



Future Truck Committee Information Report: 2001-1

Reliability of Alternatively Fueled Heavy Trucks Impact on Future Vehicle Design

Developed by The Maintenance Council's (TMC)
Far Horizon Subcommittee of TMC's Future Truck Committee

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INTRODUCTION

This report was prepared to support current and future TMC Future Truck Position Papers on alternative fuels and provide proponents of alternative fuels a measure of the distance they must go to approach diesel engine/fuel reliability. Reliability, in terms of the probability of running so many failure-free miles, is not quantified in any of the reports on alternative fuel usage in heavy trucks. Rather, proxies, such as "uptime," or utilization as a percentage of diesel truck miles, or maintenance cost comparisons are used. The reliability of heavy trucks fueled by LNG, CNG, and ethanol was calculated using failure data from a number of alternative fuel demonstration projects sponsored by the U.S. Department of Energy (DOE) and one conducted by a motor carrier as a private venture. The results are compared to diesel truck reliability. Reliability of two liquid

natural gas (LNG) refueling facilities was also calculated. This report is not intended to be a complete description of the various alternative fuel projects from which the raw data was taken. The reader is referred to the references for other details (fuel economy, emissions, etc.) of the various projects.

There are two important caveats:

1. These calculations are not definitive for a given project (there was not a large amount of raw data), but rather they are a general indicator of magnitude relative to diesel vehicles.
2. These projects were experiments using developmental and prototype engines. It is fully expected that if and when alternatively fueled engines mature, their reliability will be equivalent to that of diesel engines.

METHOD

The failures of alternatively fueled heavy trucks and that of the refueling station were taken from raw data and draft reports provided by ATA as part of its task in preparing final reports on various alternative fuel demonstration projects for the DOE, and from reports by other organizations under DOE contract. The failure is a system failure, the system being the combination vehicle. It is supposed to travel from an origin to a destination. If it failed to complete that trip, or would not start in order to commence a new trip for the system—for whatever reason—failed. These failures were analyzed using Weibull Analysis as per the New Weibull Handbook, 2nd Edition, and the reliability at various mileages or months calculated using:

$$R=e^{-(t/n)^\beta}$$

Where:

R = reliability at interval t

t = miles or months

n = the characteristic time to failure in Weibull Analysis.

β = the slope of the line in the Weibull plot

to obtain the probability of running various miles or months without failure. Figure 1 is a Weibull plot for a diesel automobile which shows the parameters t, β and n. In the case of the refueling station, the reliability was in terms of time (i.e., probability of running so many months before a failure). Maintenance data was not reported in a comprehensive fashion in these projects. Failures are alluded to but they are not always related to the mileage at which they occurred. However, according to the Weibull handbook analyses can be done with only a few data points.

The reliability of a 1978 Ford CLT 9000 with a Cummins 350 engine was used as the comparison diesel fueled vehicle because it was the only heavy truck for which we had complete maintenance records for over 500,000 miles of operation. There was one other diesel-fueled tractor and that was the control vehicle in the Vons Companies project.

VEHICLE RELIABILITY

The following projects were investigated:

1. Walmart LNG—The tractor was a 1994 Navistar 9670 powered by a Detroit Diesel Corp. (DDC) Series 60G DDEC III Developmental Engine. Project ran from June 1995 to November 1996 and covered 84,479 miles (See Reference 1.). Results are shown in Figure 2. R, the vertical axis of the graph, is the reliability; the probability that the vehicle will run a given number of miles without a failure. For example, the Walmart tractor was calculated to have a probability of a little less than 80 percent of running 20,000 miles without a failure. The diesel-fueled Ford by comparison had almost a 100 percent probability of doing this. System failures were caused by frequent need to replace spark plugs, and an engine rebuild. A complete description of the Series 60G is in Reference 1.

2. UNOCAL LNG—1991 Peterbilt 379 tractor with a DDC Series 60G engine. Project ran from August 1995 until March 1997 and covered 30,075 miles. Causes of system failure were spark plugs, fuel tank leak, engine cylinder replacement (see Reference 1),. Results are shown in Figure 2.

3. Con-Way Western Express LNG—Two Ford LN 8000 tractors with Cummins C 8.3-250G engines (see Reference 1). Data from both vehicles was combined on the Weibull plot. The testing started in December 1995 and proceeded intermittently through November 1996. Due to non-vehicle related problems, the tractors accumulated only 10,216 miles between them. Their reliability is shown in Figure 2.

4. The Vons Companies CNG—A Caterpillar G3406LE natural gas engine in a 1992 Ford LTLA-9000 tractor. This was a 14-month project during which the vehicle ran more than 30,000 miles on compressed natural gas (CNG). The G3406LE engine (350 hp) was developed specifically for this project and thus was, as

were the DDC Series 60 engines, a developmental /experimental engine. The results of the reliability calculation for the CNG fueled tractor is shown on Figure 3 along with the reliability of the diesel control vehicle. (This had a Caterpillar 3406B ATAAC engine of 350 hp). The project report is Reference 2.

5. Penske/Houston Airgas LNG—DDC Series 50 natural gas engines in two 1996 Freightliner Model D11264ST chassis with flatbeds (see Reference 3). The project ran from June 1996 through November 1998/ Results of reliability calculations are shown in Figure 3.

6. Praxair (formerly Liquid Carbonic) LNG—Three 1995 Freightliner conventional Class 8 tractors with DDC Series 60 natural gas engines of 370 hp. The vehicles ran from about May 1995 to May 1997 (see Reference 4). The miles each of the three trucks ran was not reported, but from logs of downtime it was estimated that the vehicles ran less than 60,000 miles combined on LNG. Results of reliability calculations for each LNG fueled tractor are shown in Figure 4. Note that the interval, “t,” is expressed in months, rather than miles.

7. Archer Daniels Midland (ADM) Ethanol—Four ethanol-fueled White GMC WIM-64T tractors with DDC 6V-92TA engines (see Reference 5). Fuel was E95, composed of 95 percent anhydrous ethanol and five percent light hydrocarbon denaturant. Project started in March 1992. It was not reported when the project was completed. Maintenance/engine data for one of the four tractors, covering April 1992 through August 1993, was used to calculate reliability. During that period, the tractor ran 119,884 miles. Its reliability is shown in Figure 5.

FUEL STATION RELIABILITY

We were able to find information on the failures of two LNG refueling stations and thus were able to calculate their reliability.

1. DDC Station—The reliability of this refueling station was calculated using failure data from a log kept by DDC on a permanent (as opposed to a temporary facility they had been using). The log covered the period January 1996 to March 1997. The log was a chronology hence the interval in Figure 7 is expressed in months. A description of the facility is found in Reference 6.

2. ALT USA Site—This was used for a while to fuel the Con-Way tractors and a short list of problems over a 60-day period was reported in Reference 1.

REFERENCES

1. *LNG Heavy Truck Demonstration Program*, Arcadis Geraghty and Miller, April 10, 1998 (originally published Sept. 27, 1996 as Acurex Environmental Corp. FR-96-110).

2. *Alternative Fueled Truck Demonstration CNG Program: Caterpillar G3406LE Development and Demonstration*, Acurex Environmental Final Report FR-94-123, Acurex Environmental Corp., 555 Clyde Ave., Mountain View, CA 94039

3. *Case History (draft) Penske Truck Leasing/Houston Airgas Operation of LNG Powered Heavy-Duty Straight Trucks*, Penske Truck Leasing and the Trucking Research Institute, National Renewable Energy Laboratory (NREL) Contract No. ACV-6-16606, June 1999. Available from the American Trucking Associations (ATA) Engineering Department.

4. *Utilizing LNG as a Fuel in Heavy-Duty Tractors*, Draft Final Report, Liquid Carbonic/Praxair and the Trucking Research Institute, NREL Contract No. RAC-4-1445-1. Available from ATA's Engineering Dept.

5. *The Ethanol Heavy-Duty Truck Fleet Demonstration Project*, Ill. Dept. of Commerce and Community Affairs, NREL Contract DE-AC36-83CD10093, May 1997

6. *Operate LNG Powered Heavy-Duty Trucks in Commercial Hauling*, Draft Final Technical Report, Detroit Diesel Corp., and the Trucking Research Institute, NREL Contract No. AAC-5-15131-01, May 1998. Available from ATA's Engineering Dept. 

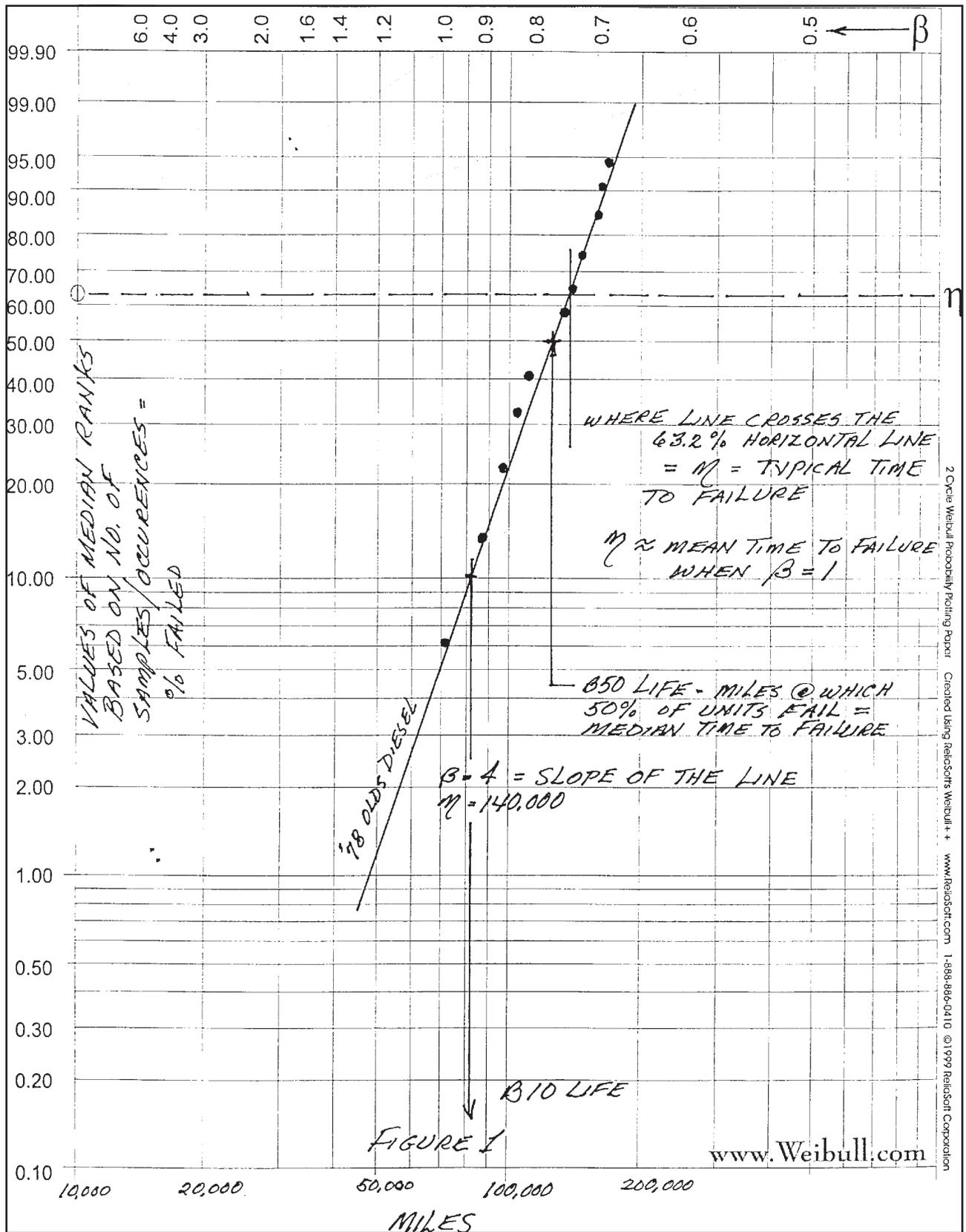


Figure 1

Three LNG Projects Compared to a 1978 Diesel tractor

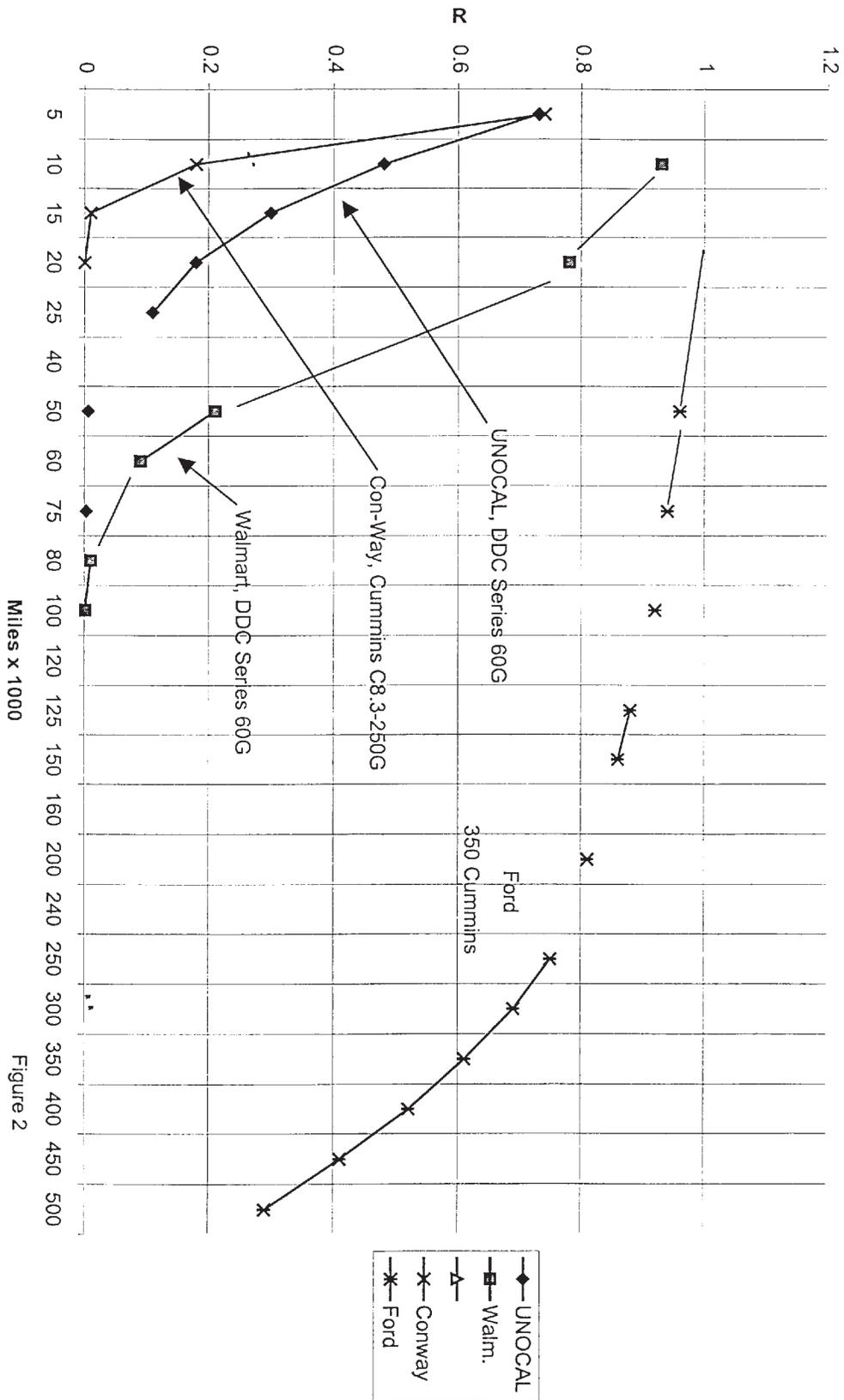


Figure 2

Penske LNG, Vons CNG & Diesel Control

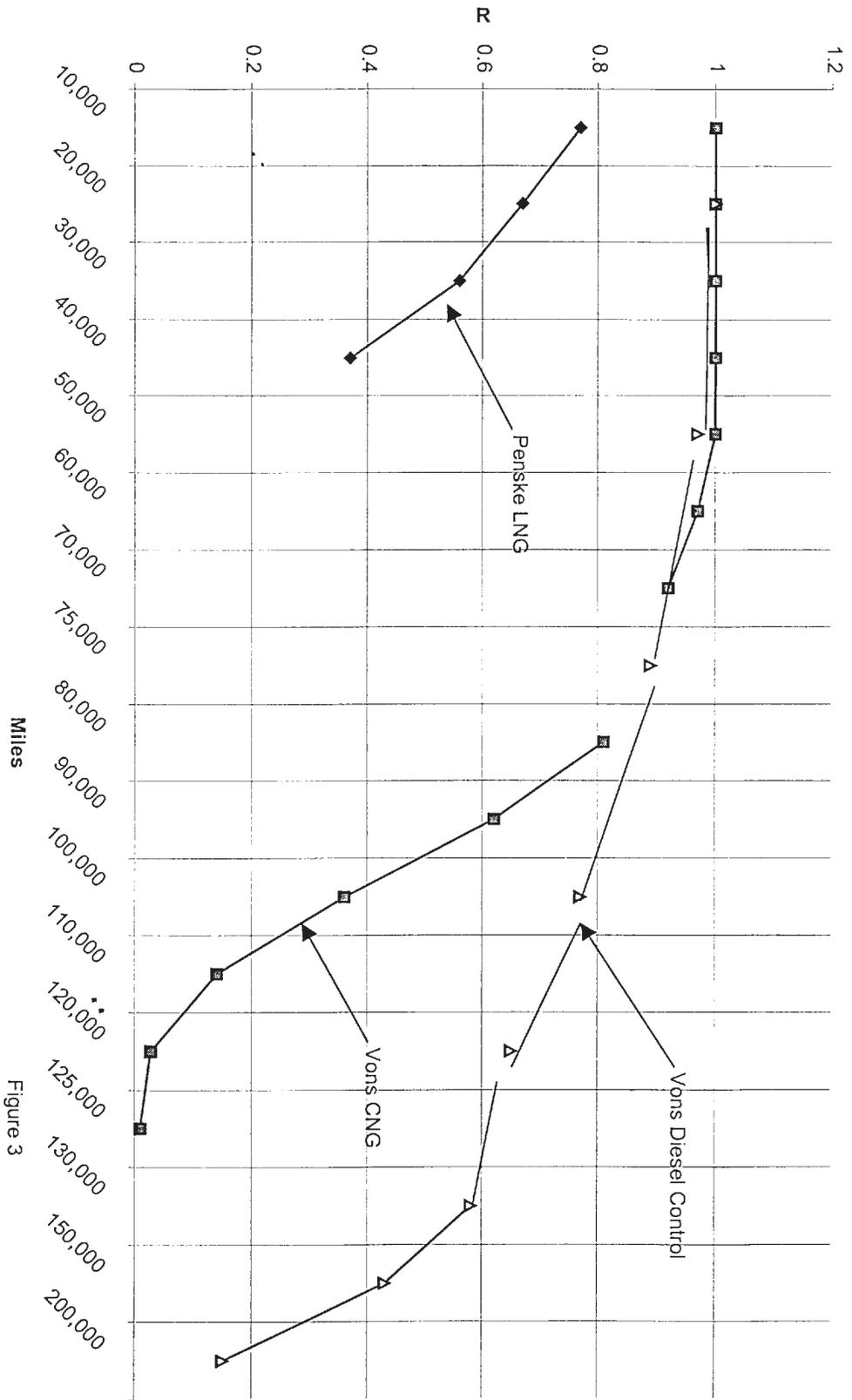


Figure 3

Praxair LNG Trucks

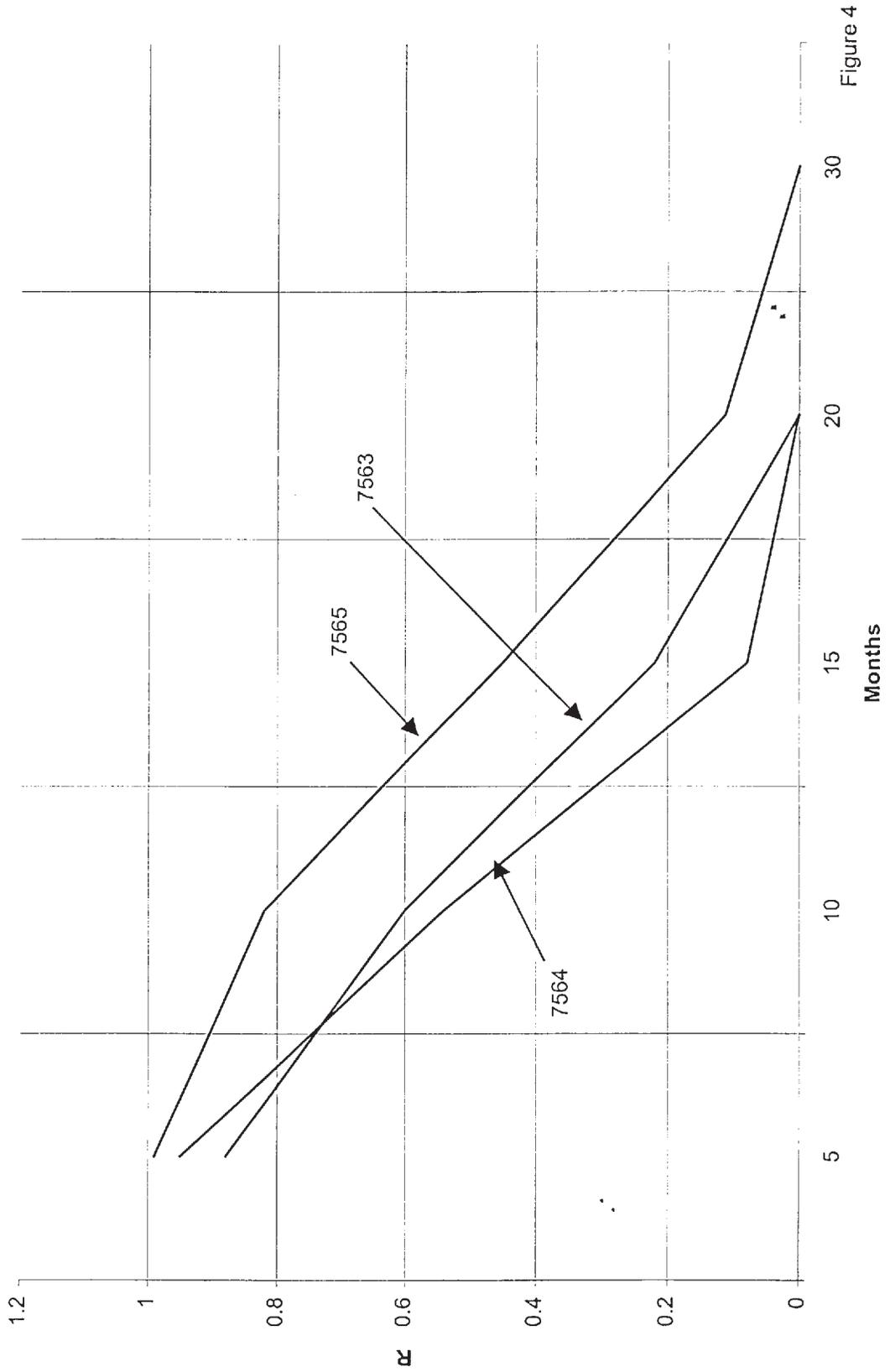


Figure 4

Figure 4

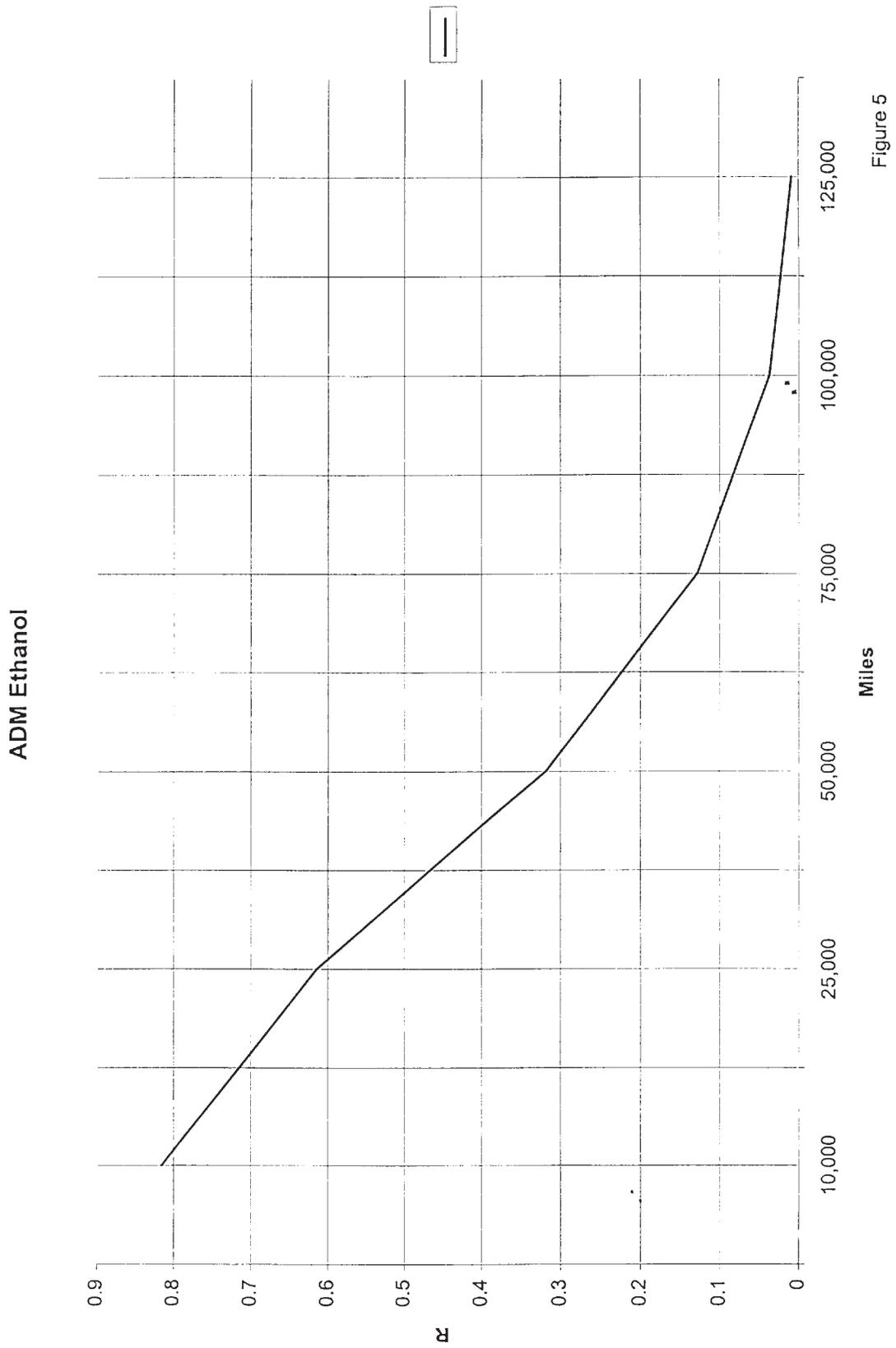


Figure 5

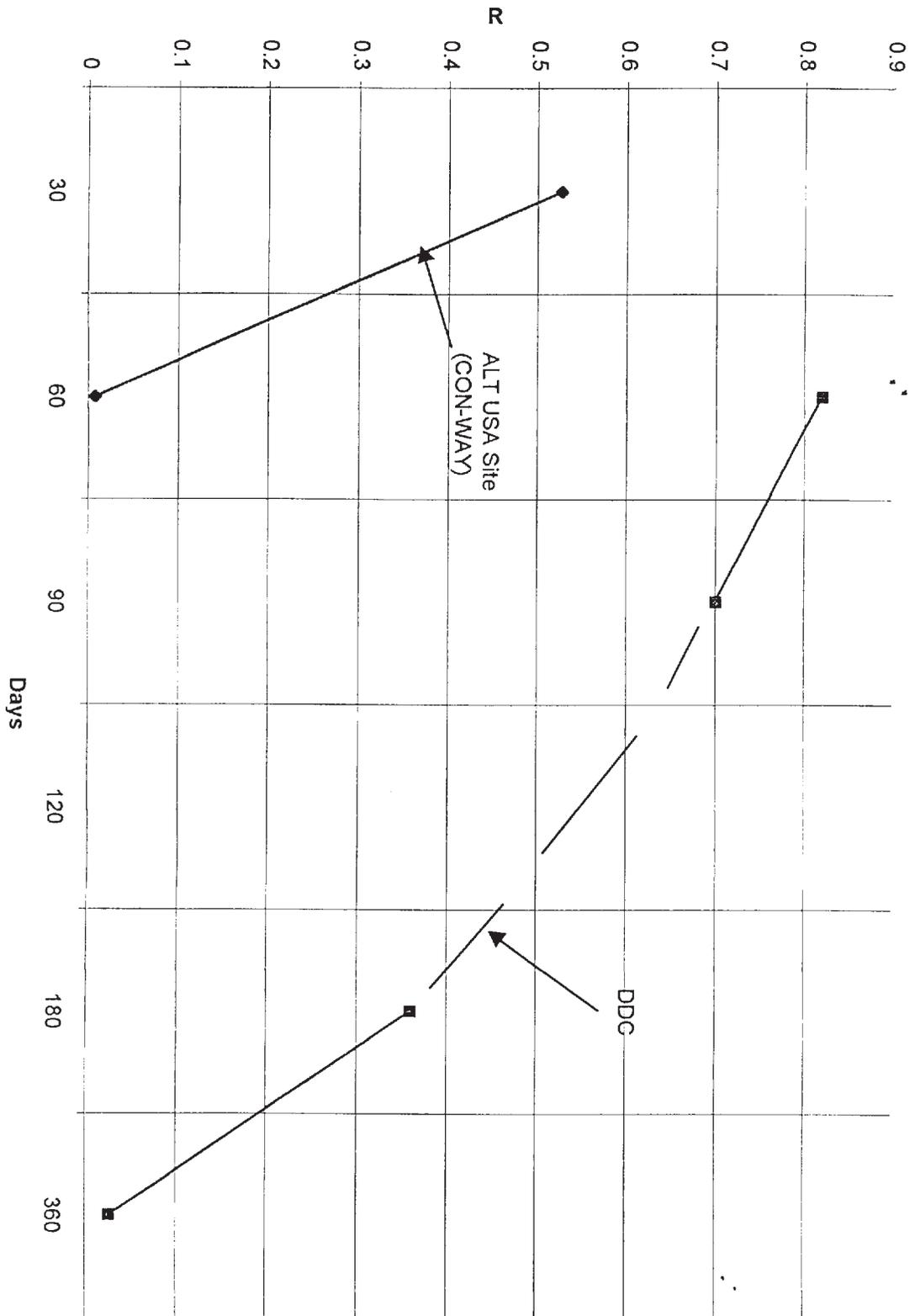


Figure 6, LNG Fueling Stations

Figure 6