

Diesel Initiative for Retrofit Technology (D.I.R.T.) Program

Regional Air Quality Council

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Project Description

On and off-road diesel vehicle exhaust contributes up to 25 percent of the total particulate matter 2.5 (PM 2.5) inventory in the Denver metro area. In addition, diesel vehicles contribute to other criteria air pollutants such as hydrocarbons (HC), carbon monoxide (CO) and oxides of nitrogen (NOx). All of these pollutants can cause breathing and respiratory problems in sensitive populations that include the young, elderly and those with pre-existing ailments. According to 2004 American Lung Association data, 31 percent of the population of Denver and Adams Counties are home to sensitive populations diagnosed with asthma, bronchitis, emphysema and cardiovascular disease.

Reducing the amount of diesel exhaust emissions in the Denver metro area will not only make it easier for people with respiratory ailments to breathe, it will also help the area stay in compliance with the National Ambient Air Quality Standards (NAAQS). Reducing particulate matter also helps reduce the Denver region's visibility problem known as the "Brown Cloud." Additionally, components of diesel fuel contribute to air toxics in the Denver metro area. Hazardous air pollutants (HAPS) are currently an issue being addressed by the Colorado Department Public Health and Environment's (CDPHE) Air Toxics Program.

To assist CDPHE with their efforts, the Regional Air Quality Council (RAQC), CDPHE and the Western Regional Air Partnership (WRAP) developed the Diesel Initiative for Retrofit Technology (D.I.R.T.) Program. The program's area of focus was designated as areas with high concentrations of sensitive populations and environmental justice areas. In 2004, program partners developed a \$75,000 grant and applied to the Environmental Protection Agency's (EPA) Voluntary Diesel Retrofit Program for funding assistance to implement this effort. The grant was approved in October 2004.

The program was designed as a demonstration project with the goal to demonstrate the use of individually verified technologies in an unverified suite of retrofit applications with the primary focus on older off-road engines between model years 1985 – 1995. The unverified applications that program partners focused on retrofitting include, but were not limited to, the following:

- Front-end loaders with engines of 110 horsepower or greater;
- Compactors with engines of 250 horsepower or greater;
- Graders with engines of 125 horsepower or greater;
- Dump trucks with engines of 125 horsepower or greater
- Bulldozers with engines of 250 horsepower or greater.

Since no ultra low sulfur diesel (ULSD) was available at the time of program development, the decision was made to utilize verified diesel oxidation catalysts (DOC) and closed crankcase filtration (CCF) units on the off-road applications listed above. Discussions with equipment manufacturers at the time of project development indicated that limited real-world testing had occurred utilizing this combination of technology in applications that are subjected to the extreme operating conditions experienced by off-road construction equipment.

The combination DOC and CCF installations were to be focused on older vehicles due to the disproportionately higher emissions these vehicles have compared to newer vehicles. In addition, many heavy-duty diesel engines have open crankcase vents where blow-by emissions are unregulated and vented to the atmosphere. These crankcase emissions contribute approximately

25 percent of a vehicle's overall emissions and are the primary in-cab pollutant that can impact driver health. CCF equipment captures and filters this source of vehicle emissions.

The off-road construction industry was the primary focus of our efforts since this industry has historically been reluctant to participate in environmental programs. This project will be used to demonstrate to the off-road construction industry that diesel retrofits are a simple, sound technology that can be used to reduce worker and community exposure to air toxics. Additionally, project partners provided education to fleet operators that cleaner off-road equipment will help their industry's image in the Denver area and limit the need for additional government regulation. Therefore, the project will not only demonstrate new technologies in off-road applications, but will also identify, analyze, and share with the off-road construction industry the lessons learned from undertaking this unique project and promote others to take action.

Project Partners and Program Goals

The primary project partners for the D.I.R.T. Program included the CDPHE Air Toxics Program, WRAP, the Rocky Mountain Clean Diesel Collaborative (RMCDC), Brannan Sand and Gravel Company, the City of Commerce City and the local office of the Associated General Contractors (AGC). Other stakeholders associated with the project include the Rocky Mountain Fleet Manager's Association (RMFMA) and Healthy Air for Northeast Denver (HAND).

Since this was the first retrofit project undertaken in the Denver metro area to address emissions from off-road construction equipment, this project provided project partners with knowledge which will be utilized to develop larger off-road retrofit programs. Program partners understand that on-road fleets are more open to participating in government retrofit efforts. Private off-road fleets do not seem as interested. This effort challenged metro area stakeholders to develop new relationships between government and the construction industry. The program's objectives were simple and included:

- Investigating and demonstrating specific retrofit solutions in real-world applications;
- Reducing emissions from fleets operating around sensitive populations;
- Partnering with the off-road construction industry to promote retrofit efforts;
- Providing education to fleets that by embracing voluntary retrofit programs they can reduce the need for additional government regulation;
- Offering program data and lessons learned to any stakeholder or party interested in retrofitting diesel equipment; and
- Capturing the highest quality data necessary for the project, including:
 - Ease of installation;
 - Performance in untested off-road operating conditions (i.e., monitor for problems related to vibration, etc.);
 - Effects on maintenance;
 - Longevity of product in comparison to manufacturers' claims; and
 - Emissions reductions.

All program goals were met except the project timeline. Unfortunately, RAQC and project partners could not anticipate how difficult it would be to secure private construction fleet participation.

Outreach

Initially the RAQC planned to find a private contractor to work with to implement this program. The ideal candidate fleets were identified as construction companies that worked on hospitals since these facilities would house high numbers of sensitive populations. A secondary criterion that would be utilized to identify candidate fleets was their proximity to EPA environmental justice areas. EPA defines environmental justice (EJ) as the “fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.” Some areas in the Denver metro area have historically not been fairly treated in the siting of higher polluting facilities. It was these areas that the RAQC was determined to focus on in implementing this project.

Between 2004 – 2006, the RAQC presented the D.I.R.T. funding and retrofit opportunity at numerous meetings and conferences throughout the State of Colorado. However, the construction industry was originally not interested in participating in this effort. Therefore, the RAQC sought to work with other public entities to implement this project. The RAQC began working with the RMFMA to identify interested fleets. RMFMA invited the RAQC to present at its meetings and conferences.

Also at this time, EPA began its Healthy Air for Northeast Denver (HAND) Project. This project’s goal is to reduce risk from toxic air pollution in northeast Denver through voluntary and community-selected projects. The HAND project pulled together representatives of community groups, government agencies, industry associations and others to learn about issues and needs related to air quality. The group reviewed air quality data and identified strategies that included diesel retrofit projects, anti-idling campaigns and pollution prevention workshops. The goal was to implement projects collaboratively with community, industry, academia and government of all levels.

Northeast Denver was selected since this area is an environmental justice area with a legacy of heavy industry and a very high concentration of heavy-duty diesel vehicles and fleet operations, a number of current and former Superfund Sites and extensive multi-modal transportation that includes highways and railways. EPA designated the HAND project area as being bound on the south by Martin Luther King Boulevard; 64th Street to the north; Pecos Street to the west; and Dahlia Street to the east. The area includes the neighborhoods of Globeville, Sunnyside, Elyria/Swansea, Cole, Clayton and part of Commerce City.

According to EPA, community members indicated that air pollution was their number one environmental concern during listening sessions to develop this project. Since the RAQC and CDPHE were formal stakeholders in the HAND project, both agencies believed it was an excellent opportunity to parallel EPA’s efforts and assist EPA in attaining the goals of the HAND effort. Due to the HAND effort, RAQC began targeting municipal and county fleets in the northeast Denver metro area through the RMFMA.

In early 2006 the outreach effort paid off. Commerce City Public Works became interested in participating in the D.I.R.T. Program. The City offered to retrofit 15 vehicles. Unfortunately, many of the units were not candidates for retrofit due to the lower horsepower of the vehicle engines. Through the inspection process, it was determined that four of their large dump trucks would be retrofitted under the program.

Upon completion of the Commerce City effort, the RAQC and project partners continued to search for interested fleets to participate in this effort. Numerous fleets expressed interest but did not commit to the project. The RAQC then developed a partnership with the Associated General Contractor's (AGC) Association to find one of their member fleets to participate. AGC sent out a notice to all its member organizations regarding the grant and received no responses. A speaking engagement with member companies was held in the fall of 2006. Unfortunately no fleet contacts came from this effort either.

In mid-2006, EPA Region 8, CDPHE and RAQC began to develop the Rocky Mountain Clean Diesel Collaborative (RMCDC). In the fall of 2006, the RMCDC held its first retrofit conference that again touted the D.I.R.T. Program and included an off-road breakout sessions to educate and entice the off-road industry to embrace retrofit efforts. Many interested fleets attended the conference but the conference did not lead to project partners identifying a private construction company to work with.

In early 2007, the program retrofit contractor, Instrument Sales and Service (ISS), had the opportunity to develop a relationship with a private construction firm named Brannan Sand and Gravel Company. Through discussions with Brannan Sand and Gravel, ISS and the RAQC secured a commitment from the company to participate in the D.I.R.T. Program. It was this relationship that was critical to a successful finish on the D.I.R.T. Program.

Overall, the focus on outreach was very helpful in developing the program and educating off-road fleets about diesel retrofit and idling reduction programs. Unfortunately, the outreach effort took much longer than anticipated to secure fleet interest. The finding from this effort is that the construction industry is difficult to reach except through one-on-one interactions.

Technology

The RAQC initially anticipated having a competitive bid process to secure the equipment under this grant. Unfortunately, only one equipment manufacturer was ever listed on the EPA's Verified Retrofit Technology List during this project for the combination DOC and CCF. EPA approved utilizing the vendor without going through a competitive bid process.

ISS teamed up with Donaldson to provide EPA-verified Series 6000 diesel oxidation catalysts (DOC) and Spiracle closed crankcase filtration system (CCFS) for all vehicles in this project (See Appendix A for specific part numbers). This technology is simple and not fuel dependant. DOCs are muffler replacements designed to reduce emissions at the tailpipe. They are simple technologies that require no maintenance and last for many years. The primary benefit of this equipment is up to a 26 percent reduction in particulate matter and higher reductions for other criteria pollutants. Spiracle closed crankcase filtration units close off and recirculate crankcase emissions back into the exhaust system to eliminate harmful unfiltered exhaust gases. The primary benefit of this equipment is that it reduces in-cab fumes and captures oil emitted at the crankcase.

Vehicles and Engines Involved

Again, the program was designed as a demonstration project with the goal to demonstrate the use of individually verified technologies in an unverified suite of retrofit applications with the primary focus on older off-road engines between model years 1985 – 1995. The unverified applications that program partners focused on retrofitting include, but were not limited to, the following:

- Front-end loaders with engines of 110 horsepower or greater;
- Compactors with engines of 250 horsepower or greater;
- Graders with engines of 125 horsepower or greater;
- Dump trucks with engines of 125 horsepower or greater
- Bulldozers with engines of 250 horsepower or greater.

As the project was implemented, partners found that the vast majority of local governments and large private fleets do not retain many vehicles in the model years 1985 – 1995 since the equipment is not as fuel efficient as newer equipment. Since it was difficult to find model year 1985 – 1995 equipment, project partners were required to open the model year window to newer vehicles. In addition, municipal fleets do not have large numbers of strictly off-road loaders, compactors, graders and bulldozers. Most local governments contract large construction projects requiring this equipment out to a private contractor.

Project partners found dump trucks in local government fleets to begin the retrofit effort to demonstrate to private fleets a project like this could be implemented successfully. Commerce City Public Works retrofitted four 2000 – 2002 Freightliner FL80 dump trucks in February of 2006 (See Appendix A for details). These vehicles are used on off-road construction projects and could also be used as snow plows if needed during winter storms. They have operated approximately 7,000 miles on average and the retrofits have encountered no problems. They have operated approximately 2,000 miles in the last quarter.

Brannan Sand and Gravel Company elected to retrofit three types of units. These included dump trucks, aggregate hauling tractors and off-road maintenance vehicles. The model years ranged between 1995 – 2000 with horsepower ranging between 275 – 410 (See Appendix A for detail). The retrofits were installed in March and April of 2007. Many of these units are very high mileage units and travel up to 20,000 miles per year. The units have traveled very little since the retrofits were installed but are now beginning to operate as construction season begins in the Denver metro area.

The vehicles that were retrofitted include a variety of applications, engines and model years. Project partners were satisfied with the units that were ultimately retrofitted but hoped that front-end loaders, compactors, graders, bulldozers could have been identified and included in the project. These units remain a high priority for future retrofit efforts.

Emissions Benefits and Cost Analysis

Emissions reductions were developed utilizing fleet reported operating hours of retrofitted vehicles, brake horsepower per hour for each unit and EPA emissions certification standards. Percentage reductions from EPA's Verified Retrofit Technology List for the Donaldson 6000 DOC and Spiracle equipment combination were then applied to determine the project's emissions reductions (see Appendix A for methodology). Utilizing certification standards for the emissions calculations provides a conservative calculation since it does not account for engine degradation over many years. Annual emissions reductions for the total program were estimated at a minimum of 0.3 TPY of PM, 35 TPY of CO and 7 TPY of HC. Overall, the annual cost per ton reduced was approximately \$2,150.

Lifetime benefits for the project were developed using a straight-line calculation and a five year life of equipment. The life of equipment is based on warranties and real world reports on DOC

life. Over five years, the project results in the reduction of a minimum of 1.6 tons of PM, 175 tons of CO and 33 tons of HC.

Fleet management and technicians indicated that installation of the equipment is straightforward. At this time there have been no maintenance or performance issues reported from either Commerce City Public Works or Brannan Sand and Gravel Company with over 7,000 miles on some units since the retrofits took place.

Lessons Learned

The most significant challenge was finding fleets to participate in a demonstration project of this nature. The combination DOC and Spiracle had not been fully tested in off-road construction equipment and private companies had not been interested in participating until late in the project. Initially private construction companies and their industry groups indicated they were not interested in working with government on environmental projects. This industry is difficult to reach since they are usually extremely busy and do not have open forums to provide outreach through.

Since no private construction companies were interested, it was decided that a public fleet was the best candidate to test this equipment. This allowed us to monitor any issues that developed after installation and limit the potential for negative publicity if vehicle breakdowns occurred due to the installed equipment. Once this partnership was developed, the project began to move forward. However, program partners still could not find a private construction company to work with.

Once our partnership with AGC was developed, program partners hoped a private fleet would commit to the project. Unfortunately this did not occur. Over time, the project retrofit contractor found a construction fleet that was interested in participating. Brannan Sand and Gravel Company helped make this a successful project.

Through this project we developed a partnership with Brannan Sand and Gravel Company and Commerce City Public Works. Both fleet managers embraced the technology and the goal to reduce air pollution near the sensitive populations in the environmental justice areas they operate in. Due to this project, Brannan Sand and Gravel Company has expressed interest in idling reduction efforts if the RAQC can provide funding for engine preheat technology. The RAQC hopes that other construction firms hear about this positive experience and participate in our future efforts to implement diesel retrofit programs in the private construction industry.

Budget

The RAQC received \$75,000 from the EPA Sensitive Populations grant funding. Table 1 shows the funding allocation to each fleet in the project. Project funding was spent on 21 Donaldson 6000 diesel oxidation catalysts and 21 Donaldson Spiracle closed crankcase filtration units.

Table 1 – Overall Grant Budget

	Expenditure	Cost
Commerce City Equipment	4 DOC+CCF	\$12,456.72
Brannan Equipment	17 DOC+CCF	\$62,543.28
Total		\$75,000

Project partners and fleets provided \$15,205 in match funding for the project for a total project cost of \$90,205. This funding is detailed below in Table 2.

Table 2 – Match Budget

	Cost
Commerce City Staff Time	\$ 658.25
Brannan Staff Time	\$9,382.50
RAQC Staff Time	\$5,164.25
Total	\$15,205

Conclusion

Overall, all program goals were met for this project. Project partners successfully:

- ✓ Demonstrated specific retrofit solutions in real-world applications;
- ✓ Reduced emissions from fleets operating around sensitive populations in environmental justice areas;
- ✓ Partnered with the off-road construction industry to promote retrofit efforts;
- ✓ Provided education to fleets about retrofits and their benefits;
- ✓ Offered program data and lessons learned through many conferences, workshops, and one-on-one meetings; and
- ✓ Captured high quality data that showed significant emissions reductions for twenty-one retrofits, found the equipment is easy to install, found that retrofit problems related to off-road operations are minimal and have no effect on maintenance and last longer than manufacturers’ claims.

The primary benefit of this project was the impact on the health of sensitive populations. While it is difficult to measure the impact of reduced emissions from twenty-one retrofits around the sensitive populations/environmental justice areas we worked in, project partners feel confident that our efforts did provide some help. Again, American Lung Association indicates, 31 percent of the population of Denver and Adams Counties are home to sensitive populations diagnosed with asthma, bronchitis, emphysema and cardiovascular disease. Reducing particulate matter by any amount is a benefit to these sensitive populations.

The second most important aspect of this project was that it led to the development of a \$1.5M Congestion Mitigation and Air Quality (CMAQ) retrofit and idling reduction grant. Currently, fourteen municipal, county and state fleets are involved in the project. The D.I.R.T. project had a direct impact on the development of this new effort.

A final benefit is that project partners were finally able to secure a private construction company’s commitment to participate in a government operated retrofit project. Our hope is that this small effort will reduce industry mistrust of government and EPA sponsored projects in the future.

Contact Information

Steve McCannon is Program Manager of diesel retrofit efforts for the RAQC. Steve can be reached at (303) 629-5450x230 or smccannon@raqc.org.

APPENDIX A

Commerce City	Vehicle Type	Retrofit Equipment	Date Retrofitted	MY	HP	Brake HP	Hours of Operation	PM/gr	CO/gr	HC/gr
	Freightliner FL80 DUMP	Donaldson M111213 DOC/S040004 Spiracle	2/28/06	2000	260	208	1,700	35,360	5,480,800	459,680
	Freightliner FL80 DUMP	Donaldson M111213 DOC/S040004 Spiracle	2/28/06	2001	285	228	1,700	38,760	6,007,800	503,880
	Freightliner FL80 DUMP	Donaldson M111213 DOC/S040004 Spiracle	2/28/06	2002	285	228	1,700	38,760	6,007,800	503,880
	Freightliner FL80 DUMP	Donaldson M111213 DOC/S040004 Spiracle	2/28/06	2001	285	228	1,700	38,760	6,007,800	503,880
Brannan										
	INTL 4900 T/A DUMP	Donaldson M111274 DOC/S040004 Spiracle	2/12/07	1997	275	220	1,500	33,000	5,115,000	429,000
	INTL 4900 T/A DUMP	Donaldson M111274 DOC/S040004 Spiracle	2/14/07	1997	275	220	1,500	33,000	5,115,000	429,000
	INTL 4900 T/A DUMP	Donaldson M111274 DOC/S040004 Spiracle	2/13/07	1997	275	220	1,500	33,000	5,115,000	429,000
	INTL 4900 T/A DUMP	Donaldson M111274 DOC/S040004 Spiracle	2/14/07	1995	275	220	1,500	33,000	5,115,000	429,000
	INTL 4900 T/A DUMP	Donaldson M111274 DOC/S040004 Spiracle	2/13/07	1996	275	220	1,500	33,000	5,115,000	429,000
	INTL 4900 T/A DUMP	Donaldson M111274 DOC/S040004 Spiracle	2/13/07	1997	275	220	1,500	33,000	5,115,000	429,000
	INTL 4900 T/A DUMP	Donaldson M111274 DOC/S040004 Spiracle	2/15/07	1997	275	220	1,500	33,000	5,115,000	429,000
	INTL 4900 T/A DUMP	Donaldson M111274 DOC/S040004 Spiracle	2/14/07	1997	275	220	1,500	33,000	5,115,000	429,000
	INTL 4900 T/A DUMP	Donaldson M111274 DOC/S040004 Spiracle	2/12/07	1997	275	220	1,500	33,000	5,115,000	429,000
	INTL 9200 T/A AG TRACTOR	Donaldson M111015 DOC/S040005 Spiracle	2/19/07	1998	410	328	1,700	55,760	8,642,800	724,880
	INTL 9200 T/A AG TRACTOR	Donaldson M111015 DOC/S040005 Spiracle	2/19/07	1998	410	328	1,700	55,760	8,642,800	724,880
	INTL 9200 T/A AG TRACTOR	Donaldson M111015 DOC/S040005 Spiracle	2/19/07	1998	410	328	1,700	55,760	8,642,800	724,880
	INTL 9200 T/A AG TRACTOR	Donaldson M111015 DOC/S040005 Spiracle	2/19/07	1998	410	328	1,700	55,760	8,642,800	724,880
	INTL 9200 T/A AG TRACTOR	Donaldson M111015 DOC/S040005 Spiracle	2/19/07	1998	410	328	1,700	55,760	8,642,800	724,880
	INTL 9200 T/A AG TRACTOR	Donaldson M111015 DOC/S040005 Spiracle	2/19/07	1998	410	328	1,700	55,760	8,642,800	724,880
	KW T-300 OFFROAD MAINT	Donaldson M111274 DOC/S040005 Spiracle	2/15/07	2000	275	220	2,000	44,000	6,820,000	572,000
	KW T-300 OFFROAD MAINT	Donaldson M111274 DOC/S040005 Spiracle	2/15/07	1995	410	328	2,000	65,600	10,168,000	852,800
	Total Vehicle Emission (Grams)							892,800	138,384,000	11,606,404
	Total Emissions (Pounds)							1,967	304,811	25,565
	Total Equipment Percentage Reduction							33%	23%	52%
	Annual Emissions Reductions (PPY)							649	70,106	13,294
	Annual Emissions Reductions							0.32	35.05	6.65

(TPY)										
Five Year Project Emissions Reductions (Tons)								1.62	175.27	33.23

Cost Analysis	Annual	Life of Project
Project Cost	\$ 90,205	\$ 90,205
Total Tons Reduced	42	210
Cost Per Ton	\$ 2,146	\$ 429