

is not sufficient to support passively controlled regeneration of a DPF. Thus, either on-board or off-board active filter regeneration is necessary.

In sizing an actively regenerated filter for these small horsepower engines, the only significant selection criterion is the desired time interval between active regenerations. For example, if the user wishes to regenerate a filter no more often than once per day, then the filter must have the capacity to store the maximum amount of soot generated by the subject engine over the period of one day while maintaining acceptable engine backpressure. If physical space to mount a filter is limited, the smallest filter having adequate soot storage capacity at the maximum acceptable backpressure would be selected. If space constraints are not an issue, a larger capacity filter would also be acceptable, with the larger size permitting a longer time interval between regenerations.

As a point of reference, a once-per-day actively regenerated DPF for a 60 hp personnel transport tractor operated for one shift per day is about 20 inches long by about 10 inches in diameter, and such filters are commercially available from multiple sources. If the same filter is fitted to a 30 hp engine having the same duty cycle and emission rate (expressed as g/bhp-hr), that filter will function just as well, but the time interval between regenerations would roughly double. Based on this DPF selection process, there is probably no lower limit to the size engine that can be effectively filtered using any of several commercially available active systems.

DPFs for low horsepower engines can also be provided by the original equipment manufacturer (OEM) or distributor as standard or optional equipment. An example is a Series 7 Toyota forklift equipped with a 40 hp 1DZ-II diesel engine for which a DPF-II diesel particulate filter is offered as an OEM or dealer-installed option. The DPF unit is about 14-inches long and about 8-inches in diameter, and is mounted on the rear of the forklift body.

Regarding high horsepower applications of DPF systems, for purposes of this discussion, "high" horsepower is meant to include engines of 250 horsepower and higher because this is the horsepower range addressed by the commenter. Engines of this size would typically be installed on production equipment such as loaders and haulage trucks and are commercially available from several manufacturers.

There are two approaches to filtering diesel particulate emissions that can be implemented on high horsepower

engines using current commercially available DPF units: large capacity single unit DPFs; and multiple DPFs that are either manifolded to the same exhaust pipe, or separate DPFs that are provided on each side of a dual exhaust system.

An example of a large capacity single unit DPF system is the Engelhard model 9121A 15-inch long by 15-inch diameter Pt-catalyzed filters installed on the LHD and haulage trucks that were the subject of MSHA's compliance assistance diesel emissions tests at the Greens Creek mine. The LHD and all three haulage trucks were equipped with the same MSHA Approved 12.7 L engines rated at 475 hp at 2100 rpm. The LHD engine was derated to 300 hp, but this value still exceeds the commenter's threshold level of concern of 250 hp, and the truck engines were generating the full 475 hp. These DPFs passively regenerated on both the loader and haulage trucks, and the emission testing demonstrated filter efficiencies of greater than 90%.

The other approach to filtering high horsepower engines is to provide multiple filters. When an engine's exhaust is routed through a single exhaust pipe, the exhaust can be split into two parallel paths, with each path being equipped with a filter. When an engine has a dual exhaust system (*i.e.* separate exhaust pipes on either side of the engine, which is the most common arrangement on high horsepower engines), a DPF can be fitted to each exhaust pipe. This approach actually simplifies a DPF installation on an engine with dual exhausts, as installing a single filter would require modification of the exhaust system to join together the dual exhausts into a single exhaust pipe upstream of the filter. On underground equipment where space is at a premium, it may be easier to install two smaller filters than to find a space large enough to install one large filter.

Depending on the horsepower of an engine, space constraints, method of filter regeneration, and other factors, it may be necessary to split an engine's exhaust into more than two parallel paths for DPF installation. For example, each side of a dual exhaust system could be split into two parallel paths to facilitate the installation of DPFs on all four of the resulting exhaust pipes. There is no upper limit on the horsepower of an engine that could be filtered with standard, commercially available DPFs. For example, MSHA is aware of a stationary diesel-powered generator station rated at about 12,000 hp that has been filtered in this manner.

Although sizing a ceramic (SiC or cordierite) DPF is a rather complicated

process that must take into account consideration for engine horsepower, engine DPM emissions (g/bhp-hr), duty cycle, constraints on regeneration, and other factors, the "rule-of-thumb" starting point for most filter manufacturers is typically 8 cubic inches of filter media volume per horsepower for an engine having a DPM emission rate of 0.1 g/bhp-hr. Due to manufacturing complications for larger units, the filter media is typically limited to a maximum size of 15-inches long by 15-inches in diameter. These dimensions correspond to a maximum of 330 hp per filter for an engine having an emission rate of 0.1 g/bhp-hr. For cleaner engines like those used in the Greens Creek mine testing, these dimensions correspond to a proportionally larger horsepower engine.

If each side of a dual exhaust system is split only once, requiring four separate DPFs, installation of 15x15 filters on each of the four branches would adequately filter a 0.1 g/bhp-hr emission engine rated at greater than 1,300 hp, which is larger than any engine currently used in underground metal and nonmetal mining, or likely to be used in the foreseeable future.

Importance of preventing exhaust leaks: Because the DPF is greater than 95% effective in removing elemental carbon from the exhaust, it is extremely important that the exhaust system upstream of the DPF be leak-tight. Leaks will leave a shadow of soot and are thus self-evident unless covered by insulation that disperses the leaking exhaust so that no distinct soot shadow is produced. Flex-pipe joints should be fastened securely using wide band clamps. Operators should not use flat flanges with gaskets, but use tapered tongue and groove joints to attain a positive seal.

Alternative Options

In addition to the feasibility of engineering control technology that was discussed at the NIOSH workshops (low emission engines, maintenance, fuels, and DPFs), MSHA believes that enhancing ventilation and enclosing miners in cabs or other filtered areas also are effective engineering controls for significantly reducing DPM exposures.

Administrative controls can effectively reduce miners' exposure to DPM. These include such practices as: reducing diesel engine idling time, reducing lugging of engines, designating certain areas "off limits" for operating diesel equipment, and establishing speed limits and one way travel.