GL01911

UNIVERSITY OF UTAH RESEARCH INSTITUTE
UURI
EARTH SCIENCE LABORATORY
391 CHIPETA WAY, SUITE C
SALT LAKE CITY, UTAH 84108—1295
TELEPHONE 801-524-3422

March 17, 1987

Mr. Joe Iovenetti
Thermal Power
3333 Mendocino Ave., Ste. 120
Santa Rosa, California 95401

Dear Joe:

Enclosed are the results of laboratory resistivity measurements on four core samples which were done at Montana Tech by Bill Sill. The values Bill found are certainly lower by a factor of 5 to 20 than what might be expected for unaltered basalt. You will note by comparison with the resistivity logs that the core measurements are factors of 3 to 5 higher than the logs show. It seems evident, however, that the areas of anomalously low resistivity as indicated in this area by T/MT surveys really exist. We have started some lithologic and X-ray work on samples from this hole to help determine the cause of such low resistivities.

Sincerely,

Phillip M. Wright
Technical Vice President

Enclosures

PMW:leo

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March 17, 1987

Mr. Charles M. Swift
Chevron Resources Company
595 Market Street
San Francisco, California 94120-7147

Dear Charlie:

Enclosed are the results of laboratory resistivity measurements on four core samples which were done at Montana Tech by Bill Sill. The values Bill found are certainly lower by a factor of 5 to 20 than what might be expected for unaltered basalt. You will note by comparison with the resistivity logs that the core measurements are factors of 3 to 5 higher than the logs show. It seems evident, however, that the areas of anomalously low resistivity as indicated in this area by T/MT surveys really exist. We have started some lithologic and X-ray work on samples from this hole to help determine the cause of such low resistivities.

Sincerely,

Phillip M. Wright
Technical Vice President

Enclosures

PMW:leo

MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY

BUTTE, MONTANA 59701

February 25, 1987

Howard P. Ross
University of Utah Research Institute
Earth Science Laboratory
391 Chipeta Way, Suite C
Salt Lake City, Utah 84108-1295

Dear Howard,

Enclosed is the data on the rock samples you sent up. We had to saw one of the sampes as it split after saturation. I'll send along an invoice with the samples.

Regards,

Bill

William R. Sill, Chair
Department of Physics and
Geophysical Engineering

Encl:

WRS:wi

ELECTRICAL MEASUREMENTS - SAMPLES 4228, 4450, 4625, 4733

Electrical measurements were performed on four core samples of volcanic rock. The summary of the measurements are presented in Table 1. Listings of the data and plots of the amplitude and phase as a function of frequency are in the Appendix. The frequency range of the measurements is 10^{-2} to 10^{2} Hz. Two different solutions of NaCl were used to saturate the samples under vacuum; these were .01 and .1 molar. After soaking in these solutions for several days the resistivity of the bath solution was measured. The .01 M solution "equilibrated" at 5 Ωm and the .1 M at 1 Ωm. At the lower salinity there was an obvious contamination of the .01 M salt solution by residual "salts" in the samples and this is fairly typical. Extrapolation of the 1 Ωm and 5 Ωm data to a solution resistivity of 10 Ωm gives the results in the last column of Table 1.

Porosity was determined from the difference in wet and dry weights and the volume of the sample. Sample 4228 had a very low porosity and this was checked several times. This sample also has a measured resistivity that is independent of the solution resistivity, indicating that surface conduction is the dominant process in this sample. The other samples show a more normal change in resistivity with solution resistivity which indicates a more typical trade off between bulk pore water conduction and surface conduction.

TABLE 1

SUMMARY OF MEASUREMENTS

Sample ([illegible])	D (cm)	L (cm)	Porosity (%)	ρ_r (Ωm) in ρ_ω = 5Ωm	ρ_r (Ωm) in ρ_ω = 1Ωm	ρ_r (Ωm) extrapolated to ρ_ω = 10Ωm
4228	4.7	12.3	.5 (?)	236 (?)	245	240
4450	4.7	11.9	10.6	15.0	11.5	17
4625	4.7	6.9	14.8	28.4	16.1	36
4733	4.7	12.3	16.3	18.5	12.8	22

Porosity determined from wet and dry weight measurements

ρ_ω = measured resistivity of saturating solution

APPENDIX 1

DATA LISTINGS

FILE: UURI_4228M SAMPLE: 4228 Date: FEB0987

Temp.: 24.4 °C Geometric Factor: .0141 Solution restivity: 5.18 ohm-m

Frequency (Hz)	Resistivity (ohm-m)	Phase Diff. (rad)
9.766E-03	2.358E+02	-2.558E-03
1.953E-02	2.357E+02	-1.759E-03
3.906E-02	2.360E+02	-2.398E-03
9.766E-02	2.355E+02	-2.056E-03
1.953E-01	2.352E+02	-3.202E-03
3.906E-01	2.348E+02	-3.562E-03
9.766E-01	2.344E+02	-6.215E-03
1.953E+00	2.339E+02	-1.004E-02
3.906E+00	2.327E+02	-1.457E-02
9.766E+00	2.297E+02	-2.043E-02
1.953E+01	2.273E+02	-1.958E-02
3.906E+01	2.256E+02	-1.789E-02
9.766E+01	2.238E+02	-2.010E-02

FILE: UURI_4450M SAMPLE: 4450 Date: FEB1087

Temp.: 22.7 °C Geometric Factor: .0146 Solution restivity: 5.18 ohm-m

Frequency (Hz)	Resistivity (ohm-m)	Phase Diff. (rad)
9.766E-03	1.525E+01	-1.311E-03
1.953E-02	1.514E+01	-2.311E-03
3.906E-02	1.507E+01	-1.770E-03
9.766E-02	1.497E+01	-2.463E-03
1.953E-01	1.493E+01	-2.863E-03
3.906E-01	1.490E+01	-3.428E-03
9.766E-01	1.483E+01	-4.174E-03
1.953E+00	1.478E+01	-4.541E-03
3.906E+00	1.474E+01	-5.048E-03
9.766E+00	1.468E+01	-5.704E-03
1.953E+01	1.463E+01	-5.273E-03
3.906E+01	1.458E+01	-4.602E-03
9.766E+01	1.454E+01	-4.762E-03

FILE: UURI_4625M SAMPLE: 4625 Date: FEB1287

Temp.: 23.8 °C Geometric Factor: .0251 Solution restivity: 5.18 ohm-m

Frequency (Hz)	Resistivity (ohm-m)	Phase Diff. (rad)
9.766E-03	2.821E+01	-4.357E-03
1.953E-02	2.810E+01	-4.189E-03
3.906E-02	2.800E+01	-3.959E-03
9.766E-02	2.790E+01	-5.350E-03
1.953E-01	2.782E+01	-5.833E-03
3.906E-01	2.774E+01	-5.860E-03
9.766E-01	2.764E+01	-6.140E-03
1.953E+00	2.755E+01	-6.485E-03
3.906E+00	2.747E+01	-6.724E-03
9.766E+00	2.735E+01	-6.778E-03
1.953E+01	2.726E+01	-6.368E-03
3.906E+01	2.718E+01	-6.107E-03
9.766E+01	2.710E+01	-5.305E-03

FILE: UURI_4733M SAMPLE: 4733 Date: FEB0987

Temp.: 24.4 °C Geometric Factor: .0141 Solution restivity: 5.18 ohm-m

Frequency (Hz)	Resistivity (ohm-m)	Phase Diff. (rad)
9.766E-03	1.805E+01	-2.930E-03
1.953E-02	1.812E+01	-3.791E-03
3.906E-02	1.813E+01	-3.611E-03
9.766E-02	1.807E+01	-4.959E-03
1.953E-01	1.821E+01	-5.354E-03
3.906E-01	1.820E+01	-6.239E-03
9.766E-01	1.816E+01	-7.203E-03
1.953E+00	1.812E+01	-8.007E-03
3.906E+00	1.807E+01	-9.026E-03
9.766E+00	1.798E+01	-9.725E-03
1.953E+01	1.792E+01	-9.836E-03
3.906E+01	1.796E+01	-9.573E-03
9.766E+01	1.779E+01	-9.520E-03

FILE: 4228_UURIm SAMPLE: 4228 Date: FEB1687

Temp.: 21.6 °C Geometric Factor: .0141 Solution restivity: 1.20 ohm-m

Frequency (Hz)	Resistivity (ohm-m)	Phase Diff. (rad)
9.766E-03	2.448E+02	-2.423E-03
1.953E-02	2.451E+02	-7.562E-04
3.906E-02	2.450E+02	-1.792E-03
9.766E-02	2.446E+02	-2.190E-03
1.953E-01	2.444E+02	-3.089E-03
3.906E-01	2.442E+02	-3.960E-03
9.766E-01	2.438E+02	-5.995E-03
1.953E+00	2.432E+02	-9.642E-03
3.906E+00	2.421E+02	-1.473E-02
9.766E+00	2.399E+02	-2.131E-02
1.953E+01	2.363E+02	-1.975E-02
3.906E+01	2.344E+02	-1.820E-02
9.766E+01	2.325E+02	-2.099E-02

FILE: 4450_UURIm SAMPLE: 4450 Date: FEB1687

Temp.: 21.8 °C Geometric Factor: .0148 Solution restivity: 1.20 ohm-m

Frequency (Hz)	Resistivity (ohm-m)	Phase Diff. (rad)
9.766E-03	1.146E+01	-3.004E-03
1.953E-02	1.139E+01	-2.525E-03
3.906E-02	1.134E+01	-2.961E-03
9.766E-02	1.130E+01	-3.095E-03
1.953E-01	1.128E+01	-3.243E-03
3.906E-01	1.125E+01	-3.497E-03
9.766E-01	1.122E+01	-3.868E-03
1.953E+00	1.119E+01	-4.273E-03
3.906E+00	1.116E+01	-4.683E-03
9.766E+00	1.112E+01	-5.191E-03
1.953E+01	1.109E+01	-5.095E-03
3.906E+01	1.106E+01	-4.970E-03
9.766E+01	1.103E+01	-4.912E-03

FILE: 4625_UURIm SAMPLE: 4625 Date: FEB1687

Temp.: 21.6 °C Geometric Factor: .0251 Solution restivity: 1.20 ohm-m

Frequency (Hz)	Resistivity (ohm-m)	Phase Diff. (rad)
9.766E-03	1.578E+01	-4.532E-03
1.953E-02	1.574E+01	-4.218E-03
3.906E-02	1.570E+01	-4.643E-03
9.766E-02	1.564E+01	-4.761E-03
1.953E-01	1.560E+01	-4.999E-03
3.906E-01	1.556E+01	-5.364E-03
9.766E-01	1.550E+01	-5.623E-03
1.953E+00	1.546E+01	-5.202E-03
3.906E+00	1.541E+01	-6.248E-03
9.766E+00	1.534E+01	-6.792E-03
1.953E+01	1.529E+01	-5.522E-03
3.906E+01	1.524E+01	-6.184E-03
9.766E+01	1.519E+01	-6.456E-03

FILE: 4733_UURIm SAMPLE: 4733 Date: FEB1687

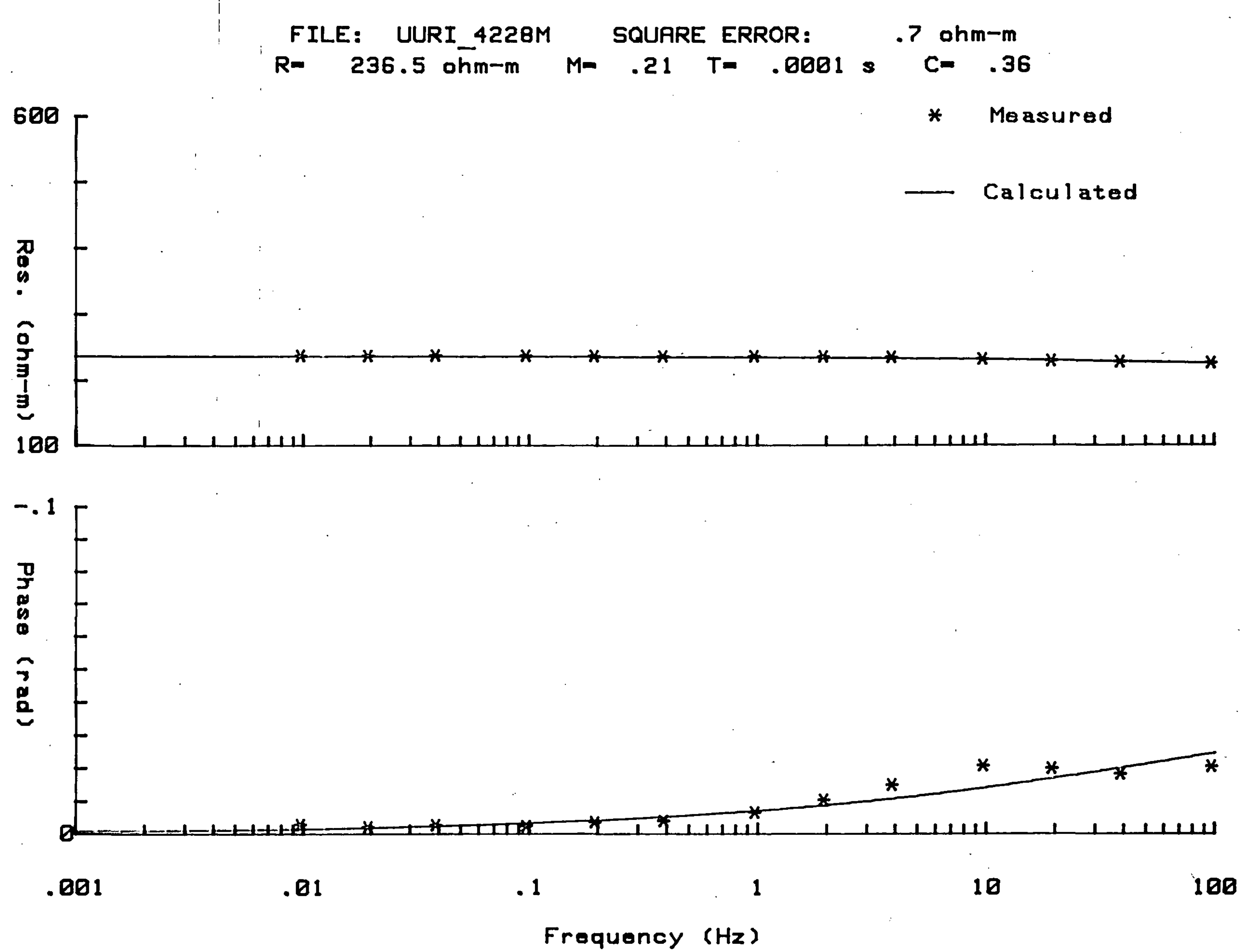
Temp.: 22.0 °C Geometric Factor: .0141 Solution restivity: 1.20 ohm-m

Frequency (Hz)	Resistivity (ohm-m)	Phase Diff. (rad)
9.766E-03	1.269E+01	-4.449E-03
1.953E-02	1.265E+01	-3.975E-03
3.906E-02	1.261E+01	-4.193E-03
9.766E-02	1.257E+01	-4.611E-03
1.953E-01	1.253E+01	-4.996E-03
3.906E-01	1.250E+01	-5.775E-03
9.766E-01	1.245E+01	-6.550E-03
1.953E+00	1.241E+01	-7.245E-03
3.906E+00	1.236E+01	-8.422E-03
9.766E+00	1.229E+01	-9.409E-03
1.953E+01	1.224E+01	-9.637E-03
3.906E+01	1.218E+01	-1.019E-02
9.766E+01	1.210E+01	-1.066E-02

APPENDIX 2

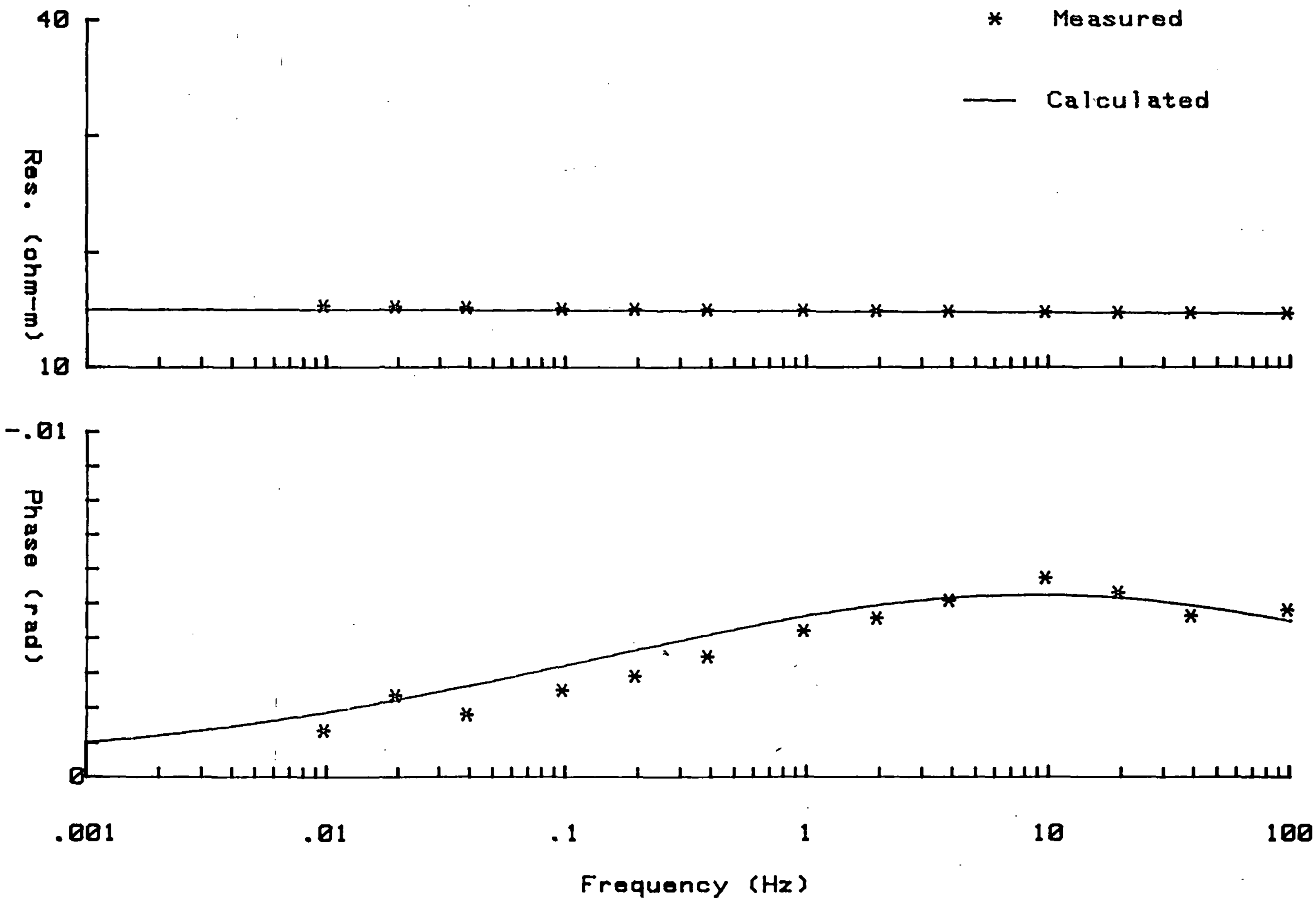
PLOTS OF AMPLITUDE AND PHASE

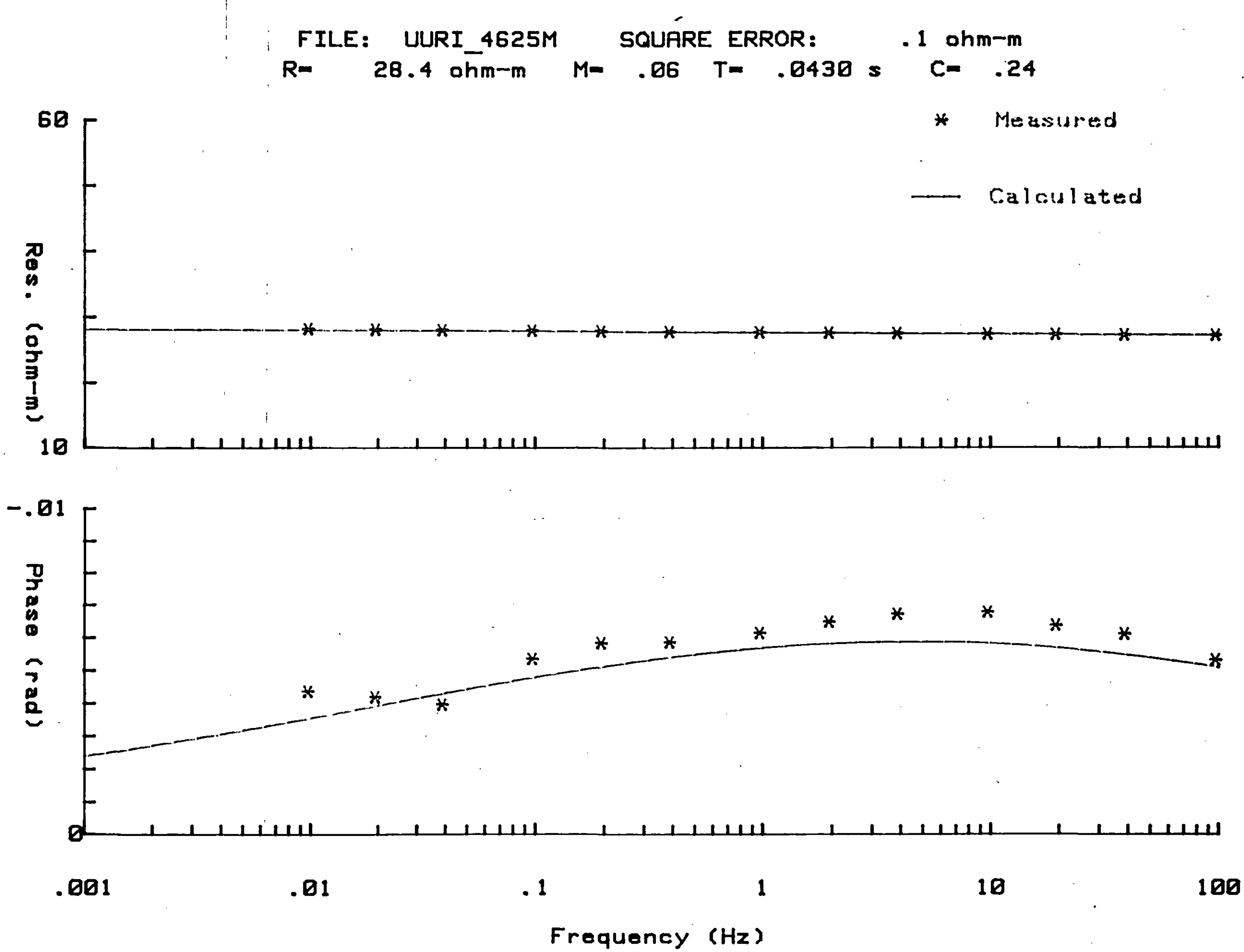
AT R_ω = 5 ohm-meter



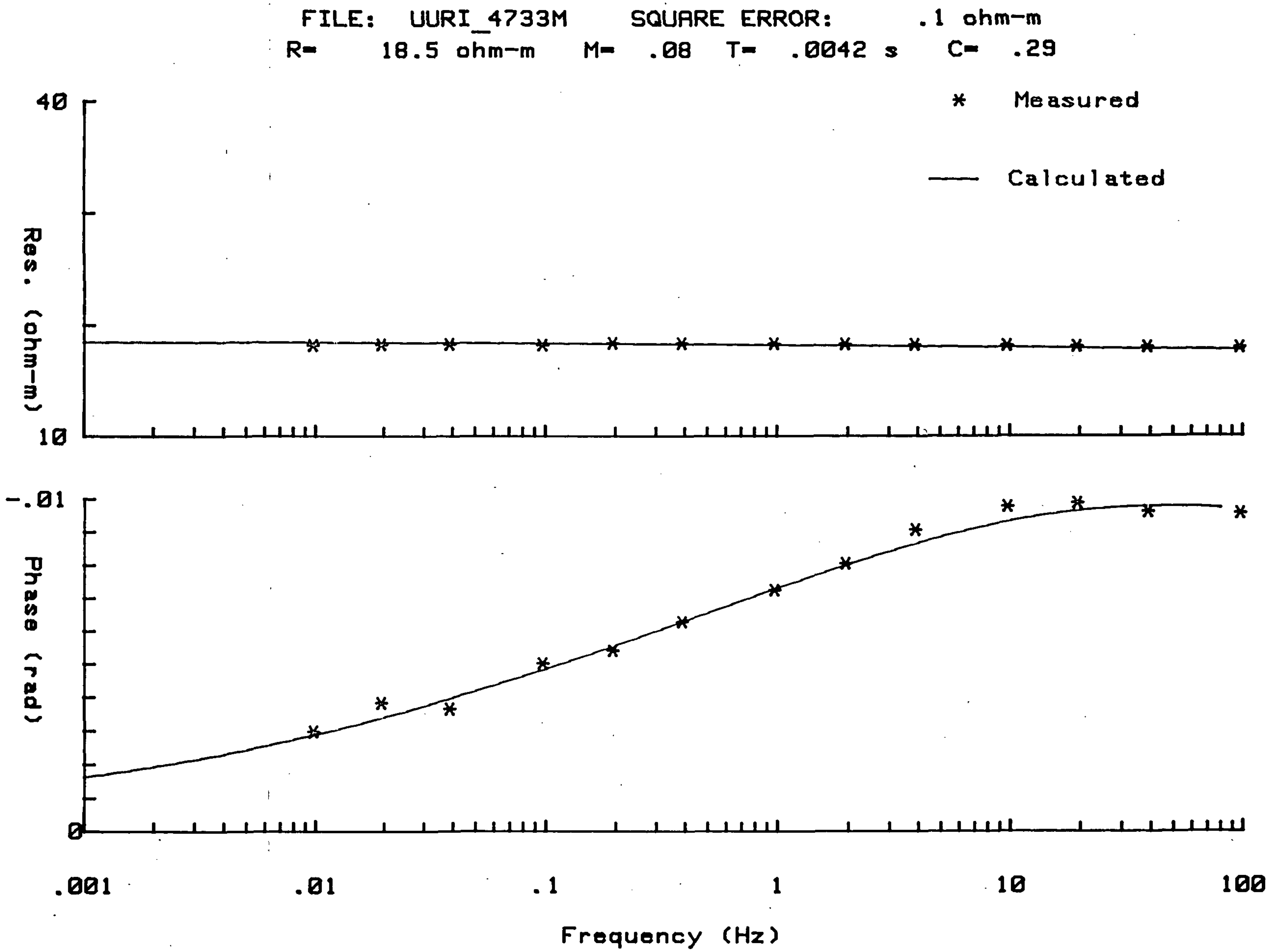
FILE: UURI_4228M SQUARE ERROR: .7 ohm-m
R= 236.5 ohm-m M= .21 T= .0001 s C= .36
600
100
Res. (ohm-m)
* Measured
— Calculated
-.1
0
Phase (rad)
.001
.01
.1
1
10
100
Frequency (Hz)

FILE: UURI_4450M SQUARE ERROR: .1 ohm-m
R= 15.0 ohm-m M= .04 T= .0200 s C= .32





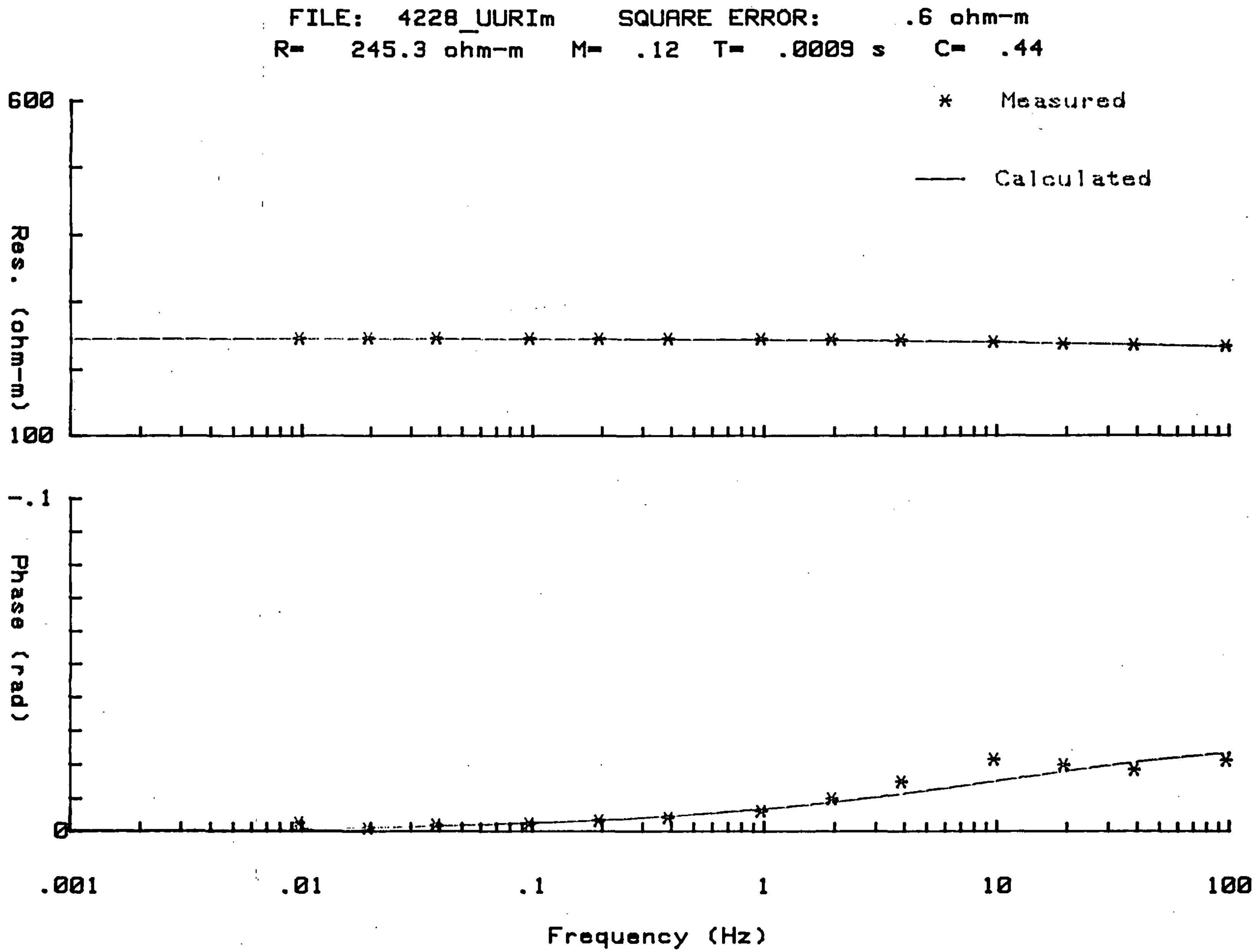
FILE: UURI_4625M SQUARE ERROR: .1 ohm-m
R= 28.4 ohm-m M= .06 T= .0430 s C= .24
* Measured
Calculated
Res. (ohm-m)
60
10
Phase (rad)
-.01
0
.001
.01
.1
1
10
100
Frequency (Hz)

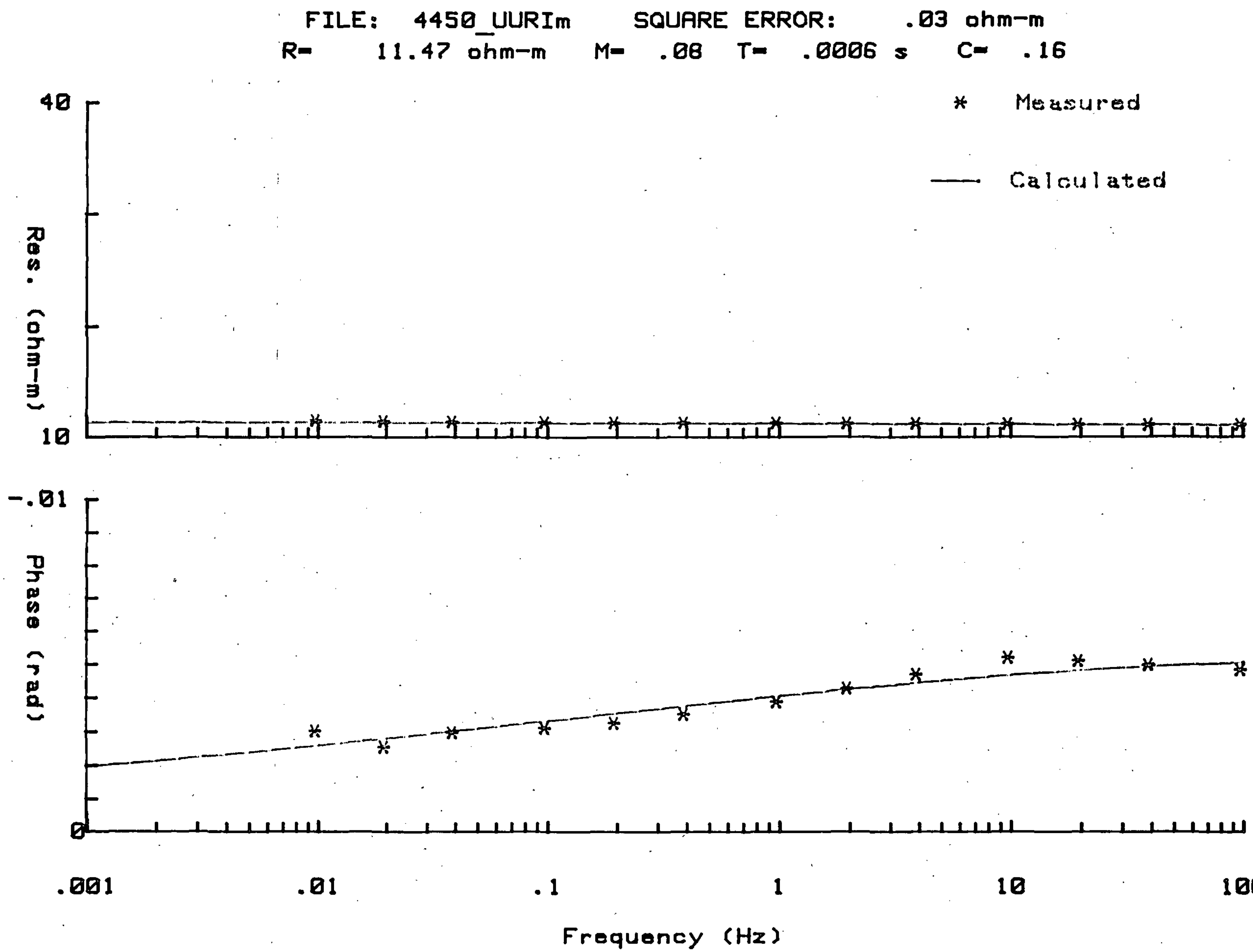

FILE: UURI_4733M SQUARE ERROR: .1 ohm-m
R= 18.5 ohm-m M= .08 T= .0042 s C= .29
* Measured
Calculated
Res. (ohm-m)
40
10
Phase (rad)
-.01
0
.001
.01
.1
1
10
100
Frequency (Hz)

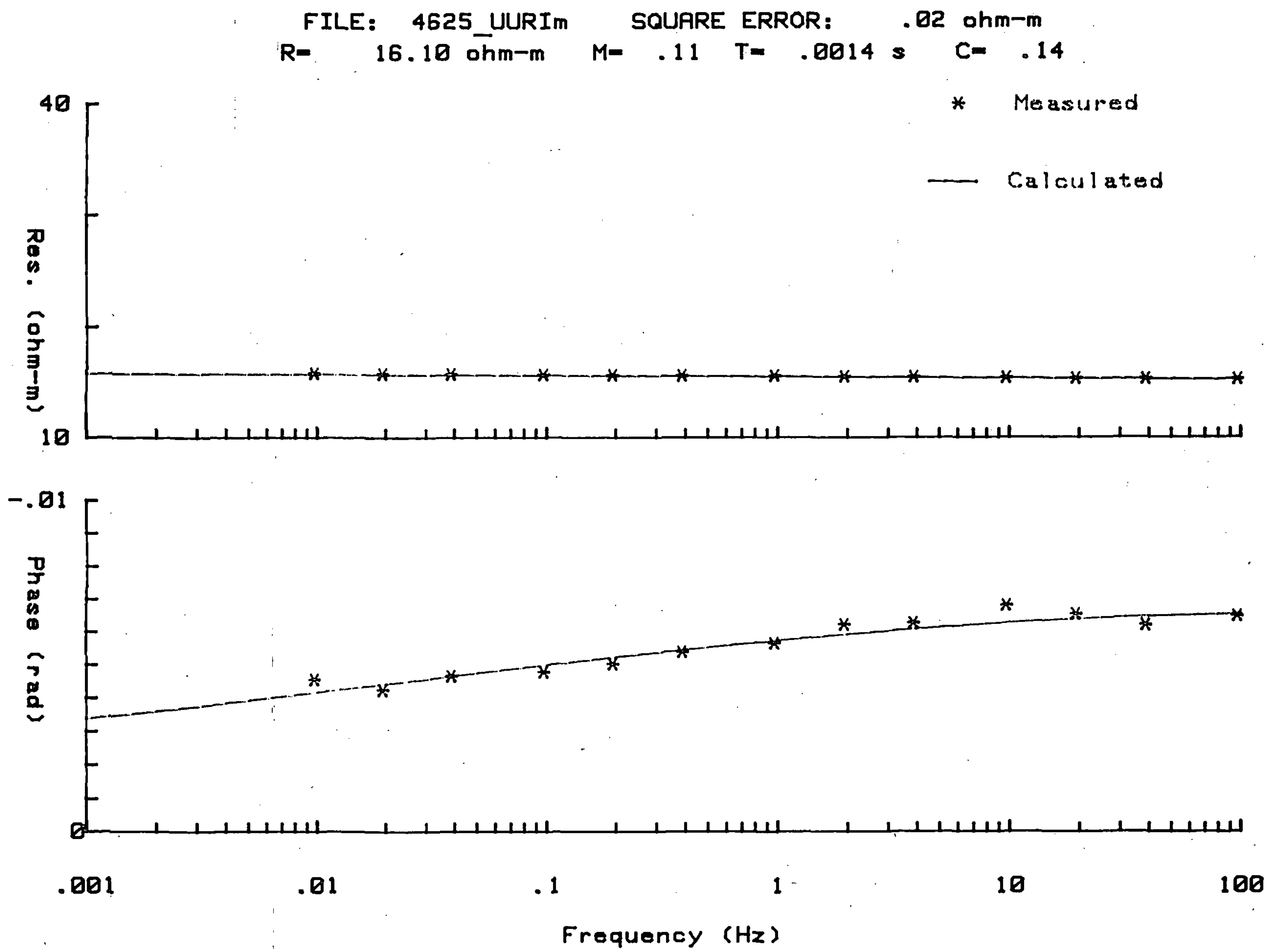
APPENDIX 3

PLOTS OF AMPLITUDE AND PHASE

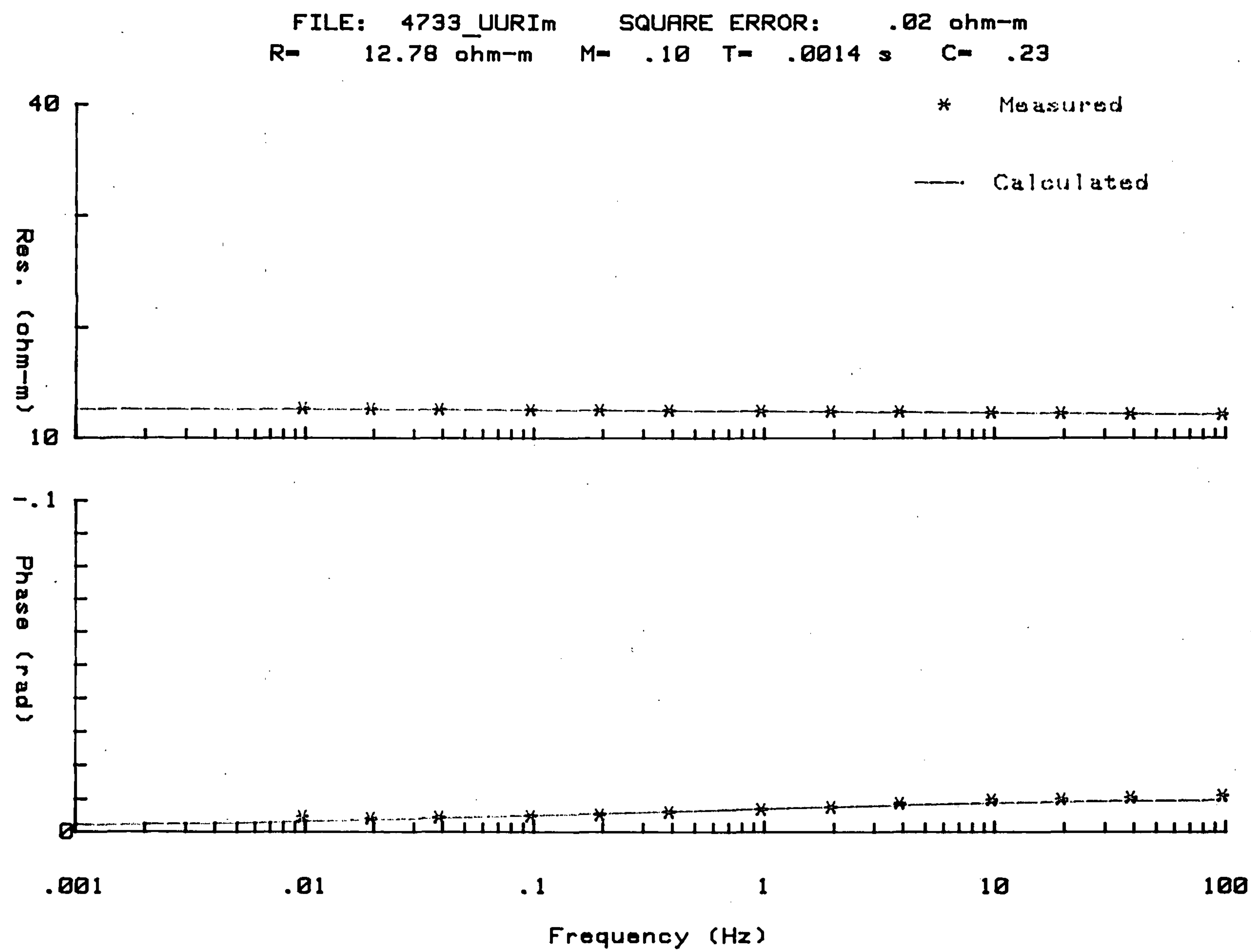
AT R_ω = 1 ohm-meter

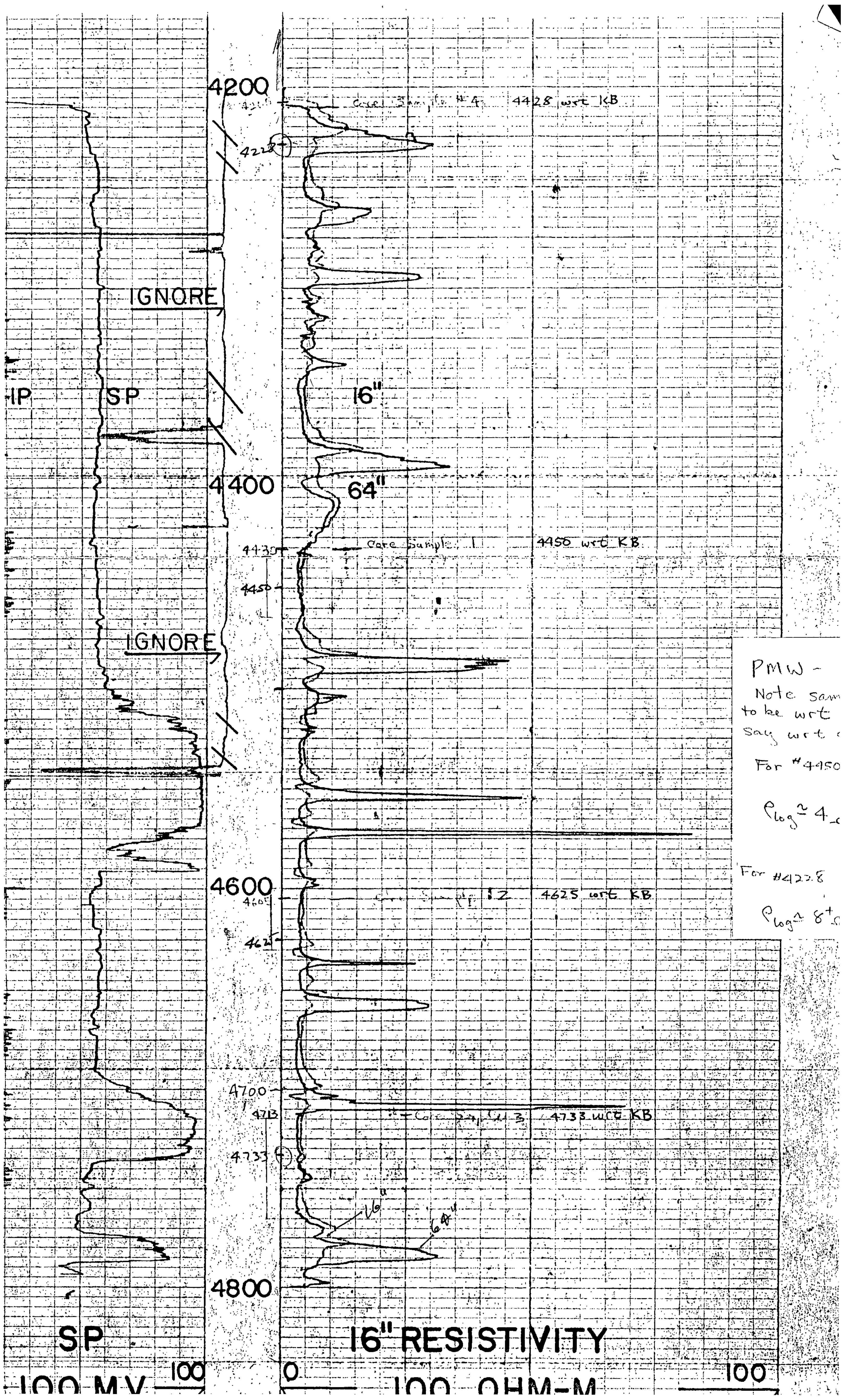

FILE: 4228_UURIm SQUARE ERROR: .6 ohm-m
R= 245.3 ohm-m M= .12 T= .0009 s C= .44
* Measured
Calculated
Res. (ohm-m)
600
100
Phase (rad)
-.1
0
.001
.01
.1
1
10
100
Frequency (Hz)


FILE: 4450_UURIm SQUARE ERROR: .03 ohm-m
R= 11.47 ohm-m M= .08 T= .0006 s C= .16
* Measured
Calculated
40
10
Res. (ohm-m)
-.01
0
Phase (rad)
.001
.01
.1
1
10
100
Frequency (Hz)



FILE: 4625_UURIm SQUARE ERROR: .02 ohm-m
R= 16.10 ohm-m M= .11 T= .0014 s C= .14
Measured
Calculated
40
10
Res. (ohm-m)
-.01
0
Phase (rad)
.001
.01
.1
1
10
100
Frequency (Hz)


FILE: 4733_UURIm SQUARE ERROR: .02 ohm-m
R= 12.78 ohm-m M= .10 T= .0014 s C= .23
* Measured
Calculated
Res. (ohm-m)
40
10
Phase (rad)
-.1
0
.001
.01
.1
1
10
100
Frequency (Hz)



4200
Core Sample #4 4428 wrt KB
4228
IGNORE
IP
SP
16"
64"
4400
4430
Core Sample 1
4450 wrt KB
4450
IGNORE
4600
4605
Core Sample #2 4625 wrt KB
4625
4700
4713
Core Sample #3 4733 wrt KB
4733
16"
64"
4800
SP
16" RESISTIVITY
100 MV
100
0
100 OHM-M
100
PMW -
For #4450
For #4228

MORDENITE

	QUARTZ	PLAGIOCL.	CLINO-PYROXENE *	~~[illegible]~~ MORDENITE	SMECTITE ⊗	CELADONITE	AMORPHOUS BELOW DET. LIM. ‡								
4228.3-4228.8'	1	41	~10?				48								
4732.5-4733.0'	2	47	~10?	3	13	TR	25								

* PATTERN OBSCURED BY THAT OF PLAGIOCLASE. NEED THIN-SECTION

‡ MOSTLY GLASS, BUT WOULD IN-CLUDE TRACE & MINOR ACCESSORY PHASES

⊗ DIOCTAHEDRAL; PROBABLY MONTMORILLO-NITE.

notes

1. 4733 - pure smectite - no illite interlayers
dioctahedral -- means low temp, prob ≈ 100°C.
This checks up temp log

- green = celadonite
white = mordenite
black in vesicles = smectite

4228 - trace hematite

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391 CHIPETA WAY, SUITE C
SALT LAKE CITY, UTAH 84108—1295
TELEPHONE 801-524-3422

February 2, 1987

Dr. William Sill
Department of Physics and Geophysical Engineering
Montana College of Mineral Science and Technology
West Park Street
Butte, Montana 59701

Dear Bill:

Transmitted herewith are four samples of NX drill core for electrical resistivity measurements as we discussed last week. The samples are from a geothermal well drilled in the Oregon Cascades. All four samples are volcanic rocks corresponding to the following depths:

Sample No. 1	4450 ft.
Sample No. 2	4625 ft.
Sample No. 3	4733 ft.
Sample No. 4	4228 ft.

We would like to have resistivity measurements for the 0.01 to 10 Hz range for two different fluid resistivities, 10 ohm-m and 1.0 ohm-m. If an IP measurement is recorded simultaneously or at small additional cost we would like you to obtain these data also.

Bill, please refer to Purchase Order No. 200-2110 when you submit your invoice for payment. Also please indicate how the purchase order and payment should be directed (MCMST, William Sill, etc.). Please call me at (801) 524-3444 if you think this service will exceed $200, or if you need any additional information.

We were pleased to learn that your electrical properties lab was up and running and could perform these measurements for us. I hope that the Ennis Hot Spring report is nearing completion and that you have some good ideas for the next State Cooperative Program solicitation.

Regards,

Howard

Howard P. Ross

✓ PMW

TABLE 1

SUMMARY OF MEASUREMENTS

Sample ([illegible])	D (cm)	L (cm)	Porosity (%)	ρ_r (Ωm) in ρ_ω = 5Ωm	ρ_r (Ωm) in ρ_ω = 1Ωm	ρ_r (Ωm) extrapolated to ρ_ω = 10Ωm
4228	4.7	12.3	.5 (?)	236 (?)	245	240
4450	4.7	11.9	10.6	15.0	11.5	17
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Porosity determined from wet and dry weight measurements

ρ_ω = measured resistivity of saturating solution