December 1998 • NREL/SR-540-25154

Subcontractor Report

Development of LNG-Powered Heavy-Duty Trucks in Commercial Hauling

Trucking Research Institute
Alexandria, Virginia

Detroit Diesel Corporation
Detroit, Michigan

National Renewable Energy Laboratory

1617 Cole Boulevard
Golden, Colorado 80401-3393

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Contract No. DE-AC36-98-GO10337

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NREL Technical Monitor: M. Frailey

Prepared under Subcontract No. AAC-5-15131-01

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Executive Summary

The National Renewable Energy Laboratory (NREL), with funding from the United States Department of Energy (DOE), and the Trucking Research Institute (TRI) contracted Detroit Diesel Corporation (DDC) to develop and operate a liquid natural gas (LNG) fueled tractor powered by a DDC Series 50 prototype natural gas engine.

The tractor was operated by the DDC transportation fleet between Detroit, Michigan, and Canton, Ohio. The vehicle accumulated less than 5,000 miles, in part because of tractor downtime associated with developmental changes, but primarily because of LNG fueling station issues.

The DDC fueling station persistently vented natural gas to the atmosphere and was inoperable on an automatic basis. The lack of a reliable fueling station combined with tractor changes and mismatched vehicle specifications between the LNG and diesel trucks defeated relevant performance, maintenance, and operational data comparisons.

Fleet operation started in June 1996 and ended in November 1996. The project ended in March 1997 when the DDC fueling station was closed. Although the fleet operation period was brief, the engine performance and driveability was improved with several engine calibration changes. Although DDC's LNG tractor operation stopped, the natural gas development work at DDC continued and led to emission-certified, production versions of both the Series 50G and the Series 60G. Sales of DDC natural gas engines were up in 1998 and another increase is expected in 1999 because of the recent announcement of a closed-loop version of the Series 60G.

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Background

The U.S. Department of Energy (DOE) has designated the National Renewable Energy Laboratory (NREL) as "field manager" for the implementation of certain portions of the Alternative Motor Fuels Act of 1988. Section 400BB of the Act makes a commitment to demonstrate and evaluate the use of alternative fuels in heavy-duty vehicles.

The Trucking Research Institute (TRI), under subcontract to NREL, acts as a project manager who brings together all interested trucking industry parties, fuel suppliers, and local governmental agencies and collects operational data for the Alternative Fuels Data Center at NREL. DOE, NREL, and TRI are interested in accumulating fuel-neutral data on operations with alternative fuels. These data will ensure that industry and public policy makers have reliable information on which to base their business and policy decisions.

The Detroit Diesel Corporation (DDC) has a business and civic interest in pursuing development and application of liquefied natural gas (LNG) fuel technologies, particularly their application to heavy-duty over-the-road line-haul trucks. DDC expressed a willingness to power one of its own fleet vehicles, which delivers manufactured goods between its Detroit, Michigan, and Canton, Ohio facilities, with a DDC Series 50 prototype natural gas engine using LNG as the fuel.

Objective

The overall objective of this program was to collect data from heavy-duty alternative fuel trucks, along with data from a similarly configured diesel vehicle to compare emissions, performance, and durability. Although this objective was not met, the project did compile a record of the developmental work and experience in alternative fuel heavy-duty truck operations.

Data Collection

Persistent difficulties with the refueling station severely limited the LNG vehicle operation. In addition, incompatible vehicle specifications (different transmission, axle ratio, and gross vehicle weight rating) between the LNG truck and the diesel control trucks made the comparisons invalid. As a result, accumulated vehicle mileage is the only data that were collected.

LNG Truck

The LNG truck used a T-400 Kenworth tandem drive axle tractor that was built to haul a maximum weight of 50,000 lb. It was a day-cab configuration with leaf spring suspension, and a Rockwell 10-speed transmission (with 10th gear direct). The truck started the demonstration with 10-in. x 22-in. tires and Eaton axles with a final drive ratio of 3.25. The truck is pictured in Figure 1.

Figure 1. Kenworth T-400 LNG Tractor

Detroit Diesel received the truck as a "glider" (cab- and chassis-less drivetrain) and installed a Series 50 diesel engine. The production rating of this engine in a transit coach application is 275 hp @ 2100 rpm and 890 ft-lb of torque @ 1200 rpm. After some tests, the truck was converted from a Series 50 diesel to a prototype Series 50 natural gas engine rated experimentally at 300 hp @ 2100 rpm with 1000 ft-lb of torque @ 1200 rpm.

The truck chassis was modified to provide storage for LNG. Fuel was stored onboard in twin Minnesota Valley Engineering fuel tanks capable of storing a total 172 usable gallons at an operating pressure of 125 psig. Fuel is delivered to the engine through .75-in. stainless steel tubing from the fuel tanks to a "T" fitting that combines the fuel from both tanks. The LNG is then fed to a vaporizer that

exposes the cold fuel (-126° C) to an engine coolant temperature of 85°C – 93°C. This converts the LNG to a gaseous phase. The gas then flows through a quarter turn, manual shutoff valve to a Racor FC 115 filter and finally to the engine (see Figures 2 and 3).

The engine fuel system shown in Figure 3 is a DDC design mounted to the engine. The system contains an electric shutoff valve, low pressure regulators, gas control valve, mixer, and throttle assembly.

Diesel Control Vehicles

The diesel control vehicle was changed during the demonstration. Initially, a vehicle from a customer's fleet in Lansing, Michigan, was used. The final vehicle was from DDC's transportation fleet. The DDC Series 50 diesel engine used in the control vehicle is a four-cylinder variation of the DDC Series 60 (six-cylinder) engine. The Series 50 was primarily designed to fill the needs of the transit bus industry. Because the Series 50 is fairly new to truck applications, the quantity in fleet service was small. It was difficult to find a fleet operating Series 50 engines that would be willing to share operational data. The first fleet operators who agreed to provide data misunderstood our requirements and thought we wanted only one month

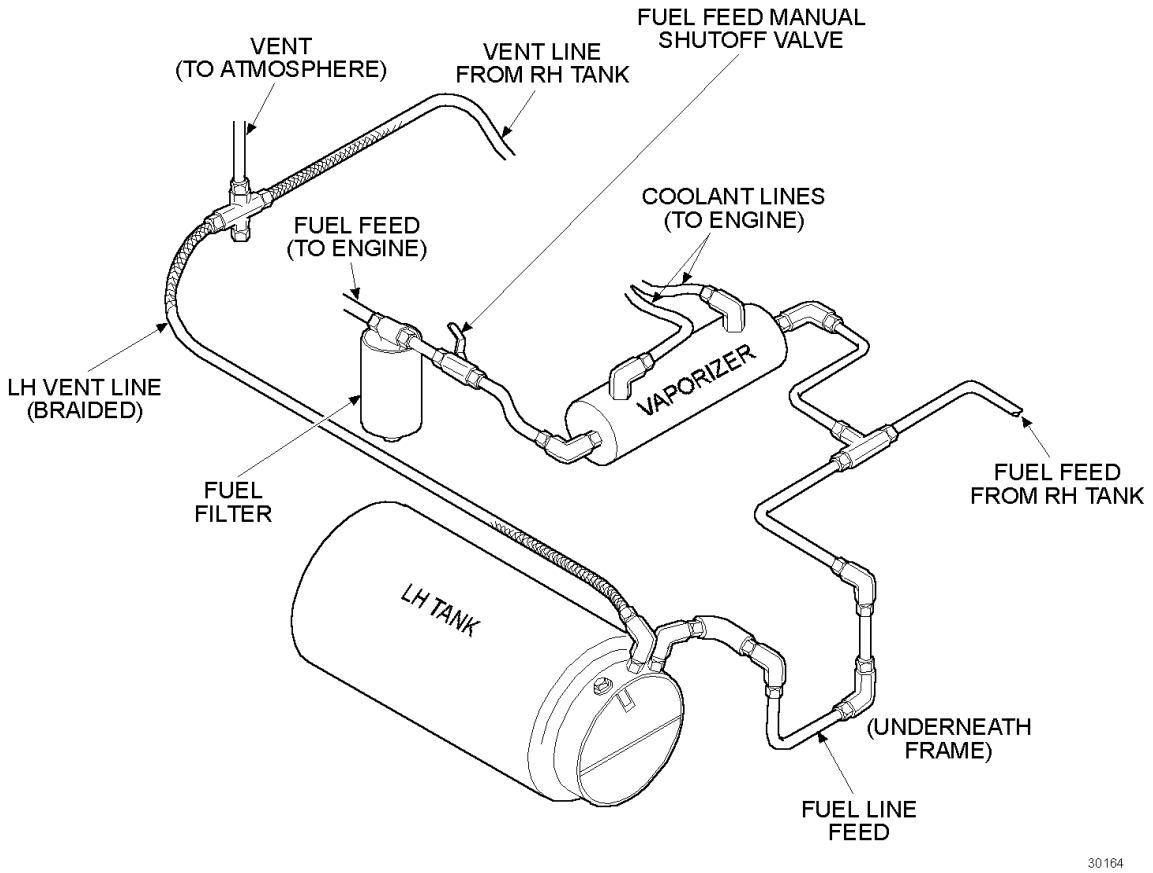


Figure 2. LNG Fuel System

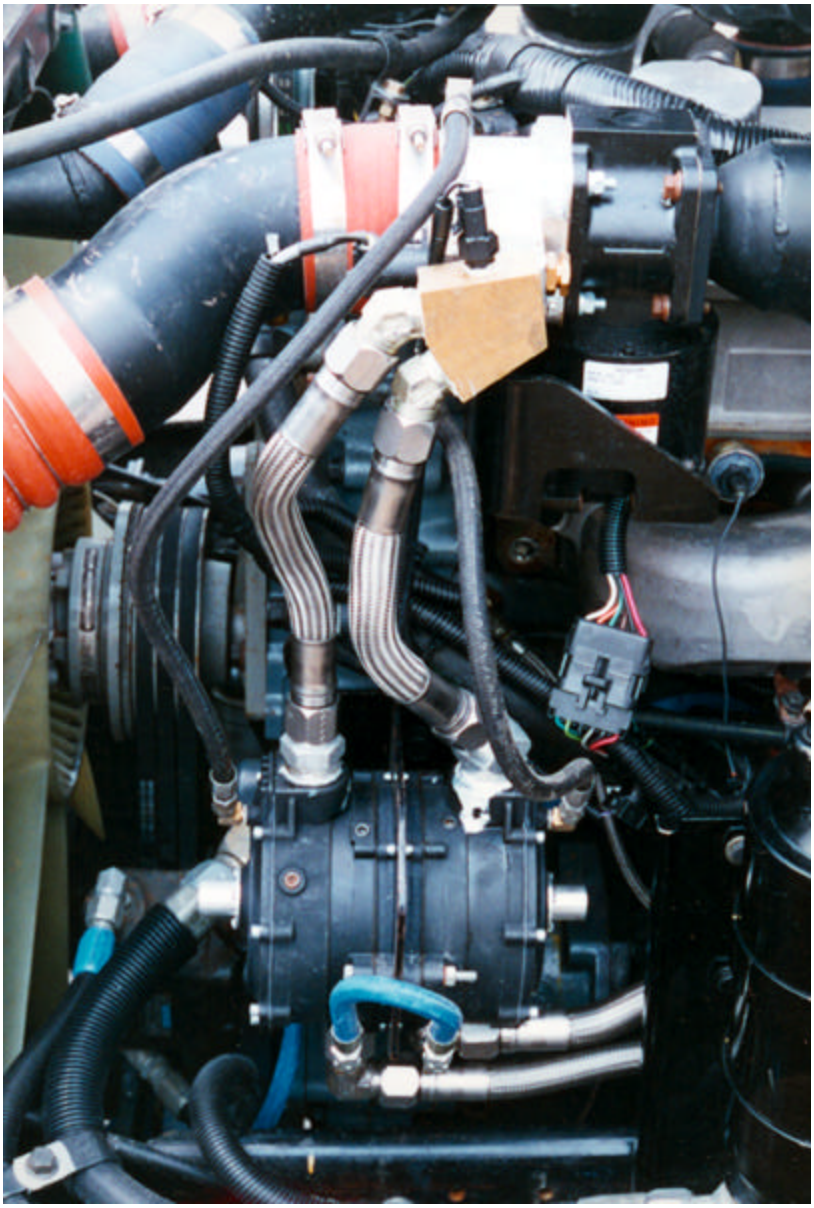


Figure 3. Engine Fuel System Components

of data. Eventually, DDC put a Series 50 diesel in its own transportation fleet in an effort to solve the problem of a control vehicle. However, different transmission, axle ratio, and gross vehicle weight rating made performance and fuel economy comparisons invalid.

LNG Vehicle Development and Operation

During January and February 1996, the truck was operated as an engineering test vehicle. Various hardware and software components were developed and evaluated. At least two iterations of software were tested on this vehicle to ensure proper functioning. The truck was also used to evaluate some aspects of the construction of the new fuel station.

The truck was shown to the DDC Transportation Fleet in March 1996 in anticipation of the fuel station coming on-line in the near future. The truck was to operate between DDC's Redford manufacturing plant outside Detroit and its service parts warehouse in Canton, Ohio. DDC Transportation elected to initially operate the truck on local routes to increase confidence in the truck and then assign the truck to the Canton run. Before placing the truck into service, DDC Transportation requested two changes. First, because LNG is odorless, a gas leak detector system had to be installed. Second, the tractor tires were too tall for the DDC trailers and had to be replaced with smaller ones.

A leak detector system sold by Troy Design and Manufacturing (TDM), DDC's vehicle modification vendor, was chosen. It is a product of Russian Aerospace Technology that was available, simple to install, easily maintained, and inexpensive.

Changing the wheels and tires had a negative effect on performance. Reducing the tire diameter increased the tire revolutions per mile, and in turn, decreased gradeability and performance.

Vehicle operation was also constrained by the delay in fuel station completion and the uncertainty of its operation once it was complete. Figure 4 shows the mileage accumulated by the LNG truck and the DDC diesel control vehicle in the calendar year of 1996. The LNG tractor accumulated less than 5,000 miles. This is approximately 17% of the miles accumulated by the diesel control tractor.

Data collection on the two vehicles began in June. The LNG tractor accumulated more than 700 miles, but drivers complained about a lack of horsepower under heavy load at warmer ambient temperatures (24°C–29°C). DDC engineers rode with various drivers on several occasions and determined that some of the horsepower loss was caused by the fuel temperature compensation strategy in the engine calibration tables within the memory of the engine control module (ECM). The ECM would increase or decrease fuel flow depending on fuel temperature, air inlet temperature, coolant temperature, and oil temperature. In this case, the fuel temperature compensation caused too much of a reduction in fuel flow and resulted in a loss of horsepower. The calibration tables were adjusted and the problem appeared to be solved. Although the LNG tractor accumulated 2500 miles for the month of July, it still drew complaints from the drivers resulting from a lack of horsepower on hot days.

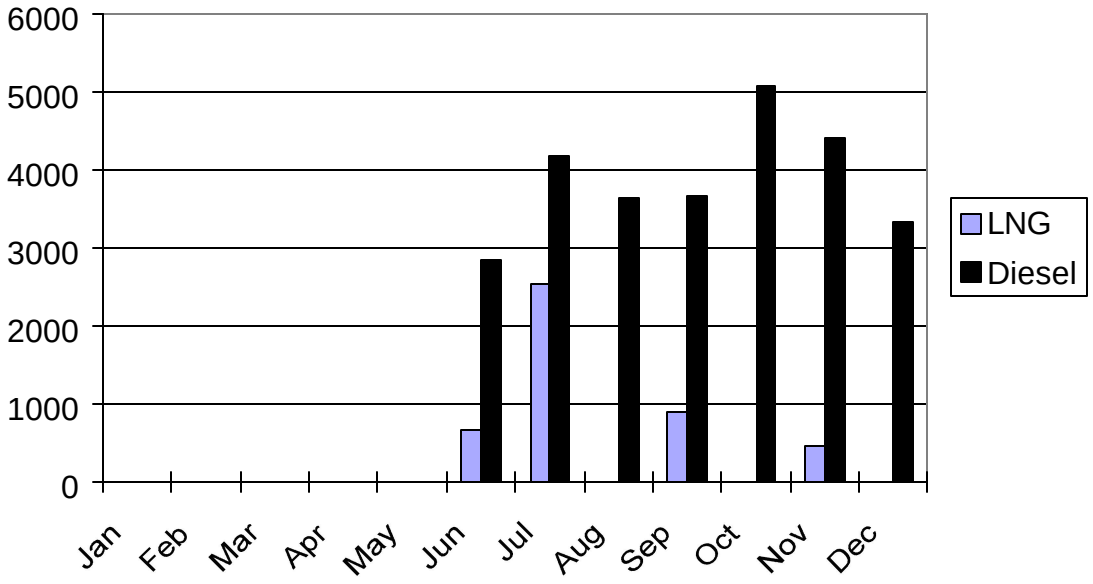


Figure 4. Accumulated Mileage

To substantiate the complaints of low horsepower, the truck was run on the DDC chassis dynamometer. The horsepower was found acceptable from 1200 rpm to 2000 rpm; however, above 2000 rpm the horsepower dropped off substantially. Again, the engine calibration was reviewed and a recommendation was made to slightly richen the fuel mixture above 2000 rpm. This significantly increased the horsepower above 2000 rpm as illustrated by the corrected horsepower curve (HPC) versus the original horsepower curve (HPO) in Figure 5.

After the calibration was modified, engineers again rode with one of the regular drivers. Although performance was improved, the truck was still lacking power. At this time it was decided to run computer performance simulations with DDC's Spec Manager®. This is an in-house design tool used by Detroit Diesel to predict truck performance based on the variables of horsepower, cab frontal area, gearing, and tire size.

The results predicted the truck would have insufficient horsepower to attain geared speed in top gear on a 0% grade. There should be at least 0.6% gradeability at cruise speed in top gear when the gross combination weight (GCW) is below 90,000 lb. The model also showed this truck would require 436 seconds to achieve a top speed of 66 mph and would have traveled 6.9 miles in the process. The program suggested increasing the axle ratio, which would lower the top speed slightly, but improve overall performance (see Appendix).

Table 1 shows the suggested ratios and the resultant change in vehicle performance.

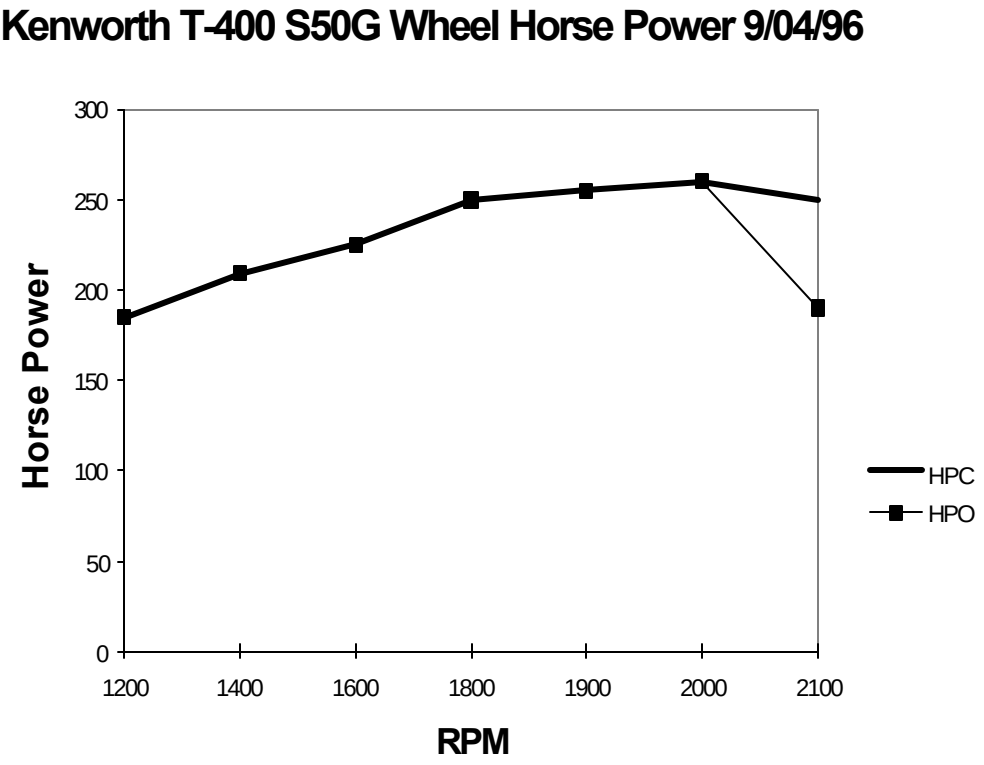


Figure 5. S50G Wheel Horsepower

Table 1. Truck Performance Versus Axle Ratio

Axle Ratio	Max. Geared Road Speed	Time to Max. Speed	Distance to Max. Speed	Gradeability
3.25:1 (original)	66 mph	435.9 sec. or 7:20 m:s	6.9 miles	0.0%
3.36:1	66 mph	255 sec or 4:14 m:s	3.6 miles	0.01%
3.55:1	63 mph	170 sec or 2:50 m:s	2.1 miles	0.03%
3.70:1	60.1 mph	142 sec or 2:20 m:s	1.6 miles	0.5%

A meeting was held with the DDC transportation department to present the facts described above. The general consensus of the drivers and manager was to change to the 3.70:1 ratio. The local repair shop was contacted and the modifications were scheduled.

The LNG truck accumulated no mileage in August because of a fueling station problem (see details in the DDC Fueling Station section). Then, in September, it accumulated just under 1000 miles before a

fuel gauge sending unit failed. The transportation department decided to discontinue operation of the LNG truck until the fuel gauge could be repaired. The fuel gauge sending unit was a one-time failure on this truck; however, DDC's general experience with LNG fuel gauges, on 10 to 15 prototype vehicles, has not been favorable. Accuracy has always been coarse with a tolerance of (+/-) one-quarter of a tank. In addition, reliability has not been up to commercial customer expectations. Additional development would increase accuracy and reliability.

The LNG truck accumulated no mileage in October because of a fueling station problem (see details in the DDC Fueling Station section). The truck was returned to DDC's transportation fleet in November with a 3.70:1 axle ratio and a new fuel gauge sending unit. Drivers reported that performance was much improved, but uncertain fuel availability and station operation limited the truck operation to less than 500 miles in November. Continued fueling station issues resulted in a decision to stop operation of the LNG truck until the fueling issues were resolved.

As noted in the subsequent section on the DDC fueling station, November would be the last of the LNG truck operation in the DDC transportation fleet. Fortunately it was only the operation of the Series 50G in the DDC fleet and not the development of heavy-duty natural gas engines that ended. DDC's natural gas engine development continued and resulted in emission-certified, production versions of the Series 50G as well as the Series 60G. DDC's total natural gas engine production through 1997 was around 1,000 and 1998 sales were over 400. With the recent announcement of a 340 horsepower, closed-loop Series 60G, DDC expects to sell even more natural gas engines in 1999.

Temporary Fueling Station

DDC's LNG fleet of test buses and trucks was initially fueled by at a temporary fuel station located off site at TDM. The station was a temporary installation, but provided fuel for DDC vehicles until the "permanent station" could be constructed on DDC property. The TDM station was a thermal vacuum (TVAC) common modular container for shipping cryogenic liquids supplied by Jack B. Kelley Company (JBK) of Amarillo, Texas. The container was modified to dispense fuel with the addition of a pump and meter to record fuel usage. The unit has a built-in computer to monitor station functions and to detect leaks. The computer also controlled diagnostic action and recorded fuel quantity dispensed. All functions are displayed on a local panel as well as at the home office in Amarillo, Texas, via modem and phone line. Figure 6 is a photo of the temporary station.

The temporary station was up and running after minimal site preparation in June 1995. A containment pit was built, some traffic barriers installed, and electrical and telephone lines were run out to the unit. Local inspections went smoothly and the TDM station was operational.

Many problems were encountered during the first month of operation. Cryogenic gaskets leaked and were replaced. Cryogenic joint flanges had to be re-tightened after a week or so of operation and two cryogenic pumps failed because of seal leaks. There were numerous computer and software glitches and several computer power supplies failed. These had to be replaced and the

Figure 6. Temporary Fueling Station at TDM

software was revised numerous times. The software was responsible for diagnostic protection of the station in monitoring critical temperatures and pressures and advising both local and remote operators of a malfunction. The computer was also tasked to back up the mechanical safety systems to protect the station from fire, over-pressure, loss of commercial electrical power, and other eventualities. In addition to its other tasks, the computer controlled dispensing of fuel and recording of fuel dispensed during normal automatic operation of the station.

The temporary station developed into a reliable and simple-to-operate fueling station that provided fuel consistently. The major drawback of this station was the 20-minute cool-down time required for the first fueling of the day. The fuel pump seals were designed to function at cryogenic temperatures of -126°C and below. To operate the station, it was necessary to circulate LNG into the pump until the pump temperature was within range. To reduce fueling time, the driver would call when he was 20 minutes away from the fueling station. TDM would then start the cool-down sequence and have the station ready when the truck arrived. Once the pump was cooled down, total fueling time was only 10 minutes including connecting the hose and filling both tanks separately. This system was used for five months, five days a week.

This manner of operation worked well during TDM's normal business hours. If fuel was needed after hours or during a weekend, a technician had to be called in on overtime, which added to the cost of operation.

DDC Fueling Station

In October 1995, the DDC fuel station was opened with the same type of JBK equipment used at TDM, but with a larger containment pit to accommodate the compressed liquid natural gas (CLNG) storage cylinders and a canopy over the actual fueling area. During Phase One, this station operated at about the same level of reliability as the TDM station, except there was no one on site to cool down the station prior to the arrival of a truck. The driver had to refuel alone. Several incidents of equipment malfunction compelled DDC to hire TDM technicians to travel to DDC (15 minutes) in case of problems with the station during fueling. Figure 7 shows the DDC fueling station.

In November 1995, JBK representatives announced that they wanted to implement Phase Two. This upgrade to the DDC fueling station would eliminate the 20-minute cool-down period and add the CLNG facility. Eliminating the 20-minute cool down was accomplished by submerging the cryogenic pump in a vessel filled with LNG. The station would always be cooled down and fueling could be immediate. The addition of a CLNG pump/compressor @ 4000 psi and a cascade of four CLNG cylinders would provide CNG vehicles with a quick-fill option.

The station was filled with 4,150 gallons of LNG, for the first time, on March 26, 1996. Initial attempts to fuel from both the LNG and CLNG dispensers failed. On April 1 an engineer from Cryenco, the fuel station supplier, arrived to diagnose the problem. The engineer found three

Figure 7. DDC Refueling Station

problems: unacceptable pressure differentiation, unacceptable valve operation, and inoperable card readers. Two additional Cryenco engineers were on site by the second week of April and the corrections were, supposedly, in place by the end of April. Fuel was available during May, but only on a manual basis (the Cryenco team did all the fueling). The station would not function unattended and needed additional corrections. Because reliable fueling was not yet available, the LNG tractor was not operated in May.

The Cryenco team continued to work on the station and on June 14 officially declared the station operational. Personnel from DDC and other LNG and CNG customers were trained to operate the station and the DDC S50G LNG truck began operation.

At the end of June it was discovered that the station was excessively venting natural gas into the atmosphere. Technicians were unable to account for an estimated 1,840 gallons of LNG. The remaining fuel in the tank was allowed to vent over the scheduled plant shutdown in July. Upon return from the summer shutdown, the tank was refilled with 3,630 gallons of LNG. The LNG truck accumulated 2500 miles in the month of July, but excessive venting continued. DDC was now reluctant to refill the tank until the excessive venting issues were resolved. The Cryenco team returned to the site and the station was unavailable from August through September 12.

The station was back on-line in mid-September and the LNG truck accumulated just under 1000 miles. Card reader problems reoccurred in October and no miles were accumulated on the LNG truck. The LNG truck was operated in November, but repair and replacement of dome regulators severely limited the number of miles run. Although it was not known at the time, this marked the end of the LNG truck operation for the DDC fleet.

The fueling station continued to have major problems during December. The transportation department was working overtime because of year-end close out and could not depend on the fueling station. Once again it was decided to not operate the LNG truck. Card reader problems and venting persisted in January and February. In fact, card reader problems continued to plague the station until it was officially closed in March of 1997.

Conclusions

The dysfunctional CLNG fueling station and its premature closing was a disappointment to all involved in this on-road development project. It hampered the operation and development, as well as the longer term goal of collecting relevant data for comparing performance, maintenance, and operational characteristics of natural gas and diesel fueled trucks. It did, however, present a hands-on example of the importance of reliable fueling to a commercial fleet.

Although the on-road development period of the prototype Series 50G was brief, drivers quickly identified performance issues that were later corrected through engine calibration changes. The first

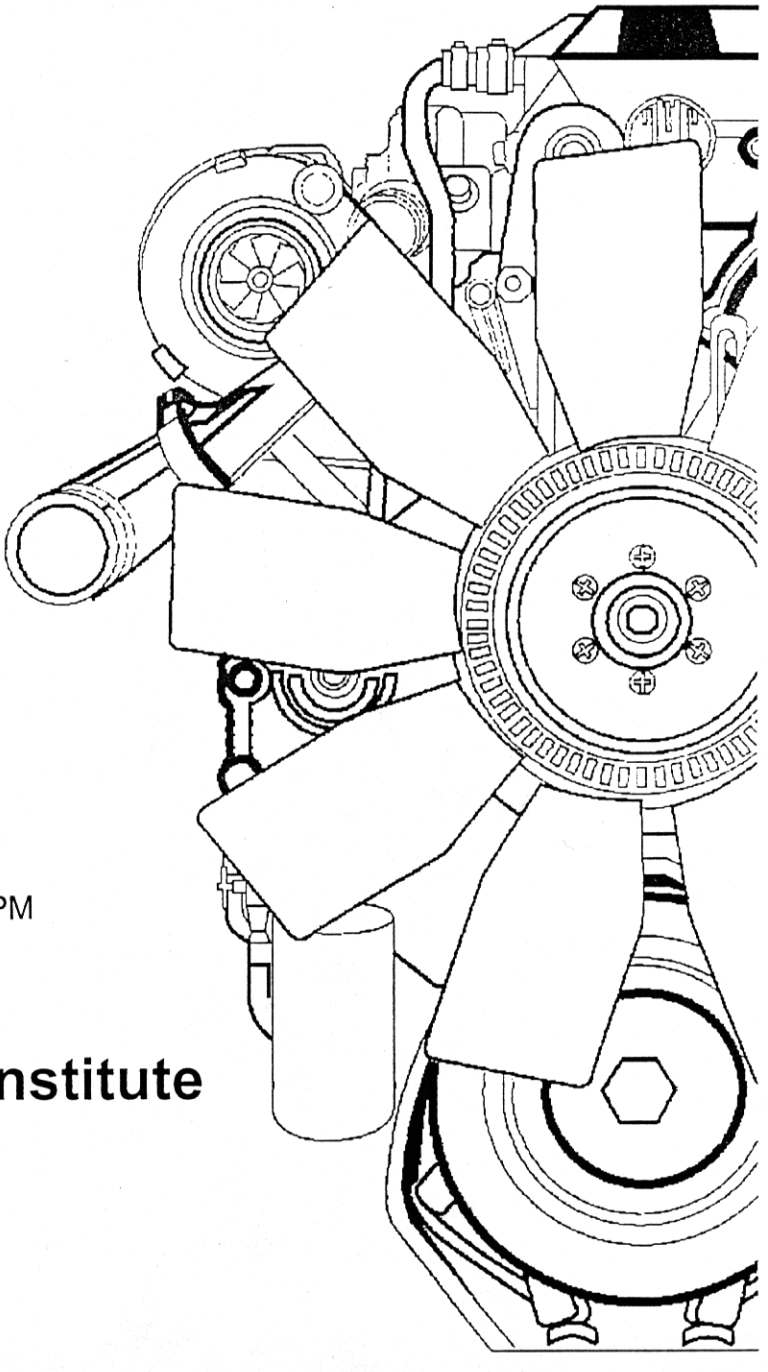
calibration change corrected an over aggressive fuel temperature compensation strategy and markedly improved the horsepower in hot ambient conditions. The second calibration change increased the fuel to air ratio to increase horsepower at engine speeds above 2000 rpm.

When the CLNG station closed and the LNG truck was removed from the fleet, DDC continued development through other commercial fleets. This continued development improved DDC's natural gas engine technology and led to emission-certified production versions of both the Series 50G and Series 60G.

Appendix: Detroil Diesel Driveline Analysis

DETROIT DIESEL

Driveline Analysis



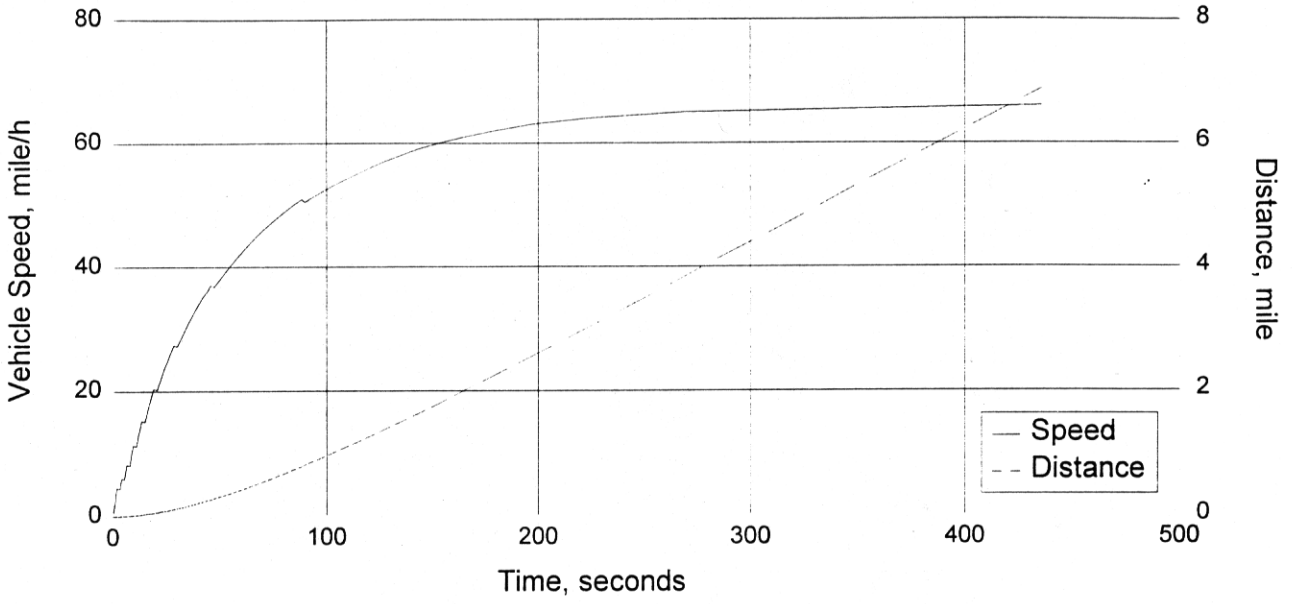
BASE CONFIGURATION
3.25 REAR AXLE RATIO
MAXIMUM SPEED 66 MPH @ 2027 RPM
435 SECONDS TO REACH 66 MPH

Trucking Research Institute

December 02, 1997

Acceleration

DETROIT DIESEL
Spec Manager



VEHICLE CONFIGURATION

Application	Line Haul Tractor
Vehicle Type	Conv. Truck/Trailer
Description	Van
Vehicle Speed Limit	60.0 mile/h
Vehicle Cruise Speed	60.0 mile/h
Aerodynamics	None
Height	13.5 ft
Width	102.0 in.
Number of Trailers	1
Side	Smooth
Top	Closed
Gap	18.0 in.
Weight (GVW)	80000 lb
Total Number of Axles	5

DRIVE TRAIN

Engine Series	SERIES 50
Rated Power	300 hp @ 2100 r/min
Peak Torque	1000 lb.ft @ 1200 r/min
Droop	125 r/min
T800 Torque	578.0 lb.ft
Fan Type	On/Off (Clutch)
Air Conditioning	Yes
Transmission Manufacturer	Rockwell
Transmission	RM10-115A
Shift Schedule	Standard
Drive Axle Manufacturer	Eaton
Drive Axle (Ratio)	Tandem (3.25)
Tire Type	Low Profile Radial
Tire Model	255/70 R22.5
Tire Size	567 revs/mile

ENVIRONMENT

Surface Type	Smooth Concrete (1.0)
Terrain	Nearly Flat (0% - 1.5%)

ACCELERATION

Speed mile/h	Engine RPM r/min	Time s	Distance ft	Distance mile	Acceleration mile/h/s
Forward 1, Ratio 15.023; Start					
1.7	800	0.9	1.1	0.000	1.96
2.0	923	1.0	1.4	0.000	2.38
3.0	1384	1.3	2.7	0.001	3.00
4.0	1846	1.7	4.4	0.001	3.00
4.6	2100	1.9	5.7	0.001	2.63
Forward 2, Ratio 11.140; Manual Shift					
4.4	1514	3.4	15.6	0.003	-0.09
5.0	1711	3.6	16.9	0.003	3.00
6.0	2053	3.9	19.8	0.004	2.78
6.1	2100	4.0	20.3	0.004	2.48
Forward 3, Ratio 8.258; Manual Shift					
6.0	1523	5.5	33.6	0.006	-0.09
7.0	1775	5.8	37.1	0.007	2.75
8.0	2029	6.2	41.5	0.008	2.47
8.3	2100	6.4	43.0	0.008	2.24
Forward 4, Ratio 6.019; Manual Shift					
8.1	1505	7.9	61.1	0.012	-0.09
9.0	1664	8.2	65.8	0.012	2.31
10.0	1849	8.7	72.0	0.014	2.22
11.0	2033	9.2	79.8	0.015	1.99
11.4	2100	9.4	83.0	0.016	1.84
Forward 5, Ratio 4.484; Manual Shift					
11.2	1544	10.9	107.8	0.020	-0.10
12.0	1653	11.3	115.2	0.022	1.82

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Acceleration

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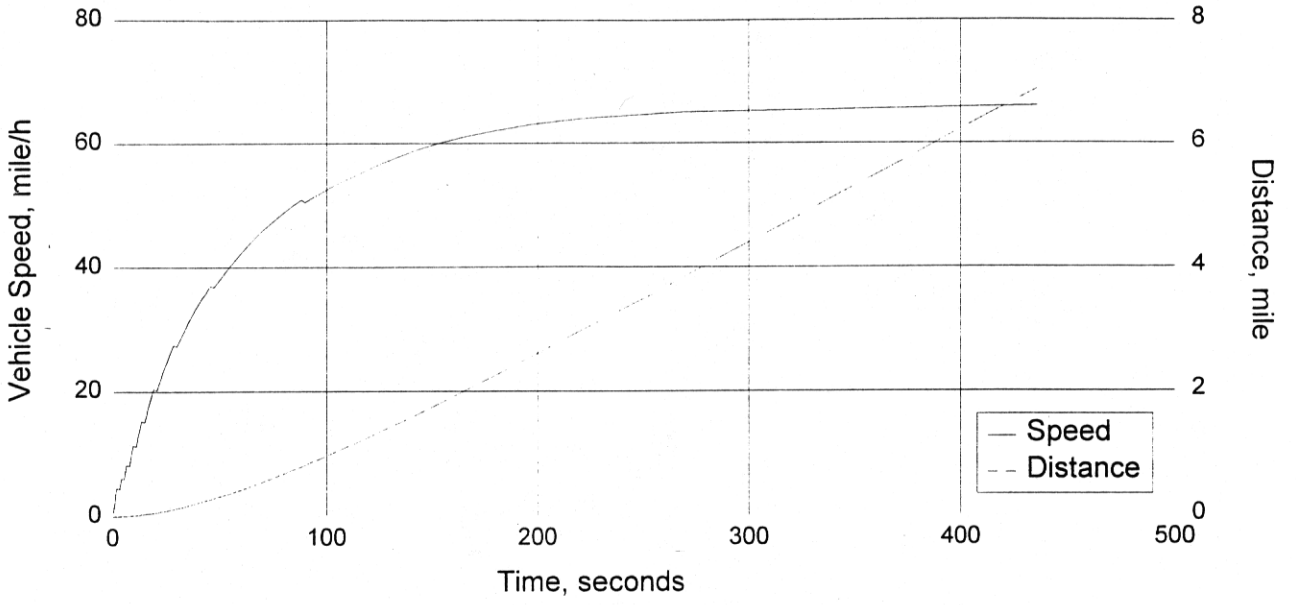

VEHICLE CONFIGURATION

Application	Line Haul Tractor
Vehicle Type	Conv. Truck/Trailer
Description	Van
Vehicle Speed Limit	60.0 mile/h
Vehicle Cruise Speed	60.0 mile/h
Aerodynamics	None
Height	13.5 ft
Width	102.0 in.
Number of Trailers	1
Side	Smooth
Top	Closed
Gap	18.0 in.
Weight (GVW)	80000 lb
Total Number of Axles	5

DRIVE TRAIN

Engine Series	SERIES 50
Rated Power	300 hp @ 2100 r/min
Peak Torque	1000 lb.ft @ 1200 r/min
Droop	125 r/min
T800 Torque	578.0 lb.ft
Fan Type	On/Off (Clutch)
Air Conditioning	Yes
Transmission Manufacturer	Rockwell
Transmission	RM10-115A
Shift Schedule	Standard
Drive Axle Manufacturer	Eaton
Drive Axle (Ratio)	Tandem (3.25)
Tire Type	Low Profile Radial
Tire Model	255/70 R22.5
Tire Size	567 revs/mile

ENVIRONMENT

Surface Type	Smooth Concrete (1.0)
Terrain	Nearly Flat (0% - 1.5%)

ACCELERATION

Speed mile/h	Engine RPM r/min	Time s	Distance ft	Distance mile	Acceleration mile/h/s
13.0	1790	11.9	125.5	0.024	1.77
14.0	1928	12.5	137.5	0.026	1.65
15.0	2066	13.2	151.5	0.029	1.51
15.2	2100	13.3	155.4	0.029	1.44
Forward 6, Ratio 3.351; Manual Shift					
15.1	1553	14.8	188.8	0.036	-0.11
16.0	1647	15.5	203.4	0.039	1.42
17.0	1750	16.2	220.9	0.042	1.39
18.0	1853	16.9	240.1	0.045	1.33
19.0	1955	17.7	261.9	0.050	1.24
20.0	2058	18.6	286.5	0.054	1.16
20.4	2100	19.0	297.3	0.056	1.11
Forward 7, Ratio 2.485; Manual Shift					
20.2	1543	20.5	342.0	0.065	-0.13
21.0	1603	21.2	364.7	0.069	1.05
22.0	1679	22.2	395.5	0.075	1.02
23.0	1755	23.2	428.3	0.081	1.01
24.0	1832	24.2	463.7	0.088	0.97
25.0	1908	25.3	502.9	0.095	0.92
26.0	1984	26.5	546.0	0.103	0.87
27.0	2061	27.7	593.3	0.112	0.82
27.5	2100	28.3	619.5	0.117	0.79
Forward 8, Ratio 1.842; Manual Shift					
27.3	1543	29.8	679.8	0.129	-0.15
28.0	1584	30.8	719.5	0.136	0.73
29.0	1641	32.2	777.9	0.147	0.72
30.0	1697	33.6	839.5	0.159	0.70
31.0	1754	35.1	904.5	0.171	0.69

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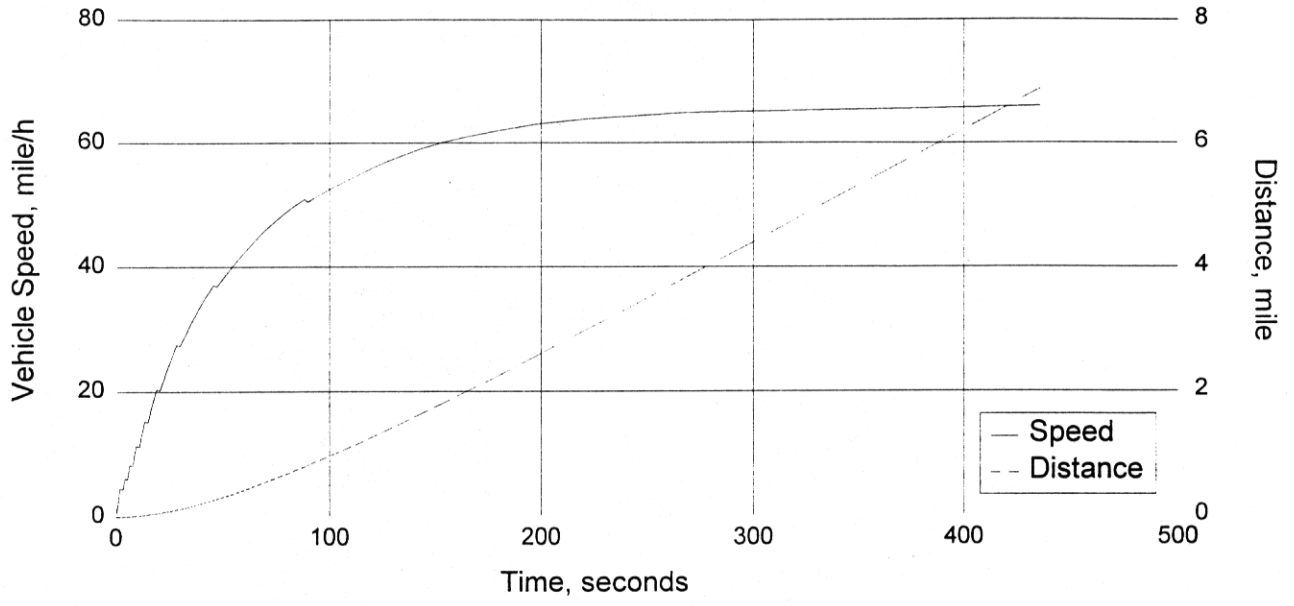
Acceleration



VEHICLE CONFIGURATION

Application	Line Haul Tractor
Vehicle Type	Conv. Truck/Trailer
Description	Van
Vehicle Speed Limit	60.0 mile/h
Vehicle Cruise Speed	60.0 mile/h
Aerodynamics	None
Height	13.5 ft
Width	102.0 in.
Number of Trailers	1
Side	Smooth
Top	Closed
Gap	18.0 in.
Weight (GVW)	80000 lb
Total Number of Axles	5

DRIVE TRAIN

Engine Series	SERIES 50
Rated Power	300 hp @ 2100 r/min
Peak Torque	1000 lb.ft @ 1200 r/min
Droop	125 r/min
T800 Torque	578.0 lb.ft
Fan Type	On/Off (Clutch)
Air Conditioning	Yes
Transmission Manufacturer	Rockwell
Transmission	RM10-115A
Shift Schedule	Standard
Drive Axle Manufacturer	Eaton
Drive Axle (Ratio)	Tandem (3.25)
Tire Type	Low Profile Radial
Tire Model	255/70 R22.5
Tire Size	567 revs/mile

ENVIRONMENT

Surface Type	Smooth Concrete (1.0)
Terrain	Nearly Flat (0% - 1.5%)

ACCELERATION

Speed mile/h	Engine RPM r/min	Time s	Distance ft	Distance mile	Acceleration mile/h/s
32.0	1810	36.6	973.6	0.184	0.67
33.0	1867	38.2	1048.6	0.199	0.64
34.0	1923	39.8	1130.0	0.214	0.60
35.0	1980	41.6	1218.2	0.231	0.57
36.0	2037	43.4	1313.9	0.249	0.54
37.0	2093	45.3	1417.7	0.269	0.52
37.1	2100	45.6	1430.8	0.271	0.50
Forward 9, Ratio 1.342; Manual Shift					
36.8	1517	47.1	1512.1	0.286	-0.20
37.0	1525	47.5	1533.8	0.290	0.46
38.0	1566	49.7	1655.4	0.314	0.45
39.0	1607	52.0	1784.0	0.338	0.44
40.0	1649	54.3	1919.7	0.364	0.43
41.0	1690	56.7	2062.5	0.391	0.42
42.0	1731	59.2	2212.5	0.419	0.41
43.0	1772	61.7	2370.8	0.449	0.39
44.0	1814	64.4	2540.3	0.481	0.38
45.0	1855	67.2	2724.1	0.516	0.36
46.0	1896	70.2	2923.8	0.554	0.33
47.0	1937	73.4	3141.2	0.595	0.31
48.0	1978	76.8	3378.5	0.640	0.29
49.0	2020	80.4	3638.1	0.689	0.27
50.0	2061	84.3	3923.1	0.743	0.25
51.0	2100	88.4	4221.1	0.799	0.24
Forward 10, Ratio 1.000; Manual Shift					
50.5	1551	89.9	4332.7	0.821	-0.29
51.0	1566	92.2	4507.6	0.854	0.21
52.0	1597	97.2	4886.6	0.925	0.20
53.0	1628	102.6	5295.8	1.003	0.19
54.0	1658	108.2	5737.8	1.087	0.18

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Acceleration

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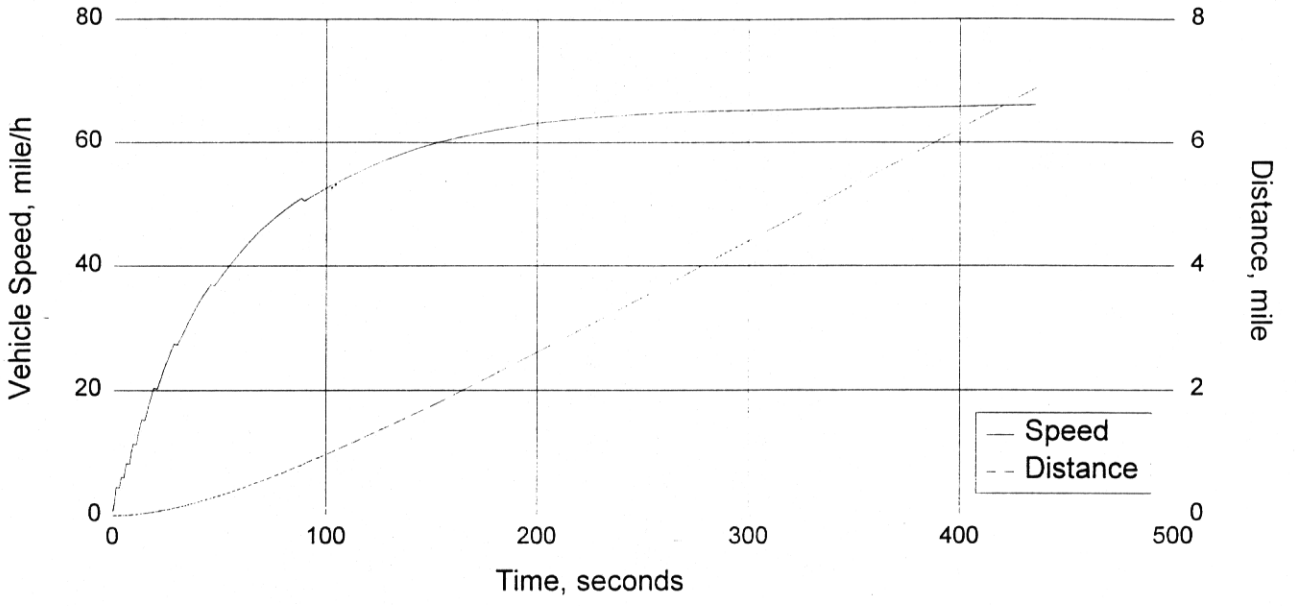
Spec Manager



VEHICLE CONFIGURATION

Application	Line Haul Tractor
Vehicle Type	Conv. Truck/Trailer
Description	Van
Vehicle Speed Limit	60.0 mile/h
Vehicle Cruise Speed	60.0 mile/h
Aerodynamics	None
Height	13.5 ft
Width	102.0 in.
Number of Trailers	1
Side	Smooth
Top	Closed
Gap	18.0 in.
Weight (GVW)	80000 lb
Total Number of Axles	5

DRIVE TRAIN

Engine Series	SERIES 50
Rated Power	300 hp @ 2100 r/min
Peak Torque	1000 lb.ft @ 1200 r/min
Droop	125 r/min
T800 Torque	578.0 lb.ft
Fan Type	On/Off (Clutch)
Air Conditioning	Yes
Transmission Manufacturer	Rockwell
Transmission	RM10-115A
Shift Schedule	Standard
Drive Axle Manufacturer	Eaton
Drive Axle (Ratio)	Tandem (3.25)
Tire Type	Low Profile Radial
Tire Model	255/70 R22.5
Tire Size	567 revs/mile

ENVIRONMENT

Surface Type	Smooth Concrete (1.0)
Terrain	Nearly Flat (0% - 1.5%)

ACCELERATION

Speed mile/h	Engine RPM r/min	Time s	Distance ft	Distance mile	Acceleration mile/h/s
55.0	1689	114.2	6214.9	1.177	0.17
56.0	1720	120.5	6731.2	1.275	0.16
57.0	1751	127.3	7295.3	1.382	0.15
58.0	1781	134.7	7922.3	1.500	0.13
59.0	1812	143.1	8639.5	1.636	0.12
60.0	1843	152.8	9486.6	1.797	0.10
61.0	1873	164.4	10511.9	1.991	0.09
62.0	1904	178.6	11796.7	2.234	0.07
63.0	1935	197.1	13494.4	2.556	0.05
64.0	1966	223.5	15952.2	3.021	0.04
65.0	1996	269.2	20272.1	3.839	0.02
66.0	2027	435.9	36288.7	6.873	0.01

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Gradeability

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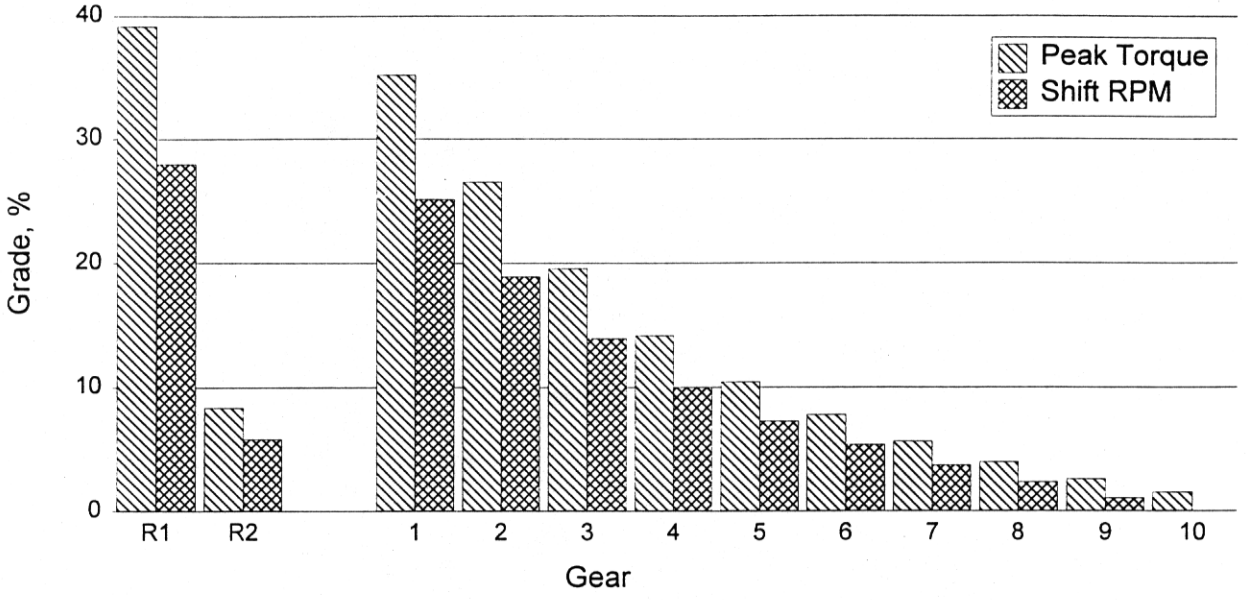
Spec Manager



VEHICLE CONFIGURATION

Application	Line Haul Tractor
Vehicle Type	Conv. Truck/Trailer
Description	Van
Vehicle Speed Limit	60.0 mile/h
Vehicle Cruise Speed	60.0 mile/h
Aerodynamics	None
Height	13.5 ft
Width	102.0 in.
Number of Trailers	1
Side	Smooth
Top	Closed
Gap	18.0 in.
Weight (GVW)	80000 lb
Total Number of Axles	5

DRIVE TRAIN

Engine Series	SERIES 50
Rated Power	300 hp @ 2100 r/min
Peak Torque	1000 lb.ft @ 1200 r/min
Droop	125 r/min
T800 Torque	578.0 lb.ft
Fan Type	On/Off (Clutch)
Air Conditioning	Yes
Transmission Manufacturer	Rockwell
Transmission	RM10-115A
Shift Schedule	Standard
Drive Axle Manufacturer	Eaton
Drive Axle (Ratio)	Tandem (3.25)
Tire Type	Low Profile Radial
Tire Model	255/70 R22.5
Tire Size	567 revs/mile

ENVIRONMENT

Surface Type	Smooth Concrete (1.0)
Terrain	Nearly Flat (0% - 1.5%)

GRADEABILITY

Gear	Peak Torque Speed mile/h	Peak Torque Gradeabil'y %	Shift RPM r/min	Shift RPM Speed mile/h	Shift RPM Gradeabil'y %
R1	-2.3	39.2	2100	-4.1	28.0
R2	-10.5	8.4	2100	-18.3	5.8
1	2.6	35.2	2100	4.6	25.1
2	3.5	26.5	2100	6.1	18.9
3	4.7	19.6	2100	8.3	13.9
4	6.5	14.1	2100	11.4	10.0
5	8.7	10.4	2100	15.2	7.3
6	11.7	7.8	2100	20.4	5.4
7	15.7	5.6	2100	27.5	3.7
8	21.2	4.0	2100	37.1	2.3
9	29.1	2.6	2100	51.0	1.1
10	39.1	1.5	2100	68.4	-0.2

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Additional Notes:

Gradeability at Vehicle Speed Limit (60.0 mile/h, 1843 r/min) in top gear: 0.4%
Gradeability at Maximum Speed (65.9 mile/h, 2023 r/min) in top gear: 0.0%

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Operating Range

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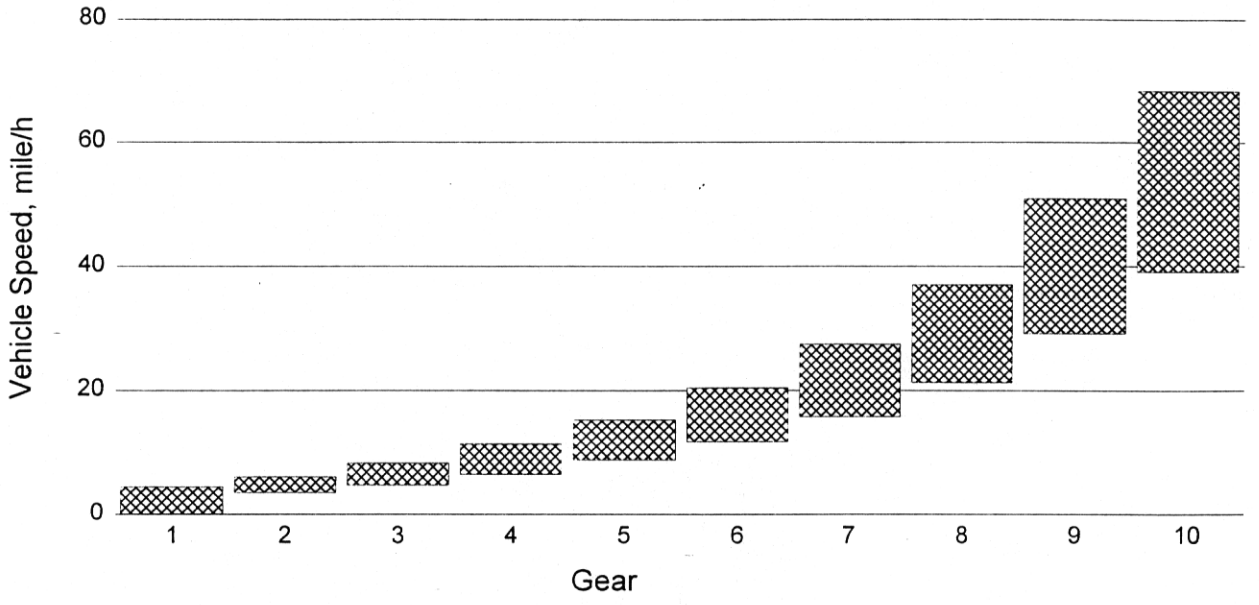
Spec Manager



VEHICLE CONFIGURATION

Application	Line Haul Tractor
Vehicle Type	Conv. Truck/Trailer
Description	Van
Vehicle Speed Limit	60.0 mile/h
Vehicle Cruise Speed	60.0 mile/h
Aerodynamics	None
Height	13.5 ft
Width	102.0 in.
Number of Trailers	1
Side	Smooth
Top	Closed
Gap	18.0 in.
Weight (GVW)	80000 lb
Total Number of Axles	5

DRIVE TRAIN

Engine Series	SERIES 50
Rated Power	300 hp @ 2100 r/min
Peak Torque	1000 lb.ft @ 1200 r/min
Droop	125 r/min
T800 Torque	578.0 lb.ft
Fan Type	On/Off (Clutch)
Air Conditioning	Yes
Transmission Manufacturer	Rockwell
Transmission	RM10-115A
Shift Schedule	Standard
Drive Axle Manufacturer	Eaton
Drive Axle (Ratio)	Tandem (3.25)
Tire Type	Low Profile Radial
Tire Model	255/70 R22.5
Tire Size	567 revs/mile

ENVIRONMENT

Surface Type	Smooth Concrete (1.0)
Terrain	Nearly Flat (0% - 1.5%)

OPERATING RANGE

Gear	Trans Ratio	Total Reduction	Step %	Peak Torque Speed mile/h	Shift RPM r/min	Shift RPM Speed mile/h
1	15.02	48.82	34.86	2.6	2100	4.6
2	11.14	36.21	34.90	3.5	2100	6.1
3	8.26	26.84	37.20	4.7	2100	8.3
4	6.02	19.56	34.23	6.5	2100	11.4
5	4.48	14.57	33.81	8.7	2100	15.2
6	3.35	10.89	34.85	11.7	2100	20.4
7	2.49	8.08	34.91	15.7	2100	27.5
8	1.84	5.99	37.26	21.2	2100	37.1
9	1.34	4.36	34.20	29.1	2100	51.0
10	1.00	3.25	N/A	39.1	2100	68.4

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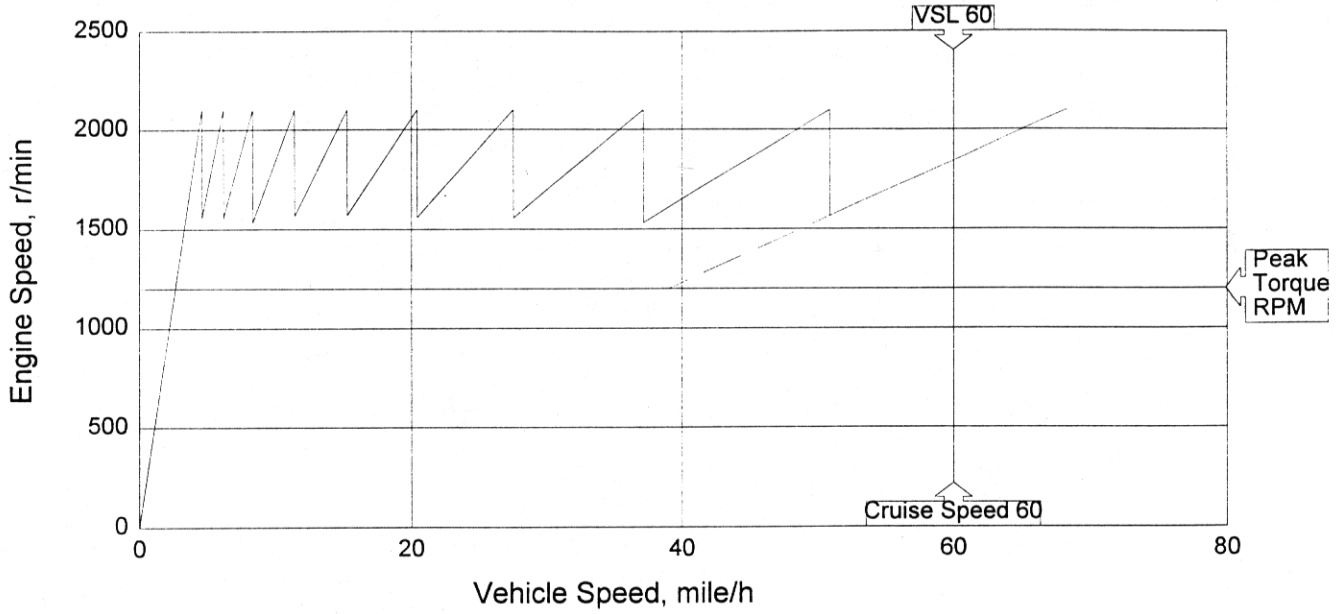
Shift Schedule

DETROIT DIESEL
Spec Manager



VEHICLE CONFIGURATION

Application	Line Haul Tractor
Vehicle Type	Conv. Truck/Trailer
Description	Van
Vehicle Speed Limit	60.0 mile/h
Vehicle Cruise Speed	60.0 mile/h
Aerodynamics	None
Height	13.5 ft
Width	102.0 in.
Number of Trailers	1
Side	Smooth
Top	Closed
Gap	18.0 in.
Weight (GVW)	80000 lb
Total Number of Axles	5

DRIVE TRAIN

Engine Series	SERIES 50
Rated Power	300 hp @ 2100 r/min
Peak Torque	1000 lb.ft @ 1200 r/min
Droop	125 r/min
T800 Torque	578.0 lb.ft
Fan Type	On/Off (Clutch)
Air Conditioning	Yes
Transmission Manufacturer	Rockwell
Transmission	RM10-115A
Shift Schedule	Standard
Drive Axle Manufacturer	Eaton
Drive Axle (Ratio)	Tandem (3.25)
Tire Type	Low Profile Radial
Tire Model	255/70 R22.5
Tire Size	567 revs/mile

ENVIRONMENT

Surface Type	Smooth Concrete (1.0)
Terrain	Nearly Flat (0% - 1.5%)

SHIFT SCHEDULE

Gear	Trans Ratio	Total Reduction	Step %	RPM After Shift r/min	Shift RPM r/min	Shift RPM Speed mile/h
R1	16.71	54.31	N/A	N/A	2100	-4.1
R2	3.73	12.11	N/A	N/A	2100	-18.3
1	15.02	48.82	34.86	N/A	2100	4.6
2	11.14	36.21	34.90	1557	2100	6.1
3	8.26	26.84	37.20	1557	2100	8.3
4	6.02	19.56	34.23	1531	2100	11.4
5	4.48	14.57	33.81	1564	2100	15.2
6	3.35	10.89	34.85	1569	2100	20.4
7	2.49	8.08	34.91	1557	2100	27.5
8	1.84	5.99	37.26	1557	2100	37.1
9	1.34	4.36	34.20	1530	2100	51.0
10	1.00	3.25	N/A	1565	2100	68.4

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Additional Notes:

Vehicle Speed Limit (60.0 mile/h) RPM in top gear is 1843 r/min
Cruise Speed (60.0 mile/h) RPM in top gear is 1843 r/min
1st reverse ratio (16.71) clutch engagement (800 r/min) velocity: 1.56 mile/h
1st forward ratio (15.02) clutch engagement (800 r/min) velocity: 1.73 mile/h

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Startability

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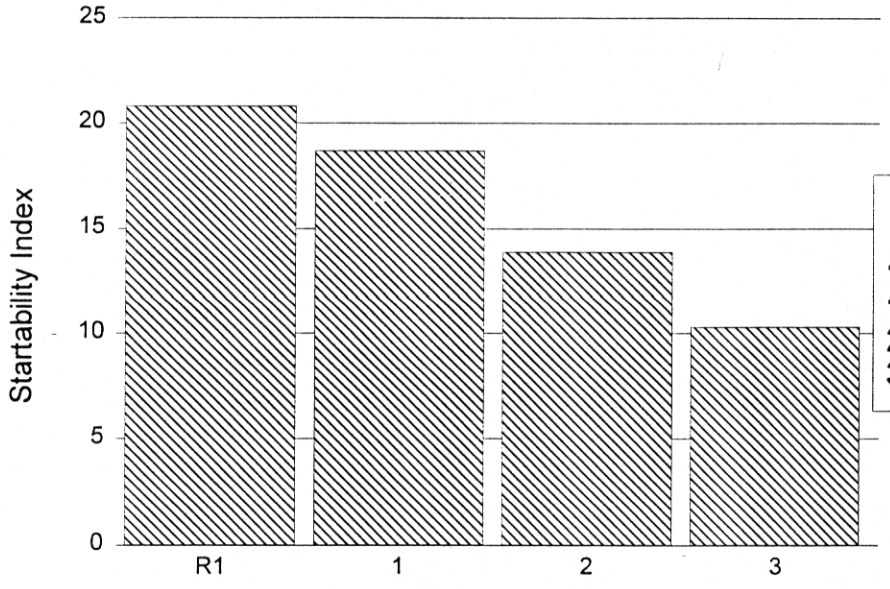
Spec Manager



Recommended Limits

14 - Turnpike Application
16 - General On Highway
25 - Moderate On/Off Highw
30 - Severe On/Off Highway

VEHICLE CONFIGURATION

Application	Line Haul Tractor
Vehicle Type	Conv. Truck/Trailer
Description	Van
Vehicle Speed Limit	60.0 mile/h
Vehicle Cruise Speed	60.0 mile/h
Aerodynamics	None
Height	13.5 ft
Width	102.0 in.
Number of Trailers	1
Side	Smooth
Top	Closed
Gap	18.0 in.
Weight (GVW)	80000 lb
Total Number of Axles	5

DRIVE TRAIN

Engine Series	SERIES 50
Rated Power	300 hp @ 2100 r/min
Peak Torque	1000 lb.ft @ 1200 r/min
Droop	125 r/min
T800 Torque	578.0 lb.ft
Fan Type	On/Off (Clutch)
Air Conditioning	Yes
Transmission Manufacturer	Rockwell
Transmission	RM10-115A
Shift Schedule	Standard
Drive Axle Manufacturer	Eaton
Drive Axle (Ratio)	Tandem (3.25)
Tire Type	Low Profile Radial
Tire Model	255/70 R22.5
Tire Size	567 revs/mile

ENVIRONMENT

Surface Type	Smooth Concrete (1.0)
Terrain	Nearly Flat (0% - 1.5%)

STARTABILITY

Gear	Startability Index
R1	20.8
1	18.7
2	13.9
3	10.3

Recommended Startability Index (Minimum Required)
- 14 - Turnpike Application
- 16 - General On Highway
- 25 - Moderate On/Off Highway
- 30 - Severe On/Off Highway

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Vehicle Power Capabilities

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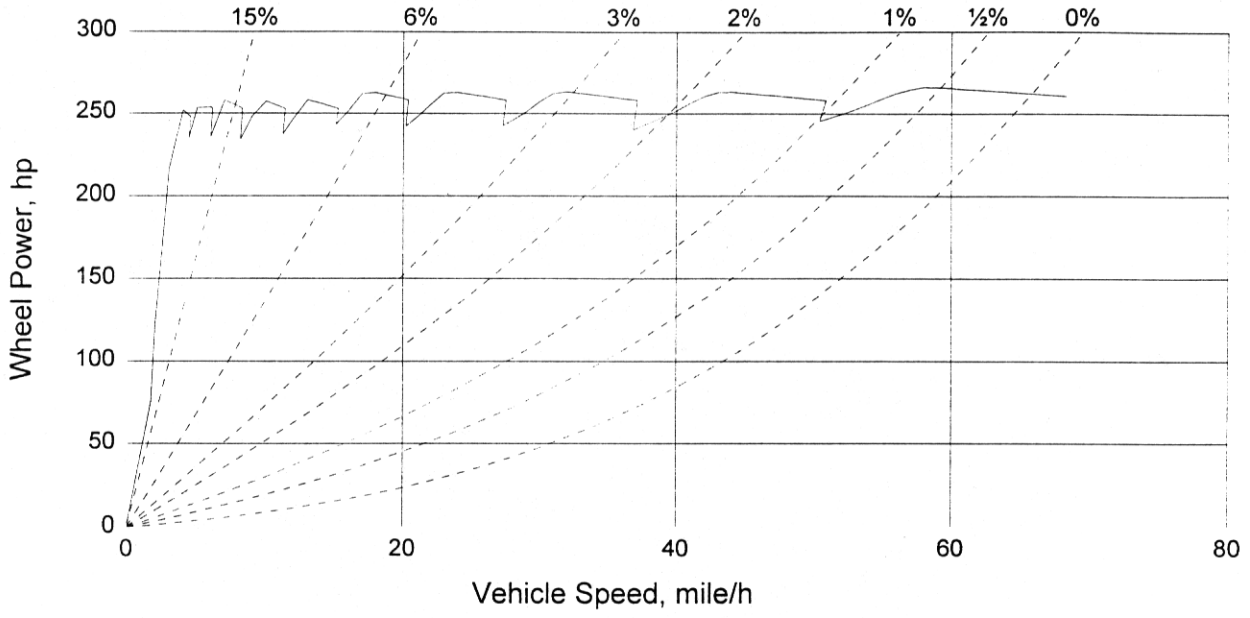

VEHICLE CONFIGURATION

Application	Line Haul Tractor
Vehicle Type	Conv. Truck/Trailer
Description	Van
Vehicle Speed Limit	60.0 mile/h
Vehicle Cruise Speed	60.0 mile/h
Aerodynamics	None
Height	13.5 ft
Width	102.0 in.
Number of Trailers	1
Side	Smooth
Top	Closed
Gap	18.0 in.
Weight (GVW)	80000 lb
Total Number of Axles	5

DRIVE TRAIN

Engine Series	SERIES 50
Rated Power	300 hp @ 2100 r/min
Peak Torque	1000 lb.ft @ 1200 r/min
Droop	125 r/min
T800 Torque	578.0 lb.ft
Fan Type	On/Off (Clutch)
Air Conditioning	Yes
Transmission Manufacturer	Rockwell
Transmission	RM10-115A
Shift Schedule	Standard
Drive Axle Manufacturer	Eaton
Drive Axle (Ratio)	Tandem (3.25)
Tire Type	Low Profile Radial
Tire Model	255/70 R22.5
Tire Size	567 revs/mile

ENVIRONMENT

Surface Type	Smooth Concrete (1.0)
Terrain	Nearly Flat (0% - 1.5%)

VEHICLE POWER CAPABILITIES

Speed	Engine RPM	Gross Engine	Net Engine	Wheel Power	DriveIn Loss	Resistance Air	Resistance Roll.	Grade-ability
mile/h	r/min	hp	hp	hp	hp	hp	hp	%
Forward 1, Ratio 15.023; Start								
1.7	800	88.0	85.1	75.7	9.3	0.0	1.3	20.1
2.0	923	140.1	136.1	121.1	14.9	0.0	1.5	28.0
3.0	1384	253.3	243.9	217.1	26.8	0.0	2.3	33.6
4.0	1846	300.0	283.2	252.1	31.1	0.0	3.2	29.2
4.6	2100	300.0	278.2	247.6	30.5	0.1	3.6	25.1
Forward 2, Ratio 11.140; Manual Shift								
4.4	1514	269.6	258.3	234.8	23.5	0.1	3.5	24.5
5.0	1711	293.2	278.8	253.4	25.3	0.1	4.0	23.4
6.0	2053	300.0	279.1	253.8	25.4	0.1	4.9	19.4
6.1	2100	300.0	278.2	252.9	25.3	0.1	5.0	18.9
Forward 3, Ratio 8.258; Manual Shift								
6.0	1523	270.7	259.2	235.7	23.6	0.1	4.9	18.0
7.0	1775	299.4	283.8	258.0	25.8	0.2	5.7	16.9
8.0	2029	300.0	279.6	254.2	25.4	0.3	6.6	14.5
8.3	2100	300.0	278.2	252.9	25.3	0.3	6.9	13.9
Forward 4, Ratio 6.019; Manual Shift								
8.1	1505	268.6	257.5	234.1	23.4	0.3	6.8	13.1
9.0	1664	286.8	273.2	248.4	24.8	0.4	7.6	12.5
10.0	1849	300.0	283.1	257.4	25.7	0.6	8.5	11.6
11.0	2033	300.0	279.5	254.1	25.4	0.8	9.5	10.4
11.4	2100	300.0	278.2	252.9	25.3	0.9	9.8	10.0
Forward 5, Ratio 4.484; Manual Shift								
11.2	1544	272.9	261.2	237.5	23.7	0.8	9.7	9.5

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Vehicle Power Capabilities

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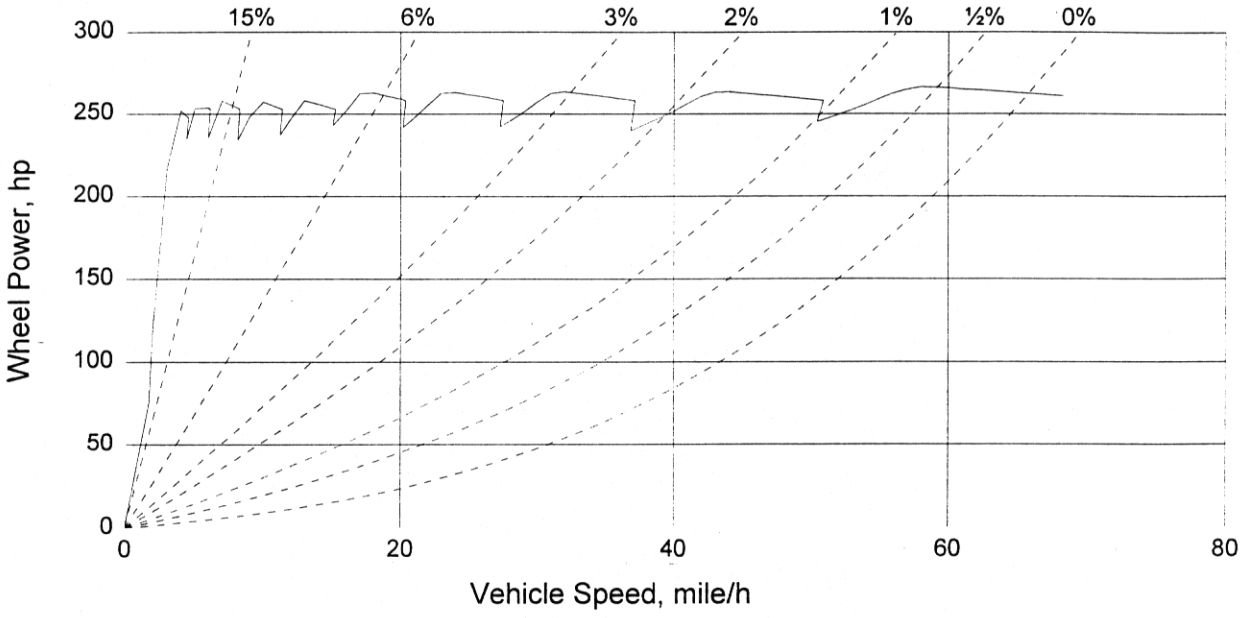

VEHICLE CONFIGURATION

Application	Line Haul Tractor
Vehicle Type	Conv. Truck/Trailer
Description	Van
Vehicle Speed Limit	60.0 mile/h
Vehicle Cruise Speed	60.0 mile/h
Aerodynamics	None
Height	13.5 ft
Width	102.0 in.
Number of Trailers	1
Side	Smooth
Top	Closed
Gap	18.0 in.
Weight (GVW)	80000 lb
Total Number of Axles	5

DRIVE TRAIN

Engine Series	SERIES 50
Rated Power	300 hp @ 2100 r/min
Peak Torque	1000 lb.ft @ 1200 r/min
Droop	125 r/min
T800 Torque	578.0 lb.ft
Fan Type	On/Off (Clutch)
Air Conditioning	Yes
Transmission Manufacturer	Rockwell
Transmission	RM10-115A
Shift Schedule	Standard
Drive Axle Manufacturer	Eaton
Drive Axle (Ratio)	Tandem (3.25)
Tire Type	Low Profile Radial
Tire Model	255/70 R22.5
Tire Size	567 revs/mile

ENVIRONMENT

Surface Type	Smooth Concrete (1.0)
Terrain	Nearly Flat (0% - 1.5%)

VEHICLE POWER CAPABILITIES

Speed	Engine RPM	Gross Engine	Net Engine	Wheel Power	DriveIn Loss	Resistance Air	Resistance Roll.	Grade-ability
mile/h	r/min	hp	hp	hp	hp	hp	hp	%
12.0	1653	285.3	271.9	247.2	24.7	1.0	10.5	9.2
13.0	1790	299.9	284.1	258.3	25.8	1.3	11.5	8.9
14.0	1928	300.0	281.6	256.0	25.6	1.6	12.5	8.1
15.0	2066	300.0	278.9	253.5	25.3	2.0	13.6	7.4
15.2	2100	300.0	278.2	252.9	25.3	2.1	13.8	7.3
Forward 6, Ratio 3.351; Manual Shift								
15.1	1553	273.8	262.0	243.1	18.8	2.0	13.7	7.1
16.0	1647	284.6	271.2	251.7	19.5	2.4	14.7	6.9
17.0	1750	297.5	282.4	262.1	20.3	2.9	15.7	6.7
18.0	1853	300.0	283.0	262.7	20.4	3.4	16.9	6.3
19.0	1955	300.0	281.1	260.9	20.2	4.0	18.0	5.9
20.0	2058	300.0	279.0	259.0	20.1	4.7	19.2	5.5
20.4	2100	300.0	278.2	258.2	20.0	5.0	19.6	5.4
Forward 7, Ratio 2.485; Manual Shift								
20.2	1543	272.8	261.1	242.3	18.8	4.8	19.4	5.1
21.0	1603	279.3	266.6	247.5	19.2	5.4	20.3	4.9
22.0	1679	288.9	275.0	255.3	19.8	6.2	21.5	4.8
23.0	1755	298.0	282.8	262.5	20.3	7.1	22.8	4.7
24.0	1832	300.0	283.4	263.0	20.4	8.1	24.0	4.5
25.0	1908	300.0	282.0	261.7	20.3	9.1	25.3	4.3
26.0	1984	300.0	280.5	260.3	20.2	10.3	26.6	4.0
27.0	2061	300.0	279.0	258.9	20.1	11.5	27.9	3.8
27.5	2100	300.0	278.2	258.2	20.0	12.2	28.5	3.7
Forward 8, Ratio 1.842; Manual Shift								
27.3	1543	272.9	261.1	242.4	18.8	11.9	28.2	3.5
28.0	1584	277.2	264.9	245.8	19.1	12.8	29.2	3.4
29.0	1641	283.8	270.5	251.1	19.5	14.3	30.5	3.3

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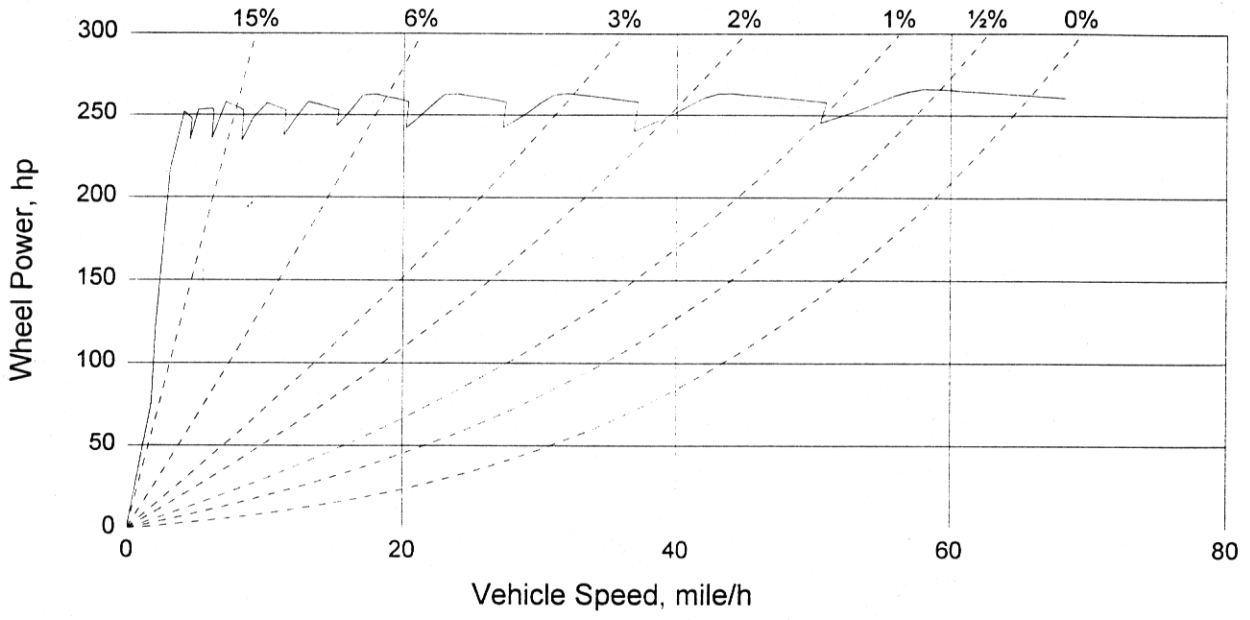
Vehicle Power Capabilities

DETROIT DIESEL
Spec Manager



VEHICLE CONFIGURATION

Application	Line Haul Tractor
Vehicle Type	Conv. Truck/Trailer
Description	Van
Vehicle Speed Limit	60.0 mile/h
Vehicle Cruise Speed	60.0 mile/h
Aerodynamics	None
Height	13.5 ft
Width	102.0 in.
Number of Trailers	1
Side	Smooth
Top	Closed
Gap	18.0 in.
Weight (GVW)	80000 lb
Total Number of Axles	5

DRIVE TRAIN

Engine Series	SERIES 50
Rated Power	300 hp @ 2100 r/min
Peak Torque	1000 lb.ft @ 1200 r/min
Droop	125 r/min
T800 Torque	578.0 lb.ft
Fan Type	On/Off (Clutch)
Air Conditioning	Yes
Transmission Manufacturer	Rockwell
Transmission	RM10-115A
Shift Schedule	Standard
Drive Axle Manufacturer	Eaton
Drive Axle (Ratio)	Tandem (3.25)
Tire Type	Low Profile Radial
Tire Model	255/70 R22.5
Tire Size	567 revs/mile

ENVIRONMENT

Surface Type	Smooth Concrete (1.0)
Terrain	Nearly Flat (0% - 1.5%)

VEHICLE POWER CAPABILITIES

Speed	Engine	Gross	Net	Wheel	DriveIn	Resistance		Grade-
	RPM	Engine	Engine	Power	Loss	Air	Roll.	ability
mile/h	r/min	hp	hp	hp	hp	hp	hp	%
30.0	1697	291.4	277.2	257.3	19.9	15.8	31.9	3.3
31.0	1754	297.9	282.7	262.4	20.3	17.4	33.3	3.2
32.0	1810	300.0	283.8	263.4	20.4	19.2	34.7	3.1
33.0	1867	300.0	282.8	262.4	20.3	21.0	36.1	2.9
34.0	1923	300.0	281.7	261.4	20.3	23.0	37.6	2.8
35.0	1980	300.0	280.6	260.4	20.2	25.1	39.1	2.6
36.0	2037	300.0	279.5	259.4	20.1	27.3	40.6	2.5
37.0	2093	300.0	278.3	258.3	20.0	29.6	42.1	2.4
37.1	2100	300.0	278.2	258.2	20.0	29.9	42.3	2.3
Forward 9, Ratio 1.342; Manual Shift								
36.8	1517	270.0	258.7	240.1	18.6	29.2	41.8	2.2
37.0	1525	270.8	259.4	240.7	18.7	29.6	42.1	2.1
38.0	1566	275.3	263.2	244.3	18.9	32.1	43.6	2.1
39.0	1607	279.8	267.1	247.9	19.2	34.7	45.2	2.0
40.0	1649	284.8	271.4	251.9	19.5	37.4	46.8	2.0
41.0	1690	290.4	276.3	256.5	19.9	40.3	48.4	1.9
42.0	1731	295.6	280.9	260.7	20.2	43.3	50.0	1.9
43.0	1772	299.2	283.7	263.3	20.4	46.5	51.6	1.8
44.0	1814	300.0	283.8	263.3	20.4	49.8	53.3	1.7
45.0	1855	300.0	283.0	262.6	20.4	53.3	55.0	1.6
46.0	1896	300.0	282.2	261.9	20.3	56.9	56.7	1.5
47.0	1937	300.0	281.4	261.2	20.2	60.7	58.4	1.4
48.0	1978	300.0	280.6	260.5	20.2	64.7	60.2	1.3
49.0	2020	300.0	279.8	259.7	20.1	68.8	61.9	1.2
50.0	2061	300.0	279.0	258.9	20.1	73.1	63.7	1.1
51.0	2100	300.0	278.2	258.2	20.0	77.4	65.5	1.1
Forward 10, Ratio 1.000; Manual Shift								
50.5	1551	273.7	261.9	245.5	16.4	75.4	64.7	1.0
51.0	1566	275.3	263.2	246.8	16.4	77.6	65.5	1.0

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Vehicle Power Capabilities

DETROIT DIESEL
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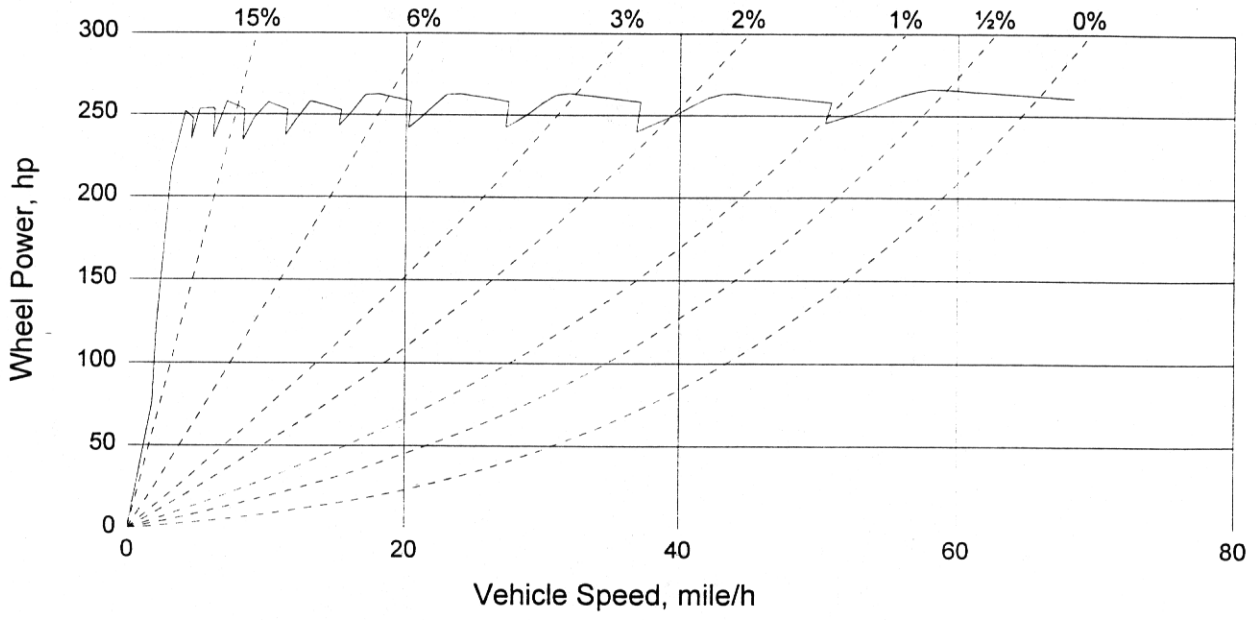

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Drive Axle (Ratio)	Tandem (3.25)
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Tire Model	255/70 R22.5
Tire Size	567 revs/mile

ENVIRONMENT

Surface Type	Smooth Concrete (1.0)
Terrain	Nearly Flat (0% - 1.5%)

VEHICLE POWER CAPABILITIES

Speed	Engine RPM	Gross Engine	Net Engine	Wheel Power	DriveIn Loss	Resistance Air	Resistance Roll.	Grade-ability
mile/h	r/min	hp	hp	hp	hp	hp	hp	%
52.0	1597	278.7	266.1	249.5	16.6	82.3	67.4	0.9
53.0	1628	282.2	269.2	252.3	16.8	87.1	69.2	0.8
54.0	1658	286.1	272.6	255.5	17.0	92.1	71.1	0.8
55.0	1689	290.3	276.3	259.0	17.3	97.3	73.0	0.8
56.0	1720	294.3	279.7	262.3	17.5	102.7	74.9	0.7
57.0	1751	297.6	282.5	264.8	17.6	108.3	76.9	0.7
58.0	1781	299.6	284.0	266.2	17.7	114.1	78.8	0.6
59.0	1812	300.0	283.8	266.1	17.7	120.1	80.8	0.5
60.0	1843	300.0	283.2	265.5	17.7	126.4	82.8	0.4
61.0	1873	300.0	282.7	265.0	17.7	132.8	84.8	0.4
62.0	1904	300.0	282.1	264.5	17.6	139.4	86.9	0.3
63.0	1935	300.0	281.5	263.9	17.6	146.3	89.0	0.2
64.0	1966	300.0	280.9	263.3	17.5	153.3	91.0	0.1
65.0	1996	300.0	280.3	262.8	17.5	160.6	93.1	0.1
66.0	2027	300.0	279.7	262.2	17.5	168.2	95.3	-0.0
67.0	2058	300.0	279.0	261.6	17.4	175.9	97.4	-0.1
68.0	2088	300.0	278.4	261.0	17.4	183.9	99.6	-0.2
68.4	2100	300.0	278.2	260.8	17.4	187.0	100.4	-0.2

+ Reference Disclaimer

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Spec Manager version 1.0

The following is a list of advisory notes, which may affect the performance and/or fuel economy of the configured vehicle. A tip follows each one to provide assistance in improving the configuration.

Insufficient hp to attain geared speed in top gear on a 0% grade.

In order to increase gradeability at requested speed, this vehicle requires more horsepower at requested speed. Try changing to a higher rated engine or changing axle ratios to increase the speed.

There should be at least 0.6 % gradeability at Cruise Speed in top gear if the GCW is below 90000 lb.

In order to increase gradeability at requested speed, this vehicle requires more horsepower at requested speed. Try changing to a higher rated engine or changing axle ratios to increase the speed.

For best fuel economy and performance, please contact a DDC application engineer about gearing recommendations for SERIES 50 engines with gross weights above 80000 lb.

Change the rear axle's numerical ratio to either increase or decrease the Vehicle Speed Limit RPM.

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REPORT DOCUMENTATION PAGE

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13. ABSTRACT *(Maximum 200 words)* In support of the U.S. Department of Energy's development, deployment, and evaluation of alternative fuels, NREL and the Trucking Research Institute contracted with Detroit Diesel Corporation (DDC) to develop and operate a liquid natural gas fueled tractor powered by a DDC Series 50 prototype natural gas engine. This is the final report on the project.

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15. NUMBER OF PAGES
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