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Test Complete:	31 March 2021				

NATIONAL TECHNICAL SYSTEMS TEST REPORT FOR TOTAL HARMONIC DISTORTION TESTING OF THE HARMONIC DISSIPATION DEVICE

Prepared For
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ABSTRACT

One (1) Harmonic Dissipation Device was subjected to Total Harmonic Distortion testing. The intent of the test was to validate the EUT's ability to reduce harmonic currents, and improve power factor on 120/208 VAC, 60 Hz power systems. Performance testing shall be conducted in several different installation configurations within the AC power distribution panel as specified by the Line Loss Pro. The test was conducted in accordance with NTS Test Procedure TP-PR134509, Rev. 0, *Performance Testing of the Harmonic Dissipation Device* requirements.

Revision History

Rev.	Description	Issue Date
0	Initial Release	04/09/2021

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ABBREVIATIONS & ACRONYMS

°C	Degrees Celsius
AC	Alternating Current
cm	Centimeters
dB	Decibel
EMI	Electromagnetic Interference
EUT	Equipment Under Test
Hz	Hertz
M&TE	Measurement & Test Equipment
mΩ	Milliohms
NCR	No Calibration Required
NIST	National Institute of Standards and Technology
NTS	National Technical Systems
P/N	Part Number
RF	Radio Frequency
RMS	Root Mean Squared
S/N	Serial Number
THD_V	Voltage Total Harmonic Distortion
Vrms	Volts RMS

TOTAL HARMONIC DISTORTION TEST SUMMARY

Responsible Test Conductor: Jeffrey Viel

1.0 EQUIPMENT UNDER TEST (EUT)

The test hardware consisted of one (1) Harmonic Dissipation Unit. The Harmonic Dissipation Unit is a passive inductive harmonic filter intended to reduce harmonic current produced by nonlinear loads within a facility's low voltage power distribution system. See Figure 1 for a photograph of the EUT.

As shown in Figure 2, the circuit consists of which are wired into This configuration provides significant self-inductance as well as mutual inductance and capacitance between the The Harmonic Dissipation Unit is also equipped with controls to adjust or tune these properties for optimum performance once installed.

The Harmonic Dissipation Unit's resist the flow of current which result in a harmonic current phase shift within the system. The mutual capacitance that exists between the also stores energy which aids in power factor correction.

Table 1.0-1 Parametric Data for the EUT

Parameters	Dimensions	[redacted]
Water Heater		
Length	5 ½"	10 AWG 36"L
Width	4 ¾"	
Depth	1 1/2	
Weight	1280lbs dry 1470lbs wet	

2.0 TEST REQUIREMENTS WITH MEASUREMENT ACCURACIES

The purpose of this test is to validate the EUT's ability to reduce harmonic currents, and improve power factor on 120/208 VAC, 60 Hz power systems. Performance testing shall be conducted in several different installation configurations within the AC power distribution panel as specified by the Line Loss Pro.

Total Harmonic Distortion is expressed as a percentage, which indicates how much of harmonic voltage/current is added to the fundamental frequency. It is calculated using the following formula:

$$THD_X = \frac{\sqrt{\sum_{h=2}^{50} X_h^2}}{X_1}$$

- h is the harmonic order (up to the 50th harmonic);
- X1 is the amplitude of the fundamental 60 Hz voltage or current;
- Xh is the amplitude of the harmonic order h voltage or current.

Measurement Accuracies
All measurements shall have the following accuracies:

Frequency Accuracy
The frequency accuracy of the recorded measurements must be within ±2%. Verification with a frequency counter or other measuring device is required.

Amplitude Accuracy
Amplitude accuracy is ±2 dB.

2.1 Test Specifications

- NTS Test Procedure TP-PR134509, Rev. 0, *Performance Testing of the Harmonic Dissipation Device*
- IEEE-519 Specification, Rev. 2014, *IEEE Recommended Practice and requirements for Harmonic Control in Electric Power Systems*
- IEC 61000-4-7 Specification, Rev. 2009, Edition 2.1, *Testing and measurement techniques – General guide on harmonics and inter-harmonics measurements and instrumentation, for power supply systems and equipment connected thereto*

3.0 TEST SETUP

3.1 Test Equipment

The instrumentation used in the performance of these tests is periodically calibrated and standardized within manufacturer's rated accuracies and are traceable to the National Institute of Standards and Technology. The calibration procedures and practices are in accordance with ANSI/NCSL Z540-1 and ISO 17025:2017. Certification of calibration is on file subject to inspection by authorized personnel. See Table 3.0-1 for a list of equipment used for this test.

TABLE 3.0-1: NTS-FURNISHED MEASUREMENT & TEST EQUIPMENT (M&TE)

Asset Number	Mfct	Description	M/N	S/N	Range	Start Date	End Date	Last Cal	Cal Interval (Months)	Cal Due
WC043152	AEMC Instruments	Power Analyzer	8336	141984NGH	N/A	03/30/2021	03/31/2021	11/11/2020	12	11/11/2021
WC057063	Universal Shielding	EMI Chamber 1	USC-26	N/A	N/A	03/30/2021	03/31/2021	07/01/2005	NCR	NCR
WC057116	Solar Electronics	Feedthrough Capacitor (10uF)	6512-106R	271154	N/A	03/30/2021	03/31/2021	NCR	NCR	NCR
WC057122	Solar Electronics	Feedthrough Capacitor (10uF)	6512-106R	271134	N/A	03/30/2021	03/31/2021	NCR	NCR	NCR

Calibration Abbreviations
CAL calibrated
NCR no calibration required

3.2 Test Setup

The test was set up by installing the EUT on a ground plane in shielded chamber #1. The basic test setup shown in Figure 4 consisted of a single phase power source (120VAC, 60 Hz), with a power analyzer current loop, and terminated into a standard low voltage circuit b A THD test circuit as shown in Figure 5 was connected to a This circuit produced a harmonic rich source representative to the time domain waveforms shown in Figure 6. The Harmonic Dissipation Unit was installed in a number of configurations based on the layout as shown in Figure 7 and Figure 8, respectively.

Once the M&TE was in place, it was powered on and at least 30 minutes was allowed for it to warm-up and stabilize.

3.2.1 Chamber: The testing was performed in a 3.05 meters by 4.27 meters by 3.05 meters (height) shielded chamber, with no RF absorber material on the walls, ceiling, or floor of the chamber.

3.2.2 Ground Plane: The ground plane consisted of a 0.64 millimeter thick copper sheet that sat on top of a test bench 85 centimeters above the floor of the chamber, and had a minimum surface area of 2.25 square meters. This sheet was bonded to ground via the floor of the shielded chamber (which was grounded to earth) in multiple places, using bond straps with a length to width ratio no greater than 5:1. The bond straps were positioned so that no bond strap was more than 1 meter from the next closest bond strap. The bonding resistance between the ground plane and the chamber floor was verified to be ≤2.5 milliohms. The actual bonding results as measured on 2021-02-08 were (facing the ground plane):

Far Left: 0.4 mΩ Center Left: 0.4 mΩ Center Right: 0.4 mΩ Far Right: 0.4 mΩ

4.0 TEST DESCRIPTION

4.1 Non-NTS Personnel, Including Organization, Present for All or Part of the Test

Pat Sella, a representative of Line Loss Pro

4.2 Powered/Operational State of the Hardware and by Whom

For this test method, the EUT was powered by a single AC power input (nominally 115 Vrms, 60 Hz, single phase). The actual input voltage was 120 Vrms, and the input frequency was 60 Hz. The EUT required no minimum stabilization time before testing could begin. Throughout the Total Harmonic Distortion testing, the EUT was operated by the NTS test engineer (Jeffrey Viel).

4.3 Test Activities and Resulting Measurements from Observed/Recorded Data

1. The basic setup shown in Figure 4 shall be maintained.
2. Power shall be applied.
3. Voltage, Current, Power (KW & KVA), power factor, and THD shall be recorded without the Harmonic Dissipation Unit installed. Measurements shall be made to the 50th harmonic. The harmonic measurements shall be conducted for 5 minutes.
4. Remove power.
5. Install the Harmonic Dissipation Unit in one of the configurations shown in Figure 7 and Figure 8.
6. Repeat all measurements described in step 3.
7. Repeat step 4 and 5 until all of the installation configurations shown in Figure 7 and Figure 8 have been tested.
8. Compare each set of measurements to the baseline measurements taken in step 3.
9. Calculate the harmonic reduction and power factor improvements for each measurement.

With the EUT installed in the test condition was applied to the EUT and the relevant information was recorded by the test conductor. Table 4.0-1 summarizes the test results. See the Appendix for the Raw Data collected during the test.

TABLE 4.0-1: TEST ACTIVITIES & RESULTS

Test Condition	Measured Input Voltage (Vrms)	Measured Input Frequency (Hz)	THD_V (%)	Target Dwell Time (MM:SS)	Actual Dwell Time (MM:SS)	Comments
1	119.5	60.0	10.24	05:00	05:05	All configurations yielded the same results

4.4 Limitations or Departures from the Test Requirements

None

5.0 CONCLUSION

In all of the test configurations, the EUT was able to increase the power factor by 49.7% which will decrease the total current draw of the system.

Figure 1: Harmonic Dissipation Unit Photograph

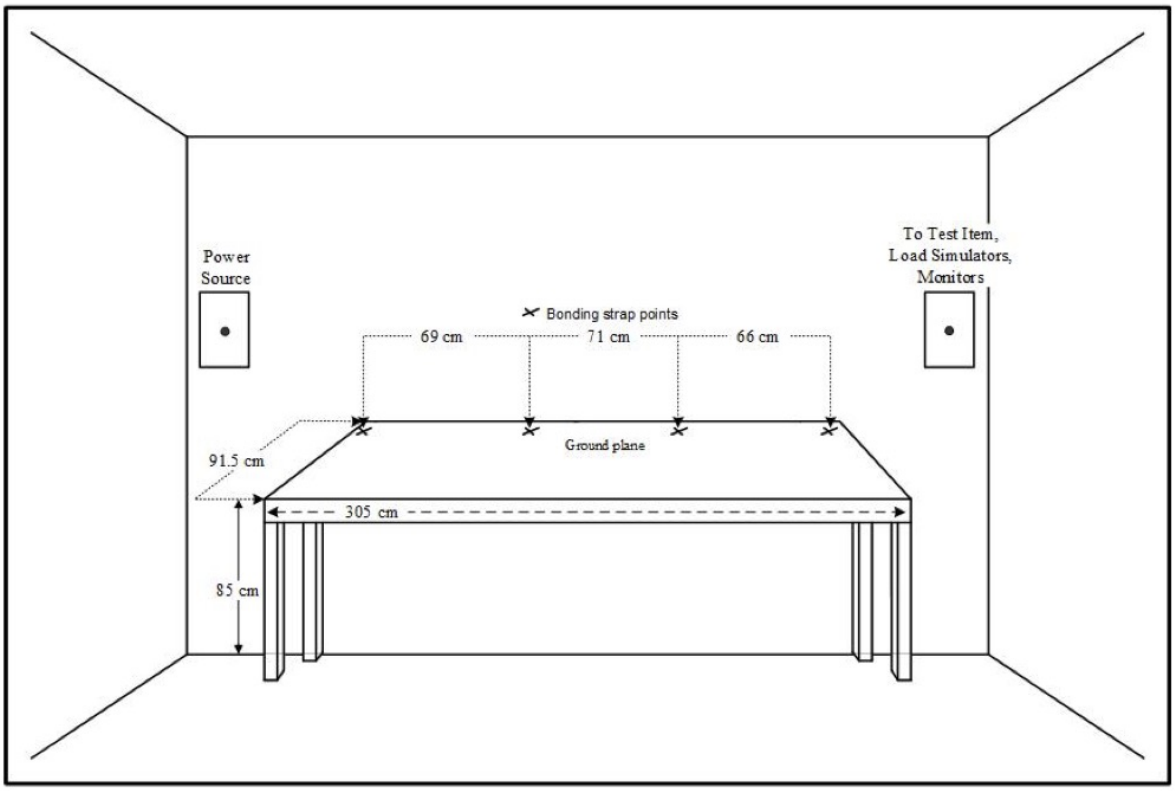

Figure 3: Shielded Chamber #1 (3.05 x 4.27 x 3.05 meters)

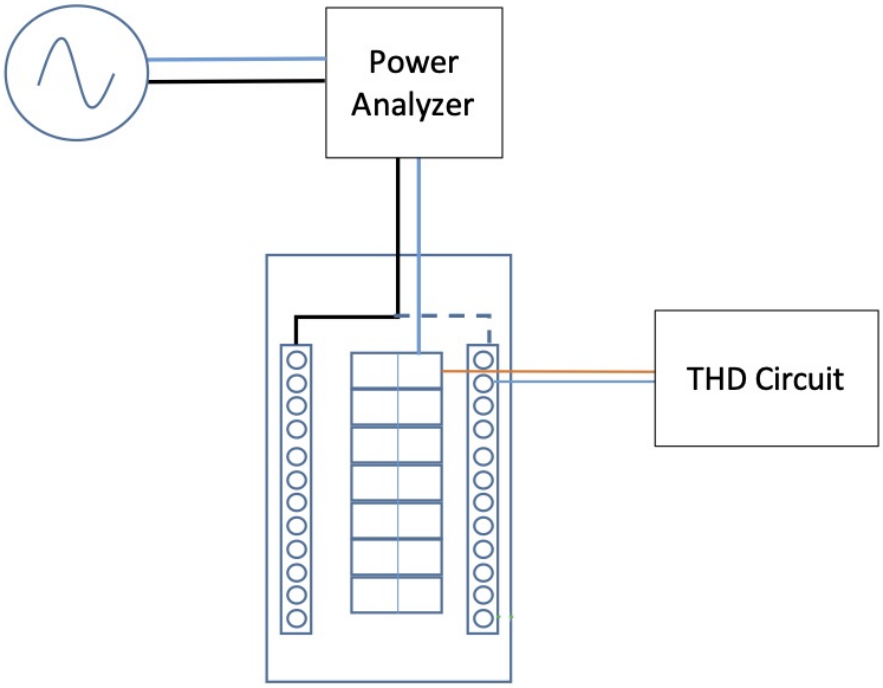

Figure 4: Basic Test Setup Diagram

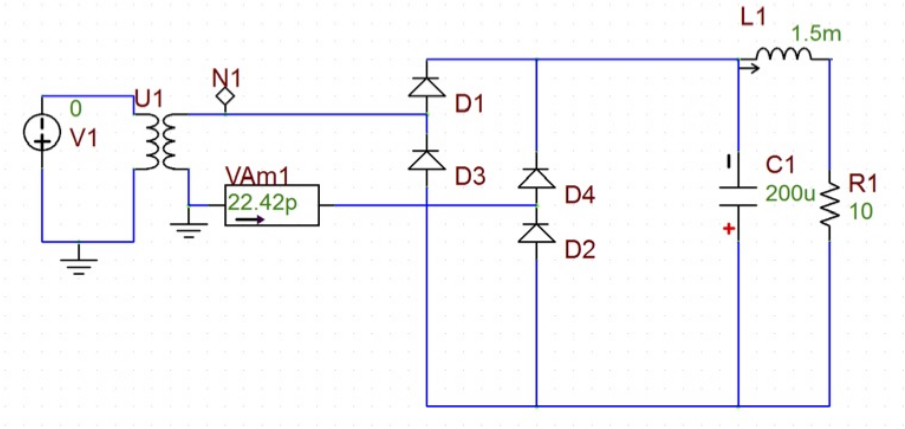

Figure 5: THD Circuit

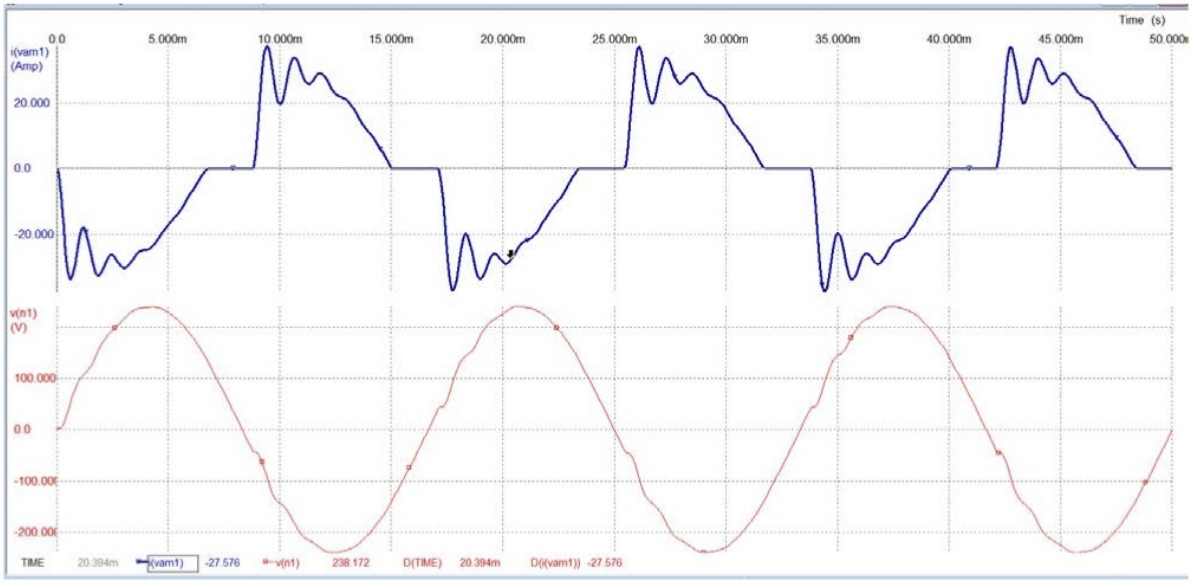

Figure 6: THD Voltage and Current waveforms

Figure 9: Overall Test Setup

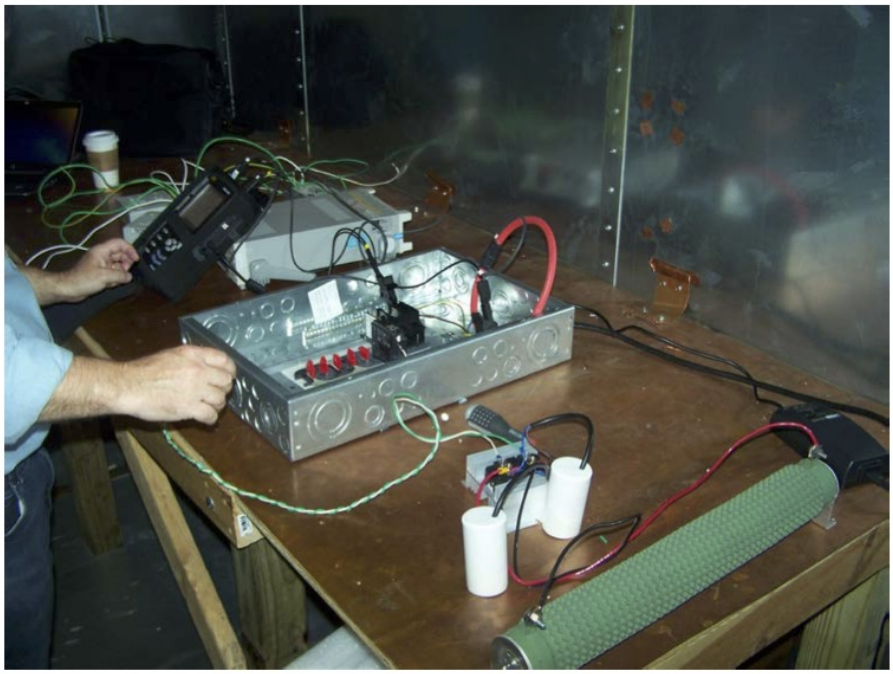

Figure 10: View of Measurement & Test Equipment

APPENDIX: RAW DATA

	THDI%	(V)	(I)	kVA	W (kW)	kVAR	PF	Ph (deg)
Baseline	21.41424759	111.1	14.86	1.650946	0.768	1.461	0.465	62.31
LineLoss	20.83876436	113	15.03	1.69839	1.59	0.597	0.936	20.58
Delta %	**0.57%**						**49.68%**	
Harmonic Content								
I Harm	Baseline (%)	LL (%)	Delta %		I Harm	Baseline (I)	LL(I)	Delta
2	0.00%	0.00%	0.00%		2	0	0	0
3	12.60%	12.10%	0.50%		3	1.87236	1.81863	0.05373
4	0.00%	0.00%	0.00%		4	0	0	0
5	11.90%	12.00%	-0.10%		5	1.76834	1.8036	-0.03526
6	0.00%	0.00%	0.00%		6	0	0	0
7	8.20%	8.10%	0.10%		7	1.21852	1.21743	0.00109
8	0.00%	0.00%	0.00%		8	0	0	0
9	5.40%	5.10%	0.30%		9	0.80244	0.76653	0.03591
10	0.00%	0.00%	0.00%		10	0	0	0
11	3.50%	3.60%	-0.10%		11	0.5201	0.54108	-0.02098
12	0.00%	0.00%	0.00%		12	0	0	0
13	4.60%	4.60%	0.00%		13	0.68356	0.69138	-0.00782
14	0.00%	0.00%	0.00%		14	0	0	0
15	3.10%	3.00%	0.10%		15	0.46066	0	0.46066
16	0.00%	0.00%	0.00%		16	0	0	0
17	2.70%	2.40%	0.30%		17	0.40122	0.36072	0.0405
18	0.00%	0.00%	0.00%		18	0	0	0
19	1.30%	1.50%	-0.20%		19	0.19318	0.22545	-0.03227
20	0.00%	0.20%	-0.20%		20	0	0.03006	-0.03006
21	1.80%	1.60%	0.20%		21	0.26748	0.24048	0.027
22	0.00%	0.10%	-0.10%		22	0	0.01503	-0.01503
23	1.60%	1.80%	-0.20%		23	0.23776	0.27054	-0.03278
24	0.00%	0.00%	0.00%		24	0	0	0
25	1.30%	1.29%	0.01%		25	0.19318	0.193887	-0.000707
26	0.00%	0.00%	0.00%		26	0	0	0
27	0.90%	1.10%	-0.20%		27	0.13374	0.16533	-0.03159
28	0.00%	0.00%	0.00%		28	0	0	0
29	0.50%	0.40%	0.10%		29	0.0743	0.06012	0.01418
30	0.00%	0.00%	0.00%		30	0	0	0
31	0.60%	0.70%	-0.10%		31	0.08916	0.10521	-0.01605
32	0.00%	0.00%	0.00%		32	0	0	0
33	0.50%	0.50%	0.00%		33	0.0743	0.07515	-0.00085
34	0.00%	0.00%	0.00%		34	0	0	0
35	0.30%	0.30%	0.00%		35	0.04458	0.04509	-0.00051
36	0.00%	0.00%	0.00%		36	0	0	0
36	0.40%	0.40%	0.00%		36	0.05944	0.06012	-0.00068

38	0.00%	0.00%	0.00%		38	0	0	0
39	0.30%	0.30%	0.00%		39	0.04458	0.04509	-0.00051
40	0.00%	0.00%	0.00%		40	0	0	0
41	0.30%	0.20%	0.10%		41	0.04458	0.03006	0.01452
42	0.00%	0.00%	0.00%		42	0	0	0
43	0.30%	0.20%	0.10%		43	0.04458	0.03006	0.01452
44	0.00%	0.00%	0.00%		44	0	0	0
45	0.20%	0.20%	0.00%		45	0.02972	0.03006	-0.00034
46	0.00%	0.00%	0.00%		46	0	0	0
47	0.20%	0.10%	0.10%		47	0.02972	0.01503	0.01469
48	0.00%	0.00%	0.00%		48	0	0	0
49	0.20%	0.00%	0.20%		49	0.02972	0	0.02972
50	0.00%	0	0.00%		50	0	0	0
			0.91%					0.481083

End of Test Report