

**IN-DEPTH SURVEY REPORT:**  
**CONTROL TECHNOLOGY FOR AGRICULTURAL ENVIRONMENTAL  
ENCLOSURES**

**AT**

**JOHN DEERE MANUFACTURING CO., INC.**

**REPORT WRITTEN BY**  
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**Public Health Service**  
**Centers for Disease Control and Prevention**  
**National Institute for Occupational Safety and Health**  
**Division of Physical Sciences and Engineering**  
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**Cincinnati, Ohio 45226**

PLANT SURVEYED

John Deere Product Engineering  
Center  
P O Box 8000  
Waterloo, IA

SIC CODE

5083

SURVEY DATE

April 15-19, 1996 (Laboratory  
Evaluation)  
August 5-9, 1996 (Field Evaluation)

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## **DISCLAIMER**

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## INTRODUCTION

Agriculture is one of our Nation's most dangerous occupations. Agricultural workers and their families experience a disproportionate share of injuries and diseases associated with numerous chemical, biological, and physical hazards<sup>(1)</sup>. Some of these diseases include asthma, hypersensitivity pneumonitis, chronic and acute bronchitis, and organic dust toxic syndrome.

This study was conducted to provide information on the effectiveness of agricultural cabs designed to protect workers from pesticides and other agriculture air contaminants and identify improvements to enhance the enclosure's efficacy. Survey reports will be distributed to various agencies and persons according to standard procedures in 41 CFR 85a and will be available from National Technical Information Service (NTIS).

## STUDY OBJECTIVES

The main goal of the agricultural enclosures project is to evaluate the ability of enclosures on agricultural vehicles to reduce operator exposure to pesticides and other agriculture air contaminants. The major objectives for the laboratory and field evaluation were to

- evaluate the effectiveness of the filter system
- identify aerosol size distribution inside and outside the enclosure
- evaluate air infiltration into the cab by identifying potential leak sources
- evaluate the protection factor provided by agricultural cabs (outside concentration / inside concentration)

## CAB DESIGN

See Figure 1 and 2 for air flow diagrams into the cab<sup>(2,3)</sup>. The laboratory and field evaluation were performed on a John Deere 7000 series tractor cab equipped with a High Efficiency Particulate Air filter (HEPA filters are designed to be at least 99.97% efficient at filtering aerosols of size  $\geq 3 \mu\text{m}$ ) inside the fresh air filter housing. The cab was equipped with the standard recirculation filters inside the cab. Fresh air enters the ventilation system from the front top portion of the cab above the door. The fresh air flows through ventilation ducts over the cab and down through the front right side structure beam (part of the Roll Over Protection System (ROPS)) into the fresh air filter housing located beneath the right side of the cab. The fresh air is then pulled through the fresh air blower and transported through ventilation ducts to the evaporator/heater core housing. At this point the fresh air and recirculated air is pulled through the recirculation blower and transported to the outlet louvers inside the cab.

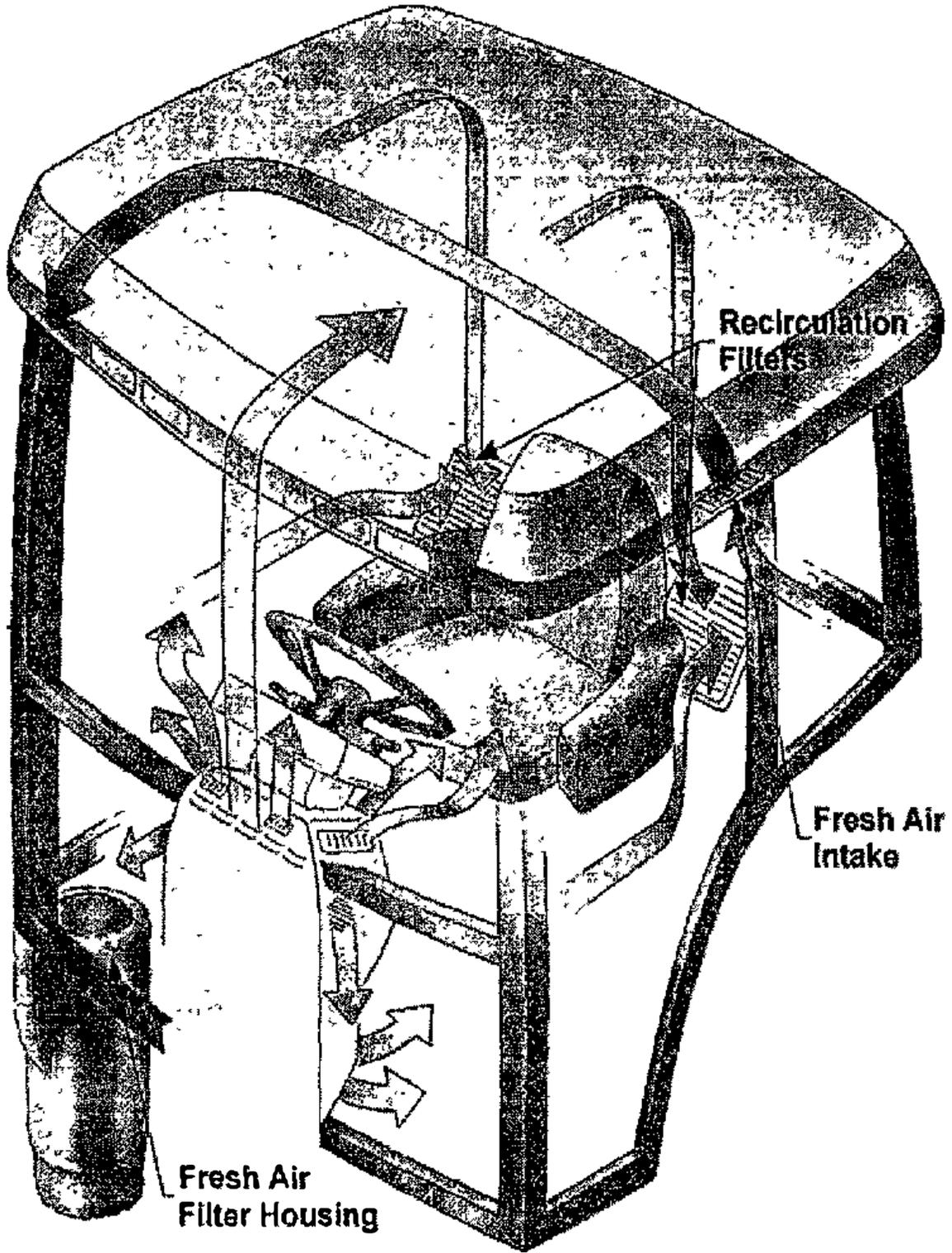


Figure 1. Diagram of air flow inside cab.<sup>(2)</sup>

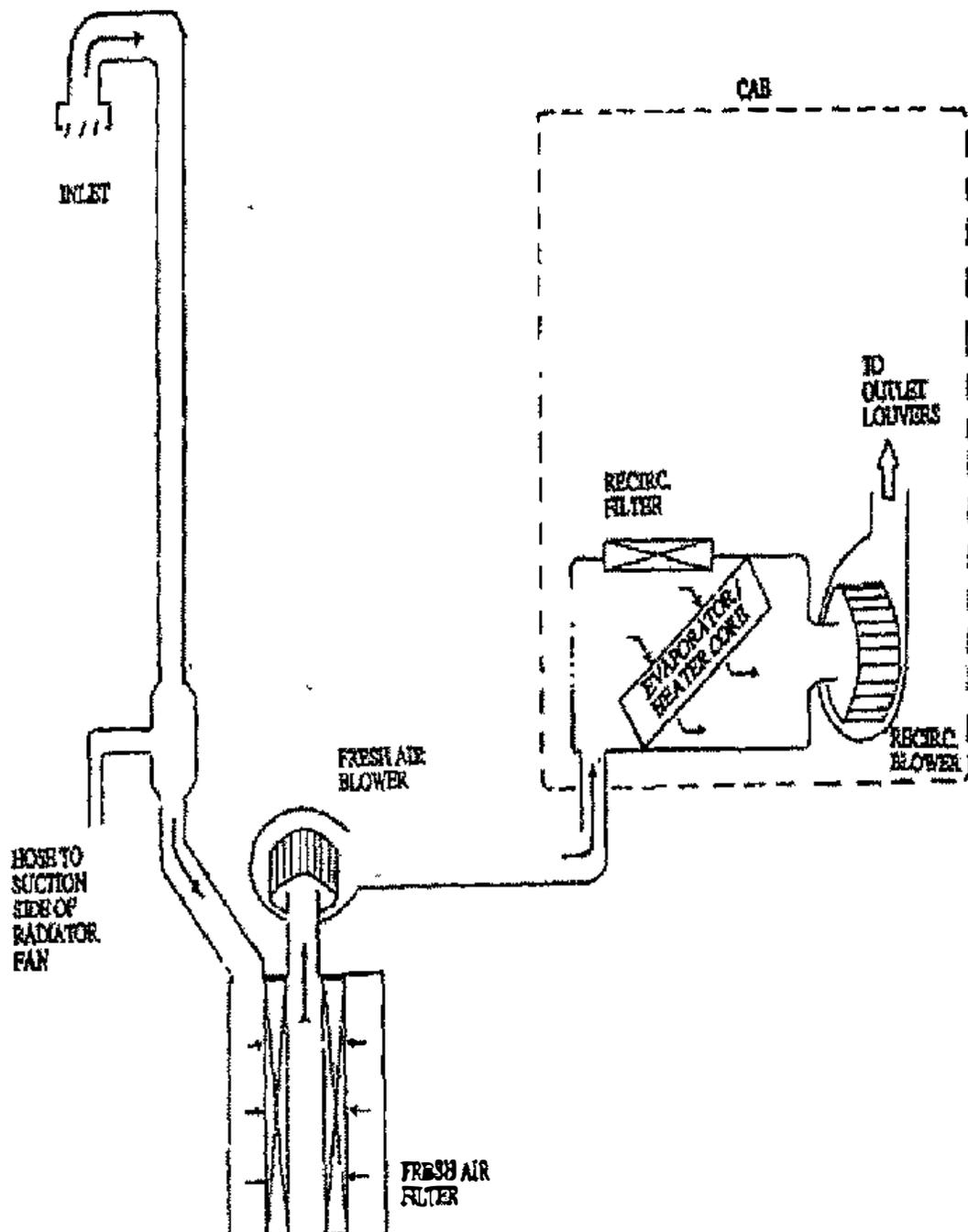


Figure 2. Air flow diagram of ventilation system.<sup>(3)</sup>

## METHODS

Preliminary surveys were conducted on three different manufactured agriculture enclosures. Two of these enclosures (made by two different manufacturers) have been approved for respiratory protection in the state of California. The results obtained during the preliminary surveys identified the need for both a laboratory and field evaluation of an environmental enclosure to help identify any potential aerosol leaks into the cab. The laboratory and field evaluations were performed on a John Deere 7000 series tractor cab. Measurements taken inside and outside of the cab were collected while the tractor was stationary during the laboratory evaluation (located at the John Deere Product Engineering Center, Waterloo, IA) and while the tractor was driven over a tilled field during the field evaluation (field evaluation was conducted in Yuba City, CA). The tractor was driven over the tilled field in an effort to assess how well the cab remains sealed and its ability to remove particulate in field conditions.

The following instrumentation was used to measure the concentration of ambient aerosol outside and inside of the cab:

1. Hand-held Particle Counter (Model 227b, Mect-One Inc, Grants Pass, OR) counts the number of individual particles larger than  $0.3 \mu\text{m}$ . The Hand-held Particle Counter (HPC) was used with a sampling rate of 2.8 liters per minute (lpm), a sampling period of 14 seconds, and a time between sampling periods of 1 second. Two channels were used to store the number of particle counts in a time interval. One channel stored the total number of particles counted greater than  $0.3 \mu\text{m}$ . The second channel stored the total number of particles larger than  $3.0 \mu\text{m}$ . This instrument sizes the particles based upon the amount of light scattered by individual particles.<sup>(4)</sup>
2. Portable Dust Monitor (Model 1105 and 1106, Grimm Labor Technik GmbH & Co Kg, Ainning, Germany) counts the individual number of particles in eight size channels between  $0.7 - 15 \mu\text{m}$  (model 1105 used during the laboratory evaluation) and  $0.3 - 6.5 \mu\text{m}$  (model 1106 used during the field evaluation). Particles are sized based upon the amount of light scattered by individual particles. The Portable Dust Monitor (PDM) operates at a flow rate of 1.2 lpm.<sup>(5)</sup>
3. PortaCount® Plus (Model 8020, TSI Incorporated, St. Paul, MN) was used to measure ambient particle concentration inside and outside of the enclosure. The ratio of the two measurements was used to calculate a protection factor. Particles enter the PortaCount® Plus through a saturator tube where they are combined with alcohol vapor. The particles then pass through a condenser where the alcohol condenses on the particles, which increases the particle size. The enlarged particles then pass through a laser beam that produces flashes of light that are detected by a photodetector. Particle concentrations are determined by the amount of light flashes. The PortaCount® Plus counts particles in a range of  $0.02$  to greater than  $1 \mu\text{m}$  with a flow rate of  $0.1$  lpm (TSI Incorporated, St. Paul, MN).<sup>(6)</sup>

The PortaCount® Plus was used to measure leakage of particles (in the range of 0.02 - 10 µm) into the cab during both evaluations. Condensation nuclei was measured in the ambient air outside the cab and inside the cab. The PortaCount® Plus is equipped with two sampling probes. One sampling probe was used to collect aerosol concentrations inside the cab and the other sampling probe was used to collect ambient aerosol concentrations outside the cab. This test was performed in an effort to evaluate the protection factor of the cab during both lab and field conditions.

The PortaCount® Plus collected twelve separate samples during each field test run. Four separate field test runs were completed. Each of the twelve separate samples (obtained during a field test run) were collected over a 60 second period. A protection factor (ratio between particle concentrations outside and inside the enclosure) was calculated for each sample. A low protection factor is an indicator of particle leakage into the cab or an indicator of particle generation sources inside the cab.

During both evaluations, one HPC and PDM were placed inside the tractor cab to count particles. These instruments were used to evaluate the enclosure's overall ability to protect the worker from aerosol exposure. Another HPC and PDM were placed directly outside the cab near the air intake. During the evaluations, the instruments were switched to obtain additional readings. The instruments located inside the cab were placed outside, and the instruments located outside the cab were placed inside. The HPCs and PDMs were run for approximately 30 minutes and then switched. This process was repeated 4 times, both to collect enough data for analysis and to limit the effect of instrument bias.

### **Data Analysis and Evaluation**

All data collected from the HPC and PDM were downloaded into a portable computer and placed in a spreadsheet for analysis. Penetration of different size aerosols, efficiency of the filter system, and protection factors were determined by comparing data collected (with the HPC and PDM) inside the enclosure with data collected directly outside the enclosure.

### **Ventilation Measurements**

The air velocity into the fresh air inlet was measured with a velometer. An autozero digital micromanometer, MP series 4 (Solomat, a Neotronics company, Norwalk, CT), was used during the evaluations to measure air pressure inside the cab. A Metrosomic dl-3200 data logger (Metrosomic Inc., Rochester, NY) was used to record the data output of the digital micromanometer throughout both evaluations. During the laboratory evaluation the ventilation system was run off a battery charger since the tractor was not started inside the building. Ventilation measurements during the field evaluation were collected while the tractor was running.

## RESULTS

### Laboratory Evaluation

The HPC raw particle counts for the laboratory evaluation are listed in Appendix A. The HPC counts naturally occurring ambient particles in the size range of 0.3 - 3.0  $\mu\text{m}$  and particles greater than 3.0  $\mu\text{m}$ . The HPC results during the laboratory evaluation indicate that the filter system in the cab was 99% efficient at removing particles in the size range between 0.3 and 3.0  $\mu\text{m}$  with a mean protection factor (outside concentration/inside concentration) of 86 in this size range. The HPC results also indicated that the ventilation system in the cab was 99% efficient at removing particles larger than 3.0  $\mu\text{m}$  with a mean protection factor of 80 in this size range. The PDM raw particle counts for the laboratory study are listed in Appendix B. Table 1 gives the protection factor and efficiency for each particle size range counted by the PDM. The PDM used in the laboratory study (model 1105) counted aerosols in eight different size ranges (0.7 - 15  $\mu\text{m}$ ). PDM results indicated that the ventilation system on the cab was 99% efficient at removing particles larger than 0.7  $\mu\text{m}$ . The PDM results were also used to calculate protection factors. Protection factors ranged from 112 - 275 (outside/inside concentration).

**Table 1. Filtration Efficiency and Protection Factors by particle size as shown by the PDM (model 1105).**

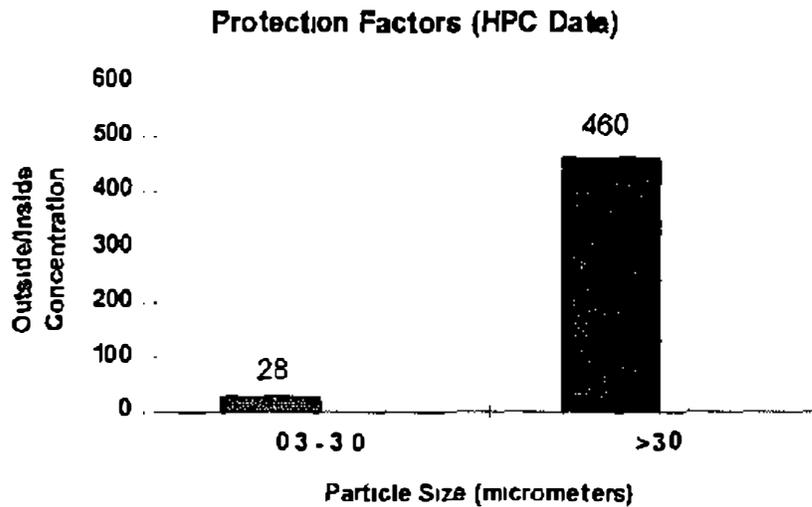
Particle Size ( $\mu\text{m}$ )	0.7 - 1	1 - 2	2 - 3.5	3.5 - 5	5 - 7.5	7.5 - 10	10 - 15
Efficiency of Cab	99%	99%	99%	99%	99%	99%	99%
Protection Factor (outside/inside)	200	198	112	147	214	275	123

The PortaCount® Plus counts particles smaller than 1  $\mu\text{m}$  and was used during the laboratory evaluation to calculate a protection factor for the cab. The mean protection factor (obtained with the PortaCount® Plus) during the laboratory evaluation was 38 for particles smaller than 1  $\mu\text{m}$ .

### Field Test Evaluation

The field evaluation was conducted in Yuba City, CA. The tractor was driven over a tilled field in an effort to assess how well it remains sealed and its ability to remove particulate in field conditions.

The HPC raw particle counts for the field evaluation are listed in Appendix C. Results of the HPC are summarized in Figure 3. The HPC results during the field evaluation indicate that the filter system in the cab was 96% efficient at removing particles in the size range between 0.3 and 3.0  $\mu\text{m}$  with a mean protection factor (outside concentration/inside concentration) of 28 in this particle range. The HPC results also indicated that the ventilation system in the cab was 99% efficient at removing particles larger than 3.0  $\mu\text{m}$  with a mean protection factor of 460 in this size range.



**Figure 3. HPC Data Protection Factors**

The PDM raw particle counts for the field study are listed in Appendix D. The PDM used in the field study (model 1106) counted aerosols in eight different size ranges from 0.4 to 6.5  $\mu\text{m}$ . The filtration efficiency of the cab and protection factor at each different size range measured by the PDM are listed in Table 2. Protection factors ranged from 32 - 4000 (outside/inside concentration).

**Table 2. Filtration Efficiency and Protection Factors by particle size as shown by the PDM (model 1106).**

Particle Size ( $\mu\text{m}$ )	0.42	0.61	0.87	1.41	2.65	4.18	5.7	6.5
Efficiency of Cab	99%	98%	97%	99%	99%	99%	99%	99%
Protection Factor (outside/inside)	84	41	32	130	260	1100	2200	4000

The PortaCount® Plus was used during the field evaluation to calculate the cab's protection factor for particles < 1 µm. The mean protection factor (obtained with the PortaCount® Plus) during the field evaluation was 43 (outside/inside concentration for particles < 1 µm). The PortaCount® Plus results confirmed the data collected with the HPC and PDM. As indicated by the HPC and PDM, the filtration system on the cab provided lower protection factors for smaller particles.

Ventilation measurements were taken at the top right corner of the cab where the fresh air flows through the opening of the structure beam (part of the ROPS system). The area of the opening is 0.35 square feet. During the laboratory evaluation the average air velocity entering this opening was 1700 fpm which resulted in an air volume of 600 cfm. During the field evaluation ventilation measurements were collected at the same location. The average air velocity during the field evaluation was 2000 fpm which resulted in an air volume of 700 cfm. Pressure measurements inside the cab were also collected during both evaluations with an autozero digital micromanometer. The data output of the micromanometer was recorded with a data logger. The pressure remained positive inside the cab during both evaluations with a mean pressure reading of 0.78 inches of water during the laboratory evaluation (tractor was running when pressure measurements were obtained), and 0.75 inches of water during the field evaluation.

## CONCLUSIONS

The HPC and the PDM both indicated that the cab is more than 99% efficient at removing aerosols larger than 3.0 µm in diameter. PDM results indicate that protection factors are greater than 100 (outside/inside concentration) for particles larger than 1.41 µm during the field evaluation. During the laboratory evaluation protection factors were greater than 100 for particles larger than 0.75 µm. The results obtained with the PortaCount® Plus indicate that the cab provided a mean protection factor of 38 (during laboratory evaluation) and 43 (during field evaluation) for aerosols smaller than 1.0 µm in diameter. As the particle size decreases (< 1 µm), the efficiency of the cab starts to decrease and protection factors are less than 100 (see Table 1). This indicates that there may be some leakage of small particles into the cab.

The pressure measurements collected inside the cab indicated that the cab remained under positive pressure during both our evaluations at approximately 0.75 inches of water. The positive pressure inside the cab reduces the possibility of aerosols entering the cab through leak sources other than around the filters and seals in the ventilation system. Therefore, any leakage of small particles (< 2 µm) into the cab may be a result of these small particles penetrating around the seals used to hold the filters in place in the ventilation system. There is also a possibility that some of the small aerosols (inside the cab) could be generated by the blowers or generated from the operator movement inside the cab.

## REFERENCES

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- 4 Met One, Inc Model 227 Hand-Held Particle Counter, Operating Guide, Met One, Inc Grants Pass, Oregon
- 5 Grimm Dust Monitor Instruction Manual, Series 1 100 v 5 10 E, Grimm Labortechnik GmbH & Co KG, Airing, Germany
- 6 TSI [1993] PortaCount Plus Model 8020, Operation and Service Manual, Rev C, TSI Incorporated, St Paul, MN

## APPENDIX A

LABORATORY EVALUATION

Time	Par/cc 0 3-3 0		Time	Par/cc>3 0	
	(inside)	(outside)		(inside)	(outside)
0 00	6 44	252 17	0 00	0 02	0 19
14 00	6 43	255 05	14 00	0 01	0 19
28 00	6 22	257 53	28 00	0 00	0 16
42 00	6 00	261 87	42 00	0 01	0 14
56 00	5 78	265 63	56 00	0 00	0 13
70 00	5 68	266 40	70 00	0 00	0 13
84 00	5 59	266 46	84 00	0 00	0 10
98 00	5 90	265 55	98 00	0 00	0 11
112 00	5 63	265 71	112 00	0 00	0 09
126 00	5 58	266 59	126 00	0 00	0 10
140 00	5 89	271 56	140 00	0 00	0 11
154 00	5 70	273 96	154 00	0 02	0 12
168 00	5 77	271 20	168 00	0 00	0 09
182 00	5 87	264 35	182 00	0 00	0 10
196 00	6 13	267 54	196 00	0 00	0 11
210 00	5 97	267 12	210 00	0 00	0 11
224 00	6 15	267 49	224 00	0 00	0 11
238 00	6 16	271 35	238 00	0 00	0 12
252 00	6 36	268 74	252 00	0 00	0 13
266 00	6 06	269 60	266 00	0 00	0 11
280 00	6 34	270 23	280 00	0 00	0 09
294 00	6 77	270 42	294 00	0 00	0 14
308 00	6 93	270 62	308 00	0 00	0 11
322 00	6 90	266 87	322 00	0 00	0 11
336 00	7 02	265 15	336 00	0 00	0 10
350 00	6 77	270 46	350 00	0 00	0 12
364 00	6 87	269 80	364 00	0 00	0 11
378 00	6 53	270 14	378 00	0 00	0 10
392 00	6 76	273 40	392 00	0 00	0 10
406 00	6 72	276 00	406 00	0 00	0 11
420 00	6 33	275 69	420 00	0 00	0 11
434 00	6 17	274 56	434 00	0 00	0 11
448 00	6 62	273 12	448 00	0 00	0 09
462 00	6 53	269 67	462 00	0 00	0 08
476 00	6 55	270 28	476 00	0 00	0 10
490 00	6 63	270 12	490 00	0 00	0 10
504 00	6 60	269 49	504 00	0 00	0 09
518 00	6 42	266 91	518 00	0 00	0 11
532 00	6 66	266 26	532 00	0 00	0 10
546 00	6 31	267 36	546 00	0 00	0 11
560 00	6 44	271 37	560 00	0 00	0 13
574 00	6 28	272 59	574 00	0 00	0 11

588 00	6 43	272 90	588 00	0 00	0 12
602 00	6 52	275 55	602 00	0 00	0 10
616 00	6 56	278 03	616 00	0 00	0 10
630 00	7 11	275 82	630 00	0 00	0 12
644 00	6 90	272 26	644 00	0 00	0 16
658 00	6 64	268 14	658 00	0 00	0 11
672 00	6 56	268 54	672 00	0 00	0 11
686 00	6 66	267 71	686 00	0 00	0 10
700 00	6 37	264 59	700 00	0 00	0 11
714 00	6 25	266 09	714 00	0 00	0 11
728 00	6 03	267 08	728 00	0 00	0 11
742 00	6 10	266 39	742 00	0 00	0 11
756 00	6 03	268 48	756 00	0 00	0 09
770 00	6 14	268 08	770 00	0 00	0 11
784 00	6 11	267 96	784 00	0 00	0 10
798 00	6 21	266 55	798 00	0 00	0 07
812 00	6 04	263 93	812 00	0 00	0 13
826 00	6 05	268 18	826 00	0 00	0 15
840 00	5 98	265 12	840 00	0 00	0 13
854 00	5 86	268 07	854 00	0 00	0 14
868 00	6 16	271 12	868 00	0 00	0 15
882 00	5 98	272 25	882 00	0 00	0 14
896 00	6 18	270 32	896 00	0 00	0 11
910 00	6 14	270 86	910 00	0 00	0 13
924 00	5 84	267 96	924 00	0 00	0 13
938 00	5 96	266 39	938 00	0 01	0 15
952 00	6 10	268 17	952 00	0 01	0 17
966 00	5 92	267 12	966 00	0 00	0 13
980 00	6 05	267 42	980 00	0 00	0 13
994 00	5 90	268 01	994 00	0 00	0 16
1008 00	5 90	264 75	1008 00	0 00	0 23
1022 00	5 74	268 39	1022 00	0 01	0 24
1036 00	5 76	269 35	1036 00	0 00	0 25
1050 00	5 74	269 10	1050 00	0 00	0 15
1064 00	5 78	269 37	1064 00	0 00	0 17
1078 00	5 99	266 44	1078 00	0 00	0 14
1092 00	6 16	267 15	1092 00	0 00	0 15
1106 00	5 81	265 16	1106 00	0 00	0 18
1120 00	5 92	263 59	1120 00	0 00	0 15
1134 00	5 69	265 34	1134 00	0 00	0 17
1148 00	5 99	266 73	1148 00	0 01	0 17
1162 00	5 95	262 66	1162 00	0 00	0 16
1176 00	5 74	258 24	1176 00	0 00	0 15
1190 00	5 75	260 03	1190 00	0 01	0 19
1204 00	5 86	264 35	1204 00	0 00	0 13
1218 00	5 79	264 38	1218 00	0 00	0 10
1232 00	5 86	268 90	1232 00	0 01	0 16
1246 00	5 25	265 10	1246 00	0 00	0 16
1260 00	5 62	263 42	1260 00	0 00	0 17

1274 00	5 63	262 88	1274 00	0 00	0 13
1288 00	5 79	26209	1288 00	0 00	0 11
1302 00	6 23	259 18	1302 00	0 00	0 14
1316 00	6 15	264 26	1316 00	0 00	0 17
1330 00	5 85	26639	1330 00	0 00	0 14
1344 00	6 66	26202	1344 00	0 00	0 13
1358 00	6 49	26066	1358 00	0 00	0 16
1372 00	6 59	264 51	1372 00	0 00	0 12
1386 00	6 06	264 51	1386 00	0 00	0 12
1400 00	6 67	26394	1400 00	0 00	0 21
1414 00	6 45	260 57	1414 00	0 00	0 13
1428 00	6 12	264 34	1428 00	0 00	0 14
1442 00	6 03	264 16	1442 00	0 00	0 11
1456 00	5 90	263 01	1456 00	0 00	0 17
1470 00	5 70	26383	1470 00	0 00	0 11
1484 00	5 77	25943	1484 00	0 00	0 14
1498 00	6 04	258 92	1498 00	0 00	0 10
1512 00	6 26	257 15	1512 00	0 00	0 15
1526 00	6 24	258 31	1526 00	0 00	0 13
1540 00	6 27	260 00	1540 00	0 00	0 12
1554 00	6 11	257 03	1554 00	0 00	0 11
1568 00	5 75	259 06	1568 00	0 00	0 13
1582 00	5 75	258 27	1582 00	0 00	0 11
1596 00	5 51	262 05	1596 00	0 00	0 16
1610 00	5 74	263 49	1610 00	0 00	0 12
1624 00	5 67	263 76	1624 00	0 00	0 26
1638 00	5 58	263 23	1638 00	0 00	0 19
1652 00	5 33	263 72	1652 00	0 00	0 16
1666 00	5 43	262 52	1666 00	0 00	0 13
1680 00	5 55	265 61	1680 00	0 00	0 16
1694 00	5 51	26690	1694 00	0 00	0 13
1708 00	5 69	266 87	1708 00	0 00	0 13
1722 00	5 51	264 61	1722 00	0 00	0 15
1736 00	5 34	265 93	1736 00	0 00	0 16
1750 00	5 68	263 92	1750 00	0 00	0 13
1764 00	5 50	266 09	1764 00	0 00	0 11
1778 00	5 65	264 33	1778 00	0 00	0 12
1792 00	5 40	262 71	1792 00	0 00	0 11
1806 00	5 57	261 68	1806 00	0 00	0 11
1820 00	5 57	26425	1820 00	0 00	0 13
1834 00	5 41	26743	1834 00	0 00	0 16
1848 00	5 61	264 16	1848 00	0 00	0 17
1862 00	5 48	263 62	1862 00	0 00	0 17
1876 00	5 61	26332	1876 00	0 00	0 15
1890 00	5 95	267 30	1890 00	0 00	0 16
1904 00	6 07	263 13	1904 00	0 00	0 17
1918 00	6 08	26528	1918 00	0 00	0 15
1932 00	5 14	34458	1932 00	0 00	0 15
1946 00	4 36	34078	1946 00	0 00	0 11

1960 00	3 92	336 32	1960 00	0 00	0 11
1974 00	3 28	340 17	1974 00	0 00	0 12
1986 00	3 17	339 90	1986 00	0 00	0 11
2002 00	2 85	338 82	2002 00	0 00	0 11
2016 00	2 62	340 08	2016 00	0 00	0 15
2030 00	2 49	342 19	2030 00	0 00	0 12
2044 00	2 41	342 52	2044 00	0 00	0 13
2058 00	2 30	340 36	2058 00	0 00	0 12
2072 00	2 11	341 99	2072 00	0 00	0 13
2086 00	2 23	348 69	2086 00	0 00	0 12
2100 00	2 08	352 65	2100 00	0 00	0 13
2114 00	2 03	357 72	2114 00	0 00	0 12
2128 00	2 05	351 53	2128 00	0 00	0 13
2142 00	2 06	352 58	2142 00	0 00	0 15
2156 00	1 89	359 68	2156 00	0 00	0 13
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2198 00	1 94	356 82	2198 00	0 01	0 14
2212 00	2 03	356 18	2212 00	0 00	0 12
2226 00	2 01	352 07	2226 00	0 00	0 11
2240 00	1 95	347 08	2240 00	0 00	0 09
2254 00	2 08	348 70	2254 00	0 00	0 12
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2282 00	1 89	352 96	2282 00	0 00	0 35
2296 00	2 15	351 40	2296 00	0 00	0 24
2310 00	1 85	351 83	2310 00	0 00	0 18
2324 00	1 87	354 69	2324 00	0 01	0 23
2338 00	1 87	359 18	2338 00	0 00	0 20
2352 00	1 90	332 49	2352 00	0 00	0 21
2366 00	1 97	356 92	2366 00	0 00	0 18
2380 00	2 02	360 25	2380 00	0 00	0 20
2394 00	1 92	356 98	2394 00	0 00	0 16
2408 00	1 99	358 26	2408 00	0 00	0 17
2422 00	1 91	342 99	2422 00	0 00	0 15
2436 00	1 99	357 61	2436 00	0 00	0 14
2450 00	1 99	348 61	2450 00	0 00	0 12
2464 00	2 04	343 75	2464 00	0 00	0 17
2478 00	1 91	340 20	2478 00	0 00	0 13
2492 00	2 05	345 49	2492 00	0 00	0 14
2506 00	2 02	350 29	2506 00	0 01	0 17
2520 00	2 17	353 01	2520 00	0 00	0 26
2534 00	1 91	354 64	2534 00	0 01	0 22
2548 00	1 89	352 83	2548 00	0 00	0 19
2562 00	2 04	351 33	2562 00	0 00	0 20
2576 00	2 02	353 72	2576 00	0 01	0 19
2590 00	1 97	358 52	2590 00	0 01	0 19
2604 00	2 14	357 22	2604 00	0 00	0 18
2618 00	2 08	361 95	2618 00	0 00	0 21
2632 00	2 01	359 56	2632 00	0 00	0 16

2646 00	1 96	357 31	2646 00	0 00	0 14
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2688 00	2 07	35834	2688 00	0 00	0 12
2702 00	2 10	357 84	2702 00	0 00	0 11
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2744 00	1 92	35209	2744 00	0 00	0 12
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2940 00	2 16	367 27	2940 00	0 00	0 16
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3052 00	2 22	363 81	3052 00	0 00	0 16
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3108 00	2 06	362 08	3108 00	0 00	0 17
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3150 00	2 19	363 88	3150 00	0 00	0 12
3164 00	2 21	366 38	3164 00	0 00	0 11
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3192 00	2 34	36363	3192 00	0 00	0 13
3206 00	2 19	366 97	3206 00	0 01	0 12
3220 00	2 09	365 39	3220 00	0 00	0 13
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3262 00	2 20	373 28	3262 00	0 00	0 13
3276 00	2 19	370 10	3276 00	0 00	0 13
3290 00	2 22	369 58	3290 00	0 00	0 12
3304 00	2 27	370 62	3304 00	0 00	0 09
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3332 00	2 42	368 12	3332 00	0 00	0 12
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3724 00	2 20	371 16	3724 00	0 01	0 11
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3780 00	1 99	362 37	3780 00	0 00	0 10
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3808 00	2 05	368 25	3808 00	0 00	0 10
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4074 00	3 14	254 24	4074 00	0 00	0 10
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4340 00	2 84	240 91	4340 00	0 00	0 13
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5516 00	2 70	240 18	5516 00	0 00	0 18
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5768 00	2 70	255 75	5768 00	0 00	0 10
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6006 00	2 93	229 94	6006 00	0 00	0 07
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6216 00	2 75	216 26	6216 00	0 00	0 07
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6314 00	2 46	218 19	6314 00	0 00	0 07
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6468 00	2 15	248 91	6468 00	0 00	0 13
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6496 00	1 95	254 89	6496 00	0 00	0 12
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6580 00	2 21	269 50	6580 00	0 00	0 12
6594 00	1 95	241 24	659400	0 00	0 11
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6762 00	2 02	225 77	6762 00	0 00	0 10
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6818 00	2 06	232 53	6818 00	0 00	0 10
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6846 00	1 97	259 94	6846 00	0 00	0 10
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6902 00	2 08	258 49	6902 00	0 00	0 09
6916 00	2 06	276 78	6916 00	0 00	0 08
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6944 00	2 05	265 50	6944 00	0 01	0 07
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7014 00	2 01	308 17	7014 00	0 00	0 10
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7070 00	1 90	310 23	7070 00	0 00	0 14
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7224 00	2 00	259 38	7224 00	0 00	0 32
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7518 00	1 83	24101	7518 00	0 00	0 22
7532 00	1 91	24102	7532 00	0 00	0 31
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7574 00	1 97	24545	7574 00	0 00	0 22
7588 00	1 88	24000	7588 00	0 00	0 17
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7616 00	1 99	240 75	7616 00	0 00	0 21
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7686 00	1 70	25324	7686 00	0 00	0 23
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7966 00	1 96	20881	796600	0 00	0 09
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8036 00	1 74	168 85	8036 00	0 00	0 08
8050 00	1 75	16347	8050 00	0 00	0 09
8064 00	1 84	158 05	8064 00	0 00	0 12
8078 00	1 76	154 22	8078 00	0 01	0 08
8092 00	1 87	152 05	8092 00	0 00	0 08
8106 00	1 69	154 00	810600	0 00	0 09
8120 00	1 64	148 78	8120 00	0 00	0 09

8134 00	1 68	146 42	8134 00	0 00	0 10		
8148 00	1 55	144 98	8148 00	0 00	0 09		
8162 00	1 62	140 31	8162 00	0 00	0 08		
8176 00	1 66	142 66	8176 00	0 01	0 10		
8190 00	1 72	144 13	8190 00	0 00	0 07		
8204 00	1 74	136 28	8204 00	0 00	0 08		
8218 00	1 85	130 94	8218 00	0 00	0 09		
8232 00	1 76	130 84	8232 00	0 00	0 10		
8248 00	1 65	127 03	8246 00	0 01	0 09		
8260 00	1 77	126 34	8260 00	0 00	0 07		
8274 00	1 70	122 69	8274 00	0 00	0 06		
8288 00	1 62	121 09	8288 00	0 00	0 06		
8302 00	1 69	122 16	8302 00	0 00	0 08		
8316 00	1 82	120 09	8316 00	0 00	0 09		
833000	1 76	128 87	8330 00	0 00	0 06		
8344 00	1 75	124 19	8344 00	0 00	0 10		
			8358 00	0 00	0 06		
			8372 00	0 00	0 08		
			8386 00	0 01	0 08		
			8400 00	0 00	0 09		
			8414 00	0 00	0 09		
			8428 00	0 00	0 09		
			8442 00	0 00	0 09		
			8456 00	0 00	0 12		
			8470 00	0 00	0 10		
			8484 00	0 00	0 09		
			8498 00	0 00	0 09		
			8512 00	0 00	0 08		
			8526 00	0 00	0 07		
			8540 00	0 00	0 13		
			655400	0 00	0 06		
			8568 00	0 00	0 07		
			658200	0 00	0 09		
			8596 00	0 00	0 11		
			8610 00	0 00	0 07		
			6624 00	0 00	0 09		
			8638 00	0 00	0 10		
			8652 00	0 00	0 08		
			8666 00	0 00	0 08		
			8680 00	0 00	0 08		
			8694 00	0 00	0 07		
			8708 00	0 00	0 08		
			8722 00	0 00	0 08		
			8736 00	0 00	0 11		
			8750 00	0 00	0 12		
			8764 00	0 00	0 11		
			8778 00	0 00	0 10		
			8792 00	0 00	0 11		
			8806 00	0 00	0 09		

		8820 00	0 00	0 09
		8834 00	0 00	0 11
		8848 00	0 01	0 11
		8862 00	0 00	0 10
		8876 00	0 00	0 10
		8890 00	0 00	0 10
		8904 00	0 00	0 08
		8918 00	0 00	0 10
		8932 00	0 00	0 09
		8946 00	0 00	0 10
		8960 00	0 00	0 07
		8974 00	0 00	0 08
		8988 00	0 01	0 10
		9002 00	0 00	0 08
		9016 00	0 00	0 10
		9030 00	0 00	0 11
		9044 00	0 00	0 16
		9058 00	0 00	0 17
		9072 00	0 00	0 21
		9086 00	0 00	0 18
		9100 00	0 00	0 25
		9114 00	0 00	0 24
		9128 00	0 00	0 26
		9142 00	0 00	0 25
		9156 00	0 00	0 26
		9170 00	0 00	0 27
		9184 00	0 00	0 23
		9198 00	0 00	0 27
		9212 00	0 00	0 23
		9226 00	0 00	0 27
		9240 00	0 00	0 23
		9254 00	0 01	0 20
		9268 00	0 00	0 25
		9282 00	0 00	0 30
		9296 00	0 00	0 32
		9310 00	0 00	0 33
		9324 00	0 00	0 30
		9338 00	0 00	0 25
		9352 00	0 00	0 28
		9366 00	0 00	0 31
		9380 00	0 00	0 28
		9394 00	0 00	0 22
		9408 00	0 00	0 24

## APPENDIX B

PDM LABORATORY RESULTS							
INSIDE AVERAGE PARTICLE COUNTS BETWEEN RANGES							
Particle range	(0.7 to 1)	(1 to 2)	(2 to 3.5)	(3.5 to 5)	(5 to 7.5)	(7.5 to 10)	(10 to 15)
	3 561243	1 021328	0 157221	0 035344	0 01036	0 002438	0 002438
OUTSIDE AVERAGE PARTICLE COUNTS BETWEEN RANGES							
Particle range	(0.7 to 1)	(1 to 2)	(2 to 3.5)	(3.5 to 5)	(5 to 7.5)	(7.5 to 10)	(10 to 15)
	711 1773	202 053	17 58135	5 206581	2 223644	0 670323	0 298598
PENETRATION (INSIDE/OUTSIDE)							
Particle range	(0.7 to 1)	(1 to 2)	(2 to 3.5)	(3.5 to 5)	(5 to 7.5)	(7.5 to 10)	(10 to 15)
	0 005008	0 005055	0 008942	0 006788	0 004659	0 003636	0 008163
EFFICIENCIES AT EACH PARTICLE RANGE (1-Penetration)							
Particle range	(0.7 to 1)	(1 to 2)	(2 to 3.5)	(3.5 to 5)	(5 to 7.5)	(7.5 to 10)	(10 to 15)
	0 994992	0 994945	0 991058	0 993212	0 995341	0 996364	0 991837
PROTECTION FACTORS (Outside/Inside)							
Particle range	(0.7 to 1)	(1 to 2)	(2 to 3.5)	(3.5 to 5)	(5 to 7.5)	(7.5 to 10)	(10 to 15)
	199 6992	197 8335	111 8256	147 3103	214 6471	275	122 5

## APPENDIX C

FIELD EVALUATION					
Particle Concentrations Inside			Particle Concentrations Outside		
TIME	>30	0 3-30	TIME	>30	0 3-30
SEC	PAR/CC	PAR/CC	SEC	PAR/CC	PAR/CC
0	0 022959	2 331122	0	0 188265	38 79949
14	0 015306	2 219388	14	0 179082	38 05102
28	0 006122	2 511735	28	0 254082	61 30102
42	0 053571	2 413776	42	0 156122	36 22653
56	0 042857	2 504082	56	0 218878	35 39235
70	0 145408	3 319898	70	0 169898	35 57143
84	0 122449	3 081122	84	0 195918	35 05867
98	0 09949	2 658673	98	0 183673	36 27092
112	0 194388	4 181633	112	0 189796	35 16276
126	0 091837	3 316837	126	0 192857	35 12143
140	0 05051	2 602041	140	0 157653	36 47908
154	0 047449	2 643367	154	0 159184	40 19694
168	0 068878	2 680102	168	0 234184	34 55663
182	0 045918	2 686224	182	0 191327	43 60867
196	0 035204	2 42602	196	0 367347	136 9622
210	0 035204	2 804082	210	0 543367	150 375
224	0 032143	2 419898	224	0 404082	123 0444
238	0 032143	2 678571	238	0 361224	142 1617
252	0 041327	2 418367	252	0 345918	143 5776
266	0 021429	2 44898	266	0 296939	121 774
260	0 029082	2 459694	280	0 261735	99 98112
294	0 035204	2 698469	294	0 237245	85 14337
308	0 02602	2 363265	308	0 194388	73 21684
322	0 021429	2 585204	322	0 309184	136 1372
336	0 016837	2 611224	336	0 292347	124 5367
350	0 021429	2 422959	350	0 264796	116 4566
364	0 018367	2 288265	364	0 188265	70 21837
378	0 042857	2 55	378	0 20051	76 05153
392	0 071939	2 781122	392	0 341327	140 3204
406	0 070408	2 566837	406	0 381122	144 5571
420	0 079592	2 768878	420	0 24949	127 7923
434	0 084184	2 719898	434	2 364798	73 55357
448	0 079592	2 912755	448	1 414286	38 32806
462	0 110204	3 078061	482	0 886224	33 06429
476	0 087245	2 932653	476	1 561224	34 54592
490	0 062755	2 703061	490	0 809694	33 71786
504	0 082653	2 782653	504	4 769388	38 6801
518	0 067347	2 712245	518	0 463776	33 31071
532	0 052041	2 583673	532	1 533673	34 67143
546	0 045918	2 531633	546	15 04133	61 67908
560	0 042857	2 205612	560	25 57041	73 18469
574	0 045918	2 340306	574	31 4648	68 32806
588	0 044388	2 637245	588	59 25918	69 4852

602	0 027551	2 553061	602	40 07298	74 94031
616	0 047449	2 464286	616	16 87194	49 56582
630	0 058163	2 193367	630	6 494388	48 28469
644	0 039796	2 297449	644	1 832143	33 28929
658	0 058163	2 171939	658	6 087245	46 07296
672	0 033673	2 031122	672	1 945408	39 28316
686	0 044388	2 207143	686	0 214286	32 33112
700	0 045918	2 289796	700	0 79898	32 43827
714	0 044388	2 227041	714	2 554592	33 29847
728	0 030612	2 170408	728	0 788265	32 00969
742	0 041327	2 520918	742	0 338265	3 218 112
756	0 039796	2 231633	756	7 161735	47 11684
770	0 02602	2 432143	770	37 18929	72 14082
784	0 053571	2 202551	784	37 43571	62 60204
798	0 05051	2 462755	798	52 16327	61 98061
812	0 070408	2 872959	812	36 09949	61 17092
826	0 061224	2 687755	826	2 455102	39 36122
840	0 045918	2 407653	840	11 69082	54 37041
854	0 041327	2 311224	854	9 189796	50 86531
868	0 041327	2 378571	868	11 39541	43 61939
882	0 039796	2 295918	882	4 07602	36 92296
896	0 030612	2 364796	896	0 414796	31 36837
910	0 029082	2 05102	910	0 394898	31 89184
924	0 016837	2 003571	924	5 315816	37 6699
938	0 02602	1 960714	938	1 333163	33 94898
952	0 041327	1 980612	952	18 22959	49 33316
966	0 09949	2 346429	966	31 04082	56 5301
980	0 058163	2 159694	980	85 23061	60 08571
994	0 035204	2 214796	994	5 364796	38 46122
1008	0 04898	2 243878	1008	57 29082	57 38571
1022	0 058163	2 306633	1022	67 54592	60 82194
1036	0 030612	2 144388	1036	49 27806	63 67959
1050	0 04898	2 248469	1050	56 42143	63 18827
1064	0 047449	2 083163	1064	20 6051	54 96122
1078	0 041327	2 295918	1078	46 66837	66 4898
1092	0 030612	2 081633	1092	21 42551	52 55051
1106	0 042857	2 228571	1106	1 114286	33 59694
1120	0 04898	2 191837	1120	1 189286	32 89286
1134	0 045918	2 364796	1134	9 17602	38 76429
1148	0 068878	2 464286	1148	19 72959	54 72398
1162	0 045918	2 421429	1162	10 49847	46 81071
1176	0 05051	2 644898	1176	2 012755	33 68724
1190	0 041327	2 530102	1190	7 327041	39 77449
1204	0 029082	2 514796	1204	9 717857	48 67959
1218	0 035204	2 478061	1218	22 57653	66 29388
1232	0 045918	2 398469	1232	40 45408	68 01122
1246	0 030612	2 248469	1246	70 4801	58 66531
1260	0 042857	2 272959	1260	67 07755	57 72704
1274	0 052041	2 259184	1274	38 34796	56 13367

1288	0 038265	1 99898	1288	25 42806	47 66786
1302	0 035204	2 028061	1302	3 088776	35 74745
1316	0 052041	2 095408	1316	4 458673	34 77551
1330	0 035204	2 103061	1330	12 34286	41 10918
1344	0 036735	1 82602	1344	0 593878	30 91684
1358	0 052041	1 985204	1358	9 330612	31 90867
1372	0 082653	2 089286	1372	50 25918	52 29949
1386	0 110204	2 130612	1386	34 93316	56 03571
1400	0 070408	2 037245	1400	2 703061	59 66786
1414	0 036735	2 021939	1414	0 375	40 22449
1428	0 022959	1 842857	1428	0 312245	46 97296
1442	0 021429	1 66	1442	0 241837	58 20612
1466	0 015306	1 607653	1466	0 226531	54 33981
1470	0 02449	1 875	1470	0 257143	61 47398
1484	0 036735	1 758673	1484	0 333673	120 7423
1498	0 067347	1 591837	1498	0 341327	129 626
1512	0 030612	1 429592	1512	0 25102	69 05051
1526	0 045918	1 483163	1526	0 240306	44 65714
1540	0 041327	1 365306	1540	0 240306	47 00204
1554	0 047449	1 285714	1554	1 836735	57 04439
1568	0 012245	1 219898	1568	0 420918	101 0051
1582	0 021429	1 423469	1582	1 053061	63 2801
1596	0 019898	1 181633	1596	0 189796	56 16633
1610	0 035204	1 258163	1610	0 20051	55 90102
1624	0 053571	1 45102	1624	0 234184	44 5102
1638	0 041327	1 353061	1638	0 192857	56 58673
1652	0 027551	1 503061	1652	0 15	47 08776
1666	0 019898	1 581122	1666	0 179082	44 55612
1680	0 016837	1 648469	1680	0 142347	35 32959
1694	0 007653	1 542857	1694	0 195918	49 22449
1708	0 033673	1 588776	1708	0 159184	52 125
1722	0 035204	1 706633	1722	0 166837	46 37602
1736	0 036735	1 464796	1736	0 153061	35 06786
1750	0 038265	1 764796	1750	0 162245	33 77908
1764	0 029082	1 608673	1764	0 179082	36 59541
1778	0 042857	1 683673	1778	0 214286	34 13571
1792	0 02602	1 54898	1792	0 20051	54 94133
1806	0 02449	1 418878	1806	17 47041	82 8398
1820	0 030612	1 369898	1820	27 88622	75 8602
1834	0 032143	1 62551	1834	1 541327	183 8464
1848	0 032143	1 530612	1848	0 717857	160 0546
1862	0 032143	1 547449	1862	0 373469	89 91888
1876	0 027551	1 518367	1876	19 96071	76 14337
1890	0 035204	1 553571	1890	72 36735	64 00408
1904	0 036735	1 406633	1904	60 66122	60 93673
1918	0 045918	1 464694	1918	87 47296	51 97347
1932	0 030612	1 467857	1932	10 8398	46 12959
1946	0 029062	1 604082	1946	0 769898	32 7
1960	0 045916	1 397449	1960	0 569388	32 03571

1974	0 029082	1 515306	1974	0 269388	31 3699
1988	0 052041	1 596429	1988	0 433163	31 21378
2002	0 035204	1 581122	2002	0 762245	31 74643
2016	0 029082	1 535204	2016	16 34082	46 55357
2030	0 019898	1 490816	2030	24 07194	64 59184
2044	0 022959	1 642347	2044	25 41735	62 0648
2058	0 019898	1 593367	2058	64 46786	69 12704
2072	0 027551	1 565816	2072	96 20816	63 33673
2086	0 030612	1 542857	2086	71 04337	65 13061
2100	0 027551	1 69898	2100	96 44694	64 40357
2114	0 010714	1 490816	2114	40 65153	73 14949
2128	0 015306	1 198469	2128	88 03469	67 4801
2142	0 009184	1 411224	2142	10 0898	41 90969
2156	0 016837	1 247449	2156	3 440816	34 54439
2170	0 047449	1 536735	2170	1 284184	32 19643
2184	0 059694	1 434184	2184	6 439286	37 18622
2198	0 055102	1 457143	2198	38 27755	54 76837
2212	0 094898	1 596429	2212	50 34184	71 11531
2226	0 052041	1 963776	2226	9 373469	40 11888
2240	0 019898	1 783163	2240	1 714286	33 7102
2254	0 045918	1 718878	2254	5 618878	36 82653
2268	0 053571	1 838265	2268	0 34898	31 73418
2282	0 065816	1 741837	2282	4 477041	36 28163
2296	0 047449	1 611735	2296	1 910204	38 14898
2310	0 036735	1 746429	2310	0 451531	58 57653
2324	0 055102	1 630102	2324	1 388265	68 55153
2338	0 038265	1 682143	2338	55 32551	65 68776
2352	0 02602	1 501531	2352	24 93827	49 77398
2366	0 030612	1 614796	2366	7 180102	41 95102
2380	0 02449	1 581122	2380	20 89745	52 25357
2394	0 018367	1 372959	2394	8 005102	42 25714
2408	0 02602	1 447959	2408	1 646939	33 63061
2422	0 042857	1 483163	2422	10 67755	40 32245
2436	0 045918	1 516837	2436	20 0801	63 43929
2450	0 030612	1 481633	2450	13 19388	57 56786
2464	0 027551	1 418878	2464	15 54643	56 91582
2478	0 042857	1 421939	2478	30 0551	66 3398
2492	0 05051	1 429592	2492	88 29184	70 97755
2506	0 02449	1 446429	2506	27 06122	61 98061
2520	0 036735	1 40051	2520	49 23061	67 6852
2534	0 02602	1 391327	2534	53 18418	60 59082
2548	0 015306	1 39898	2548	55 40051	64 82143
2562	0 019898	1 527551	2562	70 83367	70 58724
2576	0 021429	1 412755	2576	9664898	66 16378
2590	0 022959	1 435714	2590	62 32194	66 02143
2604	0 015306	1 395918	2604	6 48199	61 94082
2618	0 019898	1 421939	2618	6 846429	38 31888
2632	0 016837	1 379082	2632	0 890816	34 1449
2646	0 016837	1 571939	2646	1 421939	32 38316

2660	0 02449	1 564286	2660	0 538776	32 19031
2674	0 02449	1 440306	2674	14 42143	43 19694
2688	0 033673	1 428061	2688	4 604082	35 47194
2702	0 02449	1 336224	2702	1 028571	31 82296
2716	0 02602	1 522959	2716	9 061224	37 74337
2730	0 02449	1 294898	2730	44 62806	64 07296
2744	0 032143	1 414286	2744	21 48214	54 89082
2758	0 013776	1 379082	2758	52 88112	73 19082
2772	0 013776	1 408163	2772	53 36173	66 9
2786	0 022959	1 594898	2786	99 94745	63 42398
2800	0 021429	1 576531	2800	16 46327	51 98429
2814	0 02449	1 484694	2814	16 11735	53 43673
2828	0 012245	1 45102	2828	27 74847	67 2551
2842	0 027551	1 432653	2842	62 7949	72 22041
2856	0 021429	1 35	2856	90 15918	65 20714
2870	0 016837	1 425	2870	42 65663	54 47755
2884	0 010714	1 405102	2884	5 152041	35 2148
2898	0 02602	1 417347	2898	1 52449	30 44541
2912	0 027551	1 498469	2912	1 336224	29 64337
2926	0 022959	1 331633	2926	2 987755	33 11786
2940	0 019898	1 40051	2940	0 880102	30 0352
2954	0 030612	1 382143	2954	16 17551	42 47602
2968	0 036735	1 322449	2968	16 95459	57 49133
2982	0 027551	1 579592	2982	51 22194	63 04898
2996	0 009184	1 440306	2996	26 55459	48 58929
3010	0 012245	1 29949	3010	2 981633	34 45255
3024	0 027551	1 389796	3024	34 87194	46 13724
3038	0 021429	1 32398	3038	101 8821	69 34439
3052	0 009184	1 579592	3052	54 27245	62 10306
3066	0 019898	1 412755	3066	9 085714	39 48061
3080	0 019898	1 235204	3080	0 64898	32 30357
3094	0 016837	1 282653	3094	0 488265	31 84847
3108	0 030612	1 423469	3108	4 166327	34 66224
3122	0 02602	1 578061	3122	1 314796	31 42194
3136	0 041327	1 481633	3136	1 628571	30 90306
3150	0 044388	1 584184	3150	8 797959	39 00765
3164	0 030612	1 359184	3164	5 187245	35 61735
3178	0 064286	2 256122	3178	16 87347	50 53163
3192	0 062755	2 311224	3192	8 265306	39 43929
3206	0 062755	2 098469	3206	22 92398	49 57653
3220	0 055102	2 367857	3220	24 38671	59 15663
3234	0 082653	2 22398	3234	8 482653	42 24949
3248	0 056633	2 357143	3248	45 825	70 54439
3262	0 065816	2 288265	3262	1 2 9551	45 34133
3276	0 065816	2 444388	3276	1 686735	32 55153
3290	0 094898	2 90051	3290	0 601531	31 04541
3304	0 039796	2 393878	3304	28 78622	55 0852
3318	0 064286	2 155102	3318	4 865816	36 75612
3332	0 047449	2 288265	3332	1 383673	33 15918

3346	0 053571	2 380102		3346	0 909184	33 21735
3360	0 033673	2 253061		3360	0 512755	32 48878
3374	0 027551	2 257653		3374	0 655102	32 51327
3388	0 059694	2 519388		3388	0 918367	32 39694
3402	0 038265	2 715306		3402	0 252551	94 14796
3416	0 032143	2 589796		3416	0 192857	69 45306
3430	0 039796	2 563776		3430	0 179082	52 64082
3444	0 039796	2 216327		3444	0 17602	35 29592
3458	0 035204	2 320408		3458	0 163776	36 32908
3472	0 071939	2 309694		3472	0 194388	71 14266
3486	0 042857	2 340306		3486	0 264796	77 79796
3500	0 039796	2 170408		3500	0 254082	63 2602
3514	0 02602	2 219388		3514	0 355102	110 0526
3528	0 047449	2 064796		3528	0 205102	44 1949
3542	0 036735	2 155102		3542	15 17143	58 34082
3556	0 032143	2 20102		3556	53 49796	68 83469
3570	0 032143	2 292857		3570	34 63163	60 00306
3584	0 047449	2 271429		3584	47 23469	59 34031
3598	0 033673	2 416837		3598	35 77347	51 8648
3612	0 035204	2 412245		3612	1 744898	35 82551
3626	0 039796	2 418367		3626	0 477551	33 21276
3640	0 038265	2 208673		3640	0 231122	32 79949
3654	0 02602	2 265306		3654	0 70102	32 65255
3668	0 035204	2 497959		3668	0 606122	31 89949
3682	0 038265	2 283673		3682	0 188265	32 14439
3696	0 039796	2 422959		3696	49 03776	54 27092
3710	0 036735	2 006633		3710	3 269388	35 60357
3724	0 05051	2 187245		3724	18 27092	48 12398
3738	0 027551	2 110714		3738	14 38469	50 17959
3752	0 039796	2 222449		3752	16 87653	57 77908
3766	0 041327	2 280612		3766	18 85408	70 41735
3780	0 047449	2 136735		3780	31 78622	65 18112
3794	0 030612	2 178061		3794	75 95357	64 0148
3808	0 047449	2 263776		3808	50 87602	59 84082
3822	0 02449	2 228571		3822	50 92347	58 37143
3836	0 02449	1 801531		3836	37 86122	51 28929
3850	0 02449	2 185714		3850	5 833163	35 75357
3864	0 044388	1 821429		3864	7 314796	37 125
3878	0 038265	2 081633		3878	14 90969	37 92551
3892	0 019898	1 680612		3892	31 11429	57 10561
3906	0 019898	1 957653		3906	14 99541	66 02755
3920	0 038265	1 939286		3920	24 42704	57 83571
3934	0 04898	1 888776		3934	24 49745	63 14847
3948	0 027551	2 015816		3948	56 13061	64 17551
3962	0 019898	1 893367		3962	15 30153	51 39949
3976	0 021429	1 864286		3976	12 55102	48 52041
3990	0 032143	1 913265		3990	7 538265	40 575
4004	0 016837	1 677551		4004	17 5148	44 50408
4018	0 021429	1 928571		4018	59 13214	63 21735

4032	0 022959	1 666837		4032	47 69082	61 32704
4046	0 038265	2 077041		4046	73 3898	69 49286
4060	0 021429	1 717347		4060	79 29031	62 77194
4074	0 022959	1 959184		4074	34 78929	57 03367
4088	0 027551	1 792347		4088	14 20867	42 13469
4102	0 02602	1 786224		4102	2 175	33 88622
4116	0 018367	1 910204		4116	2 156633	31 9301
4130	0 021429	1 789286		4130	0 587755	30 96122
4144	0 021429	1 798469		4144	0 298469	31 70663
4158	0 039796	2 110714		4158	0 69949	31 25663
4172	0 027551	1 954592		4172	0 87551	31 55816
4186	0 030612	2 101531		4186	13 33622	42 34592
4200	0 019898	1 945408		4200	21 49592	47 76735
4214	0 021429	2 081633		4214	15 56633	44 48265
4228	0 02449	2 109184		4228	68 09388	65 73367
				4242	60 00612	63 4898
				4256	56 78112	59 95714
				4270	52 56122	62 0602
				4284	60 75306	63 3551
				4298	52 06531	62 02041
				4312	2 129082	33525
				4326	0 831122	31 19388
				4340	0 431633	30 64286
				4354	0 188265	29 82092
				4368	0 577041	30 10714
				4382	0 987245	31 00408
				4396	30 45765	56 55459
				4410	21 56633	61 80459
				4424	51 71786	64 85051
				4438	64 79082	67 15408
				4452	31 76327	67 88265
				4466	25 8949	60 34745
				4480	1 380612	3225918
				4494	2 543878	32 24235
				4508	5 026531	36 09949
				4522	2 222449	32 2898
				4536	20 78112	47 35408
				4550	47 10459	63 70561
				4564	23 65561	61 20765
				4578	2 609694	58 68367
				4592	1 126531	58 99898
				4606	1 982143	42 16531
				4620	2 005102	52 62551

## APPENDIX D

PDM RESULTS DURING FIELD EVALUATION

OUTSIDE AVERAGES IN EACH PARTICLE RANGE FOR EACH SEPERATE RUN

Particle Size Range	(0 35-0 5)	(0 5-0 75)	(0 75-1)	(1-2)	(2-3 5)	(3 5-5)	(5-6 5)	(>6 5)
RUN 1	65192	14061 08	4088077	9297 923	5970615	10012 31	5769 615	10431 92
RUN 2	66758 8	11620 2	3686 133	8279 733	6431 133	10146 47	5778 8	11100 27
RUN 3	79760 75	13047 69	3805 313	9765 938	673325	11699 94	6718 813	11758 31
RUN 4	63201 14	1159807	3842 357	6964 571	5303	7800 429	4325 5	8332 5

INSIDE AVERAGES IN EACH PARTICLE RANGE FOR EACH SEPERATE RUN

Particle Size Range	(0 35-0 5)	(0 5-0 75)	(0 75-1)	(1-2)	(2-3 5)	(3 5-5)	(5-6 5)	(>6 5)
RUN 1	1068 615	405 6923	151 4615	74 38462	28	10 69231	2 692308	3
RUN 2	620 1	253 4333	101 1667	54 9	20 2	6 456667	2 6	2 8
RUN 3	806 875	345 25	139 6875	71 8125	26 5625	11 125	2 1875	2 25
RUN 4	735 8929	245 5	97	54 39286	19 25	6 5	2 607143	2 142857

PENETRATION (INSIDE/OUTSIDE) SUMMARY

Particle Size Range	(0 35-0 5)	(0 5-0 75)	(0 75-1)	(1-2)	(2-3 5)	(3 5-5)	(5-6 5)	(>6 5)
RUN 1	0 016392	0 028852	0 03705	0 008	0 00469	0 001068	0 000467	0 000288
RUN 2	0 009289	0 02181	0 027445	0 006631	0 003141	0 000637	0 00045	0 000252
RUN 3	0 010116	0 026461	0 036709	0 007353	0 003945	0 000951	0 000326	0 000191
RUN 4	0 011644	0 021167	0 025245	0 00781	0 00363	0 000833	0 000603	0 000257
avg penetration	0 01186	0 024572	0 031612	0 007449	0 003851	0 000872	0 000461	0 000247
Gnmm mean diameter	0 41833	0 612372	0 866025	1 414214	2 645751	4 1833	5 700877	gt 6 5
Protection factor (outside/inside)	84 31644	40 69598	31 63349	134 2549	259 6458	1146 33	2168 172	4047 159
efficiencies (1 - penetration)	0 98814	0 975428	0 968388	0 992551	0 996149	0 999128	0 999539	0 999753