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Electrical Working Group

Head End Power Load Testing

Abstract: This recommended practice provides guidance for load testing the head end power (HEP) generating system on passenger rail vehicles.

Keywords: head end power, load testing

Summary: This document provides guidance for conducting load tests for HEP power sources, including description of load test equipment, when to conduct tests and a description of the test procedure.



Foreword

The American Public Transportation Association is a standards development organization in North America. The process of developing standards is managed by the APTA Standards Program's Standards Development Oversight Council (SDOC). These activities are carried out through several standards policy and planning committees that have been established to address specific transportation modes, safety and security requirements, interoperability, and other topics.

APTA used a consensus-based process to develop this document and its continued maintenance, which is detailed in the [manual for the APTA Standards Program](#). This document was drafted in accordance with the approval criteria and editorial policy as described. Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

This document was prepared by the Electrical Working Group as directed by the Passenger Rail Equipment Safety Standards Policy and Planning Committee.

This document represents a common viewpoint of those parties concerned with its provisions, namely transit operating/planning agencies, manufacturers, consultants, engineers and general interest groups. The application of any recommended practices or guidelines contained herein is voluntary. APTA standards are mandatory to the extent incorporated by an applicable statute or regulation. In some cases, federal and/or state regulations govern portions of a transit agency's operations. In cases where there is a conflict or contradiction between an applicable law or regulation and this document, consult with a legal adviser to determine which document takes precedence.

This document supersedes APTA PR-E-RP-011-98, Rev. 1, which has been revised. Below is a summary of changes from the previous document version:

- Updated working group roster; format updated to latest APTA standards format.
- Addition of Summary section.
- Added new Section Foreword.
- Added applicability language in the Introduction.
- Merged former sections 1.1, Scope, and 1.2, Purpose, into Scope and Purpose.
- Moved former section 2, References, to the new section References.
- Moved former section 3, Definitions, abbreviations and acronyms into new sections Definitions and Abbreviations and Acronyms.
- Added new section 1, When to conduct load testing.
- Renumbered former section 4, Load Box, to new section 2. Added portability recommendation for portable load boxes.
- Renumbered former section 4.1, Variable load testing, to new section 2.1. Added recommendation for load bank capacity.
- Renumbered former section 4.3, Meters, to new section 2.3. added recommendation for data logger capability. Added recommendation for power quality analyzer. Added recommendations for data logger capabilities.
- Renumbered former section 4.4, Cables, to new section 2.4. Added four jumper recommendation for loads over 800 A.
- Added new definitions: backup inverter, normal mode, and standby mode.



- Renumbered former section 5.2, Load test, to new section 3.2. Changed application of remaining load to be done in multiple steps. Added monitoring of voltage, frequency and THD while loading up to full rated capacity of source.



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Introduction

This introduction is not part of APTA PR-E-RP-011-98, "Head End Power Load Testing."

This standard applies to all:

1. Railroads that operate intercity or commuter passenger train service on the general railroad system of transportation; and
2. Railroads that provide commuter or other short-haul rail passenger train service in a metropolitan or suburban area, including public authorities operating passenger train service.

This standard does not apply to:

1. Rapid transit operations in an urban area that are not connected to the general railroad system of transportation;
2. Tourist, scenic, historic or excursion operations, whether on or off the general railroad system of transportation;
3. Operation of private cars, including business/office cars and circus trains; or
4. Railroads that operate only on track inside an installation that is not part of the general railroad system of transportation.

Scope and purpose

This recommended practice defines the requirements for load testing the head end power generating system on passenger rail vehicles.

The passenger rail industry phased this recommended practice into practice over the six-month period from July 1 to December 31, 1999. The recommended practice took effect January 1, 2000.

This document establishes a standard procedure for determining the performance of HEP generating system under the following conditions:

1. After initial assembly, major overhaul or repairs affecting performance of the system;
2. To determine condition of equipment as a guide to required repairs; or
3. To test equipment as required for equipment inspection reports.

Head End Power Load Testing

1. When to conduct load testing

Load testing should be conducted to verify that the HEP source is performing properly, including up to full rated load at the following times:

1. At system qualification testing (proof of design, once for the contract)
2. After initial assembly, major overhaul or repairs affecting performance of the system
3. Periodic inspection as dictated by the railroad
4. To determine condition of equipment as a guide to required repairs

On locomotives with normal/standby mode function, both HEP alternators should be tested. On locomotives with traction inverter backup of the HEP inverter, both inverters should be tested. In addition, for situations where the HEP source is new to the customer, a light load test should be conducted to verify acceptable performance with the passenger cars with which it will be used. This should include operation with a single car under minimal load conditions, such as with the HVAC system off. This is to verify source stability, harmonic performance and freedom from EMC issues under light load, and/or possibly poor phase balance conditions.

2. Load box

The load box should consist of the following:

- variable resistance load
- cooling fan(s)
- load control switching
- control panel
- instrumentation
- suitable weatherproof enclosure
- 480 Vac receptacles and cables to connect the unit to the vehicle being tested

Since locomotives and wayside power sources may be located in various places on the railroad property, load boxes should be portable, i.e., trailer-mounted, with consideration for permanent installation as appropriate.

2.1 Variable resistance load

A standardized load bank capacity suitable for the highest rated load of the HEP sources on-site (e.g. 1000 kW) is recommended. The resistance load should be balanced and variable in 10% steps or smaller from zero to full load. Suitable contactors should be provided to execute these load changes, as well as isolate the entire load. It should be possible to apply approximately 50% of the source-rated load in a single step to allow testing of the source to a step load. The resistance load should enable the HEP source being tested to be continuously loaded to at least 110% of the source rated capacity.

2.2 Controls and indicators

A control panel should be provided to operate the load box, including on/off control, load adjustment, power on and fault indication.

2.3 Meters

The control panel should be provided with the following meters (preferably with data logging capability) to show performance of the HEP system under test as follows:

1. a true-RMS voltmeter capable of reading each of the three phases and reading phase-to-phase voltage; 1% or better accuracy
2. an ammeter capable of reading each of the three phases, reading phase current; 1% or better accuracy
3. a wattmeter capable of reading combined load from all three phases; 1% or better accuracy
4. a frequency meter reading the frequency of the HEP source; ± 0.25 Hz over the range of 55 to 65 Hz or better accuracy
5. a power quality analyzer (to measure full harmonic spectrum THD), such as a Fluke Three-Phase Power Quality Logger (1738) or equal

The data logger should be capable of recording, at a minimum:

1. Voltage (V)
2. Current (A)
3. Frequency (Hz)
4. Power (kW, kVA, kVAR)
5. Power factor

The data logger should have a data download feature via USB or other nonproprietary communication medium. The instrumentation should be rugged industrial quality, suitable for the operating environment, including but not limited to ambient temperature range.

2.4 Cables

Suitable cabling should be provided to connect the load box to the equipment under test.

If the load box will be used in the field on complete locomotives (or power cars), a suitable pair (or two pairs as necessary) of receptacles and jumper cables should be provided to connect the load box to two (or four) of the HEP receptacles on the vehicle under test. For HEP applications of 800 A or less, a single pair of jumper cables provides sufficient rating for testing. However, if the source capacity is above that, two pairs jumper cables are necessary. The load box end of the cable system should provide the trainline complete circuit for safety (by providing continuity between the #1 control pins of the jumper cables) so HEP can be applied only when all cabling is in place.

2.5 Certification

The load box, including meters, should undergo periodic testing and calibration at least annually, or as specified by the manufacturer. A complete system functional test should be performed annually. Records should be kept with the equipment and should be available upon request by test observers.

3. Procedure

3.1 Setup

1. Following facility safety rules related to HEP, connect the load box to the HEP unit to be tested.
2. Check the load box instrumentation for proper initial readings.
3. Activate the load box, fan started, etc., but with zero load applied.
4. Warm up the HEP source as required to bring the engine up to normal operating temperature required before a load is applied.

3.2 Load test

In each of the following steps, observe the instruments to confirm the engine governor and voltage regulator respond correctly to the change. Particularly during the large-change steps, confirm that control of the engine speed is maintained; that the engine does not bog down when the load is applied; that it does not run away when the load is decreased; and that under/over frequency or voltage trips do not occur.

1. Apply load in steps up to the full source rated load.
2. Drop half the load in one step.
3. Drop the entire remaining load in one step.
4. Apply 50% of the rated load in one step.
5. Apply the remaining load (to attain full rated load) in as few steps as necessary to fulfill the requirements of the design, contract or test equipment.
6. Drop entire load in one step.
7. Gradually apply the load up to full rated capacity of the source. As the load is increased, monitor:
 - Voltage: Steady state, it should remain $\pm 2\%$ over the range.
 - Frequency: Steady state, it should remain $\pm 1\text{Hz}$ over the range.
 - THD: It should not exceed 5% between 10% and 100% load.
8. Allow the system to operate for 30 minutes. (If the railroad requirement differs, that specified time should apply.) At the end of this period:
 - Confirm that the prime mover continues to operate normally (no overheating, etc.).
 - Confirm that the HEP switch gear shows no distress or signs of overheating.

For systems that employ split-bus trainlines, the following should also apply:

9. Conduct steps 7 and 8 above with the load box connected only to the left side trainline bus.
10. Conduct steps 7 and 8 above with the load box connected only to the right side trainline bus.
11. If the single bus rating is less than the HEP rating with both buses active, then conduct steps 7 and 8 with the load applied to both buses simultaneously and the load at full system rated load.

3.3 Completion

1. Reduce the load to zero and shut down the HEP source. If required, allow the system to cool off before shutting down the engine.
2. Following facility safety rules, disconnect the load box.
3. Complete the documents recording the load test.

The data sheet in Appendix A should be used to record test results of the head end power load test unless a different form is required by the railroad. In either case, the data sheet should be fully completed, signed and filed for future reference.

References

IEEE Std 100-1996, “The IEEE Standard Dictionary of Electrical and Electronics Terms,” April 1997.
<https://standards.ieee.org/ieee/100/256/>

Definitions

backup inverter: The traction inverter used on some locomotives as a backup should the normal HEP inverter fail. In this operating mode, the traction inverter is configured to produce 480 Vac, 60 Hz output rather than that used for traction.

head end power (HEP): A system by which 480 VAC, three-phase electrical power, to operate auxiliaries, is provided to railroad vehicles via a trainline system. The power source can be locomotive (hence “head end”), power car or wayside power source.

HEP jumper cable: A cable assembly, having a six-conductor (three power and three control pins) plug on one or both ends, which is used to provide a flexible electrical connection between two cars and/or locomotives or wayside equipment.

HEP receptacle: The receptacle(s) mounted on the ends of rail vehicles and wayside equipment into which the HEP jumper cables mate.

HEP switchgear: The contractors, circuit breakers, power switches, overload protection and associated control components used to connect the HEP power source to the trainline system.

HEP trainline: An electrical cable system that allows HEP power to be transmitted over the entire length of a train. It includes both power and control conductors. The trainline may connect to equipment in each vehicle, or it may simply pass straight through, providing a power path between vehicles on opposite ends of that vehicle.

load box: A piece of wayside equipment used to provide a test load and for an HEP source to allow its performance to be measured. The equipment consists of a variable resistance load, cooling fan, load control switching, control panel and instrumentation.

normal mode: On a locomotive where the prime mover drives both the traction alternator and the HEP alternator, the operating mode in which HEP is supplied by the HEP alternator.

standby mode: On a locomotive where the prime mover drives both the traction alternator and the HEP alternator, the operating mode in which HEP is supplied by the traction alternator. In this mode, the locomotive cannot supply traction power. This mode is used primarily in terminals since the engine should consume less fuel and generate less noise when operating in this mode, as it operates at a lower speed than in normal mode.

trainline complete (TLC): A series continuity check circuit used to determine that all trainline jumper cables throughout the consist are plugged in. The circuit provides an indication at the HEP control panel and is interlocked with the HEP main contactor/circuit breaker to allow trainlines to be energized only when the TLC is established.

wayside power: An installation that provides HEP from a ground-based source, used to provide power to the consist when the onboard source is unavailable, such as in a yard. Generally, utility power is used, though sometimes a diesel generator is provided.

Abbreviations and acronyms

A	amp
EMC	electromagnetic compatibility
HEP	head end power
HVAC	heating, ventilation and air conditioning
Hz	hertz
kVA	kilovolt-amp
kVAR	kilovolt-amp reactive
kW	kilowatt
RMS	root mean square
THD	total harmonic distortion
TLC	trainline complete
USB	Universal Serial Bus
V	volt
Vac	volts alternating current

Document history

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Appendix A: Sample data sheet

HEAD END POWER LOAD TEST

Locomotive/car number: _____ Date of test _____

HEP system serial number: _____ Tester: _____

Reason for conducting load test: _____

Serial number of load box: _____

Date of load box certification: _____

Setup

- 1. Load box instrumentation reads properly.
- 2. HEP system warmed up for _____ minutes.

Load Test

- 1. Apply load in steps up to full source rated load
 - Voltage: _____ Volts
 - Current: _____ Amps
 - Power: _____ Watts
 - Frequency: _____ Hertz
 - THD: _____ %
- 2. Drop 50% of the load in one step.
- 3. Drop entire remaining load in one step.
- 4. Apply 50% of the rated load in one step.
- 5. Apply the remaining load (to attain full rated load) in several steps.
- 6. Drop entire load in one step.

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7. Gradually apply the load up to full rated capacity of the source. Allow the system to operate for 30 minutes. (If the railroad requirement differs, that specified time should apply.) At the end of this period:

Confirm that the engine (and inverter if equipped) continues to operate normally (no overheating, etc.)

Confirm that the HEP switch gear shows no distress or signs of overheating.

Record the following:

Time at full load: _____ Min.

Voltage: _____ Volts

Current: _____ Amps

Power: _____ Watts

Frequency: _____ Hertz

THD: _____ %

For systems that employ split-bus trainlines, the following should also apply:

8. Conduct step 7 above with the load box connected only to the left side trainline bus.

9. Conduct step 7 above with the load box connected only to the right side trainline bus.

10. If the single bus rating is less than the HEP rating with both buses active, then conduct step 7 with the load applied to both buses simultaneously and the load at full system rated load.