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Agricultural machinery – Rice husk fed heating system – Methods of test

BUREAU OF PRODUCT STANDARDS*

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National Foreword

The Philippine Agricultural Engineering Standards PAES 265:2015, Agricultural machinery – Rice husk fed heating system – Methods of test was approved for adoption as Philippine National Standard by the Bureau of Philippine Standards upon the recommendation of the Agricultural Machinery Testing and Evaluation Center (AMTEC) and the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development of the Department of Science and Technology (PCAARRD-DOST).

Foreword

The formulation of this national standard was initiated by the Agricultural Machinery Testing and Evaluation Center (AMTEC) under the project entitled "Development of Standards for Rice Production and Postproduction Machinery" which was funded by the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD) of the Department of Science and Technology (DOST).

This standard has been technically prepared in accordance with PAES 010-2 – Rules for the Structure and Drafting of International Standards.

The word "shall" is used to indicate mandatory requirements to conform to the standard.

The word "should" is used to indicate that among several possibilities one is recommended as particularly suitable without mentioning or excluding others.

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

ASAE S248.3 MAR1976 (R2005) - Construction and Rating of Equipment for Drying Farm Crops

ANSI/ASABE S593 MAY2006 - Terminology and Definitions for Biomass Production, Harvesting and Collection, Storage, Processing, Conversion and Utilization

Johnson, G.I., Highley, E., and Champ, B.R. Grain Drying in Asia. Proceedings of an International Conference. Thailand, 1995

Mullinger, Peter and Jenkins, Barrie.2008. Industrial and Process Furnaces: Principles, Design and Operation. 1st Ed. Elsevier Ltd.

Primer on Philippine Grains Standardization Program of the National Food Authority.

Trinks, W., Mawhenney, M.H., Shannon, R.A., Reed, R.J., Garvey, J.R. 2004Industrial furnaces.6th ed. John Wiley and Sons, Inc.

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1 Scope

This standard specifies the methods of test and inspection for rice husk fed heating system. Specifically, it shall be used to:

1.1 verify the mechanism, dimensions, materials, accessories of the rice husk fed heating system and the list of specifications submitted by the manufacturer;

1.2 determine the performance of the machine;

1.3 evaluate the ease of handling and safety features; and

1.4 report the results of the tests.

2 References

The following normative documents contain provisions, which through reference in this text constitute provisions of this National Standard:

PNS/PAES 102:2000 Agricultural Machinery – Operator's Manual – Content and Presentation

PNS/PAES 264:2015 Agricultural Machinery – Rice Husk Fed Heating System – Specifications

3 Definitions

For the purpose of this standard the following definitions and those given in PNS/PAES 264:2015 – Agricultural Machinery – Rice Husk Fed Heating System – Specifications shall apply:

3.1
burning efficiency
ratio of the actual and the theoretical heating value of fuel, expressed in percent

3.2
furnace efficiency
ratio of the heat transferred and heat available in furnace, expressed in percent

3.3
furnace heat capacity
actual heat supplied by the furnace
ratio of the product of the change in enthalpy and air flow rate, to the specific volume of fresh air

3.4
heating system efficiency
ratio of actual and theoretical heat supplied by the fuel to the furnace, expressed in percent

3.5
latent heat of vaporization
heat absorbed by a unit mass of a material at its boiling point in order to convert the material into a gas without temperature change

3.6
overall height
distance between the horizontal supporting plane surface and the horizontal plane touching the uppermost part of the furnace.

NOTE: All parts of the furnace projecting upwards are contained between these two planes.

3.7
overall length
distance between the vertical planes at the right angles to the median plane of the furnace and touching its front and rear extremities.

NOTE: All parts of the furnace, in particular, components projecting at the front and at the rear are contained between these two planes. Where an adjustment of components is possible, it shall be set at minimum length.

3.8
overall width
distance between the vertical planes parallel to the median plane of the machine, each plane touching the outermost point of the furnace on its respective side.

NOTE: All parts of the furnace projecting side wards are contained between these two planes.

3.9
sensible heat
heat absorbed or evolved by a substance during a change of temperature that is not accompanied by a change of state

4 General Conditions for Test and Inspection

4.1 Role of manufacturer

The manufacturer shall submit specifications and other relevant information about the unit and shall abide with the terms and conditions set forth by an official testing agency.

4.2 Role of operator

An officially designated operator shall be skilled and shall demonstrate, operate, adjust, and repair as the case maybe, related to the operation of the furnace. Manufacturers/dealers should provide appropriate authorization documents.

4.3 Test site conditions

Testing shall be where the unit is installed. The site should have ample provisions for material handling and workspace and electric connections and suitable for normal working condition.

4.4 Test instruments

The instrument to be used shall have been calibrated and checked by the testing agency prior to the test. The list of minimum test instruments and materials needed to carry out the heating system test is shown in Annex A.

4.5 Test materials

The amount of rice husk to be supplied shall be sufficient for the duration of the test.

4.6 Termination of test

If during testing, the furnace has a major component breakdown or malfunctions, the test engineer from the official testing agency shall terminate the test.

5 Test and Inspection

5.1 Verification of the technical data and information of the manufacturer

5.1.1 This inspection is carried out to verify the dimensions, materials and accessories of the furnace in comparison with the list of technical data and information of the manufacturer.

5.1.2 The heating system shall be installed in a plain and leveled surface.

5.1.3 The items to be inspected and verified shall be recorded in Annex B.

5.2 Performance test

5.2.1 This is carried out to obtain actual data on the overall furnace performance.

5.2.2 Fuel to be used

5.2.2.1 Rice husk prepared for each trial shall be of the same quality.

5.2.2.2 Rice husk shall meet the required moisture content for efficient burning. The moisture content shall beat most 16 % wet basis.

5.2.2.3 Initial weight of the fuel shall be taken before loading it to the furnace. The data shall be obtained and recorded.

5.2.3 Initial data on the fuel to be used to operate the furnace shall be recorded in Annex C.

5.2.4 Operation of the furnace.

The furnace shall be operated at the recommended settings of the manufacturer. All data obtained and observations of breakdown or abnormalities on the furnace shall be recorded in Annex C. After the test run, the furnace shall be cleaned and then prepared for the next test trial. These procedures shall be repeated for the succeeding test trials. An instruction manual which conforms to PNS/PAES 102:2000 Agricultural Machinery – Operator's Manual – Content and Presentation shall be provided.

5.2.5 The furnace shall be tested without the dryer

5.2.5.1.1 Type of blower for the suction of heated air coming from the furnace shall be determined and provided by the manufacturer.

5.2.5.1.2 Test duration shall be two hours after steady state operation and needed measurements (heated air temperature from blower, air flow rate from blower and ambient air temperature) shall be obtained and recorded every ten minutes interval.

5.2.6 Firing of Furnace

Small amount of flammable material shall be used to start the fire on the combustion chamber of the furnace. The amount of fuel used and time for the furnace to reach stable temperature shall be obtained and recorded.

5.2.7 Heating system efficiency and furnace efficiency shall be computed using the data obtained during testing and the formula in Annex D.

5.2.8 Flue gas Analysis

For direct fired furnace, the gas emitted by the furnace due to the burning process of the rice husk shall be tested for its Carbon monoxide (CO), NOx, SOx and particulate matter content in percentage. Flue gas shall be sampled on the opening of flue gas chimney to be able to acquire the gas percentage components. Data obtained shall be recorded on Annex C.

5.2.9 Fuel Consumption Determination

Total amount of rice husk consumed and the total time of operation shall be recorded.

5.2.10 Test trials

At least two test trials shall be adopted during the test.

5.2.11 Data recording and observations

5.2.11.1 All data obtained and any observations of defects on the furnace structure during and after each test trial shall be recorded in Annex C.

5.2.11.2 Visual inspection test shall be made on welded parts of the furnace and shall be recorded in Annex C.

5.2.12 Sampling

5.2.12.1 Sampling for fuel

Three-50 g samples of rice husk shall be randomly collected to be analyzed in the laboratory. Half (25g) of the 50g sample shall be used for laboratory analysis and the other half (25g) shall be used for reference purposes or for validation.

5.2.12.2 Sampling for ash from furnace

During each test trial, three-50 g samples shall be randomly collected from the ash discharge mechanism of the furnace to be analyzed in the laboratory. Half (25g) of 50g sample shall be used for laboratory analysis and the other half (25g) shall be used for reference purposes or for validation.

5.2.12.3 Handling of samples

Samples to be taken to the laboratory shall be placed in appropriate containers and properly labeled.

6 Laboratory Analysis

Laboratory analyses shall be made to determine work quality of the furnace. Burning Efficiency of the system shall be computed and the procedure is given in Annex D. The laboratory test data sheet to be used is given in Annex E.

7 Formula

The formula to be used during calculations and testing are given in Annex F.

8 Test Report Format

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

8.1 Title

8.2 Summary

8.3 Purpose and Scope of Test

8.4 Methods of Test

8.5 Description of the Machine

Table 1 – Machine Specifications

8.6 Results and Discussions

8.7 Observations (include pictures)

Table 2 – Performance test data

8.8 Names, signatures and designation of test engineers

Annex A
Minimum List of
Test Instruments and Materials

A.1	**Instruments**	**Quantity**
A.1.1	Thermocouples (Type K)	1
A.1.2	Digital Timers (range: 60 minutes) Accuracy: 0.1 sec	
A.1.3	Tape Measure (with maximum length of 5m)	1
A.1.4	Weighing Scale (capacity: 100 kg) 0.01 kg accuracy	
A.1.5	Vernier Caliper Accuracy: 0.1 mm	1
A.1.6	Moisture Meter	1
A.1.7	Scientific Calculator	1
A.1.8	Electric Furnace	1
A.1.9	Flue Gas Analyzer	1
A.1.10	Digital Camera	1
A.1.11	Velocity Meter	1
A.1.12	Thermometer	1
A.1.13	Crucibles (capacity: 25g)	6
A.1.14	Desiccator	1
A.2	**Materials**	
A.2.1	Labeling tags which include	20
A.2.1.1	Date of test	
A.2.1.2	Furnace test	
A.2.1.3	Trial number	
A.2.1.4	Type of sample	
A.2.1.5	Psychometric Chart	

Annex B

Specifications of Rice Husk Fed Heating System

Name of Applicant/ Distributor: _____
Address: _____
Tel No: _____
Name of Manufacturer: _____
Address: _____
Tel No: _____

General Information

Make: _____ Type: _____
Serial No: _____ Brand/Model: _____
Production date of Furnace: _____
Testing Agency: _____ Test Engineer: _____
Date of Test: _____ Location of Test: _____

Items to be inspected

ITEM	Specification of Manufacturer	Verification by the Testing Agency
B.1 Hopper		
B.1.1 Materials of construction		
B.1.2 Number		
B.1.3 Dimensions, mm		
B.1.3.1 Length		
B.1.3.2 Width		
B.1.3.3 Thickness		
B.1.4 Screw feeder		
B.1.4.1 Dimensions, mm		
B.1.4.1.1 Diameter		
B.1.4.1.2 Length		
B.1.4.1.3 Thread thickness		
B.1.4.1.4 Thread height		
B.1.4.2 Prime mover		
B.1.4.2.1 Brand		
B.1.4.2.2 Model		
B.1.4.2.3 Serial number		
B.1.4.2.4 Type (stroke/ignition)		
B.1.4.2.5 Rated power, kW		
B.1.4.2.6 Rated speed, rpm		
B.1.4.2.7 Cooling system		
B.1.4.2.8 Starting system		
B.1.4.2.9 Weight, kg		
B.2 Combustion chamber		
B.2.1 Frame		
B.2.1.1 Materials of construction		

ITEM	Specification of Manufacturer	Verification by the Testing Agency
B.2.1.2 Dimensions, mm		
B.2.1.2.1 Length		
B.2.1.2.2 Width		
B.2.1.2.3 Thickness		
B.2.2 Walls		
B.2.2.1 Materials of construction		
B.2.2.2 Dimensions, mm		
B.2.2.2.1 Length		
B.2.2.2.2 Width		
B.2.2.2.3 Thickness		
B.2.2.3 Number of lining(s)		
B.2.2.4 Insulation material used		
B.2.3 Combustion air inlet device used		
B.3 Heat exchanger (for indirect-fired furnace only)		
B.3.1 Type of furnace		
B.3.2 Tubes		
B.3.2.1 Materials of construction		
B.3.2.2 Dimensions, mm		
B.3.2.2.1 Length		
B.3.2.2.2 Diameter		
B.3.2.2.3 Thickness		
B.3.2.3 Orientation		
B.4 Chimney (for indirect-fired furnace only)		
B.4.1 Materials of construction		
B.4.2 Dimensions, mm		
B.4.2.1 Length		
B.4.2.2 Width		
B.5 Plenum (from furnace to dryer)		
B.5.1 Materials of construction		
B.5.2 Dimensions, mm		
B.5.2.1 Length		
B.5.2.2 Width		
B.6 Ash discharge unit		
B.6.1 Type		
B.6.2 Materials of construction		
B.6.3 Dimensions, mm		
B.6.3.1 Length		
B.6.3.2 Width		
B.6.4 Ash pan		
B.6.4.1 Materials of construction		
B.6.4.2 Dimensions, mm		
B.6.4.2.1 Length		
B.6.4.2.2 Width		
B.6.5 Ash arrester		

ITEM	Specification of Manufacturer	Verification by the Testing Agency
B.6.5.1 Materials of construction		
B.6.5.2 Dimensions, mm		
B.6.5.2.1 Height		
B.6.5.2.2 Width		
B.6.5.3 Maximum capacity, kg		
B.6.5.4 Fans		
B.6.5.4.1 Materials of construction		
B.6.5.4.2 Diameter of fan wheel		
B.6.5.4.3 Flow rate, m^3/min		
B.6.5.4.4 Static pressure, mmH_2O		
B.6.5.4.5 Fan air speed, m/s		
B.7 Safety features:		
B.8 Other special features:		

Annex C

Performance Test Data Sheet

Test Trial No._____Date: _____
Test Engineer: _____Location: _____
Assistants: _____ Test Specimen: _____
Test Requested by: _____Manufacturer: _____

ITEM	Trials			Ave
	1	2	3	
C.1 Information of Rice Husk				
C.1.1 Weight consumed, kg				
C.1.2 Moisture content, %				
C.1.3 Bulk density, kg/m^3				
C.2 Performance Test Data				
C.2.1 Ambient air temperature, °C				
C.2.1.1 Wet bulb				
C.2.1.2 Dry bulb				
C.2.2 Ambient air relative humidity, %				
C.2.3 Air flow rate, m^3/s				
C.2.4 Heated air temperature from furnace, °C				
C.2.5 Drying air temperature, °C				
C.2.6 Total operating time, h				
C.2.7 Furnace firing time, h				
C.2.8 Heating value of rice husk material, kcal/kg				
C.2.9 Fuel consumption rate, kg/h				
C.2.10 Weight of ash residue sample after operation, g				
C.2.11 Weight of ash residue sample after further burning in electric furnace, g				
C.2.12 Weight rice husk before complete burning in electric furnace, g				
C.2.13 Weight of ash after completely burning the material in electric furnace, g				
C.2.14 Percentage ash residue (dry basis) in the sample collected from the furnace				
C.2.15 Percentage of ash in rice husk after complete burning in electric furnace				
C.2.16 Heat available in furnace, kJ/h				
C.2.17 Volume flow rate of air, m^3/h				
C.2.18 Mass of ash collected after burning in furnace, g				
C.2.19 Fan air velocity, m/s				
C.2.20 Speed of blower (shaft), rpm				
C.2.21 Speed of prime mover (shaft), rpm				
C.2.22 Welding Acceptance Test				
C.2.22.1 Crack prohibition				
C.2.22.2 Weld/base-metal fusion				
C.2.22.3 Crater cross section				

ITEM	Trials			Ave
	1	2	3	
C.2.22.4 Weld profile				
C.2.22.5 Time of inspection				
C.2.22.6 Undersize welds (if any)				
C.2.22.7 Undercut				
C.2.22.8 Porosity (presence of air holes on the welded part)				

C.3 Rice Husk Furnace performance

ITEM	
C.3.1 Hopper load capacity, kg	
C.3.2 Fuel consumption rate, kg/h	
C.3.3 Heat transferred at the heat exchanger, kJ/h	
C.3.4 Heated air temperature at the heat exchanger, °C	
C.3.5 Heat released by ash residue sample per kg of ash residue, kJ/kg	
C.3.6 Heating system efficiency, %	
C.3.7 Burning efficiency, %	
C.3.8 Furnace efficiency, %	
C.3.9 Cracking/scaling on any part of the furnace (observation)	
C.3.10 Temperature stability (stable or unstable)	
C.3.11 Fracture on the parts of furnace after operation (observation)	
C.3.12 Capable to maintain the maximum temperature allowable during the entire operation (observation)	

C.4 General information of fuel samples and ash samples brought to AMTEC laboratory for analysis

ITEM	RICE HUSKS	DISCHARGE ASH
Initial dry weight, g		
Residue weight, g		
Ash, %		
Ash Residue, %		

C.5 Evaluate the following observations:

Item	Remarks
C.5.1 Ease of cleaning	
C.5.2 Ease of repairing of parts	
C.5.3 Ease of operation	
C.5.4 Safety	
C.5.5 Availability of the switches needed	
C.5.6 Ease of transporting the furnace	

C.6 Flue Gas Analysis:

Trials	Temperature, °C	Composition of dry exhaust gas, mg/Ncm		
		CO	NO_x	SO_x
1				
2				
3				

C.7 Other Observations:

_____
_____
_____
_____
_____

Annex D

Determination of Burning Efficiency

D.1 Get three-50 g sample from the ash discharge mechanism. For each test trial, two crucibles shall be prepared and labeled for the rice husk and ash residue from furnace. The weight of each crucible shall be determined and recorded.

D.2 In each test trials, weigh 25g of rice husk samples and 25g ash residue samples from furnace, placed it in the crucibles and record the initial weight of crucibles plus samples.

D.3 The samples shall be totally burned using electric furnace for 5 hours at 1000°Ctemperature.

D.4 After removing the samples from the electric furnace, the crucibles with the burned samples should be placed in desiccators and allowed to cool to the ambient temperature.

D.5 Weigh the crucible plus the burned sample. Record the final weight. Calculate the burning efficiency using Formula in Annex E.

D.6 Other physical observations on the ash samples shall be recorded in Annex E.

Annex E

Laboratory Test Data Sheet

Machine Tested:_____ Analyzed by:_____
Date of Test: _____ Date Analyzed: _____

E.1 Burning Efficiency Determination

Trial Number	Initial Weight of Crucible	Initial Weight of Crucible + Samples	Final Weight of Crucible + Samples	Final Weight of Burned Samples	Burning Efficiency, %
Trial 1					
Rice husk sample					
Ash sample					
Trial 2					
Rice husk sample					
Ash sample					
Trial 3					
Rice husk sample					
Ash sample					
Average Burning Efficiency, %					

E.2 Other Observations:

_____
_____
_____
_____
_____
_____
_____

Annex F

Formula

F.1 Fuel Consumption Rate

$$F_c = \frac{F_{bf}}{T_o}$$

where:

Fc is the fuel consumption rate, kg/h
F_{bf} is the total fuel consumed, kg
T_{op} is the total time of operation, h

F.2 Heating System Efficiency

$$Eff_t = \frac{Q_{supplied}}{FCR \text{ x } HV_f} \; x \; 100$$

$$Q_{supplied} = \frac{\Delta h \text{ x } \forall}{V} \; x \; 60$$

where:

Eff_t is the heating system efficiency, %
$Q_{supplied}$ is the heat supplied, kcal/h
FCR is the fuel consumption rate, kg/h
HVF is the heating value of fuel, kcal/kg
~ 13,927 kJ/kg (Rice Husks at 7% MC)
Δh is the change in enthalpy, kJ/kg d.a.
$\forall$ is the air flow rate, m^3/min
V is the specific volume of fresh air, m^3/kg d.a.

F.3 Burning Efficiency

$$Eff_b = \frac{100 - A_r}{100 - A} \; x \; 100$$

$$A_r = \left(1 + \frac{A_s - A_b}{A_b}\right) \text{ x } A$$

$$A = \frac{W_{ash}}{W_t}$$

where:

Eff_b	is the burning efficiency, %
A_r	is the percentage of ash residue (dry basis) in the sample collected from the furnace
A	is the percentage of ash in rice husk after complete burning in electric furnace
A_s	is the weight of ash residue sample, g
A_b	is the weight of ash residue sample after further burning in electric furnace, g
W_{ash}	is the weight of ash after completely burning the rice husk in electric furnace, g
W_t	is the total weight of the rice husk before complete burning in electric furnace, g

F.4 Furnace Efficiency

$$Eff_{furnace} = \frac{Q_{he}}{Q_a} \text{ x } 100$$

$$Q_{transferred} = V \text{ x } \rho_{air} \text{ x } Cp_{air} \text{ x } (T_f - T_i)$$

$$Q_{available} = (HV_f \text{ x } m_f) - (Q_{ash} \text{ x } m_{ash})$$

$$Q_{ash} = \frac{(1 - Eff_b \text{ x } HV_f)}{m_{ash}}$$

where:

$Eff_{furnace}$	is the efficiency of furnace, %
$Q_{transferred}$	is the heat transferred at the heat exchanger, kJ/h
$Q_{available}$	is the heat available in furnace, kJ/h
V	is the volume flow rate of air, m^3/h
ρ_{air}	is the density of heated air, kg/ m^3
Cp_{air}	is the specific heat of heated air at the heat exchanger, kJ/kg-K
T_f	is the heated air temperature at the heat exchanger, °C
T_i	is the ambient air temperature, °C
HV_f	is the heating value of fuel, kcal/kg ~ 13,927 kJ/kg (Rice Husks at 7% MC)
m_f	is the rice husk consumed, kg/h
Q_{ash}	is the heat released by ash residue sample per kg of ash residue, kJ/kg
m_{ash}	is the mass of ash collected after burning, kg

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