

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

- SAE J184 Qualifying a Sound Data Acquisition System
- SAE J1116 Categories of Off-Road Self-Propelled Work Machines
- SAE J2130 Self-Propelled Sweepers and Cleaning Equipment

2.1.2 ANSI and ISO Publications

Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

- ANSI S1.4 Specifications for Sound Level Meters ANSI S 1.4A-1985—Amendment to ANSI S 1.4-1983
- ANSI S 1.40 Specification for Acoustic Calibrators
- ANSI S1.9-1996 (R2006) Instruments for the Measurement of Sound Intensity
- ISO 9614-1:1993 Acoustics—Determination of sound power levels of noise sources using sound intensity—Part 1: Measurement at discrete points
- ISO 9614-2:1996 Acoustics—Determination of sound power levels of noise sources using sound intensity—Part 2: Measurement by scanning
- ISO 9614-3:2002 Acoustics—Determination of sound power levels of noise sources using sound intensity—Part 3: Precision method for measurement by scanning
- ISO 6165-1997 Earth-moving machinery—Basic types—Vocabulary
- ISO 6393:1998 Acoustics—Measurement of exterior noise emitted by earth-moving machinery—Stationary test conditions
- ISO 6395:1996 Acoustics—Measurement of exterior noise emitted by earth-moving machinery—Dynamic test conditions (includes Amend.1:1996)

2.1.3 IEC Publications

Available from International Electrotechnical Commission, 3, rue de Verambe, P.O. Box 131, 1211 Geneva 20, Switzerland, Tel: +41-22-919-02-11, www.iec.ch.

- IEC 60942 Ed.3.0 (2003-01) Electroacoustics—Sound calibrators
- IEC 61043 Ed.1.0 (1993-11) Electroacoustics—Instruments for the measurement of sound intensity—Measurements with pairs of pressure sensing microphones
- IEC/TS 62370 Ed.1.0 (2004-05) Electroacoustics—Instruments for the measurement of sound intensity—Electromagnetic and electrostatic compatibility requirements and test procedures
- IEC 61672-1 Ed.1.0 (2002-05) Electroacoustics—Sound level meters—Part 1: Specifications

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this document.

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J1057 Identification Terminology of Earthmoving Machines

SAE J1349 Engine Power Test Code—Spark Ignition and Compression Ignition—Net Power Rating

SAE Technical Paper 850991 In-Place Dynamic Sound Power Test Method

2.2.2 ISO Publications

Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ISO 1585-1992 Road Vehicles—Engine Test Code—Net Power

ISO 3744:1994 Acoustics—Determination of sound power levels of noise sources using sound pressure—Engineering method in an essentially free field over a reflecting plane

ISO 11205:2003 Acoustics—Noise emitted by machinery and equipment—Engineering method for the determination of emission sound pressure levels in situ at the work station and at other specified positions using sound intensity

2.2.3 IEC Publication

Available from International Electrotechnical Commission, 3, rue de Verambe, P.O. Box 131, 1211 Geneva 20, Switzerland, Tel: +41-22-919-02-11, www.iec.ch.

IEC Publication 60804 (1985) Integrating—Averaging Sound Level Meters (plus amendments)

3. INSTRUMENTATION

3.1 The integrating sound pressure level system is used in conjunction with a free field over a reflecting plane (4.1.1).

3.1.1 The integrating sound level meter must permit the determination of the value of the A-weighted sound pressure level, energy averaged, over a time period dependent on the machine test cycle. IEC 61672-1 Ed.1.0 (2002-05).

3.1.2 Any alternate system in place of a meter must perform the same functions required in 3.1.1.

3.1.3 The components of the measuring instrumentation system shall meet the Type 1 requirements given in the relevant clauses of IEC 61672-1 Ed.1.0 (2002-05) or ANSI S1.4. Systems shall be qualified according to SAE J184 for the frequency range of interest.

3.1.4 The acoustic calibrator used for calibration prior to and after the test sequence shall have an accuracy within ± 0.5 dB and meet the requirements of ANSI S1.40 or IEC 60942 Ed.3.0 (2003-01).

3.1.5 A microphone windscreen shall not be used except when it is required to reduce wind induced noise that is within 15 dB of the sound level of the source being measured. When a windscreen is used, it shall not affect the sound level of the source being measured by more than ± 0.5 dB(A) under zero wind speed conditions.

- 3.2 The sound intensity measurement system frequency response, linearity, A-weighting, and crest factor specifications shall conform to the Type 1 requirements of ANSI S1.9 or of SAE J184 for the frequency range of interest. Alternatively use IEC 61043 Ed.1.0 (1993-11) and IEC/TS 62370 Ed.1.0 (2004-05) to assemble an acceptable intensity system.
- 3.3 The anemometer or other device used in measurement of ambient wind speed and direction shall be accurate within $\pm 10\%$ at 20 km/h.
- 3.4 The engine speed indicator shall be accurate within $\pm 2\%$ of the indicated reading.
- 3.5 The ambient temperature measurement shall be accurate within $\pm 1^\circ\text{C}$.

4. PROCEDURE

4.1 Test Site

A non-absorbing reflecting plane is required.

- 4.1.1 For sound pressure level instrumentation, a free field is required above the reflecting plane. There shall be no sound-reflecting obstacles within a distance from the source equal to three times the radius of the measuring hemisphere.
- 4.1.2 For sound intensity instrumentation the presence of reflecting objects is less critical, but no absorbing object or additional noise source other than the machine being measured shall be inside the measurement surface. This system permits measurements in most factory environments.

4.2 Measurement Surface

Size and shape depend on the instrumentation selected and the machine dimensions:

- 4.2.1 For sound pressure level instrument systems the measurement surface is a hemisphere with the radius determined by the length of the main body of the basic machine structure, excluding major attachments such as dozer blades, buckets, and booms. The radius (r) of the measurement hemisphere surface is given in Table 1 according to the basic length (l).

TABLE 1 - HEMISPHERE RADIUS RECOMMENDATION

Basic Length (l) of the Machine	Radius (r) of Hemispherical Measurement Surface
$l \leq 1.5 \text{ m}$	4 m
$1.5 \text{ m} \leq l \leq 4 \text{ m}$	10 m
$l > 4 \text{ m}$	16 m

As a guideline for larger machines, over 6.5 m, the hemisphere radius should be 2.5 times the length of the basic machine not including attachments.

- 4.2.2 For sound intensity systems, rectangular and spherical surfaces are convenient for calculating surface segments and reproducibility. Though not required by this document, a hemispherical measurement surface is described to show the process and demonstrate the factors to be considered: perpendicular orientation of probe axis and the minimum number of surface segments. The measurement hemisphere radius should be large enough to enclose the machine and its moving attachments. A semi-cylindrical surface with hemispherical ends has proven satisfactory for long machines.

4.3 Measurement Surface and Microphone Positioning

4.3.1 For sound pressure level instrument systems, the measurement surface shall be a hemisphere of radius (r) given in Table 1. Location coordinates of the microphone positions are given in Table 2 and Figure 1.

TABLE 2 - COORDINATES OF THE MICROPHONE LOCATION POINTS

Location No.	Figure No.	$X/r^{(1)}$	Y/r	Z/r	Z
1	2	0.70	0.70	—	1.5 m
2	4	-0.70	0.70	—	1.5 m
3	6	-0.70	-0.70	—	1.5 m
4	8	0.70	-0.70	—	1.5 m
5	10	-0.27	0.65	0.71	—
6	12	0.27	-0.65	0.71	—

1. The positive X axis is the machine primary direction of travel.

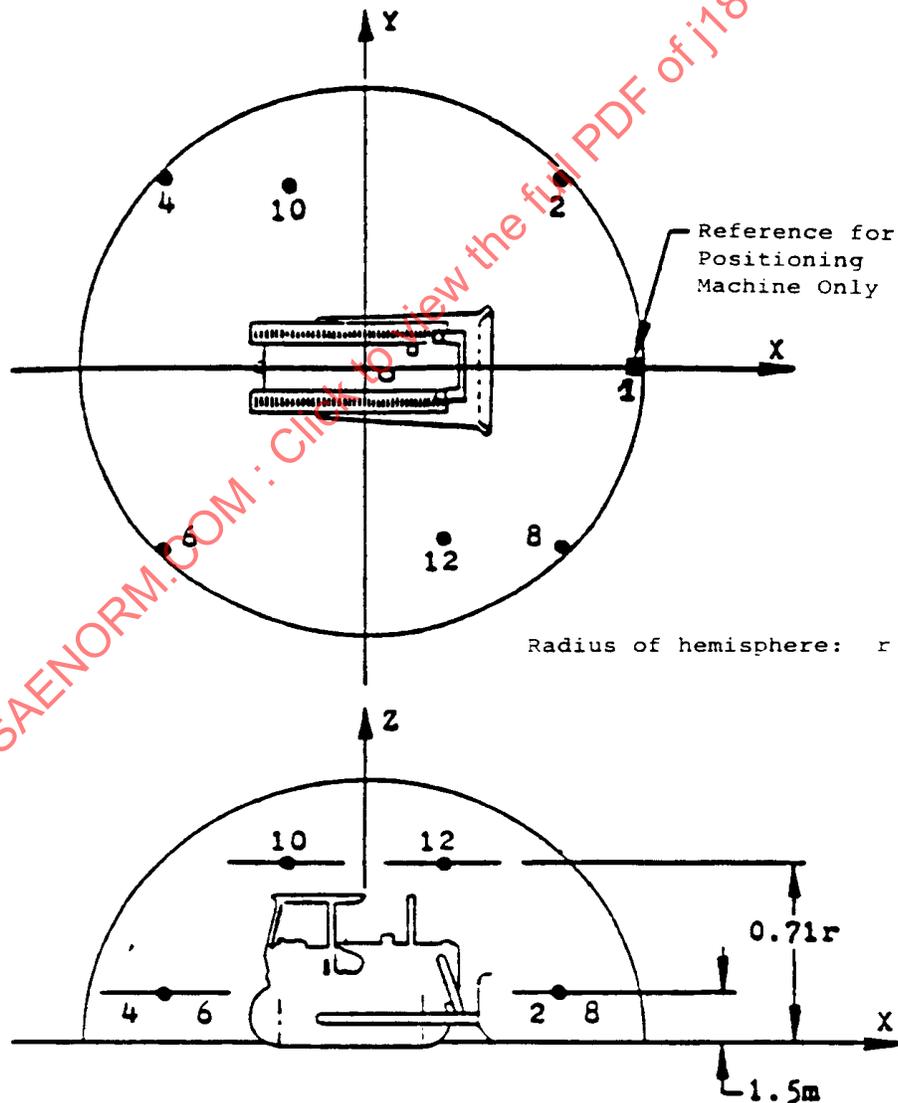


FIGURE 1 - HEMISPHERE MEASUREMENT SURFACE FOR SOUND PRESSURE

4.3.2 For sound intensity systems the microphone probe axis shall be held perpendicular to the measurement surface. Two general methods are currently in use with their respective merits. Close scanning or area scanning will provide more information than just sound power but is more complex and labor intensive. Though not excluded, close scanning will not be detailed further. Fixed microphone locations at a sufficient number of representative surface segments must be further from the machine which results in lost detail, but simply and accurately determines sound power.

A hemispherical measurement surface is easily understood and implemented. Microphone positioning is most easily accomplished with a quarter arc boom pivoted to rotate above the hemisphere center. The arc boom provides the correct orientation of the microphone probe toward the hemisphere center located on the reflecting plane. Microphone repositioning becomes the simple horizontal rotation of the supporting arc boom to the next position (until the microphone probe must be moved higher along the arc boom for the upper layers). The suggested 24 microphone position array is described (at least 20 positions shall be used on a close enclosing hemisphere to ensure accuracy). The area is obtained by multiplying the hemisphere radius squared by the microphone location segment area factor given in Table 3 and illustrated in Figure 2. To qualify the number of surface segments necessary for a different measurement surface shape, continue doubling the number of surface segments until the change with each increase is less than 0.5 dB sound power.

TABLE 3 - MICROPHONE LOCATION SEGMENT AREA FACTORS

Segments per Layer	Elevation Vertical Angle	Counterclockwise Angle Relative to Front	Segment Area Factor Multiply by (r) Squared
Bottom - 12	75 degree	Start @ 0, inc. 30 degree	0.270
Middle - 8	45 degree	Start @ 0. inc. 45 degree	0.248
Upper - 4	15 degree	Start @ 45, inc. 90 degree	0.263

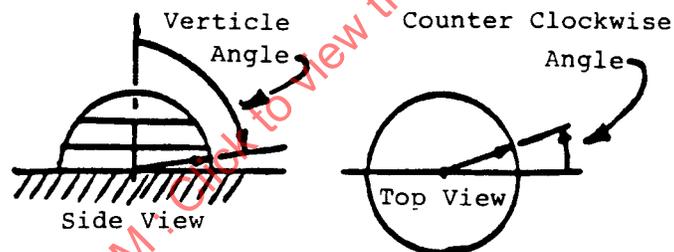


FIGURE 2 - ORIENTATION OF VERTICAL AND CLOCKWISE ANGLES

4.4 Machine Location

The basic machine structure will be centered over the hemisphere center and the front pointed toward position No. 1. Attachments will be installed and operable. The attachment will be carried at travel height (normally 0.3 m for front buckets or blades) except when attachment motion is required during the cycle. When specified, the machine shall be elevated to obtain clearance between the ground and the wheels or tracks to permit operation of the power train without machine travel.

4.4.1 Wheeled machines (except excavators and backhoes) shall be mounted on stands allowing the powered wheels to turn freely without touching the ground. Ground clearance shall not exceed 75 mm. Backhoe loaders in the backhoe mode will have the bucket and stabilizers in the fully down position on high friction material such as rubber belting.

4.4.2 Tracked machines (except excavators) shall be mounted on stands above a hardwood (or similar material) skid surface allowing the tracks to slide freely without moving the machine. Stand height shall be adjusted to allow a suggested 25 to 50 mm clearance between the track chain and track rollers. The skid surface height shall not exceed 100 mm above the reflecting plane. Graphite or grease may be used to lubricate the hardwood skin surface.

NOTE: Supporting track weight on the skid allows realistic tensioning of the upper track spans since tension affects noise; any other method of controlling track tension while maintaining the same sound characteristics is allowed.

The hardwood skid may be permanent or installed on a plate for temporary use. Proper care in making the plate and shimming it on the reflecting plane will reduce plate noise contribution to insignificance.

4.4.3 Wheeled and tracked excavator machines shall be in contact with the reflecting plane or protecting rubber belting or any other non-absorptive material.

4.5 Machine Operation

The machine shall be operated at a stabilized running temperature for the prevailing ambient condition. All engines on a multi-engined machine shall be operated concurrently. Sound data on the machine shall be measured under the two operating conditions as follows:

4.5.1 Static Condition

The machine will be operated at the manufacturer's specified rated engine speed under no-load condition with the transmission in neutral.

4.5.2 In-Place Dynamic Condition

Machine operations are described in Appendices A through E. For machine types not listed use the dynamic cycle in the EU Sound directive or devise a cycle to characterize machine work and describe the cycle along with the data.

4.6 Climatic Conditions

Ambient wind and temperature shall be measured at a height of 2 m above the ground and recorded. Measurements shall not be conducted outdoors when precipitation is falling or when the test surface is covered with snow or temperature is below $-10\text{ }^{\circ}\text{C}$ or above $+50\text{ }^{\circ}\text{C}$ or if the wind velocity exceeds 8 m/s.

4.7 Measurements

4.7.1 Criteria for A-weighted background noise measured at the microphone positions shall be as follows:

4.7.1.1 For sound pressure level instruments, background noise shall be at least 10 dB below the measured level of the machine under test.

4.7.1.2 For sound intensity systems, background noise can equal that of the machine as long as no other noise source is within the measurement hemisphere. If background noise within 5 dB of the vector measurement is present, it shall be constant within 2 dB during the measurement and during the entire data accumulation.

4.7.2 Integration Period

Shall be the duration of one cycle unless the event being simulated is a drive-through or static rated speed test, in which case, a single integration period of 20 to 30 s at each microphone location is recommended. It is recommended that three correctly executed cycles be measured at each microphone location. The surface segment measurements will be used to obtain the surface energy average sound pressure level \bar{L}_{pAeq} . The measurements from each surface segment will be energy-averaged together for comparison. The average of the highest two (within 2 dB of each other) will be used to obtain the surface energy average sound pressure level \bar{L}_{pAeq} .

4.7.3 Number of Dynamic Cycles

Three dynamic cycles shall be carried out resulting in three measurements to be taken at each of the six microphone positions. Calculate the three sets of data obtained at all microphone positions. If two of the three values so obtained do not differ by more than 1 dB, further measurements are not necessary. If this is not the case, continue taking measurements until two values within 1 dB of each other are obtained. Report the arithmetic mean of the two highest values that are within 1 dB of each other as the value of the A-weighted sound power level.

4.8 Calculations

4.8.1 For sound pressure level systems, the surface energy average sound pressure level L_{pAeq} shall be calculated from each set of measured values of the energy average A-weighted equivalent continuous sound pressure level from all six microphone locations based on an energy average. The sound power level is obtained by adding an area factor, $10 \log (S/S_0)$, and the environmental factor K.

$$L_{WAeq} = \bar{L}_{pAeq} + 10 \log (S/S_0) - K \quad \text{decibels} \quad \text{Ref: 1pW} \quad (\text{Eq. 1})$$

where:

S is the area of the measurement surface in square meters.

Ref: $S_0 = 1 \text{ m}$. ($S = 2 \pi r^2$ for a hemispherical measurement surface.)

(See Table 4.)

TABLE 4 - AREA FACTOR FOR STANDARD RADIUS HEMISPHERES

Radius	10 Log(S/S ₀)
4 m	20 dB
10 m	28 dB
16 m	32 dB

The methods described within ISO 3744 should be used to determine the environmental factor K or to determine if the reflecting plane is suitable. For test sites, which consist of a hard, flat surface such as asphalt or concrete and with no sound-reflecting obstacles within a distance from the source equal to three times the greatest distance from the source center to the lower measurement points, it may be assumed that the environmental correction factor K is less than or equal to 0.5 dB and is, therefore, negligible.

4.8.2 For sound intensity systems, the products of the sound intensity vectors times the represented perpendicular surface segments are summed. The surface correction factor K may be ignored if less than 0.5 dB. The total is sound power in decibels.

4.9 Information to be Recorded

4.9.1 Machinery Under Test

The machine manufacturer, model number, arrangement, major attachments, engine speed at rated speed no-load condition, and maximum governed engine speed (during the in-place dynamic test only) shall be recorded. The machine operation will be specified either as a base mode operation under the appendix, or detailed to include gear selection, attachment operation, engine speeds, and if tracked, the track tension adjustment.

4.9.2 Instrumentation

State the instruments used during the tests to include name, type, manufacturer, and serial number.

4.9.3 Acoustical Data

The measurement surface radius, microphone placement, average background sound pressure level, machine energy averaged sound pressure level or energy average sound intensity, and calculated sound power level, in A-weighted decibels, for the static and in-place dynamic test conditions.

4.10 Information to be Reported

- 4.10.1 The machine manufacturer, model number, arrangement, major attachments, engine speed at rated speed no-load condition for the static test, and maximum governed engine speed for the in-place dynamic test shall be recorded. For tracked machines, the track tension adjustment will be reported. The machine operation will be specified either as a base mode operation under the appendix, or detailed to include gear selection, attachment operation, and engine speeds.
- 4.10.2 The sound power level in A-weighted decibels for both the static and in-place dynamic test conditions rounded to the nearest decibel.

5. GENERAL COMMENTS

- 5.1 It is recommended that persons trained and experienced in the current techniques of sound measurements select the instrumentation and conduct the tests. Attention to detail and a thorough understanding of the machine and test instrumentation operational requirements shall be prerequisites of all personnel attached to the evaluation program.
- 5.2 Proper use of all test instrumentation is essential to obtain valid measurements. Operating manuals or other literature furnished by the instrument manufacturer should be referred to for both recommended operation of the instrument and precautions to be observed.
- 5.2.1 The effects of ambient weather conditions on the performance of all instruments (for example: temperature, humidity, barometric pressure, and stray magnetic fields) must be known. Instrumentation can be influenced by low or high temperature, and caution should be exercised.
- 5.2.2 Proper signal levels, terminating impedances, and cable lengths on multi-instrument measurement systems must be known.
- 5.2.3 Proper acoustical calibration procedure, to include the influence of extension cables, etc., should be performed. Field acoustical calibration shall be made immediately before and after the testing of each piece of earthmoving machinery. The calibration before and after shall not vary by more than ± 0.5 dB for tests to be valid.
- 5.2.4 The overall effect due to an alternate test environment on the sound level measurement shall not exceed ± 1.0 dB(A) from the sound power measurement made at the test site described in 4.1.
- 5.3 It should be recognized that variations in measured sound levels may occur due to variations in test site, ambient weather differences (temperature, wind, and their gradients), test equipment differences, and inherent differences between nominally identical machines.

6. NOTES

6.1 Marginal Indicia

A change bar (I) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

APPENDIX A - EXCAVATORS (HYDRAULIC OR ROPE OPERATED)

Preface

(This appendix forms an integral part of the document.)

A.1 DEFINITION (IN ACCORDANCE WITH ISO 6165)

A self-propelled crawler or wheeled machine with an upper structure capable of a minimum of 360-degree rotation, which excavates, elevates, swings, and dumps material by the action of a bucket fitted to the boom and arm or telescoping boom, without moving the chassis or undercarriage during any one cycle of the machine.

A.2 SAFETY AND OPERATION

All relevant safety precautions and the manufacturer's operating instructions shall be followed during the test.

Any signal devices, such as forward warning horn or backup alarm, shall not be activated during the test.

A.3 SETUP OF THE MACHINE

The excavator shall be equipped with the bucket, such as hoe, shovel, grab type, or dragline, designated for the manufacturer's production version. Engine and hydraulic systems shall be warmed to normal operating conditions for the prevailing ambient temperature. The engine governor control shall be set to the maximum position (high idle). All actuating movements shall be carried out at maximum velocity but without activating relief valves or contacting end-of-travel mechanical barriers. The excavator shall be located on a hard reflecting plane as specified in 4.1.

A.4 OPERATION OF THE MACHINE

A.4.1 Basic Machine Cycle

The dynamic cycle, without moving material, as described in A.4.2 to A.4.5, comprises three 90-degree swings to the left of the operator and back, with the machine positioned so the center of rotation of the upper structure of the excavator (which is defined as the machine center for the purpose of locating the machine) shall coincide with the center of the hemisphere shown in Figure 1. The longitudinal axis of the machine shall coincide with the x-axis and the front of the machine shall face position 1.

Each swing shall be from the x-axis to the y-axis, and back to the x-axis. A single cycle consists of three continuous 90-degree swings to the left and back while moving the front end attachment through a complete sequence for each 90-degree swing and back.

A.4.2 Hoe Attachment

The aim of the dynamic cycle is to simulate trench excavation and dumping the material adjacent to the trench. At the beginning of the cycle, the boom and arm shall be adjusted to place the bucket at 75% of the maximum reach with the bucket 0.5 m above the ground surface. The cutting edge of the bucket in the rolled forward position shall be at an angle of 60 degrees to the test site measurement surface.

First raise the boom and simultaneously retract the arm so that the bucket remains 0.5 m above the test site for 50% of the remaining boom and arm travel distance. Then roll back or curl the bucket. Lift the bucket by raising the boom and continue to retract the arm to simulate the adequate clearance (30% of maximum bucket lift height) needed to swing across the edge of the trench. Execute a 90-degree swing to the left of the operator. Raise the boom during the swing and extend the arm until the bucket has reached 60% of maximum boom lift height. Then uncurl the arm until it is 75% extended. Roll forward or uncurl the bucket until the cutting edge is vertical. Execute a return swing to the starting position with the boom being lowered and bucket being curled.

Repeat the sequence of events two more consecutive times in order to complete a single dynamic cycle.

NOTE: The single dynamic cycle is repeated three times to meet the requirements of three dynamic cycles as defined in 4.7.3.

A.4.3 Shovel Bucket Attachment

The aim of the work cycle is to simulate excavation at the height of a high wall. At the beginning of the cycle, with the bucket cutting edge parallel to the ground, the bucket shall be 0.5 m above the test site in the 75% retracted position.

First extend the bucket 75% of travel while maintaining the original bucket orientation. Then roll back or curl the bucket and raise it to 75% of maximum lift height and 75% of dipper arm extension. Execute a 90-degree swing to the left of the operator and at the end of the swing actuate the bucket dump mechanism. Execute a return swing to the starting position with the bucket 0.5 m above the test site in the 75% retracted position.

Repeat the sequence of events two more consecutive times in order to complete a single dynamic cycle.

NOTE: The single dynamic cycle is repeated three times to meet the requirements of three dynamic cycles as defined in 4.7.3.

A.4.4 Grab Type Attachment

The aim of the work cycle is to simulate excavation of a pit. At the beginning of the cycle, the grab shall be open and 0.5 m above the test site.

First close the grab. Then raise the grab to half of the maximum lift height. Execute a 90-degree swing to the left of the operator. Open the grab. Execute a return swing while lowering the attachment to the starting position.

Repeat the sequence of events two more consecutive times in order to complete a single dynamic cycle.

NOTE: The single dynamic cycle is repeated three times to meet the requirements of three dynamic cycles as defined in 4.7.3.

A.4.5 Dragline Attachment

The aim of the work cycle is to simulate excavation of a layer in a trench and dumping of the material adjacent to the trench. For the duration of the cycle, the boom shall be positioned at an angle of 40 degrees. The bucket shall hang vertically under the end of the boom and 0.5 m above the test site with drag chains not touching the ground.

First retract the bucket to bring it as close as possible to the machine while maintaining the distance of 0.5 m above the test site. When the bucket has been retracted, execute a 90-degree swing to the left of the operator. Simultaneously, raise the bucket to 75% of maximum lift height and extend to maximum reach in the loaded bucket position. Execute a return swing. Simultaneously, actuate the bucket dump and retract the bucket to the starting position.

Repeat the sequence of events two more consecutive times in order to complete a single dynamic cycle.

NOTE: The single dynamic cycle is repeated three times to meet the requirements of three dynamic cycles as defined in 4.7.3.

APPENDIX B - TRACTORS WITH DOZER EQUIPMENT

Preface

(This appendix forms an integral part of the document.)

B.1 DEFINITION (IN ACCORDANCE WITH ISO 6165)

A self-propelled crawler or wheeled machine used to exert a push or pull force through mounted equipment.

B.2 SAFETY AND OPERATION

All relevant safety precautions and the manufacturer's operating instructions shall be followed during the test.

Any signal devices, such as forward warning horn or backup alarm, shall not be activated during the test.

B.3 SETUP OF THE MACHINE

The tractor shall be equipped with the dozer designated for the manufacturer's production version. Engine and hydraulic systems shall be warmed to normal operating conditions for the prevailing ambient temperature.

B.4 OPERATION OF THE MACHINE

B.4.1 The machine shall be positioned and elevated at the center of the hemisphere as defined in 4.4.

The machine shall be operated with the dozer in a lowered carry position 0.3 m ± 0.05 m above the ground plane of the hemisphere. The machine shall be operated at maximum governed engine speed (high idle) in a constant simulated forward and reverse travel mode. The simulated forward travel velocity shall be close to but not exceeding 4 km/h for crawler and steel-wheeled machines and 8 km/h for rubber-tired wheeled machines. The matching gear ratio shall be used in the reverse travel mode, regardless of the velocity. For the majority of machines, this will be first forward and first reverse. Hydrostatic drive machines may use a range of 3.5 to 4 km/h (crawler or steel-wheeled) and 7 to 8 km/h (rubber-tired) because of difficulty in setting ground speed controls for exact travel speeds.

These modes of operation are nonstop with no movement of the dozer equipment. If the lowest gear results in a velocity higher than the specified velocity, it shall be used with the engine operating at maximum governed speed (high idle). For hydrostatic drive machines with the engine at maximum governed engine speed (high idle), the ground speed control shall be set to match to specified velocities stated.

NOTE: Three separate forward and reverse cycles should be carried out to meet the requirements of three dynamic cycles as defined in 4.7.3.

B.4.2 Calculation for Combined Simulated Forward and Reverse Travel Mode Cycles

Since the forward and reverse modes of operation are two distinct modes, both the time and sound pressure level shall be measured as separate entities for each travel direction. The formula to be used for the calculation of the equivalent continuous A-weighted sound pressure level, $L_{pAeq,T}$, in decibels, for the combined dozer cycle is given by the following:

$$L_{pAeq,T} = 10 \log \frac{V_1 V_2}{V_1 + V_2} \left[\left(\frac{1}{V_1} \times 10^{0.1 L_{pAeq,1}} \right) + \left(\frac{1}{V_2} \times 10^{0.1 L_{pAeq,2}} \right) \right] \quad (\text{Eq. B1})$$

where:

V_1 is the velocity for the simulated forward travel mode.

V_2 is the velocity for the simulated reverse travel mode.

$L_{pAeq,1}$ and $L_{pAeq,2}$ are the quantities determined during the measurements at V_1 and V_2 velocities.

Use 1/V (where V represents velocity) for the in-place dynamic test instead of time used for the moving test to proportion the duration of forward and reverse travel.