

Foreword

The pursuance of this standard was initiated by the Agricultural Machinery Testing and Evaluation Center (AMTEC) under the project entitled "Enhancing the Implementation of AFMA Through Improved Agricultural Engineering Standards" which was funded by the Bureau of Agricultural Research (BAR) of the Department of Agriculture (DA).

This standard was reviewed by the Technical Committee for Study 1- Development of Standards for Agricultural Production Machinery and was circulated to various private and government agencies/organizations concerned for their comments and reactions. This standard was presented to the Philippine Society of Agricultural Engineers (PSAE) and subjected to a public hearing organized by the National Agriculture and Fisheries Council (NAFC). The comments and reactions received during the presentation and public hearing were taken into consideration in the finalization of this standard.

This standard has been technically revised in accordance with PNS 01:Part 4:1998 - Rules for the Structure and Drafting of Philippine National Standards.

In the preparation of this standard, the following documents/publications were considered:

International Organization for Standardization (ISO) 2288:1997 Agricultural tractors and machines – Engine Test Code – Net Power

Organisation for Economic Co-operation and Development (OECD) Small Engines Code

AMTEC Standard

Agricultural Machinery – Small Engine – Methods of Test

1 Scope

This standard specifies the bench methods for testing fully equipped internal combustion engines with one or two cylinders of up to 20 kW rating used for agricultural purposes. This is applicable to naturally aspirated two-stroke and four-stroke gasoline and diesel engines. Specifically, it shall be used to:

- 1.1 verify the requirements specified in PAES 116 and the specifications submitted by the manufacturer
- 1.2 evaluate the operator's manual as to clarity, usefulness and adaptability
- 1.3 determine the laboratory performance of the engine
 - 1.3.1 for ease of starting
 - 1.3.2 at varying speed
 - 1.3.3 at continuous running condition
- 1.4 prepare a report on the results of the tests

2 Reference

The following normative document contains provisions, which, through reference in this text, constitute provisions of this standard:

PAES 103:2000, Agricultural Machinery – Method of Sampling.

PAES 116:2001, Agricultural Machinery – Small Engine – Specifications

3 Definitions

For the purpose of this standard, the following definitions shall apply:

3.1**bore**

diameter of the cylinder

3.2

compression ratio

ratio of the cylinder volume on top of the piston (piston displacement and combustion chamber) when it is at its lowest position to the volume remaining above the piston when it is at its highest position (combustion chamber)

$$CR = \frac{PD + V}{V}$$

where: $PD = A \times l$

where:

CR is the compression ratio

PD is piston displacement, cm^3

A is the area of the cylinder, cm^2

l is the length of stroke, cm

V is the volume of combustion chamber, cm^3

3.3

continuous brake power

power recommended by the manufacturer for satisfactory operation under continuous duty condition within a specified speed range

3.4

engine

heat engine

mechanical device that converts heat energy produced by combustion of fuel into mechanical energy

3.4.1

compression-ignition engine

engine in which combustion is achieved by compressing the air until a high temperature is achieved to initiate combustion of fuel

3.4.2

spark-ignition engine

engine in which combustion occurs through the initiation of a spark on the fuel and air mixture

3.5

engine performance

maximum brake power, fuel consumption and operating characteristics of the engine at different speeds

3.6

fuel consumption

volume of fuel consumed by the engine on per hour basis

3.7

fully equipped engine

engine equipped with all the accessories necessary to perform its intended functions such as air cleaner, exhaust system, radiator, generator, starter and related parts

3.8

maximum brake power

highest power developed at a given speed

3.9

net power

power output of a “fully equipped” engine

3.10

peak brake power

highest power developed

3.11

rated brake power

power indicated in the specification sheet or plate at a given rated speed submitted by the manufacturer

3.12

rated engine speed

speed in revolutions per minute specified by the manufacturer

3.13

specific fuel consumption

quantity of fuel consumed by an engine on the basis of per horsepower hour

3.14

stroke

length of the piston travel

3.15

torque

product of the force and the perpendicular distance from the line of action of that force to the axis of rotation and is expressed in kg-m

4 General Conditions for Test and Inspection

4.1 Engine on Test

The engine submitted for test shall be sampled in accordance with PAES 103. The applicant/manufacturer shall submit the technical data and information on the engine

4.2 Role of the manufacturer/dealer

The manufacturer/dealer shall submit to the official testing agency the specifications and other relevant information on the small engine. An official representative shall be appointed to conduct minor repair, handle, adjust and witness the test. It shall be the duty of the representative to make all decisions on matters of adjustment and preparation of the machine for testing. The manufacturer/dealer shall abide with the terms and conditions set forth by the official testing agency.

4.3 Running-in

The engine to be tested shall be run-in prior to the test as recommended by the manufacturer.

4.4 Fuel and lubricating oil

The fuel and lubricating oil to be used shall conform to the specifications and readily available in the market. Specified amount of lubricant shall be filled before the test and as a rule, shall not be changed during the entire test.

4.5 Suspension of test

If during test run, the machine malfunctions so as to affect the machine's performance, the test may be suspended with the concurrence of the official testing agency and the manufacturer's representative.

5 Tests and Inspection

5.1 Verification of Manufacturer's Technical Data and Information

5.1.1 This inspection is carried out to verify that the main dimensions, weight of the engine and other pertinent data conform to the list of technical data and information submitted by the manufacturer.

5.1.2 A plain and level surface shall be used for this investigation.

5.1.3 The items to be inspected and verified are given in Annex A.

5.2 Performance Tests

5.2.1 Test conditions

5.2.1.1 The test shall be conducted at full throttle for both spark-ignition and compression-ignition engines.

5.2.1.2 Performance data shall be obtained under stabilized normal operating conditions, with an adequate fresh air supply to the engine.

5.2.1.3 The temperature of the inlet air to the engine (ambient air), shall be measured not more than 0.15 m from the point of entry to the air cleaner or if no air cleaner is used, from the air inlet horn. The thermometer and thermocouple shall be shielded from radiant heat and located directly in the air stream. It shall also be shielded from fuel spray-back.

5.2.1.4 No data shall be taken until torque, speed and temperature have been maintained substantially constant for at least 1 minute.

5.2.1.5 The engine speed during a run or reading shall not deviate from the selected speed by more than $\pm 1\%$ or ± 10 rpm, whichever is greater.

5.2.1.6 Observed torque, output shaft speed, fuel consumption, temperature, vibration and sound emitted by the engine shall be recorded and shall in each case be the average of three stabilized values.

5.2.1.7 The temperature of the lubricating oil measured in the oil sump or at the outlet from the oil cooler, if fitted, shall be maintained within the limits established by the engine manufacturer.

5.2.1.8 The exhaust temperature shall be measured at a point in the exhaust pipe(s) adjacent to the outlet flange(s) of the exhaust manifold(s).

5.2.2 Varying speed test

5.2.2.1 This is carried out to determine the engine performance using an engine dynamometer.

5.2.2.2 Torque, fuel consumption, temperatures, vibrations, and sound emitted by the engine shall be measured at different speeds starting from rated speed at rated power. In case the rated power cannot be attained, the highest power developed at rated speed shall be used.

5.2.2.3 Engine speed shall be regulated by the load applied to the engine.

5.2.2.4 To establish points on the curve, runs shall be made at increments not greater than 200 rpm throughout the speed range.

5.2.2.5 The lowest speed at which measurements are to be made shall be at 600 rpm. In case the engine cannot be operated at this speed, it shall be at the lowest speed the engine can operate.

5.2.2.6 Sounds emitted by the engine shall be measured 7.5 m away from the exhaust pipe and at a height of 1.2 m from the ground.

5.2.2.7 Results shall be presented in tabular and graphical forms. The following curves shall be presented:

5.2.2.7.1 Maximum Brake Power vs. Shaft Speed

5.2.2.7.2 Torque vs. Shaft Speed

5.2.2.7.3 Fuel Consumption vs. Shaft Speed

5.2.2.7.4 Specific Fuel Consumption vs. Shaft Speed

5.2.2.8 Items to be measured and recorded are given in Annex B.1.

5.2.3 Continuous running test

5.2.3.1 This is carried out to evaluate the operating performance and find out any abnormality or trouble during continuous operation.

5.2.3.2 The engine shall be run continuously for five hours at the continuous speed and power specified by the manufacturer. If the engine cannot attain this power, it shall be set at the maximum power the engine can attain at its specified continuous speed.

5.2.3.3 If the continuous rated speed and power is not specified by the manufacturer, the engine shall be operated at 80% of the observed peak brake power and shall be run continuously on the bench for five hours.

5.2.3.4 Data shall be taken every 30 minutes.

5.2.3.5 Items to be measured and recorded are as given in Annex B.2.

5.2.4 Starting Test

5.2.4.1 This is carried out to determine the ease of starting the engine under both cold and hot starting.

5.2.4.2 The engine shall be mounted at a height convenient for the operator conducting the test and shall be disconnected from the dynamometer.

5.2.4.3 The attempts to start the engine shall be made using the normal procedure recommended by the manufacturer.

5.2.4.4 The temperature of fuel, transmission oil and ambient air shall be recorded before the test.

5.2.4.5 The number of attempts made to start the engine shall be recorded.

5.2.4.6 For cold start test, the engine shall be in thermal equilibrium with the environment. The engine should start within 10 attempts. Otherwise, the engine is considered hard to start.

5.2.4.7 For hot start test, the engine shall be run for one hour at rated speed and should stall upon application of load. Immediately thereafter, the engine should start within 5 attempts. Each attempt shall consist of five operations of the electric starter, rope starter, crank or other mechanical device. If a complete attempt of five operations is unsuccessful, the engine must be started by some means and run for one hour and then stalled before starting the next attempt. If these all fail, the engine is considered hard to start.

5.2.4.8 The starting test shall be made for three trials.

5.2.4.9 Record sheet is given in Annex C.

6 Correction Factors

6.1 Definition of factor K

Correction factor K is the factor multiplied to the observed power to determine the engine power under the reference atmospheric conditions specified in 6.2.

6.2 Reference atmospheric conditions

6.2.1 Temperature : 20°C

6.2.2 Total pressure : 1013 mb

NOTE: In the temperature range 10 to 35 °C, the effect of humidity on the correction factor value may be rejected (though in some cases the effect may not be negligible), taking into account the accuracy of the measurements.

6.3 Limitations in use of correction formula

The correction formula is only valid where the correction factor is between 0.96 and 1.04. If these limits are not met, the corrected value obtained shall be given and the test conditions (temperature and pressure) shall be precisely stated in the test report.

NOTE: The test may be carried out in an air-conditioned test rooms where the atmospheric condition can be controlled.

6.4 Determination and application of correction factors

6.4.1 Spark-ignition engines (carburetor or injection) factor K_a

$$K_a = \frac{1013}{P_b} \times \left(\frac{T + 273}{293} \right)^{0.5}$$

where:

P_b is the total atmospheric pressure, mb
 T is the ambient temperature, °C

This factor shall be multiplied to the observed brake power, without taking into account the mechanical efficiency of the engine.

6.4.2 Diesel engine- Factor K_d^*

The correction factor for naturally aspirated 4-stroke and scavenge blown 2-stroke diesel engines, which applies only at constant fuel delivery, is calculated by means of the formula:

$$K_d = \left(\frac{1013}{P_b} \right)^{0.65} \times \left(\frac{T + 273}{293} \right)^{0.5}$$

where: P_b is the total atmospheric pressure, mb
 T is the ambient temperature, °C

The correction shall be made using the correction factor K_d if:

- a) the correction factor K exceeds 1.04 or is less than 0.96 or
- b) the fuel delivery, measured during the engine test, is less than 50 mm³/L swept volume or more than 75 mm³/L swept volume.

However, the value of this coefficient, the pressure and temperature conditions during the test, and the specific fuel delivery in mm³/L shall be stated in test report.

* Although the formula given above are recommended at present, these must be considered only as provisional. Studies are being made to establish more accurate formula which will take into account particularly the fuel/air ratio.

7 Data Analysis

The formulas to be used during calculations and testing are given in Annex D.

8 Test Report

The test report shall include the following information in the order given:

- 8.1** Name of Testing Agency
- 8.2** Test Report Number
- 8.3** Title
- 8.4** Summary
- 8.5** Purpose and Scope of Test
- 8.6** Methods of Test
- 8.7** Description of the Engine
- 8.8** Table1 – Engine Specifications
- 8.9** Table 2 – Results of Starting Test
- 8.10** Table 3 – Results of Varying Load Performance Test
- 8.11** Table 4 – Results of Continuous Running Test
- 8.12** Observations
- 8.13** Name and Signature of Test Engineers

Annex A

Inspection Sheet for Small Internal Combustion Engines

Name of Applicant : _____

Address : _____

Telephone No. : _____

Name of Distributor : _____

Address : _____

Name of Manufacturer : _____

Factory Address : _____

GENERAL INFORMATION

Brand: _____ Model : _____

Serial No. : _____ Classification : _____

Production date of engine to be tested : _____

Items to be inspected

| ITEMS | Manufacturer's Specifications | Verification by the Testing Agency |
|--|-------------------------------|------------------------------------|
| A1 Dimension and weight of engine | | |
| A1.1 Overall length, mm | | |
| A1.2 Overall width, mm | | |
| A1.3 Overall height, mm | | |
| A1.4 Weight of the engine, kg | | |
| A2 Engine specification | | |
| A2.1 Brand | | |
| A2.2 Model | | |
| A2.3 Serial No. | | |
| A2.5 Type | | |
| A2.5.1 Based on number of strokes to complete one cycle | | |
| A2.5.1.1 Two-stroke | | |
| A2.5.1.2 Four-stroke | | |
| A2.5.2 Based on number of cylinder | | |
| A2.5.2.1 One | | |
| A2.5.2.2 Two | | |
| A2.5.2.3 Three | | |
| A2.5.3 Based on the cylinder arrangement | | |
| A2.5.3.1 Vertical or in-line | | |
| A2.5.3.2 Horizontal | | |
| A2.5.3.3 V-type | | |

| ITEMS | Manufacturer's Specifications | Verification by the Testing Agency |
|---|-------------------------------|------------------------------------|
| A2.6 Maximum brake power at rpm, kW | | |
| A2.7 Continuous brake power at rpm, kW | | |
| A2.8 Bore x stroke, mm | | |
| A2.9 Displacement volume, cm ³ | | |
| A2.10 Fuel system | | |
| A2.10.1 Fuel used | | |
| A2.10.1.1 Gasoline | | |
| A2.10.1.2 Diesel | | |
| A2.10.2 Type of fuel feed | | |
| A2.10.3 Tank capacity, L | | |
| A2.11 Cooling system | | |
| A2.11.1 Water-cooled | | |
| A2.11.2 Air-cooled | | |
| A2.12 Lubrication system | | |
| A2.12.1 Splash type | | |
| A2.12.2 Forced-feed | | |
| A2.13 Starting system | | |
| A2.13.1 Rope recoil | | |
| A2.13.2 Hand cranked | | |
| A2.13.3 Electrically started | | |
| A2.14 Governor system | | |
| A2.15 Air cleaner | | |
| A2.16 Exhaust system | | |
| A3 Other attachments/accessories | | |

Annex B
Performance Data Sheet

B1 Varying Speed Test

Engine on test
 Brand : _____
 Model : _____
 Serial No. : _____

Test Conditions:
 Ambient Temperature
 Dry bulb, °C : _____
 Wet bulb, °C : _____
 Relative Humidity, %: _____
 Atmospheric Pressure, mb: _____

Date of test: _____

| Engine Speed rpm | Torque kg-m | Maximum Brake Power kW | Fuel Consumption L/h | Specific Fuel Consumption g/kW-h | Noise Level db(A) | Vibration, g | | | Temperature, °C | | |
|---------------------|----------------|---------------------------|-------------------------|-------------------------------------|----------------------|--------------|--------|--------|-----------------|------------|-------------|
| | | | | | | x-axis | y-axis | z-axis | Cooling Water | Engine Oil | Exhaust Air |
| | | | | | | | | | | | |
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Observations:

13 **B2 Continuous Running Test**

Engine on test

Brand : _____

Model : _____

Serial No. : _____

Test Conditions:

Ambient Temperature

Dry bulb, °C : _____

Wet bulb, °C : _____

Relative Humidity, %: _____

Atmospheric Pressure, mb: _____

Date of test: _____

| Time h | Engine Speed rpm | Torque kg-m | Maximum Brake Power kW | Fuel Consumption L/h | Specific Fuel Consumption g/kW-h | Noise Level db(A)* | Vibration, g | | | Temperature, °C | | |
|-----------|------------------------|----------------|------------------------------|----------------------------|--|--------------------------|--------------|--------|--------|------------------|---------------|----------------|
| | | | | | | | x-axis | y-axis | z-axis | Cooling Water | Engine Oil | Exhaust Air |
| 0 | | | | | | | | | | | | |
| 0.5 | | | | | | | | | | | | |
| 1.0 | | | | | | | | | | | | |
| 1.5 | | | | | | | | | | | | |
| 2.0 | | | | | | | | | | | | |
| 2.5 | | | | | | | | | | | | |
| 3.0 | | | | | | | | | | | | |
| 3.5 | | | | | | | | | | | | |
| 4.0 | | | | | | | | | | | | |
| 4.5 | | | | | | | | | | | | |
| 5.0 | | | | | | | | | | | | |
| Ave. | | | | | | | | | | | | |

*Measured 7.5 m from the exhaust pipe of the engine and 45° with respect to the engine shaft.

Observations :

Annex C
Starting Test Data Sheet

| Items | Cold Starting | Hot Starting |
|---|----------------------|---------------------|
| C1 Ambient temperature, °C Dry bulb Wet bulb | | |
| C2 Fuel Temperature, °C | | |
| C3 Engine Oil Temperature, °C | | |
| C4 Number of attempts to start the engine | | |
| C5 Ease of cranking/starting | | |

Annex D

Formulas Used During Calculations and Testing

D1 Varying Load Test

D1.1 Output Power, P_o , (kW)

$$P_o = \frac{T \times N}{974}$$

where: T is the shaft torque, kg-m
 N is the shaft speed, rpm

D1.2 Fuel Consumption, F_C , (L/h)

$$F_C = \frac{V}{t}$$

where: V is the volume of fuel consumed, L
 t is the total operating time, h

D1.3 Specific Fuel Consumption, SFC , (g/kW-h)

$$SFC = \frac{F_c \times \rho_f}{P_o}$$

where: F_c is the fuel consumption, L/h
 ρ_f is the density of fuel, g/L
 P_o is the output power, kW

D2 Continuous Running Test

The formulas, which were used during the calculation of maximum brake power, fuel consumption and specific fuel consumption for continuous-running test, are the same formulas as those used for varying load test.