SAE International™ SURFACE VEHICLE STANDARD

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Agricultural Tractor Test Code

***Foreword*—**This document is being cancelled due to outdated tractor performance test codes contained therein.

***1. Scope*—**The purpose of this SAE Standard is to define test conditions, give a description of the tests to be made, specify data to be obtained, show formulas and calculations, define terms, and establish a uniform method of reporting so that performance data obtained on various makes and models of tractors, tested in accordance with this document, will be comparable regardless of where the test is made. It is obvious, because of the many present day tractor models available in a number of types with numerous items of special or optional equipment, that the scope of this document must be limited to obtaining and reporting only the most significant of widely used performance data.

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2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest version of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J709d—Agricultural Tractor Tire Loadings, Torque Factors, and Inflation Pressures
SAE J919c—Sound Measurement—Off-Road Work Machines—Operator—Singular Type
SAE J1008—Sound Measurement—Self-Propelled Agricultural Equipment—Exterior
SAE J1150—Terminology for Agricultural Equipment
SAE J1170—Front and Rear Power Take-Off for Agricultural Tractors
SAE TSB 003—Rules for SAE Use of SI (Metric) Units

2.2 Related Publication—The following publication is provided for information purposes only and is not a required part of this document.

2.2.1 ISO PUBLICATION—Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002.

ISO/DIS 789/1—Agriculture tractor test procedure—Power tests

3. Definitions

3.1 Agricultural Tractor——See SAE J1150.

3.2 Ballast—Any substance that is added to or removed from the tractor for the purpose of changing traction or stability. It may be added or removed at the will of the operator, and its presence is not always essential for operation of the complete tractor. Mounted equipment may be used as ballast.

3.3 Spark Ignition Engine—An internal combustion engine in which the ignition of the air-fuel mixture is accomplished by a spark inside the combustion chamber but generated from a source outside the combustion chamber. The mixing of the fuel and air in conventional spark ignition engines occurs before compression, the fuel metering being accomplished by a carburetor or similar device. The control on the amount of air fuel mixture admitted to the cylinders is usually secured by means of a throttle valve in accordance with power requirements.

3.3.1 COMPRESSION IGNITION ENGINE—An internal combustion engine in which the ignition of the air-fuel mixture is accomplished by the heat of compression. The initial mixing of the fuel and air in the conventional compression ignition engine occurs near the end of the compression stroke, the fuel being metered into the combustion chamber by means of a suitable fuel metering mechanism, with the quantity varied in accordance with power requirements.

3.3.2 RATED SPEED OF THE ENGINE—The speed in revolutions per minute specified by the tractor manufacturer for continuous operation at maximum power for a particular operation. There may be one or more speeds specified. For example, there may be different rated speeds for operation at the mechanical power outlet, at the power take-off shaft, and at the drawbar.

3.3.3 HIGH IDLE ENGINE OR POWER OUTLET SPEED—The high idle speed in revolutions per minute, sometimes called maximum no-load speed, necessary to provide the required full load speed, sometimes called rated speed, for maximum power at the mechanical power outlet, power take-off shaft, or drawbar.

3.4 Selective Gear Fixed Ratio Transmission—A transmission of such design that the ratio of engine speed to final drive member speed can be changed but with interruption of power to the final drive members.

3.4.1 TORQUE MULTIPLIER—A mechanism capable of automatically multiplying the engine torque. In this case, the increased torque produces a corresponding increase in drawbar pull.

NOTE—The torque converter falls into this classification.

3.4.2 TORQUE MULTIPLIER LOCKOUT—A means by which the torque multiplier can be made inoperative.

3.4.3 AUTOMATIC POWER SHIFTING FIXED RADIO TRANSMISSION—It is of such design that it automatically shifts from one fixed ratio to another.

3.4.4 OPERATOR CONTROLLED POWER SHIFTING FIXED RADIO TRANSMISSION

3.4.4.1 Full Range—This type of transmission is of such design that the operator can change from any fixed ratio to any other fixed ratio with the tractor under power.

3.4.4.2 Partial Range—This type of transmission is of such design that the operator can change from certain fixed ratios to other fixed ratios with the tractor under power.

3.4.5 INFINITELY VARIABLE TRANSMISSION—This type of transmission is of such design that the operator can infinitely vary the ratio between engine and final drive members throughout part or all of the speed range of the tractor. This type of transmission includes electrical, hydrostatic, friction, and any other devices.

3.5 Mechanical Power Outlet—Any outlet through which the tractor engine power can be delivered to a dynamometer, such as a belt pulley, power take-off shaft, or any other shaft or outlet.

3.5.1 MAXIMUM POWER AT THE MECHANICAL POWER OUTLET—The average maximum sustained power the tractor delivers to a dynamometer through a mechanical power outlet with adjustments as specified by the manufacturer.

3.5.2 POWER AT THE STANDARD POWER TAKE-OFF SPEEDS—The power the tractor delivers to a dynamometer through a mechanical power outlet at SAE standard power take-off speed or speeds.

3.6 Maximum Drawbar Power—The maximum power the tractor is capable of delivering at the drawbar on the test runway or runways.

3.7 Maximum Available Drawbar Power—The average maximum sustained power the tractor delivers at the drawbar during several complete circuits of the drawbar test course. Power shall be determined from the average drawbar pull obtained over two or more complete circuits of the drawbar test course and the average travel speed concurrently obtained on the test runway or runways.

3.8 Specific Fuel Consumption—The ratio between the mass of fuel consumed per unit of time and the corresponding measured power. Distinction should be made between specific fuel consumption based on the power obtained at a mechanical power outlet and that based on the power obtained at the drawbar.

3.9 Specific Volumetric Consumption—The ratio between the measured power and the corresponding volume of fuel consumed per unit of time. Distinction should be made between specific volumetric consumption based on the power obtained at mechanical power outlet and that based on the power obtained at the drawbar.

3.10 Drawbar Pull Versus Travel Speed—Sometimes referred to as the lugging ability of the tractor. This shows the ability of the tractor to produce increased drawbar pull with the corresponding reduction in travel speed.

4. Test Conditions

4.1 The tractor tested shall represent a production model in all respects. The tractor manufacturer shall supply the tractor when a certified test report is desired. The manufacturer shall supply a list of technical specifications of the tractor's construction giving detailed information regarding the powerplant, transmission, final drive, miscellaneous special and optional equipment, center of gravity of tractor with operator, machine clearance circles, and turning radii with and without brakes. The manufacturer shall also supply printed information covering all operating and servicing instructions necessary for the satisfactory operation of the tractor. All specifications shall be subject to verification.

4.1.1 The tractor manufacturer shall appoint an official representative to be present during certification runs. It shall be the duty of the manufacturer's representative to make all decisions where permissible choices or company policy are concerned. He shall also prepare the tractor for test, operate it during limber-up, make any adjustments required, and at conclusion of the test, prepare tractor for final inspection and reassemble after inspection.

4.1.2 The tractor shall be equipped with the most frequently installed items of optional equipment; however, the manufacturer should ascertain the optional equipment requirements of the specific test station, when tests are to be made for certification. Power consuming accessories shall be disconnected only if it is practical for the operator to do so as a normal farming practice. Any equipment on the tractor shall be complete and operable. The equipment shall be such that it does not interfere with the conduct of the test.

4.1.3 The tractor shall be operated as recommended by the manufacturer. Tracks or wheel and tire equipment, adjustments, servicing operations, and selection of fuel and types of lubricants shall conform to instructions printed in the published information delivered with the tractor.

4.1.4 Commercially available fuel shall be used providing it meets the manufacturer's specifications.

4.1.5 Commercially available lubricants shall be used providing they meet the manufacturer's specifications.

4.1.6 Where choices of adjustments or operating conditions are made by the manufacturer, the guide in making such choices should be the suitability for general operation.

4.1.7 Unless otherwise specified, controls that are easily manipulated from tractor seat may be used to secure optimum performance during runs.

4.1.8 The maximum drawbar hitch-point height shall be established in accordance with 7.3 as defined under Section 7.

4.1.9 Drive wheel or track slippage shall be calculated as shown under Section 7, and shall not exceed 15% for tractors equipped with pneumatic tires or 7% for tractors equipped with steel lugs or tracks.

4.2 All measurements shall be obtained with instruments and test equipment having an accuracy representative of good laboratory practice.

Power at the mechanical power outlet shall be measured by means of a dynamometer. The laboratory fuel supply shall be arranged so that the fuel pressure at the carburetor or the fuel transfer pump is equivalent to that which exists when the tractor fuel tank is half full. The equipment should be arranged so that the fuel temperature is comparable to that which exists in normal operation of the tractor when fuel is taken from the tractor fuel tank.

4.2.1 Laboratory air temperature readings shall be 23 °C ± 7 °C (73 °F ± 13 °F) (dry-bulb) and readings shall be taken at a sufficient distance from the tractor to record actual ambient temperature. The test area shall be well ventilated. Engine exhaust gas shall be discharged from the test area. If an auxiliary laboratory exhaust stack is used, it shall be of such design that it does not change the engine performance. Laboratory atmospheric pressure shall not be less than 96.6 kPa (28.6 in Hg).

4.2.2 The test tractor shall be equipped with track or tire and wheel equipment regularly supplied to the trade. Additional mass may be added as ballast if the manufacturer regularly supplies it for sale. When liquid ballast is used in tires, the inflation pressure shall be determined at the same height as the valve with the valve in the lowest position. Individual tire inflation pressures shall be in accordance with the manufacturer's instructions, and at these pressures, the tire load including the mass of a 75 kg (165 lb) operator on the tractor seat shall not exceed the limitations of SAE J709d.

Because the traction coefficient of a tire changes with wear, the tread bar height of the test tire prior to the start of run 5.3.1 shall be not less than 65% of that of a new tire. To establish tread bar height, the tire shall be mounted and inflated as for the runs covered in 5.3.1. The height of the tire tread bars shall be measured by use of a 3-point gage. The gage shall be placed astride of the tread bar and perpendicular to the direction of the tread bar as close to the tire centerline as possible. Two legs of the gage shall be positioned at the base of the tread bar (at the point of tangency between the tire carcass and the radius joining the tread bar to the carcass). The third point of the gage shall be in the center of the tread bar. The tread bar height shall be the difference in elevation between the two outside legs of the gage and the center point. The tread bar height measured in this manner shall be taken for a minimum of four equally spaced locations around the periphery of the tire. The results of these measurements shall be averaged and compared to similar data on a new tire of the same make, size, and type.

4.3 The drawbar test course shall be a hard surface on which data can readily be reproduced. It shall be constructed according to modern highway construction standards and of sufficient strength to withstand the heaviest tractor. The drawbar test runway or runways shall be straight, level, and not less than 91.4 in (300 ft) long with the approach of such length that speed and pull can be stabilized before entering the runway. For tractors equipped with rubber tires, the recommended surface materials of the drawbar test course are, in the order of preference:

4.3.1 CONCRETE—The runway or runways of the drawbar test course shall have a minimum of expansion joints. The surface shall have a uniform gritty texture with a corrugated appearance. This type of finish is also known as a belted finish.

4.3.2 BITUMINOUS—These materials are generally known as tar-macadam or asphaltic concrete.

4.3.3 EARTH—Test courses having earthen surfaces shall be well-packed and substantially free of loose material. This requires a soil that will adhere together when properly prepared and maintained. Suitable maintenance equipment shall be provided for grading, applying water, and packing both the subsurface and the surface. The use of this type of surface is discouraged for testing tractors equipped with pneumatic tires.

For tractors having steel lugs or tracks, the test course should be earth as described in 4.3.3.

4.4 All information published in the test report shall represent the performance of a complete tractor. Power measurements shall be taken as delivered to the test equipment from a mechanical power outlet, if available, and from the drawbar.

4.4.1 The test report shall accurately define the tractor type and list all items of special or optional equipment used during the run.

4.5 For official certification, the Test Station shall provide facilities and personnel to conduct the performance runs, record all data, prepare, certify, and publish the report.

4.6 Until satisfactory correction formulas are developed for all tractors, only observed data will be published. However, the necessary wet and dry-bulb air temperatures and barometric pressure are recorded and published so that correction formulas may be applied.

5. Detailed Description of Test Procedure

5.1 Preparation of Tractor for Performance Runs

5.1.1 The purpose of these preparatory runs is to stabilize the tractor performance for the later runs by operating the tractor to remove stiffness, check its condition, and make permissible adjustments to assure normal operation.

5.1.2 The tractor shall be limbered-up in accordance with the manufacturer's recommendations.

Limber-up shall be accomplished with approximately the same mass as will be used for the maximum drawbar power runs.

Minor adjustments are permissible during and at the end of this run. Adjustments shall be limited to those which conform to the published instructions supplied with the tractor.

The recording of hours of operation for the entire test shall begin with the start of this run.

Prior to the start of this run, the engine crankcase shall be drained and refilled with new oil of the type and viscosity recommended by the manufacturer as stated in the published information delivered with the tractor. The oil used to fill the crankcase, any oil added or withdrawn during the test, and the oil drained from the crankcase at the conclusion of the test shall be weighed and specific gravity taken, in order that the total volume of oil used during the entire test can be determined.

Specific gravity data are to be obtained at or converted to 15/15 °C (60/60 °F).

Prior to the start of this run, the transmission and other oil reservoirs on the tractor shall be filled with lubricants of the type and viscosity recommended by the manufacturer.

5.2 Mechanical Power Outlet Performance

5.2.1 MAXIMUM POWER-FUEL CONSUMPTION

5.2.1.1 The purpose of this run is to determine the maximum power as delivered through a mechanical power outlet to a dynamometer at the manufacturer's specified engine or mechanical power outlet speed; and to record the corresponding fuel consumption.

NOTE—This power can be measured through a belt pulley, power take-off shaft, or any other mechanical power outlet depending upon limitations of test equipment.

5.2.1.2 During the preparation for this run, the manufacturer shall establish fuel settings and ignition or injection timing, which shall remain unchanged throughout the test. The governor and the position of the manually operated governor control shall be adjusted to provide the high idle engine or power outlet speed specified by the manufacturer for maximum power operation.

5.2.1.3 Data recorded at intervals of not more than 10 min shall include engine crankshaft revolutions per minute, dynamometer revolutions per minute, mechanical power outlet shaft revolutions per minute, coolant temperature, wet and dry-bulb air temperatures, fuel consumed, and dynamometer torque. Speeds of engine, mechanical power outlet, and dynamometer shall be taken simultaneously. The coolant temperature shall be taken in the radiator top tank. The barometric pressure shall be recorded at the beginning of the run and at I h intervals thereafter. The duration of the run shall be a minimum of 2 h continuous operation.

NOTE—In order to determine belt slippage, simultaneous determinations of the revolutions of both drive and driven pulleys shall be taken at no-load for a minimum of 1000 revolutions of the drive pulley with the belt tension used for this run. Belt slippage shall be calculated as shown under Section 7. Belt tension shall be adjusted for optimum power and remain unchanged throughout run. Usually optimum power is obtained with approximately 1% slippage.

5.2.2 VARYING POWER–FUEL CONSUMPTION

5.2.2.1 The purpose of this run is to determine fuel consumption and speed when power is varied.

5.2.2.2 All adjustments shall be the same as in 5.2.1.2.

5.2.2.3 Data recorded shall be the same as in 5.2.1.3. The duration of the run shall be for 2 h of continuous operation.

5.2.2.4 The run shall consist of six power settings, each to be run for a period of 20 min in the following order:

a. 85% of dynamometer torque obtained at maximum power, run 5.2.1.
b. Zero dynamometer torque.
c. One-half of 85% of dynamometer torque obtained at maximum power, run 5.2.1.
d. Dynamometer torque at maximum power.
e. One-quarter of 85% of dynamometer torque obtained at maximum power, run 5.2.1.
f. Three-quarters of 85% of dynamometer torque obtained at maximum power, run 5.2.1.

NOTE—These percentages represent long and continuous past practice and are necessary to maintain continuity in procedure and meaning of the results.

5.2.3 POWER AT STANDARD TAKE-OFF POWER SPEED—(This run is made only when the engine speed at maximum power does not correspond to the engine speed at SAE standard power take-off speeds as specified in SAE J1170.)

5.2.3.1 The purpose of this run is to determine power at the standard power take-off speed or speeds, and to record the corresponding fuel consumption.

5.2.3.2 All adjustments shall be the same as in 5.2.1.2.

5.2.3.3 Data recorded shall be the same as in 5.2.1.3. The duration of each run shall be a minimum of 1 h of continuous operation.

5.3 Drawbar Performance

5.3.1 MAXIMUM DRAWBAR POWER

5.3.1.1 The purpose of this run is to determine the maximum power in not more than 12 forward gears or 12 travel speeds as selected by the manufacturer. The maximum travel speed shall not exceed the safety limitations of track or test equipment.

5.3.1.2 All engine adjustments shall be the same as in 5.2.1.2 unless the manufacturer specifies a different engine revolutions per minute for drawbar operation than for mechanical power outlet operation, run 5.2.1. In this case, the position of the manually operated governor control shall be adjusted to provide the maximum high idle engine or power outlet revolutions per minute specified by the manufacturer for drawbar operation.

The tractor tire and wheel or track equipment shall conform to the manufacturer's recommendations. Ballast added shall meet requirements specified under 4.2.2 of Section 4.

The tractor shall be weighed with operator and ballast (if ballast is used) after tractor has been properly serviced, fuel tank and radiator filled, and all test equipment in place. For wheel type tractors, the total weight of the tractor, the weight on the front wheels, and the weight on the rear wheels shall be recorded and reported with and without ballast, but including a 75 kg (165 lb) operator.

In the interests of steering control and to obtain more uniform results, the maximum drawbar hitch point height shall be established in accordance with 7.3 as defined under Section 7. Preliminary drawbar runs at maximum drawbar pull shall be made to establish maximum hitch point height. The height as related to the tractor shall remain unchanged throughout all drawbar tests.

The effective circumference of the drive wheels or tracks shall be determined by driving the tractor over the drawbar test runway or runways and counting the revolutions of each drive wheel or track. The tractor shall be driven at low speed, without drawbar pull, and with all ballast in place (if ballast is used).

Drive wheel or track slippage is calculated as shown under Section 7. If drive member slippage is excessive, the drawbar pull shall be reduced until slippage does not exceed 15% for tractors equipped with pneumatic tires and 7% for tractors equipped with steel lugs or tracks. Where there are two or more travel speeds in which maximum power will be limited by drive member slippage, only one travel speed shall be checked.

5.3.1.3 Data recorded shall include: average drawbar pull and engine crankshaft revolutions per minute maintained over test runway or runways, drive member revolutions to traverse the test runway or runways, time to traverse the test runway or runways, engine coolant temperature, wet and dry-bulb air temperatures, and barometric pressure. Test results reported are recommended to be an average of two or more suitable runs over the drawbar test runway or runways. Two suitable runs would be those in which test conditions are stabilized, and during which the average travel speed for the two runs is within 1% of each other.

5.3.2 VARYING DRAWBAR POWER–FUEL CONSUMPTION AND SOUND LEVEL AT OPERATOR STATION

5.3.2.1 The purpose is threefold: first, to determine fuel consumption with the tractor operating at maximum available power, at 75% of the drawbar pull obtained at maximum power in run 5.3.1, and at 50% of the drawbar pull obtained at maximum power in run 5.3.1. Second, to determine the sound level at the operator's station under these load conditions. Third, to determine whether the tractor will maintain a preselected drawbar power output for 10 h and to measure fuel consumed during the run.

5.3.2.2 Except for the run specified under 5.3.2.4(d), all engine adjustments and other items shall be the same as in 5.3.1.2. The gear or travel speed shall be selected by the manufacturer within the speed range normally used in agricultural operations. All runs shall be of sufficient duration to assure accuracy of data.

5.3.2.3 Data recorded shall be the same as obtained in 5.3.1.3 with two exceptions as follows:

a. The drawbar pull shall be the average determined from draft data taken over the complete circuit of the drawbar test course.
b. Sound level measurements at the operator's station are added.

The sound level measurements at the operator's station shall be conducted according to the instrumentation and procedure specified in SAE J919c. The load conditions for these measurements will be those described in 5.3.2.4 of this code instead of the load conditions described in SAE J919c in paragraph 3.3.

5.3.2.4 Fuel consumption runs and measurement of sound level at the operator's station shall be made with the tractor operating as follows:

a. At maximum available power, which is the maximum sustained power the tractor is capable of delivering at the drawbar for a predetermined length of time.
b. At 75% of the drawbar pull obtained in run 5.3.1.
c. At 50% of the drawbar pull obtained in run 5.3.1.
d. At reduced engine speed, where both engine and travel speed ratio are adjusted to produce the pull and travel speed recorded under 5.3.2.4(c).

NOTE—For tractors equipped with torque multiplier with lockout, the four runs shall be made in both torque-multiplier drive and with the torque multiplier in lockout.

5.3.3 DRAWBAR PULL VERSUS TRAVEL SPEED

5.3.3.1 The purpose of this run is to determine the drawbar pull-travel speed characteristic, or lugging ability, of the tractor in the gear or transmission setting selected in run 5.3.2.

5.3.3.2 All adjustments and other items shall be the same as in 5.3.1.2. (It would be desirable to make this run immediately after the maximum drawbar power run has been made in run 5.3.1 in the gear or at the travel speed selected for run 5.3.2.)

Drive member slippage shall not exceed 15% for tractors equipped with pneumatic tires or 7% for tractors equipped with steel lugs or tracks.

5.3.3.3 Data recorded shall be the same as paragraph 5.3.1.3.

5.3.3.4 A series of runs shall be made starting at maximum power. In each succeeding run, the necessary drawbar pull shall be applied to the tractor to reduce the drive member speed in increments of approximately 10%, using drive member speed at maximum power as 100%. A sufficient number of runs shall be made to establish speed at which maximum drawbar pull is obtained, or speed at which maximum drawbar pull is limited by drive member slippage or cooling capacity of torque multiplier when tractor is equipped with torque multiplier.

NOTE—

a. For tractors equipped with torque multiplier and lockout, runs shall be made in both torque multiplier drive and with torque multiplier in lockout.
b. For tractors equipped with an automatic powershifting fixed ratio transmission, the same procedure shall be followed except that the test shall be terminated at the first automatic shift.
c. For tractors equipped with transmissions having infinitely variable engine-to-final drive ratios under the control of the operator, no runs are required. Actual drawbar pull, drawbar power, and speed obtained in run 5.3.1 shall be published.

5.3.4 EXTERIOR SOUND LEVEL—The exterior sound level measurements will be conducted according to the instrumentation and procedures specified in SAE J1008.

6. Final Inspection

6.1 The purpose of the final inspection is to check some of the most significant items of the manufacturer's tractor specifications against the tractor tested, and to inspect the condition of some of the most critical tractor parts. It is suggested that the check of specifications include bore and stroke, valve lift, valve sizes, compression ratio, and carburetor size.

7. Calculations and Formulas

7.1 Drive Wheel or Track Slippage

$$\text{Percent slip} = 100\left(\frac{R - r}{R}\right) \qquad \text{(Eq. 1)}$$

where:

R = Total drive wheel revolution count to traverse the drawbar runway under load
r = total drive wheel revolution count to traverse the drawbar test run way under no-load

7.2 Belt Slippage

$$\text{Percent belt slip} = 100\left(\frac{RN - n}{RN}\right) \qquad \text{(Eq. 2)}$$

where:

$R = \dfrac{\text{Driven pulley revolutions with no-load}}{\text{Drive pulley revolutions with no-load}}$

N = drive pulley rpm with load
n = driven pulley rpm with load

7.3 Stability Factor

$$\text{Stability Factor K} = \frac{Fw \times Wb}{P \times h} \qquad \text{(Eq. 3)}$$

where:

Fw = static front end weight
Wb = wheelbase
P = maximum drawbar pull parallel to ground
h = height of static line of pull perpendicular to ground
K = 1.25 (minimum)—may be more

8. Uniform Method of Publishing Results—All information shall be published in either the SI (Système Internationale, see SAE TSB 003) units and U. S. customary units, or the SI units only.

The following shows what information shall be published in the certified report, how it is obtained, and how it shall be published: