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.

Current edition approved April 1, 2004. Published May 2004. Originally published approved in 1997. Last previous edition approved in 1998 as D6172–98$^{\varepsilon 1}$. DOI: 10.1520/D6172-98R04.

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*:

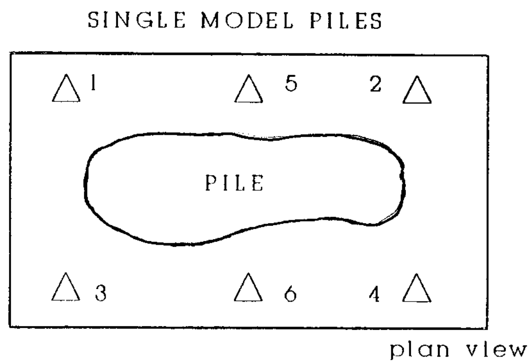
8.4.1 Establish ground control reference points and values for determining the scale and vertical datum of the resultant topographic map or *xyz* observations necessary to calculate the volume. Install a minimum of six ground control points per stereo model. Distribute these points equally to bracket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

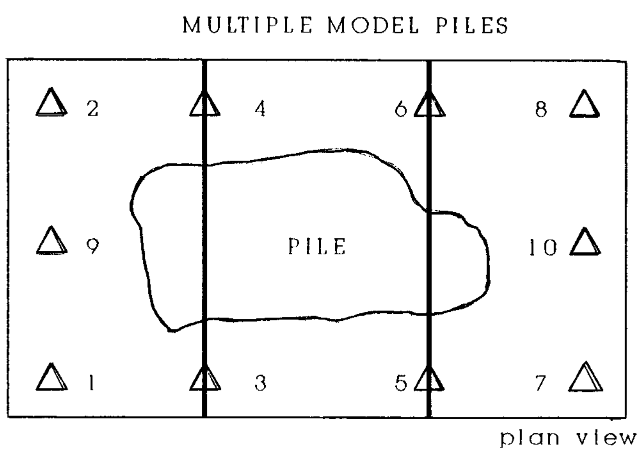
8.4.3.1 Establish two baselines at each inventory site, plus one additional base line for each additional model, to cover the inventory site. These baselines can be established by two separate procedures.

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).

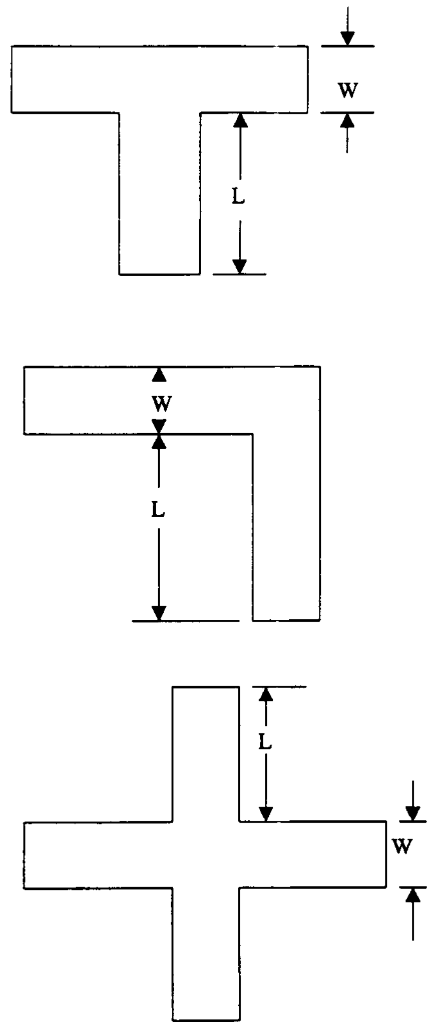
8.4.4.3 It is necessary to run a tied-in level loop over all of the control points so that all points are on the same vertical datum. At no time shall any control point be assigned a value from survey observations that are not contained in a closed loop.

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



TARGET SIZE

PHOTO SCALE	(W) WIDTH OF LEG
1:1800 to 1:3600	1 ft. [0.3048 m]
1:3600 to 1:6000	1 ft. [0.3048 m]
1:6000 to 1:7200	2 ft. [0.6096 m]

(L) LENGTH OF LEGS
2 ft. [0.6096 m] to 3 ft.[0.9144 m]
3 ft. [0.9144 m] to 4 ft.[1.2192 m]
4 ft. [1.2192 m] to 5 ft.[1.524 m]

NOTE 1—Place targets so that the point being targeted is at the center intersection of the panels with the exception of the L or chevron panel. On the L or chevron panel, the point being marked is the intersection of the inside edges of the panel material.

NOTE 2—Panel material can be plastic flagging, paint, lime, rock dust, waterproof paper, or other types of white or black material. Avoid using other colors except in color photography projects. Color selection is dependent on the background in which the target is placed. For instance, dry, exposed ground appears white in a black-and-white photograph and a black target used in this case. **Caution—**Fluorescent orange appears the same color as grass in black-and-white photography.

NOTE 3—Avoid plastic flagging material for paneling purposes in grazing areas.

NOTE 4—Ground control accuracy requirements are as follows: vertical control ±1⁄10 of a contour interval and horizontal control ±1⁄100 of the map scale.

NOTE 5—Double the length of the target panels in wooded areas.

NOTE 6—Place panel used as vertical targets in relatively flat or gently sloping areas.

FIG. 2 Panel Configuration

created in ground-freezing zones. Check the vertical position of each structure to verify that it is level with its monument before each inventory flight.

8.5.1.2 *Test Method 2—Temporary Targets*—Install temporary targets such as wood, cloth, plastic, rock dust, or other suitable material of contrasting color on monuments that are flush with the ground before each flight.

8.5.1.3 For Test Method 1 (see 8.5.1.1) and Test Method 2 (see 8.5.1.2), all targets must be placed flush with the elevation they are representing and be on a essentially flat solid plane for at least the area of the target.

8.5.1.4 *Test Method 3—Photo-Identifiable Features*—Select and establish ground control values for points that exist on the ground and can be used as photo-identifiable target features such as concrete pads, road intersections, parking lot areas, utility poles, and so forth, before the first volume calculations. Record and use these newly establish photo-identifiable points for future volume calculations. Such points do not require remarking for each inventory. (See Fig. 2 for target shapes and sizes.)

8.5.2 Check panels are placed on the stockpile surface for use in checking the confidence level of the volume. Perform surveys to establish the *xyz* coordinates of the test panels to the same quality as the control points. Obtain the elevations on the inventory material surface adjacent to the reference target and not on the target surface itself.

8.6 *Aerial Photography*:

8.6.1 Use aircraft equipped with all necessary equipment to fulfill all safety airspace regulations required by the Federal Aviation Administration and other government agencies especially the required avionics for "*Code One*" airspace if the project site is near a military or major commercial airport.

8.6.2 The minimum sun angle is 25° above the horizon with no clouds, plumes, or shadows obscuring the stereo operator's ability to delineate precisely the topographic features of the stockpile.

NOTE 7—The photography can be obtained with a continuous high cloud overcast provided that sufficient light exists for the proper exposure of photography.

8.6.3 Use a camera equipped with an f/4 lens or image motion compensation when the sun angle is less than 30° above the horizon and when Note 7 applies.

NOTE 8—The continental United States falls between 25 and 49° North latitude; Alaska reaches a 68° North latitude; Hawaii falls between 20 and 22° North latitude. Sun angles of 25° will only be a problem in latitudes North of 40°. At 49° of North latitude (approximate U.S./Canada border), there exists approximately three months of time (November through January) when the sun angle can present a problem.

8.6.4 Use a photo-scale range from 1:2400 to 1:3600 to compile stockpile volumes for inventory of materials. Photo scales of higher ratio will lessen the vertical accuracy of the surface readings and should only be used with the understanding and authorization of the contracting agency.

8.6.5 Perform aerial photography with the lowest altitude that will allow a site to be photographed in one stereo model or one flight line.

NOTE 9—Stockpile owners require most stockpile inventory projects to be flown within a specific time frame. Therefore, a preplan schedule is suggested to allow adequate time to schedule the flight crew.

8.7 *Procedures to Determine Volume*:

8.7.1 *Contour Test Method*—Use contours of 1 and 2 ft (0.3048 and 0.6096 m) as standard practice, however, 2-ft (0.6096-m) contours shall be used only for even, steep sloped surfaces. Use 1-ft (0.3048-m) contours for stereo compilation in areas of gentle slopes such as base area, top area, gentle sloping sides, and irregular surfaces. Relatively flat areas with irregular surfaces should require 0.50-ft (15.24-cm) intervals.

8.7.1.1 Begin contouring with the lowest point on the base that is covered by material. Continue contours of 1 and 2 ft (0.3048 and 0.6096 m) progressing up the pile. Place one spot elevation at the highest point above all top contours. Place spot elevations at 1-in. (2.54-cm) intervals above top contours whose area exceeds 2 in. (5.08 cm) of linear distance in any direction.

8.7.1.2 Extract base quantities from either individual contours or as a lump sum from the total of all the contours affected by the base. This choice will be determined by the tonnage calculation procedure chosen.

8.7.1.3 Manually operated planimeters are not permitted to determine areas of contours after they have been compiled.

8.7.2 *Cross-Section Test Method*—Read across sections, across the entire pile, at 10-ft (3.08-m) maximum spacing plus additional sections at any major break between sections. Locate the first and last section at the end edges of the material. Take readings along each section at 50-ft (15.224-m) intervals and at all breaks in grade. Take additional readings in radius segments between continuous gradient areas, such as at the top and base of piles, at each 0.5-ft (0.1524-m) change in elevation.

8.7.2.1 Establish a baseline tied to the pile base when using the cross-section procedure.

8.7.2.2 Establish the baseline of the cross sections parallel to the pile-dressing sweeps. See Section 8.1.1.

8.7.2.3 Use mechanical guide devices that lock the operator on specific cross sections.

8.7.2.4 Do not use a manually operated planimeter to determine the areas of cross sections after they have been compiled.

NOTE 10—Large shallow piles are difficult to measure reliably by photogrammetric procedures. If more than 80 % of the surface area of a pile has a gradient of 2 % or less, other measurement procedures should be used.

8.7.2.5 Provide a planimetric map of the storage area showing the specific location of the baseline, its zero point, gridlines with values based on the ground control, and the perimeter line of the inventoried coal.

9. Calculation

9.1 *Contour Test Method*—Volume is computed by averaging the areas of adjacent contours and multiplying that average area by the vertical distance between the two contours. Top slices are computed by using the highest spot or the average of the highest spots as zero area and averaging that value against the area of the highest contour. Multiply that value by the vertical distance between the top contour and any spots above to determine cubic values.

9.2 *Cross-Section Test Method*—The volume is computed by averaging the areas of adjacent cross sections and multiplying the average area by the horizontal distance between the two sections.

9.3 *Selection of the Volume Confidence Level*—The volume confidence level is based on two standard deviations.

9.4 *Calculation of Percent Error of the Volume*—Check panels in accordance with Section 7 are the basis for determining the confidence interval of the stockpile surface elevations.

9.5 The ground survey determinations shall be achieved using the *Federal Geodetic Control Committees Manual*[4] for second-order Class Two procedures to ensure the reliability of the ground control values.

9.6 The error at any individual check panel location is independent of the error at any other check panel location.

9.7 The depth of the stockpile at any boring location check panel is the surface elevation minus the base elevation.

Example—Boring 1; Pile depth = 463.2 ft (141.2 m) – 440.0 ft. (134.1 m) = 23.2 ft (7.1 m)

9.8 Develop a table as shown in the example Table 1 to organize the check panel data.

9.9 Determine the means of X_1 and X_2:

[4] *Standards and Specifications for Geodetic Control Networks*, Federal Geodetic Control Committee (FGCC), National Geodetic Information Branch, (N/CG17X2) NOAA, Rockville, MD 20852.

TABLE 1 Example Check Panel Data

Date:		Stockpile I.D.______		Base Elevation: 440.0 ft
Boring Location Number	Mapping Firm, X_1	Ground Survey, X_2	Difference, d	Difference Squared, d^2
1	23.2	23.3	–0.1	0.01
2	23.0	22.8	0.2	0.04
3	23.1	23.2	–0.1	0.01
4	24.6	24.6	0.0	0.00
5	24.4	24.6	–0.2	0.04
6	23.5	23.5	0.0	0.00
7	22.8	22.8	0.0	0.00
8	24.0	24.4	–0.4	0.16
9	22.6	22.7	–0.1	0.01
10	24.1	24.1	0.0	0.00
11	23.7	23.3	0.4	0.16
12	22.2	21.3	0.9	0.81
13	28.4	28.4	0.0	0.00
n	ΣX_1	ΣX_2	Σd	Σd^2
13	309.6	309.0	0.6	1.24

$$X_1 = \frac{\Sigma X_1}{n} = \frac{309.6}{13} = 23.8154 \quad (1)$$

$$X_2 = \frac{\Sigma X_2}{n} = \frac{309.0}{13} = 23.7692 \quad (2)$$

9.10 Determine the variance and the standard deviation of the difference (d):

$$\text{Variance} = \frac{\Sigma d^2 - (\Sigma d)^2 / n}{n - 1} = \frac{1.24 - (0.6)^2 /13}{13 - 1} = 0.101\ 025\ 6 \quad (3)$$

$$\text{Standard Deviation} = \sqrt{\text{Var}} = \sqrt{0.101\ 026} = 0.317\ 845 \quad (4)$$

9.11 Determine the coefficient of variation (CV):

$$\text{CV} = \frac{sd}{(\bar{X}_1 + \bar{X}_2) / 2} = \frac{0.317\ 845}{23.792\ 3} = 0.013\ 359\ 15 \quad (5)$$

9.12 Determine the standard error of the mean:

$$S_e = \frac{\text{CV}}{\sqrt{n}} = \frac{0.013\ 359\ 15}{\sqrt{13}} = 0.003\ 705\ 16 \quad (6)$$

9.13 Determine the precision in percentage at two standard deviations:

$$\text{Confidence Interval @ } 2\ S_d = (2\ S_e) = 2(0.003\ 705\ 16) = 0.007\ 410\ 32 \quad (7)$$

9.14 Determine the confidence interval in percentage at two standard deviations.

$$\begin{aligned}\text{Confidence Interval @ } 2\ S_d &= 100(2\ S_e) \\ &= 100(0.007\ 410\ 32) \\ &= 0.741\ 0\ \%\end{aligned} \quad (8)$$

NOTE 11—This percentage is used for the plus or minus (±) confidence interval of the volume determination. It is recognized that this is one dimensional. The assumption is made that the ability to determine cross sections and contours is directly dependent on the ability to determine elevations.

9.15 This percentage is used in the stockpile tonnage standard.

10. Report

10.1 The nature of report varies depending on the needs of the user.

10.2 A minimum report includes a copy of the aerial photograph imprinted with the time, date, and name of site and a printout broken down by contour slice or cross section showing total volume of each slice and the individual pile total.

10.3 A copy of the resulting topographic map is required with the contour test method and optional with the cross-section test method. The cross-section test method requires the planimetric map described in 8.7.2.5. Include a copy of the base map used for the report or a description of the base map used including the drawing number or other descriptive reference.

11. Precision and Bias

11.1 *Precision*—The precision of the result is given by Eq 7.

11.2 *Bias*—Since there is no accepted reference method for determining the bias for the procedure for volume of bulk materials, bias has not been determined.

NOTE 12—The precision statement will attempt to verify the ±2 % industry accepted error.

12. Keywords

12.1 aerial; inventory; photogrammetric; photography; stockpile; volume