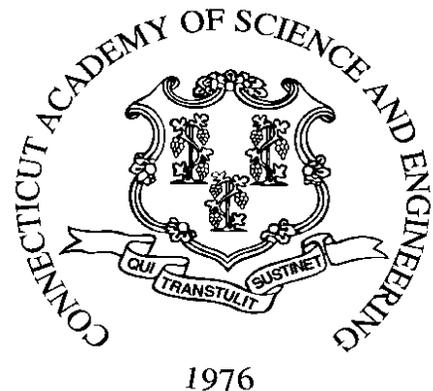


Committee Report:
Review of CTTRANSIT
Diesel Bus Research
Program

MARCH 18, 2003

A REPORT BY

THE CONNECTICUT
ACADEMY OF SCIENCE
AND ENGINEERING



FOR

The Connecticut Department of
Transportation
And
CTTRANSIT™

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This limited-scope study consists of recommendations by the ad hoc Committee on Diesel Bus Research. The content of this report lies within the province of the Academy's Technical Boards on Transportation Systems and on the Environment. The report is hereby released with the consent of the Committee.

Richard H. Strauss
Executive Director

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**CONNECTICUT ACADEMY OF SCIENCE AND ENGINEERING
REVIEW COMMITTEE REPORT
CTTRANSIT DIESEL BUS RESEARCH PROGRAM
MARCH 2003**

STATEMENT OF INQUIRY: To assure alignment of current bus project goals and investment with stakeholders' interest and needs. The Academy's Review Committee will provide its written assessment of the proposed Diesel Bus Research Program.

Program Introduction and Overview

The CTTRANSIT diesel bus research program committee and the CT Academy review committee met on March 3, 2003 to review the proposed environmental testing program for both new conventional diesel and hybrid diesel-electric ("hybrid") buses. Of primary concern was a review of the types of testing equipment under consideration for conducting the necessary tests. Following the joint committee meeting, the CT Academy review committee met to develop its recommendations for presentation to CTTRANSIT. The following provides an overview and introduction to the proposed research program as well as the salient conclusions of the Academy's review committee.

Hybrid bus characteristics:

- The new hybrid buses will be compared with new conventional diesel buses with regard to both emissions and reliability.
- Most of the systems/components of the hybrid buses are the same as those on the conventional diesel buses, except for the batteries, hybrid drive system, and electrical controllers.
- The CTTRANSIT hybrid buses are the first buses being manufactured with "parallel" drive systems. These systems have been used in trucks operated by the military.
- Battery Life: Nickel metal hydride battery is expected to last 6 years, which would require only one replacement during the 12-year bus service life.

Hybrid bus benefits:

- Savings expected from hybrid buses:
 - Regenerative braking on the hybrids will reduce brake wear and therefore increase maintenance intervals for brake maintenance/replacement.
 - Increased fuel economy in the range of 20-25%.
 - Expected longer engine time between overhaul (TBO) intervals.
- Reduced emissions expected as compared to a conventional diesel bus:
 - Much lower NO_x, PM, CO, and greenhouse gas emissions.
- It was noted that in older buses engine noise covered up other system noises that may become more apparent to customers as engine system noises are reduced.
- Brake squeal noise should be significantly lower.

Program timeline:

➤ Schedule:

- Delivery expected in 2 months (end of April 2003).
- Test equipment purchased and delivered in 3 months (May-June 2003)
- Testing to begin in late Spring or early Summer 2003.

Testing Program

➤ Testing period for EGA and PM will be two years in three eight month cycles, using two new hybrid diesel-electric buses and two identical new conventional diesel buses. These buses will be operated during the indicated periods, as follows:

- 1st - 8-month period: on #1 diesel fuel.
- 2nd - 8-month period: on Ultralow sulfur diesel fuel, without a PM filter.
- 3rd - 8-month period: on Ultralow sulfur diesel fuel & PM filter.

➤ Environmental testing considerations:

- Operating environment for buses is mixed, with buses operating on local, high speed and hilly routes. There was a question regarding how specific the records of the type of routes the buses travel on need to be - type of route - number of stops, etc.
- Weather and temperature information will be collected.
- CTTRANSIT will maintain complete maintenance records for the buses, including all fluid consumptions, e.g. engine oil, transmission fluid and fueling records. Also, software/controller problems.
- Fuel Testing- the diesel fuel specification used by CTTRANSIT has a range of acceptable levels of sulfur that could have a significant impact on the results of any testing. Analysis of sulfur content in fuel for emission tests is necessary.

➤ Operational surveys:

- Survey of drivers at the 8th month mark of operations - or possibly earlier.
- Survey of customers (riders) is being considered.
- Survey of bus maintenance personnel was not discussed.

➤ Types of testing equipment

- CEM: Continuous Emissions Monitors - most widely used and accepted method of testing for bus emissions.
- FTIR: Fourier Transform Infrared Spectrometer - used extensively in laboratory and now can be used in operational tests. Requires more intensive computer skills and effort to produce results. Calibration process used for FTIR equipment is an estimate.

➤ Testing of the following are under consideration for the research program:

- Total (non-methane) hydrocarbons/aldehydes
- SO₂
- CO₂
- CO
- NO_x
- O₂
- Particulate matter, allowing determination of overall grams per mile, and distribution of particle sizes.

Connecticut Academy of Science and Engineering Review Committee Assessment

Possible Actions for Consideration

CEM test equipment should be purchased for the testing program for the following reasons:

- Most widely accepted method of testing bus emissions.
- Easiest to use by maintenance technicians responsible for operating the test equipment.
- Equipment proven credible with the EPA should be used.
- Measurements should be done credibly even though they need not be certified to an absolute standard.

Testing program methodology:

- Accepted current testing methodology and protocols, such as the SAE J2711 “Recommended Practice for Measuring Fuel Economy and Emissions of Hybrid-Electric and Conventional Heavy Duty Vehicles” should be utilized. Consider using methods of testing and the equipment that could be traced to EPA standards.
- In addition to emissions testing, detailed operational/maintenance cost data should be collected to determine the variances in the cost of operation and reliability between the hybrid buses and the conventional diesel buses, including MTBF information.
- Hot Testing:
 - The equipment purchased should have the capability for “hot testing” which would include aldehydes.
 - Additionally, if looking for absolute results, need to use testing methods similar to other studies. If only looking for variance between CTTRANSIT bus types, then can go with cold testing, however, this would eliminate the ability to collect data with regard to aldehydes.
- Consideration should be given to at a minimum testing those emissions as required by EPA as well as additional emissions components to include any or all of the following:
 - Total (non-methane) hydrocarbons/aldehydes
 - SO₂
 - CO₂
 - CO
 - NO_x
 - O₂
 - Particulate matter, allowing determination of overall grams per mile, and distribution of particle sizes.
 - The testing for nanoparticles is desirable.
 - Contacts for PM testing equipment are as follows:
 - Rupprecht & Patashnick, Inc., 25 Corporate Circle, Albany, NY 12203; 518-452-0065. e-mail: info@rpco.com
 - Thermo Electron, Environmental Instrument Division, Thermal Anderson Product Line, 27 Forge Parkway, Franklin, MA 02038; 800-241-6898

- Sensors, Inc., 6812 S. State Road, Saline, MI 48176-8708; 734-429-2100; e-mail sales@sensors-inc.com; web address: www.sensors-inc.com
- It is recommended that fuel samples should be tested by taking a fuel sample from each bus at the time of testing so as to be certain about the exact specifications of the fuel in use at such time, *i.e.* sulfur content.
- Additionally, it may be advantageous for the testing program to begin as soon as possible after the new buses are put into service for the purpose of completing the testing program in a timely manner so as to have results available as a tool in making decisions about future bus purchases.
- A study of methods used by others for the purpose of reviewing their testing methodologies in an effort to assure credibility and general acceptance of the proposed testing program could be helpful.
- An additional contact regarding vehicle emissions testing at the Engine Research Center of the University of Wisconsin is as follows:

Professor Rolf D. Reitz, Wisconsin Distinguished Professor
Engine Research Center, University of Wisconsin
1018A Engineering Research Building
1500 Engineering Drive, Madison, WI 53706
Telephone: 608-262-0145; e-mail: reitz@engr.wisc.edu
web address: www.erc.wisc.edu

CONNECTICUT ACADEMY OF SCIENCE AND ENGINEERING

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