

Appendix C—Citation Threshold Values (CTV)

I. Interpretation of the CTV Table

Each CTV was calculated to ensure that, if the CTV is met or exceeded, noncompliance with the applicable dust standard can be inferred with at least 95-percent confidence. It is assumed that whatever applicable dust standard happens to be in effect at the sampling location is binding, and that a citation is warranted whenever there is sufficient evidence that an established standard has been exceeded. The CTV table does not depend on how the applicable dust standard was established, or on any measurement uncertainties in the process of setting the applicable dust standard.

The CTV table provides criteria for testing a tentative, or presumptive, hypothesis that the true single-shift average dust concentration did not exceed the applicable dust standard (S) at each of the individual locations sampled during a particular shift. For purposes of this test, the mine atmosphere at each such location is presumed to be in compliance unless the corresponding single-shift measurement provides sufficient evidence to the contrary. The “true single-shift average” does *not* refer, in this context, to an average across different occupations, locations, or shifts. Instead, it refers entirely to the dust concentration at the specific location of the sampler unit, averaged over the course of the particular shift during which the measurement was obtained. The CTV table is *not* designed to estimate or test the average dust concentration across occupational locations, or within any zone or mine area, or in the air actually inhaled by any particular miner.

The CTV table ensures that noncompliance is cited only when there is a 95-percent level of confidence that the applicable dust standard has actually been exceeded. A single-shift measurement that does not exceed the applicable CTV value, does not necessarily imply probable compliance with the applicable dust standard—let alone compliance at a 95-percent confidence level. For example, a single-shift measurement of 2.14 mg/m³ would not, according to the CTV table, indicate noncompliance with sufficient confidence to warrant a citation if S = 2.0 mg/m³. This does not imply that the mine atmosphere was in compliance on the shift and at the location sampled. On the contrary, unless contradictory evidence were available, this measurement would indicate that the MMU was probably *out* of compliance.

However, because there is a small chance that the measurement exceeded the standard only because of measurement error, a citation would not be issued. Additional measurements would be necessary to verify the apparent lack of adequate control measures. Similarly, a single-shift measurement of 1.92 mg/m³ would not warrant citation; but, because of possible measurement error, neither would it warrant concluding that the mine atmosphere sampled was in compliance. To confirm that control measures are adequate, it would be necessary to obtain additional measurements.

Furthermore, even if a single-shift measurement were to demonstrate, at a high confidence level, that the mine atmosphere was in compliance at the sampling location on a given shift, additional measurements would be required to demonstrate compliance on each shift. For example, if S = 2.0 mg/m³, then a valid measurement of 1.65 mg/m³ would demonstrate compliance on the particular shift and at the particular location sampled. It would not, however, demonstrate compliance on other shifts or at other locations.

II. Derivation of the CTV Table

To understand how the CTVs are derived and justified, it is first necessary to distinguish between variability due to measurement error and variability due to actual differences in dust concentration. The variability observed among individual measurements obtained at different locations (or at different times) combines both: dust concentration measurements vary partly because of measurement error and partly because of genuine differences in the dust concentration being measured. This distinction, between measurement error and variation in the true dust concentration, can more easily be explained by first carefully defining some notational abbreviations.

One or more dust samples are collected in the same MMU or other mine area on a particular shift. Since it is necessary to distinguish between different samples in the same MMU, let X_i represent the MRE-equivalent dust concentration measurement obtained from the i^{th} sample. The quantity being measured is the true, single-shift average dust concentration at the i^{th} sampling location and is denoted by μ_i . Because of potential measurement errors, μ_i can never be known with complete certainty. A “sample,” “measurement,” or “observation” always refers to an instance of X_i rather than μ_i .

The overall measurement error associated with an individual measurement is nothing more than the difference between the measurement (X_i) and the quantity being measured (μ_i). Therefore, this error can be represented as

$$\varepsilon_i = X_i - \mu_i.$$

Equivalently, any measurement can be regarded as the true concentration in the atmosphere sampled, with a measurement error added on:

$$X_i = \mu_i + \varepsilon_i.$$

For two different measurements (X_1 and X_2), it follows that X_1 may differ from X_2 not only because of the combined effects of ε_1 and ε_2 , but also because μ_1 differs from μ_2 .

The probability distribution of X_i around μ_i depends only on the probability distribution of ε_i and should not be confused with the statistical distribution of μ_i itself, which arises from spatial and/or temporal variability in dust concentration. This variability (*i.e.*, among μ_i for different values of i) is not associated with inadequacies of the measurement system, but real variation in exposures due to the fact that contaminant generation rates vary greatly in time and contaminants are heterogeneously distributed in workplace air.

Since noncompliance determinations are made relative to individual sampling locations on individual shifts, derivation of the CTV table requires no assumptions or inferences about the spatial or temporal pattern of atmospheric dust concentrations—*i.e.*, the statistical distribution of μ_i . MSHA is not evaluating dust concentrations averaged across the various sampler locations. Therefore, the degree and pattern of variability observed among different measurements obtained during MSHA sampling are not used in establishing any CTV. Instead, the CTV for each applicable dust standard (S) is based entirely on the distribution of measurement errors (ε_i) expected for the maximum dust concentration in compliance with that standard—*i.e.*, a concentration equal to S itself.

If control filters are used to eliminate potential biases, then each ε_i arises from a combination of four weighing errors (pre- and post-exposure for both the control and exposed filter capsule) and a continuous summation of instantaneous measurement errors accumulated over the course of an eight-hour sample. Since the eight-hour period can be subdivided into an arbitrarily large number of sub-intervals, and some fraction of ε_i is associated with each sub-interval, ε_i can be represented as comprising the sum of an