United States Environmental Protection Agency

Air and Radiation

EPA420-R-04-003
March 2004

Case Study: Chicago Locomotive Idle Reduction Project

EPA420-R-04-003
March 2004

Case Study: Chicago Locomotive Idle Reduction Project

Certification and Compliance Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

Summary

The installation and use of a combined "Diesel Driven Heating System" and a "SmartStart System" on a locomotive switch yard engine reduced overall idling times by 80%. This resulted in an annual reduction of 12,738 gallons of diesel fuel over 298 in-service days or 42.7 gallons per day. If a railroad's average locomotive availability per year is 92% or 335 days (industry average), annual fuel savings would be 14,339 gallons. At $1.00 per gallon of diesel fuel, the combined savings from the idle reduction technology has a reasonable payback of about 2.5 years. In addition to fuel savings, the technology reduces noise, oil consumption, maintenance costs, and extends engine life. If these savings could be accurately calculated, the payback would be less than 2.5 years.

Over the same 298 day in-service time, the oxides of nitrogen (NO_x) emissions reduced from this locomotive switch yard engine amounted to 2.1 tons, and the particulate matter emissions reduced was 0.06 tons. If the locomotive had been in-service for the industry average, the NO_x emission reduction would have been 2.4 tons per year and the PM emissions would have been 0.07 tons per year. At a capital cost of $35,500 for the idle reduction technology, with a conservative life range of 10 years, the up-front cost to reduce one ton of NO_x is $1,420. This does not include the cost savings from reduced fuel consumption which accrue to the locomotive owner.

Lessons Learned

1. Crew compliance to shut down idling locomotives is highly variable and conditioned upon past training. In the past, crews were trained to never shut down a locomotive in temperatures below 40º F to prevent freeze damage to the locomotive engine. With a Diesel Driven Heating System, a locomotive can be shut down in freezing temperatures as well as warm temperatures. However, some crews revert back to old habits. In this case, combining the Diesel Driven Heating System with a SmartStart system takes the shutdown decision out of the hands of the locomotive operator and provides the greatest idle reduction.

2. In colder climates, select an idle reduction technology that provides the necessary heat for the locomotive engine allowing for easy restarts. The Diesel Driven Heating System allowed for easy restarts in the coldest temperatures encountered (0ºF). Additional testing also showed that the Diesel Driven Heating System could maintain the engine temperature above 100ºF at ambient temperatures much colder than 0ºF. In warmer climates, the use of SmartStart allows for idle control by shutting down the engine when inactive.

3. Select an idle reduction technology that provides sufficient detail on engine performance such as days/hours in service, shutdown time, idle time, and reasons for idling. This allows for greater confidence in reporting actual fuel savings and emission reductions.

Remote monitoring can also be done via Internet and satellite link to access reports any time and to determine locomotive location. This information can be used to validate that the emissions reductions were achieved in a non-attainment area.

Background

In May, 2001, the President's National Energy Policy directed the Environmental Protection Agency (EPA) to develop ways to reduce demand for petroleum transportation fuels by working with industry to establish a program to reduce emissions and fuel consumption from idling vehicles. EPA began by talking to industry leaders about the reasons for idling, the alternatives, the locations, and the obstacles. Based on these discussions, we came to the following conclusions:

- When not utilized, locomotive engines idle primarily to protect the engine during cold weather, normally at temperatures below 40^{o} F. Other reasons for idling include maintaining a comfortable temperature inside the cab, having a readily available engine for service, concern that once shut down the engine may not restart, and the custom or habit of not shutting down the engine.

- Idle Reduction Technologies exist. They range from automatic shut-down/start up systems to auxiliary engines to electrification. They cost from $4,000 to $40,000. Some are new, while others have been around for a long time.

- Most idling takes place at rail yards. Line haul engines may stop for an overnight period, and switch yard engines stay in the yard full time.

- The obstacles for reducing idling include: (1) uncertainty about payback of idle reduction technologies; (2) up-front capital costs for idle reduction technologies; (3) lack of knowledge or testing of idle reduction technologies; and (4) ingrained habits or customs.

In general, the issue of long duration engine idling is not new. Railroad company owners know the amount of fuel consumed by long duration idling. Decision making comes down to economics: return on investment. To begin changing the norm, we must highlight the issue of return on investment.

Project Development

Chicago, Illinois is widely known as a major hub of railroad activity. In fact, the largest switch yard in the country is in this city (Belt Rail Yard). Considering the impact of locomotives on this area, in terms of emissions, EPA decided to issue a grant to implement a locomotive idle reduction demonstration project in Chicago.[1] At about the same time, the City of Chicago, Department of Environment, contacted EPA about the possibility of a noise reduction demonstration project with locomotives due to citizen complaints. EPA and the City of Chicago contacted two railroad companies to participate in the demonstration project: Burlington Northern and Santa Fe Railway Company (BNSF) and Wisconsin Southern Railroad Company (WS). EPA contacted the Kim Hotstart Manufacturing Company to evaluate their Diesel Driven Heating System as the idle reduction technology. Later, ZTR Control Systems included their "SmartStart" system on one of the locomotives. Finally, EPA invited the Department of Transportation, Federal Railroad Administration, to conduct noise testing.

In May, 2002, the principal partners (EPA, Chicago, BNSF, WS, and Kim Hotstart) met and discussed project goals and funding. The project goals were to evaluate the idle reduction technology for its ability to reduce emissions, conserve fuel, reduce noise, reduce oil consumption, reduce maintenance, and satisfy the engine operators. All principal partners contributed financially to the project. In addition, Kim Hotstart and ZTR provided installation assistance and training.

The project officially began on September 23, 2002, with a press event at the BNSF rail yard at 432 West 14th Street in Chicago.

Project Locomotives

Seven locomotives were selected for evaluation with the idle reduction technology, as follows:

#	Railroad	Model	Engine	Manuf	Loco #	HP	Yr of Manuf.	Idle Location
1	BNSF	GP38	16-645E	EMD	2194	2000	1970	Corwith
2	BNSF	GP38	16-645E	EMD	2195	2000	1970	Corwith
3	BNSF	GP38	16-645E	EMD	2133	2000	1971	Corwith
4	WS	SD40-2	16-645E3	EMD	4002	3000	1973	Belt
5	WS	SD40-2	16-645E3	EMD	4003	3000	1973	Belt
6	WS	SD40-2	16-645E3	EMD	4005	3000	1973	Belt
7	WS	SD40-2	16-645E3	EMD	4001	3000	1973	Belt

[1] Illinois EPA's 1996 Periodic Inventory and Demonstration Plan submitted to EPA on May 12, 1999, shows that emissions from rail in the Chicago nonattainment area are 5.77 tons/day of volatile organic mass; 23.19 tons/day of oxides of nitrogen; and 8.09 tons/day of carbon monoxide. These inventory figures do not reflect idling emission from locomotive fleets because of a lack of available data needed to estimate such figures.

Idle Reduction Technology

Kim Hotstart's Diesel Driven Heating System (DDHS) specifications are as follows:

- Dimensions: 23" (w) x 47" (l) x 34.5" (h)
- Alternator - 72-volt, 80 ampere
  - Powers electric immersion heater for main engine water
  - Charges locomotive batteries
  - Powers locomotive cab heaters
- Temperature controller regulates main engine coolant temperature above 100ºF
- Locomotive engine coolant and oil heating supplied through multiple heat exchangers on the DDHS engine
- 12-volt DC signal is supplied for visible/audible/wireless alarm (supplied by customer)
- Control box is a NEMA (National Electrical Manufacturers Association) 12 enclosure that contains electrical control and monitoring components. Controls and indicators include a High Speed Hour Meter, Total Hours Meter, Amps Meter and Engine Controls (Manual/Off/Auto). LED diagnostic indicators are also provided
- Install location: walkway of the switcher or inside the cab body
- Upon locomotive shut-down, the DDHS is automatically started. Upon locomotive start-up, the DDHS is automatically shut-down
- Cost: $28,000

In addition to the DDHS, an automatic shut-down/start up system was installed on one of the BNSF engines (#2133). This system, SmartStart, manufactured by ZTR Control Systems, is a microprocessor technology that automatically manages the shutdown and restart of locomotive engines while parked idling. It continually monitors existing conditions against a preprogrammed set of values. This system monitors the following operating conditions: reverser and throttle position, air brake cylinder pressure, engine coolant and ambient air temperature, and battery voltage and charging amperage. This system was configured to start and stop the DDHS as needed to keep the locomotive batteries charged and the engine above 100ºF. Cost: $7,500.

Idling Hours Reduced

To determine the amount of idling hours reduced, we examined the locomotive's engine performance over one year. One of the lessons learned from this project is the amount of information available to determine engine operating performance. The DDHS is able to report total hours it operated from a non-resettable meter. This meter provides engine run time from the moment of installation and first use. To track its use you need to take readings on a regular basis. The DDHS hours of operation, however, revealed very little about the locomotive engine performance. For two of the WS engines, the DDHS reported running an average of 1,200 hours for the year, thereby reducing this amount of idling in hours. For two of the BNSF engines, for the same period, the DDHS reporting running an average of 350 hours for the year, thereby reducing this amount of idling in hours. The wide discrepancy between the two sets of locomotive engine performance is not explained. Further research into these engines revealed that the engine operators were not shutting down the idling locomotives when required by company policy.

Compare the DDHS reporting to the SmartStart and a different picture develops. Here are some details from the SmartStart system:

- From August 24, 2002 to September 7, 2003 (roughly one year), the BNSF locomotive with the SmartStart (#2133) was in service for 298.4 days and out of service for 76.5 days. Therefore, for one year, the locomotive was only operational for 79% of the time (vs. Industry average of 92%). The reduced locomotive availability was due to locomotive maintenance and upgrades not related to the idle reduction technology. The value of this information is knowing that the time available to reduce idling emission reductions is not a full year or 92% of the year, but only 298.4 days.

- Of the 298.4 days in service (or 7,162 total hours), the engine was shut down for 3,978 hours (55% of total in-service hours). Of this block of time, the engine was manually shut down for 1,477 hours (37%), and the idle reduction technology successfully shut down the engine for 2,501 hours (63%).

- Of the remaining 3,184 hours the engine was operating, almost 85% of this time was still spent idling (2,687 hours). One would question why the idle reduction technology did not reduce this amount of idling. The SmartStart provides an answer. Of the 2,687 idling hours, 62% of the time was spent in working idle (e.g., coasting down a hill or on a flat) which could not be reduced, and 38% was spent in parked idle. The parked idling should be reduced by the idle reduction technology, but the SmartStart details the reasons the idle reduction technology could not reduce this amount. Some of this time is described as "unavoidable" and some of it as "manageable." The "unaviodable" portion refers to events beyond the control of the idle reduction technology. The "manageable" portion describes some kind of action taken by the operator which prevented the idle reduction technology from operating (e.g., not placing the reverser in center position).

Emission Reductions

The BNSF 2133 recorded 2,501 hours of reduced idling attributable to the idle reduction technology. Part of the idle reduction technology, however, emits NO_x and PM. The DDHS uses a Lister Petter engine which is certified by EPA under 40 CFR Part 89. The certified emission levels of the Lister Petter (manufacture year 2002) for NO_x is 6.69 g/kw-hr and for PM is 0.540 g/kw-hr. After converting from g/kw-hr to g/bhp-hr, and then to g/hr using an average load factor of 8 hp, emissions from the DDHS are 71 g/hr for NO_x emissions and 5.7 g/hr for PM emissions. Taking only the amount of time the DDHS operated (1,255 hours), we can subtract the emissions associated from the DDHS from the total emissions reduced from the locomotive engine.

To calculate the emission reductions we use the emission reduction methodology from EPA's "Guidance for Quantifying and Using Long Duration Switch Yard Locomotive Idling Emission Reductions in State Implementation Plans." For switch yard locomotives powered by 2-stroke engines, the average NO_x emission factor at idle is 800 grams per hour, and the average PM emission factor at idle is 26 grams per hour. Therefore, for the BNSF 2133, the annual NO_x emission reduction is 2.1 tons per year and the annual PM emissions is 0.06 tons per year.

The number of committed switch yard engines per rail yard varies throughout the country and among the railroad companies, and depends greatly on that particular yard's needs. Typical numbers range from one to twenty engines, with an average of about five switchers per rail yard. If all five switchers at a typical rail yard are retrofitted with idle reduction technologies, the potential NO_x emission reductions could be 12.5 tons per year at a cost of $1,420 per ton of NO_x reduced.

Noise Reductions

On September 4, 2002, the Federal Railroad Administration (FRA) conducted stationary locomotive noise tests for this demonstration project. The purpose of the tests was to compare noise levels of idling locomotives equipped with the DDHS versus locomotives without the DDHS.

The first set of tests was conducted at the Burlington Northen Santa Fe Railroad (BNSF) Facility in Cicero, IL. The tests were conducted at 100 feet from the locomotive with the 100 foot clear zone parameters established. The locomotive, when using the DDHS, operated at approximately 8-10 decibels quieter than when idling the engine. It was so quiet, in fact, that from where the dosimeter was positioned, at 100 feet, the test technicians could not hear the DDHS. At approximately 30 feet the test technicians were finally able to hear the DDHS operating. The test was conducted with the DDHS muffler facing toward the dosimeter. The muffler is mounted outside of the locomotive car body on the side frame.

The second set of tests was conducted at the Belt Railway of Chicago in Bedford Park, Il. The tests were conducted in the West Yard with no outside noise sources except for a few airplanes flying in and out of Midway Airport. There were three tests conducted on the WSOR Locomotive #4001. All tests were conducted in accordance with the stationary locomotive criteria. The first test was with the locomotive at idle, the second with the DDHS operating, and the third with the locomotive at throttle notch three (typical notch setting when ambient temperature is $< 10^{o}$ F). The locomotive, when using the DDHS, operated at approximately 8-10 decibels quieter than when idling the engine. The difference between notch three and the DDHS operating was approximately 15 decibels quieter.

Note that the sound level scale in decibels is a logarithmic rather than linear scale. This means that as the sound level goes down, the effective decrease is much more. For example, the 10 decibel reduction noted by the test technicians above means the sound is twice as low. It can be concluded that the application of the DDHS reduced noise levels considerably when compared to the main engine idling, almost to the point of not being able to hear any noise form the locomotive at 100 feet.

For More Information

For more information on EPA's locomotive idle reduction projects, contact Paul Bubbosh at Bubbosh.Paul@epa.gov, or (202) 343-9322.

For more information on Kim Hotstart's DDHS, contact Terry Judge at tjudge@kimhotstart.com, or (509) 536-8672.

For more information on ZTR's SmartStart, contact Bill O'Neil at boneill@ztr.com, or (952) 233-4384.