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Agricultural machinery – Biomass Furnace – Methods of Test

BUREAU OF PRODUCT STANDARDS

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National Foreword

This Philippine Agricultural Engineering Standards PAES 243:2010, Agricultural machinery – Biomass Furnace – Methods of Test was approved for adoption as Philippine National Standard by the Bureau of Product Standards upon the recommendation of the Agricultural Machinery Testing and Evaluation Center (AMTEC) and the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development of the Department of Science and Technology (PCARRD-DOST).

PHILIPPINE AGRICULTURAL ENGINEERING STANDARD PAES 243: 2010
Agricultural Machinery – Biomass Furnace – Methods of Test

Foreword

The formulation of this national standard was initiated by the Agricultural Machinery Testing and Evaluation Center (AMTEC) through the project "Development of Standards for Agricultural Production and Postharvest Machinery" funded by the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development – Department of Science and Technology (PCARRD – DOST)

This standard has been technically prepared in accordance with BPS Directives Part 3:2003 – 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 the preparation of this standard, the following documents/publications were considered:

Belonio, Alexis T. *Agricultural engineering formula*. Department of Agricultural Engineering and Environmental Management, College of Agriculture, Central Philippine University, Iloilo City, Philippines. 2003

Mullinger, Peter and Jenkins, Barrie. *Industrial and process furnaces: principles, design and operation*. 1st ed. Elsevier Ltd. 2008

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

Dioquino, Oscar Atencia Jr. *Design modification, testing and evaluation of biomass furnace with waste heat recovery system using corncob as fuel*. Undergraduate Thesis. Agricultural and Bio-process Division, Institute of Agricultural Engineering, College of Engineering and Agro-Industrial Technology, University of the Philippines Los Baños. April 2007

Bausas, Michael de los Santos. *Performance evaluation and optimization of amdp-abprod rice hull furnace*. Undergraduate Thesis. Agricultural and Bio-process Division, Institute of Agricultural Engineering, College of Engineering and Agro-Industrial Technology, University of the Philippines Los Baños. November 2008

AMTEC Test Reports for Biomass Furnace

CONTENTS

1 Scope

This standard specifies the methods of test and inspection for biomass furnace. Specifically, it shall be used to:

1.1 verify the mechanism, dimensions, materials, accessories of the biomass furnace 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:

PAES 242:2008 Agricultural Machinery – Biomass Furnace – Specifications

3 Definitions

For the purpose of this standard, the definitions given in PAES 242 and the following 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 biomass furnace, expressed in percent

3.3
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

3.4
overall height
distance between the horizontal supporting plane surface and the horizontal plane touching the uppermost part of the biomass furnace.

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

3.5
overall length
distance between the vertical planes at the right angles to the median plane of the biomass furnace and touching its front and rear extremities.

NOTE: All parts of the biomass 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.

3.6
overall width
distance between the vertical planes parallel to the median plane of the machine, each plane touching the outermost point of the biomass furnace on its respective side.

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

3.7
sensible heat
heat absorbed or evolved by a substance during a change of temperature that is not accompanied by a change of state

3.8
heating system efficiency
ratio of actual and theoretical heat supplied by the fuel to the furnace, expressed in percent

4 General Conditions for Test and Inspection

4.1 Role of manufacturer

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

4.2 Role of the 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.

4.3 Test site conditions

Testing shall be where the biomass furnace 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 biomass furnace test is shown in Annex A.

4.5 Test Materials

The amount of biomass fuel to be supplied shall be sufficient for two hours of continuous operation.

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 biomass furnace in comparison with the list of technical data and information of the manufacturer.

5.1.2 The biomass furnace 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 Biomass fuel to be used

5.2.2.1 Biomass fuel prepared for each trial shall be of the same quality.

5.2.2.2 Biomass fuel shall meet the required moisture content for efficient burning. Moisture content for biomass fuels shall be the following:

Corn cobs	10% (maximum)
Rice hulls	7% (maximum)

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

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

5.2.4 Operation of the biomass furnace.

The biomass 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.

5.2.5 Biomass furnace shall be tested by either of the following method:

5.2.5.1 Biomass furnace without 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.

5.2.5.2 Biomass furnace with dryer attached

5.2.5.2.1 Biomass furnace shall be attached to a dryer with full grain holding capacity.

5.2.5.2.2 Test duration shall be two hours after steady state operation and needed measurements (heated air temperature to the dryer, air flow rate to the dryer 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 biomass furnace. The amount of biomass fuel used and time for the furnace to reach stable temperature shall be obtained and recorded.

5.2.7 Heating system efficiency (for furnace with dryer attached only) and Furnace efficiency shall be computed using the data obtained during testing and the formula in Annex D.

5.2.8 Flue gas Analysis

The gas emitted by the furnace due to the burning process of the biomass fuel shall be tested for its Carbon monoxide (CO), NO_x, SO_x and particulate matter content in percentage. Flue gas analyzer shall be placed 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 Biomass Fuel Consumption Determination

Total amount of biomass fuel consumed and the total time of operation shall be recorded.

5.2.10 Test trials

At least two test trials shall be adopted.

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 biomass furnace and shall be recorded in Annex C.

5.2.12 Sampling

5.2.12.1 Sampling for biomass fuel

Three-50 g samples of biomass fuel 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 biomass furnace

During each test trial, three-50 g samples shall be randomly collected from the ash discharge mechanism of the biomass 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 biomass furnace. The laboratory test data sheet to be used is given in Annex D.

6.1 Burning Efficiency

6.1.1 For each test trial, two crucibles shall be prepared and labeled for the biomass fuel and ash residue from biomass furnace. The weight of each crucibles shall be determined and recorded.

6.1.2 In each test trials, weigh 25g of biomass fuel samples and 25g ash residue samples from biomass furnace, placed it in the crucibles and record the initial weight of crucibles plus samples.

6.1.3 The samples shall be totally burned using electric furnace for 5 hours at 1000°C temperature.

6.1.4 After removing the samples from the electric furnace, the crucibles with the burned samples should be placed in a desiccator and allowed to cool to the ambient temperature.

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

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

7 Formula

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

8 Test Report

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 (made of Tungsten-Molybdenum, maximum temperature 2,600°C)	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	Dessicator	1
A.2	**Materials**	
A.2.1	Biomass fuel (wood chips, rice hulls, corn cobs)	
A.2.2	Labeling tags which include	20
A.2.2.1	Date of test	
A.2.2.2	Biomass furnace test	
A.2.2.3	Trial number	
A.2.2.4	Type of sample	

Annex B

Specifications of Biomass Furnace

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

GENERAL INFORMATION

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

Items to be inspected

ITEMS	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		

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 grain 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.6.2 Ash pan		
B.6.2.1 Materials of construction		
B.6.2.2 Dimensions, mm		
B.6.2.2.1 length		
B.6.2.2.2 width		
B.6.3 Ash arrester		
B.6.3.1 Materials of construction		

B.6.3.2 Dimensions, mm		
B.6.3.2.1 height		
B.6.3.2.2 width		
B.6.3.3 Maximum capacity, kg		
B.6.3.1 Fans		
B.6.3.1.1 Materials of construction		
B.6.3.1.2 Diameter of fan wheel		
B.6.3.1.3 Flow rate, m^3/min		
B.6.3.1.4 Static pressure, mmH_2O		
B.6.3.1.5 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: _____

	Trials			Ave
C.1 Information on Biomass Fuel	**1**	**2**	**3**	
C.1.1 type				
C.1.2 weight consumed, kg				
C.1.3 moisture content, %				
C.1.4 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 fuel/biomass material, Kcal/kg				
C.2.9 Biomass 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 biomass material before complete burning in electric furnace, g				
C.2.13 Weight of ash after completely burning the biomass material in electric furnace, g				
C.2.14 Percentage ash residue (dry basis) in the sample collected from the biomass furnace				
C.2.15 Percentage of ash in biomass material 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 biomass 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				
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 Biomass Furnace performance

C.3.1 Hopper load capacity, kg	
C.3.2 Biomass 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

ITEMS	BIOMASS FUEL	DISCHARGE ASH
Initial dry weight, g		
Residue weight, g		
Ash, %		
Ash Residue, %		

C.5 Evaluate the following observations:

Items	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

Laboratory Test Data Sheet

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

D.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					
Biomass fuel sample					
Ash sample					
Trial 2					
Biomass fuel sample					
Ash sample					
Trial 3					
Biomass fuel sample					
Ash sample					
Average Burning Efficiency, %					

D.2 Other Observations:

_____
_____
_____
_____
_____
_____
_____

Annex E

Formula

E.1 Biomass Fuel Consumption Rate

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

where:

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

E.2 Heating System Efficiency

$$Efft = \frac{Q_{sup}}{FCR \times HV_F} \times 100$$

$$Qs = \frac{\Delta h \times \forall}{v} \times 60$$

where:

Efft = heating system efficiency, %
Qsup = heat supplied, KCal/h
FCR = fuel consumption rate, kg/h
HVF = heating value of fuel, KCal/kg (see Table 1)
Δh = change in enthalpy, kJ/kg d.a.
$\forall$ = air flow rate, m^3/min
V = specific volume of fresh air, m^3/kg d.a.

E.3 Burning Efficiency

$$Effb = \frac{100 - A_r}{100 - A} \times 100$$

$$Ar = \left(1 + \frac{A_s - A_b}{A_b}\right) \times A$$

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

where:

Effb	=	burning efficiency, %
Ar	=	percentage of ash residue (dry basis) in the sample collected from the biomass furnace
A	=	percentage of ash in biomass material after complete burning in electric furnace
As	=	weight of ash residue sample, g
Ab	=	weight of ash residue sample after further burning in electric furnace, g
W_{ash}	=	weight of ash after completely burning the biomass material in electric furnace, g
Wt	=	total weight of the biomass material before complete burning in electric furnace, g

E.4 Furnace Efficiency

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

$$Q_{he} = V \times D_{air} \times Cp_{air} \times (T_f - T_i)$$

$$Q_a = (HV_{BM} \times M_{BM}) - (H_{ash} \times m_{ash})$$

$$H_{ash} = \frac{(1 - Eff_D \times HV_{BM}}{m_{ash}}$$

where:

$Eff_{furnace}$	=	efficiency of furnace, %
Q_{he}	=	heat transferred at the heat exchanger, kJ/h
Qa	=	Heat available in biomass furnace, kJ/h
V	=	volume flow rate of air, m^3/h
D_{air}	=	density of heated air, kg/ m^3
Cp_{air}	=	specific heat of heated air at the heat exchanger, kJ/kg-K
T_f	=	heated air temperature at the heat exchanger, °C
T_i	=	ambient air temperature, °C
HV_{BM}	=	heating value of biomass material, kJ/kg
M_{BM}	=	biomass material consumed, kg/h
H_{ash}	=	heat released by ash residue sample per kg of ash residue, kJ/kg
m_{ash}	=	mass of ash collected after burning, kg

Table 1. List of heating value of fuels that are usually use in biomass furnace (Mark's Standard Handbook for Mechanical Engineering)

Biomass Fuel	Heating Value, kJ/kg	Heating Value, BTU/lb
Corn cobs (at 10% MC)	21,587	9,300
Rice hulls (at 7% MC)	13,927	6,000
Wood chips (at 36%-58% MC)	20,100	8650

Philippine Agricultural Engineering Standards

AMTEC-UPLB – PCARRD Project: "Development of Standards for Agricultural Production and Postharvest Machinery"

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