Designation: D6172 – 98 (Reapproved 2004)

Standard Test Method for Determining the Volume of Bulk Materials Using Contours or Cross Sections Created by Direct Operator Compilation Using Photogrammetric Procedures[1]

This standard is issued under the fixed designation D6172; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers procedures concerning site preparation, technical procedures, quality control, and equipment to direct the efforts for determining volumes of bulk material. These procedures include practical and accepted methods of volumetric determination.

1.2 This test method allows for only two volume computation methods.

1.2.1 *Contour Test Method*—See 8.1.1 and 9.1.

1.2.2 *Cross-Section Test Method*—See 8.1.2 and 9.2

1.2.3 This test method requires direct operator compilation for both contours and cross-section development.

1.2.4 The use of Digital Terrain Model software and procedures to create contours or cross sections for volume calculation is NOT encompassed in this test method.

NOTE 1—A task group has been established to develop a test method for Digital Terrain Modeling (DTM) procedures. It will address all known data collection procedures such as conventional ground survey, photogrammetry, geodetic positioning satellite (GPS), and so forth.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in parentheses. The values stated in each system are not exact equivalents; therefore, each system is used independently of the other. Combining values from the two systems can result in nonconformance with the specification.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Terminology

2.1 *Definitions of Terms Specific to This Standard:*

2.1.1 *base map*—a map showing the soil surface of a site used for material storage including control monument locations and values and surface elevations.

2.1.2 *calibration forms/reports*—equipment calibrations performed by federal agencies or equipment manufacturers.

2.1.3 *check panel*—a target used for the sole purpose of marking a point on the surface of the stockpile whose value is used to verify the setup of the stereo model.

2.1.4 *check point*—targeted points within the stockpile area for the purpose of checking the accuracy of the photogrammetry. Elevations are established by ground surveying at these points. Points should be evenly spaced at various different elevations in the stockpile.

2.1.5 *ground control*—surveyor provided *xyz* values of targets or specific points near the project area necessary to scale and level the stereo model.

2.1.6 *monument*—a ground control point used to be a reference position of survey values.

2.1.7 *peripheral material*—material existing within the site that is above the recognized base and outside of the obvious stockpile perimeter.

2.1.8 *stereo model*—the overlapping area covered by two adjacent aerial photographs used to create measurement observation.

2.1.9 *stereo operator*—a person who is trained and competent to make quality measurement observations from aerial photographs, using a stereo instrument, for the purpose of creating volume computations.

2.1.10 *stereo report form*—a formal document that displays pertinent information required to evaluate and reestablish the stereo model setup parameters.

2.1.11 *sweeps*—repetitive traverse of a pile, by equipment, to create a cleaner geometric shape.

2.1.12 *target*—a geometric shape of contrasting color used to mark a ground feature such as a monument, or check point that otherwise would not be visible on the aerial photograph.

2.1.13 *topographic map*—a drawing that uses contours to define graphically the shape of a surface.

[1] This test method is under the jurisdiction of ASTM Committee D05 on Coal and Coke and is the direct responsibility of Subcommittee D05.07 on Physical Characteristics of Coal.

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3. Summary of Test Method

3.1 *Contour Test Method*—The contour test method is the horizontal slice method of determining volume. After creating a new contour map of the pile, the cubic volume is computed by averaging the areas of adjacent contours and multiplying by the vertical distance between them. See 9.1.

3.2 *Cross-Section Test Method*—The cross-section test method is the vertical slice method of determining volume. Using elevations obtained in parallel lines across the surface and base of the pile the cubic volume is computed by averaging the areas of adjacent cross sections and multiplying by the horizontal distance between them. See 9.2.

4. Significance and Use

4.1 This test method audits the volume of material in a stockpile and is used with a density value to calculate a tonnage calculation value used to compare the book value to the physical inventory results. This test method is used to determine the volume of coal or other materials in a stockpile.

5. Required Preproject Setup Data

5.1 The following information is required from the owner to conduct and evaluate the work effort properly:

5.1.1 Geographic location,

5.1.2 Report completion date,

5.1.3 Date, time, and preflight notification procedure,

5.1.4 Size of overall stock area (length, width, height, and approximate volume),

5.1.5 Configuration (clean or rough),

5.1.6 Type of base map (grid, flat, or contour),

5.1.7 Number of piles and separate computations required, including the approximate number of surge piles and peripheral material computations,

5.1.8 The location of the pile in relation to cooling towers and stacks,

5.1.9 The basic ground control configuration or who will establish required control,

5.1.10 The placement of control and check panels and responsibility for placement,

5.1.11 The number of photographs, maps, and computations required by the owner as the final report.

6. Apparatus

6.1 Aircraft, fixed wing equipped for aerial photography missions and carrying a Code One Air Space Avionics.

6.2 Aerial camera, first order, precision, cartographic camera for obtaining photography usable for mapping and having a U.S. Geologic Survey calibration report date within the last three years.

6.3 Stereo-plotting instrument, optic train analog, or analytical instrument equipped with encoders and interfaced with a three-axis digitizer, computer collection with storage capability, having a certificate of calibration less than three years old, issued by a manufacturer trained technician. When the cross section is used, the instrument shall have an electronic or mechanical cross-section guide device that locks the operator on specific cross sections.

7. Calibration and Standardization

7.1 *Horizontal Variance*—The ground control point value and its plotted location on the topographic map, used for the volumetric determination, will be within 0.01 in. (0.002 54 mm) at map scale of its true position.

7.1.1 The horizontal placement of all planimetric features on the manuscript, including the contour lines, will be as follows: 90 % of all features will be placed to within 0.025 in. (0.635 mm) of their true position at the original map scale, and the remaining 10 % will not exceed 0.05 in. (1.27 mm) of their true position at the original map scale as determined by test surveys.

7.1.2 Test surveys to determine the horizontal map accuracy shall begin and end on one or more of the horizontal control points used for the photo control.

7.1.3 The quality of any horizontal control or test survey line shall meet or exceed FGCC control standards for Second Order Class 2 surveys.

7.1.4 The quality and procedures of all photogrammetry related operations shall be controlled as set forth in the *Manual of American Society of Photogrammetry*[2] and the *Guidelines for Aerial Mapping*[3] or their successors.

7.2 *Vertical Variance*—The vertical control is to be within 0.1 ft (3.048 cm) of its true value.

7.2.1 The vertical accuracy of all contours and spot elevations shall be as follows: 90 % of all contours correct to within ½ of a contour interval. The remaining 10 % are not to exceed one full contour interval. Ninety percent of all spot elevations shall be correct to within ¼ of a contour interval and the remaining 10 % cannot exceed ½ of a contour interval as determined by test surveys.

7.2.2 Begin and end test surveys to determine the vertical map accuracy on one or more of the vertical control points used for the photo control.

7.2.3 The accuracy of any vertical ground control point or test survey line shall meet or exceed FGCC control standards for Second Order Class 2 surveys.

7.2.4 Check panel values are withheld, requiring the mapping firm to provide elevations for these test panels. Before performing, any stereo compilation of the check panels shall agree within 0.3 ft (9.144 cm).

7.2.5 The aerial camera has a calibration report from the USGS Camera Calibration Laboratory that is current within three years of flight date. Calibration requirements are as follows (the following are published in SI units only):

7.2.5.1 *Calibrated Focal Length*—153 ± 3 mm.

7.2.5.2 *Radial Distortion*—No reading shall exceed 10 um. One half of all readings shall be less than 6 um.

7.2.5.3 *Resolving Power*—Average weighted area resolution (AWAR) shall not be less than 60 um.

7.2.5.4 Magazine platen does not depart from a true plane by more than 13 µm.

[2] *Manual of American Society of Photogrammetry*, 410 Governor Lane, Suite 210B, Bethesda, MD 20814–2160.

[3] *Guidelines for Aerial Mapping*, U.S. Department of Transportation, Bureau of Highways, U.S. Government Printing Office, Washington, DC 20402.

7.2.5.5 *Model Flatness*—Spread shall not exceed 30 µm (sum of the largest plus and minus readings) with a maximum reading of 18 µm at any one point.

7.2.5.6 Black-and-white high-speed or color film shall be used.

7.2.5.7 Filters commensurate with film types and atmospheric conditions are used.

7.3 Stereo compilation instruments shall be recalibrated within three years of use and calibration forms provided.

7.4 Stereo model report forms shall be used to record the setup parameters including the control point residuals before compilation and the model setup caliper readings necessary to reset the model. This will include before and after compilation analysis. Include a copy of the model report form in the volume report.

7.5 Model setups shall be checked by a second qualified individual before compilation. A second qualified individual shall check completed models before volume calculations.

7.6 Minimum standards for photo-control point residuals shall be within 0.2 ft (6.096 cm) vertically and 0.5 ft (15.24 cm) horizontally. The SI values reflected are to correct conversion.

8. Procedure

8.1 *Material and Site Preparation*:

8.1.1 Smooth all pile surfaces, separate all piles of differing materials, creating more uniform geometric shapes, to result in increased precision of computed volumes. Smooth the pile surface making directional sweeps parallel to the stockpile baseline when using the cross-section test method.

8.1.2 Compute and make part of the report peripheral material volumes.

8.1.3 Separate material of differing types with a line of material, of a contrasting color, unless the separation is a visible slope break.

8.1.4 Outline foreign material contained within the stockpile limits with a white line and notify the contractor.

NOTE 2—The use of a toe of slope delineation between stockpile and peripheral material is expedient and recommended since a stereo operator can precisely define it.

8.1.5 Do not mark stockpiles or photographs to show the separation of materials having a definite grade break.

8.1.6 Account for volumes for all hidden structures beneath the stockpile surface that do not contain material, for example, piers, bunkers, and tunnels.

8.1.7 Account for volumes in the materials handling system containing material not accounted for as burned, for example, conveyors, silos, hoppers, and bunkers.

NOTE 3—The recommended procedure for site and pile delineation is to create these lines, on a base drawing, using an area large enough to contain operating volumes, and then the use of controlled stocking procedures.

8.2 *Stockpile Base Determination*—Obtain correct base information. Establish a correct base throughout the stockpile limits to minimize volume deviations caused by inaccurate base data. Establish a maximum stockpile perimeter limit that includes all future expected expansions. Create base elevations within the maximum pile limits. In that originally constructed base surface elevations can change as a result of many factors, it is important to monitor base surfaces such as suggested in Note 5.

8.2.1 *Test Method 1*—Use elevations taken from points on a grid map or a contour map correct within 3 in. (7.62 cm) and on the same horizontal and vertical datum as the control used for the mapping. Use this base data for all future inventories. If such data is not available, a postpile base can be compiled using one of the test methods described in 8.2.2 or 8.2.3.

8.2.2 *Test Method 2*—Select an elevation commensurate with the average ground level (flat base) and use as a constant for all future volume determinations.

8.2.3 *Test Method 3*—Use the toe of slope at the base around the perimeter of the pile area creating an assumed base. Connect open-ended contours by a straight line to establish the base contours. Use this base for all future inventories except when the perimeter of the pile becomes larger, in which case, extend the expanded ends of the base contours to include the expanded area.

NOTE 4—Since 8.2.2 and 8.2.3 are assumed procedures, the first inventory using either test method can create a difference from the actual volume. All succeeding inventories using the same base will reflect relative pile volumes.

8.3 Observe potential base changes and notify the owner.

NOTE 5—Developing new base data or monitoring base in a stockpile can be achieved by drilling and measuring areas under the pile and the use of ground surveys or aerial photography for exposed areas of the base around the stockpile. In that stockpiles can settle into the base, periodic boring checks can be made to ascertain base stability. Rotate boring locations, to achieve better random sampling of the base elevations, in subsequent inventories. Split spoon sampling procedures are considered more accurate for determining vertical locations than the small diameter auger procedure.

8.3.1 Report any base undercutting observed during the inventory and recommend base map corrections. Update the base maps during planned or known pile depletion times.

8.3.2 Use the same or updated base data for future inventories, since valid base data is paramount to correct volume calculations.

8.4 *Ground Control*:

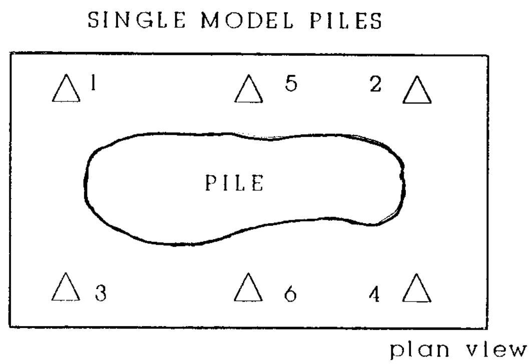
8.4.1 Establish ground control reference points and values for determining the scale and vertical datum of the resultant topographic map or *xyz* observations necessary to calculate the volume. Install a minimum of six ground control points per stereo model. Distribute these points equally to bracket the stockpile. (See Fig. 1).

8.4.2 Verify that horizontal and vertical control is accurate, recognizing its importance in any consistent inventory procedure. Use the same datum consistently for both the base map and the ground control.

8.4.3 *Horizontal Control*:

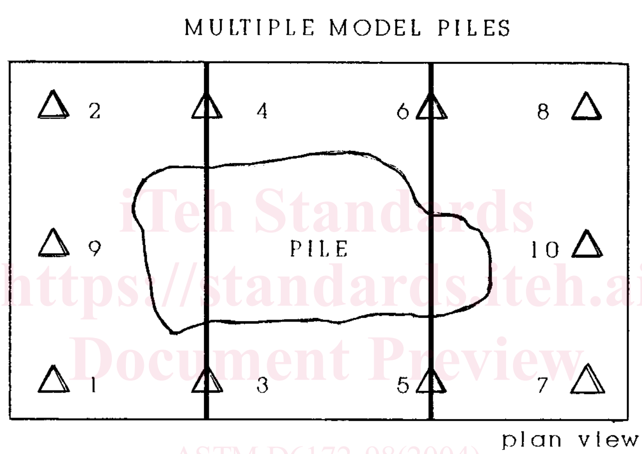
8.4.3.1 Establish two baselines at each inventory site, plus one additional base line for each additional model, to cover the inventory site. These baselines can be established by two separate procedures.

8.4.3.2 The recommended procedure is to traverse over three separate monuments and compute coordinate values for each of the three monuments for the first model and two



Vertical = 1 thru 4 are minimum, 5 & 6 are option;

Horizontal = Any 3 of 1 thru 4 are minimum.



Vertical = 1 thru 8 are minimum, 9 & 10 are optional;

Horizontal = First model, any 3 of 1 thru 4 are minimum; Second model any 2 of 3 thru 6 are minimum. Repeat same configuration as Model 2 for any added models.

FIG. 1 Stereo Model and Control Configuration

additional points for each successive model. Tie this traverse to the grid system used to prepare the original base map (see Fig. 1).

8.4.3.3 Establish baselines with measured distances between three separate monument points, which is an acceptable alternate. Orient the pile to the base map using photo-visible planimetric features when using this procedure. This is a usable option, but not recommended (see Fig. 1).

8.4.3.4 Include all control points and monuments in the traverse loop when a traverse is used to establish horizontal control values.

8.4.4 *Vertical Control*:

8.4.4.1 It is necessary to establish a minimum of six vertical points per stereo model.

8.4.4.2 When the stockpile requires more than one stereo model, an additional three points per model must be added (see Fig. 1).

8.4.4.3 It is necessary to run a tied-in level loop over all of the control points so that all points are on the same vertical datum. At no time shall any control point be assigned a value from survey observations that are not contained in a closed loop.

NOTE 6—If a base map does not exist for a stock volume area, it is not necessary to be concerned about the tying of any control since an assumed base will be necessary.

8.5 *Targeting*:

8.5.1 Mark ground control points (monuments) by one of the following procedures:

8.5.1.1 *Test Method 1—Permanent Targets*—Construct and place rigid structures, such as concrete panels (see Fig. 2), in locations in which they will remain undisturbed and only require checking and cleaning before each flight. Exercise care to keep the structures unattached from monuments when