

Particulate Trap Installation in a MAN Articulated Transit Bus

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The increasing Environmental Protection Agency standards for diesel engine exhaust emissions are forcing the transit industry to find a means of cleaning up the air. A particulate trap oxidizer system is currently accomplishing this task on two-cycle transit bus engines. At Phoenix Transit System this same technology is being applied to a Maschinenfabrik Augsburg-Nürnberg AG (MAN) four-cycle engine to demonstrate that four-cycle exhaust can also be cleaned. The particulate trap system installation in the MAN bus is summarized. The initial temperature testing was conclusive that all system components were operating within component manufacturers' specifications. Smoke opacity testing on the particulate-trap-equipped bus resulted in readings of 0 percent smoke opacity compared with a similar MAN bus with as much as 27 percent opacity. Operating data are being collected to determine if the system is applicable to a four-cycle transit bus engine in a desert environment similar to that in Phoenix, Arizona.

The transit industry is currently being pressured by federal government, city government and citizens to clean up the air. In 1994, the Environmental Protection Agency (EPA) will be introducing standards for diesel engines that cannot be met unless current diesel engines are redesigned, another form of fuel is used, or a means to filter the exhaust to meet the new requirements is provided.

The retrofitting of current operating diesel engines with an exhaust filter system is a viable means of meeting future EPA standards. These systems also have the potential to be applied to new engines to meet the standards required for the manufacturer without redesigning the engine. Currently, a particulate trap oxidizer system is available as a retrofit package for a two-cycle Detroit Diesel engine. The same particulate trap system has been adapted to a four-cycle transit bus engine at Phoenix Transit System (PTS). Two MAN articulated transit bus exhaust systems were retrofitted using the Donaldson dual-trap electric oxidizer system. The initial retrofit package cost is approximately \$16,000 each.

The particulate trap system replaces the original muffler system of the four-cycle MAN MLUM D2566 engine. The MAN bus (Figure 1) was chosen to demonstrate that the smoke from a four-cycle diesel engine, which normally has increased opacity over that of a two-cycle engine, can be eliminated. PTS is evaluating the particulate trap system in the following areas: (a) its applicability in extreme heat conditions encountered in the desert environment, (b) whether the system will cause any adverse side effects, and (c) if the use of a four-cycle engine, which produces hotter exhaust gases than a typical two-cycle, will tend to magnify the extreme operating conditions.

OPERATIONAL CHARACTERISTICS

The Donaldson dual particulate trap system is designed to filter up to 85 percent of the diesel-emitted particulate. The system used by PTS consists of three components: a ceramic wall-flow monolith filter element, regeneration system, and the controls that bring about regeneration. When the engine is started, the particulate trap system will direct the exhaust flow through the trap assembly filter element that is the most full. This is determined through a series of calculations by the electronic controller that monitors engine air flow, temperature readings, and differential pressure across the filter elements. Exhaust flow continues through the filter until it is loaded to the maximum allowable level, at which point the exhaust flow is diverted to the other trap assembly. The loaded filter is regenerated to remove the particulate and is then left idle until the next loading cycle.

INSTALLATION

Planning

The first step was to evaluate how the components of the particulate trap package would be oriented to occupy the space available. Careful inspection was conducted to determine if all the components could be located close together. In addition, the location of each component was carefully evaluated for ease of serviceability. After measurements were taken, sketches were drawn to get a complete understanding



FIGURE 1 MAN articulated transit bus with a four-cycle engine.

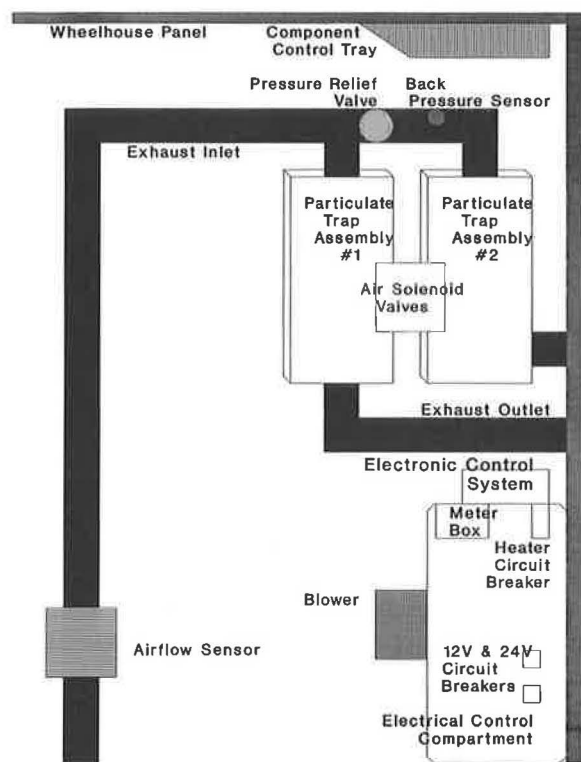


FIGURE 2 Schematic of dual particulate trap system installed in a MAN articulated bus.

of the overall retrofit. Using the sketches, all the components were laid on the floor to visualize the orientation and location of the final installation.

One mechanic was chosen to complete the entire installation. This provided a better control and continuity throughout the installation and also reduced the instruction time required when several individuals are involved in a large, continuous project.

Procedure

The Donaldson dual particulate trap system (schematic shown in Figure 2) was installed in the MAN articulated bus with minimal modifications to the water lines and the exhaust system. The original muffler system (Figure 3) was removed, leaving only two muffler supports and the exhaust piping from the engine. Both of the supports were shortened, one was repositioned, and two were added and aligned to provide support to the front and rear of each trap at a height to ensure sufficient ground clearance.

One modification required to make the particulate trap system conform to the MAN four-cycle engine was to shorten the trap exhaust-pipe-inlet assembly provided in the Donaldson package. This allowed a straight section to be inserted to connect the existing exhaust piping to the inlet assembly. An additional bracket was added to support the inserted piping span. The shortening of the inlet assembly required the exhaust back-pressure relief valve and the exhaust back-pressure sensor to be relocated on the inlet assembly. It was also important to keep the exhaust outlet pipes as short as possible to minimize the back pressure and to maintain separation and

to avoid opposite flow into the nonoperating trap. The last modification pertained to the three coolant water lines, which occupied the space required by the larger particulate trap system. The modified lines were routed in a manner to provide clearance and system integrity.

The air flow sensor was positioned between the engine intake manifold and the intake air cooler. This location is different from the two-cycle engine system where the sensor is located between the engine air filter and the turbocharger compressor inlet. Because of space restrictions, this was the only placement possible without major system modifications.

The electronic control system is housed in a single sealed box designed so that it can be mounted on the bus exterior. In an attempt to minimize the wiring lengths required, the box was mounted within the same cavity as the particulate traps, near the exhaust outlet pipes. The component control tray, which contains the pressure sensors, electrically operated air solenoid valves, and two filter heater relays, was located on the forward side of the wheelhouse panel to control wiring and minimize hose lengths. The blower that supplies the necessary air to sustain regeneration was mounted on the back side of the electrical control compartment. The air solenoid valves, which control the air supplied by the blower, were mounted above the traps. They were connected to the blower with heater hose, and to the traps with corrugated steel tubing for protection from the heat generated by the traps.

To maintain an operational record of the particulate trap system, a meter box was installed in the side electrical com-

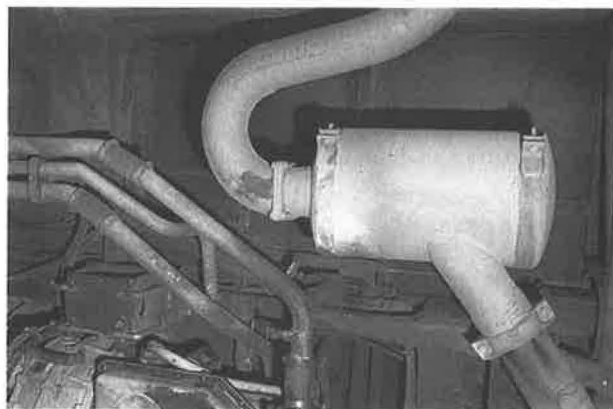


FIGURE 3 Original muffler system.

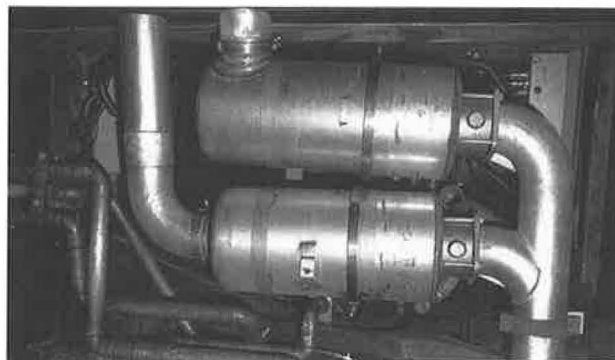


FIGURE 4 Dual particulate trap system.

TABLE 1 ADDITIONAL MATERIALS REQUIRED

<u>Mounting Materials</u>	
<u>Quantity</u>	<u>Description</u>
3	2" Rubber Bushing
1	14" x 14" x 1/8" Steel Plate
6'	1 1/2" x 1 1/2" x 1/16" Steel Square Tubing
3'	2" x 1/8" Steel Flat Bar
2'	1 1/2" x 1 1/2" x 1/8" Steel Angle
5'	5" Exhaust Pipe
1	5" Exhaust Pipe Clamp/Support
<u>Plumbing Materials</u>	
<u>Quantity</u>	<u>Description</u>
9'	2" Copper Tubing
6	2" Copper 90's
7'	1 1/2" Copper Tubing
5	1 1/2" Copper 90's
1	2" x 2" x 1 1/2" Copper T Connector

partment. The meter box monitors critical data relative to the operation of the entire system, such as total run time, run time on each trap, and the number of regenerations per trap. Using the meter box, PTS is obtaining a detailed log of the operational characteristics of the particulate trap system. Also mounted inside the electrical control compartment were the 12-volt and 24-volt system circuit breakers, and the heater circuit breaker to allow for easy servicing when necessary.

A 7-psi pressure switch was integrated into the generator oil supply line to signal the particulate trap system run-relay switch when the bus engine is operating. A pressure switch was used in place of the generator R-terminal to avoid possible voltage spikes. The completed installation of the Donaldson dual particulate trap system in a MAN articulated transit bus is shown in Figure 4.

Materials

The materials required to install a dual particulate trap system on a MAN bus are outlined in Table 1, which shows all materials needed in addition to the particulate trap system kit.

Time

The time required to install the entire particulate trap system was shortened for the second installation because of the knowledge gained from the first installation. The second installation necessitated only 100 hours, whereas the first installation took approximately 25 percent more time.

INITIAL TESTING RESULTS

Tests were conducted to determine what temperature the components of the particulate trap system were being subjected to. Thermocouples were located on all the system components and temperatures were recorded during transit bus operating conditions. All tests were conclusive that the components were operating within the manufacturers' component/temperature specifications.

Testing was also conducted to determine the opacity of the exhaust emissions. Three different operational load tests were done: idle, pull-off, and 80 percent of governed speed, which is the Arizona state emissions test. Both of the particulate-trap-equipped buses recorded an opacity level of 0 percent for all levels of load testing. A control bus similar to the particulate trap buses was tested for comparison purposes. The opacity levels of the control bus were 2, 27, and 3 percent, respectively.

Further testing is planned on a mobile emissions tester capable of testing heavy-duty vehicle emissions using the EPA test cycle. The tester is a joint project between the former Urban Mass Transportation Administration (now the Federal Transit Administration) and the Department of Energy (DOE). DOE has contracted with West Virginia University for the development and operation of the equipment. In addition, PTS is planning to conduct testing quarterly at the Phoenix facility using an opacity meter.

CONCLUSION

The stricter EPA standards are forcing the transit bus industry to search for solutions to meet these requirements. A particulate trap retrofit can solve this problem on a two-cycle diesel engine. PTS is demonstrating that the Donaldson particulate trap system can be adapted to a MAN four-cycle engine, resulting in exhaust emissions comparable with the future EPA guidelines.

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