

TABLE 11.12-2 (ENGLISH UNITS)  
EMISSION FACTORS FOR CONCRETE BATCHING <sup>a</sup>

Source (SCC)	Uncontrolled			Controlled		
	Total PM	Emission Factor Rating	Total PM <sub>10</sub>	Emission Factor Rating	Total PM	Emission Factor Rating
Aggregate transfer <sup>b</sup> (3-05-011-04,-21,23)	0.0069	D	0.0033	D	ND	ND
Sand transfer <sup>b</sup> (3-05-011-05,22,24)	0.0021	D	0.00099	D	ND	ND
Cement unloading to elevated storage silo (pneumatic) <sup>c</sup> (3-05-011-07)	0.73	E	0.47	E	0.00099	0.00034
Cement supplement unloading to elevated storage silo (pneumatic) <sup>d</sup> (3-05-011-17)	3.14	E	1.10	E	0.0089	0.0049
Weigh hopper loading <sup>e</sup> (3-05-011-08)	0.0048	D	0.0028	D	ND	ND
Mixer loading (central mix) <sup>f</sup> (3-05-011-09)	0.572 or Eqn. 11.12-1	B	0.156 or Eqn. 11.12-1	B	0.0184 or Eqn. 11.12-1	0.0055 or Eqn. 11.12-1
Truck loading (truck mix) <sup>g</sup> (3-05-011-10)	1.118	B	0.310	B	0.098 or Eqn. 11.12-1	0.0263 or Eqn. 11.12-1
Vehicle traffic (paved roads)	See AP-42 Section 13.2.1, Paved Roads					
Vehicle traffic (unpaved roads)	See AP-42 Section 13.2.2, Unpaved Roads					
Wind erosion from aggregate and sand storage piles	See AP-42 Section 13.2.5, Industrial Wind Erosion					

ND = No data

<sup>a</sup> All emission factors are in kg of pollutant per Mg of material loaded unless noted otherwise. Loaded material includes course aggregate, sand, cement, cement supplement and the surface moisture associated with these materials. The average material composition of concrete batches presented in references 9 and 10 was 846 kg course aggregate, 648 kg sand, 223 kg cement and 33kg cement supplement. Approximately 75 liters of water was added to this solid material to produce 1826 kg of concrete.

<sup>b</sup> Reference 9 and 10. Emission factors are based upon an equation from AP-42, section 13.2.4 Aggregate Handling And Storage Piles, equation 1 with  $k_{PM-10} = .35$ ,  $k_{PM} = .74$ ,  $U = 10\text{mph}$ ,  $M_{\text{aggregate}} = 1.77\%$ , and  $M_{\text{sand}} = 4.17\%$ . These moisture contents of the materials ( $M_{\text{aggregate}}$  and  $M_{\text{sand}}$ ) are the averages of the values obtained from Reference 9 and Reference 10.

<sup>c</sup> The uncontrolled PM & PM-10 emission factors were developed from Reference 9. The controlled emission factor for PM was developed from References 9, 10, 11, and 12. The controlled emission factor for PM-10 was developed from References 9 and 10.

<sup>d</sup> The controlled PM emission factor was developed from Reference 10 and Reference 12, whereas the controlled PM-10 emission factor was developed from only Reference 10.

<sup>e</sup> Emission factors were developed by using the AP-42 Section 13.2.4, Aggregate and Sand Transfer Emission Factors in conjunction with the ratio of aggregate and sand used in an average yard<sup>3</sup> of concrete. The unit for these emission factors is kg of pollutant per Mg of aggregate and sand.

<sup>f</sup> References 9, 10, and 14. The emission factor units are kg of pollutant per Mg of cement and cement supplement. The general factor is the arithmetic mean of all test data.

<sup>g</sup> Reference 9, 10, and 14. The emission factor units are kg of pollutant per Mg of cement and cement supplement. The general factor is the arithmetic mean of all test data.

### 13.2.1.3 Predictive Emission Factor Equations<sup>10,29</sup>

The quantity of particulate emissions from resuspension of loose material on the road surface due to vehicle travel on a dry paved road may be estimated using the following empirical expression:

$$E = k (sL)^{0.91} \times (W)^{1.02} \quad (1)$$

where:  $E$  = particulate emission factor (having units matching the units of  $k$ ),  
 $k$  = particle size multiplier for particle size range and units of interest (see below),  
 $sL$  = road surface silt loading (grams per square meter) ( $g/m^2$ ), and  
 $W$  = average weight (tons) of the vehicles traveling the road.

It is important to note that Equation 1 calls for the average weight of all vehicles traveling the road. For example, if 99 percent of traffic on the road are 2 ton cars/trucks while the remaining 1 percent consists of 20 ton trucks, then the mean weight "W" is 2.2 tons. More specifically, Equation 1 is *not* intended to be used to calculate a separate emission factor for each vehicle weight class. Instead, only one emission factor should be calculated to represent the "fleet" average weight of all vehicles traveling the road.

The particle size multiplier ( $k$ ) above varies with aerodynamic size range as shown in Table 13.2.1-1. To determine particulate emissions for a specific particle size range, use the appropriate value of  $k$  shown in Table 13.2.1-1.

To obtain the total emissions factor, the emission factors for the exhaust, brake wear and tire wear obtained from either EPA's MOBILE6.2<sup>27</sup> or MOVES2010<sup>29</sup> model should be added to the emissions factor calculated from the empirical equation.

Table 13.2.1-1. PARTICLE SIZE MULTIPLIERS FOR PAVED ROAD EQUATION

Size range <sup>a</sup>	Particle Size Multiplier $k^b$		
	g/VKT	g/VMT	lb/VMT
PM-2.5 <sup>c</sup>	0.15	0.25	0.00054
PM-10	0.62	1.00	0.0022
PM-15	0.77	1.23	0.0027
PM-30 <sup>d</sup>	3.23	5.24	0.011

<sup>a</sup> Refers to airborne particulate matter (PM-x) with an aerodynamic diameter equal to or less than x micrometers.

<sup>b</sup> Units shown are grams per vehicle kilometer traveled (g/VKT), grams per vehicle mile traveled (g/VMT), and pounds per vehicle mile traveled (lb/VMT). The multiplier  $k$  includes unit conversions to produce emission factors in the units shown for the indicated size range from the mixed units required in Equation 1.

<sup>c</sup> The  $k$ -factors for PM<sub>2.5</sub> were based on the average PM<sub>2.5</sub>:PM<sub>10</sub> ratio of test runs in Reference 30.

<sup>d</sup> PM-30 is sometimes termed "suspendable particulate" (SP) and is often used as a surrogate for TSP.

Equation 1 is based on a regression analysis of 83 tests for PM-10.<sup>3, 5-6, 8, 27-29, 31-36</sup> Sources tested include public paved roads, as well as controlled and uncontrolled industrial paved roads. The majority of tests involved freely flowing vehicles traveling at constant speed on relatively level roads. However, 22 tests of slow moving or "stop-and-go" traffic or vehicles under load were available for inclusion in the data base.<sup>32-36</sup> Engine exhaust, tire wear and break wear were subtracted from the emissions measured in the test programs prior to stepwise regression to determine Equation 1.<sup>37, 39</sup> The equations retain the quality rating of A (D for PM-2.5), if applied within the range of source conditions that were tested in developing the equation as follows:

Silt loading:	0.03 - 400 g/m <sup>2</sup> 0.04 - 570 grains/square foot (ft <sup>2</sup> )
Mean vehicle weight:	1.8 - 38 megagrams (Mg) 2.0 - 42 tons
Mean vehicle speed:	1 - 88 kilometers per hour (kph) 1 - 55 miles per hour (mph)

The upper and lower 95% confidence levels of equation 1 for PM<sub>10</sub> is best described with equations using an exponents of 1.14 and 0.677 for silt loading and an exponents of 1.19 and 0.85 for weight. Users are cautioned that application of equation 1 outside of the range of variables and operating conditions specified above, e.g., application to roadways or road networks with speeds above 55 mph and average vehicle weights of 42 tons, will result in emission estimates with a higher level of uncertainty. In these situations, users are encouraged to consider an assessment of the impacts of the influence of extrapolation to the overall emissions and alternative methods that are equally or more plausible in light of local emissions data and/or ambient concentration or compositional data.

To retain the quality rating for the emission factor equation when it is applied to a specific paved road, it is necessary that reliable correction parameter values for the specific road in question be determined. With the exception of limited access roadways, which are difficult to sample, the collection and use of site-specific silt loading (sL) data for public paved road emission inventories are strongly recommended. The field and laboratory procedures for determining surface material silt content and surface dust loading are summarized in Appendices C.1 and C.2. In the event that site-specific values cannot be obtained, an appropriate value for a paved public road may be selected from the values in Table 13.2.1-2, but the quality rating of the equation should be reduced by 2 levels.

Equation 1 may be extrapolated to average uncontrolled conditions (but including natural mitigation) under the simplifying assumption that annual (or other long-term) average emissions are inversely proportional to the frequency of measurable (> 0.254 mm [ 0.01 inch]) precipitation by application of a precipitation correction term. The precipitation correction term can be applied on a daily or an hourly basis<sup>26, 38</sup>.

For the daily basis, Equation 1 becomes:

$$E_{ext} = [ k (sL)^{0.91} \times (W)^{1.02} ] (1 - P/4N) \quad (2)$$

where  $k$ ,  $sL$ ,  $W$ , and  $S$  are as defined in Equation 1 and

$E_{ext}$  = annual or other long-term average emission factor in the same units as  $k$ ,

$P$  = number of "wet" days with at least 0.254 mm (0.01 in) of precipitation during the averaging period, and

Table 13.2.1-3 (Metric And English Units). TYPICAL SILT CONTENT AND LOADING VALUES FOR PAVED ROADS AT INDUSTRIAL FACILITIES<sup>a</sup>

Industry	No. of Sites	No. Of Samples	Silt Content (%)		No. of Travel Lanes	Total Loading x 10 <sup>-3</sup>			Silt Loading (g/m <sup>2</sup> )	
			Range	Mean		Range	Mean	Units <sup>b</sup>	Range	Mean
Copper smelting	1	3	15.4-21.7	19.0	2	12.9 - 19.5	15.9	kg/km	188-400	292
Iron and steel production	9	48	1.1-35.7	12.5	2	45.8 - 69.2	55.4	lb/mi	0.09-79	9.7
Asphalt batching	1	3	2.6 - 4.6	3.3	1	0.006 - 4.77	0.495	kg/km	76-193	120
Concrete batching	1	3	5.2 - 6.0	5.5	2	0.020 -16.9	1.75	lb/mi	11-12	12
Sand and gravel processing	1	3	6.4 - 7.9	7.1	1	12.1 - 18.0	14.9	kg/km	53-95	70
Municipal solid waste landfill	2	7	-	-	2	43.0 - 64.0	52.8	lb/mi	1.1-32.0	7.4
Quarry	1	6	-	-	2	1.4 - 1.8	1.7	kg/km	2.4-14	8.2
Corn wet mills	3	15	-	-	2	5.0 - 6.4	5.9	lb/mi	0.05 - 2.9	1.1

<sup>a</sup> References 1-2,5-6,11-13. Values represent samples collected from *industrial* roads. Public road silt loading values are presented in Table-13.2.1-2. Dashes indicate information not available.<sup>b</sup> Multiply entries by 1000 to obtain stated units; kilograms per kilometer (kg/km) and pounds per mile (lb/mi).

**Emission Factor Documentation for AP-42,  
Section 13.2.1**

**Paved Roads**

**Measurement Policy Group  
Office of Air Quality Planning and Standards  
U.S. Environmental Protection Agency**

**January 2011**

Federal Register Methods for PM<sub>10</sub> or PM<sub>2.5</sub>, calibrations required to correlate the combined sampling platform and instrumentation with standardized plume profiling testing used to quantify mass emissions from roads and procedures for collecting information for use in road surface characteristics or emissions.

#### **4.2.2. EMISSIONS FACTOR DEVELOPMENT.**

A total of 103 individual tests are available. All tests quantified PM<sub>10</sub> emissions. Lastly, plume profiling was the test method. Of these, 81 emissions tests included mean vehicle weight, road silt loading, and vehicle speed. The remaining tests included all of these parameters except vehicle speed. These emissions tests measured PM<sub>10</sub> emissions associated with engine exhaust, tire wear, brake wear and material deposited on the road surface. Policy decisions within EPA make it necessary to separate particulate matter emissions associated with the operation of the vehicles (engine exhaust, tire wear and brake wear) and those associated with the road surface characteristics. These policy decisions are based in part on the recent and future efforts to control engine exhaust emissions. Many of the emissions tests performed to quantify particulate matter emissions from paved roads were conducted in the mid 1980's to middle 1990's. Several of the emissions studies have experienced comparable upwind and downwind concentrations with downwind particulate that appears to consist of a large percentage of organic or carbonaceous material. The first separation of vehicle associated emissions and pavement associated emissions was in the 2003 update. This update used the national VMT weighted fleet average PM<sub>10</sub> emissions factor of 0.2119 g/VMT to subtract from the existing emissions factor equation as a means of separating the emissions from engine exhaust, tire wear and brake wear from the composite paved road emissions factor. A fleet average vehicle weight of 3.75 tons is associated with this emissions factor. Since the average vehicle weight used in the development of the paved road emissions factor equation was about 10 tons, the PM<sub>10</sub> emissions factor for engine exhaust, tire wear and brake wear probably underestimated these emissions. In addition, because of the range and variation in mean vehicle weight, the use of an average for adjustment value introduces excessive error in the estimated road dust emissions estimates. Improved test specific adjustments for vehicle exhaust, tire wear and brake wear can be made since (1) average vehicle weights are available for each test series, (2) PM<sub>10</sub> emissions factors estimates for each vehicle class are available using the MOVES model and (3) PM<sub>10</sub> emissions estimates for slowly moving and stop and go truck traffic are available. By subtracting the estimated test specific vehicle emissions from the measured emissions prior to performing the stepwise multiple regression, emissions associated with the road surface material will be isolated.

##### **4.2.2.1. Compilation and Adjustment of Final Data Base.**

In keeping with the results from the data set review, a final data base was compiled by combining the following sets:

1. The January 1983 EPA data base,
2. the August 1983 EPA data base,
3. the July 1984 EPA data base,
4. the May 1990 USX data base,

5. the April 1997 EPA data base, and
6. the May 2008 CRA data base.

While several of the test reports include detailed information on the number of light duty vehicles, moderate weight trucks and heavy weight trucks, none provide detailed information on vehicle class as used to estimate emissions of vehicle exhaust, tire wear and break wear. For this assessment the vehicle classes will be separated into two vehicle classes. One group of vehicle class will include the six classes of light duty vehicles/trucks and motorcycles. The other group of vehicle class includes gas and diesel heavy duty trucks. Other assumptions used to estimate vehicle associated emissions include:

- The test fleet includes a mixture of light duty vehicles, heavy duty gas trucks and heavy duty diesel trucks when the average vehicle weight is less than 23 tons.
- The test fleet includes a mixture of light duty vehicles and heavy duty diesel trucks when the average vehicle weight is between 23 tons and 35 tons.
- The test fleet includes only heavy duty diesel trucks when the average vehicle weight is more than 35 tons.

First, the average vehicle weight and emissions are determined for the two classes of vehicles used to estimate the adjustment for the measured emissions. The vehicle weights and VMT distribution presented in Table 4-16 are used to calculate the average vehicle weight. The VMT adjusted gross vehicle weight is calculated for each class of vehicle by multiplying the VMT distribution by the average gross vehicle weight for the class. The individual vehicle class VMT adjusted gross vehicle weights are summed to arrive at the two VMT adjusted gross vehicle weights used in this assessment. For light duty vehicles, the VMT adjusted gross vehicle weight is 3320 pounds. For heavy duty trucks, the VMT adjusted gross vehicle weight is 3742 pounds. The sums of the VMT distributions for these two classes of vehicles are obtained by summing the individual VMT distributions for the two classes of vehicles used in this assessment. For light duty vehicles, the VMT distribution is 0.928. For heavy duty trucks, the VMT distribution is 0.0717. Dividing the VMT adjusted gross vehicle weights by the VMT distributions and converting to tons yields the average vehicle weights for the two classes of vehicles. For light duty vehicles, the average gross vehicle weight is 1.79 tons. For the combination of heavy duty gas and diesel trucks, the average gross vehicle weight is 26.09 tons.

Next, an algorithm is developed to provide test run specific ratios of light duty vehicles and heavy duty trucks. The algorithm is developed by solving the following two equations.

$$W_t = (R_{LD} \times W_{LD}) + (R_{HD} \times R_{HD})$$

$$1.00 = R_{LD} + R_{HD}$$

where:  $W_t$  = Test report average vehicle weight

$W_{LD}$  = Average Light Duty Vehicle Weight (1.78848 tons)

$R_{HD}$  = Average Heavy Duty Truck Weight (26.09135 tons)

$R_{LD}$  = Light duty vehicle ratio

$R_{HD}$  = Heavy duty truck ratio



For test runs where the average vehicle weight is less than 23 tons, the resulting algorithm to estimate the ratio of heavy duty gas/diesel trucks in each test series is:

$$R_{HD} = (W_i - 1.78848) / (26.09135 - 1.78848)$$

For tests where the average vehicle weight is more than 23 tons, the resulting algorithm to estimate the ratio of heavy duty diesel trucks in each test series is:

$$R_{HD} = (W_i - 1.78848) / (35 - 1.78848)$$

Run specific emissions estimates for vehicle exhaust, brake wear and tire wear are estimated using the EPA Office of Transportation and Air Quality MOVES (MOTOR Vehicle Emission Simulator) 2010 model<sup>29</sup>. For all tests with vehicle speed greater than 10 mph only emissions for freely moving traffic is calculated. Emissions for a representative mix of light duty vehicles and for a representative mix of heavy duty trucks are calculated. For each test series, information on the date of the test, the location of the test program, ambient temperature during the test, average vehicle speed, and other general information required to generate a valid PM<sub>10</sub> emissions calculation with the MOVES model. While the MOVES model has the ability to generate start up emissions, all test conditions are assumed to include only vehicles which have achieved normal operating temperatures. For all test series with average vehicle speeds greater than 10 mph, the MOVES model calculated only running exhaust, tire wear and brake wear emissions. For heavy duty vehicles, the running emissions ranged from 0.645 g/VMT to 4.896 g/VMT. For light duty vehicles, the running emissions ranged from 0.0196 g/VMT to 0.1324 g/VMT. For test series with average vehicle speeds below 9.9 mph, in addition to running exhaust, tire wear and brake wear emissions; exhaust emissions during acceleration and idling are included. A separate MOVES model run estimated the average emissions for the non steady state emissions at 11.06 g/hour. The emissions factor for this driving condition was calculated by dividing the hourly emissions by the average vehicle speed. Summing the product of emissions factors from heavy duty trucks and light duty vehicles and the ratio of heavy duty vehicles and light duty vehicles provides an estimate of the total engine exhaust; tire wear and brake wear emissions for the test run.

The test run specific emissions factor estimate for engine exhaust, tire wear and brake wear is subtracted from the test run measured emissions factor to produce the test run specific emissions factor due to road surface material. To allow log transformation of the data, values of zero or less were set to 0.01 g/VMT. Table 4-17 presents the final dependent and independent variables for all of the useable test series that were assembled for developing the paved road emissions factor equation. There were 10 test runs of the 103 available data where downwind emissions were not measureable. Six of the data were associated with low speed traffic at corn refining facilities and four of the data were high or moderate speed urban traffic. None of these ten data were included in the data analyzed to estimate the predictive emissions factor equation. There were 3 out of the 103 available data sets where the estimated emissions from engine exhaust, tire wear and brake wear were equal to or comparable to the measured emissions. Two of the three test runs were on roads where the average vehicle speed was 55 mph. Emissions of two additional test runs with vehicle speeds of 55 mph had engine exhaust, tire wear and brake wear emissions greater than 160% of the road emissions. The silt level for one of the 55 mph test runs was greater than all

other 55 mph data sets and was performed to characterize emissions from a road that had been sanded for traction control. For slightly slower moving traffic (40 – 45 mph), three of the five test runs had significant percentage of engine exhaust; tire wear and brake wear emissions. One of the remaining two runs had silt levels greater than 60% of the entire data set and the test was performed to characterize emissions from a road that had been sanded for traction control.

Graphical presentations of the final PM<sub>10</sub> data base are shown in Figures 4-1 through 4-5. Because of the large range of silt loadings and estimated emissions factors, the data are plotted on a logarithmic scale for the first three figures. Figure 4-1 presents the data base by silt loading with five ranges of average vehicle weight depicted with different shape and color data points. The figure shows that with increasing silt loading there is an increase in the PM<sub>10</sub> emissions factor. Figure 4-2 presents the data base by average vehicle weight with seven ranges of silt loading depicted with different shape and color data points. Although there is a significant overlap of the different vehicle weight data, there appears to be some relationship between average vehicle weight and the PM<sub>10</sub> emissions factor. As with silt loading, it appears that the PM<sub>10</sub> emissions factor increases with increasing vehicle weight. The wider spread of the data around the center line of the data makes the relationship more difficult to discern. Figure 4-3 presents the relationship between silt loading and average vehicle weight with eight ranges of emissions factors depicted with different shape and color data points. Although very poor, there appears to be a weak relationship between silt loading and vehicle weight. The cause of this relationship is probably due to the selection of the test location and parameters than any physical force that would cause this relationship. Figure 4-4 presents the relationship between average vehicle speed and the PM<sub>10</sub> emissions factor. It appears that between 10 and 55 mph, the emissions factor decreases with increasing speed. Below 10 mph there does not appear to be a speed relationship. Figure 4-5 presents the relationship between silt loading and vehicle speed with five ranges of PM<sub>10</sub> emissions factors. The silt loading appears to decrease with increasing speed above 10 mph. In addition, there seems to be a clear increase in PM<sub>10</sub> emissions factor as silt loading increases and speed decreases. Figure 4-6 presents a three dimensional view of the silt loading, vehicle weight and PM<sub>10</sub> emissions factors. One data point seems to be very uncharacteristic of the general trend of the data. Figure 4-7 provides a two dimensional view of the data with the data identifier in the label. For three data points, the PM<sub>10</sub> emissions factor is also included in the label. The point which has the uncharacteristic emissions is point Z-3 with a PM<sub>10</sub> emissions factor of 1819 g/VMT. While this value is the highest emissions factor of all of the 92 test data, both the vehicle weight and silt loading for this run are near other data which are under 100 g/VMT. As a result, this data was flagged as a potential outlier. This data was reassessed following log transformation and the variation was determined to be comparable with other data and was included in the final data set used to estimate the predictive equation. Figure 4-8 presents the three dimensional view of the test data with silt loading, vehicle weight and PM<sub>10</sub> emissions factor with test run Z-3 removed. With point Z-3 removed, there appears to be two regimes of the data. Most of the data had silt loadings below 20 g/m<sup>2</sup> with few gaps down to 0.013 g/m<sup>2</sup>. There are ten data with silt loadings spread out from 50 g/m<sup>2</sup> to almost 400 g/m<sup>2</sup> with no data between these two regimes. There appears to be one incline associated with the lower silt loading data and a significantly greater incline for the higher silt loading data. This greater incline is the result of a small number of data collected prior to 1983. These data have higher silt loadings than the default silt loading for the peak additive contribution value for roads with average daily

traffic volume counts of less than 500. While there may be a very small number of streets that reach this silt loading level, these are believed to be unrepresentative of typical well managed urban or rural roads during any season. As a result, these data are flagged as extreme values and were not included in the final data set used to estimate the predictive equation.

# PM<sub>10</sub> Emissions Factor by Vehicle Speed

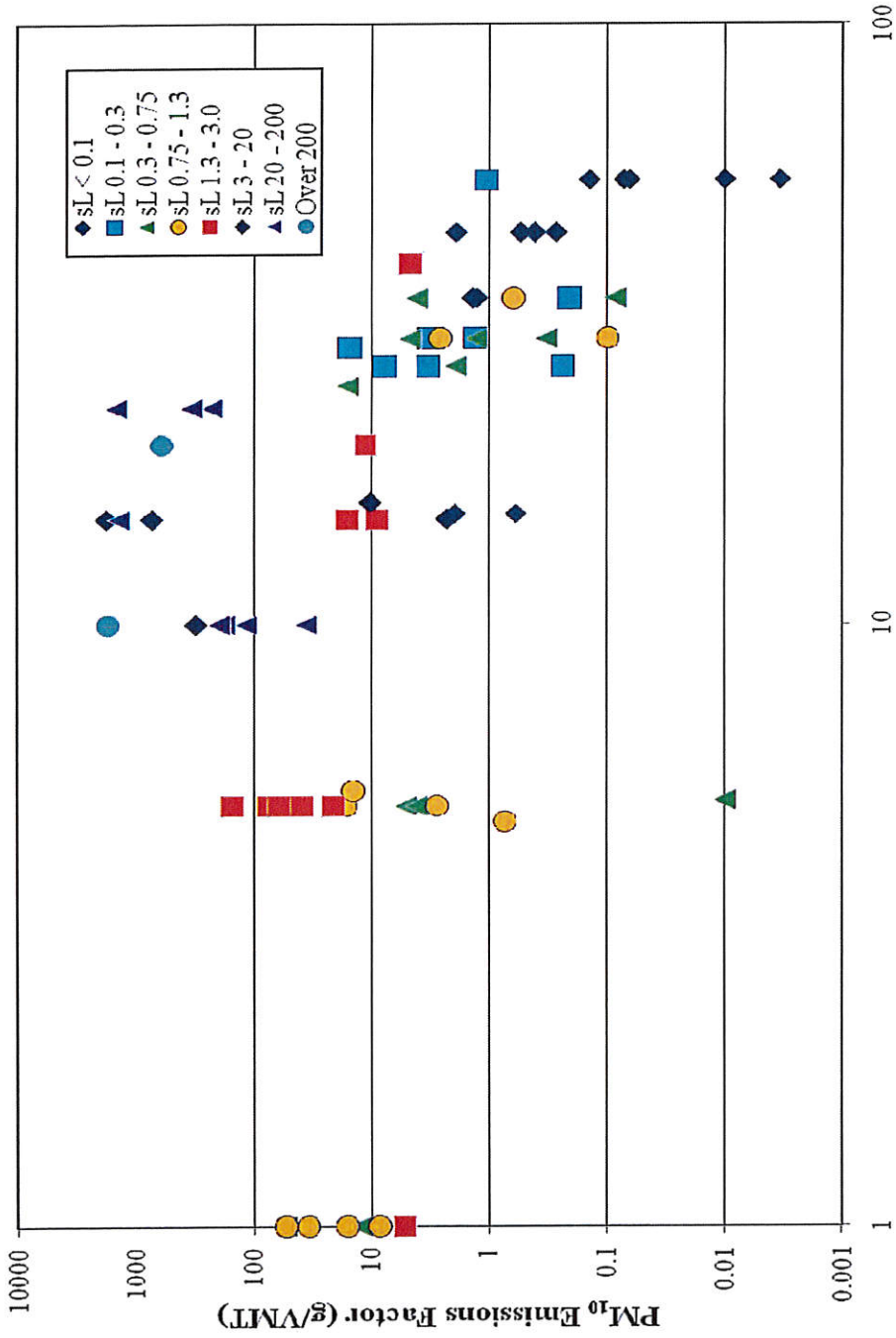


Figure 4-4. PM<sub>10</sub> Emissions Factors by Vehicle Speed.

#### 4.2.2.2. Emission Factor Development.

Stepwise multiple linear regression was used to develop a predictive model with the final data set. The potential correction factors included:

- silt loading, sL
- mean vehicle weight, W
- mean vehicle speed, S

All variables were log-transformed in order to obtain a multiplicative model as in the past. Table 4-18 presents the correlation matrix of the log-transformed independent and dependent variables. The most notable feature of the correlation matrix is the high degree of correlation between silt loading and emissions factors. The correlation between emissions factor, weight and speed is much lower than with silt loading. The high correlation between weight and speed is believed to be the result of the large data collected by the corn refiners association to characterize emissions at terminals. This suggests that obtaining accurate silt loading information is the most important independent variable to obtain for accurately estimating emissions factors.

**Table 4-18 Correlation Matrix for log-transformed PM<sub>10</sub> data.**

	PM <sub>10</sub> Emission factor (g/VMT)	Silt loading (g/m <sup>2</sup> )	Weight (tons)	Speed (mph)
PM <sub>10</sub> Emission factor (g/VMT)	1			
Silt loading (g/m <sup>2</sup> )	0.8010	1		
Weight (tons)	0.3280	-0.1841	1	
Speed (mph)	-0.4066	-0.2785	-0.7784	1

Initially several regression analysis were performed using the Data Analysis tools in MS Excel to evaluate a range of independent variables. The independent variables included silt loading, average vehicle weight, the product of silt loading and vehicle weight, the square of silt loading (after log transformation) and the square of the vehicle weight (after log transformation). In addition, the influence of including and excluding flagged test runs were explored. The primary criteria for selecting the most appropriate form and supporting data set was the predictive performance of the equation using the combination of the correlation coefficient, the P-value and the relative percent difference from the actual emissions factor for the test series with silt loadings and vehicle weights in the range of default values used in the national inventory. The stepwise regression was first performed using the "Regression" function in the "Analysis Tool" of Excel. It was determined that the use of the speed term either produced equations with P-values greater than 0.1 or produced equations with independent parameter relationships that were illogical (i.e. increased emissions with decreased weight). It was also determined that the inclusion of data with silt loadings greater than 20 g/m<sup>2</sup> produced equations which uniformly overestimated test data with lower silt loadings without a significant improvement in estimating the high silt loading data. Also, the exclusion of the ten data with high silt loadings did not significantly change the predictive accuracy of the equation for the ten high silt loading test runs. The 93 test data with positive measured emissions were provided to a statistician for subsequent analysis with SAS.

Several additional assessments were performed to determine an equation that provided a high correlation coefficient, a low average percent error for test series with targeted independent variables and which provided a reasonable level of predictive accuracy for test series where the independent variables were outside the targeted range. The equation which produced the highest correlation coefficient was one which forced the intercept to zero. This equation performed well and was consistent with engineering assessments of the physical influences on emissions. This equation used only silt loading and average vehicle weight as the independent variables. It was decided that the traditional scaling factors of 2 for silt loading and 3 for average vehicle weight were no longer required and resulted in simpler calculation of paved roads emissions factors. The resulting equation for PM<sub>10</sub> is:

$$EF = 1.0 (sL)^{0.912} (W)^{1.021}$$

Table 4-19 shows the statistical output. The predicted exponents for silt and weight are 0.912 and 1.021 respectively and have a coefficient of determination (R<sup>2</sup>) of 0.72. The standard error associated with the silt and weight terms are 0.12 and 0.08 respectively. As a result, it is expected that 95% of future data would fall within equations with exponents of 0.677 and 1.14 for the silt term and 0.852 and 1.19 for the weight term.

The range of conditions which existed at the test sites used in developing the equation was as follows:

Silt loading:	0.03 - 400 g/m <sup>2</sup> 0.01 - 570 grains/square foot (ft <sup>2</sup> )
Mean vehicle weight:	1.8 - 38 megagrams (Mg) 2.0 - 42 tons
Mean vehicle speed:	1 - 88 kilometers per hour (kph) 1 - 55 miles per hour (mph)

The quantity of particulate emissions generated by either type of drop operation, per kilogram (kg) (ton) of material transferred, may be estimated, with a rating of A, using the following empirical expression:<sup>11</sup>

$$E = k(0.0016) \frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \text{ (kg/megagram [Mg])}$$

$E = k(0.0032) \frac{\left(\frac{U}{5}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \text{ (pound [lb]/ton)}$
--

(1)

where:

- E = emission factor
- k = particle size multiplier (dimensionless)
- U = mean wind speed, meters per second (m/s) (miles per hour [mph])
- M = material moisture content (%)

The particle size multiplier in the equation, k, varies with aerodynamic particle size range, as follows:

Aerodynamic Particle Size Multiplier (k) For Equation 1				
< 30 μm	< 15 μm	< 10 μm	< 5 μm	< 2.5 μm
0.74	0.48	0.35	0.20	0.053 <sup>a</sup>

<sup>a</sup> Multiplier for < 2.5 μm taken from Reference 14.

The equation retains the assigned quality rating if applied within the ranges of source conditions that were tested in developing the equation, as follows. Note that silt content is included, even though silt content does not appear as a correction parameter in the equation. While it is reasonable to expect that silt content and emission factors are interrelated, no significant correlation between the 2 was found during the derivation of the equation, probably because most tests with high silt contents were conducted under lower winds, and vice versa. It is recommended that estimates from the equation be reduced 1 quality rating level if the silt content used in a particular application falls outside the range given:

Ranges Of Source Conditions For Equation 1			
Silt Content (%)	Moisture Content (%)	Wind Speed	
		m/s	mph
0.44 - 19	0.25 - 4.8	0.6 - 6.7	1.3 - 15

To retain the quality rating of the equation when it is applied to a specific facility, reliable correction parameters must be determined for specific sources of interest. The field and laboratory procedures for aggregate sampling are given in Reference 3. In the event that site-specific values for



# Low Profile Round Silo Dust Collectors

## General Information

C&W's Low Profile Round (LPR) Silo Dust Collectors offer you Pulse-Jet technology and our cartridge filters to provide an efficient yet inexpensive solution for dust control. These collectors are compact and user-friendly with a low-profile and POP in-out filter media exchange, with no tools or need to remove blow pipes. They can also expand to higher capacities without having to replace the units.

## Options

- Automatic On/Off Flow Switch
- Minihelic Gauge
- Special Adaptable Mounting Flange
- Air Tank Auto-Drain
- Silo Anti-Overfill System
- Pressure Relief Valves and Bin Indicators



## Specs

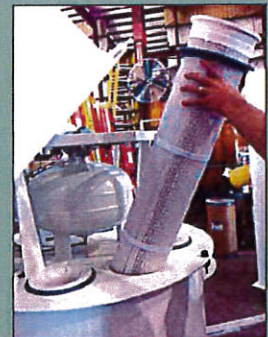
Specifications	LPR-4-S	LPR-6-S	LPR-8-S
Total Filtration Area (sq. ft.)	184	276	368
Number of Cartridges	4	6	8
Cartridge Size	8" x 39"	8" x 39"	8" x 39"
Air to Cloth Ratio	6.35	6.37	6.35
Overall Height *	72"	72"	72"
Flange Diameter	44" o.d.	44" o.d.	44" o.d.
Approx. Weight (lbs.)	670	695	720
Compressed Air Required	3	3	3
CFM Recommended**	1,170	1,760	2,340
Min. Design Efficiency***	99.99%	99.99%	99.99%
Cleaning Mechanism	Pulse Jet	Pulse Jet	Pulse Jet

\*Includes Mounting Flange change CFM recommended    \*\* CFM shown for typical application. Unique application may change CFM recommended    \*\*\*Using Standard Test Conditions

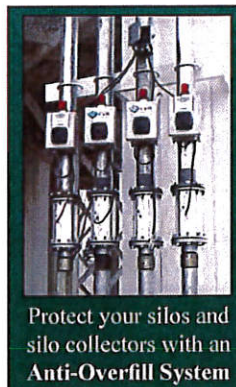
### Most Popular add-on:



Flow switch: Detects the flow of air through the silo and turns the cleaning cycle on while silo is being filled. When the flow of material into the silo stops, unit automatically turns the cleaning cycle off.



Easy Cartridge Replacement: Pop-in/Pop-out



Protect your silos and silo collectors with an Anti-Overfill System

C&W Manufacturing and Sales Co.  
1-800-880-DUST  
www.cwmfg.com





C&W Manufacturing and Sales, Co.  
P.O. Box 908  
Crowley, TX 76036

6933 Shelmor Rd  
Alvarado, TX 76009

Phone: 817.783.5000 • Fax: 817.783.2353  
Email: [info@cwmfg.com](mailto:info@cwmfg.com) • Website: [www.cwmfg.com](http://www.cwmfg.com)

**Item # LPR-8-S, Round Silo Dust Collector**

C&W's Low Profile Round (LPR) Silo Dust Collectors offer you Pulse-Jet technology and our cartridge filters to provide an efficient yet inexpensive solution for dust control. These collectors are compact and user-friendly with a low-profile and POP in-out filter media exchange, with no tools or need to remove blow pipes. They can also expand to higher capacities without having to replace the units.



**Specifications**

CFM Recommended (CFM shown for typical application.)	2340
Total Filtration Area	368 ft <sup>2</sup>
No. of Cartridges	8
Cartridge Length	39 in
Cartridge Width	8 in
Minimum Design Efficiency (Using Standard Test Conditions)	99.99 %
Overall Height (Includes Mounting Flange)	72 in
Flange Outer Diameter	44 in
Approximate Weight	720 lb
Compressed Air Required	3
Cleaning Mechanism	Pulse Jet
Options	<ul style="list-style-type: none"> <li>• Automatic On/Off Flow Switch</li> <li>• Minihelic Gauge</li> <li>• Special Adaptable Mounting Flange</li> <li>• Air Tank Auto-Drain</li> <li>• Silo Anti-Overfill System</li> <li>• Pressure Relief Valves and Bin Indicators</li> </ul>

Notes

Unique application may change CFM recommended

# AIR FILTERING PRODUCTS



## DUST CONTROL & PRODUCT RECLAIM

- MATERIAL PROCESSING
- MOBILE EQUIPMENT
- MANUFACTURING PROCESSES

**Metroplex Products, Inc.**

---

2901 ST. LOUIS AVE.  
FORT WORTH, TEXAS 76110

## AIR QUALITY MAINTENANCE



**MOBILE  
EQUIPMENT**

**mpi**™



**MANUFACTURING  
PROCESSES**

**m-plex**™



**MATERIAL  
PROCESSING**

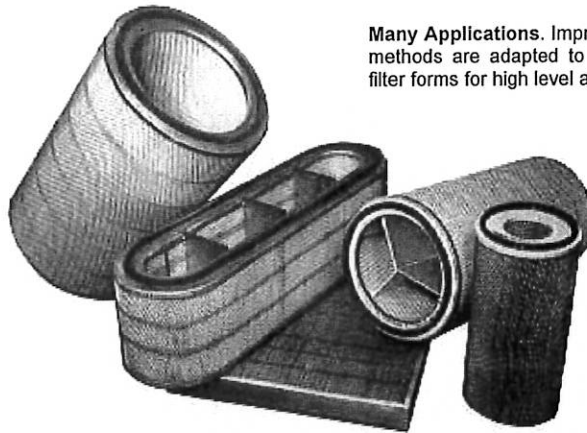
Metroplex Products, Inc. manufactures innovative self-cleaning air filtering products for a growing number of diverse industries. Our products provide for continuous removal of airborne contaminants from work processes involving dry bulk solids material, industrial facilities and mobile equipment.

Since 1977, effective mechanical separation and highly efficient pleated filter cleaning by MPI has provided exciting solutions to solids-gas separation and nuisance dust control problems. Our products have been identified consistently with the highest industry standards of performance and quality.

### Advanced Technology -- Products

The company's technology base is founded in solids-gas flow and separation. Continued research expands this base for developing products to meet the needs of our customers. We are committed to providing the best of the technology for air quality maintenance.

Products are designed to provide solids-gas preseparation for reduced filter particle loading. Efficient final filtering cleans process gas flow streams to levels that meet or exceed environmental requirements.



**Many Applications.** Improved filter cleaning methods are adapted to numerous pleated filter forms for high level air quality control.

*Our Products Manufactured Under Patents and Patents Pending - U.S. and Foreign*

**Metroplex Products, Inc.** 2901 ST. LOUIS AVE. FORT WORTH, TEXAS 76110 817/923-8241  
Copyright ©1987



Best of Technology

MULTI-JET CLEANING

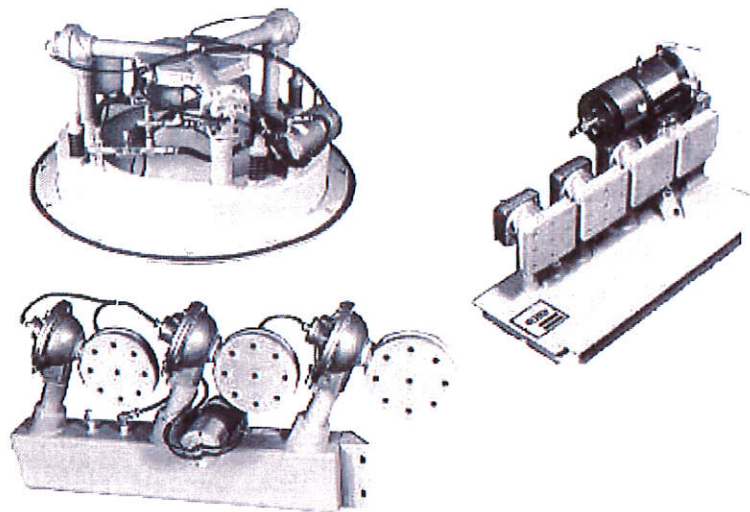
Multi-Jet reverse pulse filter cleaning increases gas filtering rates, conserves gas flow energy and broadens the potential of pleated media.

High energy cleaning allows media gas filtering velocities twice that of conventional systems. Efficient removal of filtered material reduces process gas stream flow drag and extends filter life. Large eductor-flow tube bores provide low velocity process gas flow to conserve gas flow energy.

### Multi-Jet Versatility

Multi-Jet cleaning utilizes quick-release 45 to 65 psig gas through grouped multiple orifices to produce diverging and overlapping high energy jetting. Orifice patterns conform to large or diverse shapes of filter flow tubes.

Pleated filters of oval, panel, or cylindrical form, segmented or otherwise, are easily adapted to the patented Multi-Jet reverse filter cleaning system.



### Multi-Jet Operation

Controlled, quick-release of jetted and educted gas dynamically seals the tube bore opening by means of a solid gas wall. Ahead of the seal, high energy gas flow overpowers collected material to reverse flush filter media. Multi-Jet filter cleaning is thus complete and predictable.

"Because of technological progress and product improvements, all design and dimensional data shown in this catalog is subject to change without notice. Technical information has been prepared from actual test results under controlled environmental conditions and data is considered to be reliable; but no responsibility can be assumed for its accuracy under varied field conditions."

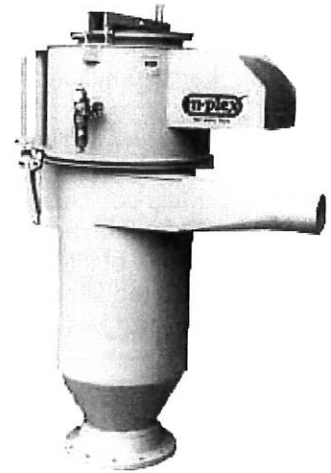


*Best of Technology*

**CYCLONE FILTER  
MODEL CF**

### **Proven Design**

The flange-mount Cyclone-Filter is a member of the proven M-PLEX Mono-Filter Series of Self-Cleaning Cartridge Filter Systems. The Cyclone-Filter includes a single, self-cleaning cartridge filter incorporated in a cyclonic separator to provide compact, central filtered venting for dry bulk material processing.

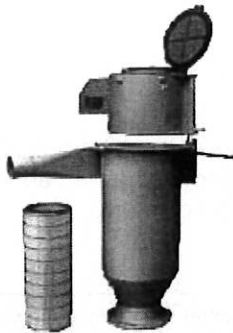


### **Efficient Filter Cleaning-Assured Process Air-Flow**

Efficient Multi-Jet cleaning of material from the segmented bore filter assures free flow of process air. Non-electric, pneumatic timed filter cleaning is by 45/65 psi air in multiple overlapping jets. This results in low residual flow drag across the filter and reliable discharge of high quality filtered air.

### **Exclusive Filter Guard**

For positive pressure systems, the Filter Guard pressure relief vents air and solids to atmosphere in case of system overfilling or abnormal surging. This desirable feature provides an extra margin to process control and filter life.



### **Swing-Away Top Housing - Easy to Maintain**

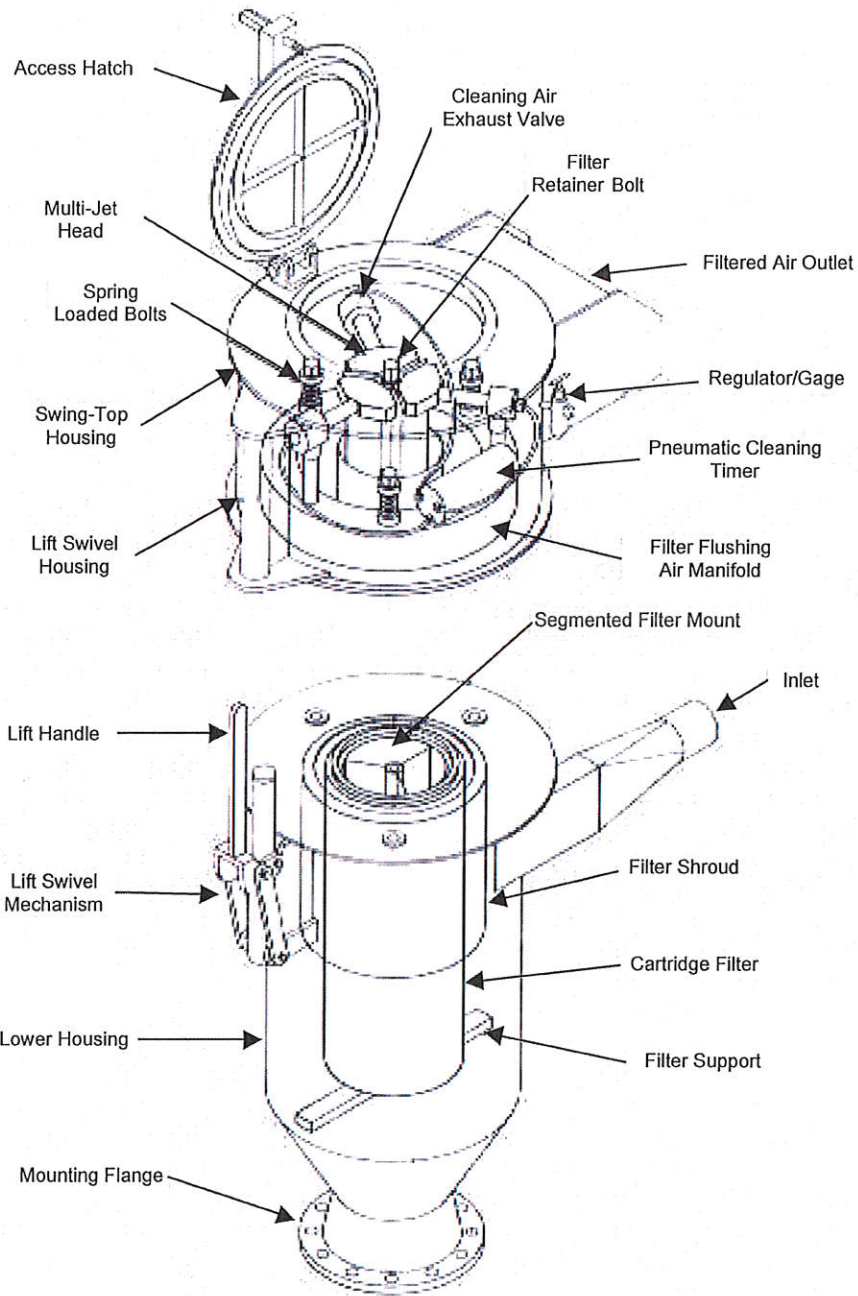
Swing-away of the top housing provides convenient access for servicing the cartridge filter. The filter is vertically lifted and may be bagged during removal from the lower housing. This feature permits impressive maintenance time savings when compared to conventional systems.

**Metroplex Products, Inc.**  
PATENTS AND PATENTS PENDING

2901 ST. LOUIS AVE. FORT WORTH, TEXAS 76110 817/923-8241

Copyright ©1988

## CYCLONE FILTER



MODEL	OVERALL HEIGHT	NOMINAL DIAMETER	MAXIMUM AIR FLOW	APPROX. SHIP WT.
CF-200	71"	26"	1,000 cfm	750 lb.
CF-400	90"	35 1/4"	2,000 cfm	1,100 lb.
CF-600	118"	45"	3,000 cfm	1,500 lb.
CF-800	129"	50 1/2"	4,000 cfm	1,800 lb.
CF-1000	138"	55 1/2"	5,000 cfm	2,200 lb.
CF-1200	147"	60 1/2"	6,000 cfm	2,500 lb.
CF-1400	154"	64 1/2"	7,000 cfm	2,700 lb.
CF-1600	161"	68 1/2"	8,000 cfm	2,900 lb.
CF-1800	168"	72 1/2"	9,000 cfm	3,100 lb.
CF-2000	173"	75 1/2"	10,000 cfm	3,400 lb.

CONSULT YOUR SALES REPRESENTATIVE - DIMENSIONS AND SPECIFICATIONS ARE SUBJECT TO CHANGE  
WITHOUT NOTICE. APPROXIMATE SHIPPING WEIGHT IS LESS CRATE

## I. INTRODUCTION

M-PLEX Self-Cleaning Cyclone-Filter Systems provide reliable and constant filtered venting of pneumatic transfer and blending dry bulk material processing operations.

The cyclone-filter is to be mounted onto a scavenge material reclaim tank in either a flange or ring-mount configuration. Flange-mounting is utilized whenever tank discharge is by positive pressure means. Valving between the cyclone-filter flange and the tank is required to isolate the cyclone-filter from the tank during the pressure/discharge cycle. Ring-mounting may be utilized whenever the tank discharge is by vacuum, gravity, or mechanical means. Under these conditions, isolation of the cyclone-filter from the tank for material discharge may not be required.

Each material processing vent line should be manifolded into a plant central vent line. The plant central vent line, in turn, is vented directly into the cyclone-filter inlet. When the cyclone-filter is ring-mounted, secondary or remote processes may be vented directly into the reclaim tank. In either case, the cyclone-filter provides simultaneous venting of multiple material processing operations.



## II. CYCLONE-FILTER DESCRIPTION

The cyclone-filter utilizes centrifugal force, gravity, and a self-cleaning cartridge filter to remove scavenge material from the vented air stream before discharging filtered air to atmosphere.

The cyclone inlet induces cyclonic flow to the vented air stream as it enters the cyclone-filter housing. Dust "heavies" are thrown by centrifugal force along the inside wall or the housing. Losing velocity, they spiral downward by gravity through the cyclone-filter discharge and settle in the scavenge material reclaim tank below. Dust "fines" meanwhile, remain in the vented air stream. The fines are then filtered from the vented air stream by the self-cleaning cartridge filter. Thus filtered, the vented air stream is discharged to atmosphere.

For filter cleaning, at 4/6 second intervals a jet of compressed air is automatically fired from the filter cleaning system into the segmented bore cartridge filter. This jet of cleaning air, from a quick-opening exhaust valve, is in reverse direction to the vented air stream flow. Its effect is to dislodge fines from the surface of the filter. Once dislodged, fines fall freely downward by gravity to settle with the "heavies" in the reclaim tank below.

### III. MATERIAL DISCHARGE - SCAVENGE MATERIAL RECLAIM TANK

Material can be discharged from the scavenge material reclaim tank by positive pressure, vacuum, gravity or mechanical means. For positive pressure discharge, the cyclone-filter must be isolated from the tank during the pressure/discharge cycle. Isolation can be achieved by installing a butterfly valve or similar device between the cyclone-filter's flange and the tank.

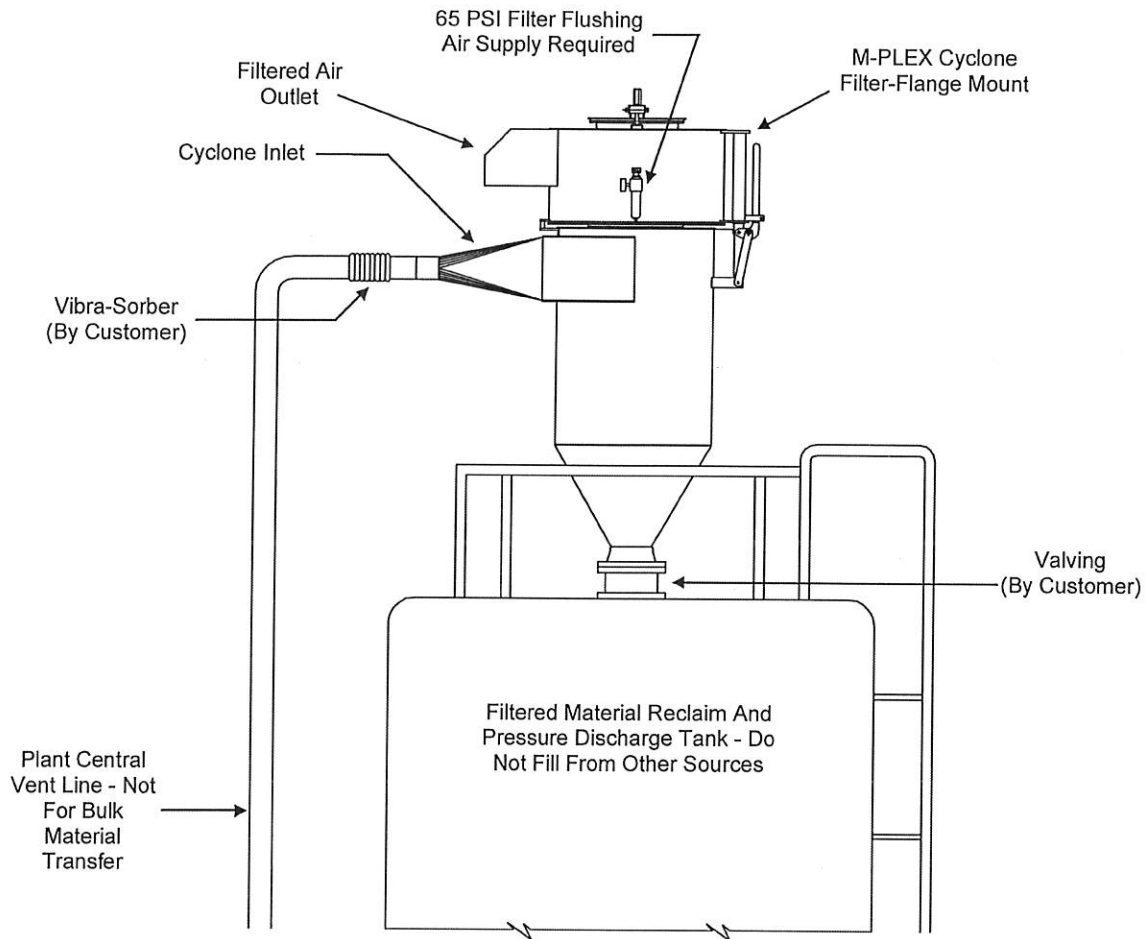
For vacuum, gravity, or mechanical discharge, isolation may not be necessary. If isolation is not required, ring mounting of the cyclone-filter to the tank may be desirable.

The scavenge material reclaim tank capacity must be selected relative to the plant operating time cycle versus the tank discharge time cycle. For example, if the tank discharge cycle is to be at eight hour intervals, select a tank capacity of 1.5 times the projected reclaim material volume expected over that time cycle interval. **IMPORTANT:** Do not undersize this tank - tank overfill will likely result in material back-up into the cyclone-filter, plugging the filter and venting the pressure relief to atmosphere.



Best of Technology

CYCLONE FILTER  
MODEL CF



**FEATURES**

1. Single cartridge filter - 1,000 to 10,000 cfm.
2. High efficiency cyclonic preseparation reduces solids to air loading at filter - Extends filter life, lowers filter cleaning energy requirements.
3. Final filtration utilizes self-cleaning cartridge filter element. No visible discharge emissions.
4. Swing-away top housing provides convenient access for servicing filter.
5. Filter Guard pressure relief vents air and solids to atmosphere in case of system overfill or abnormal surging. Consult MPI for cracking pressure limits.
6. Standard finish - Prime coat.
7. Fan and motor drive, optional. Consult MPI.
8. Proper operation requires continuous material discharge from Cyclone Filter. Do not retain material in Cyclone Filter housing or cone.
9. Safe installation requires M-PLEX Filter Systems to be securely anchored. Allowances in the anchor base, mounting structure, and all support members should be made for material and wind loadings, total system operating weight, and other induced stresses and loadings. **WARNING:** When rigging M-PLEX Filter Systems, use clevises, not hooks - Use all lifting lugs.
10. Securely attach all components and seal against leakage.
11. This product in any form is not for filtering explosive or hazardous solids-gases.
12. Refer to M-PLEX Manual MP-361 for complete M-PLEX Filter System Guidelines, Limitations, and Safety Precautions.

# Section 8

## Map(s)

---

See Attached Figure 8-1 for Vicinity Map of Schlumberger Hobbs District facility, showing surrounding industrial area.