DC Fast Charging Infrastructure
50 kW to 350 kW

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INL's Electric Vehicle Infrastructure (EVI) Lab

- Testing and evaluation results from advanced charging systems supports:
  - Support codes and standards development and harmonization
  - Grid modernization initiative
- Measurement evaluation metrics
  - System efficiency
  - EM-field emissions
  - Power quality
  - Response to dynamic grid events
  - Cyber security vulnerability assessment
- Wide range of grid input power
  - from 120 VAC to 480 VAC 3ϕ
  - 400 kVA total capability
- Sub-system and full vehicle testing capabilities

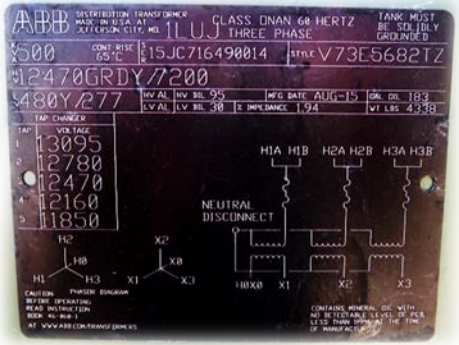
https://avt.inl.gov/panos/EVLTour/?startscene=pano5141

Current Technology: DC Fast charging

- CHAdeMO and SAE CCS
  - 50 kW power transfer
    - 480 VAC 3ϕ
    - 75 A circuit

Current Technology: DC Fast charging

- Tesla Super Charger Network
  - 120 kW power transfer to each vehicle
  - Charging complex
    (up to 8 Super Chargers at one site location)
    - 500 kVA from 12.5 kV utility electric grid feed
    - Stepped down at site to 480 VAC 3ϕ (600 A)



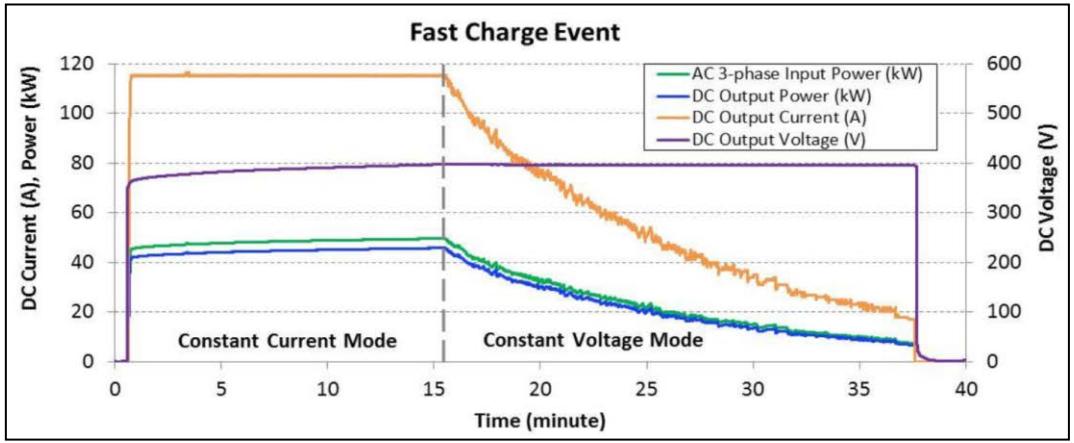
Pocatello, ID photo courtesy of Jim Francfort

Test Results: DC Fast charging

- ABB Terra 53 CJ while charging a 2015 Nissan Leaf

  Constant Current Mode

  - 92.3% AC to DC efficiency
  - -0.98 Power Factor
  - 11.0% input current THD
  - 6.1% Phase current unbalance

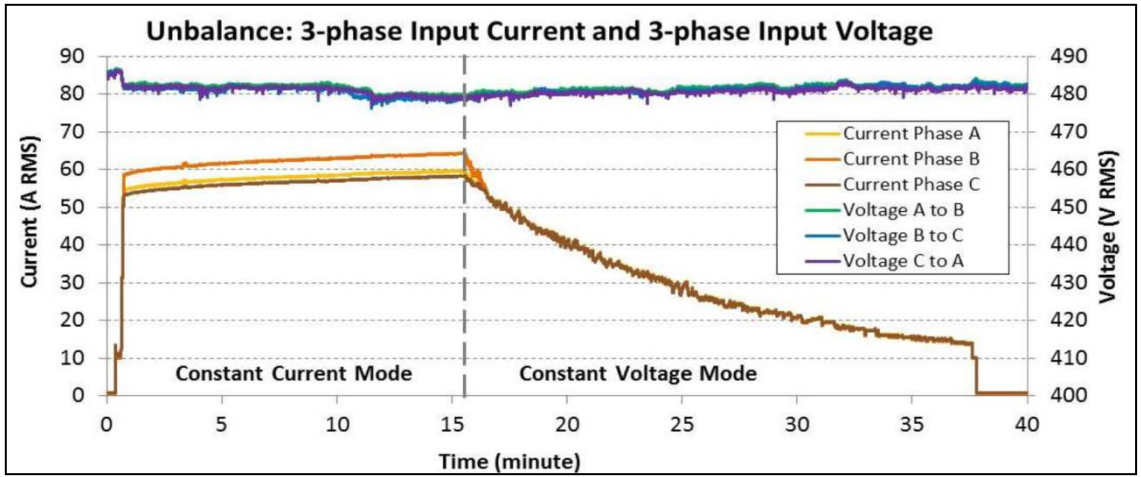


https://avt.inl.gov/sites/default/files/pdf/evse/ABBDCFCFactSheetJune2016.pdf

Current Technology: DC Fast charging

INL's test results:

- ABB Terra 53 CJ while charging a 2015 Nissan Leaf
  - Moderate phase to phase unbalance measured during constant current mode



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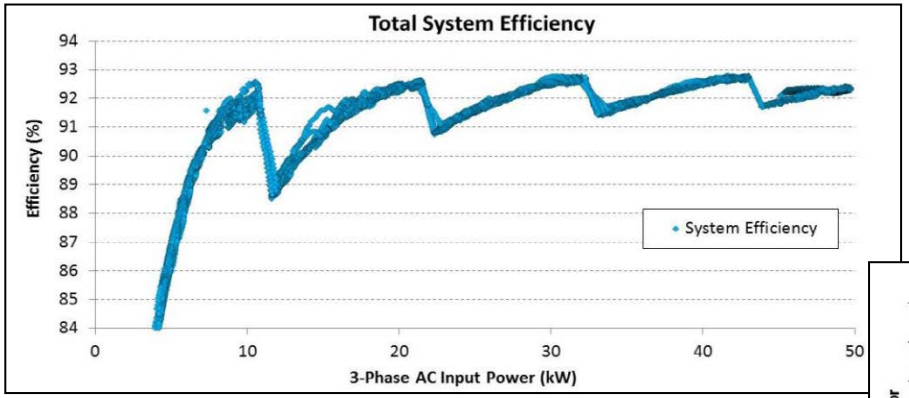

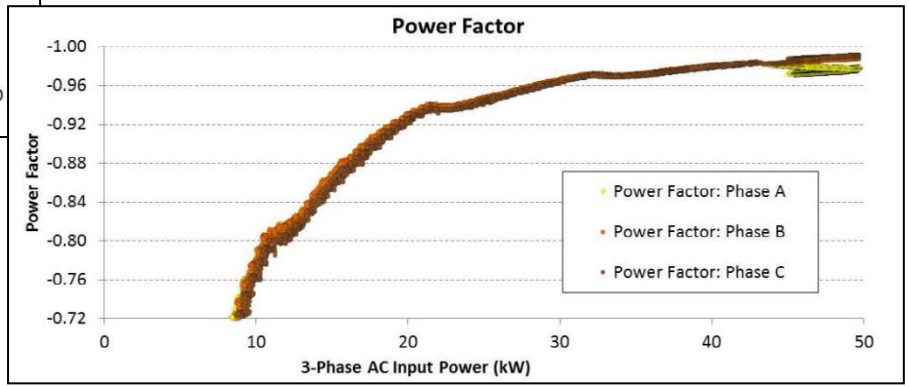

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Future Technology: Extreme Fast Charging

- Extreme Fast Charging (XFC)
  - Goal: charge in **<10 minutes**
    - 150 kW to 350 kW
  - For comparison: gasoline refueling
    - 10 gallons in **1 minute** (~20,000 kW and ~330 kWh)

- Infrastructure requirements (each XFC)
  - 480 VAC 3ϕ
  - 225 A to 525 A circuit (150 to 350 kW)

Future Technology: Extreme Fast Charging

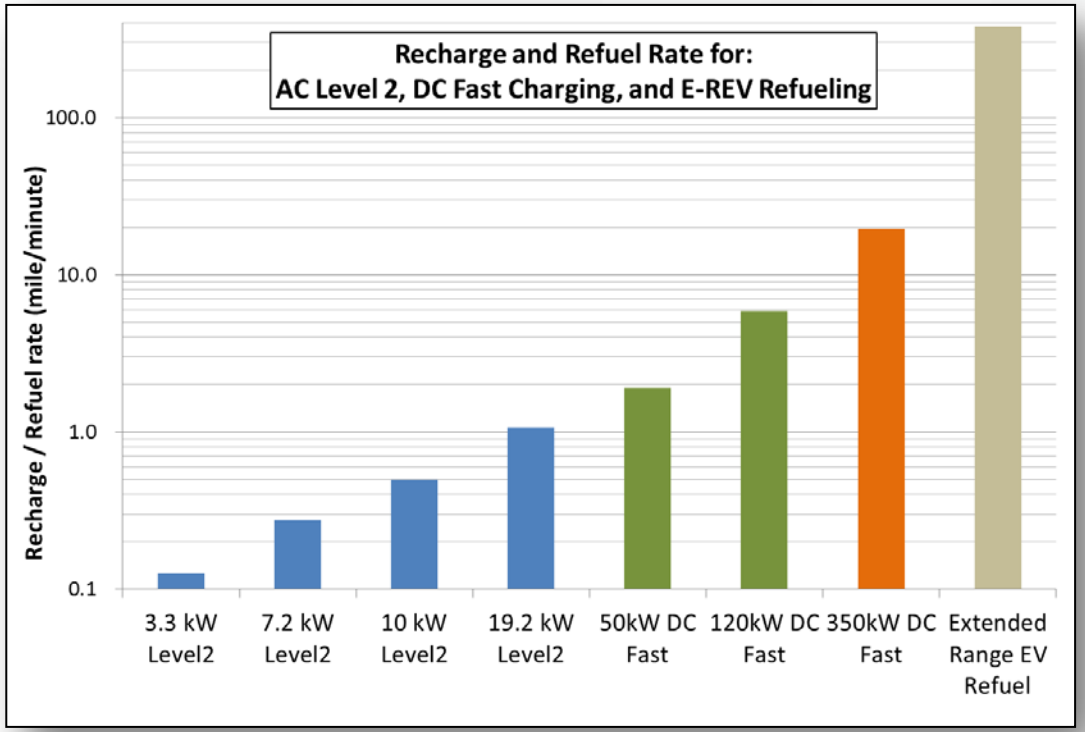
- Discrete circuit breaker and wiring sizes may limit / discretize the power level choice
  - Available breaker examples: 400A, 500A, 600A, etc.

- Potential issues
  - Distance / availability of 12 kV grid feed near the site
  - Mass of the charge cord and connector
  - Standardization (CHAdeMO, SAE CCS, Tesla, etc.)
  - Cost: component costs, installation costs, demand charges, etc.

- CHAdeMO and CCS
  - 150 kW (350A DC) charging standards in progress / near completion
    - First CHAdeMO 150kW installations expected in 2017
  - Both CHAdeMO and CCS are working towards 350 kW

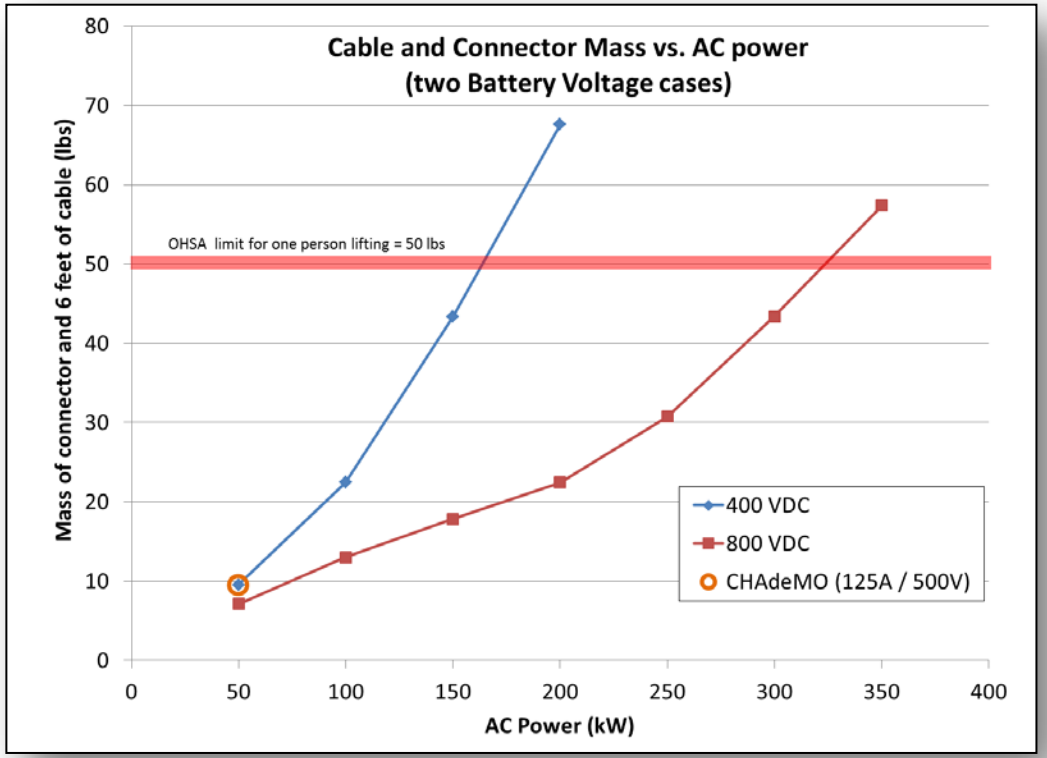
Recharge Rates of Various Methods

- Recharge Rate
  - Currently up to 120 kW
    - 6 mile/min
- Refuel rate for liquid fuel is limited by EPA to 10 gal/min (40 CFR 80.22)
  - >300 mile/min
- Proposed 350 kW fast charge
  - ~20 mile/min



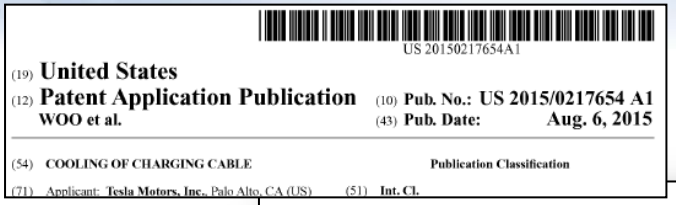
Mass of Charger Connector and Cable

- As charge power increases current and conductor size increases
  - Conductor size per NFPA 70E
  - Lifting mass limitation (OHSA)
    - 50 lbs. for one person
  - Higher battery voltage:
    - reduced charge current and therefore reduced cable size and mass
    - impacts all other vehicle high voltage component requirements



Connector and Cable Cooling

- With active cooling of the cable and connector
  - Pros:
    - Smaller wire gauge and connector
    - Reduced size, mass, cable stiffness
  - Cons:
    - Resistive losses increase with smaller wire gauge
    - Cooling system power
    - Total system cost higher
- Tesla published patents on cooling for charger connector and cable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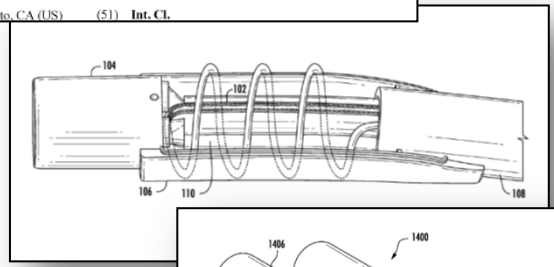
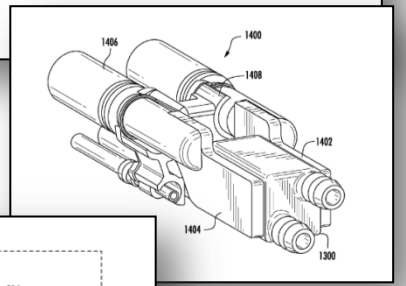
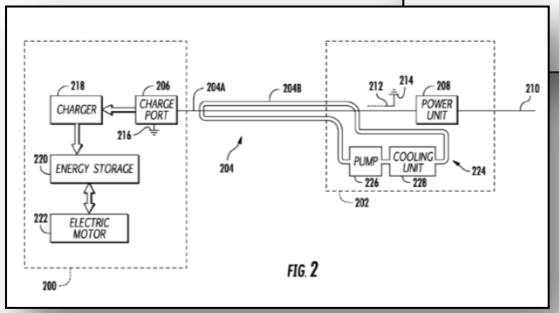
(71) Applicant: **Tesla Motors, Inc.**, Palo Alto, CA (US) (51) **Int. Cl.**







Summary

- INL's test results shows:
  - CHAdeMO DC Fast charger
    - 50 kW input power
    - 92% efficiency
    - 0.98 Power Factor

- Ongoing effort to study the feasibility of Extreme Fast Charging
  - Goal: charge in **<10 minutes**
  - 150 kW to 350 kW

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More Information

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