OHIO BRASS®

Report Number: G12-02-01
Date: February 3, 2012

HUBBELL®
POWER SYSTEMS

SEISMIC QUALIFICATION OF MVN, MH4 AND MH3 SURGE ARRESTERS TO HIGH PERFORMANCE LEVEL OF IEEE 693-2005

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Date: 2/3/2012

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Date: 2/3/2012

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Date: 2/6/2012

COMMONWEALTH OF PENNSYLVANIA
REGISTERED PROFESSIONAL
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Bulletin EU1595

Report Number: G12-02-01
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INTRODUCTION

The industry standard to which Hubbell Power Systems - Ohio Brass qualifies the seismic capability of its arresters is IEEE 693-2005. This report qualifies that standard Ohio Brass MVN, MH4 and MH3 series arresters up to a certain size (i.e. length and mass) meet the "HIGH PERFORMANCE LEVEL" as demonstrated by a shake table test on a test stand.

IEEE 693-2005 allows seismic qualification based on the concept of "qualifying equipment by group." This permits product of different voltage ratings, but of similar physical structure (such as surge arresters) to be combined into groups for qualification purposes, with the most seismically vulnerable piece of equipment of each group being analyzed or tested. Key parameters affecting the seismic capability are: grade of porcelain used; diameter of the porcelain housings and thickness of the housing walls (particularly at the bottom end of the arrester where the porcelain enters the end fitting); the types of end fitting used; and the overall mass and center of gravity of the arrester. We use this concept of "qualifying by group" to use the results of one shake table test to qualify many arresters.

SHAKE TABLE TEST

Seismic tests in accordance with IEEE 693 have been performed on arrester model number MH4420GH420AA. This arrester was installed over a sub base model number 272145-3076 and the entire assembly had a mass of 938 lb (425 kg) and a center of gravity of 83.7 in (2126 mm) from the base. An additional 15 lb (6.8 kg) was added to simulate the line terminal per the standard. This assembly was mounted on a 98 in (2489 mm) test stand, which was mounted to the shake-table platform.

The shake table portion of the test was performed on December 20, 2011 at Clark Testing Laboratory in Jefferson Hills, PA. Details of the seismic test set up and test measurements are given in the Clark Test Lab report, number EL: 9959 (Annex II of this report). Results of post-seismic electrical tests are presented in Table 1.

The arrester was subjected to a shake table test with a response spectrum that was at least <u>twice</u> the high required response spectrum of Figure A.1 of IEEE 693-2005. The actual test spectra used for horizontal and vertical accelerations are shown on pages IV-2 to IV-4 of report EL: 9959 Post-seismic resonance search tests met the evaluation requirements of IEEE 693.

To be qualified to the high seismic performance level, IEEE 693-2005 requires that an arrester tested to the 1.0g ZPA level survives the shake-table test with no structural damage, and that it remains functional, as demonstrated by successfully passing routine production tests after the shake-table test. These tests consist of measurement of reference voltage, partial discharge and watts loss, and performance of a seal-leak tests. Results are summarized in Table 1. Arrester MH4420GH420XX meets the requirements for high seismic performance level.

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TABLE 1.
Electrical test measurements on 3-unit arrester MH4420GH420XX after shake-table test

Unit	MCOV (kVrms)	Reference Voltage (kVpk) at 17mApk	
		Test value	Factory Limits
Bottom	105.6	138.95	137.46 – 144.34
Middle	115.2	151.74	149.96 – 157.46
Top	115.2	151.32	149.96 – 157.46

Unit	MCOV (kVrms)	Watts loss (w) at 1.2 x MCOV	
		Test value	Factory Limits
Bottom	105.6	78.05	108.9
Middle	115.2	82.08	118.8
Top	115.2	81.25	118.8

Unit	MCOV (kVrms)	PD (pC) at 1.05 x MCOV	
		Test value	Factory Limits
Bottom	105.6	4.96	10 max
Middle	115.2	4.81	10 max
Top	115.2	4.12	10 max

QUALIFICATION BY PRODUCT GROUPING OF OTHER ARRESTERS

IEEE 693-2005 provides for "qualification by product grouping", whereby all members of a "group" are considered to be qualified to the same level as the most seismically vulnerable member of the group. All Hubbell Power Systems - Ohio Brass MVN, MH4 and MH3 arresters use the same general porcelain profile (weathershed shape, wall thickness) and the same type of end fittings. For seismic analysis purposes, according to provisions in IEEE 693-2005, they can be considered to all be part of a "group". The most seismically vulnerable member of the group would then be that arrester having the greatest mass, greatest total height and highest center of gravity.

SUMMARY

The above results provides information necessary to qualify all standard Hubbell Power Systems - Ohio Brass MVN, MH4 and MH3 arresters to the high performance level of IEEE 693-2005, provided that the mass, total height and height of center of gravity of those arresters do not exceed the corresponding characteristics of arrester model MH4420GH420XX. That is, MVN, MH4 and MH3 arresters are qualified to the high seismic performance level of IEEE 693-2005 if

Mass ≤ 938 lb (425 kg)
Center of Gravity ≤ 83.7 in (2126 mm) from base

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ANNEX 1

SHAKE TABLE TEST REPORT
ARRESTER MODEL MH4420GH420AA

EL:9959
JANUARY 2012

IEEE693 SEISMIC QUALIFICATION TEST
FOR THE
HUBBELL POWER SYSTEMS
TYPE MH4, IEC CLASS 4
PORCELAIN SURGE ARRESTER

ANT:5453

P.O. # 4501742303

CLARK TESTING

Clark Testing Laboratory
1801 Route 51
Jefferson Hills, PA 15025

EL:9959
JANUARY 2012

IEEE693 SEISMIC QUALIFICATION TEST
FOR THE
HUBBELL POWER SYSTEMS
TYPE MH4, IEC CLASS 4
PORCELAIN SURGE ARRESTER

ANT:5453

P.O. # 4501742303

Clark Testing Laboratory
1801 Route 51
Jefferson Hills, Pennsylvania 15025

Prepared by: Date 1/31/2012

John R. Antenucci

John R. Antenucci, Manager
Clark Testing Laboratory

Approved by: Date 2/1/12

Quality Assurance (Q.A.)
Clark Testing Laboratory

Approved by: Date 1/31/2012

Albert Molnar

Albert Molnar, P.E.
EAD Corporation

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1.0 INTRODUCTION

1.1 Seismic Test

The purpose of this test was to subject the Hubbell Power Systems Porcelain Surge Arrester, Type MH4 IEC Class 4, to a seismic test that, in a conservative manner, simulated an earthquake event. The intention of the tests described in this report was to satisfy present seismic requirements as identified in IEEE 693-2005.

1.2 Arrangements

Tests were conducted at the Clark Testing Laboratory in Jefferson Hills, PA between the dates of December 16, 2011 and December 20, 2011 under Hubbell Power Systems Purchase Order 4501742303.

2.0 TEST ARRANGEMENTS

2.1 Test Procedure

The IEEE693-2005 Test Standard entitled "IEEE Recommended Practice for Seismic Design of Substations" was used for conducting this test program.

2.2 Test Article

One (1) Hubbell Power Systems Porcelain Surge Arrester, Type MH4 IEC Class 4, Serial # MH4420GH420AA, was used for the testing. The following is a breakdown of the arrester components:

- Top section, Serial # PSEMH4UAG40144, weighing 290 lbs.
- Middle section, Serial # PSEMH4UAG40144, weighing 290 lbs.
- Bottom section, Serial # PSEMH4UAG40132, weighing 285 lbs.
- Three (3) arrester insulating sub-bases, weighing 13 lbs. each
- Grading Ring, Serial # 272807-3001, weighing 25 lbs.
- One (1) line terminal, weighing 9 lbs.

The total weight of the arrester assembly was 938 lbs. One (1) 15 lb. line terminal dummy weight was added for the testing.

2.3 Test Mounting

The 8'-2" test stand was mounted to the seismic table using three (3) 1"-8 Grade 5 bolts and one (1) 1"-8 strain bolt with flat washers and lock washers. The arrester insulating sub-bases were bolted to the test stand using the center ½"-13 all-thread. The arrester was bolted to the tops of the insulating sub-bases using the center ½"-13 all-thread with nuts, flat washers and lock washers. Page 4 of Appendix I contains the details of the mounting. Figure 1 contains the arrester mounted on the seismic test table.

2.4 Test Monitoring

A total of eleven (11) piezo-resistive accelerometers, two (2) strain gages and one (1) load bolt were mounted on the seismic table and the surge arrester to monitor acceleration, strain and load levels during the seismic test run. Page 4 of Appendix I contains a list of the accelerometer locations for the test. Page 6 of Appendix I contains a list of the strain gage and strain bolt locations for the test. Figures 2 through 7 show the transducer locations for the testing.

2.5 Test Input

The arrester was subjected to triaxial random input motions that were independent in three orthogonal directions. Correlation coefficients were computed (Appendix V) to ensure that the triaxial input motions were statistically independent. In addition, stationarity of the motions were computed (Appendix V) to assure that frequency content of the waveform was statistically constant (contained sufficient energy) during its strong motion part.

2.6 Shake Table Characteristics

The shake table has the following characteristics:

Hexagonal table with 10 ft. across flats, bare table weight of about 5400 lbs., three (3) Actuators with 38,000 lbs. force, stroke normally utilized ±4" (maximum stroke available ±4.95"), capacity of servo valves 200 gals/min., peak velocity of 50"/second and peak zero period accelerations of 2 g up to 10,000 lbs. unit and about 5 g up to 1000 lbs. unit.

2.7 Test Equipment

Figure 11 shows the lists of all test equipment utilized during the test program. Test equipment was in calibration and the calibrations are traceable to the National Institute of Standards and Technology (NIST).

2.8 Test Record Logbook

Appendix I contains a copy of the Clark Testing Laboratory test record logbook, which tracks daily test activities during the test program.

3.0 TEST DESCRIPTION

3.1 Visual Inspection

Before the start of the seismic test program, the surge arrester was visually inspected for damage.

3.2 Resonance Search

Prior to the start and after completion of the seismic test run, resonance search tests were conducted in three orthogonal directions. The runs were made in the frequency range of 1 Hz to 34 Hz in one direction at a time using a sinusoidal sweep at an acceleration input level of 0.1g +0.05g. The sweep rate was servo-controlled to 1octave/minute. This test identifies the required natural frequencies in the arrester.

3.3 High Performance Level

A Performance Level (1.0g ZPA or 2 x High Level) test was performed on the surge arrester. The horizontal Performance Level Required Response Spectra (RRS) is shown in Figure 8. The vertical Performance Level RRS is shown in Figure 9. The independent time histories for the test were generated in such a way that the Test Response Spectra (TRS) corresponding to them envelop the individual RRS. Cross correlation functions were generated between the three (3) different time history of acceleration signals: hor.x/hor.y, hor.y/ver. and ver./hor.x (X:1, Y:2). Mean Square values for signals in the horizontal x, horizontal y and vertical z were also generated. The Cross correlation between two (2) time history records, X and Y, was computed from the expression $fxy/(fxx \times fyy)^{0.5}$ where fxx and fyy are the mean square values of horizontal X and horizontal Y time histories respectively & fxy is the Cross correlation between X and Y. The acceptance criterion is that the Cross correlation be less than 0.3. Then, computations were performed to check stationarity (contains sufficient energy through the 30 second waveform) of the three time histories. Stationarity factors were calculated by comparing the maximum and minimum power spectral density values for ten (10) consecutive three (3) second time segments to the corresponding average power spectral density values of the input motions. The IEEE693 random waveform was used for developing the spectrum.

4.0 TEST SEQUENCE AND TEST RESULTS

4.1 Visual Inspection

Visual inspection was performed during this test program. The Hubbell personnel reported there was no apparent structural damage.

4.2 Resonance Search Test

The arrester was mounted and the resonant frequency search was performed as specified in Section 3.2. The results in the form of transmissibility plots are shown on pages 2 through 9 of Appendix II. The 1st resonant frequency for the arrester was as follows:

Top of Surge Arrester

F-B (2.86 Hz), S-S (2.5 Hz) & Vertical (No Resonance)

Top of Fixture

F-B (16.8 Hz), S-S (15.0 Hz) & Vertical (No Resonance)

Center of Gravity of Arrester

F-B (2.85 Hz) & S-S (2.53 Hz)

The Hubbell representatives performed visual mechanical inspections of the surge arrester and reported there was no apparent mechanical damage.

4.3 High Performance Level

A Performance Level Earthquake (1.0g ZPA) was performed on the surge arrester. The Performance Level Earthquake (2 x High Level of Figure A1 of IEEE693-2005) run was made using the horizontal RRS shown in Figure 8 and the vertical RRS shown in Figure 9. The Test Response Spectrum (TRS) curves adequately enveloped the RRS; the run was acceptable. Pages 2 through 11 of Appendix III contain the time history of acceleration, strain, load and displacement plots for all transducers. Pages 2, 3 and 4 of Appendix IV contain the test response spectrum plots from the test run. The cross correlation coefficients between hor.x/hor.y, hor.y/ver. and ver./hor.x were computed and are 0.13, 0.11 and 0.15 respectively for the accepted seismic test. These calculations were based on data from Cross correlation function plots shown on page 2 of Appendix V. These values show that the time histories were statistically independent. Pages 3, 4 and 5 of Appendix V contain the stationarity check data and based on that data the frequencies in the input time histories contained sufficient energy at all times. Table 1 contains the transducer peaks for the seismic test. The Hubbell personnel performed a visual inspection of the arrester and reported there was no apparent damage.

4.4 Post Seismic Resonance Search Test

The resonant frequency search was performed as specified in Section 3.2. During the Side to Side axis sweep it was noticed that the surge arrester was moving more than in the pre-seismic sweeps. The test was stopped and the Hubbell personnel inspected the surge arrester. They found the standoff mounting bolts were loose. The bolts were torqued back to the required value (45 ft-lbs). The Side to Side sweep was repeated. The results in the form of transmissibility plots are shown on pages 10 through 17 of Appendix II. The 1st resonant frequency for the arrester was as follows:

Top of Surge Arrester

F-B (2.34 Hz), S-S (2.01 Hz) & Vertical (No Resonance)

Top of Fixture

F-B (23.6 Hz), S-S (15.0 Hz) & Vertical (No Resonance)

Center of Gravity of Arrester

F-B (2.33 Hz) & S-S (2.01 Hz)

The Hubbell representatives performed visual mechanical inspections of the surge arrester and reported there was no apparent mechanical damage.

Note

The surge arrester was disassembled and a closer inspection of the insulating sub-bases was performed by the Hubbell personnel. They found that the back left insulating sub-base mounting stud was slightly yielded (Figure 10).

5.0 CONCLUSION

The Hubbell Power Systems Porcelain Surge Arrester, Type MH4 IEC Class 4, Serial # MH4420GH420AA was tested using requirements of IEEE693-2005. The results satisfy the project technical requirements.

TABLE 1

Transducer Peak Readings for the Surge Arrester 1.0g Seismic Test

Porcelain Surge Arrester, Type MH4 IEC Class 4 1.0g Seismic Test		
Transducer	Minimum	Maximum
A1	-1.25	1.12
A2	-1.27	1.33
A3	-0.88	0.91
A4	-4.32	3.69
A5	-3.91	4.57
A6	-1.06	1.01
A7	-2.24	2.25
A8	-2.55	2.2
A9	-0.88	0.94
A10	-3.37	2.48
A11	-2.54	2.85
Rd4 from Stand Top	-5.07	5.01
Rd5 from Stand Top	-6.85	6.36
Rd4 from Table Top	-5.32	5.29
Rd5 from Table Top	-7.32	6.85
Sg1	-682	521
Sg2	-465	473
Sb1	-4406	2863

Ledger

1.) Accelerometer (A) readings are in g.
2.) Strain bolt readings are in pounds.
3.) Strain gage readings are in micro-inches/inch.
4.) Displacement readings are in inches

Figure 1. Type MH4, IEC Class 4, Surge Arrester mounted on the Tri-axial Table

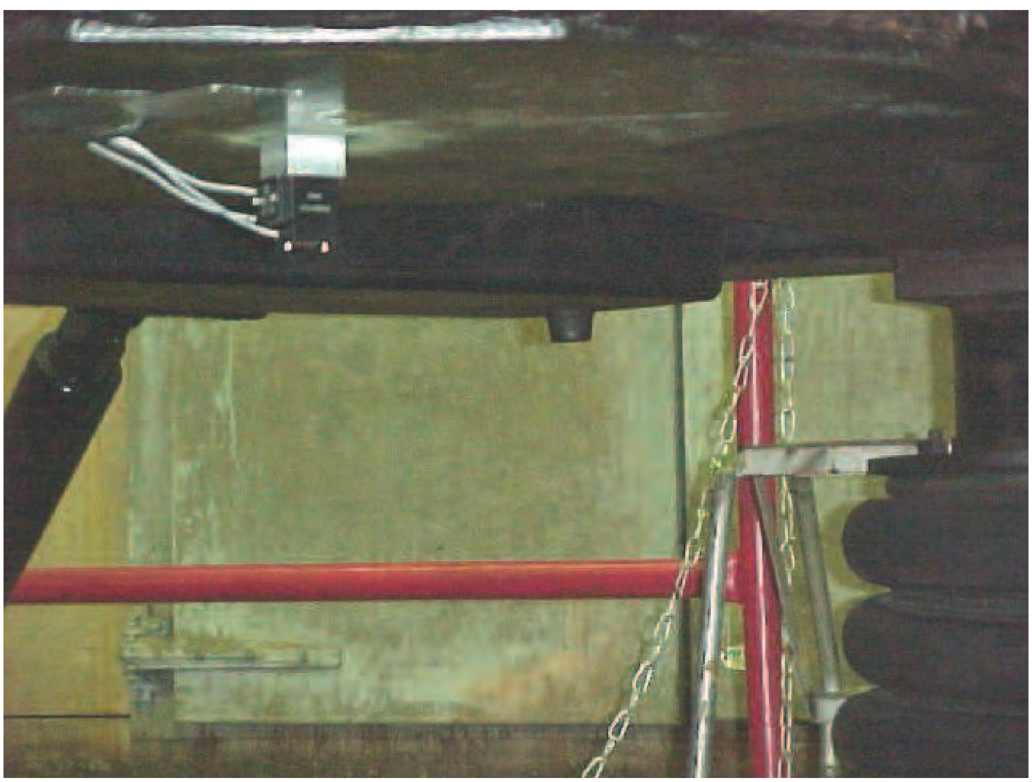

Figure 2. Accelerometer Locations A1, A2 and A3

Figure 3. Accelerometer Locations A4, A5 and A6

Figure 4. Accelerometer Locations A7, A8 and A9

Figure 5. Accelerometer Locations A10 and A11

Figure 6. Strain Gage Locations Sg1 and Sg2

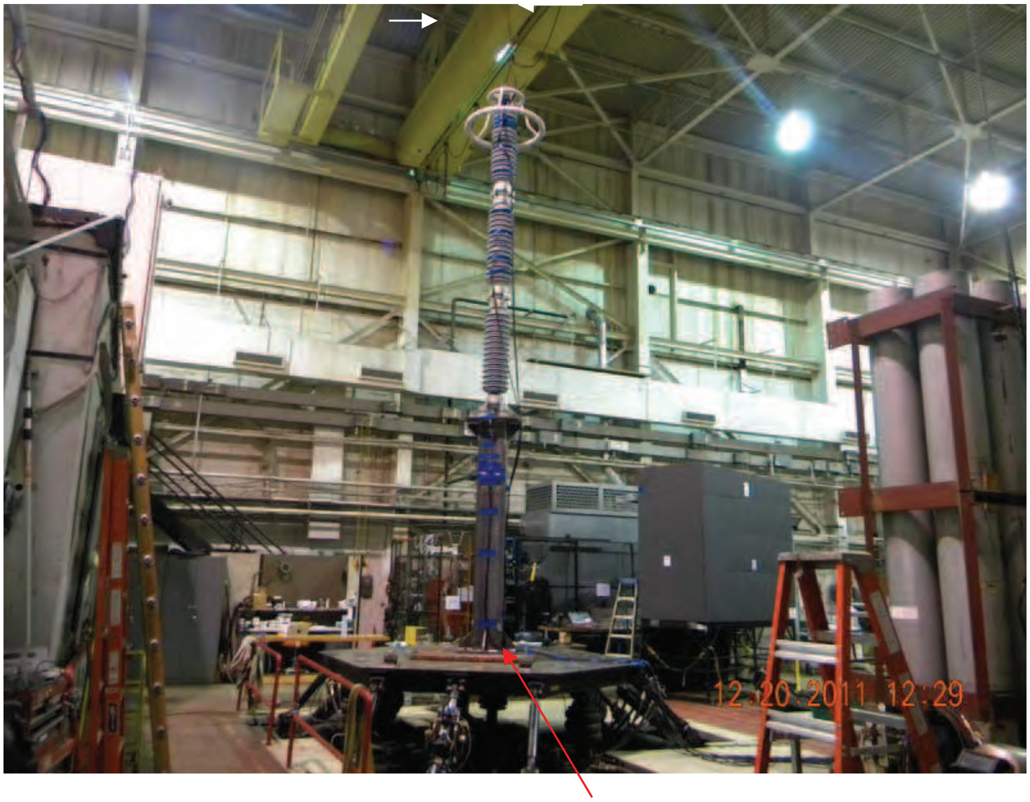

Figure 7. Strain Bolt Location Sb1

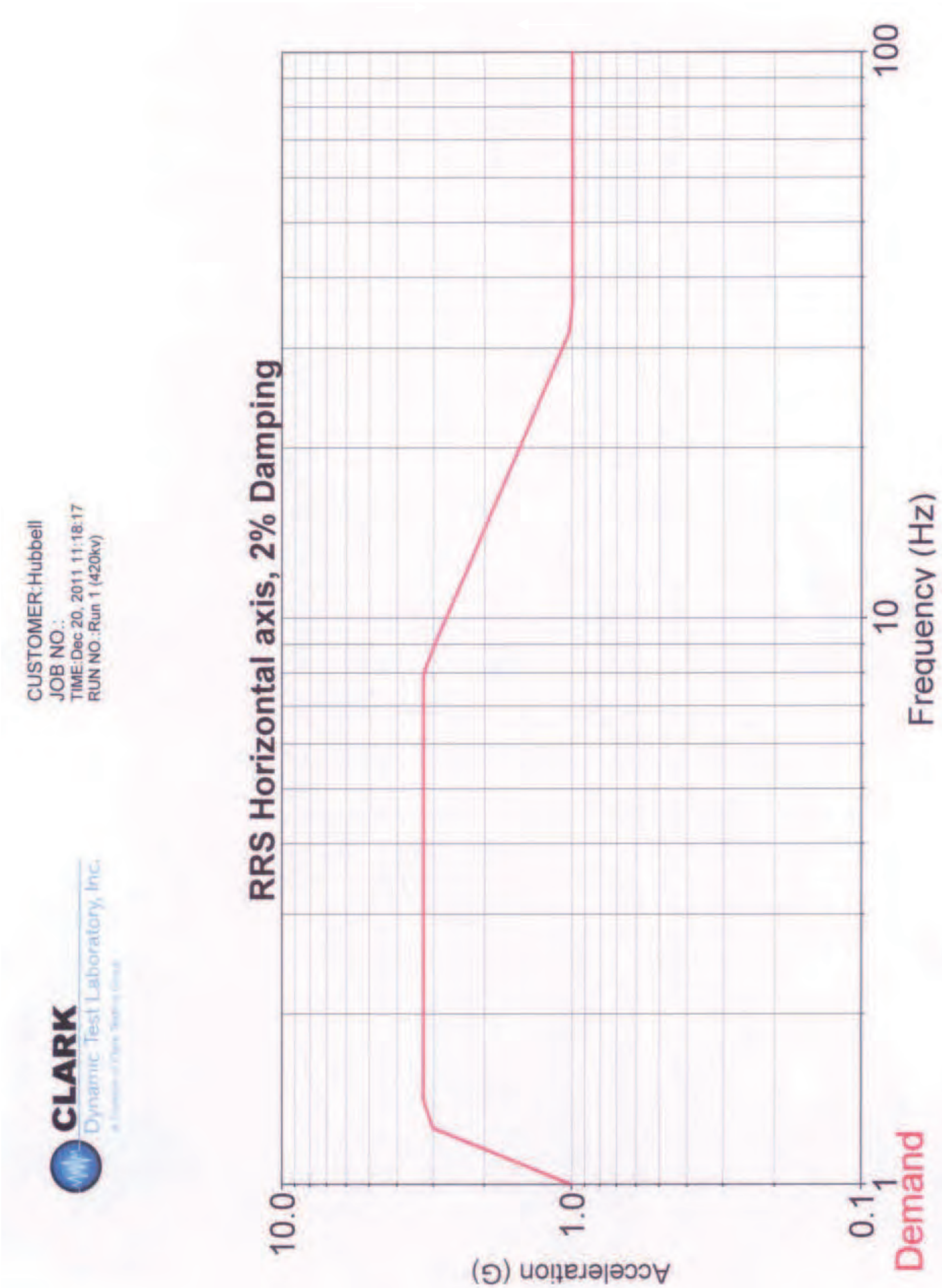

Figure 8. High Performance Seismic Response Spectrum (Horizontal)

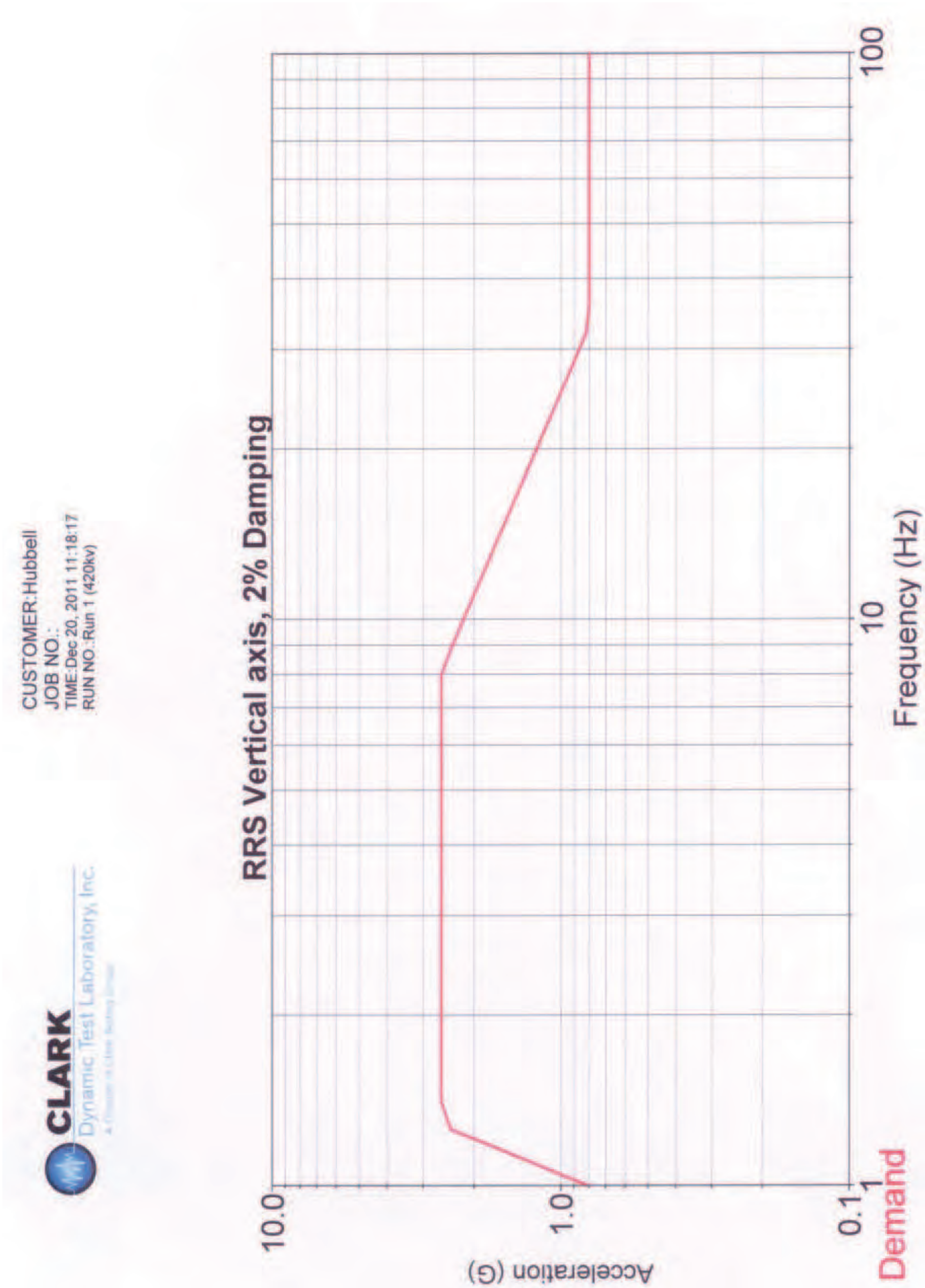

Figure 9. High Performance Seismic Response Spectrum (Vertical)

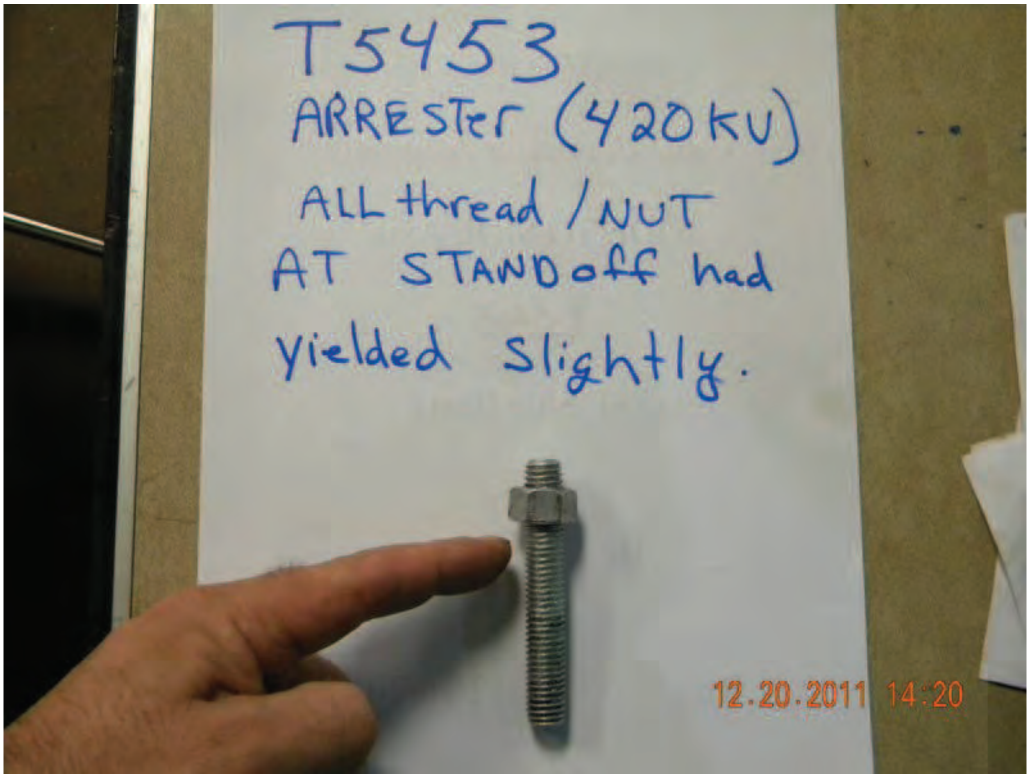

Figure 10. Back Left Insulating Sub-base mounting Stud Slightly Yielded

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Traceability Report

Status	Location	Mcbee #	Instrument	Model #	Manfacturer	Serial #
6/19/2012	Clark Testing	10236	Signal Conditioner	2310	Vishay Instruments	045017
6/19/2012	Clark Testing	10246	Signal Conditioner	2310	Vishay Instruments	045256
6/16/2012	Clark Testing	4059	Vibration Controller	VR 8500	Vibration Research	ldf2le
6/16/2012	Clark Testing	4058	Vibration Controller	VR 8500	Vibration Research	ldflba
6/16/2012	Clark Testing	4055	Vibration Controller	VR 8500	Vibration Research	IB87CE
6/16/2012	Clark Testing	4056	Vibration Controller	VR 8500	Vibration Research	IB8302
6/16/2012	Clark Testing	4057	Vibration Controller	VR 8500	Vibration Research	IB 9028
6/16/2012	Clark Testing	4060	Vibration Controller	VR 8500	Vibration Research	ld0389
1/10/2012	Clark Testing	4174	Accelerometer	7596A-30	Endevco	31298
1/10/2012	Clark Testing	4176	Accelerometer	7596A-30	Endevco	31300
1/10/2012	Clark Testing	4180	Accelerometer	7596A-30	Endevco	31304
7/25/2012	Clark Testing	4183	Accelerometer	7596A-30	Endevco	31434
7/25/2012	CLARK TESTING	4184	Accelerometer	7596A-30	Endevco	31435
7/25/2012	Clark Testing	4185	Accelerometer	7596A-30	Endevco	31436
7/25/2012	Clark Testing	4186	Accelerometer	7596A-30	Endevco	31437
9/22/2012	Clark Testing	4138	Accelerometer	7596A-30	Endevco	31483
9/23/2012	Clark Testing	4139	Accelerometer	7596A-30	Endevco	31485
10/4/2012	Clark Testing	4086	Torque Wrench	Digitork 25 - 250' lbs	Craftsman	5100903873

Figure 11. Equipment Calibration List (Continued on next page)

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Traceability Report

Status	Location	Mcbee #	Instrument	Model #	Manfacturer	Serial #
6/19/2012	CLARK TESTING	10050	Signal Conditioner	2310	Vishay Instruments	033556
3/4/2012	Clark Testing	4087	Accelerometer	7290A-30	Endevco	35838
3/10/2012	CLARK TESTING	4091	TORQUE WRENCH	85055 (0 ------ 600 FT/L	GEARWRENCH	110132916
3/30/2012	Clark Testing	1160	Strain Bolt 1/2 - 13NC x 2-	SXS-FB 350 OHMS	STRAINSERT	Q20849-3
3/4/2012	Clark Testing	4088	Accelerometer	7290A-30	Endevco	35840
9/14/2012	CLARK TESTING	4242	LOAD BOLT 7/8 x 9 x 3	SXS - 350	STRAINSERT	STAMP # 37
10/3/2012	Clark Testing	4243	Torque Wrench	25-250 ft/lbs	Craftsman Digitork	5110597689

Figure 11. Equipment Calibration List

APPENDIX I

CLARK TESTING LABORATORY
TEST RECORD LOGBOOK

Appendix I Page 2 of 8

UUT Number: UUT 1

Type of Unit: MH4, IEC CLASS 4 ARRESTER

Serial Number: MH4420GH420 AAA

Model Number: —

Weight of Unit: 938 LBS

RECEIPT INSPECTION

No apparent damage to outside containers upon receiving
No apparent damage to individual pieces of unit

Signature(s) person making entry: [signature] / [signature] Date 12/16/11
Read and understood by [signature] Date 1/30/12

Appendix I Page 3 of 8

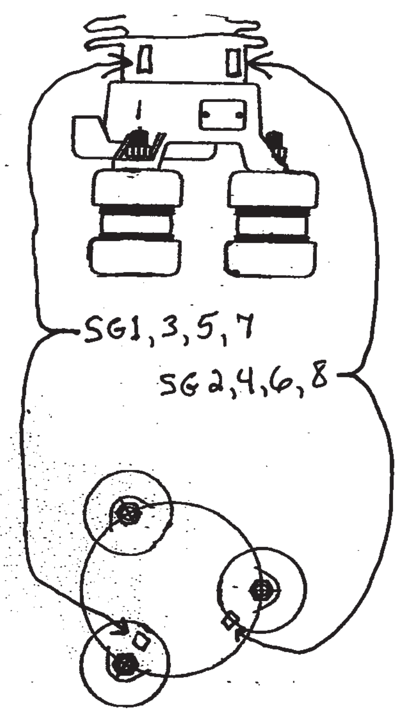
12-17-11

START APPLYING STRAIN GAGES ON BOTTOM SECTION ONLY OF EACH OF THE 4 UUT'S. EACH ONE WILL GET 2 GAGES

12-18-11

CONTINUED MOUNTING STRAIN GAGES

TYPICAL STRAIN GAGE LOCATIONS FOR ALL 4 UUT'S



STRAIN GAGE DATA SHEET FOR ALL STRAIN GAGES

MM MICRO-MEASUREMENTS & SR-4®

General Purpose

STRAIN GAGES

FOR COMPLETE TECHNICAL DATA, VISIT WWW.VISHAYPG.COM

GRID RESISTANCE IN OHMS	TC OF GAGE FACTOR, %/100°C
350.0±0.3%	(+1.3±0.2)

GRID	GAGE FACTOR @ 24°C	TRANSVERSE SENSITIVITY
1	2.115±0.5%	(+0.2 ±0.2)%
2		
3		
NOM		

THERMAL OUTPUT COEFFICIENTS FOR 1018 Steel

ORDER	FAHRENHEIT	CELSIUS
0	-2.34E+2	-1.03E+2
1	+4.93E+0	+5.94E+0
2	-2.75E-2	-7.65E-2
3	+4.01E-5	+2.34E-4
4	0.00 E+0	0.00 E+0

FOIL LOT NUMBER A65AD833 BATCH NUMBER VF498617

ITEM CODE	QUANTITY	CODE
3247	5	212312

RoHS COMPLIANT

MADE IN UNITED STATES

CEA-06-250UW-350

Signature(s) person making entry: [signature] Date 12-18-11

Read and understood by: [signature] Date 1/30/12

12-19-11

CLARK MACHINIST LAIDOUT BOTTOM OF FIXTURE ~~AN~~ CK 12-19-11 TO FIT MOUNTING PLATE - DRILLED (4) 1" HOLES FOR THRU BOLTS INTO MOUNTING PLATE. ALSO MATCHED AND DRILLED (3) 1/2-13 HOLES ON TOP OF FIXTURE FOR MOUNTING OF ARRESTER.

MOUNTED FIXTURE TO ~~MOUNTING PLATE~~ CK 12-19-11 4'X4'X2" MOUNTING PLATE USING (3) 7/8"-9 BOLTS TORQUED TO 350 FT.LBS AND (1) 7/8 STRAIN BOLT TORQUED TO 350 FT.LBS.

MOUNTED (3) ARRESTER ~~INSULATING~~ SUBBASE UNITS TO TOP OF FIXTURE

MOUNTED ACCELEROMETERS TO ARRESTOR (1) TRIAXIAL ON TOP OF ARRESTOR ALSO (1) BIAXIAL ON CG OF ARRESTOR AND (1) TRIAXIAL ON TOP OF FIXTURE.

ASSEMBLED ARRESTOR USING (6) 1/2-13 BOLTS TORQUED TO 45 FT. LBS.

INSTALLED TERMINAL PAD AND GRADING RING USING (3) 1/2-13 BOLTS TORQUED TO 45 FT LBS.

ADDED 15LBS WEIGHT ONTO TERMINAL PAD USING (2) 1/2-13 BOLTS TORQUED TO 45 FT.LBS

CHANNEL ASSIGNMENT

NAME	MCREE	LOCATION
A1-FB	4180	
A2-SS	4088	TABLE CONTROL
A3-V	4087	
A4-FB	4174	
A5-SS	4186	TOP OF ARRESTER
A6-V	4138	
A7-FB	4184	
A8-SS	4185	TOP OF FIXTURE
A9-V	4139	
A10-FB	4183	BIAXLE ON CG
A11-SS	4176	

Signature(s) person making entry: Craig Kuiper Date 12-19-11

Read and understood by: JR Antunes Date 1/30/12

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12-19-11

EQUITMENT LIST

ITEM	MCREE	CAL. DUE DATE
ACCELEROMETER	4180	1-10-12
"	4088	3-4-12
"	4087	3-4-12
"	4174	1-10-12
"	4186	7-25-12
"	4138	9-22-12
"	4184	7-25-12
"	4185	7-25-12
"	4139	9-23-12
"	4183	7-25-12
ACCELOROMETER	4176	1-10-12
VR	4055	6-16-12
"	4056	6-16-12
"	4057	6-16-12
"	4058	6-16-12
"	4059	6-16-12
VR	4060	6-16-12
TORQUE WRENCH	4091	3-10-12
"	4243	10-3-12
TORQUE WRENCH	4086	10-4-12
VISAY	10050	6-19-12
"	10236	6-19-12
"	10246	6-19-12
Strain bolt	4242	9-14-12
"	1160	3-30-12

Signature(s) person making entry: Craig Kiefer Date 12-19-11

Read and understood by: JR Antonucci Date 1/30/12

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12-20-11

THE FIRST UNIT TESTED WILL BE UUT1 WHICH IS THE MH4420GH420 WHICH CONSISTS OF:

25 LBS. 272807-3001 GRADING RING
290 LBS. PSEMH4UAG40144 TOP
285 LBS. " 144
290 LBS. " 132 BOTTOM
39 LBS. (3) ARRESTOR INSULATING SUBBASE (13 LBS. EACH)
9 LBS. LINE TERMINAL

Additional to the (11) accelerometers for first seismic set-up. (2) strain gages (1) Strain bolt.

Name	Mcbee	Location
SG1-FB		→ Bottom section
SG2-SS		→ Bottom section
SB1	4242	→ front-Right base of Pedestal (fixture)

PERFORMED SINE SWEEP SIDE TO SIDE AXIS 1-34-1HZ. .07g (1 OCT-MIN)

PERFORMED SINE SWEEP ~~SIDE~~ FRONT TO BACK AXIS 1-34-1HZ. .07g (1OCT/MIN) 12-20-11 CK

PERFORMED SINE SWEEP VERTICAL AXIS 1-34-1HZ. .07g (1 OCT/MIN)

Run 1
Performed IEEE 693 Seismic Earthquake 1.0g ZPA
Post inspection No apparent change.
Performed Post sine Sweep Side to Side axis 1-34 Hz @ .07g (1oct/min)
Note: During sweep noticed arrester moving more than the Pre-sweeps.

Signature(s) person making entry: [signature] Date 12-20-11
Read and understood by: Mark Jacobvice Date 12-20-11

Appendix I Page 7 of 8

12-20-11

Per Customer - Retorqued the standoff mounting bolts, and start sweep over.

Performed sine sweep side to side axis 1-34Hz @ .07 g (1oct/min)

Performed sine sweep front to back axis 1-34Hz @ .07 g (1oct/min)

Performed sine sweep vertical axis 1-34 Hz @ .07 g (1oct/min).

Note: when removing arrester from Pedestal. Found back-Left standoff mounting bolt was slightly yielded. Photo taken.

The following spread sheet from Run 1 Peak Levels.

T5453	Run 1		
	Min	Max	
A1-FB	-1.25	1.12	g's
A2-SS	-1.27	1.33	
A3-V	-.88	.91	
A4-FB	-4.32	3.69	
A5-SS	-3.91	4.57	
A6-V	-1.06	1.01	
A7-FB	-2.24	2.25	
A8-SS	-2.55	2.20	
A9-V	-.88	.94	
A10-FB	-3.37	2.48	
A11-SS	-2.54	2.85	
Sg.1	-682	521	u"
Sg2	-465	473	u"
SB.1	4,406	2,863	lbs.
RD4	-5.07	5.01	inches
RD5	-6.85	6.36	
RD4 [illegible]	-5.32	5.29	
RD5 [illegible]	-7.32	6.85	

Signature(s) person making entry: Mark Jacovino Date 12-20-11

Read and understood by: JR [illegible] Date 1/30/12

Appendix I Page 8 of 8

Clark Testing Laboratory

Contract Number: ANT:5453

Customer: Hubbell Power Systems.

Test Specification: IEEE693-2005 (Arrester Seismic)

Steps Completed: Frequency Searches (Before and After) 1.0g zpa Performance Level Seismic

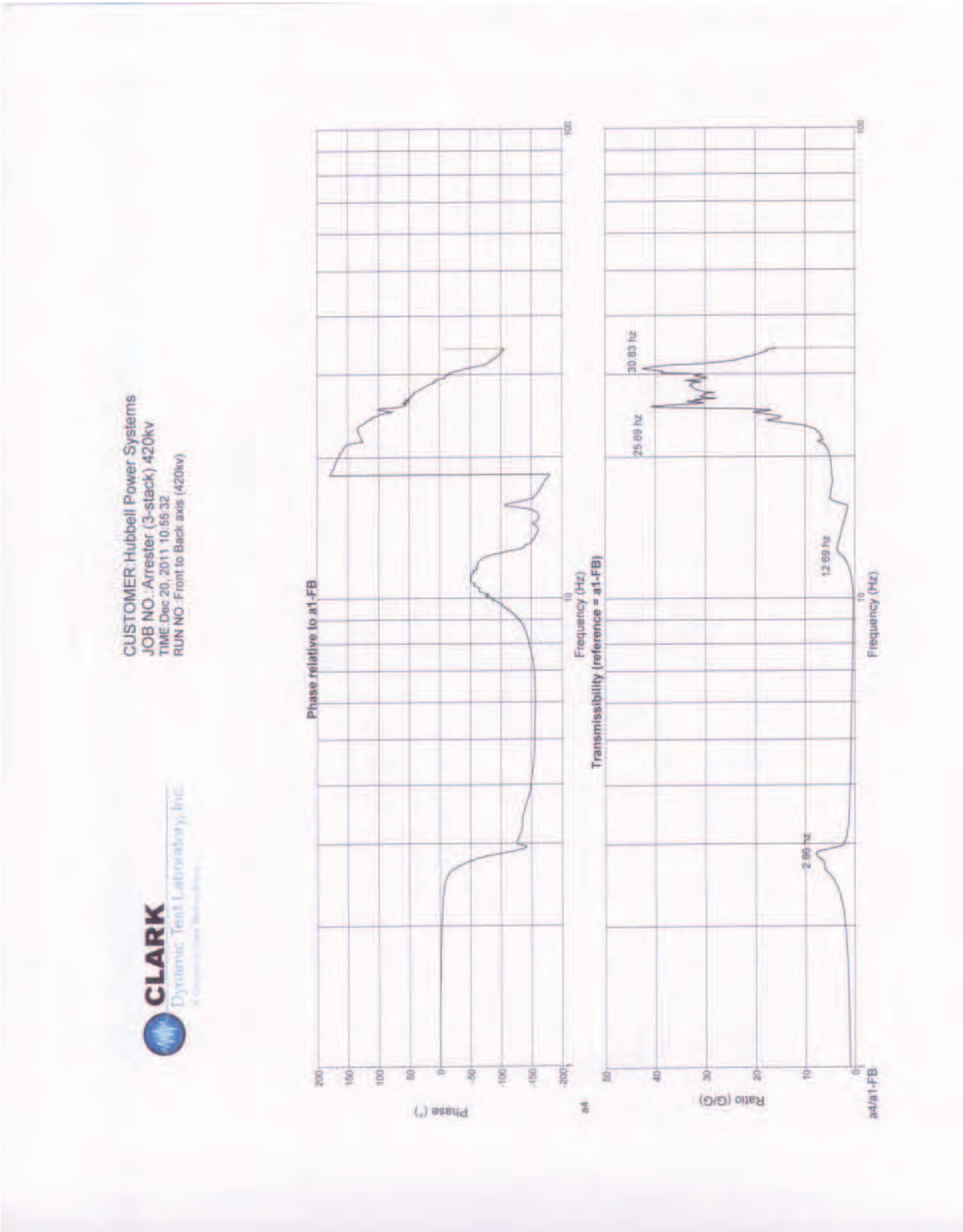
Authorized Customer Representative/Date:

Reviewed by Clark Dynamic Q.A./Date: [signature] 2/1/12

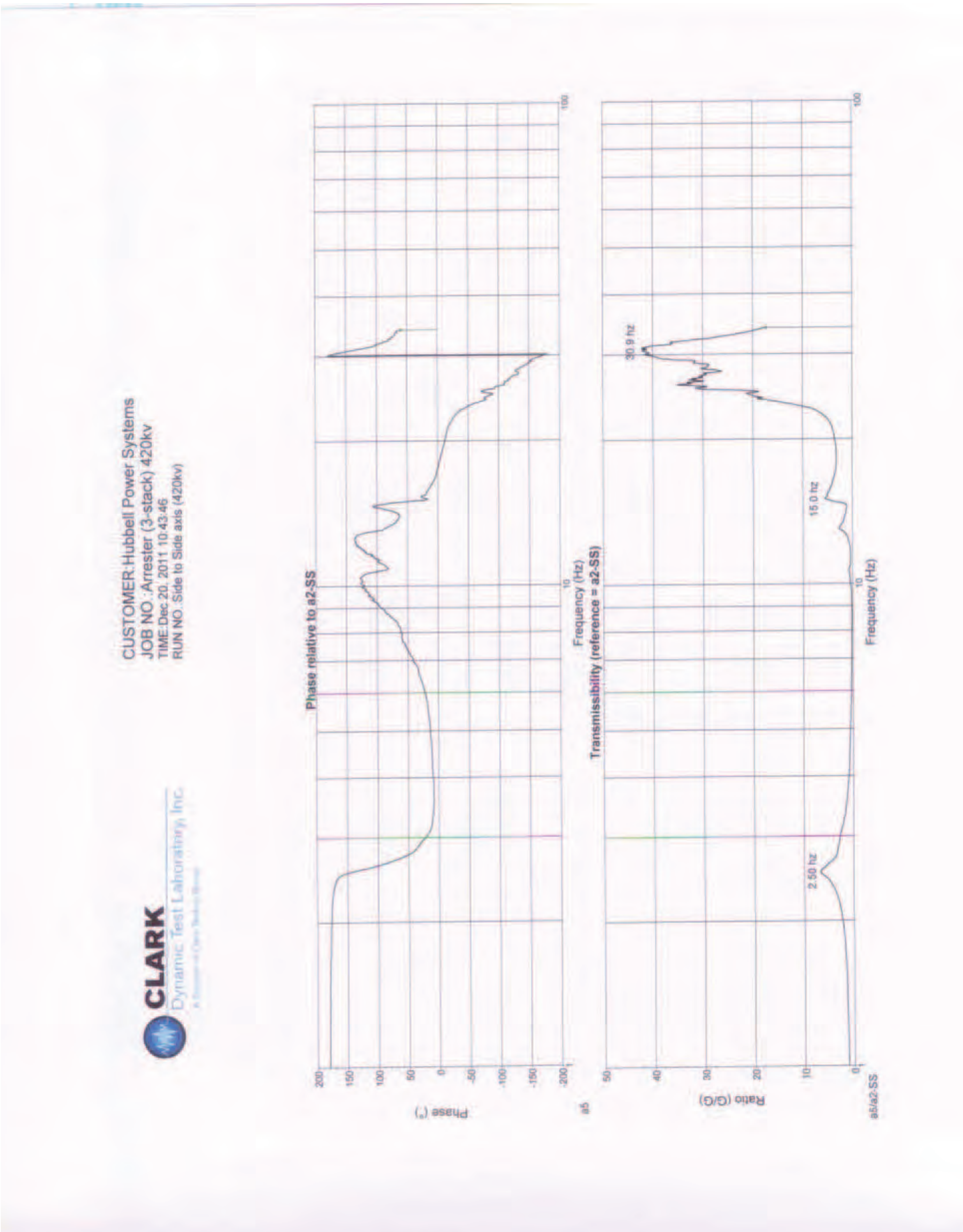
Read and understood by - witness [signature] Date 1/30/12

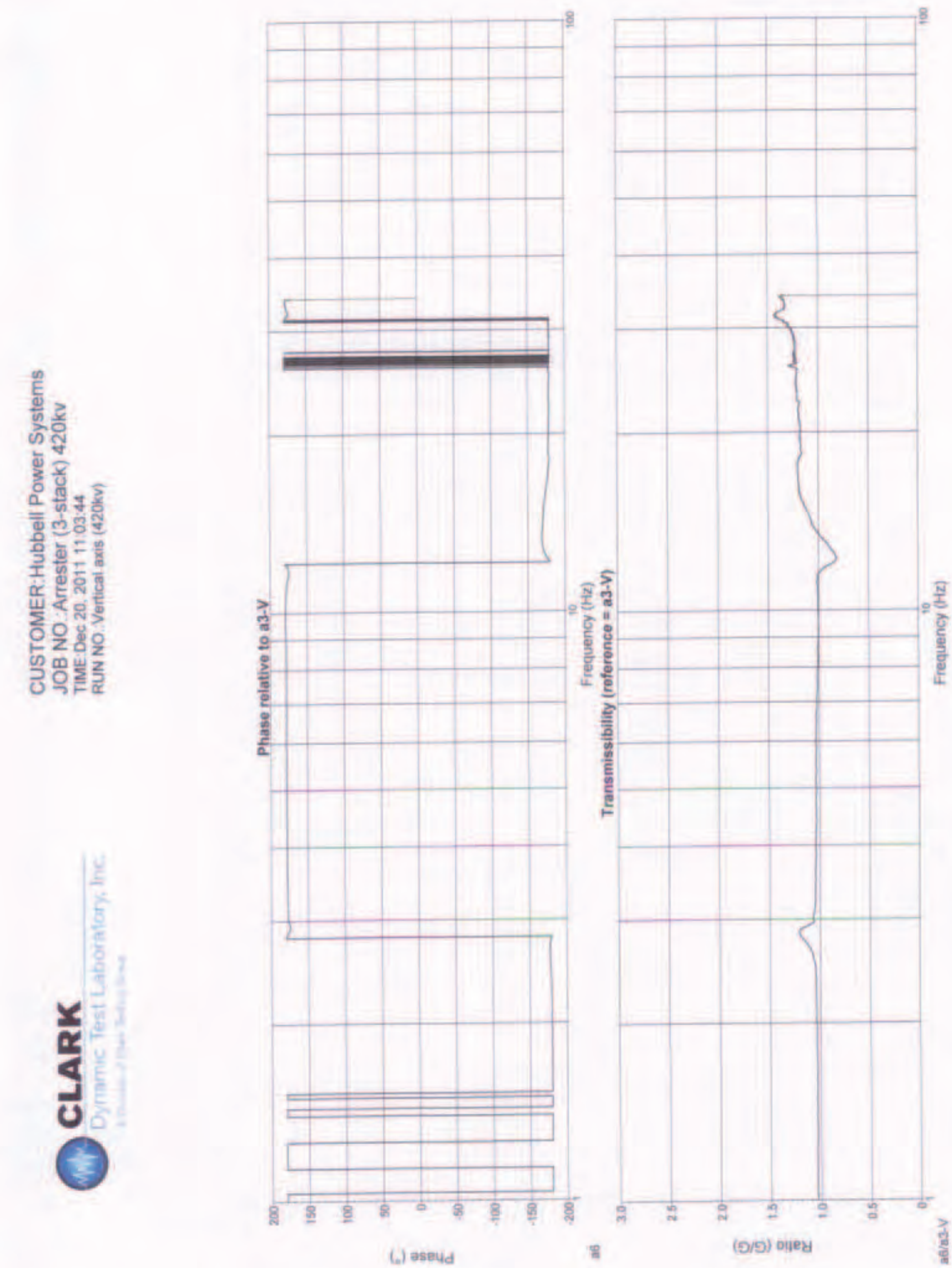
APPENDIX II

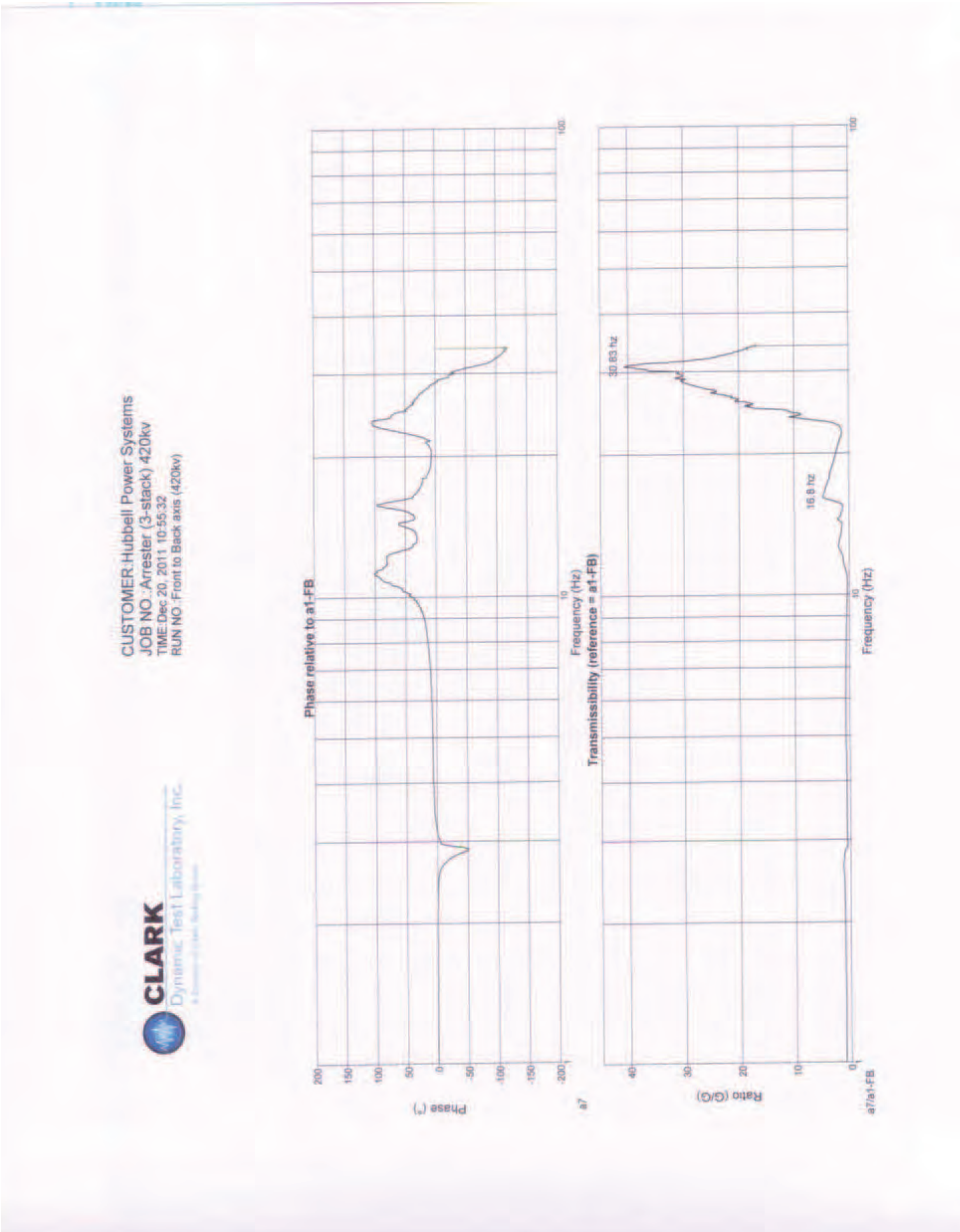
TRANSMISSIBILITY PLOTS

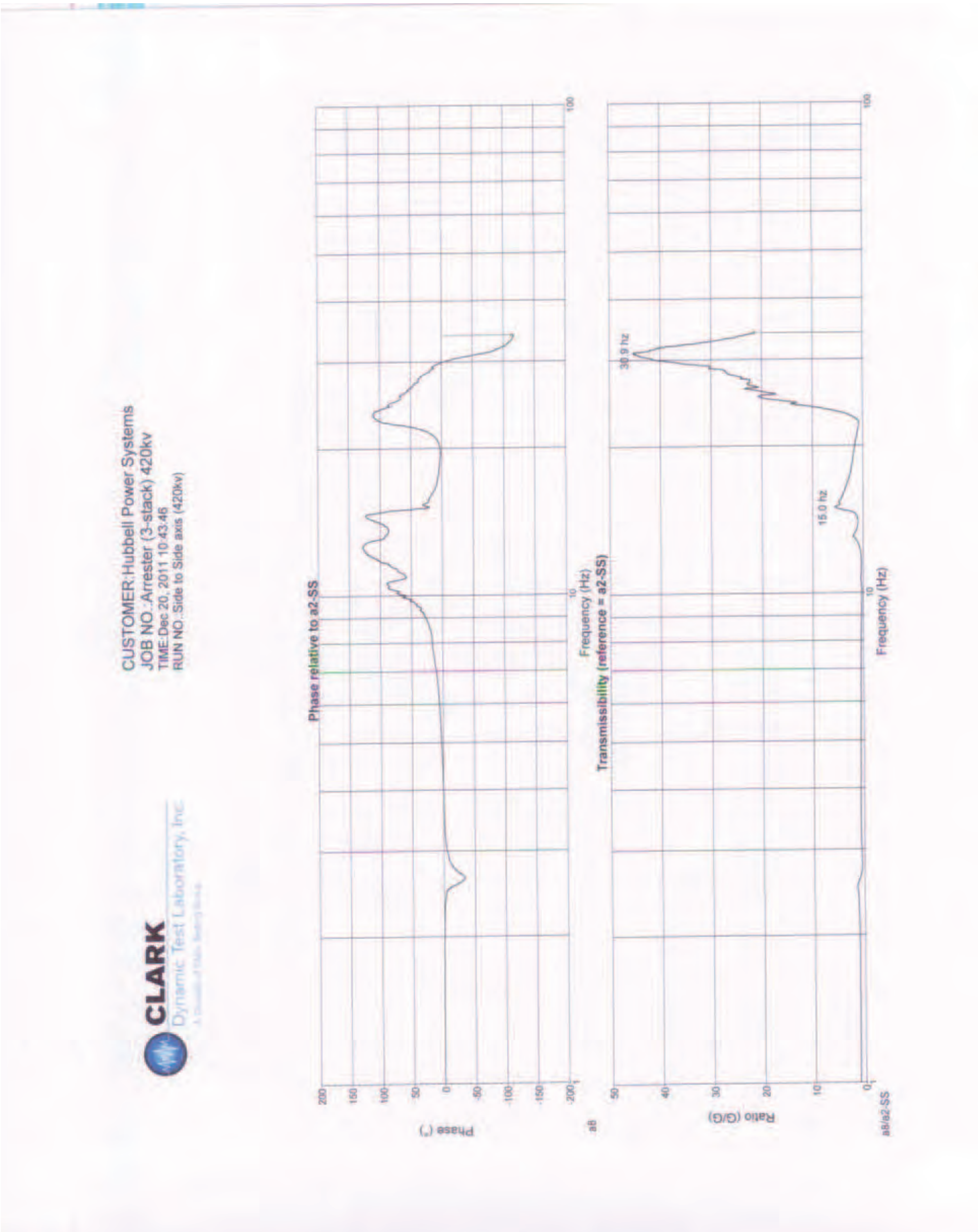


CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER: Hubbell Power Systems
JOB NO.: Arrester (3-stack) 420kv
TIME: Dec 20, 2011 10:55:32
RUN NO.: Front to Back axis (420kv)
Phase relative to a1-FB
Phase (°)
a4
Frequency (Hz)
Transmissibility (reference = a1-FB)
Ratio (G/G)
a4/a1-FB
2.96 hz
12.69 hz
25.69 hz
30.83 hz
Frequency (Hz)

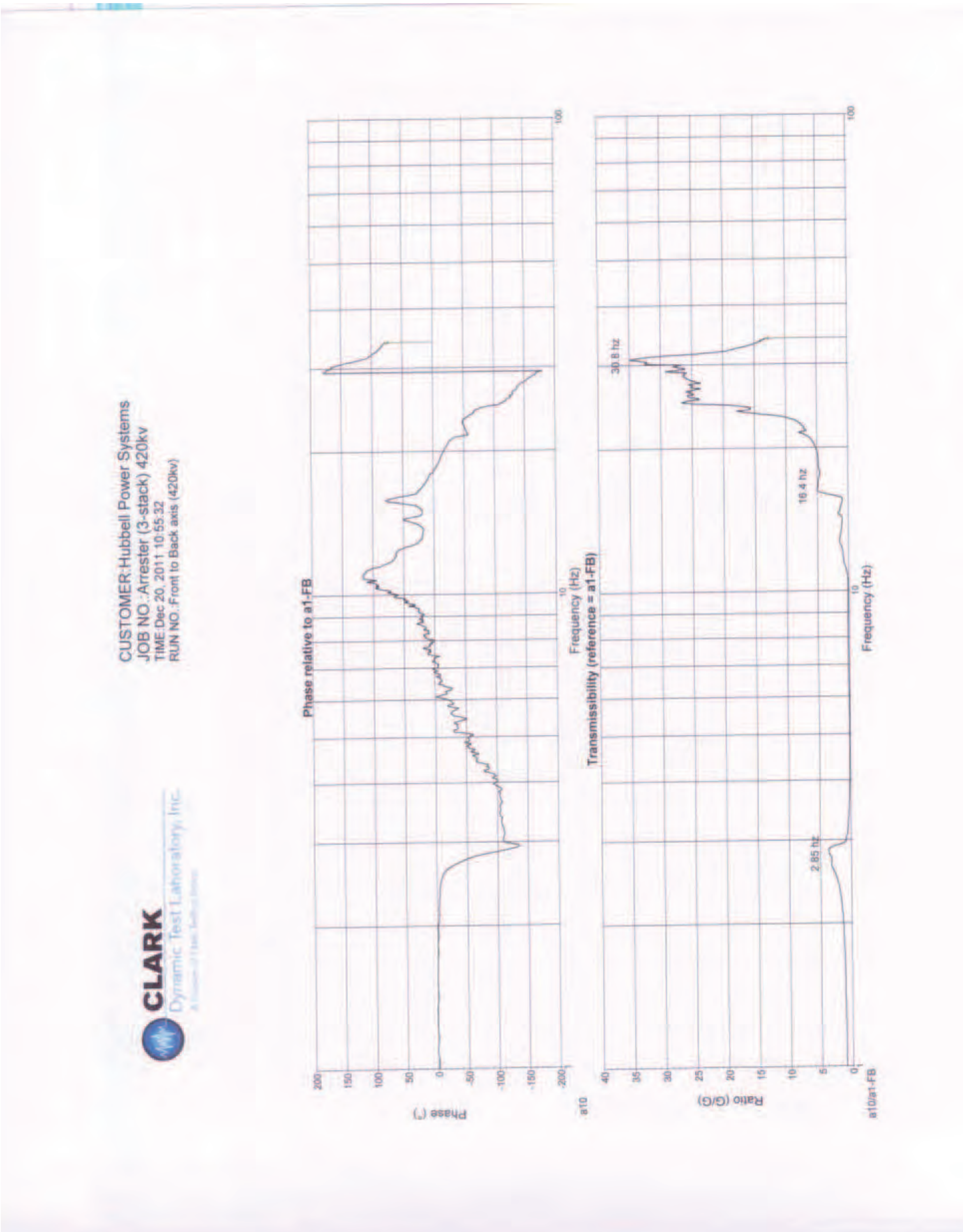

CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER:Hubbell Power Systems
JOB NO.:Arrester (3-stack) 420kv
TIME:Dec 20, 2011 10:43:46
RUN NO.:Side to Side axis (420kv)
Phase relative to a2-SS
Phase (°)
a5
Frequency (Hz)
Transmissibility (reference = a2-SS)
Ratio (G/G)
a5/a2-SS
30.9 hz
15.0 hz
2.50 hz
Frequency (Hz)

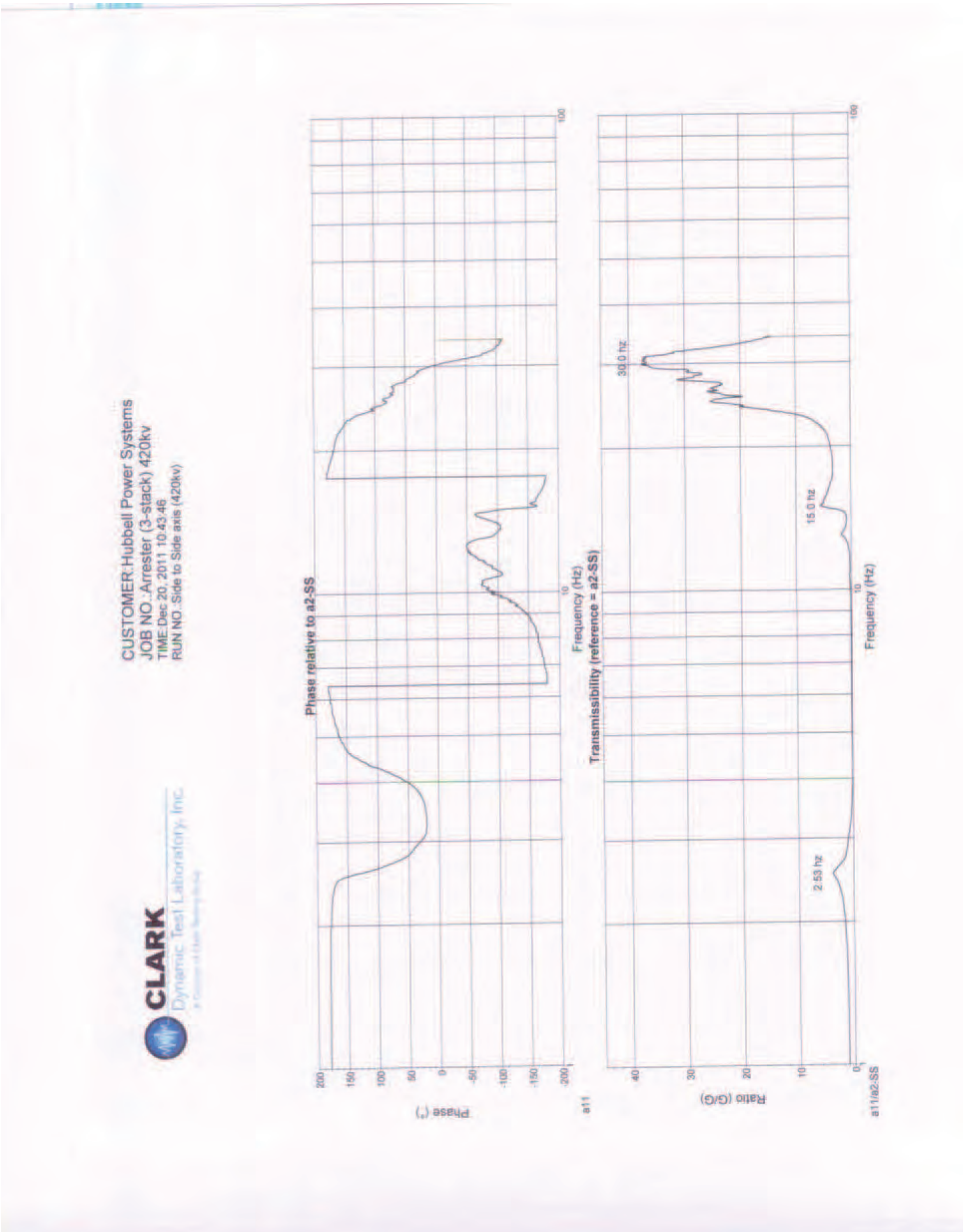

CUSTOMER:Hubbell Power Systems
JOB NO.:Arrester (3-stack) 420kv
TIME:Dec 20, 2011 11:03:44
RUN NO.:Vertical axis (420kv)
CLARK
Dynamic Test Laboratory, Inc
Phase relative to a3-V
Phase (°)
a6
Frequency (Hz)
Transmissibility (reference = a3-V)
Ratio (G/G)
a6/a3-V
Frequency (Hz)

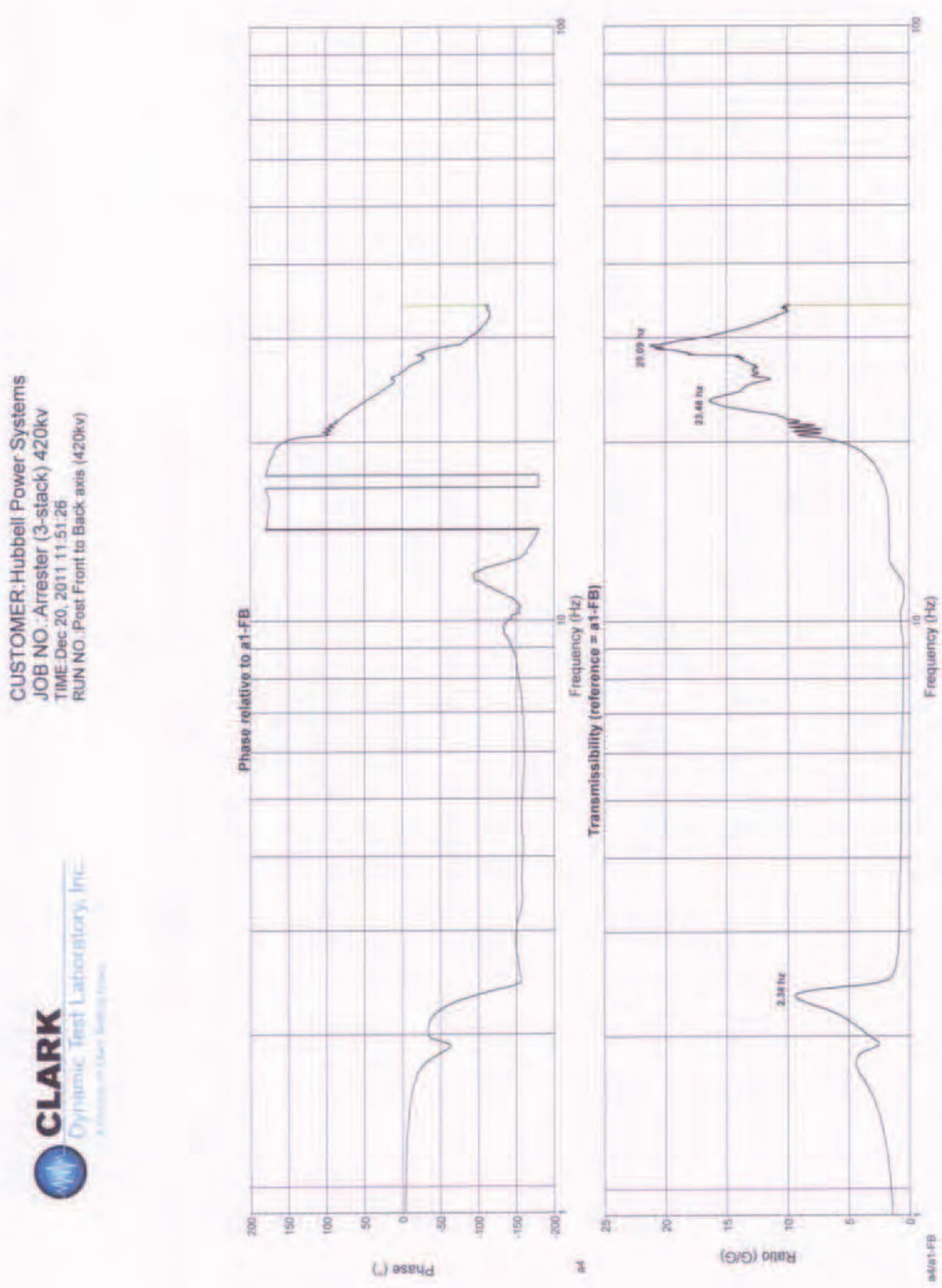

CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER:Hubbell Power Systems
JOB NO.:Arrester (3-stack) 420kv
TIME:Dec 20, 2011 10:55:32
RUN NO.:Front to Back axis (420kv)
Phase relative to a1-FB
Phase (°)
a7
Frequency (Hz)
Transmissibility (reference = a1-FB)
Ratio (G/G)
30.83 hz
16.8 hz
a7/a1-FB
Frequency (Hz)

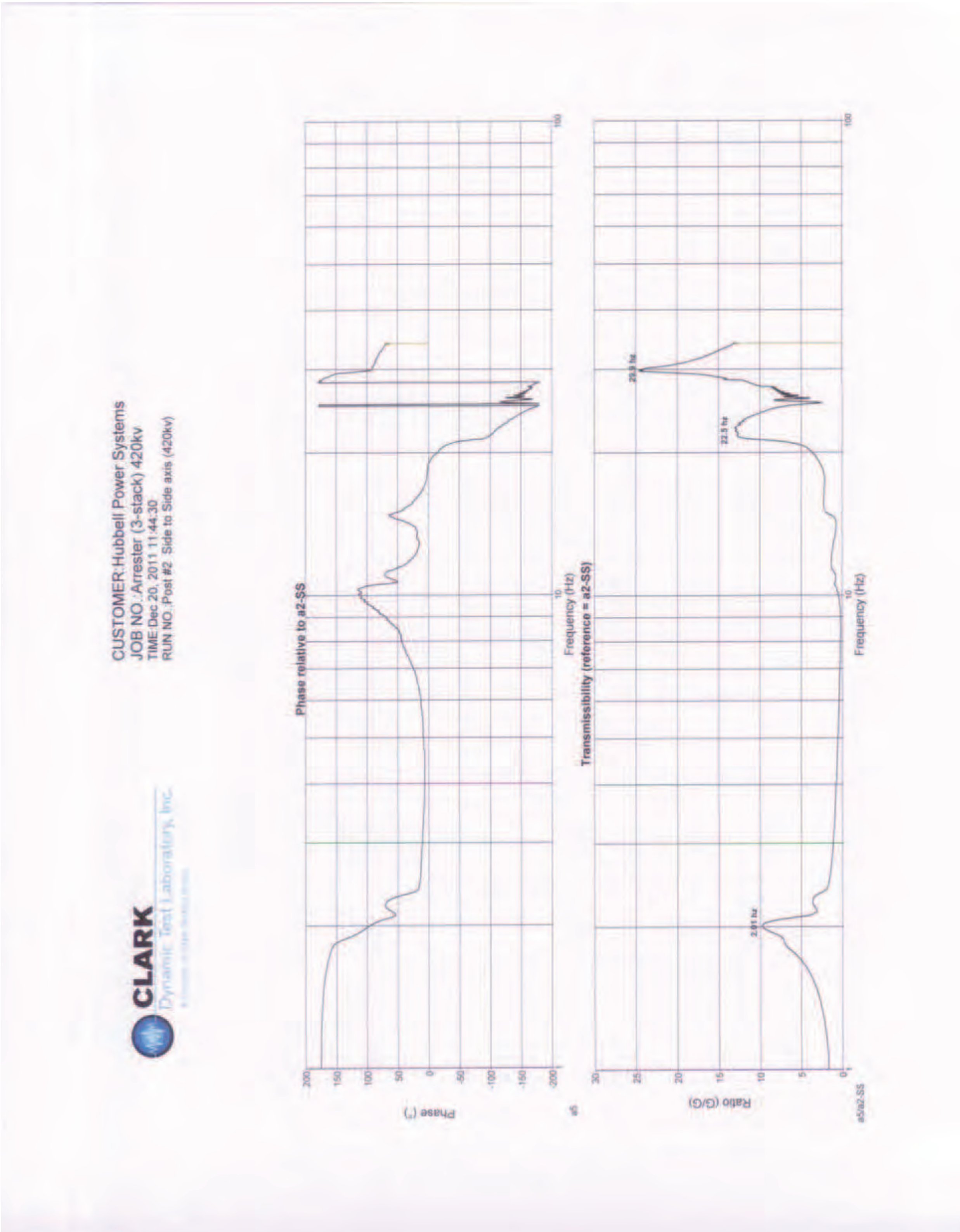

CLARK
Dynamic Test Laboratory, Inc
CUSTOMER:Hubbell Power Systems
JOB NO.:Arrester (3-stack) 420kv
TIME:Dec 20, 2011 10:43:46
RUN NO.:Side to Side axis (420kv)
Phase relative to a2-SS
Phase (°)
Frequency (Hz)
a8
Transmissibility (reference = a2-SS)
Ratio (G/G)
30.9 hz
15.0 hz
Frequency (Hz)
a8/a2-SS

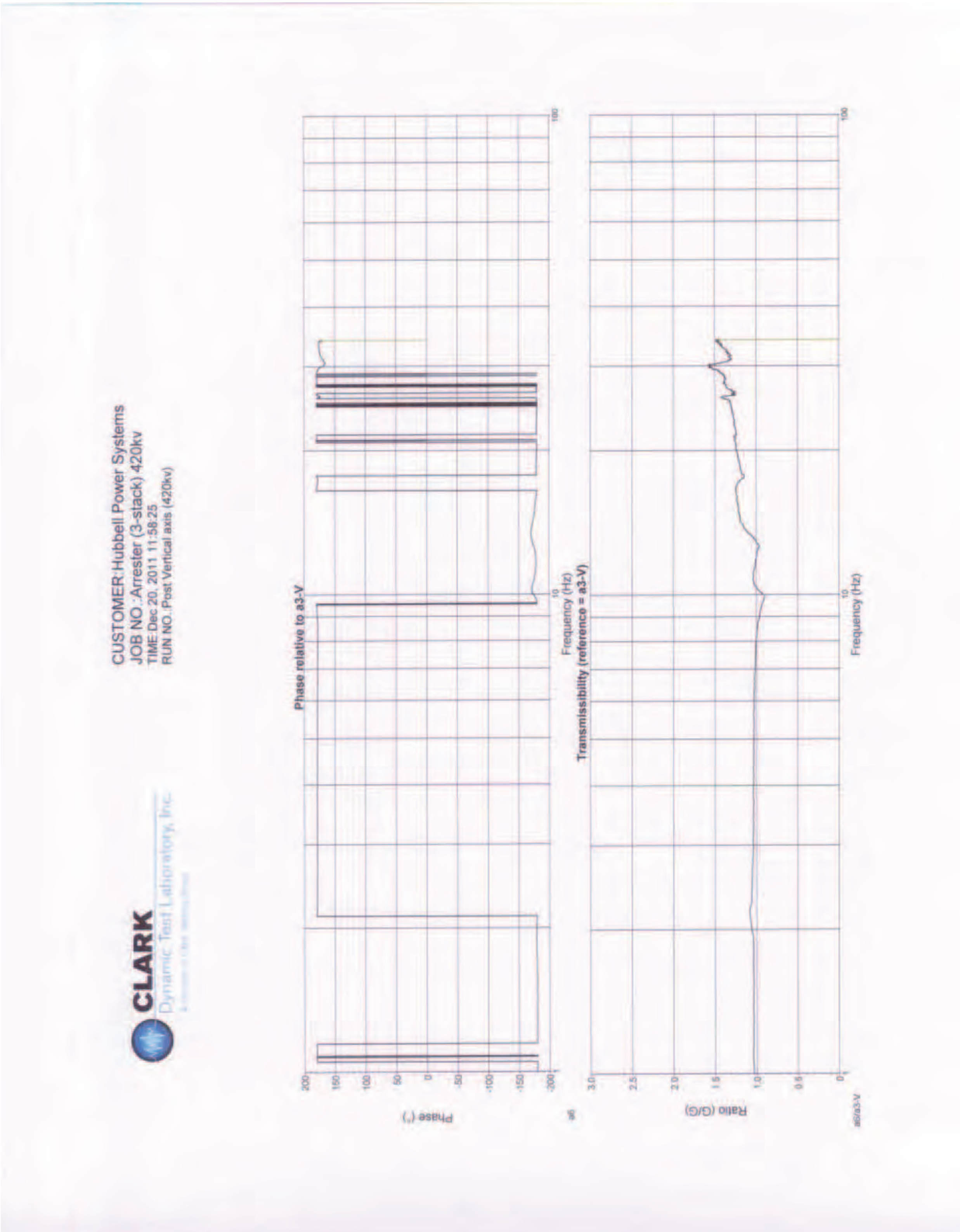

CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER:Hubbell Power Systems
JOB NO.:Arrester (3-stack) 420kv
TIME:Dec 20, 2011 11:03:44
RUN NO.:Vertical axis (420kv)
Phase relative to a3-V
Phase (°)
a9
Frequency (Hz)
Transmissibility (reference = a3-V)
Ratio (G/G)
a9/a3-V
Frequency (Hz)

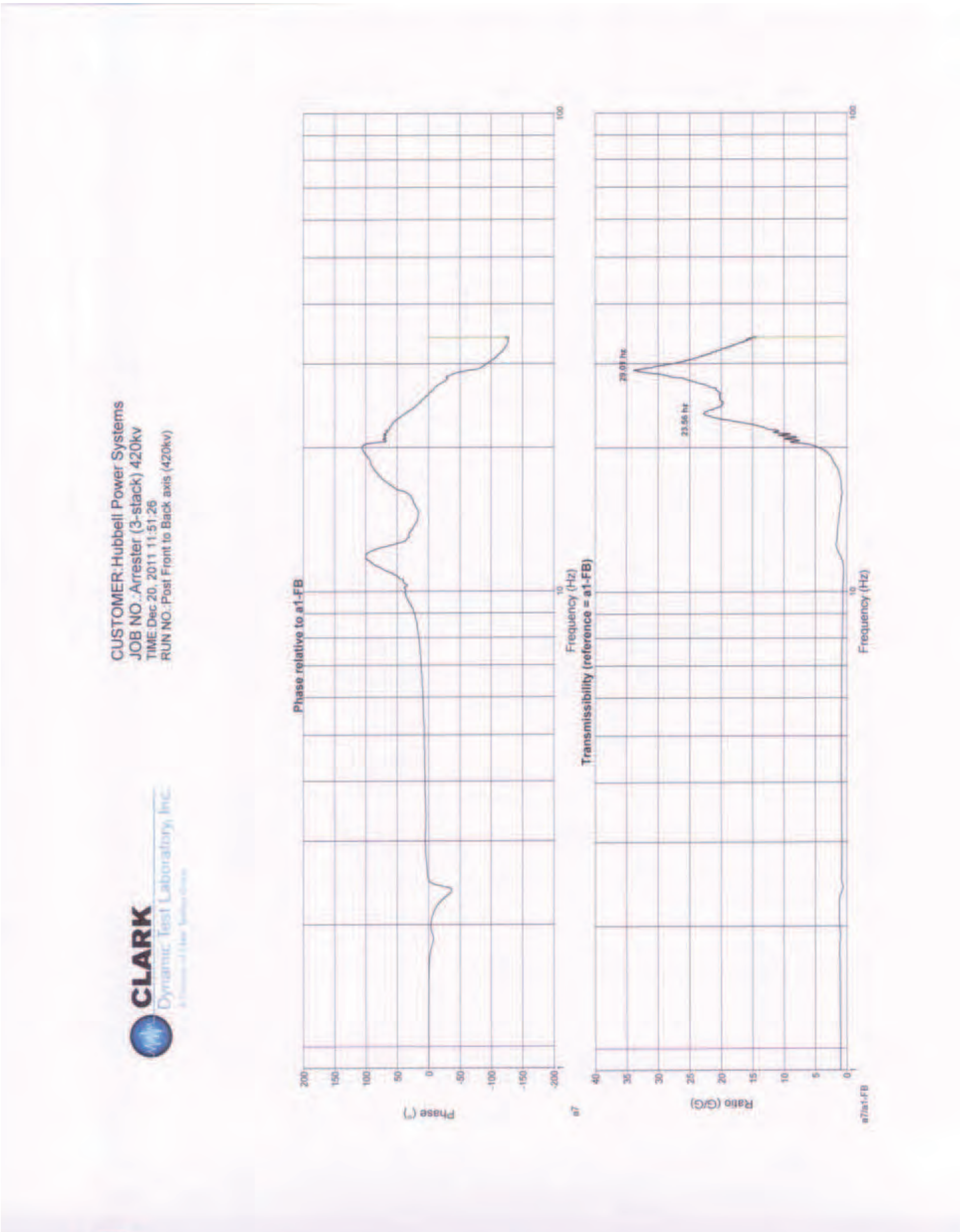

CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER:Hubbell Power Systems
JOB NO.:Arrester (3-stack) 420kv
TIME:Dec 20, 2011 10:55:32
RUN NO.:Front to Back axis (420kv)
Phase relative to a1-FB
Phase (°)
Frequency (Hz)
a10
Transmissibility (reference = a1-FB)
Ratio (G/G)
Frequency (Hz)
a10/a1-FB
2.85 hz
16.4 hz
30.8 hz

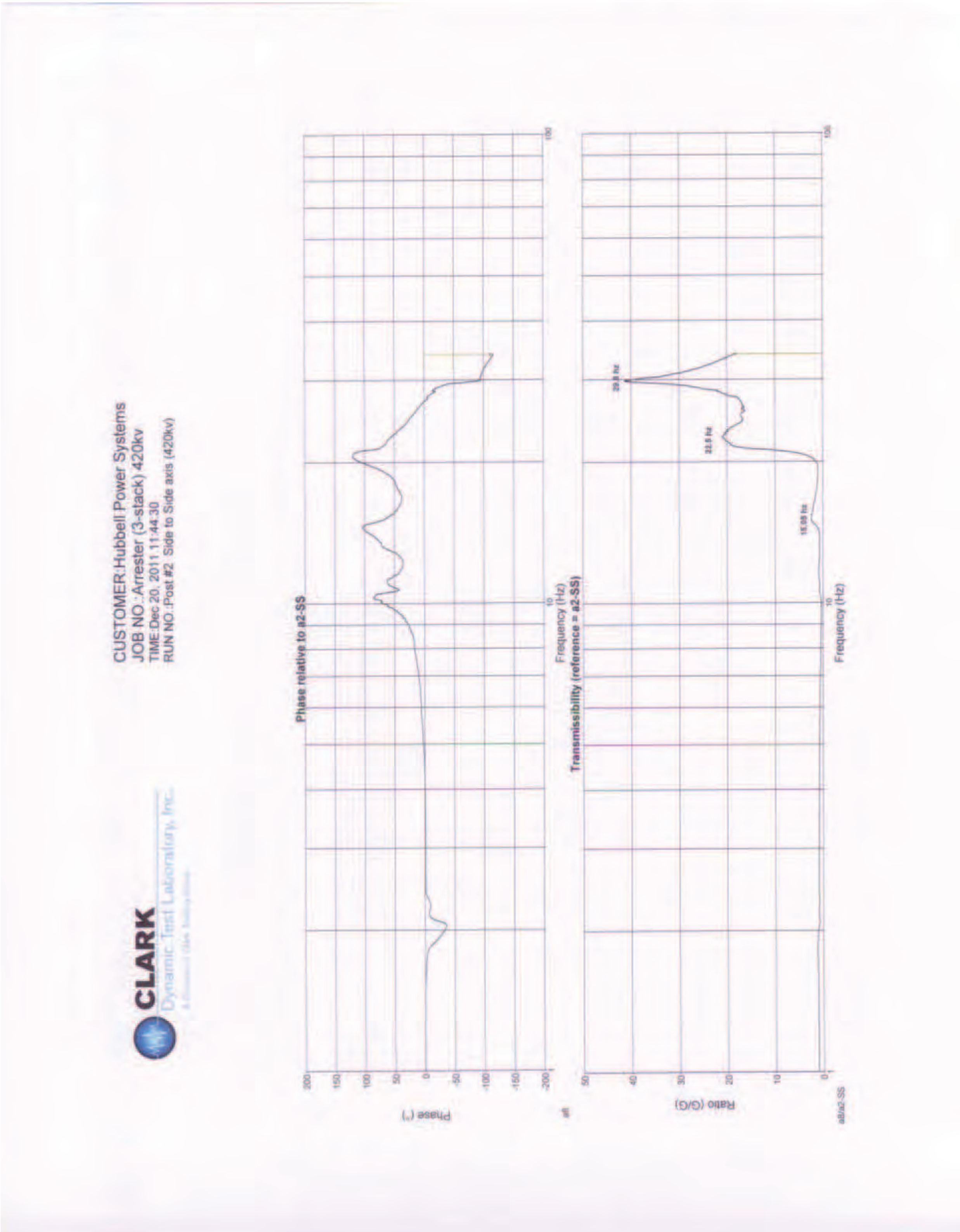

CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER:Hubbell Power Systems
JOB NO.:Arrester (3-stack) 420kv
TIME:Dec 20, 2011 10:43:46
RUN NO.:Side to Side axis (420kv)
Phase relative to a2-SS
Phase (°)
a11
Frequency (Hz)
Transmissibility (reference = a2-SS)
Ratio (G/G)
a11/a2-SS
2.53 hz
15.0 hz
30.0 hz
Frequency (Hz)

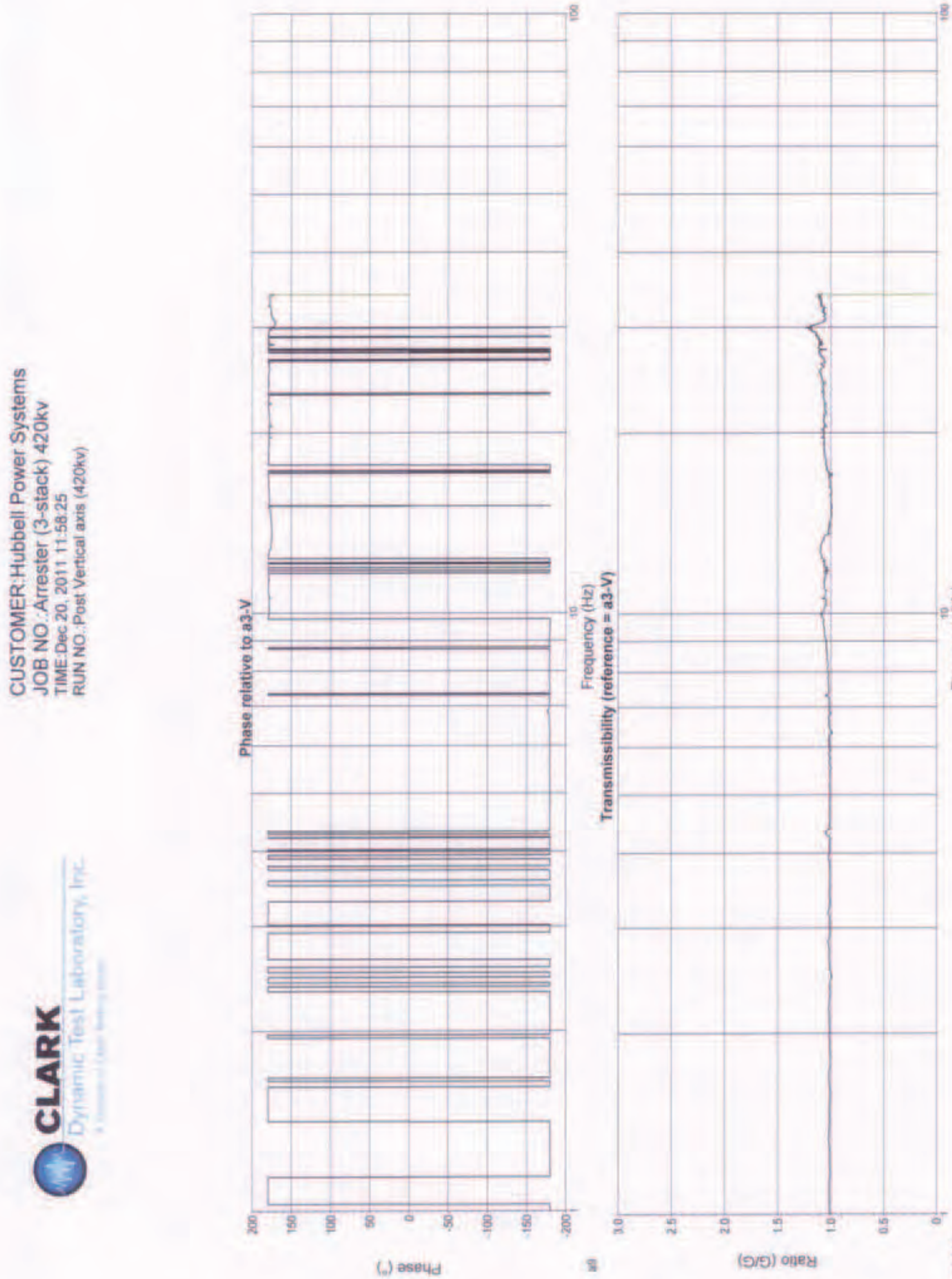

CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER:Hubbell Power Systems
JOB NO.:Arrester (3-stack) 420kv
TIME:Dec 20, 2011 11:51:26
RUN NO.:Post Front to Back axis (420kv)
Phase relative to a1-FB
Phase (°)
Frequency (Hz)
Transmissibility (reference = a1-FB)
Ratio (G/G)
Frequency (Hz)
2.38 hz
23.48 hz
25.09 hz

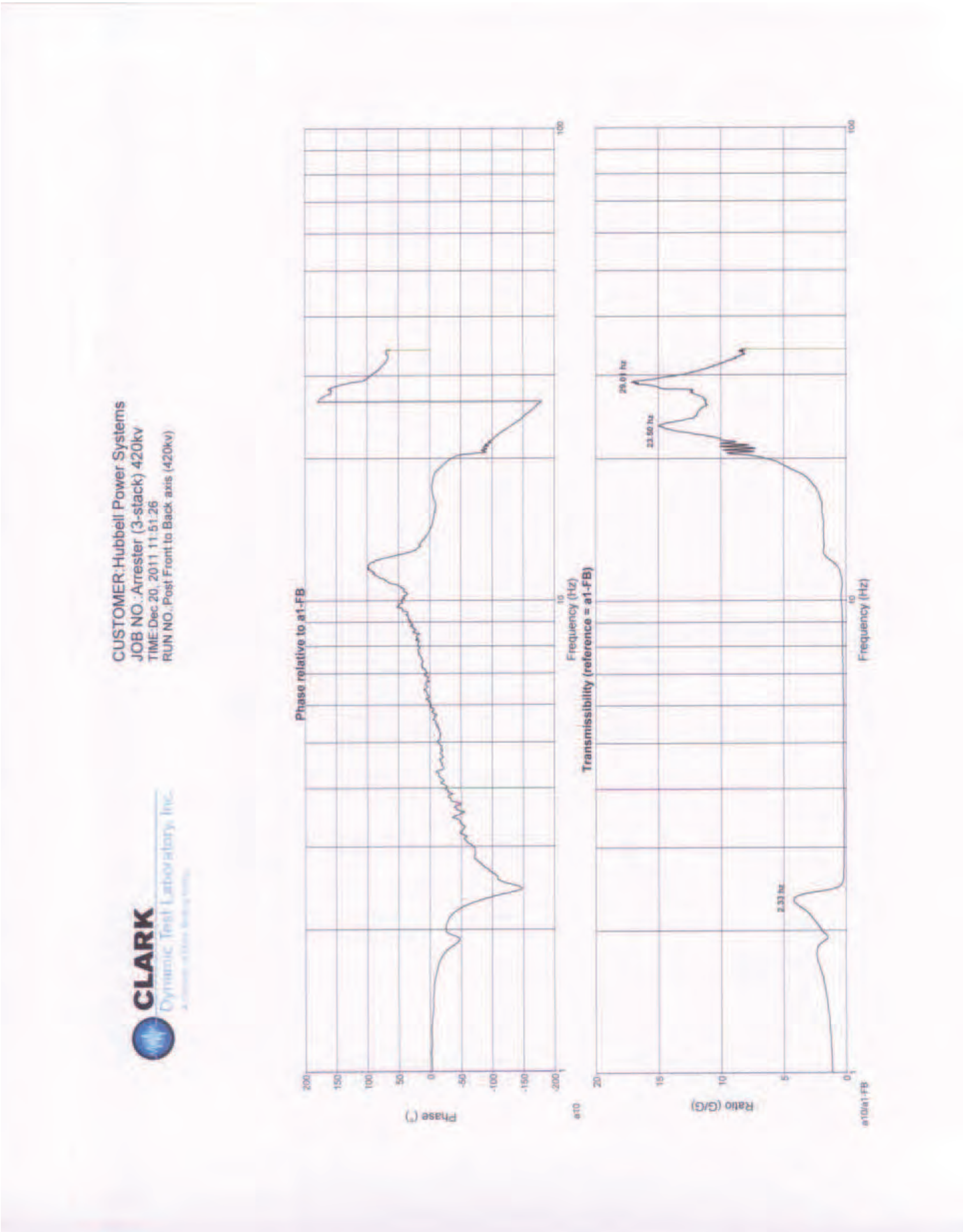

CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER: Hubbell Power Systems
JOB NO.: Arrester (3-stack) 420kv
TIME: Dec 20, 2011 11:44:30
RUN NO.: Post #2 Side to Side axis (420kv)
Phase relative to a2-SS
Phase (°)
Frequency (Hz)
Transmissibility (reference = a2-SS)
Ratio (G/G)
Frequency (Hz)

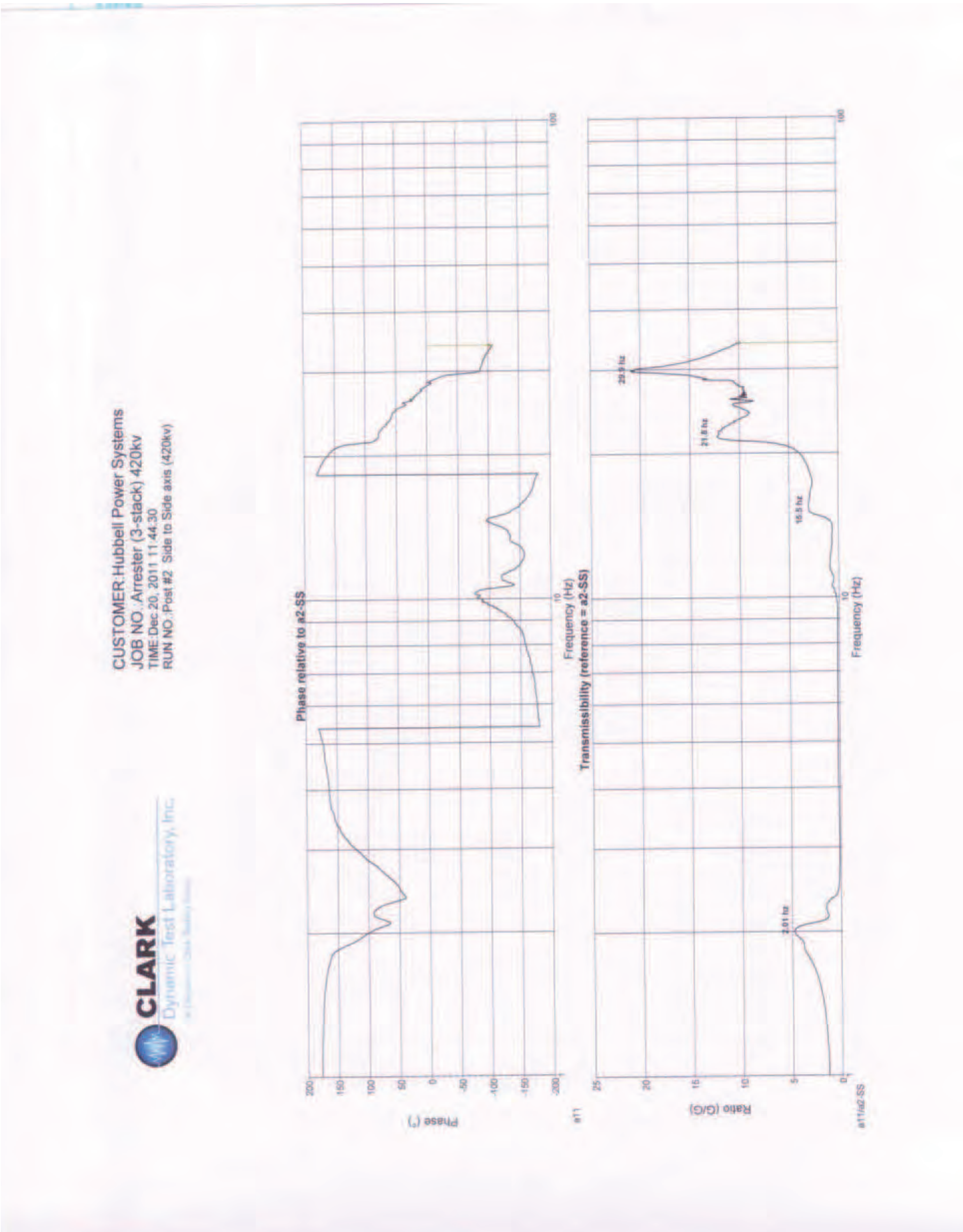

CUSTOMER:Hubbell Power Systems
JOB NO.:Arrester (3-stack) 420kv
TIME:Dec 20, 2011 11:58:25
RUN NO.:Post Vertical axis (420kv)
CLARK
Dynamic Test Laboratory, Inc.
Phase relative to a3-V
Phase (°)
Frequency (Hz)
Transmissibility (reference = a3-V)
Ratio (G/G)
Frequency (Hz)


CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER:Hubbell Power Systems
JOB NO.:Arrester (3-stack) 420kv
TIME:Dec 20, 2011 11:51:26
RUN NO.:Post Front to Back axis (420kv)
Phase relative to a1-FB
Phase (°)
Frequency (Hz)
Transmissibility (reference = a1-FB)
Ratio (G/G)
29.01 hz
23.56 hz
Frequency (Hz)


CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER:Hubbell Power Systems
JOB NO.:Arrester (3-stack) 420kv
TIME:Dec 20, 2011 11:44:30
RUN NO.:Post #2 Side to Side axis (420kv)
Phase relative to a2-SS
Phase (°)
Frequency (Hz)
Transmissibility (reference = a2-SS)
Ratio (G/G)
Frequency (Hz)
a8/a2-SS

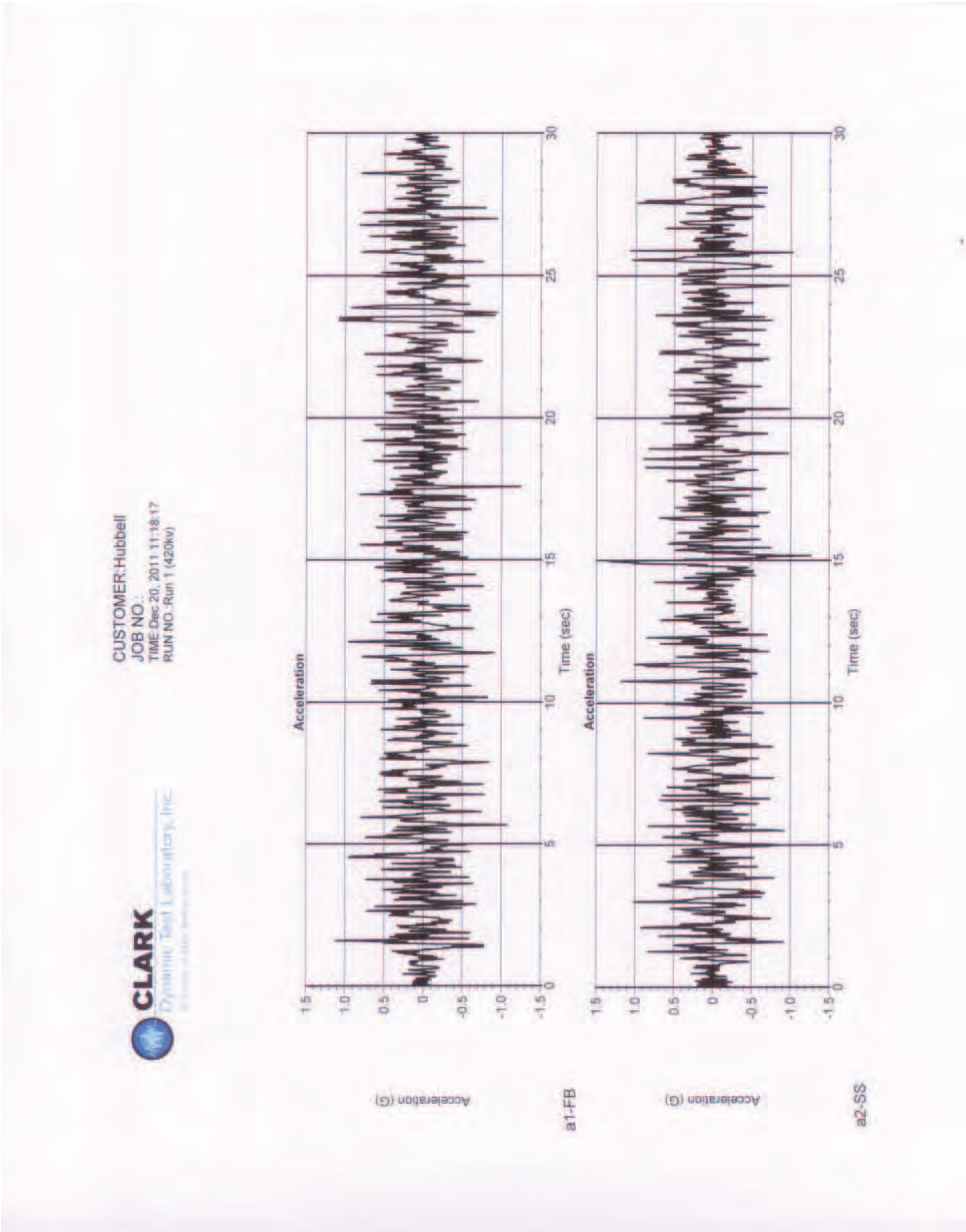

CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER:Hubbell Power Systems
JOB NO.:Arrester (3-stack) 420kv
TIME:Dec 20, 2011 11:58:25
RUN NO.:Post Vertical axis (420kv)
Phase relative to a3-V
Phase (°)
Frequency (Hz)
Transmissibility (reference = a3-V)
Ratio (G/G)
Frequency (Hz)

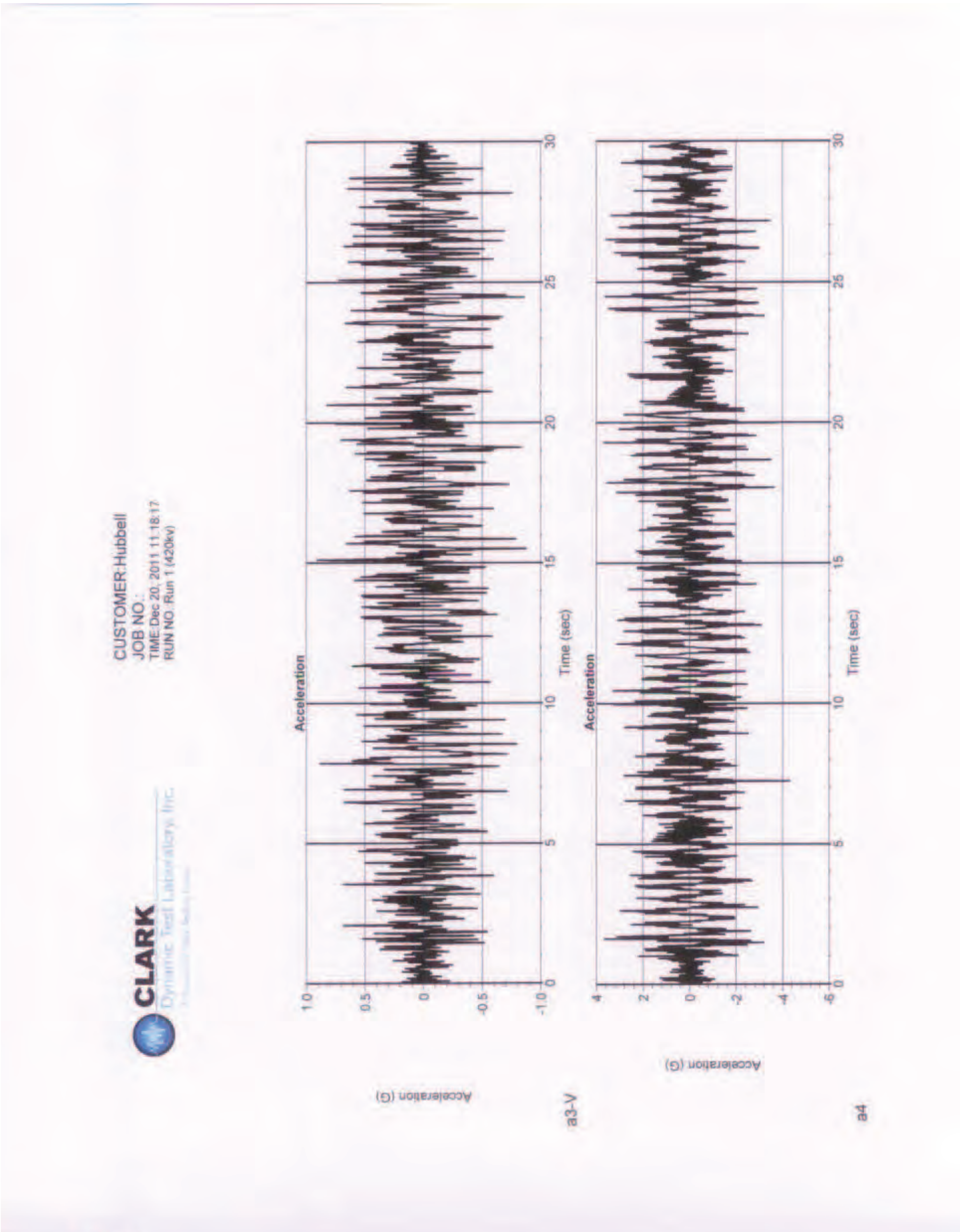

CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER:Hubbell Power Systems
JOB NO.:Arrester (3-stack) 420kv
TIME:Dec 20, 2011 11:51:26
RUN NO.:Post Front to Back axis (420kv)
Phase relative to a1-FB
Phase (°)
Frequency (Hz)
Transmissibility (reference = a1-FB)
Ratio (G/G)
29.01 hz
23.50 hz
2.33 hz
Frequency (Hz)

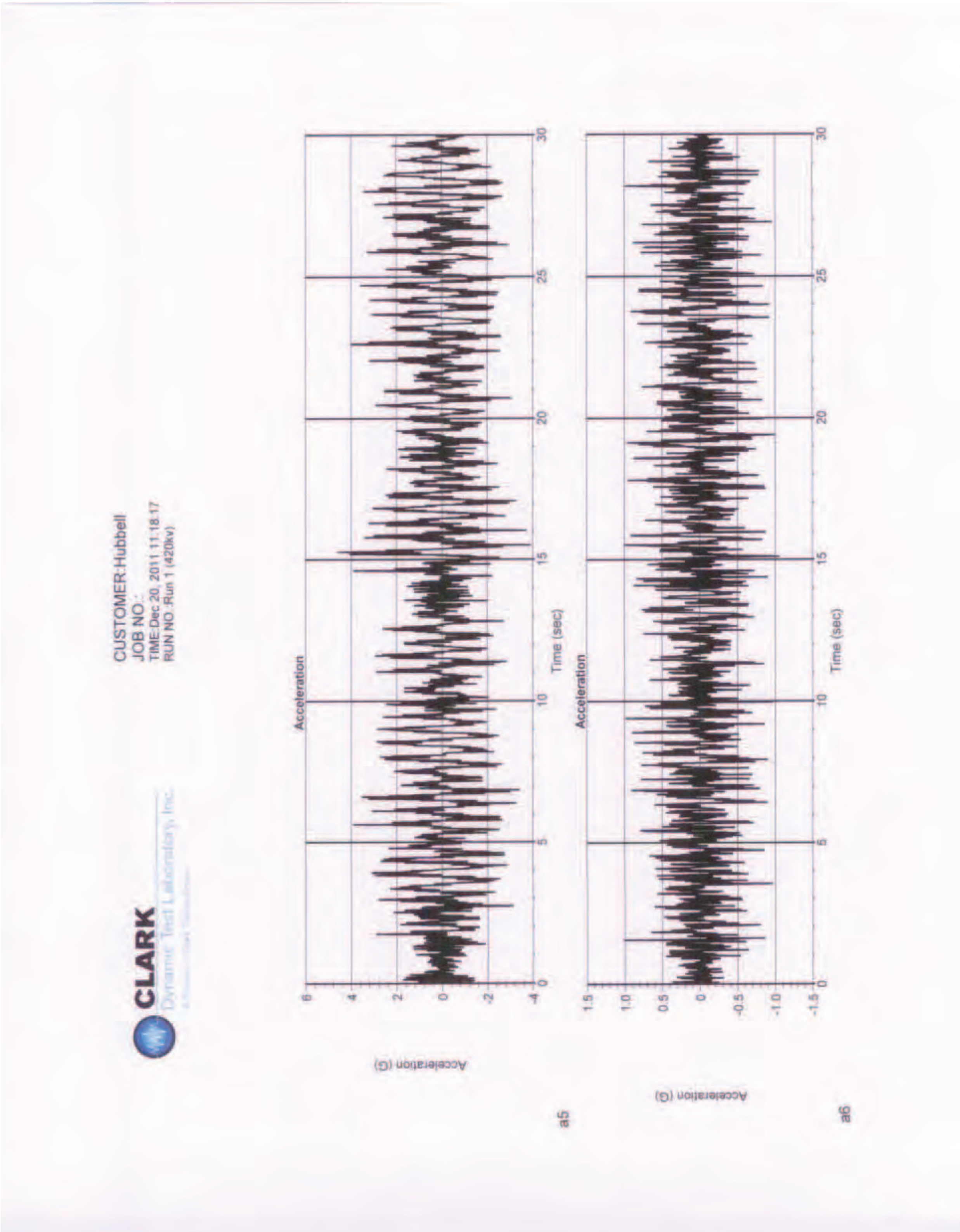

CLARK
Dynamic Test Laboratory, Inc
CUSTOMER: Hubbell Power Systems
JOB NO. Arrester (3-stack) 420kv
TIME Dec 20, 2011 11:44:30
RUN NO. Post #2 Side to Side axis (420kv)
Phase relative to a2-SS
Phase (°)
Frequency (Hz)
Transmissibility (reference = a2-SS)
Ratio (G/G)
Frequency (Hz)
2.01 hz
15.5 hz
21.8 hz
29.9 hz
a11/a2-SS

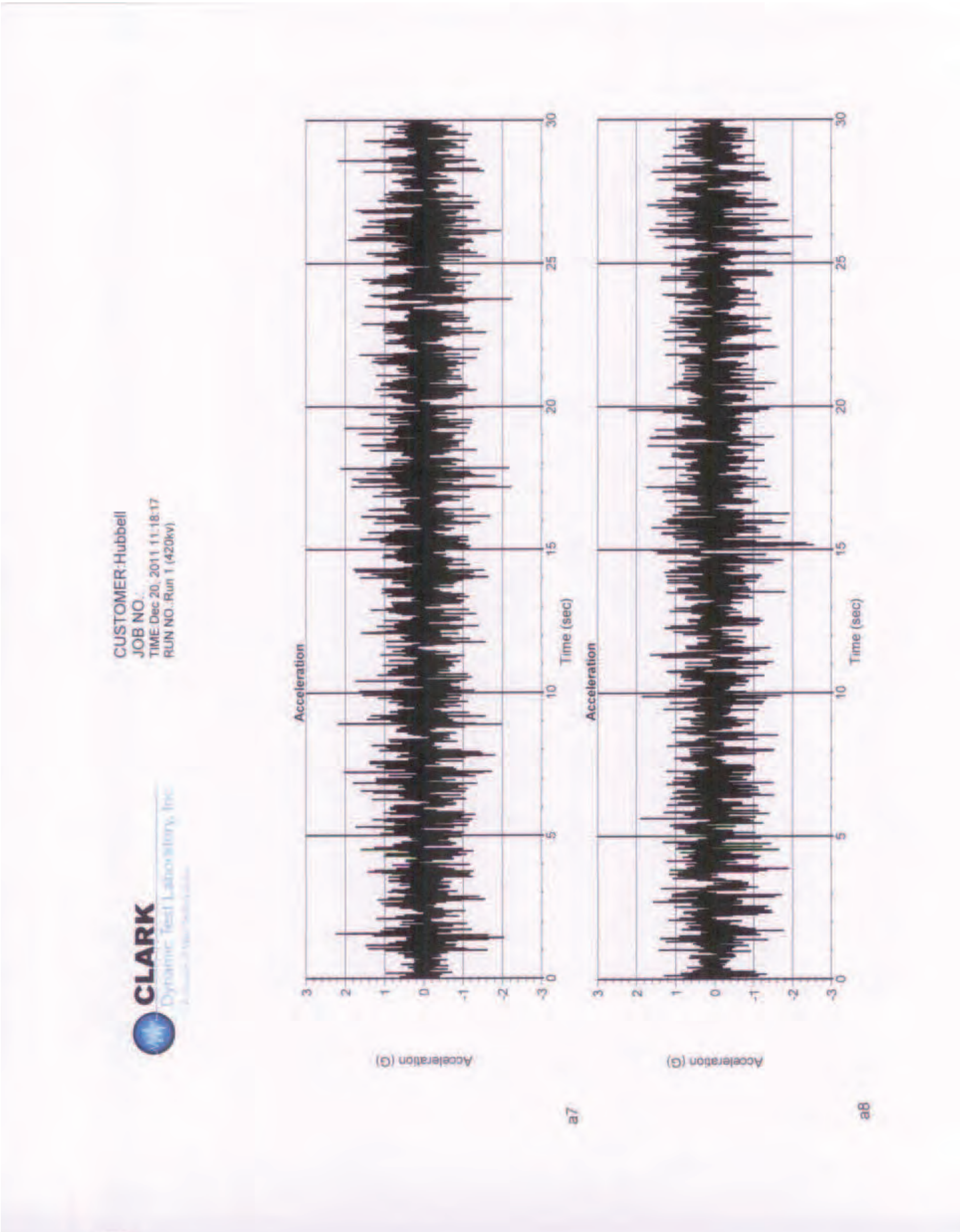
APPENDIX III

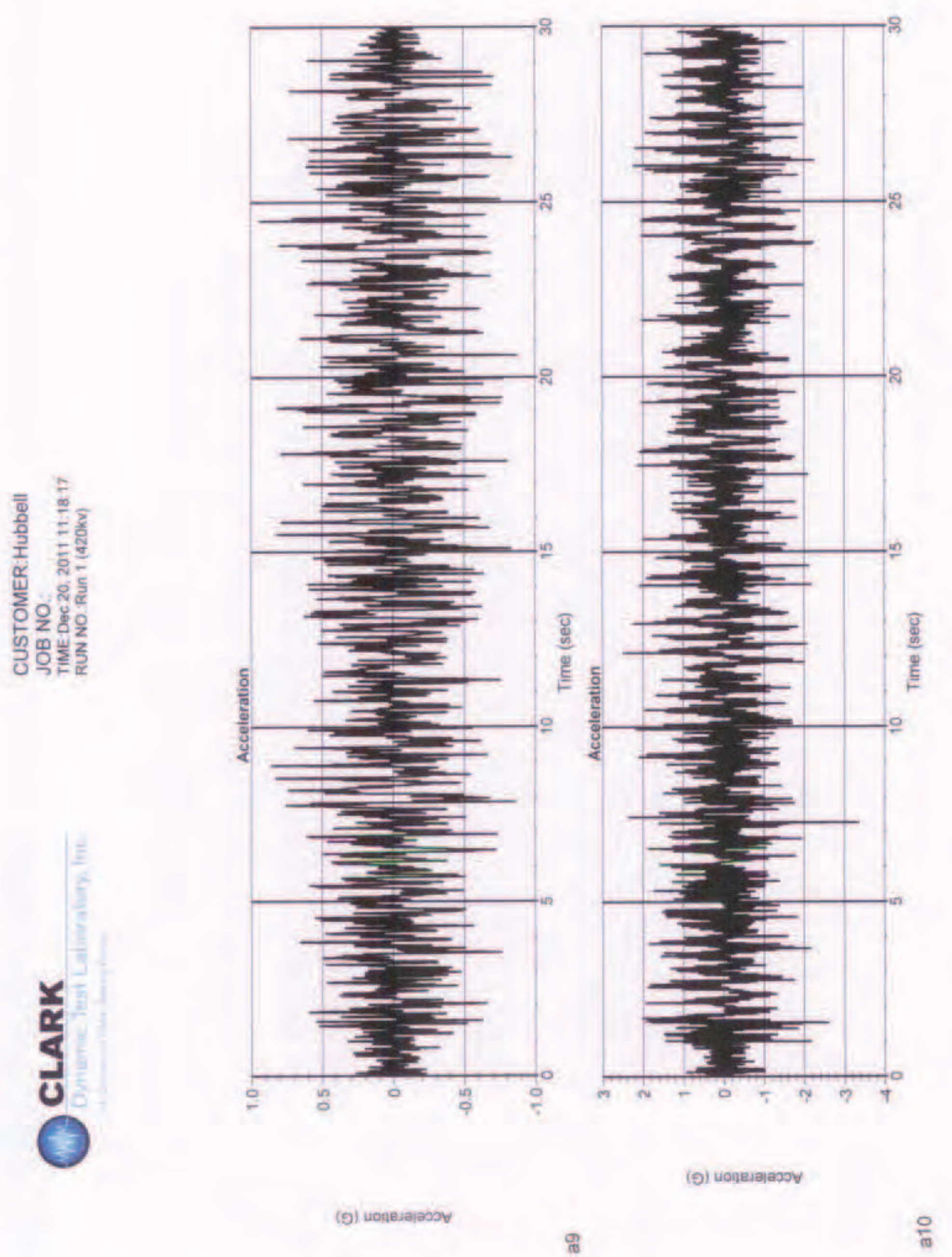
ACCELERATION, STRAIN, LOAD
&
RELATIVE DISPLACEMENT
TIME HISTORY PLOTS

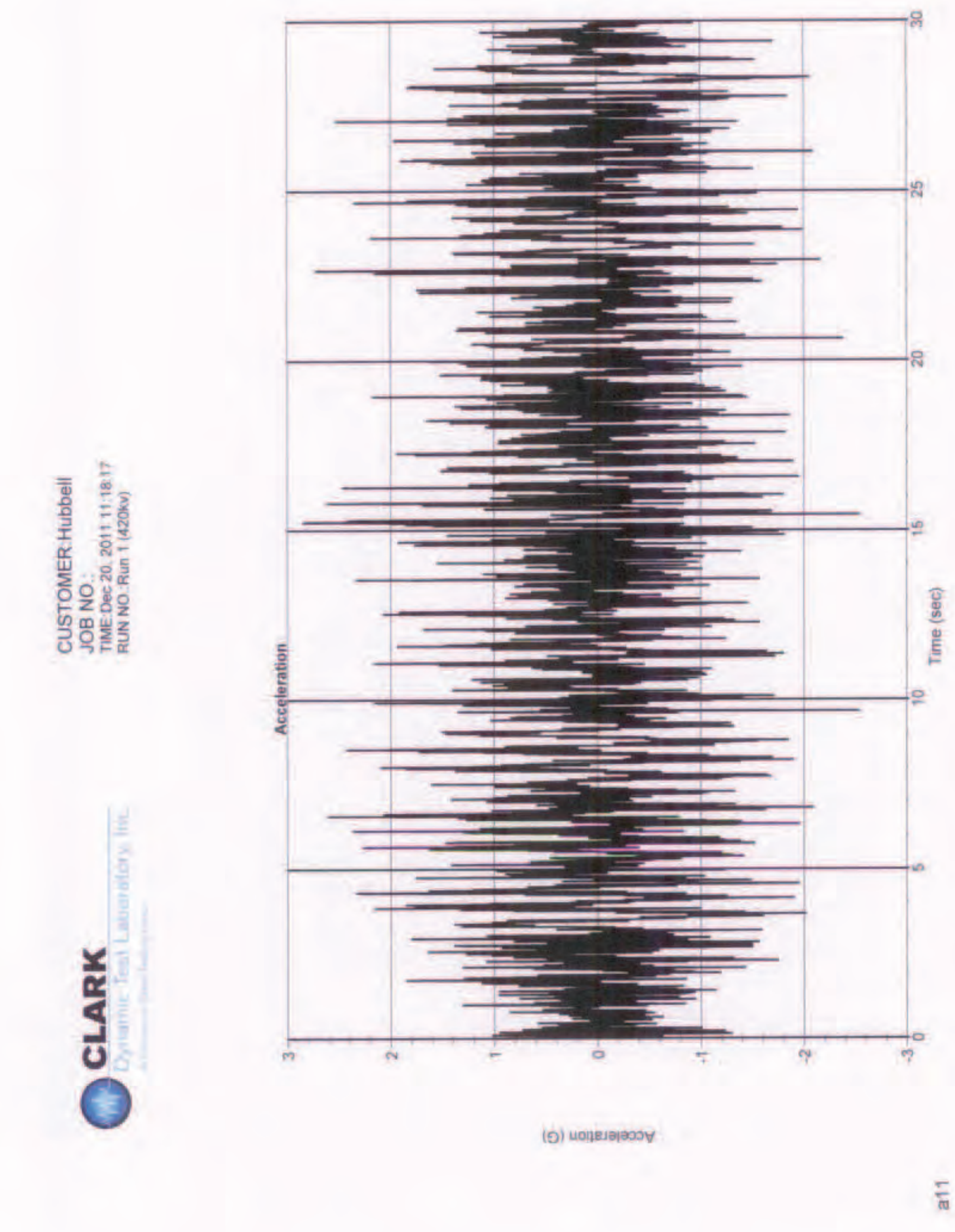

CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER:Hubbell
JOB NO.:
TIME:Dec 20, 2011 11:18:17
RUN NO.:Run 1 (420kv)
Acceleration
Acceleration (G)
Time (sec)
a1-FB
Acceleration
Acceleration (G)
Time (sec)
a2-SS


CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER:Hubbell
JOB NO.:
TIME:Dec 20, 2011 11:18:17
RUN NO. Run 1 (420kv)
Acceleration
Acceleration (G)
Time (sec)
a3-V
Acceleration
Acceleration (G)
Time (sec)
a4

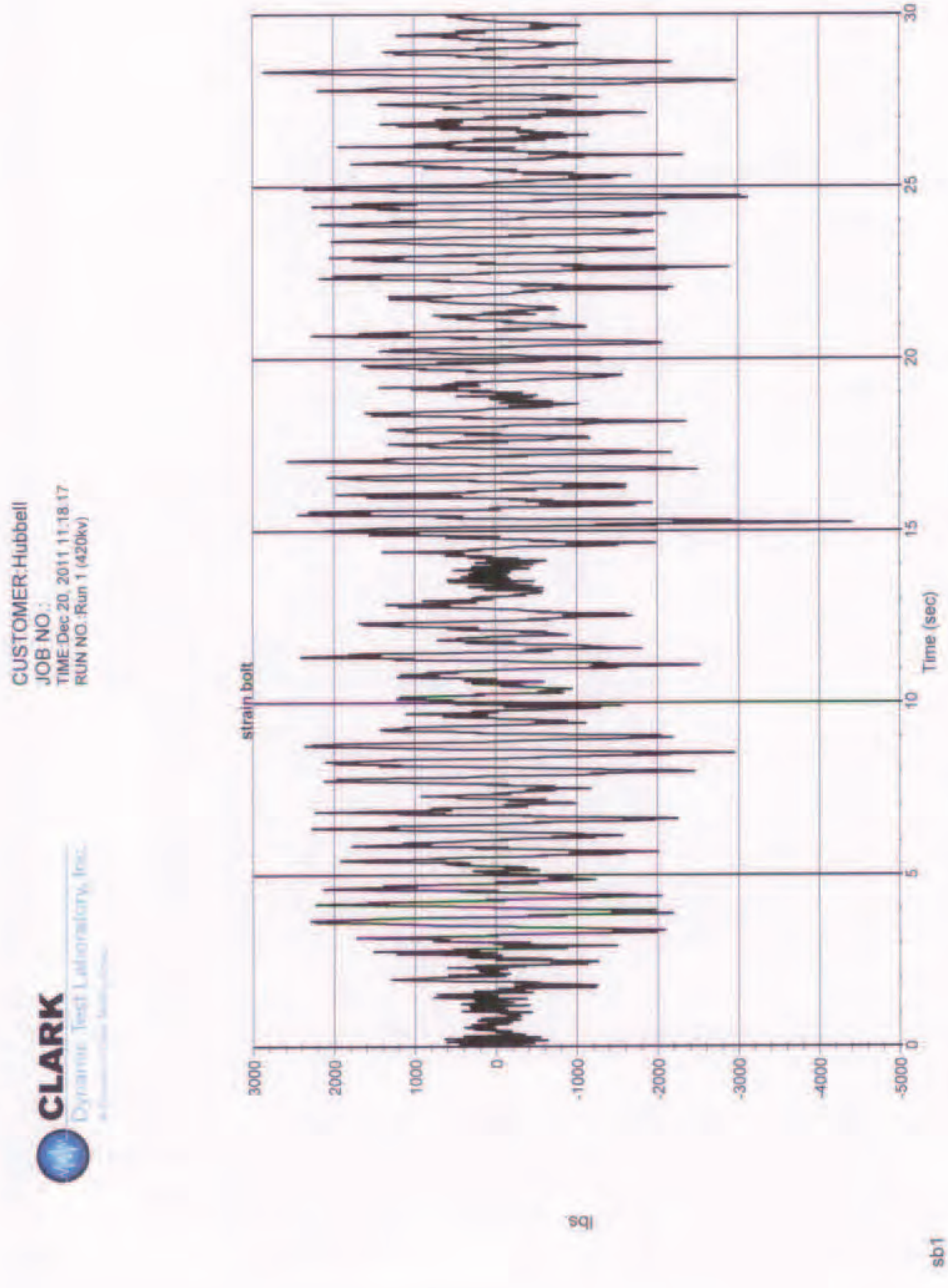

CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER:Hubbell
JOB NO.:
TIME:Dec 20, 2011 11:18:17
RUN NO.:Run 1 (420kv)
a5
Acceleration
Acceleration (G)
Time (sec)
a6
Acceleration
Acceleration (G)
Time (sec)

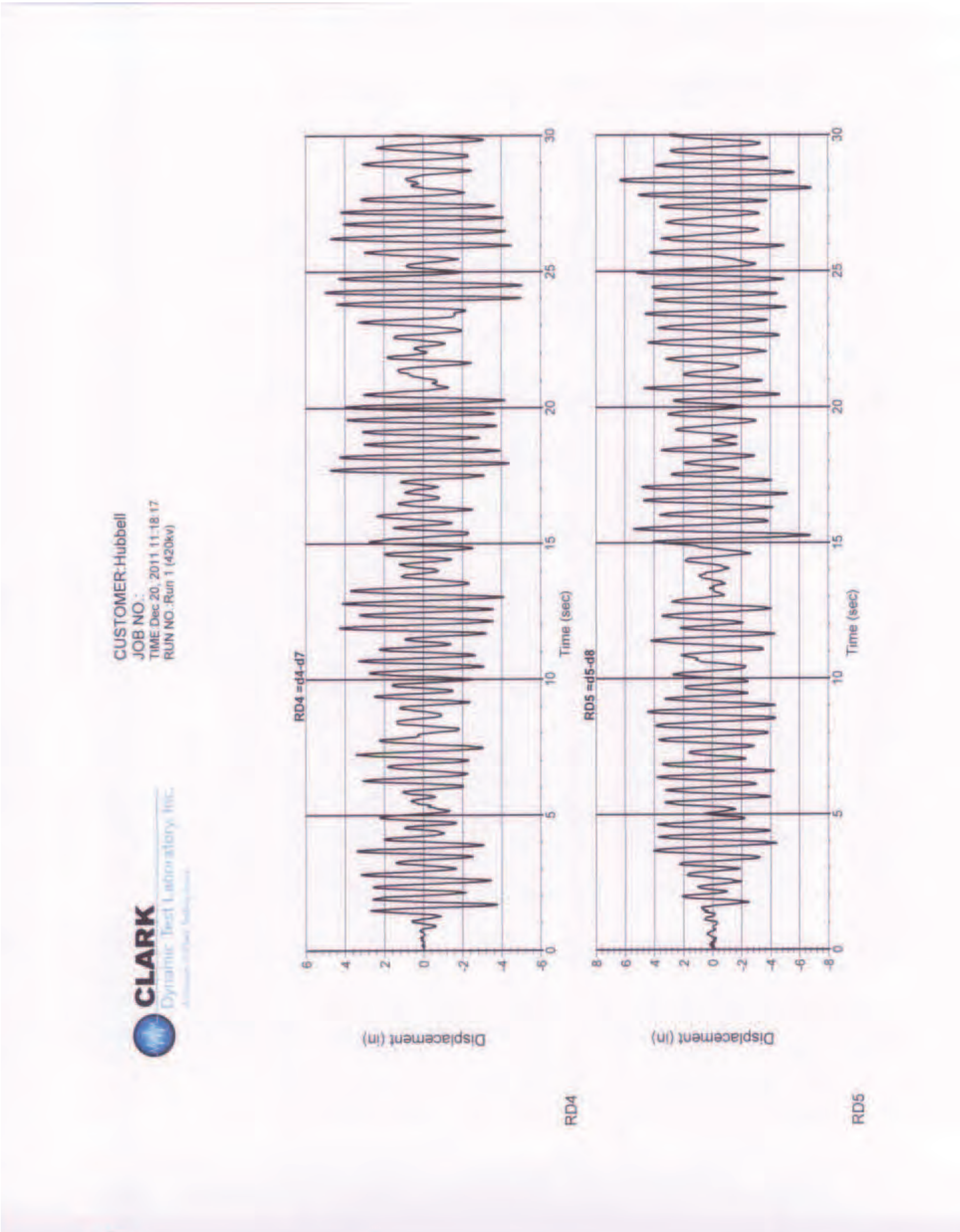

CLARK
Dynamic Test Laboratory, Inc
CUSTOMER:Hubbell
JOB NO.:
TIME:Dec 20, 2011 11:18:17
RUN NO.:Run 1 (420kv)
a7
Acceleration
Acceleration (G)
Time (sec)
a8
Acceleration
Acceleration (G)
Time (sec)

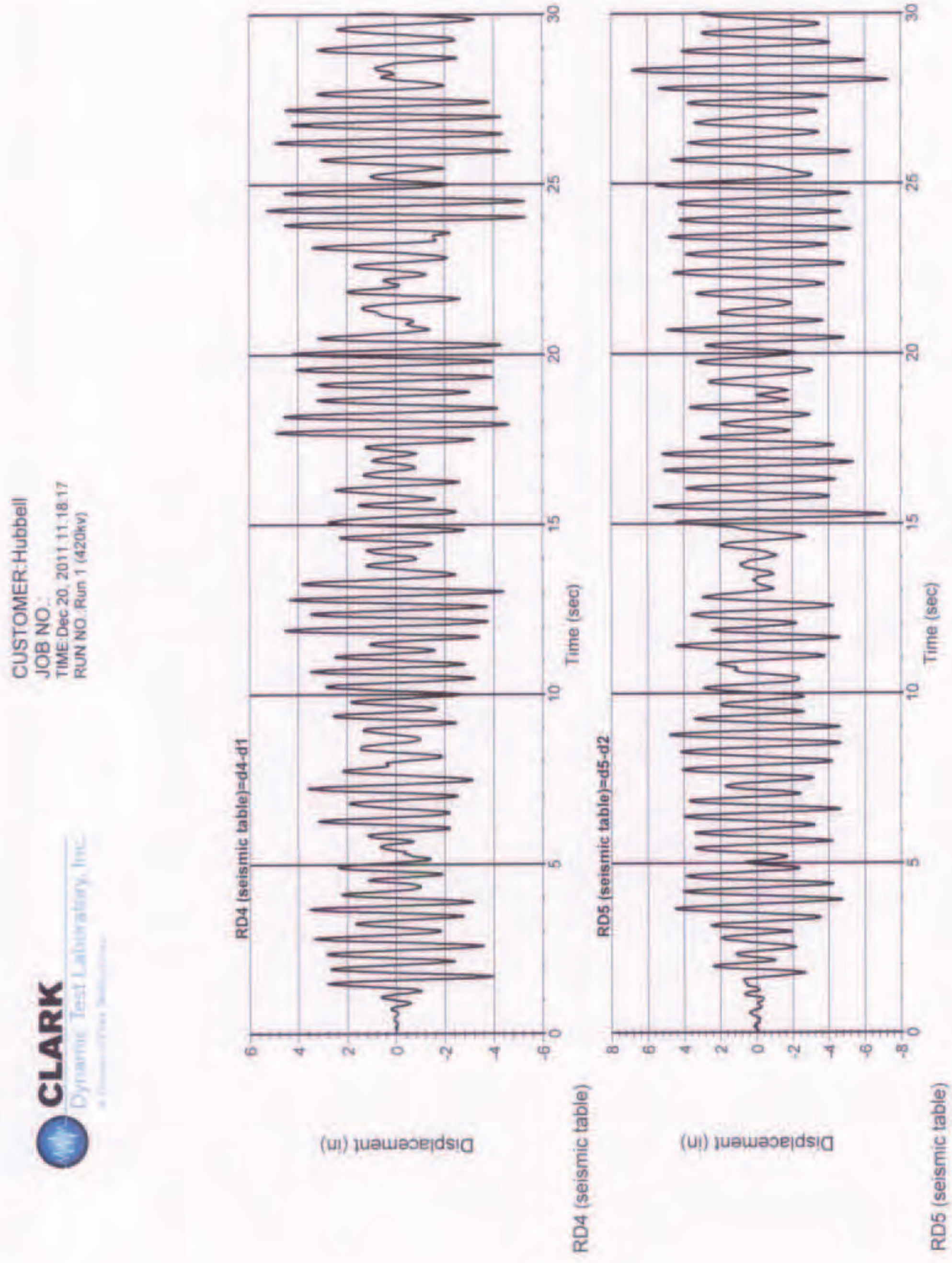

CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER:Hubbell
JOB NO.:
TIME:Dec 20, 2011 11:18:17
RUN NO.:Run 1 (420kv)
Acceleration
Acceleration (G)
Time (sec)
a9
Acceleration
Acceleration (G)
Time (sec)
a10


CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER:Hubbell
JOB NO.:
TIME:Dec 20, 2011 11:18:17
RUN NO.:Run 1 (420kv)
Acceleration
Acceleration (G)
Time (sec)
3
2
1
0
-1
-2
-3
0
5
10
15
20
25
30
a11


CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER: Hubbell
JOB NO.:
TIME: Dec 20, 2011 11:18:17
RUN NO.: Run 1 (420kv)
microstrain
Time (sec)
sg1
microstrain
Time (sec)
sg2

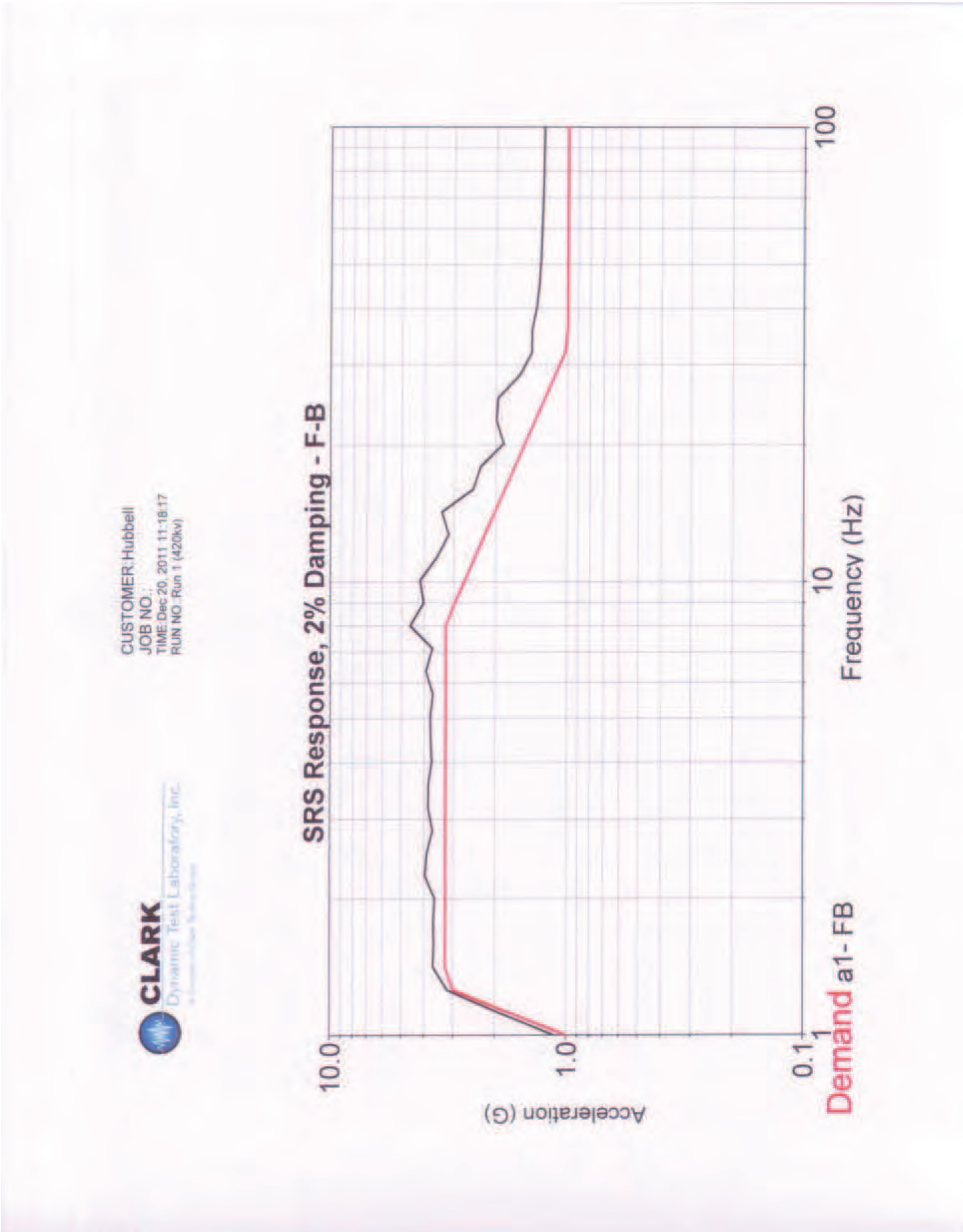

CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER:Hubbell
JOB NO.:
TIME:Dec 20, 2011 11:18:17
RUN NO.:Run 1 (420kv)
strain bolt
lbs
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
0
5
10
15
20
25
30
Time (sec)
sb1

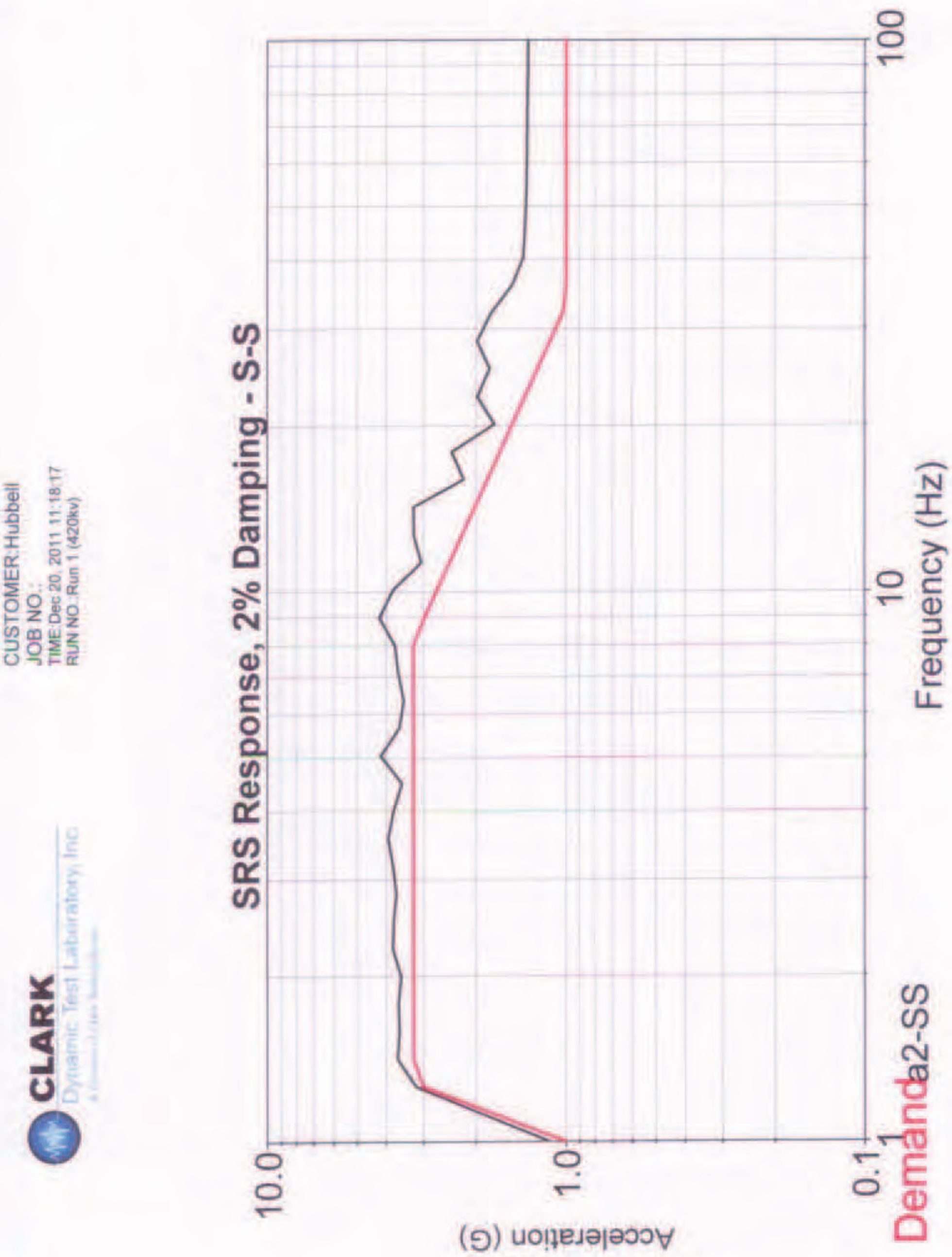

CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER:Hubbell
JOB NO.:
TIME Dec 20, 2011 11:18:17
RUN NO.:Run 1 (420kv)
RD4 =d4-d7
RD5 =d5-d8
Displacement (in)
Time (sec)
RD4
RD5

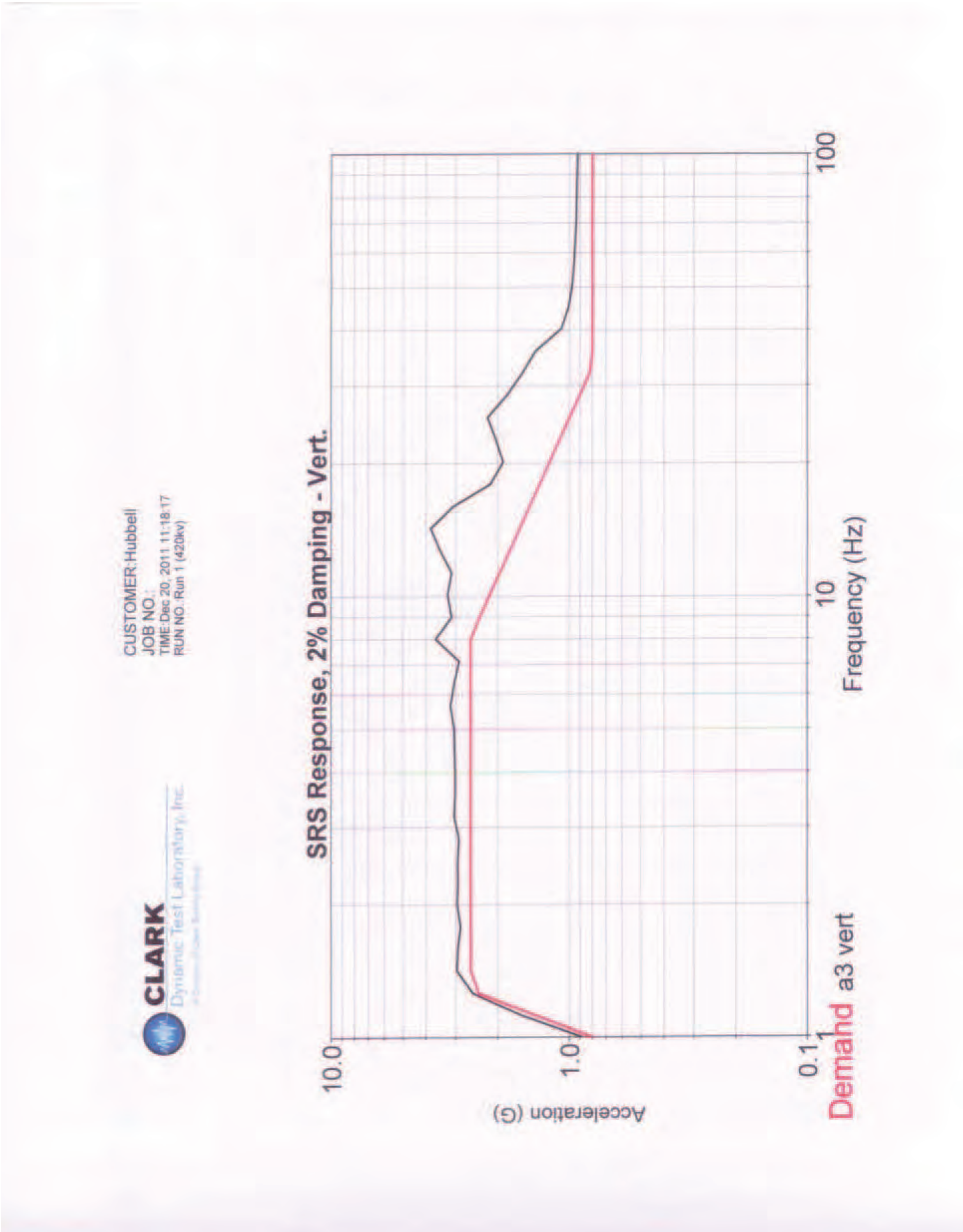

CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER:Hubbell
JOB NO.:
TIME:Dec 20, 2011 11:18:17
RUN NO.:Run 1 (420kv)
RD4 (seismic table)=d4-d1
Displacement (in)
Time (sec)
RD4 (seismic table)
RD5 (seismic table)=d5-d2
Displacement (in)
Time (sec)
RD5 (seismic table)

APPENDIX IV

RESPONSE SPECTRUM PLOTS


CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER:Hubbell
JOB NO.:
TIME:Dec 20, 2011 11:18:17
RUN NO.:Run 1 (420kv)
SRS Response, 2% Damping - F-B
Acceleration (G)
10.0
1.0
0.1
1
10
100
Frequency (Hz)
Demand a1- FB

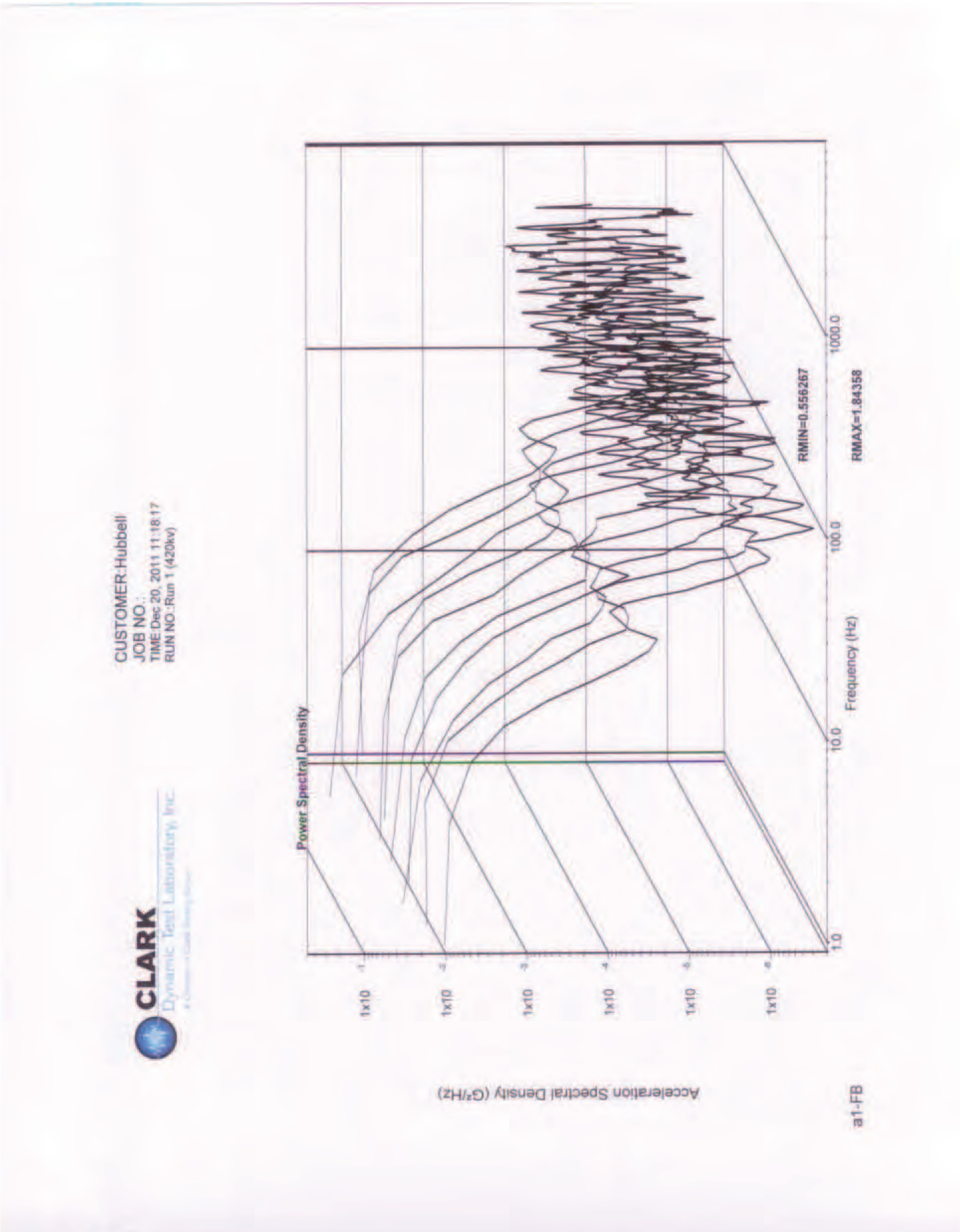

CLARK
Dynamic Test Laboratory, Inc
CUSTOMER:Hubbell
JOB NO.:
TIME:Dec 20, 2011 11:18:17
RUN NO.:Run 1 (420kv)
SRS Response, 2% Damping - S-S
Acceleration (G)
10.0
1.0
0.1
1
10
100
Frequency (Hz)
Demand
a2-SS

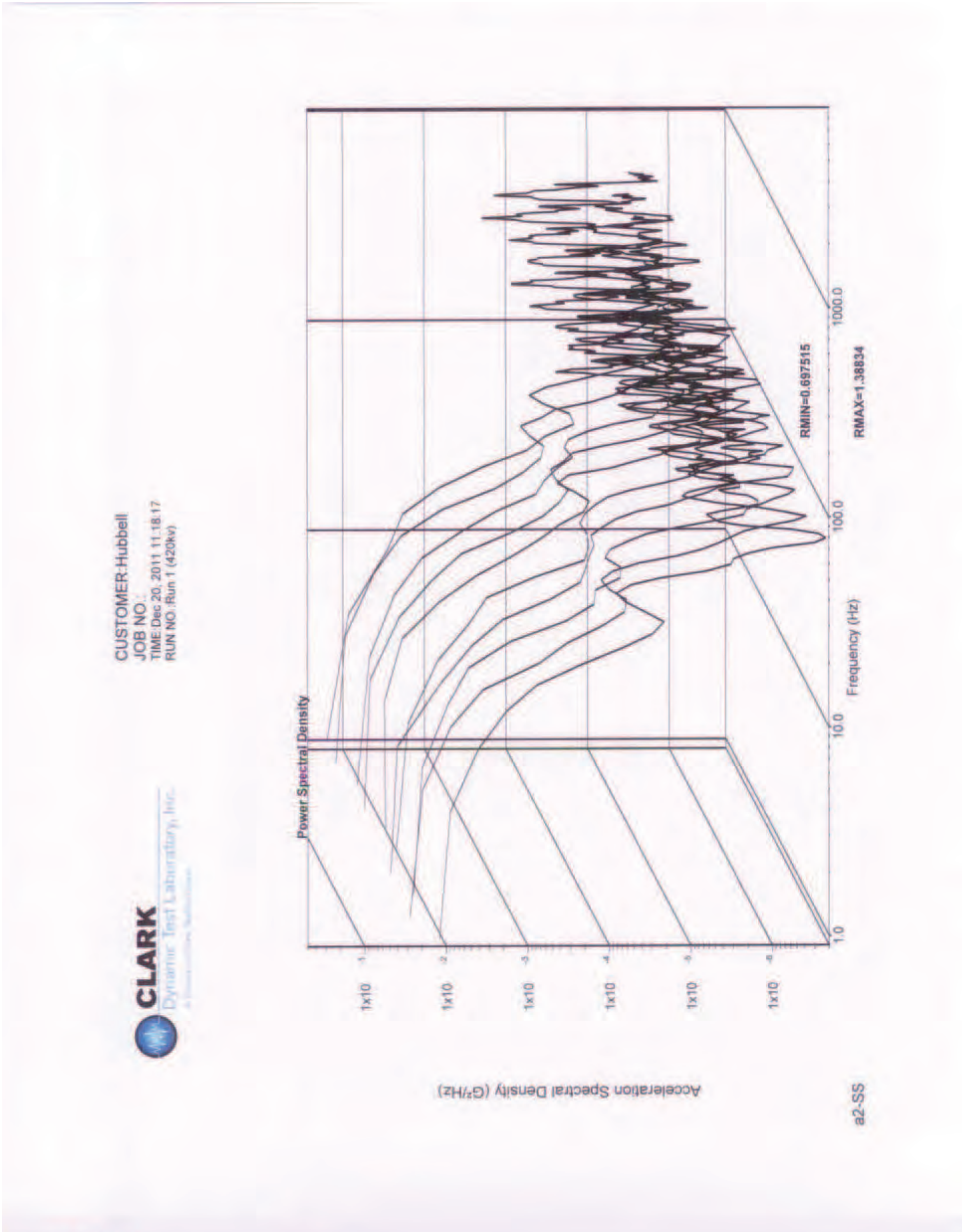

CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER:Hubbell
JOB NO.:
TIME:Dec 20, 2011 11:18:17
RUN NO. Run 1 (420kv)
SRS Response, 2% Damping - Vert.
Acceleration (G)
10.0
1.0
0.1
1
10
100
Frequency (Hz)
Demahd a3 vert

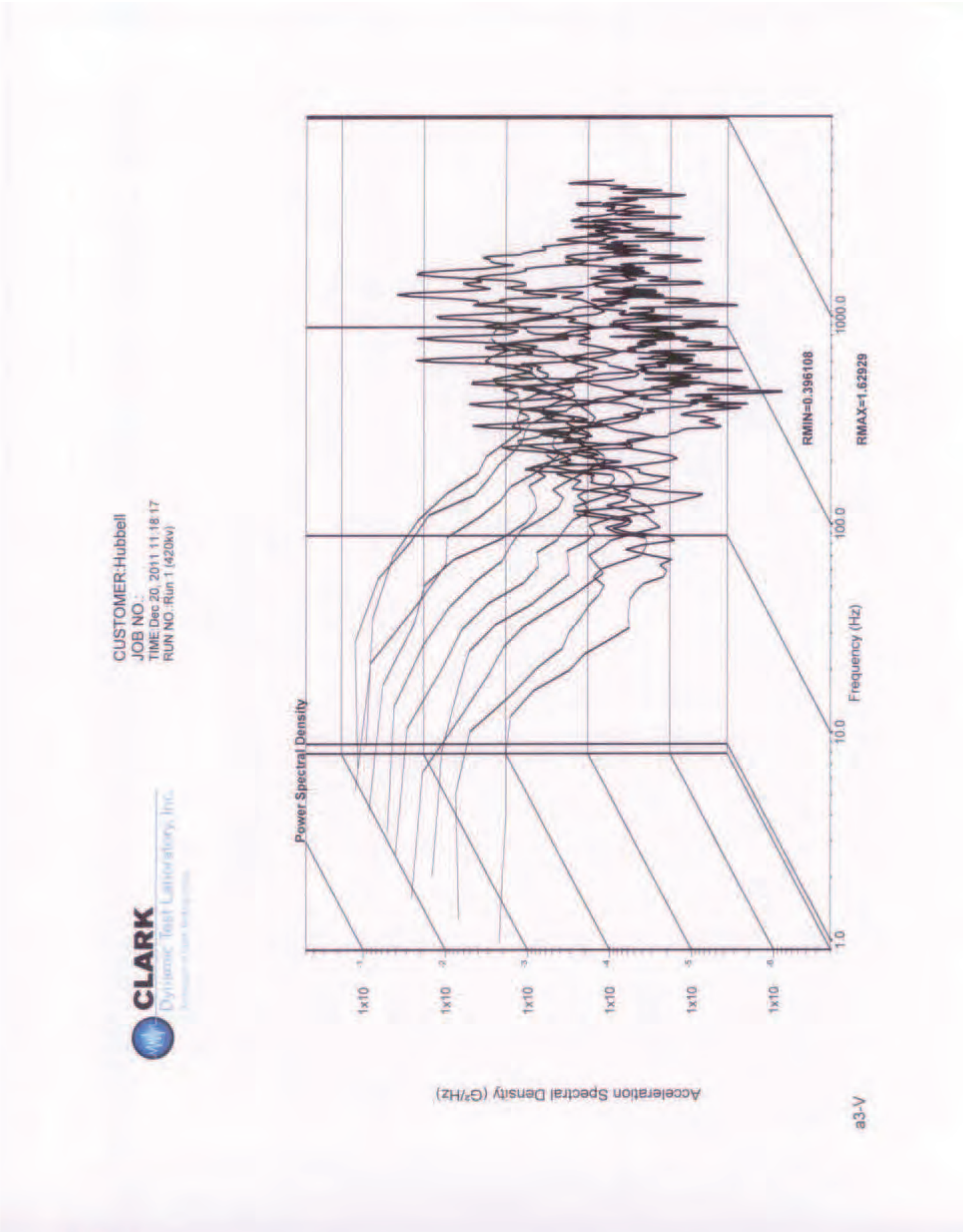
APPENDIX V

CROSS CORRELATION PLOTS
AND
STATIONARITY CHECK DATA


CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER:Hubbell
JOB NO.:
TIME:Dec 20, 2011 11:18:17
RUN NO.:Run 1 (420kv)
Correlation with a1- FB
a2-SS
Correlation
Time Delay (sec)
Correlation with a1- FB
a3 vert
Correlation
Time Delay (sec)
Correlation with a2-SS
a3 vert
Correlation
Time Delay (sec)


CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER:Hubbell
JOB NO.:
TIME:Dec 20, 2011 11:18:17
RUN NO.:Run 1 (420kv)
Power Spectral Density
Acceleration Spectral Density (G²/Hz)
1x10-1
1x10-2
1x10-3
1x10-4
1x10-5
1x10-6
1.0
10.0
100.0
1000.0
Frequency (Hz)
RMIN=0.556267
RMAX=1.84358
a1-FB


CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER:Hubbell
JOB NO.:
TIME:Dec 20, 2011 11:18:17
RUN NO.:Run 1 (420kv)
Power Spectral Density
Acceleration Spectral Density (G²/Hz)
Frequency (Hz)
RMIN=0.697515
RMAX=1.38834
a2-SS


CLARK
Dynamic Test Laboratory, Inc.
CUSTOMER:Hubbell
JOB NO.:
TIME:Dec 20, 2011 11:18:17
RUN NO.:Run 1 (420kv)
Power Spectral Density
Acceleration Spectral Density (G²/Hz)
1x10-1
1x10-2
1x10-3
1x10-4
1x10-5
1x10-6
1.0
10.0
100.0
1000.0
Frequency (Hz)
RMIN=0.396108
RMAX=1.62929
a3-V