



Utilizing Genset Technology In Locomotive Power At Intermodal Railyard Operations

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SUMMARY

In the intermodal industry, locomotives are used to move railcar mounted containers from dockside to truck distribution centers. The United State Government EPA regulations for diesel engine emissions have had a significant impact on the emission standards for locomotive engines, including those utilized in intermodal operations.

In this paper, we will review the EPA emission standards for locomotives used in intermodal transfer operations. These locomotives fall into the yard switching category. In addition, we will present the emissions data on conventional locomotives historically used for yard switching operations in the intermodal industry. The intermodal industry can meet the EPA emission standards by replacing conventional locomotive engines with modern, low emissions diesel engines.

Utilizing genset technology in locomotive power at intermodal railyard operations provides the industry with a sustainable, lower environmental impact option than conventional locomotive power. NOx emissions can be reduced by as much as 84%.

Fuel consumption is a major operating cost component for yard switching at intermodal sites. We will present comparative data on yard switching locomotive fuel consumption to use as a basis for evaluating the cost of using genset locomotive power. Fuel savings of up to 65% have been realized in some switching operations.

Operational staff in the intermodal industry will be concerned with the tractive effort of the switching locomotives. In this paper, we will summarize how to calculate tractive effort, and present comparative data on the tractive effort provided by conventional yard switching locomotives vs genset locomotives. The Railserve LEAF Gen-Set Locomotive delivers greater tractive effort utilizing a 600 HP engine than conventional switch engines of up to 1750 HP.

EMISSION STANDARDS FOR LOCOMOTIVES

The EPA has established emission standards for diesel-powered locomotives in a variety of applications. The classification depends upon the type of operation the locomotive is deployed to perform. Line haul service includes Class I Railroads such as BNSF, Union Pacific, CSX, Norfolk Southern, KCS, CN and CP. Yard switching locomotives, are all those operations serviced by locomotives under 2300 HP. In between are hybrid locomotive operations often called short lines. These usually involve both yard switching and line haul activity. However, the line haul distances are shorter than Class I railroads. For the scope of this paper, the EPA emission standards for yard switching locomotives are shown below in Figure¹.

| | PM ₁₀ | HC | NO _x | CO |
|--|------------------|------|-----------------|------|
| UNCONTROLLED | 0.44 | 1.01 | 17.40 | 1.83 |
| TIER 0 | 0.44 | 1.01 | 12.60 | 1.83 |
| TIER 0+ | 0.23 | 0.57 | 10.60 | 1.83 |
| TIER 1 | 0.43 | 1.01 | 9.90 | 1.83 |
| TIER 1+ | 0.23 | 0.57 | 9.90 | 1.83 |
| TIER2 | 0.19 | 0.51 | 7.30 | 1.83 |
| TIER 2+ | 0.11 | 0.26 | 7.30 | 1.83 |
| TIER 3 | 0.08 | 0.26 | 4.50 | 1.83 |
| TIER 4 | 0.015 | 0.08 | 1.00 | 1.83 |
| + INDICATES THAT THESE ARE THE REVISED STANDARDS IN 40 CFR PART 1033 | | | | |

Figure 1: EPA Switch Engine Emission Limits (g/bhp-hr)

The EPA has defined emission standards² for locomotive categories. See Figure 2 for the standard emissions defined for a conventional diesel locomotive. In this paper we will focus on the yard switching locomotive standards since these would apply to most intermodal yard operations. The EMD engine data is the average emissions data defined by the EPA for conventional switching locomotives.

| Weighted Average Switch Emissions | | | | |
|-----------------------------------|----------------|----------------|------------------|----------------|
| Model | HC g/bhp-hr | CO g/bhp-hr | NO x g/bhp-hr | PM g/bhp-hr |
| EMD 16-567C | 1.25 | 2.13 | 17.27 | 0.40 |
| EMD 12-645E | 0.76 | 1.71 | 17.39 | 0.38 |
| EMD 16-645E | 0.74 | 1.72 | 17.55 | 0.38 |
| Weighted Average | 0.88 | 1.83 | 17.44 | 0.38 |

Figure 2: EPA Baseline Emissions Data For Switching Locomotives

Genset locomotives use modern, ultra-low emissions diesel engines to provide power to the wheels of the locomotive. These engines are supplied by a wide range of manufacturers. Caterpillar, Detroit Diesel, Deutz and Cummins all supply engines suitable for use as a yard switching genset locomotive. In this evaluation, we will use Cummins engine data, but many engine manufacturers provide similar results for emissions from their comparable line of engines.

The Cummins diesel engine emissions are reported on a certificate issued by the California Air Resources Board, (CARB). This certificate shows the following emissions for a genset engine, see Figure 3. Note, the CERT level is the measured amount of emissions. The STD line on the chart below is the EPA standard for Tier 3 classification.

CARB certificate data for Cummins QSX15L engine

| RATED POWER CLASS | EMISSION STANDARD CATEGORY | | EXHAUST (g/kw-hr) | | | | | OPACITY (%) | | |
|-------------------|----------------------------|------|-------------------|-----|----------|-----|------|-------------|-----|------|
| | | | HC | NOx | NMHC+NOx | CO | PM | ACCEL | LUG | PEAK |
| 225 ≤ kW < 450 | Tier 3 | STD | N/A | N/A | 4.0 | 3.5 | 0.20 | 20 | 15 | 50 |
| | | FEL | N/A | N/A | N/A | N/A | 0.13 | N/A | N/A | N/A |
| | | CERT | -- | -- | 3.6 | 0.7 | 0.09 | 16 | 2 | 23 |

Figure 3: CARB Emissions Data For Genset Engine

Using the data from Figures 2 and 3, the percent of NOx emissions reduction can be calculated. Divide the EPA standard emissions for Switch Engines by the CARB certificate emissions measured.

Keen observers will note the units of measure are slightly different:

CARB certificate = 3.6 g/kw-hr
EPA standard for Switch engines = 17.4 g/BHP-hr.

Since the units are different, a correction factor must be applied, according to Appendix P of the EPA Locomotive Emissions Regulatory Support Document ³.

The emission standards and rates presented in this document, which are expressed in g/bhp-hr, can be converted to g/kW-hr by multiplying them by 1.341.

Thus, the % emissions reduction is calculated by the following equation:

$$\text{Reduction \%} = 1 - (3.6 \text{ g/kw-hr} / (17.4 \text{ g/BHP-hr} * 1.341)) = 84.6\%$$

FUEL CONSUMPTION COMPARISON BETWEEN CONVENTIONAL AND GENSET LOCOMOTIVES

Genset locomotives operate much more efficiently than conventional engines with respect to diesel fuel consumption per hour of operation. The retail cost of diesel fuel is currently hovering just below \$4.00/gallon. Over the past few years, diesel fuel has ranged from a low of \$2.50/gallon in 2009 to a high of \$4.00/gallon. See Figure 4 for a chart of the Energy Information Administration graph of recent diesel fuel pricing.

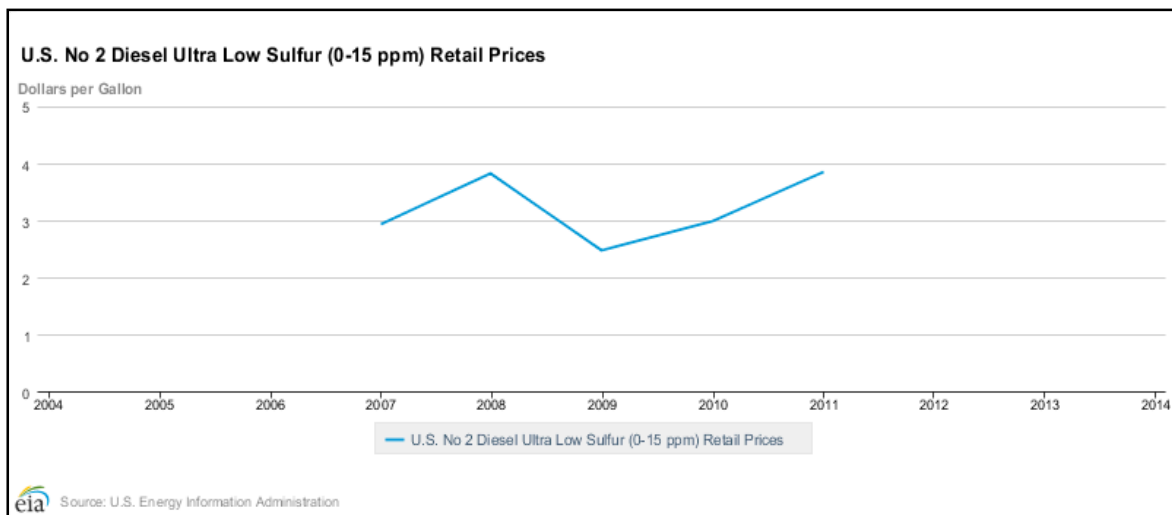


Figure 4: EIA Average U.S. Retail Diesel Fuel Price History

Locomotives use “off-road” diesel fuel. The U.S. Energy Information Administration does not provide data on “off-road” fuel prices, but the difference is the amount of taxation for highway-approved fuel. The EIA estimates this tax at 13% for the U.S. The rate varies somewhat by state. Currently, the “off-road” diesel price would be around \$3.48/gallon. (13% off the \$4.00 price above)

Locomotive fuel consumption in any specific application is a function of the workload being performed by the locomotive. The workload is typically described in terms of the “notch position” of the locomotive. This refers to the control stand lever that the operator uses to regulate the speed of the locomotive. As notch number increases, the engine runs harder, similar to pressing down on the accelerator of a car. Thus, at higher notch numbers, more fuel is consumed. There are 8 notches in most locomotive controls. As the table in Figure 5 demonstrates, fuel consumption for conventional locomotives can vary from a low of around 3 gallon per hour (gph) while idling, up to a high range of 188 gph while at maximum notch. The most common switch engines for use in intermodal yards would be similar to the GP 9 or GP 38 locomotives. These engines have a maximum consumption of 108 gph and 122.4 gph, respectively, at the highest notch level.

In most yard switching applications, the conventional locomotive switch engine may idle up to 50% of the time. Fuel consumption for switching is therefore on the lower half of the total notch position chart since the engine consumes less fuel while idling. Based on data generated from the Railservice fleet of 175 switching locomotives, the average fuel consumption is typically around 14.5 gph for a conventional yard switching locomotive.

Genset switching operations consume considerably less fuel. The fuel savings are derived from both a more efficient transfer of the electric power to the traction motors that drive the wheels, and also from fewer idling hours. Most genset locomotives are programmed to shutdown after the locomotive has not moved for 5 minutes, thus greatly reducing idle time. Start times for the genset are also much faster than that required for a conventional locomotive. A genset can be re-started at the push of a button, while the conventional locomotive engine has a lengthy 30-minute startup process.

Locomotive Fuel Use in Gallons Per Hour

| | Notch | | | | | | | | | | |
|-----------|-------|------|------|------|------|-------|-------|-------|-------|------|----------|
| | Idle | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | DB | Low Idle |
| SW1000/01 | 3 | 5 | 6.1 | 13.4 | 22.2 | 31 | 39.9 | 49.7 | 60.2 | - | - |
| SW900 | 3.1 | 5.2 | 6.4 | 13.9 | 23.7 | 32.9 | 41.1 | 51.6 | 62.9 | - | - |
| SW1200 | 3.3 | 5.1 | 6.3 | 13.8 | 23.1 | 29.6 | 41.3 | 54.4 | 68.9 | - | - |
| SW1500 | 3.8 | 6.5 | 11.5 | 25.2 | 38.6 | 52.5 | 62.1 | 79.6 | 92.6 | - | - |
| MP15DC | 3.8 | 5.8 | 13.6 | 24.1 | 35.8 | 48.3 | 61.9 | 75.1 | 87.9 | - | - |
| MP15AC | 3.8 | 5.8 | 13.6 | 24.1 | 35.8 | 48.3 | 61.9 | 75.1 | 87.9 | - | - |
| GP15-1 | 3.8 | 5.8 | 13.6 | 24.1 | 35.8 | 48.3 | 61.9 | 75.1 | 87.9 | - | - |
| GP9 | 3.5 | 4.4 | 13.4 | 23.6 | 36.8 | 56 | 67.7 | 82.2 | 108.1 | - | - |
| GP10 | 3.5 | 8 | 15 | 25 | 39.7 | 54.5 | 70 | 88 | 108 | - | - |
| GP38 | 4.6 | 7 | 16 | 31.4 | 46.8 | 63.8 | 83.1 | 102.8 | 122.4 | 15 | 3.8 |
| GP/SD38-2 | 4.6 | 7 | 16 | 31.4 | 46.8 | 63.8 | 83.1 | 102.8 | 122.4 | 15 | 3.8 |
| GP40/-1 | 5.5 | 7.4 | 24.9 | 41.4 | 57.2 | 79 | 108.5 | 145.8 | 167.7 | 21 | 4.3 |
| GP40-2 | 5.2 | 9.3 | 25.4 | 44.1 | 60.5 | 79.7 | 100.2 | 133 | 164.4 | 18.4 | 4.1 |
| GP30 | 3.5 | 7.2 | 18.9 | 31 | 44.9 | 61.1 | 75.2 | 102.1 | 124.9 | - | - |
| GP35 | 5 | 11 | 20.9 | 34.9 | 51.2 | 72.1 | 96.2 | 124.3 | 143.6 | - | 4 |
| GP39-2 | 4 | 6 | 19 | 32.2 | 44.8 | 59.3 | 78.5 | 107.5 | 128.8 | 16 | - |
| SD50 | 2.9 | 15.1 | 23.9 | 51.9 | 79.3 | 96.2 | 125.7 | 162.5 | 178.2 | - | - |
| SD40-2 | 5.5 | 9.1 | 24.9 | 41.4 | 57.2 | 79 | 108.5 | 145.2 | 167.7 | 21 | 4.3 |
| SD45 | 6 | 9.8 | 28.1 | 47.8 | 67.5 | 91.7 | 127 | 171.5 | 194 | 25 | 4.7 |
| SD60 | 3 | 12 | 23 | 48 | 66.6 | 88 | 135 | 160 | 183 | 11 | - |
| SD70M | 3 | 11.7 | 23 | 46.6 | 64.1 | 87.3 | 130.7 | 164.5 | 189 | 5.7 | - |
| B40-8 | 3.4 | 16.1 | 22.7 | 47.3 | 72 | 99.8 | 129.5 | 162 | 193 | 3.9 | - |
| C40-8 | 3.4 | 16.1 | 22.7 | 47.3 | 72 | 99.8 | 129.5 | 162 | 193 | 3.9 | - |
| C44-9 | 3.4 | 11.8 | 26.8 | 54.6 | 78.9 | 109.7 | 140.5 | 171.6 | 211.2 | 3.4 | - |

Gallons / Hr.

Figure 5: Conventional locomotive fuel consumption by Notch position ⁴



Railservice tracks the fuel consumption of both the genset and conventional locomotives that we operate. We find the following typical fuel consumption for relatively comparable operating demand:

RailServe LEAF Gen-Set Locomotive ~ average fuel consumption of 4 gph
RailServe Conventional locomotive ~ average fuel consumption of 14.5 gph.

Thus fuel savings can be estimated by the following equation:

$$\text{Fuel savings} = (\text{hours of operation}) * (14.5 \text{ gph} - 4.0 \text{ gph}) * \text{cost of fuel } (\$3.50/\text{gallon})$$

A switch engine that operates 16 hours per day can be estimated to save \$588/day, or \$214,620/yr at \$3.50/g cost of fuel.

Note: each switching operation will have unique locomotive operating demands. The savings for each operation must be evaluated based on the specific situation.

TRACTIVE EFFORT COMPARISON BETWEEN CONVENTIONAL AND GENSET LOCOMOTIVES

Tractive effort refers to how hard a locomotive can pull. It is defined by this equation ⁵

$$\text{Tractive Effort} = \text{Locomotive weight} * \text{adhesion coefficient}$$

Where the adhesion coefficient is measured at the point where the locomotive's wheel meets the rail. The generally accepted Adhesion coefficient maximum for metal to metal is 0.38.

For any diesel electric locomotive, tractive effort is at its maximum at very low speed. The maximum is limited only by either the adhesion of the wheels to the rail or by the amp rating of the traction motors. A GP7 at 1500 HP and GP 40 at 3000 HP have very similar tractive effort at starting speed, about 68,000 lbs. Genset locomotives have some extra electronics in them that can boost this number by about 15% by watching wheel RPM and ground speed.

Railroads are limited by how much weight a wheel can put on a rail based upon the type of track. Most track limits the wheel weight to 40,000. Adhesion between the wheel and rail is a direct function of the weight on the wheel. The main determiner of tractive effort is the adhesion between the wheel and rail. More weight = more adhesion. Thus a GP 9 at 1750 HP and an SW 1500 at 1500 HP have about 68,000 lbs maximum sustained tractive effort while at a stand still. Again, genset locomotives are equipped with advanced control logic that allows tractive effort to be increased by about 15%.

The graph shown in Figure 6 below compares the Tractive effort of a LEAF Genset locomotive to that of a conventional yard switching locomotive. Even though the yard switchers are 1500 HP and 1750

HP respectively, the 600 HP LEAF locomotive has more tractive effort at the low speeds typically used in switchyard operations.

Not until higher speeds are reached does the higher HP have an impact of delivering higher tractive effort. Since most switching operations run at an average speed below 5 mph, the genset locomotive tractive effort is greater than conventional locomotives in switching operations.

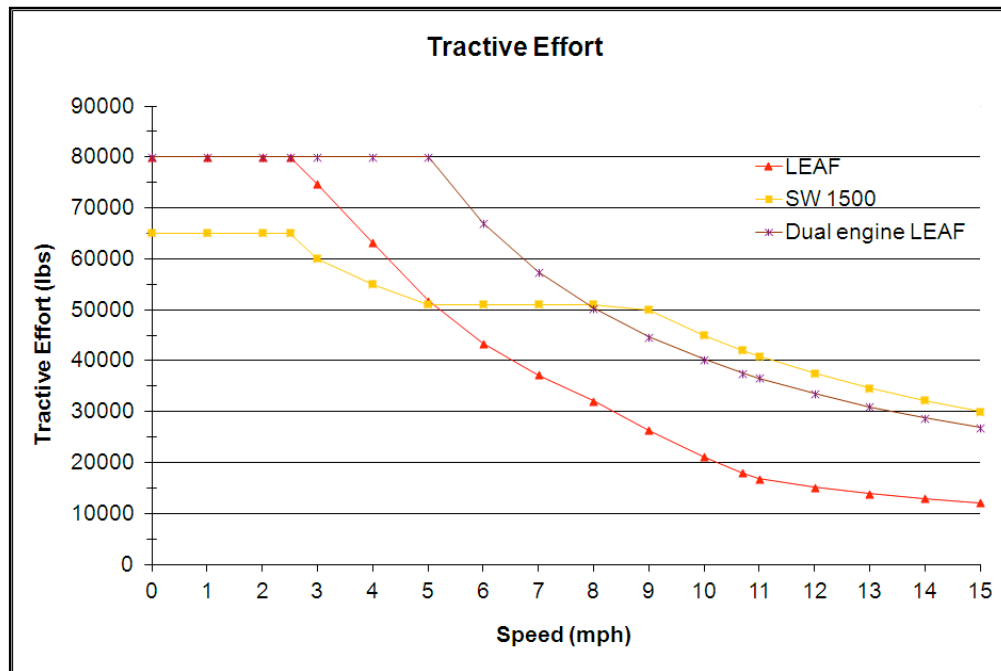


Figure 6: Tractive Effort Comparison of Genset Locomotive vs SW 1500 Conventional Locomotive ⁶

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