PHILIPPINE NATIONAL STANDARD

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Agricultural machinery – Biomass Furnace – Specifications

BUREAU OF PRODUCT STANDARDS

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National Foreword

This Philippine Agricultural Engineering Standards PAES 242:2010, Agricultural machinery – Biomass Furnace – Specifications 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).

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:

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

Unpublished Graduate Thesis. Nguyen, T.N. *Design and development of a direct-fired rice husk furnace for flat bed paddy dryer*. Undergraduate Thesis. Agricultural and Bio-process Division, Institute of Agricultural Engineering, College of Engineering and Agro-Industrial Technology, University of the Philippines Los Baños. 1995

AMTEC Test Reports for Biomass Furnace

1 Scope

This standard specifies the manufacturing and performance requirements for biomass furnace.

2 References

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

AWS D1.1:2000 Structural Welding Code - Steel

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

PAES 103:2000 Agricultural Machinery – Method of Sampling

PAES 311:2001 Engineering Materials - Screws for Agricultural Machines – Specifications and Applications

PAES 313:2001 Engineering Materials – Bolts and Nuts for Agricultural Machines – Specifications and Applications

PAES 243:2010 Agricultural Machinery – Biomass Furnace – Methods of Test

3 Definitions

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

3.1
biomass
organic materials used as renewable source of energy like wood chips, corncobs and rice hulls, etc.

3.2
biomass furnace
enclosed structure for intense heating by fire using any biomass like woodchips, corncobs and rice hulls as fuel

3.3
hearth
fire resistant surface located at the heating chamber of the biomass furnace

3.4
workload
materials to be processed (i.e. dried, burned, melted, etc.) using biomass furnace

3.5
grate
framework of metal bars or fire bricks used to hold biomass fuel in furnace for more efficient combustion

4 Classification

Biomass furnace shall be classified according to:

4.1 Heat transfer

4.1.1 Direct-fired biomass furnace

Flue gas and other products of combustion goes into the dryer. (see Figure 1)

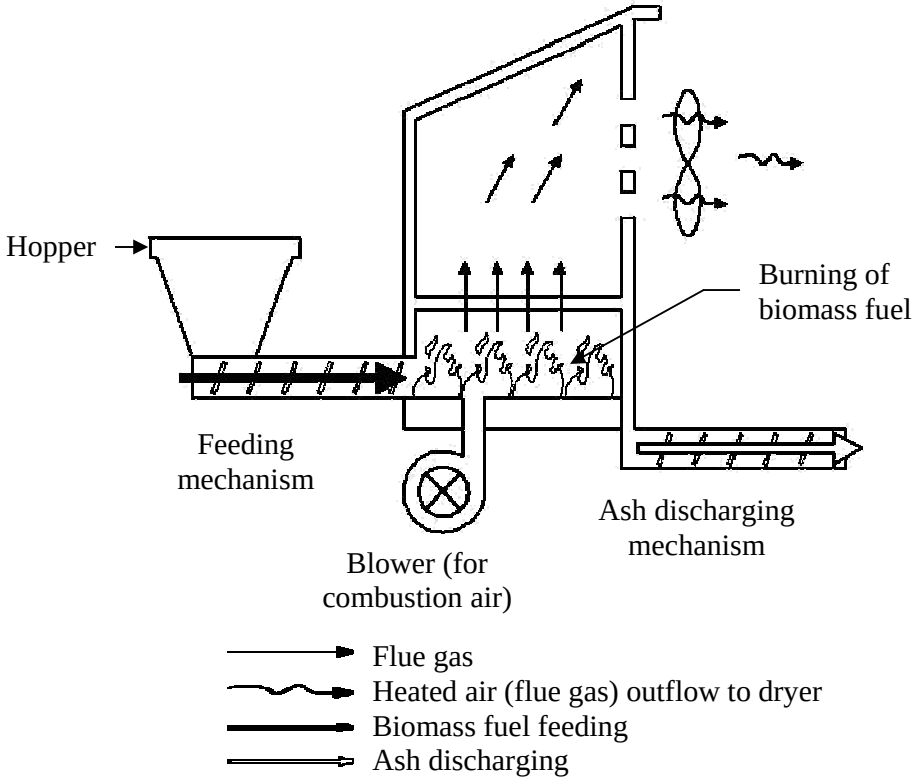

Figure 1. Diagram of direct-fired biomass furnace

Direct-fired biomass furnace shall be further classified according to mode of feeding:

4.1.1.1 Cyclonic

Biomass fuels are fed on the combustion chamber in cyclonic manner using a blower. The biomass fuels in this type of furnace are burned while in suspension.
(see Figure 2)

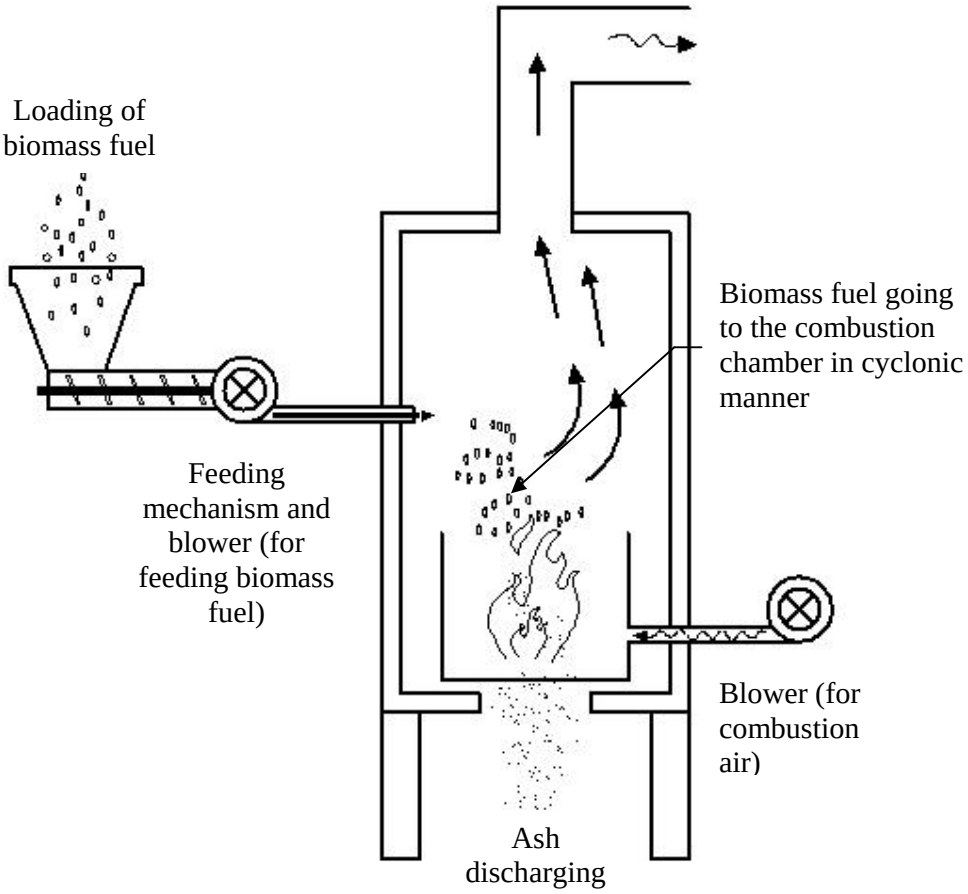

Figure 2. Flow diagram inside cyclonic type biomass furnace

4.1.1.2 Step-grate

Biomass furnace with combustion chamber that have stair-liked arrangement of grate. (see Figure 3)

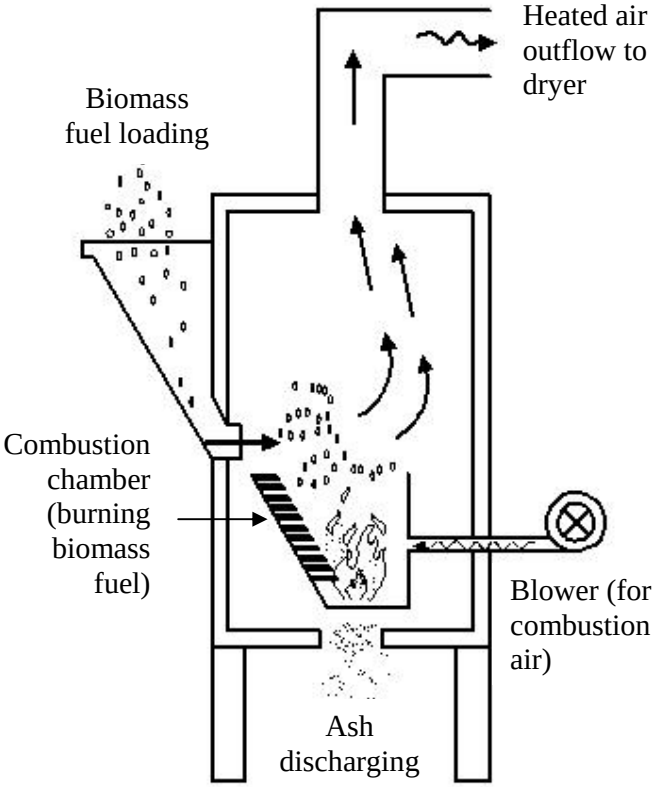

Figure 3. Flow diagram inside step-grate biomass furnace

4.1.1.3 Gravity

Biomass furnace that uses gravitational force on feeding the biomass fuel. (see Figure 4)

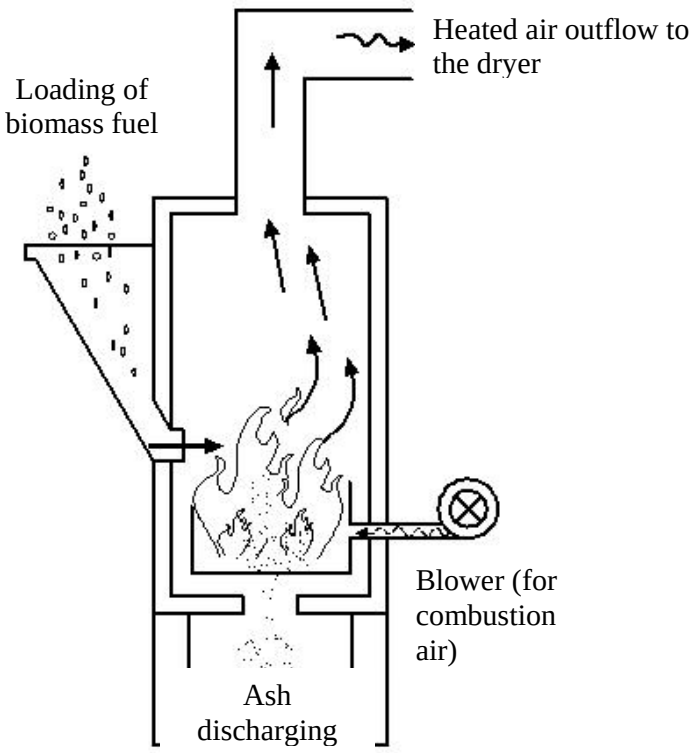

Figure 4. Flow diagram inside biomass furnace using gravity in fuel feeding

4.1.2 Indirect-fired biomass furnace

This type of biomass furnace shall use a heat exchanger to prevent flue gas and other products of combustion to go with the drying air. (see Figure 5)

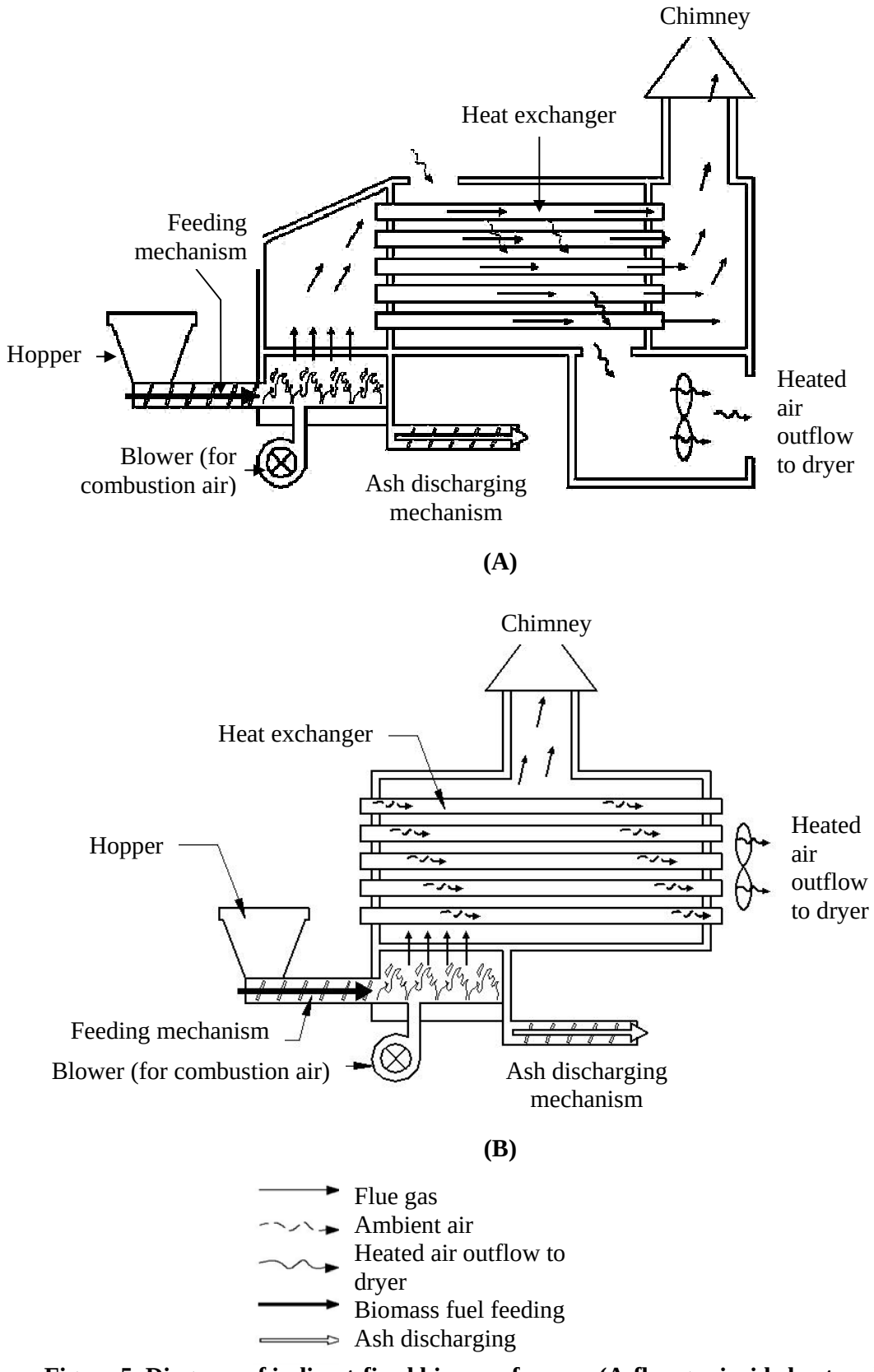

Figure 5. Diagram of indirect-fired biomass furnace (A-flue gas inside heat exchanger; B-flue gas outside heat exchanger)

Indirect-fired biomass furnace shall be further classified as follows:

4.1.2.1 Dry type biomass furnace

Uses ambient air to be heated inside or outside the heat exchanger and be used as drying air. (see Figure 6)

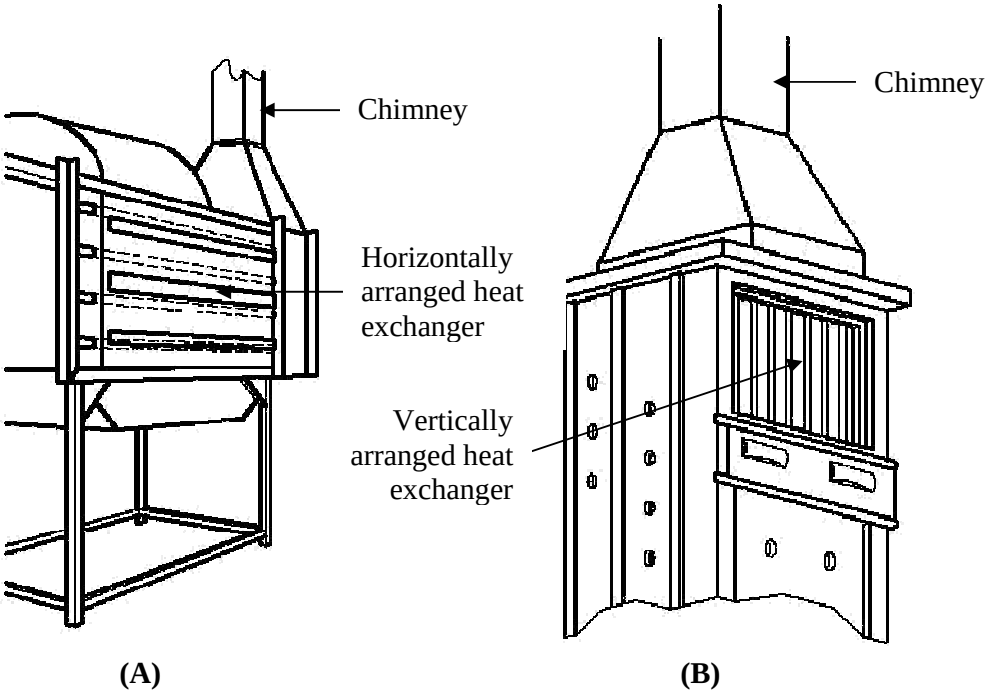

Figure 6. Dry type biomass furnace using (A) horizontal and (B) vertical heat exchanger

4.1.2.2 Wet type biomass furnace

Uses hot fluid as medium of heat transfer. (see Figure 7)

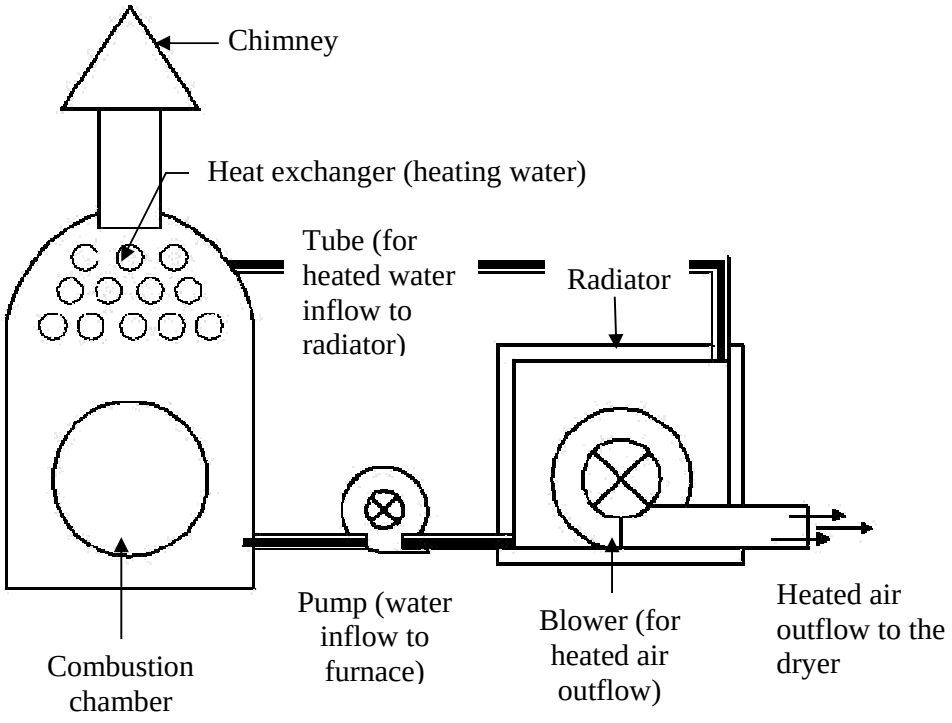

Figure 7. Flow diagram of heated air inside wet-type biomass furnace

4.2 Heat Resisting Lining

4.2.1 Brick lining

Heat resisting lining of the furnace using layer/s of fire bricks

4.2.2 Ceramic fiber lining

Heat resisting lining of the furnace using ceramic materials

4.2.3 Monolithic lining

Heat resisting lining of the furnace using aggregates and bonding agent(s)

Classifications of this type of lining, but not limited to these, are the following:

4.2.3.1 Castable refractory

Consist of course and fine grains with suitable bonding cement. These are poured in place using molds or pouring forms after mixing with water.

4.2.3.2 Trowelable refractory

Kind of castable refractory mortar with a consistency that makes it easy to trowel into place. These are very useful for patching and for shaping complex surfaces.

4.2.3.3 Plastic refractory

Contain a binder material, and are tempered with water so that they have suitable plasticity for pounding or ramming into place.

4.2.3.4 Ramming refractory

Similar to that of plastic refractory but stiffer.

4.2.3.5 Patching refractory

Tempered with water and/or with a binder added for softer plasticity and permits patching in place.

4.2.3.6 Gunning refractory

Have course and fine refractory grains and bonding agents, suitable for installation with a gunning machine.

4.2.3.7 Injection refractory

Can be injected in a slurry state into small places such as gaps and wide cracks, and for filling molds with narrow passageways.

4.2.3.8 Vibratable refractory

Castable refractory materials that should be vibrated to fill all the voids in a mold.

4.2.3.9 Coating refractory

Form of a thin slurry that can be brushed onto or otherwise coated on the working surface of other refractory.

4.2.3.10 Refractory mortars

Finely ground refractory materials that, when tempered with water, become trowelable for bonding layered-up refractory shapes.

5 Manufacturing Requirements

5.1 The biomass furnace shall have combustion chamber and walls with heat resisting lining, insulation, steel supporting structure and casing, hopper with feeding mechanism, ash discharge unit, ash arrester, heat exchanger (for indirect-fired) and flue gas chimney (for indirect-fired).

5.2 Single layer heat resisting lining of the combustion chamber and walls shall be able to withstand the operating temperature of at most 760 °C (1400 °F).

5.3 Biomass furnace that is operating with higher temperature than 760 °C (1400 °F) shall have a multi-layer wall of hearth.

5.4 Multi-layered lining shall compose of two to three layers of refractory and an insulator.

5.5 The heat resisting lining of the combustion chamber and walls of biomass furnace shall be made of individual bricks, monolithic linings and/or ceramic fiber lining.

5.5.1 Brick lining shall be made of fire brick from fireclay and kaolin or silica brick.

5.5.1.1 The brick shall be staggered to avoid direct gas path from the hot gas side to the shell.

5.5.1.2 Bricks shall be assembled using high temperature mortar based on high alumina cement.

5.5.1.3 Ceramic fiber board or insulating brick shall be used for multi-layered brick lining.

5.5.1.4 Expansion joints between the bricks shall be provided at regular intervals to prevent overstressing the brick during operation. (see Figure 8)

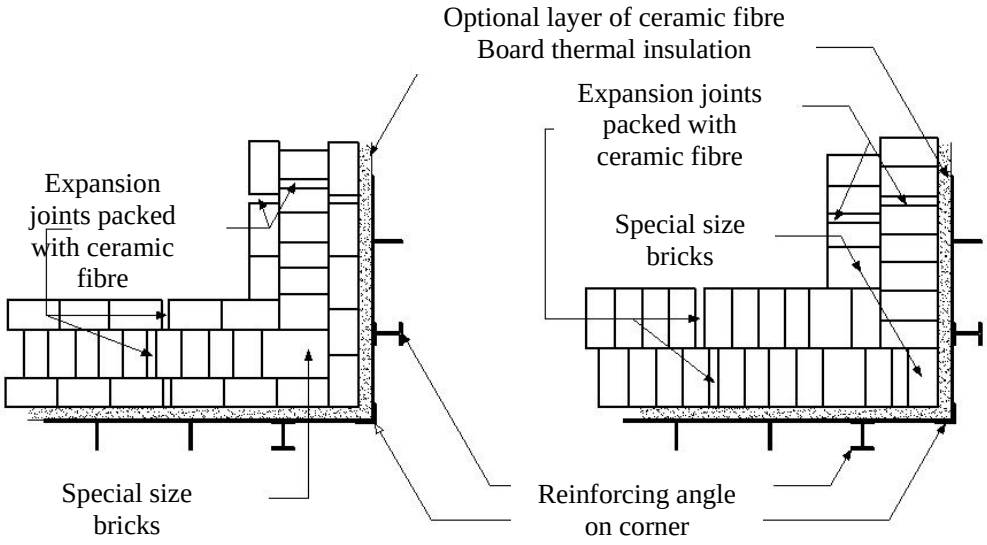

Figure 8. Lining arrangement of the biomass furnace using bricks. (Industrial and Process Furnace, Principle, Design and Operation by Mullinger and Jenkins)

5.5.2 Monolithic lining shall be made of refractory materials graded to a range of sizes together with bonding agent attached to anchors.(see Figure 9)

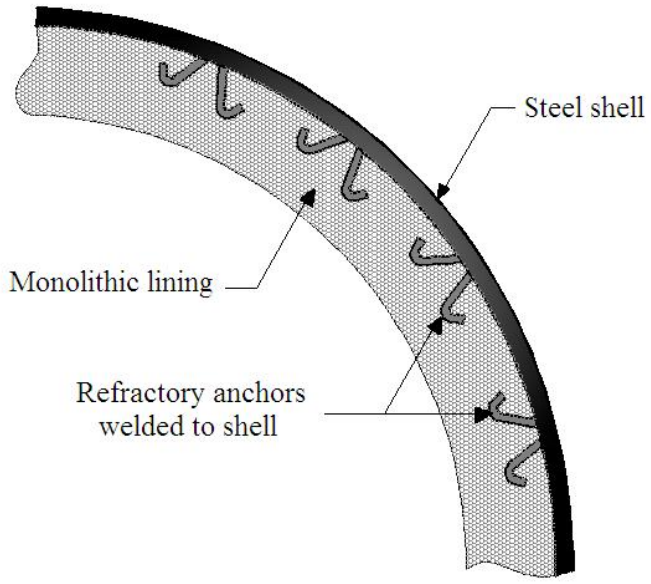

Figure 9. Monolithic type of lining used for biomass furnace. (Industrial and Process Furnace, Principle, Design and Operation by Mullinger and Jenkins)

5.5.2.1 For castable refractory, anchors shall be welded or bolted to the furnace shell. The anchors shall be made of low thermal expansion steel metal (e.g. Chromium-base steel, Tungsten-base steel, Molybdenum-base steel) and/or high temperature stainless steel. (see Figure 10)

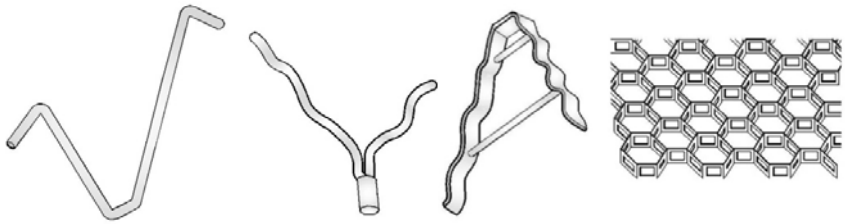

Figure 10. Different shapes of refractory anchors. (Industrial and Process Furnace, Principle, Design and Operation by Mullinger and Jenkins)

5.5.2.2 Castable refractory shall be made of heat resisting aggregates and alumina cement that can be poured into forms.

5.5.2.3 It shall be made into a gas tight structure to avoid heat loss

5.5.3 Ceramic fiber lining shall be made of ceramic fiber with studs or proprietary fixings welded to steel shell. (see Figure 11)

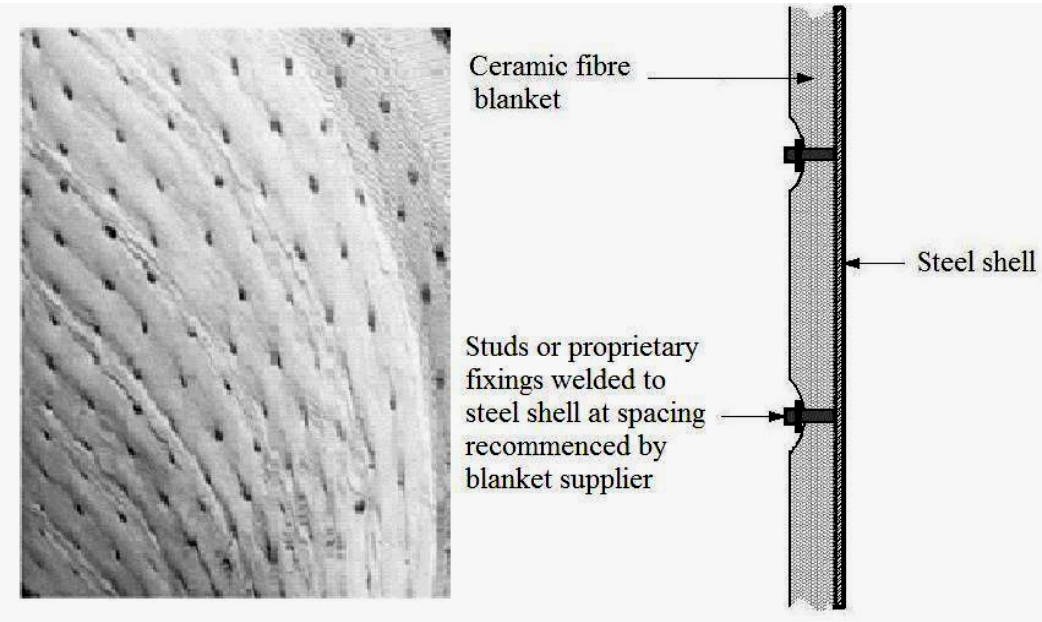

Figure 11. Ceramic fiber used for biomass furnace wall lining. (Industrial and Process Furnace, Principle, Design and Operation by Mullinger and Jenkins)

5.6 Insulation shall be made of fireproof materials like ceramic fiber paper or ceramic wool, 85% magnesia, rock wool and/or mineral wool. It shall be placed between wall linings and steel frame of the biomass furnace.

5.7 Supporting structure and casing shall compose of steel shell or plate work and load bearing frame.

5.7.1 The supporting structure and casing shall be able to support the entire load of the biomass furnace during operation.

5.7.2 It shall be painted with light color paint or aluminum paint.

5.8 Hopper should be made of metal sheet to minimize the friction between the biomass fuel and the surface of hopper. The angle of hopper shall conform to the angle of repose of the biomass fuel as shown in Table 1.

Table 1. Angle of repose for corncob and rice hull.

Biomass	Angle of Repose
Corncob	30°-36°
Rice Hull	35°-50°

5.9 Hopper should have feeding section (e.g. screw feeder, rotary, etc.) to convey the biomass fuel directly to the combustion chamber.

5.10 Combustion chamber shall have a force draft blower and/or passages/opening for air inlet to ensure the complete burning of biomass fuel. For rice hull furnace, this blower or chimney shall be able to support combustion and sustain temperature of 700 °C to 750 °C to avoid crystallization of silica and caking. (Nguyen, 1995)

5.11 Wet-type indirect-fired biomass furnace shall have induced draft either by blower or chimney.

5.12 For indirect-fired biomass furnace, fire tube for dry type furnace and boiler tube for wet type furnace shall be used in heat exchanger.

5.13 The center to center distance of the heat exchanger tubes installed shall be more than 1.25 times the tubes outside diameter.

5.14 Total cross sectional area of heat exchanger used in biomass furnace shall be equal to the cross sectional area of the duct connected to the plenum used in grain dryer.

5.15 Tube layout for heat exchanger should be triangular patterns for efficient heat transfer. (see Figure 12)

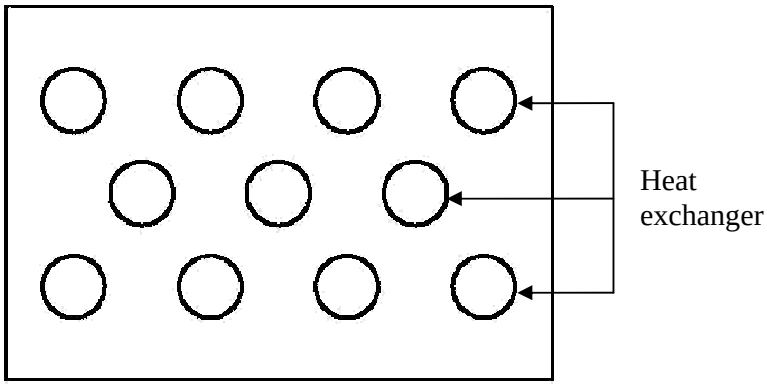

Figure 12. Triangular arrangement of heat exchanger

5.16 Tubes of heat exchanger shall have provision for ease of replacement.

5.17 Grate for grate-type biomass furnace shall be made of flat or square high temperature resistant stainless steel and/or high temperature steel bars such as Chromium-base steel, Tungsten-base steel, Molybdenum-base (see Table 2) welded together.

Table 2. List of high temperature resistant stainless steel. (ASM Metals Handbook)

Grade	Intermittent, °C	Continuous, °C
304	870	925
309	980	1095
310	1035	1150
316	870	925
321	870	925
410	815	705
430	870	815

5.18 Rice hull furnace with ash discharge mechanism (see Figure 13).

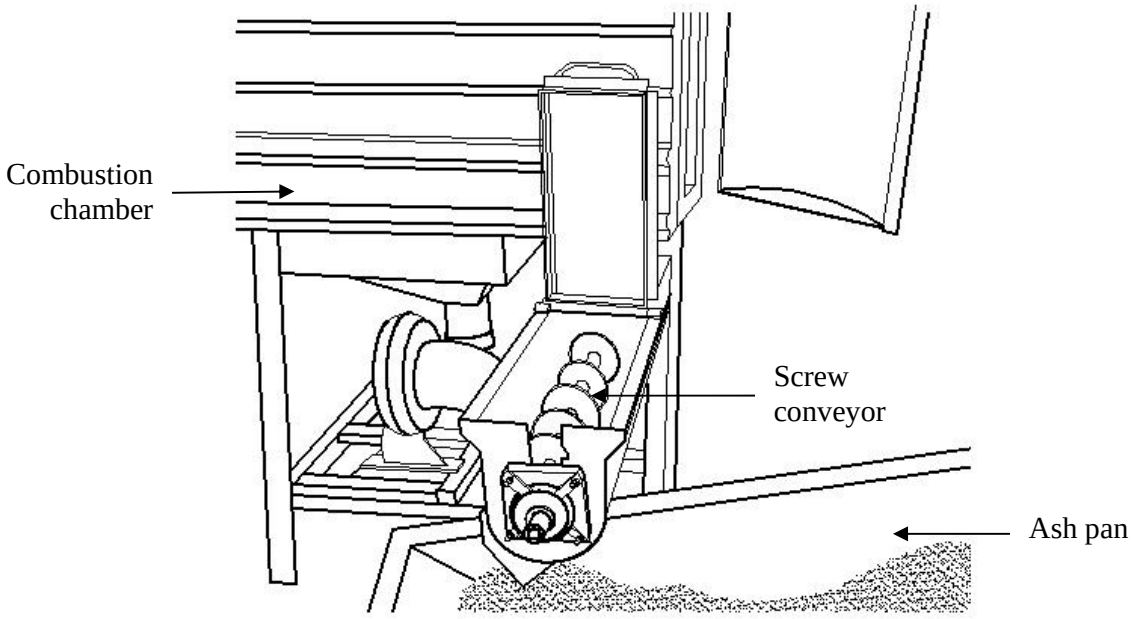

Figure 13. Example of ash discharge mechanism (screw conveyor)

NOTE: In designing rice hull biomass furnace, the following shall be considered: (1) Ash of rice hull is abrasive and acidic. (2) During operation ash temperature is high. (3) Ash content of rice hull is approximately 20%.

5.19 There should be provision for collecting and discharging the ash.

5.20 Biomass furnace (indirect-fired) shall have burning fly ash collector such as ash arrester, ash bin and/or scrubber system.

5.21 Biomass furnace (indirect-fired) should preferably have control panel for temperature monitoring.

5.22 Bolts and screws to be used shall conform to the requirements of PAES 311 and 313.

6 Performance Requirements

6.1 Average biomass fuel consumption per hour shall conform to manufacturer's specifications.

6.2 The furnace shall deliver the required heat for drying operation.

6.3 The furnace shall meet the maximum allowable operating temperature specified by the manufacturer without any damage to the furnace structure (ex. cracking and/or scaling).

6.4 Heating system efficiency of the furnace shall be at least 65% for direct-fired and 50% for indirect-fired. (PAES 201:2000)

6.5 Burning efficiency of the biomass furnace shall be at least 95%.

6.6 Furnace efficiency shall be at least 65%.

6.7 The flue gas emitted by the biomass furnace shall be within the maximum allowable level of pollutants as required by the Clean Air Act of the Philippines.

7 Safety, Workmanship and Finish

7.1 The biomass furnace shall be free from manufacturing defects that may significantly affect its performance.

7.2 The biomass furnace shall be free from sharp edges and surfaces that may be unsafe.

7.3 All surfaces shall be coated with a suitable paint material.

7.4 All welded parts shall be water-tight (for boiler-type biomass furnace) and smoothly polished and it shall pass visual inspection criteria (AWS D1.1:2000) for discontinuity of materials.

7.5 Welded joints shall not be less than 4 mm (1/8 inch) side fillet welded. Undercut shall not exceed 2 mm (1/16 inch) for any length of weld.

8 Warranty

8.1 Warranty against defective materials and workmanship shall be provided for parts and services except for normal wear and tear of consumable maintenance parts within one year from the date of purchase of the biomass furnace.

8.2 The construction shall be rigid and durable without breakdown of its major components for at least one year from the date of purchase of end-user.

9 Maintenance and Operation

9.1 Every biomass furnace unit shall be provided with basic tools, operation and parts manual containing full information on method of installation and operation. The manual which conforms to PAES 102 shall be provided.

9.2 Manufacturers/distributors shall provide after-sales service, identify wearing parts and should provide spare parts.

10 Testing

Biomass furnace shall be tested in accordance with PAES 243.

11 Marking

11.1 Each biomass furnace shall be marked in English with the following information using a stencil or by directly punching it on a plate and shall be positioned at a most conspicuous place:

11.1.1 Registered trademark of the manufacturer

11.1.2 Brand

11.1.3 Model

11.1.4 Serial number

11.1.5 Rated biomass fuel consumption, kg/h

11.1.6 Maximum allowable temperature of biomass furnace, °C

11.1.7 Name and address of the manufacturer

11.1.8 Name and address of the distributor

11.1.9 Country of manufacture (if imported) / “Made in the Philippines” (if manufactured in the Philippines)

11.2 Safety/precautionary markings shall be provided when appropriate. Marking shall be stated in English and/or Filipino.

11.3 The markings shall have a durable bond with the base surface material.

11.4 The markings shall be made of metal aluminum plate.

Philippine Agricultural Engineering Standards

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

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