

## Notice

This Engineering Guide was recently converted to a PC format and it has not been proof read by our engineering staff. Therefore, it is subject to change at a later date.

Ohio EPA

Office of Air Pollution Control

Division of Engineering

Engineering Guide #23

Question:

In determining the allowable emission rates from Figure I of OAC rule 3745-17-10, and from Table I and Figure II of OAC rule 3745-17-11, how many significant figures should be retained? (This question was submitted by Fred Klingelhafer of the Southeast District Office on October 23, 1980).

Answer:

Only two significant figures should be retained in calculating the allowable emission rates from OAC rules 3745-17-10 and -11 because the stack test results, against which such values are compared, are only accurate to two significant figures.

In recording a measured quantity, the number of significant figures used should indicate the precision or certainty with which the quantity is known. Since there is always some degree of uncertainty associated with a measurement, it is accepted practice that all the certain digits in a measured quantity and the first estimated (or doubtful) digit are considered to be significant figures.<sup>1</sup> The last figure is significant, but possibly uncertain. In other words, the digits that are necessary to accurately define a specific value or quantity are deemed significant.<sup>2</sup> Ultimately, the number of significant figures that are required to be retained is dictated by the circumstances surrounding each case.<sup>3</sup>

Figure I of OAC rule 3745-17-10 is graphical representation of an empirical relationship that exists between the allowable emission rate (lbs/million BTU) and the total heat input (million BTU/hr.). This relationship is plotted on log-log paper, i.e., paper on which both axes (or scales) are logarithmic. The equations in the upper right-hand corner of Figure I are mathematical formulas which model the empirical data represented by the two curves. Normally, these equations should be used for the purpose of accurately

calculating the allowable emission rate from Figure I.

In using these exponential equations, the rule of multiplication of significant figures must be followed, to wit, "the product...shall contain no more significant digits than are contained in the number with the fewest significant digits used in the multiplication".<sup>4</sup> Since the total heat input (H) can normally be determined to three significant figures, the calculated value of the allowable emission rate (E) could also be expressed in three significant figures.

With respect to Figure II of OAC rule 3745-17-11, because the uncontrolled mass rate of emission (U) is generally determined by stack test results, U is expressed in two significant figures. As with Figure I, the proper allowable emission rate (A) should be calculated by the given exponential equations. By application of the multiplication rule for significant figures, the allowable emission rate (A) should be expressed in two significant figures.

Table I of OAC rule 3745-17-11 expresses the allowable emission rate in three significant figures because the process weight rate can normally be determined to three significant figures.

In determining whether or not a particular source is in compliance with the allowable emission rate, that source is subjected to stack tests that are performed by the owner/operator. The final result of the stack tests is expressed in two significant figures, which is in accordance with commonly accepted industry practice. (All intermediate stack test calculations carry three significant figures, and it is only the final average of three test runs that is rounded off to two significant figures).

In order to draw a meaningful comparison between stack test results and statutory emission limits, the statutory limits (where necessary) should be rounded off to two significant figures, because in this comparison there can be no more accuracy (or significant figures) than the least accurate term involved, i.e., the stack test results.

All rounding off of numbers should be performed in accordance with the following recommended procedures:

- When a superfluous digit is less than 5, the preceding figure is retained without change.
- When the digit to be dropped is greater than

5, the preceding figure is increased by 1.

- When the last figure to be dropped is 5 exactly, round off so that the preceding digit is an even number. <sup>5, 6</sup>

In summary, while the allowable emission rate in Figure I can be calculated to three significant figures if the total heat input (H) is known to three significant figures, the calculated allowable emission rate must be rounded off to two significant figures before comparing to a stack test result. Similarly, the allowable emission rate from Table I must also be rounded off to two significant figures before comparison to stack test results. Since the uncontrolled mass rate of emission (U) is generally only known to two significant figures, the allowable emission rate from Figure II can be compared directly to a stack test result.

JO/TK/EL/rt

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## REFERENCES

1. Woodruff, B.J. Terms, Tables and Skills for the Physical Sciences. Silver Burdett Company, Morristown, N.J. (1966) pp. 17-21
2. ASTM Metric Practice Guide, E-380-76 (1976) Section 4.3.2, page 900.
  3. Ibid. Section 4.3.3, page 900.
  4. Ibid. Section 4.3.4.2, page 900.
  5. Op. cit. Reference 1, page 19.
6. Op. cit. Reference 2, page 901, which is reprinted in full:
  - "4.4 Rounding Values: ASTM E-380-76
    - 4.4.1 When a figure is to be rounded to fewer digits than the total number available, the procedure should be as follows:
      - 4.4.1.1 When the first digit discarded is less than 5, the last digit retained should not be changed. For example, 3.46325, if rounded to four digits, would be 3.463: if rounded to three digits 3.46.
      - 4.4.1.2 When the first digit discarded is greater than 5, or if it is a 5 followed by at least one digit other than 0, the last digit retained should be increased by one unit. For example 8.37652, if rounded to four digits, would be 8.377: if rounded to three digits 8.38.
      - 4.4.1.3 When the first digit discarded is exactly 5, followed only by zeros, the last digit retained should be rounded upward if it is an odd number, but no adjustment made if it is an even number. For example, 4.365, when rounded to three digits, becomes 4.36. The number 4.355 would also round to the same value, 4.36, if rounded to three digits."