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Noise Sources and Solutions for Mobile Vacuum Trucks

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Abstract

Data are presented on the noise sources of mobile vacuum trucks as they are used as a stationary source, especially the rotary positive displacement blowers used to create the vacuum. These are straight lobe blowers manufactured by several companies. In addition to the expected intake and discharge noise, the bypass or jet port noise must be considered and may be the dominant noise source. Several solutions are discussed as well as limitations on space and weight. Once the blower noise is reduced, more traditional noise reduction of the engine, transmission and cooling fan noise must also be done.

Introduction

During the past decade the use of truck mounted vacuum systems has grown dramatically. These systems, an example of which is shown in Figure 1, are used for a variety of purposes including removing solid, semi-solid and liquid materials from vats, tanks, sewers and many



Figure 1. Mobile Vacuum Truck

other locations. These systems have been used to excavate soil, sand and other wastes especially in environmentally critical areas. Similarly designed systems are also used for street sweepers and other applications requiring the removal of liquid waste. Vacuum requirements vary from 50 kPa [15 "Hg] to 91.5 kPa [27 "Hg]. The vacuum pump used in this application is often of the

straight lobe, rotary positive displacement type, sometimes called a Roots blower but produced by a variety of manufacturers. Since these are mobile applications, clean water is not available and the blowers run dry.

Simple rotary positive displacement (RPD) blowers have been used for many years in pneumatic conveying and other applications needing constant airflow at varying pressure requirements. They are ideal for a vacuum conveying system. The disadvantage is that if the inlet is blocked the blower will quickly overheat. This overheating is a major problem in high vacuum applications such as the ones found on mobile trucks. Sometimes water injection is used for cooling but as mentioned, these systems rarely have sufficient clean water for this purpose. To address this issue a secondary port has been added to the RPD blower to allow cooling flow even during a completely blocked inlet condition. Figure 2 shows a typical flow diagram for a two lobe blower with this feedback or jet port. This figure shows a 90° rotation of the shaft and corresponds to a single pulsation event. Initially the jet port was internal to the blower but to get increased cooling air flow, most vacuum blowers now have at least the option for an external connection. Note that in the two lobe design there is very little space for sealing during operation and any leakage could lead to a reduction and/or limitation of performance. To get higher performance an alternative solution was to go to a three lobe blower design which simplified the jet port configuration, and insured an adequate sealing area. This has caused a shift from the more tradition two-lobed RPD blowers used in the stationary bulk material transport industry to a three-lobed blower design which allows these alternative cooling methods as well as other design benefits. A schematic flow diagram of a typical three-lobe blower design is shown in Figure 3 for a 120° rotation of the shaft. This corresponds to two pulsations, one from each rotor.

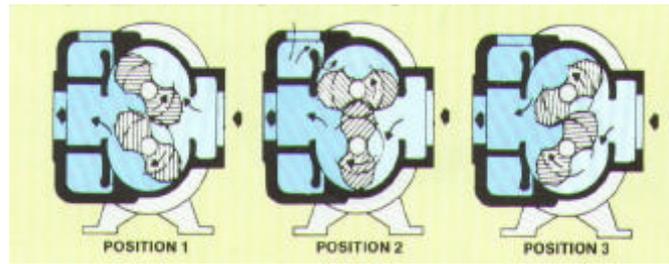


Figure 2. Two-lobe RPD Blower Flowpath

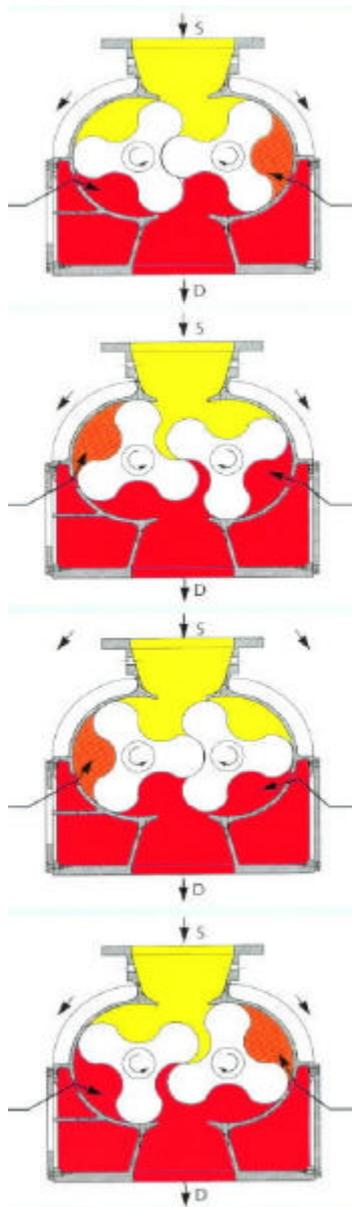
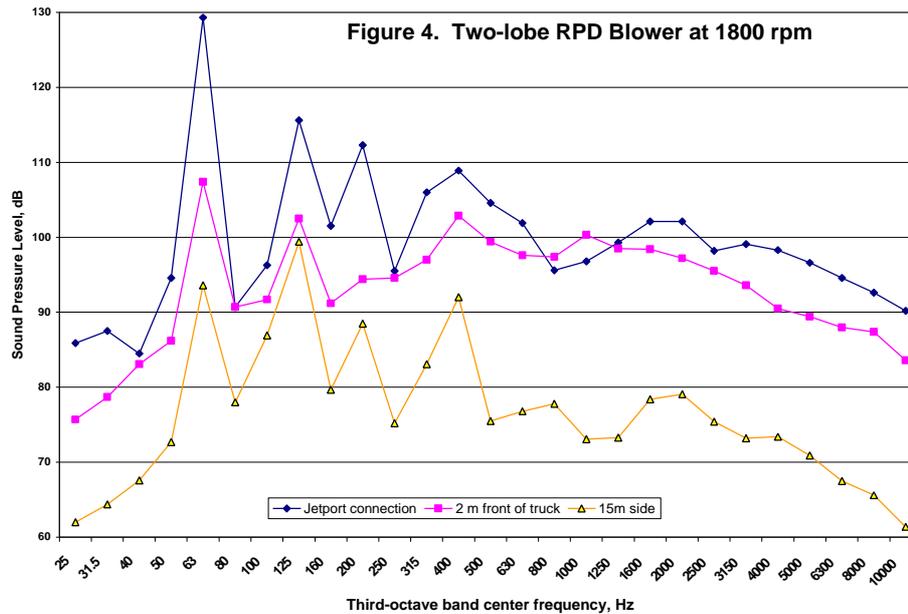


Figure 3. Three-lobe RPD Blower Flowpath

Note that the lobes counter rotate in both cases and that the delivered volume is between the rotor and the outer wall. The level of attainable vacuum is mainly determined by the leakage between the rotors but also between the rotors and outer wall. The arrows indicate the air movement and differing colors indicate the pressure rise as the air is moved from the inlet to atmospheric discharge. In most designs, the jet ports in a vacuum application are separately open to the atmosphere. These multi-ported designs offer significant challenges to the noise control engineer.

Sound Levels and Characteristics

Rotary positive displacement (RPD) blowers are significant noise sources. It has been known for many years that the predominant discharge noise is tonal in nature at multiples of what is called the “pocket passing frequency”. For a two-lobe blower this frequency is at four times the rotational frequency; for a three-lobe blower it is six times the rotational frequency. This noise is relatively well understood and to the extent allowed by weight and space restrictions



has been addressed on existing truck designs. Figure 4 shows sound levels in one-third octave bands for a typical vacuum truck using a two lobe blower running at 1800 rpm with an external jet port. This data was taken on a system under development with a premium grade of silencer on the discharge and a good grade of silencer on the jet port. The operating conditions were at a vacuum of 75 kPa [22”Hg]. It was expected that the dominant noise from the blower would be the discharge, hence the higher grade of silencer. As can be seen in Figure 4, the sound levels adjacent to the jet port are significantly louder than expected. Note the strong tonal content in the 63 Hz band and at its harmonics. The jet port measurement point is located approximately 1 meter from the silencer outlet connection. The curve at 15 meters to the side of the truck is on the side opposite the discharge silencer. Note that the lower harmonics of the jet port noise are present at this location.

Note in Figure 4 that the sound levels taken in front of the truck are almost as high as those measured adjacent to the jet port. This is not jet port noise, or even blower noise, but other sources on the truck, mainly due to engine, radiator fan and gear/transmission noise. While the RPD blower noise is highest on the side of the truck, it is not the dominant noise in front or at the rear of the truck. The rear of the truck is 5 dBA to 15 dBA quieter than any other location because of shielding and usually does not impact the overall application.

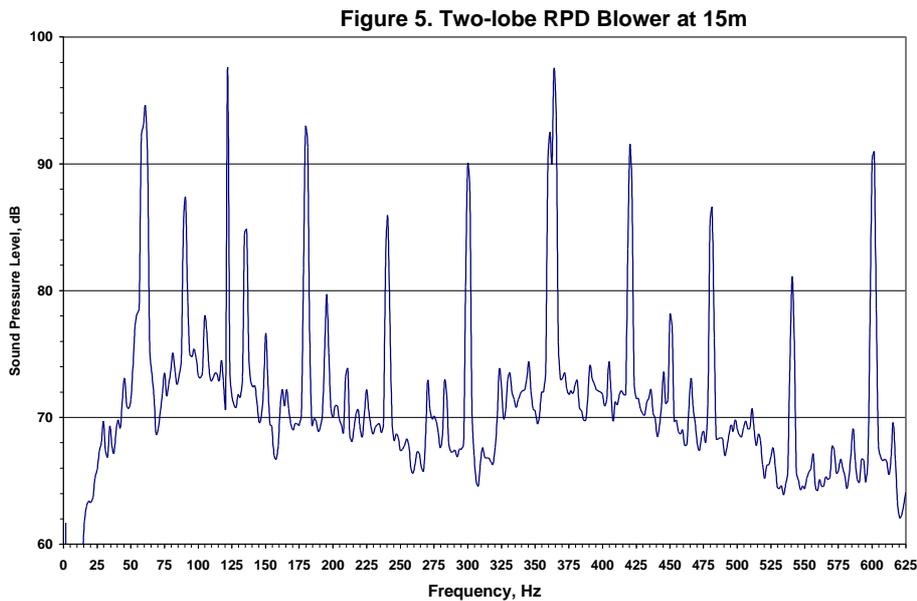
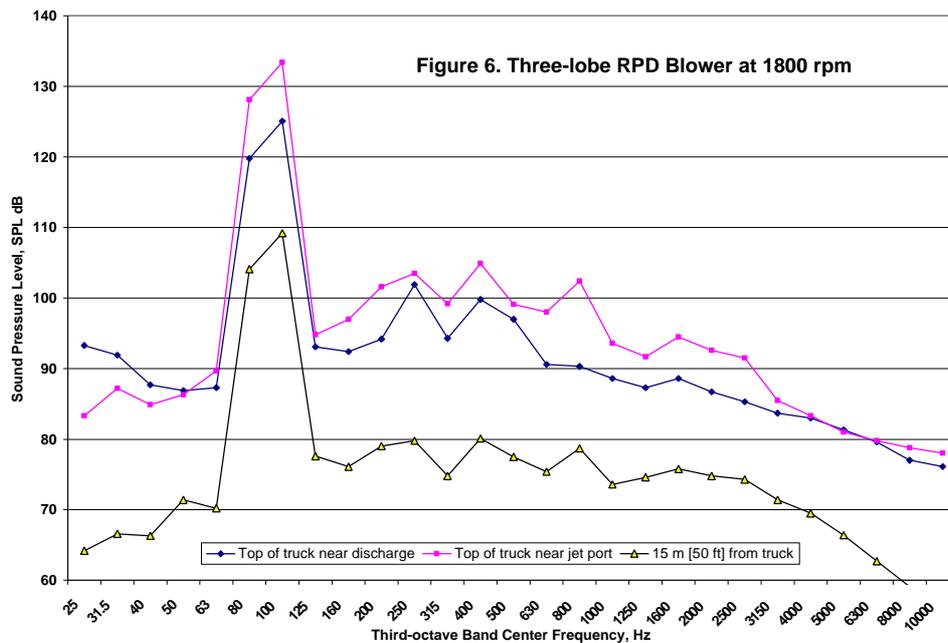


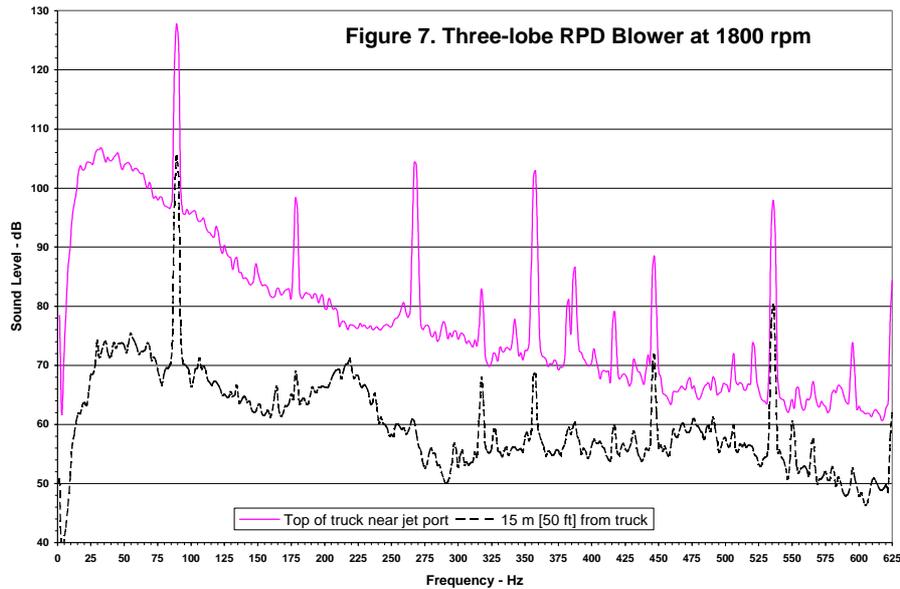
Figure 5 is a narrow band spectra of the same truck up to 625 Hz at the 15 meter location. This confirms the predominance of tones throughout this range; the first peak is at 60 Hz with harmonics at multiples of two times rotational speed, i.e., 120 Hz, 180 Hz, 240 Hz,

With the addition of a jet port one has an additional source that has different frequency characteristics than the discharge and at sound levels that are surprisingly high. Unlike the discharge the jet port noise is dominated by a fundamental frequency of either two or three times the rotational speed, half the frequency found in the discharge. It is believed that since the pulsations from the two rotors are typically isolated from one another, they do not combine into the higher frequency signature. In any case this makes the task of reducing the



jet port noise more challenging as it is at a lower frequency which adds a very special tonal characteristic to vacuum blowers with external jet ports.

Figure 6 shows a one-third octave band spectra of a three-lobe RPD blower also running at 1800 rpm and high vacuum. The two traces on the top of the truck are approximately 1 m from the opening on the silencers. This truck also had a premium grade silencer on the discharge and a good grade on the jet port. Note that the level at the jet port is almost 10 dB higher than that at the discharge; part of this difference can be explained by the difference in silencers but not all of it. Since these two opening are only 2 meters apart, it is likely that much if not all of the tonal content at the discharge is due to the jet port. The readings at 15 m [50 ft] are on the side of the truck opposite to the discharge silencer. Figure 7 shows a narrow band trace of the low frequency components of this data up to 625 Hz. Note the



dominate tone at approximate 90 Hz rather than 60 Hz that was seen in the two lobe blower case and the presence of harmonics similar to the two lobe blower case. At 15 meters other noise sources mask the higher frequency components but this tone still dominates the spectra at low frequencies.

To better suppress the jet port sound levels, a higher grade of silencer is needed. Unfortunately the space and weight restrictions of the vacuum truck may not allow a standard cylindrical silencer to accomplish the objective. Special configurations and alternative designs are available. These data were taken during just such a development project and lower overall truck levels are attainable using the same or a similar silencer on the jet port as was used on the blower discharge. An example of a special silencer to meet unique requirements is shown in Figure 8. This “in front of the wheel” silencer is used on a vacuum application and demonstrates the extent of accommodation that is sometimes necessary to address space limitations.



Figure 8. On-truck vacuum silencer

Noise Issues and Criteria

The noise issues with mobile vacuum trucks are two fold: near-field operator noise exposure and far-field neighborhood noise levels. The near-field criteria is generally specified at 1 meter from the truck at the control panel location. This is usually on the side of the truck just behind the cab. Noise levels in this area are rarely low enough that the operator does not need to wear hearing protection. Control of the blower noise is important in this area but so are gear drive noise and engine exhaust noise, as these other two sources are closely located to the control panel in most trucks. A sound level of 85 dBA at this location would be desirable but is generally not attainable without significant barriers and/or enclosures. The time exposure of the operator must be monitored to ensure that hearing damage does not occur.

The other issue is community or neighborhood noise. In many industrial locations this is not a major issue as the ambient levels are quite high already. However, when the application is in a residential area, such as cleaning storm sewer drains, the noise levels can be critical. A generally attainable level is 85 dBA at 15 meter [50 feet]. This is often not acceptable in residential areas and must be closely monitored to avoid complaints. In addition the tonal nature of the noise from the blower can be very distinctive and have an effect much greater than its contribution to the A-weighted sound level. This is especially true with an external jet port. Vacuum truck manufacturers are very aware of these issues and should be consulted for alternative solutions.

Conclusion

Sound levels attainable for mobile vacuum trucks are dependent on the compromises available to the designer. Increasing weight and/or size may limit the application of traditional techniques but alternative methods are available. The jet port has been identified as a dominant source of noise from the rotary positive displacement blowers used in these applications. Adequate silencing must be applied to ensure that the vacuum truck operation does not elicit vigorous noise complaints from residential neighbors. After the blower noise has been addressed the other sources of noise from the truck such as engine, radiator fan and gear noise must be considered.