Conductive and Wireless Charging Benchmark Testing and Results

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U.S. DEPARTMENT OF ENERGY

Outline

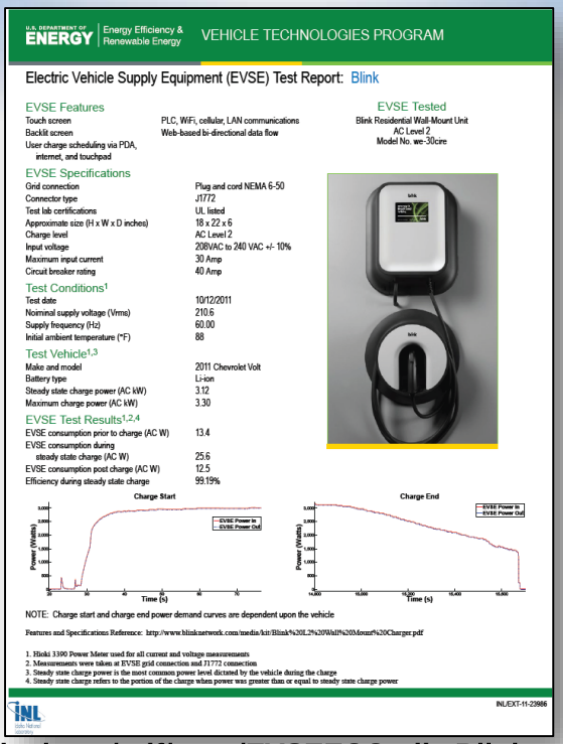
- Conductive Charging testing
  - Test equipment and scope
  - Level 2 EVSE results
  - DC Fast Charger results
  - On-Board Charger (Ac to DC) testing

- Wireless Charging testing
  - Testing Scope
  - Test equipment and apparatus
  - Testing safety

CONDUCTIVE CHARGING

EVSE Testing at INL

- Benchmark Testing and Reporting
  - Power consumption / Efficiency
    - Standby power
    - Power consumption during charge event
  - Conformance with J1772 standard
    - Safety
    - Compatibility / Interoperability
  - Testing complete and fact Sheets published
    - Twelve (12) Level 2 EVSE (using Volt)
    - One (1) DC Fast Charger (using LEAF)



ENERGY Energy Efficiency & Renewable Energy — VEHICLE TECHNOLOGIES PROGRAM

Electric Vehicle Supply Equipment (EVSE) Test Report: Blink

EVSE Features

Touch screen	PLC, WiFi, cellular, LAN communications
Backlit screen	Web-based bi-directional data flow
User charge scheduling via PDA, internet, and touchpad	

EVSE Tested

Blink Residential Wall-Mount Unit
AC Level 2
Model No. we-30cire

EVSE Specifications

Grid connection	Plug and cord NEMA 6-50
Connector type	J1772
Test lab certifications	UL listed
Approximate size (H x W x D inches)	18 x 22 x 6
Charge level	AC Level 2
Input voltage	208VAC to 240 VAC +/- 10%
Maximum input current	30 Amp
Circuit breaker rating	40 Amp

Test Conditions[1]

Test date	10/12/2011
Nominal supply voltage (Vrms)	210.6
Supply frequency (Hz)	60.00
Initial ambient temperature (°F)	88

Test Vehicle[1,3]

Make and model	2011 Chevrolet Volt
Battery type	Li-ion
Steady state charge power (AC kW)	3.12
Maximum charge power (AC kW)	3.30

EVSE Test Results[1,2,4]

EVSE consumption prior to charge (AC W)	13.4
EVSE consumption during steady state charge (AC W)	25.6
EVSE consumption post charge (AC W)	12.5
Efficiency during steady state charge	99.19%

Charge Start — Power (Watts) — Time (s) — EVSE Power In / EVSE Power Out

Charge End — Power (Watts) — Time (s) — EVSE Power In / EVSE Power Out

NOTE: Charge start and charge end power demand curves are dependent upon the vehicle

Features and Specifications Reference: http://www.blinknetwork.com/media/kit/Blink%20L2%20Wall%20Mount%20Charger.pdf

1. Hioki 3390 Power Meter used for all current and voltage measurements
2. Measurements were taken at EVSE grid connection and J1772 connection
3. Steady state charge power is the most common power level dictated by the vehicle during the charge
4. Steady state charge refers to the portion of the charge when power was greater than or equal to steady state charge power

INL/EXT-11-23986

http://avt.inel.gov/pdf/evse/EVSEECOtalityBlink.pdf

INL EVSE Benchmark Testing Capabilities

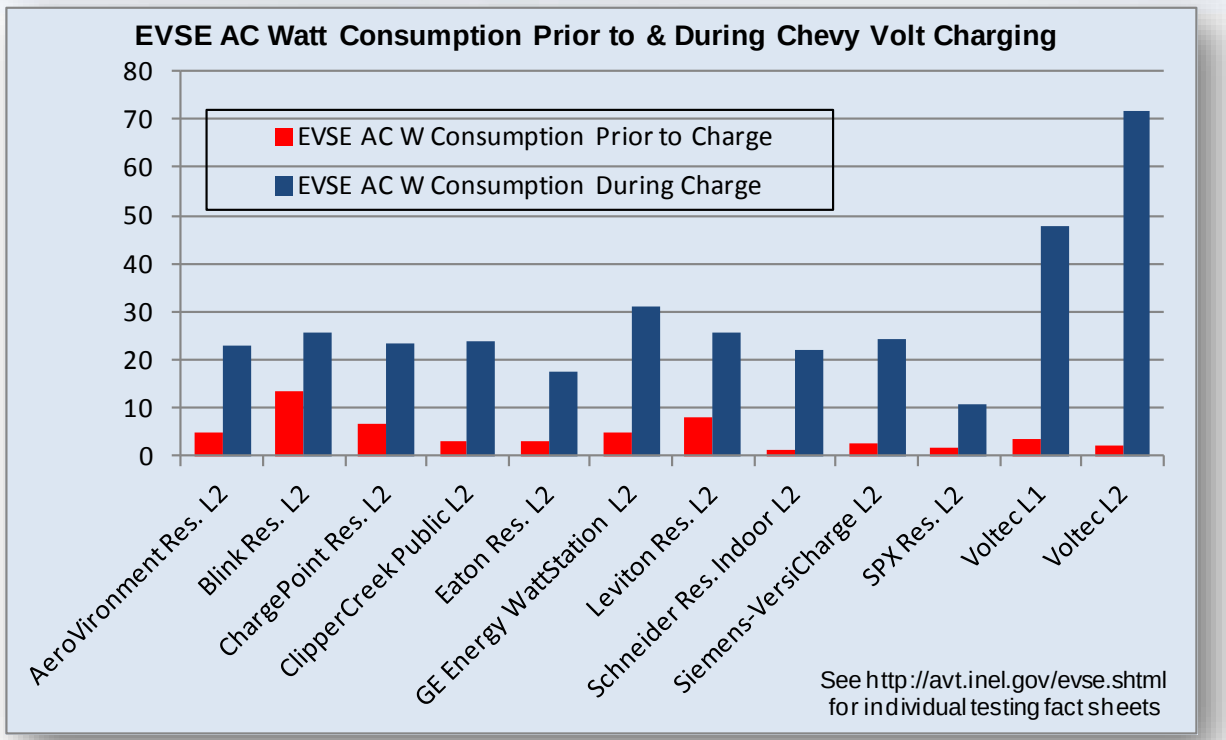
- Chroma C8000
  - Programmable AC load (and DC load)
    - 9kW AC load capability
  - J1772 communication and functionality testing

- Hioki 3390 power meter
  - 4 channel AC or DC current, voltage, power, integrated amp hours and energy, power factor, harmonics, etc.

- GridTest “Car in a Box” J1772 EVSE tester
  - 50 automated tests
    - Multiple State verification and Fault tests
    - GFCI safety testing

- Custom break-out box for multiple, non-invasive current and voltage measurements on input & output side of EVSE

Conductive EVSE Energy Consumption



- AC energy consumption measured at rest & during Chevrolet Volt charging
- Most EVSE consume 13 Watts or less at rest
- Higher power used at rest is tied to more EVSE features
- Most EVSE consume under 30 Watts during charge

DCFC Benchmarking – Leaf Charging

- 88.7% Overall charge efficiency (480VAC to ESS DC)
- 53.1 AC kW peak grid power
- 47.1 DC kW peak power to Leaf energy storage system (ESS)
- 15.0 AC kWh (grid) and 13.3 DC kWh delivered to Leaf ESS

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Production EVSE Fact Sheet: DC Fast Charger: Hasetec

Specifications

Grid connection	Hardwired
Connector type	CHAdeMo
Approximate size (H x W x D inches)	39 x 69 x 21
Charge level	DC Fast Charge
Input voltage	480 VAC - 3 Phase
Isolation Transformer[1]	75 kVA
Maximum input current[2]	120 Amp

Test Conditions

Test date	10/23/2012
Supply frequency (Hz)	60
Initial ambient temperature (°F)	65

Vehicle Charged

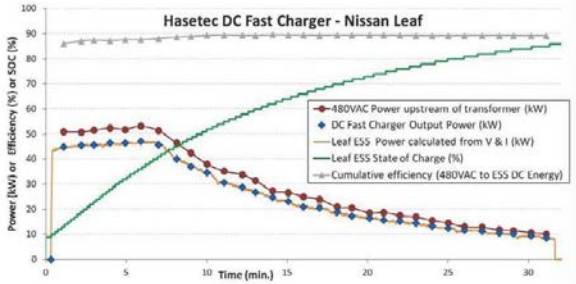
Make and model	2011 Nissan Leaf
Battery type	Li-ion
Initial Leaf ESS State of Charge[3]	9%
Final Leaf ESS State of Charge[3]	86%

DCFC Test Results[3, 4]

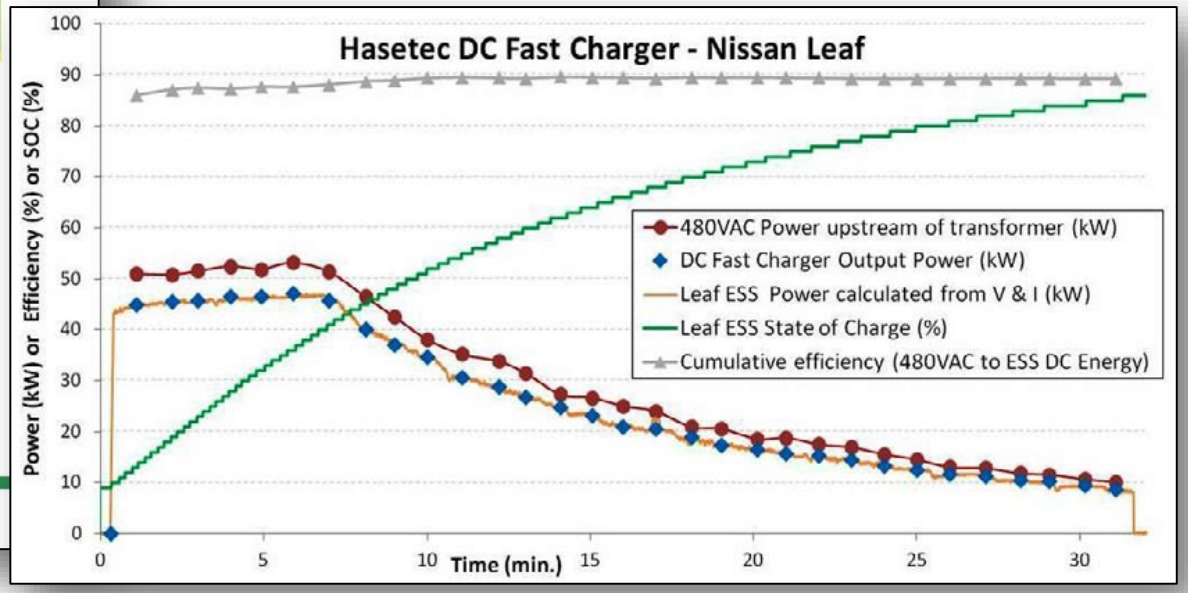
Peak Power draw from Grid (AC kW)	53.1
Energy from grid (AC kWh)	15.0
Peak Charge Power to Leaf ESS (DC kW)	47.1
Energy delivered to Leaf ESS (DC kWh)	13.3
Charge time (min:sec)	31:40
Overall Charge Efficiency (480VAC to ESS DC)	88.7%

DC Fast Charger Tested

Hasetec LI06-3P3W 50KW

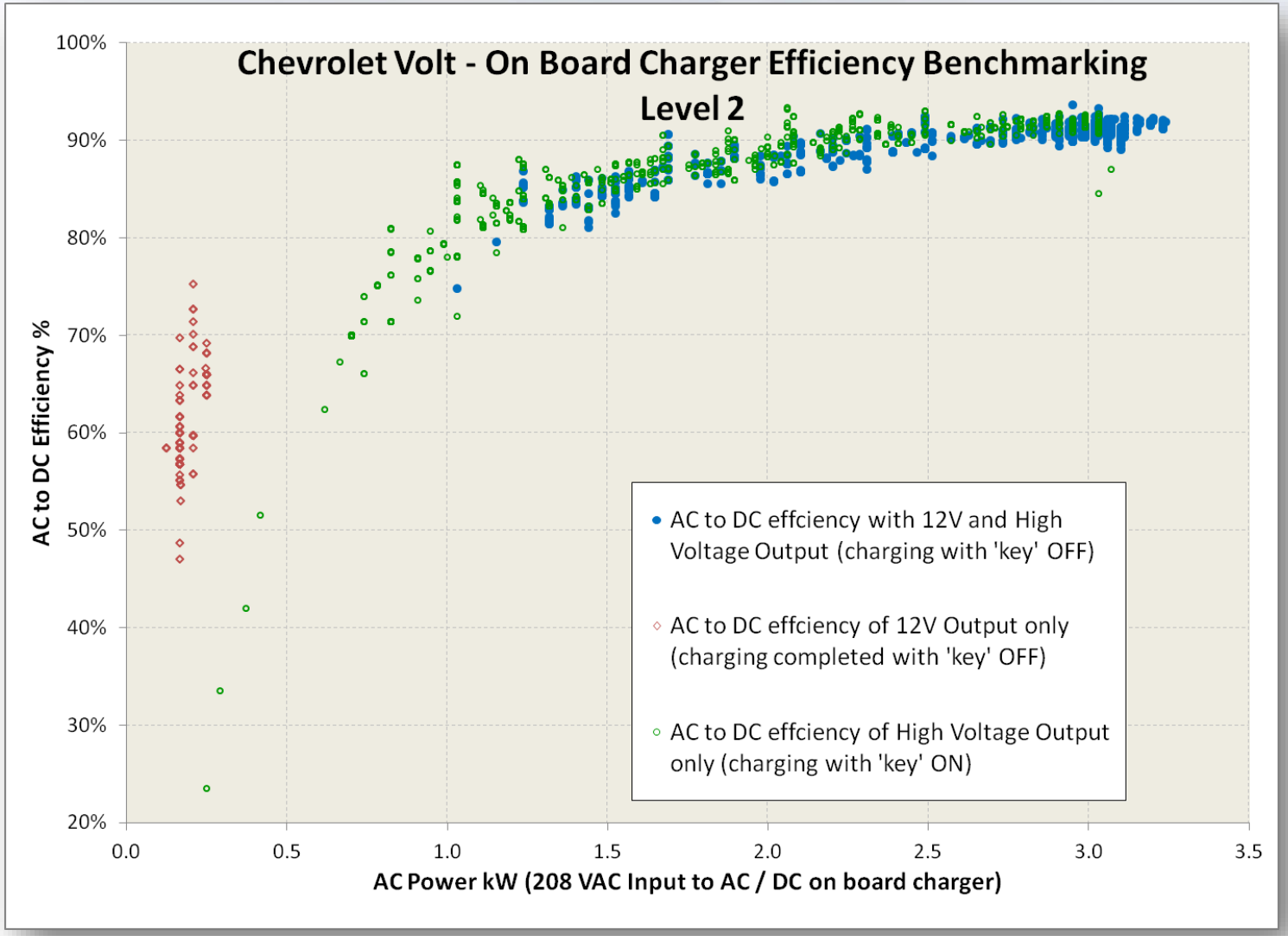


1. HPS Sentinel dry type Isolation Transformer
2. Manufacture specification = 125A max, this installation is configured to 120A max due to supply restrictions
3. Vehicle CAN message data acquisition and Hasetec DC output watthour meter used for DC measurements
4. Squre D WattHour meter used for 480VAC energy measurement on feed to transformer



http://avt.inel.gov/pdf/evse/DCFCHasetec.pdf

Conductive System Benchmarking



Entire report located at: **http://avt.inel.gov/pdf/phev/EfficiencyResultsChevroletVoltOnBoardCharger.pdf**

WIRELESS CHARGING

INL Wireless Charging Testing

- Benchmark testing of Wireless Charging Technologies
  - Laboratory system level testing at INL
  - Vehicle system testing

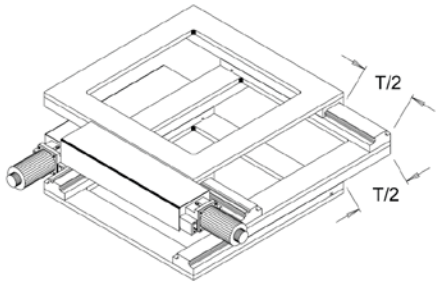
- **<u>Scope</u>: Provide Results from Testing**
  - **System Efficiency (AC input to DC output)**
  - **Electric and Magnetic Field Strength (EM field)**
  - **Impact on Grid (power quality, harmonics, etc.)**
  - **Support SAE J2954 committee**

INL Wireless Charging Test Parameters

- Parameters tested that impact primary scope
  - Coil Misalignment (X, Y, θ, Tilt, and Gap)
  - Power transfer at various level
  - Magnetic & Electric field strength at various locations
  - Temperature (warm-up impact)
  - Operating Frequency
  - Debris in between or near coils
  - Coil interoperability
    - Company A ground coil
    - Company B vehicle coil

INL Wireless Charging Test Equipment

- Programmable Loads
  - AC Loads (9.0 kW) Chroma 63804
  - DC loads (58 kW) Chroma 63210
- Hioki 3390 Power Meter
  - 4 channel AC and DC current and voltage
  - Real-time integration for power & energy
- NARDA EHP-200a
  - Electric Field
  - Magnetic Field
- FLIR SC640 Thermal Camera
- Fiberglass uni-strut with multi-axis positioning system
- CAN communications (as required)
- Custom LabVIEW data acquisition and test host to synchronize multiple data streams



INL Wireless Charging LaboratoryTesting

Grid Power
480 & 208 VAC

Hioki Power
Meter 3390

Chroma
AC Load

Chroma
DC Load

Custom LabVIEW Host and
Data Acquisition

FLIR IR
Camera

Multi-Axis
Positioning
System

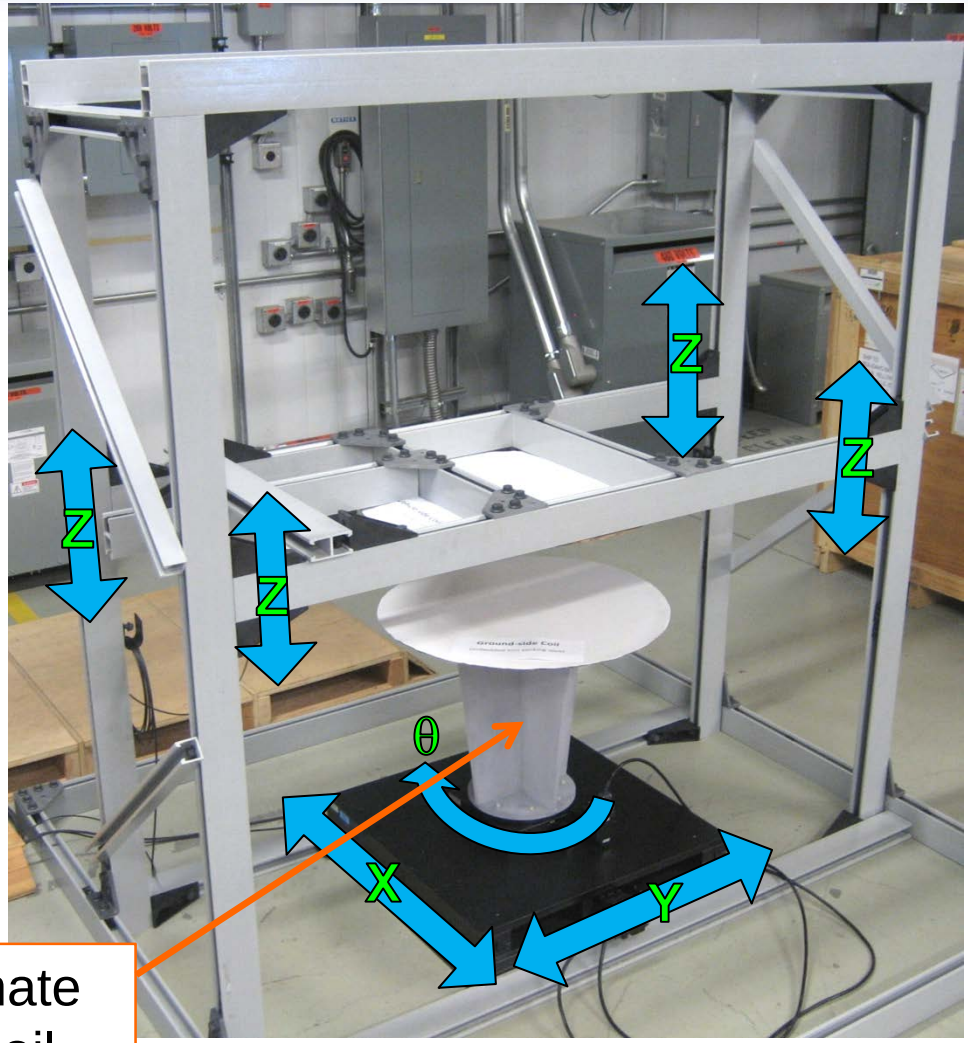
Polycarbonate
Primary Coil
Support

Narda EM Field
Meter (EHP-200a)

Fiberglass
Unistrut
Secondary Coil
Support

INL Wireless Charger Coil Positioning

- Primary Coil
  - Software position control
    - Ball-screw table with servo motor actuation
    - X, Y, θ
  - Supported by polycarbonate stand-off (distance from EM)
- Secondary Coil
  - Suspended from fiberglass unistrut frame
  - Manually adjusted to fixed position
    - Z position (coil to coil Gap)
    - Tilt by differential Z

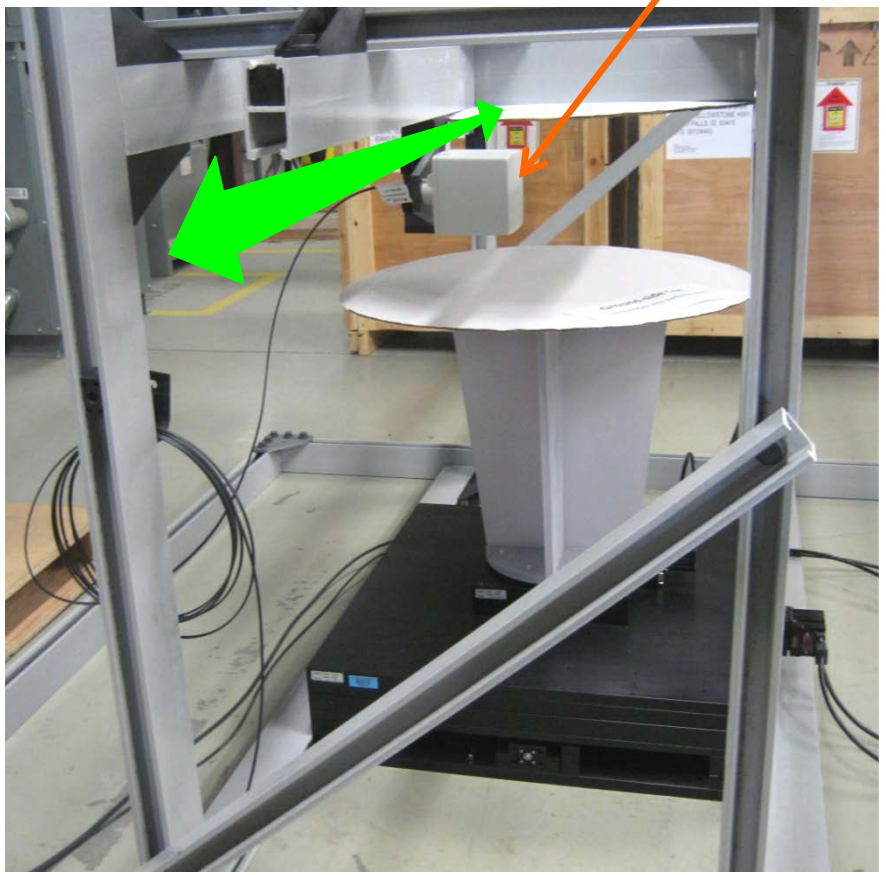


Polycarbonate Primary Coil Support

INL Wireless Charging: EM Field Measurement

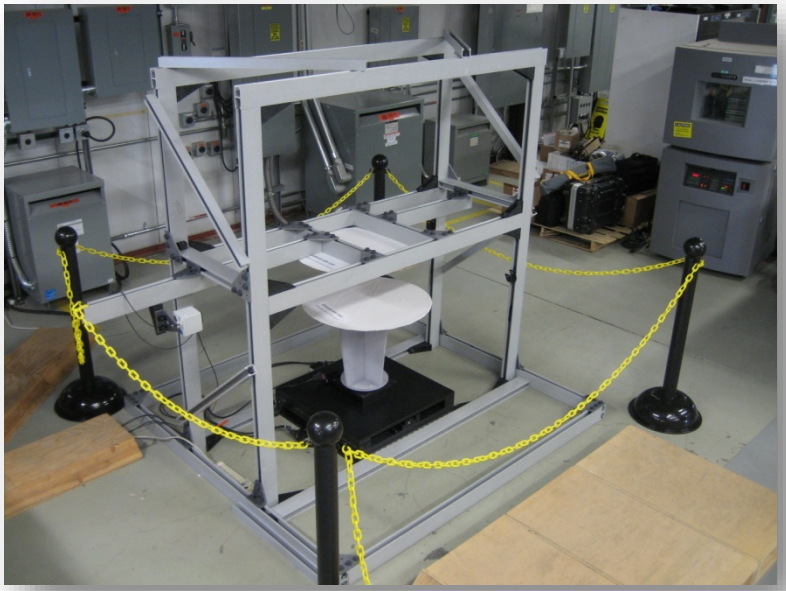
- NARDA EHP-200a mounted relative to secondary coil
  - Adjustable position from >1.0m to edge of secondary coil in Y-axis direction
  - Z position: typically centered between coils (adjustable)
  - Test plans measurements include
    - Along Y-axis
      - 0.5m, 0.8m, 1.0m, 1.3m
    - Above secondary coil
    - Below primary coil

Narda EM Field Meter (EHP-200a)



Safety is #1 priority : INL Wireless Charging Testing

- EM field ICNIRP limit: 6.25 μT
  - *(**I**nternational **C**ommission on **N**on-**I**onizing **R**adiation **P**rotection)*
- INL boundary set at 1.0m from coils center
  - INL pre-test “worst-case EM field” measurement for every WPT system to ensure proper boundary distance (increase if necessary)
  - Also prevents positioning system “pinch-point” hazard
- Warning Signs posted
  - Building entrance
    - Personnel with pacemakers
  - At boundary around wireless charger
    - Beyond the point: Electromagnetic fields



Safety is #1 priority : INL Wireless Charging Testing

- E-Stop buttons
  - Power shut down (AC supply disconnect)
  - Positioning system shut down
- FLIR Infrared camera
  - Monitor temperatures near coils since Magnetic field may cause excessive localized heating in debris / foreign objects

Summary

- INL has completed testing on twelve Level 2 EVSE & one DCFC
  - Fact Sheets are posted on **http://avt.inel.gov/evse.shtml**

- INL is currently testing the first Wireless Charging System
  - A fact sheet will soon be published showing the results for:
    - Efficiency and EM field
      - Gap
      - Power
      - Coil to Coil alignment
      - EM field meter location
      - Temperature (warm-up impact)
    - Power Quality and Harmonics
    - Surface Temperature (customer accessible areas)

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the U.S. Department of Energy's
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More Information

http://avt.inl.gov