AP-42 13.2.3

Background Documentation for AP-42
Section ~~11.2.4~~

Heavy Construction Operations
Draft Report

For Emission Inventory Branch
Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency

EPA Contract No. 68-D0-0123
Work Assignment No. 44

MRI Project No. 9712-44

April 2, 1993

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For Emission Inventory Branch
Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

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NOTICE

This document is a preliminary draft. It has not been formally released by the U.S. Environmental Protection Agency and should not at this stage be construed to represent Agency policy. It is being circulated for comments on its technical merit and policy implications.

PREFACE

This draft report was prepared for Mr. Dennis Shipman of the Emission Inventory Branch, Technical Support Division, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, under EPA Contract No. 68-D0-0123, Work Assignment No. I-44. This report describes the background and revision of AP-42 Section 11.2.4, "Heavy Construction Operations." Midwest Research Institute's Project Leader for the assignment is Dr. Gregory E. Muleski. Mr. Brian Henk and Dr. Muleski prepared this report.

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April 2, 1993

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SECTION 1

INTRODUCTION

The document "Compilation of Air Pollutant Emissions Factors" (AP-42) has been published by the U.S. Environmental Protection Agency (EPA) since 1972. Supplements to AP-42 have been routinely published to add new emission source categories and to update existing emission factors. AP-42 is routinely updated by EPA to respond to new emission factor needs of EPA, state, and local air pollution control programs and industry.

An emission factor relates the quantity (weight) of pollutants emitted to a unit of activity of a specified type of source. The uses for the emission factors reported in AP-42 include:

1. Estimates of emissions for a specific type of source facility.
2. Estimates of areawide emissions associated with a particular type of activity.
3. Evaluation of emissions relative to ambient air quality.

The purpose of this report is to provide background information from test reports and other information to support the revision of AP-42 Section 11.2.4, "Heavy Construction Operations."

The principal pollutant of interest in this report is "particulate matter" (PM), with special emphasis placed on "PM-10"—particulate matter no greater than 10 μmA (microns in aerodynamic diameter). PM-10 forms the basis for the current National Ambient Air Quality Standards (NAAQSs) for particulate matter.

PM-10 thus represents the size range of particulate matter that is of the greatest regulatory interest. Nevertheless, formal establishment of PM-10 as the standard basis is relatively recent, and many emission tests have referenced other particle size ranges. Other size ranges employed in this report are:

TSP Total Suspended Particulate, as measured by the standard high-volume (hi-vol) air sampler. TSP was the basis for the previous NAAQSs for particulate matter. TSP consists of a relatively coarse particle size fraction. While the particle capture characteristics of the hi-vol sampler are dependent upon approach wind velocity, the effective D50 (i.e., 50% of the particles are captured and 50% are not) varies roughly from 20 to 50 µmA.

SP Suspended Particulate, which is often used as a surrogate for TSP, defined as PM no greater than 30 µmA. SP also may be denoted as "PM-30."

IP Inhalable Particulate, defined as PM no greater than 15 µmA. Throughout the late 1970s and the early 1980s, it was clear that EPA intended to revise the NAAQSs to reflect a particle size range finer than TSP. What was not clear was the size fraction that would be eventually used, with values between 7 and 15 µmA frequently mentioned. Thus, many field studies were conducted using IP emission measurements because it was believed that IP would be the basis for the new NAAQSs. IP may also be represented by "PM-15."

FP Fine Particulate, defined as PM no greater than 2.5 µmA. FP also may be denoted as "PM-2.5."

This background report consists of five sections. Section 1 includes the introduction to the report. Section 2 gives a description of the heavy construction industry. It includes a characterization of the industry, an overview of the different process types, a description of emissions, and a description of the technology used to control emissions resulting from heavy construction operations. Section 3 is a review of emissions data collection and analysis procedures. It describes the literature search, the screening of emission data reports, and the quality rating system for both emission data and emission factors. Section 4 details the development of pollutant emission factors for the draft AP-42 section. It includes the review of specific data sets and the results of data analysis. Section 5 presents the AP-42 Section 11.2.4, Heavy Construction Operations.

SECTION 2

INDUSTRY DESCRIPTION

Heavy construction operations generally involve the erection of a building(s), single- or multifamily homes, or the installation of a road right-of-way. The Standard Industrial Classification (SIC) Code for heavy construction contractors is 1629. There is currently no Source Classification Code (SCC) for the industry. Operations commonly found in construction projects include land clearing, drilling and blasting, excavation, cut-and-fill operations (i.e., earthmoving), materials storage and handling, and associated truck traffic on unpaved roads.

2.1 CHARACTERIZATION OF THE INDUSTRY

There are approximately 2.0 million institutions in the United States operating within the various construction industries or as land subdividers and developers. These establishments accounted for nearly $605 billion in total value of business done in 1987.[1] California establishments had $88 billion in value of business done, 15% of the total. The second highest state totals were $39 billion for New York and $38 billion for Texas. Regionally speaking, the South generated the highest value of construction work with $205 billion, or 34% of the total dollar value. Table 2-1 displays the highest values of construction business done in each region by state (location of establishment).

TABLE 2-1. DOLLAR VALUE OF CONSTRUCTION BUSINESS DONE BY GEOGRAPHIC AREA AND STATE: 1987[a] (THOUSANDS)

Geographic area	State[b]	Dollar value of business done
Northeast		134,380,712
	New York	38,961,146
	Pennsylvania	27,392,699
	New Jersey	24,289,173
South		204,673,036
	Texas	38,068,185
	Florida	37,542,961
	Maryland	19,578,087
Midwest		121,278,910
	Illinois	26,212,664
	Ohio	21,119,999
	Michigan	17,255,267
West		144,713,317
	California	87,984,753
	Arizona	11,918,255
	Washington	10,740,896

[a] Reference 1.

[b] States listed had the highest dollar value totals in the geographic area.

In addition, over 6.7 billion worker hours were spent on construction operations in 1987. The South accounted for 2.6 billion hours, or 38% of the total. Table 2-2 displays the number of construction worker hours by geographic area.

TABLE 2-2. CONSTRUCTION WORKER HOURS BY GEOGRAPHIC AREA: 1987[a] (THOUSANDS)

Geographic area	Construction worker hours
Northeast	1,484,410
Midwest	1,386,902
South	2,558,976
West	1,313,274

[a] For establishments with payroll.

2.2 PROCESS DESCRIPTION

Heavy construction typically consists of several major "units" or "phases": demolition debris removal, site preparation, and construction of the particular facility or road.[2,3] These phases can in turn be broken down into even finer subdivisions of tasks or activities. Contractors use these activities in planning/scheduling tools such as CPM (critical path method) or PERT (Program Evaluation and Review Technique) to allocate equipment or personnel resources.

During the demolition/debris removal phase, debris handling and truck transport of material take place. Debris from any previously existing man-made or natural obstruction is collected and removed from the construction site. This can include removal of debris from implosion or mechanical dismemberment of a building in addition to blasting of rock formations. Bulldozers are used for land-clearing operations to remove brush and small trees.

During the second phase of construction (site preparation), the ground surface at the site is brought to final or near-final grade. This phase includes activities such as cut and fill operations as well as the transport of cut material off-site and the carrying of "foreign" fill materials onto the site. Cut and fill operations generally consist of two practices: bulldozing and pan scraping. During both of these operations, material is removed (cut) from higher portions of the work area and then transported to lower areas where material is deposited (filled) to establish the prescribed grade. Other material may be trucked on- and off-site as may be needed to achieve the final grade.

Once a site has been prepared, numerous other activities can occur. Construction of a facility or road can include such activities as building forms, spreading aggregate materials, bringing in or mixing concrete or asphalt on-site, reinforcing and structural steel operations, interior finishing, and landscaping. This third phase of the construction can consist of many more and different activities than the first two phases. Again, contractors usually define individual tasks and their interrelationships for scheduling purposes.

2.3 EMISSIONS

Emissions from heavy construction operations consist primarily of particulate matter ("dust") and occur during all phases of the construction process. Dust emissions vary substantially from day to day depending on what are the current operations, the levels of activity for those operations, and the prevailing meteorological conditions. A large portion of the emissions result from equipment traffic over temporary roads at the construction site. In addition, high wind events can lead to emissions from cleared land and material stockpiles.

Section 11.2 of AP-42 has contained an entry on the subject of construction activities since 1975.[4,5] However, unlike the other subsections in Section 11.2, the construction entry has not been substantially revised since its original inclusion. The TSP emission factor of

$$e = 1.2 \text{ tons/acre/month}$$

dates from a series of limited field tests conducted at two sites during 1972.[4,5] (The test reports are discussed in greater detail in Section 4 of this report.) A later review of these field data[6] found that the conversion of the derived emission rate is based on at least a tacit assumption that emissions occur 24 h every day of the week.

2.4 CONTROL TECHNOLOGY

Because of the relatively short-term nature of construction, fugitive dust control measures at construction sites can vary substantially from those utilized at more permanent sites.[3,7] In general, controls that are easily implemented at different locations within the site (such as water sprays or portable wind breaks) tend to be more cost-effective than more durable controls (such as chemical stabilization or paving of unpaved travel rates). Wet suppression and wind speed reduction are two common methods used to control open dust sourc at construction sites because material for wind barriers and a source of water tend to readily available on a construction site. However, several other forms of dust control are also available. Table 2-3 displays the generally recommended control measures by dust source.[7]

TABLE 2-3. CONTROL OPTIONS[a] FOR GENERAL CONSTRUCTION OPEN SOURCES OF PM-10

Emission source	Recommended control method(s)
Debris handling	Wind speed reduction Wet suppression[b]
Truck transport[c]	Wet suppression Paving Chemical stabilization[d]
Bulldozers	Wet suppression[e]
Pan scrapers	Wet suppression of travel routes
Cut/fill material handling	Wind speed reduction Wet suppression
Cut/fill haulage	Wet suppression Paving Chemical stabilization
General construction	Wind speed reduction Wet suppression Early paving of permanent roads

[a] Reference 2.

[b] Dust control plans should contain precautions against watering programs that confound trackout problems.

[c] Loads could be covered to avoid loss of material in transport, especially if material is transported off-site.

[d] Chemical stabilization is usually cost-effective for relatively long-term or semipermanent unpaved roads.

[e] Excavated materials may already be moist and not require additional wetting. Furthermore, most soils are associated with an "optimum moisture" for compaction.

SECTION 3

GENERAL DATA REVIEW AND ANALYSIS

3.1 LITERATURE SEARCH AND SCREENING

The data review for this study began with a literature and source test search. Several information sources within the EPA and outside organizations were used for the review. The AP-42 Background Files were consulted to provide information on both the industry and the current emission factors for heavy construction. Data base searches included review of information on both the Crosswalk/Air Toxic Emission Factor Data Base Management System (XATEF) and the VOC/PM Speciation Data Base Management System (SPECIATE) in an effort t locate SCC codes and emission factors related to heavy construction. EPA's Air Chief Bulletin Board System was used for general air emission background information.

Information on the construction industry, including dollar values of business done and construction worker hours, were obtained from the *1987 Census of Construction Industries, United States Summary*.[1] A search for new emission test reports and data was done using the Environline on-line catalog.

To reduce the amount of literature collected to a final group of references from which emission factors could be developed, the following general criteria were used:

1. Emissions data must be from a primary reference:

   a. Source testing must be from a referenced study that does not merely repeat information from previous studies.

   b. The document must constitute the original source of test data. For example, a technical paper was not included if the original study was contained in the previous document. If the exact source of the data could not be determined, the document was eliminated.

2. The referenced study must contain test results based on more than one test run.

3. The report must contain sufficient data to evaluate the testing procedures and source operating conditions.

A final set of reference materials was compiled after a thorough review of the pertinent reports, documents, and information according to these criteria.

3.2 EMISSION DATA QUALITY RATING SYSTEM

As part of the analysis of the emission data, the quantity and quality of the information contained in the final set of reference documents were evaluated. The following data were excluded from consideration:[8]

1. Test series averages reported in units that cannot be converted to the selected reporting units.

2. Test series representing incompatible test methods (i.e., comparison of EPA Method 5 front-half with EPA Method 5 front- and back-half).

3. Test series of controlled emissions for which the control device is not specified.

4. Test series in which the source process is not clearly identified and described.

5. Test series in which it is not clear whether the emissions were measured before or after the control device.

Test data sets that were not excluded were assigned a quality rating. The rating system used was that specified by EIB for preparing AP-42 sections.[8] The data were rated as follows:

A Multiple tests that were performed on the same source using sound methodology and reported in enough detail for adequate validation. These tests do not necessarily conform to the methodology specified in EPA reference test methods, although these methods were used as a guide for the methodology actually used.

B Tests that were performed by a generally sound methodology, but lacked enough detail for adequate validation.

C Tests that were based on an untested or new methodology or that lacked a significant amount of background data.

D Tests that were based on a generally unacceptable method but may provide an order-of-magnitude value for the source.

The following criteria were used to evaluate source test reports for sound methodology and adequate detail.

1. *Source operation.* The manner in which the source was operated is well documented in the report. The source was operating within typical parameters during the test.

2. *Sampling procedures.* The sampling procedures conformed to a generally acceptable methodology. If actual procedures deviated from accepted methods, the deviations are well documented. When this occurred, an evaluation was made of the extent such alternative procedures could influence the test results.

3. *Sampling and process data.* Adequate sampling and process data are documented in the report, and any variations in the sampling and process operation are noted. If a large spread between test results cannot be explained by information contained in the test report, the data are suspect and were given a lower rating.

4. *Analysis and calculations.* The test reports contain original raw data sheets. The nomenclature and equations used were compared to those (if any) specified by EPA to establish equivalency. The depth of review of the calculations was dictated by the reviewer's confidence in the ability and conscientiousness of the tester, which in turn was based on factors such as consistency of results and completeness of other areas of the test report.

3.3 EMISSION FACTOR QUALITY RATING SYSTEM[8]

The quality of the emission factors developed from analysis of the test data was rated utilizing the following general criteria.

A, Excellent — Developed only from A-rated test data taken from many randomly chosen facilities in the industry population. The source category is specific enough so that variability within the source category population may be minimized.

B, Above average	Developed only from A-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industries. The source category is specific enough so that variability within the source category population may be minimized.
C, Average	Developed only from A- and B-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. In addition, the source category is specific enough so that variability within the source category population may be minimized.
D, Below average	The emission factor was developed only from A- and B-rated test data from a small number of facilities, and there is reason to suspect that these facilities do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of the emission factor are noted in the emission factor table.
E, Poor	The emission factor was developed from C- and D-rated test data, and there is reason to suspect that the facilities tested do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of these factors are always noted.

The use of these criteria is somewhat subjective and depends to an extent on the individual reviewer.

3.4 METHODS OF EMISSION FACTOR DETERMINATION

Fugitive dust emission rates and particle size distributions are difficult to quantify because of the diffuse and variable nature of such sources and the wide range of particle size involved including particles which deposit immediately adjacent to the source. Standard source testing methods, which are designed for application to confined flows under steady state, forced-flow conditions, are not suitable for measurement of fugitive emissions unless the plume can be draw into a forced-flow system. The following presents a brief overview of applicable measurement techniques. More detail can be found in earlier AP-42 updates.[9,10]

3.4.1 Mass Emission Measurements

Because it is usually impractical to enclose an open dust source or to capture the entire emissions plume, only the upwind-downwind and exposure profiling methods are generally suitable for measurement of particulate emissions from most open dust sources.[9] These two methods are discussed separately below.

The basic procedure of the upwind-downwind method involves the measurement of particulate concentrations both upwind and downwind of the pollutant source. The number of upwind sampling instruments depends on the degree of isolation of the source operation of concern (i.e., the absence of interference from other sources upwind). Increasing the number of downwind instruments improves the reliability in determining the emission rate by providing better plume definition. In order to reasonably define the plume emanating from a point source, instruments need to be located at two downwind distances and three crosswind distances, at a minimum. The same sampling requirements pertain to line sources except that measurement need not be made at multiple crosswind distances.

Net downwind (i.e., downwind minus upwind) concentrations are used as input to dispersion equations (normally of the Gaussian type)[11] to backcalculate the particulate emission rate (i.e., source strength) required to generate the pollutant concentration measured. Emission factors are obtained by dividing the calculated emission rate by a source activity rate (e.g., number of vehicles, or weight of material transferred per unit time). A number of meteorological parameters must be concurrently recorded for input to this dispersion equation. At a minimum the wind direction and speed must be recorded on-site.

While the upwind-downwind method is applicable to virtually all types of sources, it has significant limitations with regard to development of source-specific emission factors. The major limitations are as follows:

1. In attempting to quantify a large area source, overlapping of plumes from upwind (background) sources may preclude the determination of the specific contribution of the area source.

2. Because of the impracticality of adjusting the locations of the sampling array for shifts in wind direction during sampling, it cannot be assumed that plume position is fixed in the application of the dispersion model.

3. The usual assumption that an area source is uniformly emitting does not allow for realistic representation of spatial variation in source activity.

4. The typical use of uncalibrated atmospheric dispersion models introduces the possibility of substantial error (a factor of three according to Reference 11) in the calculated emission rate, even if the stringent requirement of unobstructed dispersion from a simplified (e.g., constant emission rate from a single point) source configuration is met.

The other measurement technique, exposure profiling, offers distinct advantages for source-specific quantification of fugitive emissions from open dust sources. The method uses the isokinetic profiling concept that is the basis for conventional (ducted) source testing. The passage of airborne pollutant immediately downwind of the source is measured directly by means of simultaneous multipoint sampling over the effective cross section of the fugitive emissions plume. This technique uses a mass-balance calculation scheme similar to EPA Metho

5 stack testing rather than requiring indirect calculation through the application of a generalized atmospheric dispersion model.

For measurement of nonbuoyant fugitive emissions, profiling sampling heads are distributed over a vertical network positioned just downwind (usually about 5 m) from the source. If total particulate emissions are to be measured, sampling intakes are pointed into the wind and sampling velocity is adjusted to match the local mean wind speed, as monitored by anemometers distributed over height above ground level.

The size of the sampling grid needed for exposure profiling of a particular source may be estimated by observation of the visible size of the plume or by calculation of plume dispersion. Grid size adjustments may be required based on the results of preliminary testing. Particulate sampling heads should be symmetrically distributed over the concentrated portion of the plume containing about 90% of the total mass flux (exposure). For example, assuming that the exposure from a point source is normally distributed, the exposure values measured by the samplers at the edge of the grid should be about 25% of the centerline exposure.[9]

To calculate emission rates using the exposure profiling technique, a conservation of mass approach is used. The passage of airborne particulate (i.e., the quantity of emissions per unit of source activity) is obtained by spatial integration of distributed measurements of exposure (mass/area) over the effective cross section of the plume. The exposure is the point value of the flux (mass/area/time) of airborne particulate integrated over the time of measurement.[9]

3.4.2 Emission Factor Derivation

Usually the final emission factor for a given source operation, as presented in a test report, is derived simply as the arithmetic average of the individual emission factors calculated from each test of that source. Frequently the range of individual emission factor values is also presented.

As an alternative to the presentation of a final emission factor as a single-valued arithmetic mean, an emission factor may be presented in the form of a predictive equation derived by regression analysis of test data. Such an equation mathematically relates emissions to parameters when characterize source conditions. These parameters may be groupe into three categories:

1. Measures of source activity or energy expended (e.g., the speed and weight of a vehicle traveling on an unpaved road).

2. Properties of the material being disturbed (e.g., the content of suspendable fines in the surface material on an unpaved road).

3. Climatic parameters (e.g., number of precipitation-free days per year on which emissions tend to be at a maximum).

An emission factor equation is useful if it is successful in "explaining" much of the observed variance in emission factor values on the basis of corresponding variance sin specific source parameters. This enables more reliable estimates of source emissions on a site-specific basis.

A generic emission factor equation is one that is developed for a source operation defined on the basis of a single dust generation mechanism which crosses industry lines. An example would be vehicular traffic on unpaved roads. To establish its applicability, a generic equation should be developed from test data obtained in different industries.

3.5 EMISSION FACTOR QUALITY RATING SCHEME USED IN THIS STUDY

The uncontrolled emission factor quality rating scheme used in this study is identical to that used in two earlier updates[9,10] and represents a refinement of the rating system developed by EPA for AP-42 emission factors, as described in Section 3.3. The scheme entails the rating of test data quality followed by the rating of the emission factor(s) developed from the test data.

Test data that were developed from well documented, sound methodologies were assigned an A rating. Data generated by a methodology that was generally sound but either did not meet a minimum test system requirements or lacked enough detail for adequate validation received a B rating.

In evaluating whether an upwind-downwind sampling strategy qualified as a sound methodology, the following minimum test system requirements were used. At least five particulate measuring devices must be operated during a test, with one device located upwind and the other located at two downwind and three crosswind distances. The requirement of measurements at crosswind distances is waived for the case of line sources. Also wind direction and speed must be monitored concurrently on-site.

The minimum requirements for a sound exposure profiling program were the following. A one-dimensional, vertical grid of at least three samplers is sufficient for measurement of emissions from line or moving point sources while a two-dimensional array of at least five samplers is required for quantification of fixed virtual point source missions. At least one upwind sampler must be operated to measure background concentration, and wind speed must b measured on-site.

Neither the upwind-downwind nor the exposure profiling method can be expected to produce A-rated emissions data when applied to large, poorly defined area sources, or under very light and variable wind flow conditions. In these situations, data ratings based on degree of compliance with minimum test system requirements were reduced one level (letter).

After the test data supporting a particular single-valued emission factor were evaluated, the criteria presented in Table 3-1 were used to assign a quality rating to the resulting emission factor. These criteria were developed to provide objective definition for: (a) industry representativeness; and (b) levels of variability within the data set for the source category. The rating system obviously does not include estimates of statistical confidence, nor does it reflect the expected accuracy of fugitive dust emission factors relative to conventional stack emission factors. It does, however, serve as useful tool for evaluation of the quality of a given set of emission factors relative to the entire available fugitive dust emission factor data base.

TABLE 3-1. QUALITY RATING SCHEME FOR SINGLE-VALUED EMISSION FACTORS

Code	No. of test sites	No. of tests per site	Total No. of tests	Test data variability[a]	Adjustment for EF rating[b]
1	≥ 3	≥ 3	–	< F2	0
2	≥ 3	≥ 3	–	> F2	−1
3	2	≥ 2	≥ 5	< F2	−1
4	2	≥ 2	≥ 5	> F2	−2
5	–	–	≥ 3	< F2	−2
6	–	–	≥ 3	> F2	−3
7	1	2	2	> F2	−3
8	1	2	2	> F2	−4
9	1	1	1	–	−4

[a] Data spread in relation to central value. F2 denotes factor of two.

[b] Difference between emission factor rating and test data rating.

Minimum industry representativeness is defined in terms of number of test sites and number of tests per site. These criteria were derived from two principles:

1. Traditionally, three tests of a source represent the minimum requirement for reliable quantification.

2. More than two plant sites are needed to provide minimum industry representativeness.

The level of variability within an emission factor data set was defined in terms of the spread of the original emission factor data values about the mean or median single-valued factor for the source category. The fairly rigorous criterion that all data points must lie within a factor of two of the central value was adopted. It is recognized that this criterion is not insensitive to sample size in that for a sufficiently large test series, at least one value may be expected to fall outside the factor-of-two limits. However, this is not considered to be a problem because most of the current single-valued factors for fugitive dust sources are based on relatively small sample sizes.

Development of quality ratings for emission factor equations also required consideration of data representativeness and variability, as in the case of single-valued emission factors. However, the criteria used to assign ratings (Table 3-2) were different, reflecting the more sophisticated model being used to represent the test data. As a general principle, the quality rating for a given equation should lie between the test data rating and the rating that would assigned to a single-valued factor based on the test data. The following criteria were established for an emission factor equation to have the same rating as the supporting test data:

1. At least three test sites and three tests per site, plus an additional three tests for each independent parameter in the equation.

2. Quantitative indication that a significant portion of the emission factor variation is attributable to the independent parameter(s) in the equation.

Loss of quality rating in the translation of these data to an emission factor equation occurs when these criteria are not met. In practice, the first criterion was far more influential than the second in rating an emission factor equation, because development of an equation implies that a substantial portion of the emission factor variation is attributable to the independent parameter(s). As indicated in Table 3-2, the rating was reduced by one level below the test data rating if the number of tests did not meet the first criterion, but was at least three times greater than the number of independent parameters in the equation. The rating was reduced two levels if this supplementary criterion was not met.

TABLE 3-2. QUALITY RATING SCHEME FOR EMISSION FACTORS EQUATIONS

Code	No. of test sites	No. of tests per site	Total No. of tests[a]	Adjustment for EF rating[b]
1	≥ 3	≥ 3	≥ (9 + 3P)	0
2	≥ 2	≥ 3	≥ 3P	-1
3	≥ 1	-	< 3P	-1

[a] P denotes number of correction parameters in emission factor equation.

[b] Difference between emission factor rating and test data rating.

The rationale for the supplementary criterion follows from the fact that the likelihood of including "spurious" relationships between the dependent variable (emissions) and the independent parameters in the equation increases as the ratio of number of independent parameters to sample size increases. For example, a four parameter equation based on five tests would exhibit perfect explanation ($R^2 = 1.0$) of the emission factor data, but the relationships expressed by such an equation cannot be expected to hold true in independent applications.

SECTION 4

AP-42 SECTION DEVELOPMENT

4.1 REVISIONS TO SECTION NARRATIVE

The draft AP-42 section described in Section 5 of this report is an update of Section 11.2.4, "Heavy Construction," in the current version of AP-42. The section, which has not been revised to any substantive extent from its development in 1975, provides a single TSP emission factor to be used for an entire construction operation from start to end. Although the emission factor is useful and convenient for developing areawide emissions as described in Section 1, this factor can easily be considered suspect due to its age, its implicit assumption of 24-h/day and 30-day/mo source activity, and its basis on a coarser particle size range than PM-10. In other words, the existing factor is useful for providing conservatively high emission estimates for broad geographic areas of interest. However, the existing factor cannot be expected to yield very accurate estimates for a specific site for which the AP-42 user wishes to obtain a reasonably detailed inventory for control planning purposes.

In most cases, the general contractor for a construction project will have identified individual tasks for input to a working plan or schedule which estimates the amount of time spent as well as how many pieces of equipment will be used to complete certain portions of the construction. The draft replacement section presents an alternative approach based on individual tasks that consider the more basic component-dust sources of vehicle travel and material handling. That is to say, the user is asked to view a construction project as consisting of several operations, determine what traffic and material movements are required for each operation, and then use appropriate emission factors to estimate emissions for the associated traffic and material movements.

4.2 POLLUTANT EMISSION FACTOR DEVELOPMENT

A literature search was conducted in the update of Section 11.2.4. The information contained in the background file for the current version of Section 11.2.4 was re-evaluated. One additional document, which contained emission data for road construction, was documented and reviewed below for use in the revision. Table 4-1 presents the emission test reports reviewed. In addition, the SPECIATE and XATEF data systems were searched.

TABLE 4-1. APPLICABLE TEST REPORTS

Test Report I Jutze, G. A., K. Axetell, Jr., and W. Parker. *Investigation of Fugitive Dust-Sources Emissions and Control.* EPA-450/3-74-036a, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. June 1974.
Test Report II Cowherd, C., Jr., K. Axetell, Jr., C. M. Guenther, and G. A. Jutze. *Development of Emissions Factors for Fugitive Dust Sources.* EPA-450/3-74-037, Kansas City, Missouri. Prepared for U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. June 1974.
Test Report III Kinsey, J. S., P. Englehart, and A. L. Jirik. *Study of Construction Related Dust Control.* Prepared for Minnesota Pollution Control Agency, MRI Project No. 7498-L. April 1983.

4.2.1 Review of AP-42 Background File and Other Test Data

The present version of Section 11.2.4, Heavy Construction, contains one emission factor for fugitive emissions from construction sites. This factor is based on data from tests done in Phoenix, Arizona, and Las Vegas, Nevada. The following is a review of the data that support the emission factor.

4.2.1.1 Test Report I--

The study was performed in order to determine fugitive dust sources that impose a major impact on particulate levels, while examining control techniques and regulatory programs that could result in attainment of air quality standards. Phase I identified sites and developed methodologies for sampling. Phase II involved the data collection at the seven sites determined in Phase I, and heavy construction emissions were monitored at two of the seven sites, namely, Paradise Valley in Phoenix, Arizona, and a construction site in Las Vegas, Nevada.

Sampling techniques were not described in the test report, rather these procedures were explained in the Phase I report. Sampling was conducted during 32 periods between August 21 and October 22, 1972. Emission rates from the construction sites were calculated from upwind/downwind air quality measurements using the Pasquill-Gifford diffusion equation for ground-level sources. Upwind high-volume readings were subtracted from downwind measurements to isolate the fugitive dust contribution of the construction site. Under acceptable wind conditions, an average emission factor of 1.0 ton/acre of construction per month of activity was determined at the Las Vegas test site. For the Phoenix test site, an average value of 1.4 ton/acre of construction per month of activity was found.

4.2.1.2 Test Report II--

Test Report II, prepared for the EPA, further analyzed the dust emission data from Test Report I. All conclusions in the report are based on the data collected from conventional high volume samplers located at the two sites, namely, Paradise Valley in Phoenix, Arizona, and a construction area in Las Vegas, Nevada.

Test Report II provides more specific information about the testing than does Test Report I. To account for the emissions generated from diffuse and variable operations, the samplers were operated for 24-h periods. Six samplers were located in the area of the Paradise Valley site, and samples were collected between August 31 and October 22, 1972. Construction activity levels on the site were recorded daily. Data from four of the samplers were used estimate the airborne particulate contribution from the construction activity.

Average concentration levels were recorded at each station, and dispersion equation calculations were performed to generate an emission factor of 1.4 ton/acre of construction per month of activity. Data were insufficient to quantify the relationship of source emissions with activity level.

Five samplers were stationed at the Las Vegas construction site, and testing was performed from August 21 to October 22, 1972. Data from four stations were used to estimate the airborne particulate contribution from the construction site to be 1.0 ton/acre of construction per month of activity. Activity levels at the site were recorded. However, data were again insufficient to quantify the relationship of source emissions with the activity level.

The average of the two factors, 1.2 tons/acre of construction per month of activity, was recommended for estimating emissions in arid areas with watering for dust control.

4.2.1.3 Test Report III--

This report describes a field testing program conducted to "determine the overall impact of construction-related fugitive dust on the air quality of a typical urban area." Testing employed high-volume air samplers (hi-vols) to characterize ambient concentrations immediately downwind of a road construction project near Minneapolis-St. Paul. A secondary goal of the program dealt with quantifying effectiveness of watering as a control measure. Topsoil removal, earthmoving, and truck haulage were listed as the emission sources.

The program deployed identical sampling arrays on both sides of the east-west oriented right-of-way. A standard hi-vol and a hi-vol fitted with a size-selective inlet or "SSI" (with an effective 50% cutpoint of 15 µm in aerodynamic diameter) were positioned at 25 and 50 m distances both upwind and downwind from the roadway. Each SSI served as a preseparato for a five-stage cascade impactor. Each sampler was equipped with a mass flow controller. Directional wind activators controlled the sampling equipment, turning samplers on whenever the wind direction was within 67.5 degrees from perpendicular to the right-of-way. Additional meteorological equipment was also deployed to monitor wind speed and direction.

It is important to realize that, as originally conceived, the field program was designed to produce a near-field air concentration model rather than emission factors. Nevertheless, the final report employed the upwind-downwind technique to determine the TSP emission factors summarized in Table 4-2. These emission factors were subsequently combined with near-field (i.e., 25 m downwind of the source) particle size data to develop the so-called "gap filling" approach described in Reference 12:

TABLE 4-2. MEAN EMISSION FACTORS[a]

Source	PM-10 emission factor	
	kg/VKT	lb/VMT
Topsoil removal by scrapers	5.7	20
Earthmoving (scraper travel)	1.2	4.3
Truck haulage over unpaved surfaces	2.8	10

[a] Based on Reference 12's reanalysis of data presented in Test Report III. Emission factors expressed in terms of kilograms per vehicle-kilometer-traveled (pounds per vehicle-mile-traveled).

In general, Test Report III is well documented in terms of describing test conditions, sampling methodology, data reduction, and analysis. A principal limitation lies in the fact that the sampling configuration did not fully meet minimum requirements for the upwind-downwind method presented in Section 3.4. Specifically, only two samplers of each type were used downwind rather than the minimum of four.

In addition, the test report noted several experimental factors outside the test crew's control, namely:

- Inability to establish watering schedule.

- Heavy equipment bypassing the controlled areas by traveling over uncontrolled shoulders.

- Relative imbalance between number of controlled and uncontrolled tests.

The test report also noted that some simplifying assumptions were made in the after-the-fact emission factor determination. Because of these limitations, the emission factor data have been given an overall rating of between "B" and "C."

4.2.2 Review of XATEF and SPECIATE Data Base Emission Factors

No emission factors specifically referenced to heavy construction were located on either XATEF or SPECIATE data base systems. Additional inquiries were made, using keywords taken from common task descriptions at construction sites. Table 4-3 summarizes the results of these interrogations. Probably the most important feature to note about the results is the similarity between several construction and surface coal mining operations.

TABLE 4-3. RESULTS FROM XATEF AND SPECIATE STUDIES

Keyword	Results
Drilling	Three factors from surface coal mining
Blasting	Two factors from surface coal mining, one from stone quarrying
Bulldozing	Two factors from coal mining
Scraper	Three factors from surface coal mining
Unloading, crushing, grinding, screening	Several factors from food/agricultural, metals, and minerals industries

4.2.3 Summary of Data Analyses

No new emission factors were developed during the revision of Section 11.2.4. Instead, the text describing the current TSP emission factor of 1.2 tons/acre/month of activity was revised to better describe the factor's utility for areawide emission inventories.

In addition, Section 11.2.4 was revised to better enable users of AP-42 to develop more site-specific emission estimates for individual construction sites. To that end, Table 11.2.4-1 was prepared to direct persons to reasonably appropriate emission factors for particular construction operations. The table also provides guidance on the quality rating of estimates obtained, based on similarity of equipment and operations. Given the results from Section 4.2.2, it is not surprising that most of the factors in Table 11.2.4-1 come from the AP-42 section on surface coal mining.

Text has also been added to alert AP-42 readers to consider the off-site effects of mud/dirt trackout from construction. Furthermore, a table summarizing viable control options for most construction sites has been included.

In many respects, the AP-42 revision presented in the next section of this report is probably best viewed as a "temporary fix." Although AP-42 has included an entry from construction-related dust emissions for almost 20 years, there has been little emission characterization work performed that is directly applicable to construction. Recognizing an increased need for more site-specific emission estimates, the need for emission testing of general earthmoving operations will be highly rated in a technical memorandum summarizing testing needs. That is, it is anticipated that further revisions (based on specific emission testing) to Section 11.2.4 will be made in the near future.