

# MODAL ANALYSIS OF VEHICLE OPERATION AND PARTICULATE EMISSIONS FROM CONNECTICUT TRANSIT BUSES



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Paper 09-0533

## ABSTRACT

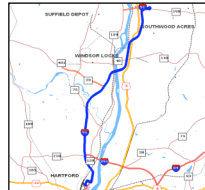
Transit buses represent a significant source of particulate exhaust emissions, especially in urban areas, but few previous studies have quantified these emissions using real-world, onboard sampling while the vehicles operate in the transportation network. In this study, real-world particle number emissions for hybrid diesel-electric (HDE) and conventional diesel (CD) buses, are examined for various vehicle operating conditions and road types in the Hartford, CT region. The results presented in this paper are based on analysis of the unique second-by-second CT Transit on-road transit bus emissions and operations dataset collected between Jan-November, 2004 [13]. The results of this analysis indicate hybrid buses operate differently from conventional diesel buses. Although the distributions of vehicle specific power (kW) values were similar between the two bus types, the distributions of engine operation parameters (load and RPM) were different. Therefore, VSP alone cannot be used to distinguish between vehicle types when modeling engine operation (and possibly emissions) from hybrid and conventional vehicles. Furthermore, the modal analysis of ultrafine particle emissions indicates there are situations where the HDE buses do not outperform the CD, and may even produce higher emission rates than the CD buses tested. Thus, there are routes and conditions where transit authorities should avoid the use of HDE buses similar to those tested here when particle emissions are of concern.

## TEST ROUTE

3 CT transit bus routes were combined to create a 62 mile test route for data collection

### Enfield Section

- 33.4 miles
- Along I-91
- 65 mph speed limit
- Majority of the route is cruising



### Farmington Section

- 12.3 miles
- Arterial roads
- 35 mph
- Signalized intersections

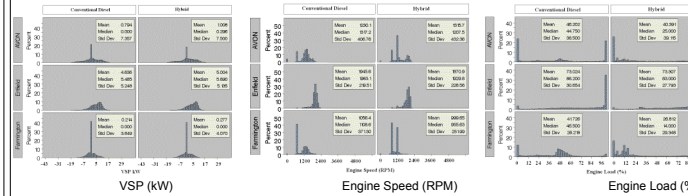


### Avon Section

- 16.2 miles
- Suburban
- 40 mph speed limit
- Steep grades

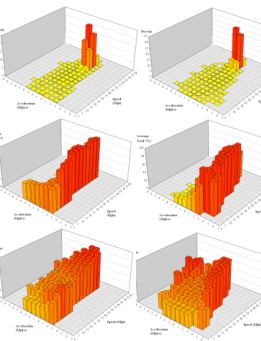


## OPERATIONAL ANALYSIS



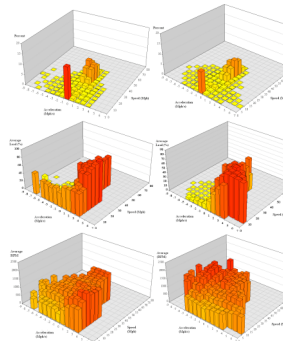
### Enfield Route

Conventional Diesel, Hybrid Diesel-Electric

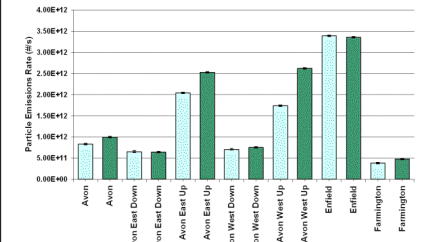


### Avon Route

Conventional Diesel, Hybrid Diesel-Electric



## EMISSIONS ANALYSIS



Enfield routes HDE and CD bus emissions rates were **not significantly** different.

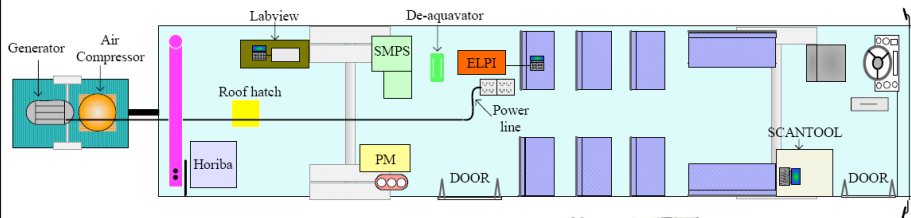
Avon Uphill The PN emissions rates for the HDE buses were larger and are **statistically different** than the CD bus type PNEs.

Avon West. The mean PN rates were **not different** based on bus type when the entire westbound Avon route was examined.

Farmington West and Avon East routes were **not different** from each other based on vehicle type.

Water Grouping		Mean	N	Route XY	Bus Type
A	A	3.40E+12	10046	Enfield North	CD
B	A	3.42E+12	14106	Enfield South	HDE
B	A	3.40E+12	13382	Enfield South	HDE
B	B	3.36E+12	11893	Enfield South	CD
C	C	2.62E+12	2334	Avon West Up	HDE
C	C	2.53E+12	2100	Avon East Up	HDE
D	D	2.04E+12	1896	Avon East Up	CD
E	E	1.74E+12	2178	Avon West Up	CD
F	F	7.53E+11	1938	Avon West Down	HDE
G	F	7.07E+11	1754	Avon West Down	CD
G	H	6.54E+11	2061	Avon East Down	CD
G	H	6.42E+11	2416	Avon East Down	HDE
I	H	6.14E+11	7065	Avon West	HDE
I	J	5.37E+11	6556	Avon West	CD
K	J	5.19E+11	17747	Farmington West	HDE
K	J	5.09E+11	5564	Avon East	HDE
K	J	5.00E+11	5362	Avon East	CD
K	L	4.31E+11	15276	Farmington West	CD
L	L	4.30E+11	18840	Farmington East	HDE
M	M	3.35E+11	17193	Farmington East	CD

## EQUIPMENT

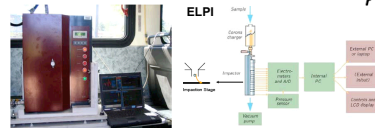


2 Conventional Diesel and 2 Hybrid Diesel Electric Buses

Electrical Low Pressure Impactor (ELPI) - Particle number (#/cm<sup>3</sup>)

Scantool - Engine speed (RPM), Engine load (%) and Vehicle speed (MPH)

Horiba OBS-1000 Exhaust Analyzer- Exhaust flowrate (L/Min)



## CONCLUSIONS

### Operations

•Vehicle operation (VSP) does not vary based on bus type. However, there are obvious differences in engine operation between CD and HDE buses.

•The diesel engines of these two bus types are operating differently as shown in the operational analysis. Therefore VSP is a measure of how the vehicle is operating. On HDE buses emissions are a function of how the diesel engine is operating not the vehicle as a unit. **Thus VSP may not be an accurate predictor variable for HDE emissions.**

•The operational analysis indicates that bus type is significant and that HDE bus operation **should not be modeled using the same equations as CD buses.**

### Emissions

•The emissions analysis indicates, driving routes and vehicle type have a significant impact on the mean particle number emissions rate generated by the bus.

•The results of this analysis are contradictory to the common belief that a HDE will produce significantly lower emissions than a CD, at least with respect to PN emissions.

## ACKNOWLEDGMENTS

This research was sponsored by the Connecticut Cooperative Highway Research Program (JHRAC, project 05-09). The authors would also like to thank the Connecticut Department of Transportation for their assistance in road grade data collection.