The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

SURFACE VEHICLE STANDARD

SAE J874 SEP93
ISO 5005-1977

REV. SEP93

Issued 1954-12
Revised 1993-09

Superseding J874 OCT85

Submitted for recognition as an American National Standard

(R) Earthmoving Machines—Method for Locating the Center of Gravity

This document is technically equivalent to ISO 5005-1977.

Foreword—This Document has not changed other than to put it into the new SAE Technical Standards Board Format. Definitions changed to Section 3. All other section numbers have changed accordingly.

Although there are many possible methods of determining the center of gravity, the intent of this SAE Standard is to specify one simple and practical method which requires the use of a weighbridge and crane.

There is no single fixed position of the center of gravity of a machine which has attachments or components that are movable. When such a machine is tilted, as it must be to find the vertical coordinates, flexible parts deflect, fluids and loose parts move, and the position of the center of gravity therefore changes. Again, particularly in the case of earthmoving machinery, the position of the center of gravity will depend upon the nature and position of any attachments or ancillary equipment with which the item is fitted. It is therefore essential in all cases to state exactly the conditions of the test.

1. ***Scope and Field of Application***—This SAE Standard specifies a method for determining the coordinates of the center of gravity of earthmoving machinery such as tractors, loaders, dumpers, and graders in any condition of loading or position of attachments.

2. ***References***—There are no referenced publications specified herein.

3. ***Definitions***—For the purpose of this document the following definitions apply:

3.1 **Machine**—The machine or other object whose center of gravity is to be determined.

3.2 **Apparatus**—The equipment required to determine the center of gravity of a machine.

3.3 **Attachment**—A piece of equipment which is available for mounting on the machine for a particular purpose (for example a bulldozer blade, winch, or bucket).

3.4 **"Left-Hand" and "Right-Hand" Sides**—These terms apply when facing in the primary direction of travel.

3.5 **Mass**—The mass of the machine as submitted for test.

TO PLACE A DOCUMENT ORDER: (724) 776-4970 FAX: (724) 776-0790
SAE WEB ADDRESS http://www.sae.org

4. ***Preparation and Loading of Machine—***The machine shall be clean and shall be tested in normal working conditions or in a specified condition agreed between the manufacturer and the testing authority.

4.1 Radiator, sump, hydraulic, and other reservoirs, shall be filled to specified working levels; the fuel tank shall be full or empty or in a specified condition as agreed between the manufacturer and testing authority.

4.2 Tools, spare tire, and loose accessories and equipment shall be complete as supplied and shall be in the normal stowage positions.

4.3 Tire pressures shall be as specified in the manufacturer's operating instructions or, if a range of pressures is allowed, at the highest pressure recommended. In the case of machines fitted with hydro-inflation tires they shall be filled in accordance with the manufacturer's operating instructions.

4.4 The attachment shall be normally put in the operating position; for example:

a. For crawler or wheeled tractors, with the dozer equipment lowered, tilt adjustment horizontal, to the lowest possible position just clear of the horizontal reference plane (see 6.3)
b. For loaders with the bucket fully crowded back and the front linkage in such a position that the lower part of it or the bucket is just clear of the horizontal reference plane
c. For graders with the cutting edge of the blade horizontal and perpendicular to the fore-and-aft axis of the machine and 20 cm above the horizontal reference plane. The front wheels shall be vertical.

The center of gravity may be determined in a similar manner with the attachment(s) in many different positions and the coordinates for these different positions recorded as indicated in the report table in Figure 1.

4.5 Articulated machines will normally be tested locked in a straight line, but the test may be required to be conducted with the joint set at the maximum or any intermediate angle.

4.6 When a scribing board is required it shall be at least 600 mm (24 in) high by 450 mm (18 in) wide, rigidly constructed, and attached to the machine in a suitable position with a smooth face vertical and parallel to the side or other appropriate plane (see Section 7).

5. ***Method of Determination***

5.1 **Principle—**The suspension and ground reaction method is used. This method involves measuring the ground reactions with the machine under test first level and second tilted in the fore-and-aft direction. The calculated horizontal distance of the center of gravity from a ground contact point is measured in each case and verticals drawn on a scribing board affixed to the machine. The intersection of the verticals (which in practice forms a small triangle) indicates the center of gravity.

5.2 **Apparatus—**The following apparatus is suggested:

5.2.1 WEIGHBRIDGE (CALIBRATED).

5.2.2 CRANE

5.2.3 DECKING

5.2.4 KNIFE EDGES (conveniently sized rolled steel angle).

Manufacturer's Name			
Machine Type		Model	
Serial No.		Chassis No.	Engine No. . . . .
Attachments		Tire Pressures Front	kPa (lbf/in^2)
		Rear	kPa (lbf/in^2)
Date of Test			
Machine Mass M	Unladen . . . . . kg(lb)	Laden	kg (lb)
Left-Hand Side			
Right-Hand Side			
Total			
	Coordinates of	center of gravity, mm	
Position of Attachment(s)	$\bar{x}$ ± $\bar{y}$ $\bar{h}$	$\bar{x}$ ± $\bar{y}$ $\bar{h}$	

FIGURE 1—REPORT TABLE

5.2.5 LEVEL

5.2.6 PLUMB RULE conveniently combined in a field level.

5.2.7 SQUARES

5.2.8 SCRIBING BOARD

5.2.9 MARKING MATERIALS

5.2.10 TAPE MEASURE

5.3 Procedure—The horizontal fore-and-aft coordinate, the lateral coordinate in the horizontal plane and the vertical coordinate of the center of gravity shall be determined as stated in 5.3.1 to 5.3.3.

5.3.1 HORIZONTAL FORE-AND-AFT COORDINATE, $\bar{x}$

5.3.1.1 Tracked Machine—Figure 2

Measure M, the mass of the whole machine, on the weighbridge.

Measure r, the reaction under the knife edge due to its mass and part of the decking.

Move the machine on to the decking part supported by the weighbridge and measure R + r.

Measure P, the distance between the knife edges. Calculate R by subtraction; (see Equation 1).

then:

$$\bar{x} = \frac{RP}{M} \qquad \text{(Eq. 1)}$$

Using this calculated value of $\bar{x}$, draw a perpendicular through the center of gravity on the scribing board affixed to the machine. Then refer x to the appropriate reference plane in accordance with Section 6.

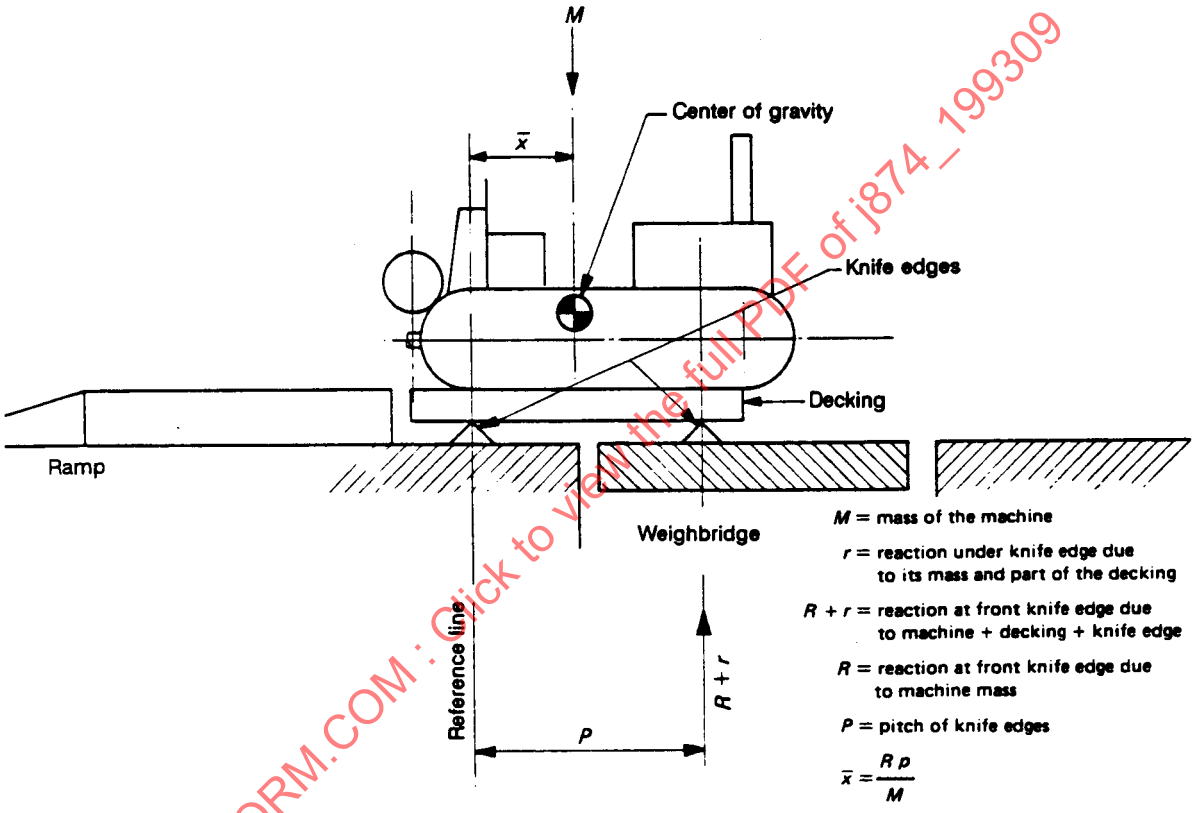


FIGURE 2—DETERMINATION OF THE FORE-AND-AFT COORDINATE, $\bar{x}$

5.3.1.2 *Wheeled Machines*—With wheeled machines it is not necessary to use decking or knife edges. With brakes off, measure axle loads and calculate x, from the pitch of the axles. Then refer x to the appropriate reference plane in accordance with Section 6.

5.3.2 LATERAL COORDINATE IN THE HORIZONTAL PLANE, $\bar{y}$—(See Figure 3)—Measure left-hand R_1 and right-hand R_2 wheels or track loadings. Calculate offset of center of gravity using track gauge or wheel track as the moment arm. (See Equations 2 and 3.)

$$b = \frac{R_2\ (\text{gauge})}{M} \qquad \text{(Eq. 2)}$$

$$\bar{y} = \frac{\text{gauge}}{2} - b \qquad \text{(Eq. 3)}$$

NOTE—It will usually be found that the right-hand and left-hand side loads do not total the mass of the machine exactly due to small differences in level between the weighbridge deck and the surround. Any error is minimized by equalizing the overlap of the side being weighed in both cases.

It is preferable to use the total right-hand side and left-hand side wheel (track) loadings to determine the mass of the machine M.

Then refer $\bar{y}$ to the appropriate reference plane in accordance with Section 6.

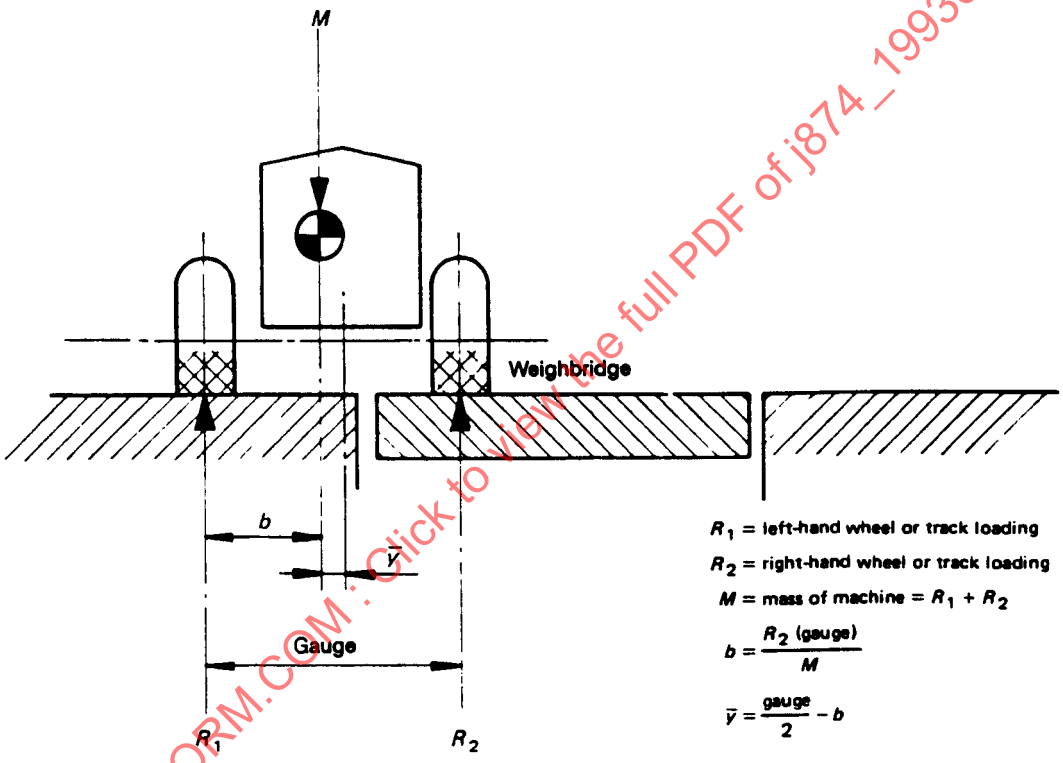
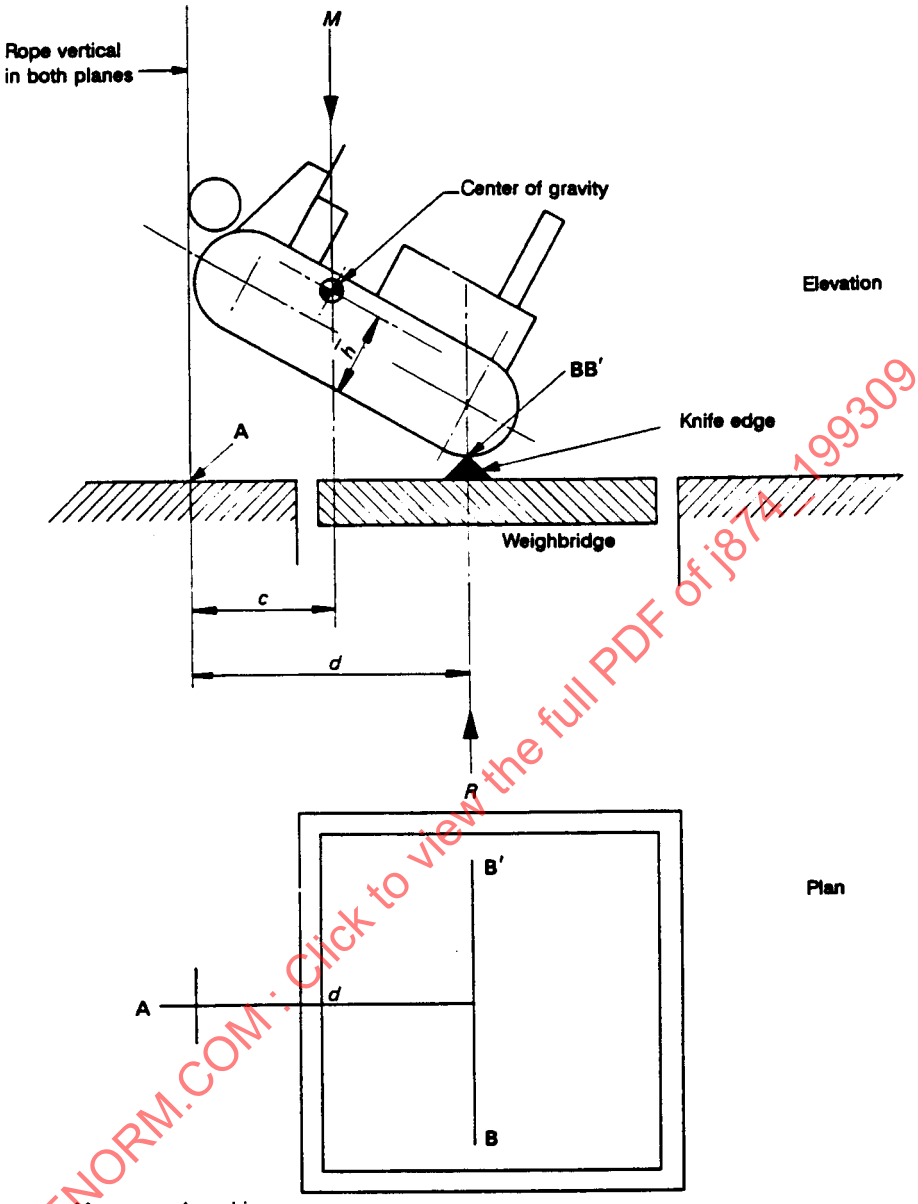


FIGURE 3—DETERMINATION OF LATERAL COORDINATE IN THE HORIZONTAL PLANE, $\bar{y}$

5.3.3 VERTICAL COORDIANTE OF THE CENTER OF GRAVITY, $\bar{h}$—(See Figure 4.)

5.3.3.1 Suspend the machine under test from one end at an angle of 15 degrees to 25 degrees from the horizontal, the other end resting on the weighbridge. The maximum convenient angle should be employed. The method is applicable either to wheeled or tracked machines, the main difference being in establishing the exact location of the point of application of the ground reaction, i.e., the ground contact. In wheeled machines, which shall be unbraked, this is vertically below the axle. In tracked machines, it is necessary to maneuver until the contact-grousers are in line BB' on either side or to make contact through a length of angle iron set on line BB'. In all cases the suspension cable shall be vertical in both planes as tested by plumb rule. This is an essential condition to ensure that the ground reactions in the horizontal plane are zero.



M = mass of machine

R = reaction under ground contact on weighbridge

d = horizontal distance of the ground contact from the line of suspension

c = horizontal distance of the center of gravity from the line of suspension

A = point of intersection of perpendicular from line of suspension and ground

BB' = line of ground contact

$\bar{h}$ = height of center of gravity above ground level

$$c = \frac{R\,d}{M}$$

FIGURE 4—DETERMINATION OF VERTICAL COORDINATE OF THE CENTER OF GRAVITY, $\bar{h}$

5.3.3.2 Measure R, the reaction at the ground contact on the weighbridge.

5.3.3.3 Measure d, the horizontal distance from the ground contact to the line of suspension.

5.3.3.4 Calculate c, the horizontal distance from the center of gravity to the line of suspension, from Equation 4:

$$c = \frac{Rd}{M} \qquad \text{(Eq. 4)}$$

5.3.3.5 Draw the vertical through the center of gravity on the scribing board fixed to the machine.

Repeat with machine suspended from the other end. The suspension angle need not be the same for both ends.

The intersection of the verticals on the scribing board gives the position of the height of the center of gravity h. Refer this to the appropriate reference plane in accordance with Section 6.

NOTE— The machine may be conveniently run on the weighbridge, square, using chalked lines. This will assist in drawing the plan. If, with tracked machines, the grousers are not in line at B and B' (see Figure 4) it is necessary to resort to trial and error by running the machine in varying circles until the required result is attained at the last approach.

6. Reference Planes—The reference planes may conveniently be taken as follows:

6.1 Vertical 1—Through the driving sprocket axle if for a crawler tractor but through the front axle, or front idler centers, if a crawler or wheeled excavator.

6.2 Vertical 2—Through the major fore-and-aft axis of a machine, i.e., midway between the wheels or tracks.

6.3 Horizontal—Ground level. A hard contact shall be assumed, i.e., no grouser penetration in the case of a tracked machine.

7. Reporting of Results

7.1 The report shall give the coordinates of the center of gravity:

a. $\bar{x}$, horizontal fore-and-aft coordinate, being the distance from vertical 1;
b. $\bar{y}$, lateral coordinate or displacement from the vertical 2; positive to the right, negative to the left;
c. h, vertical coordinate or height above the horizontal.

7.2 The position of the center of gravity shall be reported in millimeters to the nearest 10 mm from three reference planes. The reference planes, if other than those given in Section 6, shall be stated.

7.3 All details relevant to the position of the center of gravity of the machine shall be reported (see Section 4). Details and positioning of attachment(s) and loading shall be stated.

7.4 A suggested form of report is shown in Figure 1.