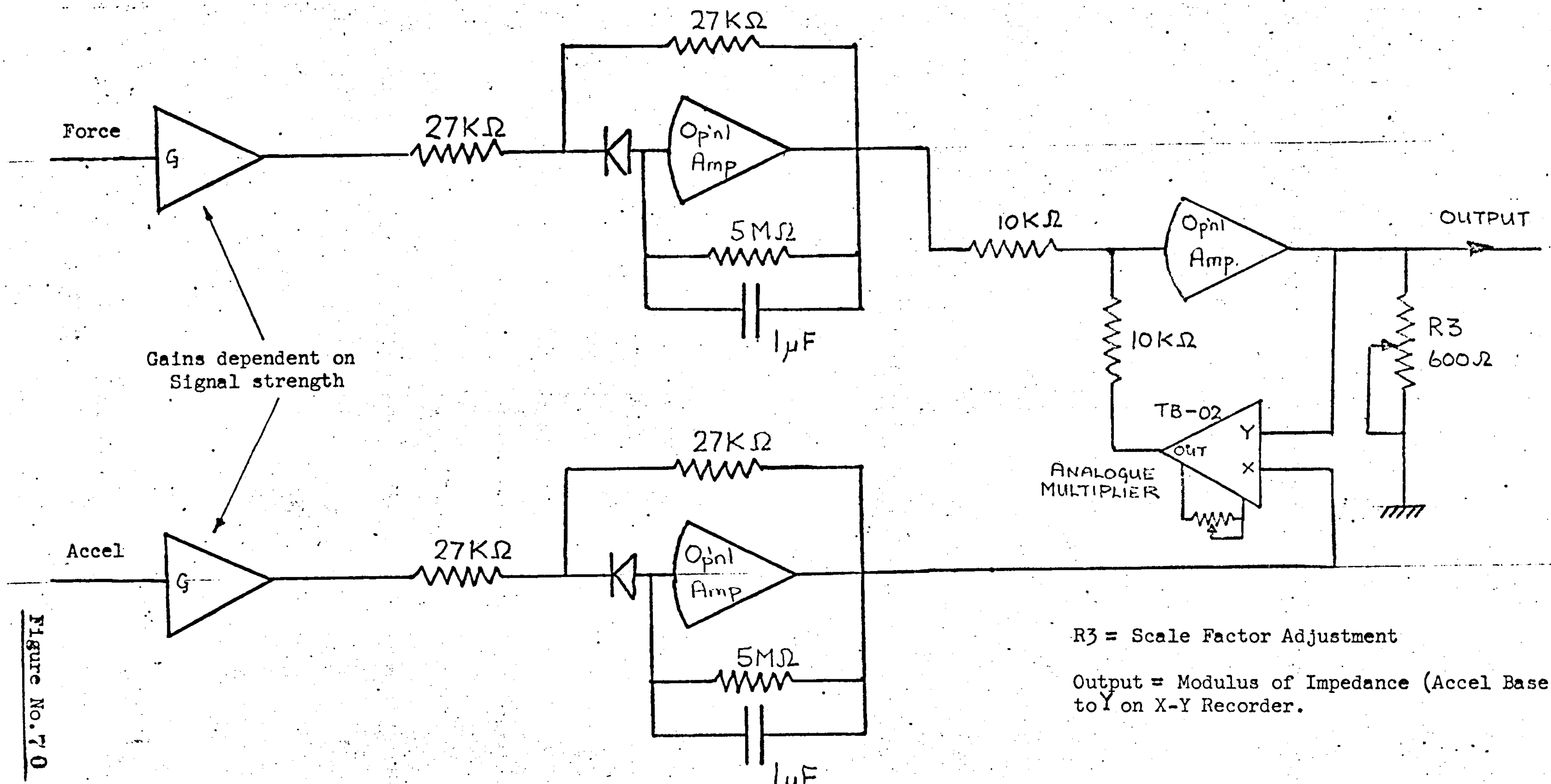


Output = Phase Angle (Force - Accel)

to Y plot on X-Y recorder.

Figure No.G9

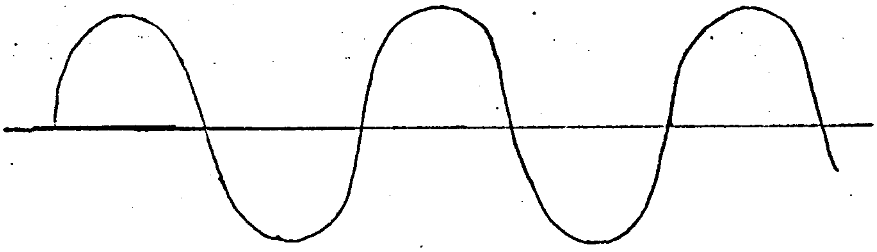
Analogue Data processesing unit - circuit diagram



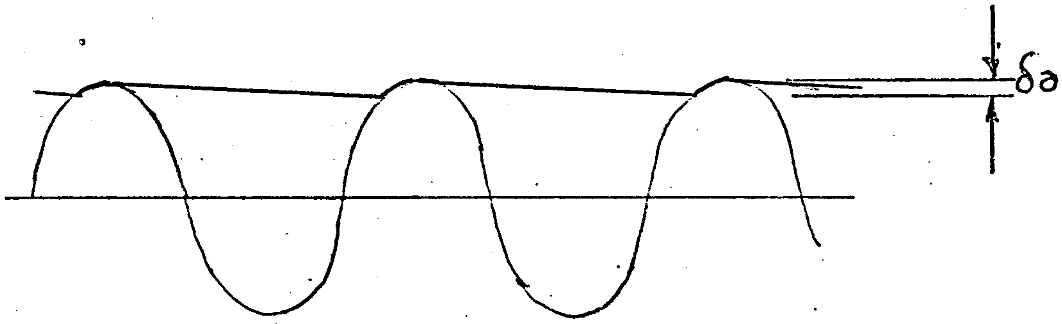
R3 = Scale Factor Adjustment

Output = Modulus of Impedance (Accel Base) to Y on X-Y Recorder.

Figure No.70



Input sine wave



'Leaky' integrator output voltage.

Figure No. 71

Typical Waveform outputs from analogue summer

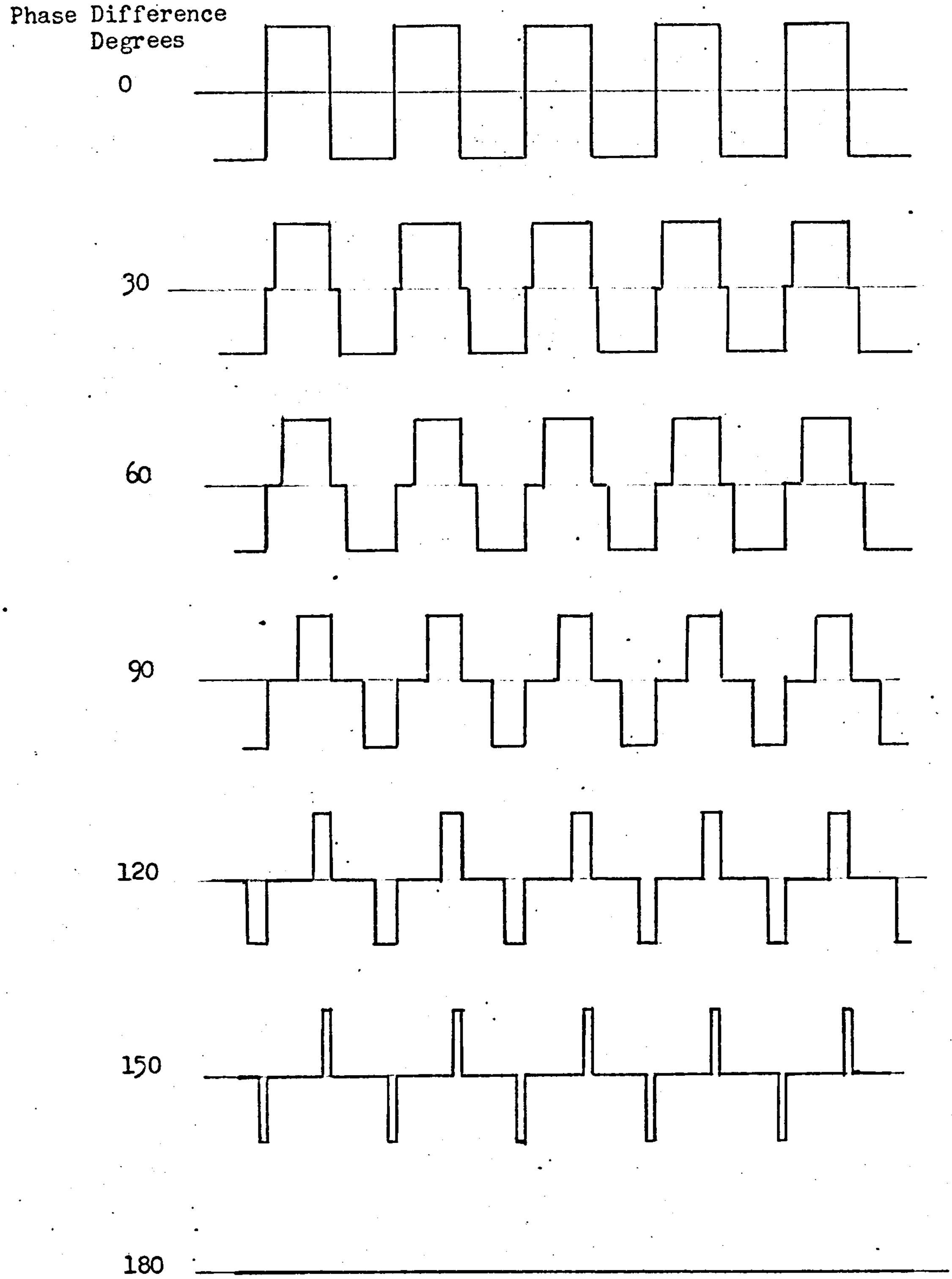
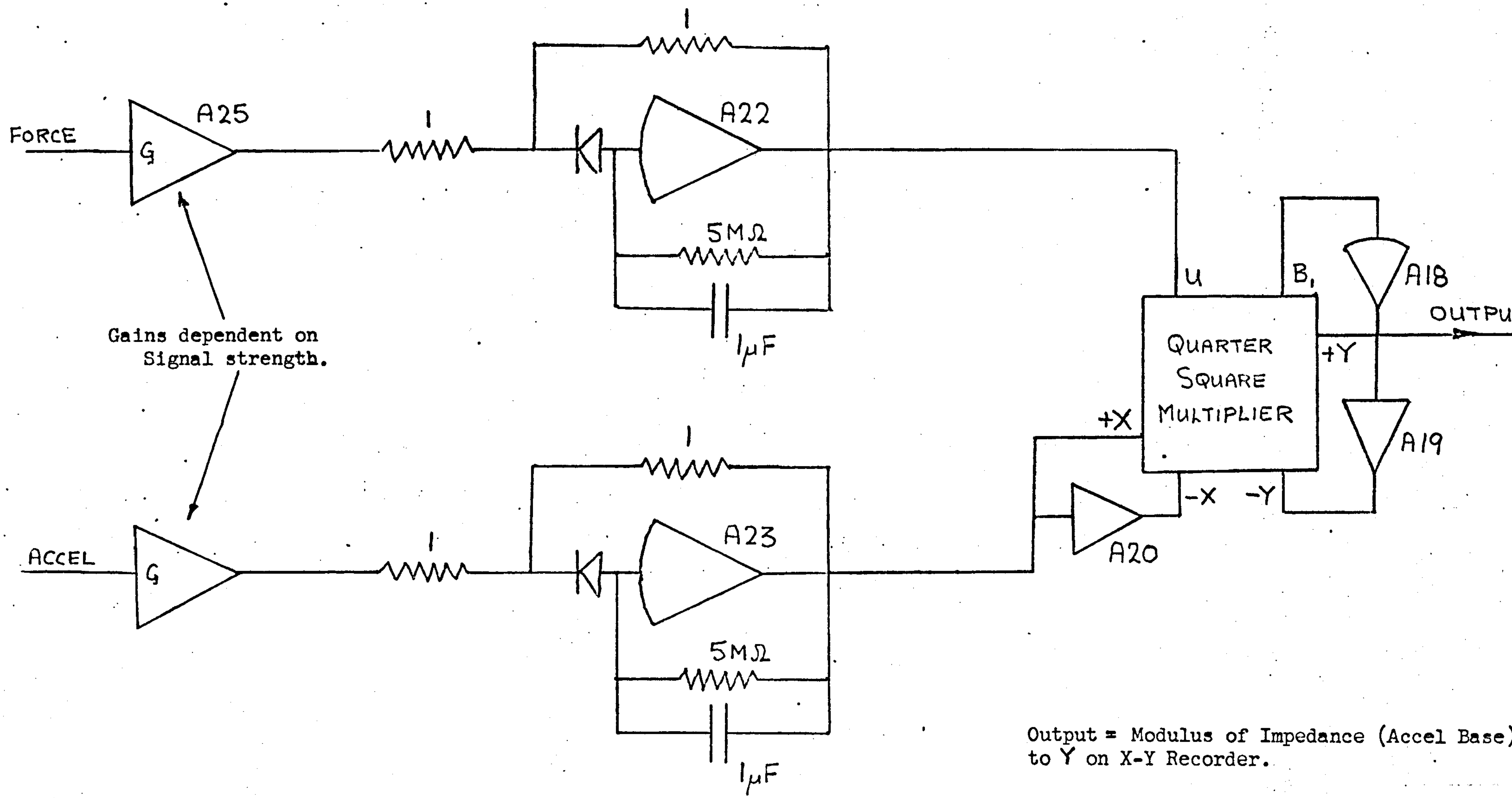


Figure No. 72

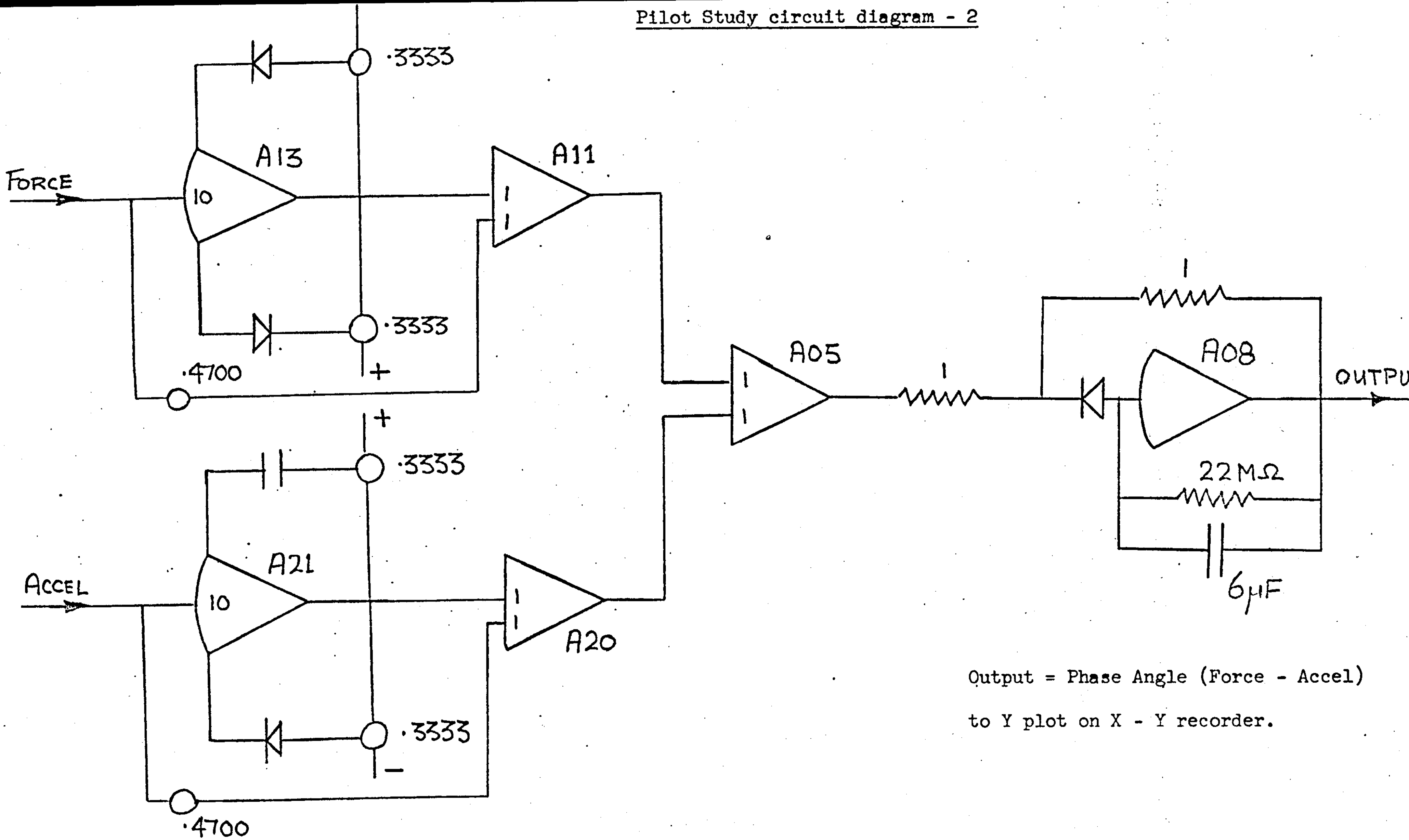
Pilot Study circuit diagram - 1.



Output = Modulus of Impedance (Accel Base) to Y on X-Y Recorder.

Figure No. 73

Pilot Study circuit diagram - 2



Output = Phase Angle (Force - Accel)

to Y plot on X - Y recorder.

Figure No.74

Pilot Study circuit diagram – 3.

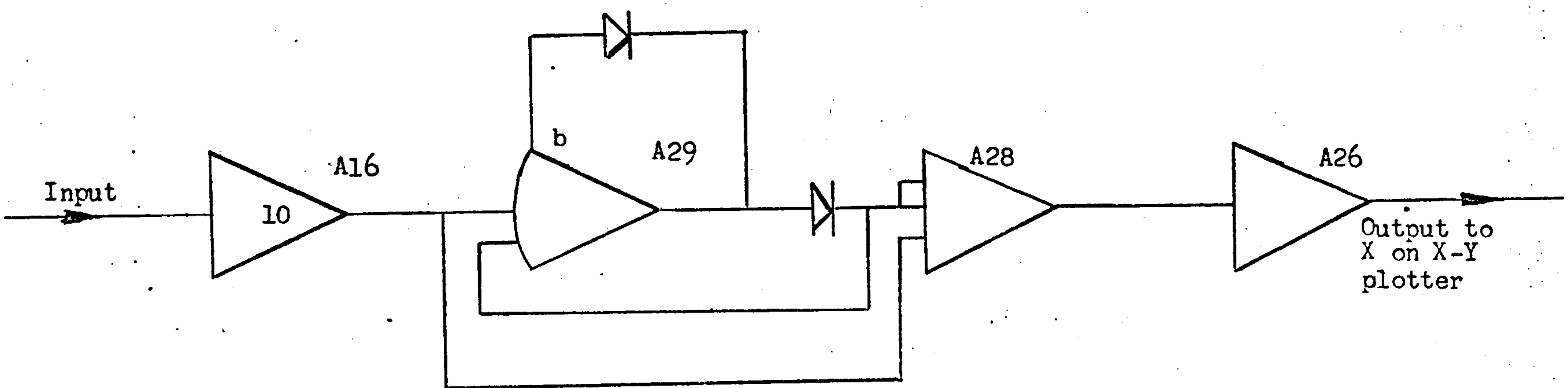
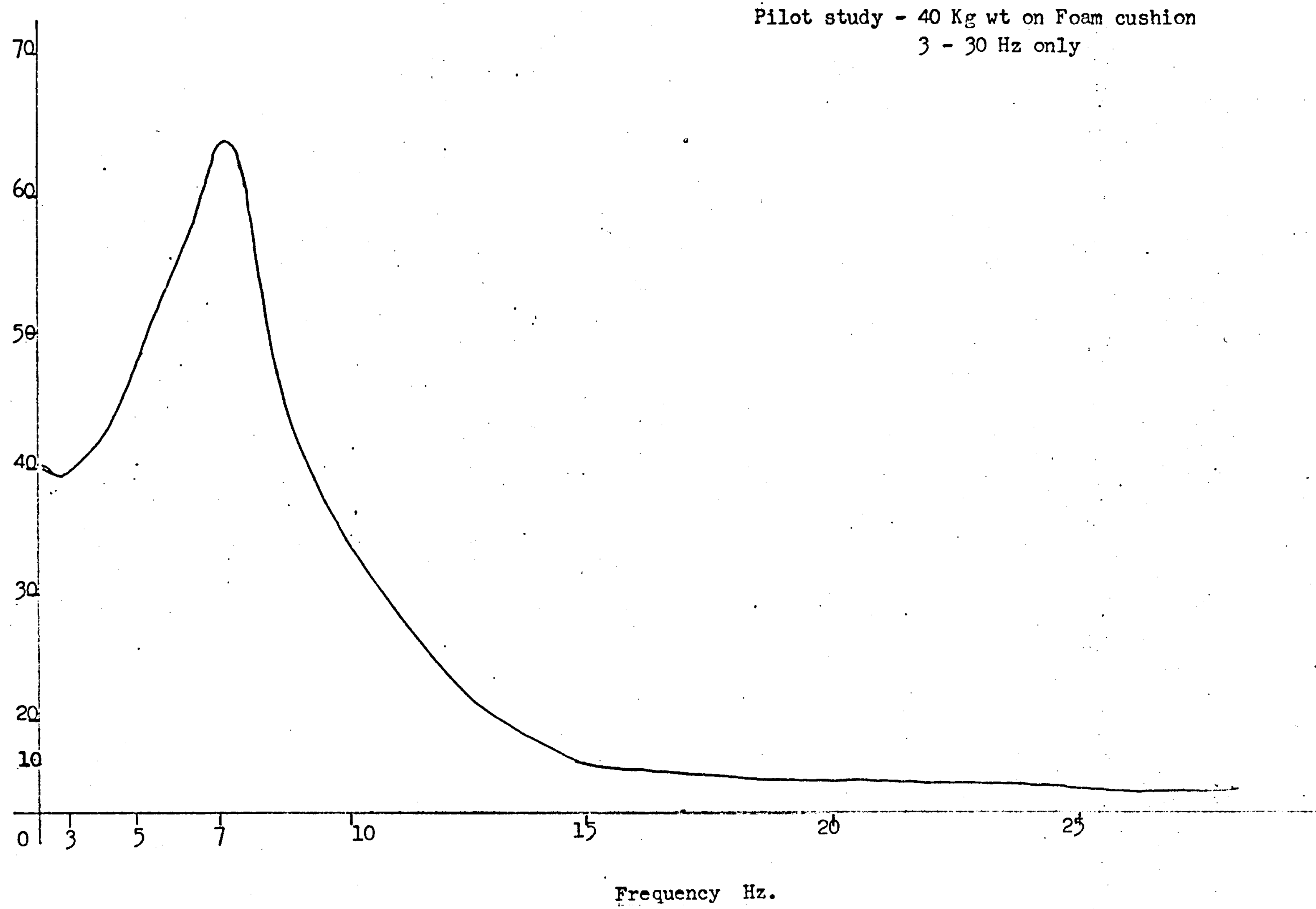


Figure No. 75

Figure No. 76



Pilot study - 40 Kg wt on Foam cushion
3 - 30 Hz only
Impedance Za Kg
70
60
50
40
30
20
10
0
3
5
7
10
15
20
25
30
Frequency Hz.

Phase Angle Pilot Test   40 kg. wt. on foam cushion.
3-30 Hz.

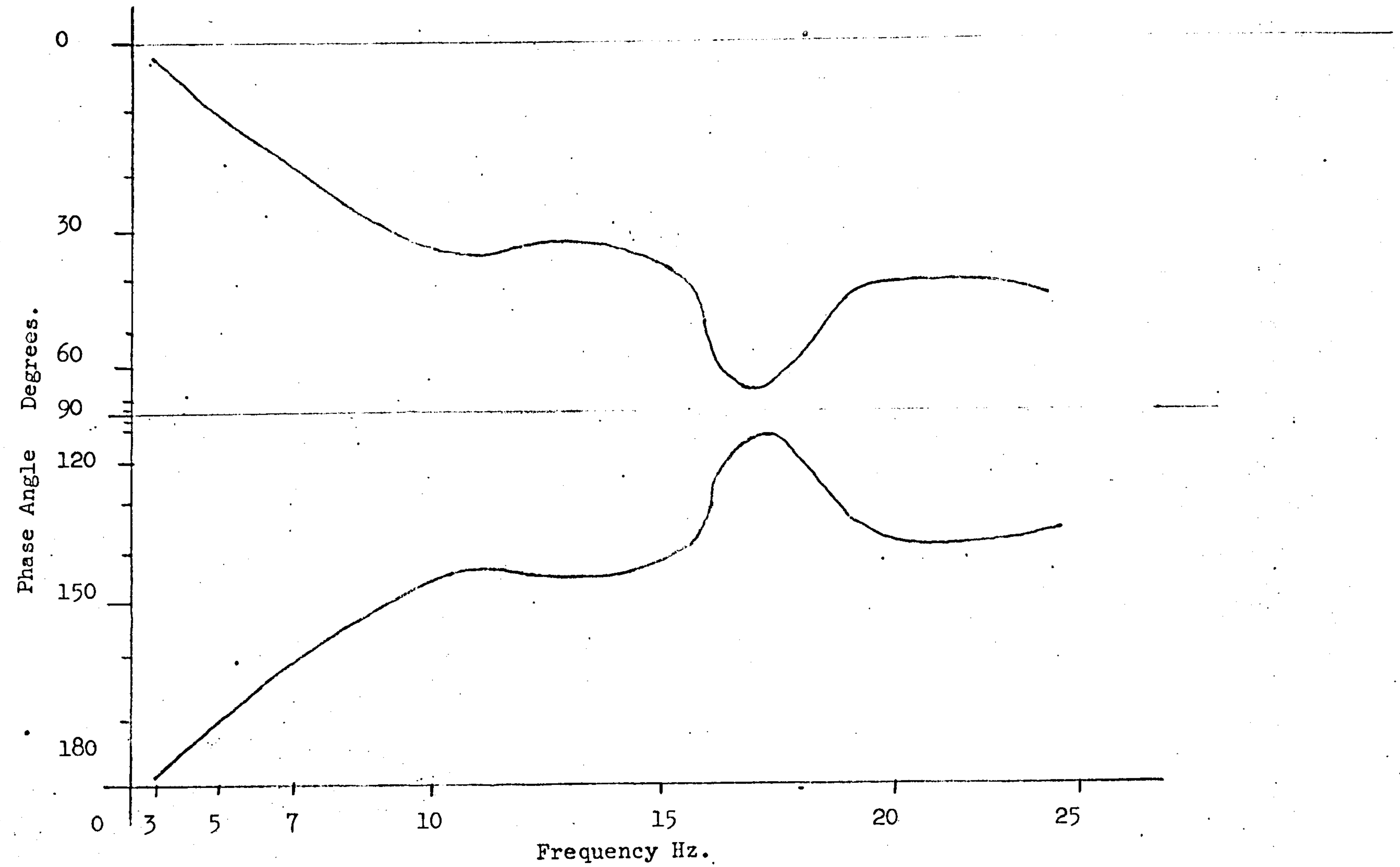


Figure No. 73

Experimental Acceleration Level compared to ISO proposed F.D.P. Limits.

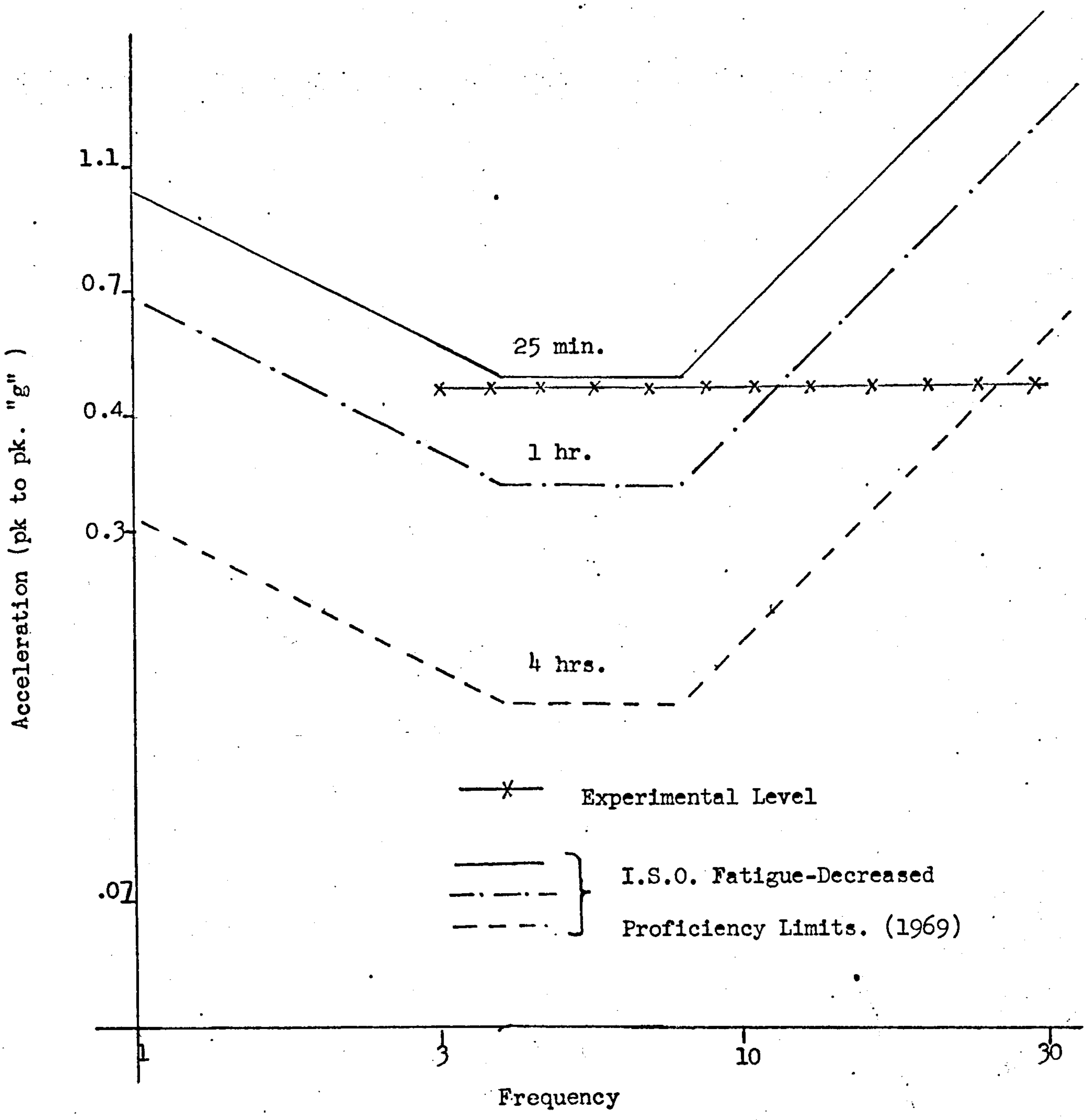
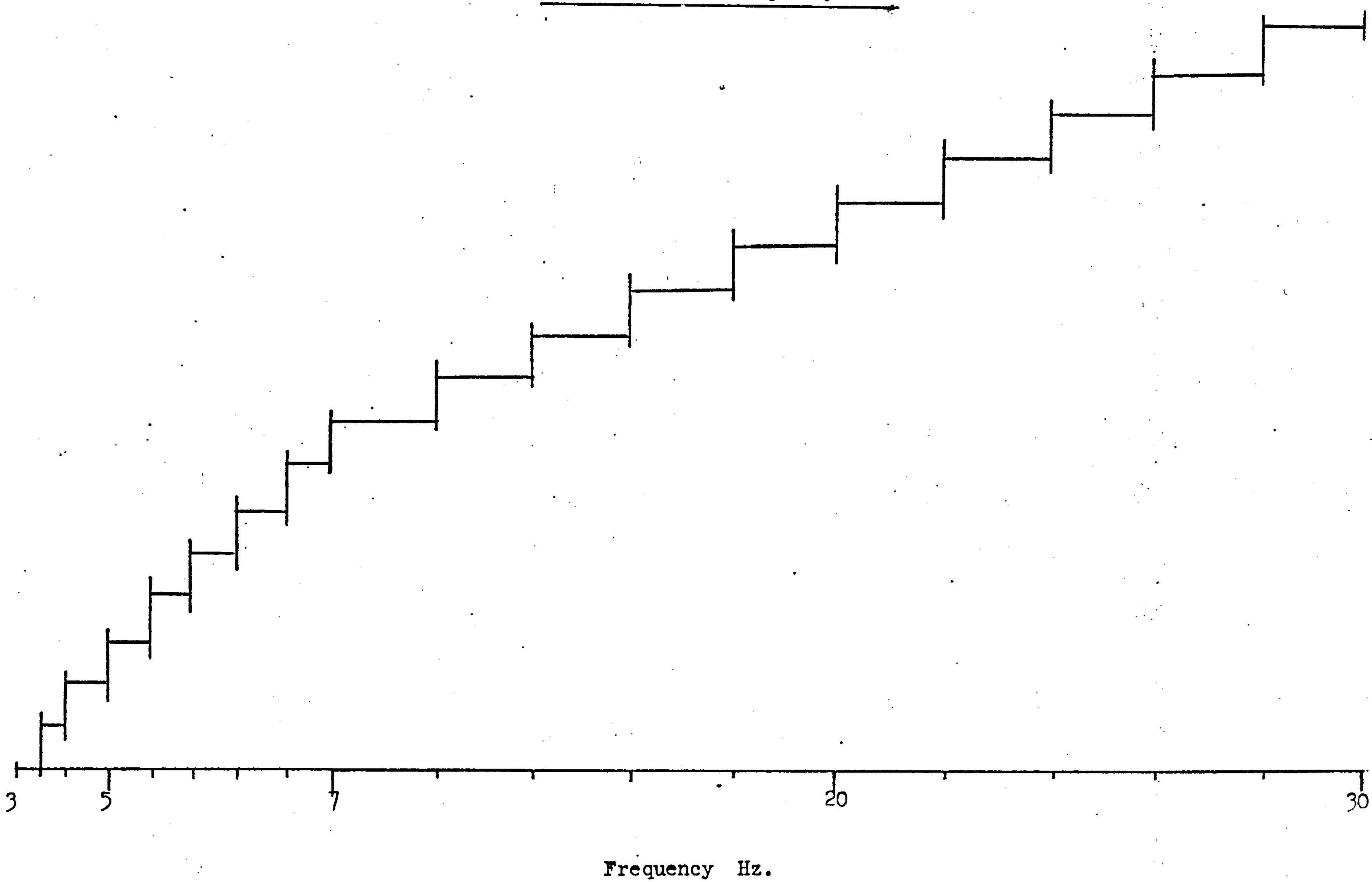


Figure No 78

Figure No. 79

Calibration of frequency axis



1st - Calibration of Modulus of Impedance Monitor

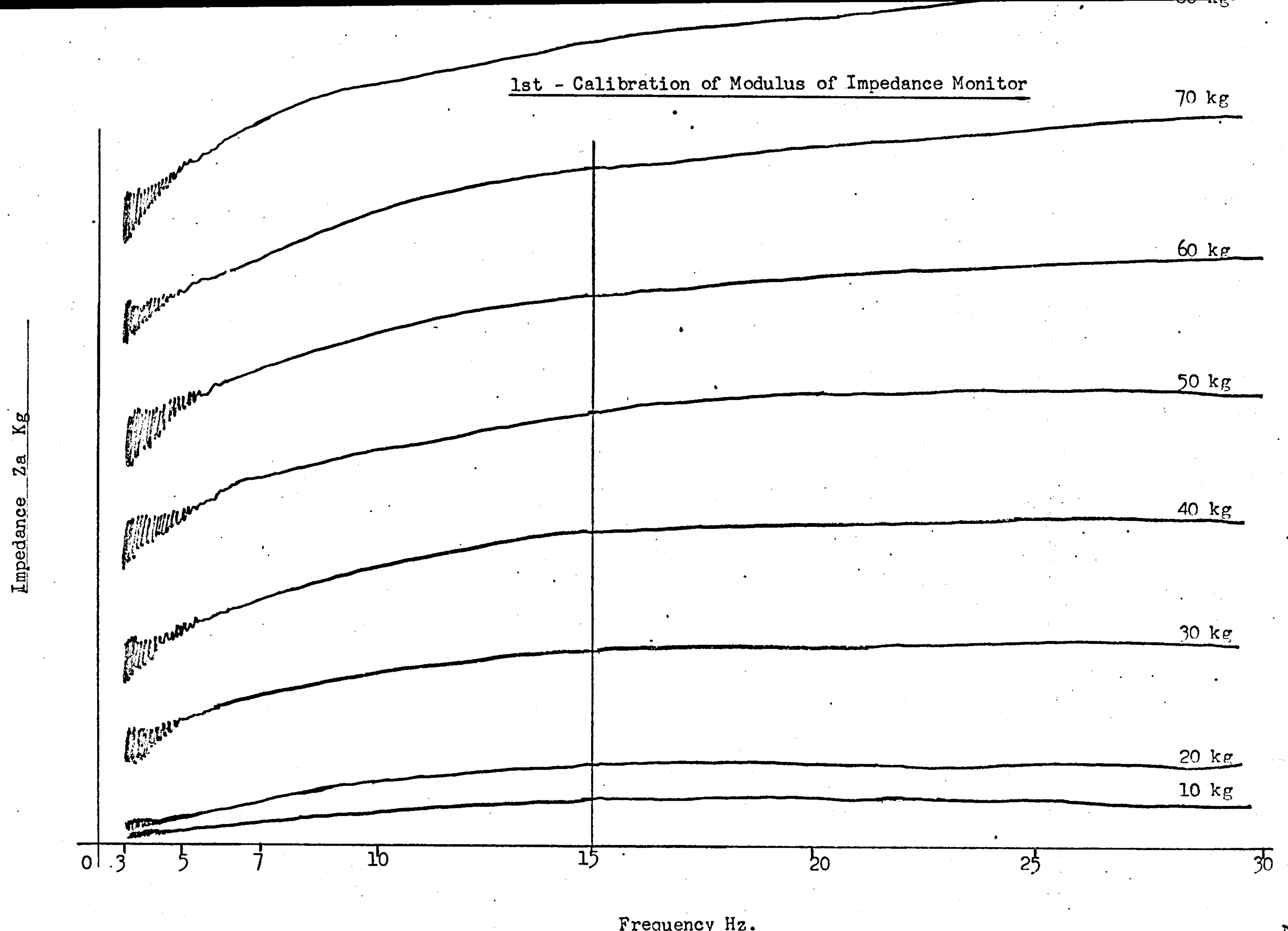


Figure No. 80

2nd - Calibration of Modulus of Impedance Monitor

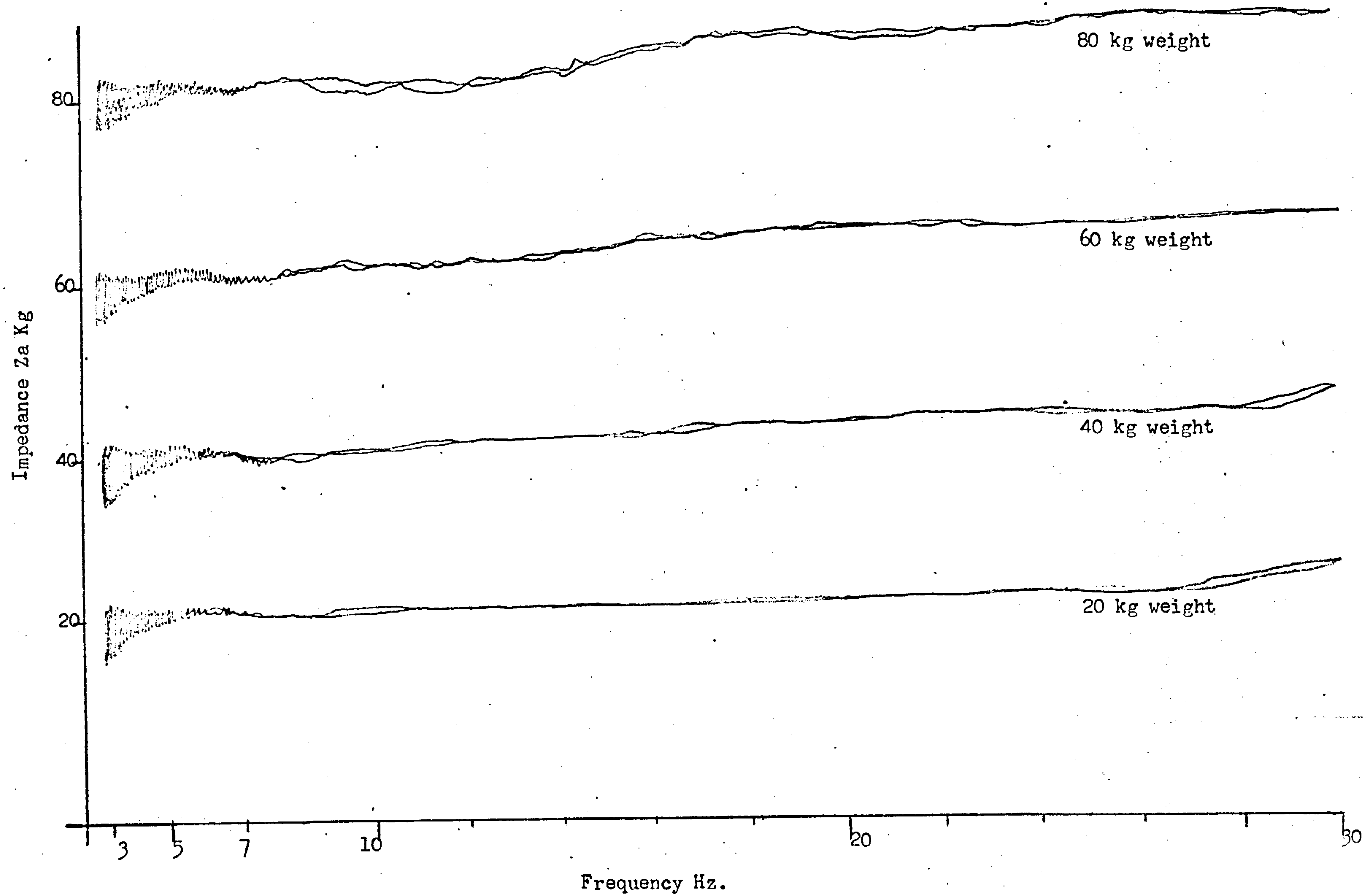


Figure No. 81

Calibration of Phase Angle Monitor

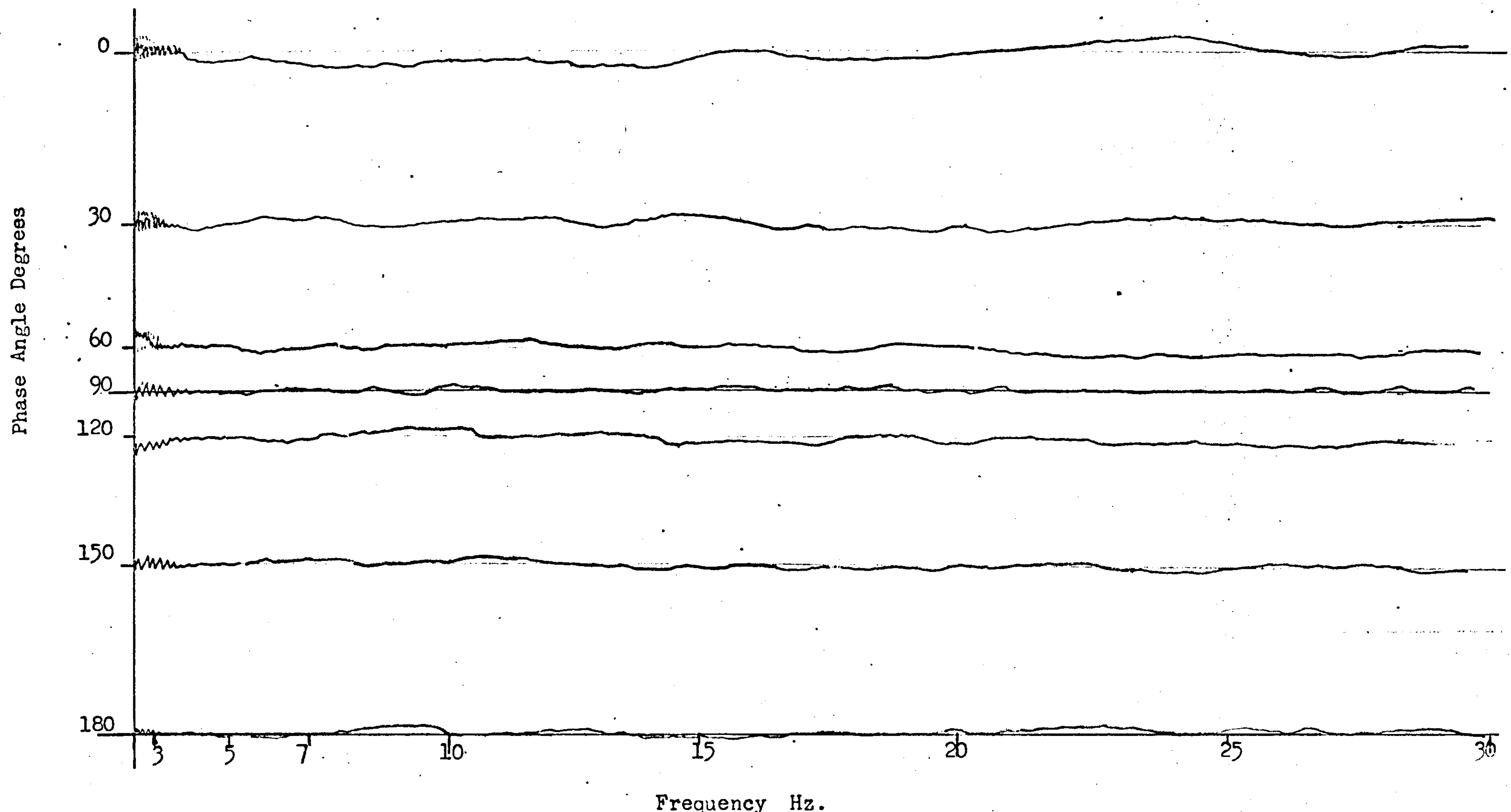


Figure No. 82

Note on Figures No. 83 to 160

Figures No. 83 to No. 160 are the plots actually obtained from the x-y plotter during the experimental programme. The modulus of impedance values given on the impedance axis are however only correct at 15 Hz and not over the entire frequency range due to the non-linearity on the response of the monitoring system. On the phase angle plots the values given on the phase angle axis are correct for the entire frequency range of 3 - 30 Hz.

MODULUS OF IMPEDANCE RESULTS FOR

FEMALE SUBJECTS

SITTING ERECT POSTURE

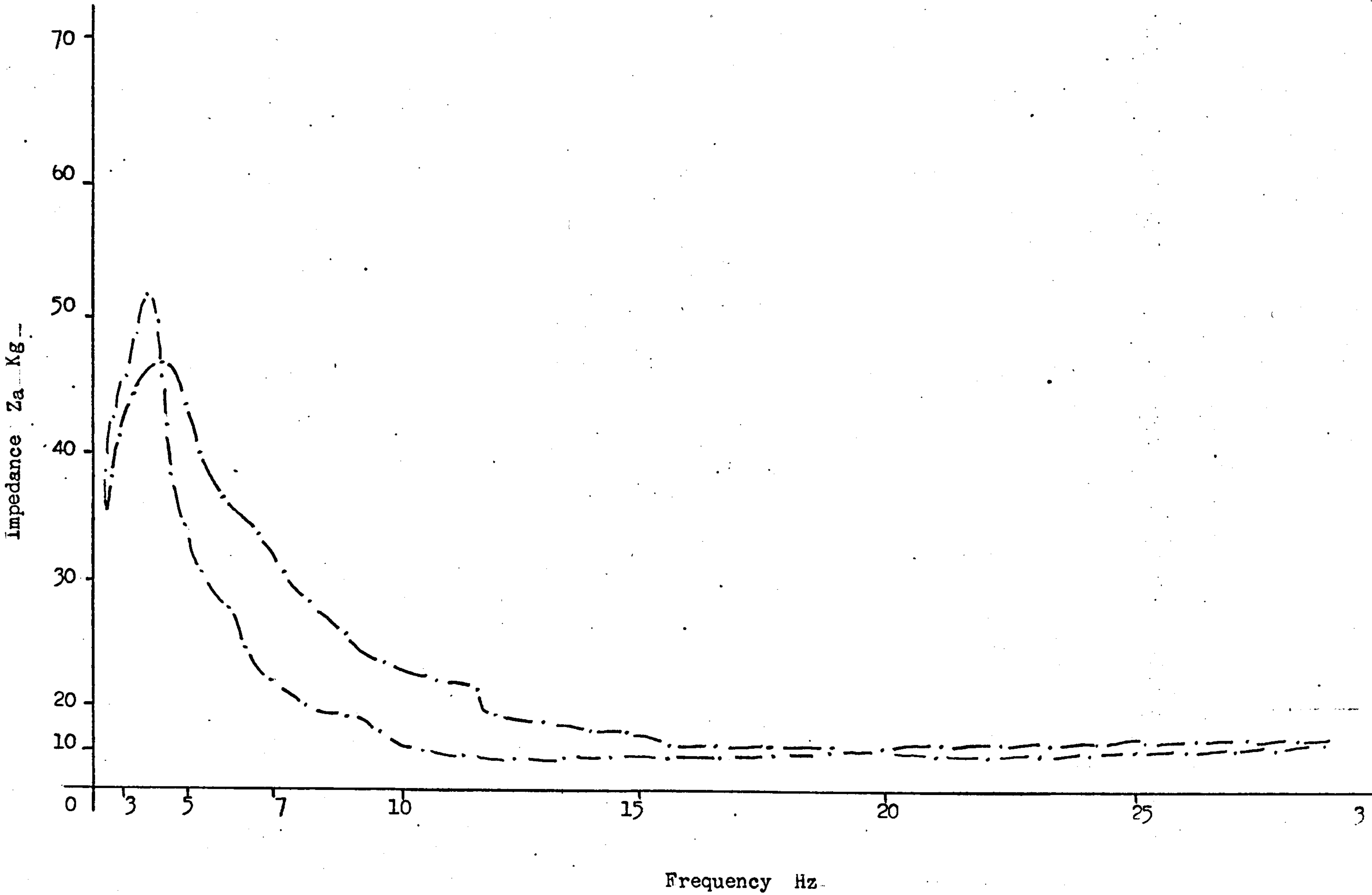
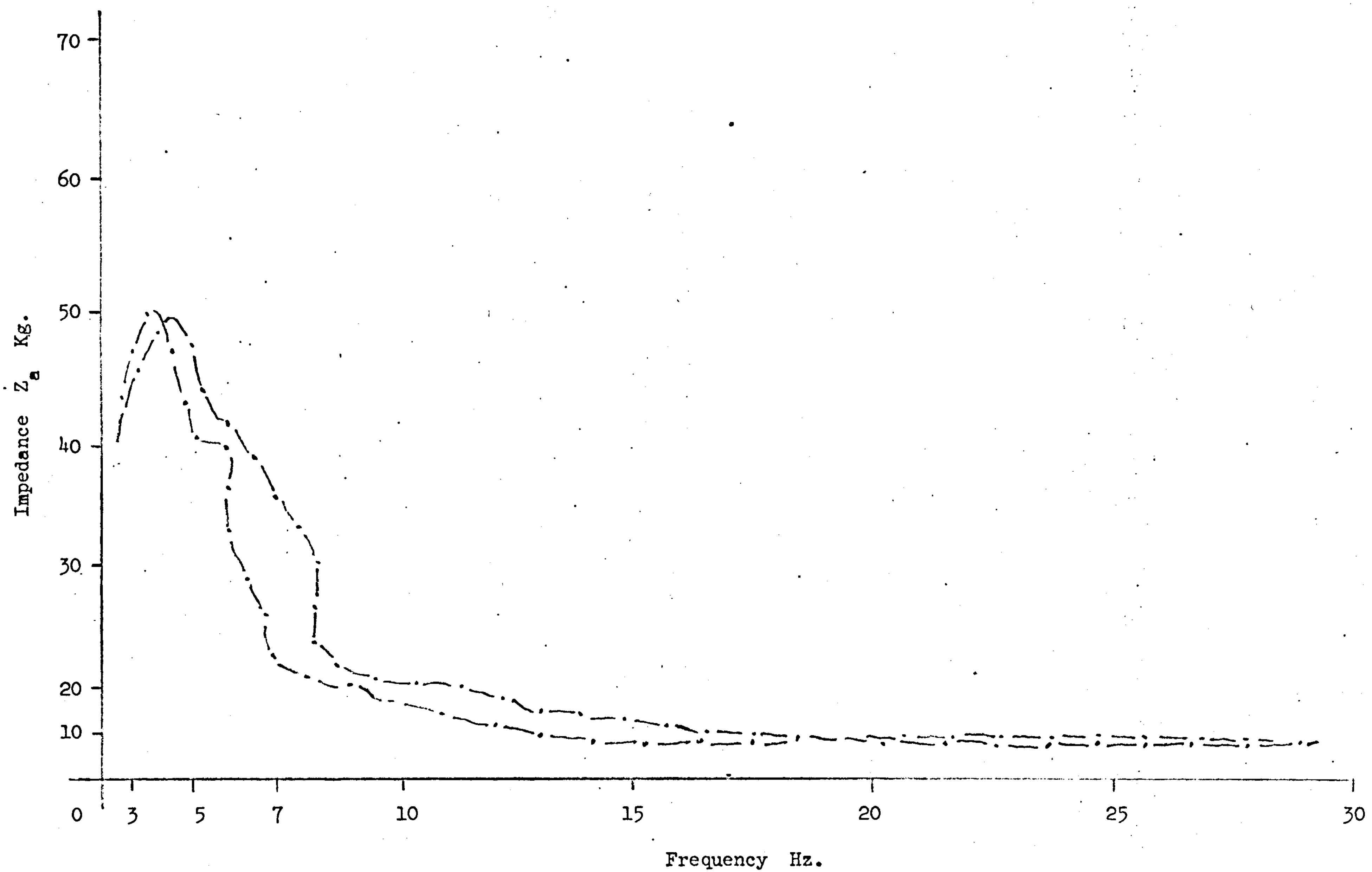


Figure No.83 F1 - E

Figure No. 4 F2 - E



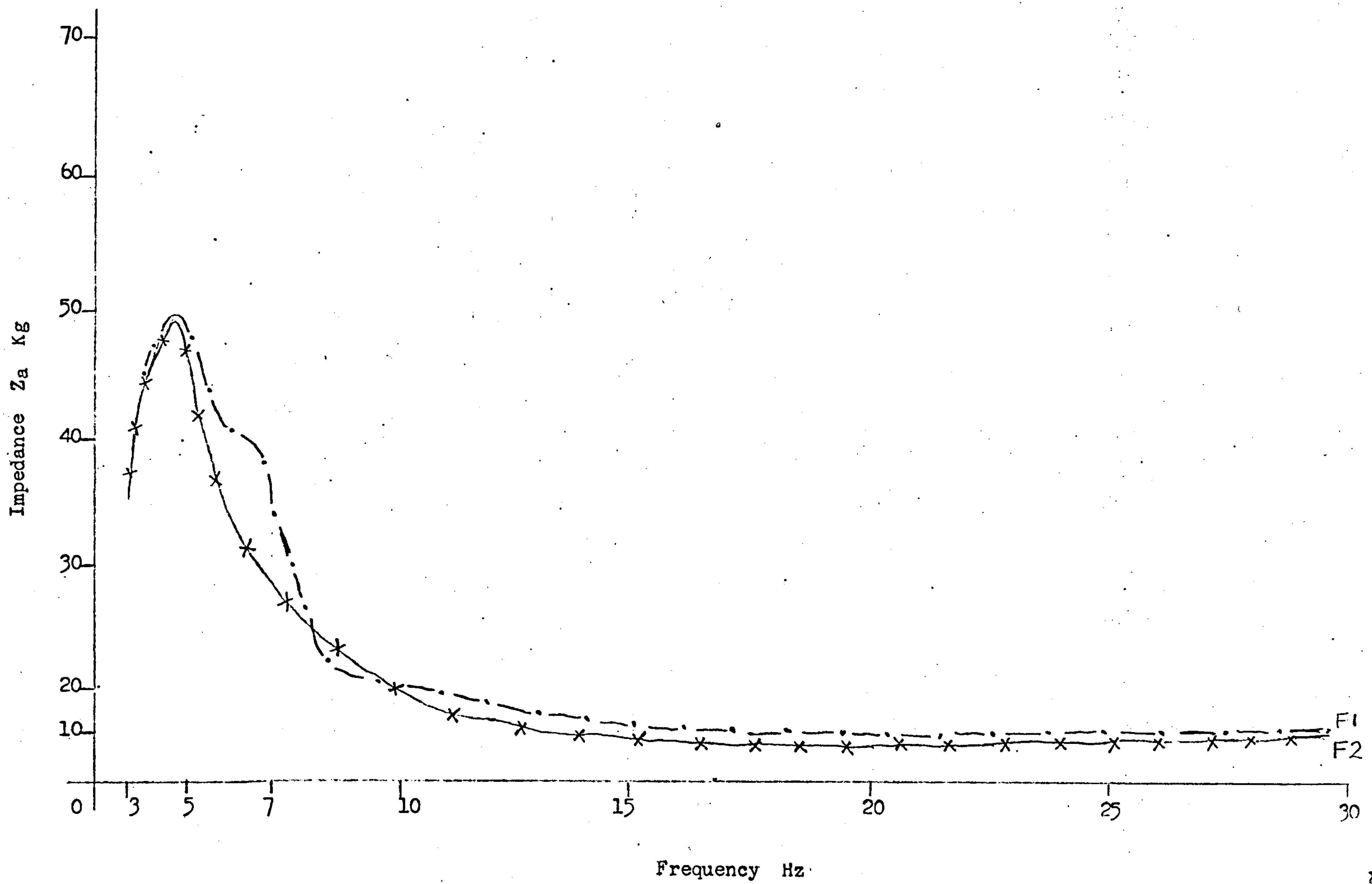


Figure No.85 F1 and 2 - E.

PHASE ANGLE RESULTS FOR

FEMALE SUBJECTS

SITTING ERECT POSTURE

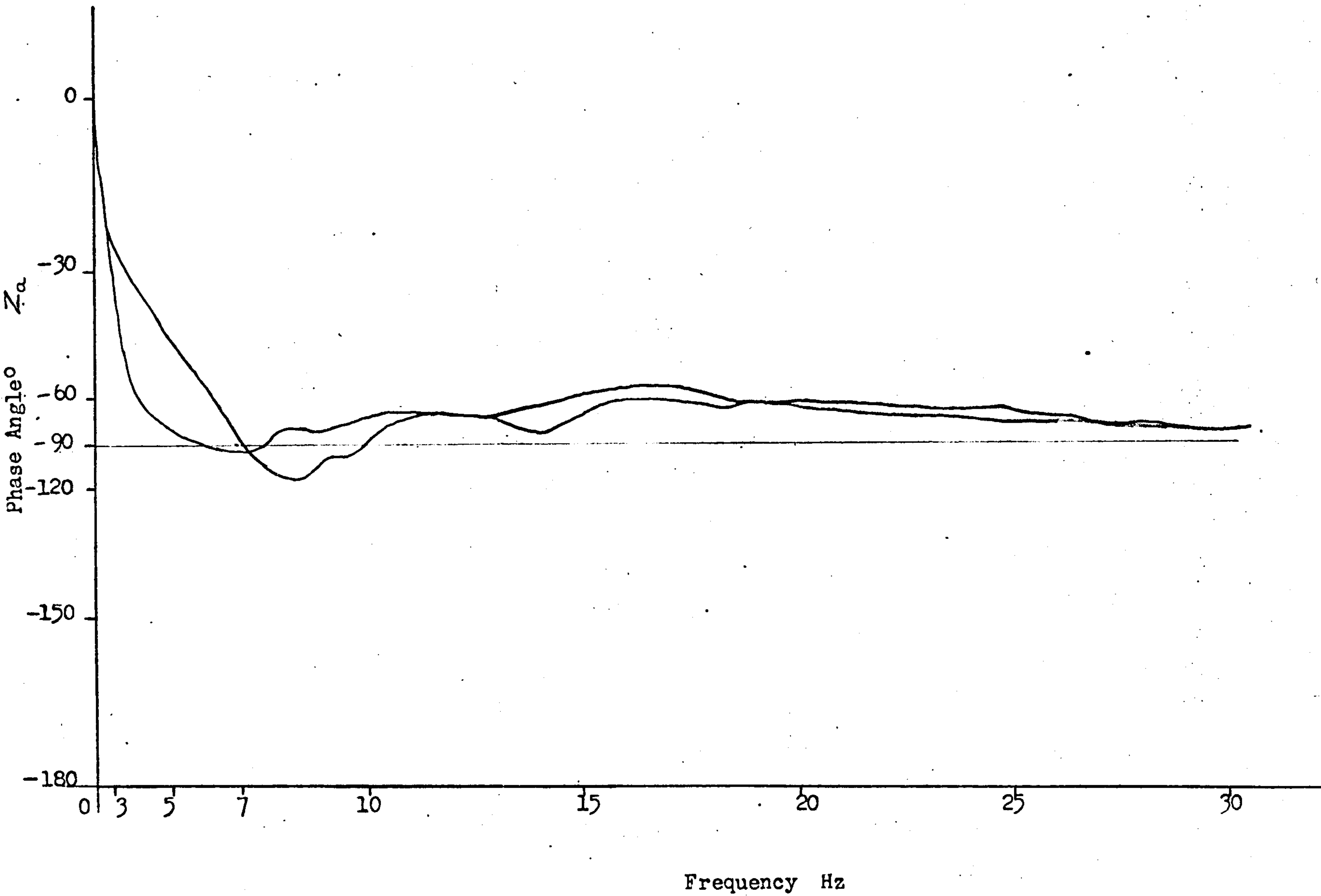


Figure No. 86 F1 - B

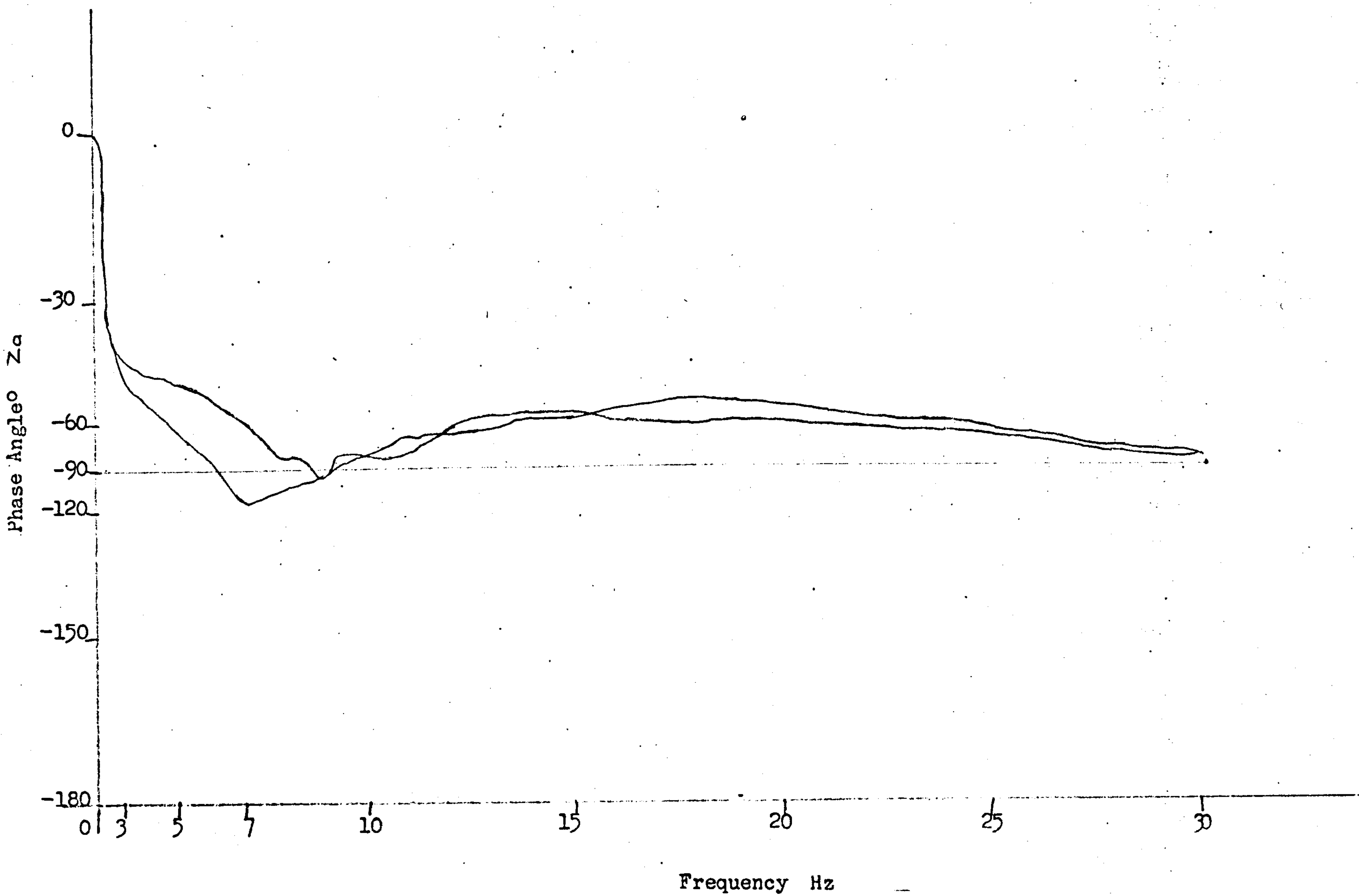


Figure No. 87 F2 - E

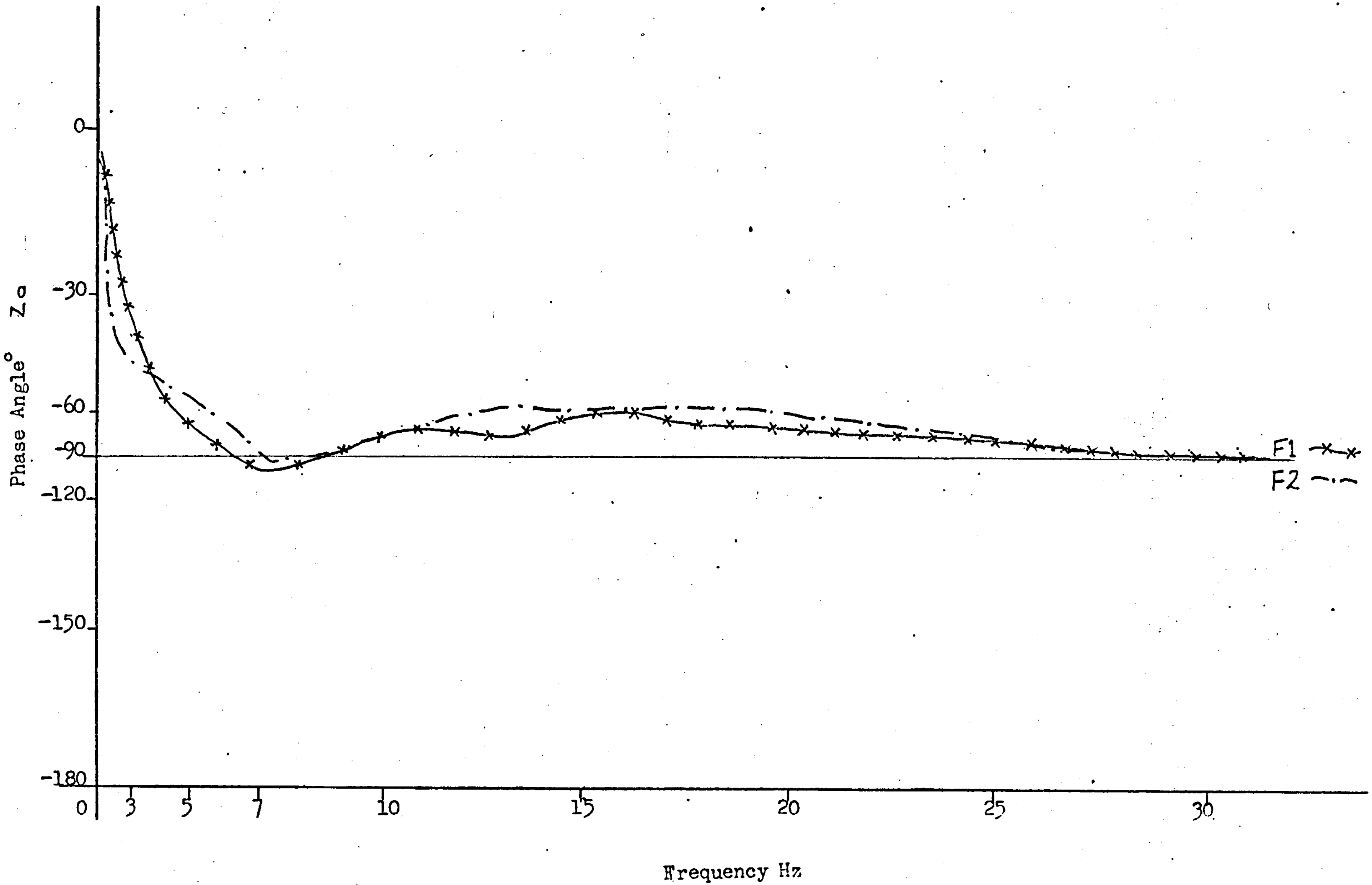


Figure No.88 F1 and 2E

MODULUS OF IMPEDANCE RESULTS FOR

FEMALE SUBJECTS

SITTING RELAXED POSTURE

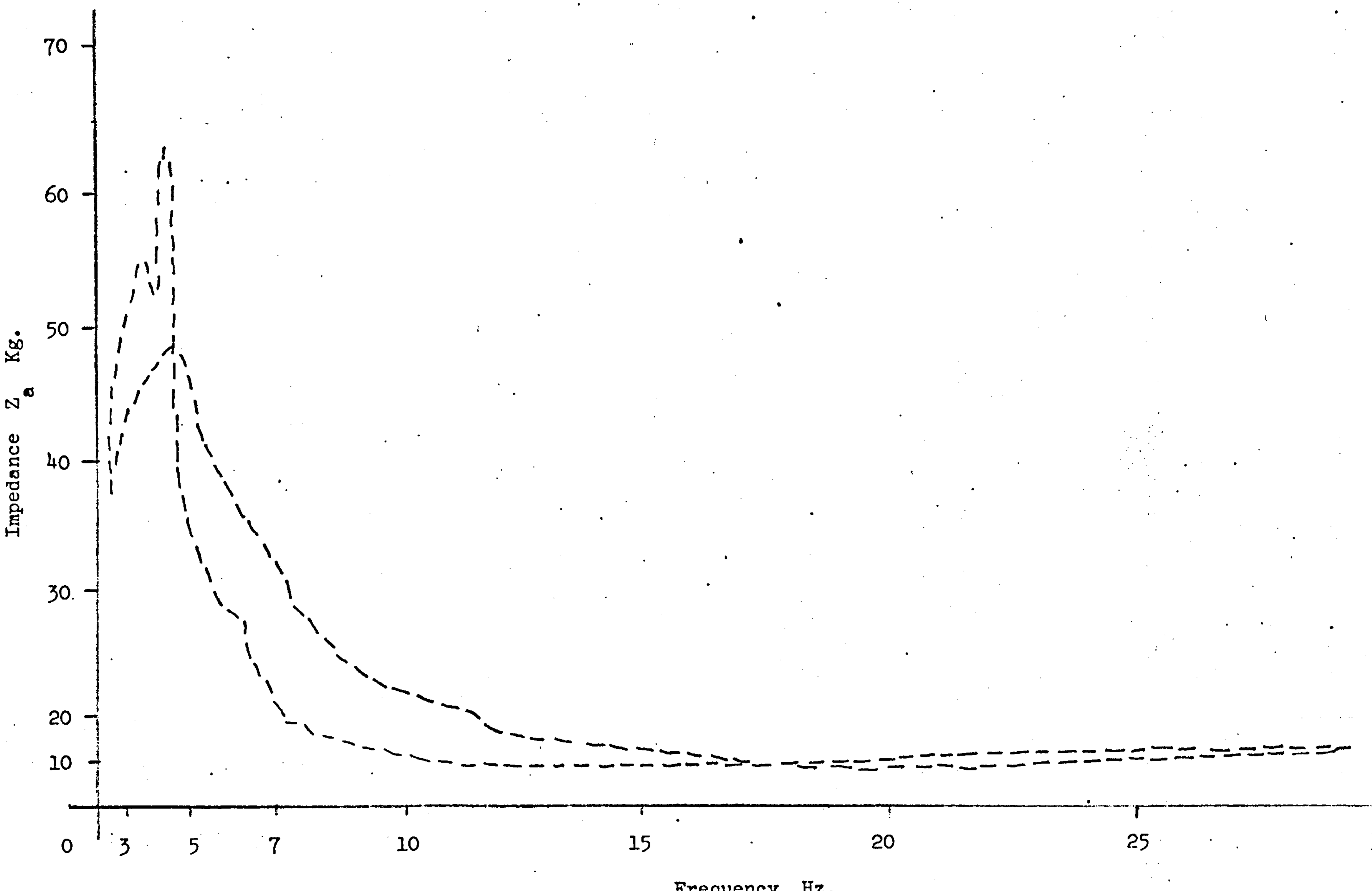


Figure No. 89 Fl - R

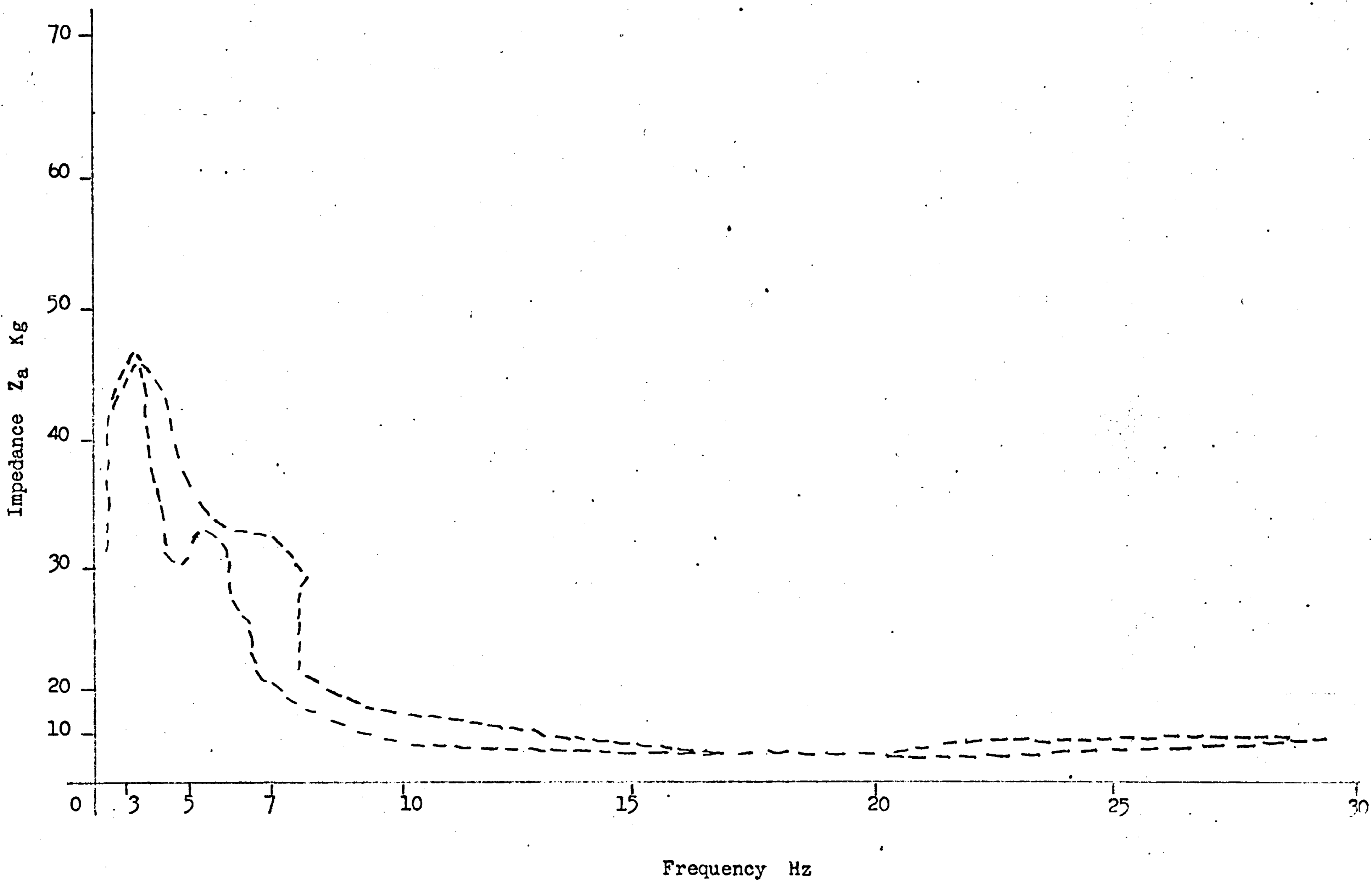


Figure No. 90 F2 - R

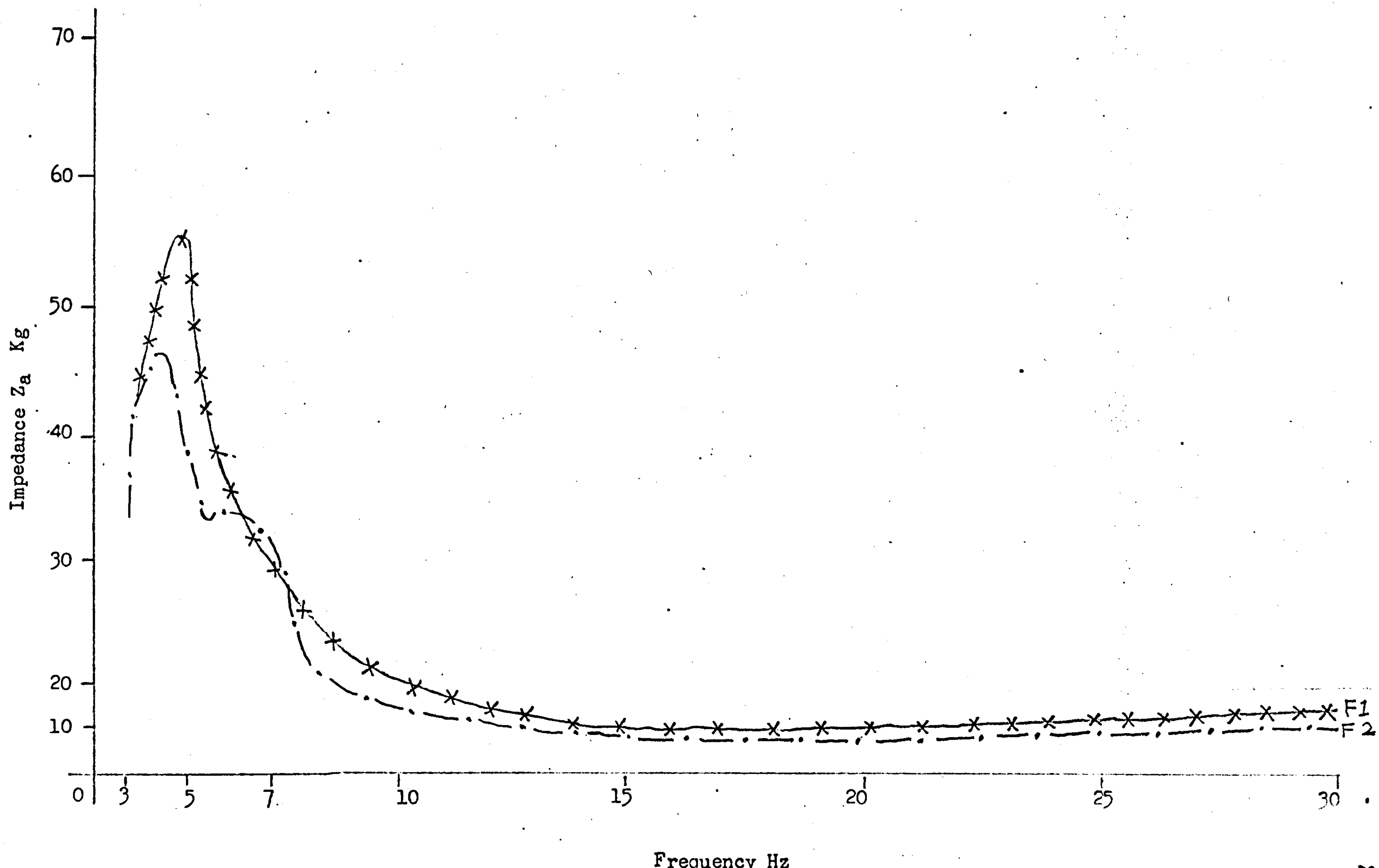


Figure No 91 F1 and 2 - R

PHASE ANGLE RESULTS FOR

FEMALE SUBJECTS

SITTING RELAXED POSTURE

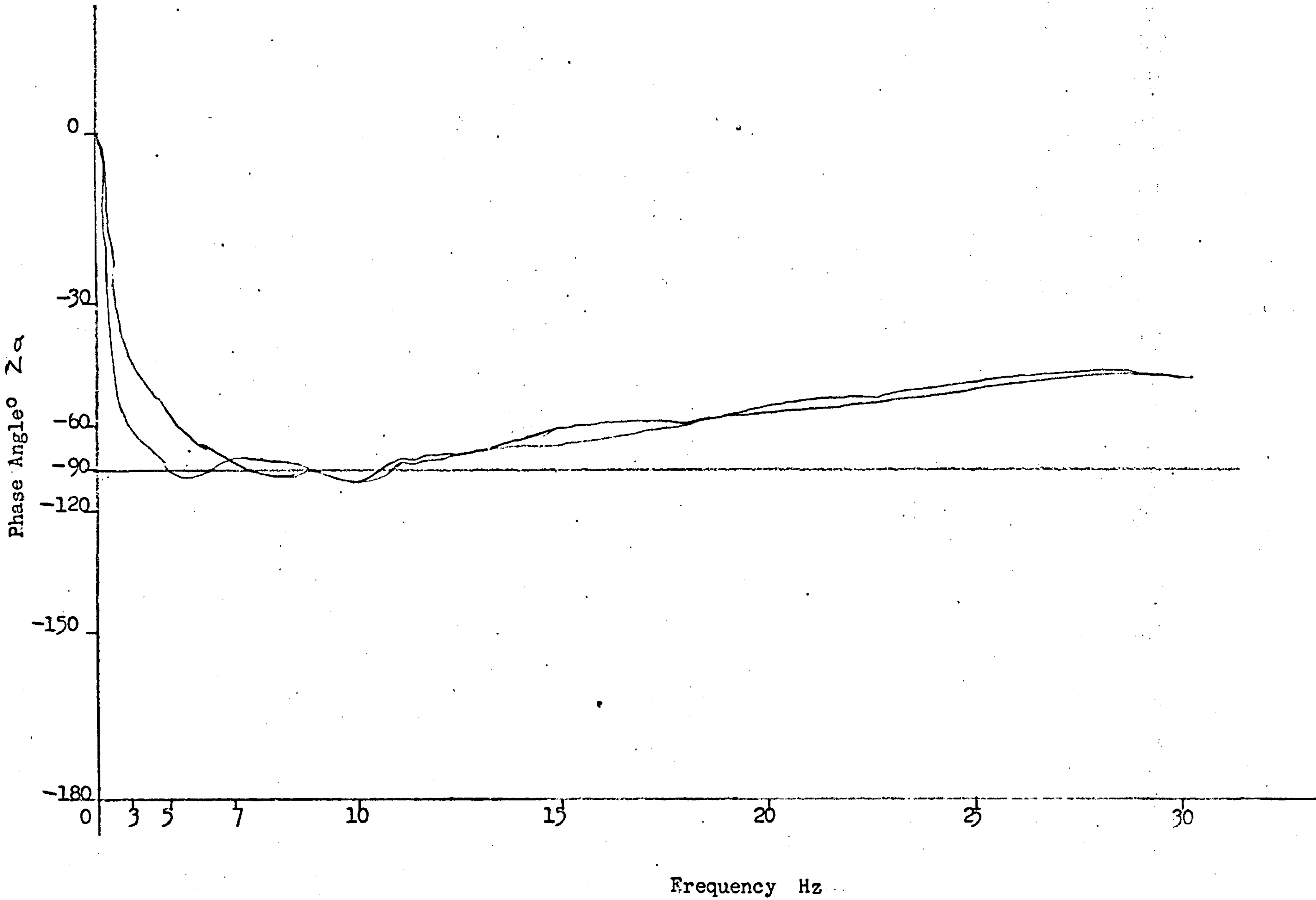


Figure No. 92 F1 - R

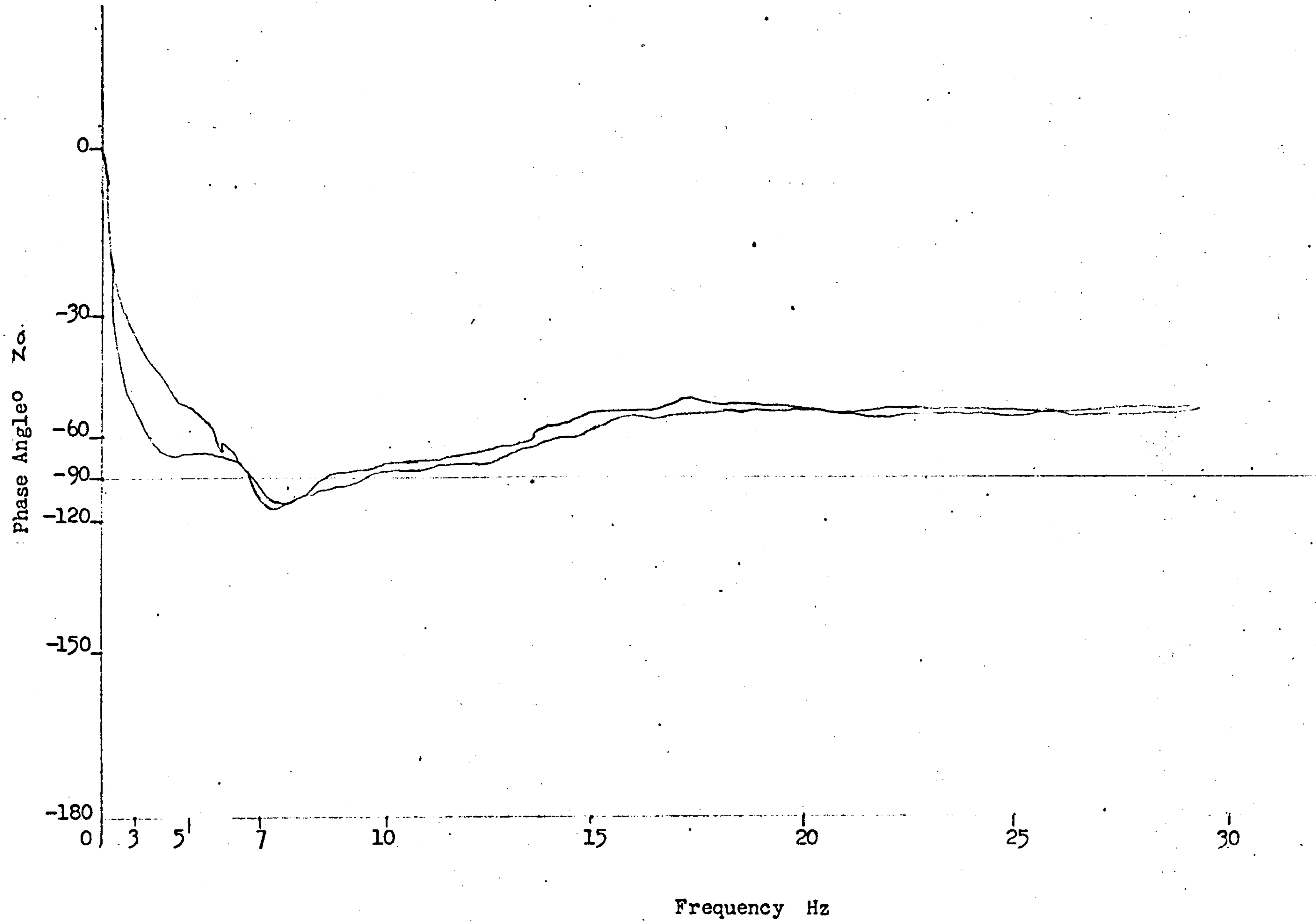


Figure No. 93 F2 - R

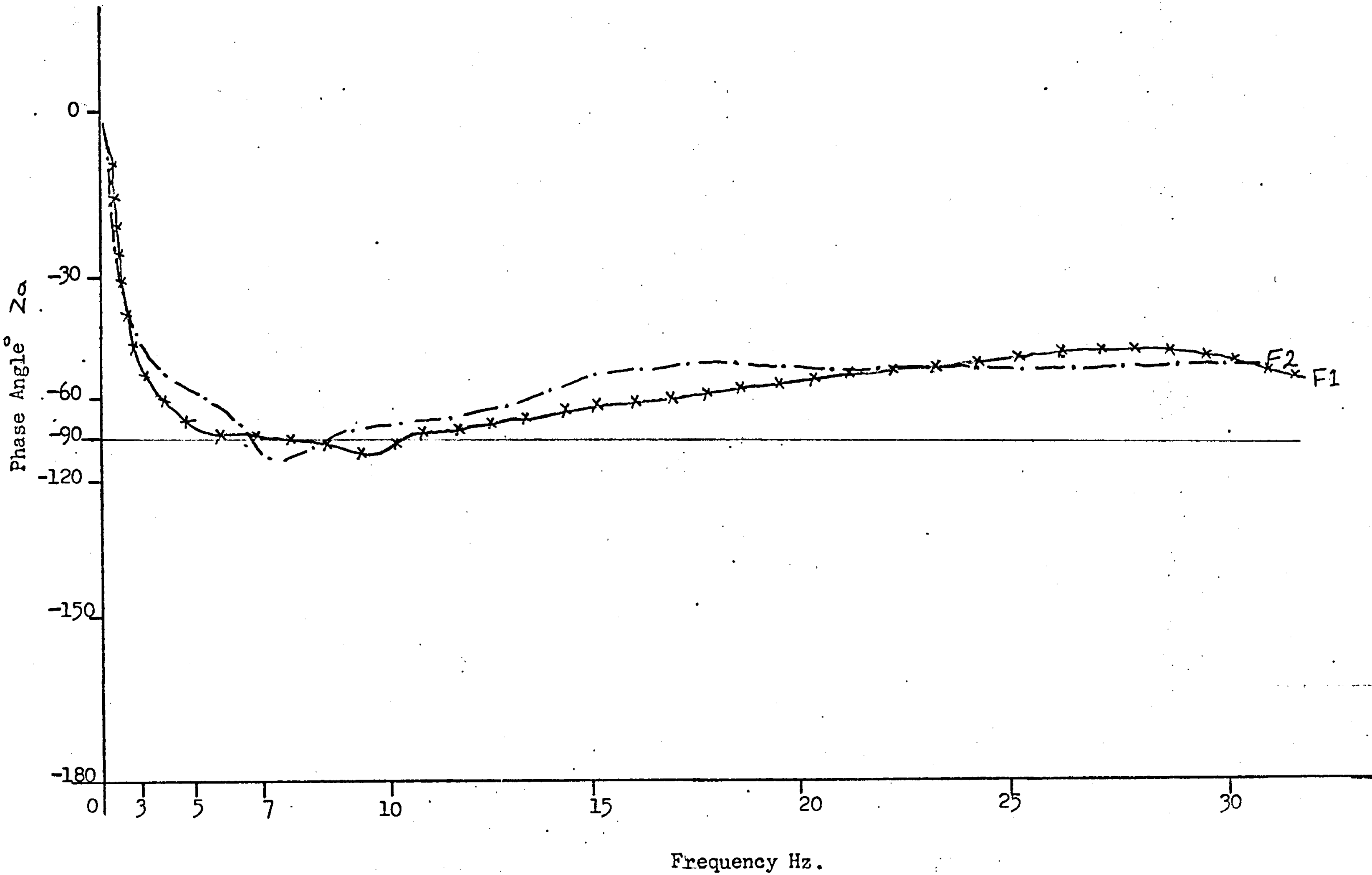


Figure No. 94 F1 and F2

MODULUS OF IMPEDANCE RESULTS FOR

MALE SUBJECTS

SITTING ERECT POSTURE

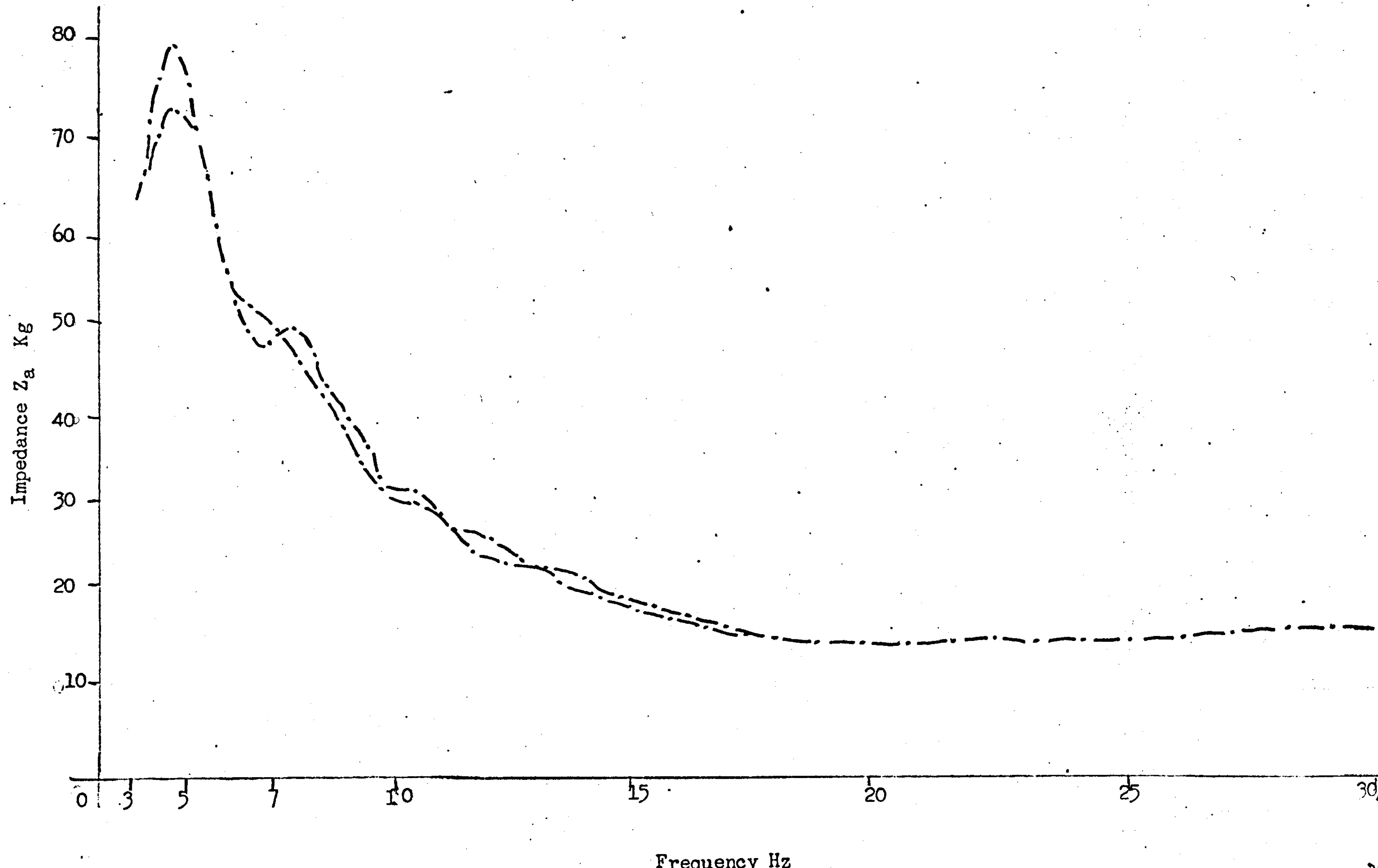


Figure No. 95 M1 - E.

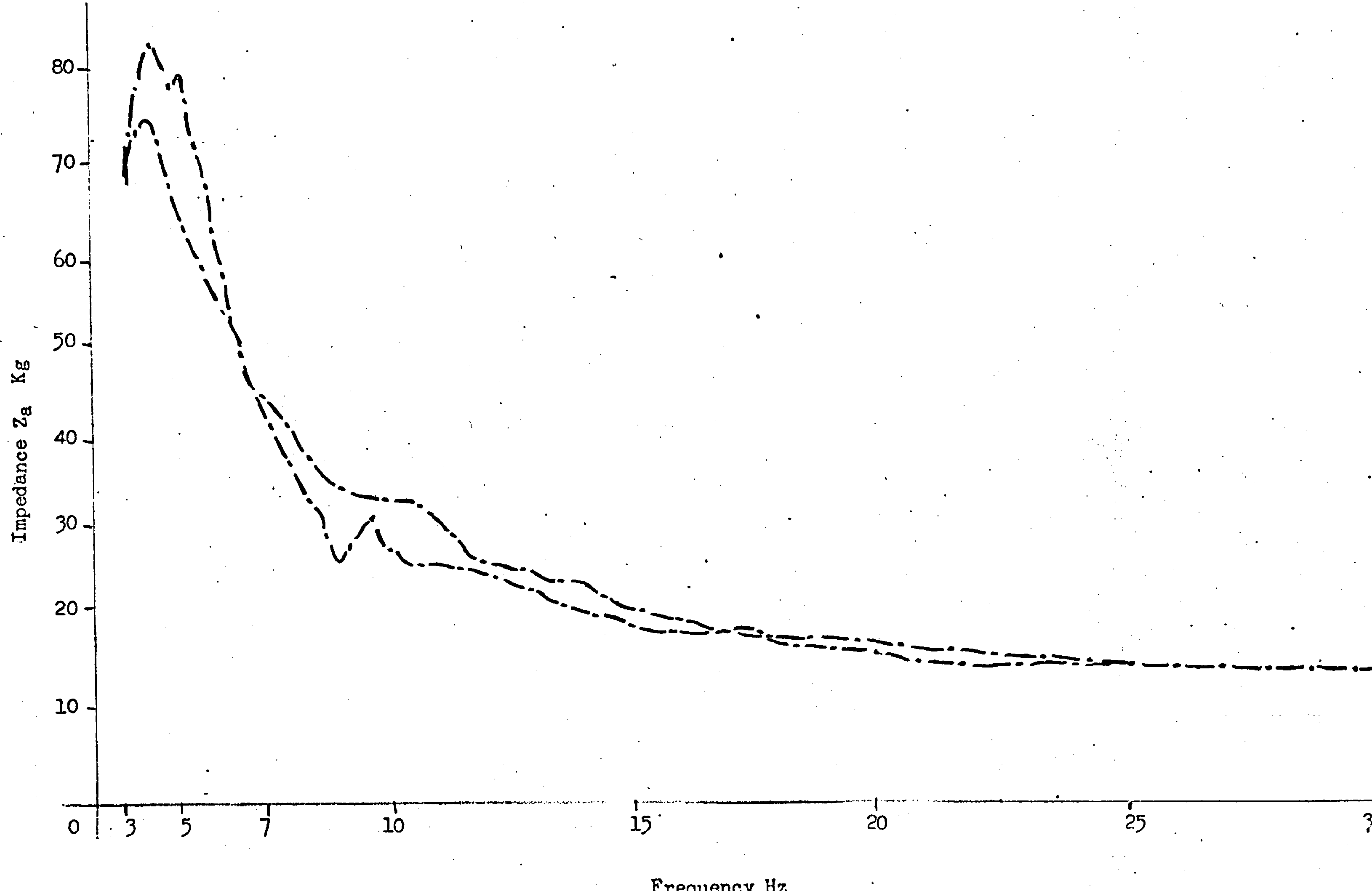
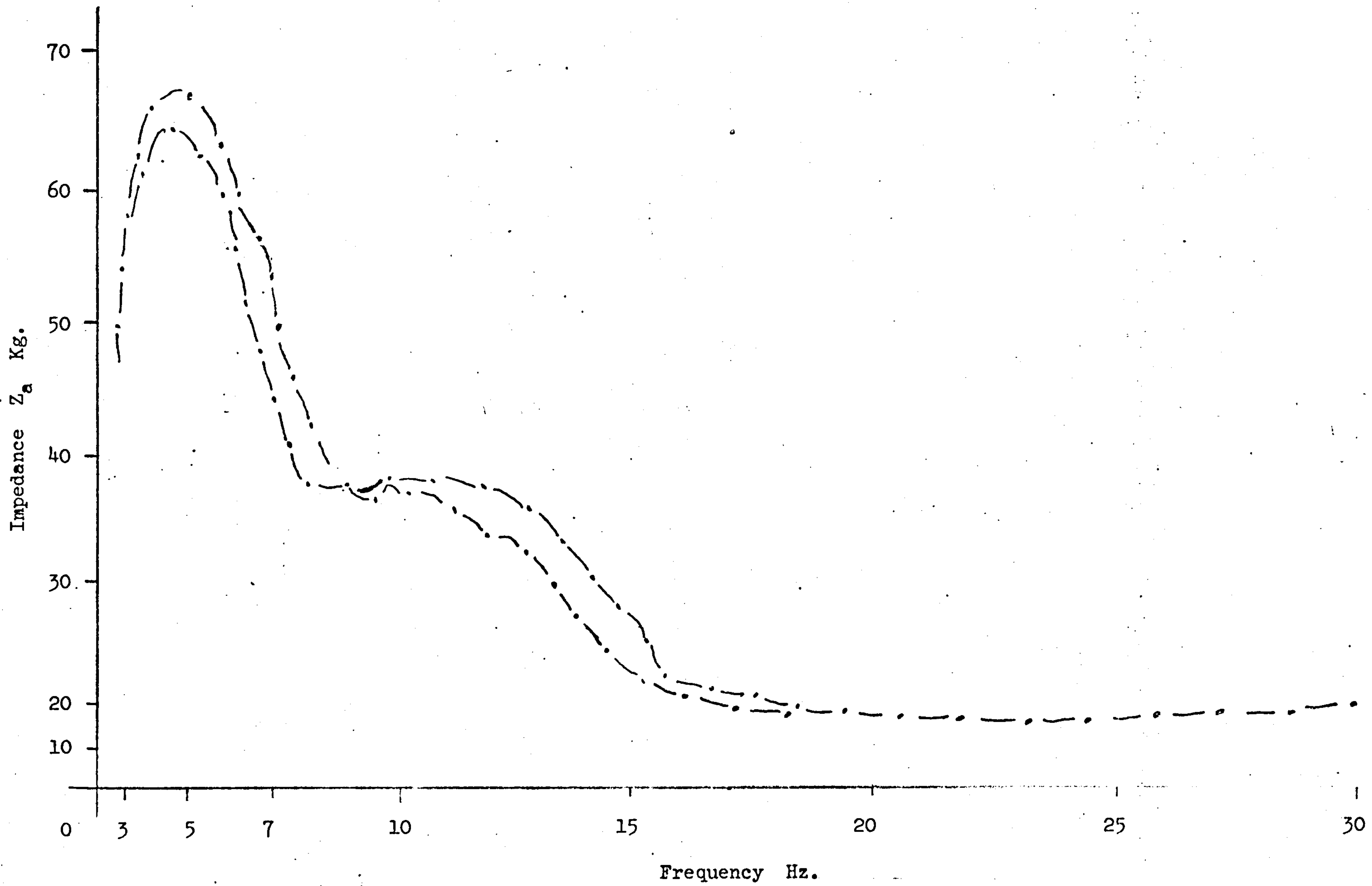


Figure No. 96 M2 - E.

Figure No. 97 M3 - E



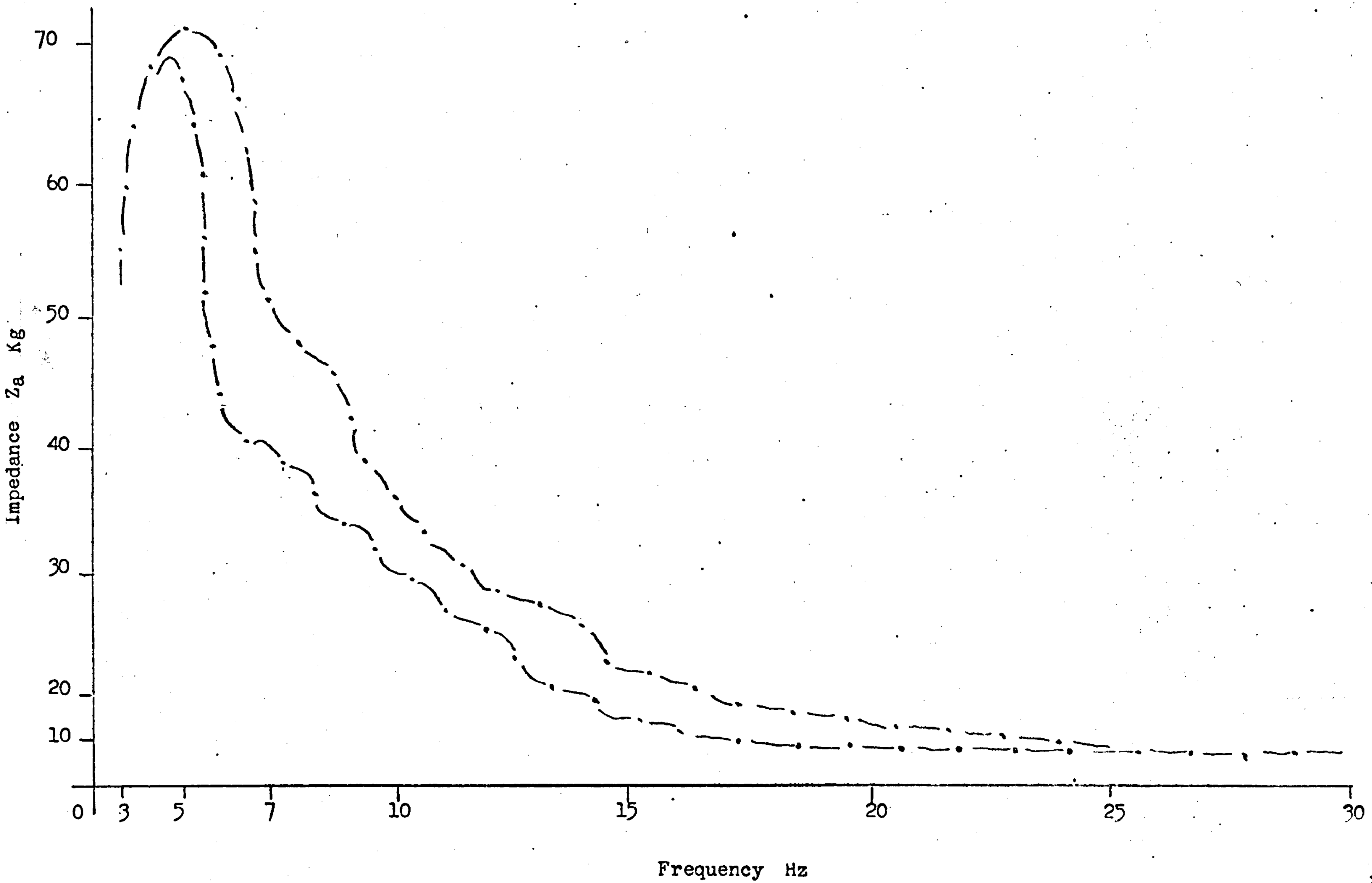


Figure No. 98 M4 - E

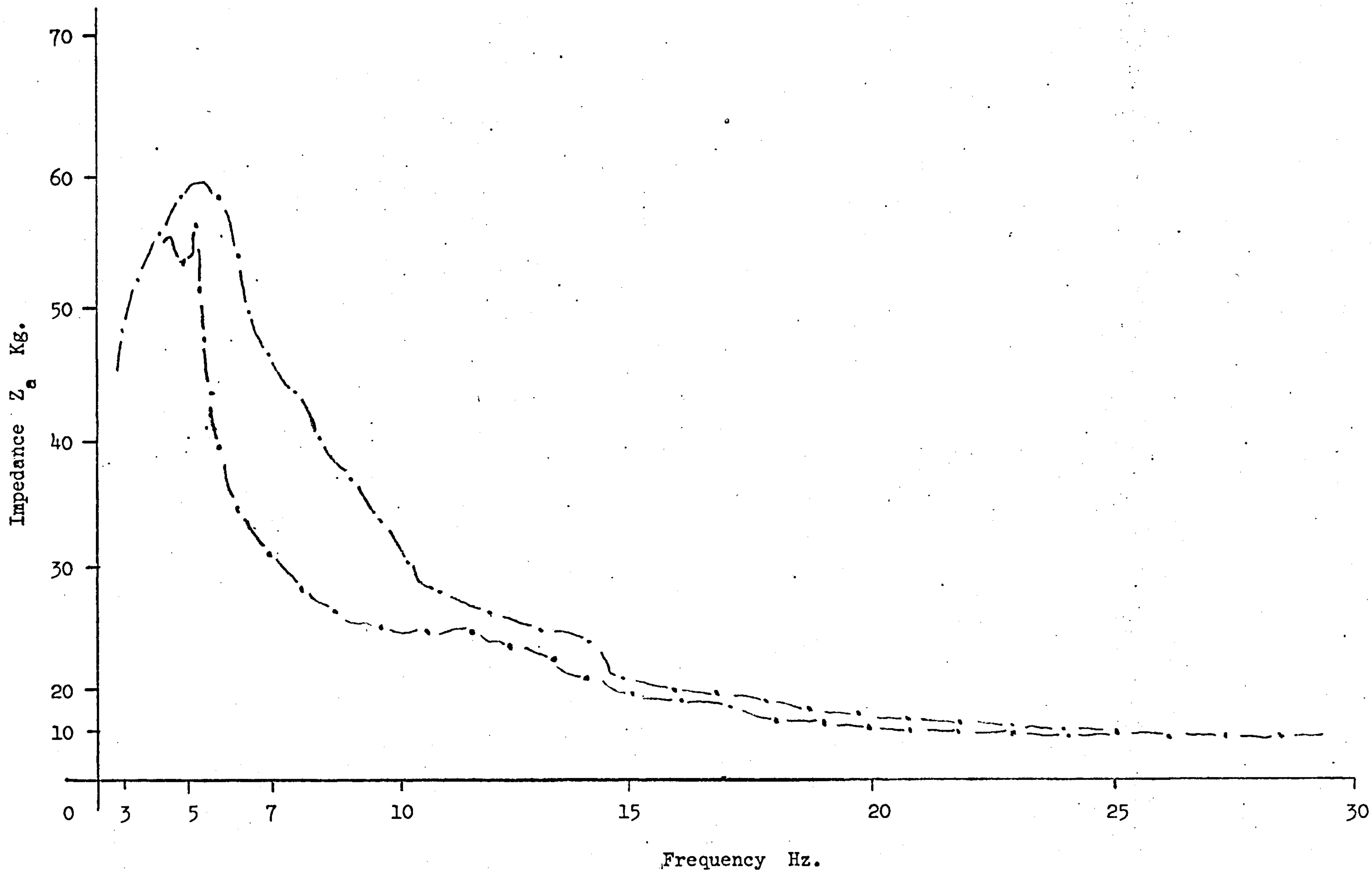


Figure No. 99 M5 - E

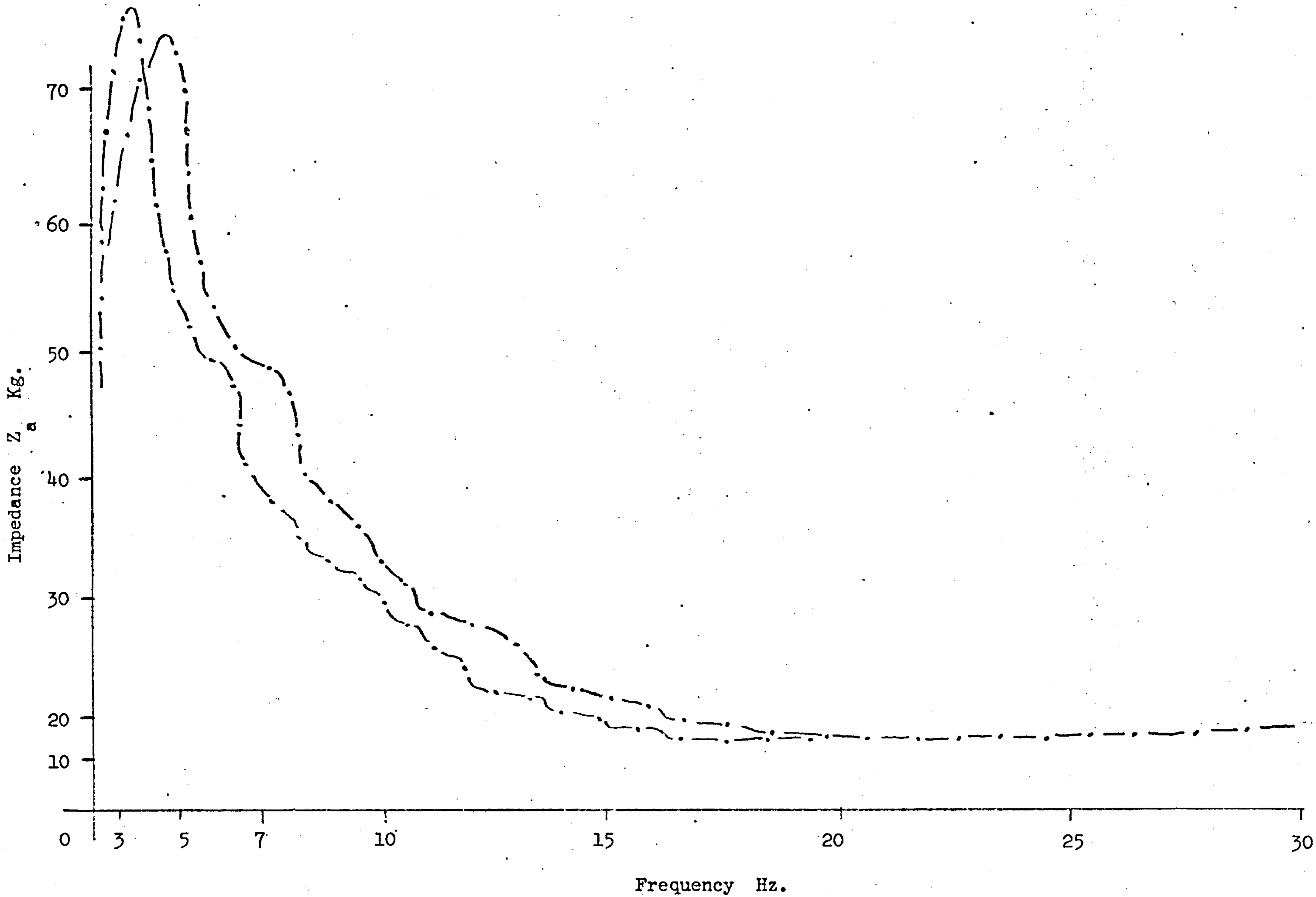


Figure No 100 M6 - E

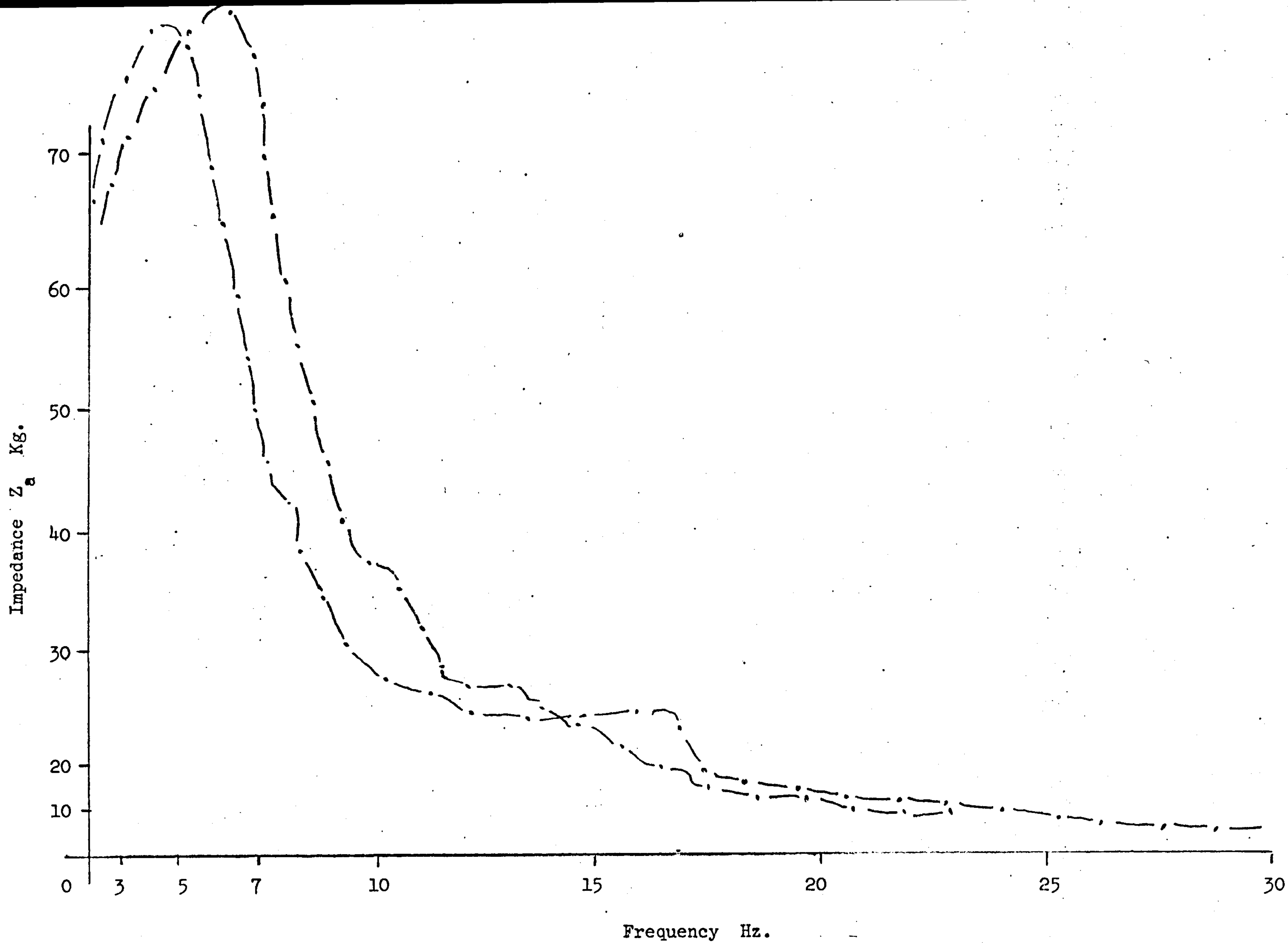


Figure No 101 M7 - E

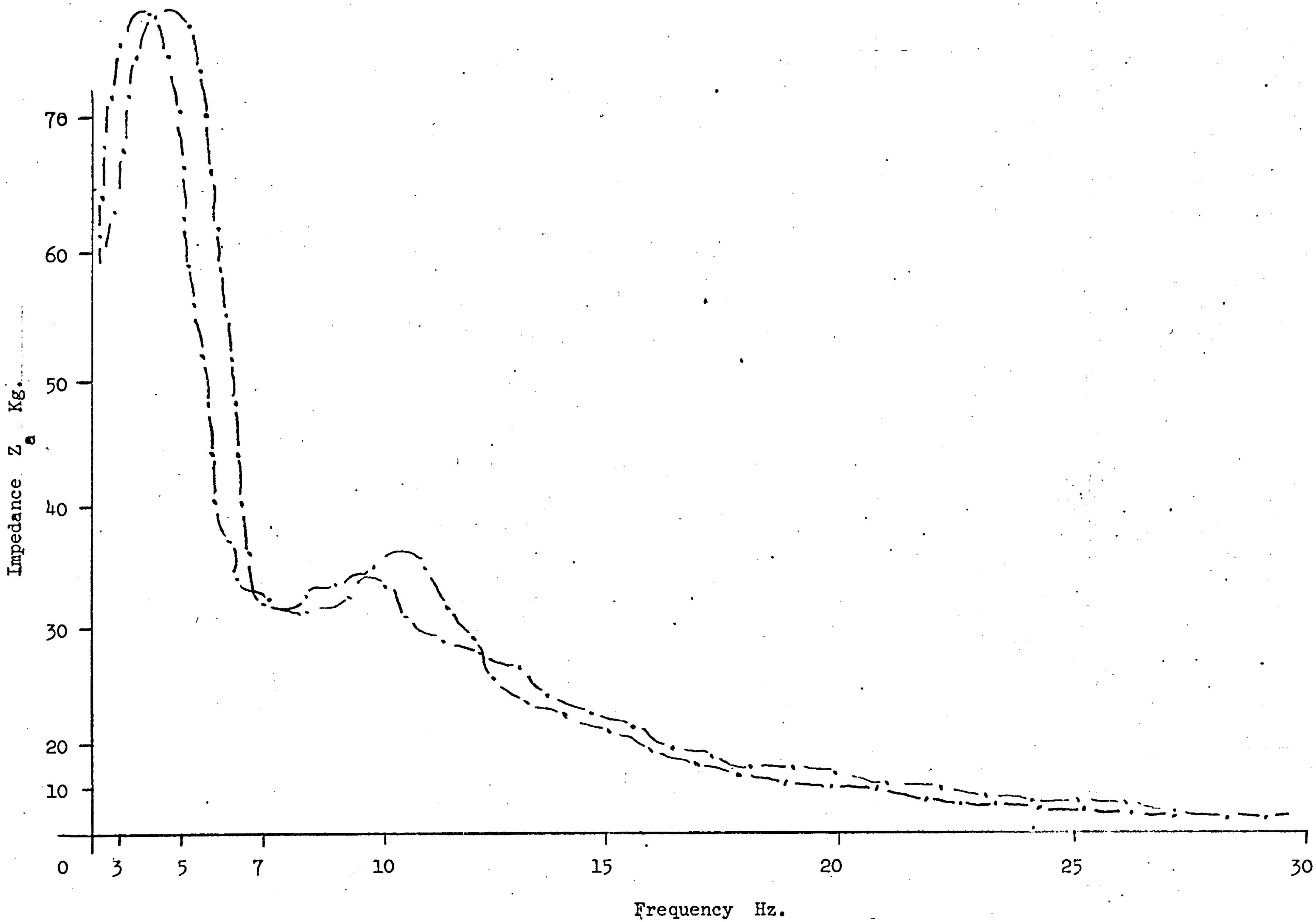


Figure No. 102 M8 - E

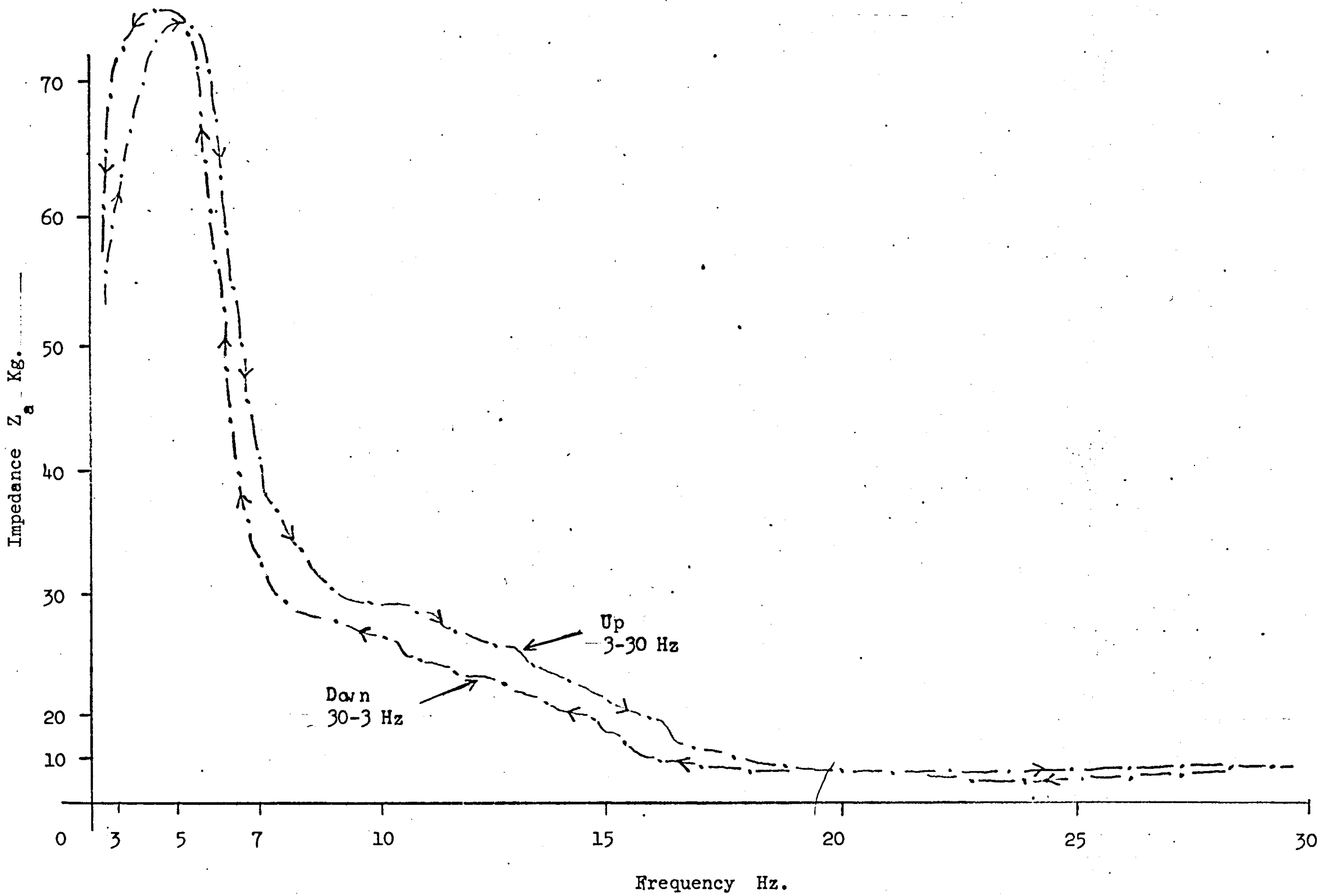
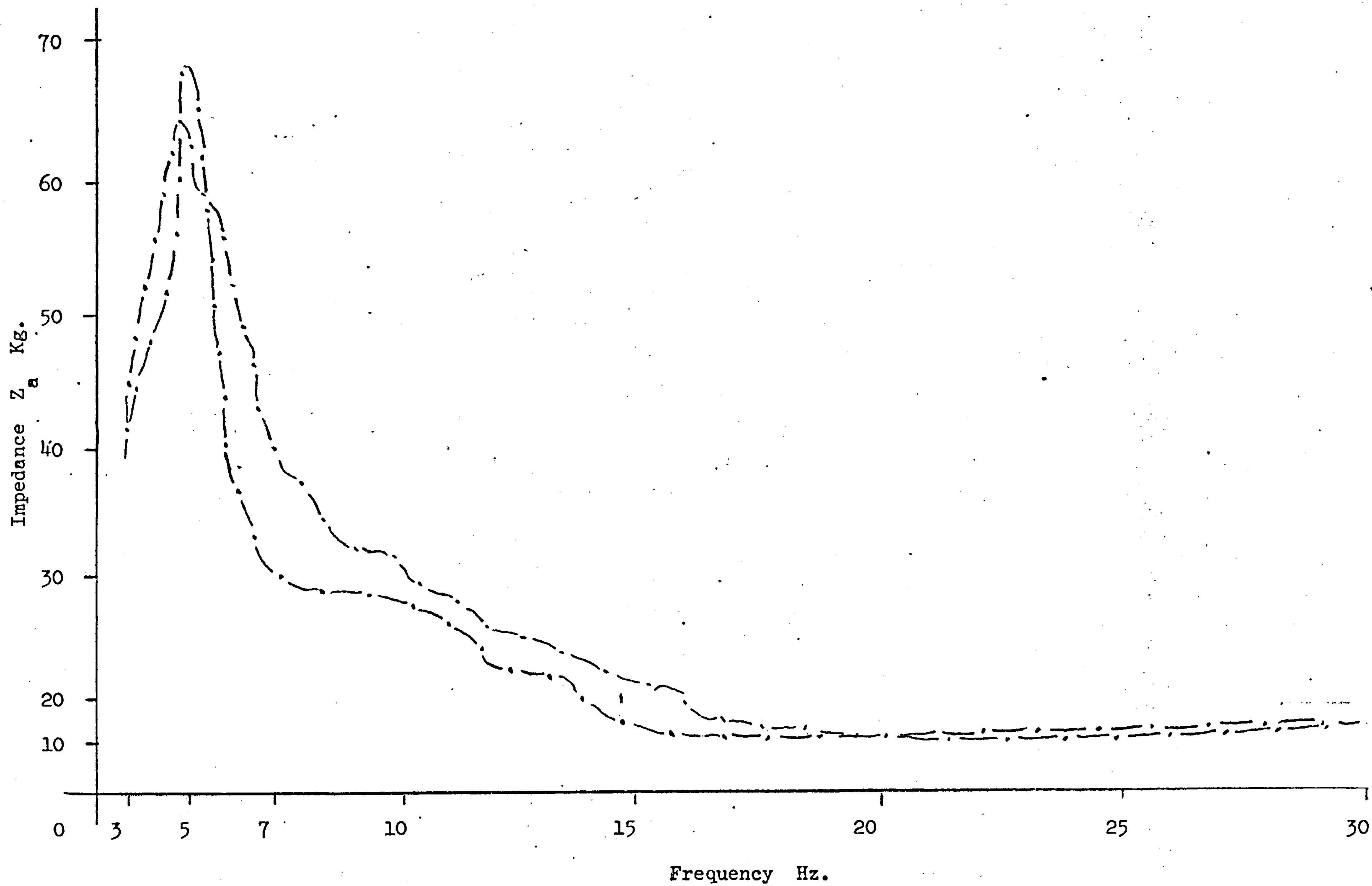


Figure No 103 M9 - E

Figure No. 104M10 - E



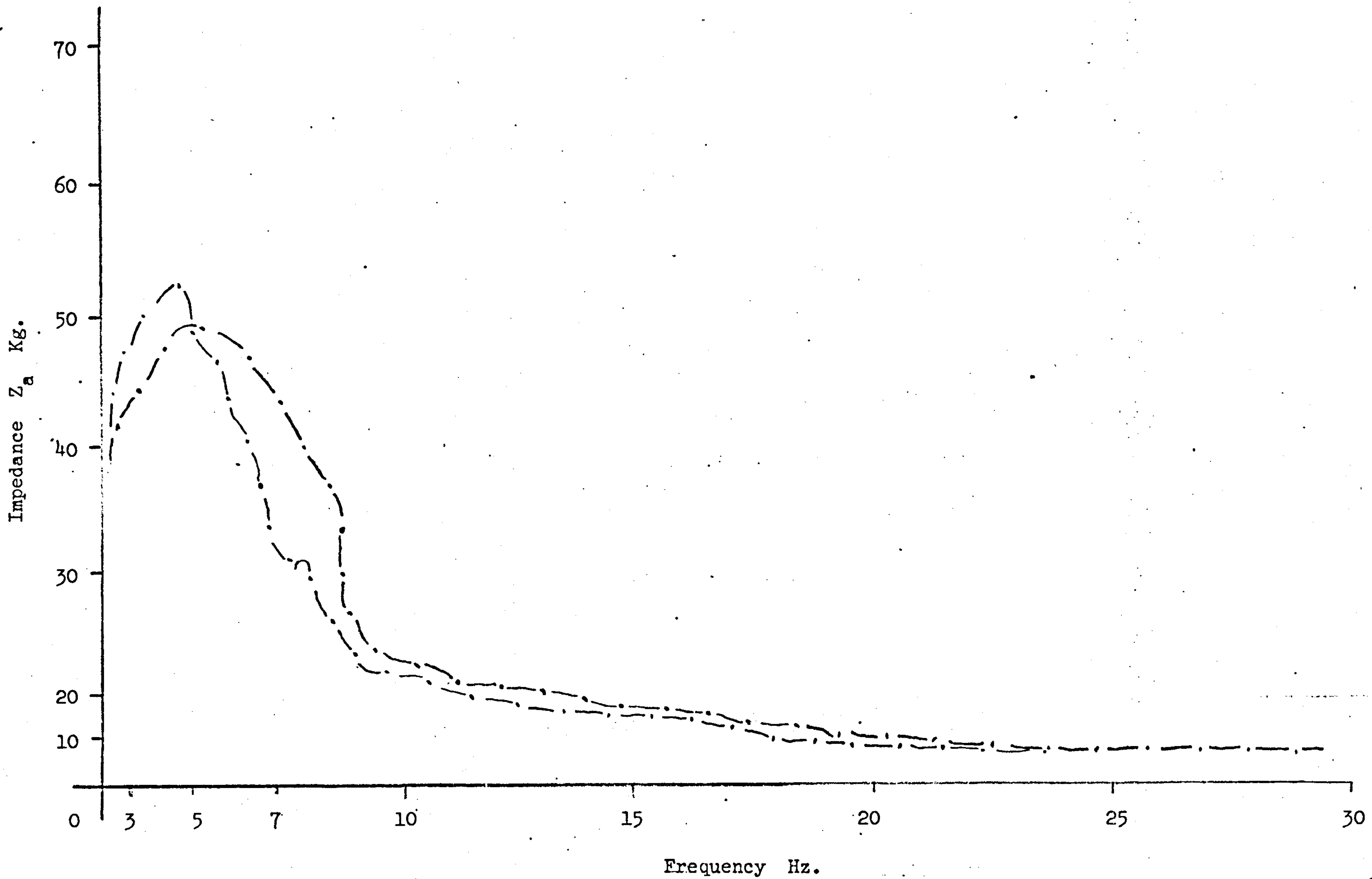


Figure No 105 M11 - E

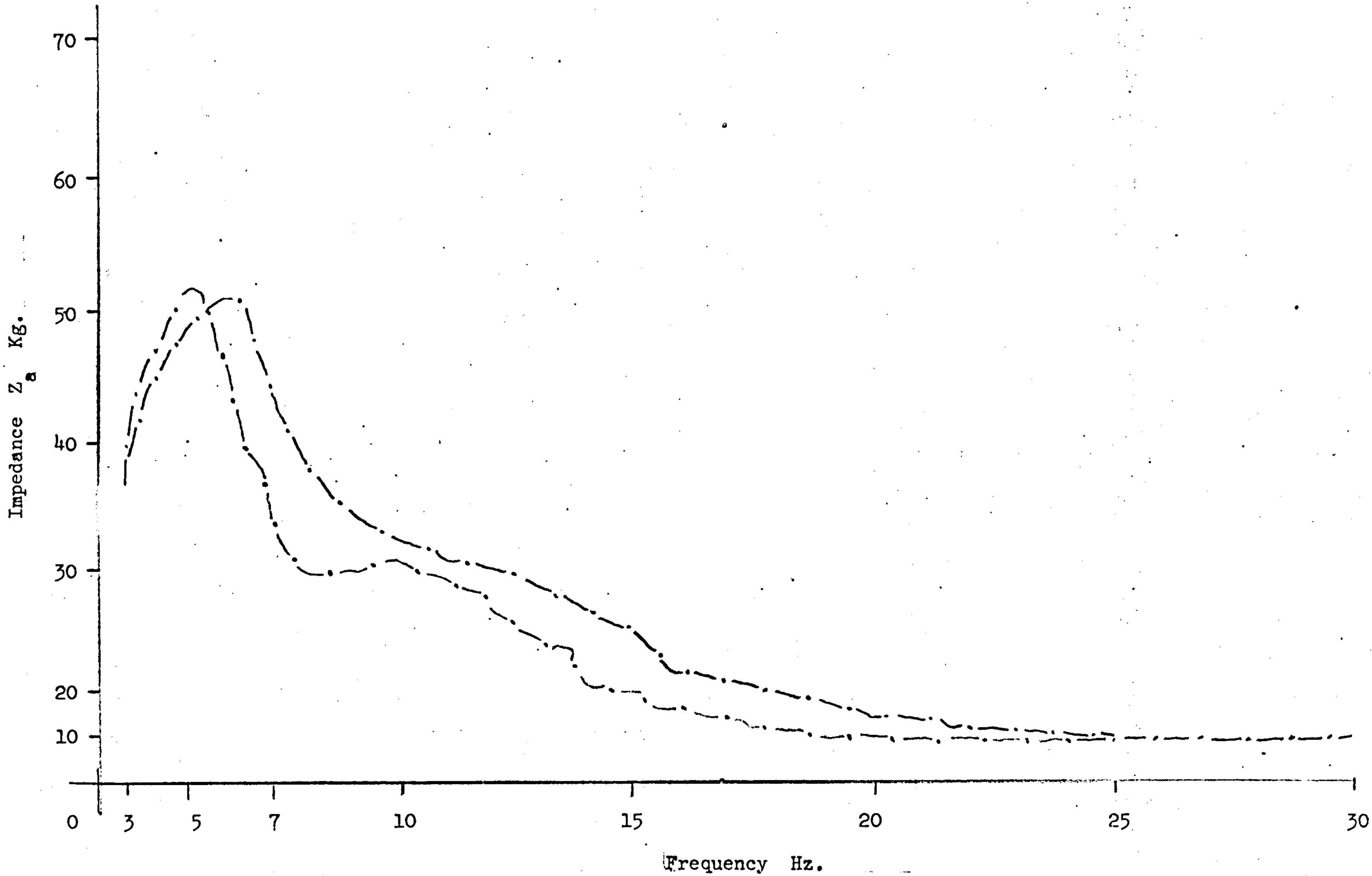


Figure No 106 M12 - E

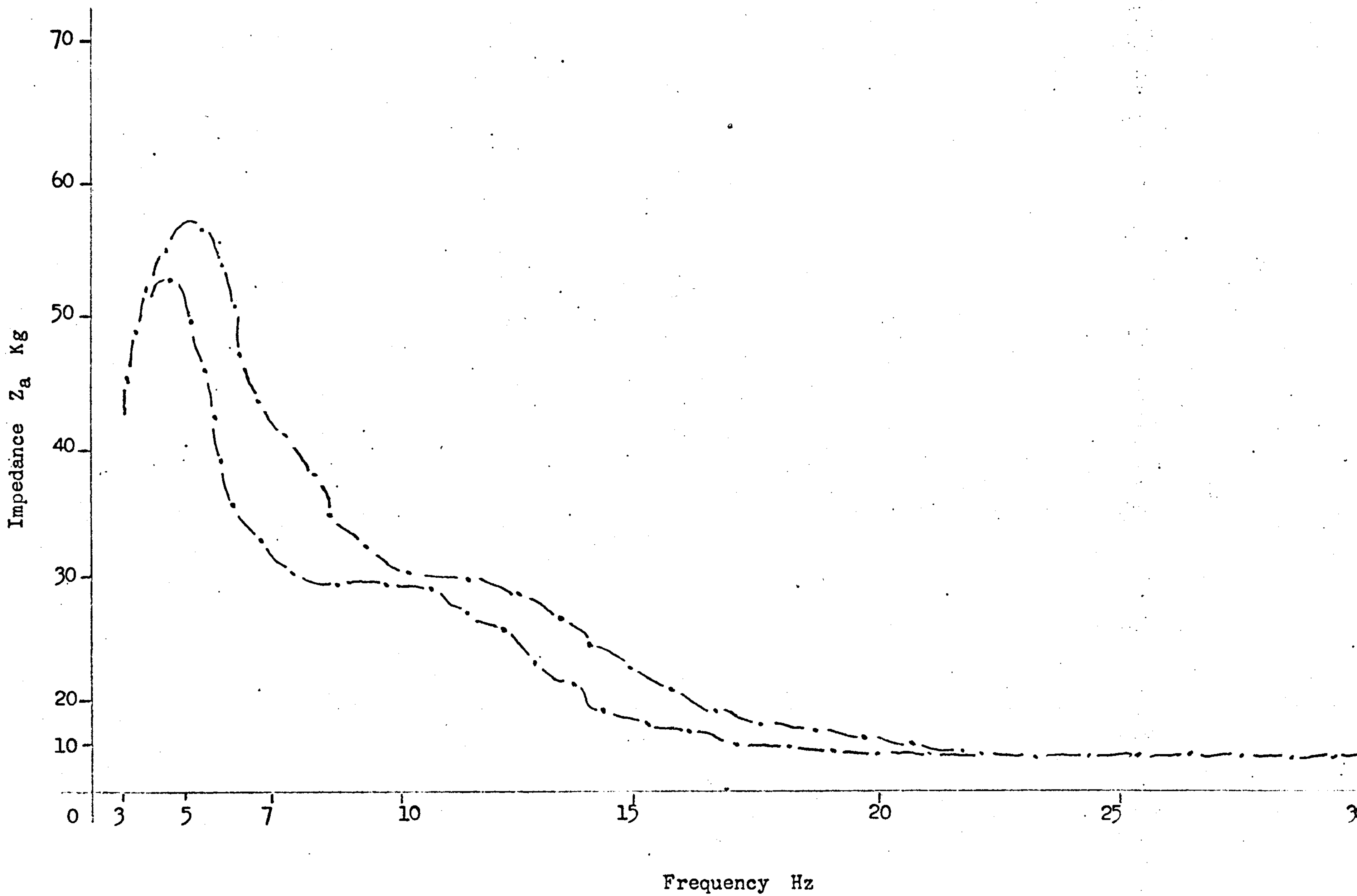


Figure No 107 M14 - E

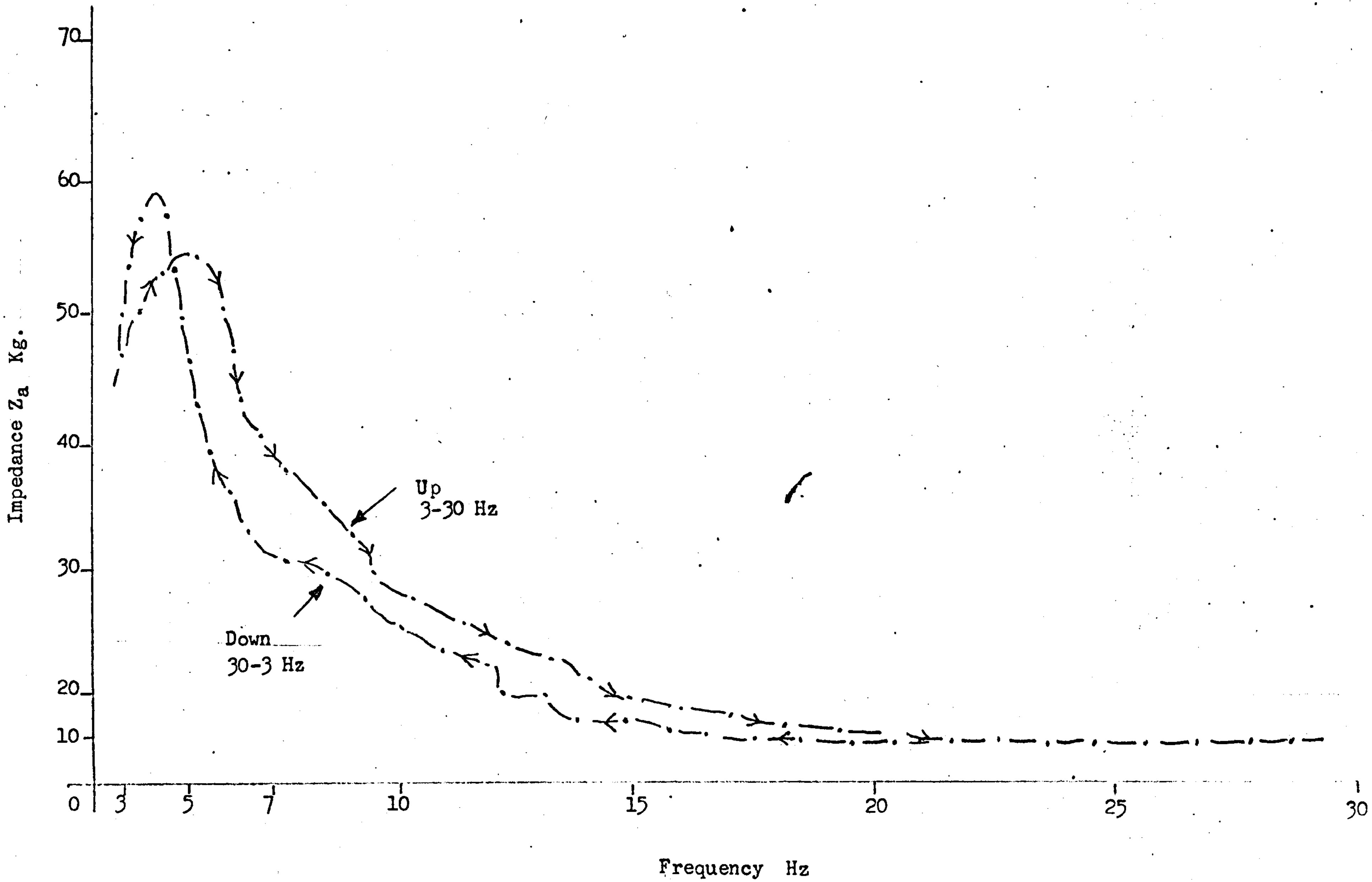


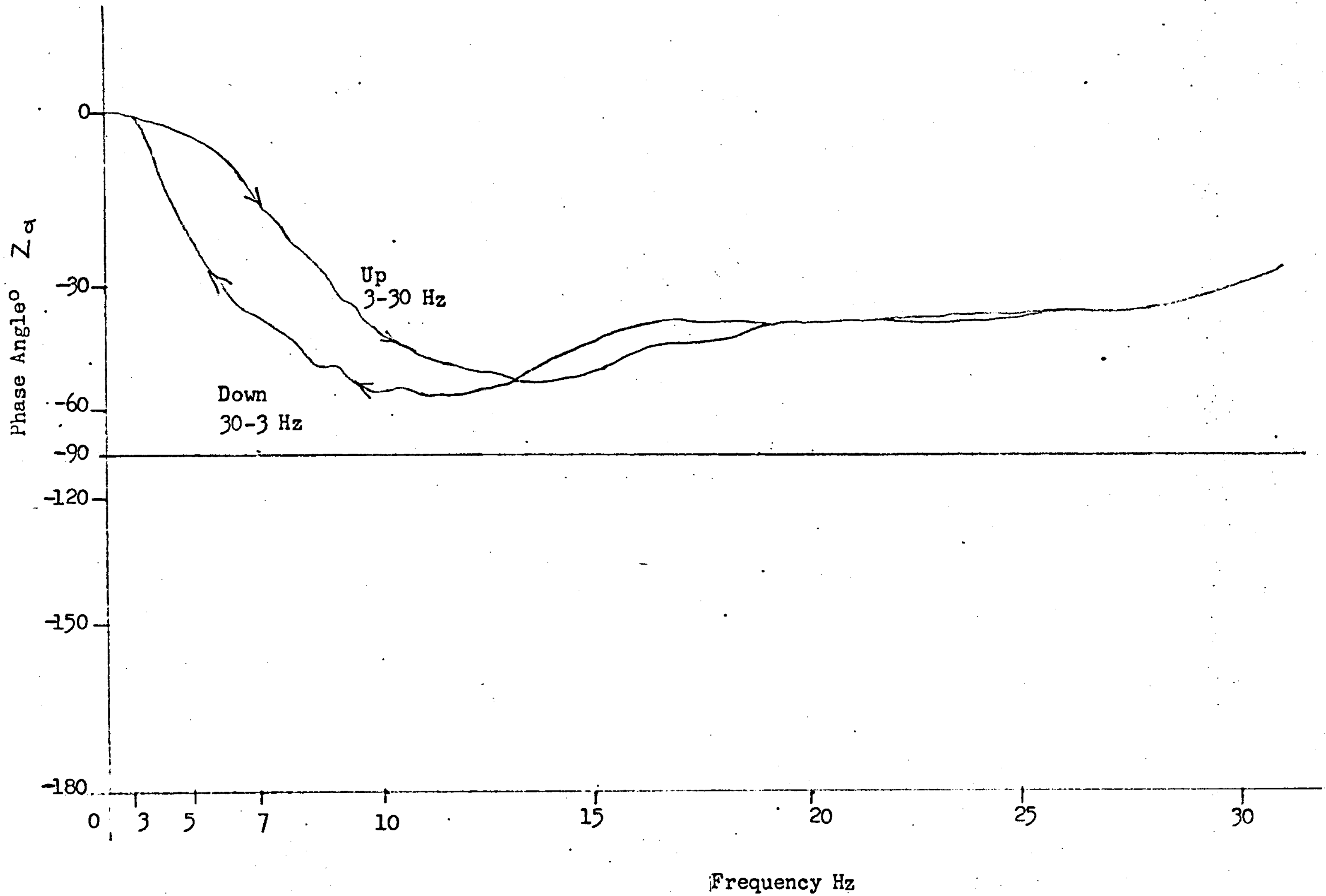
Figure No. 108M15 - E

PHASE ANGLE RESULTS FOR

MALE SUBJECTS

SITTING ERECT POSTURE

Figure No. 109M1 - E



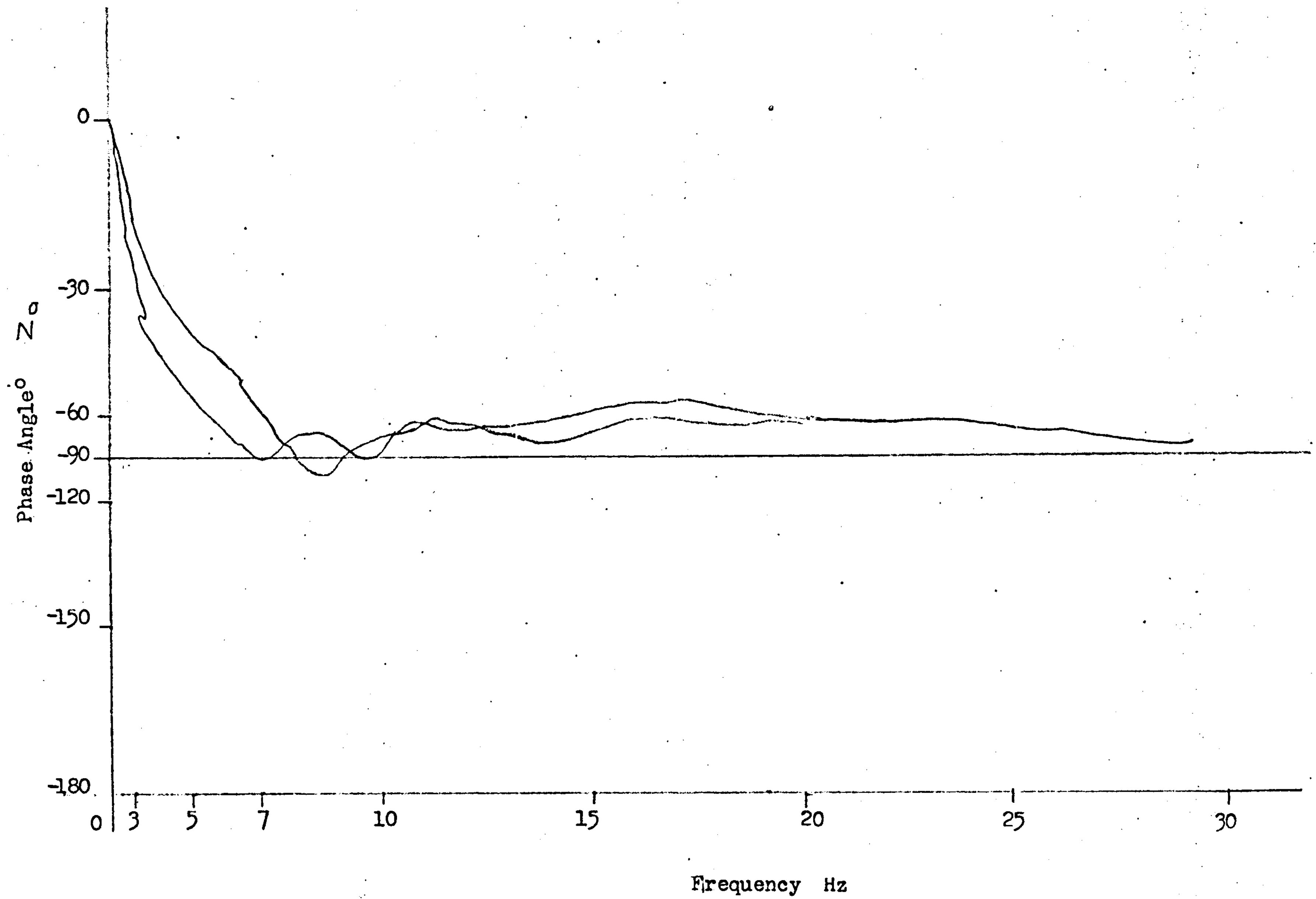


Figure No 110 M2 - E

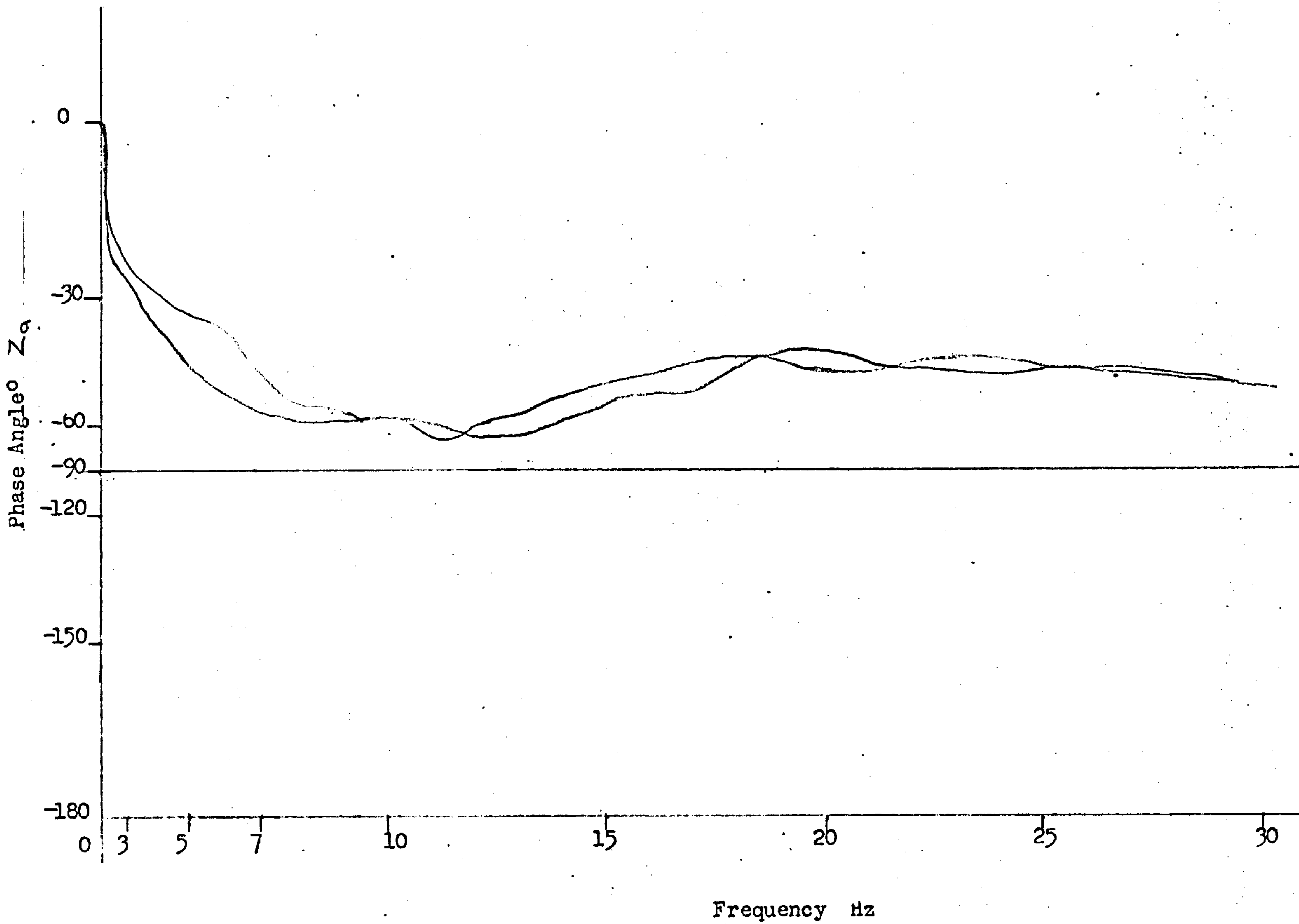


Figure No 111 M3 - E

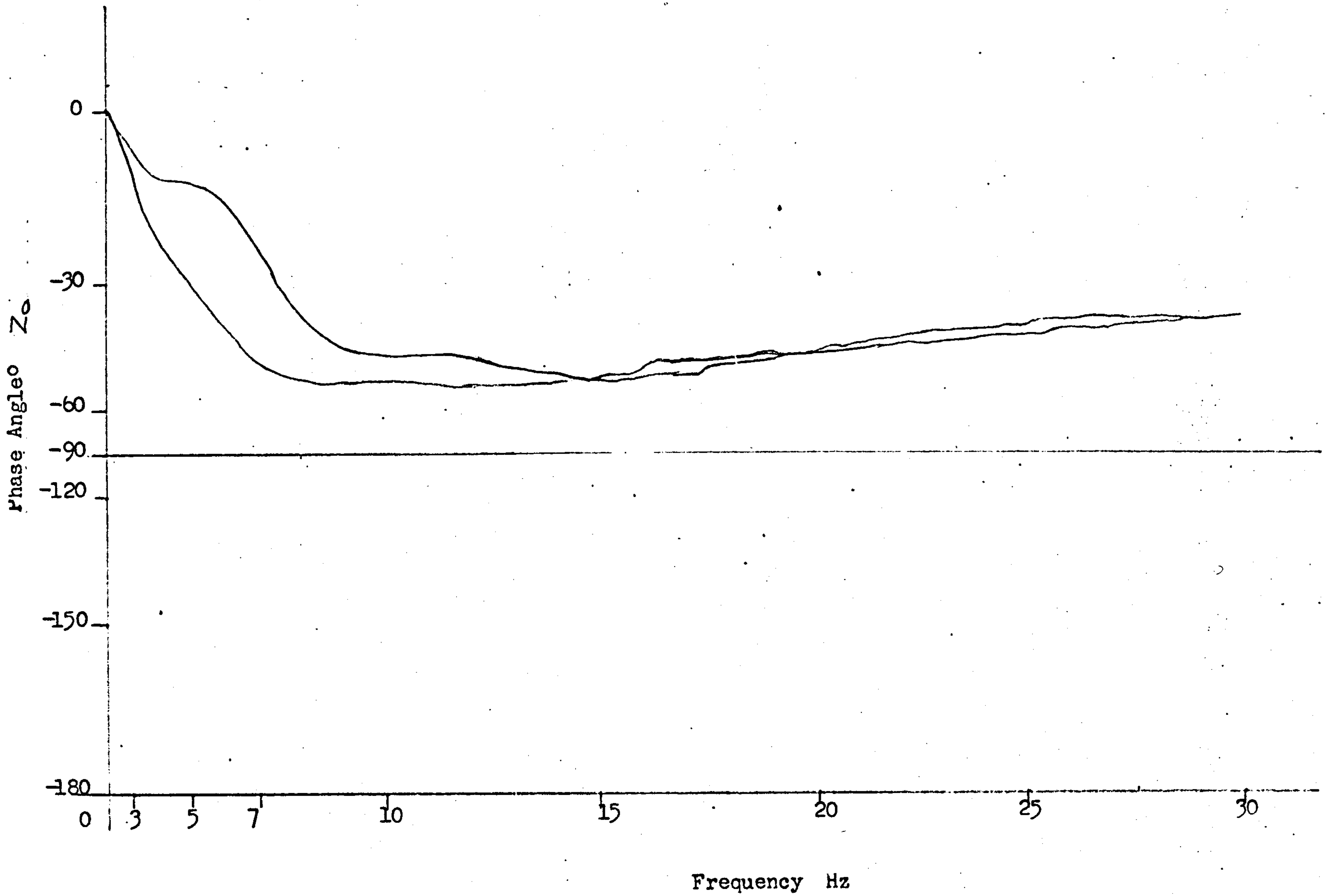


Figure No. 112 M4 - E

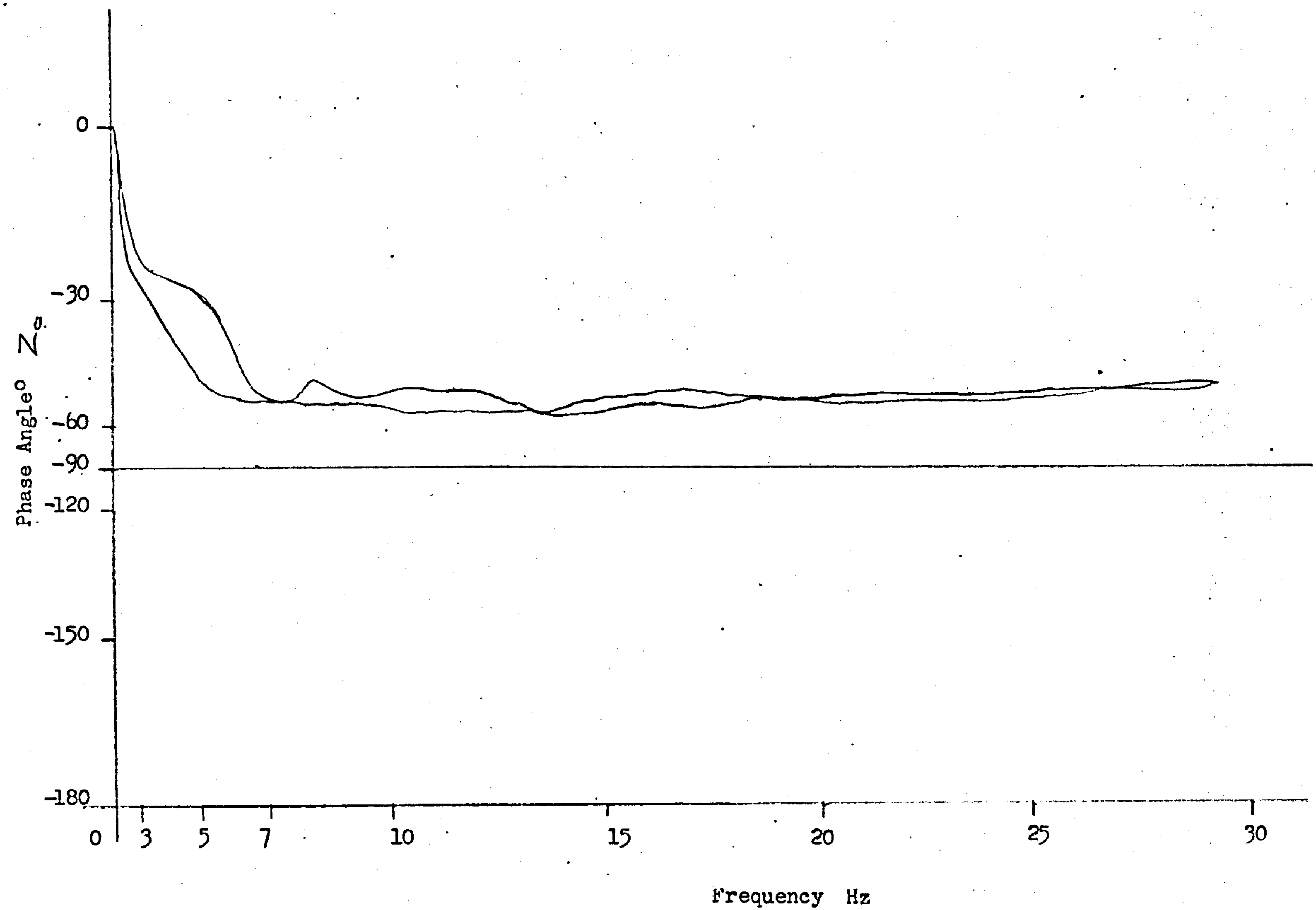


Figure No. 113 M6 - E

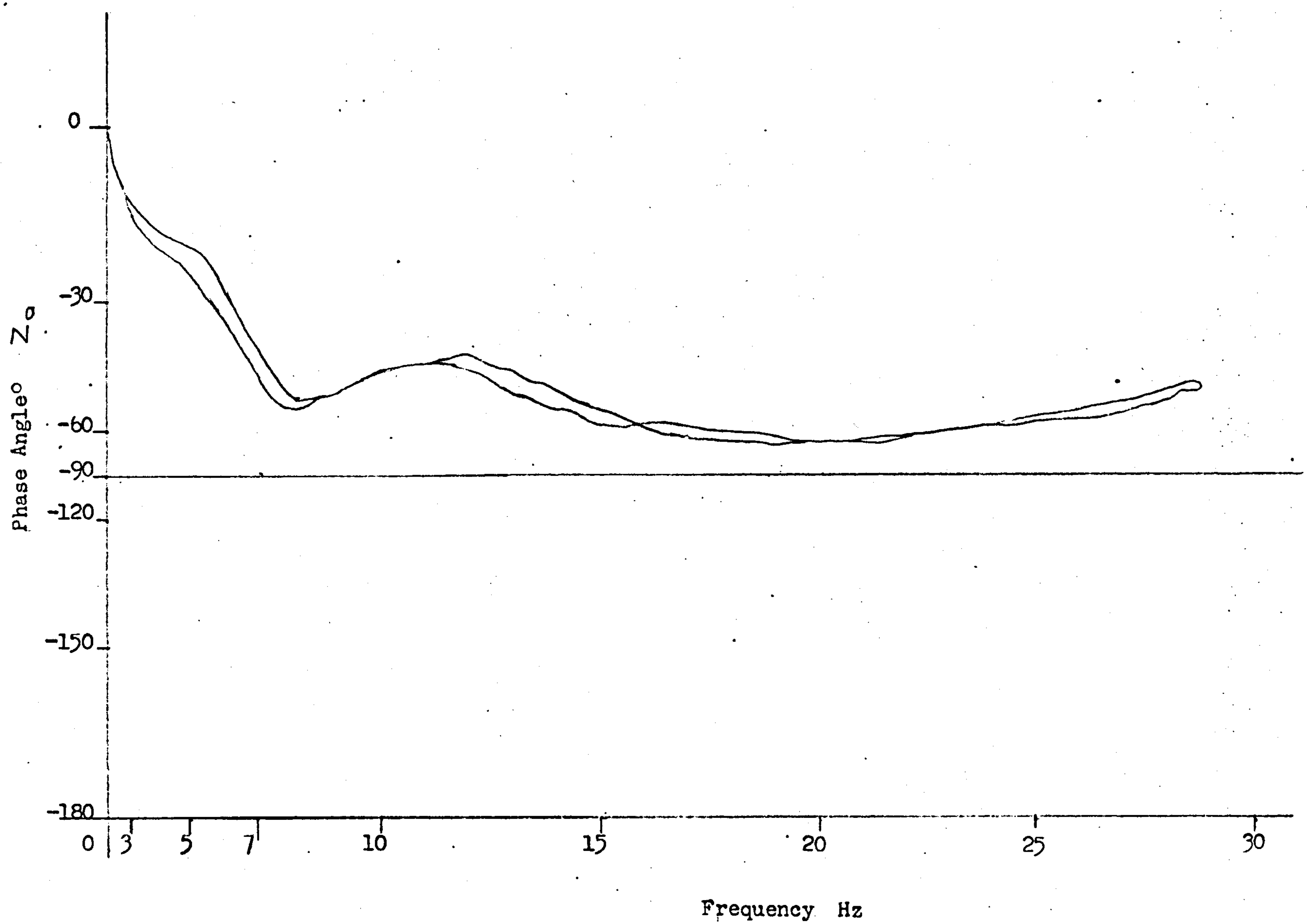


Figure No 114 M7 - E

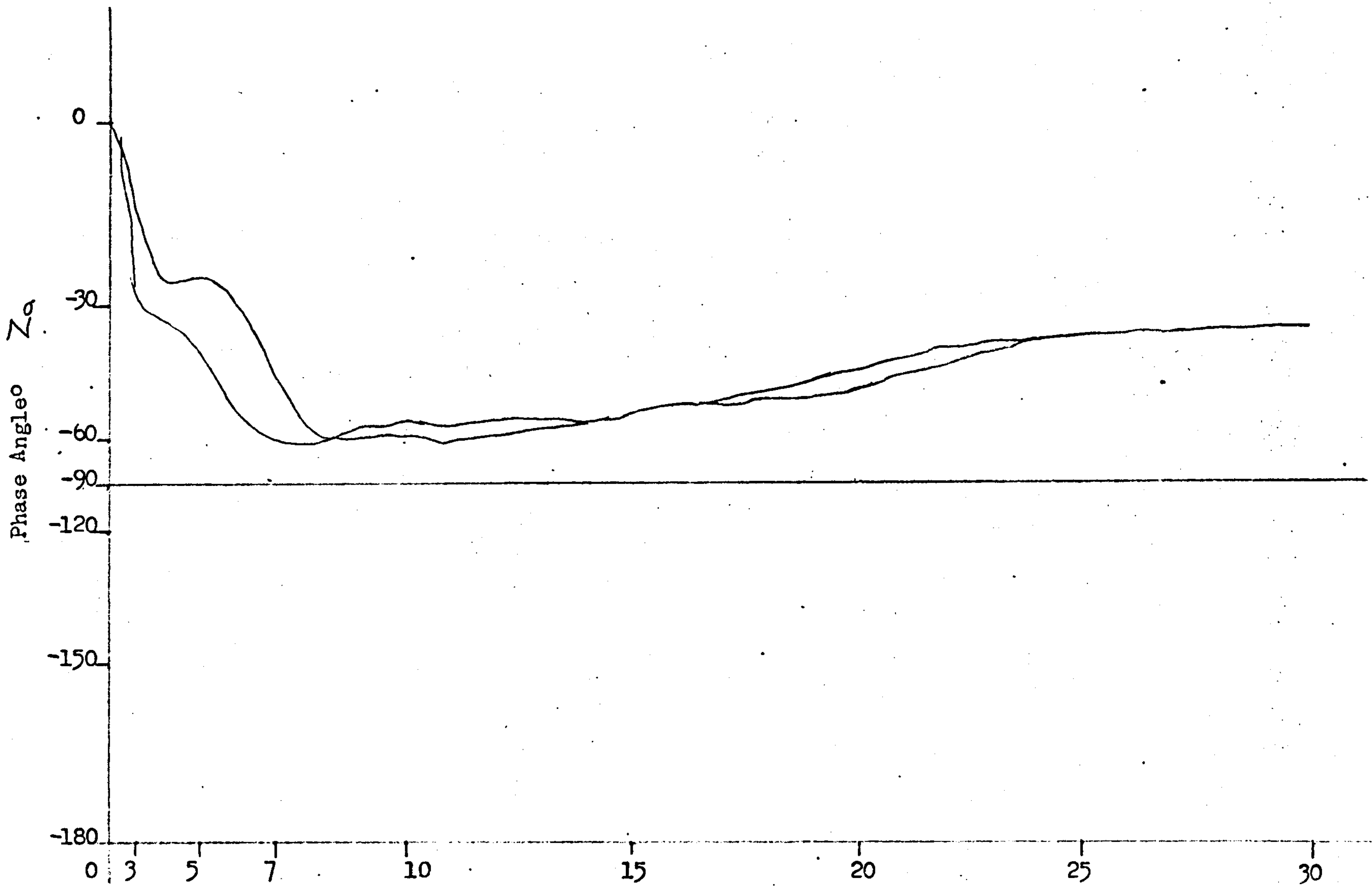


Figure No. 115 M8 - E

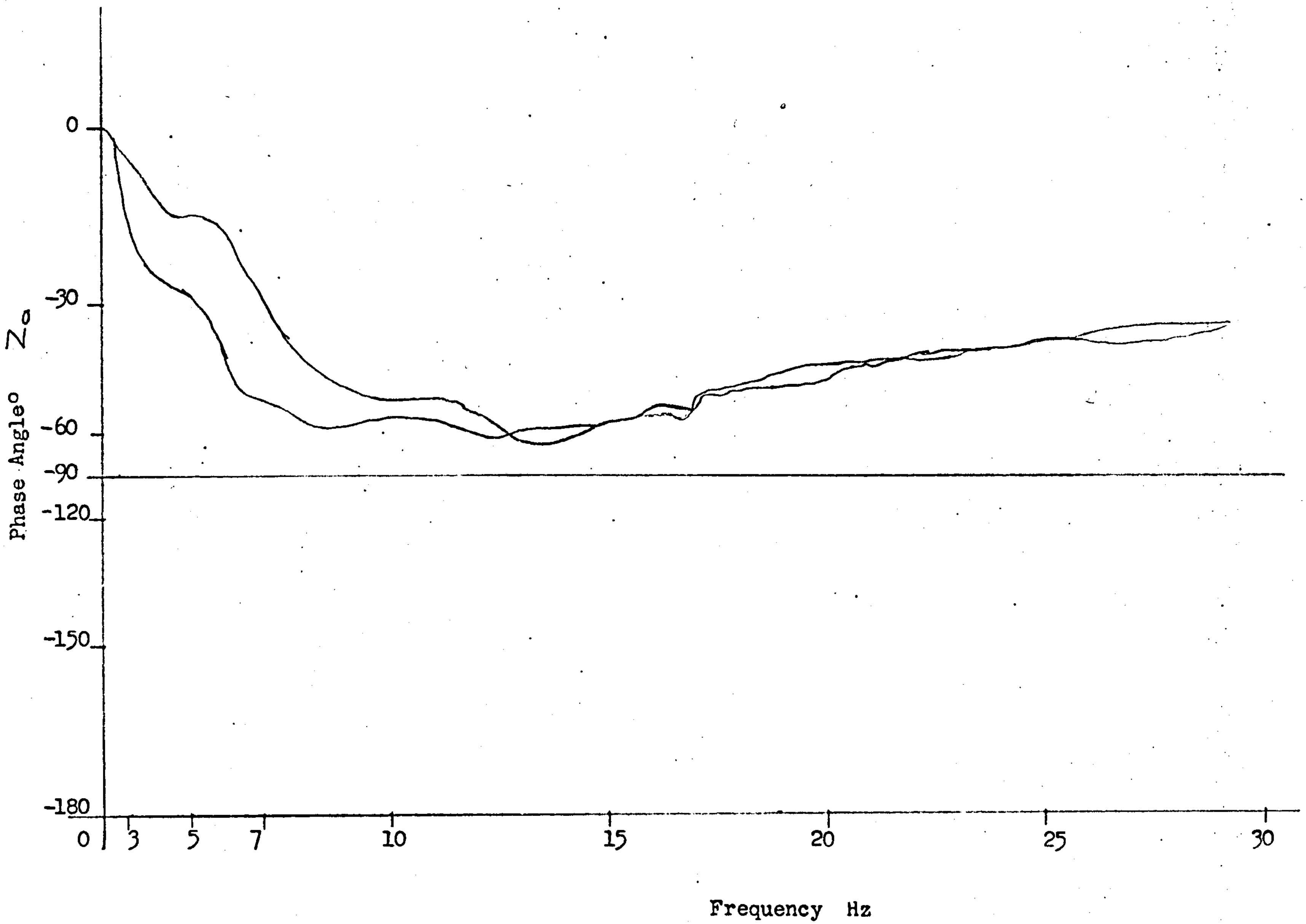


Figure No.116 M9 - E

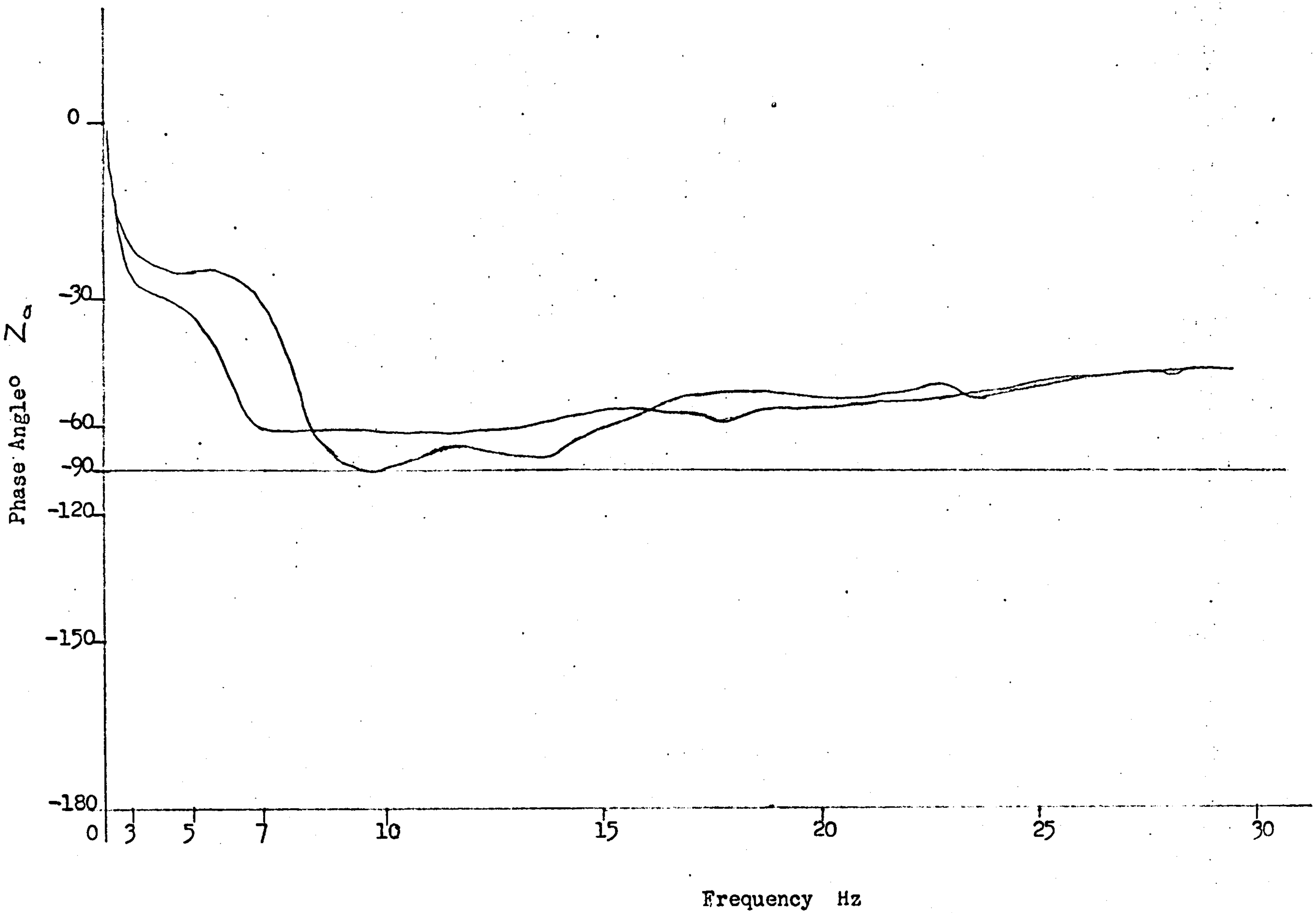


Figure No. 117 M10 - E

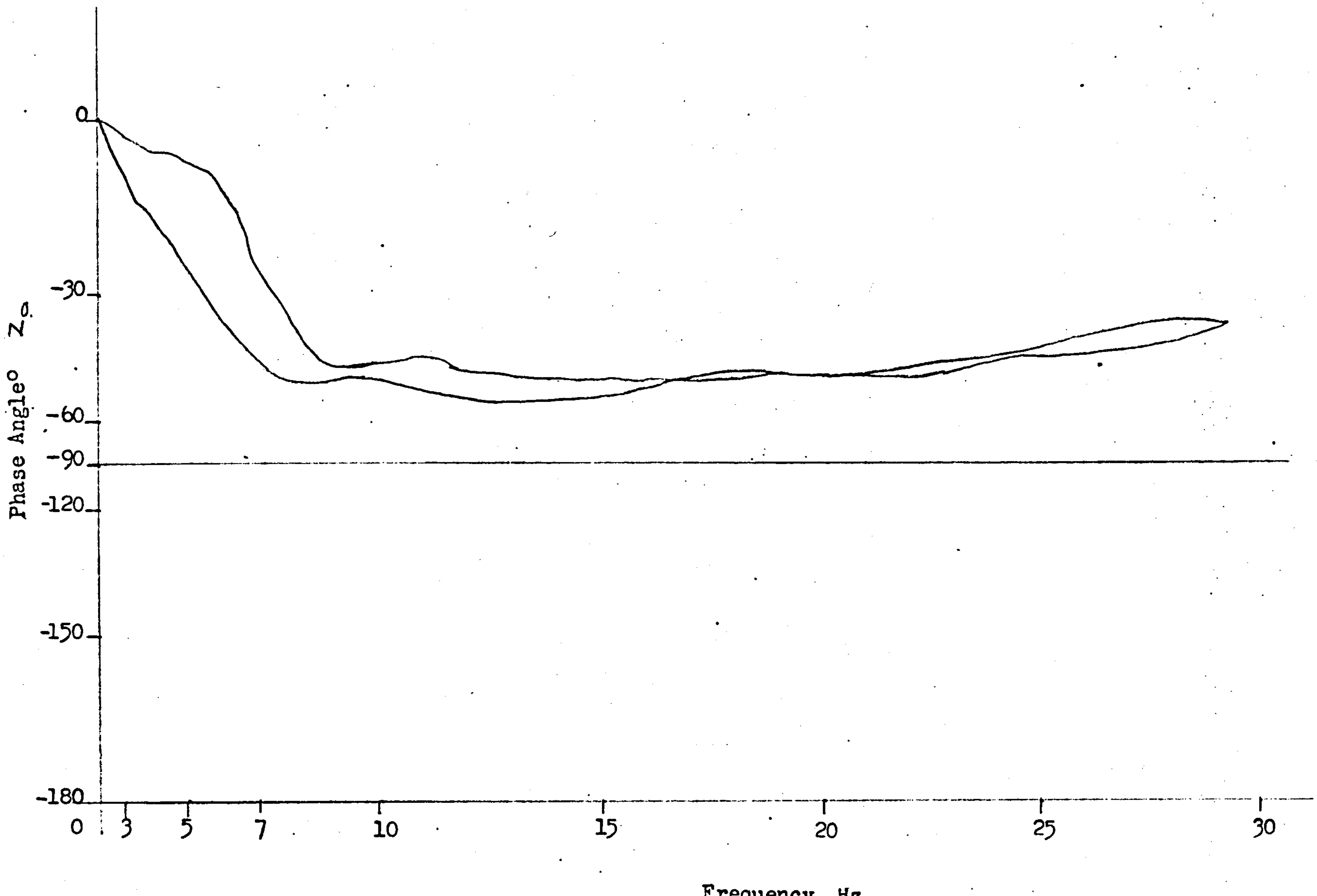


Figure No. 118 M12 - E

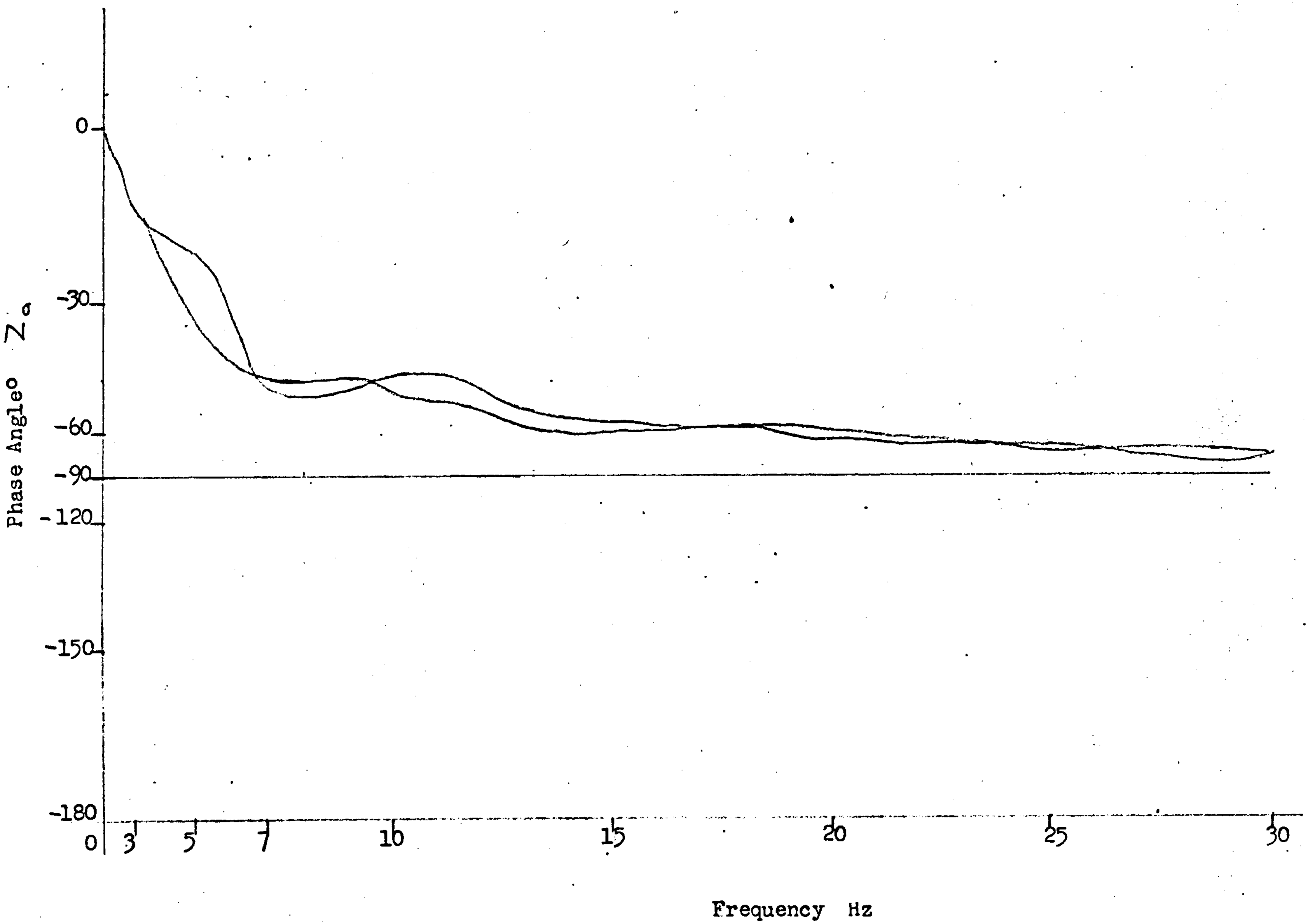


Figure No. 119 M15 - E

MODULUS OF IMPEDANCE RESULTS FOR

MALE SUBJECTS

SITTING RELAXED POSTURE

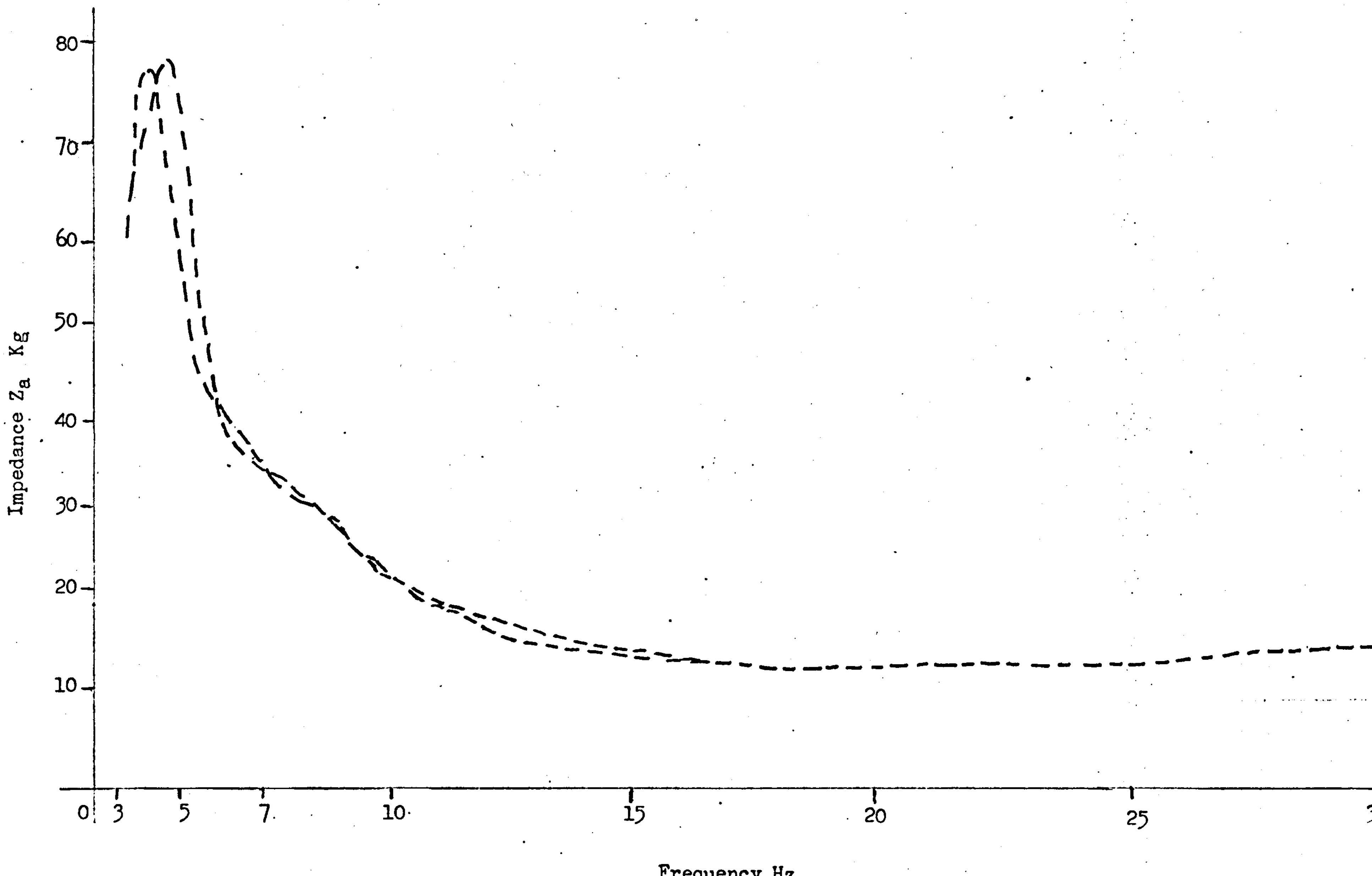


Figure No. 120 M1 - R.

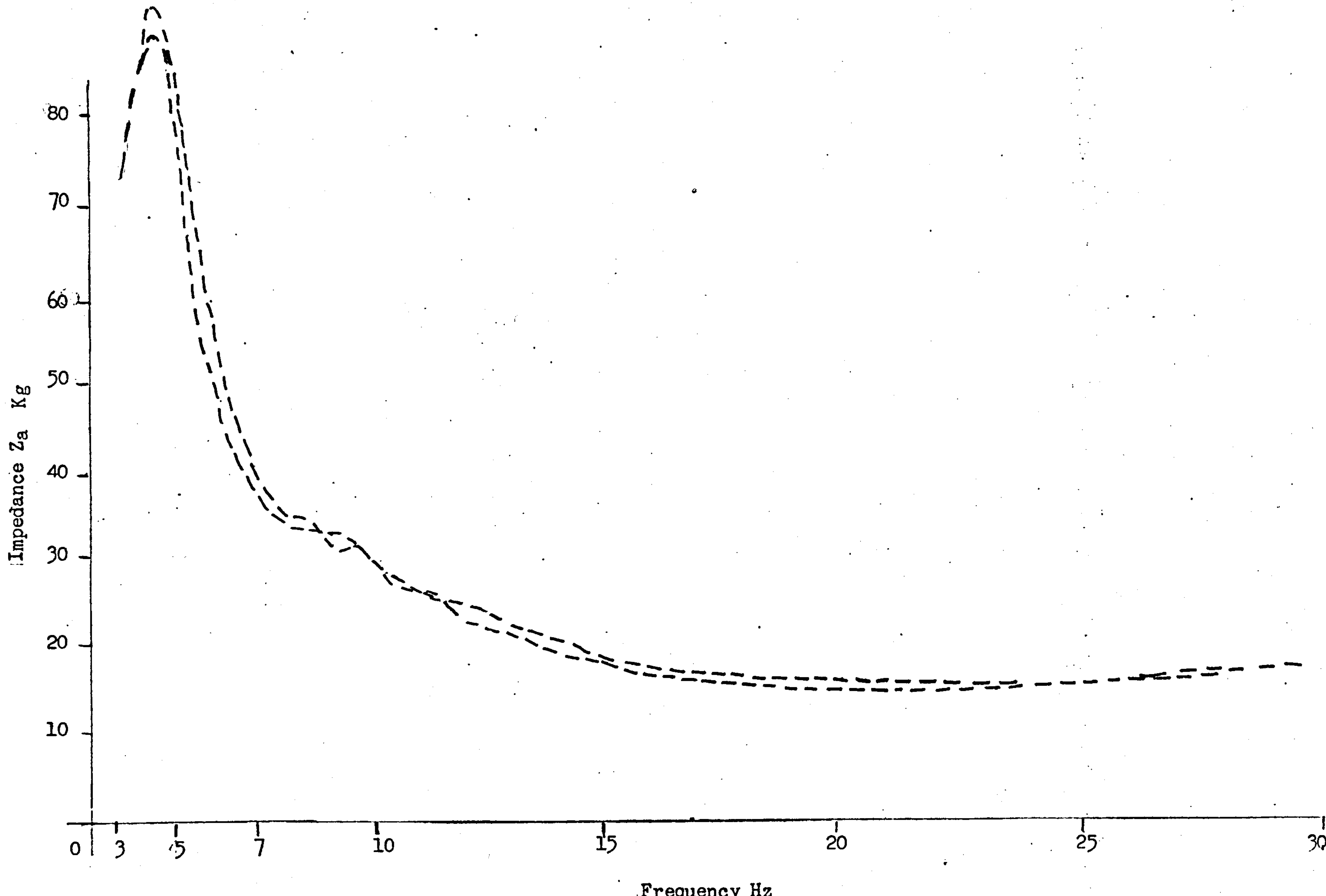


Figure No.121M2 - R.

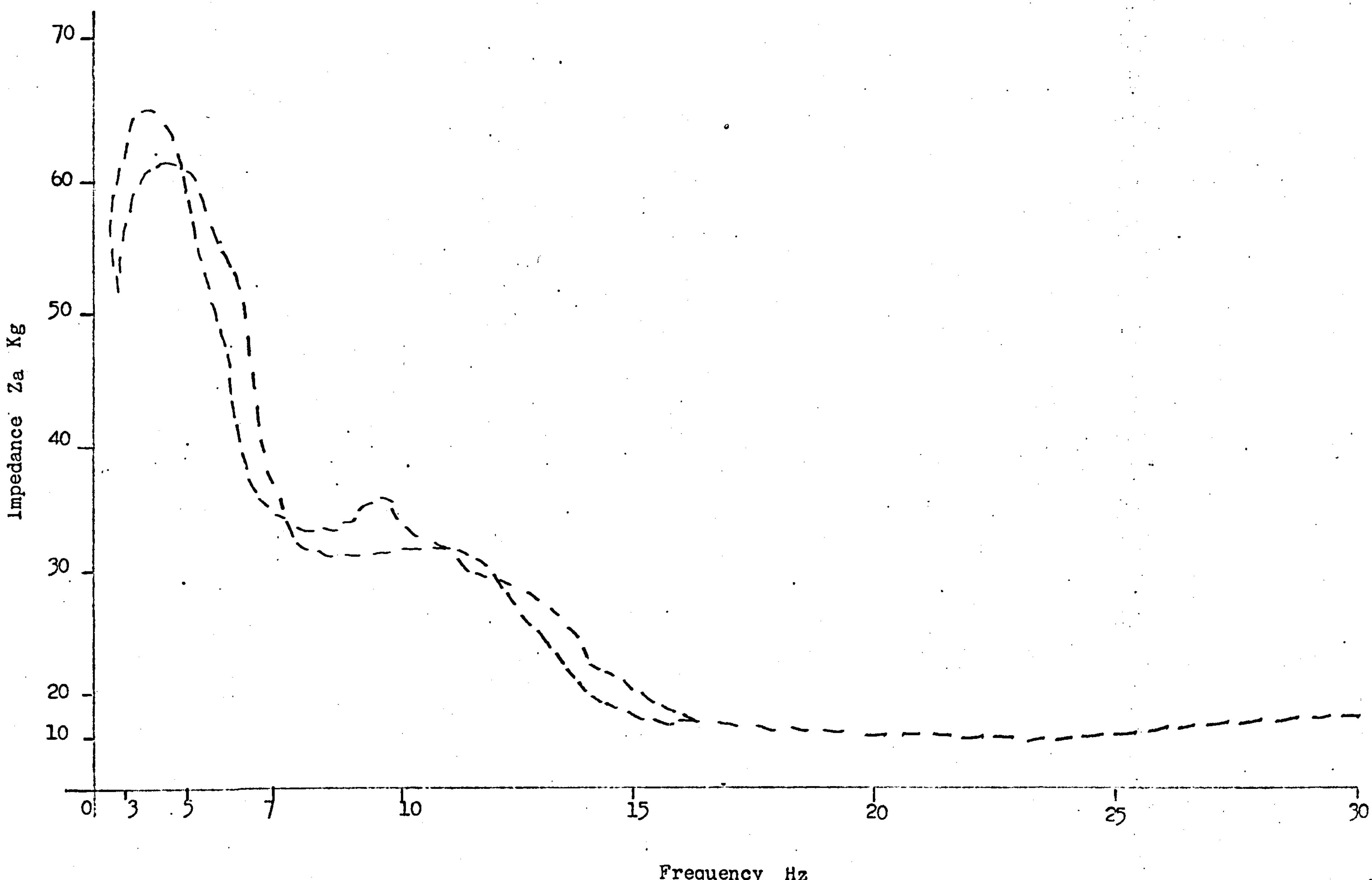


Figure No 122 M3 - R

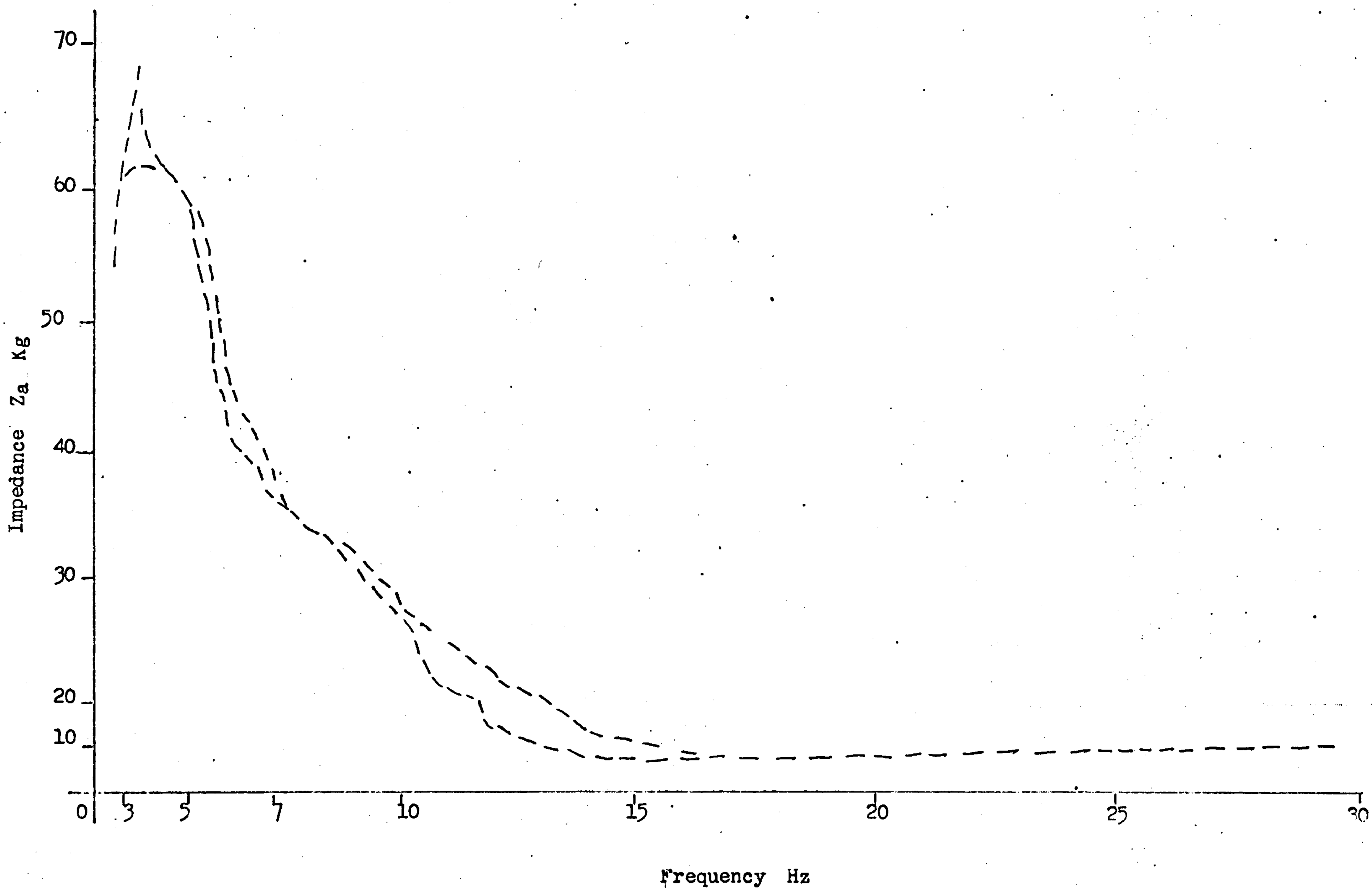


Figure No. 123 M4 - R

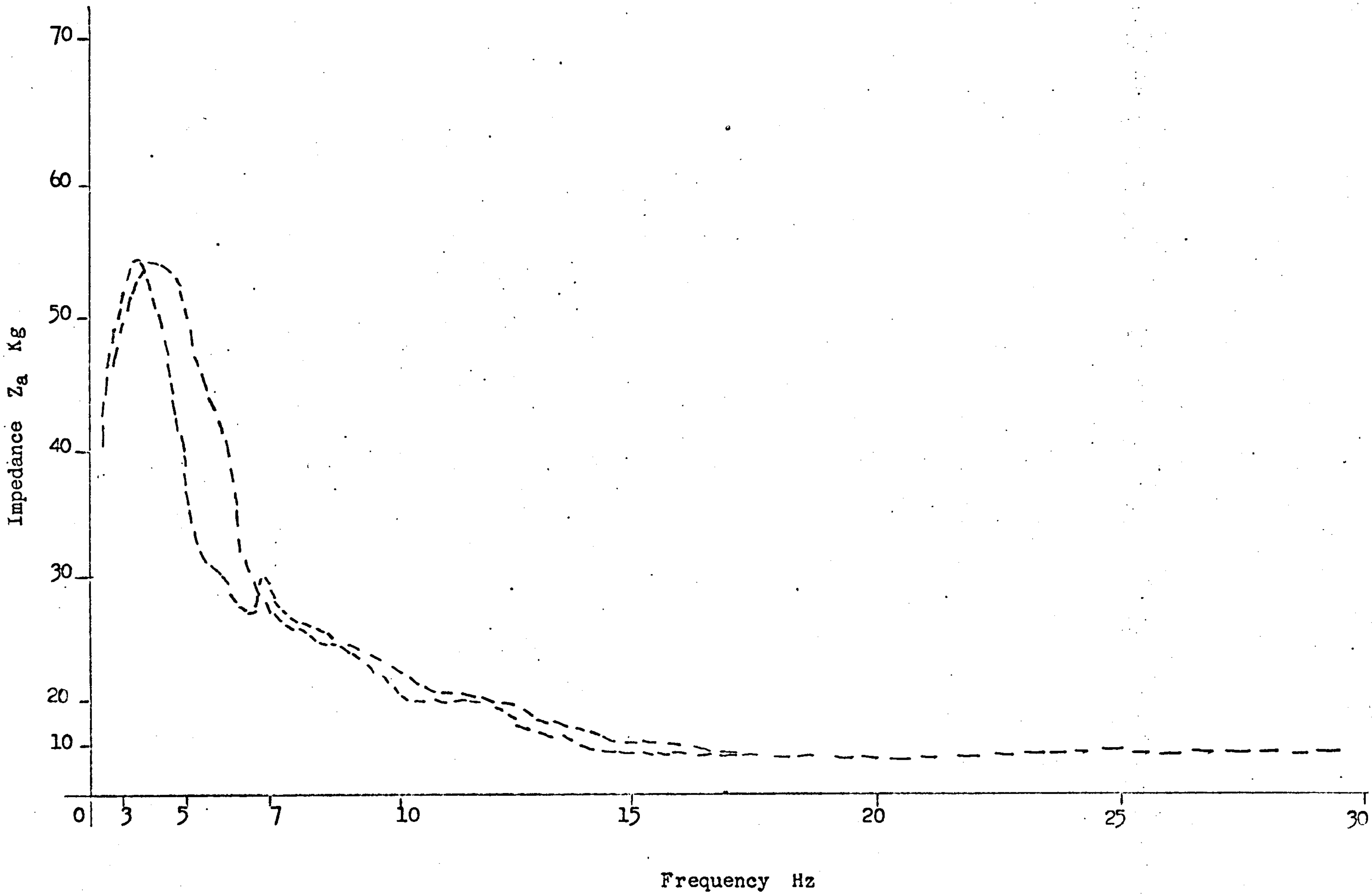


Figure No. 124 M5 - R

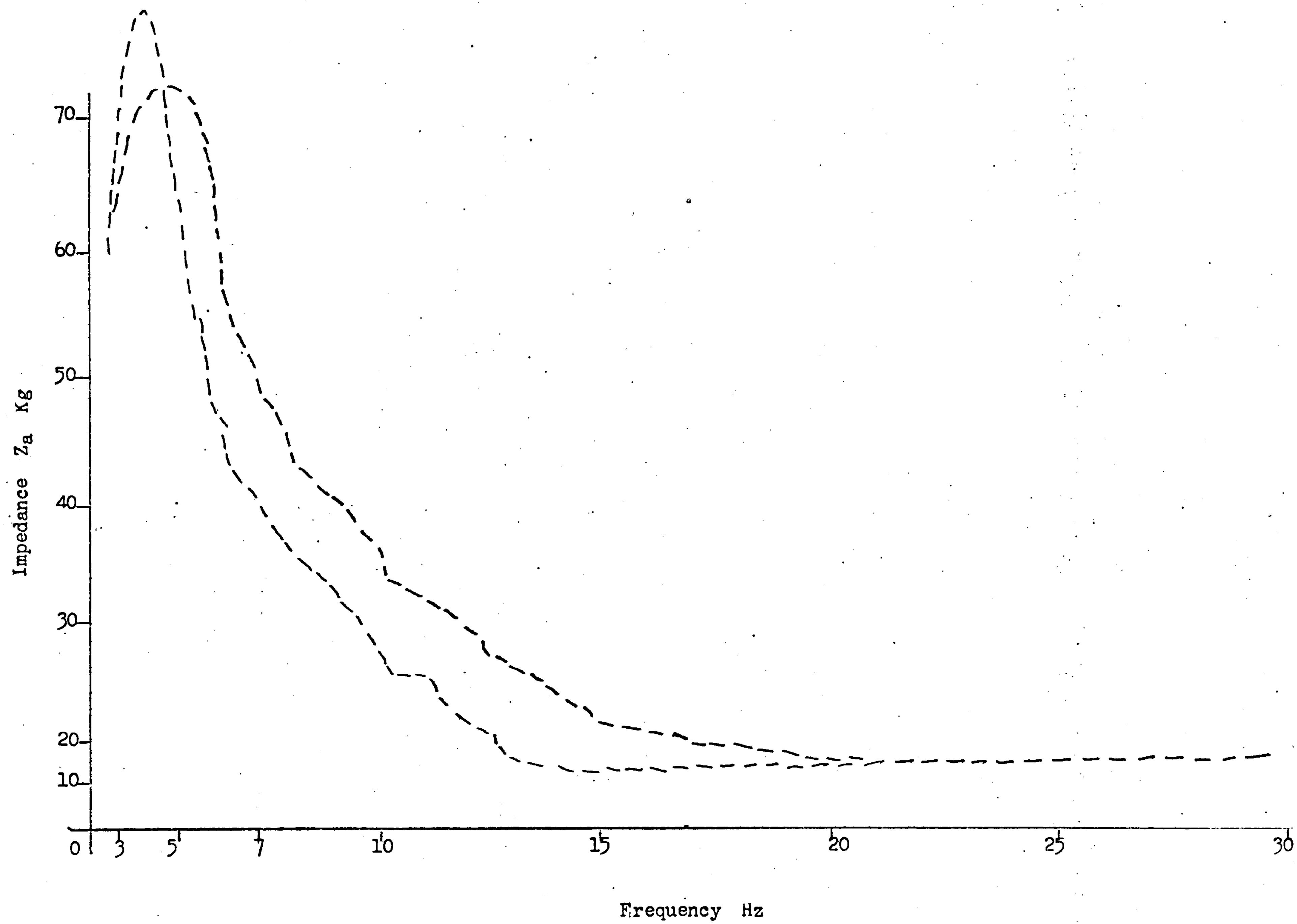


Figure No 125 M6 - R

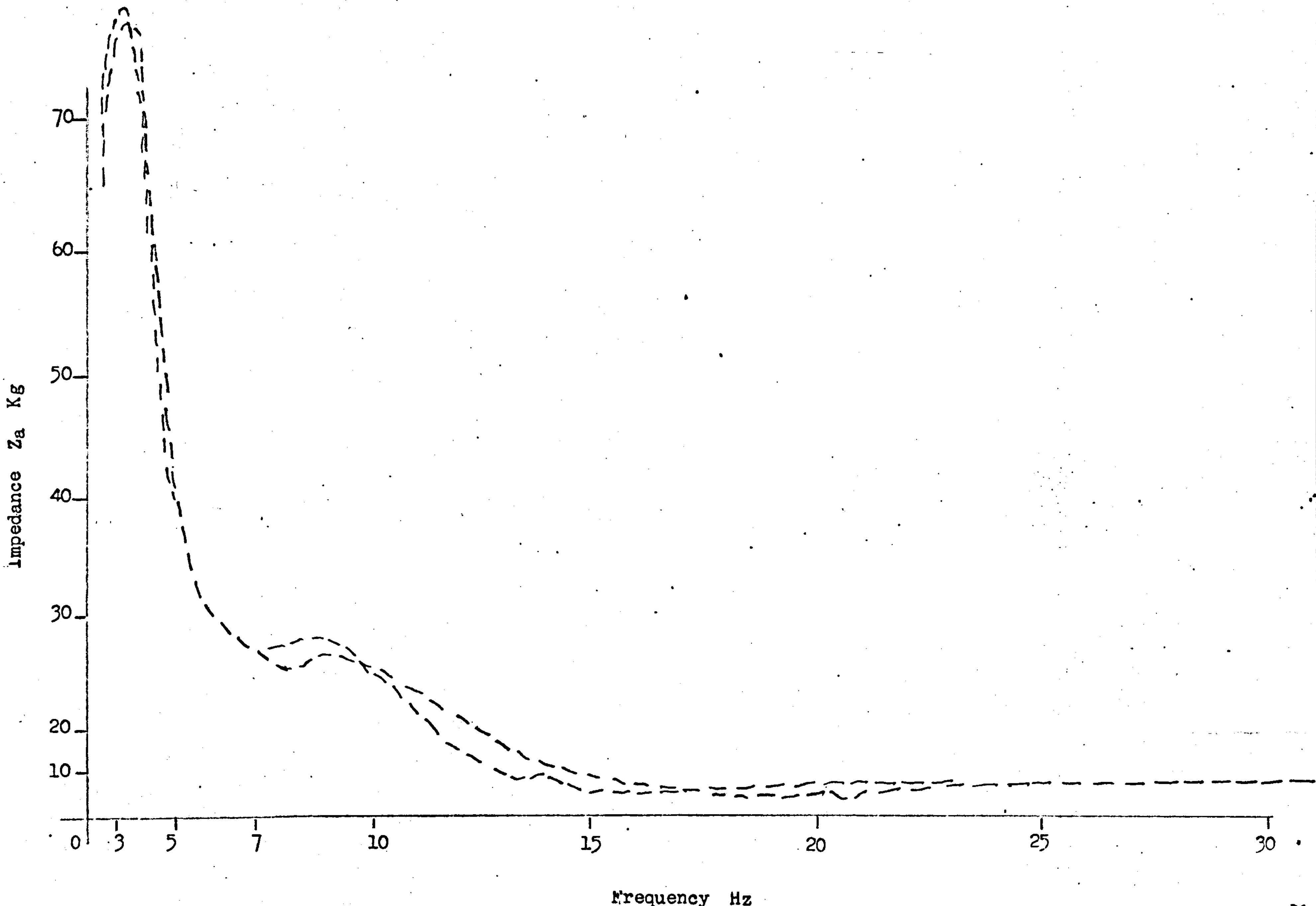


Figure No. 126M7 - R

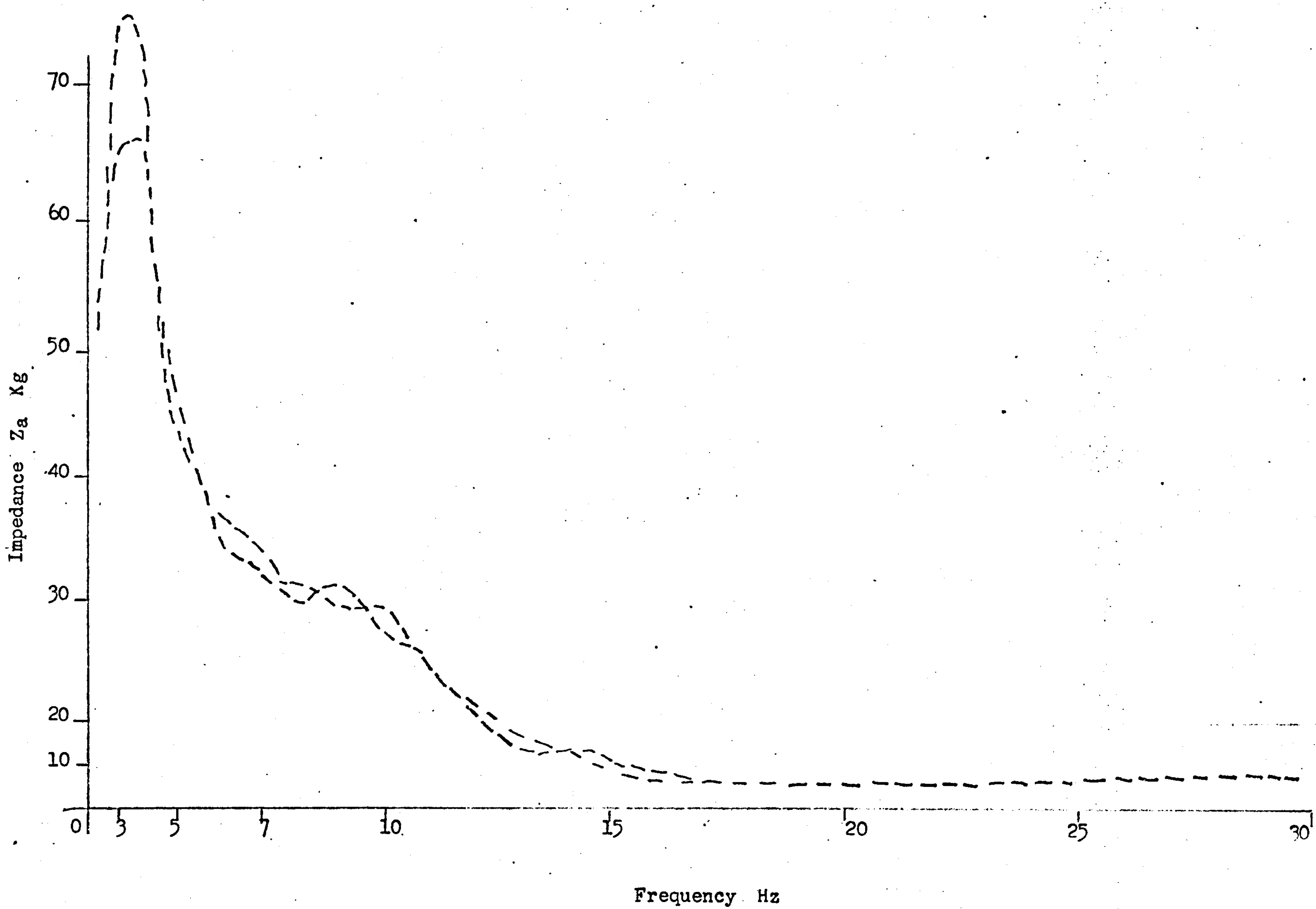


Figure No. 127 M8 - R

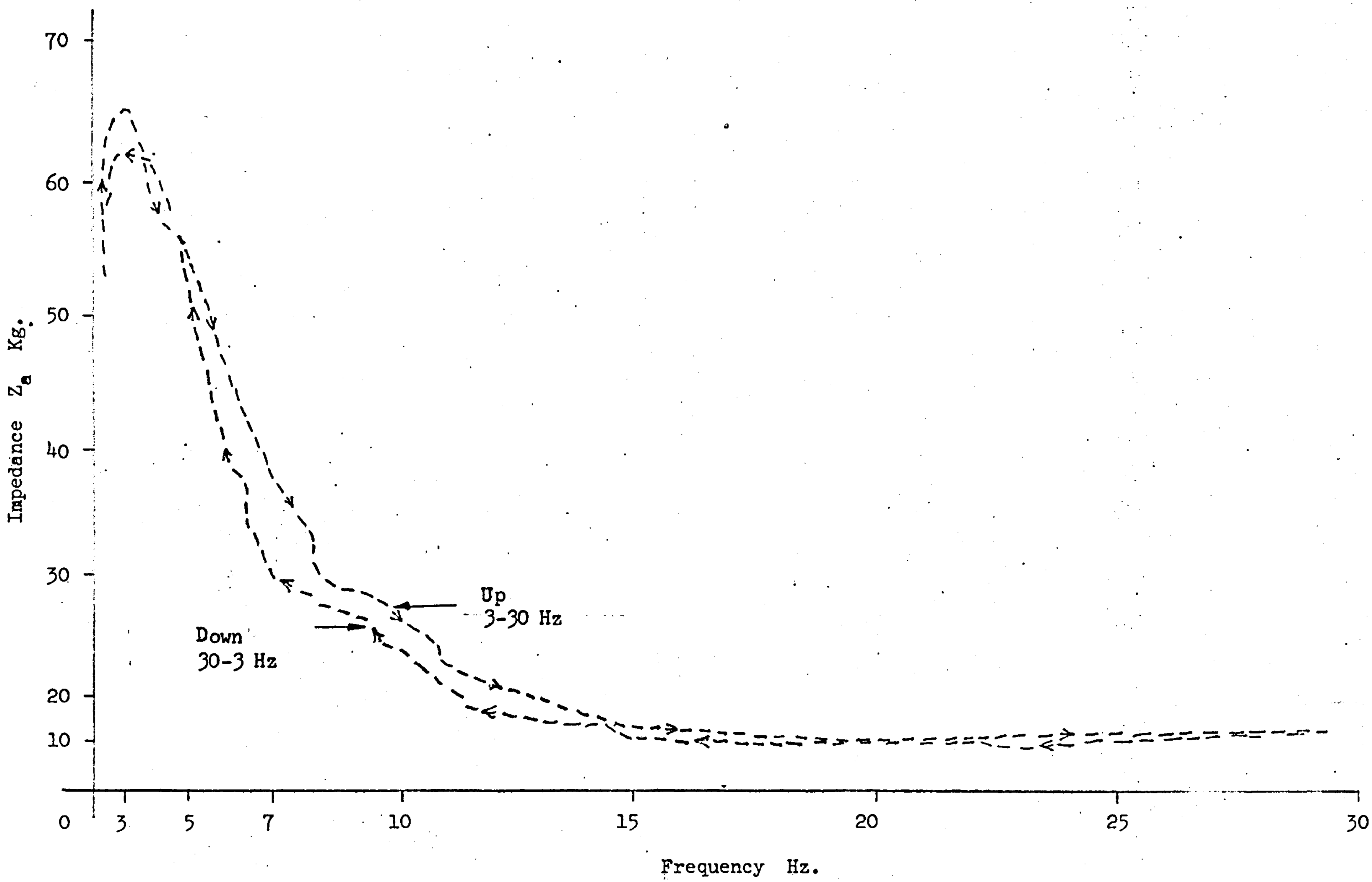


Figure No 128 M9 - R

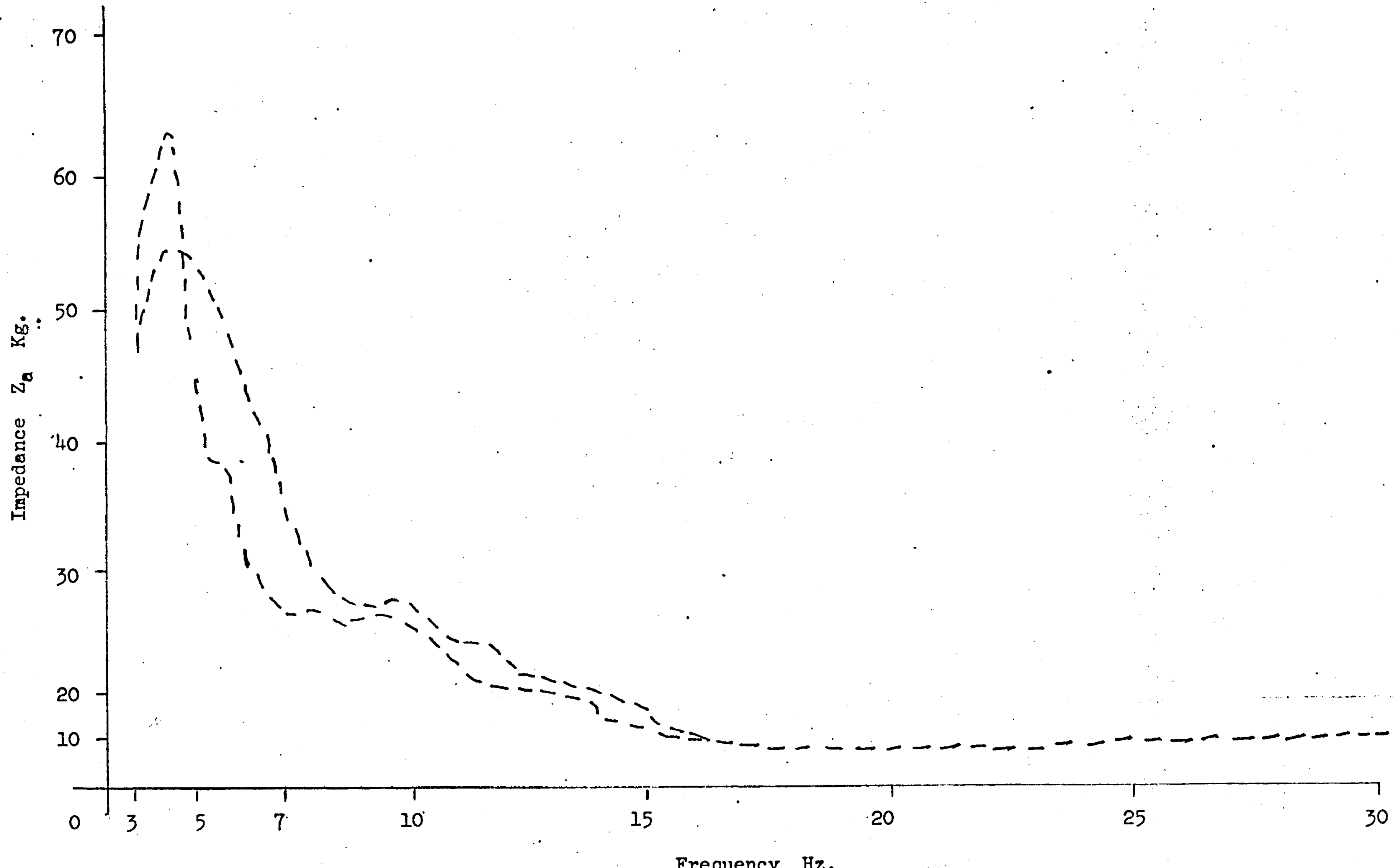


Figure No. 129 M10 - R

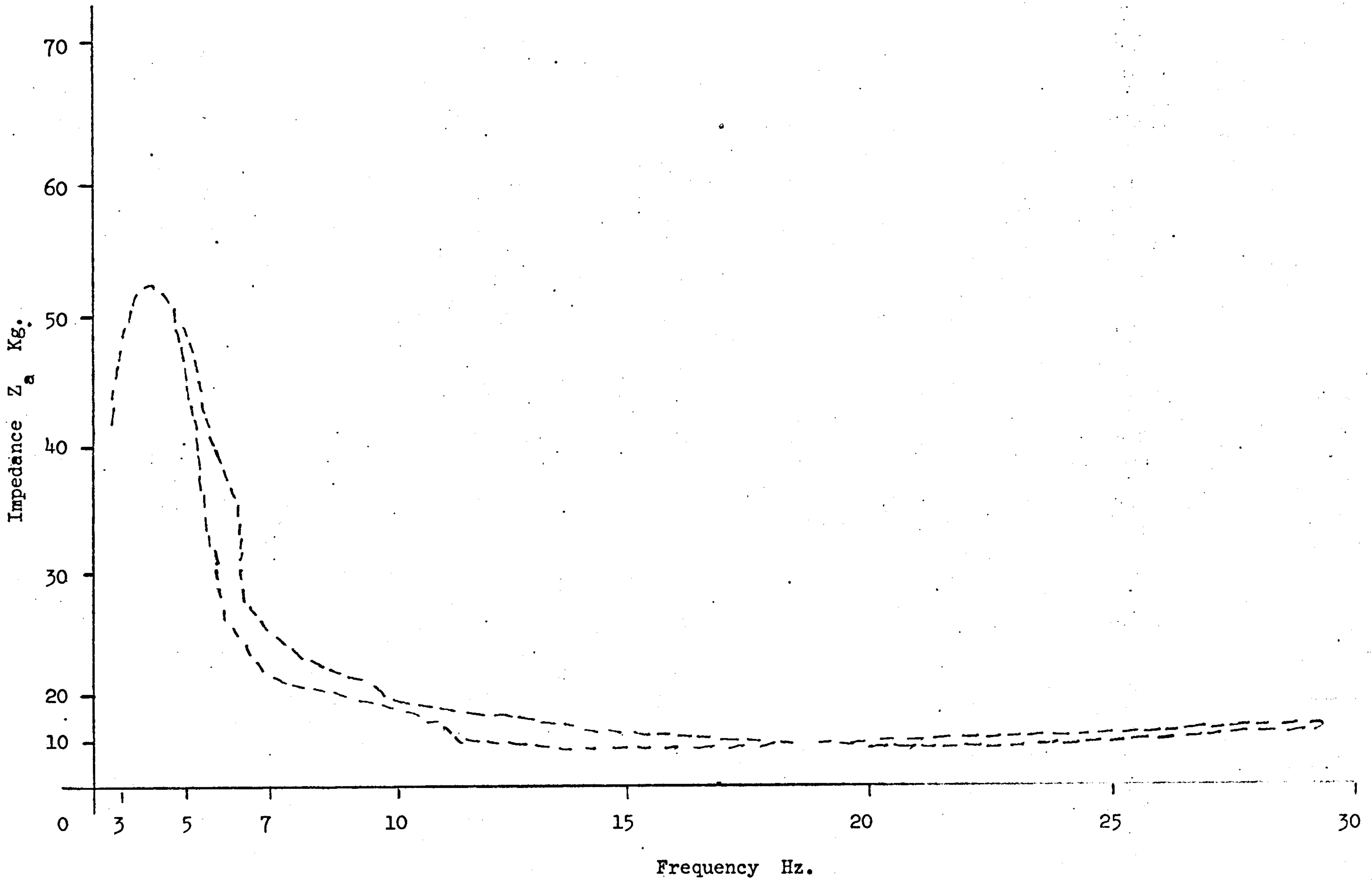


Figure No 130 M11 - R

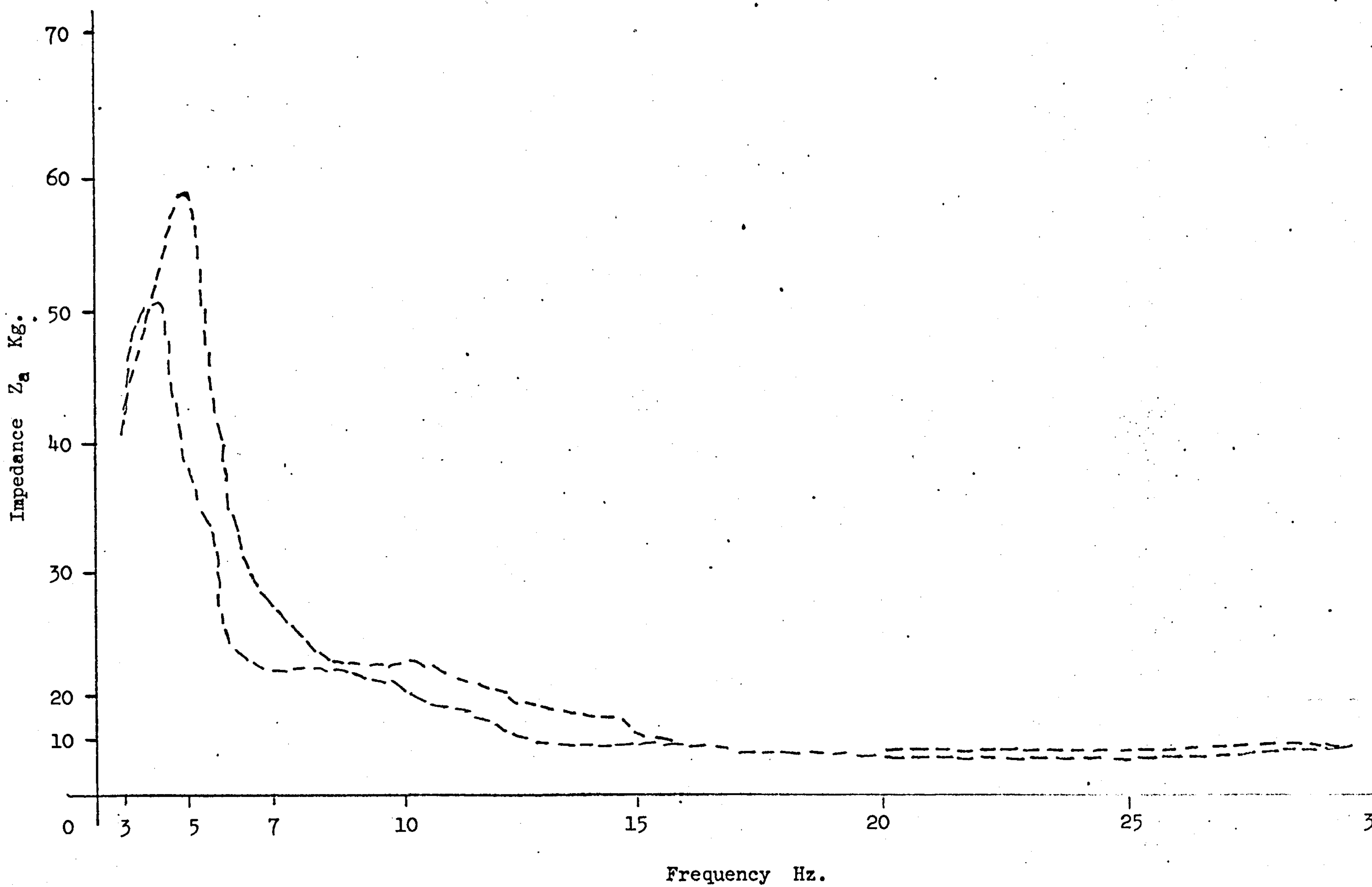


Figure No 131 M12 - R

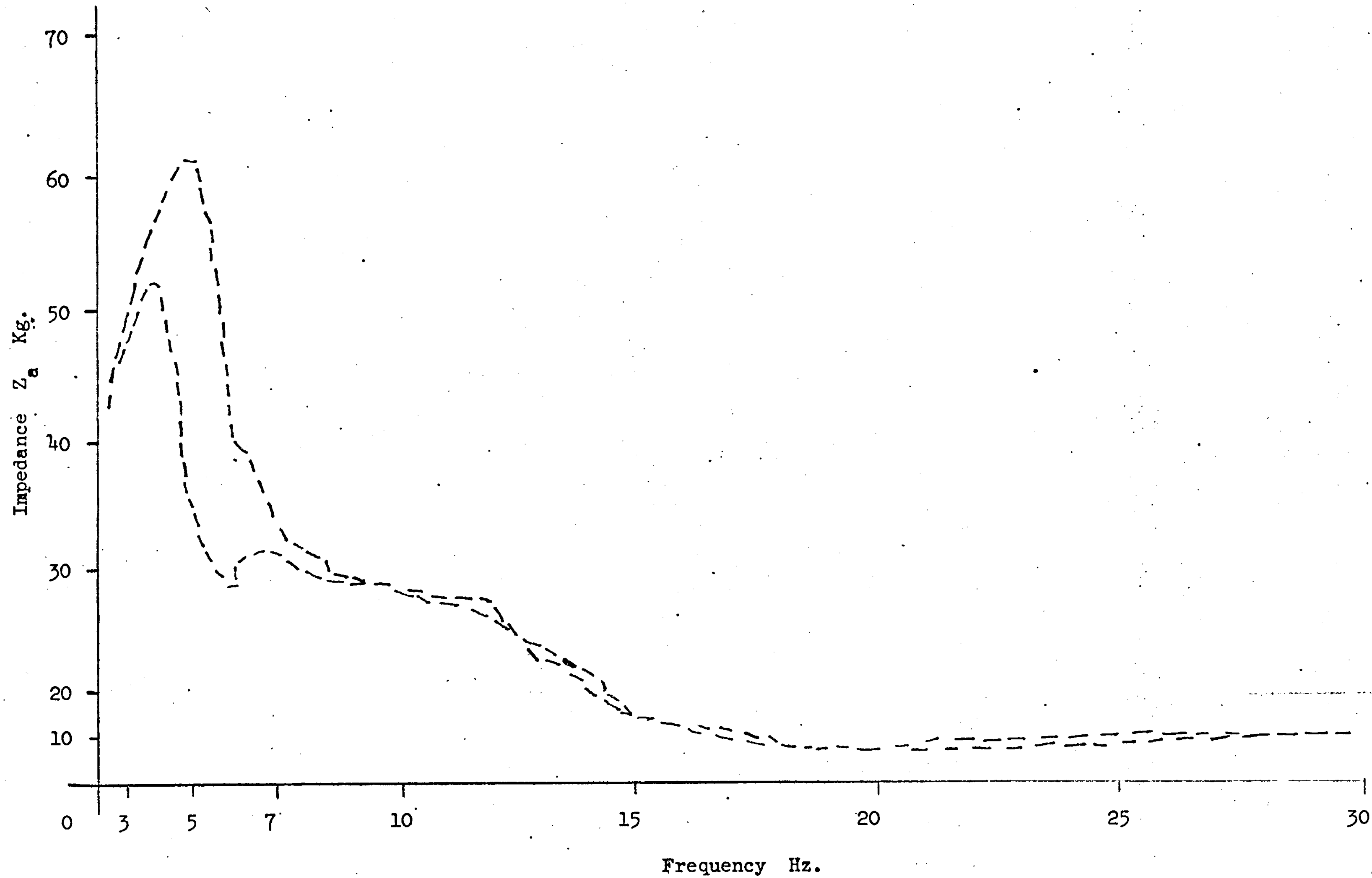


Figure No. 132 M14 - R

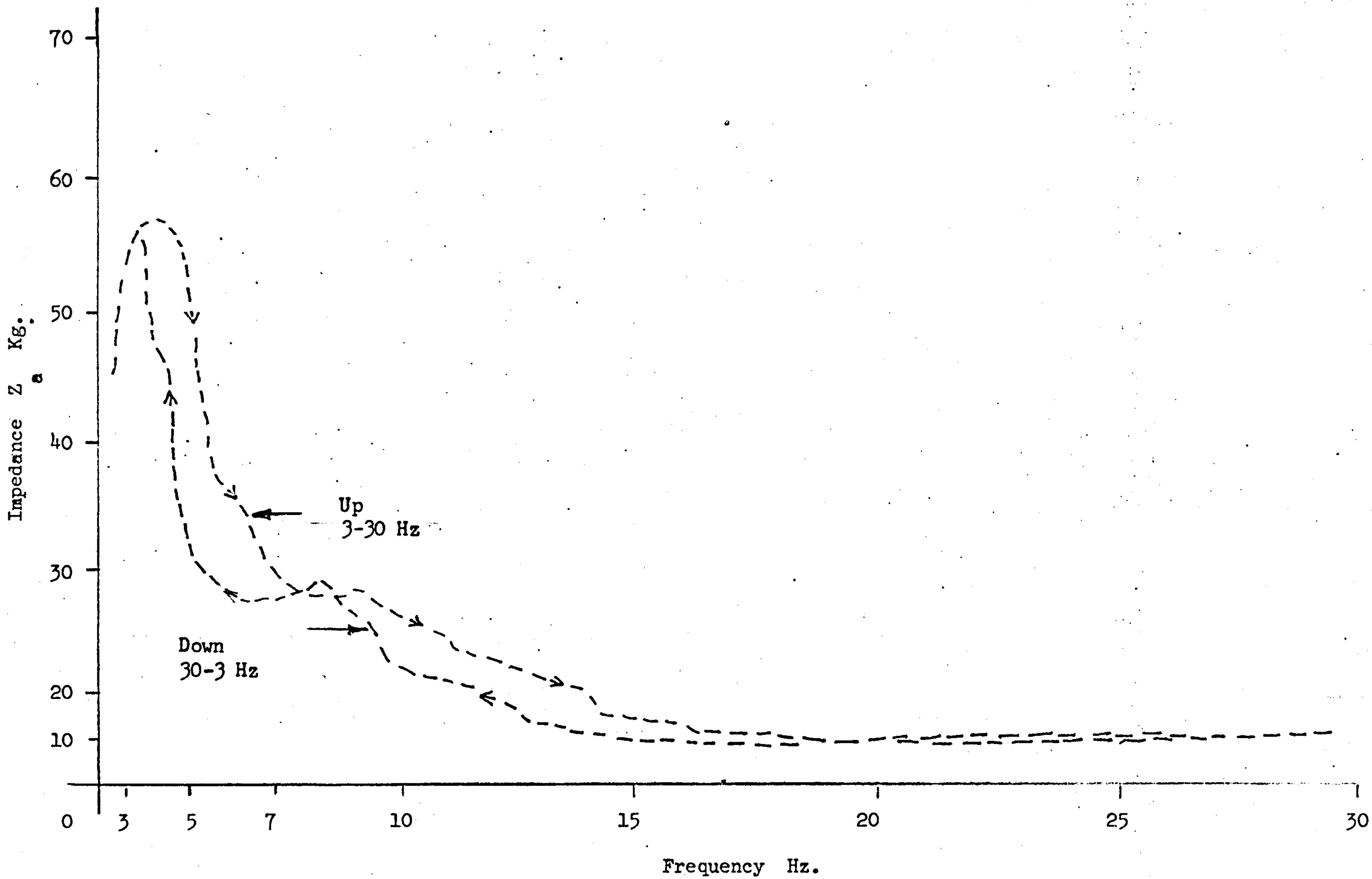
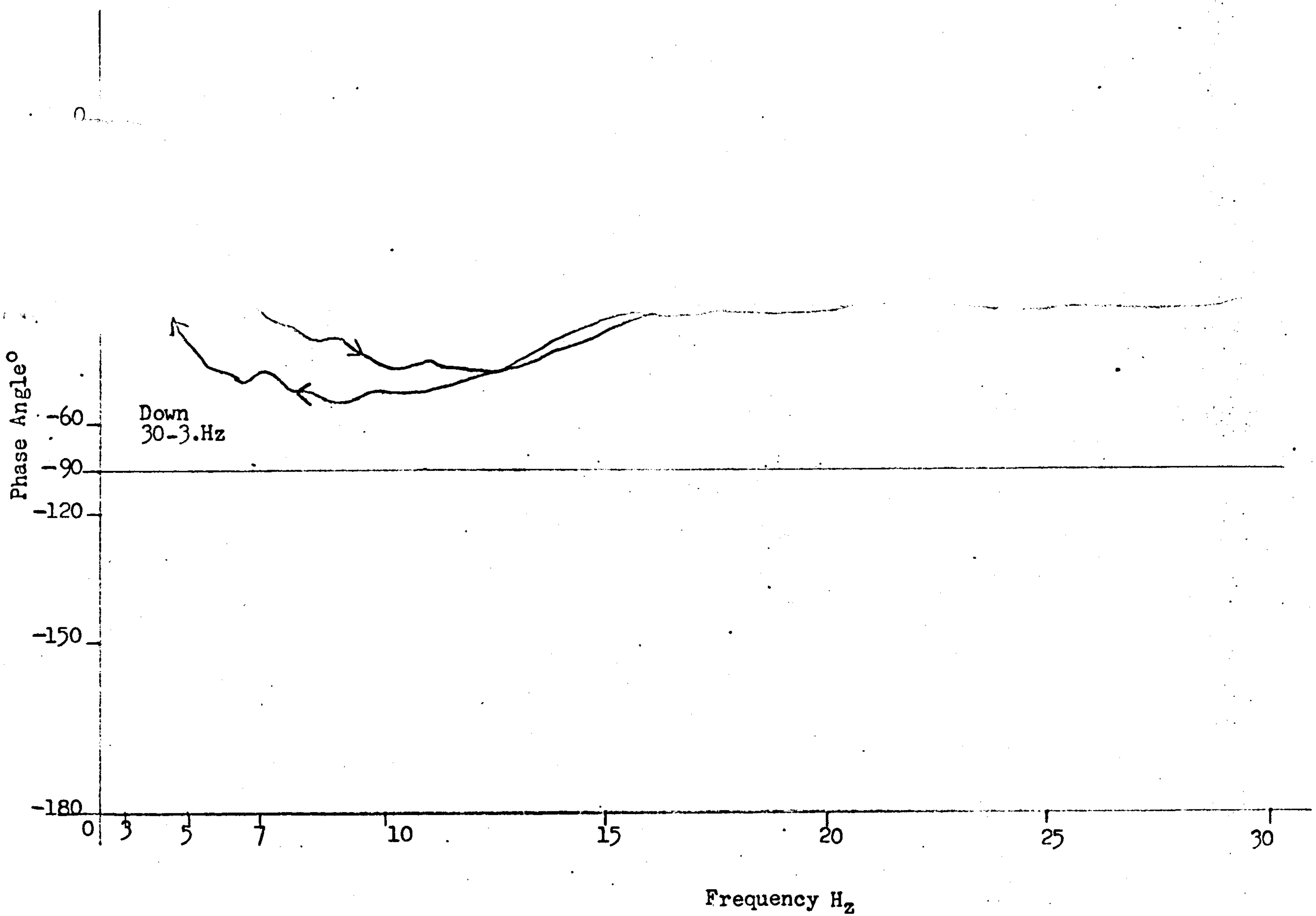


Figure No. 133 M15 - R

PHASE ANGLE RESULTS FOR

MALE SUBJECTS

SITTING RELAXED POSTURE



ure No. 134 M1 - R

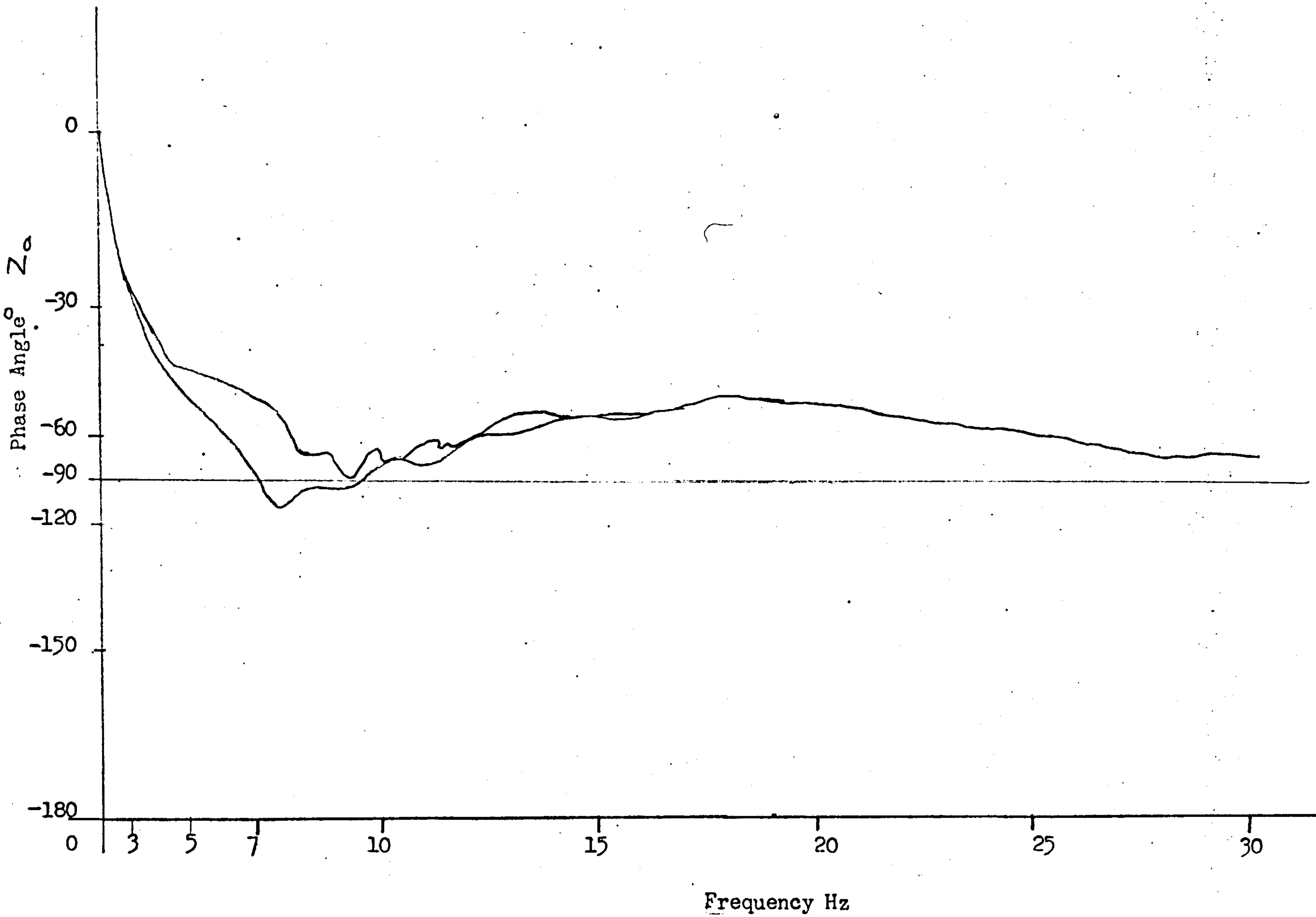


Figure No. 135 M2 - R.

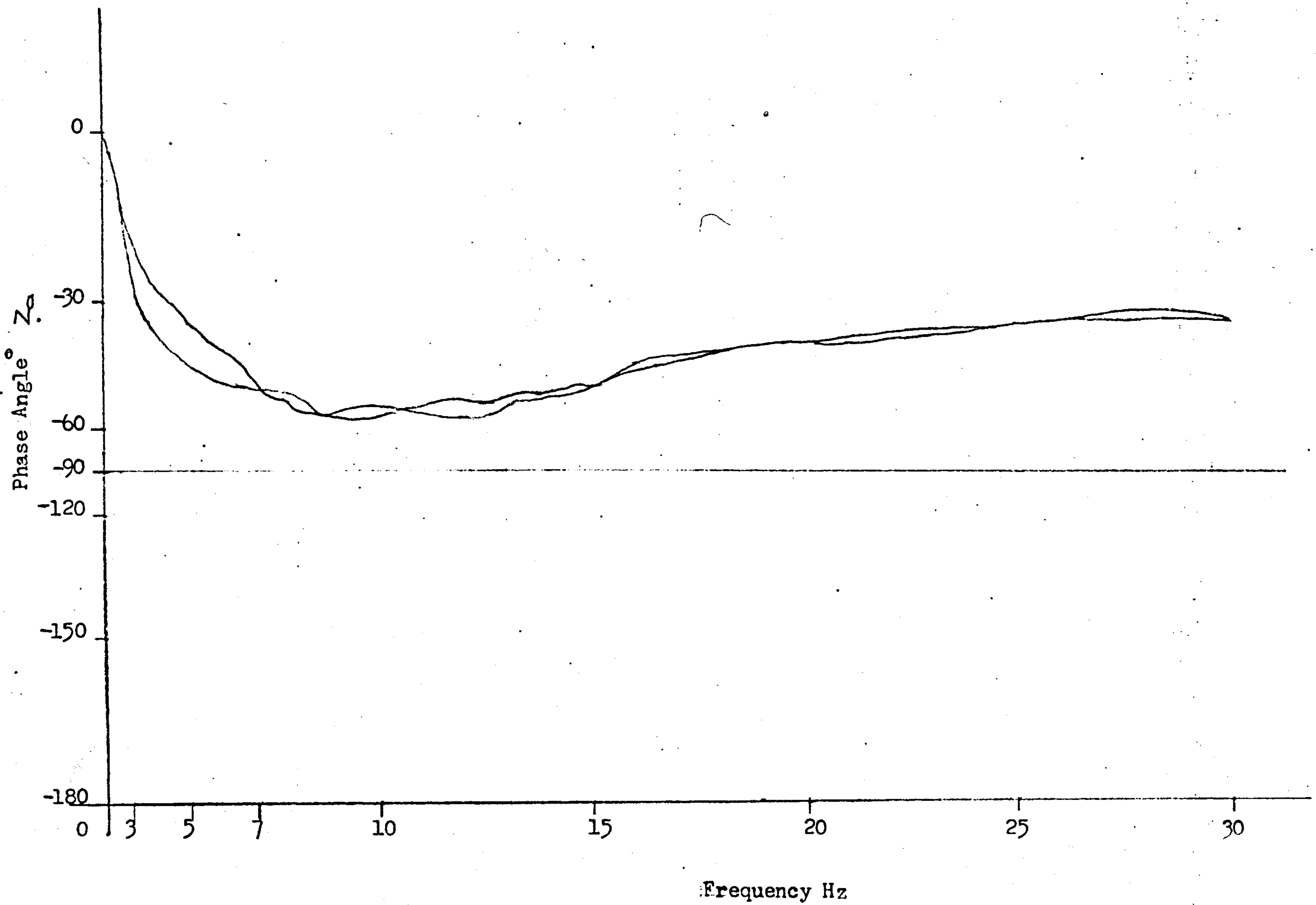


Figure No. 136 M3-R

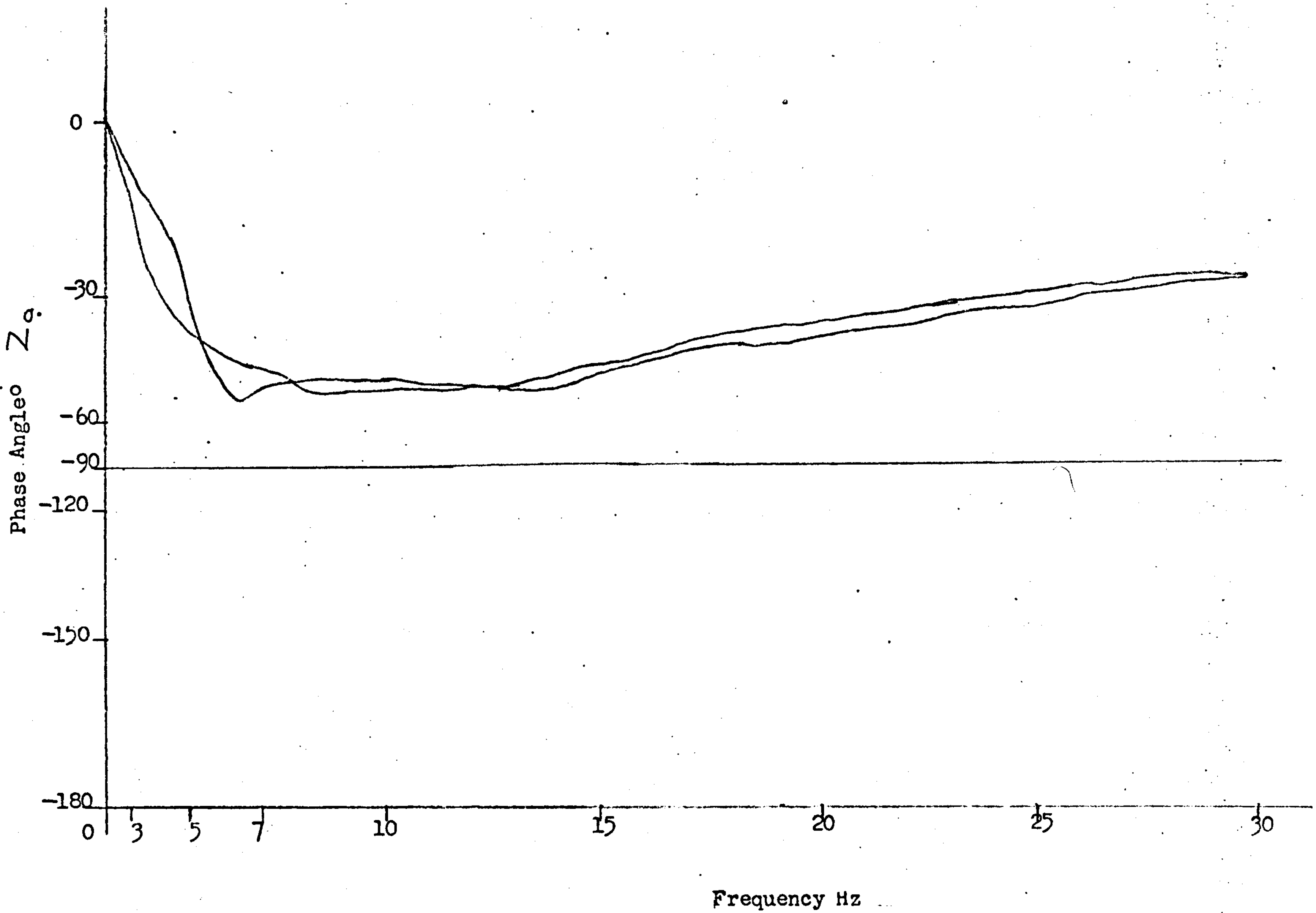


Figure No 137 M4 - R

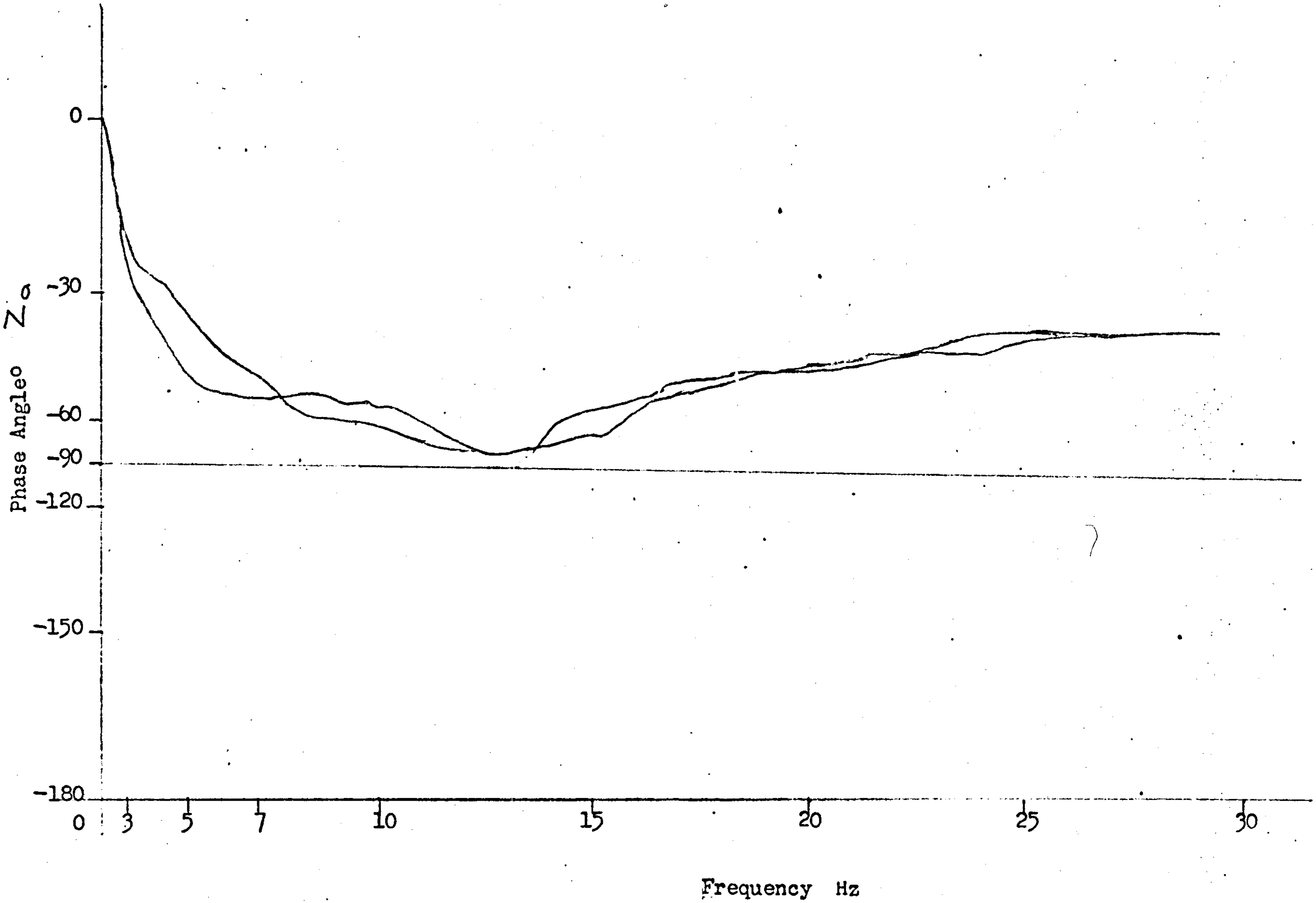


Figure No 138 M6 - R

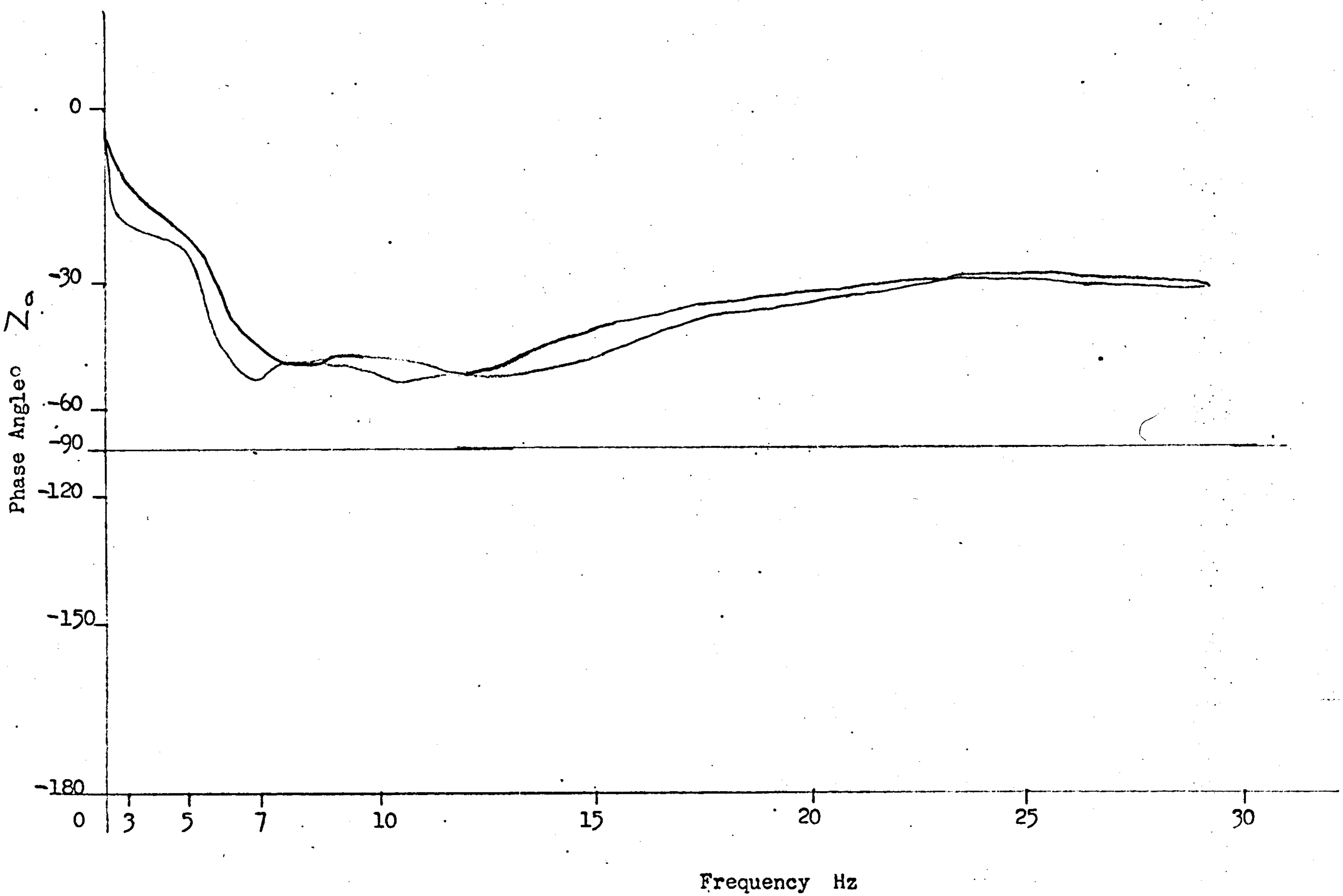


Figure No 139 M7 - R

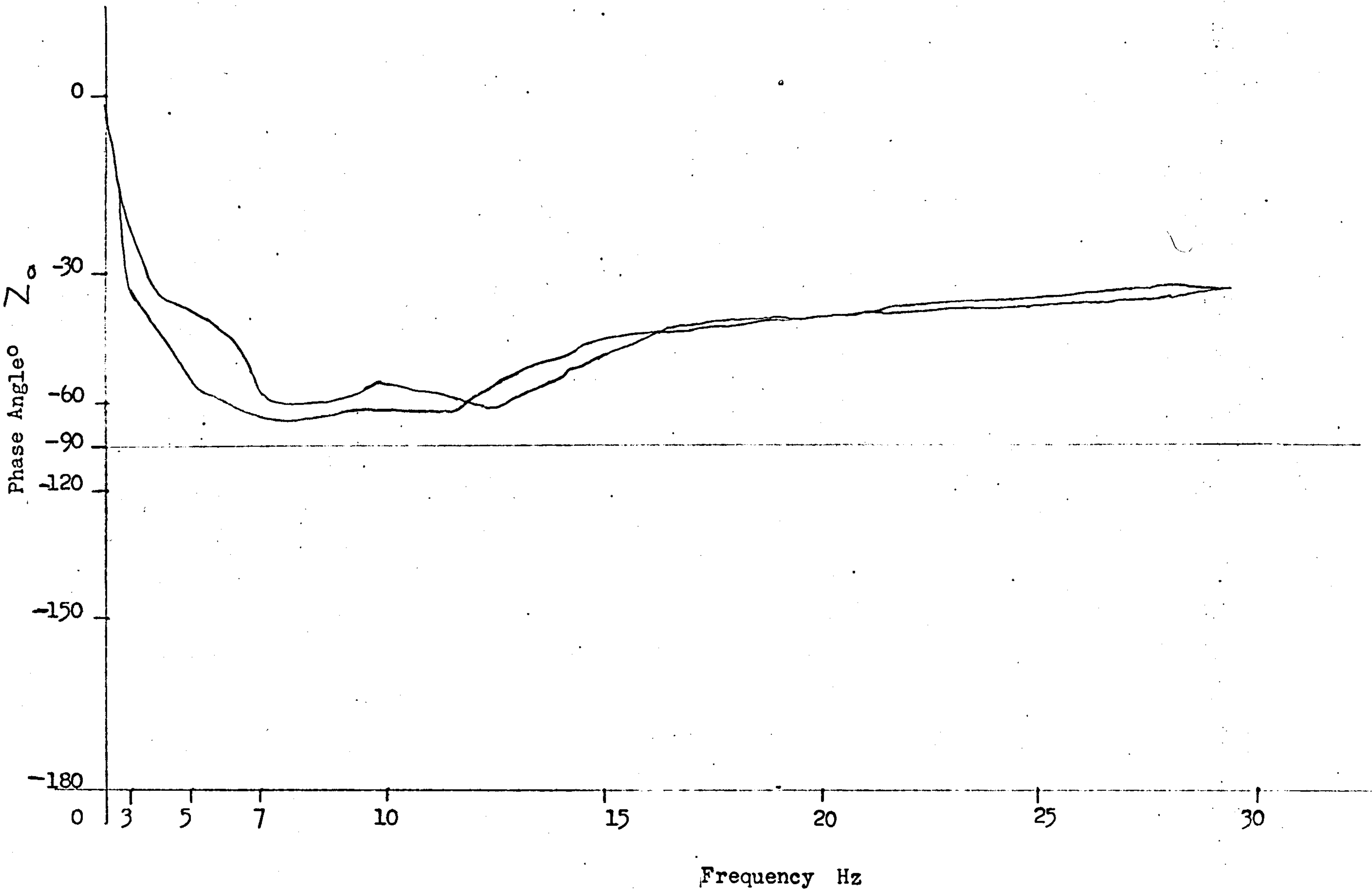


Figure No. 140 M8 - R

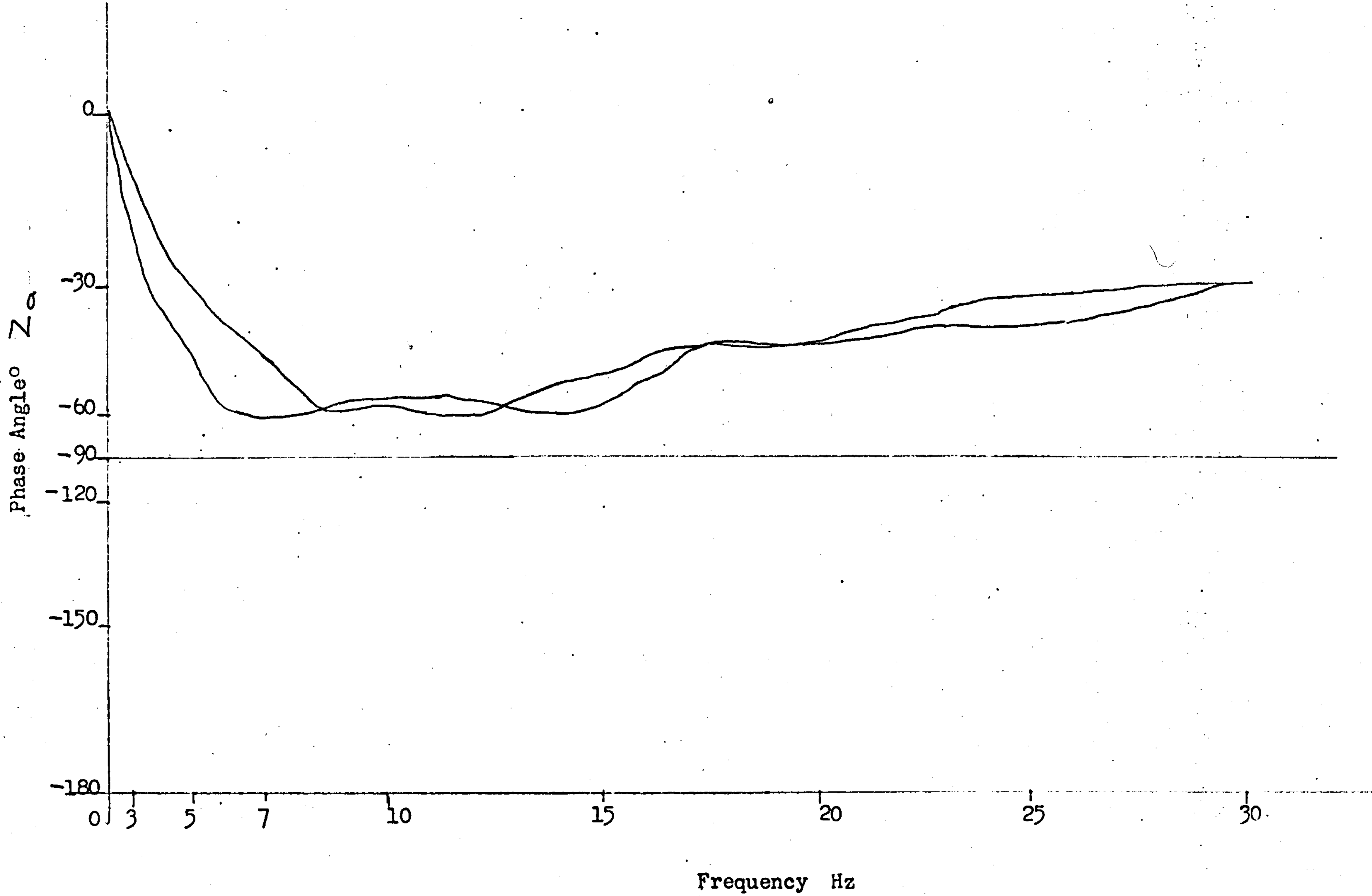


Figure No. 141 M9 - R

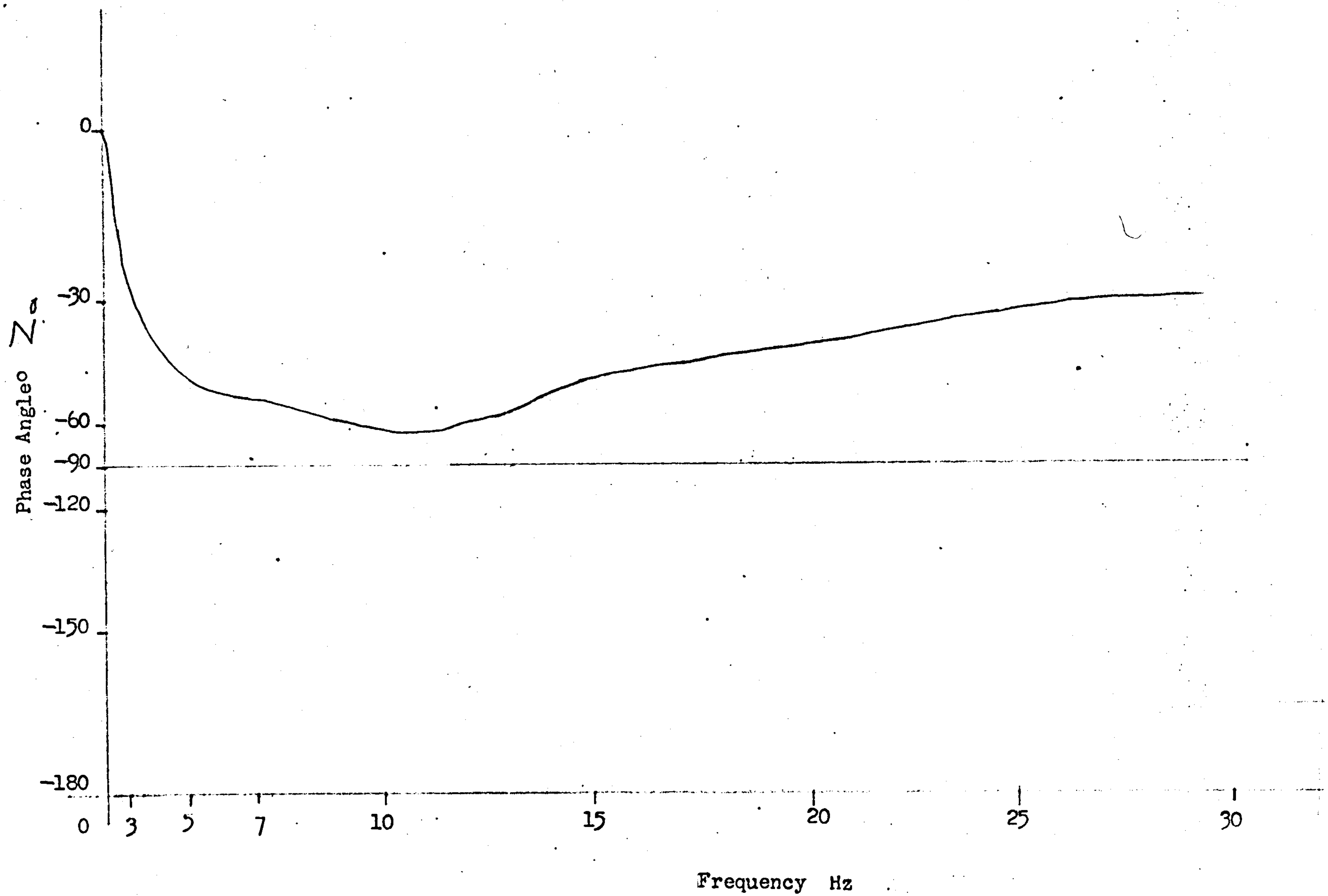


Figure No. 142 M10 - R

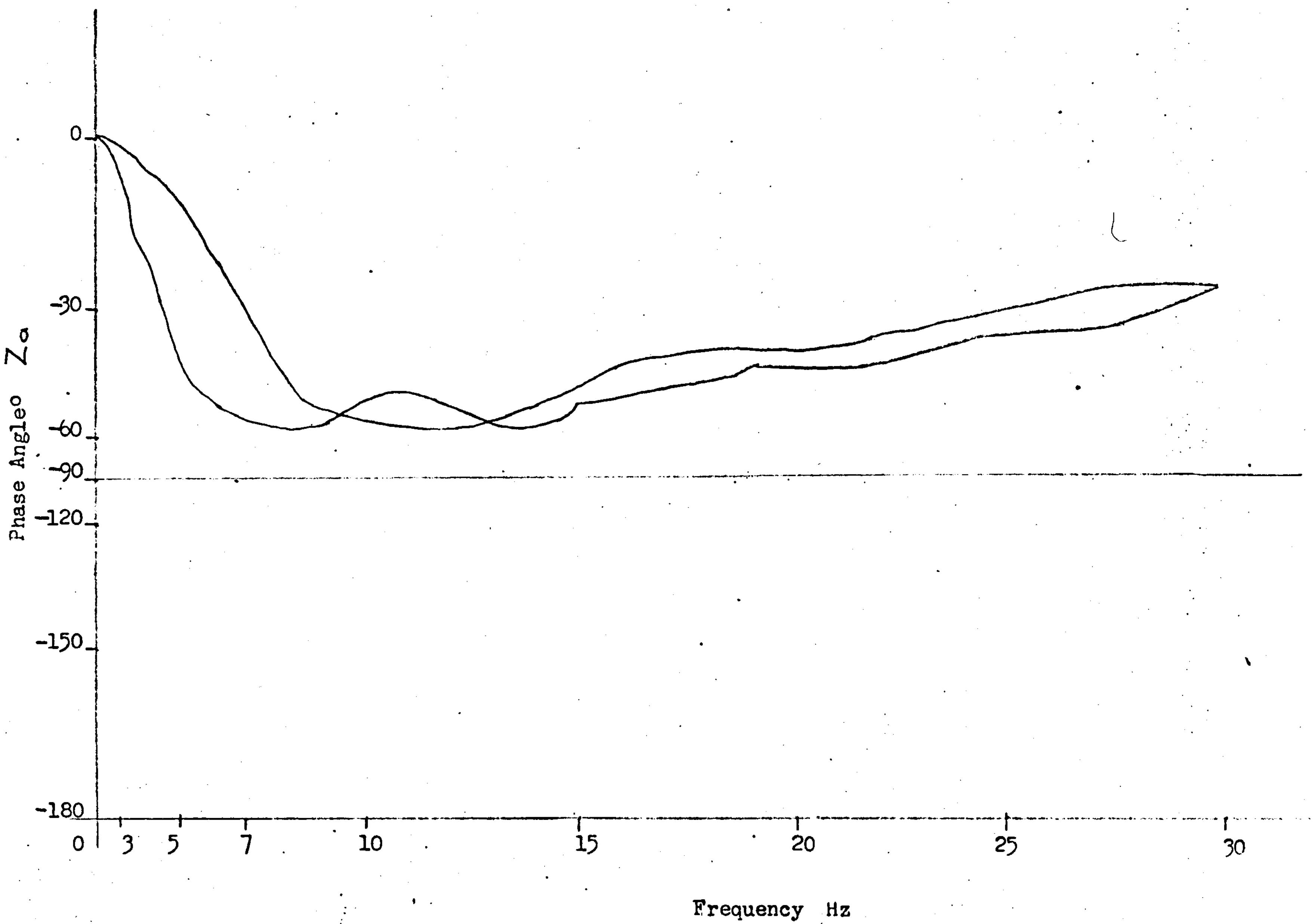


Figure No 143 M12 - R

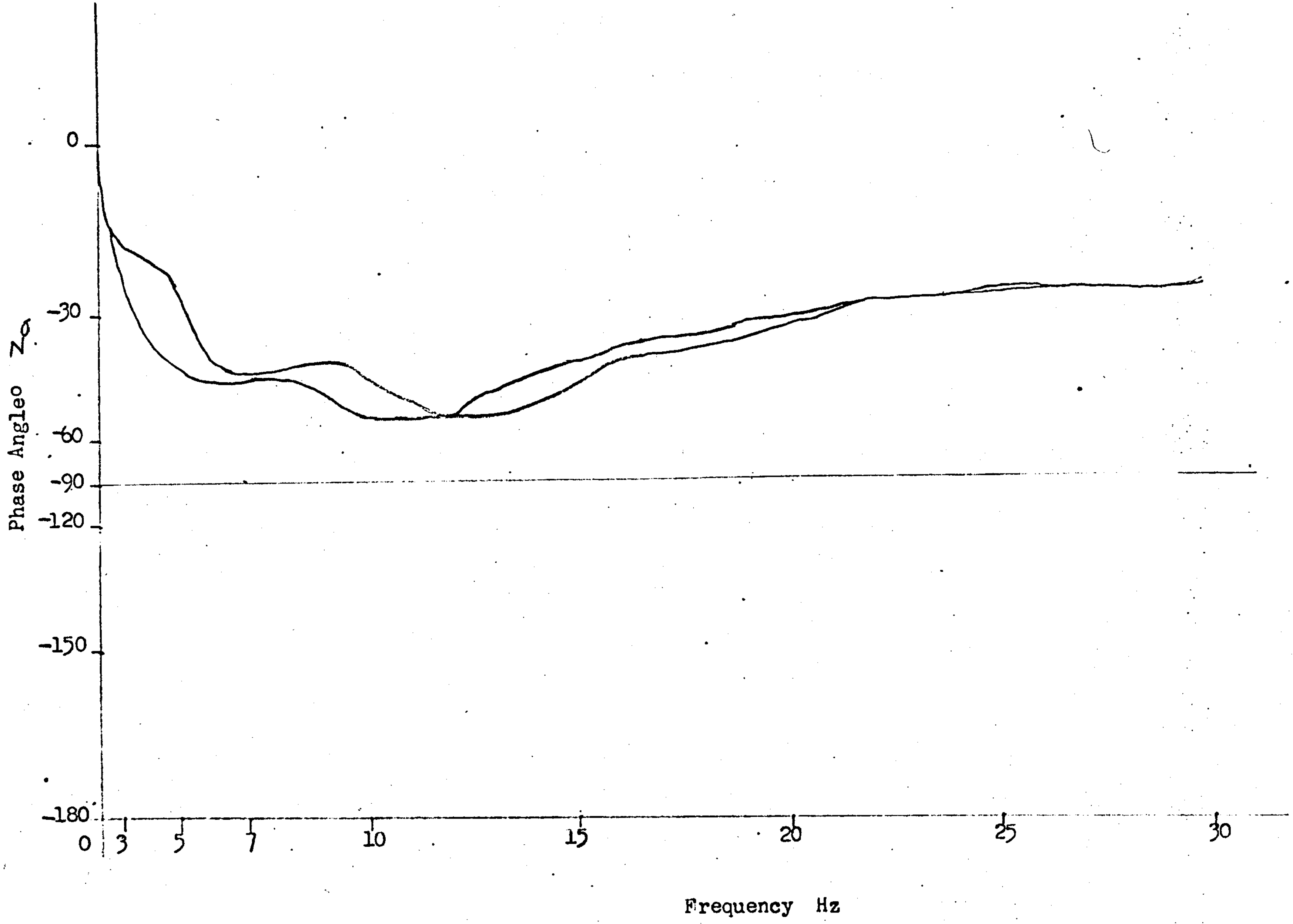


Figure No 144 M15 - R

MODULUS OF IMPEDANCE AND PHASE ANGLE RESULTS FOR

MALE SUBJECTS

TRACKING POSTURE

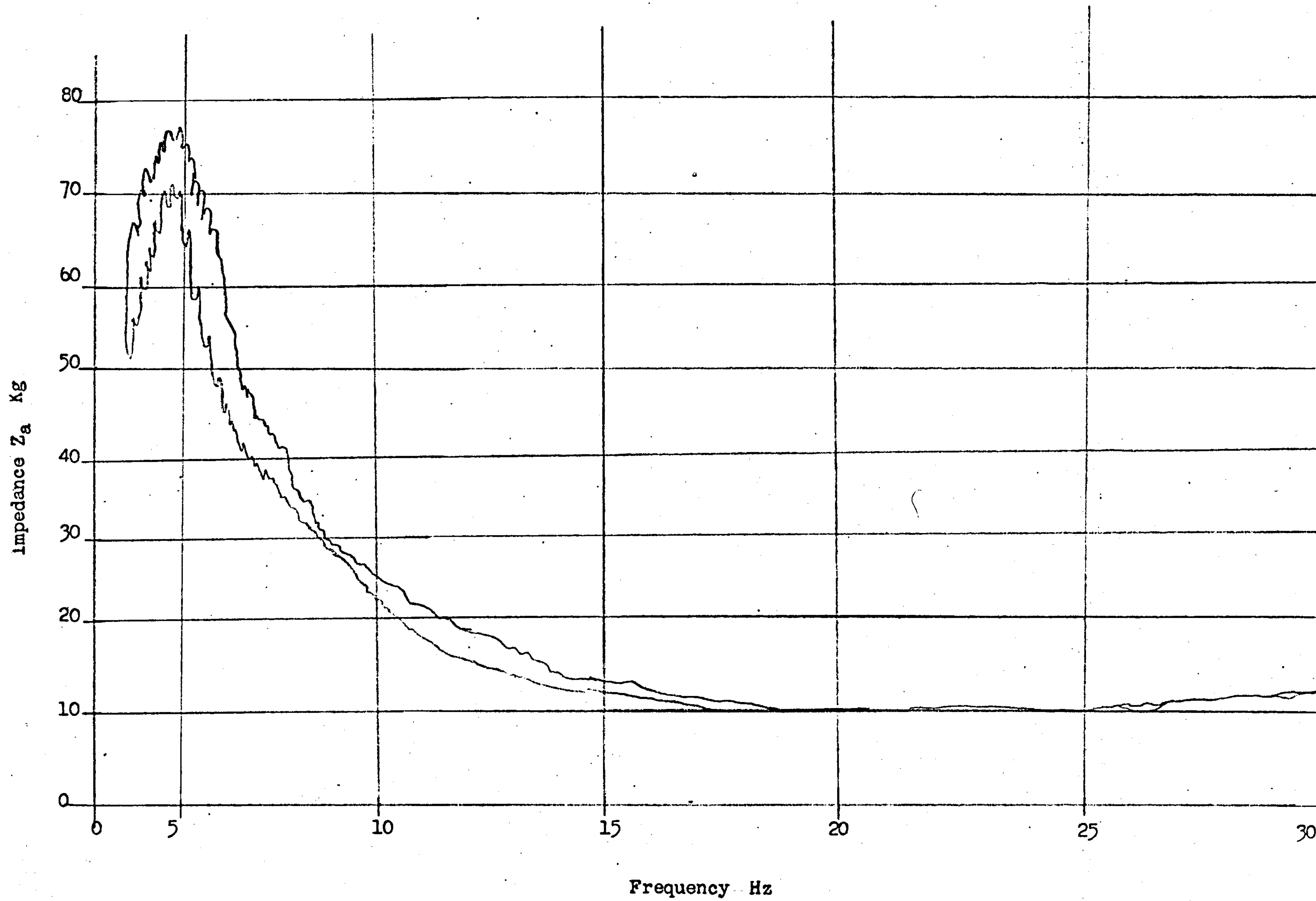


Figure No. 145 ML - T.

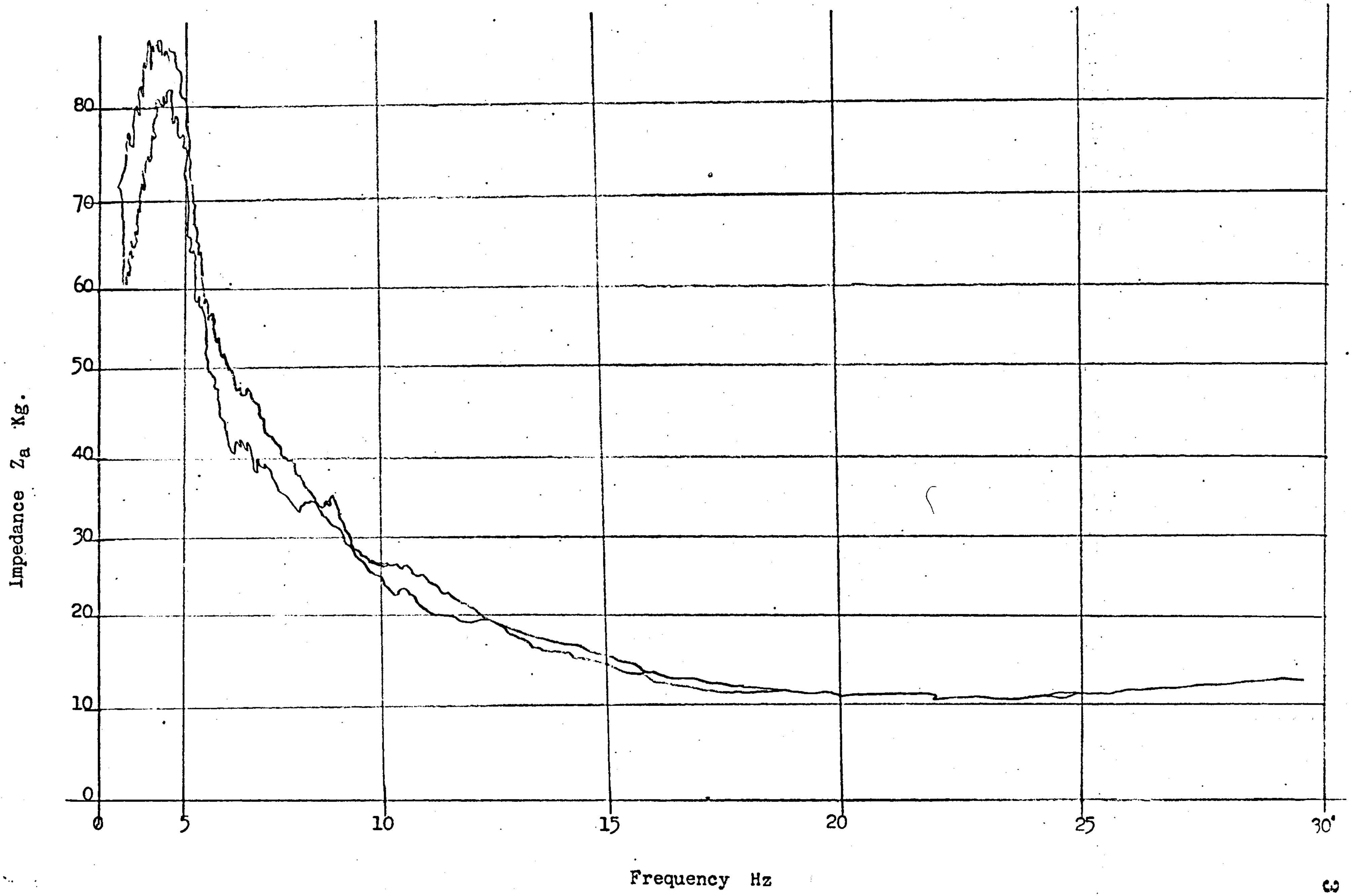


Figure No 146 M2 - T

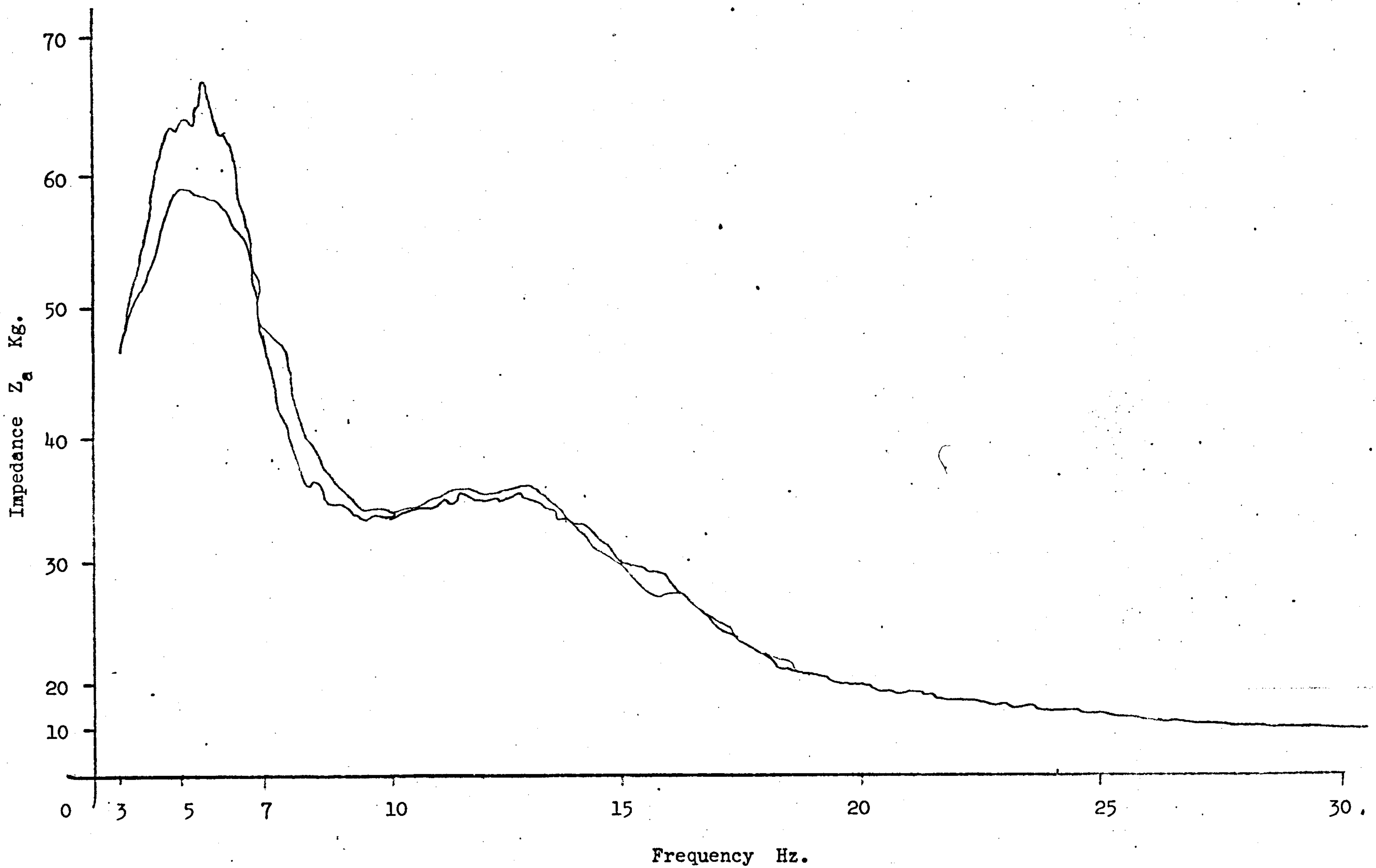


Figure No. 147 M3 - T

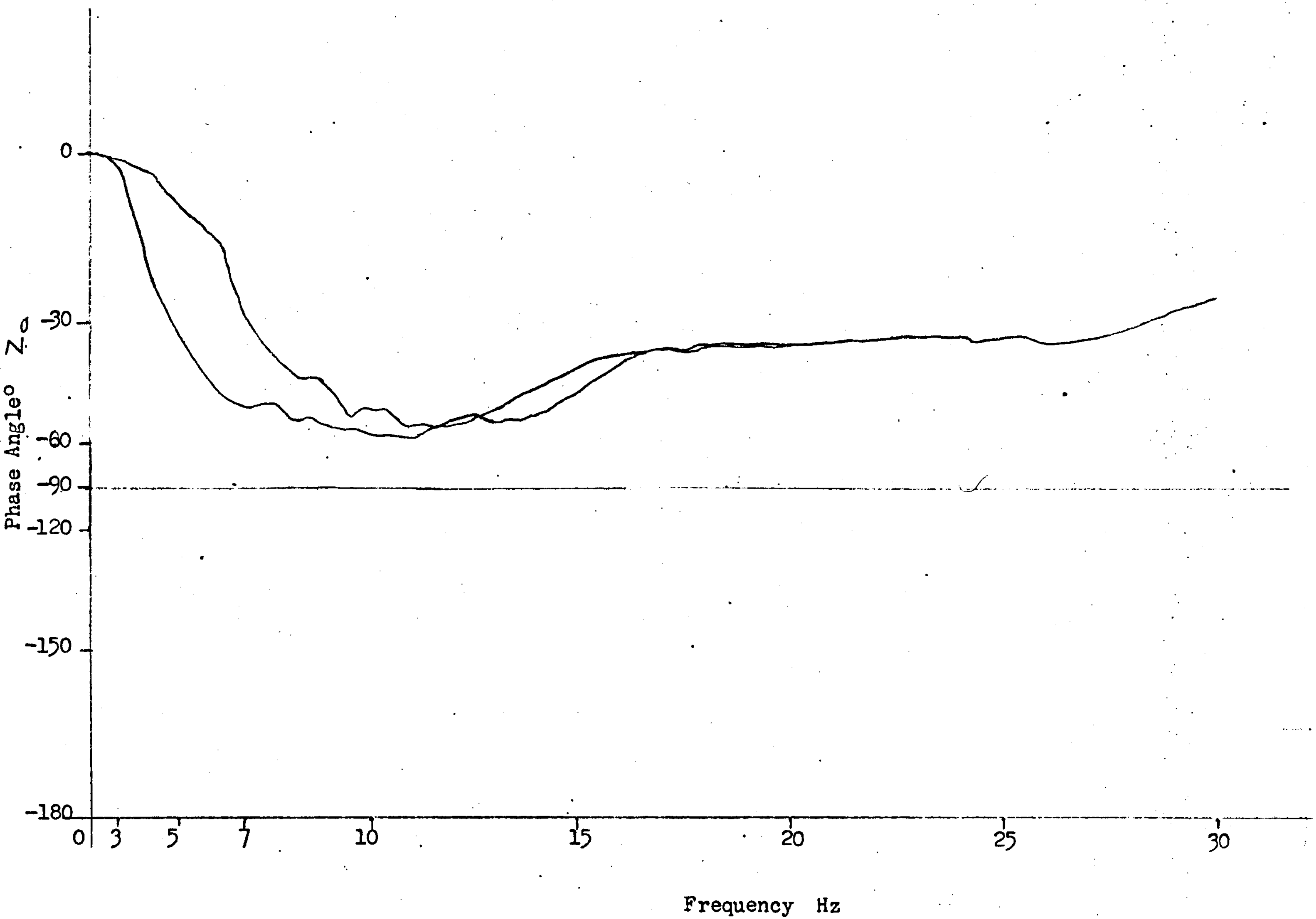


Figure No. 148 ML - 1

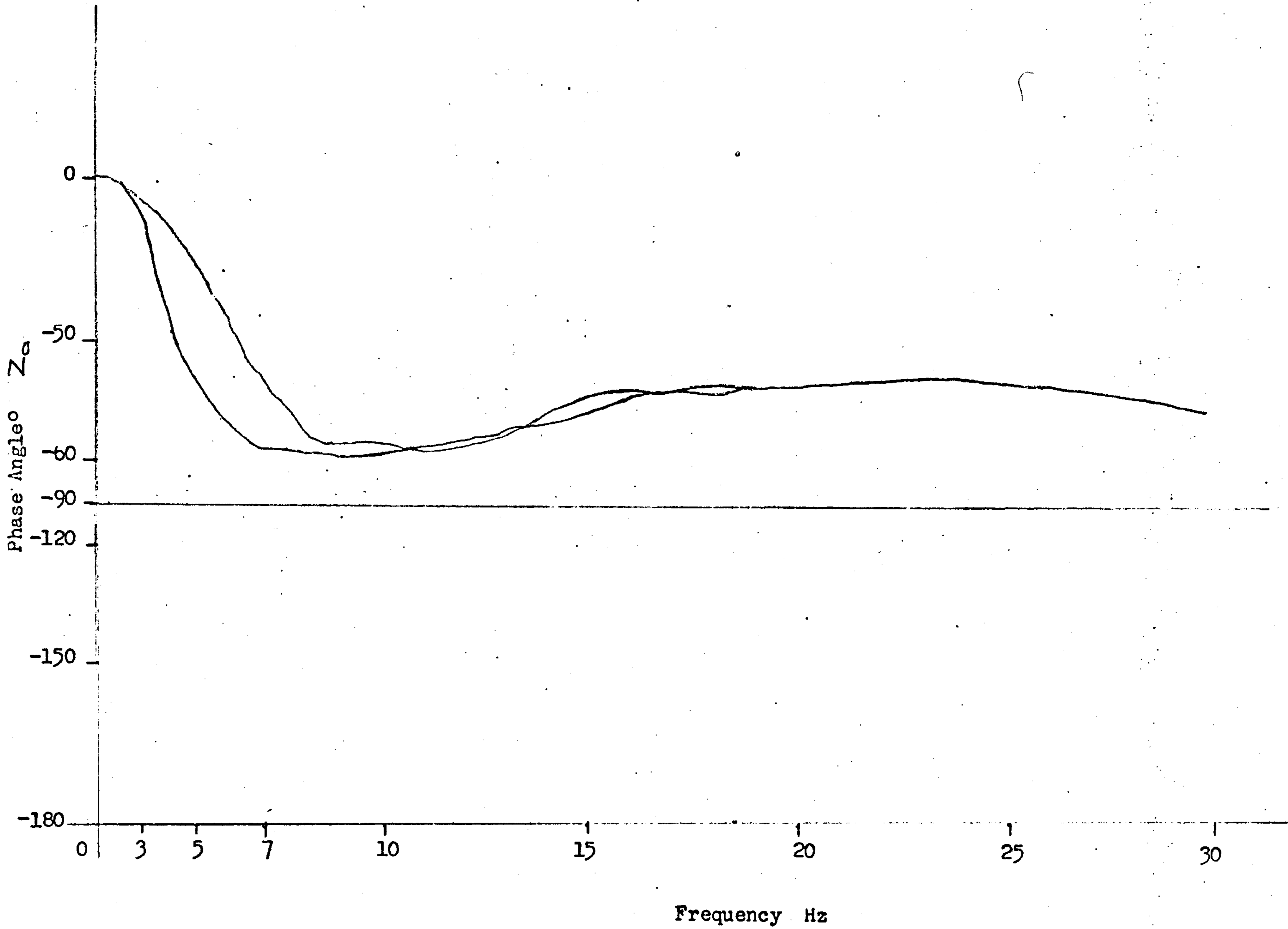


Figure No. 149 M2 - T

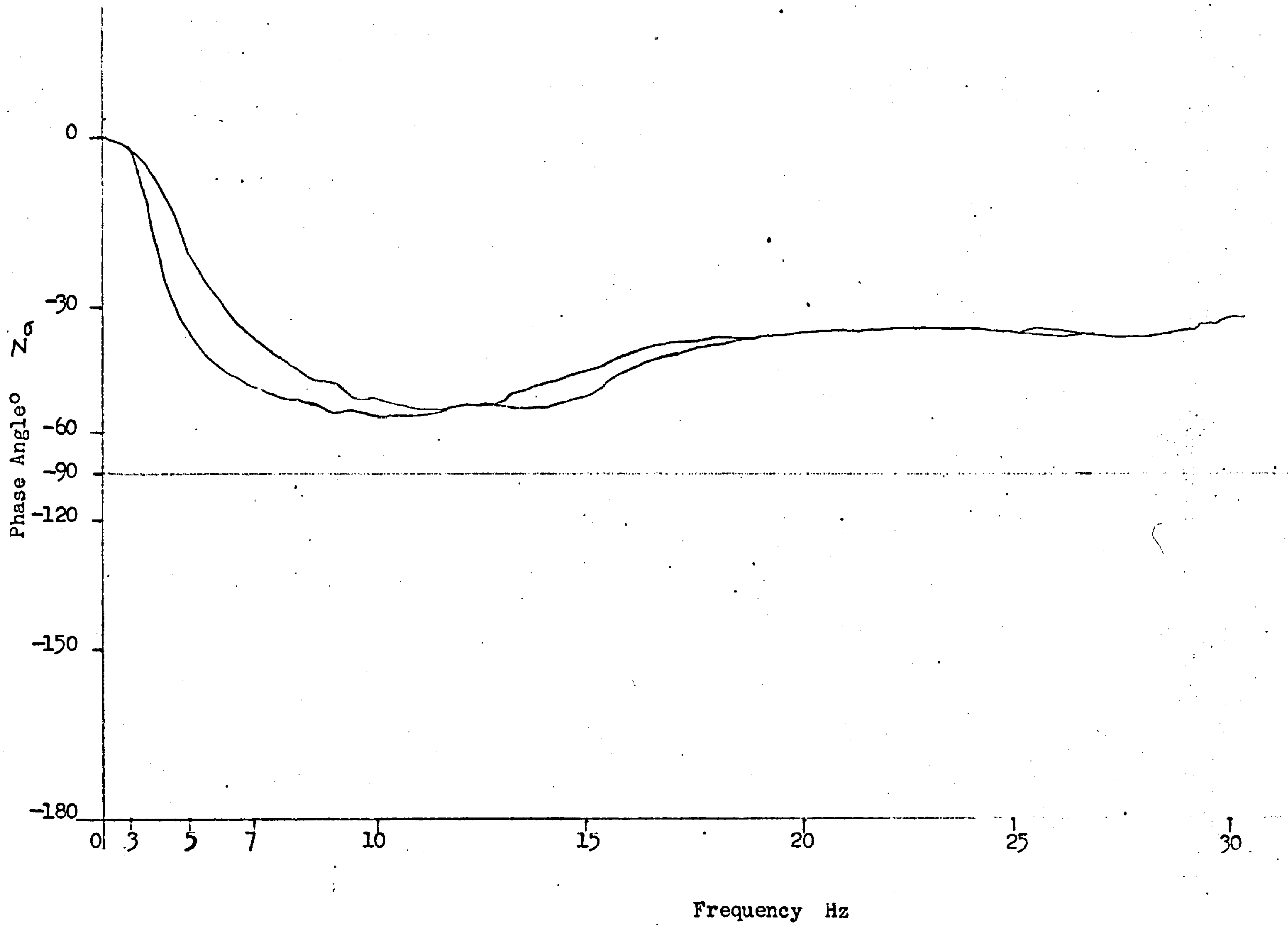


Figure No.150 M3 - T

MODULUS OF IMPEDANCE AND PHASE ANGLE RESULTS FOR

MALE SUBJECTS

VARIOUS STANDING POSTURES

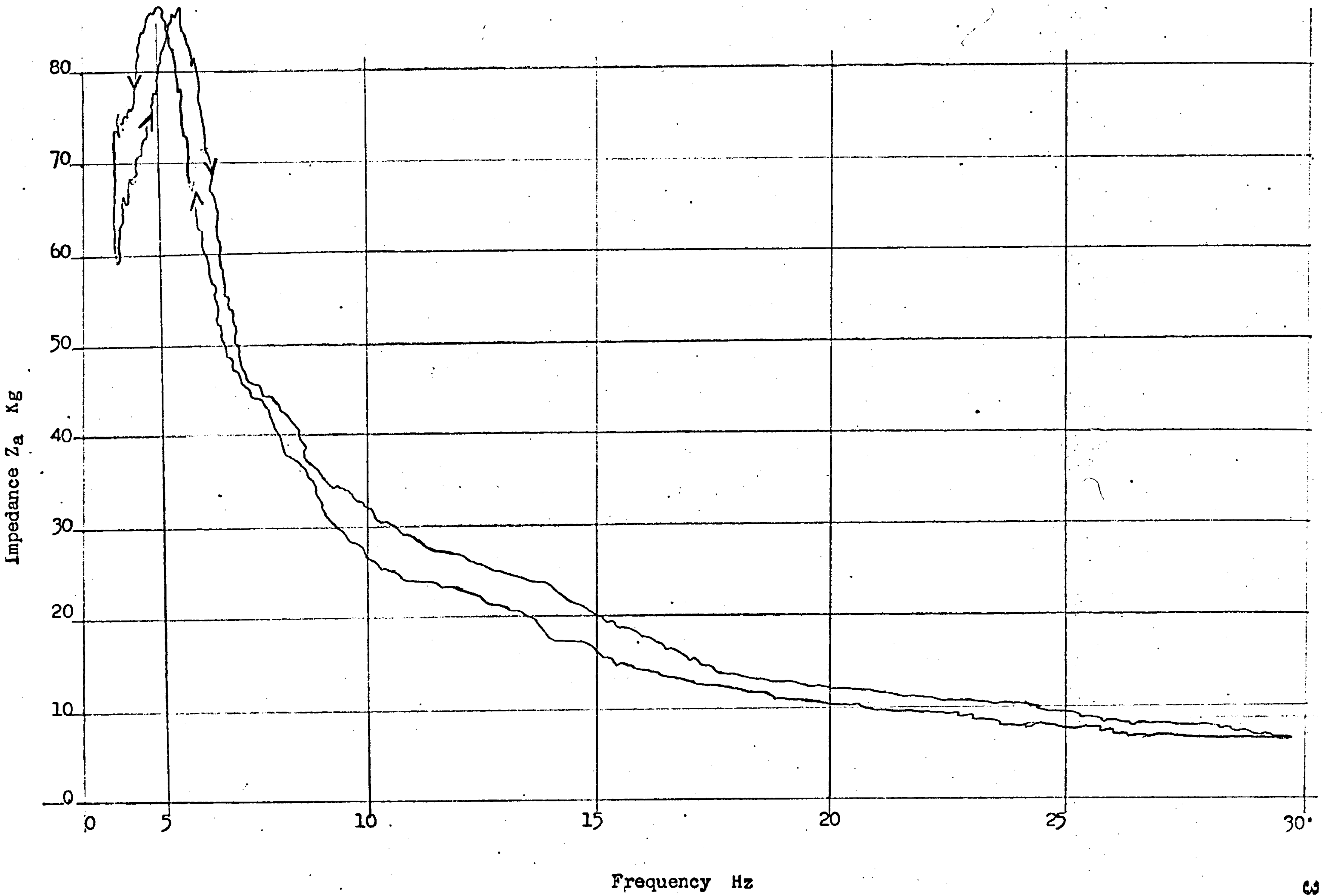


Figure No 51 M 1. - Standing Erect

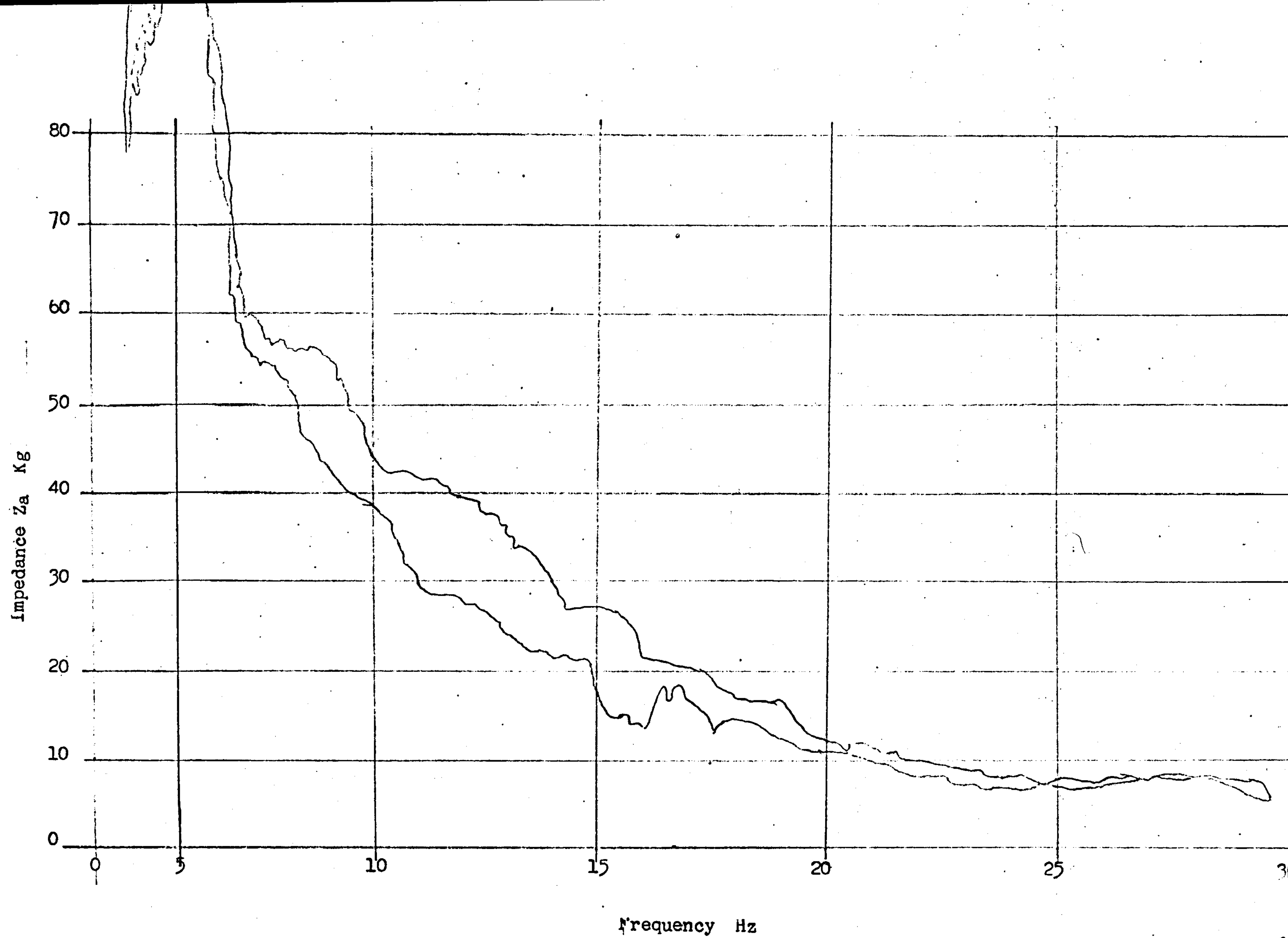


Figure No.52 M 2. - Standing Erect

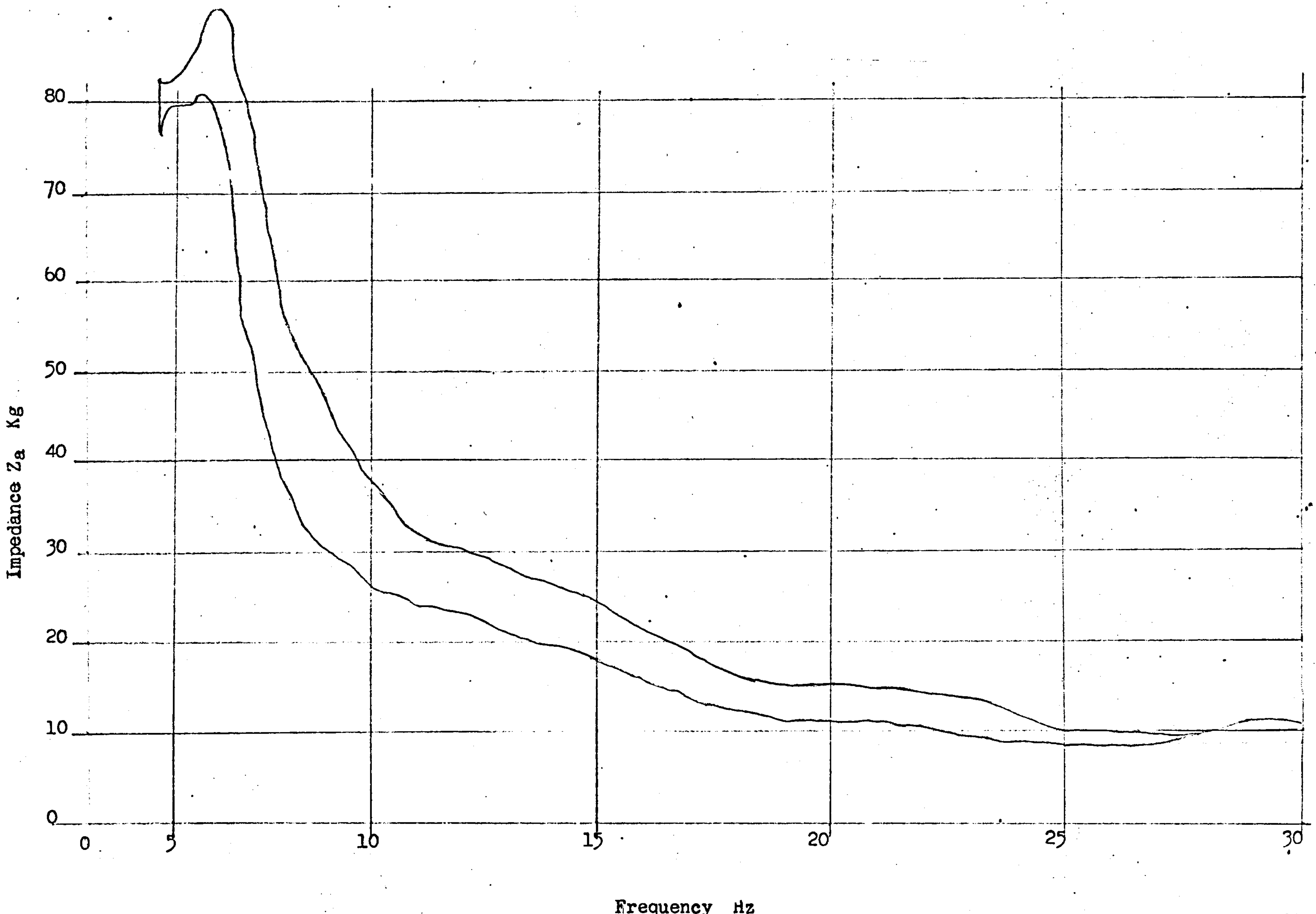


Figure No. 153 M 1. - Standing Relaxed

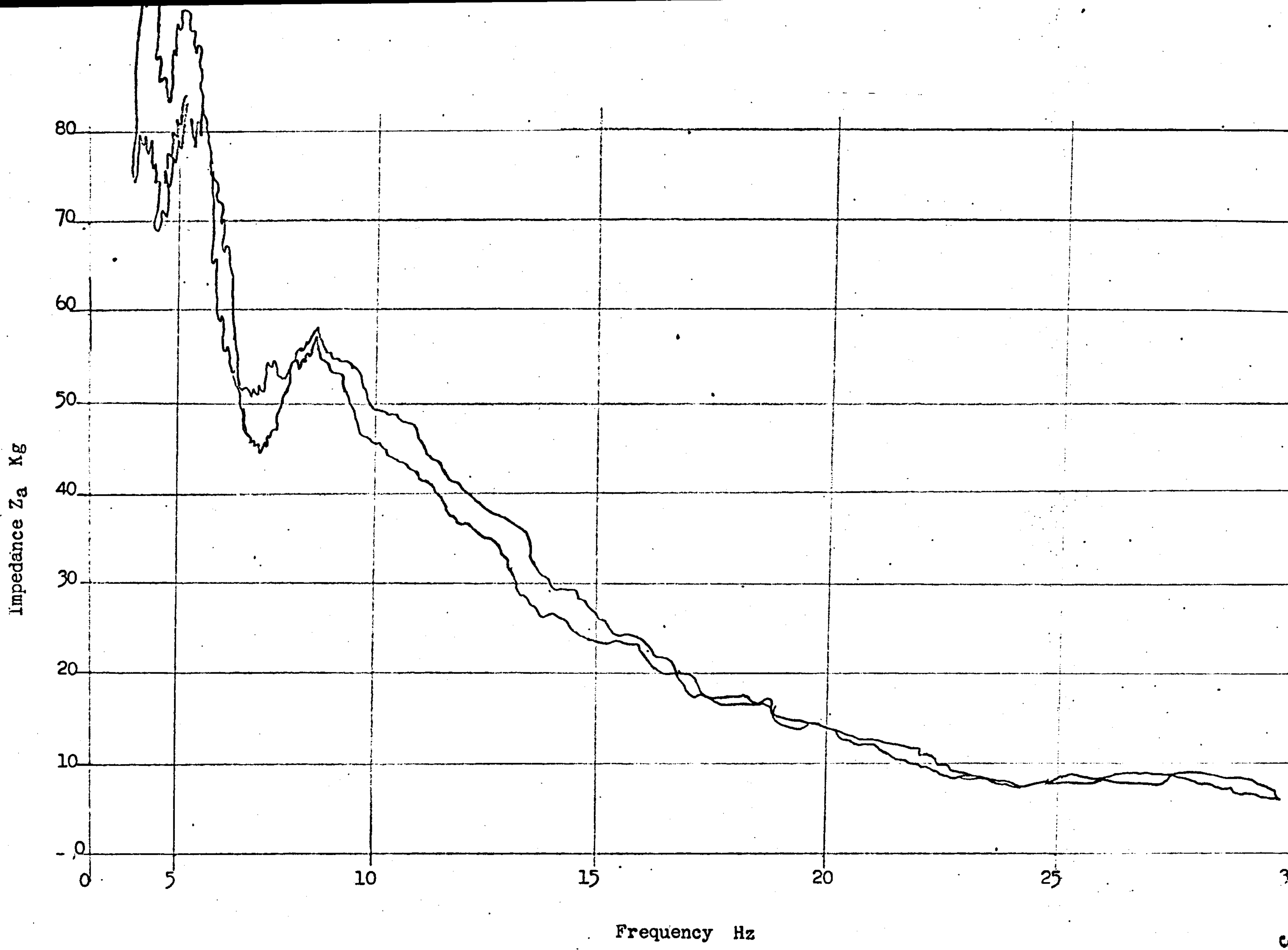


Figure No. 154 M 2. - Standing Relaxed

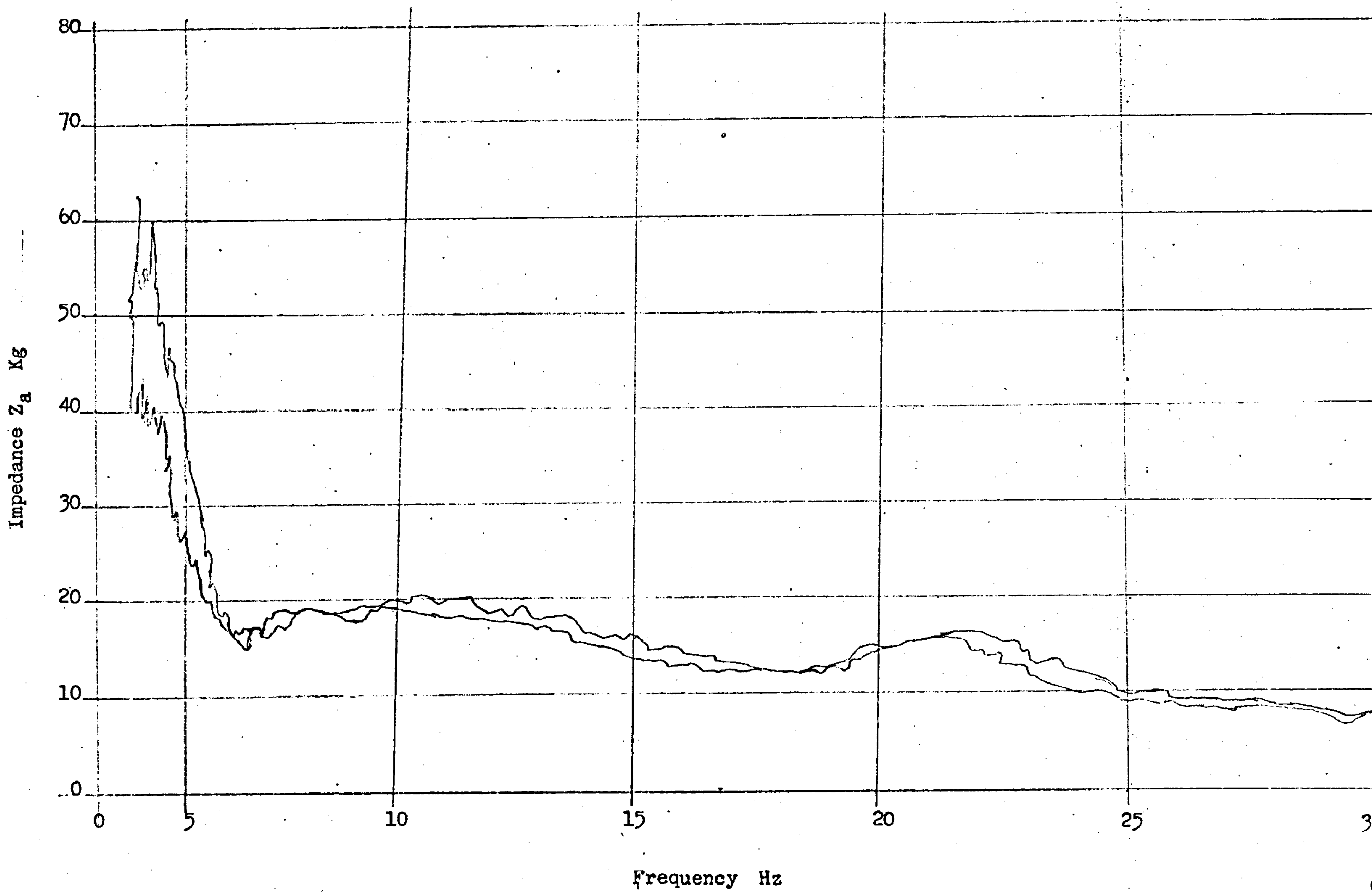


Figure No. 155 M 1. - Standing Knees Bent

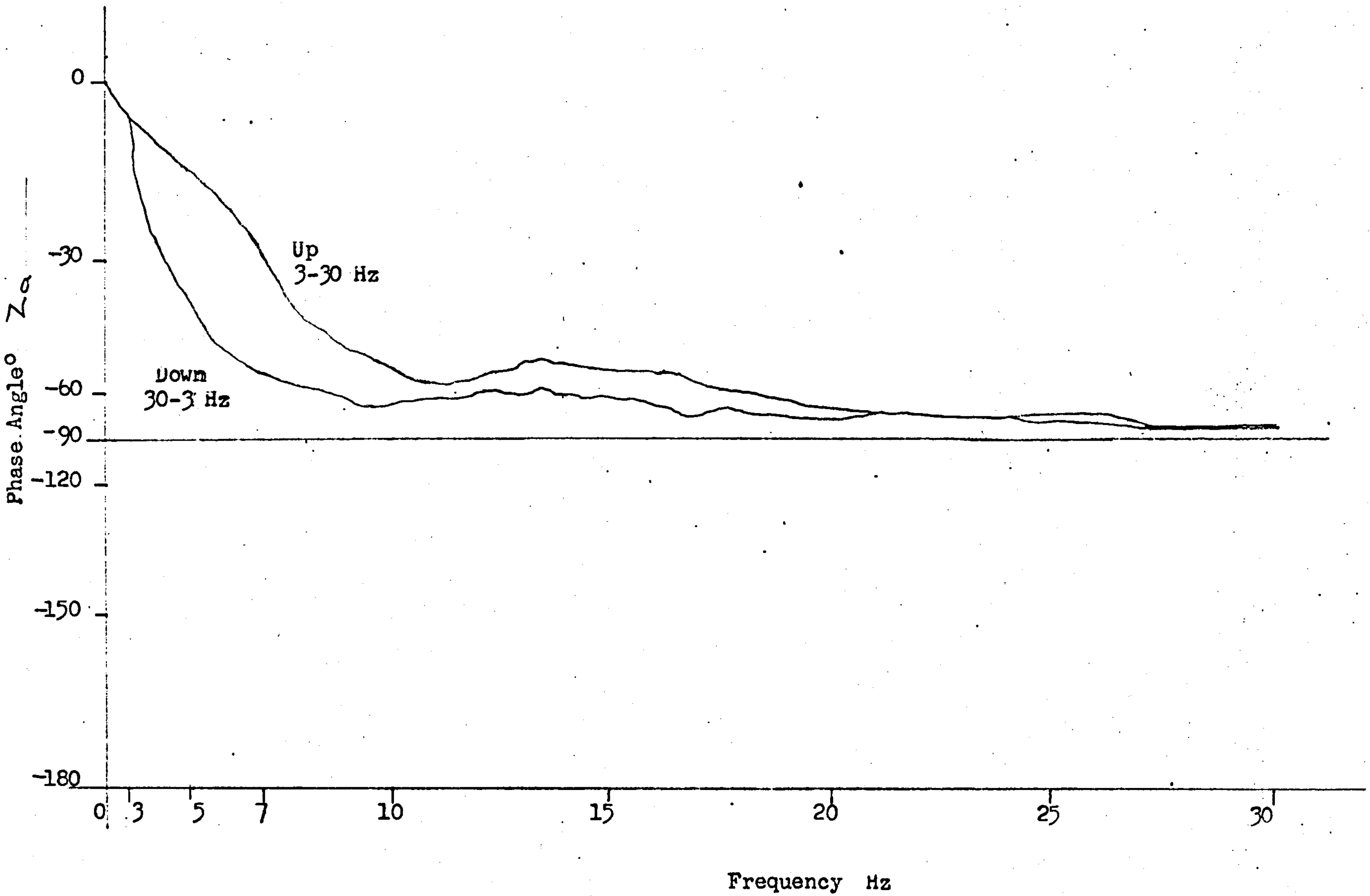


Figure No. 156 M1 - Standing Erect

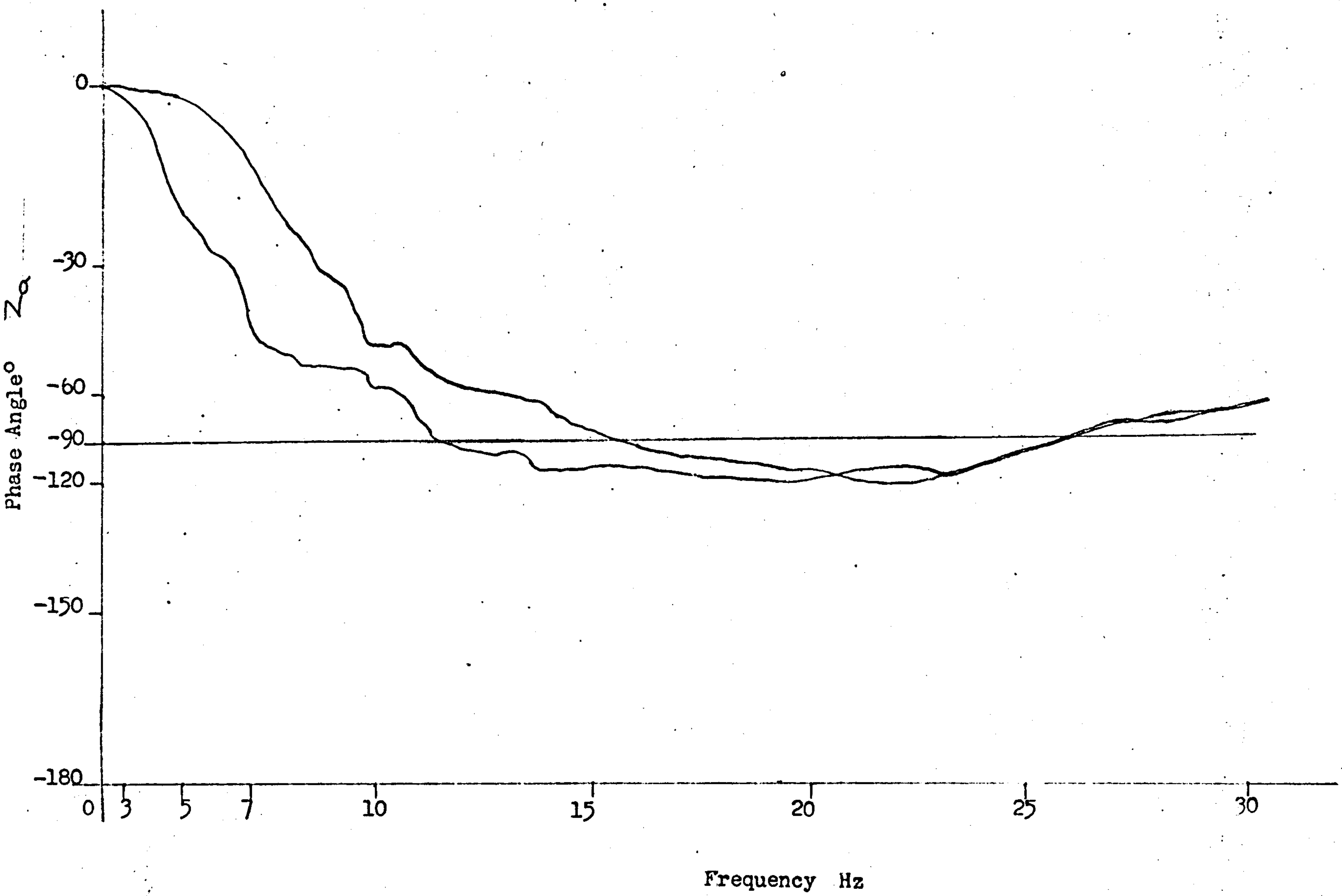


Figure No 157 M2 - Standing Erect

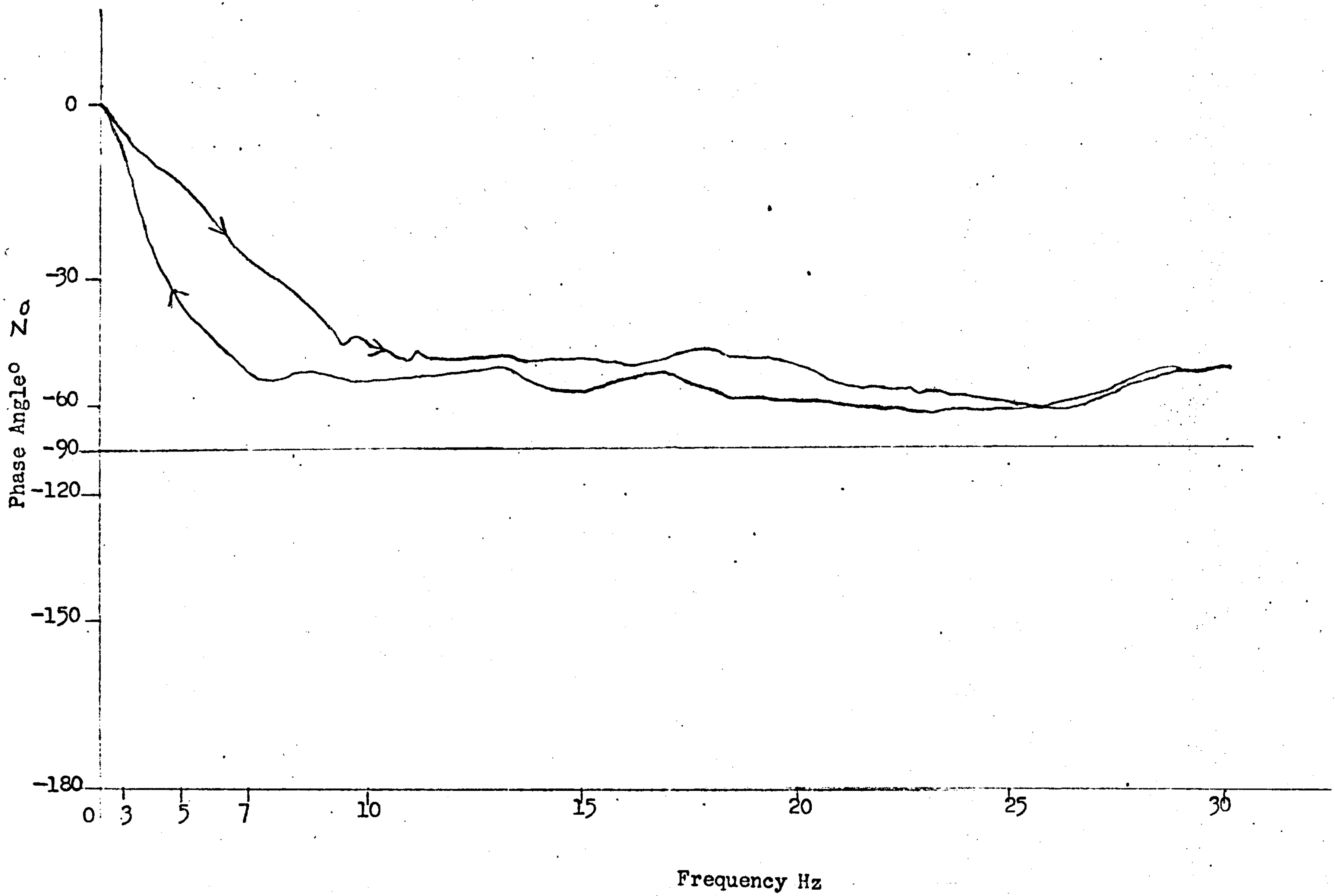


Figure No. 158ML - Standing Relaxed

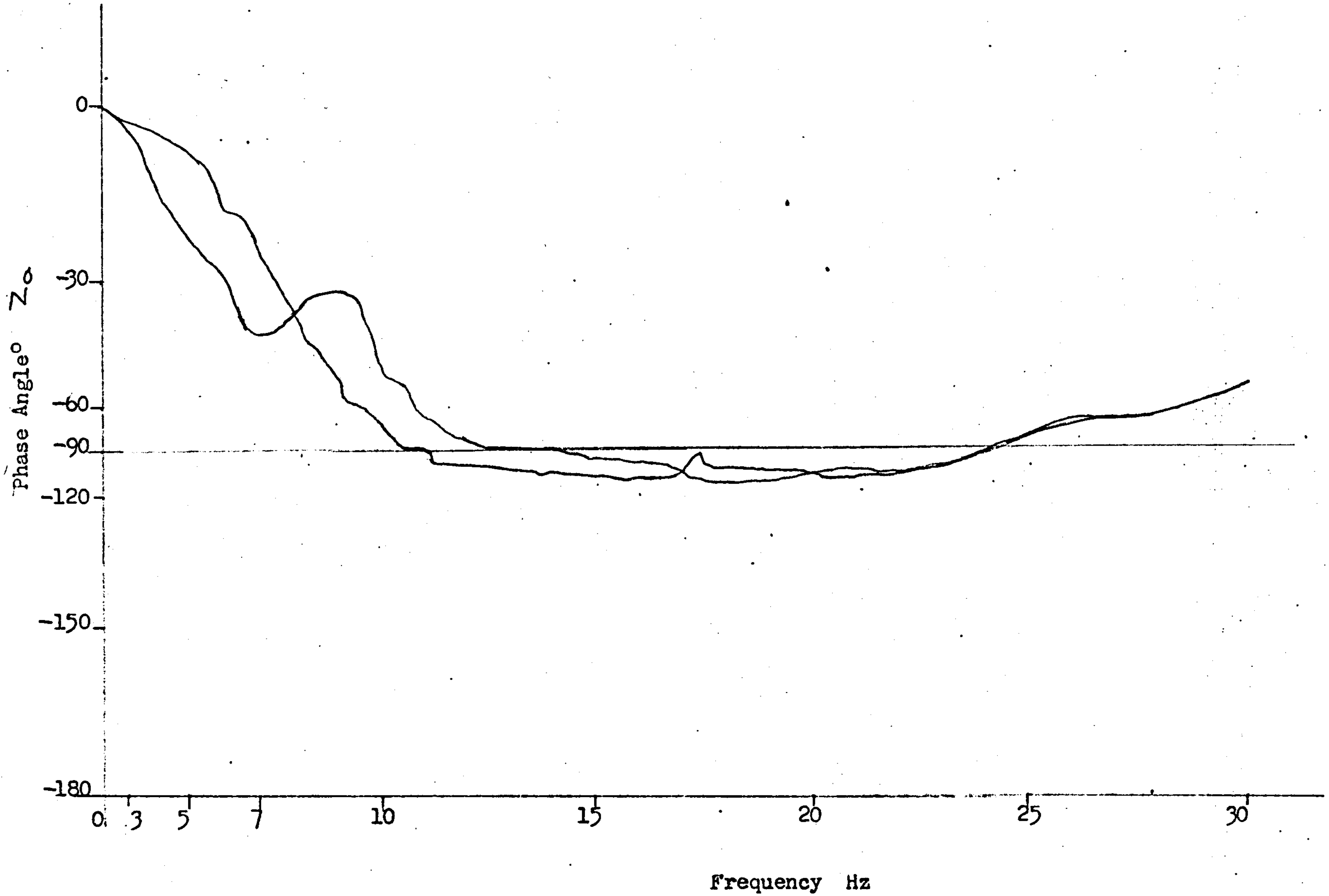


Figure No. 159 M2 - Standing Relaxed

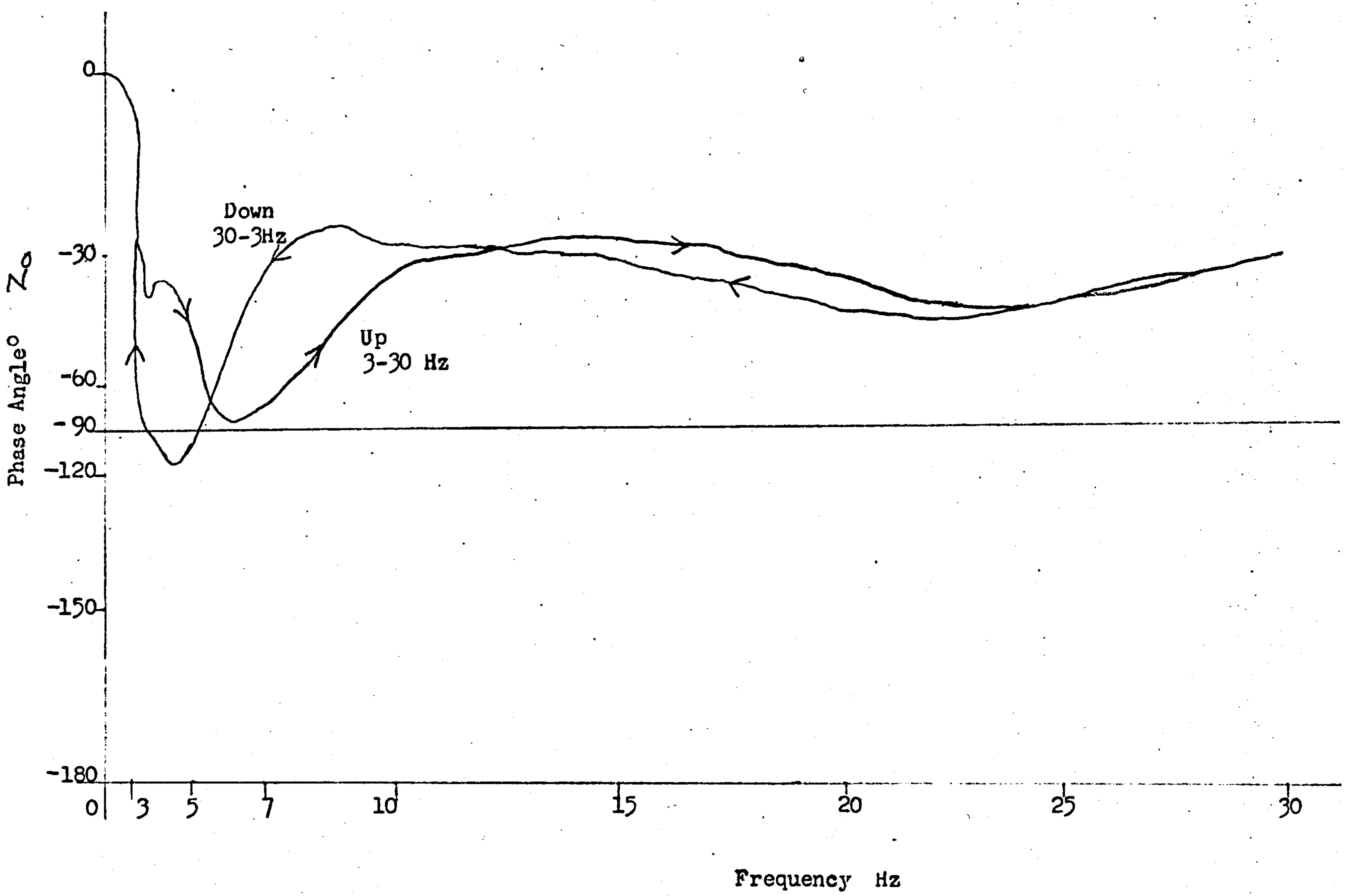


Figure No. 160 ML - Standing Knees Bent

Note on Figures No. 161 to No. 179

Figures No. 161 to No. 179 are the modulus of impedance (acceleration based), drawn from the tabulated results on a linear scale. The mean values with + and - one standard deviation are also shown, these being obtained from the statistically processed results. (Section B - 9.1).

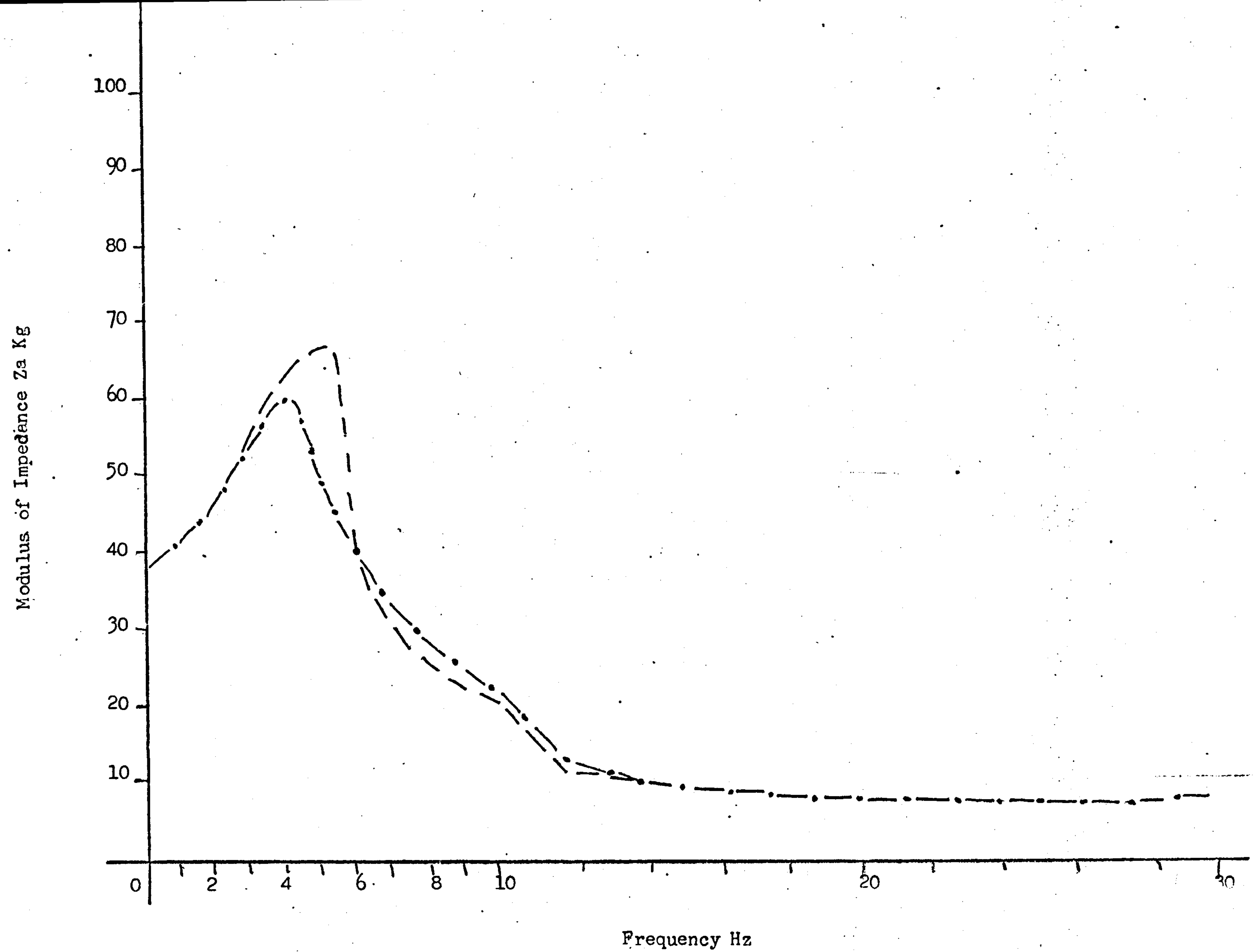


Figure No 161 Fl E and R.

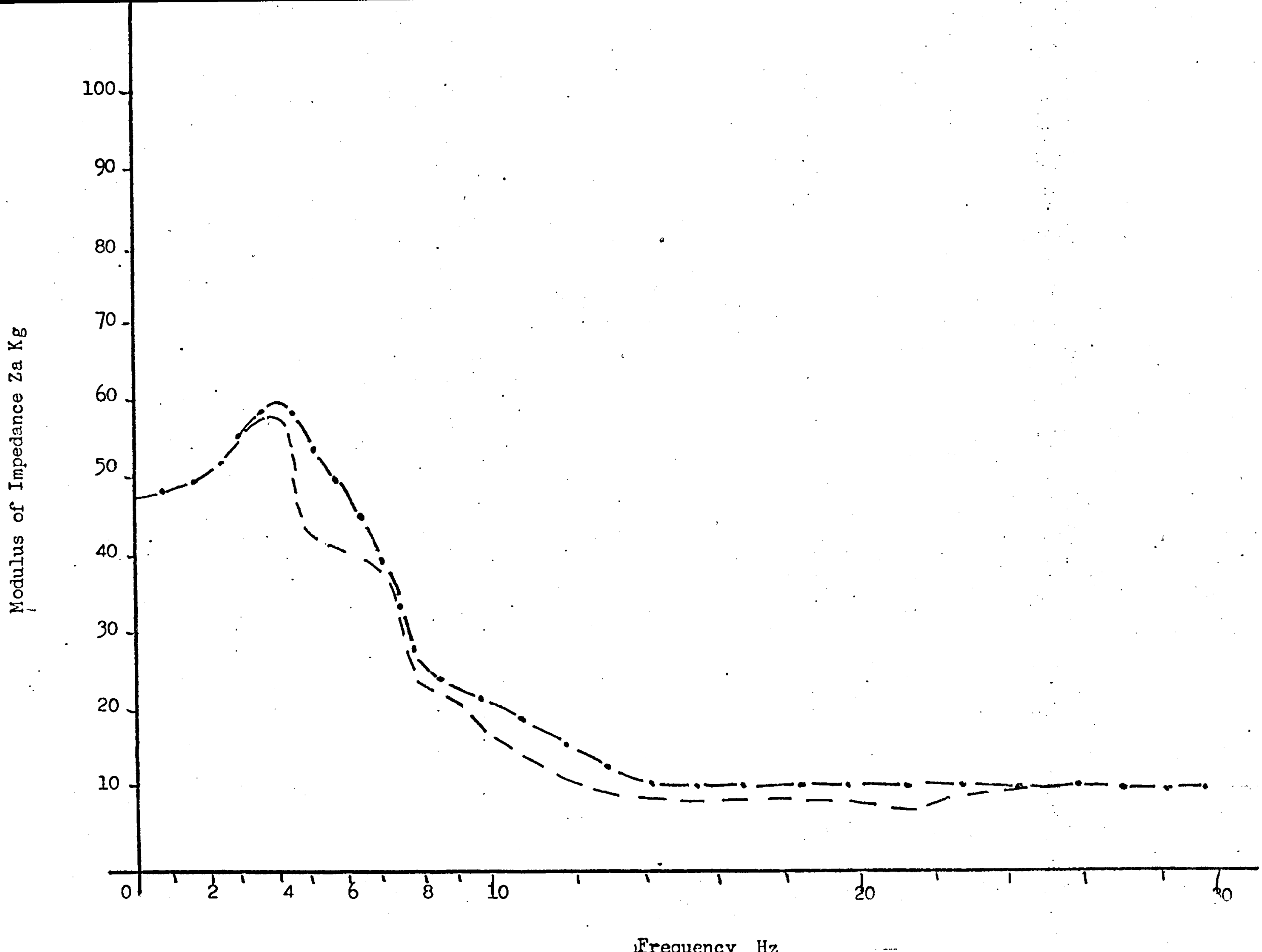


Figure No. 162 F2 E and R.

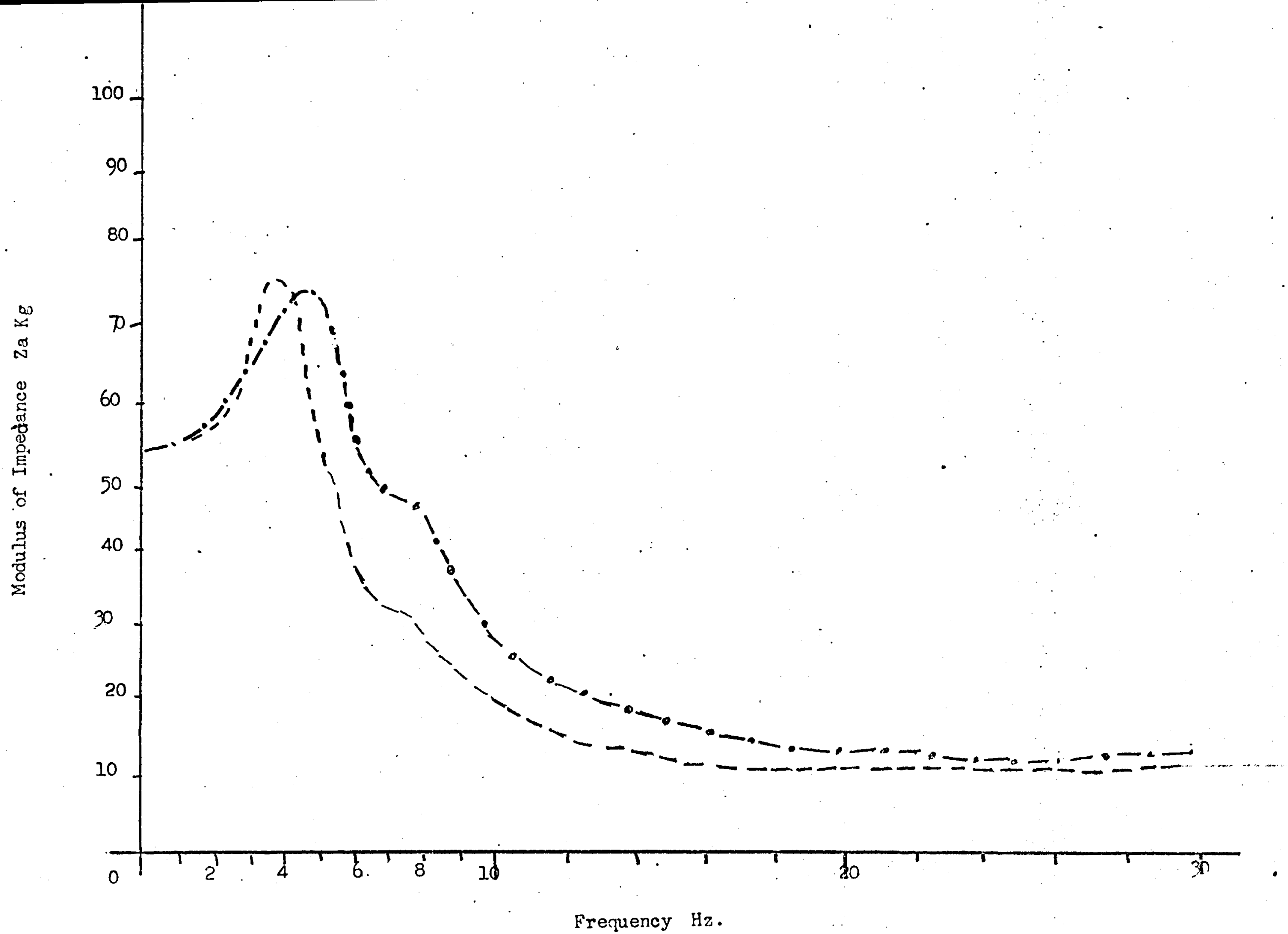


Figure No.163 M1 E and R.

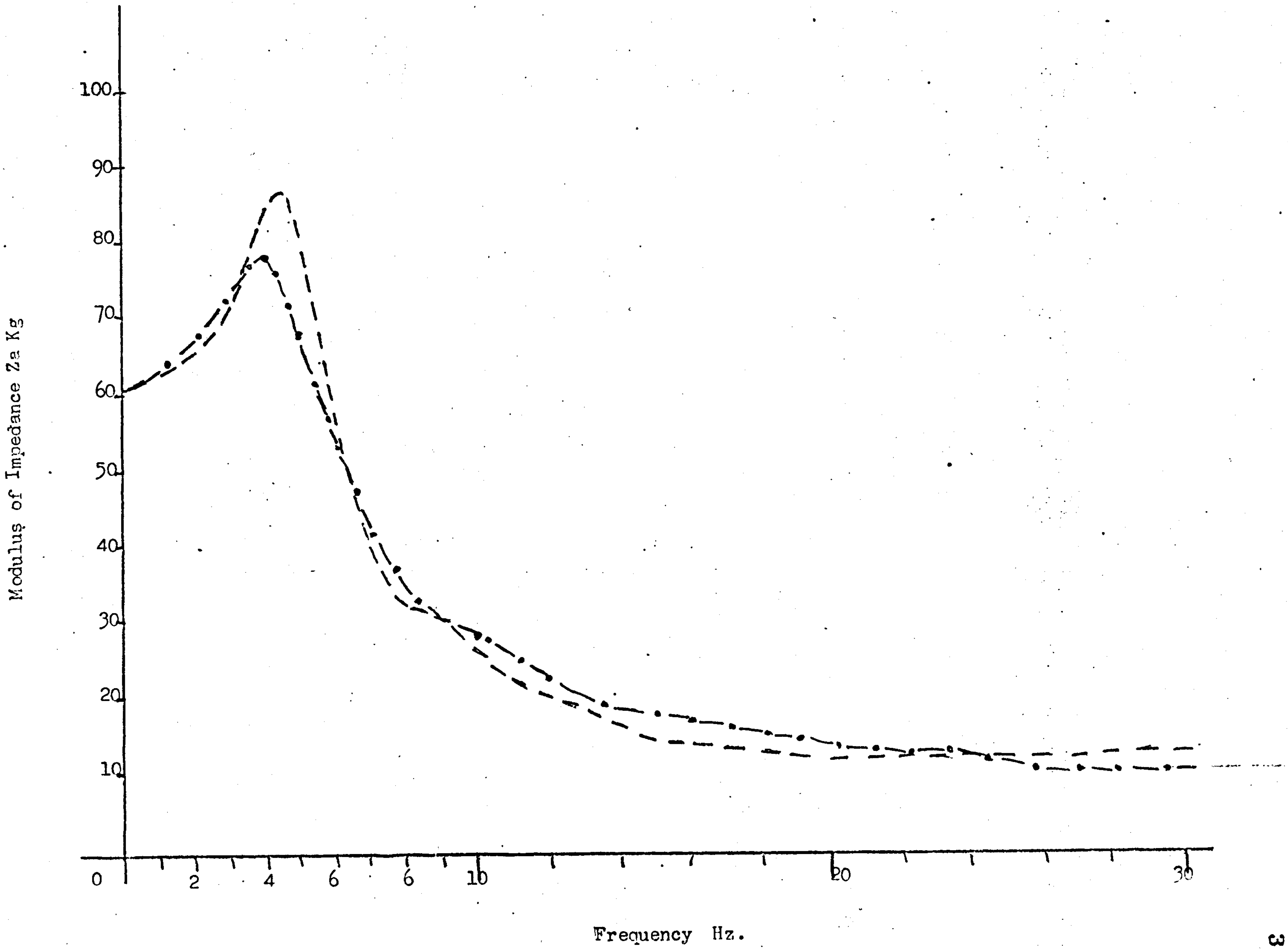


Figure No. 164 M2 E and R

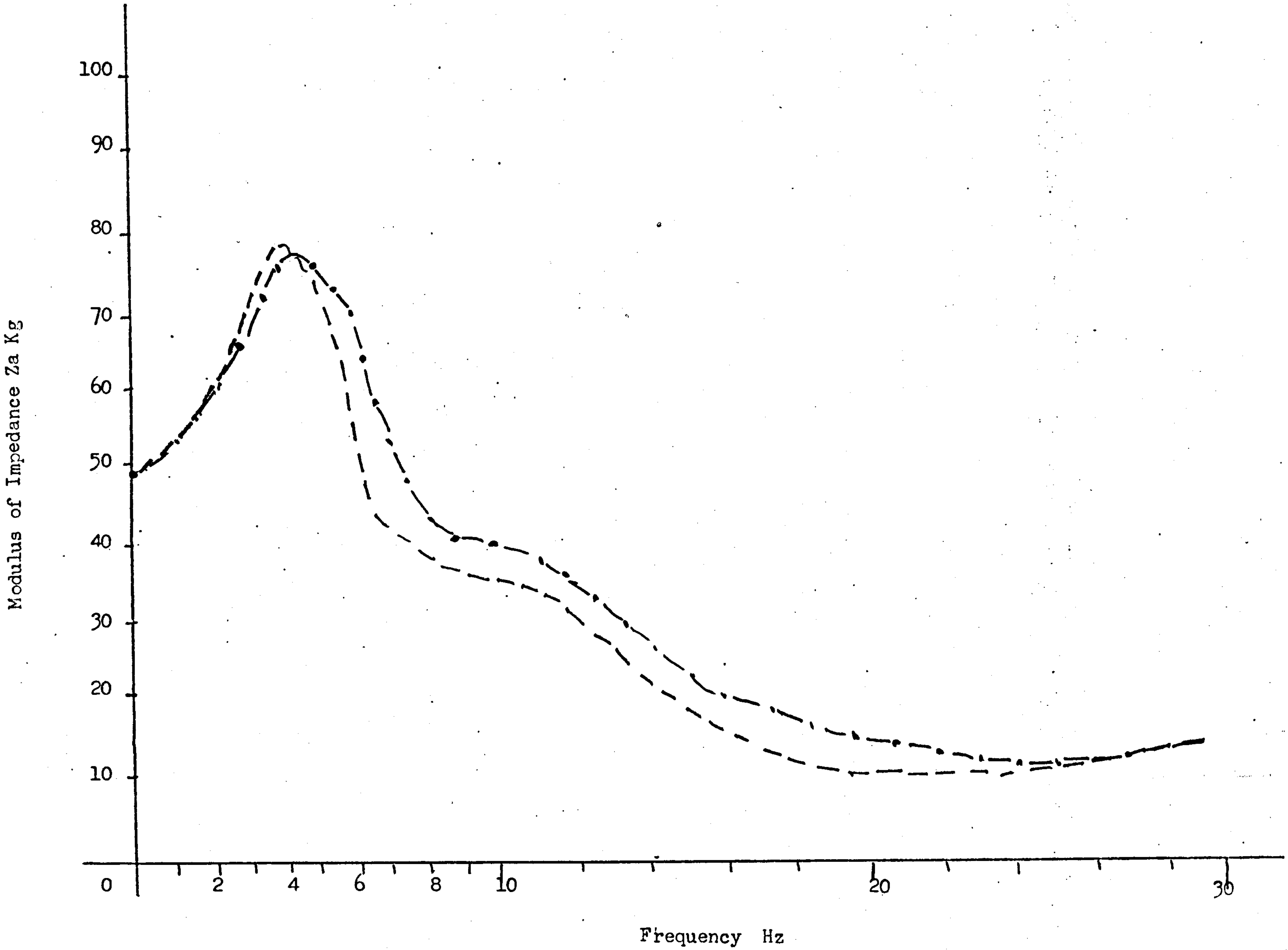


Figure No.165 M3 E and R.

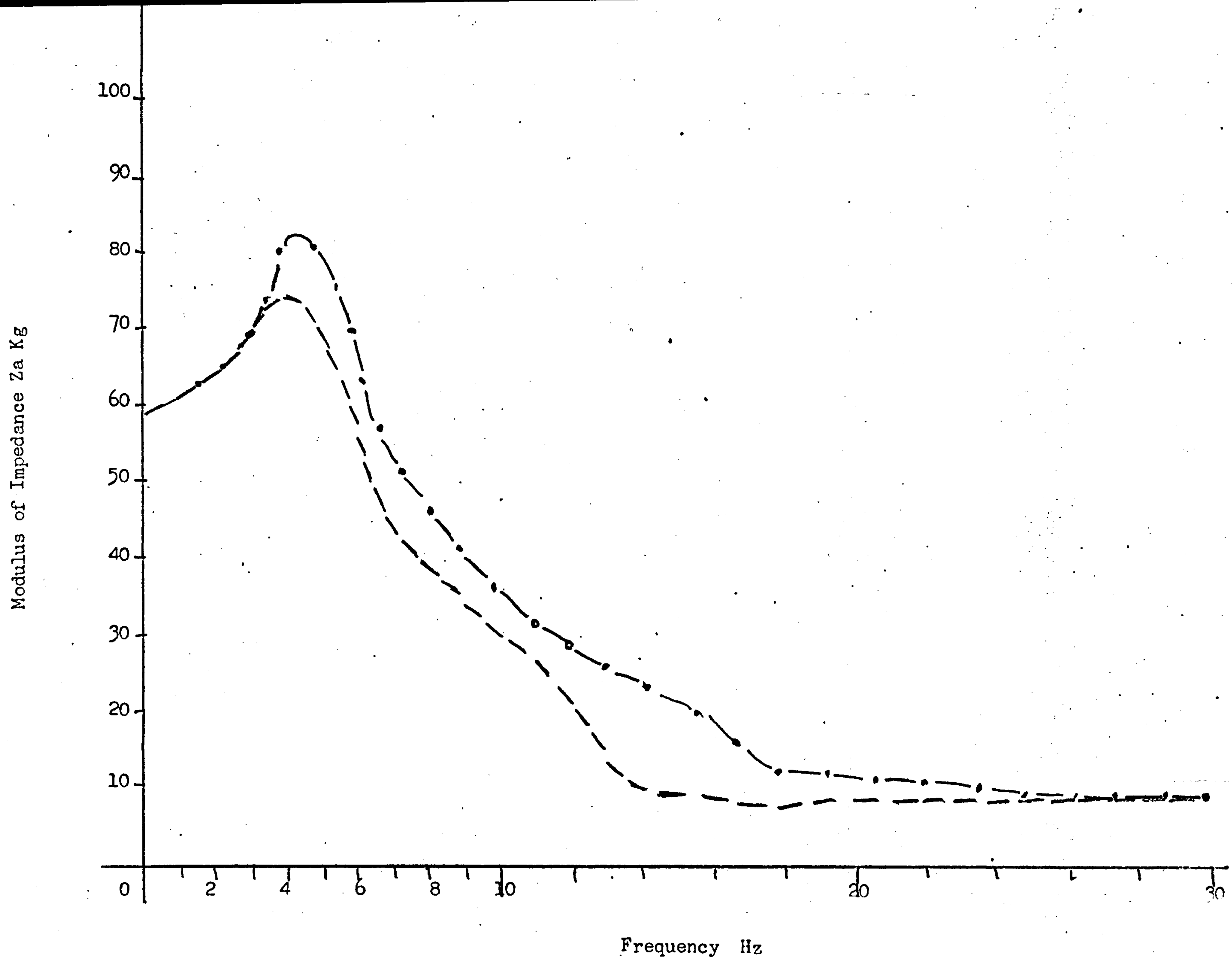


Figure No. 166 M4 E and R.

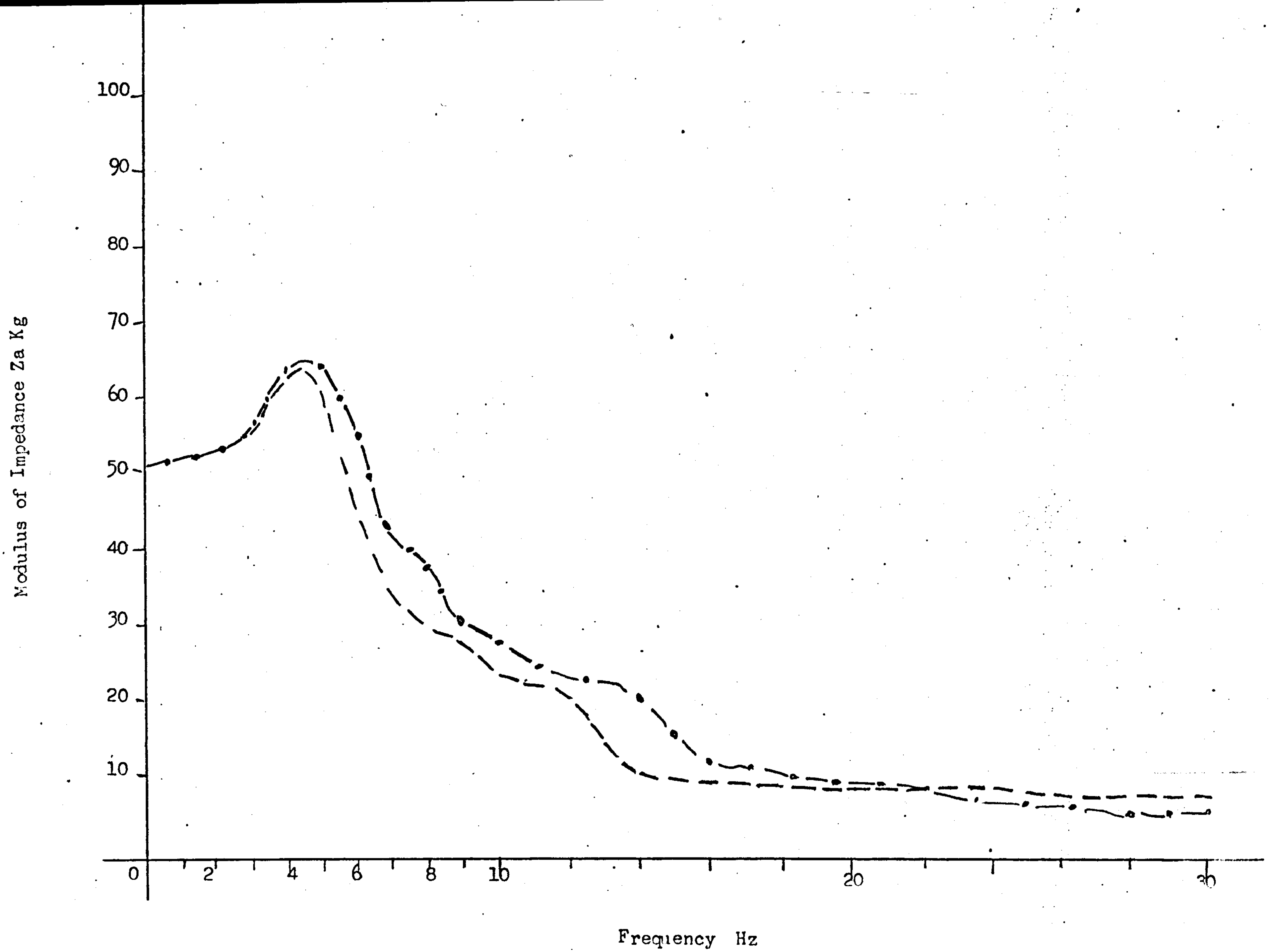


Figure No. 167 M5 E and R.

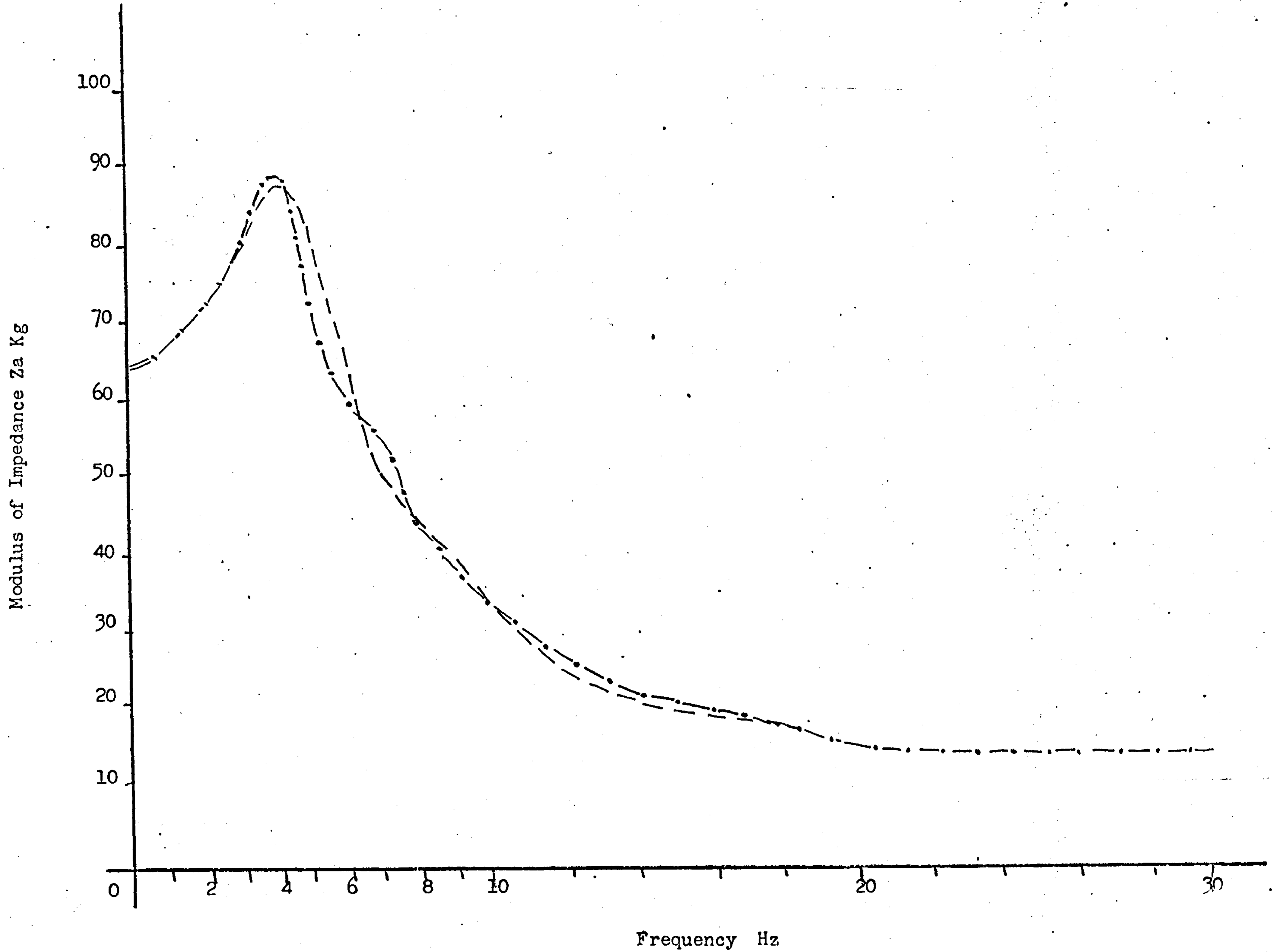


Figure No.168 M6 E and R

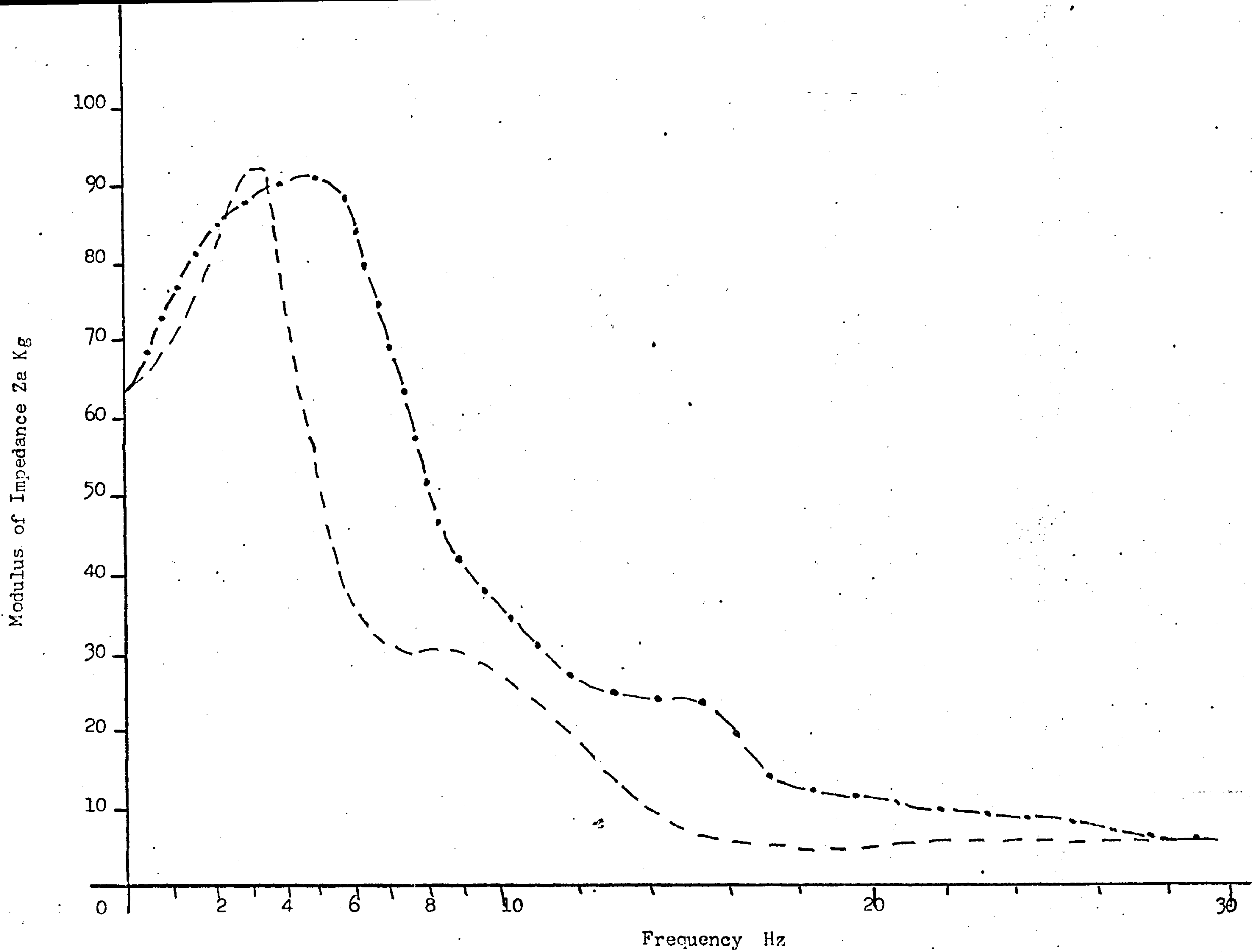


Figure No.169 M7 E and R

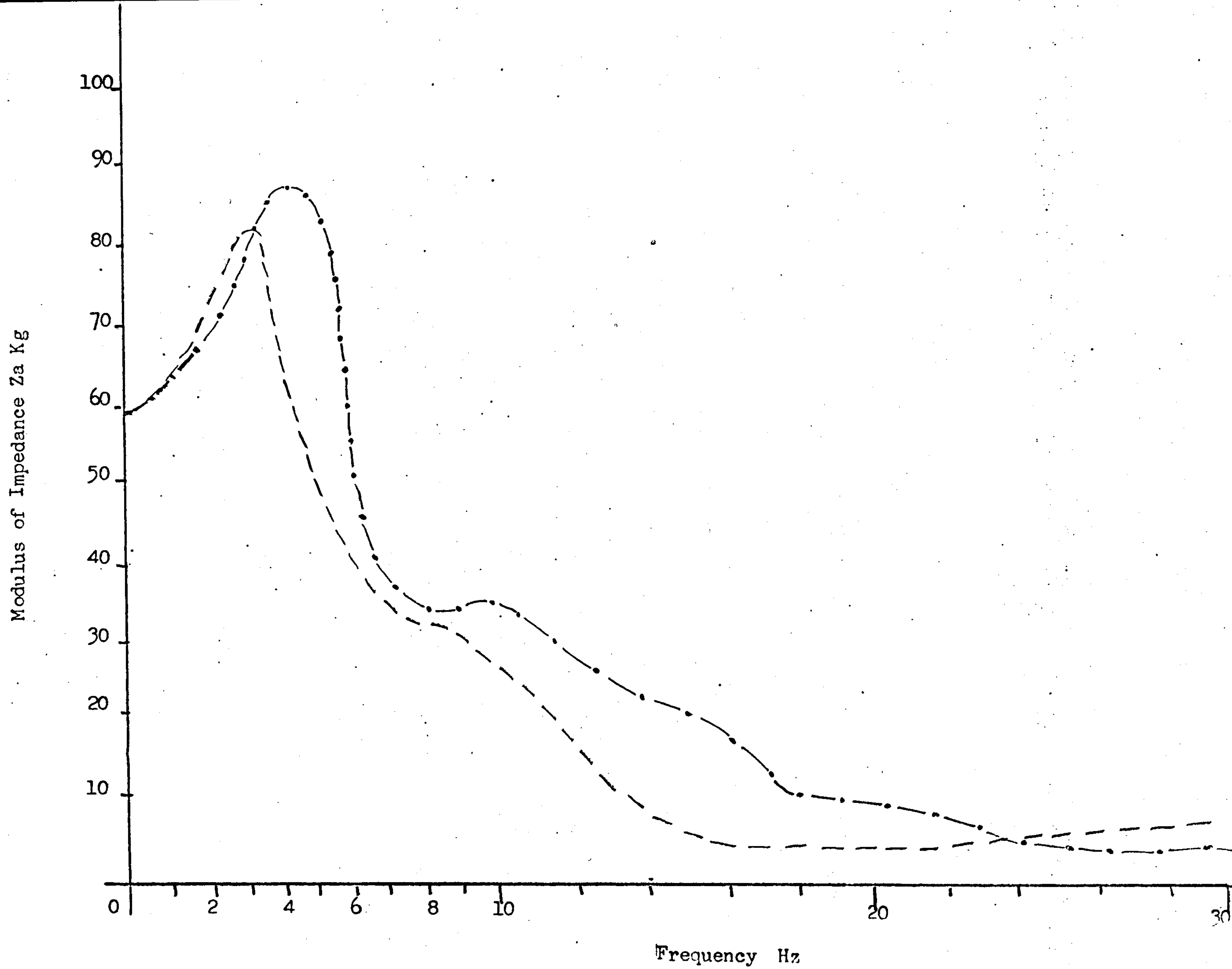


Figure No.170M8 E and R

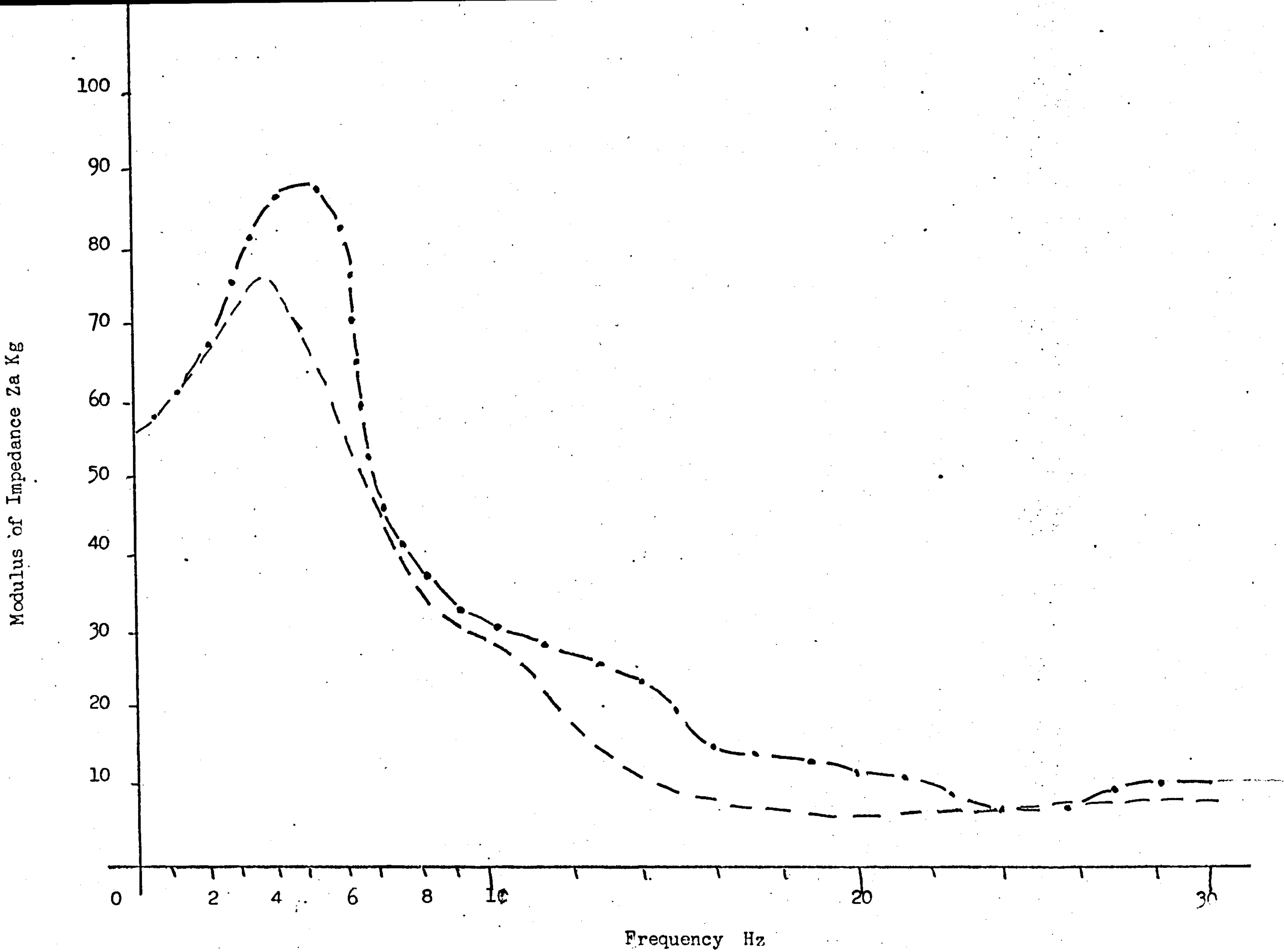


Figure No 171 M9 E and R

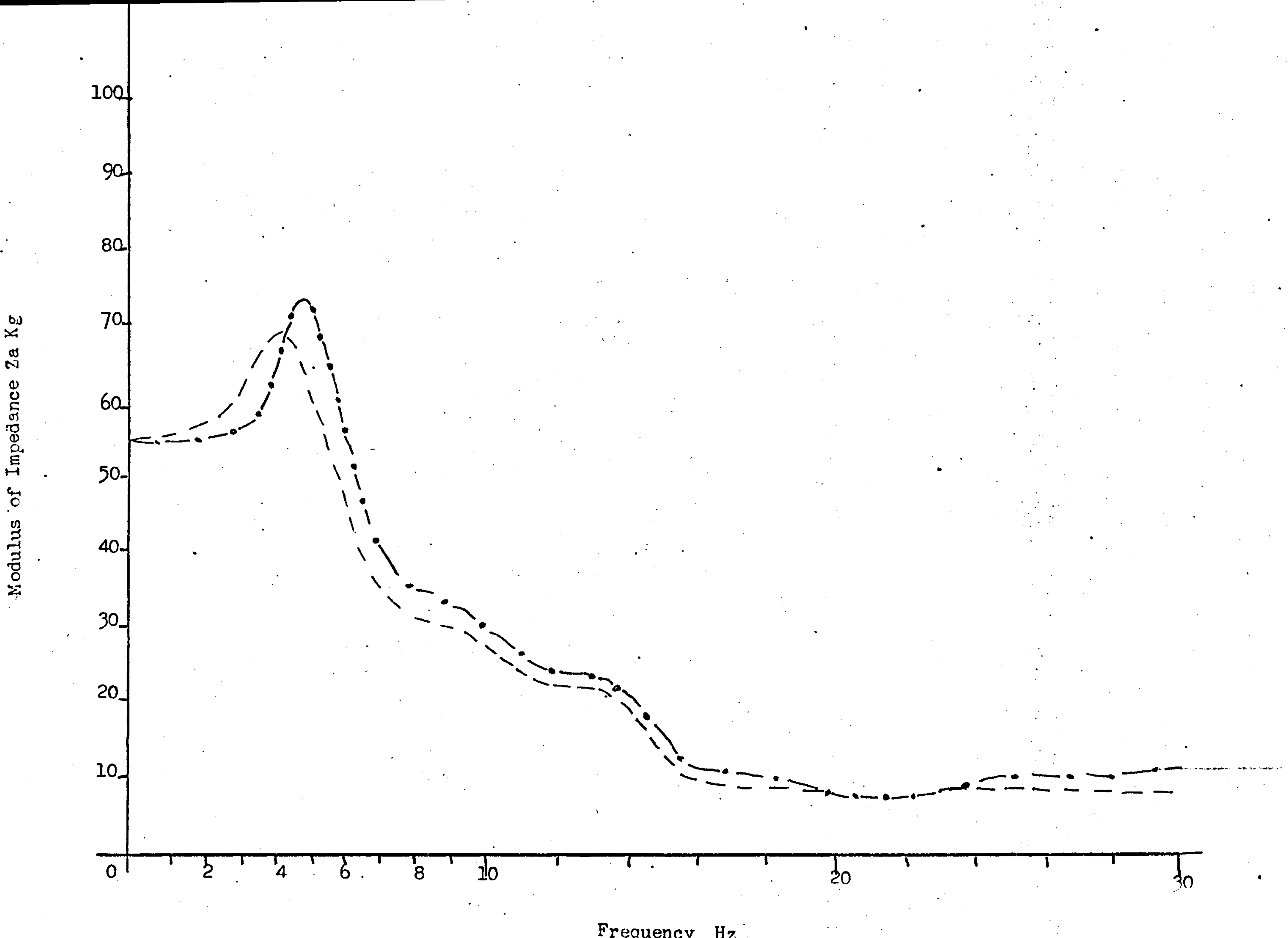


Figure No. 172 M10 E and R.

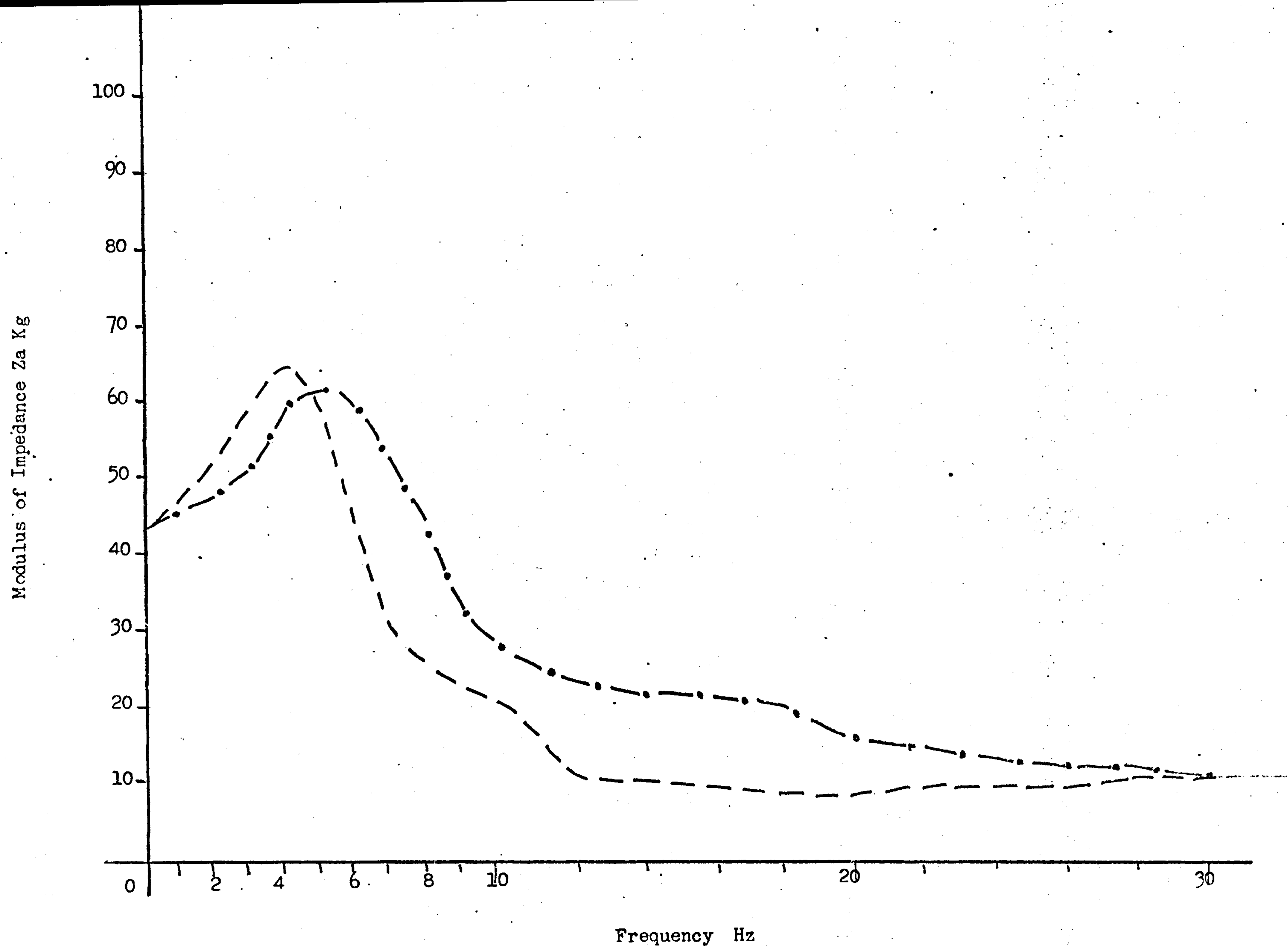


Figure No 173 M11 E and R.

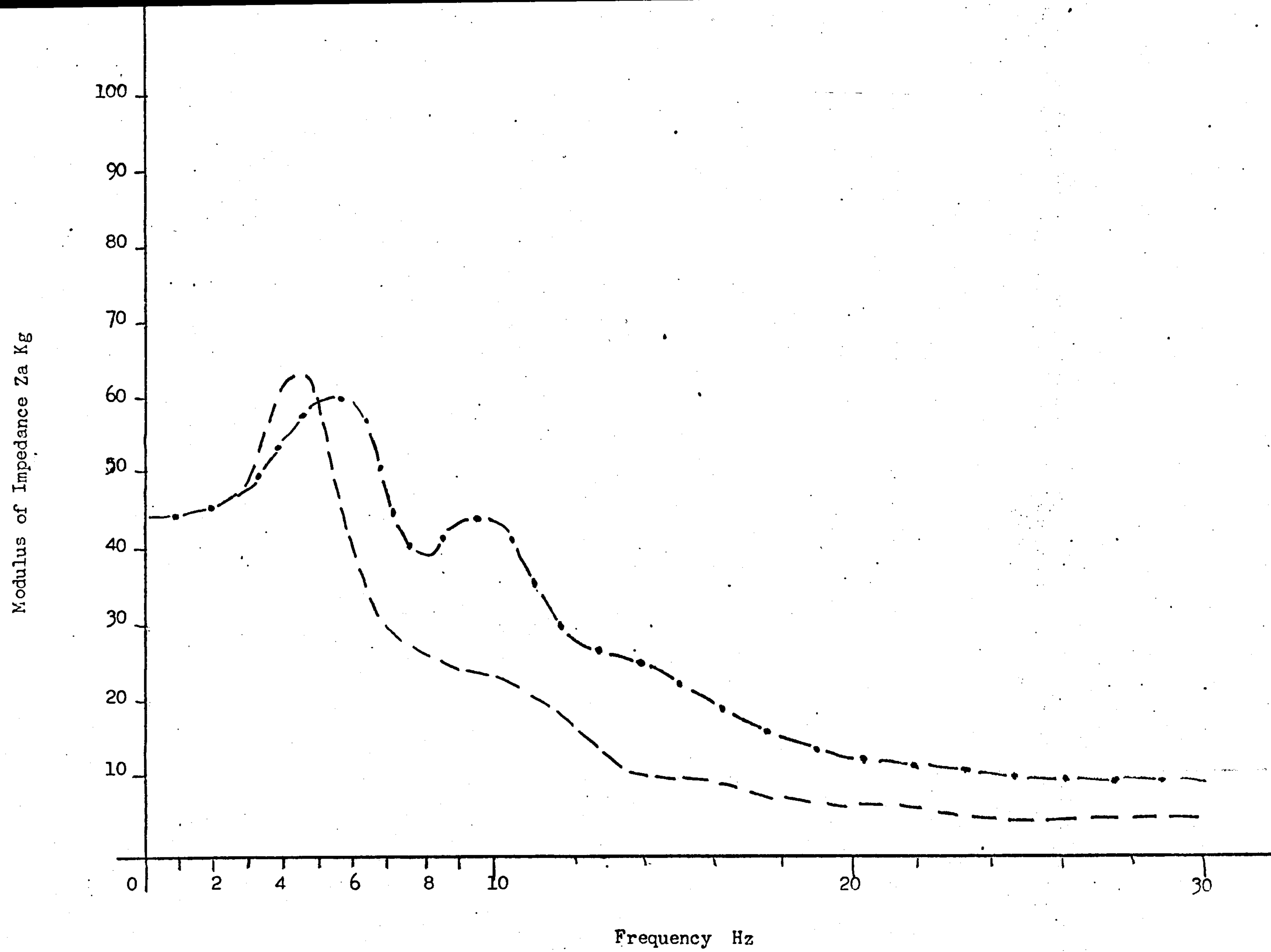


Figure No 174 M12 E and R

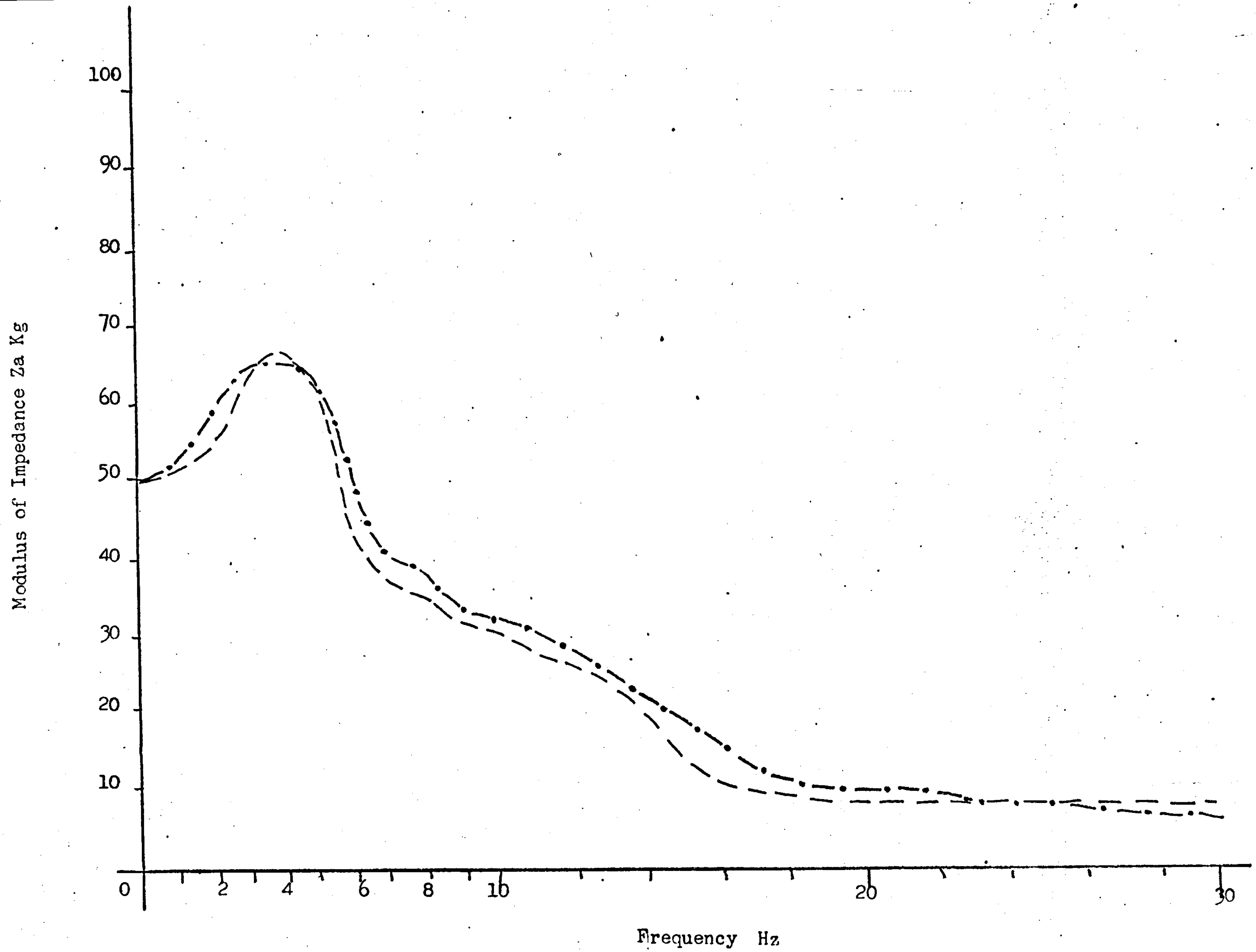


Figure No. 175 M14 E and R

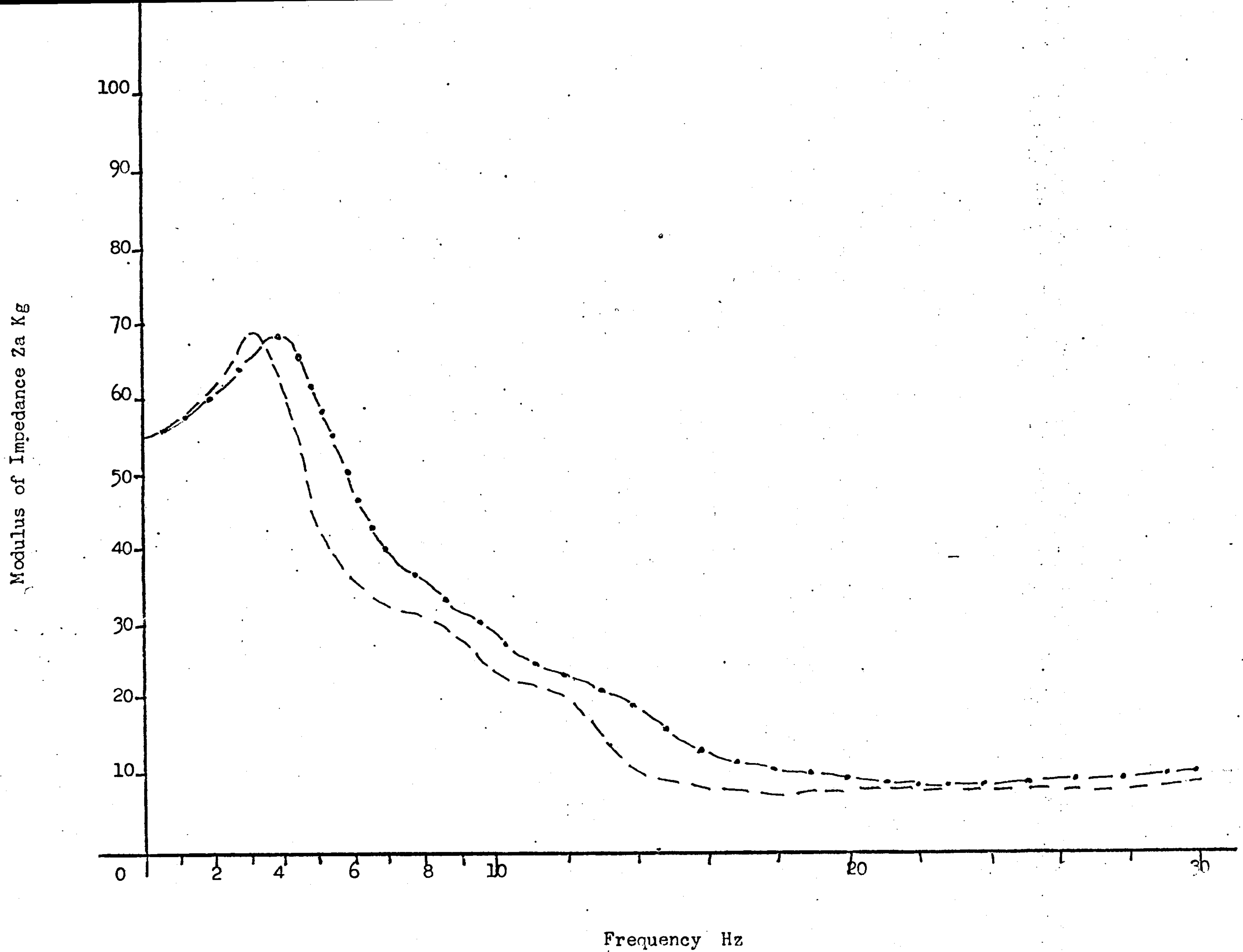
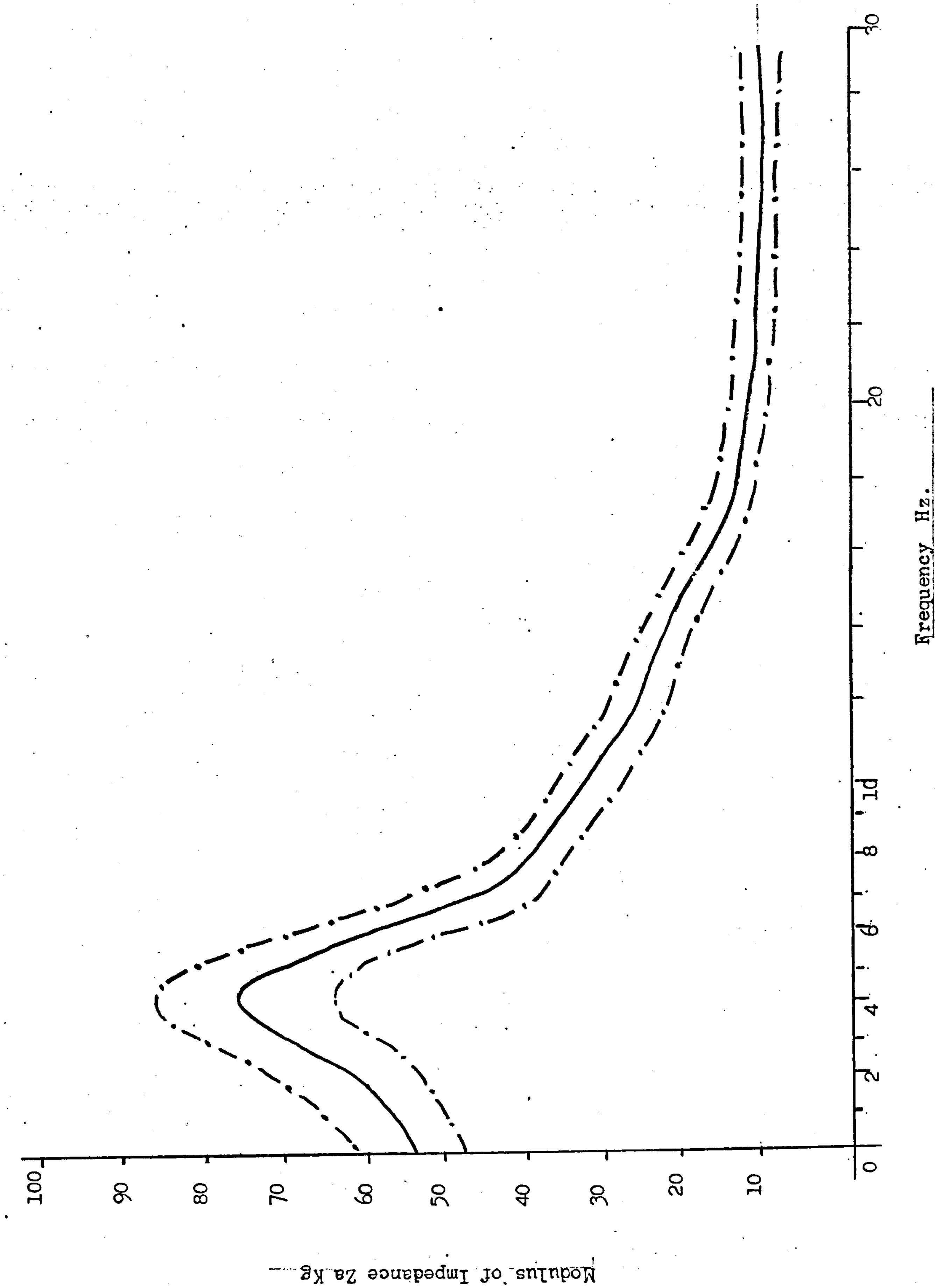


Figure No.176M15 E and R.



Mean value for 14 male subjects sitting erect + and - one standard deviation

Figure No. 177

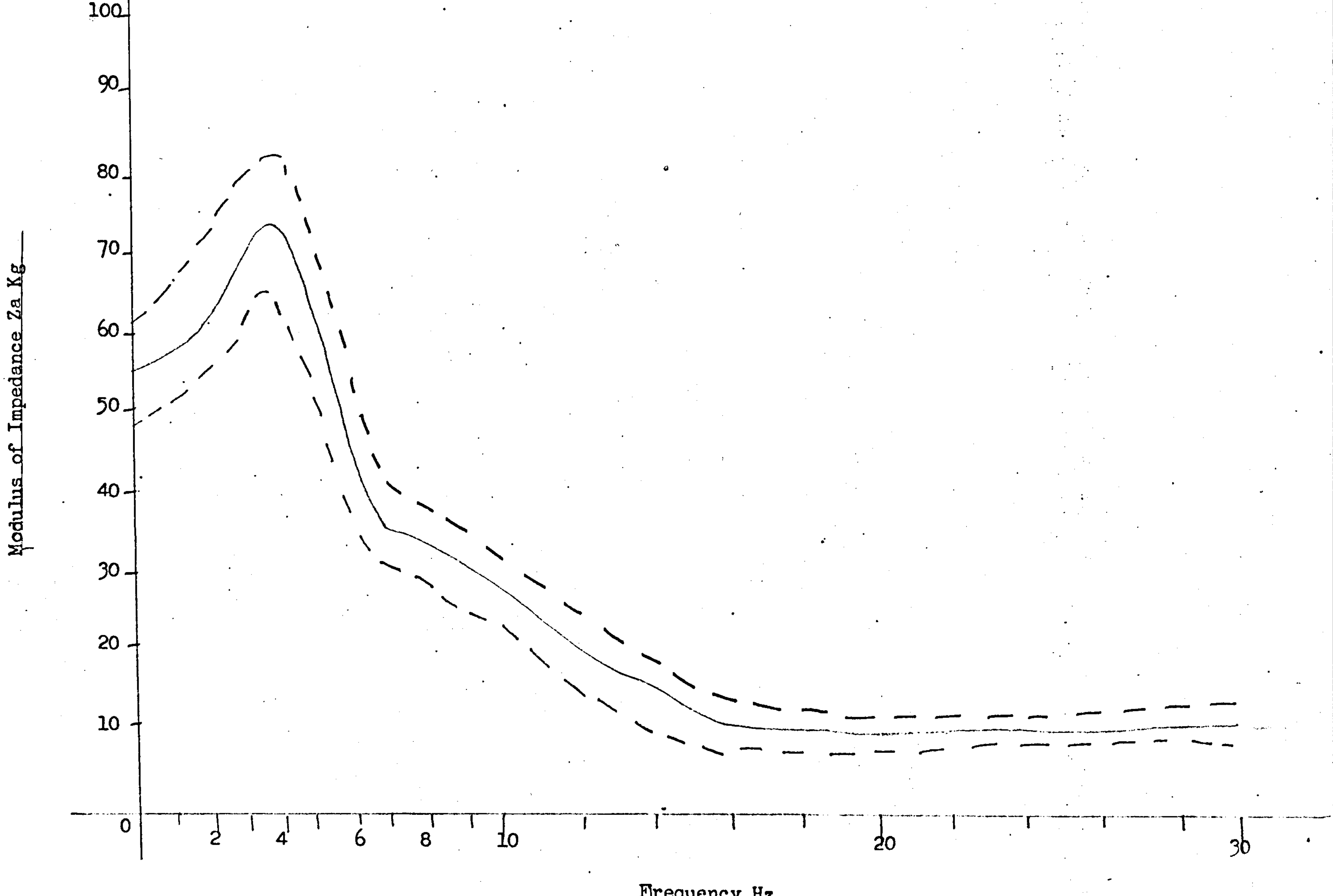
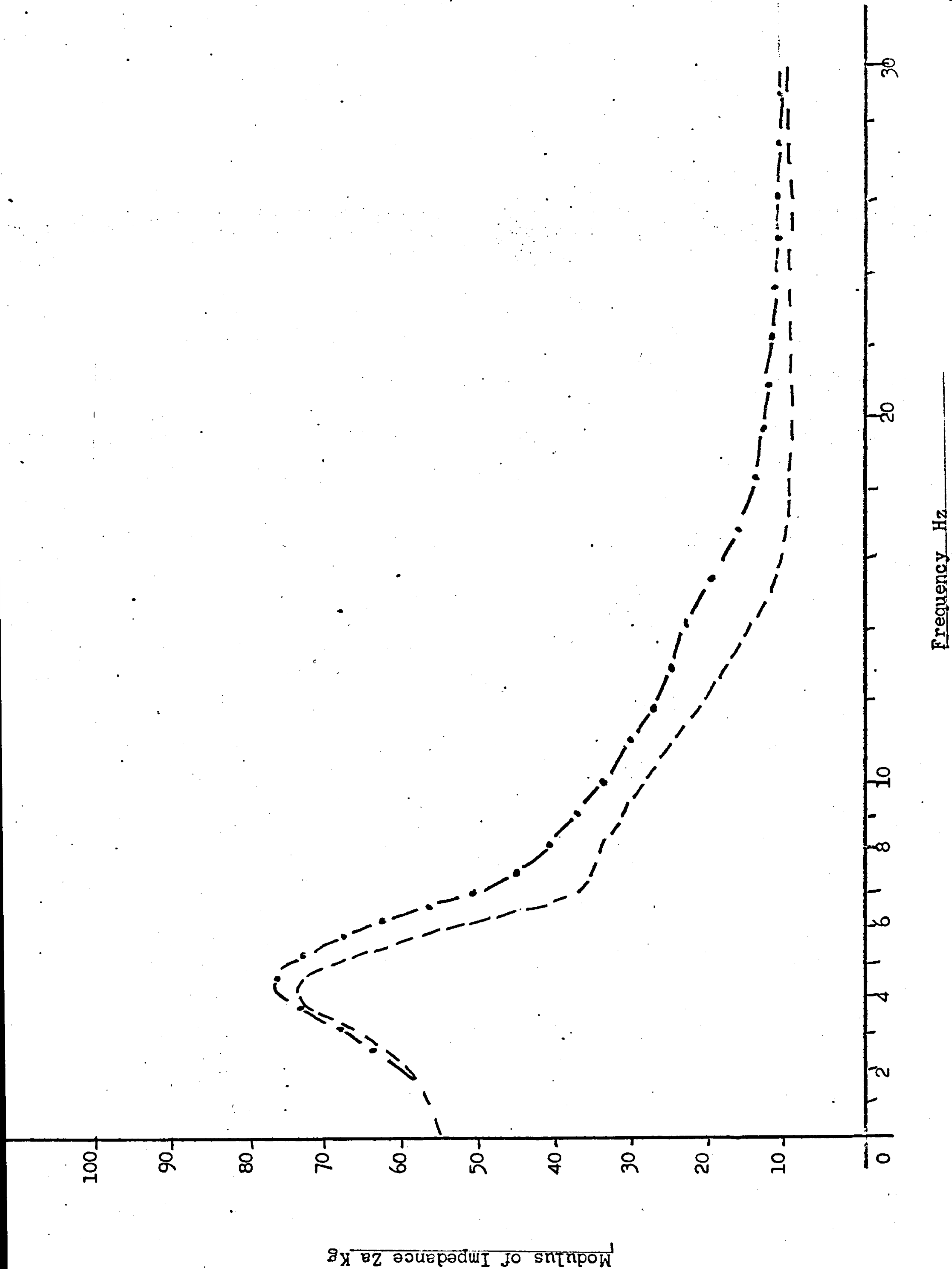


Figure No. 178

Mean value of 14 male subjects sitting relaxed + and - one standard deviation



Mean values for 14 male subjects sitting erect and relaxed

Figure No. 179

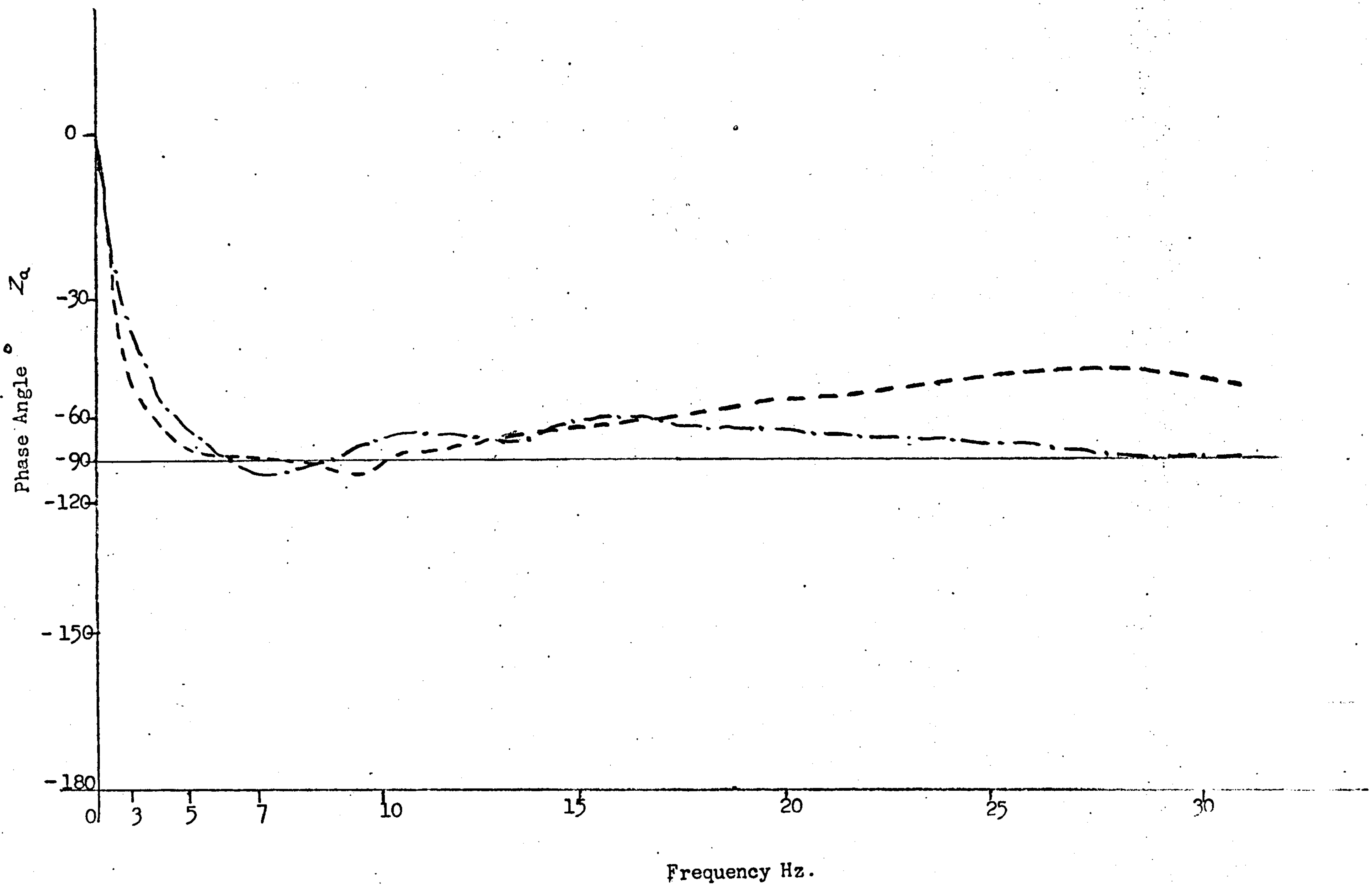


Figure No 180 F1 - E and R

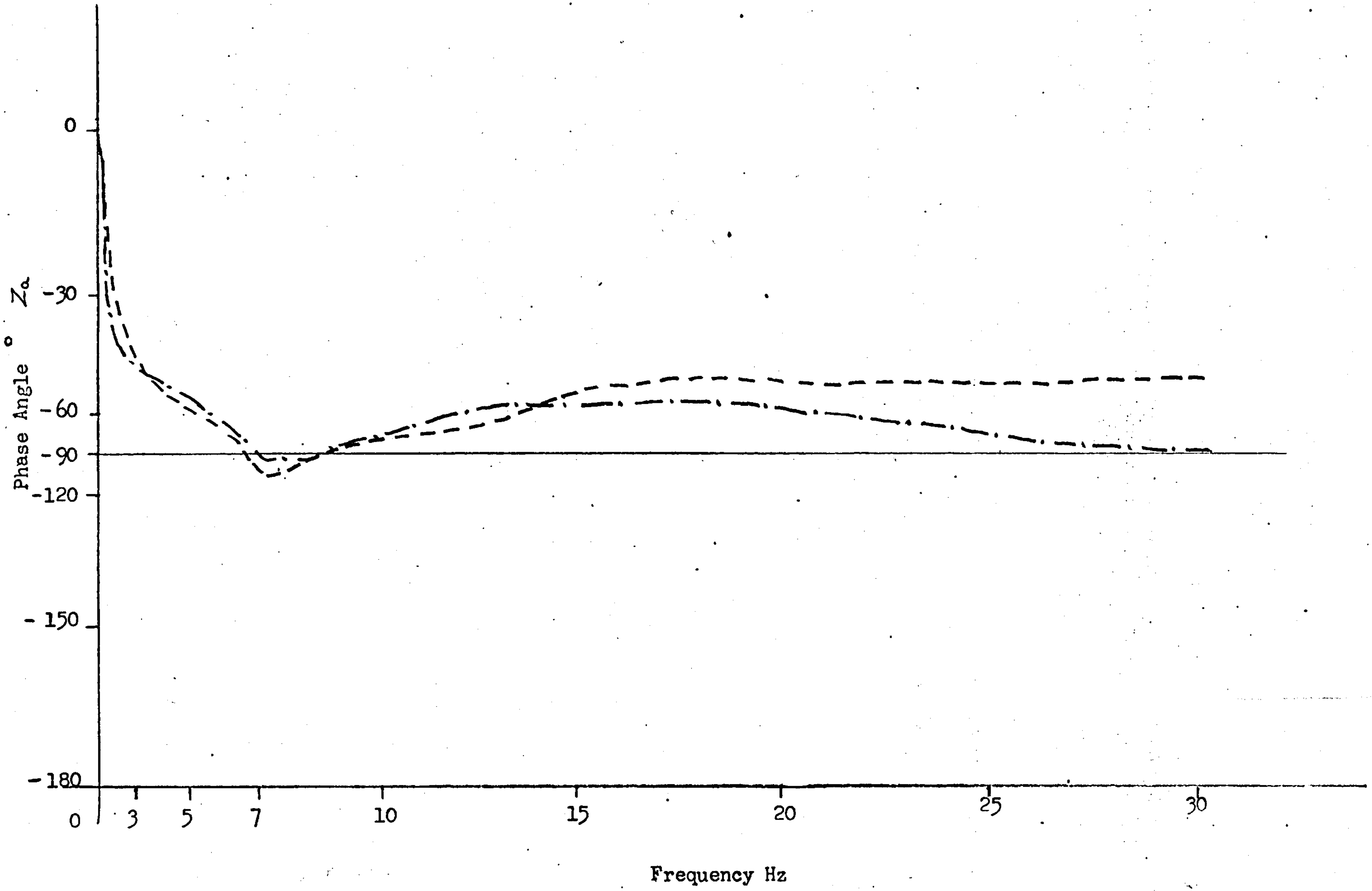


Figure No.181F2 - E and R

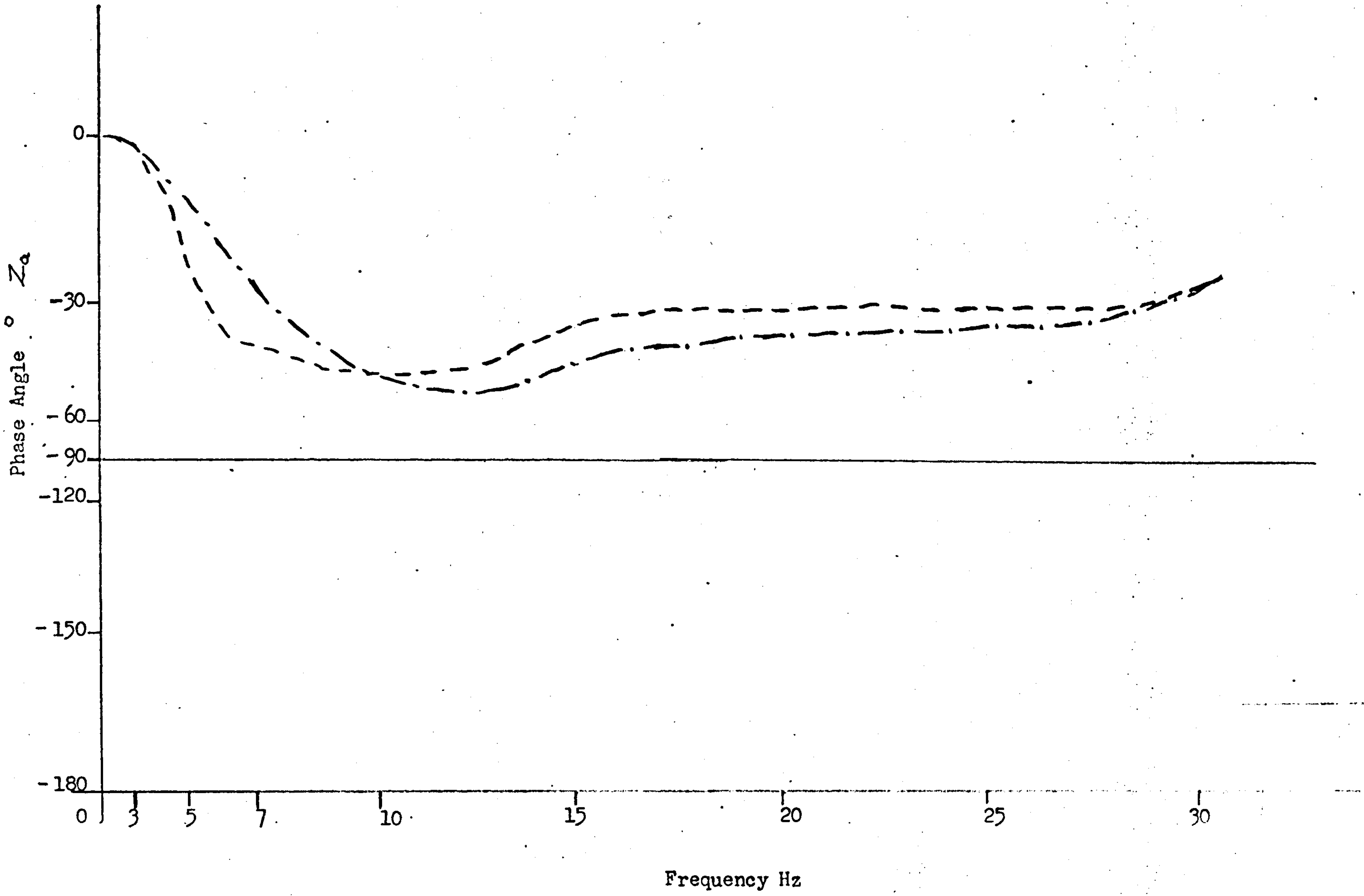


Figure No 182 M1 - E and R

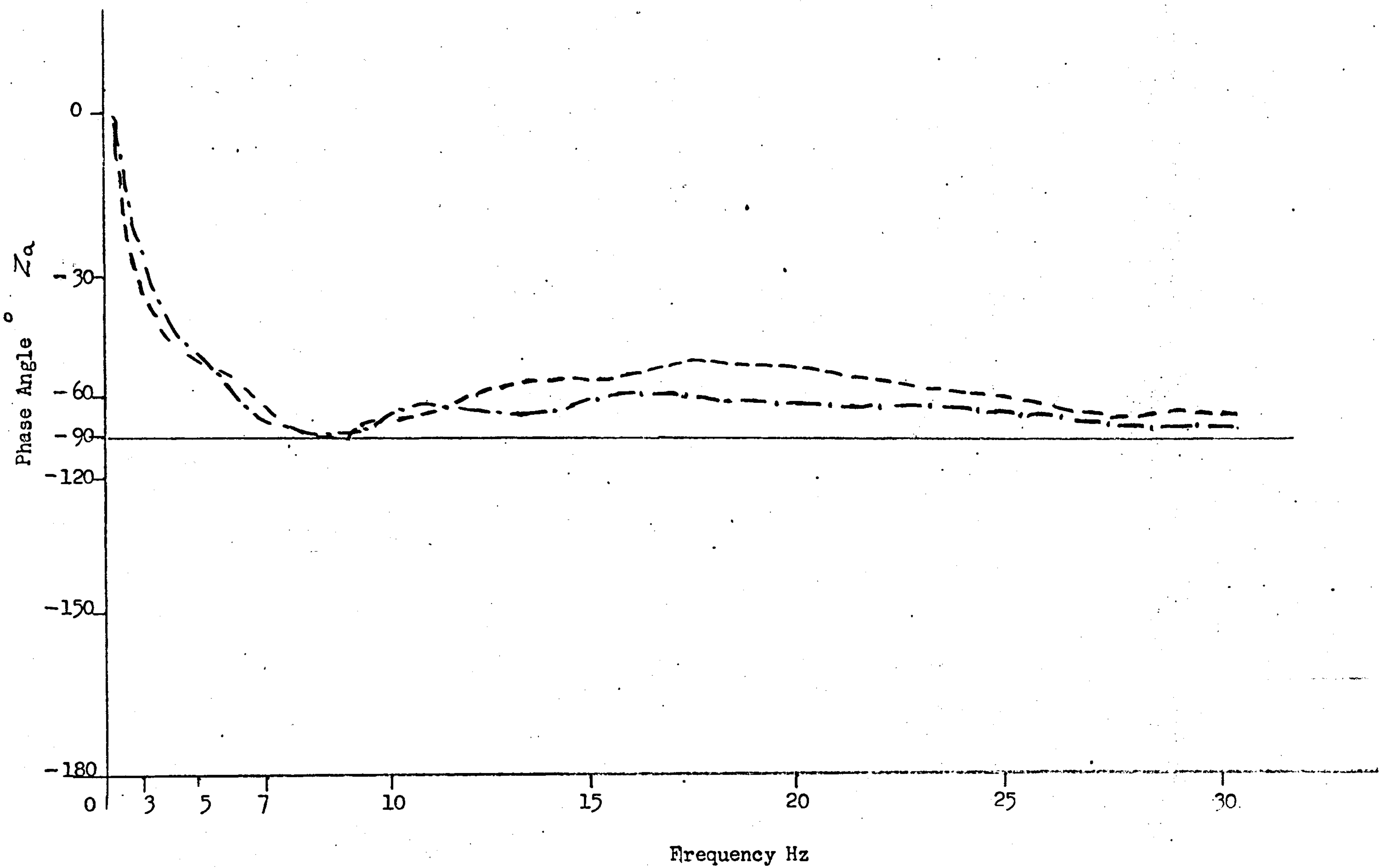


Figure No.183 M2-E and R

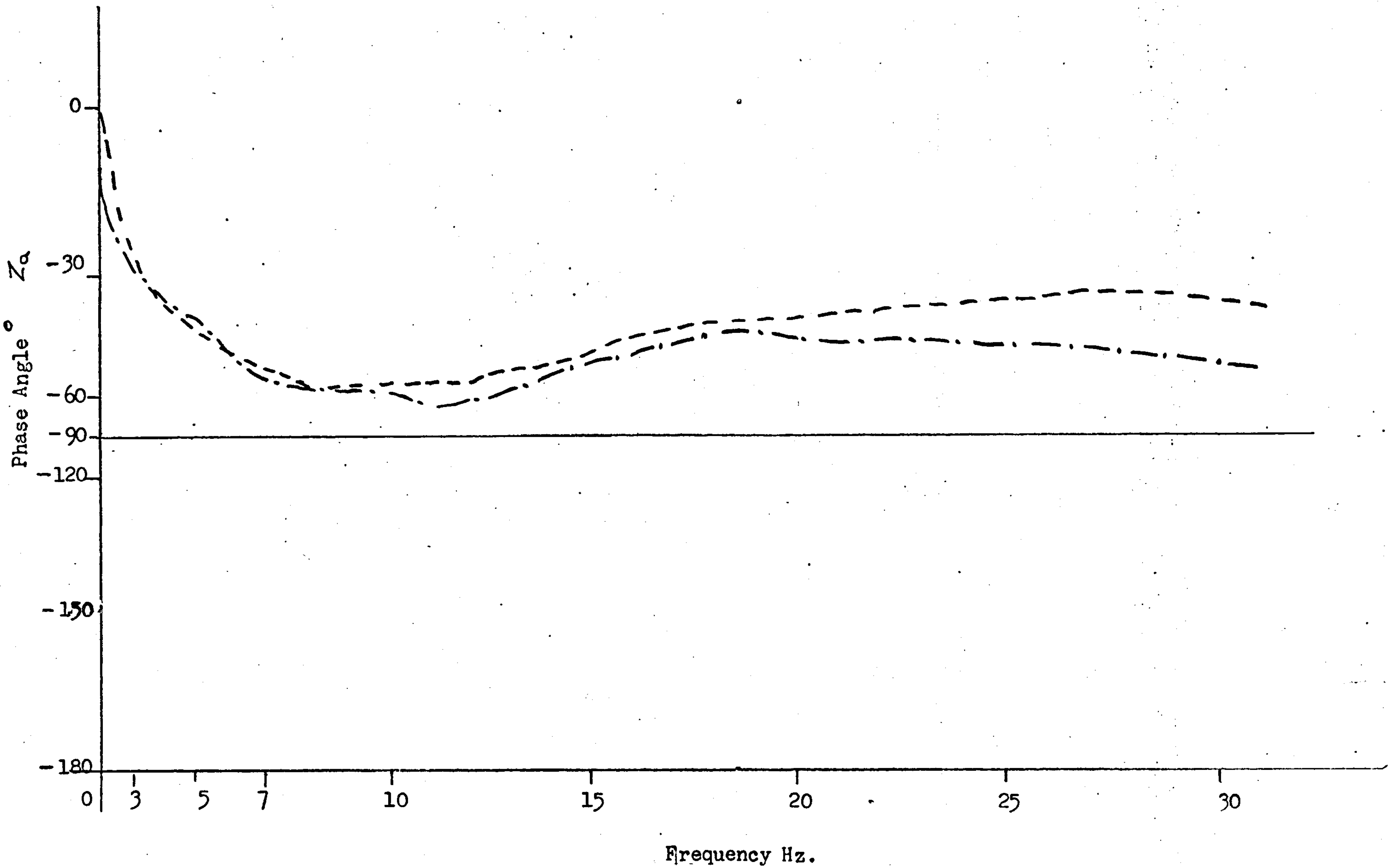


Figure No. 184M3 - E and R

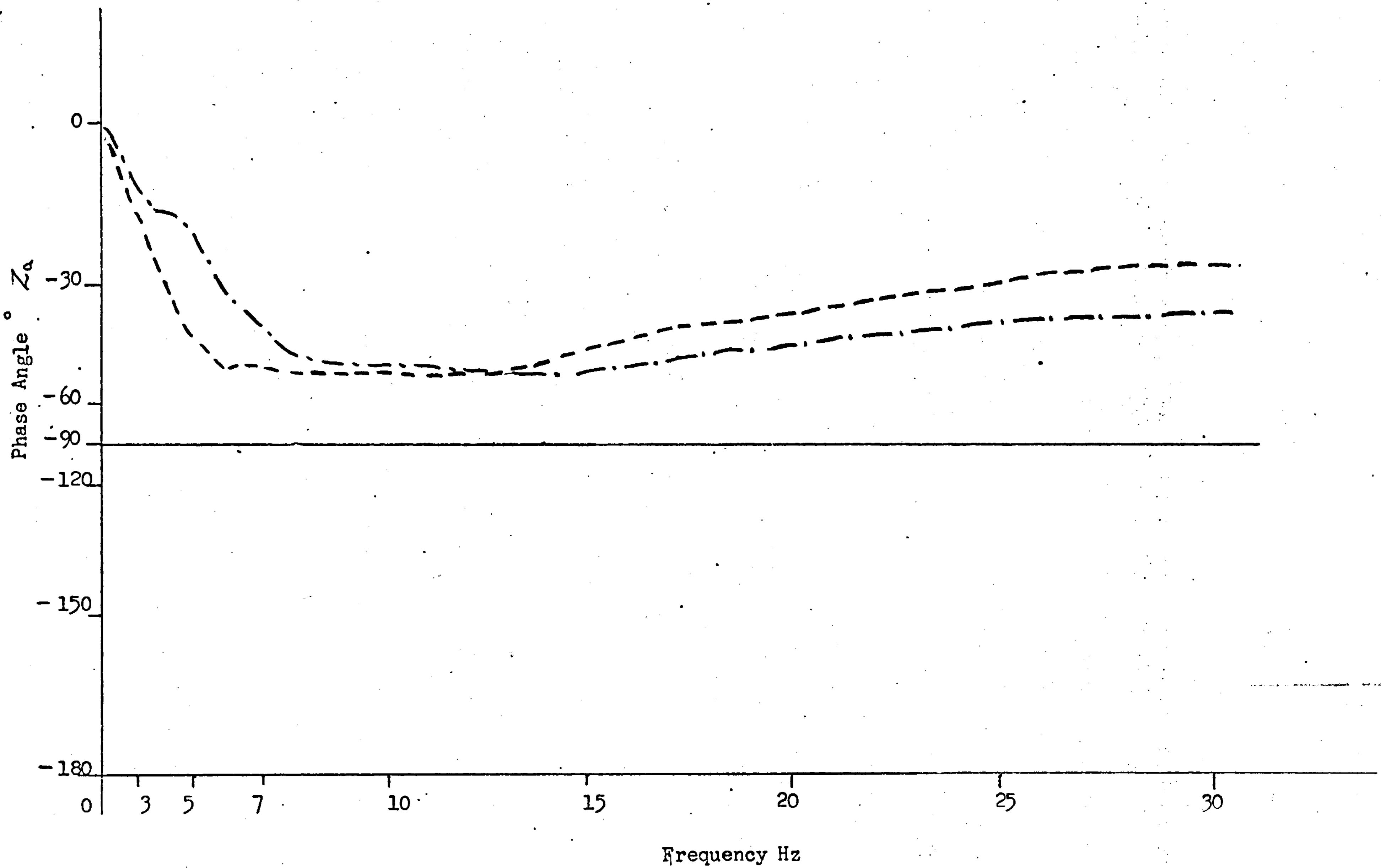


Figure No.185M4 - E and R

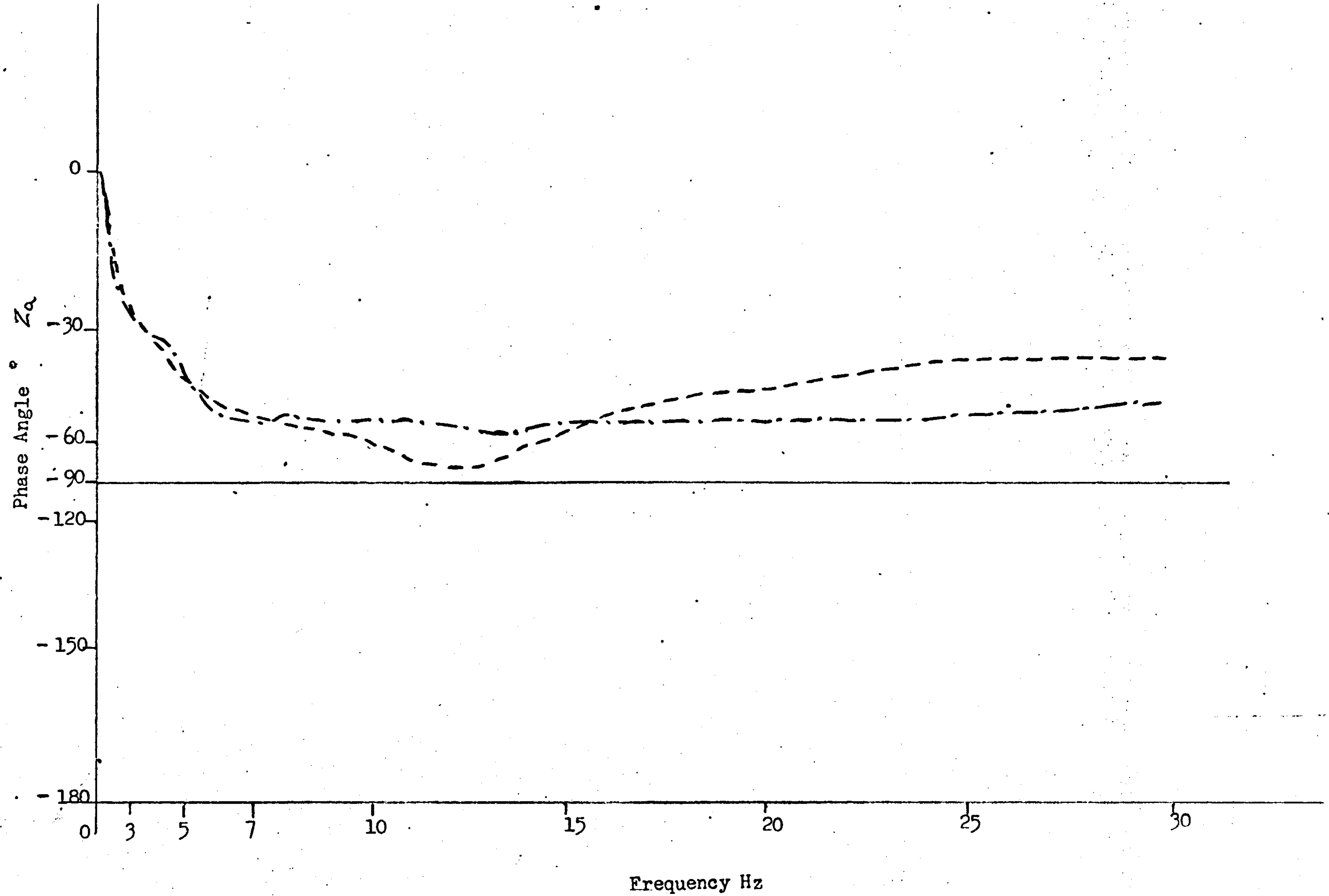


Figure No 186M6 - E and R

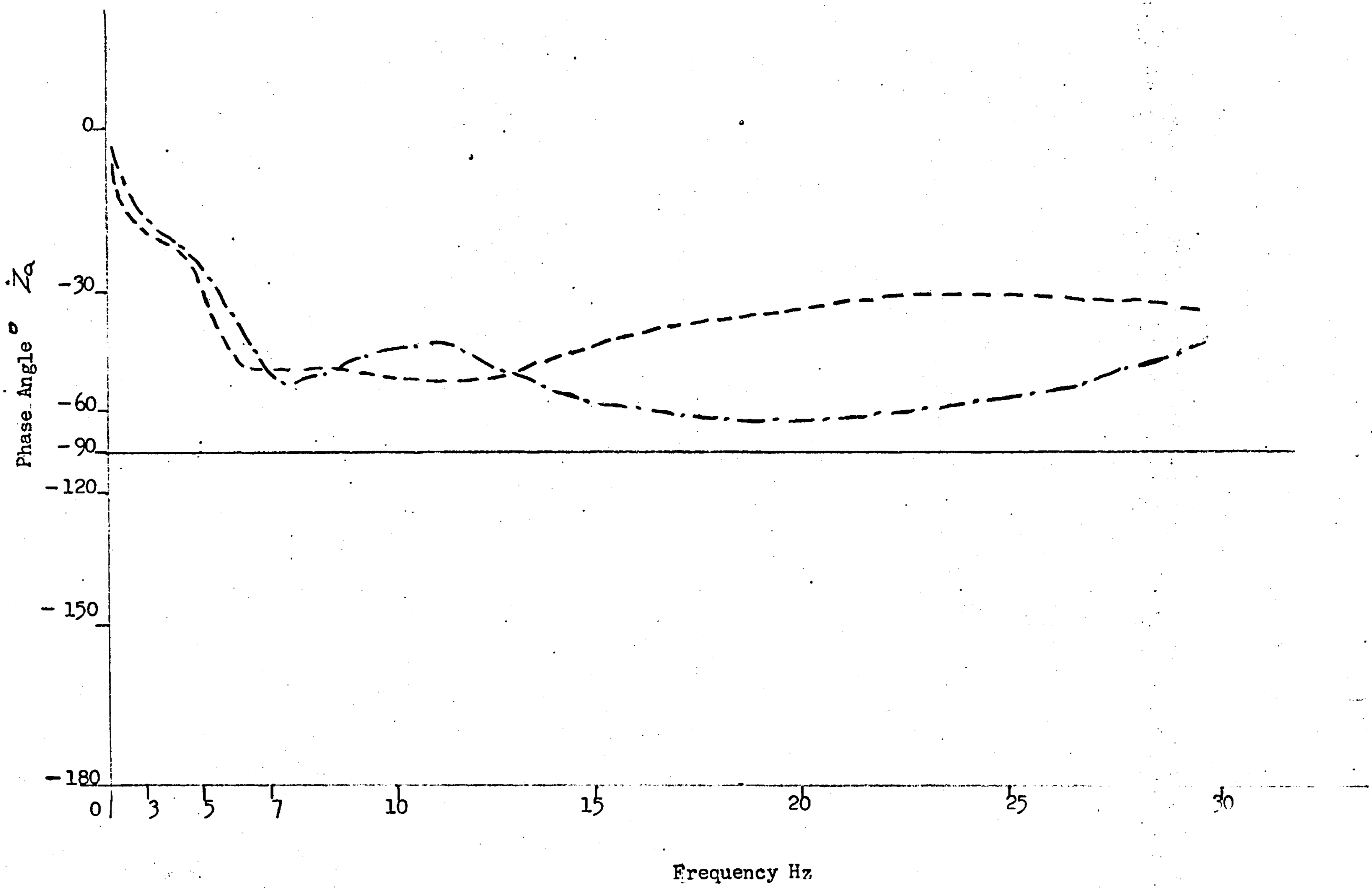


Figure No 187 M7 - E and R

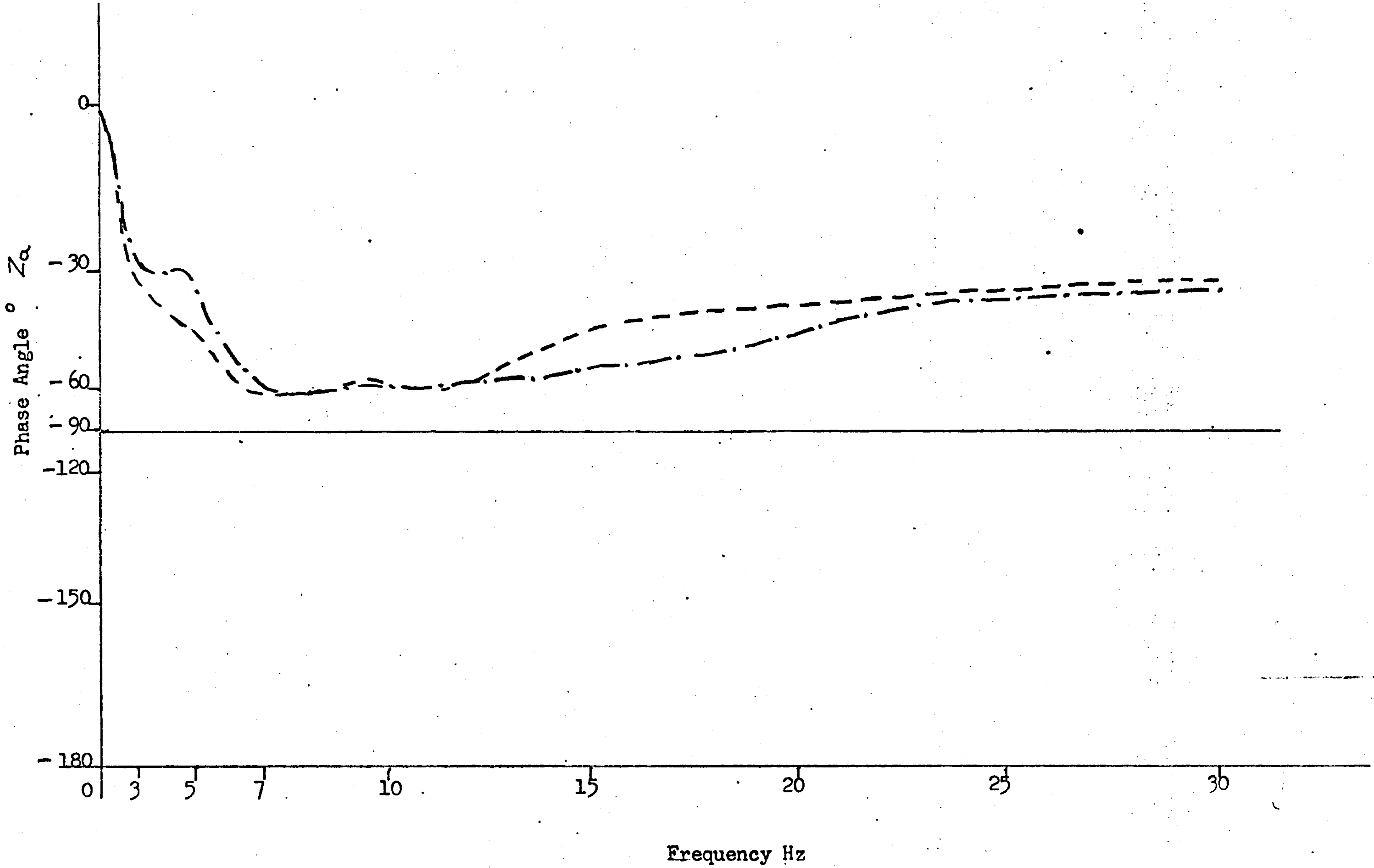


Figure No.188M8 - E and R

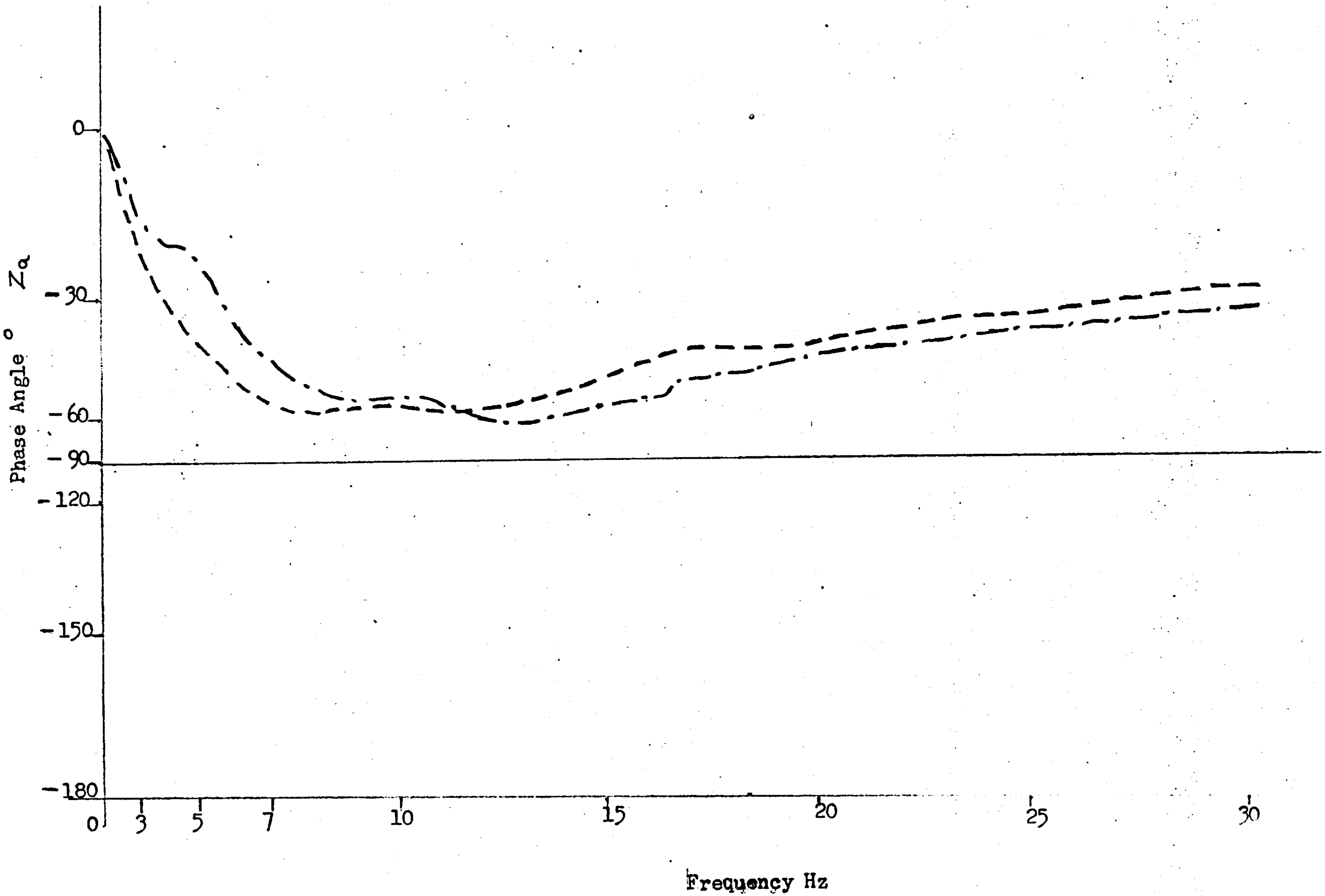


Figure No.189M9 - E and R

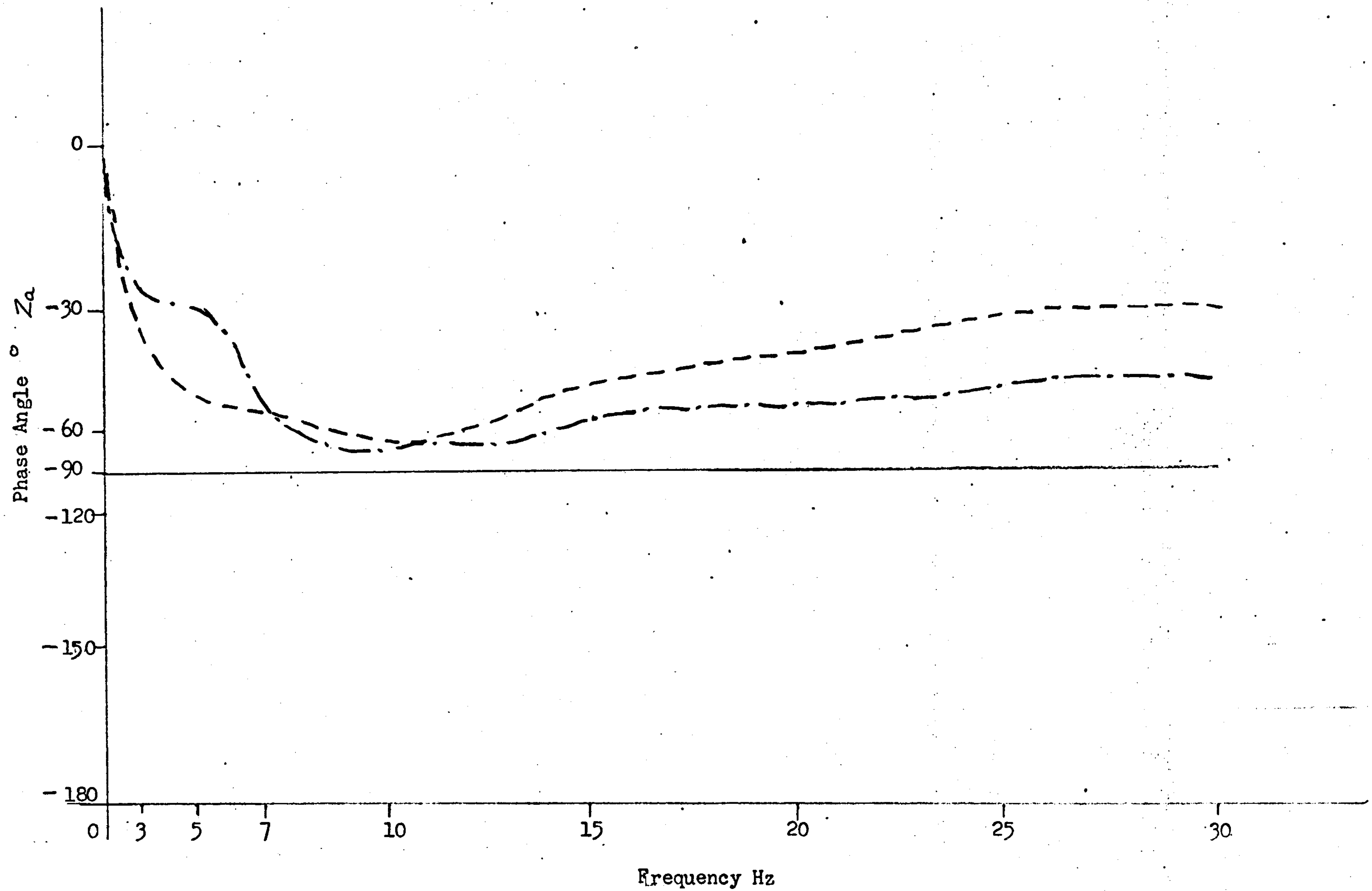


Figure No 190 M10 - E and R

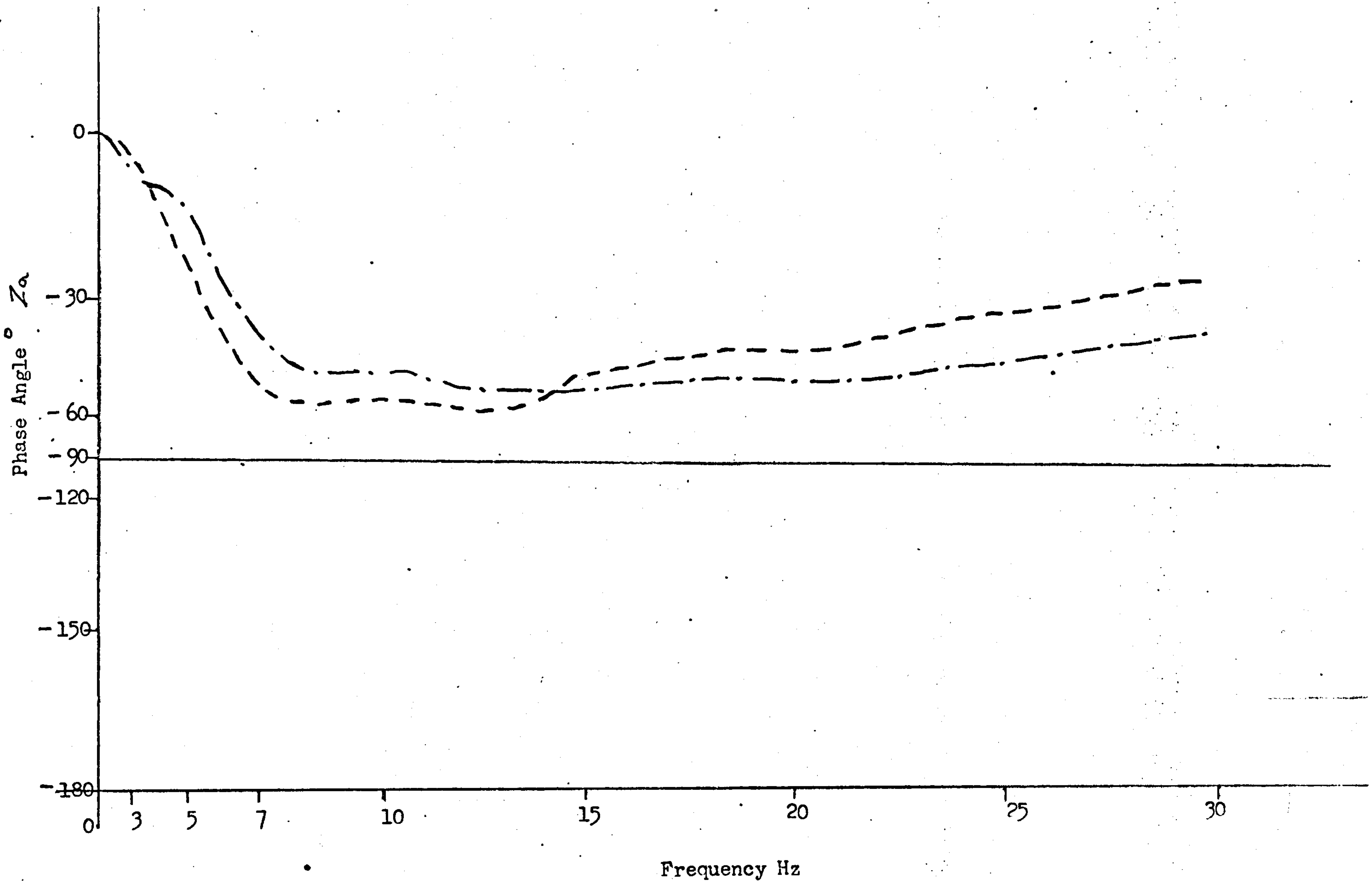


Figure No. 191 M12 - E and R

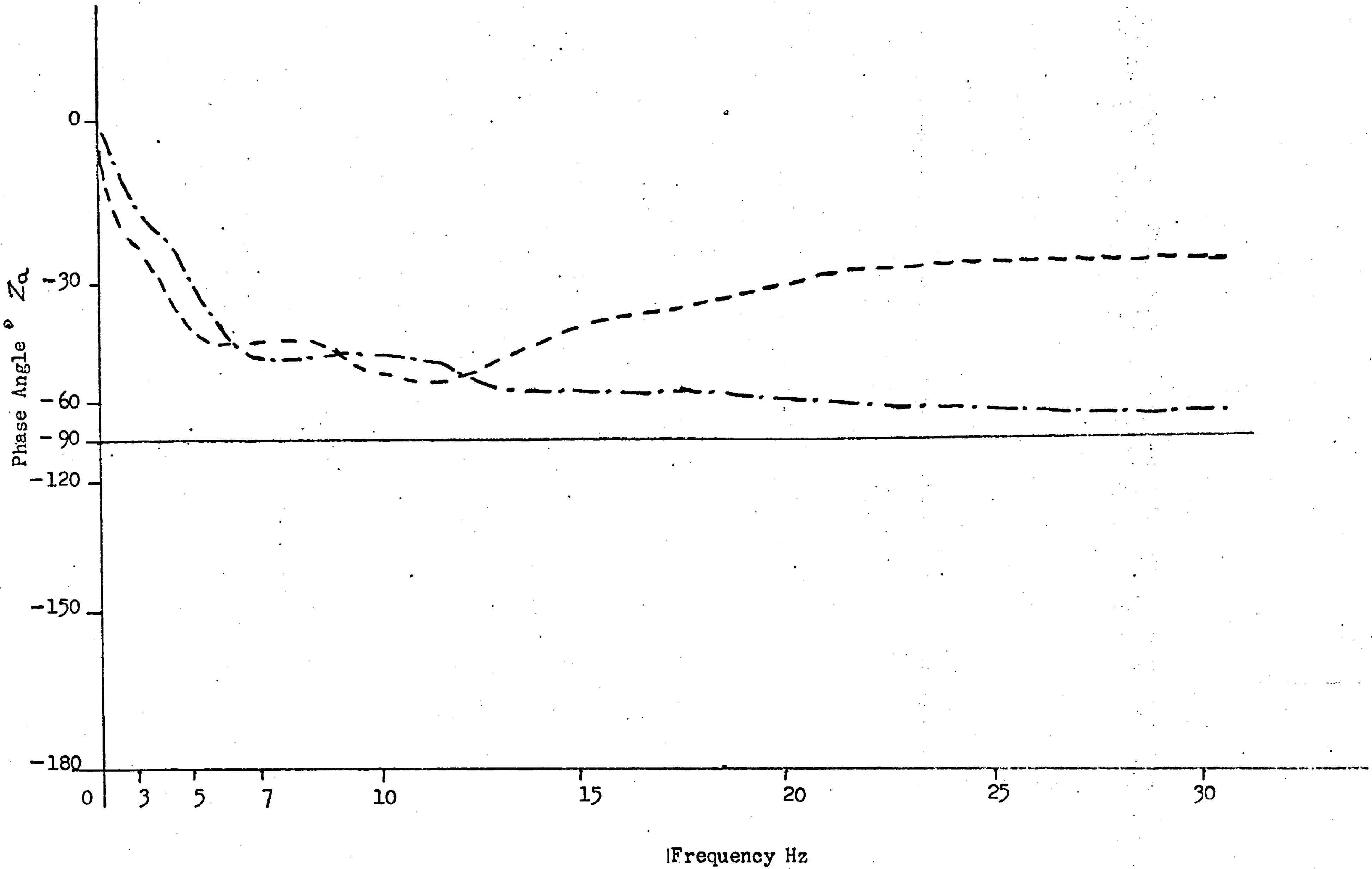
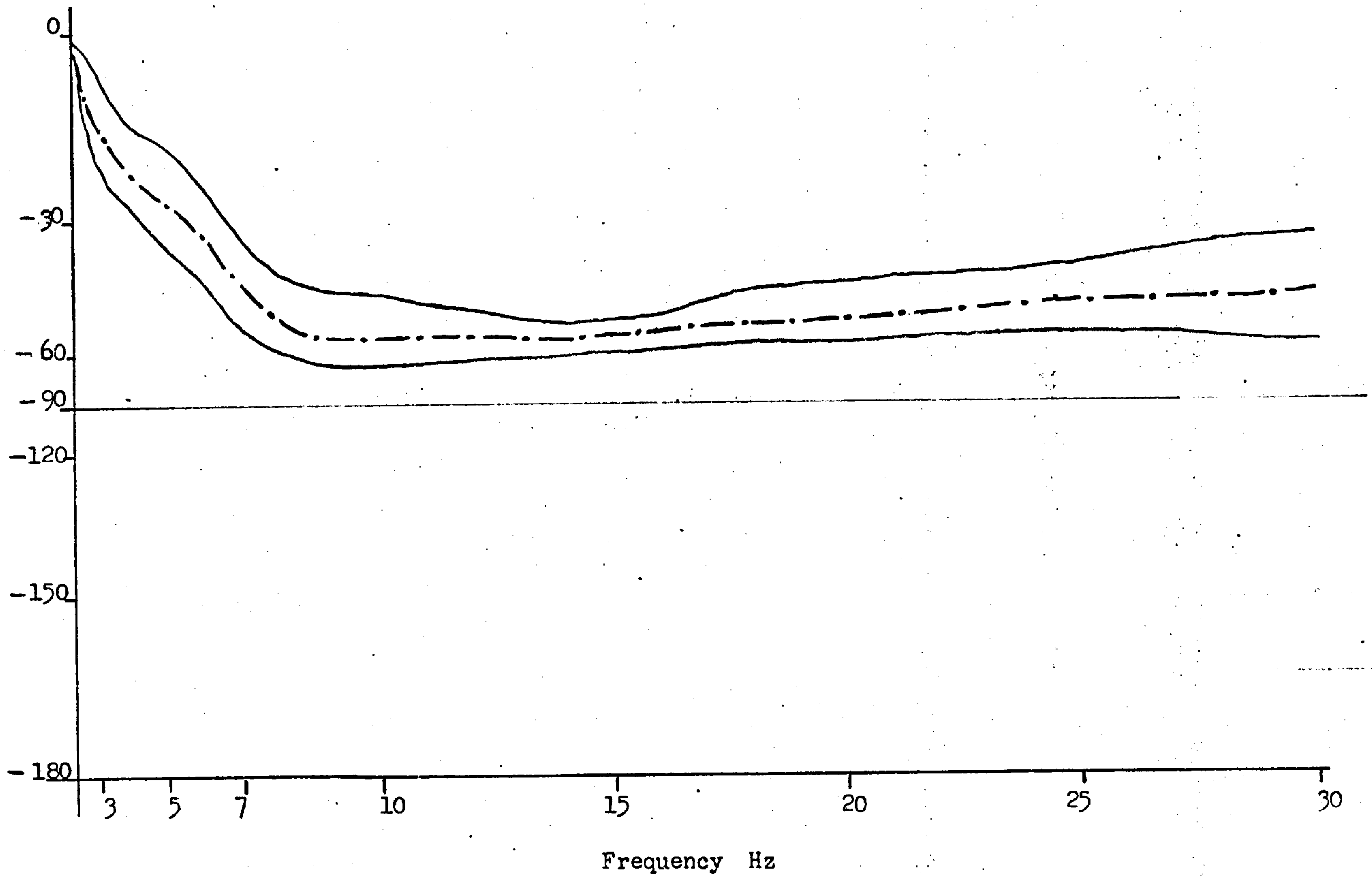
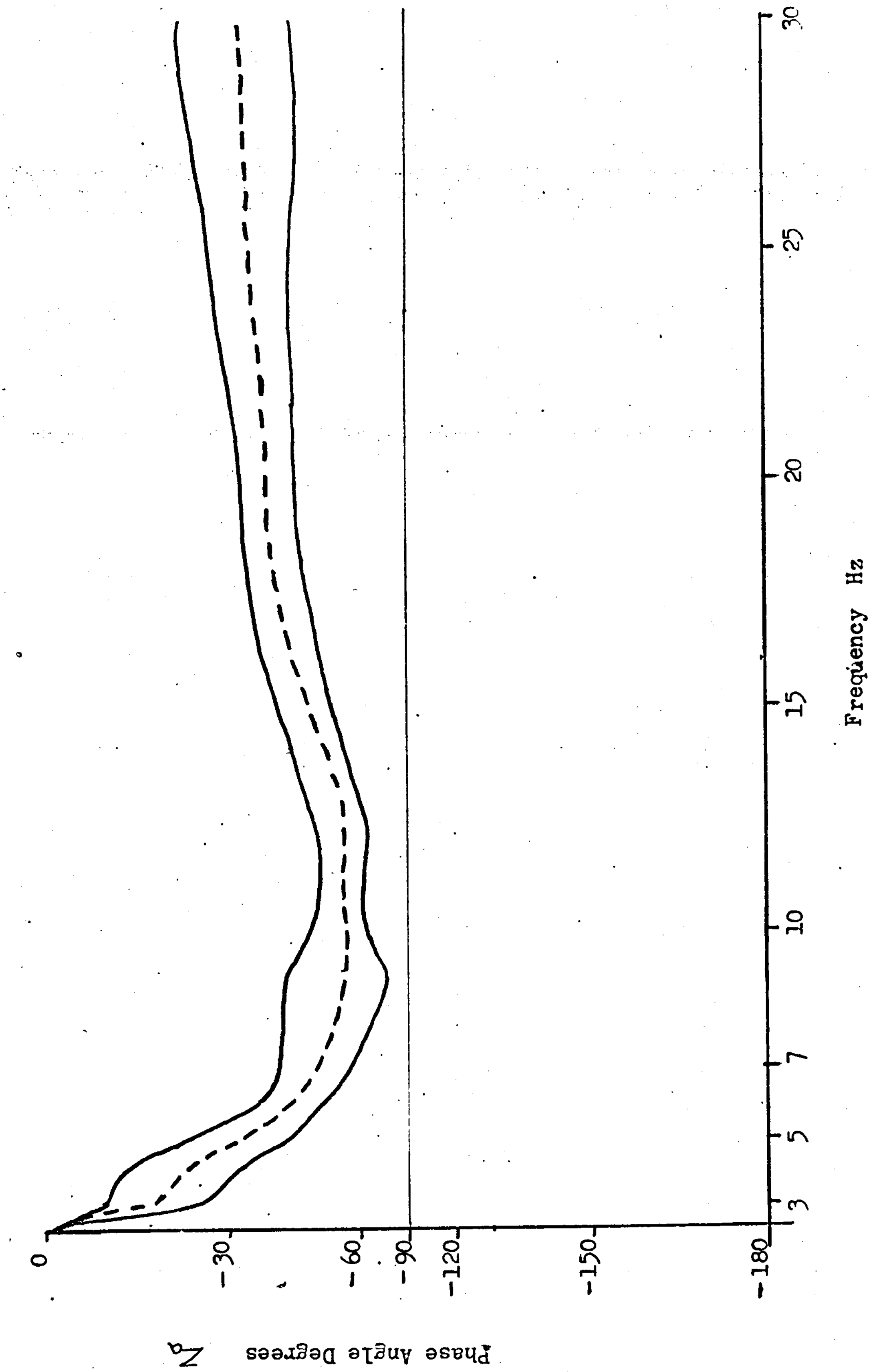


Figure No.192M15 - E and R



Mean value for 11 male subjects sitting erect + and - one standard deviation

Figure No.193



Mean value for 11 male subjects sitting relaxed + and - one standard deviation.

Figure No 194

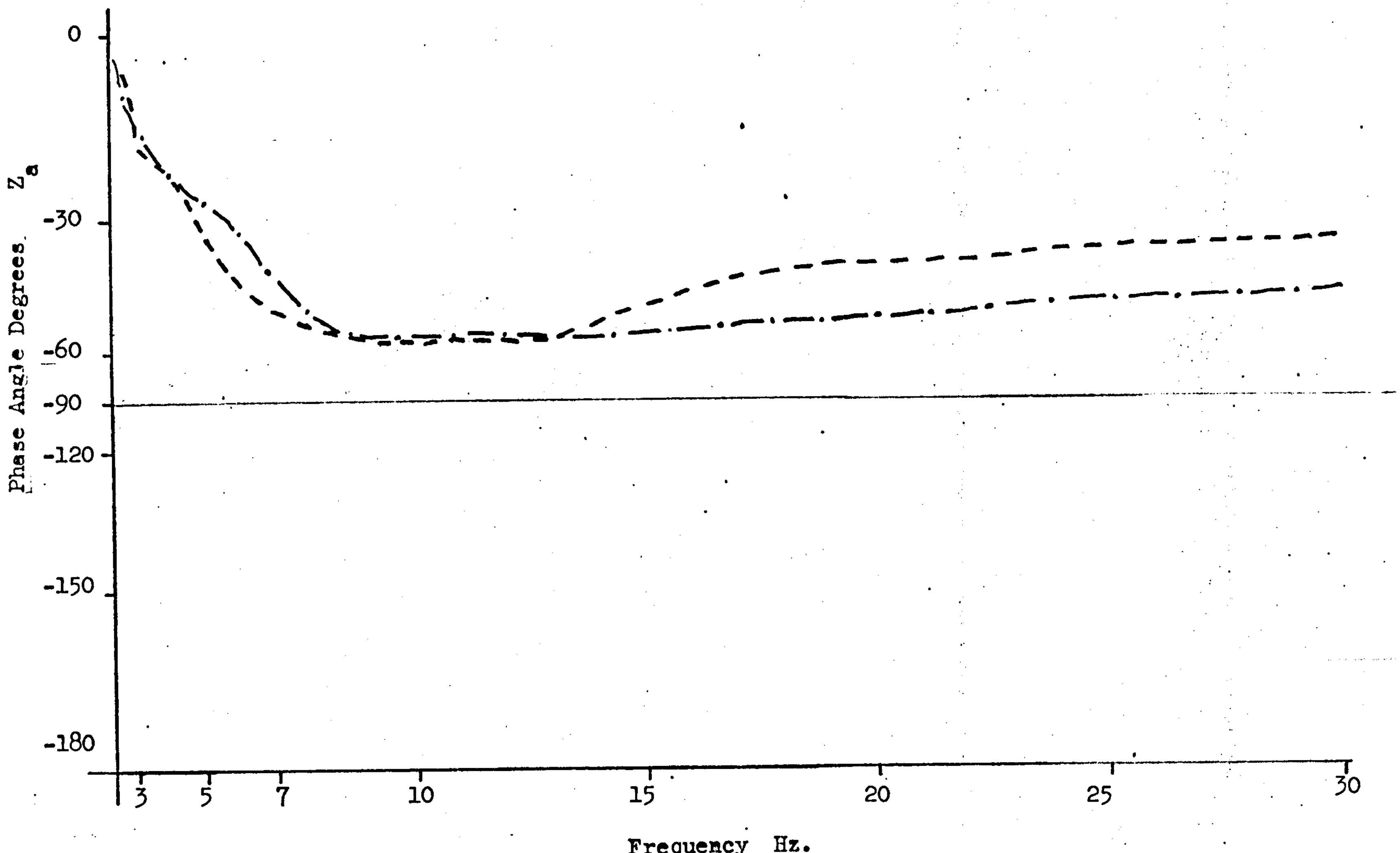


Figure No. 195

Mean values for 11 male subjects sitting erect and relaxed

Erect Posture

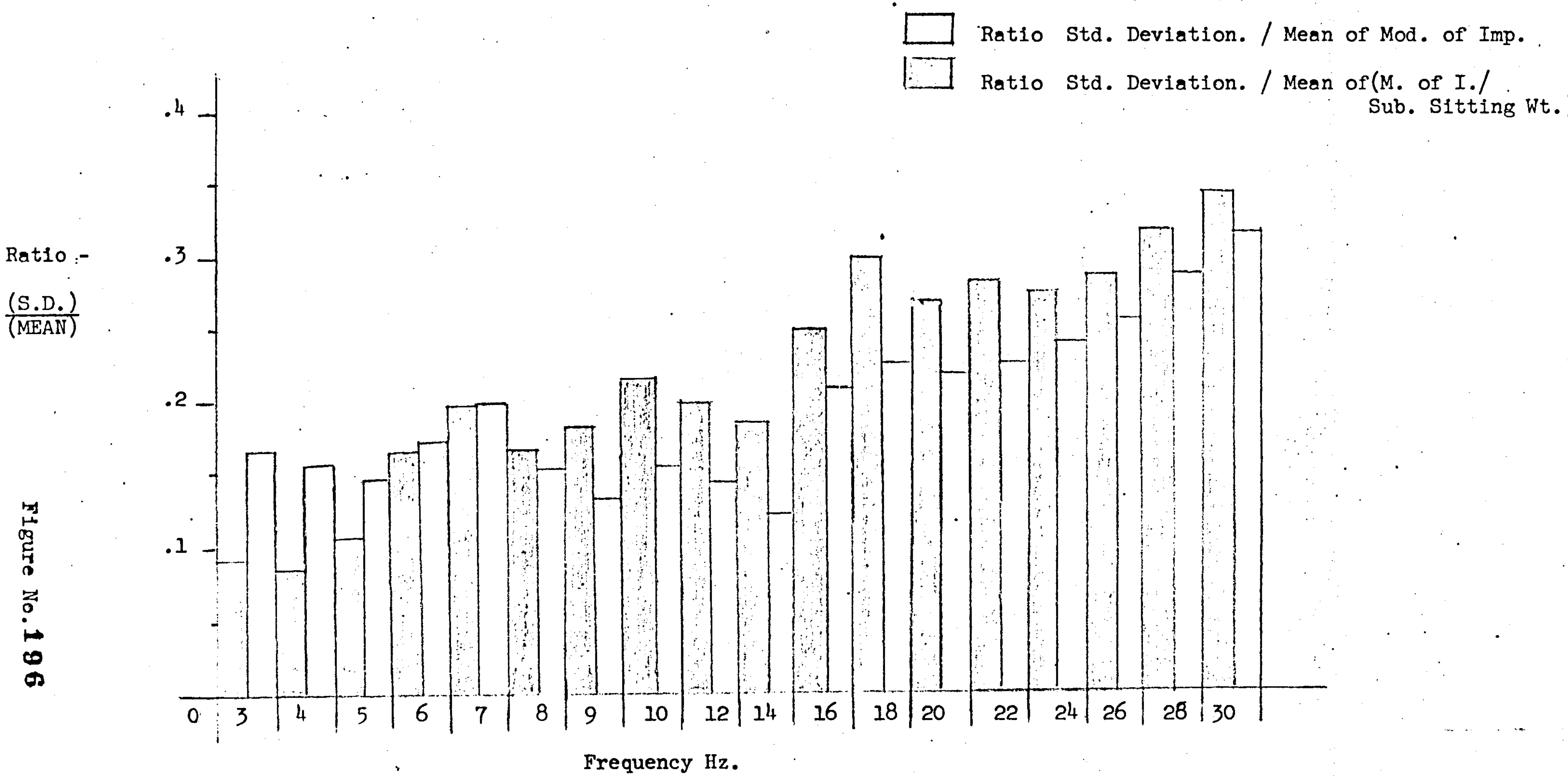


Figure No. 196

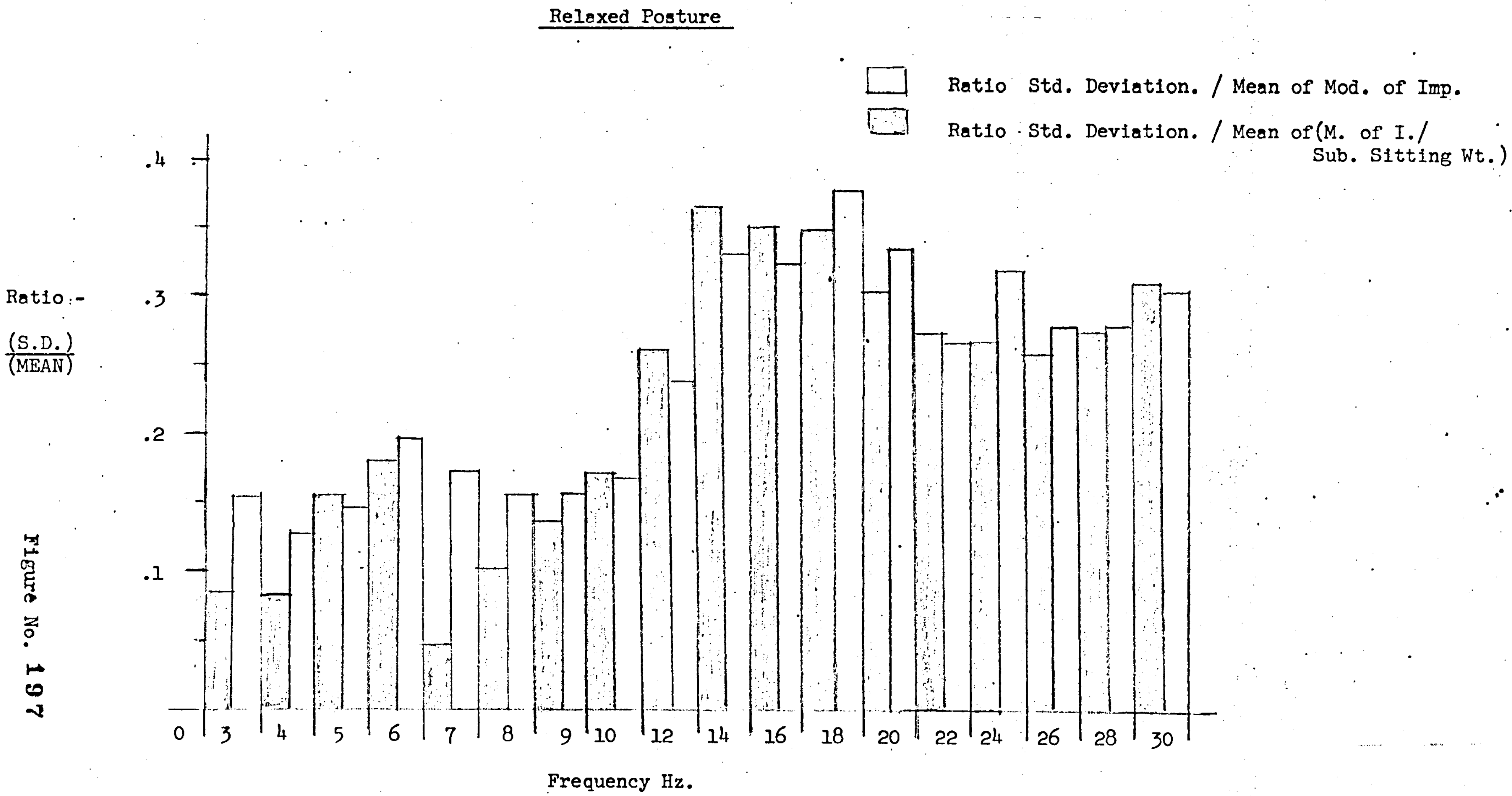
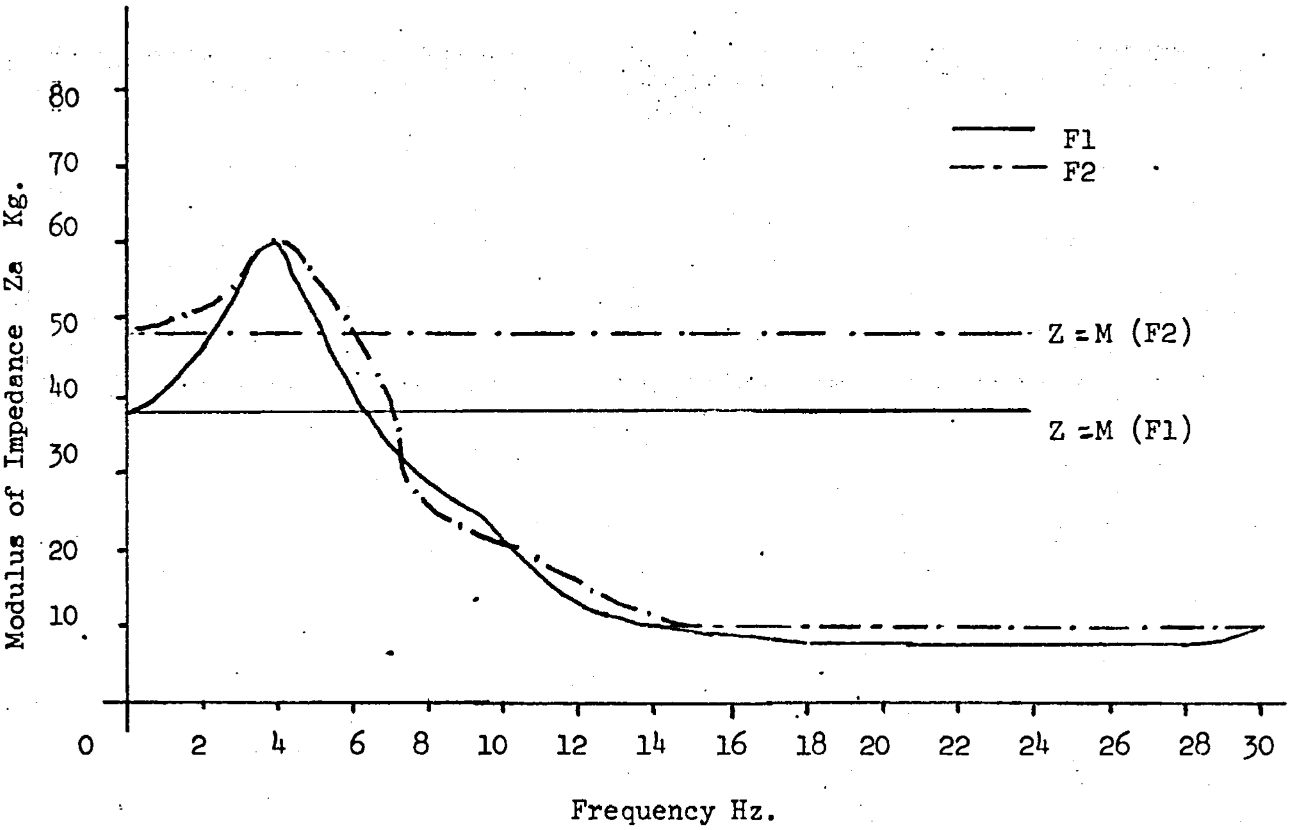
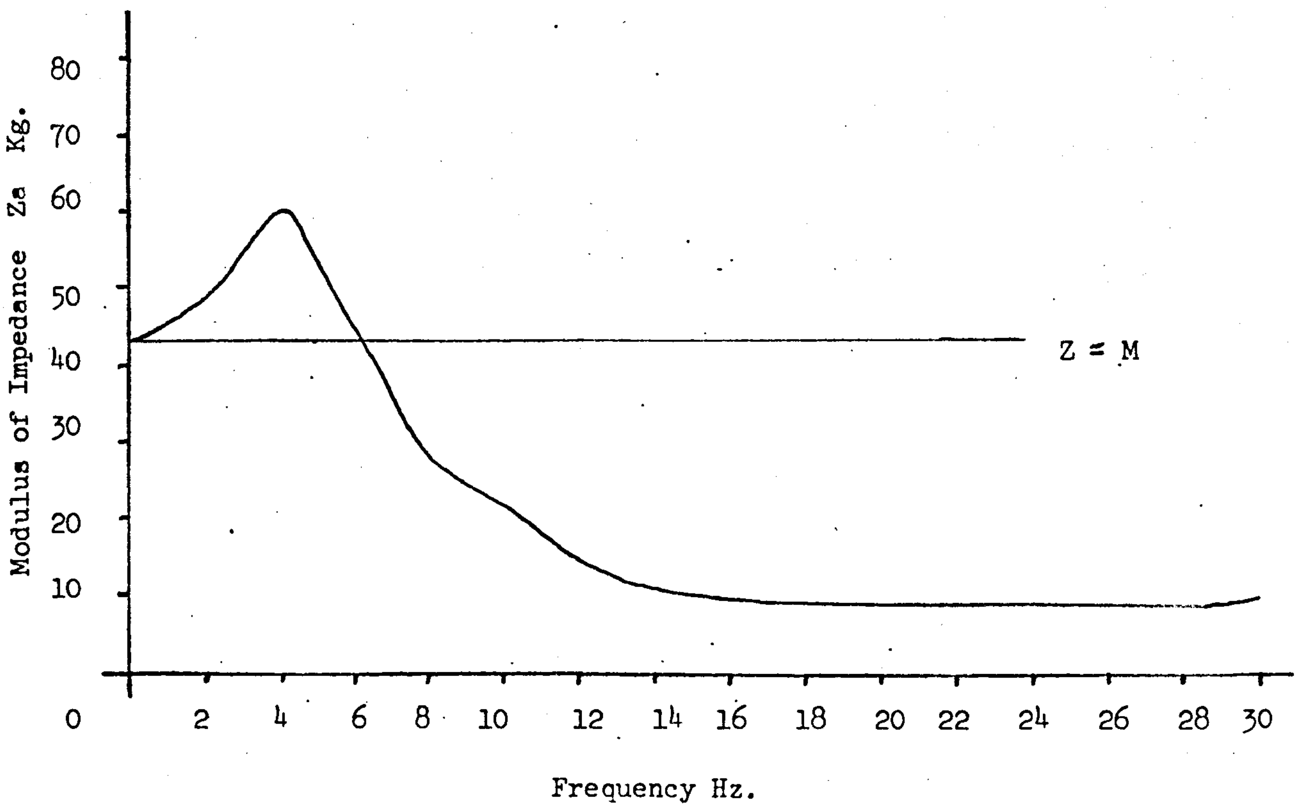


Figure No. 197

Erect Posture



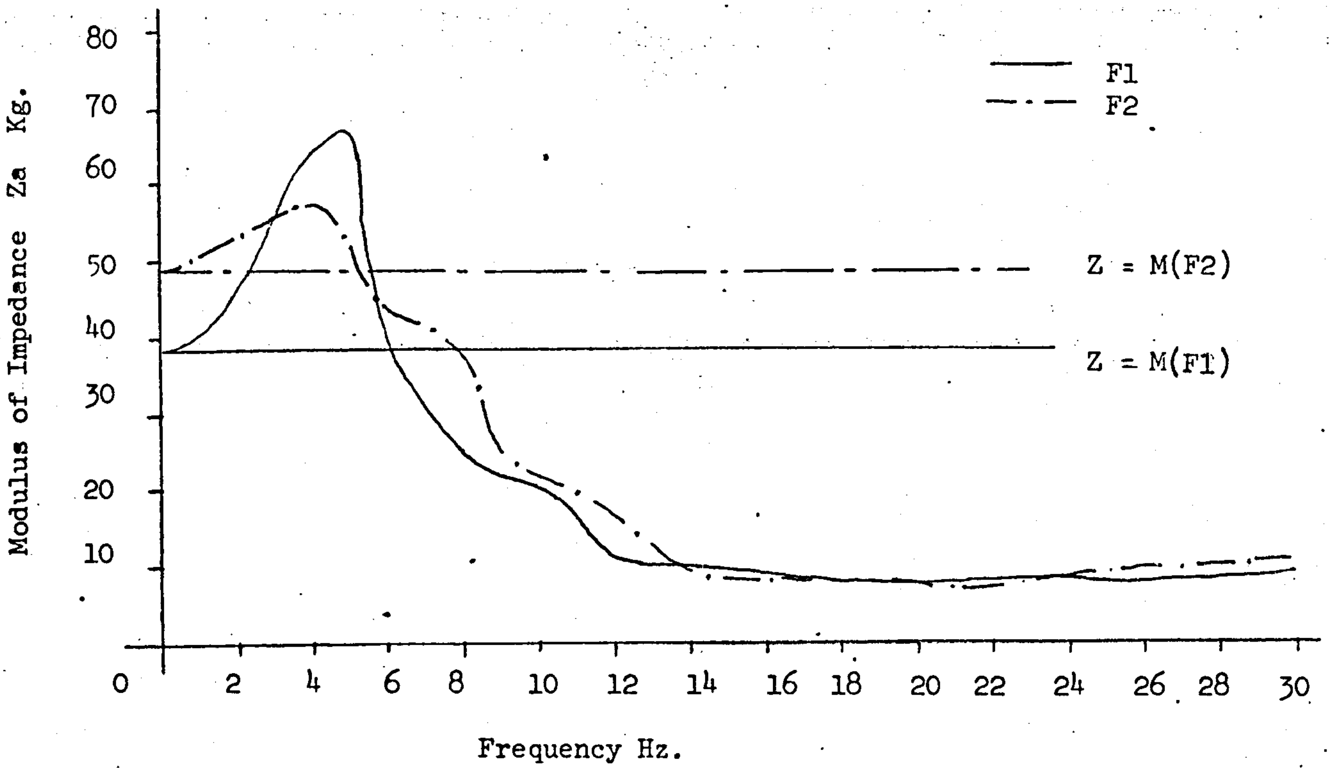
Values for F1 and F2.



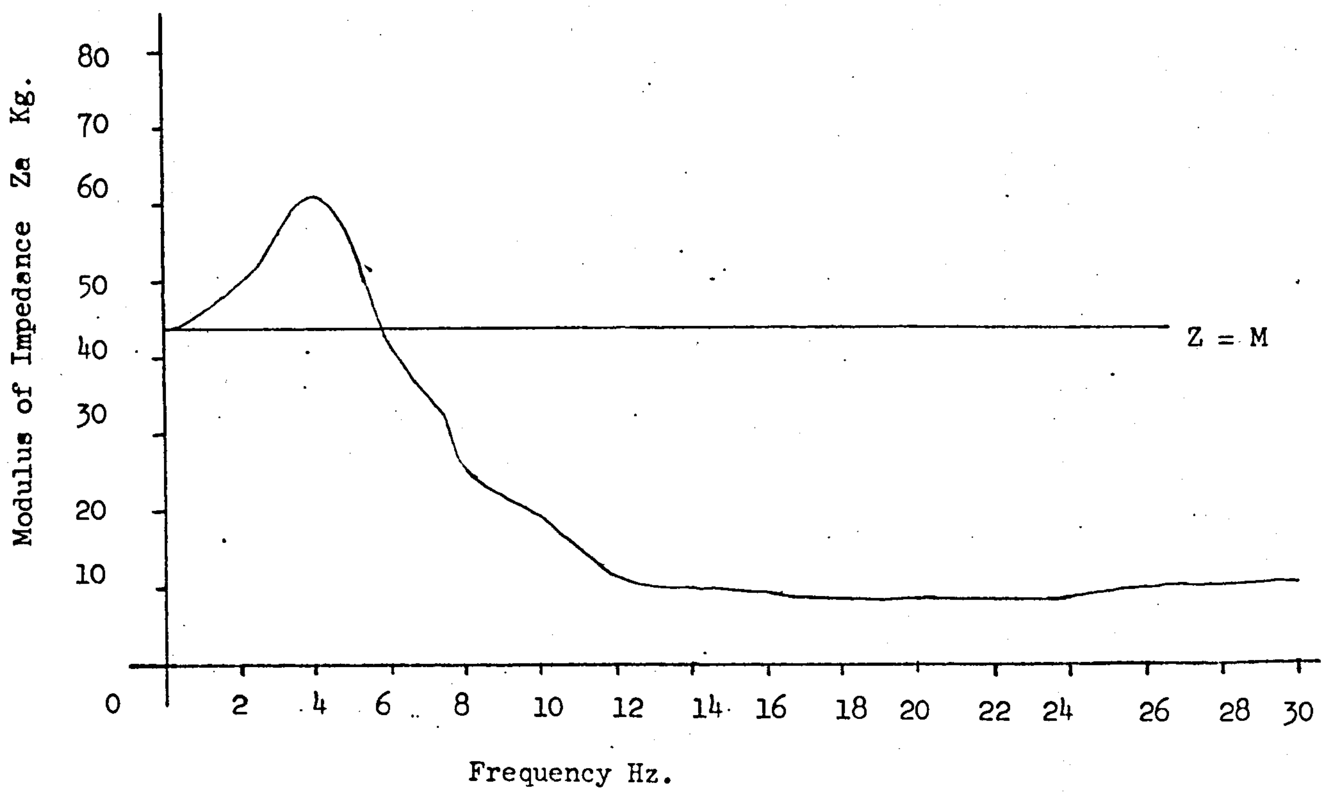
Mean value for F1 and F2.

Figure No. 198

Relaxed Posture

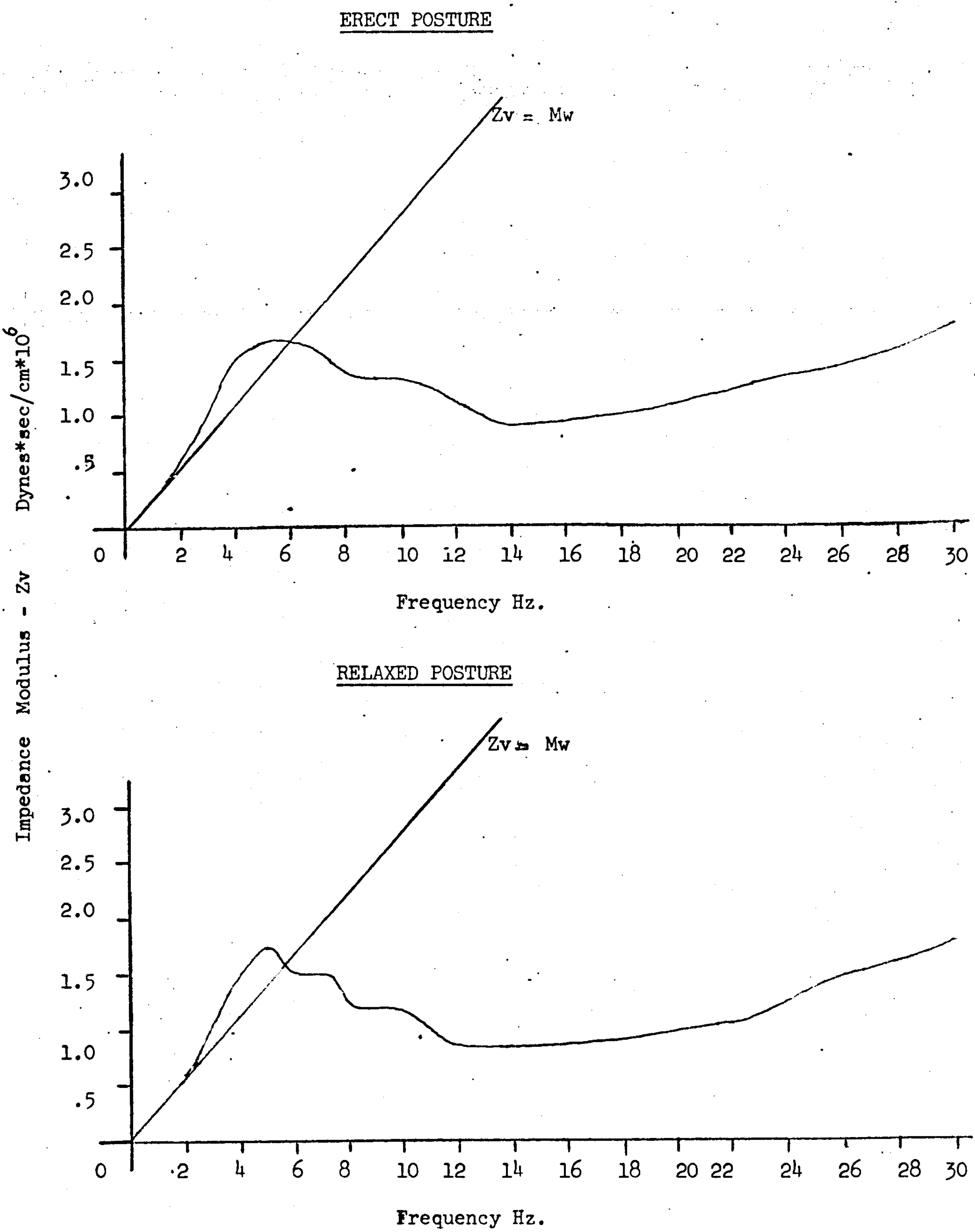


Values for F1 and F2.



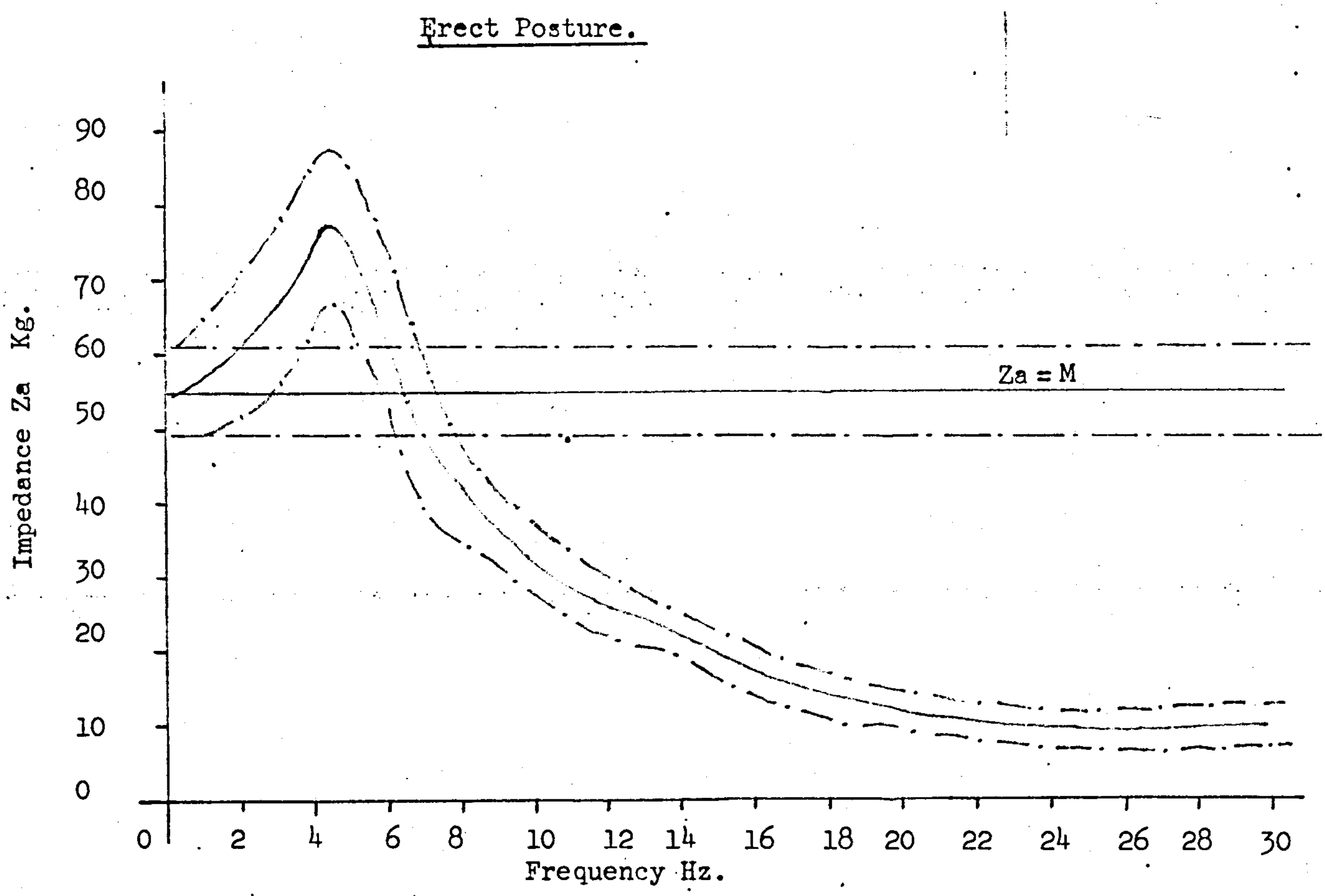
Mean value for F1 and F2.

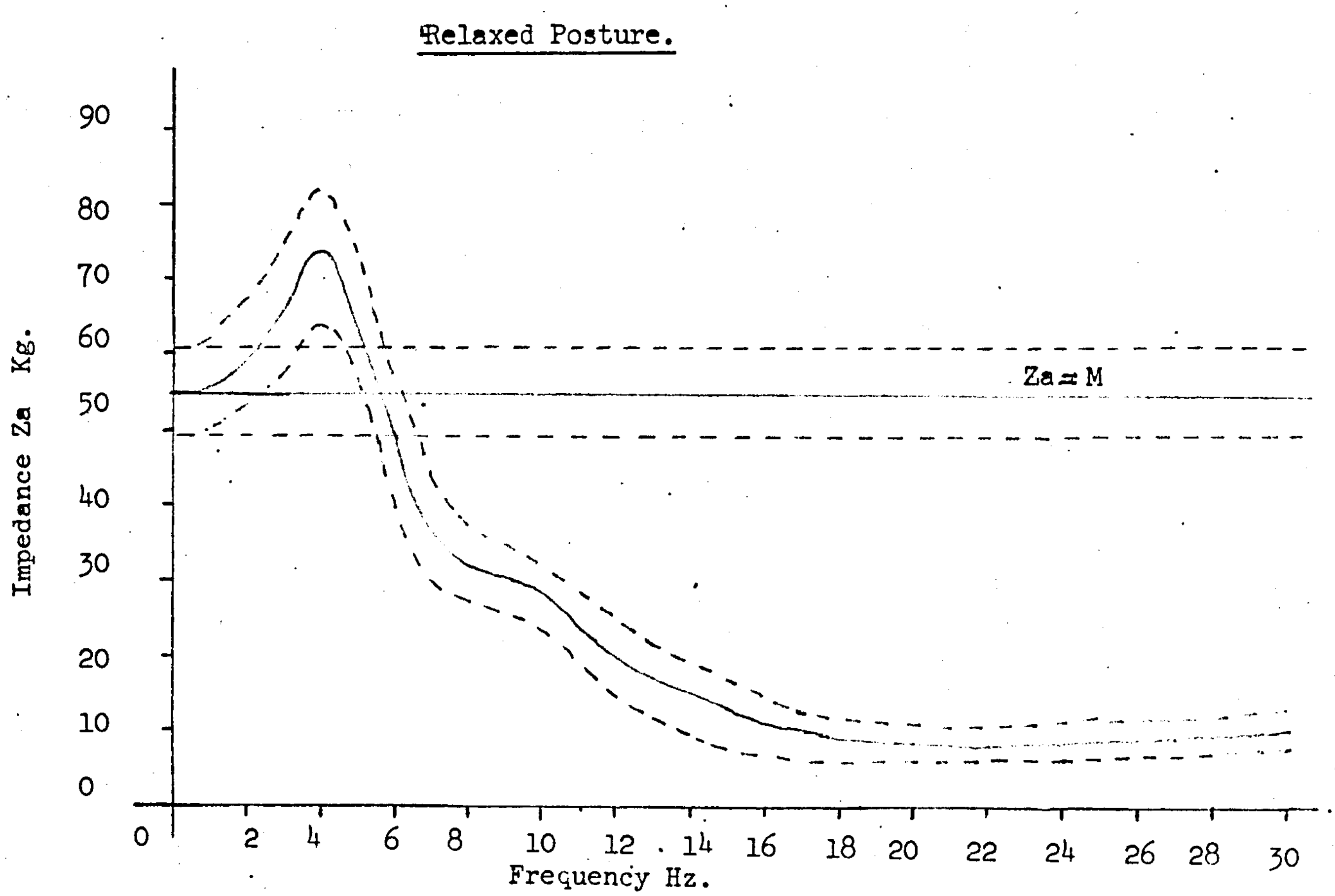
Figure No. 199



The mean values for two Female subjects.

Figure No. 200

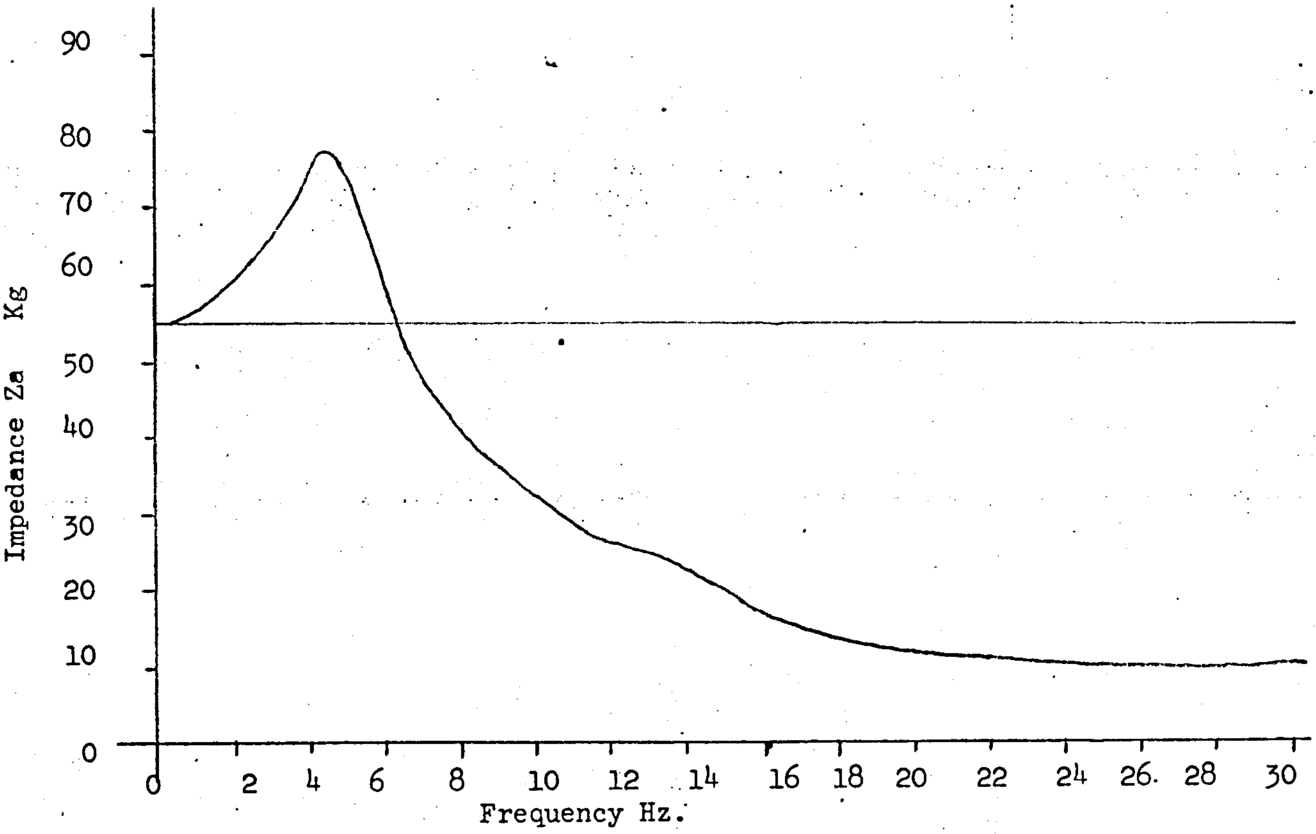




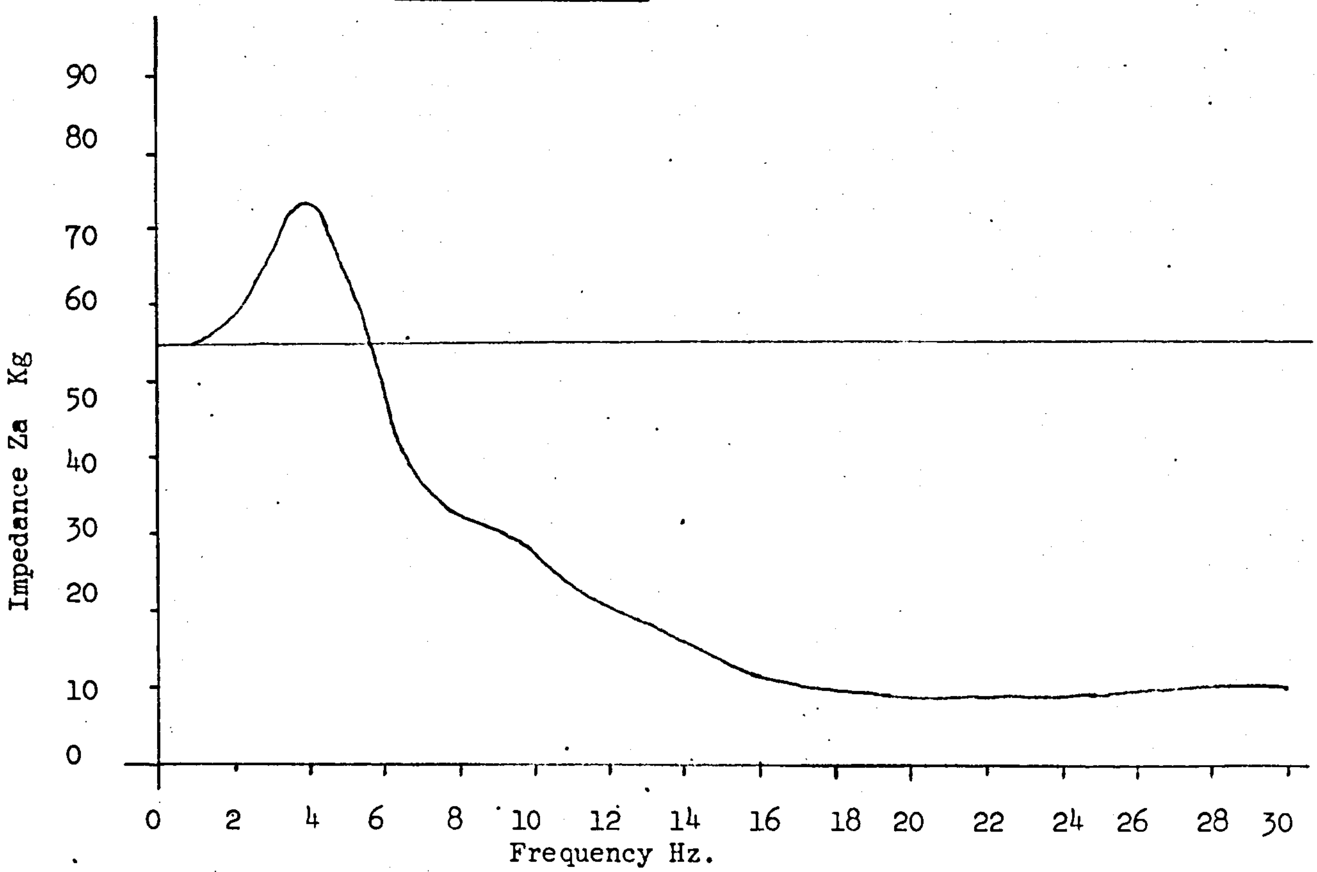
The mean values of the Modulus of Impedance for 14 Male subjects, with + and - 1 Standard Deviation shown on the graphs.

Figure No. 201

Erect Posture.

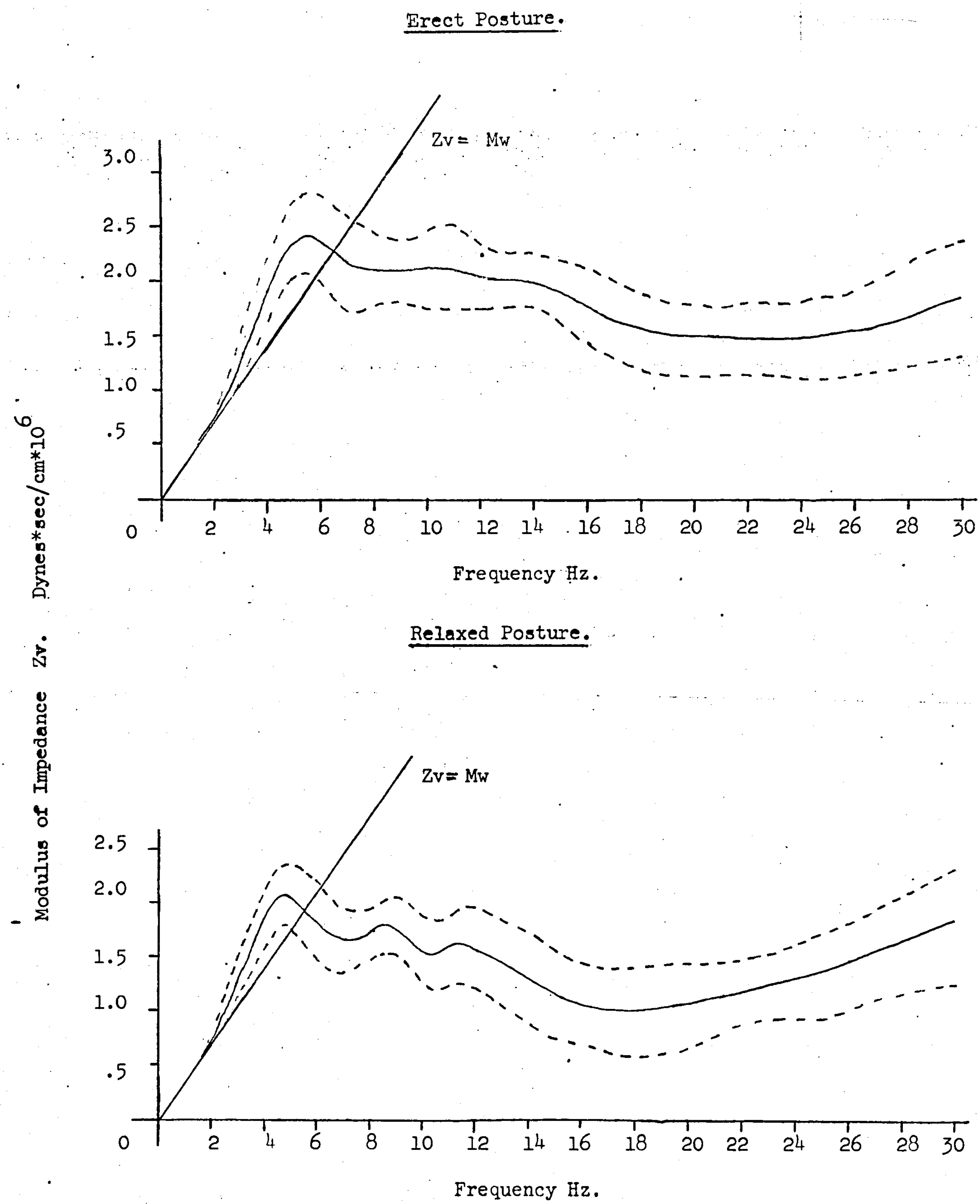


Relaxed Posture.



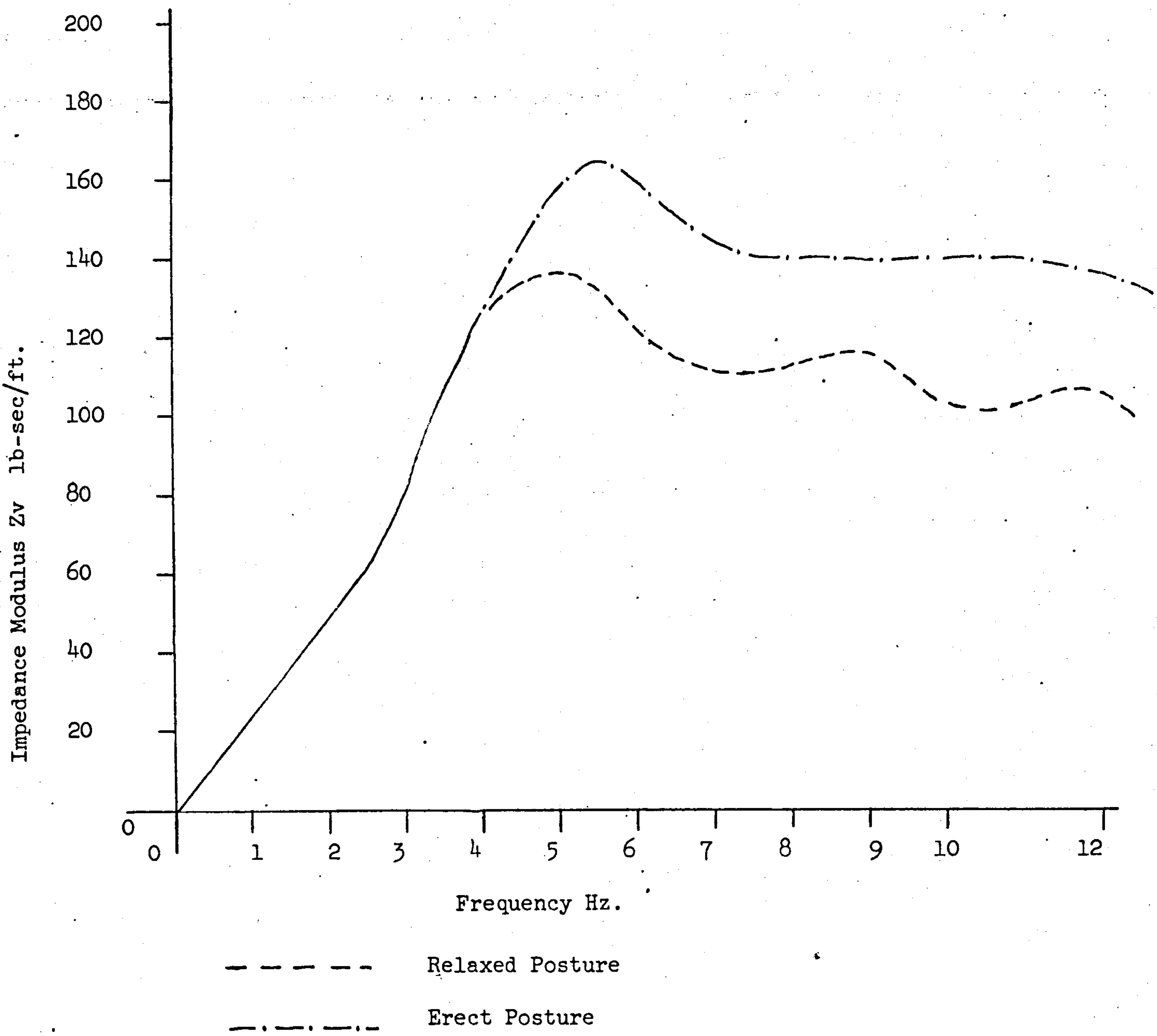
The mean values of the Modulus of Impedance for 14 Male subjects.

Figure No. 202



The mean values of the Modulus of Impedance for 14 Male subjects, with + and - 1 Standard Deviation shown on the graphs.

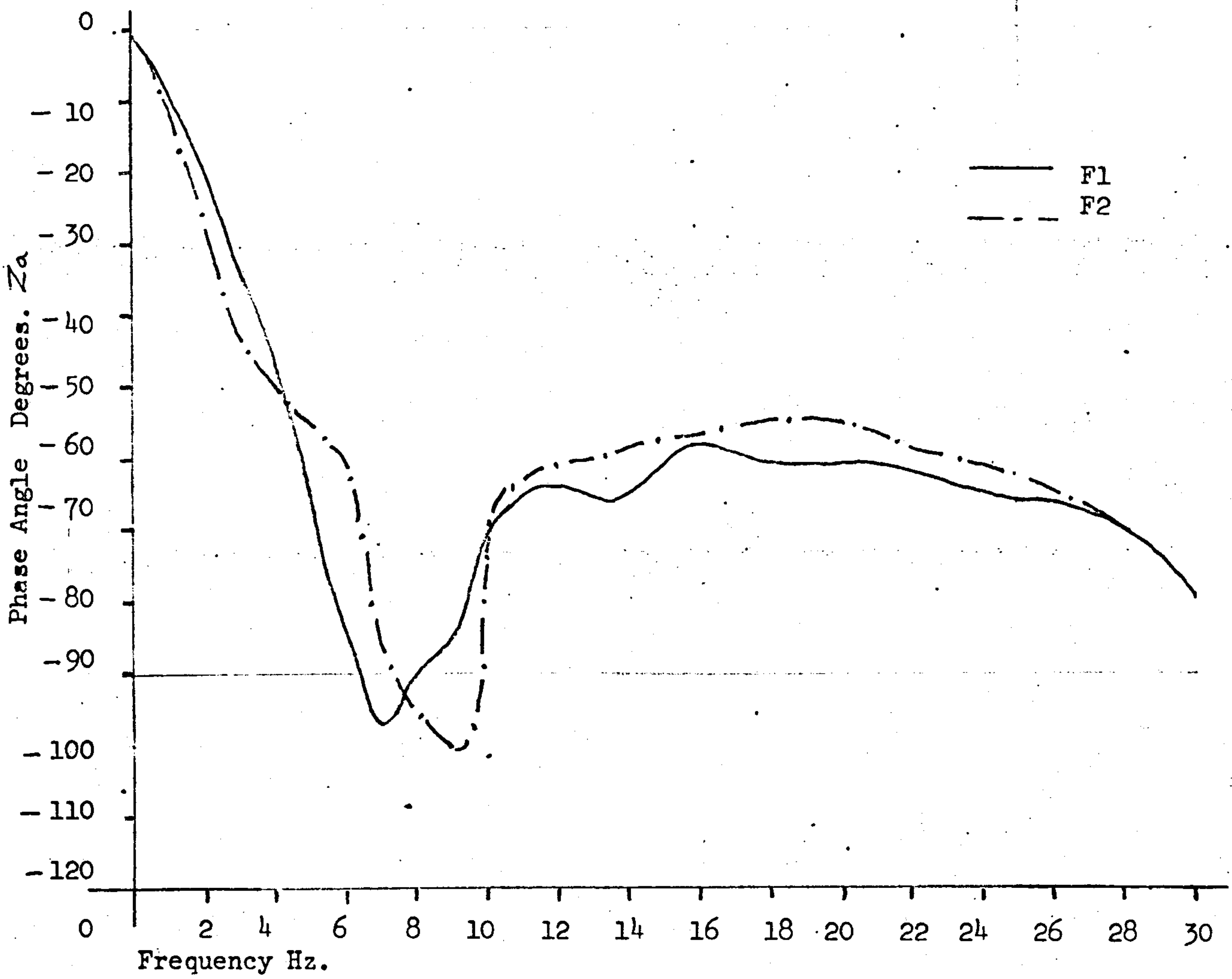
Figure No. 203



The mean values of 14 Male subjects.

Figure No. 204

ERECT POSTURE -Female subjects F1 and F2.



ERECT POSTURE- Mean value for subjects F1 and F2.

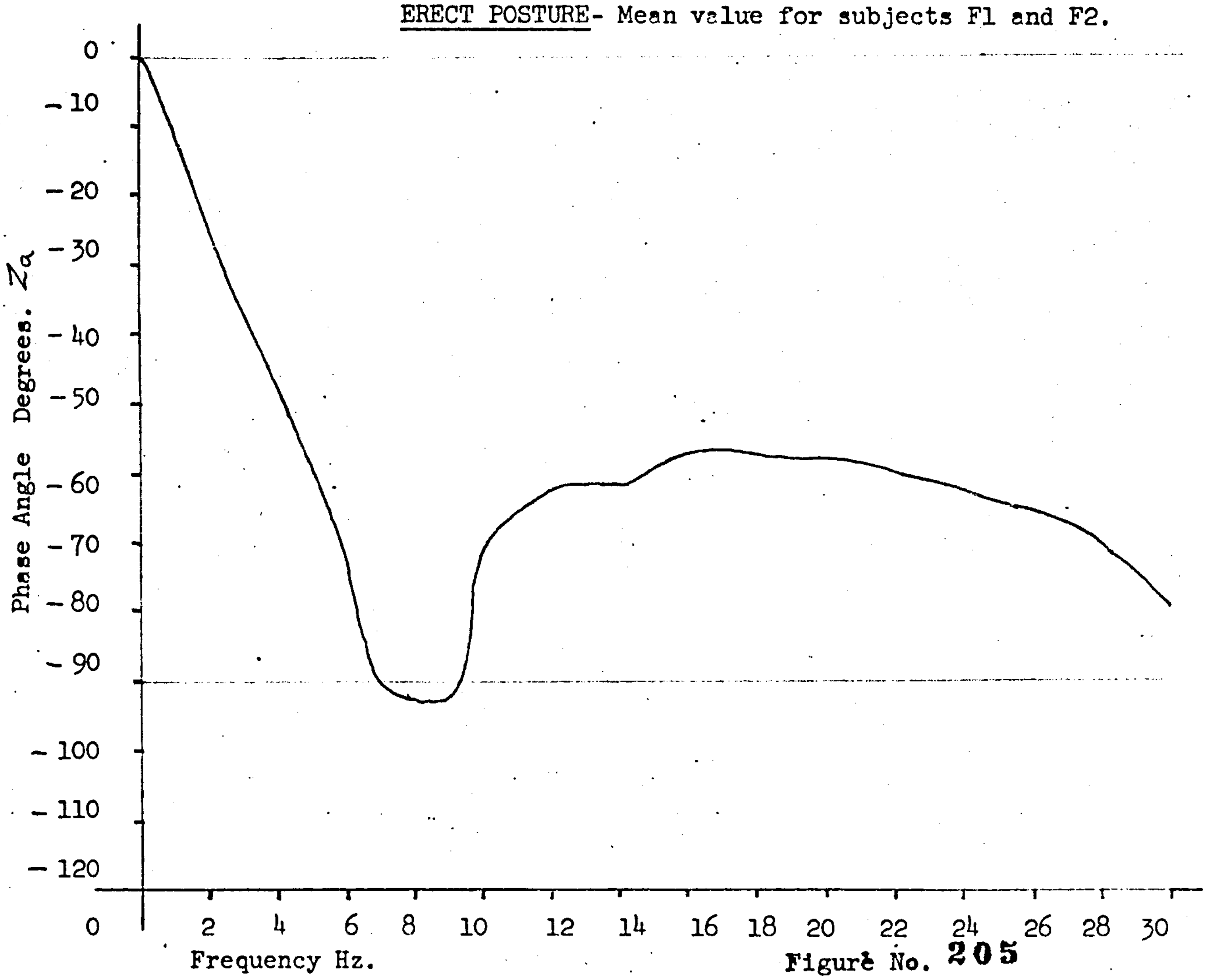
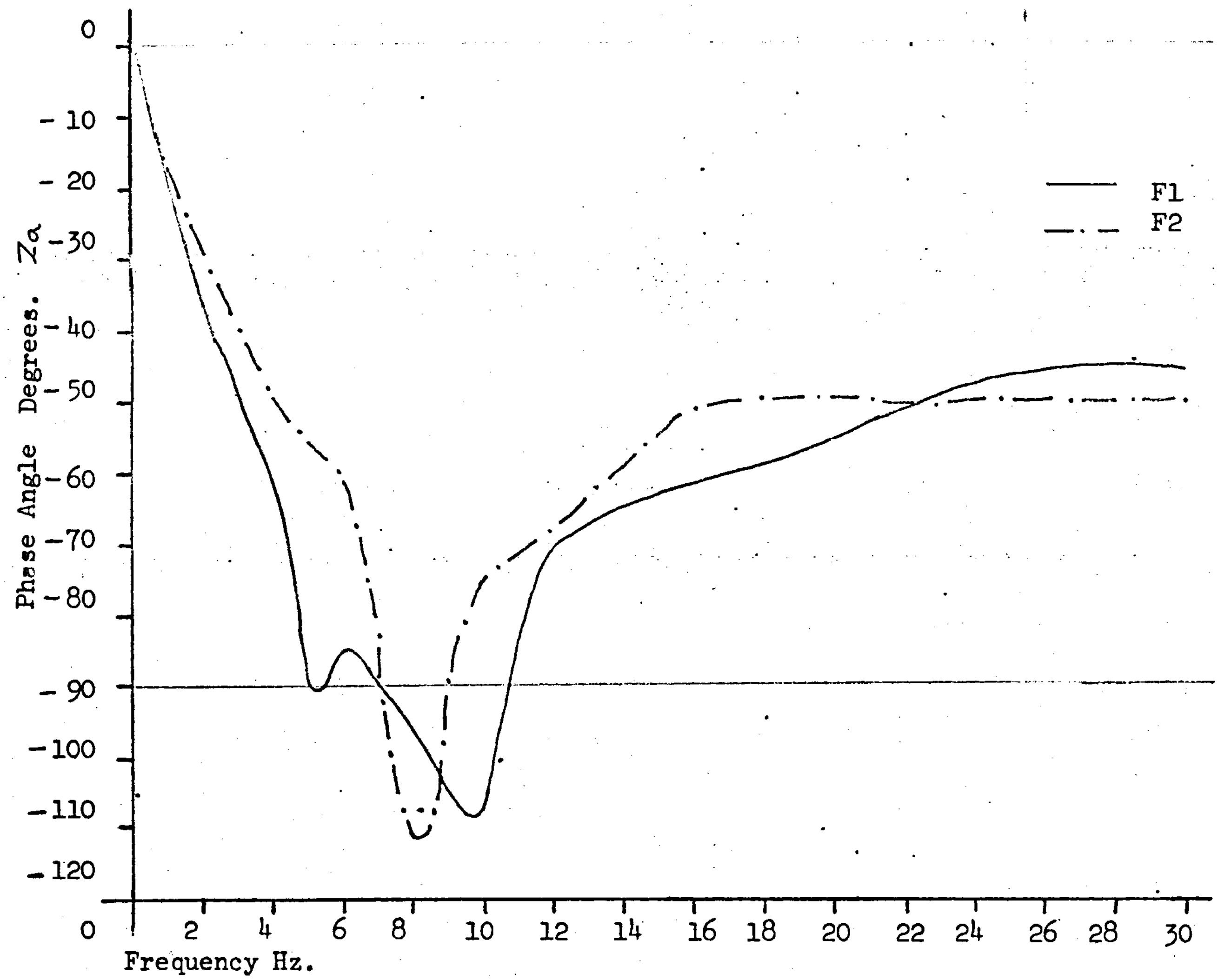


Figure No. 205

RELAXED POSTURE - Female subjects F1 and F2.



RELAXED POSTURE - Mean value for subjects F1 and F2.

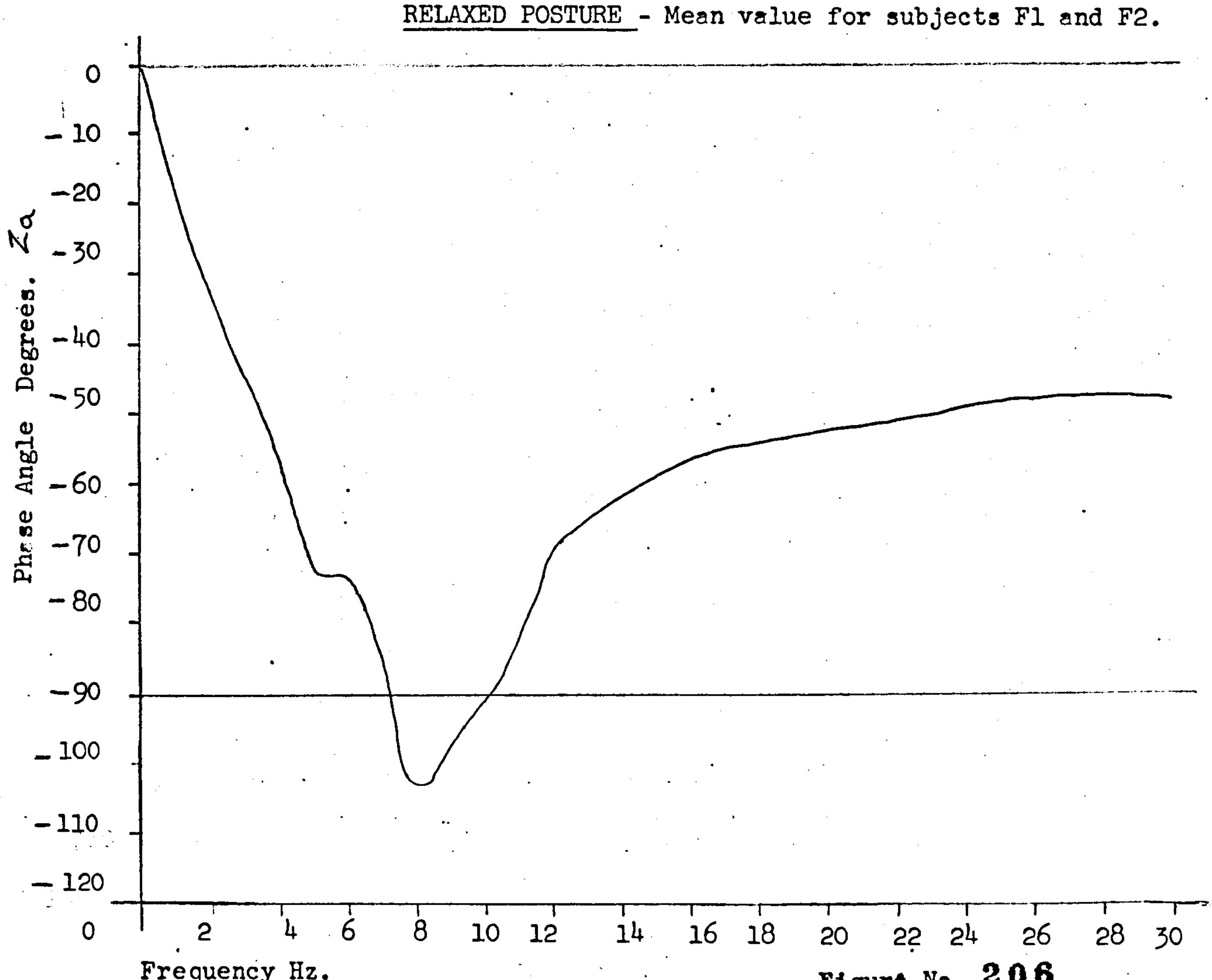
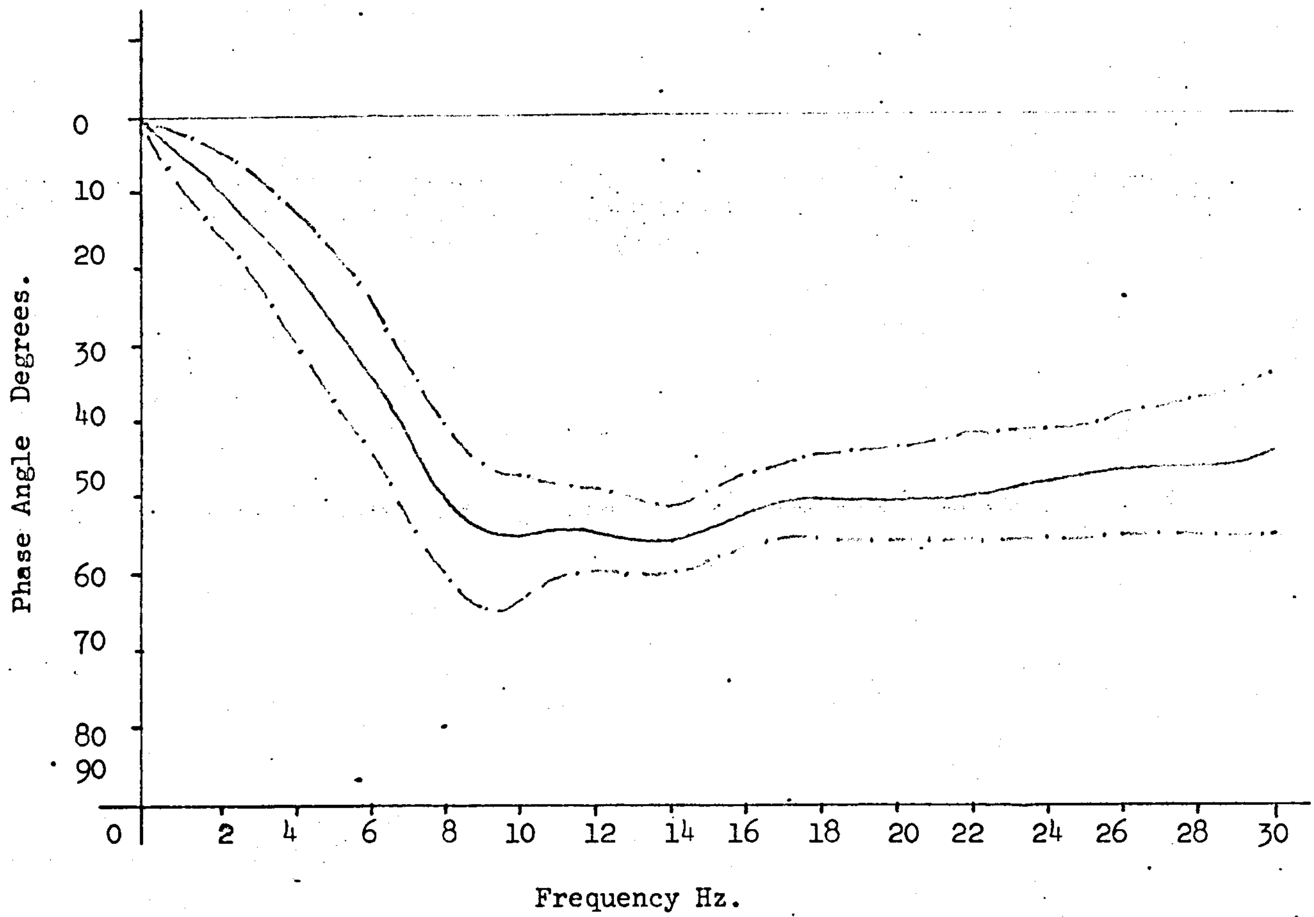
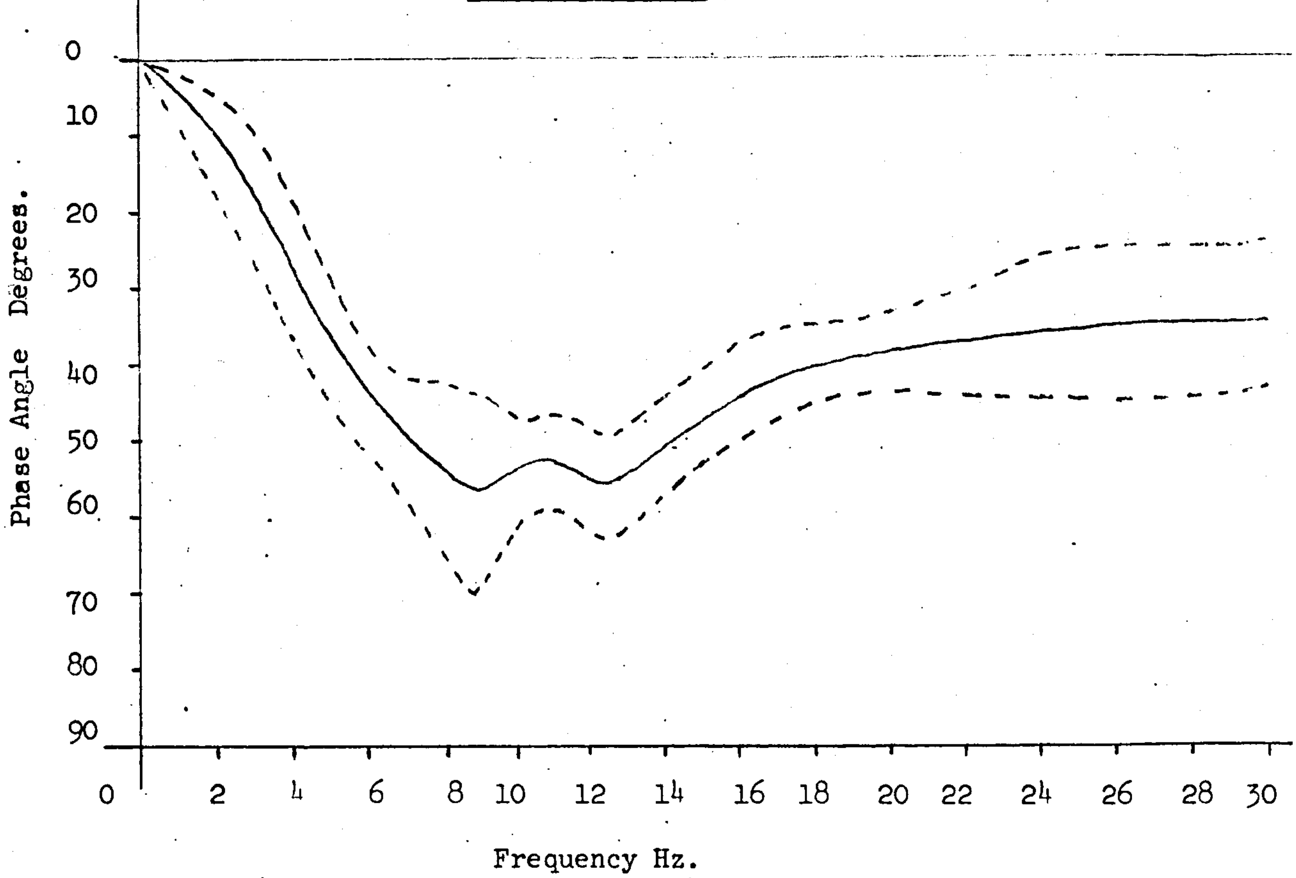


Figure No. **206**

Erect Posture

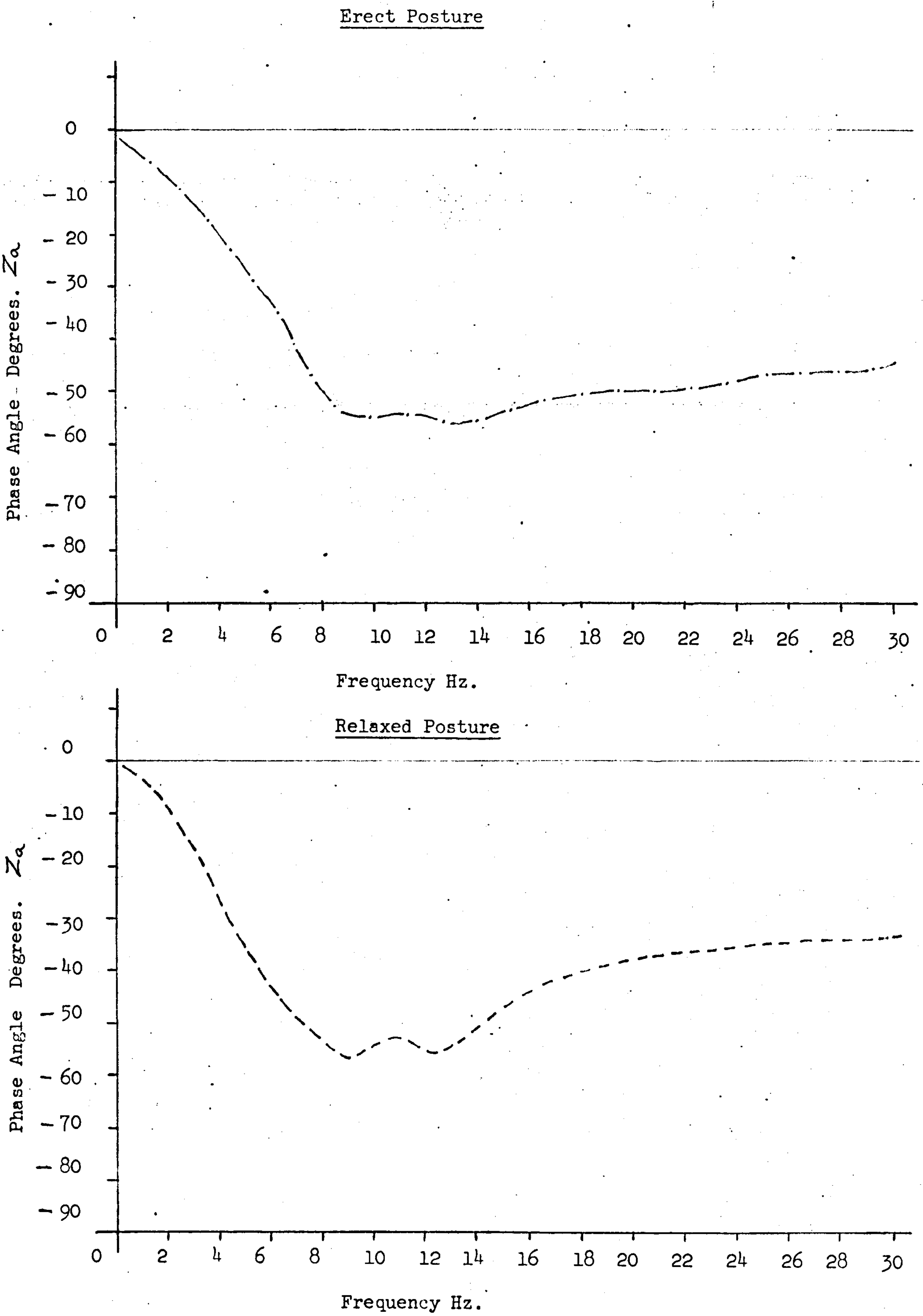


Relaxed Posture



The mean values of the Phase angle for 11 Male subjects, with +and - 1 Standard Deviation shown on the graphs.

Figure No. 207

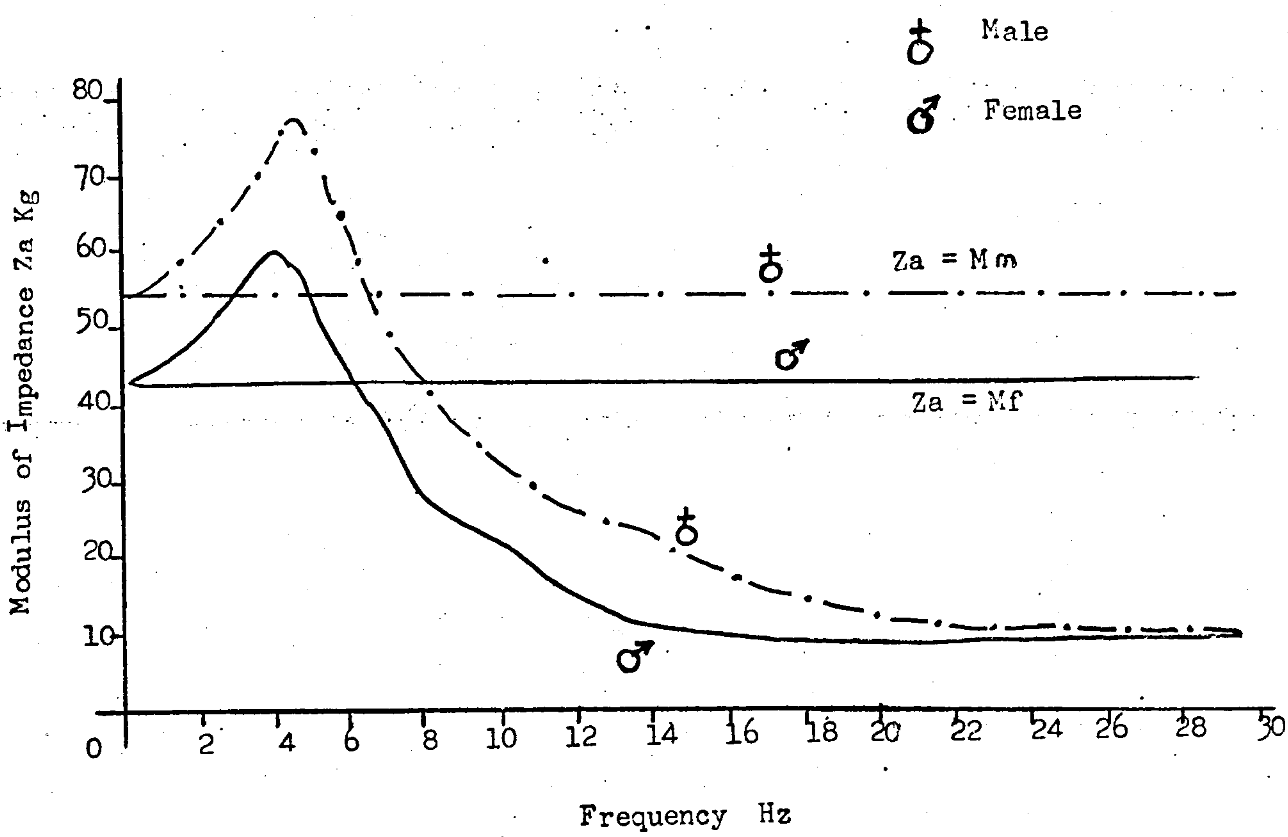


The mean values of the Phase angle for 14 Male subjects.

Figure No. 208

Comparison of Male with Female subjects.

Erect Posture



Relaxed Posture

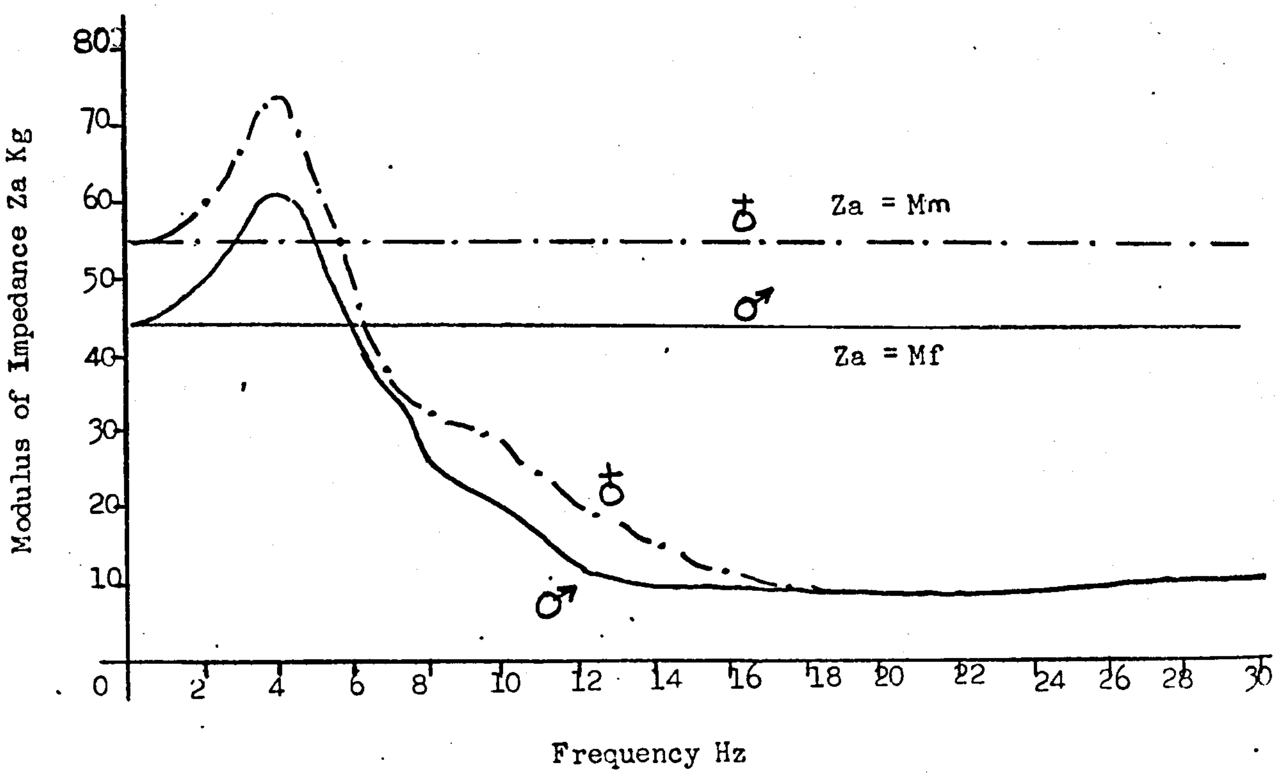
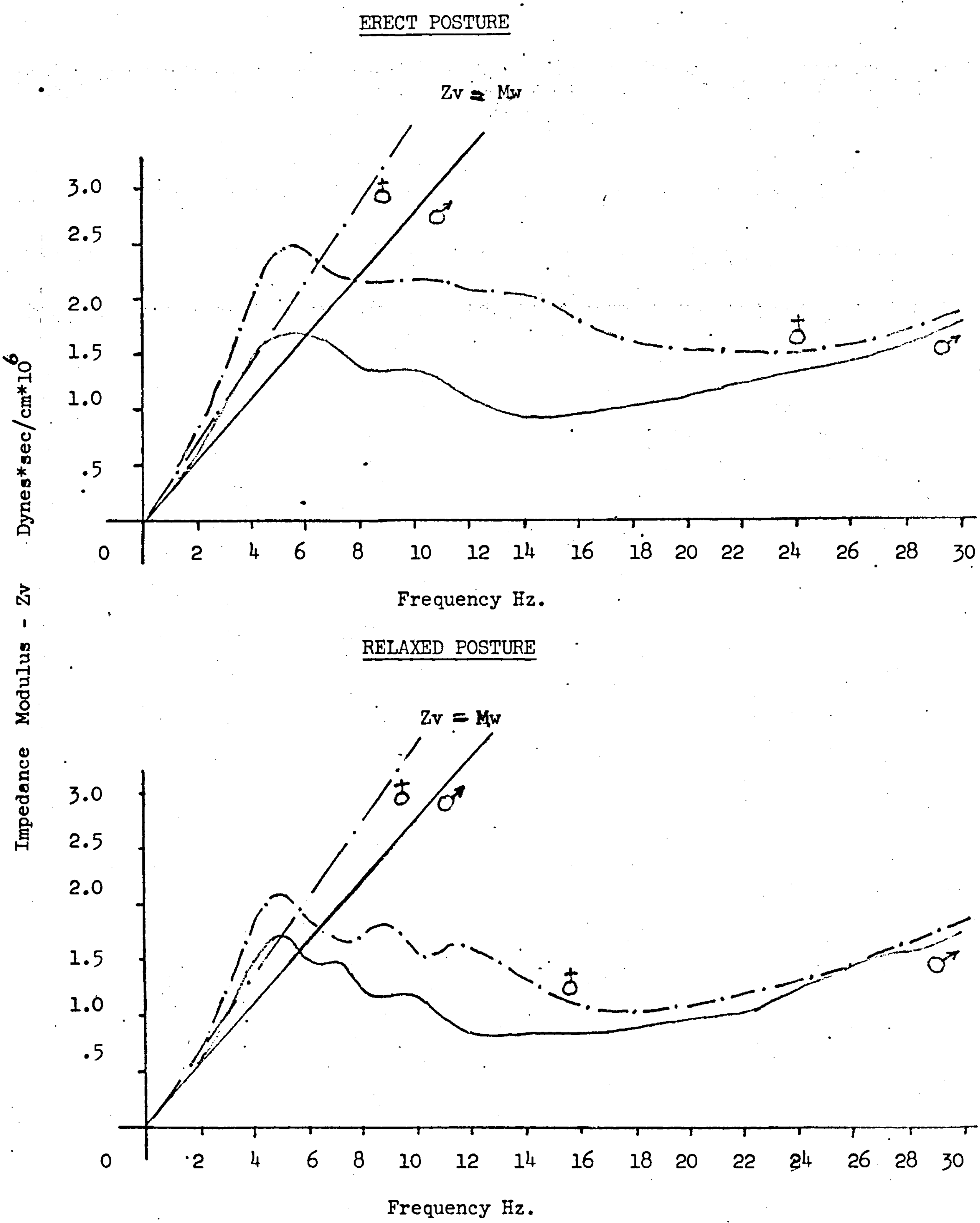


Figure No. 209

Comparison of Male with Female subjects.



♂ Mean values for F1 and F2.

♁ Mean values for 14 Male subjects.

Figure No, 210

Comparison of Male with Female subjects.

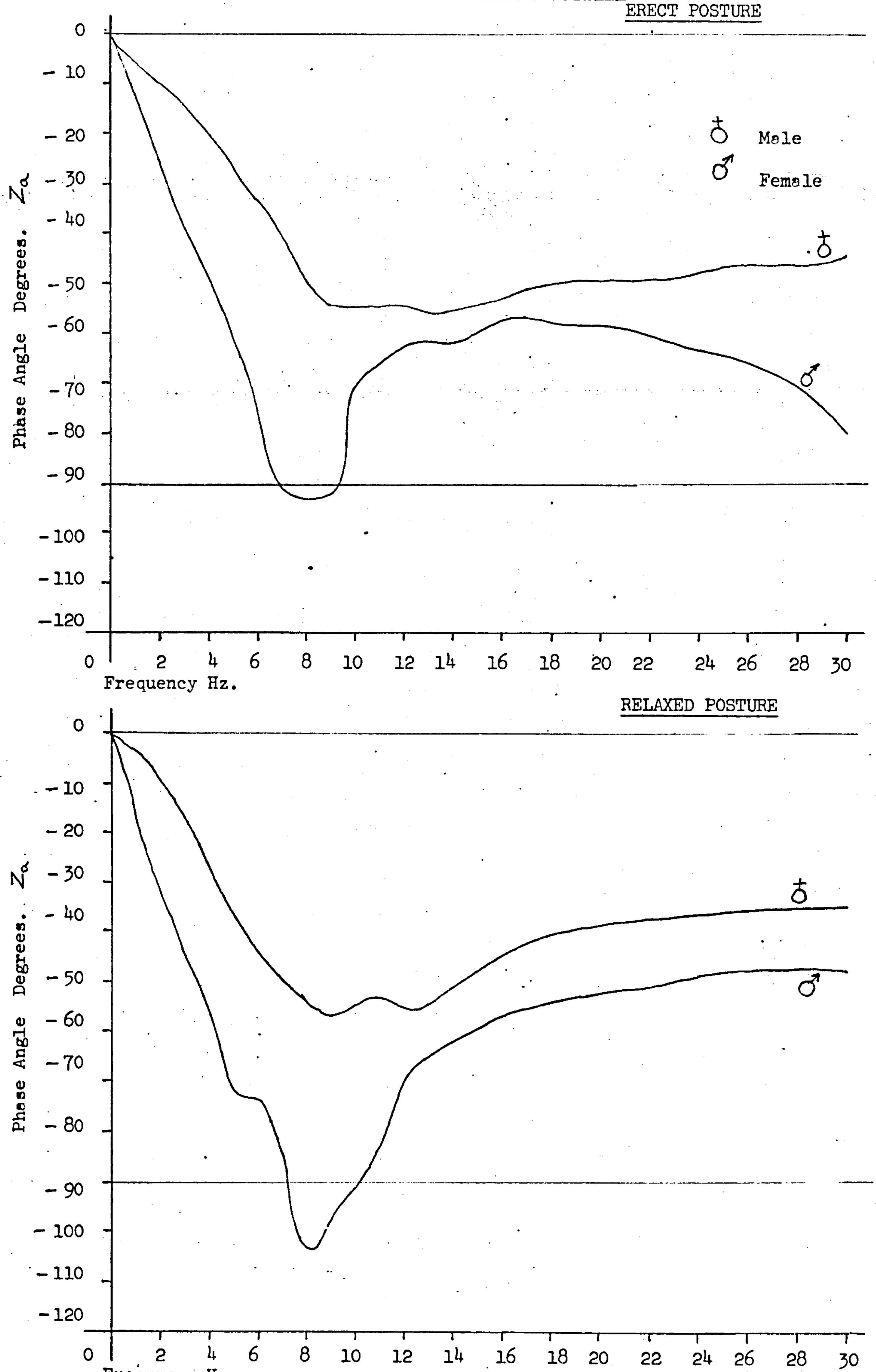
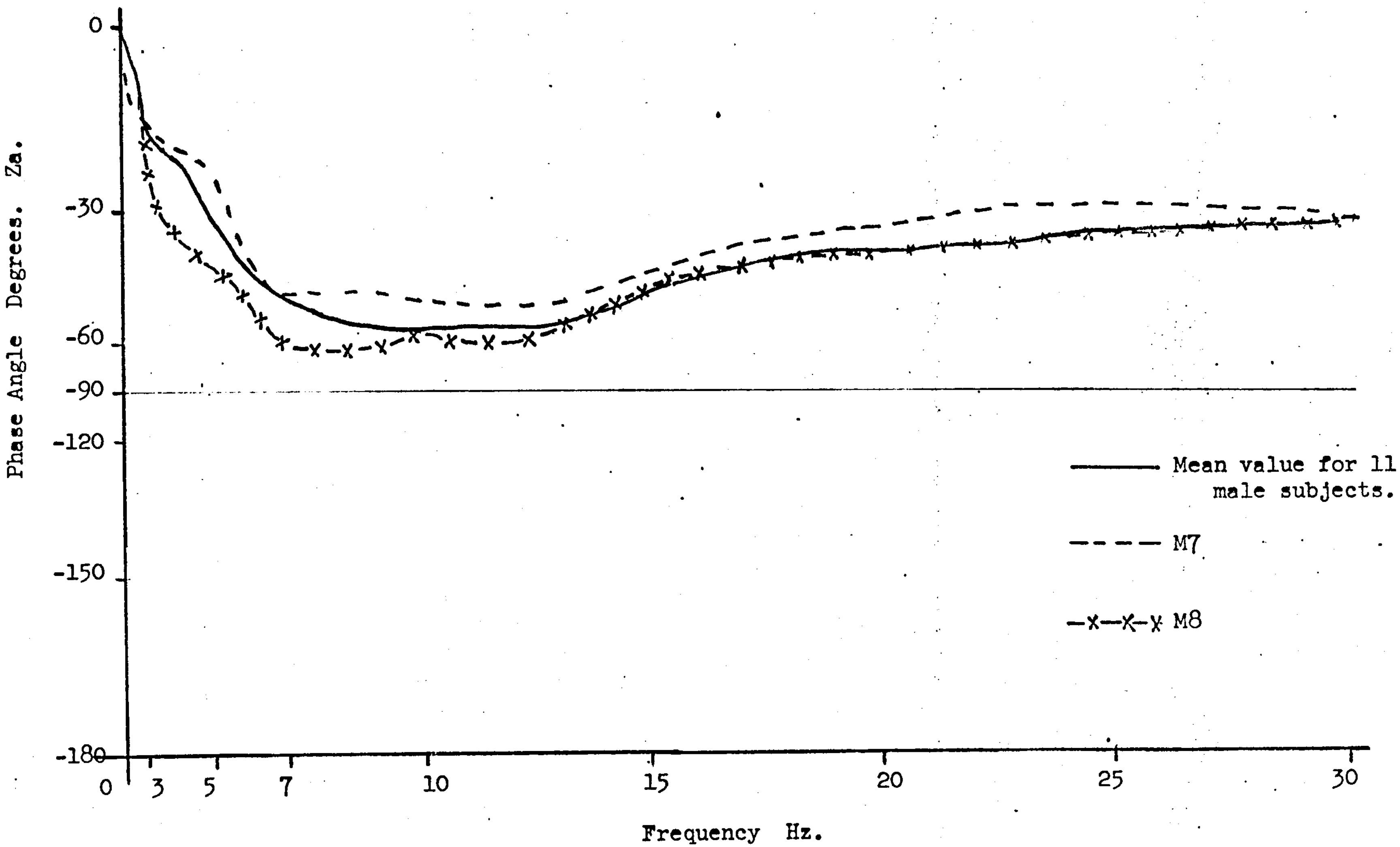


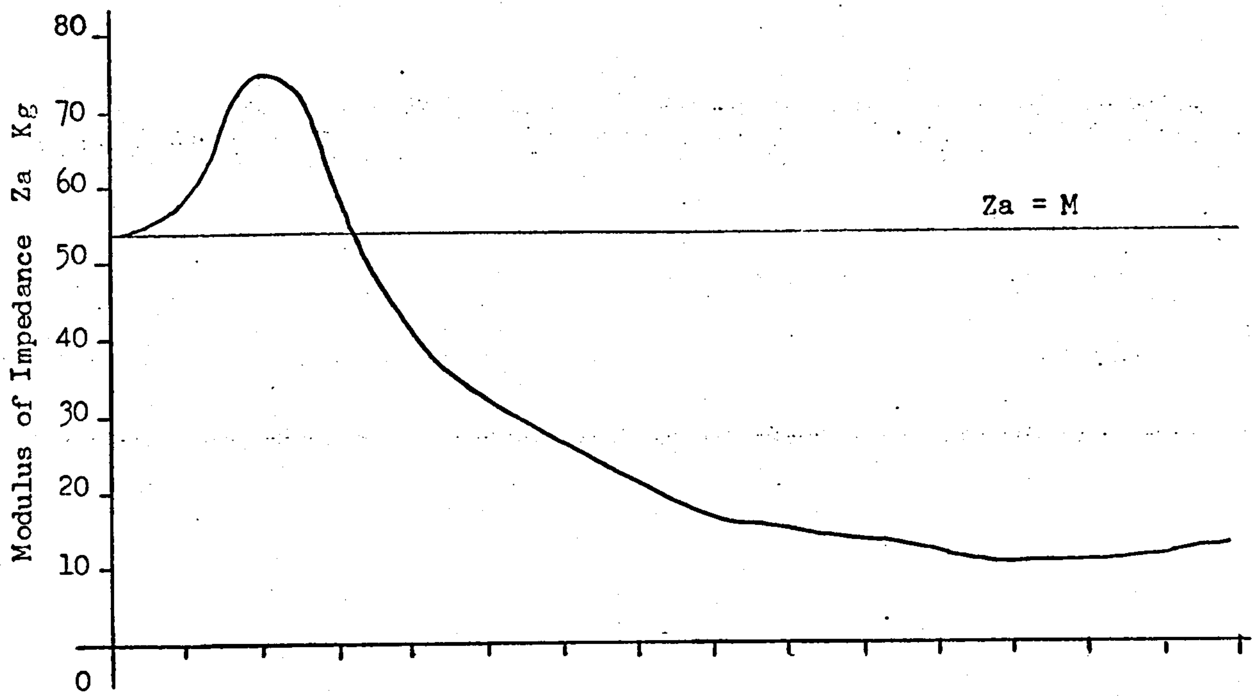
Figure No. 211



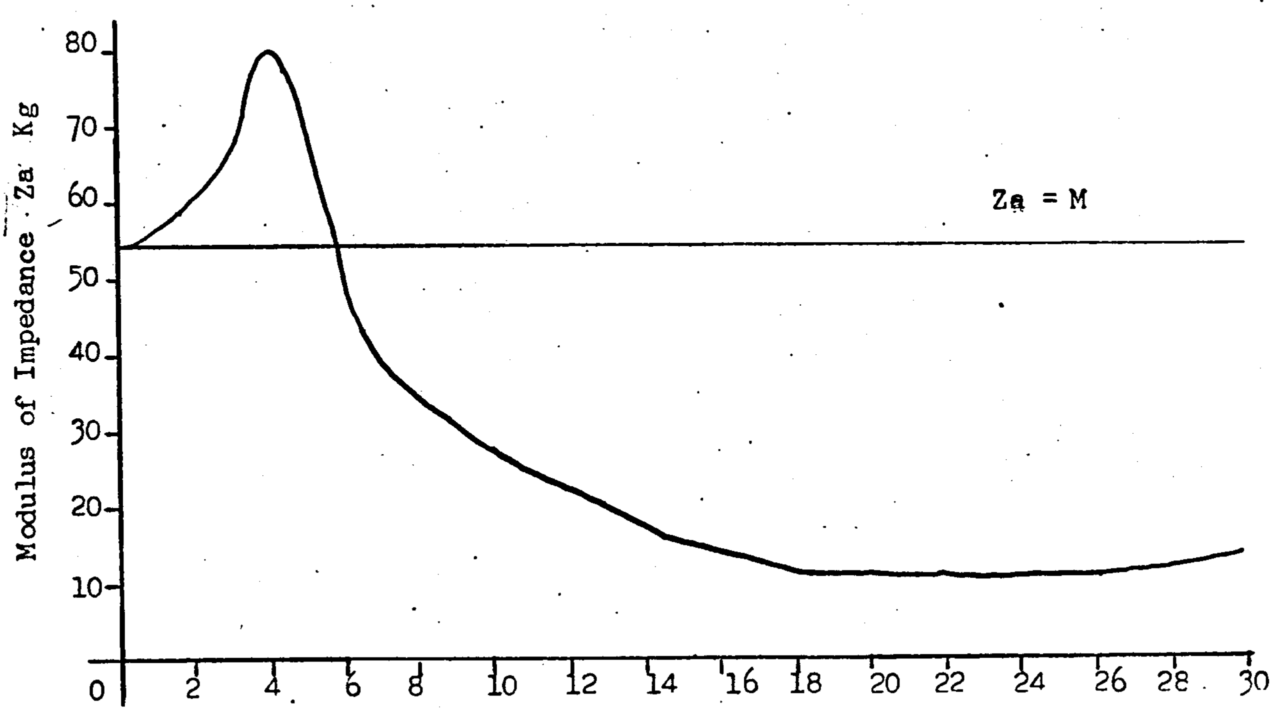
Comparison of M7 and M8 sitting relaxed to mean value for 11 male subjects.

Figure No. 234

ERECT POSTURE

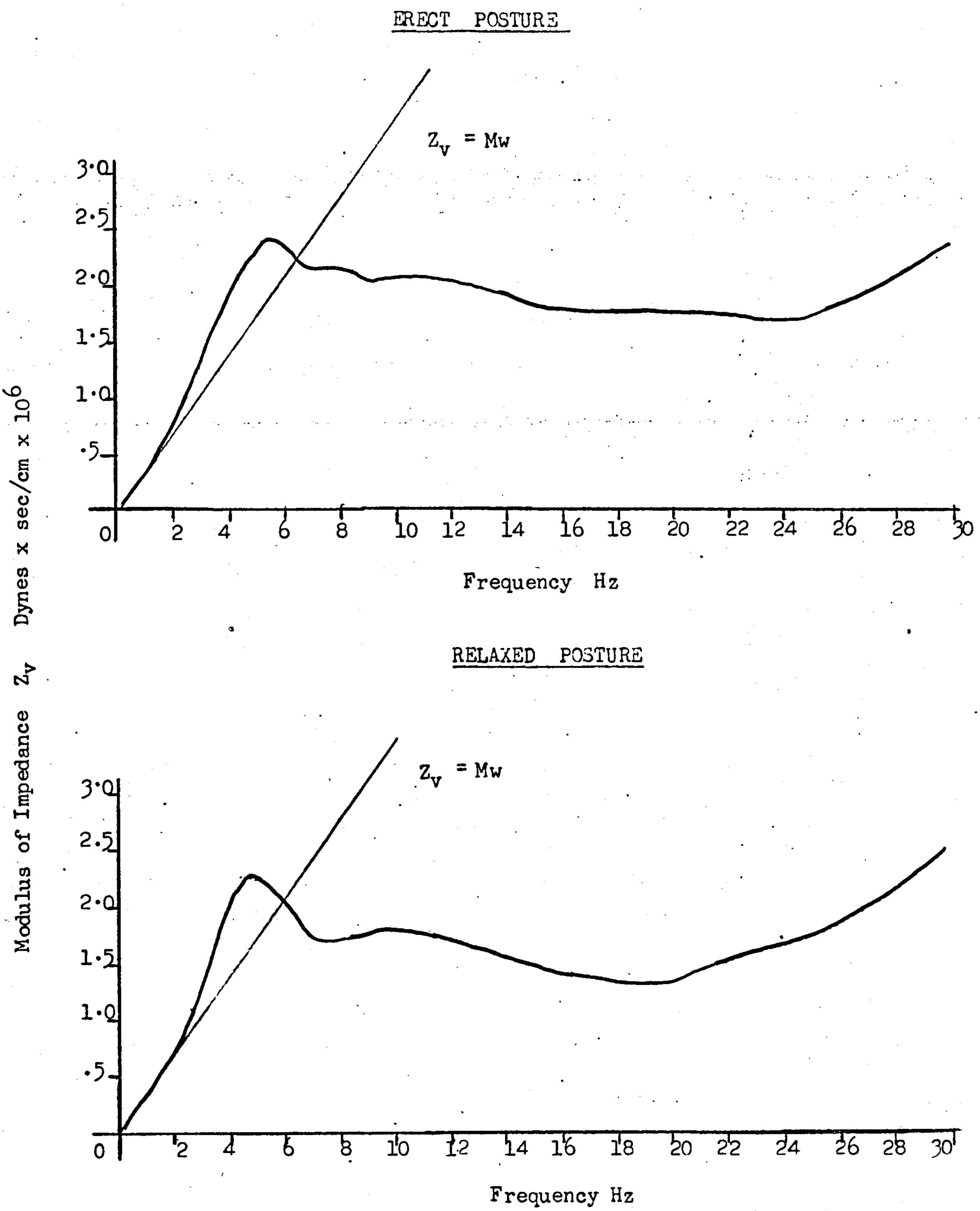


RELAXED POSTURE



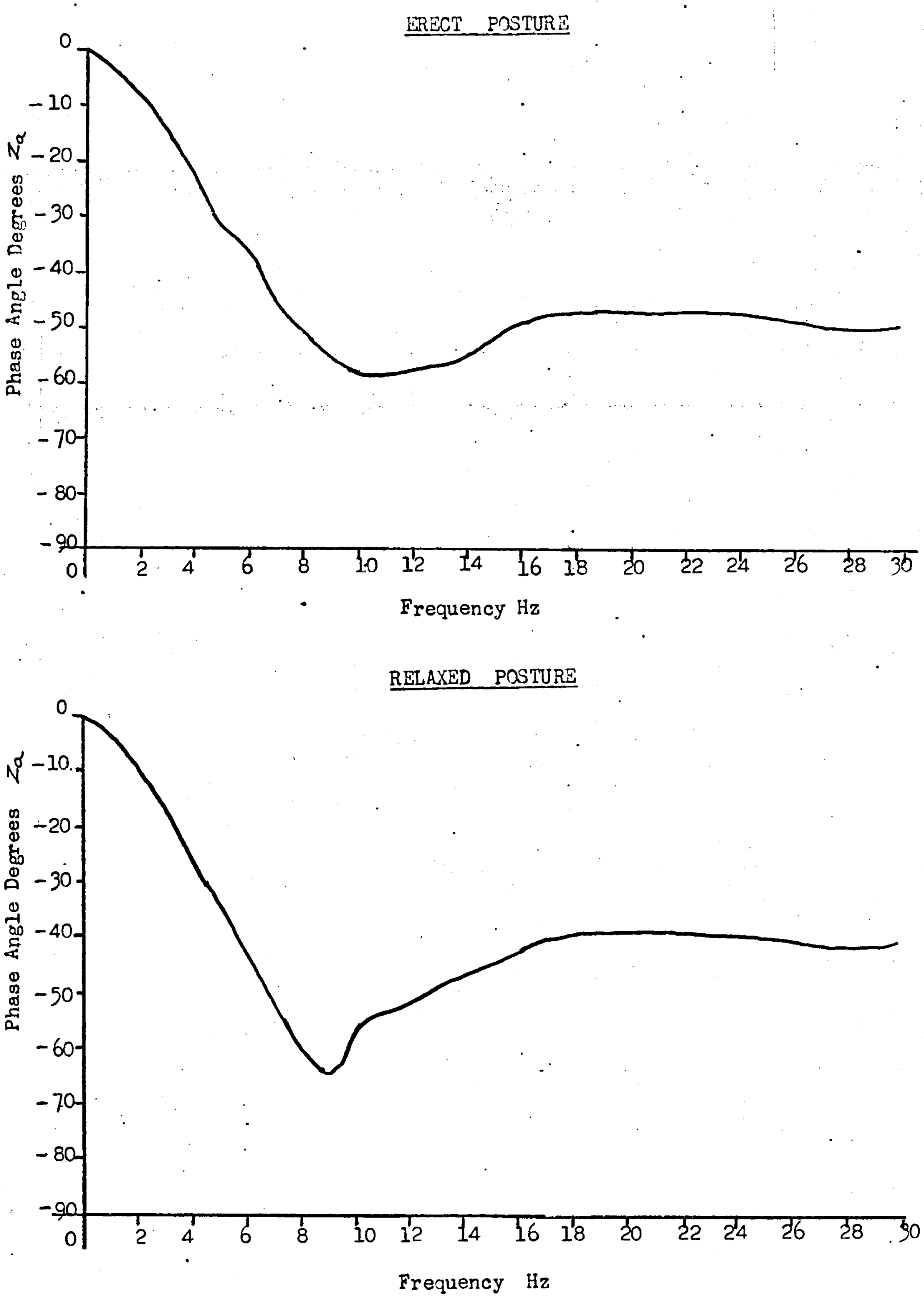
The mean values of three male subjects, M1, M2 and M3

Figure No. 212



The mean values of three male subject, M1, M2 and M3

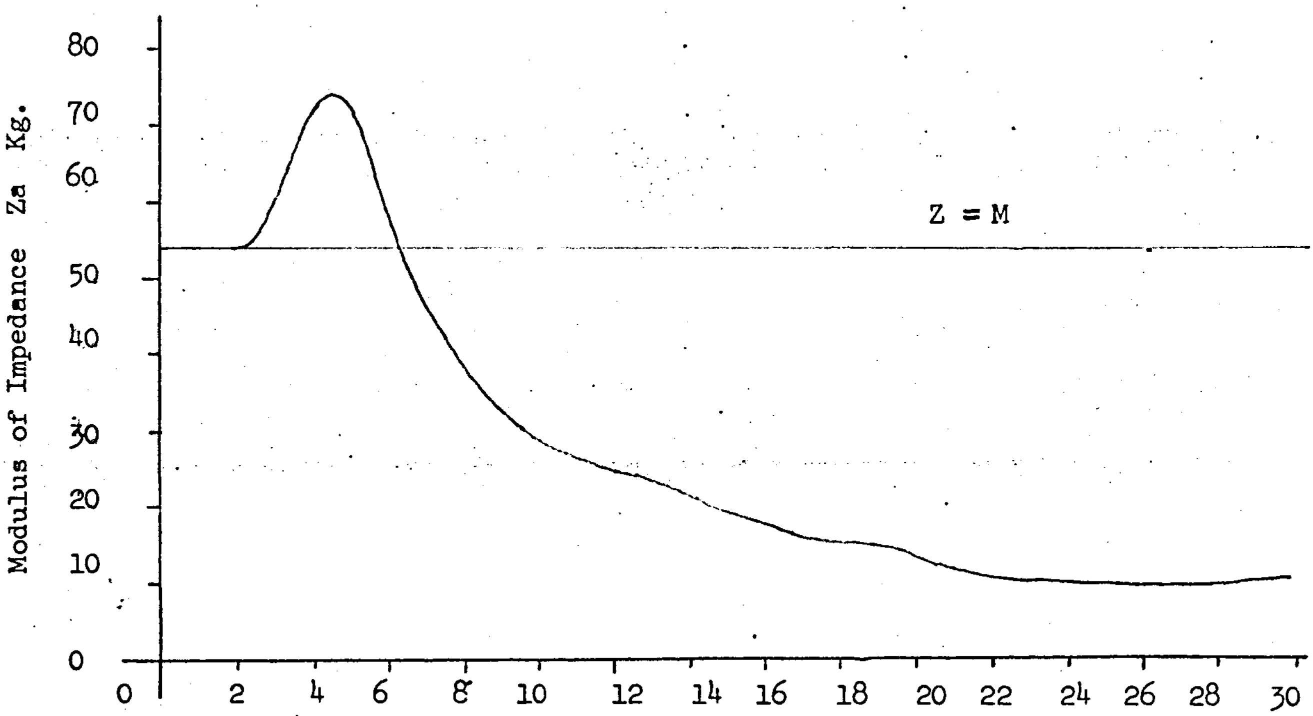
Figure No. **213**

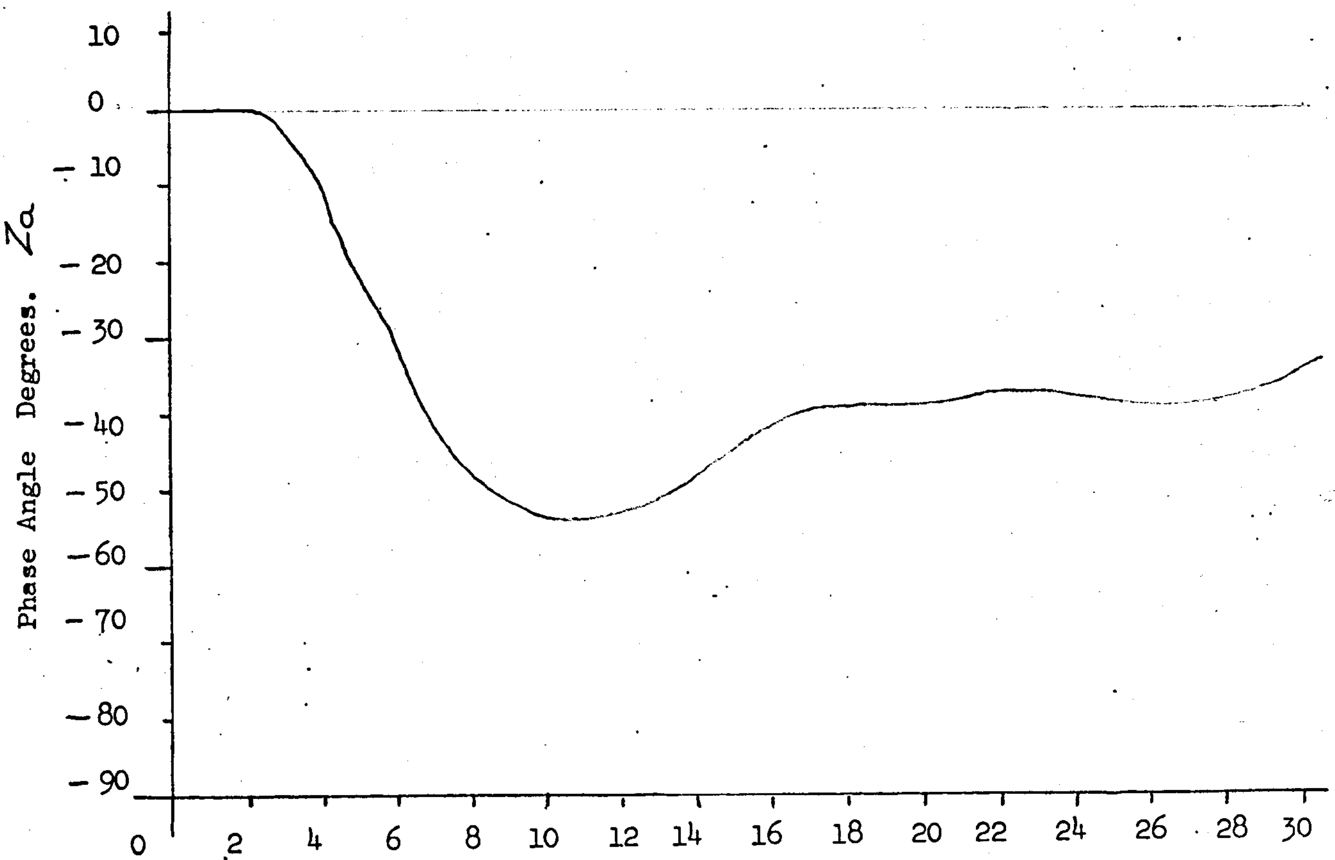


The mean values of three male subjects, M1, M2 and M3.

Figure No. **214**

Tracking

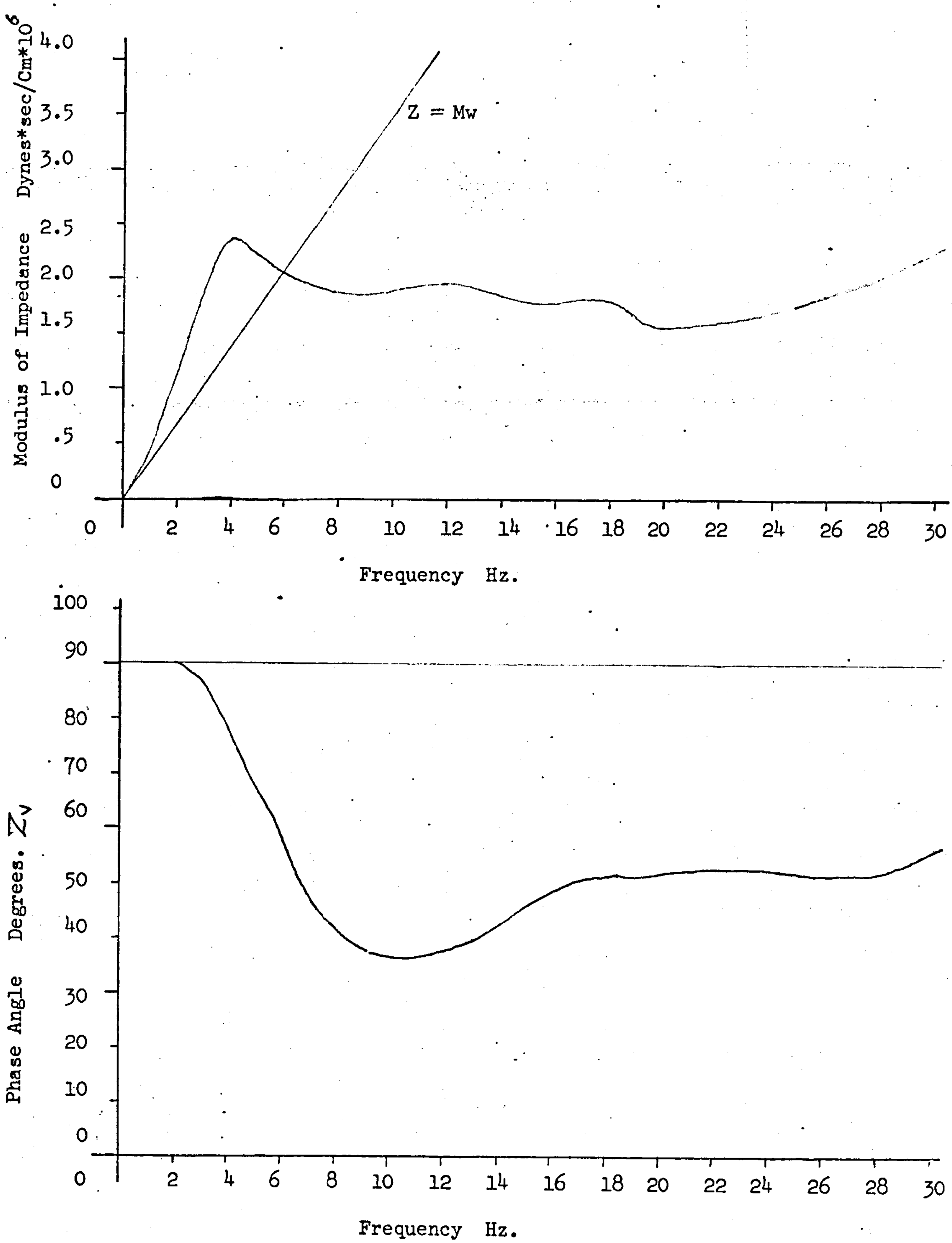




The mean values of three male subjects - M1,M2 and M3.

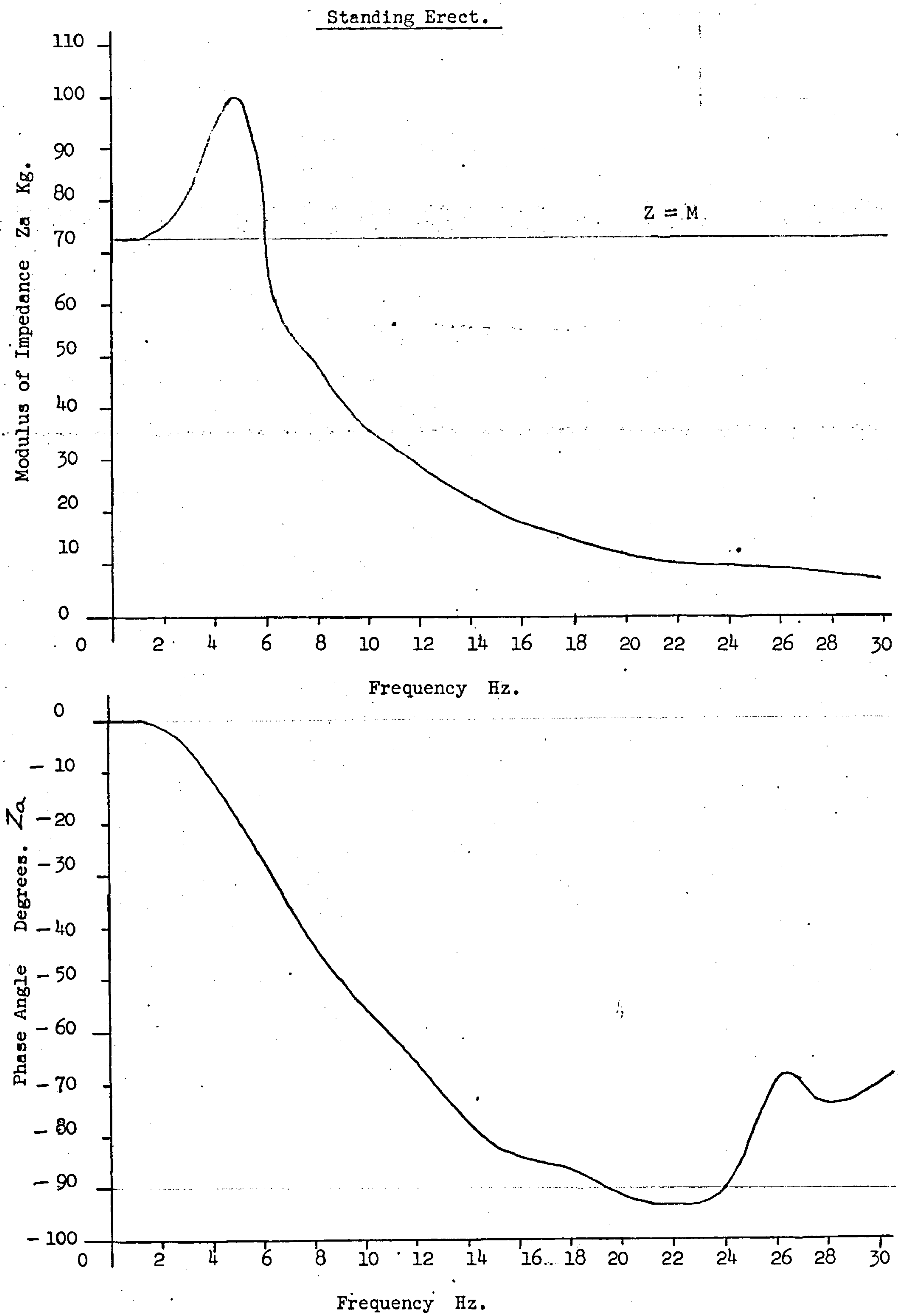
Figure No. 215

Tracking



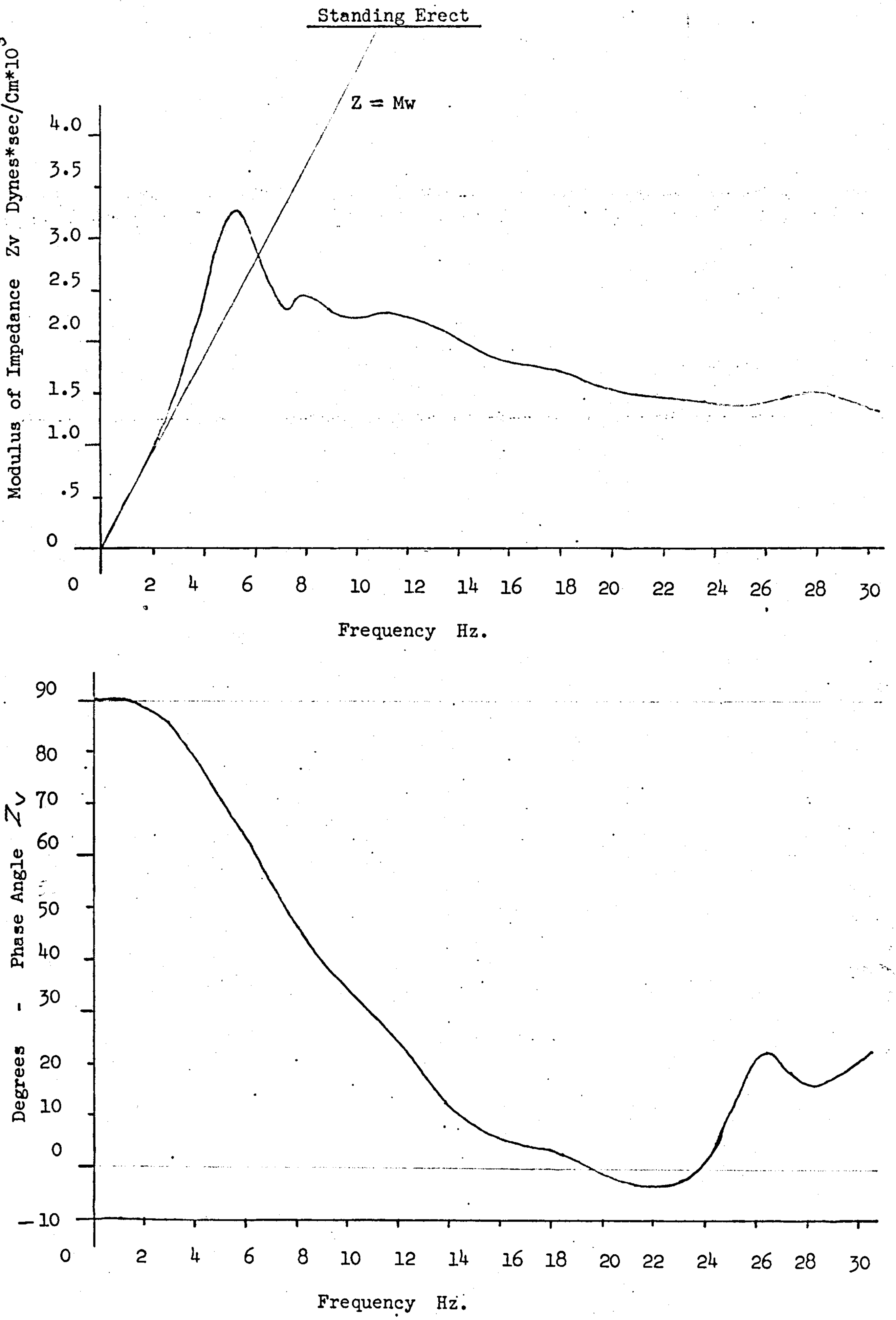
The mean values of three subjects - M1,M2 and M3.

Figure No. 216



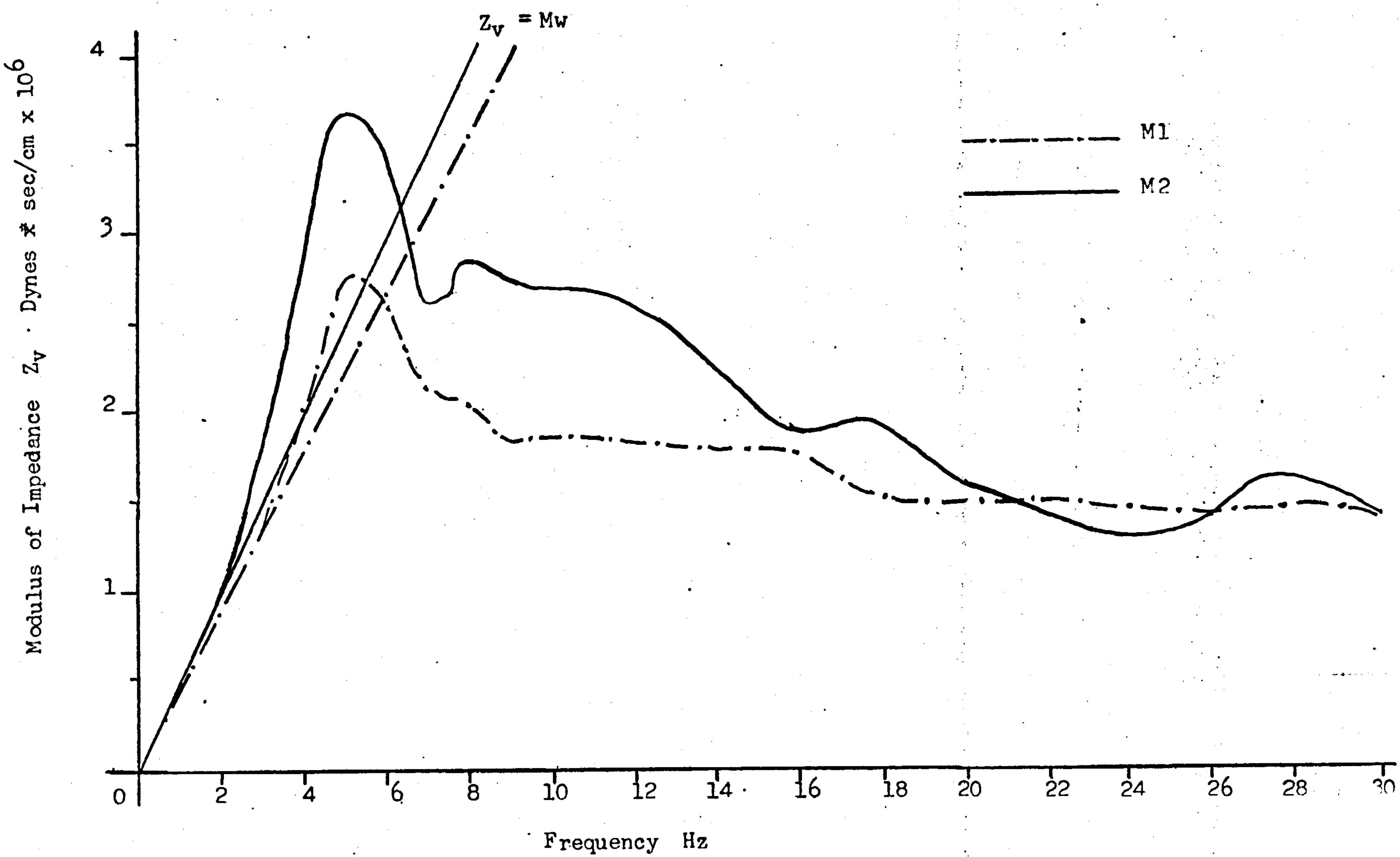
The mean values for two male subjects - M1 and M2.

Figure No. 217



The mean values for two male subjects - M1 and M2.

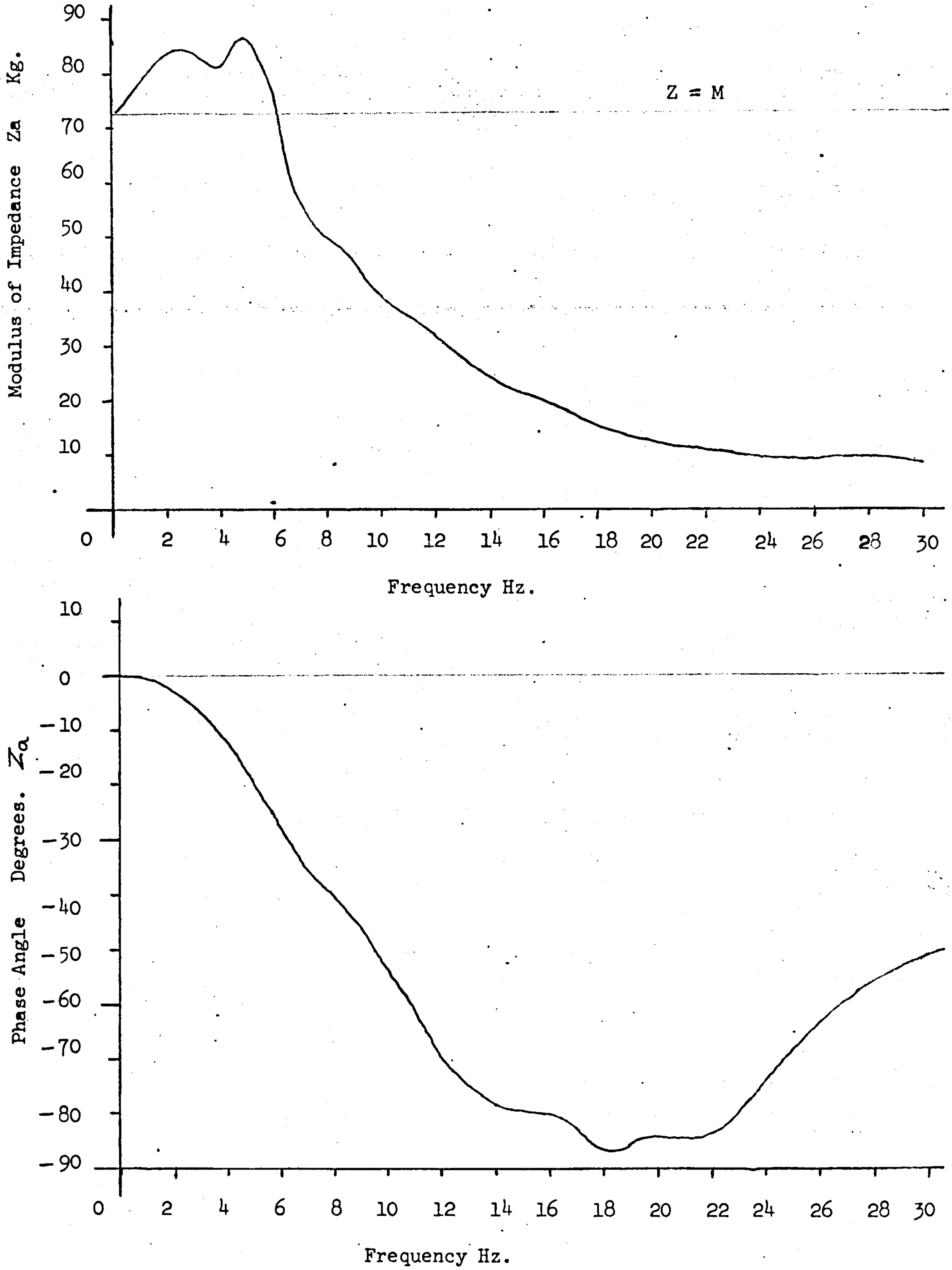
Figure No. 218



<u>Figure No.</u> **219**

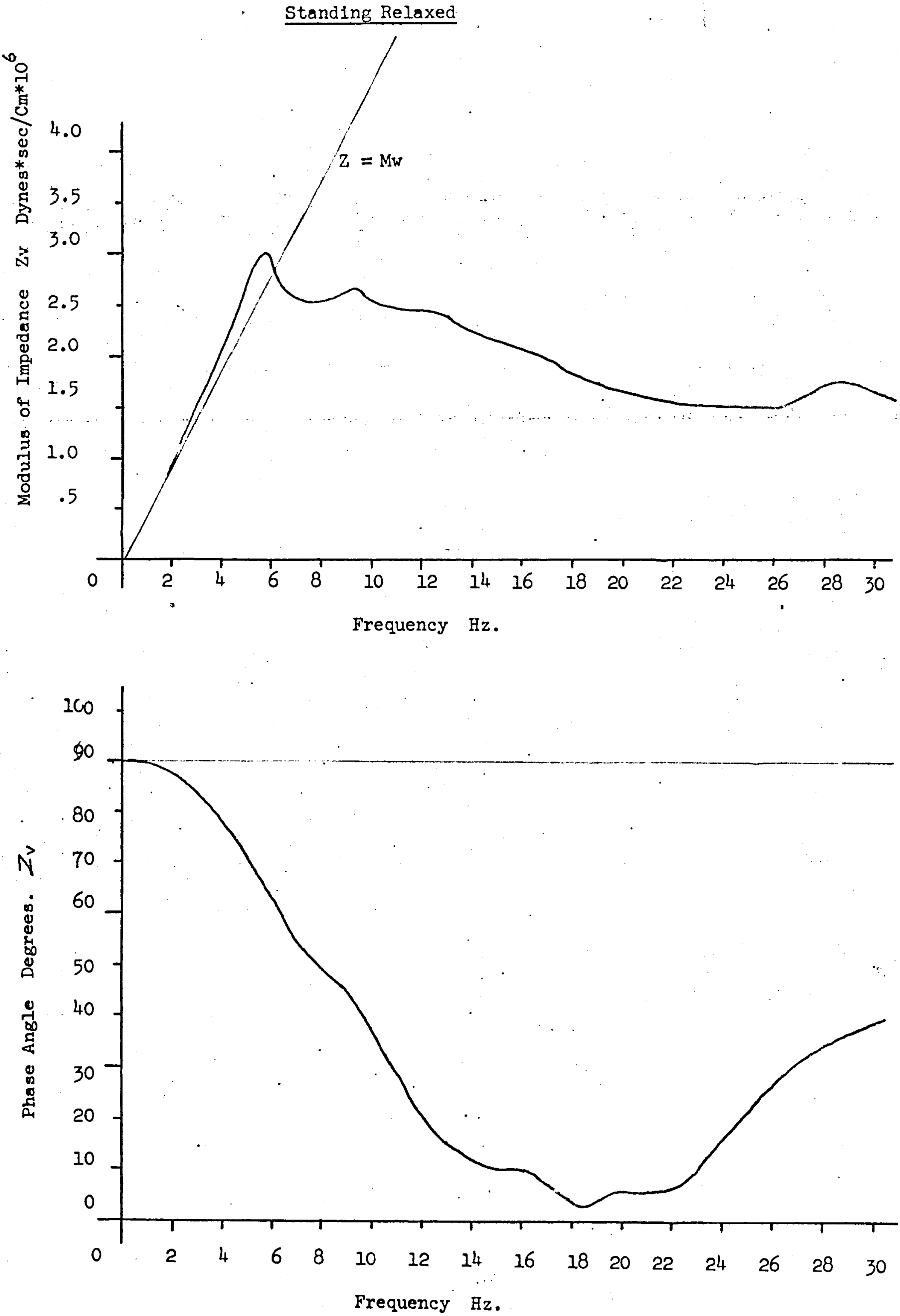
Standing Erect M1 and M2

Standing Relaxed



The mean values for two male subjects - M1 and M2.

Figure No. 220



The mean values for two male subjects - M1 and M2.

Figure No. 221

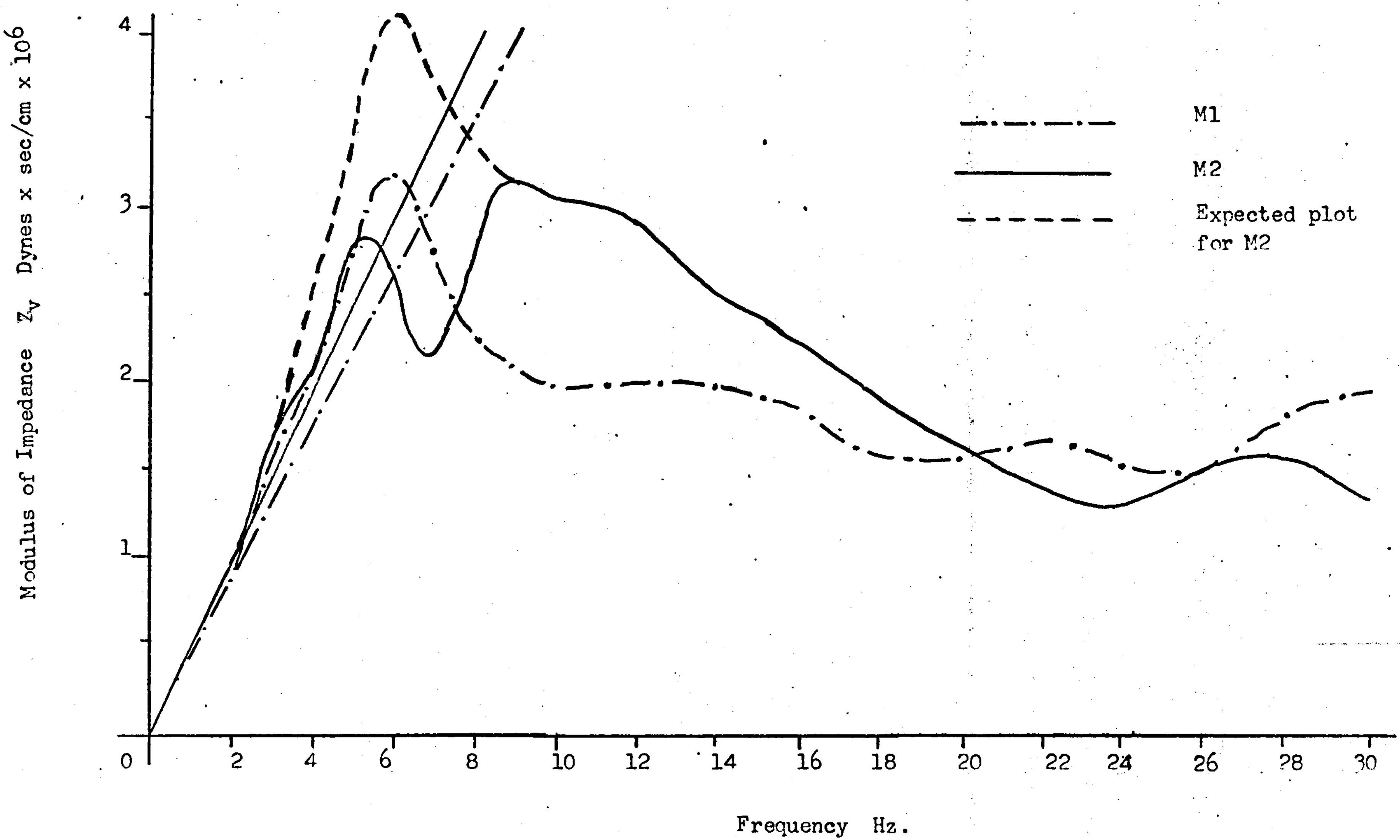
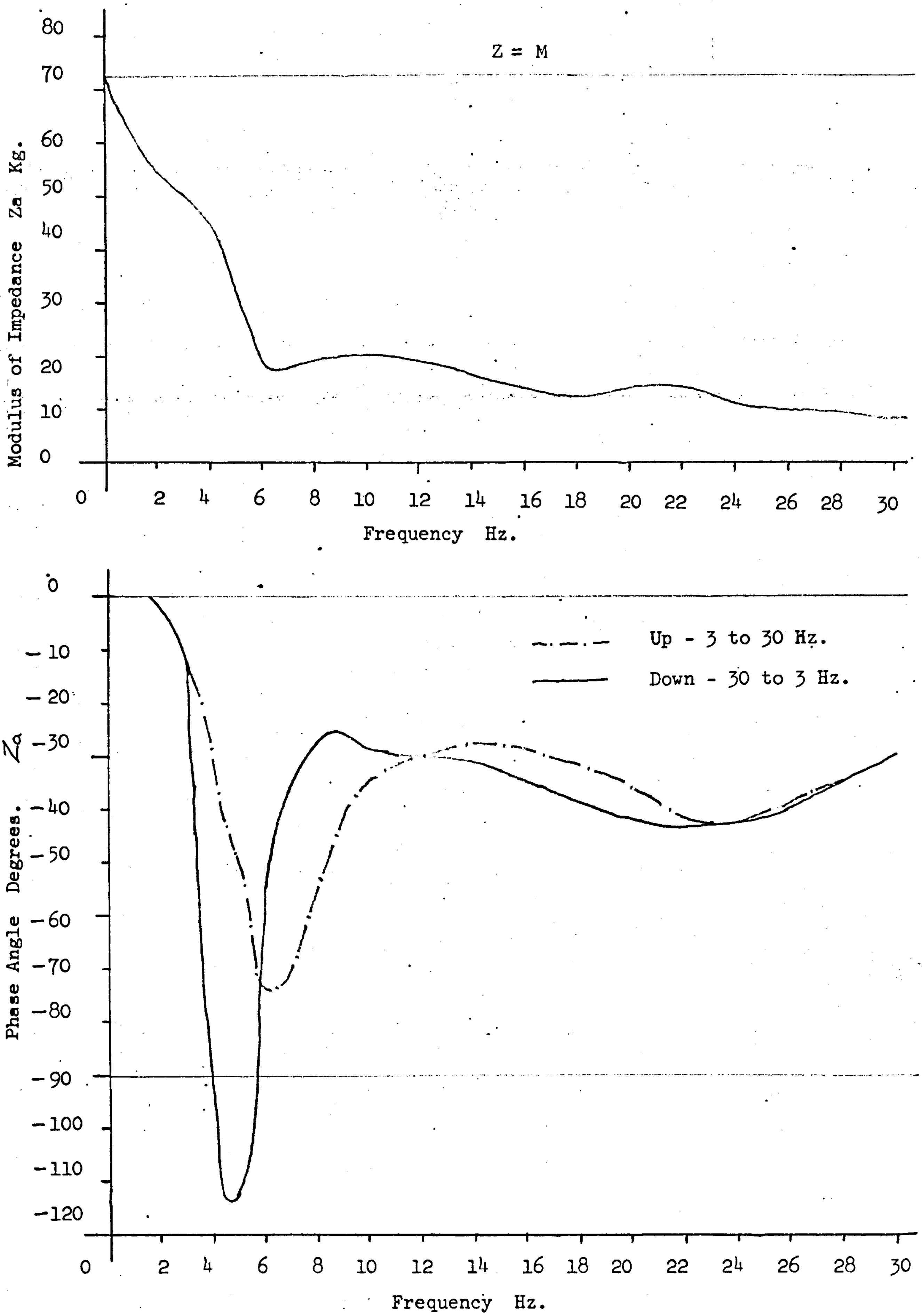


Figure No. 222

Standing Relaxed M1 and M2

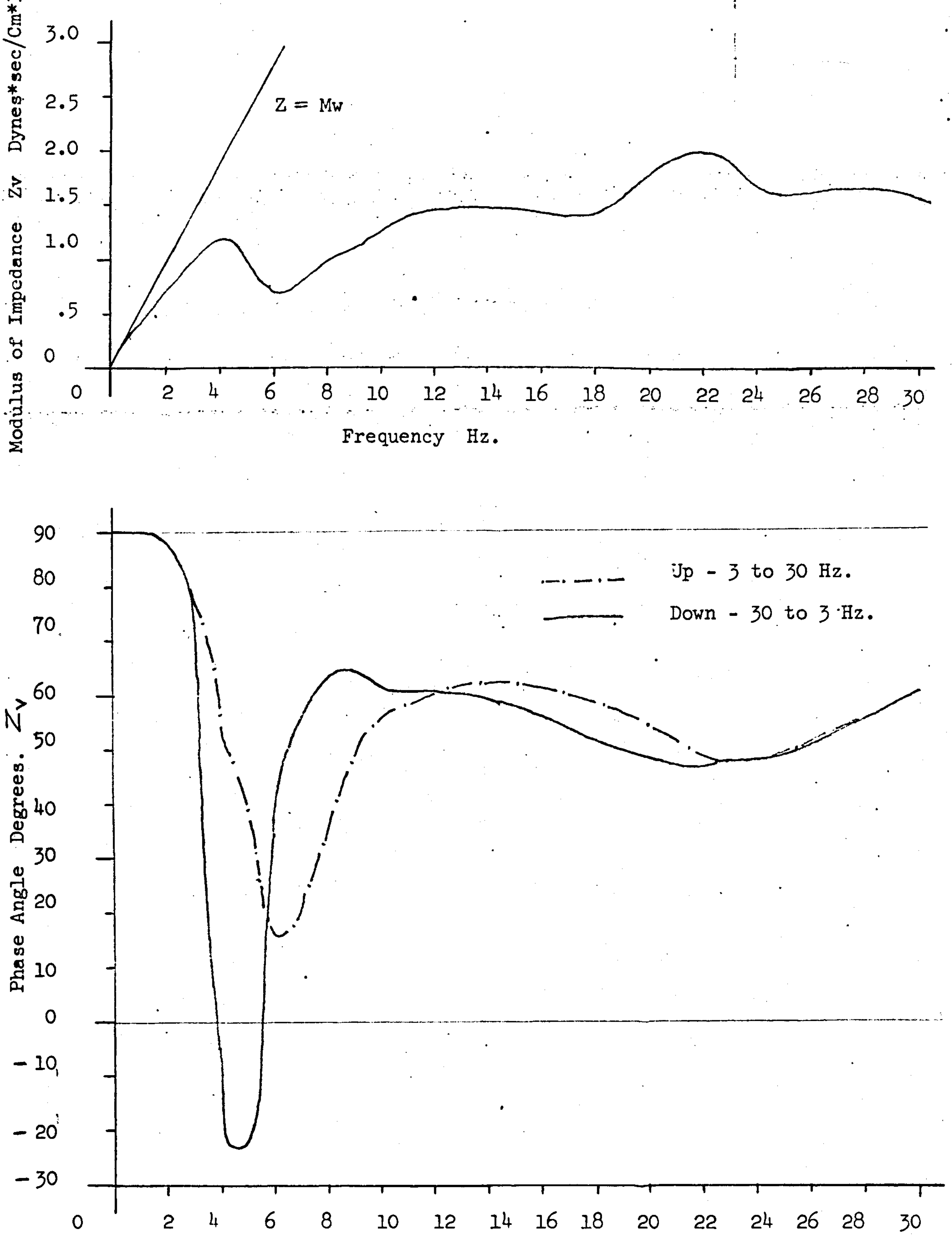
Standing Knees bent



The valūes for one male subject - M1.

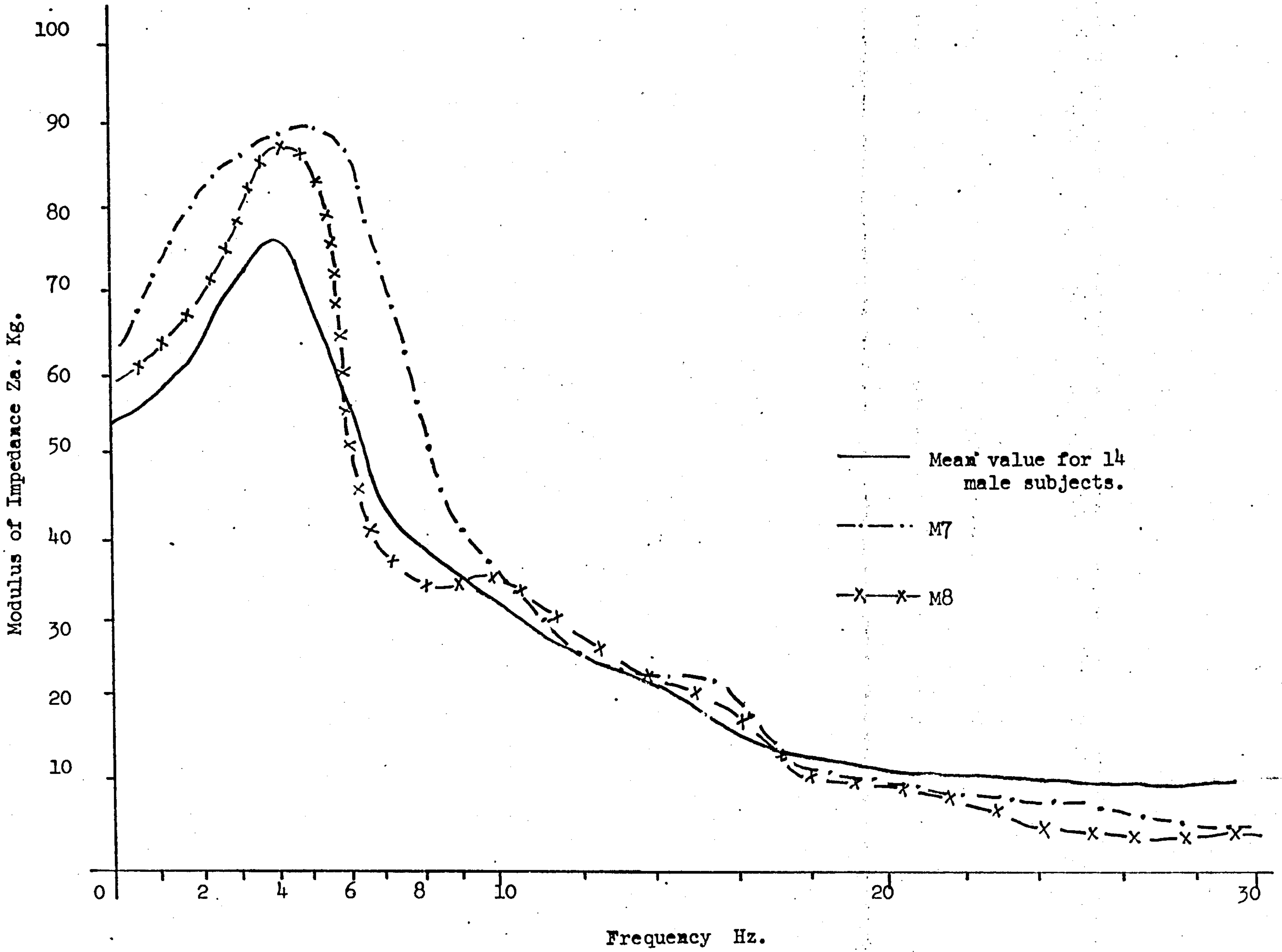
Figure No. 223

Standing Knees bent



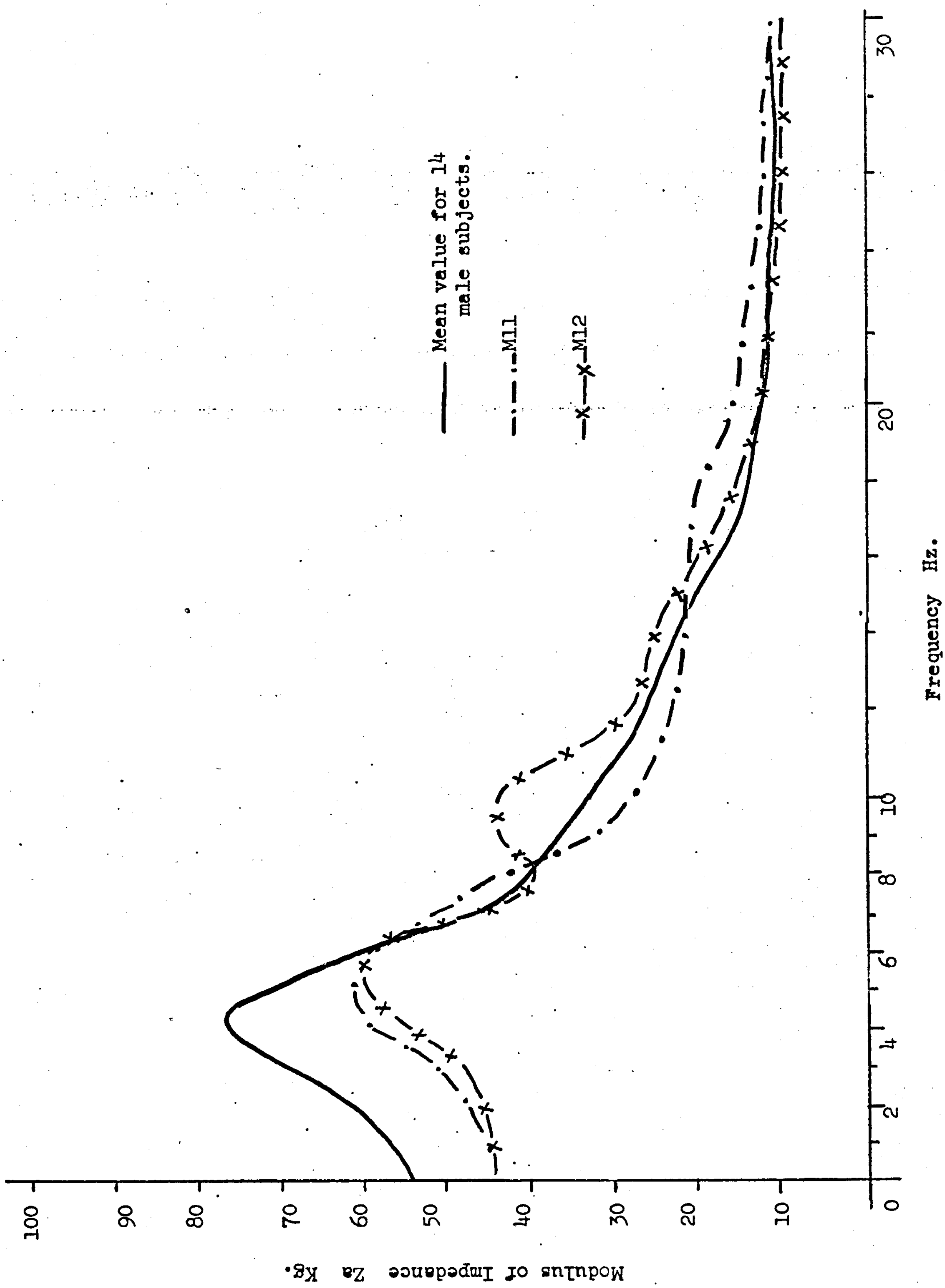
The values for one male subject - M1.

Figure No. 224



Comparison of M7 and M8 sitting erect to mean value for 14 male subjects.

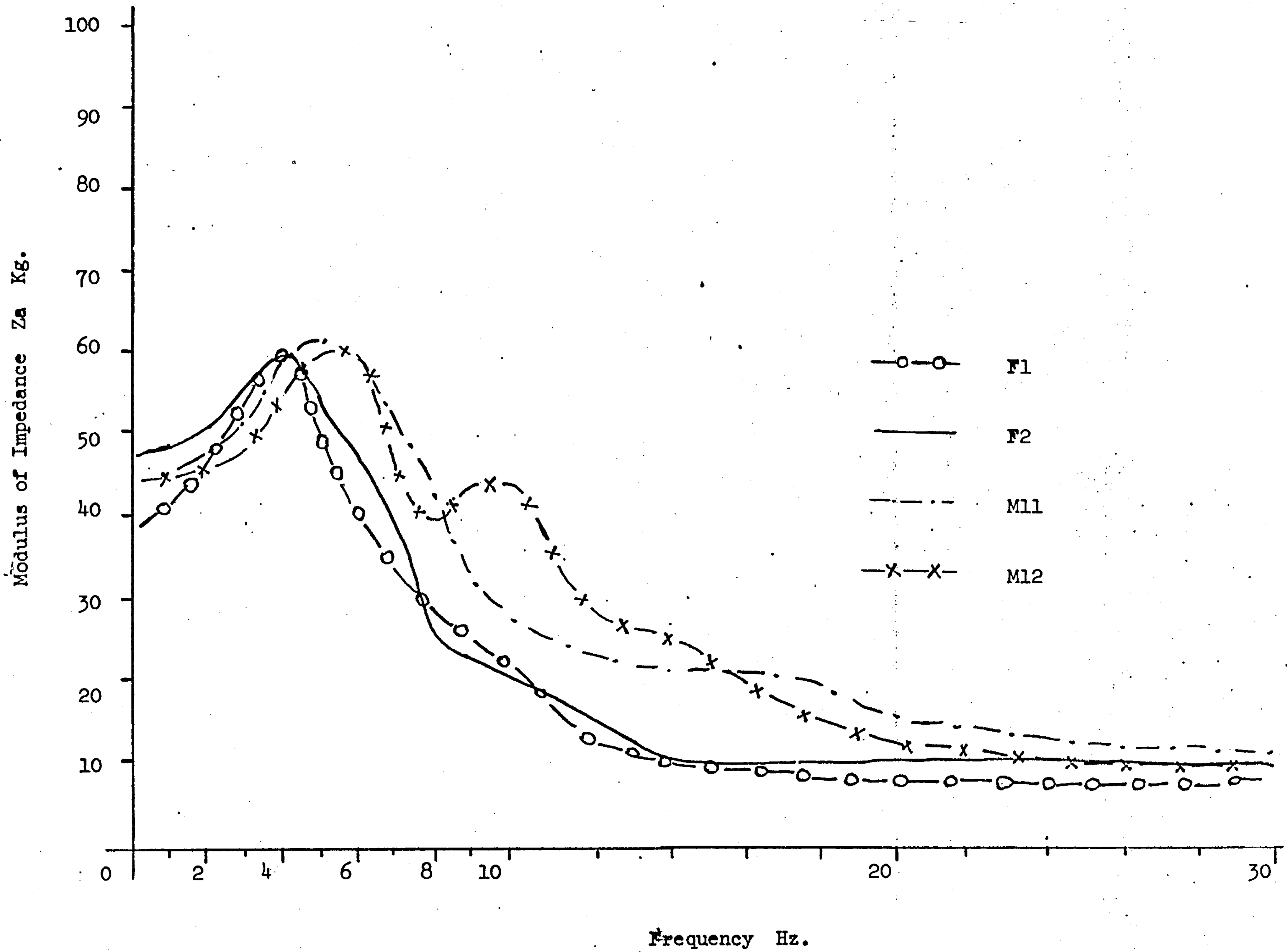
Figure No. 225



Comparison of M11 and M12 sitting erect to mean value

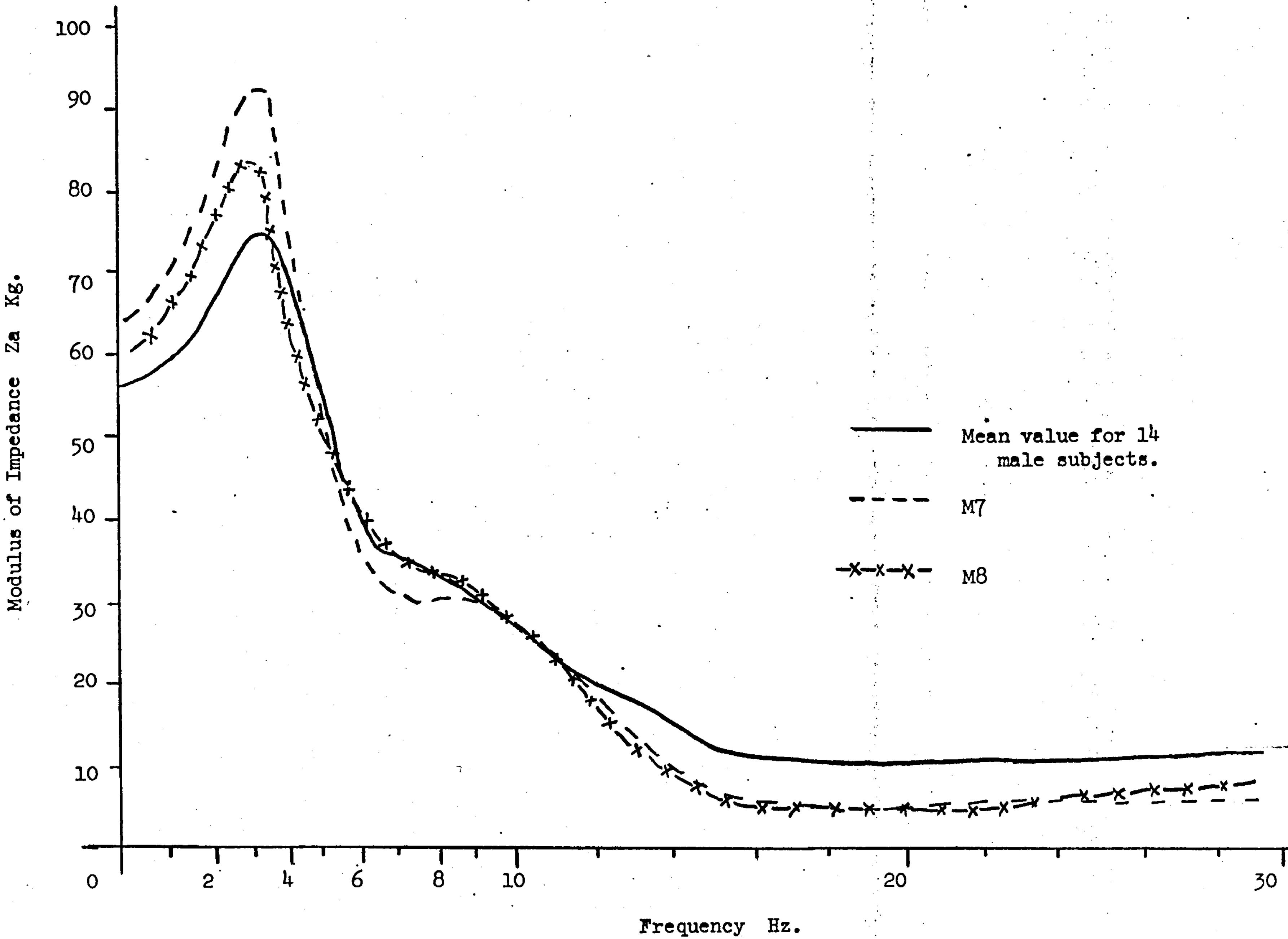
for 14 male subjects.

Figure No. 226



Comparison of F1 and F2 to M11 and M12 - Sitting Erect.

Figure No. 227



Comparison of M7 and M8 sitting relaxed to mean value for 14 male subjects.

Figure No. 228

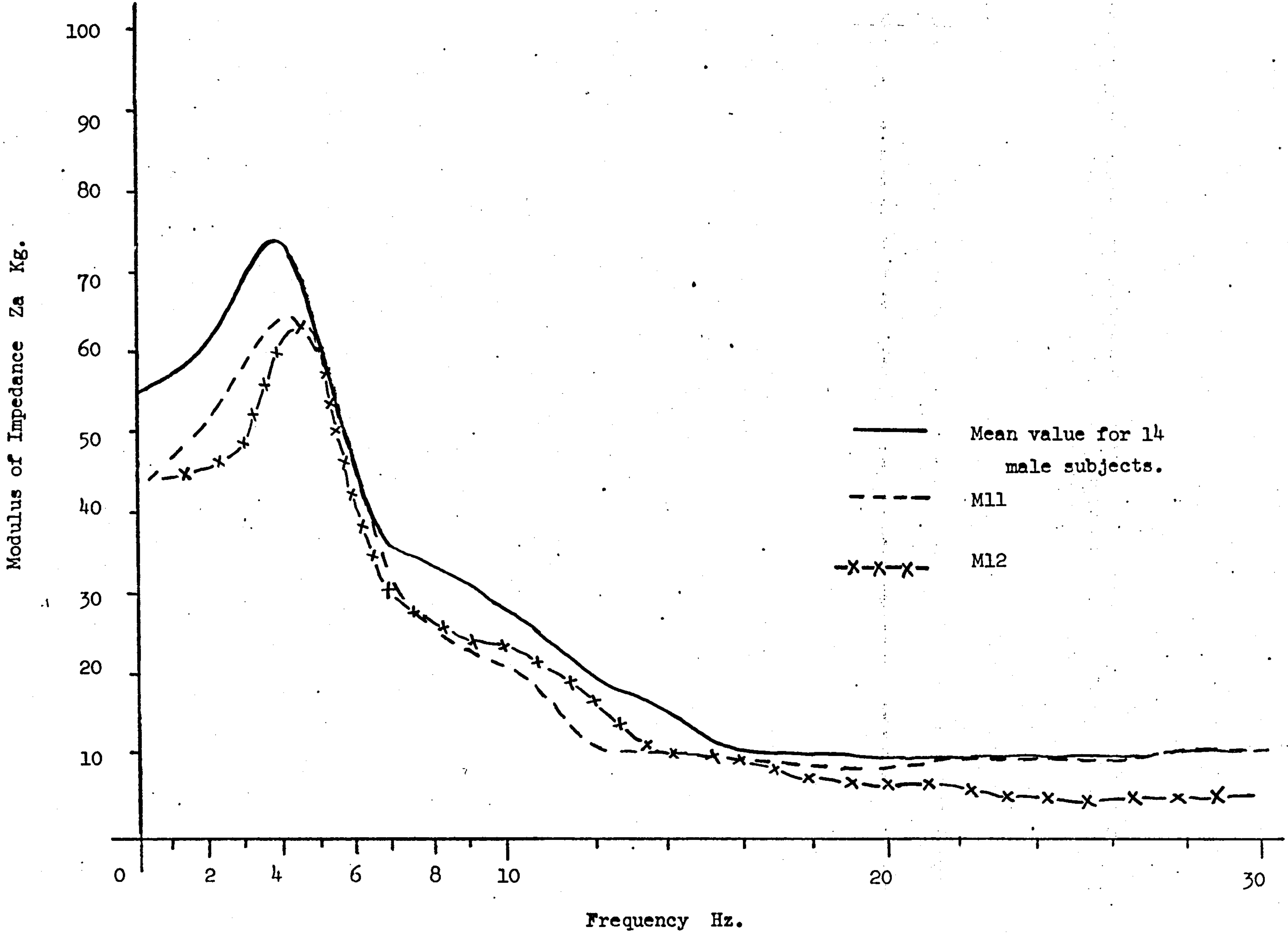
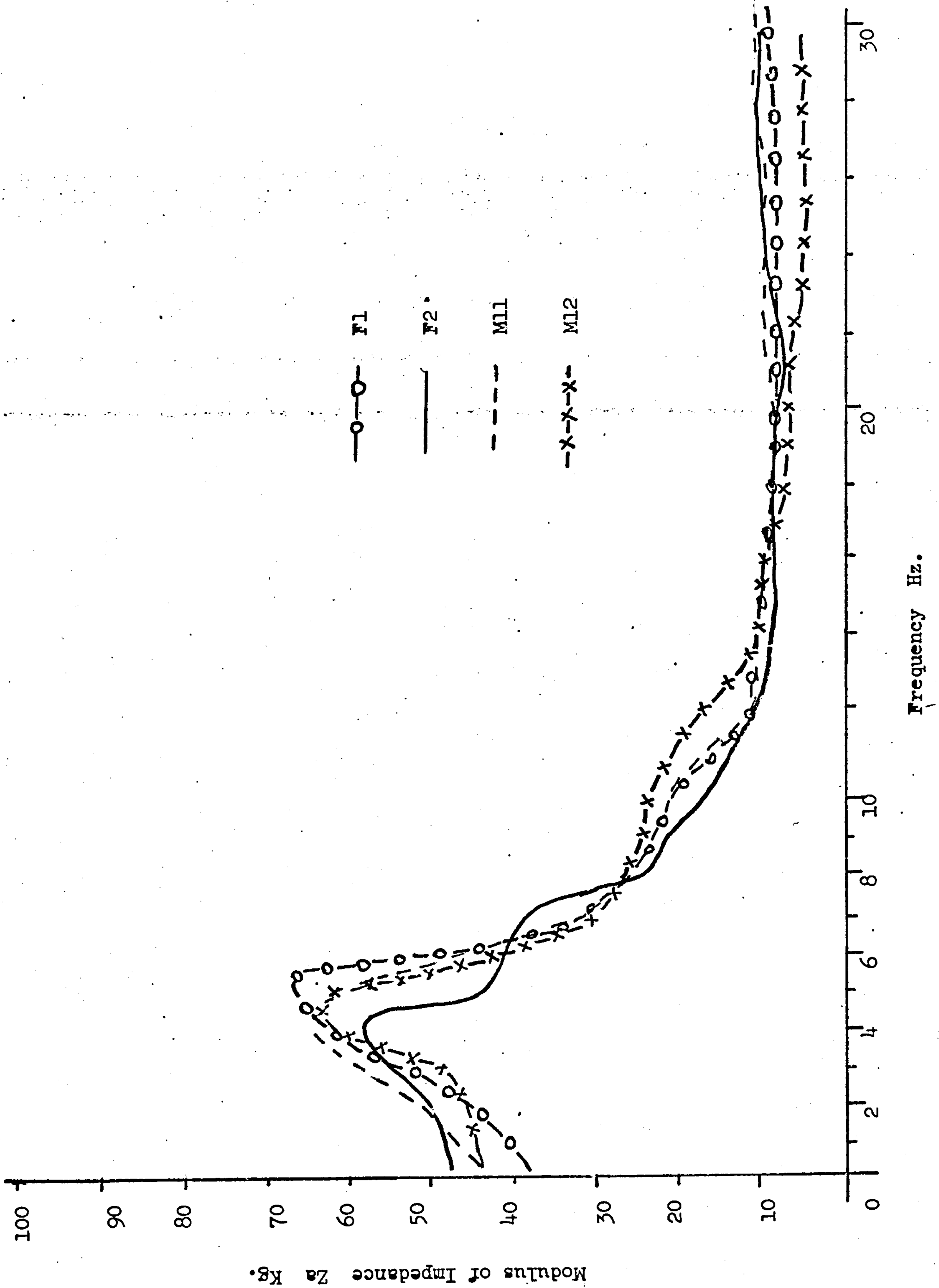


Figure No. 229

Comparison of M11 and M12 sitting relaxed to mean value for 14 male subjects.



Comparison of F1 and F2 to M11 and M12 - Sitting Relaxed.

Figure No. 230

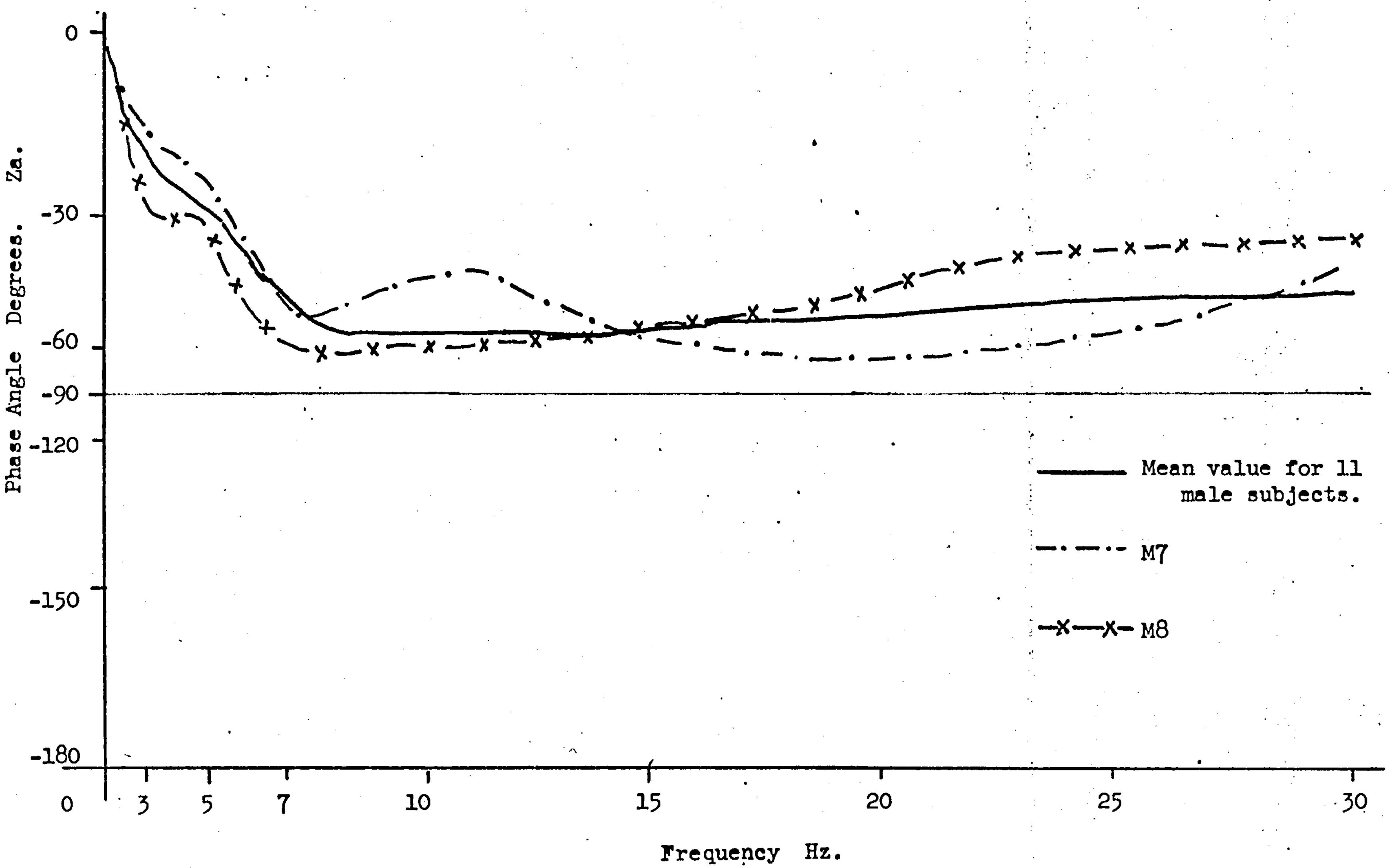
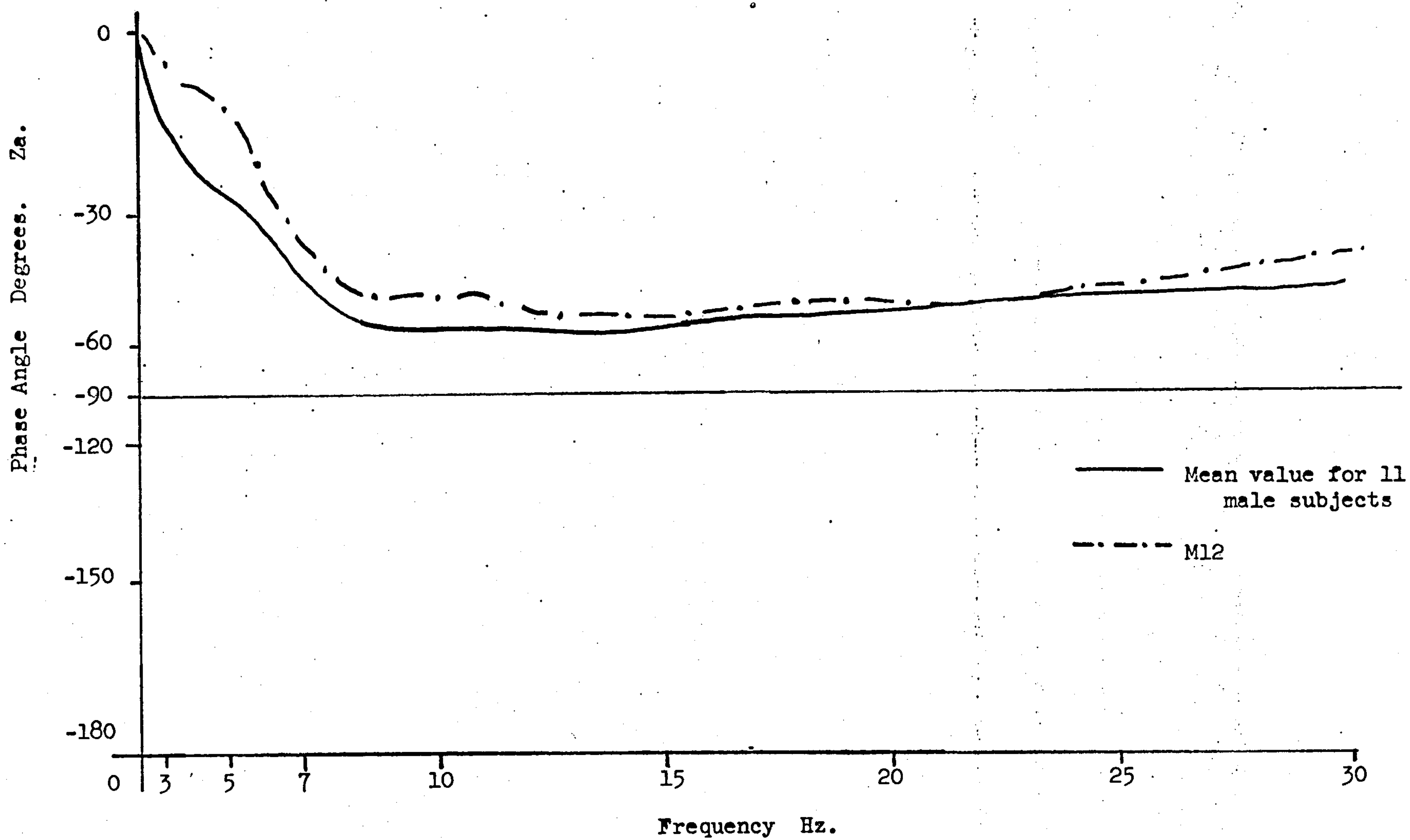


Figure No. 231

Comparison of M7 and M8 sitting erect to mean value for 11 male subjects.



Comparison of M12 sitting erect to mean value for 11 male subjects.

Figure No. 232

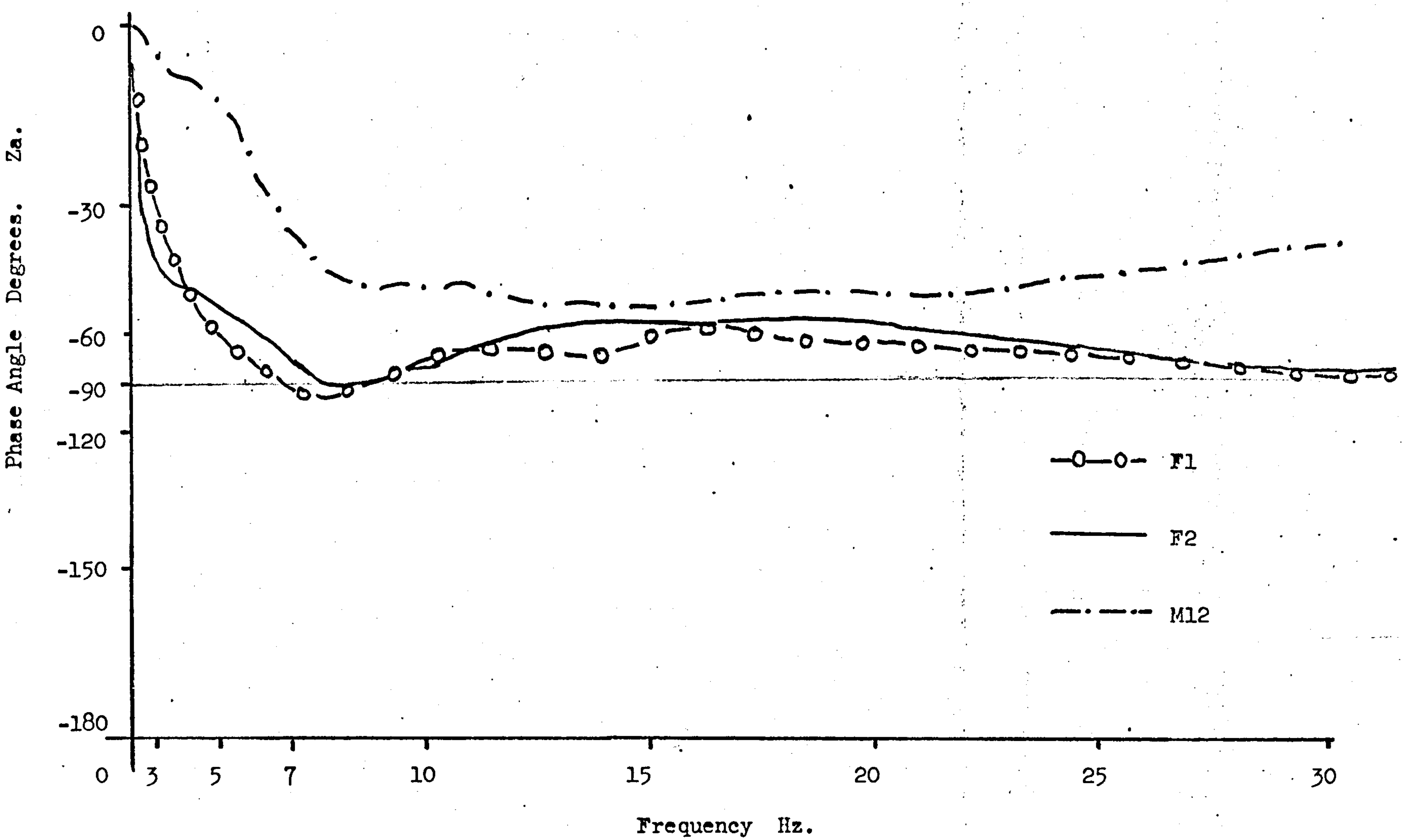


Figure No.233

Comparison of F1 and F2 to M12 - Sitting Erect.

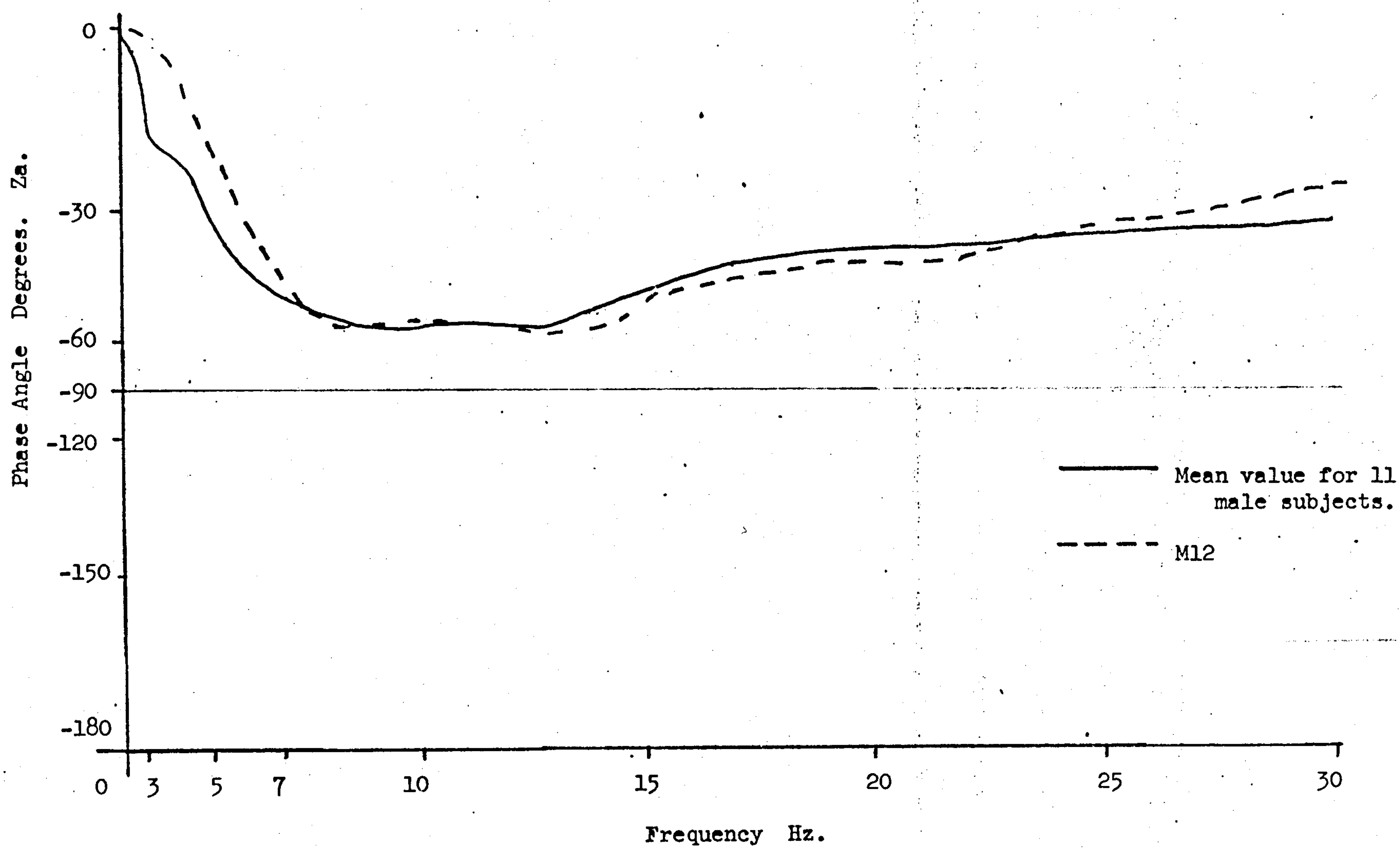
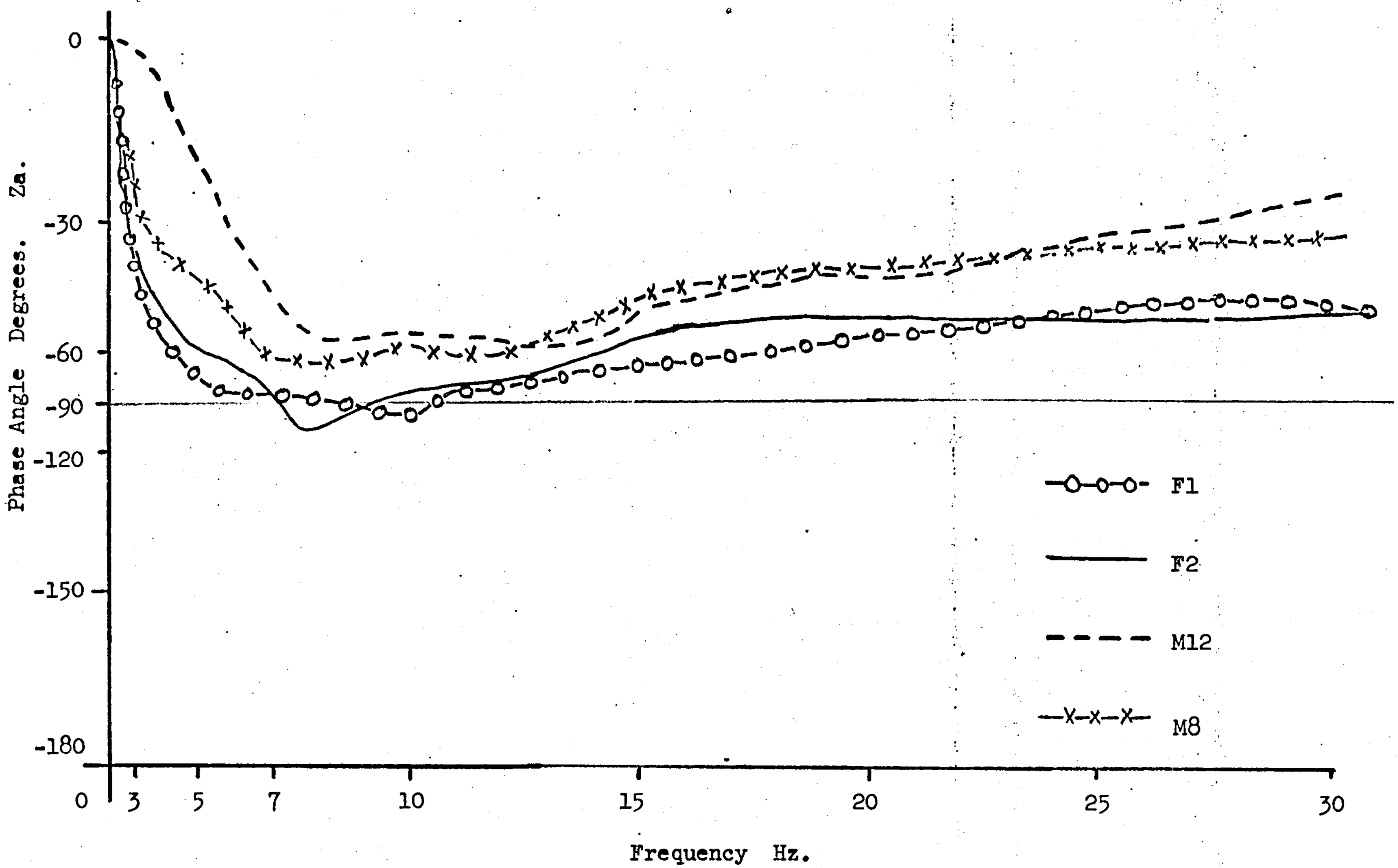


Figure No. 235

Comparison of M12 sitting relaxed to mean value for 11 male subjects.



Comparison of F1 and F2 to M12 and M8 - Sitting Relaxed.

Figure No. 236

Coermann (1963)

Data of Coermann's Subject panel

Subject Coding	Weight kgs	Height ms	Age yrs
W.B.	90	1.83	34
R.G.	84	1.88	47
B.D.	99.5	1.93	30
W.E.	70.5	1.75	29
W.G.	81.6	1.80	40
R.H.	90.8	1.80	35
E.M.	94.4.	1.83	29
G.Z	71.7	1.70	29

Table No. 3

Accuracy of Modulus of Impedance monitoring unit

(These figures are applicable to both the first and second calibrations)

Frequency Hz	Accuracy % at			
	20 kg	40 kg	60 kg	80 kg
3	7.3	6.2	5.6	5.3
5	3.7	2.9	3.1	4.2
7	1.2	2.1	2.5	2.8
10	0.2	0.1	1.0	2.1
15	-	0.1	0.5	0.7
20	-	0.1	1.2	0.7
25	0.1	0.2	1.2	0.7
30	3.0	0.3	1.5	0.7
Average over frequency range 3-30 Hz	1.9	1.5	2.1	2.2.

Accuracies are given to the nearest 0.1.%

Table No. 4

SUBJECT DATA

MALE SUBJECTS

SUBJECT NO.	HEIGHT (cm) STANDING	SITTING	WEIGHT (Kg) TOTAL	SITTING	AGE (Yrs)
M1	172	88	68.6	52.1	24
M2	173.5	89	75.5	60.2	28
M3	185	96	64.75	49.2	27
M4	180	94	74.0	59.0	26
M5	168	86	65.1	50.8	22
M6	178	92	81.5	64.7	24
M7	184	95.5	84.0	63.5	22
M8	174.3	89.5	76.0	60.6	28
M9	183	95	73.1	57.2	25
M10	184	96	70.3	54.5	22
M11	182.5	94.5	58.7	43.9	24
M12	181	94	60.2	45.1	23
M14	182	95.5	66.5	49.25	24
M15	182	95	71.8	55.0	34
MEAN	179.2	92.8	70.72	54.65	25.21
STD. DEVIATION	5.06	2.56	7.1	6.31	3.14

FEMALE SUBJECTS

SUBJECT NO.	HEIGHT (cm) STANDING	SITTING	WEIGHT (Kg) TOTAL	SITTING	AGE (Yrs)
F1	166.0	86	51.8	38.5	22
F2	167.5	87	60.7	48.6	26
MEAN	166.7	86.5	56.25	43.55	24

Table No. 5.

MODULUS OF IMPEDANCE RESULTS FOR

FEMALE SUBJECTS

SITTING ERECT POSTURE

(Fl - E)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	54	1.402
4	60	1.558
5	50	1.298
6	40	1.038
7	33	.857
8	28.5	.740
9	25.0	.649
10	21.5	.558
12	13	.337
14	10	.259
16	9	.233
18	8	.207
20	8	.207
22	8	.207
24	8	.207
26	8	.207
28	8	.207
30	9	.233

Table No. 6 Modulus of Impedance (Fl - E)

(F2 - E)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	55	1.134
4	60	1.237
5	55	1.134
6	48	.989
7	39	.804
8	26	.536
9	23	.474
10	21	.432
12	16	.329
14	11	.226
16	10	.206
18	10	.206
20	10	.206
22	10	.206
24	10	.206
26	10	.206
28	10	.206
30	10	.206

Table No. 7 Modulus of Impedance (F2 - E)

PHASE ANGLE RESULTS FOR

FEMALE SUBJECTS

SITTING ERECT POSTURE

(Fl - E)

Frequency Hz	Phase Angle Degrees
3	- 35
4	- 50
5	- 65
6	- 85
7	- 97
8	- 90
9	- 85
10	- 70
12	-64
14	-65
16	-58
18	-60
20	-61
22	-62
24	-65
26	-66
28	-70
30	-80

Table No. 8 Phase Angle (Fl - E)

(F2 - E)

Frequency Hz	Phase Angle Degrees
3	−43
4	−50
5	−55
6	−60
7	−85
8	−95
9	−100
10	−70
12	−61
14	−58
16	−57
18	−55
20	−55
22	−58
24	−61
26	−65
28	−70
30	−80

Table No. 9 Phase Angle (F2 - E)

MODULUS OF IMPEDANCE RESULTS FOR

FEMALE SUBJECTS

SITTING RELAXED POSTURE

(F1 - R)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	55	1.428
4	63	1.636
5	67	1.740
6	40	1.038
7	30	.779
8	25	.649
9	22	.571
10	20	.519
12	11	.285
14	10	.259
16	9	.233
18	8	.207
20	8	.207
22	8	.207
24	8	.207
26	8	.207
28	8	.207
30	9	.233

Table No. 10 Modulus of Impedance (F1 - R)

(F2 - R)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	55	1.135
4	57	1.175
5	43	.886
6	41	.845
7	38	.783
8	24	.494
9	21	.432
10	17	.350
12	11	.226
14	9	.185
16	8	.164
18	8	.164
20	8	.164
22	7	.144
24	9	.185
26	10	.206
28	10	.206
30	10	.206

Table No. 11 Modulus of Impedance (F2 - R)

PHASE ANGLE RESULTS FOR

FEMALE SUBJECTS

SITTING RELAXED POSTURE

(Fl - R)

Frequency Hz	Phase Angle Degrees
3	−50
4	−60
5	−90
6	−85
7	−90
8	−95
9	−105
10	−108
12	−70
14	−65
16	−62
18	−59
20	−55
22	−51
24	−48
26	−46
28	−45
30	−46

Table No. 12 Phase Angle (Fl - R)

(F2 - R)

Frequency Hz	Phase Angle Degrees
3	−40
4	−50
5	−56
6	−62
7	−80
8	−112
9	−90
10	−75
12	−68
14	−59
16	−51
18	−50
20	−50
22	−51
24	−50
26	−50
28	−50
30	−50

Table No. 13 Phase Angle (F2 - R)

MODULUS OF IMPEDANCE RESULTS FOR

MALE SUBJECTS

SITTING ERECT POSTURE

(M1 - E)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	62	1.190
4	69	1.324
5	74	1.420
6	58	1.113
7	47.5	.911
8	45	.863
9	36	.690
10	28	.537
12	21	.403
14	18	.345
16	15	.287
18	13	..249
20	12	.230
22	12	.230
24	11	.211
26	11	.211
28	12	.230
30	12	.230

Table No. 14 Modulus of Impedance (M1 - E)

(M2 - E)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	72	1.196
4	78	1.295
5	68	1.129
6	54	.897
7	41	.681
8	34	.564
9	30	.498
10	28	.465
12	22	.365
14	18	.299
16	16	.265
18	15	.249
20	14	.232
22	12	.199
24	11	.182
26	10	.166
28	10	.166
30	10	.166

Table No. 15 Modulus of Impedance (M2 - E)

(M3 - E)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance Subject Weight
3	65	1.321
4	77	1.565
5	77	1.565
6	70	1.422
7	55	1.117
8	45	.914
9	41	.833
10	40	.813
12	36	.731
14	28	.569
16	21	.426
18	18	.365
20	15	.304
22	13	.264
24	11	.223
26	12	.243
28	13	.264
30	15	.304

Table No. 16 Modulus of Impedance (M3 - E)

(M4 - E)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	68	1.152
4	81	1.372
5	82	1.389
6	70	1.186
7	54	.915
8	47	.796
9	41	.694
10	36	.610
12	28	.474
14	23	.389
16	18	.305
18	12	.203
20	11	.186
22	10	.169
24	9	.152
26	8	.135
28	8	.135
30	8	.135

Table No. 17 Modulus of Impedance (M4 - E)

(M5 - E)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	55	1.082
4	63	1.240
5	64	1.259
6	55	1.082
7	42	.826
8	37	.728
9	30	.590
10	27	.531
12	23	.452
14	20	.393
16	12	.236
18	10	.196
20	8	.157
22	8	.157
24	7	.137
26	7	.137
28	6	.118
30	6	.118

Table No. 18 Modulus of Impedance (M5 - E)

(M6 - E)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	80	1.236
4	90	1.391
5	73	1.128
6	60	.927
7	55	.850
8	44	.680
9	39	.602
10	34	.525
12	27	.417
14	22	.340
16	20	.309
18	18	.278
20	16	.247
22	15	.231
24	15	.231
26	15	.231
28	15	.231
30	15	.231

Table No. 19 Modulus of Impedance (M6 - E)

(M7 - E)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	87	1.370
4	90	1.417
5	92	1.448
6	89	1.401
7	75	1.181
8	58	.913
9	44	.692
10	37	.582
12	27	.425
14	24	.377
16	23	.362
18	13	.204
20	11	.173
22	9	.141
24	8	.125
26	7	.110
28	6	.094
30	5	.078

Table No. 20 Modulus of Impedance (M7 - E)

(M8 - E)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	77	1.270
4	89	1.468
5	88	1.452
6	64	1.386
7	39	.643
8	36	.594
9	36	.594
10	37	.610
12	29	.478
14	24	.396
16	20	.330
18	12	.198
20	10	.165
22	8	.132
24	7	.115
26	6	.099
28	5	.082
30	5	.082

Table No. 21 Modulus of Impedance (M8 - E)

(M9 - E)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3.	80	1.398
4	87	1.520
5	88	1.538
6	75	1.311
7	44	.769
8	37	.646
9	32	.559
10	30	.524
12	26	.454
14	23	.402
16	14	.244
18	12	.209
20	10	.174
22	8	.139
24	6	.104
26	6	.104
28	8	.139
30	8	.139

Table No. 22 Modulus of Impedance (M9 - E)

(M10 - E)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	55	1.009
4	63	1.155
5	74	1.357
6	58	1.064
7	41	.752
8	35	.642
9	33	.605
10	30	.550
12	24	.440
14	22	.403
16	11	.201
18	10	.183
20	8	.146
22	8	.146
24	9	.165
26	10	.183
28	10	.183
30	11	.201

Table No. 23 Modulus of Impedance (M10 - E)

(M11 - E)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	53	1.207
4	60	1.366
5	62	1.412
6	59	1.342
7	52	1.184
8	43	.979
9	32	.728
10	27	.615
12	23	.523
14	21.5	.489
16	20.5	.466
18	19	.432
20	15	.341
22	14	.318
24	12	.273
26	11	.250
28	11	.250
30	10	.227

Table No. 24 Modulus of Impedance (M11 - E)

(M12 - E)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	49	1.086
4	56	1.241
5	60	1.330
6	58	1.286
7	46	1.019
8	38	.842
9	45	.997
10	44	.975
12	29	.643
14	25	.554
16	20	.443
18	16	.354
20	12	.266
22	11	.243
24	10	.221
26	10	.221
28	10	.221
30	10	.221

Table No. 25 Modulus of Impedance (M12 - E)

(M14 - E)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	64	1.299
4	65	1.319
5	62	1.258
6	49	.994
7	40	.812
8	37	.751
9	34	.690
10	32	.649
12	28	.568
14	22	.446
16	17	.345
18	11	.223
20	10	.203
22	10	.203
24	9	.182
26	9	.182
28	8	.162
30	8	.162

Table No. 26 Modulus of Impedance (M14 - E)

(M15 - E)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	65	1.181
4	68	1.236
5	60	1.096
6	48	.872
7	40	.727
8	36	.654
9	32	.581
10	28	.509
12	23	.418
14	19	.345
16	13	.236
18	10	.181
20	9	.163
22	8	.145
24	8	.145
26	9	.163
28	9	.163
30	10	.181

Table No. 27 Modulus of Impedance (M15 - E)

PHASE ANGLE RESULTS FOR

MALE SUBJECTS

SITTING ERECT POSTURE

(M1 - E)

Frequency Hz	Phase Angle Degrees
3	0
4	− 5
5	−10
6	−17
7	−25
8	−31
9	−42
10	−47
12	−52
14	−50
16	−42
18	−40
20	−39
22	−39
24	−39
26	−38
28	−37
30	−30

Table No. 28 Phase Angle (M1 - E)

(M2 - E)

Frequency Hz	Phase Angle Degrees
3	−15
4	−33
5	−45
6	−50
7	−65
8	−68
9	−75
10	−68
12	−60
14	−63
16	−58
18	−59
20	−60
22	−60
24	−60
26	−62
28	−67
30	−70

Table No. 29 Phase Angle (M2 - E)

(M3 - E)

Frequency Hz	Phase Angle Degrees
3	—24
4	—31
5	—39
6	—42
7	—50
8	—55
9	—57
10	—59
12	—60
14	—55
16	—48
18	—43
20	—42
22	—43
24	—43
26	—45
28	—47
30	—49

Table No. 30 Phase Angle (M3 - E)

(M4 - E)

Frequency Hz	Phase Angle Degrees
3	−8
4	−15
5	−22
6	−26
7	−35
8	−45
9	−48
10	−50
12	−50
14	−52
16	−50
18	−48
20	−46
22	−43
24	−42
26	−41
28	−40
30	−39

Table No. 31 Phase Angle (M4 - E)

(M6 - E)

Frequency Hz	Phase Angle Degrees
3	−20
4	−28
5	−36
6	−45
7	−51
8	−52
9	−52
10	−53
12	−55
14	−58
16	−53
18	−53
20	−53
22	−53
24	−53
26	−51
28	−50
30	−49

Table No. 32 Phase Angle (M6 - E)

(M7 - E)

Frequency Hz	Phase Angle Degrees
3	—10
4	—18
5	—21
6	—29
7	—41
8	—51
9	—48
10	—44
12	—41
14	—50
16	—58
18	—60
20	—62
22	—60
24	—56
26	—53
28	—48
30	— 42

Table No. 33 Phase Angle (M7 - E)

(M8 - E)

Frequency Hz	Phase Angle Degrees
3	−20
4	−30
5	−34
6	−40
7	−50
8	−61
9	−60
10	−60
12	−60
14	−59
16	−52
18	−52
20	−48
22	−43
24	−41
26	−40
28	−40
30	−40

Table No. 34 Phase Angle (M8 - E)

(M9 - E)

Frequency Hz	Phase Angle Degrees
3	−10
4	−17
5	−22
6	−30
7	−40
8	−47
9	−52
10	−51
12	−57
14	−60
16	−55
18	−48
20	−43
22	−41
24	−40
26	−38
28	−36
30	−34

Table No. 35 Phase Angle (M9 - E)

(M10 - E)

Frequency Hz	Phase Angle Degrees
3	−22
4	−27
5	−30
6	−35
7	−45
8	−55
9	−65
10	−70
12	−62
14	−60
16	−50
18	−48
20	−48
22	−46
24	−45
26	−40
28	−39
30	−38

Table No. 36 Phase Angle (M10 - E)

(M12 - E)

Frequency Hz	Phase Angle Degrees
3	−5
4	−10
5	−16
6	−21
7	−30
8	−42
9	−47
10	−47
12	−49
14	−50
16	−50
18	−48
20	−48
22	−48
24	−48
26	−44
28	−41
30	−39

Table No. 37 Phase Angle (M12 - E)

(M15 - E)

Frequency Hz	Phase Angle Degrees
3	-11
4	-18
5	-26
6	-35
7	-46
8	-49
9	-49
10	-48
12	-50
14	-56
16	-56
18	-55
20	-58
22	-59
24	-59
26	-60
28	-60
30	-60

Table No. 38 Phase Angle (M15 - E)

MODULUS OF IMPEDANCE RESULTS FOR

MALE SUBJECTS

SITTING RELAXED POSTURE

(M1 - R)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	60	1.151
4	75	1.439
5	60	1.151
6	40	.767
7	32	.614
8	29	.556
9	24	.460
10	20	.383
12	15	.287
14	13	.249
16	11	.211
18	10	.191
20	10	.191
22	10	.191
24	10	.191
26	10	.191
28	10	.191
30	11	.211

Table No. 39 Modulus of Impedance (M1 - R)

(M2 - R)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	60	1.151
4	75	1.439
5	60	1.151
6	40	.767
7	32	.614
8	29	.556
9	24	.460
10	20	.383
12	15	.287
14	13	.249
16	11	.211
18	10	.191
20	10	.191
22	10	.191
24	10	.191
26	10	.191
28	10	.191
30	11	.211

Table No. 40 Modulus of Impedance (M2 - R)

(M3 - R)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	65	1.321
4	77	1.565
5	74	1.504
6	62	1.260
7	43	.873
8	39	.792
9	37	.752
10	36	.731
12	31.5	.640
14	23.0	.467
16	17.0	.345
18	12.0	.243
20	10.0	.203
22	10.0	.203
24	10.0	.203
26	11.0	.223
28	13.0	.264
30	15	.304

Table No. 41 Modulus of Impedance (M3 - R)

(M4 - R)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	68	1.152
4	74	1.254
5	71	1.203
6	60	1.016
7	45	.762
8	39	.661
9	35	.593
10	30	.508
12	21.5	.364
14	10	.169
16	8	.135
18	7	.118
20	8	.135
22	8	.135
24	8	.135
26	8	.135
28	8	.135
30	8	.135

Table No. 42 Modulus of Impedance (M4 - R)

(M5 - R)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	55	1.082
4	63	1.240
5	60	1.181
6	42.5	.836
7	33	.649
8	29	.570
9	27	.531
10	23	.452
12	20	.393
14	10	.196
16	9	.177
18	8	.157
20	8	.157
22	8	.157
24	8	.157
26	7	.157
28	7	.137
30	7	.137

Table No. 43 Modulus of Impedance (M5 - R)

(M6 - R)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	80	1.236
4	88	1.360
5	83	1.282
6	65	1.00
7	51	.788
8	45	.695
9	40	.618
10	34	.525
12	26	.401
14	21	.324
16	19	.293
18	18	.278
20	16	.247
22	15	.231
24	15	.231
26	15	.231
28	15	.231
30	15	.231

Table No. 44 Modulus of Impedance (M6 - R)

(M7 - R)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	88	1.385
4	90	1.417
5	60	.944
6	38	.598
7	32	.503
8	30	.472
9	30	.472
10	27	.425
12	20	.314
14	10	.157
16	6	.094
18	5	.078
20	5	.078
22	6	.094
24	6	.094
26	6	.094
28	6	.094
30	6	.094

Table No. 45 Modulus of Impedance (M7 - R)

(M8 - R)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	80	1.320
4	80	1.320
5	57	.940
6	45	.742
7	38.5	.635
8	34.5	.569
9	33.0	.544
10	30	.495
12	21	.346
14	11	.181
16	7	.115
18	5	.082
20	5	.082
22	5	.082
24	6	.099
26	7	.115
28	8	.132
30	8	.132

Table No. 46 Modulus of Impedance (M8 - R)

(M9 - R)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	75	1.311
4	73	1.276
5	65	1.136
6	52	.909
7	41	.716
8	33	.576
9	29	.506
10	27	.472
12	16	.279
14	10	.174
16	7	.122
18	6	.104
20	5	.087
22	6	.104
24	6	.104
26	7	.122
28	7	.122
30	7	.122

Table No. 47 Modulus of Impedance (M9 - R)

(M10 - R)

Frequency Hz	Modulus of Impedance Kg.	Modulus of Impedance / Subject Weight
3	58	1.064
4	68	1.247
5	62	1.137
6	48.5	.889
7	36	.660
8	32	.587
9	30	.550
10	28	.513
12	22.5	.412
14	20	.366
16	10	.183
18	9	.165
20	9	.165
22	8	.146
24	8	.146
26	9	.165
28	9	.165
30	9	.165

Table No. 48 Modulus of Impedance (M10 - R)

(M11 - R)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	60	1.366
4	64	1.457
5	57	1.298
6	40	.911
7	28	.637
8	25	.569
9	22.5	.512
10	20	.455
12	11	.250
14	10	.227
16	9	.205
18	8	.182
20	8	.182
22	9	.205
24	9	.205
26	9	.205
28	10	.227
30	10	.227

Table No. 49 Modulus of Impedance (M11 - R)

(M12 - R)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	50	1.108
4	63	1.396
5	60	1.330
6	40	.886
7	29	.643
8	27	.598
9	25	.554
10	24	.532
12	18	.399
14	11	.243
16	10	.221
18	8	.177
20	7	.155
22	7	.155
24	6	.133
26	6	.133
28	7	.155
30	7	.155

Table No. 50 Modulus of Impedance (M12 - R)

(M14 - R)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	63	1.279
4	67	1.360
5	63	1.279
6	42	.852
7	37	.752
8	35	.710
9	32	.649
10	30	.609
12	26	.527
14	20	.402
16	11	.223
18	9	.182
20	8	.162
22	8	.162
24	8	.162
26	8	.162
28	8	.162
30	8	.162

Table No. 51 Modulus of Impedance (M14 - R)

(M15 - R)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	68	1.236
4	62	1.127
5	43	.781
6	36	.654
7	32	.581
8	31	.563
9	28	.509
10	24	.436
12	20	.363
14	10	.181
16	8	.145
18	7	.127
20	8	.145
22	8	.145
24	8	.145
26	8	.145
28	8	.145
30	9	.163

Table No. 52 Modulus of Impedance (M15 - R)

PHASE ANGLE RESULTS FOR

MALE SUBJECTS

SITTING RELAXED POSTURE

(M1 - R)

Frequency Hz	Phase Angle Degrees
3	-2
4	-10
5	-20
6	-30
7	-37
8	-43
9	-45
10	-47
12	-45
14	-39
16	-31
18	-31
20	-30
22	-30
24	-30
26	-30
28	-30
30	-30

Table No. 53 Phase Angle (M1 - R)

(M2 - R)

Frequency Hz	Phase Angle Degrees
3	-30
4	-41
5	-47
6	-56
7	-70
8	-88
9	-95
10	-70
12	-60
14	-55
16	-55
18	-50
20	-50
22	-55
24	-58
26	-62
28	-68
30	-64

Table No. 54 Phase Angle (M2 - R)

(M3 - R)

Frequency Hz	Phase Angle Degrees
3	−20
4	−31
5	−38
6	−42
7	−48
8	−50
9	−54
10	−53
12	−51
14	−48
16	−41
18	−38
20	−36
22	−34
24	−32
26	−30
28	−30
30	−30

Table No. 55 Phase Angle (M3 - R)

(M4 - R)

Frequency Hz	Phase Angle Degrees
3	−12
4	−27
5	−38
6	−47
7	−49
8	−50
9	−50
10	−50
12	−50
14	−49
16	−44
18	−40
20	−40
22	−37
24	−34
26	−31
28	−30
30	−29

Table No. 56 Phase Angle (M4 - R)

(M6 - R)

Frequency Hz	Phase Angle Degrees
3	−25
4	−31
5	−41
6	−45
7	−50
8	−55
9	−57
10	−58
12	−70
14	−62
16	−53
18	−48
20	−44
22	−41
24	−38
26	−36
28	−36
30	−36

Table No. 57 Phase Angle (M6 - R)

(M7 - R)

Frequency Hz	Phase Angle Degrees
3	−18
4	−22
5	−28
6	−42
7	−50
8	−48
9	−47
10	−48
12	−50
14	−46
16	−40
18	−36
20	−32
22	−31
24	−30
26	−30
28	−31
30	−32

Table No. 58 Phase Angle (M7 - R)

(M8 - R)

Frequency Hz	Phase Angle Degrees
3	-20
4	-35
5	-43
6	-48
7	-55
8	-62
9	-60
10	-57
12	-60
14	-49
16	-42
18	-40
20	-40
22	-38
24	-38
26	-36
28	-35
30	-34

Table No. 59 Phase Angle (M8 - R)

(M9 - R)

Frequency Hz	Phase Angle Degrees
3	-15
4	-26
5	-37
6	-45
7	-52
8	-56
9	-58
10	-57
12	-60
14	-58
16	-49
18	-43
20	-43
22	-40
24	-38
26	-37
28	-35
30	-32

Table No. 60 Phase Angle (M9 - R)

(M10 - R)

Frequency Hz	Phase Angle Degrees
3	-24
4	-38
5	-47
6	-50
7	-51
8	-53
9	-59
10	-62
12	-60
14	-50
16	-46
18	-42
20	-40
22	-38
24	-36
26	-32
28	-31
30	-30

Table No. 61 Phase Angle (M10 - R)

(M12 - R)

Frequency Hz	Phase Angle Degrees
3	-4
4	-14
5	-20
6	-35
7	-43
8	-51
9	-55
10	-51
12	-52
14	-52
16	-43
18	-40
20	-38
22	-36
24	-32
26	-28
28	-25
30	-22

Table No. 62 Phase Angle (M12 - R)

(M15 - R)

Frequency Hz	Phase Angle Degrees
3	-18
4	-25
5	-35
6	-42
7	-42
8	-42
9	-44
10	-48
12	-52
14	-46
16	-38
18	-36
20	-32
22	-28
24	-28
26	-27
28	-27
30	-27

Table No. 63 Phase Angle (M15 - R)

MODULUS OF IMPEDANCE AND PHASE ANGLE RESULTS FOR

MALE SUBJECTS

TRACKING POSTURE

(Ml - T)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	60	1.150
4	70	1.340
5	70	1.340
6	54	1.035
7	41	.786
8	34	.652
9	28	.536
10	23	.441
12	17	.326
14	13.5	.259
16	12	.230
18	11	.211
20	10	.192
22	10	.192
24	10	.192
26	10	.192
28	11	.211
30	12	.230

Table No. 64 Modulus of Impedance (Ml - T)

(M2 - T)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	68	1.130
4	83	1.380
5	75	1.245
6	51	.847
7	41	.682
8	37	.615
9	31	.515
10	27	.449
12	20	.333
14	17	.282
16	14	.232
18	18	.299
20	12	.199
22	11	.183
24	11	.183
26	11.5	.191
28	12	.199
30	12.5	.208

Table No. 65 Modulus of Impedance (M2 - T)

(M3 - T)

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance / Subject Weight
3	58	1.182
4	63	1.280
5	71	1.442
6	68	1.381
7	53	1.078
8	43	.875
9	38	.774
10	37	.754
12	37	.754
14	34	.692
16	28	.569
18	22	.447
20	20	.407
22	12	.244
24	10	.203
26	9	.183
28	8	.163
30	7	.142

Table No. 66 Modulus of Impedance (M3 - T)

(M1 - T)

Frequency Hz	Phase Angle Degrees
3	0
4	−7
5	−15
6	−20
7	−37
8	−45
9	−48
10	−52
12	−52
14	−48
16	−40
18	−38
20	−38
22	−38
24	−37
26	−38
28	−35
30	−30

Table No. 67 Phase Angle (M1 - T)

(M2 - T)

Frequency Hz	Phase Angle Degrees
3	-5
4	-15
5	-27
6	-36
7	-47
8	-54
9	-58
10	-57
12	-55
14	-48
16	-42
18	-40
20	-40
22	-38
24	-38
26	-40
28	-42
30	-46

Table No. 68 Phase Angle (M2 - T)

(M3 - T)

Frequency Hz	Phase Angle Degrees
3	−2
4	−10
5	−25
6	−36
7	−42
8	−47
9	−50
10	−52
12	−51
14	−50
16	−42
18	−40
20	−38
22	−37
24	−37
26	−38
28	−37
30	−34

Table No. 69 Phase Angle (M3 - T)

MODULUS OF IMPEDANCE AND PHASE ANGLE RESULTS FOR

MALE SUBJECTS

VARIOUS STANDING POSTURES

Modulus of Impedance

Results for Subject M1 Standing Erect

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance/ Subject Weight
3	70	1.020
4	78	1.137
5	84	1.224
6	67	.977
7	47	.685
8	40	.583
9	32	.466
10	29	.423
12	24	.350
14	20	.292
16	17	.248
18	13	.190
20	11.5	.168
22	10.5	.153
24	9.5	.138
26	8.5	.124
28	8.0	.117
30	7.0	.102

Table No. 70

Modulus of Impedance

Results for Subject M2 Standing Erect

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance/ Subject Weight
3	94	1.245
4	108	1.430
5	115	1.523
6	90	1.192
7	59	.781
8	56	.742
9	48	.636
10	42	.556
12	34	.450
14	25	.331
16	18	.238
18	16.5	.219
20	12.0	.159
22	10	.132
24	8.5	.113
26	8.5	.113
28	9.0	.119
30	7.0	.093

Table No. 71

Modulus of Impedance

Results for Subject M1 Standing Relaxed

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance/ Subject Weight
3	80	1.166
4	81	1.181
5	85	1.239
6	82	1.195
7	61	.889
8	44	.641
9	37	.539
10	30	.473
12	26	.379
14	21.5	.313
16	18	.262
18	14	.204
20	12.5	.182
22	12.0	.175
24	10	.146
26	9	.131
28	10	.146
30	10	.146

Table No. 72

Modulus of Impedance

Results for Subject M2 Standing Relaxed

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance/ Subject Weight
3	86	1.139
4	81	1.073
5	87	1.152
6	68	.901
7	49	.649
8	54	.715
9	55	.728
10	48	.636
12	38	.503
14	28	.371
16	22	.291
18	17	.225
20	13	.172
22	10	.132
24	8.5	.113
26	9	.119
28	9	.119
30	7.0	.093

Table No. 73

Modulus of Impedance

Results for Subject M1 Standing Knees Bent

Frequency Hz	Modulus of Impedance Kg	Modulus of Impedance/ Subject Weight
3	50	.729
4	46	.671
5	31	.452
6	18.5	.270
7	17.5	.255
8	19	.277
9	19	.277
10	20	.292
12	18.5	.270
14	16	.233
16	13.5	.197
18	12	.175
20	14	.204
22	14	.204
24	10.5	.153
26	9.5	.138
28	9.0	.131
30	8.0	.117

Table No. 74

Phase Angle

Results for Subject M1 Standing Erect

Frequency Hz	Phase Angle Degrees
3	-7
4	-18
5	-27
6	-35
7	-43
8	-50
9	-57
10	-60
12	-60
14	-58
16	-63
18	-65
20	-68
22	-70
24	-70
26	-68
28	-80
30	-80

Table No. 75

Phase Angle

Results for Subject M2 Standing Erect

Frequency Hz	Phase Angle Degrees
3	−2
4	−5
5	−12
6	−17
7	−28
8	−36
9	−44
10	−52
12	−70
14	−100
16	−105
18	−108
20	−115
22	−117
24	−110
26	−70
28	−66
30	−60

Table No. 76

Phase Angle

Results for Subject M1 Standing Relaxed

Frequency Hz	Phase Angle Degrees
3	−10
4	−15
5	−25
6	−32
7	−40
8	−43
9	−48
10	−50
12	−50
14	−52
16	−50
18	−52
20	−56
22	−58
24	−60
26	−60
28	−50
30	−48

Table No. 77

Phase Angle

Results for Subject M2 Standing Relaxed

Frequency Hz	Phase Angle Degrees
3	−3
4	−7
5	−14
6	−22
7	−32
8	−38
9	−42
10	−58
12	−90
14	−105
16	−110
18	−112
20	−112
22	−110
24	− 90
26	− 66
28	− 62
30	−55

Table No. 78

Phase Angle

Results for Subject M1 Standing Knees Bent

Frequency Hz	Phase angle ° with frequency increasing	Phase angle ° with frequency decreasing
3	10	−10
4	105	−36
5	112	−50
6	55	−75
7	35	−68
8	28	−55
9	26	−42
10	29	−34
12	30	−30
14	31	−28
16	35	−29
18	39	−32
20	42	−36
22	44	−42
24	42	−42
26	40	−39
28	35	−35
30	30	−30

Table No. 79

PDP-12 Computer programme

```
 W
C FOCAL-12

01.01 ASK "# OF DATA PTS" L
01.02 IF (20-L) 02.08
01.03 FOR I=1,1,L;ASK "NUM"NNN(I)
01.04 SET T=0
01.05 SET SIGMA=0
01.06 SET AX=0
01.07 FOR I=1,1,L;SET AX=AX+NNN(I)
01.08 SET MX=AX/L
01.09 TYPE "MX=",MX,!!

02.02 FOR I=1,1,L;SET T=(MX-NNN(I))↑2+T
02.04 SET T=T/L
02.06 SET SIGMA=SIGMA+FSQT(T)
02.07 TYPE "SIGMA="SIGMA!!
02.08 QUIT
*
```

Table No. 80

Frequency Hz	$w = 2\pi f$	$\left(\frac{2\pi f}{g}\right)$
3	18.9	19.3
4	25.2	25.7
5	31.4	32.0
6	37.7	38.5
7	44.0	44.9
8	50.4	51.4
9	56.5	57.6
10	63.0	64.3
12	75.5	77.0
14	88.0	89.8
16	101.0	103.0
18	113.0	115.3
20	126.0	128.5
22	138.0	140.8
24	151.0	154.0
26	163.0	166.3
28	167.0	179.5
30	189.0	192.8

(Taking g as .981 m/sec^2)

Table No. 81

Modulus of Impedance (Za Kg) for 14 Male Subjects - Erect Posture

Frequency Hz	3	4	5	6	7	8	9	10	12	14	16	18	20	22	24	26	28	30
Subject M1	62	69	74	58	47.5	45	36	28	21	18	15	13	12	12	11	11	12	12
" M2	72	78	68	54	41	34	30	28	22	18	16	15	14	12	11	10	10	10
" M3	65	77	77	70	55	45	41	40	36	28	21	18	15	13	11	12	13	15
" M4	68	81	82	70	54	47	41	36	28	23	18	12	11	10	9	8	8	8
" M5	55	63	64	55	42	37	30	27	23	20	12	10	8	8	7	7	6	6
" M6	80	90	73	60	55	44	39	34	27	22	20	18	16	15	15	15	15	15
" M7	87	90	92	89	75	58	44	37	27	24	23	13	11	9	8	7	6	5
" M8	77	89	88	64	39	36	36	37	29	24	20	12	10	8	7	6	5	5
" M9	80	87	88	75	44	37	32	30	26	23	14	12	10	8	6	6	8	8
" M10	55	63	74	58	41	35	33	30	24	22	11	10	8	8	9	10	10	11
" M11	53	60	62	59	52	43	32	27	23	21.5	20.5	19	15	14	12	11	11	10
" M12	49	56	60	58	46	38	45	44	29	25	20	16	12	11	10	10	10	10
" M14	64	65	62	49	40	37	34	32	28	22	17	11	10	10	9	9	8	8
" M15	65	68	60	48	40	36	32	28	23	19	13	10	9	8	8	9	9	10
Mean	66.6	74.0	73.1	61.9	48.0	40.9	36.1	32.7	26.1	22.1	17.2	13.5	11.5	10.4	9.5	9.4	9.4	9.5
S.D.	11.	11.6	10.7	10.6	9.4	6.3	4.9	5.	3.8	2.7	3.6	3.0	2.5	2.4	2.3	2.4	2.7	3.0

Table No. 82 Modulus of Impedance (Za Kg) - Erect Posture

Modulus of Impedance/Subject Weight for 14 Male Subjects - Erect Posture

Frequency Hz	3	4	5	6	7	8	9	10	12	14	16	18	20	22	24	26	28	30
Subject M1	1.190	1.324	1.420	1.113	.911	.863	.690	.537	.403	.345	.287	.249	.230	.230	.211	.211	.230	.230
" M2	1.196	1.295	1.129	.897	.681	.564	.498	.465	.365	.299	.265	.249	.232	.199	.182	.166	.166	.166
" M3	1.321	1.565	1.565	1.422	1.117	.914	.833	.813	.731	.569	.426	.365	.305	.264	.223	.243	.264	.304
" M4	1.152	1.372	1.389	1.186	.915	.796	.694	.610	.474	.389	.305	.203	.186	.169	.152	.135	.135	.135
" M5	1.082	1.240	1.259	1.082	.826	.728	.590	.531	.452	.393	.236	.196	.157	.157	.137	.137	.118	.118
" M6	1.236	1.391	1.128	.927	.850	.680	.602	.525	.417	.340	.309	.278	.247	.231	.231	.231	.231	.231
" M7	1.370	1.417	1.448	1.401	1.181	.913	.692	.582	.425	.377	.362	.204	.173	.141	.125	.110	.094	.078
" M8	1.270	1.468	1.452	1.386	.643	.594	.594	.610	.478	.396	.330	.198	.165	.132	.115	.099	.082	.082
" M9	1.398	1.520	1.538	1.311	.769	.646	.559	.524	.454	.402	.244	.209	.174	.139	.104	.104	.139	.139
" M10	1.009	1.155	1.357	1.064	.752	.642	.605	.550	.440	.403	.201	.183	.146	.146	.165	.183	.183	.201
" M11	1.207	1.366	1.412	1.342	1.184	.979	.728	.615	.523	.489	.466	.432	.341	.318	.273	.250	.250	.227
" M12	1.086	1.241	1.330	1.286	1.019	.842	.997	.975	.643	.554	.443	.354	.266	.243	.221	.221	.221	.221
" M14	1.299	1.319	1.258	.994	.812	.751	.690	.649	.568	.446	.345	.223	.203	.203	.182	.182	.162	.162
" M15	1.181	1.236	1.090	.872	.727	.654	.581	.509	.418	.345	.236	.181	.163	.145	.145	.163	.163	.181
Mean	1.21	1.35	1.34	1.16	.89	.75	.67	.61	.49	.41	.32	.25	.21	.19	.1	.17	.17	.18
S.D.	.11	.11	.15	.19	.17	.13	.12	.13	.10	.08	.08	.08	.06	.05	.05	.05	.06	.06

Table No. 83 Modulus of Impedance/Subject Weight - Erect Posture

Phase Angle results for 11 Male Subjects - Erect Posture

Frequency Hz	3	4	5	6	7	8	9	10	12	14	16	18	20	22	24	26	28	30
Subject M1	0	-5	-10	-17	-25	-31	-42	-47	-52	-50	-42	-40	-39	-39	-39	-38	-37	-30
" M2	-15	-33	-45	-50	-65	-68	-75	-68	-60	-63	-58	-59	-60	-60	-60	-62	-67	-70
" M3	-24	-31	-39	-42	-50	-55	-57	-59	-60	-55	-48	-43	-42	-43	-43	-45	-47	-49
" M4	-8	-15	-22	-26	-35	-45	-48	-50	-50	-52	-50	-48	-46	-43	-42	-41	-40	-39
" M6	-20	-28	-36	-45	-51	-52	-52	-53	-55	-58	-53	-53	-53	-54	-53	-51	-50	-49
" M7	-10	-18	-21	-29	-41	-51	-48	-44	-41	-50	-58	-60	-62	-60	-56	-53	-48	-42
" M8	-20	-30	-34	-40	-50	-61	-60	-60	-60	-59	-52	-50	-48	-43	-41	-40	-40	-40
" M9	-10	-17	-22	-30	-40	-47	-52	-51	-57	-60	-55	-48	-43	-41	-40	-38	-36	-34
" M10	-22	-27	-30	-35	-45	-55	-65	-70	-62	-60	-50	-48	-48	-46	-45	-40	-39	-38
" M12	-5	-10	-16	-21	-30	-42	-47	-47	-49	-50	-50	-48	-48	-48	-48	-44	-41	-39
" M15	-11	-18	-26	-35	-46	-49	-49	-48	-50	-56	-56	-55	-58	-59	-59	-60	-60	-60
Mean	-13.2	-21.1	-27.4	-33.6	-43.5	-50.5	-54.1	-54.3	-54.2	-55.7	-52.0	-50.2	-49.7	-48.6	-47.8	-46.5	-45.9	-44.5
S.D.	7.3	8.8	10.0	9.7	10.6	9.3	9.1	8.4	6.1	4.5	4.5	5.9	7.3	7.6	7.5	8.3	9.5	11.2

Table No. 84 Phase Angle results - Relaxed Posture

Modulus of Impedance (Za Kg) for 14 Male Subjects - Relaxed Posture

Frequency Hz	3	4	5	6	7	8	9	10	12	14	16	18	20	22	24	26	28	30
Subject M1	60	75	60	40	32	29	24	20	15	13	11	10	10	10	10	10	10	11
" M2	71	85	80	55	39	32	30	26	20	16	14	13	12	12	12	12	13	13
" M3	65	77	74	62	43	39	37	36	31.5	23	17	12	10	10	10	11	13	15
" M4	68	74	71	60	45	39	35	30	21.5	10	8	7	8	8	8	8	8	8
" M5	55	63	60	42.5	33	29	27	23	20	10	9	8	8	8	8	7	7	7
" M6	80	88	83	65	51	45	40	34	26	21	19	18	16	15	15	15	15	15
" M7	88	90	60	38	32	30	30	27	20	10	6	5	5	6	6	6	6	6
" M8	80	80	57	45	38.5	34.5	33.0	30	21	11	7	5	5	5	6	7	8	8
" M9	75	73	65	52	41	33	29	27	16	10	7	6	5	6	6	7	7	7
" M10	58	68	62	48.5	36	32	30	28	22.5	20	10	9	9	8	8	9	9	9
" M11	60	64	57	40	28	25	22.5	20	11	10	9	8	8	9	9	9	10	10
" M12	50	63	60	40	29	27	25	24	18	11	10	8	7	7	6	6	7	7
" M14	63	67	63	42	37	35	32	30	26	20	11	9	8	8	8	8	8	8
" M15	68	62	43	36	32	31	28	24	20	10	8	7	8	8	8	8	8	9
Mean	67.2	73.5	63.9	47.6	36.9	32.9	30.2	27.1	20.	14.6	10.4	8.9	8.5	8.6	8.6	8.8	9.2	9.5
S.D.	10.3	9.2	9.3	9.3	6.3	5.1	4.8	4.6	4.9	4.8	3.7	3.4	2.8	2.3	2.5	2.4	2.5	2.8

Table No. 85 Modulus of Impedance (Za Kg) - Relaxed Posture

Modulus of Impedance/Subject Weight for 14 Male Subjects - Relaxed Posture

Frequency Hz	3	4	5	6	7	8	9	10	12	14	16	18	20	22	24	26	28	30
Subject M1	1.179	1.411	1.328	.913	.647	.531	.498	.431	.332	.265	.249	.215	.199	.199	.199	.199	.215	.215
" M2	1.151	1.439	1.151	.767	.614	.556	.460	.383	.287	.249	.211	.191	.191	.191	.191	.191	.191	.211
" M3	1.321	1.565	1.504	1.260	.873	.792	.752	.731	.640	.467	.345	.243	.203	.203	.203	.223	.264	.304
" M4	1.152	1.254	1.203	1.016	.762	.661	.593	.508	.364	.169	.135	.118	.135	.135	.135	.135	.135	.135
" M5	1.082	1.240	1.181	.836	.649	.570	.531	.452	.393	.196	.177	.157	.157	.157	.157	.137	.137	.137
" M6	1.236	1.360	1.282	1.004	.788	.695	.618	.525	.401	.324	.293	.278	.247	.231	.231	.231	.231	.231
" M7	1.385	1.417	.944	.598	.503	.472	.472	.425	.314	.157	.094	.078	.078	.094	.094	.094	.094	.094
" M8	1.320	1.320	.940	.742	.635	.569	.544	.495	.346	.181	.115	.082	.082	.082	.099	.115	.132	.132
" M9	1.311	1.276	1.136	.909	.716	.576	.506	.472	.279	.174	.122	.104	.087	.104	.104	.122	.122	.122
" M10	1.064	1.247	1.137	.889	.660	.587	.550	.513	.412	.366	.183	.165	.165	.146	.146	.165	.165	.165
" M11	1.366	1.457	1.298	.911	.637	.569	.512	.455	.250	.227	.205	.182	.182	.205	.205	.205	.227	.227
" M12	1.108	1.396	1.330	.886	.643	.598	.554	.532	.399	.243	.221	.177	.155	.155	.133	.133	.155	.155
" M14	1.279	1.360	1.279	.852	.751	.710	.649	.609	.527	.406	.223	.182	.162	.162	.162	.162	.162	.162
" M15	1.236	1.127	.781	.654	.581	.563	.509	.463	.363	.181	.145	.127	.145	.145	.145	.145	.145	.163
Mean	1.23	1.35	1.18	.87	.68	.60	.55	.50	.38	.26	.19	.16	.16	.16	.16	.16	.17	.18
S.D.	.10	.11	.18	.16	.03	.06	.08	.08	.10	.09	.07	.06	.05	.04	.04	.04	.05	.05

Table No. 86 Modulus of Impedance/Subject Weight - Relaxed Posture

Phase Angle results for 11 Male Subjects - Relaxed Posture

Frequency Hz	3	4	5	6	7	8	9	10	12	14	16	18	20	22	24	26	28	30
Subject M1	−2	−10	−20	−30	−37	−43	−45	−47	−45	−39	−31	−31	−30	−30	−30	−30	−30	−30
" M2	−30	−41	−47	−56	−70	−88	−95	−70	−60	−55	−55	−50	−50	−55	−58	−62	−68	−64
" M3	−20	−31	−38	−42	−48	−50	−54	−53	−51	−48	−41	−38	−36	−34	−32	−30	−30	−30
" M4	−12	−27	−38	−47	−49	−50	−50	−50	−50	−49	−44	−40	−40	−37	−34	−31	−30	−29
" M6	−25	−31	−41	−45	−50	−55	−57	−58	−70	−62	−53	−48	−44	−41	−38	−36	−36	−36
" M7	−18	−22	−28	−42	−50	−48	−47	−48	−50	−46	−40	−36	−32	−31	−30	−30	−31	−32
" M8	−20	−35	−43	−48	−55	−62	−60	−57	−60	−49	−42	−40	−40	−38	−38	−36	−35	−34
" M9	−15	−26	−37	−45	−52	−56	−58	−57	−60	−58	−49	−43	−43	−40	−38	−37	−35	−32
" M10	−24	−38	−47	−50	−51	−53	−59	−62	−60	−50	−46	−42	−40	−38	−36	−32	−31	−30
" M12	−4	−14	−20	−35	−43	−51	−55	−51	−52	−52	−43	−40	−38	−36	−32	−28	−25	−22
" M15	−18	−25	−35	−42	−42	−42	−44	−48	−52	−46	−38	−36	−32	−28	−28	−27	−27	−27
Mean	−17.1	−22.3	−35.8	−43.8	−49.7	−53.5	−56.7	−54.6	−55.5	−50.4	−43.8	−40.4	−38.6	−37.1	−35.8	−34.5	−34.4	−33.3
S.D.	8.1	9.0	9.1	6.7	8.1	11.7	13.3	6.7	6.8	6.0	6.5	5.2	5.7	7.0	7.8	9.3	11.1	10.2

Table No. 87 Phase Angle results - Relaxed Posture

Modulus of Impedance

Results for Subjects F1 and F2 Erect Posture

Frequency Hz	Mean of Modulus of Impedance Kg	Mean of Modulus of Impedance/Subject Weight
3	54.5	1.251
4	60	1.377
5	52.5	1.205
6	44	1.010
7	36	.826
8	27.25	.625
9	24	.551
10	21.25	.487
12	14.5	.332
14	10.5	.241
16	9.5	.218
18	9	.206
20	9	.206
22	9	.206
24	9	.206
26	9	.206
28	9	.206
30	9.5	.218

Table No. 88

Mean of Modulus of Impedance

Results for Subjects F1 and F2 Erect Posture

Frequency	Mean of Modulus of Impedance for F1 and F2	
Hz	Kg	(dynes x sec/cm) x 10^3
3	54.5	1030.25
4	60	1512.0
5	52.5	1648.5
6	44	1658.8
7	36	1584.0
8	27.25	1373.4
9	24	1356.0
10	21.25	1338.75
12	14.5	1094.75
14	10.5	924.0
16	9.5	959.5
18	9	1017.0
20	9	1134.0
22	9	1242.0
24	9	1359.0
26	9	1467.0
28	9	1584.0
30	9.5	1795.0

Table No. 89

Phase Angle

Results for Subjects F1 and 2 Erect Posture

Frequency Hz	Mean of Phase Angle Degrees
3	− 39
4	− 50
5	− 60
6	− 72.5
7	− 91.0
8	− 92.5
9	− 92.5
10	− 70
12	− 62.5
14	− 61.5
16	− 57.5
18	− 57.5
20	− 58
22	− 60
24	− 63
26	− 65.5
28	− 70
30	− 80

Table No. 90

Modulus of Impedance

Results for Subjects F1 and F2 Relaxed Posture

Frequency Hz	Mean of Modulus of Impedance Kg	Mean of Modulus of Impedance/Subject Weight
3	55	1.262
4	60	1.377
5	55	1.262
6	40.5	.929
7	34	.780
8	24.5	.562
9	21.5	.493
10	18.5	.424
12	11	.252
14	9.5	.218
16	8.5	.195
18	8	.183
20	8	.183
22	7.5	.172
24	8.5	.195
26	9	.206
28	9	.206
30	9.5	.218

Table No. 91

Mean of Modulus of Impedance

Results for Subjects F1 and F2 Relaxed Posture

Frequency Hz	Mean of Modulus of Impedance for F1 and F2 Kg	(dynes x sec/cm) x 10^3
3	55	1039.5
4	60	1512.0
5	55	1727.0
6	40.5	1526.85
7	34	1496.0
8	24.5	1234.8
9	21.5	1214.75
10	18.5	1165.5
12	11	830.5
14	9.5	836.0
16	8.5	858.5
18	8	904.0
20	8	1008.0
22	7.5	1035.0
24	8.5	1283.5
26	9	1467.0
28	9	1584.0
30	9.5	1795.5

Table No. 92

Phase Angle

Results for Subjects F1 and 2 Relaxed Posture

Frequency Hz	Mean of Phase Angle Degrees
3	– 45
4	– 55
5	– 73
6	– 73.5
7	– 85
8	– 103.5
9	– 97.5
10	– 91.5
12	– 69.0
14	– 62.0
16	– 56.5
18	– 54.5
20	– 52.5
22	– 51
24	– 49
26	– 48
28	– 47.5
30	– 48

Table No. 93

Modulus of Impedance

Results for 14 Male Subjects Erect Posture

Frequency Hz	Mean of Modulus of Impedance Kg	S.D. of Modulus of Impedance Kg
3	66.571	11.056
4	74.000	11.600
5	73.143	10.676
6	61.929	10.586
7	47.964	9.419
8	40.857	6.334
9	36.071	4.906
10	32.714	5.188
12	26.143	3.776
14	22.107	2.674
16	17.179	3.614
18	13.500	3.041
20	11.500	2.528
22	10.429	2.352
24	9.500	2.291
26	9.357	2.408
28	9.357	2.715
30	9.500	3.041

Table No. 94

Modulus of Impedance/Subject Weight

Results for 14 Male Subjects Erect Posture

Frequency Hz	Mean of M. of I./Sub. Wt.	S.D. of M.of I./Sub. Wt.
3	1.2141	.1077
4	1.3501	.1120
5	1.3511	.1450
6	1.1631	.1890
7	.8850	.1730
8	.7547	.1270
9	.6681	.1220
10	.6068	.1300
12	.4851	.0970
14	.4105	.0762
16	.3182	.0796
18	.2517	.0754
20	.2134	.0572
22	.1941	.0547
24	.1761	.0483
26	.1739	.0501
28	.1741	.0558
30	.1768	.0614

Table No. 95

Modulus of Impedance Results for 14 Male Subjects

Z in dynes x $\frac{sec}{cm}$ x 10^3 Erect Posture

Frequency Hz	Mean of Modulus of Impedance (Zv) dynes x sec/cm x 10^3	S.D. of Modulus of Impedance (Zv) dynes x sec/cm x 10^3
3	1283.36	213.08
4	1202.10	298.15
5	2342.63	341.90
6	2381.39	407.08
7	2152.60	422.79
8	2100.38	325.58
9	2078.76	282.74
10	2102.21	333.34
12	2013.28	290.80
14	1984.31	240.01
16	1769.80	362.30
18	1556.01	350.47
20	1477.98	324.87
22	1467.98	331.09
24	1463.19	352.82
26	1555.70	400.55
28	1679.74	487.36
30	1831.41	586.30

Table No. 96

Modulus of Impedance Results for 14 Male Subjects

Zv in lb-sec/ft. Erect Posture

Frequency Hz	Mean of Modulus of Impedance lb-sec/ft.	S.D. of Modulus of Impedance lb-sec/ft.
3	86.061	14.29
4	127.55	17.94
5	157.09	22.93
6	159.69	27.30
7	144.35	28.35
8	140.85	21.83
9	139.40	18.96
10	140.96	22.35
12	135.00	19.50
14	133.06	16.09
16	118.68	24.97
18	104.34	23.50
20	99.11	21.97
22	98.44	22.20
24	98.12	23.66
26	104.32	26.86
28	112.64	32.68
30	122.81	39.32

Table No. 97

Phase Angle

Results for 11 Male Subjects Erect Posture

Frequency Hz	Mean of Phase Angle Degrees	S.D. of Phase Angle Degrees
3	− 13.1818	7.2841
4	− 21.0909	8.8261
5	− 27.364	10.011
6	− 33.636	9.726
7	− 43.455	10.560
8	− 50.545	9.3260
9	− 54.09	9.0700
10	− 54.273	8.378
12	− 54.181	6.1173
14	− 55.727	4.453
16	− 52.00	4.5327
18	− 50.182	5.875
20	− 49.727	7.25
22	− 48.636	7.619
24	− 47.818	7.493
26	− 46.545	8.2722
28	− 45.909	9.462
30	− 44.546	11.2036

Table No. 98

Modulus of Impedance

Results for 14 Male Subjects Relaxed Posture

Frequency Hz	Mean of Modulus of Impedance Kg	S.D. of Modulus of Impedance Kg
3	67.214	10.325
4	73.500	9.210
5	63.930	9.310
6	47.571	9.270
7	36.893	6.297
8	22.893	5.135
9	30.179	4.765
10	27.071	4.559
12	20.607	4.888
14	14.571	4.821
16	10.429	3.678
18	8.929	3.369
20	8.500	2.850
22	8.571	2.293
24	8.571	2.470
26	8.766	2.430
28	9.214	2.536
30	9.500	2.847

Table No. 99

Modulus of Impedance/Subject Weight

Results for 14 Male Subjects Relaxed Posture

Frequency Hz	Mean of M.of I./Sub. Wt.	S.D. of M.of I./Sub. Wt.
3	1.228	.1025
4	1.348	.1080
5	1.176	.1821
6	.874	.1574
7	.676	.0312
8	.604	.0601
9	.553	.0753
10	.499	.0846
12	.379	.0982
14	.258	.0945
16	.194	.0682
18	.164	.0571
20	.156	.0473
22	.158	.0435
24	.157	.0424
26	.161	.0416
28	.169	.0472
30	.175	.0543

Table No. 100

Modulus of Impedance Results for 14 Male Subjects

Z in dynes x $\frac{sec}{cm}$ x 10^3 Relaxed Posture

Frequency Hz	Mean of Modulus of Impedance (Zv) dynes x sec/cm x 10^3	S.D. of Modulus of Impedance (Zv) dynes x sec/cm x 10^3
3	1295.7	199.0
4	1889.2	236.7
5	2047.6	298.2
6	1829.3	356.5
7	1655.7	282.8
8	1690.9	265.3
9	1739.3	274.9
10	1535.5	293.1
12	1587.1	376.6
14	1307.8	432.7
16	1074.5	379.1
18	1029.3	388.4
20	1092.4	366.3
22	1206.4	322.3
24	1320.0	380.5
26	1458.6	404.0
28	1653.4	456.0
30	1831.4	549.5

Table No. 101

Modulus of Impedance Results for 14 Male Subjects

Zv in lb-sec/ft. Relaxed Posture

Frequency Hz	Mean of Modulus of Impedance lb-sec/ft.	S.D. of Modulus of Impedance lb-sec/ft.
3	86.89	13.34
4	126.69	15.87
5	137.30	19.99
6	122.67	23.91
7	111.03	18.96
8	113.39	17.72
9	116.64	18.43
10	102.97	19.65
12	106.43	25.25
14	87.70	29.02
16	72.05	25.42
18	69.0[illegible]	26.04
20	73.26	24.56
22	90.90	21.61
24	88.57	25.51
26	97.81	27.09
28	110.88	30.57
30	122.81	36.85

Table No. 102

Phase Angle

Results for 11 Male Subjects Relaxed Posture

Frequency Hz	Mean of Phase Angle Degrees	S.D. of Phase Angle Degrees
3	- 17.1	8.118
4	- 22.27	9.046
5	- 35.818	9.05
6	- 43.818	6.7125
7	- 49.727	8.069
8	- 53.455	11.6953
9	- 56.7273	13.2534
10	- 54.6364	6.7187
12	-55.455	6.787
14	- 50.364	5.989
16	- 43.818	6.506
18	-40.364	5.157
20	-38.636	5.6612
22	-37.091	6.921
24	-35.818	7.791
26	- 34.455	9.267
28	-34.3636	11.105
30	-33.2727	10.2229

Table No. 103

Modulus of Impedance

Mean Values for M1, M2 and M3 E and R.

Frequency Hz	Erect Za kg	Erect Zv Dynes x sec/cm x 10^6	Relaxed Za kg	Relaxed Zv Dynes x sec/cm x 10^6
3	66.3	1.28	65.3	1.26
4	74.7	1.92	79.0	2.03
5	73.0	2.33	71.3	2.28
6	60.6	2.33	52.3	2.01
7	47.8	2.15	38.0	1.71
8	41.3	2.12	33.3	1.71
9	35.6	2.05	30.3	1.75
10	32.0	2.06	27.3	1.76
122	26.3	2.03	22.2	1.71
14	21.3	1.91	17.3	1.55
16	17.3	1.78	14.0	1.44
18	15.3	1.76	11.7	1.35
20	13.6	1.75	10.7	1.37
22	12.3	1.73	10.7	1.51
24	11.0	1.69	10.7	1.65
26	11.0	1.83	11.0	1.83
28	11.6	2.08	12.0	2.15
30	12.3	2.37	13.0	2.51

Table No. 104

Phase Angle

Mean Values for M1, M2 and M3 E. and R.

Frequency Hz	Erect Phase Angle Degrees (Za)	Relaxed Phase Angle Degrees (Za)
3	- 17.3	- 65.3
4	- 27.3	- 79.0
5	- 35.0	- 71.3
6	- 42.7	- 52.3
7	- 51.7	- 38.0
8	- 60.3	- 33.3
9	- 64.7	- 30.3
10	- 56.7	- 27.3
12	- 52.0	- 22.2
14	- 47.3	- 17.3
16	- 42.3	- 14.0
18	- 39.7	- 11.7
20	- 38.7	- 10.7
22	- 39.7	- 10.7
24	- 40.0	- 10.7
26	- 40.7	- 11.0
28	- 42.7	- 12.0
30	- 41.3	- 13.0

Table No. 105

Mean Value of Modulus of Impedance for

M1, 2 and 3 in a tracking posture

Frequency Hz	Mean of Modulus of Impedance Kg	Mean of Modulus of Impedance/Subject Wt
3	62	1.154
4	72	1.333
5	72	1.342
6	57.7	1.088
7	45	.849
8	38	.714
9	32.3	.608
10	29	.548
12	24.7	.471
14	21.5	.411
16	18.0	.343
18	17	.319
20	14	.266
22	11	.206
24	10.3	.193
26	10.17	.189
28	10.3	.191
30	10.5	.193

Table No. 106

Mean of Modulus of Impedance

Results for Subjects M1, M2 and M3 Tracking

Frequency Hz	Mean of Modulus of Impedance for M1, M2 and M3 Kg	dynes x sec/cm x 10^3
3	62	1196.6
4	72	1850.4
5	72	2304.0
6	57.7	2221.5
7	45.3	2034.0
8	38	1953.2
9	32.3	1860.5
10	29	1864.7
12	24.7	1901.9
14	21.5	1930.7
16	18	1854.0
18	15.3	1764.1
20	14.0	1799.0
22	11.0	1548.8
24	10.3	1586.2
26	10.1	1679.6
28	10.3	1848.8
30	10.5	2024.4

Table No. 107

Phase Angle Results for Subjects M1, M2 and M3

Tracking Posture

Frequency Hz	Mean Phase Angle Degrees
3	- 2.3
4	-10.7
5	- 22.3
6	- 30.7
7	- 42.0
8	- 48.7
9	- 52.0
10	- 53.7
12	- 52.7
14	- 48.7
16	- 41.3
18	- 39.3
20	- 38.7
22	- 37.7
24	- 37.3
26	- 38.7
28	-37.7
30	- 36.7

Table No. 108

Modulus of Impedance

Results for Subject M1 Standing Erect

Frequency Hz	Modulus of Impedance for M1 (Za)kg	(Zv)Dynes x sec/cm x10^6
3	70	1.35
4	78	2.00
5	84	2.69
6	67	2.58
7	47	2.11
8	40	2.06
9	32	1.84
10	29	1.86
12	24	1.85
14	20	1.80
16	17	1.75
18	13	1.50
20	11.5	1.48
22	10.5	1.48
24	9.5	1.46
26	8.5	1.41
28	8.0	1.44
30	7.0	1.35

Table No. 109

Modulus of Impedance

Results for Subject M2 Standing Erect

Frequency Hz	Modulus of Impedance for M2. (Za)kg	(Zv)Dynes x sec/cm x 10^6
3	94	1.81
4	108	2.78
5	115	3.68
6	90	3.47
7	59	2.65
8	56	2.88
9	48	2.76
10	42	2.70
12	34	2.62
14	25	2.25
16	18	1.85
18	16.5	1.90
20	12.0	1.54
22	10	1.41
24	8.5	1.31
26	8.5	1.41
28	9.0	1.62
30	7.0	1.35

Table No. 110

Modulus of Impedance

Results for M1 and M2 Standing Erect

Frequency Hz	Mean of Modulus of Impedance Kg	Mean of Modulus of Impedance/Subject Weight
.3	82	1.138
4	93	1.291
5	99.5	1.381
6	78.5	1.090
7	53	.736
8	48	.666
9	40	.555
10	35.5	.493
12	29	.402
14	22.5	.312
16	17.5	.243
18	14.8	.194
20	11.8	.164
22	10.3	.143
24	9.3	.125
26	8.5	.118
28	8.5	.118
30	7.0	.098

Table No. 111

Modulus of Impedance

Results for Subjects M1 and M2 Standing Erect

Frequency Hz	Mean of Modulus of Impedance for M1 and M2 (Za) Kg	(Zw) dynes x sec/cm x 10^3
3	82	1583
4	93	2390
5	99.5	3184
6	78.5	3024
7	53	2398
8	48	2467
9	40	2304
10	35.5	2283
12	29.0	2233
14	22.5	2021
16	17.5	1803
18	14.8	1706
20	11.8	1516
22	10.3	1450
24	9.0	1386
26	8.5	1414
28	8.5	1526
30	7.0	1350

Table No. 112

Phase Angle

Results for Subjects M1 and M2 Standing Erect

Frequency Hz	Mean Phase Angle Degrees
3	- 4.5
4	-11.5
5	- 19.5
6	- 26.0
7	- 35.5
8	- 43.0
9	- 50.5
10	- 56.0
12	-- 65.0
14	- 79.0
16	- 84.0
18	- 86.5
20	- 91.5
22	- 93.5
24	- 90.0
26	- 69.0
28	-73.0
30	-70.0

Table No. 113

Modulus of Impedance

Results for Subject M1 Standing Relaxed

Frequency Hz	Modulus of Impedance for M1 (Za)kg	(Zv)Dynes x sec/cm x 10^6
3	80	1.54
4	81	2.08
5	85	2.72
6	82	3.16
7	61	2.74
8	44	2.26
9	37	2.13
10	30	1.93
12	26	2.00
14	21.5	1.93
16	18	1.85
18	14	1.61
20	12.5	1.60
22	12	1.69
24	10	1.54
26	9	1.50
28	10	1.80
30	10	1.93

Table No. **114**

Modulus of Impedance

Results for Subject M2 Standing Relaxed

Frequency Hz	Modulus of Impedance for M2 (Za)kg	(Zv)Dynes x sec/m x 10^6
3	86	1.66
4	81	2.08
5	87	2.78
6	68	2.62
77	49	2.20
8	54	2.78
9	55	3.17
10	48	3.09
12	38	2.93
14	28	2.51
16	22	2.27
18	17	1.96
20	13	1.67
22	10	1.41
24	8.5	1.31
26	9	1.50
28	9	1.62
30	7	1.35

Table No.115

Modulus of Impedance

Results for M1 and M2 Standing Relaxed

Frequency Hz	Mean of Modulus of Impedance Kg	Mean of Modulus of Impedance/Subject Weight
3	83	1.152
4	81	1.124
5	86	1.194
6	75	1.041
7	55	.763
8	49	.680
9	46	.638
10	39	.541
12	32	.444
14	24.7	.343
16	20	.278
18	15.5	.215
20	12.8	.178
22	11	.153
24	9.8	.136
26	9	.125
28	9.5	.132
30	8.5	.118

Table No. 116

Modulus of Impedance

Results for Subjects M1 and M2 Standing Relaxed

Frequency Hz	Mean of Modulus of Impedance for M1 and M2 (Za) Kg	(Zu)dynes x sec/cm x 10^3
3	83	1602
4	81	2082
5	86	2752
6	75	2888
7	55	2570
8	49	2519
9	46	2650
10	39	2508
12	32	2464
14	24.7	2218
16	20.0	2060
18	15.5	1782
20	12.8	1645
22	11	1549
24	9.8	1509
26	9	1497
28	9.5	1705
30	8.5	1639

Table No. 117

Phase Angle

Results for Subjects M1 and M2 Standing Relaxed

Frequency Hz	Mean Phase Angle Degrees
3	- 6.5
4	- 11.0
5	- 19.5
6	- 27.0
7	- 36.0
8	- 40.5
9	- 45.0
10	- 54.0
12	- 70.0
14	- 78.5
16	- 80.0
18	- 87.0
20	- 84.0
22	- 84.0
24	- 75.0
26	- 63.0
28	- 56.0
30	- 51.5

Table No. 118

Modulus of Impedance

Results for Subject M1 Standing with knees bent

Frequency Hz	Modulus of Impedance for M1 (Za) Kg.	(Zu) dynes Sec/cm x 10^3
3	50	965
4	46	1182
5	31	992
6	18.5	712
7	17.5	786
8	19	977
9	19	1094
10	20	1286
12	18.5	1425
14	16	1437
16	13.5	1391
18	12	1384
20	14	1799
22	14	1971
24	10.5	1617
26	9.5	1580
28	9	1616
30	8	1542

Table No. 119

Sitting Erect Posture.

Frequency Hz	S.D.x100/Mean % for Modulus of Impedance/Sub Sitting Wt	S.D.x100/Mean % for Modulus of Impedance (Za)
3	8.871	16.607
4	8.296	15.675
5	10.812	14.596
6	16.251	17.093
7	19.548	19.639
8	16.841	15.503
9	18.263	13.600
10	21.416	15.859
12	20.000	14.444
14	18.540	12.094
16	25.031	21.034
18	29.920	22.528
20	26.854	21.986
22	28.195	22.549
24	27.443	24.118
26	28.816	25.740
28	32.068	29.017
30	34.689	32.014

Table No. 120

Sitting Relaxed Posture

Frequency Hz	S.D.x100/Mean % for Modulus of Impedance/Sub Sitting Wt	S.D.x100/Mean % for Modulus of Impedance (Za)
3	8.346	15.361
4	8.011	12.530
5	15.476	14.562
6	17.963	19.486
7	4.585	17.068
8	9.933	15.611
9	13.562	15.789
10	16.833	16.840
12	25.857	23.730
14	36.434	33.086
16	35.051	32.267
18	34.756	37.730
20	30.128	33.529
22	27.215	26.753
24	26.751	31.968
26	25.465	27.720
28	27.810	27.523
30	30.857	29.968

Table No. 121

SUBJECT DATA

	Coermann (1963) MALE	Suggs et al (1969) MALE	Lawes (1971) MALE	Lawes (1971) FEMALE
Standing Height cms				
Mean	181.5	-	179.2	166.7
S.D.	2.5	-	5.06	-
Max. height	193.0	-	185	167.5
Min. height	170.0	-	168	166.0
Total Weight kgs.				
Mean	85.31	77.11	70.72	56.25
S.D	3.44	-	7.1	-
Max. weight	99.5	88.5	84	60.7
Min. weight	71.7	53.5	60.2	51.8
Sitting Height cms				
Mean	-	-	92.8	86.5
S.D.	-	-	2.56	-
Max. Sit.ht.	-	-	95.5	87
Min. sit. ht.	-	-	86	86
Sitting Weight kgs				
Mean	-	60.60	54.65	43.55
S.D.	-	-	6.31	-
Max. sit. wt.	-	-	64.7	48.6
Min. sit. wt.	-	-	43.9	38.5
Age Years				
Mean	34.13	-	25.21	24
S.D.	2.15	-	3.14	-
Max. Age	47	-	34	26
Min. Age	29	-	22	22

Table No. 122

Modulus of Impedance Results

Sitting Erect

	Coermann (1963)	Suggs et al (1969)	Lawes (1971)
Frequency Range	2 - 20 Hz	1.75 - 10Hz	3 - 30 Hz
No. of Subjects	8	11	14
Primary Anti-Resonance	5 Hz 4.95	4.5Hz 2.47	5.1Hz 2.4
Secondary Anti-Resonance	11 Hz 3.30	8 Hz 1.42	11 Hz 2.11
Primary Resonance	8.5 Hz 2.90	7 Hz 1.39	8.5 Hz 2.05

Values of Impedance are given in Dynes x $sec^2/cm \times 10^6$

The results of Suggs et al are included in the sitting erect table although Suggs did not specifically define the posture he used.

Table No. 123

Modulus of Impedance Results

Sitting Relaxed

	Coermann (1963)	Lawes (1971)
Frequency Range	2 - 20 Hz	3 - 30 Hz
No. of Subjects	1	14
Primary Anti-Resonance	5.2 Hz 5.05	4.2 Hz 2.0
Secondary Anti-Resonance	11.5 Hz 2.9	9.0 Hz 1.74
Primary Resonance	9.7 Hz 2.6	7.0 Hz 1.65

Values of Impedance are in Dynes x $sec^2/cm \times 10^6$

The results from Coermann are for one subject RC, graphical data is also given for another subject, W B. See Fig. No. Two plots are given for this subject which differ considerably, so the values detailed above are for subject R.C. only

Table No.124

Modulus of Impedance Results

Standing Erect

	Coermann (1963)	Lawes (1971)
Frequency Range	2 - 20 Hz	3 - 30 Hz
No. of Subjects	1	1 (Subject M2)
Primary Anti-resonance	6 Hz 5.1	5 Hz 3.68
Secondary Anti-resonance	11.4 Hz 4.55	8.0 Hz 2.88
Primary Resonance	9.2 Hz 3.60	7.1. Hz 2.65

Vales of Impedance are given in Dynes x $sec^2/cm \times 10^6$

M2 was chosen as he was the subject of above average build (compared to the rest of the subject panel). This was to enable a more direct comparison to be made to Coermann's results.

Table No.125

SUBJECT FILE-CONFIDENTIAL

FORM OF DECLARATION

(TO BE REDECLARED FOR EACH EXPERIMENT)

PART I.

(1) Are you in good health? YES/NO*

If NO please explain

(2) Have you ever suffered from a serious illness, or had any operations? YES/NO*

If YES please explain, giving dates

(3) Have you ever been injured? (necessitating treatment by a doctor or hospital). YES/NO*

If YES please explain

(4) Do you suffer from any disability or defect affecting your daily life? YES/NO*

If YES please explain

(5) Are you at present under Medical treatment of any kind? YES/NO*

If YES please explain

(6) Are you suffering from or have you suffered from, any of the following conditions?

a) Coughing up, vomiting or passing blood YES/NO*

b) Ulcers YES/NO*

c) Haemorrhoids (piles) YES/NO*

d) Intermittent pain, blanching or numbness of the fingers. YES/NO*

e) Back injury, "strain", or back pain YES/NO*

(7) Have you during the previous month had a vaccination or innoculation, or given blood for transfusion? YES/NO*

If YES, when?

(8) Have you during the previous year had an X-ray, or undergone radiation treatment? YES/NO*

If YES, when?

(9) Have you any objection to having electrodes or other devices attached to the surface of your body? YES/NO*

(10) Have you any objection to swallowing any experimental device, and recovering it for future use? YES/NO*

(11) Would you be willing for your own doctor to be asked for his opinion as to your fitness to take part as a subject in acceleration and/or vibration experiments? YES/NO*

If YES please give your doctor's name and address:

____

____

PART II

(1) I ______________________ hereby volunteer to be an experimental subject in an Acceleration/Vibration experiment at University of Technology, Loughborough, Department of Ergonomics and Cybernetics.

(2) My replies to all the questions above are correct to the best of my knowledge and belief.

(3) I understand that the information about myself which I have given will be treated as confidential by the experimenter(s).

(4) Satisfactory explanations of the purpose of the experiment, the nature of the acceleration/vibration to be used, and how I may stop the experiment, have been given to me by the experimenter(s).

(5) While agreeing to attend for the purpose of the experiment, I fully understand that I may withdraw from taking part in the experiment, and that I am under no obligation to give any reason for my withdrawal, or to attend for further experimentation.

(6) While in the Acceleration/Vibration laboratory, or any associated laboratory, I undertake to obey the regulations in force governing its use, and the instructions given to me by the experimenter(s) regarding safety and experimental procedures, subject only to my right to withdraw as declared above.

DATE: ________________ 19__. Signature of Applicant (Subject)

____

Signature of experimenter(s). ______________________________

Signature of staff completing this declaration:

____

____

SUBJECT FILE - CONFIDENTIAL

SUBJECT CODE NO. ________

FORM OF APPLICATION TO TAKE PART AS A SUBJECT IN ACCELERATION AND/OR VIBRATION EXPERIMENTS.

PART I.

1) SURNAME ____________________ *(MR/MRS/MISS/)

2) OTHER NAMES ____________________

3) DATE OF BIRTH ____________________

4) ADDRESS (TERM) ____________________

____

TELEPHONE NO.: ____________

5) NATIONALITY ____________

6) PRESENT OCCUPATION: ____________________

DATE COMMENCED: ____________

7) PREVIOUS OCCUPATIONS (OVER PAST 5 YEARS) AND DATES

____

____

____

____

____

____

8) NEXT OF KIN: ____________________

ADDRESS: ____________________

____

TELEPHONE NO.: ____________

9) REMARKS:

* DELETE WHERE APPLICABLE

SUBJECT-FILE-CONFIDENTIAL

PART III. VALID FROM: ______ TO: ______

TO BE COMPLETED PRIOR TO EACH EXPERIMENT

DATE	HAS YOUR MEDICAL CONDITION CHANGED IF 'YES' EXPLAIN	RE-DECLARATION OF PART II IF CONSENTING 'YES' SIGNATURE SUBJECT	SIGNATURE EXPERIMENTER(s)	EXPERIMENTAL LOG NUMBER	REMARKS
	YES/NO*				
	YES/NO*				
	YES/NO*				
	YES/NO*				
	YES/NO*				
	YES/NO*				
	YES/NO*				

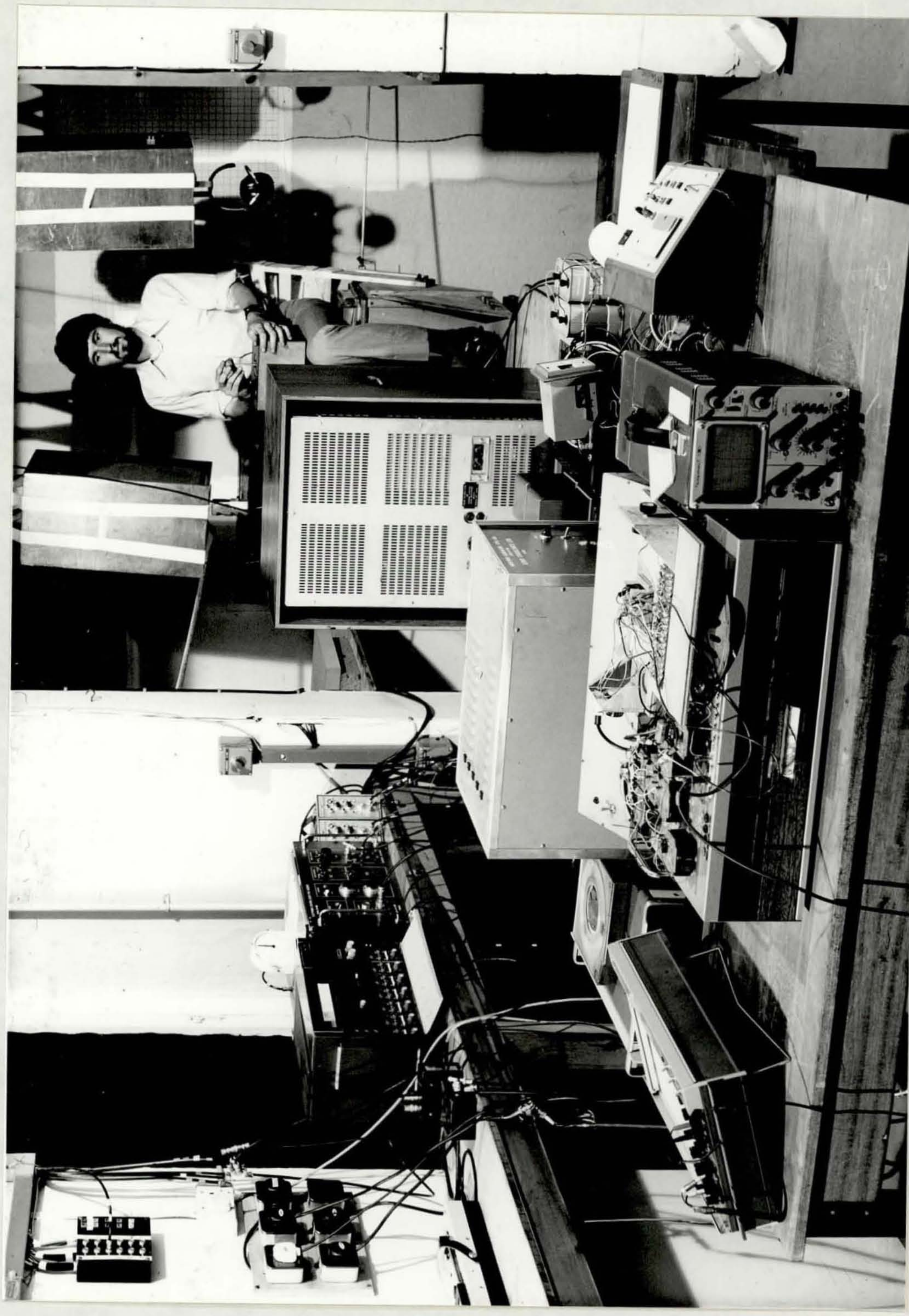


PLATE No. 1 OVERALL VIEW OF THE LABORATORY AND EQUIPMENT.

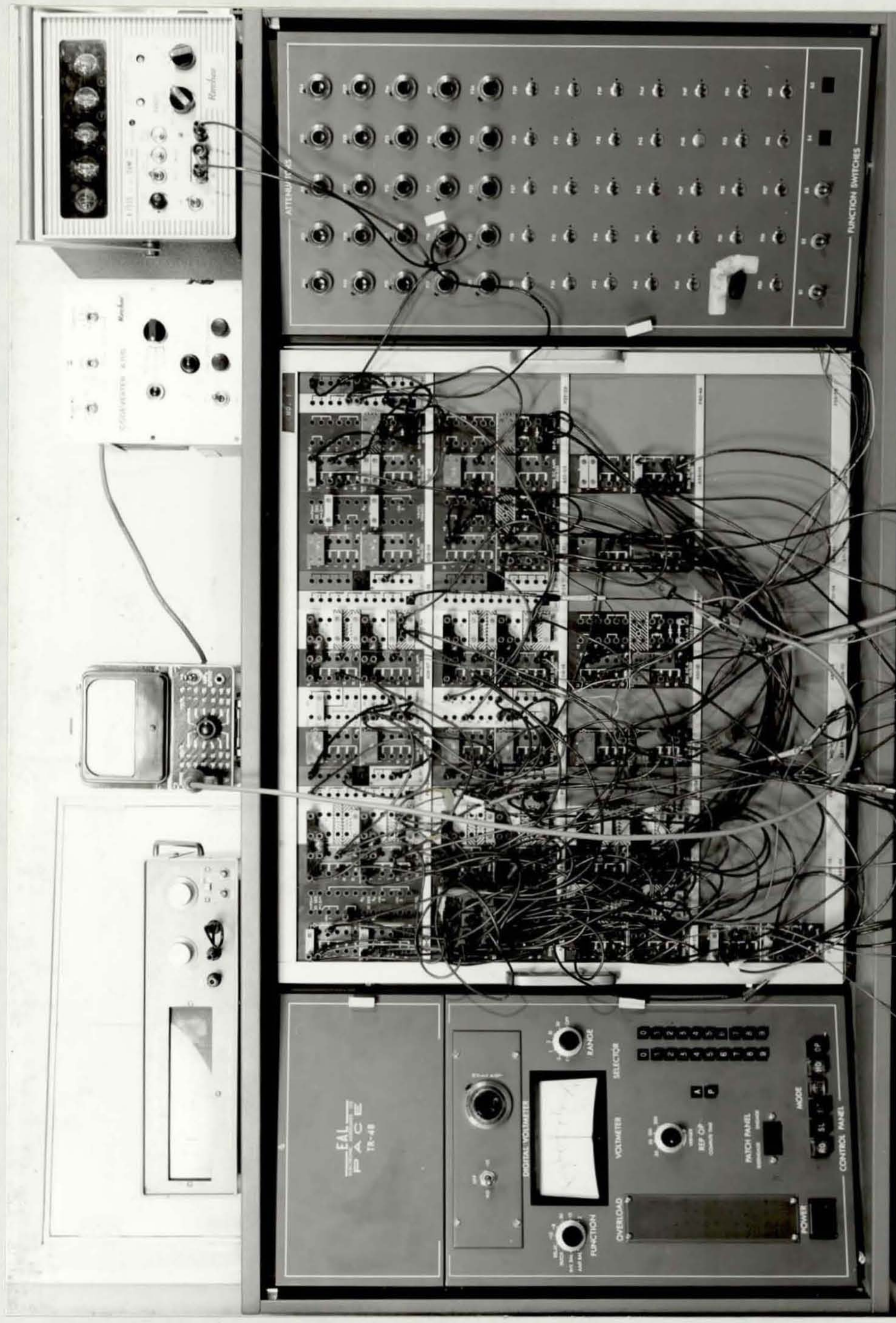


PLATE No. 2 PACE ANALOGUE COMPUTER.

PLATE No. 3 FORCE CELL. (View with base plate removed.)

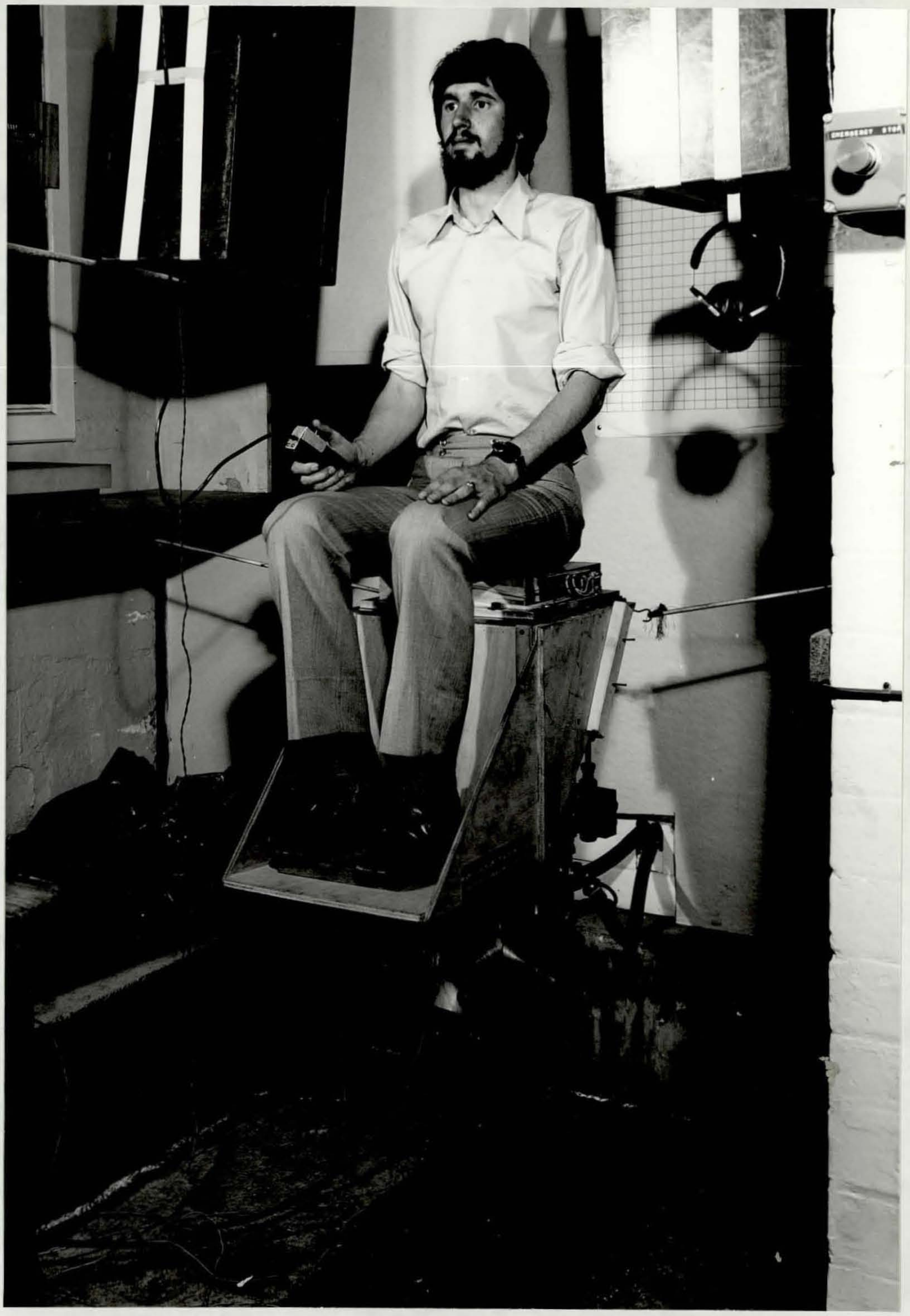


PLATE No. 4 SUBJECT IN STANDARDISED ERECT POSTURE. (Front view.)

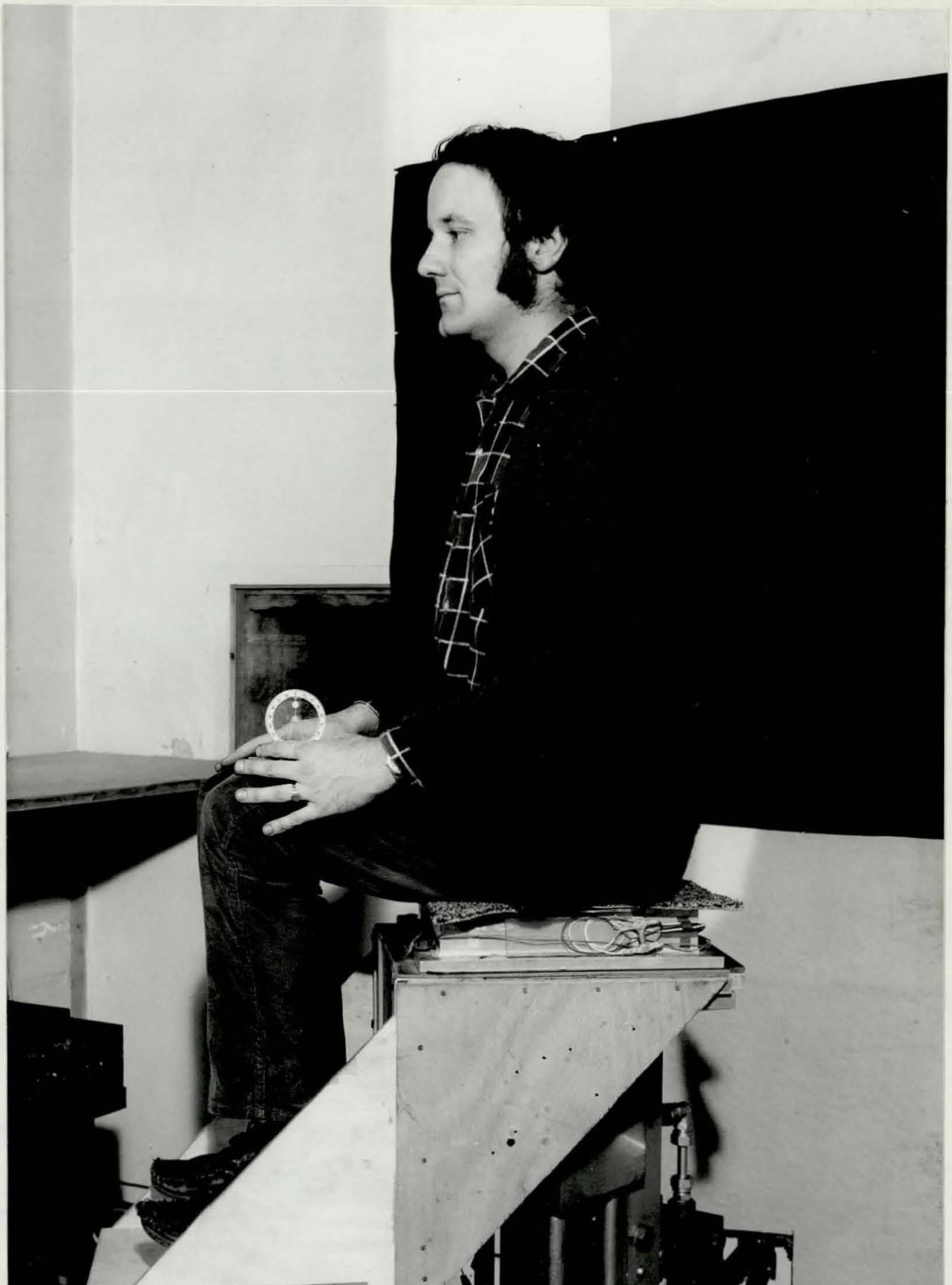


PLATE No. 5 SUBJECT IN STANDARDISED ERECT POSTURE. (Side view.)

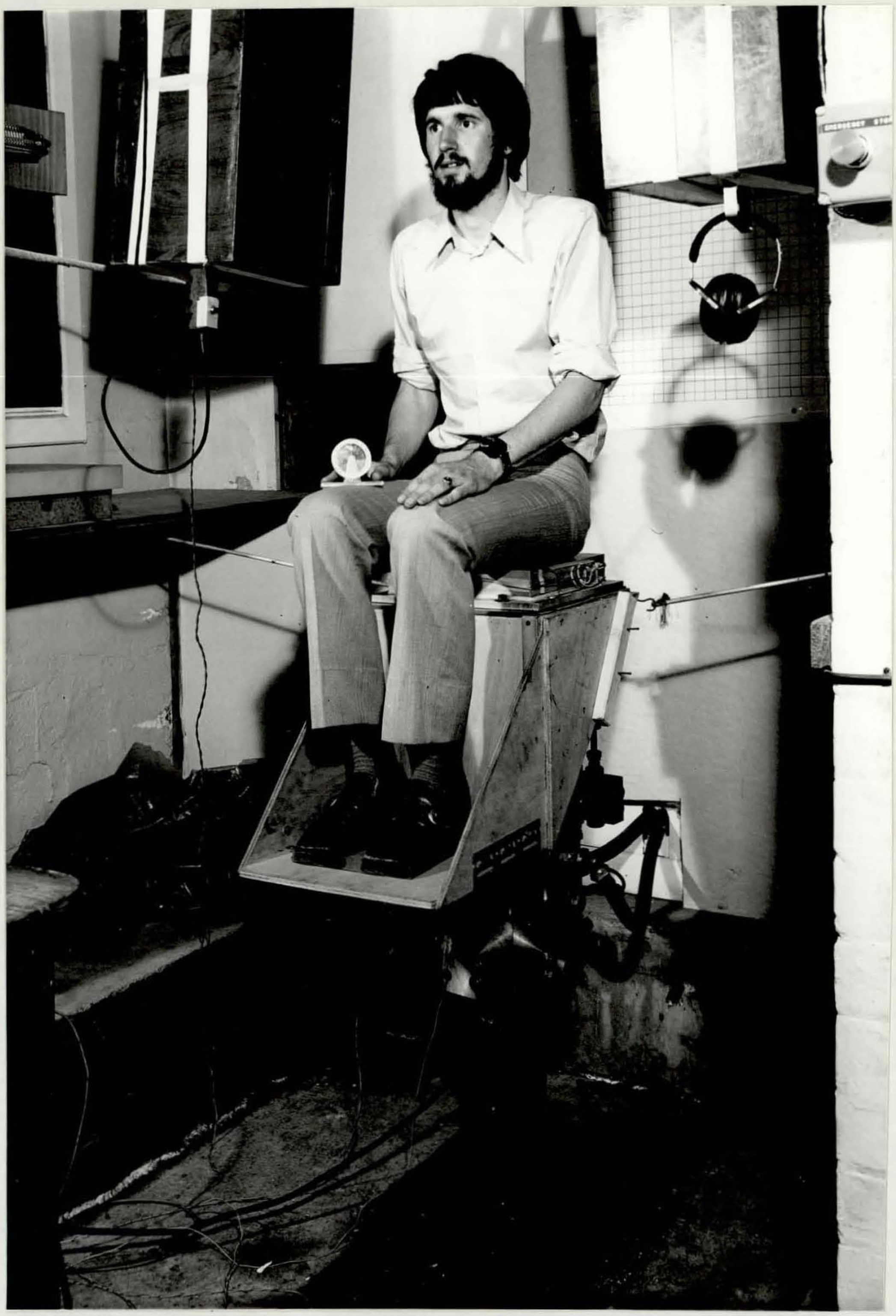


PLATE No. 6 SUBJECT IN STANDARDISED RELAXED POSTURE. (Front view.)

PLATE No. 7 SUBJECT IN STANDARDISED RELAXED POSTURE. (Side view.)

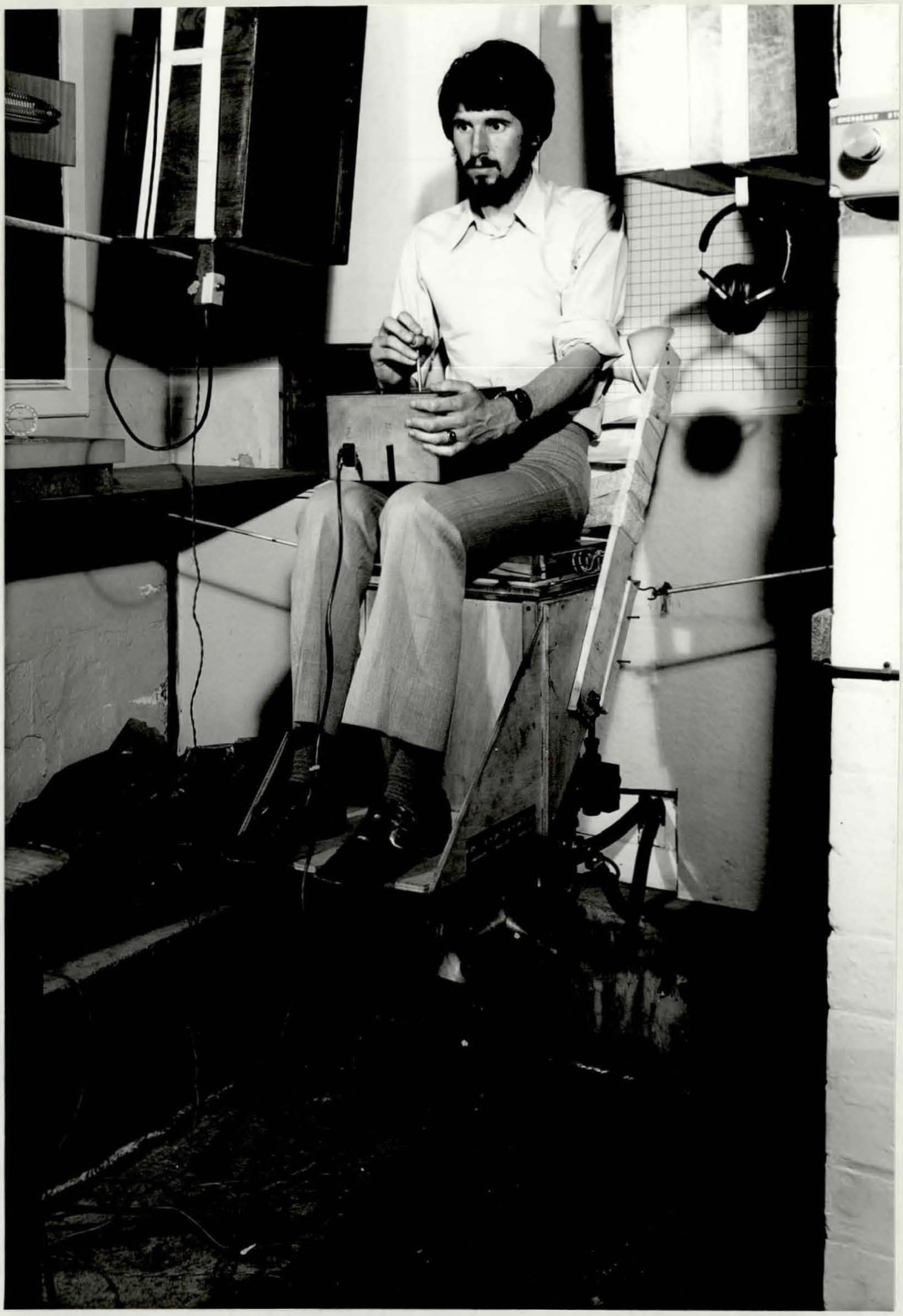


PLATE No. 8 SUBJECT IN STANDARDISED TRACKING POSTURE. (Front view.)

SECTION 3

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APPENDICES

APPENDIX 1

ACTUATOR

A.1 - 1 Introduction

The actuator installed at Loughborough University for use in human whole-body vibration experiments was a Servo-Consultants Model H.V.1. The actuator was designed by Servo-Consultants in consultation with the University. The special safety features, and the actuators installation have already been described in Section A - 3. The following specification applies to the actuator as used to conduct the Modulus of Impedance experiments; thus the specification does not include the suggested modifications listed in Section A - 5.

The distortion figures given for the actuator performance in Section A1- 5. were obtained using a Solartron direct reading Harmonic Analyser. The figures although approximate give an indication as to the percentage harmonic distortion present from the control unit oscillator, and the acceleration waveform at the actuator table for various loadings. (The acceleration being measured by a Kistler piezo-electric accelerometer attached rigidly to the underside of the actuator table).

A.1 - 2 Actuator - Performance Specification

The nature of the research programme in vibration environment to be undertaken in the Ergonomics and Cybernetics Department at Loughborough University of Technology required an actuator capable of reproducing "field" conditions in the laboratory. Experiments had been undertaken using a photgraphic technique to assess acceleration levels of certain parts of the body, during running and walking.

Using these levels and data obtained from research papers the actuator performance specification was drawn up.

The actuator was to be powered by a Fairey hydraulic power pack capable of delivering 6 gallons per minute at a pressure of 3,000 lbs. per sq. ins. (27 litres per minute at a pressure of 200 bars). Thus the hydraulic power supply, safety considerations and overall cost also influenced the actuators attainable performance.

The total piston stroke of the actuator was 10 inches (250mm) with and additional 1 inch (25mm) of travel at each end of the piston travel to act as hydraulic snubbers, preventing the piston impacting directly into the bearing housing at either end of the cylinder. The hydraulic snubbers bring the actuator piston to rest with an acceleration which is controlled by two (i.e. one for each end) pre-set pressure relief valves. The relief valves can be adjusted to cater for different piston loads and are reset before any full experimental run.

The actuator thrust was to be such that the following acceleration levels could be obtained dependent on the actuator pay load.

i) + $4g_z$ with a piston loading of 300 lbs. (140kg)

ii) + $2g_z$ with a piston loading of 500 lbs. (230kg)

The Servo valve fitted to the actuator limited the piston velocity to 50 inches/second (1.25m/sec) (up or down).

The vibrator had a dynamic range of 0 - 100 H_z, providing a working range of 50 Hz, subject to the previously specified limits.

The actuator was also designed in such a way that its overall performance could be increased by the fitting of a second servo-valve. This would also require a larger hydraulic power-pack for a significant increase in performance to be achieved.

The overall actuator performance is shown in Figure No. 10.

A.1. - 3 Actuator - Mechanical Specification

The vibrator actuator piston was hard chrome plated, and then ground to size. It moves in bronze bearings, which are shrunk into square aluminium bearing housings. The bearings are hydrostatic, consisting of three hydrostatic pads equally spaced around the bore. The piston rod is thus centralized by three forces, each of which is proportional to the pad area and the oil pressure. (The pad area is approximately $2\frac{1}{2}$ sq. ins. (16 sq. cms.)

The actuator manifold bridges the two square aluminium bearing housings, the servo valve being mounted in the middle of the manifold. Also mounted on the manifold is the pressure transducer which measures the differential pressure across the piston, the signal from this transducer is fed to the electronic control unit, to facilitate the automatic control of the pistons acceleration, during a frequency sweep.

The actuator is also fitted with hydraulic snubbers, this is obtained by the piston cutting off the service port (only a small hole is drilled into the snubber area to enable the piston to return to normal operating travel) and the piston trapping about 1" (25mm) of oil and compressing it. The oil being allowed to escape back to the exhaust line through a pre-set Dyrex relieve valve. The relief pressure setting on this valve determines , together with the actuator pay-load the retardation of the piston.

The actuator piston was drilled, and threaded at the top with a 2" B.S.P. thread to enable a fixing to be screwed into the piston to carry the required seating platform, or test rig.

An aluminium table was bolted to a flanged threaded shaft which was screwed into the actuator piston and locked by means of three allen headed grub screws. The table was made from a 15" square (380mm) of aluminium 2" (50mm) thick. The block was milled down so that there was a central boss with eight webs radiating from it. The webs were 2" (50mm) wide and were 1·25" (32mm) deep at the centre tapering away to the edge of the plate. The plate between the webs was milled down to a thickness of ·75" (18mm). The plate was also drilled and tapped to enable a piezo-electric accelerometer to be fixed to the under-side of the plate. These holes were drilled to enable the force cell to be filled on top of the plate and to enable elastic straps to be fitted which prevented the table from making large rotational movements, while moving vertically.

This particular design of table was chosen so that the platform was light, strong and possessed a high natural frequency. The table needed to be light to allow for heavy experimental rigs to be mounted on it. The platform also needed to be strong, so as not to deflect during experiments, and of a high natural frequency so that harmonic distortion was not introduced due to the actuator operating at a frequency which would excite the table into vibration.

A.1. - 4. Actuator - Electronic Control Unit Specification

A detailed block diagram of the electronic control unit is shown in Figure No. 237. The majority of the units used are conventional servo-system units, there are two units however which are not commonly used in industrial servo-systems. The operation of these two units is outlined in the following text.

A.1. 4 - 1 Control Unit 642 B

The function of this unit is to add to, or subtract from the imput signal to the servo-valve amplifier, in order to maintain the actuator output at the desired amplitude or acceleration level. The nature of the operation of the circuit requires that its time constant should be long (in order to stop the unit causing the actuator to "hunt") Due to the long time constant of the circuit it can be regarded as an outer loop controller. The actuator can thus be operated without this control unit in circuit.

The operation of the control unit is such that it rectifies the command, and feedback signals. The D.C. level of the feedback signal is now compared to the D.C. level of the command signal at the input of an integrated circuit, variable gain D.C. amphlifier. The output of this amplifier being fed to a thermistor controlled potential divider network. The thermistor's heater currents are controlled by the rectified command, and feedback signals, therefore any difference between the command and feedback voltage level will cause one thermistor to heat up more than the other. This heating of one thermistor more than the other causes the potential divider formed by the thermistors to unbalance, the unit then sends a larger (or smaller) signal than its usual datum signal to the servo-valve amplifier to correct the imbalance between the command and the feedback signals.

A.1. 4 - 2 Servo-Valve Amplifier

The purpose of the servo-valve amplifier is to process the input signals it receives from the oscillator, control unit, and the displacement transducer to obtain a push-pull differential current output. This type of push-pull output is required to operate the coils of the servo-valve.

The amplifier also incorporates a current limiting circuit between the amplifier and the servo-valve, this has the effect of limiting the piston velocity of the actuator to 50 ins./sec. (1·25m/sec.)

A.1. - 5. Actuator Performance - Harmonic Distortion

The harmonic distortion figures were obtained using a Solarton Harmonic Analyser, the actuator load and acceleration levels are shown with each set of data. The first set of tables shows the distortion figures for the internal oscillator, the second set represent the distortion obtained from a Kistler piezo-electric accelerometer mounted underneath the actuator table. Although the first set of results were for the internal oscillator only, the actuator was running with a table load as stated in the tables. (Tables No. 126 and 127)

Acceleration level Peak to peak "g"	1	1	1	1	$\frac{1}{3}$
Load Kg	60	60	60	60	60
Frequency H_z	20	15	10	4	1
Harmonic					
1.	100	100	100	100	100
2.	5·4	1·9	1·0	1·9	8·3
3.	4·3	3·2	2·2	2·1	4·7
4.	2·3	3·0	1·3	0·6	2·6
5.	0·3	0·8	2·1	1·3	4·3
6.	0·9	0·8	0·2	0·4	1·3
7.	0·4	0·1	1·8	0·5	1·5
Total % Harmonic Distortion	13·6	9·8	8·6	6·8	22·7

Table No. 128

Actuator acceleration harmonic distortion

Acceleration level Peak to peak "g"	0	1	$\frac{1}{4}$	$\frac{1}{3}$
Load Kg	0	60	60	60
Frequency H_z	20	20	20	1
Harmonic				
1.	100	100	100	100
2.	2.9	2.9	2.9	5.5
3.	1.7	1.5	1.4	1.1
4.	0.7	0.7	0.7	0.7
5.	1.4	1.4	1.5	0.5
6.	0.8	0.9	1.0	0.5
7.	0.8	0.8	1.0	0.5
Total % Harmonic Distortion	8.3	8.2	8.5	8.8

Table No. 127

Oscillator harmonic distortion.

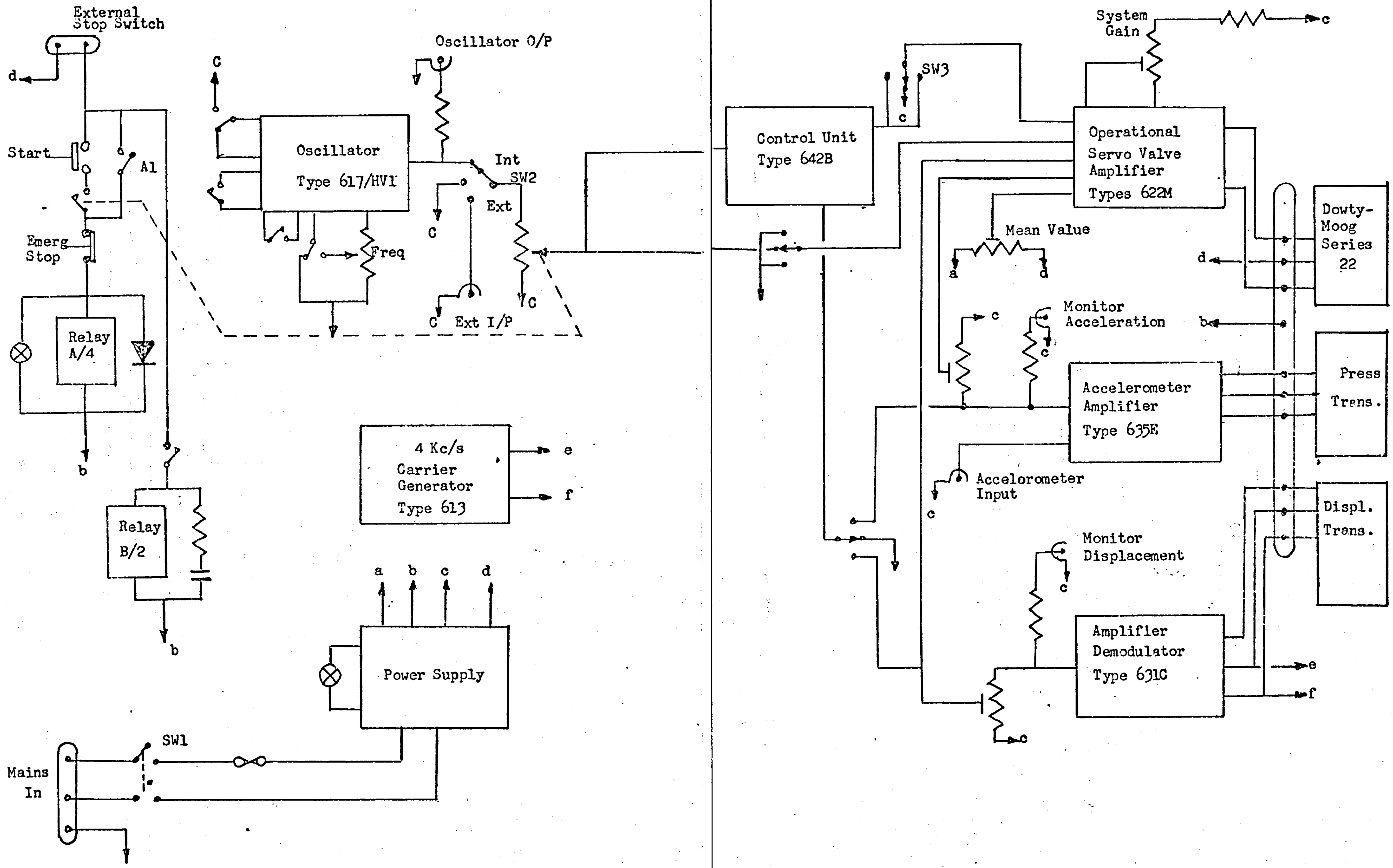


Figure No. 237

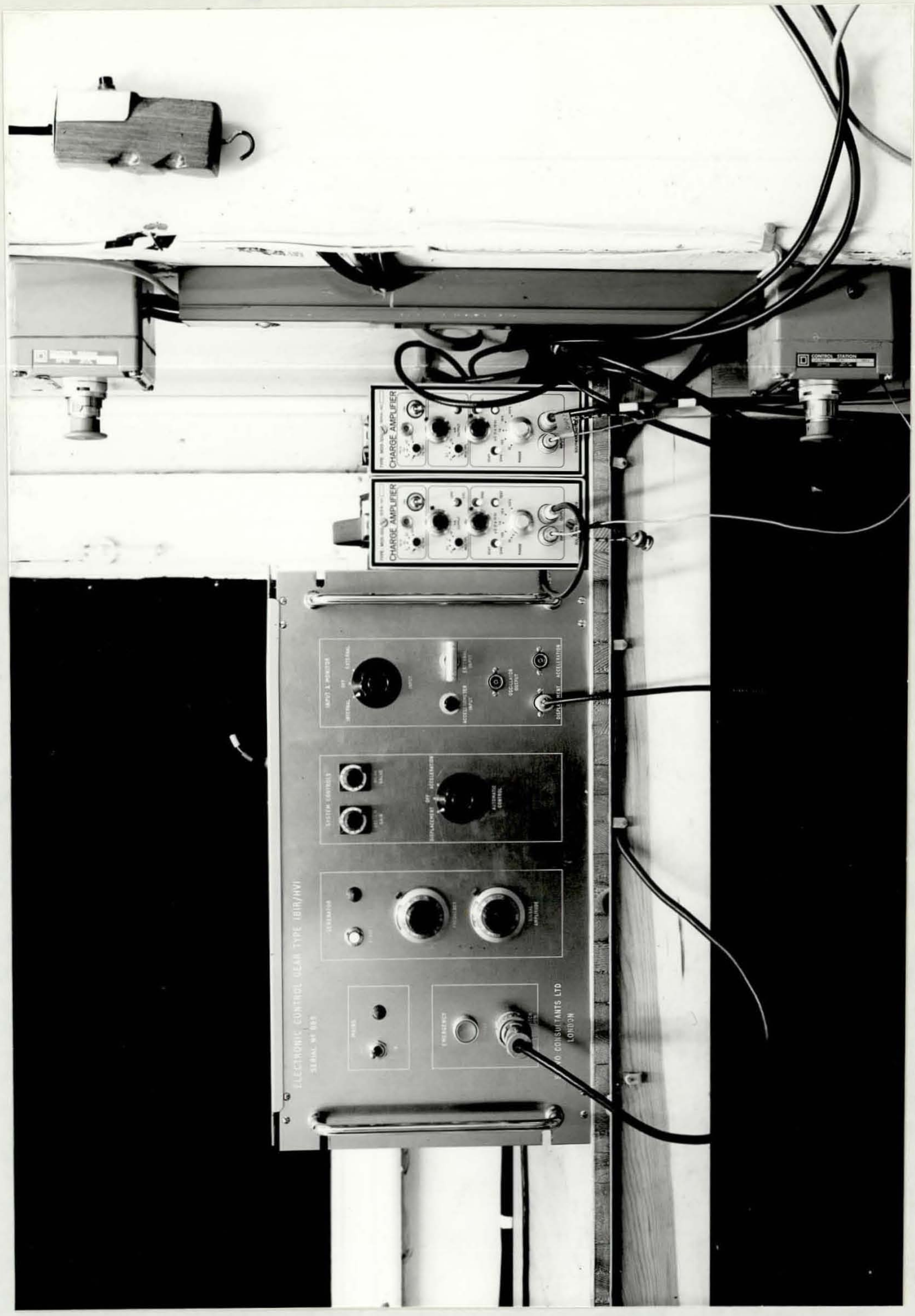


PLATE No. 9 ACTUATOR ELECTRONIC CONTROL GEAR.

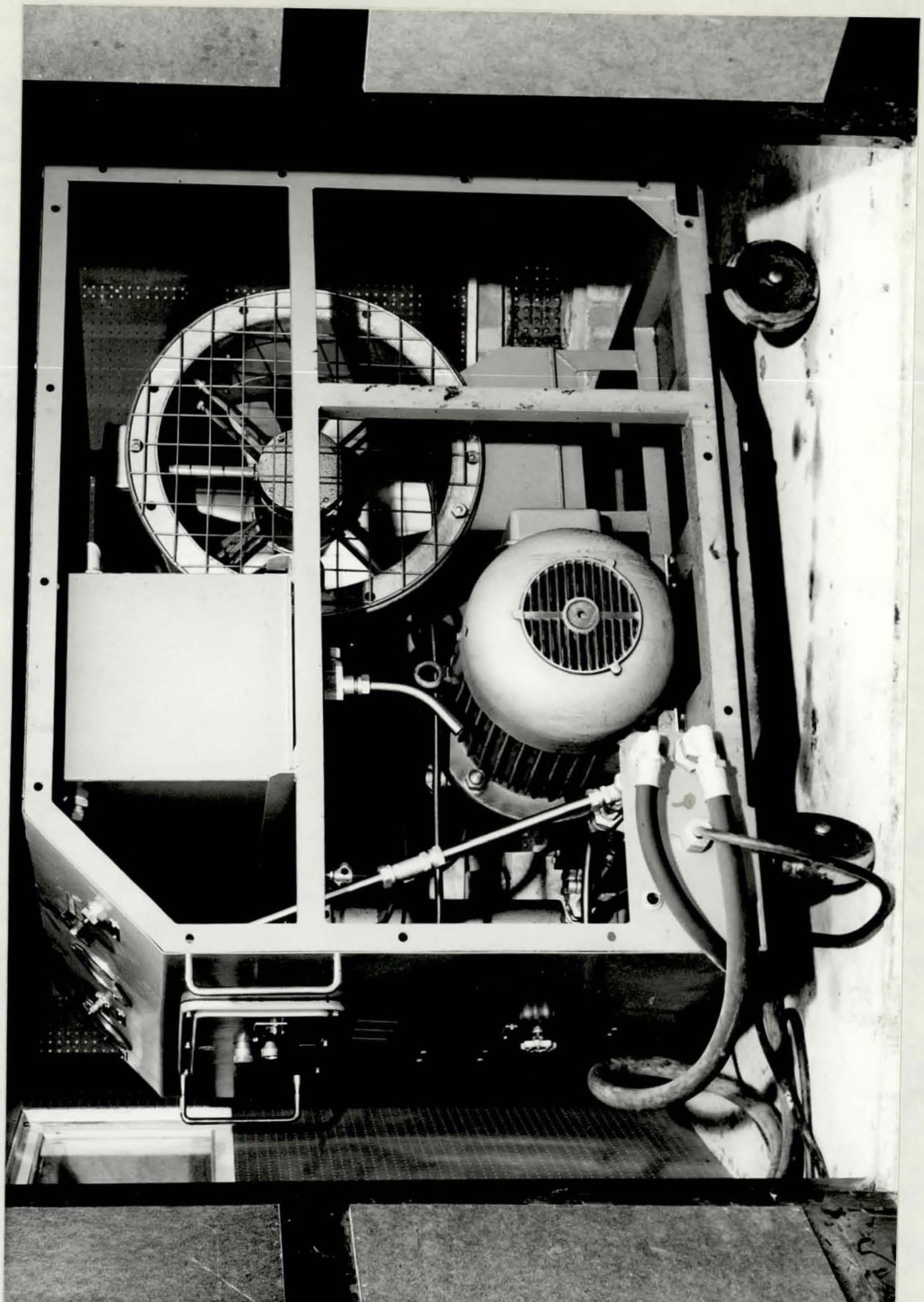


PLATE No. 10 HYDRAULIC POWER-PACK.

APPENDIX 2

PORTABLE VIBRATOR

A.2 - 1. Introduction

The portable vibrator was designed by the author for use by under-graduate members of the Ergonomics and Cybernetics Department in practical experiments related to the vibration environment. Although the portable vibrator was originally designed for under-graduate use, it has also been used in X-Ray, vibration transmissibility studies, where a portable vibration machine was required for use in conjunction with a hospital X-Ray unit.

A vibrator which could be used by under-graduate students had to be:-

a) safe - and preferably not capable of attaining an injurous acceleration level at any of its operating frequencies.

b) reliable

c) offer a useful frequency range and various acceleration levels to enable quantitative as well as qualitative experiments to be undertaken.

d) transportable

e) easy to operate

f) of a low cost.

A mechanical actuator was chosen for the portable vibrator, as this type of actuator best fulfilled the requirements laid down for the actuator. An electro- magnetic actuator was the only other type of actuator considered, but as this type of actuator is not commonly used in vibration research little data could be found to assess this type of actuator; or to help the author in the design of a small portable model. The cost of this type of actuator would also be higher than that of a mechanical actuator.

There are several mechanisms that can be used in a mechanical actuator to produce a sinusoidal motion:-

a) Slider-Crank mechanism - this is one of the most commonly used mechanisms, but it does not produce true sinusoidal motion.

b) Cam-follow mechanism - this mechanism can produce true sinusoidal motion, as well as other cyclic motions, by profiling the cam.

c) Scotch-Yoke mechanism - will produce true sinusoidal motion , but the mechanism involves a large sliding bearing which could introduce "noise" on the actuator acceleration waveform.

The cam-follower mechanism was chosen for the portable vibrator as it is simple to construct, acceleration levels can be easily changed by using different cams, and other cyclic waveforms can be obtained by cam profiling.

A.2 - 2 <u>Design Parameters for the portable vibrator</u>

The decision on the type of mechanism to be used, enabled the author to evaluate the parameters necessary for the design of the vibrator.

The most important parameter to fix initially was the operational range, in terms of frequency and acceleration level.

The actuator was to be used by undergraduate students investigating self-induced vibration, and comparing them with forced vibrations in a similar frequency range. This meant that the actuator would be required to produce vibrations in the approximate frequency range of 2 - 10 Hz. The maximum acceleration levels attainable were to be set by the I.S.O. exposure limits (1969), and the power of the motor driving the vibrator.

This type of mechanism, also sets an acceleration limit of 2g (peak to peak), or the follower, unless it is spring loaded will leave the cam on the downward stroke.

The power of the motor was calculated such that the actuator could produce an acceleration of 2g (peak to peak) for a load of 100kg (to include cam follower mechanism, actuator table, and subject), using an overall transmission efficiency of 75% (this figure was chosen because a belt drive, and speed variator were to be used for power transmission) at an operating frequency of 10 H_z. A graph showing the variation of horsepower required against operating frequency is shown in Figure No. 239. The motor used was a $\frac{1}{4}$ h.p. electric motor.

The choice of speed reduction unit (i.e. from the standard electric motor speed of 1425 r.p.m. to 120 - to - 600 r.p.m.) was limited by considerations of cost and weight, as the actuator had to be transportable. The main speed reduction was accomplished by means of two fixed pulleys, and the speed variation by means of a speed-variator (see Plate No. 11.)

the guard over the belt drives has been removed for the photograph). The use of pulleys and vee-belts as well as providing an economic speed-reduction arrangement, also has the added advantages that:-

a) the belt drives add a degree of safety in the fact that they will slip if the power transmission through them is too large.

b) The belts do not introduce as much "mechanical noise" into the actuator vibration output as an equivalent chain or gear drive would.

The cam eccentricities now had to be set to enable the vibrator to be utilised for experiments within the I.S.O. "Exposure" and Fatigue Decreases Proficiency" limits, and also to utilise at the high frequency end of the vibration spectrum of the actuator the motor power (the actuator was to be driven by a quarter horsepower electric motor). The maximum displacement cam (cam A. peak to peak displacement of 7·0mm) was designed to give an acceleration of just less than 2g (peak to peak) at the maximum operational frequency of the actuator - i.e. 8·5 H_z. The smaller cam (cam C. peak to peak displacement of 1·4mm) was set by the accuracy with which the cam could be manufactured. The third cam (cam B. peak to peak displacement of 3·8mm) was designed to be the cam for normal operation, giving a range of accelerations to cover the I.S.O. F.D.P. (Fatigue Decreased Proficiency) limits. A table (Table No. 128) and a graph (Figure No. 238) give details of the operating range of the actuator, the table being used by the under-graduate students to set the vibrator to the required acceleration level.

The material chosen for the cams was nylon reinforced with glass-fibre, a large ball-bearing in a cup housing was originally used for a follower, this however grooved the cam too much and altered the eccentricity. (and hence the attained acceleration levels.) The design was changed to incorporate a small ball race as a follower, which also meant the table had to be kept fixed in one direction. This was achieved, in the same way the table on the electro-hydraulic actuator had been fixed, by means of an elastic strap, fixed to the table and to the rigid frame of the actuator.

The actuator table was a 30cm square of 2.5mm block board which was bolted to a flange, which could be removed from the main shaft, when the actuator was being transported. The subject sits on another piece of block-board which had a 30mm layer of matted horse-hair between this and the actuator table. The horse-hair was used to act as a high-frequency mechanical filter. (A commercial filter to act over this frequency range would be very expensive).

A.2 - 3. <u>Calibration of the Portable Vibrator</u>

When the actuator had been constructed and initially tested the system was calibrated. The frequency of vibration was measured by a Smith's tachometer, this measuring the cam-shaft speed, for selected variator settings. The speeds are shown together with the variator settings in Table No. 128.

together with the peak to peak displacements for the three cams. The displacements were measured by means of a dial gauge, the cam being rotated by hand. The table was loaded with four 20 Kg cast-iron weights to simulate a subject sitting on the actuator for the calibration tests.

The acceleration levels listed in Table No. 128 and Figure No. 238 were calculated from the displacements; some acceleration levels were measured using a piezo-electric accelerometer, as a check on the theoretical results. (See Figure No. 239) The accurate calibration of the actuator was required so that under-graduate students could carry out transmissability studies with the vibrator, as well as comparing subjectively the self-induced vibrations of running, walking, etc. with the sinusoidal vibrations obtained from the actuator.

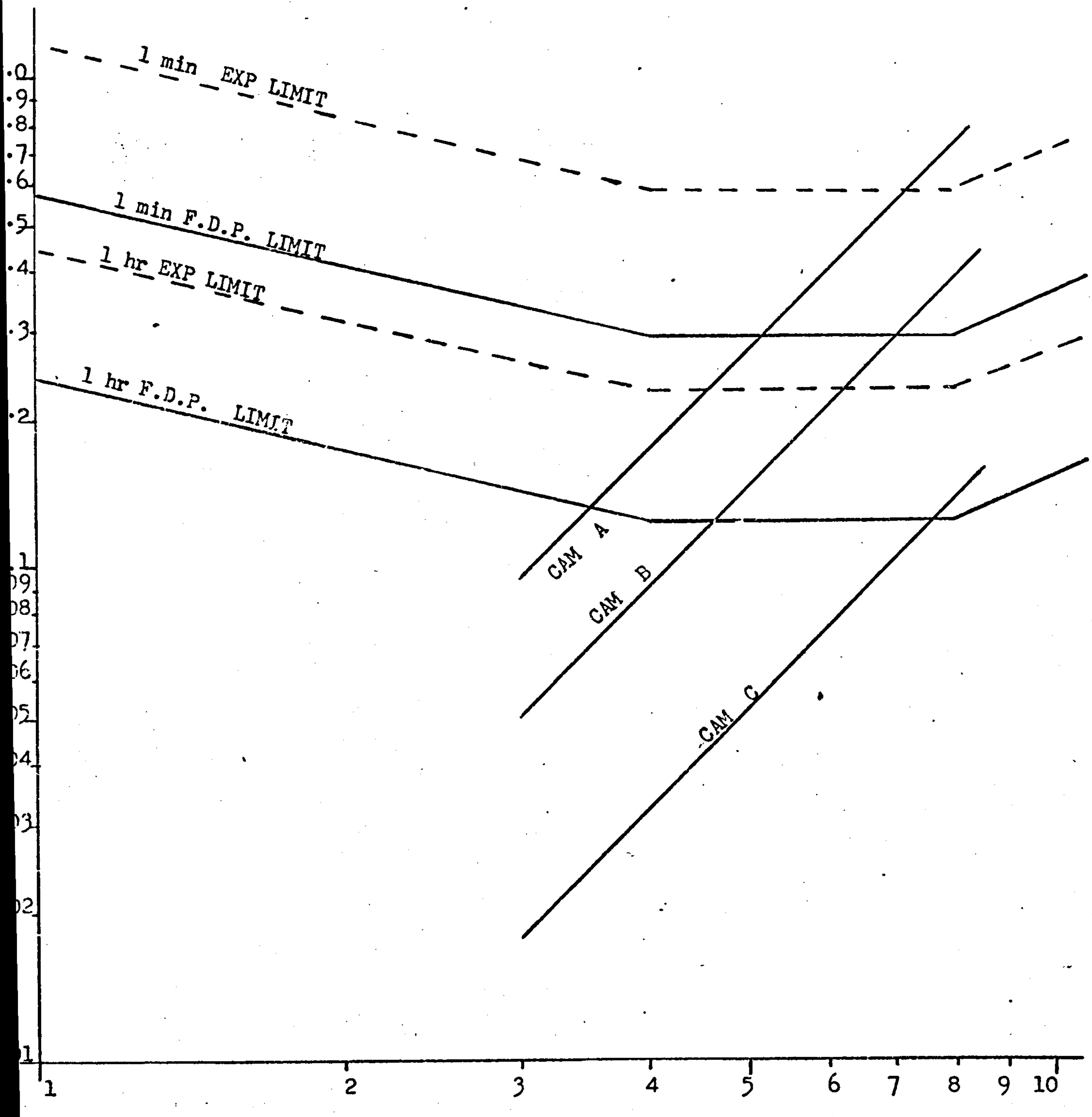


Figure No. 238 Operation range of portable vibrator

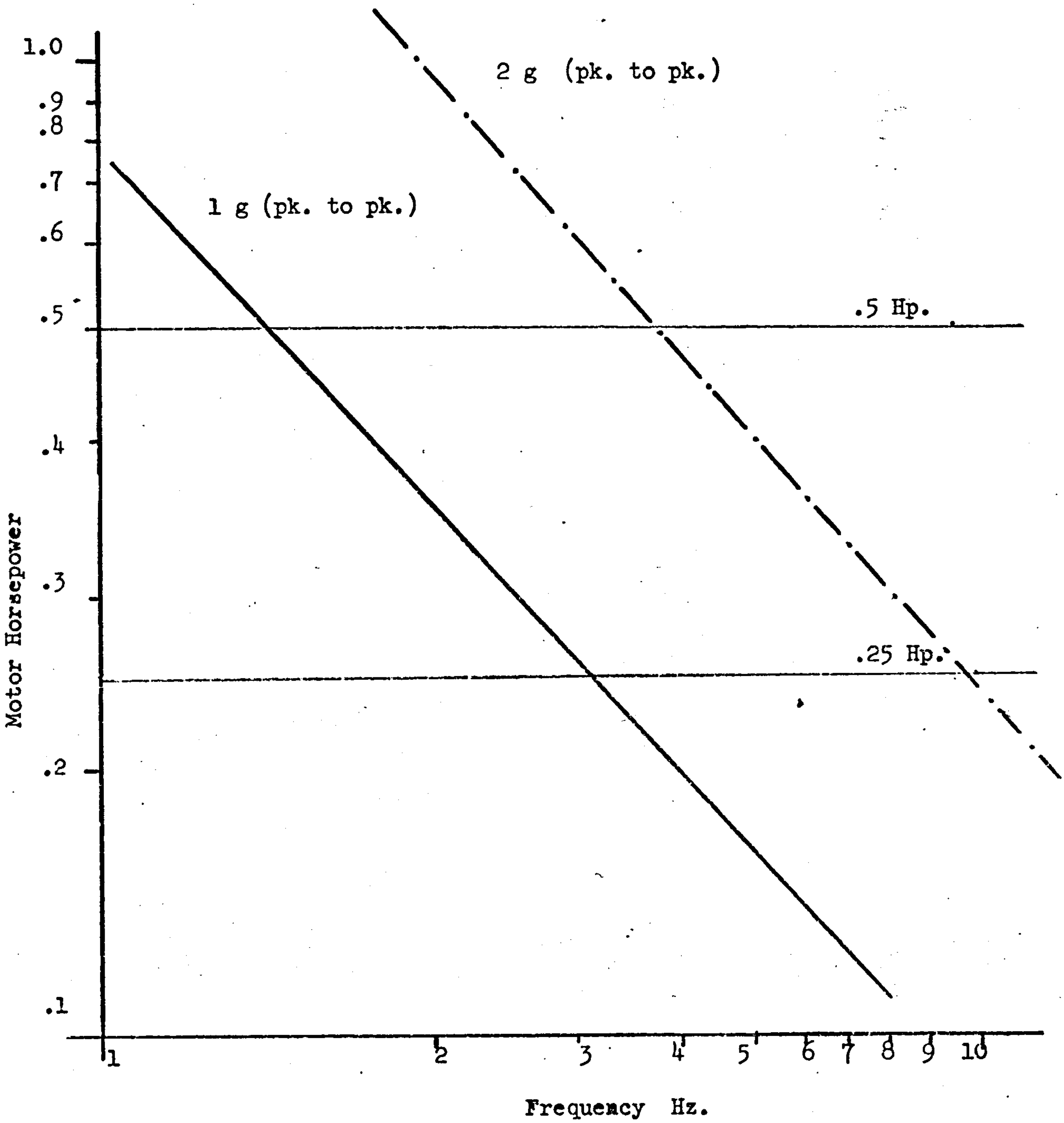


Figure No. 239

Horsepower required to operate actuator at given acceleration levels.

Frequency Hz	Acceleration "Peak to peak g"			Variator Setting
	CAM A	CAM B	CAM C	
3·0	·26	·14	·05	0
3·3	·31	·17	·06	2·5
3·85	·42	·236	·084	5
4·00	·43	·25	·09	6
4·15	·44	·264	·096	7
4·6	·60	·324	·12	8
5·0	·70	·38	·14	8·75
5·15	·76	·42	·15	9
5·8	·94	·52	·19	10
6·0	1·00	·56	·20	10·5
6·65	1·24	·684	·22	11
7·0	1·36	·76	·27	11·5
7·4	1·50	·82	·30	12
8·0	1·80	·98	·36	12·6
8·2	1·88	1·04	·38	13
8·5	2·0	1·10	·40	14

Table No. 128

Acceleration levels for the three cams

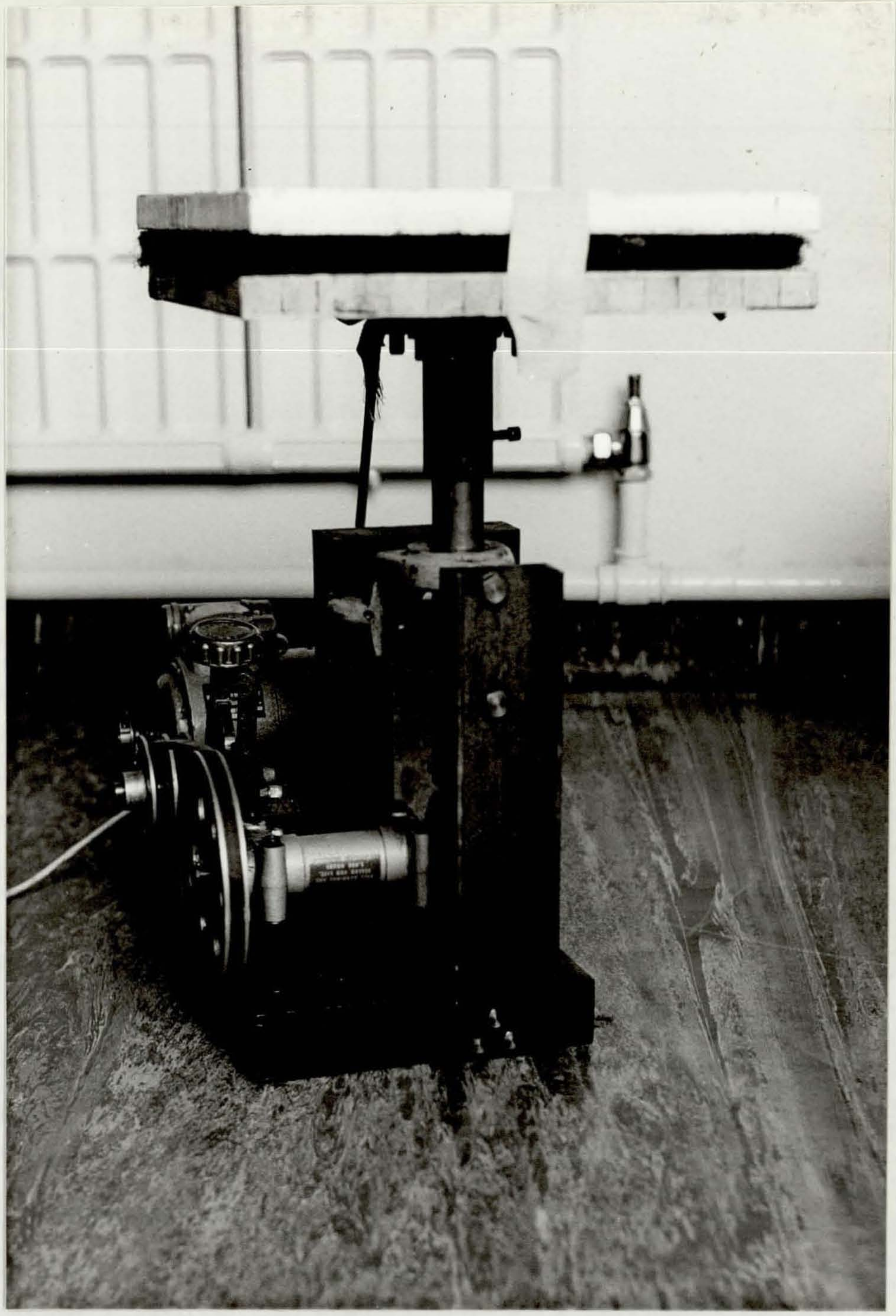


PLATE No. 11 PORTABLE VIBRATOR.

APPENDIX 3

EXPERIMENTAL INSTRUMENTATION

A.3. 1. The Force Transducer

A.3. 1 - 1 Introduction

The force transducers used were mounted into a force cell which also contained one centrally mounted accelerometer. The construction of the force cell is detailed by Sandover (1971).

The force cell contained three force transducers of the piezo-electric type. The cells were quartz load washer type manufactured by Kistler, type 903 A. The three transducers were connected in parallel to give the average value of the force across the surface of the cell.

A.3. 1 - 2 Technical Specification

The specification is for the type 903 A which is one in a range of quartz load washers with a total range from a few kp to 100,000 kp. The transducers which can be used for either dynamic or short-term static force measurement, are of a tightly welded construction, and have a high resonant frequency. (An important factor in this type of study).

Type 903 A

Bolt diameter		12mm
Maximum measuring range		6,000 kp
Dimensions		
	Diameter	28mm
	Height	11mm
Resolution		1 p
Sensitivity		40 pc/N
Capacity		45 pF
Weight		35 gr

Dimensions:

	Diameter	28mm
	Height	11mm
Resolution	1 p	
Sensitivity	40 pC/N	
Capacity	45 pF	
Weight	35 gr	

General Data

Deformation at maximum load	15
Resonant frequency	50 KH_z
Linearity (maximum error)	1%
Insulation resistance	10
Temperature Coefficient	-0·025% $/^o{}_c$
Working-temperature range	-150°C to +240°C

Note on Units

1 Kp = 1 Kgf = 2·205 lb (force)

1 p = 1 gf = 0.035 oz (force)

1 gr = 0 035 oz (mass)

The charge signal from the quartz load washer was transformed into a proportional output voltage in the charge amplifier. This output being independent on the length of the transducer cable had a maximum value of 10 volts.

The transducers are individually calibrated by the manufacturers and the three calibration charts, for the transducers used in the force cell, transducers SN 2565, SN 2566 and SN 2568, are shown on Figure No. 242, 243 and 244

The setting used for the charge amplifier was taken as being the average of the three calibration values i.e.

$$\frac{43 \cdot 3 + 43 \cdot 0 + 43 \cdot 9}{3} \quad pC/N$$
$$= 43 \cdot 3 \ pC/N$$

A.3. 2 The Acceleration Transducer

A.3. 2 - 1 Introduction

The acceleration transducer used was mounted in the middle of the two force transducers, placed under the ischial tuberosities. The accelerometer was of the piezo-electric type, using a quartz crystal.

A.3. 2 - 2 Technical Specification

The quartz accelerometer was a Kistler type 816A, and was suitable for measuring dynamic accelerations upto 5,000 g. The accelerometer had a high resonant frequency and low transverse sensitivity. (These were two important factors for the type of instrumentation required in this research topic).

Type 816A

Maximum measuring range	5,000 g
Resolution	0·006 g
Maximum transverse acceleration	500 g
Sensitivity	5·0 pc/g
Maximum transverse sensitivity	3%
Resonant frequency (mounted)	20 KH_z
Rise-time	20 seconds
Insulation resonance (minimum)	10
Capacity	165 pF

Temperature coefficient	-0.025 % /°c
Working-temperature range	-150°C to + 240°C
Weight	64 gr

The charge signal from the quartz accelerometer was transformed into a proportional output voltage in the charge amplifier. This output being, within wide limits, independent of the length of transducer cable. The transducer type 816A is capable of giving outputs between 0.05 mV/g to 5.0V/g dependent on the type of charge amplifier used.

The transducers are individually calibrated by Kistlers and are individually numbered, the calibration chart for the acceleration transducer used in the force cell (transducer number SN 24103) is shown in Figure No. 240 Page 598

The setting used for the charge amplifier is the value given on the calibration chart i.e. - 5.01 pC/g.

The accelerometer used for the commissioning of the vibrator, and for the safety checks was also a Kistler type 816A. The accelerometer was mounted on a paxolin strip on the underside of the actuator table.

The calibration chart for this transducer number SN 27422 is also shown in Figure No. 241 Page 599

Charge amplifier setting for this accelerometer is 4.96 pC/g

A.3. 3. The Charge Amplifier

A.3. 3 - 1 Introduction

The charge amplifiers are used to transform the electrostatic charges from the piezo-electric force and acceleration transducers, into electric signals. These signals can then be processed or recorded for analysis on completion of the experimental programme. The charge amplifiers used were, "VIBRO-METER calibrated charge amplifiers, type TA - 3/C".

The charge amplifiers being calibrated, means that by using the transducer calibration data, it is possible to directly relate the mechanical quantity to be measured to the amplifier output. Due to the high amplification factor (10^5) of the charge amplifier, the length of cable which runs between the transducer and the amplifier has almost no effect on the accuracy of the measurement. The amplifier sensitivity ranges between 10 to 10^6 pC f.s.d. this gives optimum adaptation to the transducer and the range of measurement required.

A.3. 3. - 2 Technical Specification

Input

Sensitivity - 10 pc to $1{\cdot}1 \times 10^6$ pC for a full scale deflection of 10 volts. The sensitivity being continuously adjustable.by a 10-turn potentiometer.

Output

Voltage	-	10 volts at full scale deflection, limited to a maximum of 15 volts
Current	-	10 mA (maximum)
Linearity	-	·01% of full scale deflection

Frequency Response

0 - 300 kH_z (rise time 1 s) the unit also has a built in switched filter with cut-off frequencies, 1-3-10-30 and 300 kH_z .

The filter descent is 12 dB/octave.

Test Signal

The test switch can be used to inject a calibration signal measurement, and to check the adjusted sensitivity.

A.3. 3. - 3 Operation of the Charge Amplifier

The grounding operation of the charge amplifier is the most important operation. The amplifier must always be grounded before it is switched on or off, and before any adjustments are made to any other controls. The amplifier should also be grounded before any transducer is connected to its input or any recording instrument to the output.

This grounding procedure is important as the amplifier can be damaged if these rules are not adhered to.

The pC charge value is calculated by means of the sensitivity value of the transduced (supplied by the manufact-urers with the transducer) and the value of the mechanical quantity to be measured.

Example sensitivity setting for the acceleration transducer type 816A No. SN 27422 to measure an acceleration level of 10 g (accelerometer calibration is shown with details on the measuring transducers). The transducer sensitivity is 4,96 pC/g. The charge value will be 4.96 x 10 pC/g x g = 49.6 pC. The adjustment is therefore made as follows:- 4.96 x 10.

The 10 turn potentiometer "pC" is adjusted to give a reading of 4.96 and the range potentiometer is set to 10. Thus for an input charge of 49.6 pC the resulting output signal is 10 volts. The maximum output voltage 10 volts corresponds to an acceleration of 10g.

The choice of the switch "STAT-DYN" depends upon the event to be measured. With events occurring at less than ·1 H_z the "STAT" position will be used. For all other events the "DYN" position will be used. When the "DYN" position is used the time constant switch has to be adjusted. In most cases the position of 1 s will be used, this will give amplification from ·2 H_z upwards. The time constant can be used as a low frequency cut-off and the FILTER as the high frequency cut-off. The optimum position of the filter is set by observation of the signal. Examples of signals obtained from the quartz transducer and charge amplifier are shown on the following pages.

A.3. 4. The Frequency-Modulated Tape Recorder

A.3. 4. - 1 Introduction

The F.M. tape recorder was used to record the force acceleration and frequency-sweep signals of the impedance data. These results could then be processed on a Pace analogue computer which is on the main University campus, as well as giving a permanent record of the experiments. A frequency modulated recording device had to be used due to low frequency of the signals (3 - 30 H_z being the experimental range), and the degree of accuracy required in reproduction of the signals.

The tape recorder used for this purpose was a Philip's portable instrumentation recorder ANA-Log 7.

A.3. 4 - 2 Technical Specification

Tape Speeds

The recorder is provided with four electrically switchable tape-speeds of 15/16 ins/sec. 3¾ ins/sec. 15 ins/sec. and 30 ins/sec. with a speed deviation of less than ·2% of the nominal stated values.

Tape Heads

The tape-recorder has seven channels, and one additional speech channel. The ANA-LOG 7 meets fully the requirements laid down by the I.R.I.G. of track width, spacing, gapazimuth alignment, and head and stack configuration, for analogue data recording.

F.M. record/reproduce data

The following table gives the frequency range and the signal to noise ratio of the recorder at its four tape speeds.

Tape Speed	Frequency Range	S/N Ratio
30 ins/sec	0 - 10,000 H_z	43 dB
15 ins/sec	0 - 5,000 H_z	43 dB
3¾ ins/sec	0 - 1,250 H_z	41 dB
15/16 ins/sec	0 - 312 H_z	38 dB

The harmonic distortion is less than 1% and the D.C. drift is less than 1·5 % of full deviation over eight hours. The non-linearity is less than 1·0 %

Input Data

The recorder has six calibrating positions of 0·1, 0·2, 0·5, 1, 2, and 5 volts. The input impedance to the recording amplifiers is more than 10 K

Output Data

The maximum output is 1 volt across an impedance of 1,000 Ω. The maximum output impedance of the recorder is 30 Ω.

Note:- The signal to noise ratio is defined as the ratio of a 0·7 V r.m.s. sine wave to the r.m.s. value of the noise. If the signal to noise ratio were defined as the ratio of 1 V to the r.m.s. value of the noise, the figures specified are 3 dB better.

A.3. 5 The X - Y Plotter

A.3. 5 - 1 Introduction

The X - Y plotter was used for the monitoring of impedance modulus during the experimental runs. It was also used for the phase-angle plots which were obtained from the Pace analogue computer, from the recorded force and acceleration signals. The plotter used was a Hewlett-Packard general purpose X - Y plotter model 7035 B ($8\frac{1}{2}$" x 11")

The X - Y recorder model 7035 B is a solid-slate general purpose plotter. Each axis has an independent servo system with no interaction between channels. The recorder will draw a graph of two related functions, from two D.C. signals representing each of these functions. The parameters listed in the specification below are only those relevant to the recording of impedance module and the phase angle relationships.

A.3.5 - 2. Technical Specification

Input ranges:- Metic 0.4 , 4,40 , 400 mV/cm and 4 V/cm with a continuous adjustment between the ranges with a vernier control.

Input resistance:		Between 10 K 1 M
Accuracy	-	0.2 % of full scale
Linearity	-	0.1 % of full scale
Resettability	-	0.1 % of full scale

A.3 6 Pace Analogue Computer

The Pace Analogue Computer used was a TR-48 (See Plate No.), which has forty-eight operational amplifiers. The computer is arranged so that about twenty of the amplifiers can be used as integrators by direct patching on the board, also available are six diode function generators which can be used as diodes, or patched up to give various functions.

The computer can also be directly linked to the x-y plotter, to enable plots to be made with direct control from the computer.

Sandover J. (1971) "Study of Human Analogues - Part 2"
Department of Ergonomics and Cybernetics,
Loughborough University of Technology.

Figure No. 240

Eichblatt für Beschleunigungsaufnehmer
Feuille de calibration pour accéléromètres
Calibration sheet for accelerometers

Type 816A SN 24103

Max. Messbereich Gamme max. de mesure Max. acceleration Range	+ —	5 000 5 000	g g
Zul. Seitenbeschleunigung Accélération transversale max. Max. transverse acceleration		500	g
Empfindlichkeit Sensibilité Sensitivity		5,01	pC/g
Seitenempfindlichkeit Sensibilité transversale Cross Axis Sensitivity	±	1,0	%
Eigenfrequenz (montiert) Fréquence propre (monté) Natural Frequency (mounted)		20	kHz
Isolationswiderstand Résistance d'isolement Insulation resistance		10^{14}	Ω
Betriebstemperatur Bereich Température d'utilisation Working temperature range	— +	150 240	°C °C
Messtemp./temp. de mesure/measuring temp.		20	°C

Prüfdat.: 4.4.67 gepr.: Wt. ausgew.: Da.

KISTLER INSTRUMENTE AG, 8400 Winterthur, Schweiz

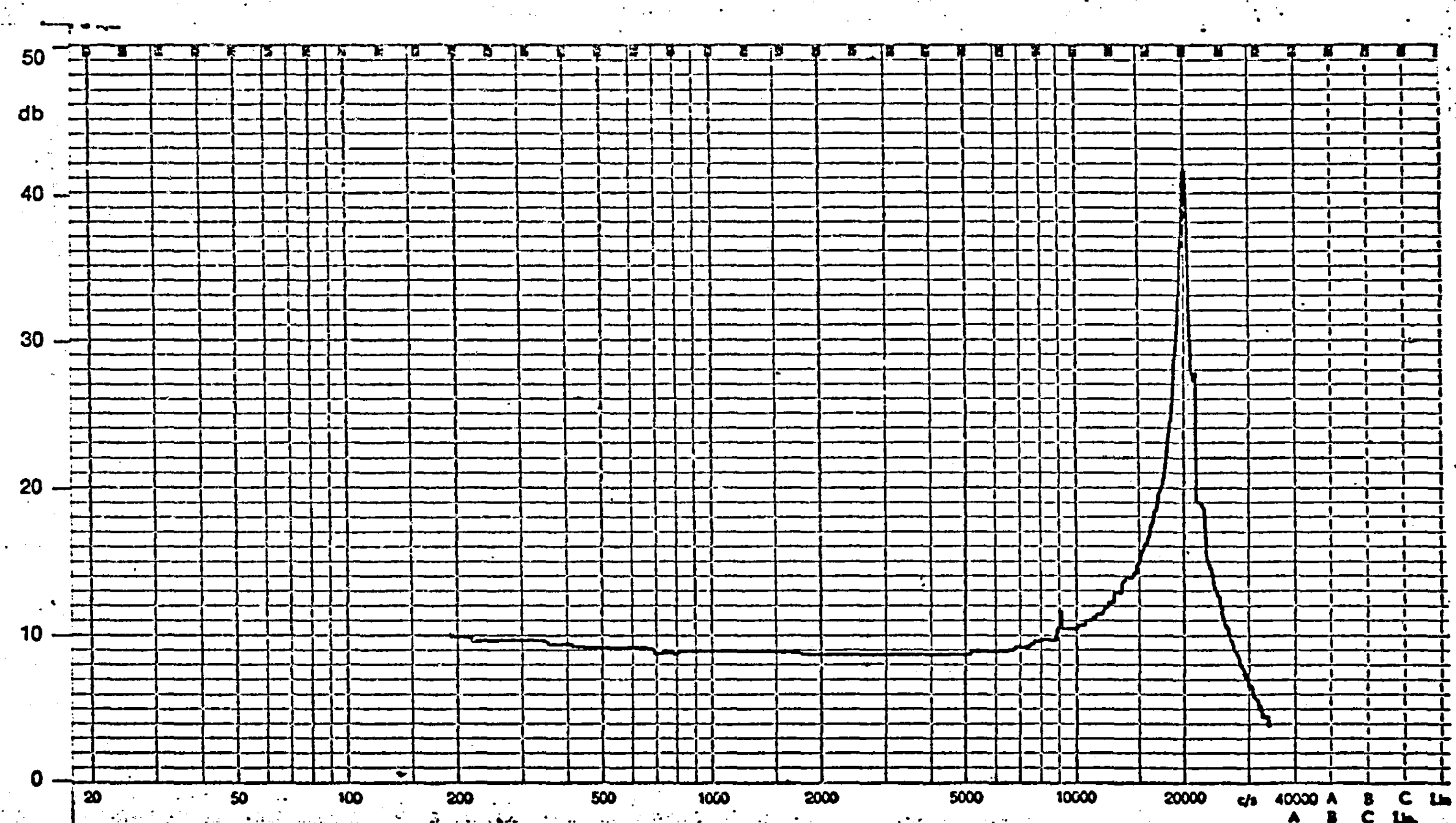


Figure No. 241

Eichblatt für Beschleunigungsaufnehmer
Feuille de calibration pour accéléromètres
Calibration sheet for accelerometers

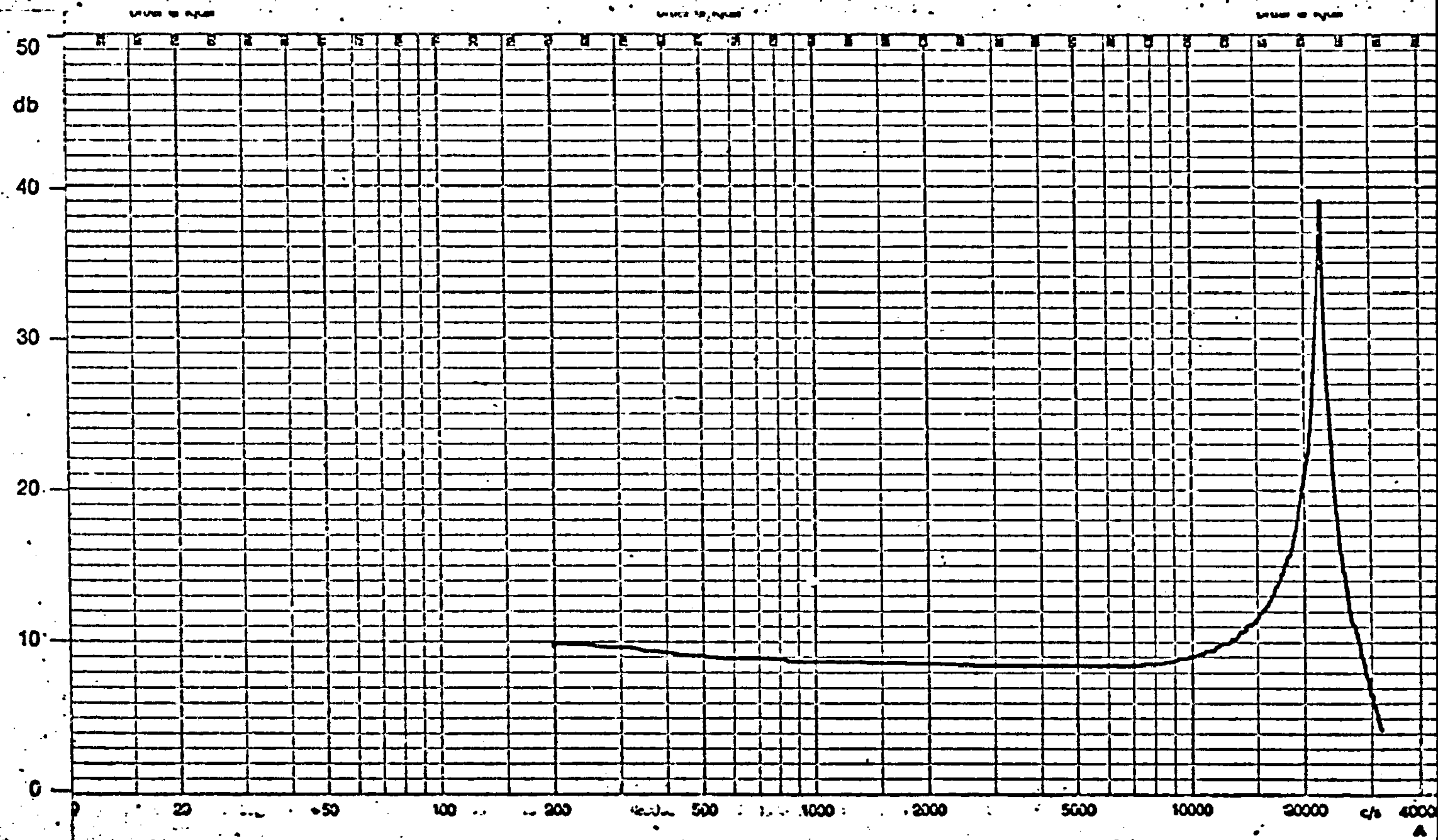
Type 816 A   SN 27422

Max. Messbereich Gamme max. de mesure Max. acceleration Range	+	5000	g
	—	5000	g
Zul. Seitenbeschleunigung Accélération transversale max. Max. transverse acceleration		500	g
Empfindlichkeit Sensibilité Sensitivity		4,96	pC/g
Seitenempfindlichkeit Sensibilité transversale Cross Axis Sensitivity	±	2,0	%
Eigenfrequenz (montiert) Fréquence propre (monté) Natural Frequency (mounted)		22	kHz
Isolationswiderstand Résistance d'isolement Insulation resistance		10^{14}	Ω
Betriebstemperatur Bereich Température d'utilisation Working temperature range	—	150	°C
	+	240	°C

Messtemp./temp. de mesure/measuring temp. 20 °C

Prüfdat.: 25.10.67 gepr.: Fi ausgew.: Wt

KISTLER INSTRUMENTE AG, 8400 Winterthur, Schweiz



599

TYPE 903 A SN 25565

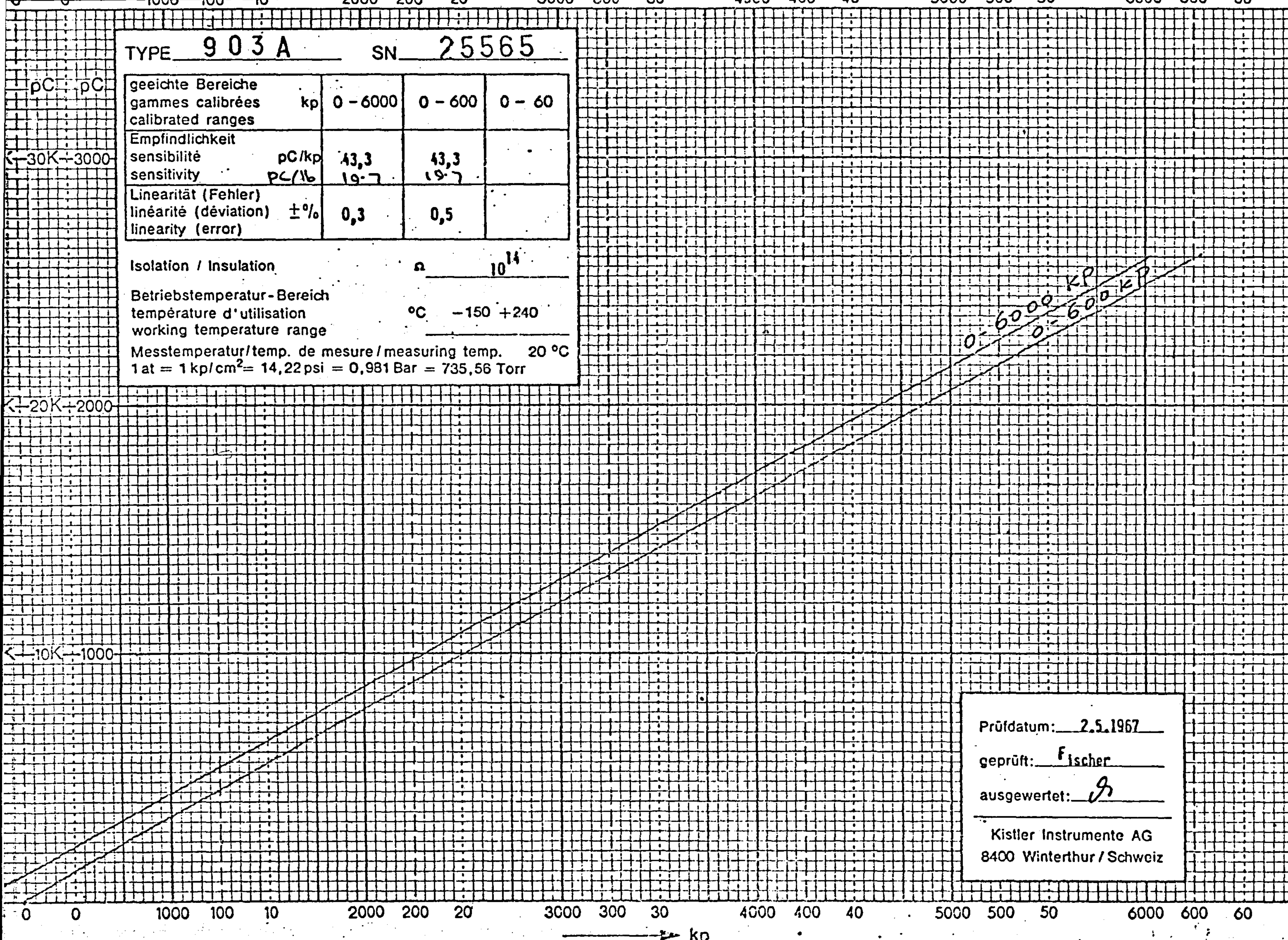
geeichte Bereiche gammes calibrées calibrated ranges	kp	0 – 6000	0 – 600	0 – 60
Empfindlichkeit sensibilité sensitivity	pC/kp pC/lb	43,3 19·7	43,3 19·7	
Linearität (Fehler) linéarité (déviation) linearity (error)	±%	0,3	0,5	

Isolation / Insulation Ω 10^{14}

Betriebstemperatur-Bereich
température d'utilisation
working temperature range °C −150 +240

Messtemperatur/temp. de mesure/measuring temp. 20 °C

1 at = 1 kp/cm² = 14,22 psi = 0,981 Bar = 735,56 Torr



Prüfdatum: 2.5.1967

geprüft: Fischer

ausgewertet: [illegible]

Kistler Instrumente AG
8400 Winterthur / Schweiz

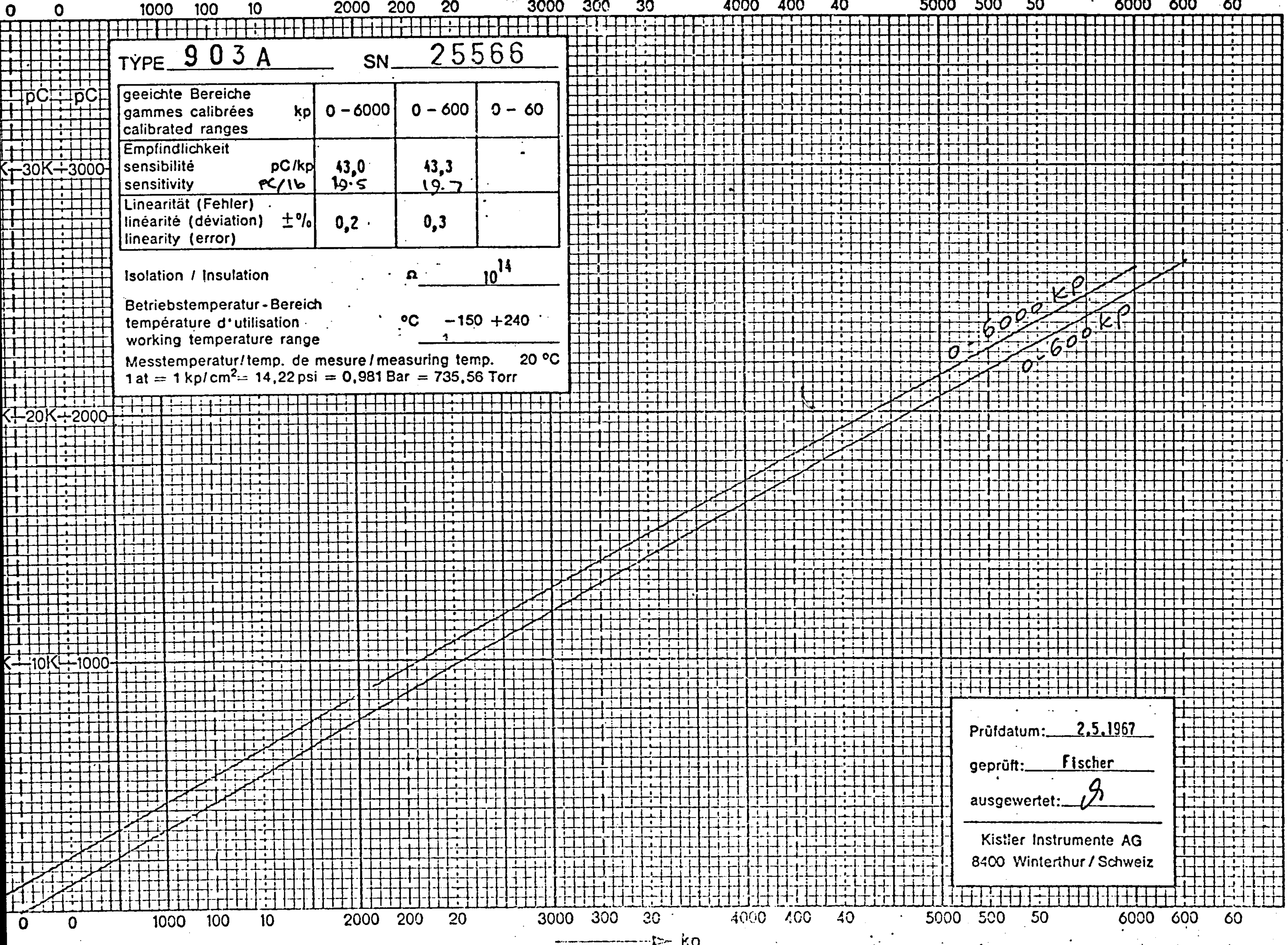
Type 903 A

SN 25565

KISTLER

Figure No. 242

600



TYPE 903 A SN 25566

geeichte Bereiche gammes calibrées calibrated ranges kp	0 – 6000	0 – 600	0 – 60
Empfindlichkeit sensibilité pC/kp sensitivity pC/lb	43,0 19.5	43,3 19.7	
Linearität (Fehler) linéarité (déviation) ±% linearity (error)	0,2	0,3	

Isolation / Insulation Ω 10^{14}

Betriebstemperatur-Bereich
température d'utilisation °C −150 +240
working temperature range

Messtemperatur/temp. de mesure/measuring temp. 20 °C

1 at = 1 kp/cm² = 14,22 psi = 0,981 Bar = 735,56 Torr

Prüfdatum: 2.5.1967

geprüft: Fischer

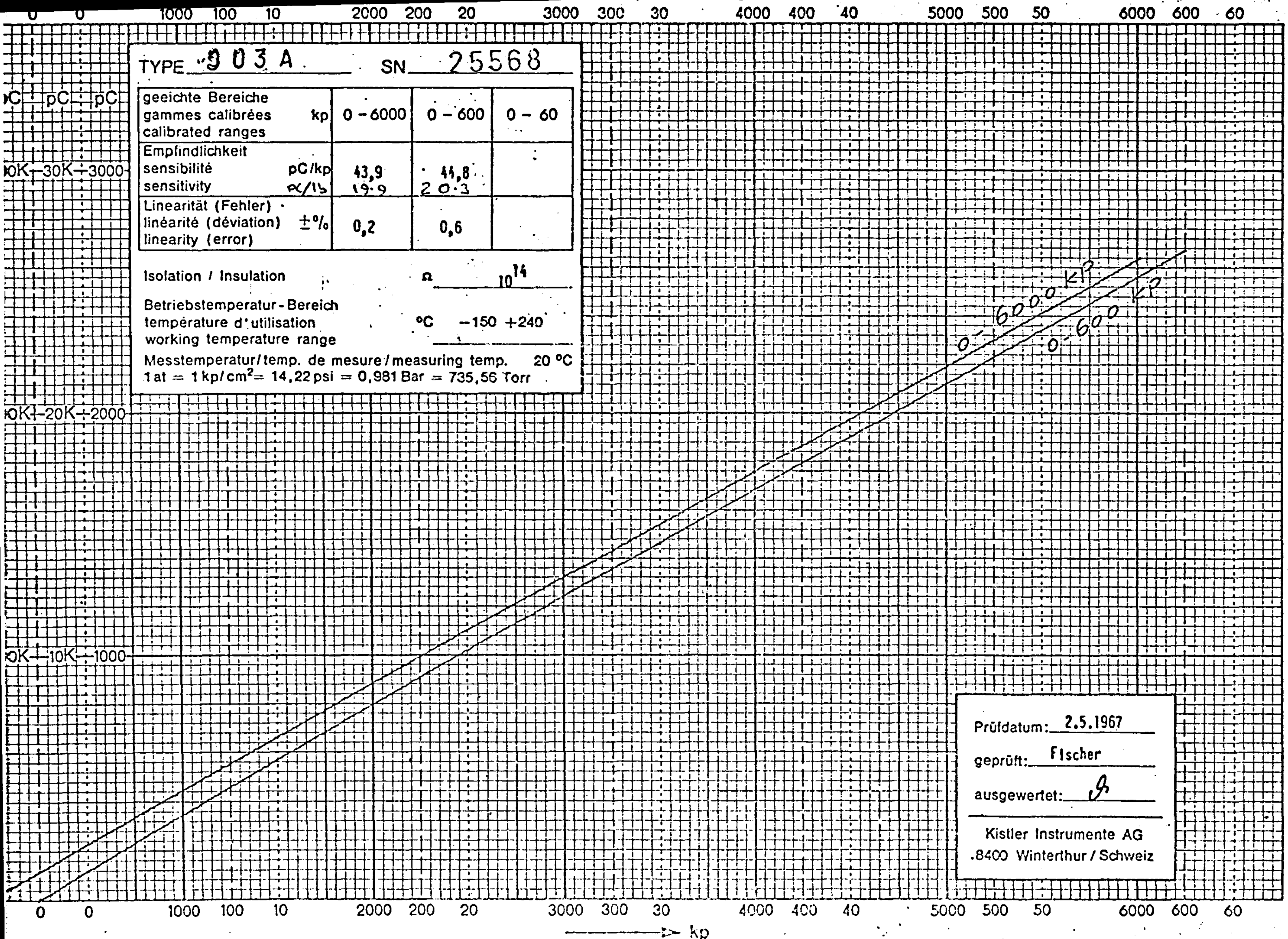
ausgewertet:

Kistler Instrumente AG
8400 Winterthur / Schweiz

Type 903 A SN 25566

Figure No. 243

KISTLER



TYPE 903 A SN 25568

geeichte Bereiche gammes calibrées calibrated ranges	kp	0 – 6000	0 – 600	0 – 60
Empfindlichkeit sensibilité sensitivity	pC/kp pC/lb	43,9 19·9	44,8 20·3	
Linearität (Fehler) linéarité (déviation) linearity (error)	±%	0,2	0,6	

Isolation / Insulation Ω 10^{14}

Betriebstemperatur-Bereich
température d'utilisation
working temperature range °C −150 +240

Messtemperatur/temp. de mesure/measuring temp. 20 °C

1 at = 1 kp/cm² = 14,22 psi = 0,981 Bar = 735,56 Torr

Prüfdatum: 2.5.1967

geprüft: Fischer

ausgewertet: 𝒮

Kistler Instrumente AG
8400 Winterthur / Schweiz

Type 903 A SN 25568

KISTLER

Figure No. 244

APPENDIX 4

AUXILIARY EQUIPMENT

A.4 Auxiliary Equipment

A.4. 1 Signal Filters

Manufacturers - Kemo Consultants Ltd.

Type - 76/L/01

Technical Specification - Cut off frequency (-3dB) at 100 Hz with a fall-off of 12 dB per octave.

A.4 2 Ultra Violet Recorder

Manufacturers - Honeywell Ltd.

Type - Visicorder 2106

Technical Specification - The specification is for the galvanometersused in the recorder - frequency range 0-3 KH_z Sensitivity 486 mV/cm

A.4 3 Driver Amplifer

Manufacturers - Honeywell Ltd.

Type - Accudata 107

Technical Specification - The amplifier has a frequency range of 0 - 20 KH_z and also can amplify signsla with a 5% D.C. shift from zero. (i.e. 5% of the peak to peak signal amplitude). Amplifier drift is less than 30 $V/^oc$

The amplifier has switched gain ranges between ·01 and 20, with potentiometer variable gain between each switched gain.

A.4. 4 Function Generator

Manufacturers - Hewlett Packard

Type - 3300A with 3302A Trigger - Phase lock unit

Technical Specification - Frequency range of 0·01 H_z to 100 KH_z, drift less than $\pm$ 0·25% maximum output voltage 15 v into a 600Ω impedance.

A.4. 5 The tracking task equipment

A.4. 5 - 1 Introduction

The tracking task was of a compensatory nature (and was the same as that used by Innocent (1971). The task used a display of a one dimensional (Y-axis) error signal whose amplitude and polarity was determined by the difference between the subject-controlled joystick voltage and the puesdo-random tracking signal voltage. The error signal was required to be reduced to a minimum (ideally zero) by the subject, the zero level being displayed simultaneously with the error signal.

A.4. 5. - 2 Equipment

The pseudo-random signal was derived from a Servo-Consultants wave-form generator. The principle of operation of this type of generator is the photo-scanning of a black paper disc which is cut to the desired random waveform. Thus the waveform is not truly random generated, but it is such that subjects cannot observe any obvious pattern to the waveform.

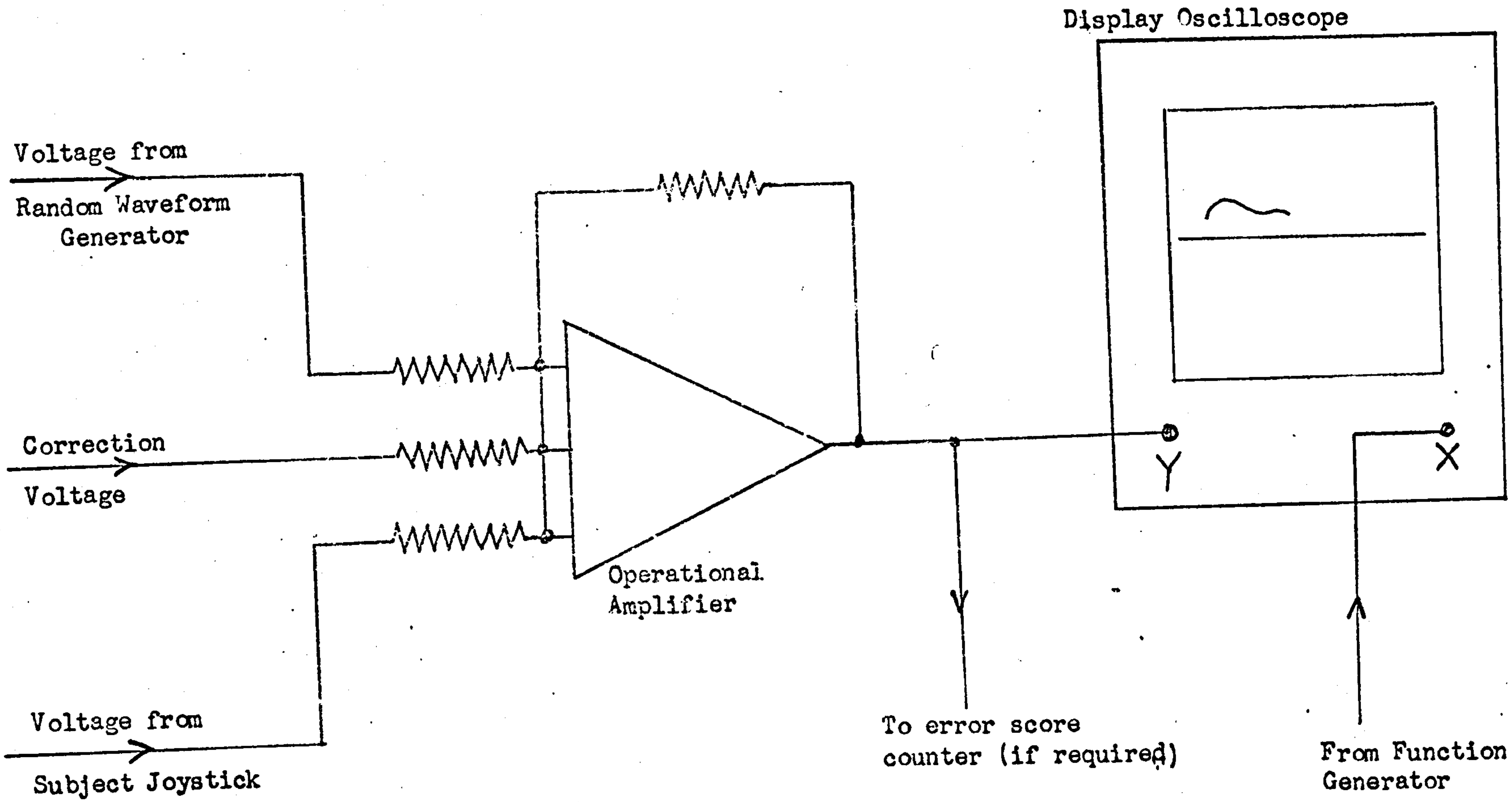
The speed of the disc can be altered to change the complexity of the task. The waveform obtained from the generator is not situated about zero, so a fixed voltage is subtracted from the pseudo random wave by an operational amplifier so that the wave is centred about the zero voltage line.

The joystick voltage is then subtracted from the pseudo-random voltage by means of the operational amplifier which is used to process the pseudo-random waveform. The resulting error voltage is then displayed on an oscilloscope.

The circuit of the tracking equipment is shown on the following page. The X plates of the display oscilloscope were driven by means of a $\frac{1}{2}$ H_Z triangular wave obtained from the Hewlett Packard function generator.

Innocent P. (1971) Unpublished M.Sc. Thesis.
Department of Ergonomics and Cybernetics.
Loughborough University of Technology.

Figure No. 245



Circuit Diagram for Tracking Task


OPERATOR SWITCHES OFF - OR POWER FAILURE - TO CONTROL-UNIT ONLY
SWITCHING TRANSIENT and OFF
EXCESSIVE COMMAND SIGNAL TRANSIENT and OFF
Ram caused to Travel Past normal working stroke un-directional
OPERATOR SWITCHES OFF - OR POWER FAILURE - TO COMPLETE SYSTEM
OPERATOR SWITCHES OFF - OR POWER FAILURE - TO HYDRAULIC POWER PACK ONLY
PUMP STOPS. S.T.D. = SECS
NOT DANGEROUS? CHECK
SUBJECT "PANIC BUTTON"
SYSTEM - OPERATED SHUT-DOWN
OPERATOR "PANIC BUTTON"
DUMP VALVE SHUT DOWN TIME = Secs (SDT)
SWITCH OF HYDRAULIC POWER PACK SDT = SECS
REMOVE ELECTRONIC SUPPLY TO MOOG VALVE SLOWLY SDT = SECS
REMOVE ELECTRONIC SUPPLY TO MOOG VALVE QUICKLY S.D.T. = SECS
DANGEROUS OR UNPLEASANT?
UNPLEASANT?
UNPLEASANT?
DANGEROUS?
EFFECTS TO BE MEASURED BY SIMULATED FAULTS ON ACTUAL INSTALLATION
RAM CAUSED TO TRAVEL PAST NORMAL WORKING STROKE. UN-DIRECTIONAL
RAM POSITION SENSORS OPERATE AND CAUSE SHUT DOWN
RAM POSITION SENSORS OPERATED INADVERTENTLY
SYSTEM OPERATED SHUT DOWN
RAM TRAVELS INTO SNUBBERS
SNUBBERS OPERATE
R
SNUBBERS FAIL OR SET INCORRECTLY
Q

OPERATOR
SYSTEM GAIN SET TOO HIGH
FAILURE OF SIGNAL GENERATOR
OPERATOR
FREQUENCY CHANGED TOO QUICKLY
DECADE FREQUENCY SWITCH
USE MULTI-TURN POT
DANGEROUS SITUATION ONLY REACHED SLOWLY
LEAD FROM DISPLACEMENT TRANSDUCER BREAKS
LOSS OF FEEDBACK
EXCESSIVE COMMAND SIGNAL
SUBJECT OPERATOR "PANIC BUTTON"
EXCESSIVE Command Signal
EXCESSIVE CURRENT DEVICE
FAIL
Mechanical failure of moog valve
Saturates System
Limits feed to moog valve (check on rig)
System Operated Shut Down
Excessive feed to moog valve
No electric feed to moog valve
Excessive command causes large pressure differential across piston
Opens relief valves across vibrator
Limits more accel of piston. SAFE? (check on rig)
FAILS
Ram travels into snubbers type wave form
in actuator working stroke DANGEROUS? (check on rig)
Causes moog valve to go hard to one end
Ram caused to travel past normal working stroke. uni-direction
RAM TRAVELS INTO SNUBBERS TYPE WAVE FORM
SNUBBER PRESSURE RELIEF VALVE FAILS
SNUBBER VALVES SET INCORRECTLY BY OPERATOR
SNUBBER VALVES SET CORRECTLY
VALVE SIEZED VIOLENT DECELERATION
VALVE OPEN RUNS INTO END STOPS
VALVE RELIEF PRESSURES SET TOO HIGH.
VALVE RELIEF PRESSURES SET TOO LOW
Q
P
Q
T
Q
P
R
S
P
Actuator ports not closed by piston.
Piston runs between ends.
DANGEROUS? (Check on rig.)
Subject or Operator "Panic Button."
Q
Actuator ports closed by piston.
Piston stops at that end - VIOLENTLY.
DANGEROUS? (Check on rig.)
R
Actuator ports closed by piston.
Piston decelerates properly to rest.
SAFE? (Check on rig.)
S
Actuator ports not closed by Piston.
Piston runs between snubbers.
UNPLEASANT? (Check on rig.)
Subject or Operator "Panic Button."
T
Actuator ports not closed by piston.
Piston runs between snubbers.
DANGEROUS? (Check on rig.)
Subject or Operator "Panic Button."