LABORATORY INVESTIGATION OF ENCLOSED CAB FILTRATION SYSTEM PERFORMANCE FACTORS

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Abstract

The National Institute for Occupational Safety and Health (NIOSH) has investigated various factor effects on cab air filtration system performance. Factors experimentally investigated were intake filter efficiency, intake air leakage, intake filter loading (filter flow resistance), recirculation filter use, and wind penetration. Adding an intake pressurizer fan to the filtration system was also investigated. Results indicate that the intake filter efficiency and recirculation filter were the two most influential factors on cab protection performance. Use of a recirculation filter significantly reduced cab penetration over the intake air filter by itself due to the multiplicable filtration of the cab interior air. Cab penetration was also affected to a lesser extent by intake filter loading and air leakage. Adding an intake pressurizer fan notably increased intake airflow and cab pressure while providing only minor changes to cab penetration.

Introduction

Overexposure to airborne respirable crystalline silica (or quartz) dust can cause silicosis, a serious or fatal respiratory lung disease. Mining has some of the highest incidences of worker-related silicosis, with mining machine operators being the occupation most commonly associated with the disease (NIOSH, 2003). The U. S. Mine Safety and Health Administration (MSHA) enacts and enforces mine worker safety and health standards to mitigate mine worker injuries and occupational diseases.

MSHA's permissible exposure limit is 2.0 mg/m^3 of airborne respirable dust for coal mine workers (U.S. Code of Federal Regulations, 2007). If more than 5% quartz mass is determined to be in the coal mine worker dust sample using MSHA's P7 infrared method (Parobeck and Tomb, 2000), the applicable respirable dust standard is reduced to the quotient of 10 divided by the percentage of quartz in the dust. MSHA's nuisance dust limit (total dust) for non-coal miners is 10 mg/m^3 as defined by the American Conference of Governmental Industrial Hygienists (U.S. Code of Federal Regulations, 2007; ACGIH, 1973). If more than 1% quartz mass is determined to be in the non-coal mine worker dust sample using the National Institute for Occupational Safety and Health (NIOSH) X-ray Method (Parobeck and Tomb, 2000), the applicable standard is then a respirable dust standard of 10 divided by the sum of the quartz percentage plus 2. Both of these dust standards are intended to limit worker respirable crystalline silica (quartz) exposure to 0.1 mg/m^3 or less for a shift.

Mine worker overexposure to quartz dust continues to be a problem at mining operations in the United States. The percentages of MSHA dust samples from 2000 to 2004 that exceeded the respirable dust standard due to quartz were 11% for sand and gravel mines, 11% for stone mines, 19% for nonmetal mines, 17% for metal operations, and 17% for coal mines (NIOSH, 2006). At surface mining operations, the occupations that have the highest frequency of exceeding the respirable dust standard are usually operators of mechanized excavation equipment such as drills, bulldozers, scrapers, front-end loaders, haul trucks, and crushers (Tomb et al., 1995).

A primary means of dust control on mechanized surface mining equipment is enclosed operator cabs with an air filtration system. Field assessment of 6 surface coal mine rock drills and 5 bulldozers by NIOSH has shown that enclosed cab dust reduction efficiency for this equipment varied from 44% to nearly 100 % (Organiscak and Page, 1999). Additional NIOSH field studies involving the retrofitting of 5 older enclosed cabs with air filtration system improvements also showed that their cab protection factors (outside to inside cab concentration ratio) varied between 2.8 and 89.3, or a cab dust reduction efficiency of 64% to 99%, respectively (Cecala et al., 2005; Cecala et al., 2004; Chekan and Colinet, 2003; Organiscak et al., 2004). These field studies indicate that cab air filtration system design and operational factors highly influence dust control effectiveness and ability to control operator dust exposure.

In order to better qualify air filtration system design and operational factor effects on enclosed cab dust control performance, controlled laboratory experiments were performed on an enclosed cab test stand at NIOSH's Pittsburgh Research Laboratory (PRL). These experiments examined the independent factor effects of intake filter efficiency, intake filter loading (airflow resistance), intake air leakage around the filter, recirculation filter use, and wind penetration. Additional experiments were also conducted on the enclosed cab test stand to investigate the effects of adding an intake pressurizer to the filtration system.

Test Apparatus And Measurement Methods

The experimental cab test apparatus was a painted plywood enclosure 183 cm high x 91.5 cm wide x 122 cm deep mounted on rolling casters (see figure 1). A mock-up Plexiglas roof-mounted heating, ventilation and air-conditioning (HVAC) system was located on the roof with a 27.6-V DC, variable speed, dual fan blower discharging air through ceiling vents into the enclosure near the door entry. One HVAC recirculation air inlet was a 30.5-cm x 61-cm opening located on the opposite side of the ceiling with a holding bracket for mounting a pleated panel filter. Another 30.5-cm x 61-cm recirculation inlet was located on the wall near the floor, opposite the door. This recirculation inlet was exteriorly connected to the mock-up HVAC system by an inlet transition, two 90 PVC elbows, and 152-mm-diameter PVC pipe. A cover panel was used to seal the floor inlet during these experiments, so recirculation air would be drawn through the ceiling inlet as with most roof-mounted HVAC systems.

Outside makeup air was supplied into the mockup HVAC system through either of two 76-mm-diameter PVC pipes connected to an exterior Plexiglas filter box. One of the PVC pipes drew air from the filter box with the recirculation fans only while the other PVC pipe could be pressurized with intake air from a 15- to 27.6-V DC, variable speed, single-fan blower located inside the filter box. Both PVC intake air pipes were fitted with ball valves so that either intake delivery system could be individually tested. The filter sampling box had an inlet hole and bracket to accommodate an intake cylindrical filter cartridge on the exterior of the box. The filter box also had a 12.7-mm-inside diameter barbed hose fitting opening for leak testing around the intake filter. Three 25.4-mm-diameter holes were uniformly spaced in the Plexiglas window on the front door and on the opposing back side wall of the cab to allow for the intake makeup air to uniformly escape the cab under positive pressure.

The cab test stand operating parameters were continuously measured with several static air pressure gages and airflow monitors that were electronically recorded to a Telog R-3307 seven-channel data acquisition system (Telog Instruments, Inc., Victor, NY).[1] The negative pressure differential across the exterior to interior of the intake filter box was measured with a 0-498 Pa Dwyer Magnehelic air pressure instrument, having a 4-20 mAmp output (Dwyer Instruments, Inc., Michigan City, IN). The cab enclosure positive pressure differential was measured with a 0-124 Pa Dwyer Magnehelic air pressure instrument, having a 4-20 mAmp output (Dwyer Instruments, Inc., Michigan City, IN). Leak into the filter box was measured with a 0-300 L/min TSI Model 4040 Thermal Mass Flowmeter, with a 0-10 V analog output (TSI, Inc., Shoreview, MN). Wind velocity was measured on the top left corner of the cab with a 0-1830 m/min AIRFLOW™ AV6 Digital Handheld Vane Anemometer with a 0-1 V analog output (AIRFLOW™, Buckinghamshire, England) to verify consistent airflow conditions during the wind tests.

Figure 1. Experimental cab test apparatus.

Other data measured and recorded for each test were intake airflow, recirculation airflow, and wind velocity around the cab. Intake airflow was centerline measured inside the 76-mm-diameter PVC intake pipe before and after test with a 0-1830 m/min TSI Model 8346 VelociCALC Hot Wire Anemometer (TSI, Inc., Shoreview, MN). The recirculation airflow was measured before and after each test with a 0-3400 m^3/hr ALNOR Standard Balometer® Capture Hood placed over the ceiling inlet/filter (TSI, Inc., Alnor Products, Shoreview, MN). Air velocity around the cab before and after each wind test was determined by averaging Davis handheld vane anemometer measurements (Davis Instrumentation, Baltimore, MD) on both sides and top of the cab (see figure 2). All pre- and post-test airflow measurements were averaged for each test.

Cab particulate protection performance was determined by relative comparisons of particle count concentrations inside (C_1) and outside (C_3) the cab test stand that was challenged with ambient air particles (see figure 2). Cab intake air particle concentrations (C_2) were also measured inside the filter box, allowing the intake filter efficiency to be determined without leaks around the filter. Portable handheld HHPC-6 particle counters with 6 custom channel sizes of 0.3, 0.5, 0.7, 1.0, 3.0, and 5.0 μm were operated at 2.83 L/min (0.1 ft^3/min) (Hach Ultra Analytics, Grants Pass, OR). Differential size particle counting was conducted in concentration mode over a sample volume of 2.83 L or for one-minute sampling periods and recorded in the instrument's internal buffer/memory. Since the largest measurable fraction of ambient air particles counted were found to be in the submicron size ranges (0.3-0.5 μm, 0.5-0.7 μm, and 0.7-1.0 μm), these channels were summed into cumulative (0.3-1.0 μm) submicron respirable particle count concentrations for cab and filter particulate performance determinations.

Three particle counting instruments were mounted inside the enclosure and remotely sampled the designated locations through 45.7-cm-lengths of 3.18-mm-inside diameter Tygon tubing with isokinetic inlet probes. The manufacturer's 11.4-mm-diameter isokinetic inlet probes were used at all locations except on the outside sampling location during the wind tests. For these tests a 3.18-mm-diameter isokinetic probe inlet was used to more closely match wind velocity to the inlet velocity.

Submicron particle cab penetrations (C_1/C_3) were determined from the corresponding 15-minute concentration averages under stable interior concentrations. After closing the enclosure door, preliminary laboratory tests indicated that the interior concentrations predominantly reached stability within 15 and 30 minutes, respectively, with and without the recirculation filter. Therefore, experimental cab testing periods were conducted for 30 and 45 minutes, respectively, with and without the recirculation filter to achieve a reasonably steady concentration averaging period for the last 15 minutes of a test. A cab concentration decay time for each test was estimated by the number of one-minute time periods it took to reach the average inside concentration for the last 15 minutes of the test. Finally, submicron particle intake filter efficiencies $(((C_3 - C_2) / C_3) \times 100\%)$ were determined for tests without intake leakage during the same last 15-minute time period as the cab penetration.

Experimental Testing

The first set of experiments examined the independent factor effects of intake filter efficiency, intake filter loading (airflow resistance), intake air leakage around the filter, recirculation filter use, and wind penetration. A Donaldson, single-stage, round pleated filter cartridge (17.8-cm-diameter x 33-cm-length) was used as the lower efficiency intake filter tested (Donaldson Company, Inc., Minneapolis, MN). A Clean Air Filter®, multi-stage, round contiguous filter cartridge (17.8-cm-diameter x 30.5-cm-length) was used as the higher efficiency intake filter tested (Clean Air Filter®, Defiance, IA). Each filter was tested in new condition (without any exposure to heavy or coarse dust loading) and a simulated loaded condition with a round cut piece of 14 GA perforated plate (2.38-mm-diameter holes staggered 4.76 mm-center-to-center) fitted flush within the interior of the filter gasket area and outlet hole. This perforated plate also had a 50.8-mm-wide strip of duct tape down the center to further increase filter resistance. The intake filter and loading test conditions were also conducted with the 12.7-mm-inside diameter hole closed or opened into the filter box to examine leakage effects around the intake filter.

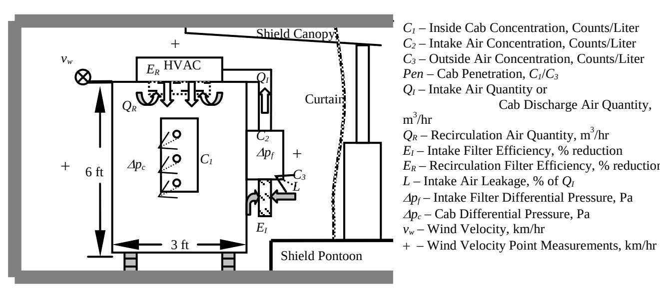

Figure 2. Laboratory cab test apparatus used in longwall test gallery.

All the intake filter and leakage configurations were further tested in combination with and without an inside cab recirculation filter. An American Air Filter (AAF) rectangular panel pleated filter (30.5-cm-width x 61-cm-lenth x 10.2-cm-depth nominal size) was the recirculation filter used. The filter had an American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Minimum Efficiency Reporting Value (MERV) of 15 or 85% to 94.9% in the 0.3-1.0 μm size range. When no recirculation filter was used, a 30.5-cm-wide x 61-cm-long x 10.2-cm-deep two-by-four wood constructed filter frame blank was used. The recirculation filter and filter blank fit into an aluminum frame holding bracket with a perforated restrictor plate (same plate material used with intake filter) on the outside area of the

[1] Mention of any company name or product does not constitute endorsement by the National Institute for Occupational Safety and Health.

bracket. This restrictor plate was used to achieve at least 42.5 m^3/hr of intake airflow for an unloaded intake filter without the recirculation filter in place.

The first series of cab filtration system testing was conducted without the intake pressurizer within PRL's longwall gallery under calm and 16 km/hr wind conditions. This cab configuration was only tested against wind in the mine gallery because its positive interior cab pressure could be exceeded by a 16 km/hr wind velocity pressure of 12 Pa during some of the tests (Heitbrink et al., 2000). Figure 2 shows the cab test position in the cross-section of the gallery with three of the cab air exit holes facing into the wind. Experimental test conditions were randomized, but testing was conducted by running a test period with one HHPC-6 sampling inside and another HHPC-6 sampling outside the cab enclosure and then switching these instruments for a subsequent second test period under the same experimental conditions. Each experimental test condition was randomly conducted twice, providing four enclosed cab testing periods. The instruments were switched for subsequent test periods to average out instrument bias.

A second series of cab filtration system testing was conducted with an intake pressurizing fan and no wind in the high bay area outside the gallery. The experimental test conditions were randomized as described above with two subsequent testing periods conducted by switching inside and outside particle counters.

Experimental Results

Cab filtration performance statistics were computed and examined for the experimental conditions tested. Table 1 (see Appendix) shows the key summary statistics (Average, *Minimum-Maximum*) for the intake filter, intake filter loading, and recirculation filter use in the first series of cab experiments with and without wind and with no intake pressurizer. Table 2 (see Appendix) shows similar key summary statistics in the second series of cab experiments with no wind and with the intake pressurizer. Intake air leakage is quantified as the percent of intake air quantity. Wind test conditions were not differentiated in table 1, since the16 km/hr wind condition did not exhibit noticeable differences in cab penetration as compared to the other experimental factors. The 16 km/hr equivalent wind velocity pressure of 12 Pa exceeded the cab pressure without wind for a small subset of tests (high efficiency intake filter, under loading), minimizing its cab penetration effect in the first series of experiments (Heitbrink et al., 2000). Submicron intake filter efficiencies (E_I, 0.3-1.0 μm size range) were measured without leakage and are shown for the intake filter test condition. The recirculation filter used had an ASHRAE MERV rating of 15 or 85% to 94.9% for the 0.3-1.0 μm size range and could not be directly measured in these experiments, due to its multiplicable filtration effect.

The two largest factors that influenced cab penetration (*Pen*) for both series of experiments were intake filter efficiency and recirculation filter use. Table 1 shows that the largest reductions in cab *Pen* were achieved with an increase in intake filter efficiency and the use of a recirculation filter. The lower efficiency filter provided an average cab *Pen* of 0.635 and 0.569 for the unloaded and loaded intake filter, respectively, without the recirculation filter. These average cab *Pens* significantly decreased to 0.134 and 0.054, respectively, with the recirculation filter. The higher efficiency filter provided an average cab *Pen* of 0.072 and 0.131 for the unloaded and loaded intake filter, respectively, without the recirculation filter. These average *Pens* significantly decreased to 0.007 and 0.009, respectively, with the recirculation filter. The recirculation filter also decreased the decay time needed for the cab interior concentrations to go down and stabilize after the cab door was closed. The average decay times were between 16 and 29 minutes without the recirculation filter, and between 7 and 9 minutes with the recirculation filter.

Similar results were seen in the second series of experiments with the pressurizer. Table 2 shows the largest reductions in cab *Pen* were achieved with an increase in intake filter efficiency and the use of a recirculation filter. The lower efficiency filter provided an average cab *Pen* of 0.693 and 0.609 for the unloaded and loaded intake filter, respectively, without the recirculation filter. These average *Pens* significantly decreased to 0.194 and 0.073, respectively, with the recirculation filter. The higher efficiency filter provided an average cab *Pen* of 0.071 and 0.108 for the unloaded and loaded intake filter, respectively, without the recirculation filter. These average *Pens* significantly decreased to 0.009 and 0.010, respectively, with the recirculation filter. The recirculation filter also decreased the decay time needed for the cab interior concentrations to go down and stabilize after the cab door was closed. The average decay times were between 17 and 25 minutes without the recirculation filter and were between 6 and 11 minutes with the recirculation filter.

Adding the intake pressurizer fan to the cab filtration system resulted in minor changes to the cab *Pen* from the increased airflow through the intake filter. Comparison of tables 1 and 2 shows that the cab *Pen* for the lower E_I intake air filter tests perceptibly increased with the addition of the pressurizer. This corresponded to higher intake airflows and decreased intake filter efficiency with the pressurizer as compared to without the pressurizer. Cab *Pen* change was negligible for the higher E_I filter with the addition of the pressurizer, corresponding to negligible changes in intake filter efficiency over the range of airflows achieved with and without the pressurizer. The pressurizer did not significantly change the recirculation airflow quantity (Q_R) for identical filter combinations.

The intake filter differential pressure, cab intake airflow quantity, and cab differential pressure all significantly changed with the experimental filter combinations and pressurizer. Figure 3 presents the cab intake airflow quantity (Q_I) relationships with intake filter differential pressure (Δp_f) and cab differential pressure (Δp_c). The intake filter differential pressure data are categorized by recirculation filter and pressurizer use with dashed lines drawn through these data groups to illustrate their associations. The data show that intake air quantity was inversely related to the negative differential pressure across the intake filter for all data groups. Also, the recirculation filter increased both the intake airflow and filter differential pressure, shifting the associated relationship to the lower right. The pressurizer additionally increased the intake airflow and filter differential pressure, further shifting these associated relationships to the lower right.

Figure 3 also shows the direct relationship between the cab's differential pressure (Δp_c) and intake air quantity (Q_I). A solid line is drawn through these points to illustrate the direct relationship. Intake airflow increases from filter combinations and pressurizer use were subsequently translated into higher positive cab differential pressures.

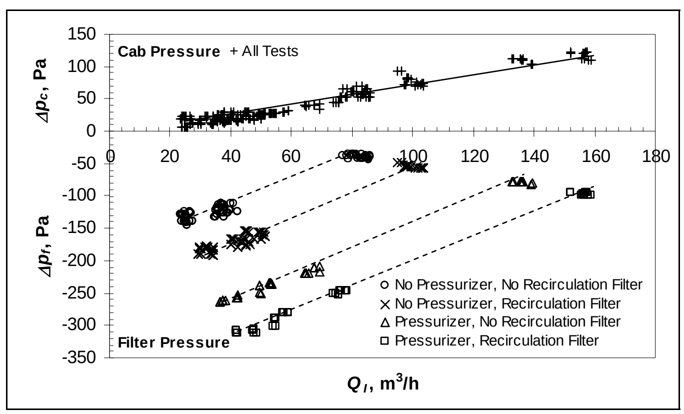

Figure 3. Cab intake airflow and differential pressure relationships.

Cab *Pen* to a lesser extent was also influenced by intake filter loading and air leakage. Figure 4 shows the relationship between leakage (*L*) and intake filter differential pressure ($-\Delta p_f$), with the 12.7-mm-diameter leakage hole open. The leakage data are categorized by recirculation filter and pressurizer use with dashed lines drawn through these data groups to illustrate their associations. This figure shows a direct relationship between intake leakage and filter differential pressure for all of the data groups. The higher efficiency intake filter and loading conditions increased the differential pressure and leakage across all data groups. The corresponding minimum and maximum leakage (*L*) and penetration (*Pen*) ranges shown in tables 1 and 2 are reflective of this effect. *Pen* for no leakage conditions was commonly between the minimum and the average value and *Pen* for leakage was commonly between the average and maximum value.

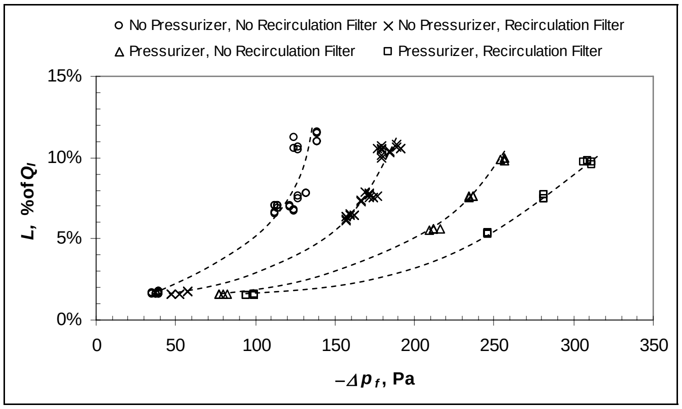

Figure 4. Intake leakage and filter differential pressure relationship.

Conclusions

Cab air filtration system factors were experimentally studied in the laboratory for submicron particulate penetration into the cab enclosure. Both series of experiments indicated that the intake filter efficiency and recirculation filter were the two most influential factors on cab penetration. The higher efficiency intake filter (> 99% capture efficiency) changed the cab penetration by an order of magnitude over the lower efficiency intake filter (between 29% and 44% capture efficiency). Using a recirculation filter (~ 90% capture efficiency) further reduced cab penetration, usually by an order of magnitude over the intake air filter by itself. The recirculation filter also significantly decreased the decay time needed for the cab interior concentrations to go down and stabilize after the cab door was closed. The average decay times were between 16 and 29 minutes without the recirculation filter and were between 6 and 11 minutes with the recirculation filter. Thus, a recirculation filter mutually reduced cab penetration and exposure time to higher peak concentrations after the cab door is closed.

Cab penetration was also affected to a lesser extent by intake filter loading and air leakage. Intake filter efficiency and filter loading increased the negative differential across the filter and on the 12.7-mm-diameter leak opening on the downstream side of the filter. This higher negative pressure differential increased the percentage of intake air leakage bypassing the filter, thus increasing cab penetration.

Adding an intake pressurizer fan to the cab filtration system increased intake airflow and cab pressure significantly with negligible changes to recirculation airflow and only small changes to cab penetration. The lower efficiency intake filter showed decreased capture efficiency at higher intake airflow rates, slightly increasing cab penetration with the pressurizer. The higher efficiency intake filter showed negligible changes in filter efficiency and cab penetration at higher intake airflows with the pressurizer. Higher intake airflows from the pressurizer increased the negative differential pressure across the intake filter and increased the positive differential pressure inside the cab. Although cab pressure was directly related to intake air quantity, it did not reflect the quality of the intake air supply and cab penetration performance.

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Disclaimer

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

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Appendix

Table 1. Cab Testing Without Pressurizer Average, *Minimum-Maximum.*

Filter Conditions			*Pen*	Q_I	$-\Delta p_f$	*L*	Q_R	$+\Delta p_c$	Decay Time
Intake	Loaded	Recirculaton	C_1/C_3	m^3/hr	Pa	% of Q_I	m^3/hr	Pa	min
Lower E_I *35%*	No	No	0.635 *0.557-0.690*	82.9 *77.1-86.0*	39 *35-45*	0.8 *0.0-1.7*	608 *574-625*	60 *52-70*	16 *1-38*
Lower E_I *32%*	No	Yes	0.134 *0.122-0.148*	99.7 *95.2-103.7*	54 *47-57*	0.8 *0.0-1.8*	540 *510-557*	78 *70-92*	7 *1-21*
Lower E_I *44%*	Yes	No	0.569 *0.426-0.637*	36.5 *34.8-37.9*	124 *114-132*	3.7 *0.0-7.8*	642 *625-663*	20 *12-30*	18 *3-38*
Lower E_I *42%*	Yes	Yes	0.054 *0.045-0.059*	42.8 *40.1-46.2*	172 *167-179*	4.3 *0.0-7.9*	573 *564-586*	22 *15-25*	9 *1-23*
Higher E_I *> 99%*	No	No	0.072 *0.027-0.132*	38.8 *35.7-42.5*	119 *112-127*	3.4 *0.0-7.1*	651 *629-663*	21 *15 -30*	27 *15-36*
Higher E_I *> 99%*	No	Yes	0.007 *0.002-0.012*	48.7 *44.5-51.3*	160 *154-167*	3.2 *0.0-6.5*	564 *540-586*	25 *17-30*	7 *2-20*
Higher E_I *> 99%*	Yes	No	0.131 *0.040-0.211*	25.3 *23.4-27.5*	135 *124-144*	3.7 *0.1-11.6*	660 *620-676*	14 *7-22*	29 *12-39*
Higher E_I *> 99%*	Yes	Yes	0.009 *0.003-0.014*	31.9 *29.2-34.3*	184 *177-192*	6.3 *0.1-10.8*	584 *561-595*	15 *10-22*	9 *1-23*

Table 2. Cab Testing With Pressurizer Average, *Minimum-Maximum.*

Filter Conditions			*Pen*	Q_I	$-\Delta p_f$	*L*	Q_R	$+\Delta p_c$	Decay Time
Intake	Loaded	Recirculaton	C_1/C_3	m^3/hr	Pa	% of Q_I	m^3/hr	Pa	min
Lower E_I *29%*	No	No	0.693 *0.636-0.720*	136.1 *132.9-139.3*	78 *77-82*	0.8 *0.0-1.6*	582 *578-591*	109 *105-112*	22 *0-36*
Lower E_I *29%*	No	Yes	0.194 *0.179-0.211*	156.0 *151.9-158.7*	97 *95-100*	0.9 *0.0-1.6*	527 *518-535*	117 *109-122*	8 *1-26*
Lower E_I *39%*	Yes	No	0.609 *0.596-0.620*	51.3 *49.6-53.4*	240 *234-251*	3.8 *0.0-7.7*	651 *629-671*	26 *22-27*	17 *3-40*
Lower E_I *39%*	Yes	Yes	0.073 *0.064-0.079*	56.4 *54.2-59.1*	288 *281-301*	3.8 *0.0-7.7*	573 *564-586*	29 *27-32*	11 *1-21*
Higher E_I *> 99%*	No	No	0.071 *0.030-0.107*	66.6 *64.6-69.3*	216 *209-219*	2.8 *0.0-5.7*	628 *608-642*	39 *35-42*	25 *12-36*
Higher E_I *> 99%*	No	Yes	0.009 *0.004 -0.012*	76.0 *73.7-78.2*	249 *246-254*	2.7 *0.0-5.4*	569 *552-581*	49 *45-52*	8 *2-21*
Higher E_I *> 99%*	Yes	No	0.108 *0.037-0.178*	39.2 *36.4-42.5*	260 *254-264*	4.0 *0.1-10.0*	657 *646-671*	17 *15-20*	20 *13-32*
Higher E_I *> 99%*	Yes	Yes	0.010 *0.003-0.018*	44.9 *41.8-48.6*	309 *306-311*	4.9 *0.1-9.8*	580 *561-595*	21 *17-22*	6 *1-16*