

**Pellet Fuels Institute (PFI) Standard Specifications for Residential/Commercial  
Densified Fuel**  
October 4, 2022

**1. Scope**

- 1.1 This specification is applicable for the determination of fuel quality grade for Residential or Commercial Densified Fuel as shown in Table 1.
- 1.2 Normative fuel properties included in these standard specifications are fines, bulk density, diameter, length, heating value, chloride, moisture content, pellet durability index, inorganic ash content, and heavy metals. Determination of these properties is mandatory for determining fuel quality grade. Additionally, for the purpose of these standard specifications it is considered normative that material type consists only of woody biomass.
- 1.3 Ash fusion is the only informative fuel property. Determination of ash fusion is not mandatory for determining fuel quality grade.
- 1.4 While this standard specification does make reference to bag weights, it is not intended as a means for enforcing weights and measures. Nor does it preclude densified fuel producers from selling product in any package size that the producer sees fit. Users of this standard specification are encouraged to abide by all applicable regulations governing bag weights in the regions to which the product is sold.
- 1.5 This specification is for the use of densified fuel producers to establish grade requirements for Residential/Commercial densified fuel. It is also for the use of pellet fuel appliance manufacturers for the purpose of designing appliances that meet air emission regulations that cite this standard specification and for users of residential/commercial densified fuel in selection of the grade most suitable to their appliance.
- 1.6 Commercial users include commercial facilities that utilize densified fuel burning appliances or equipment that have the same fuel requirements as residential appliances. Commercial applications should not be confused with industrial applications, which can utilize a much wider array of materials and have vastly different fuel requirements.
- 1.7 The values stated in inch-pound units are to be regarded as the standard. Any values given in parentheses are mathematical conversions to the International System of Units (SI units), which are provided for information only and are not considered standard. If values are stated in SI units only, they are to be regarded as the standard.
- 1.8 When testing for internal Quality Control purposes, densified fuel producers may use alternate test methods as outlined in Section 6.9 of the PFI Residential/Commercial Densified Fuel QA/QC Handbook.
- 1.9 This standard specification does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard specification to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.

**2. Referenced Documents**

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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## 2.1 Pellet Fuels Institute (PFI) Program Standards:

2.1.1 *PFI Residential/Commercial Densified Fuel Standards Program Regulations*

2.1.2 *PFI Residential/Commercial Densified Fuel QA/QC Handbook*

## 2.2 ASTM Standards<sup>1</sup>:

2.2.1 *ASTM E 873 Standard Test Method for Bulk Density of Densified Particulate Biomass Fuels.*

2.2.2 *ASTM E 871 Standard Test Method for Moisture Analysis of Particulate Wood Fuels*

2.2.3 *ASTM D 1102 Standard Test Method for Ash in Wood*

2.2.4 *ASTM E 791 Standard Test Method for Calculating Refuse-Derived Fuel Analysis Data from As-Determined to Different Bases*

2.2.5 *ASTM D 4208 Standard Test Method for Total Chlorine in Coal by the Oxygen Bomb Combustion/Ion Selective Electrode Method*

2.2.6 *ASTM D 6721 Standard Test Method for Determination of Chlorine in Coal by Oxidative Hydrolysis Microcoulometry*

2.2.7 *ASTM E 29 Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

2.2.8 *ASTM C 702 Standard Practice for Reducing Samples of Aggregate to Testing Size*

2.2.9 *IEEE/ASTM SI 10 American National Standard for Metric Practice*

## 2.3 ISO Standards<sup>2</sup>:

2.3.1 *ISO 16968 Solid Biofuels – Determination of minor elements*

2.3.2 *ISO 16994 Solid Biofuels – Determination of sulfur and chlorine*

2.3.3 *ISO 17225-2 Solid Biofuels – Fuel specifications and classes – Part 2: Graded Wood Pellets*

2.3.4 *ISO 18125 Solid Biofuels – Determination of calorific value*

2.3.5 *ISO 21404 Solid Biofuels – Determination of ash melt behavior*

## 2.4 Other Referenced Documents:

2.4.1 *Kansas State University - Mechanical Durability of Feed Pellets, Call Number: LD2668 .T4 1962 Y68*

2.4.2 *ILAC-G8 – Guidelines on Decision Rules and Statements of Conformity*

1. For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org).

2. For referenced ISO Standards, visit the ISO website, [www.iso.org](http://www.iso.org), or contact ISO Customer Service at [central@iso.org](mailto:central@iso.org)

## 3. Terminology

### 3.1 Definitions: General

3.1.1 *Additives* – Any substance other than cellulosic material that has been intentionally introduced into the fuel feed stock prior to pellet extrusion (except steam/water). Grease or other lubricants that are introduced into the fuel processing stream as part of normal mill operations are not considered additives.

3.1.2 *As-Received* – Calculation basis for a material in the delivered state

3.1.3 *Bulk Density* – The fuel mass per cubic foot of the fuel sample; determined by ASTM E873 *Standard Test Method for Bulk Density of Densified Particulate Biomass Fuels* as modified by *PFI Standard Specifications for Residential/Commercial Densified Fuel*.

3.1.4 *Densified Fuel* – Biomass intended for use as fuel that has undergone a process to increase bulk density and energy density.

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- 3.1.5 *Diameter* – The average diameter of the fuel pellets in the fuel sample.
- 3.1.6 *Fines* – The percentage of fuel material in the fuel sample passing through a 1/8 inch screen when the fuel is sampled and tested in accordance with the requirements in 8.1.4.
- 3.1.7 *Dry Basis* – Calculation basis in which the material is considered to be free of moisture.
- 3.1.8 *Heating Value* – The higher heating value of the fuel sample as determined by ISO 18125 *Solid Biofuels – Determination of calorific value*.
- 3.1.9 *Heavy Metals* – High atomic weight elements that are considered undesirable in combusted materials. For the purpose of the PFI Residential/Commercial Densified Fuel Standards Program the heavy metals referenced in ISO 17225-2 to include Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni), and Zinc (Zn) are considered heavy metals of interest. Heavy metals are determined by ISO 16968 *Solid Biofuels – Determination of minor elements*
- 3.1.10 *Inorganic Ash* – The percent inorganic material in the fuel sample as determined by ASTM D1102 *Standard Test Method for Ash in Wood*.
- 3.1.11 *Length* – The weight percent of pellets exceeding 1.5 inches in length in the fuel sample.
- 3.1.12 *Moisture* – The moisture content of the as-received fuel sample as determined by ASTM E871 *Standard Test Method for Moisture Analysis of Particulate Wood Fuels*.
- 3.1.13 *NIST* – The National Institute of Standards and Technology (NIST) is a federal technology agency that develops and promotes measurement, standards, and technology.
- 3.1.14 *Pellet Durability Index (PDI)* – A standardized parameter for specifying the ability of the fuel pellets to resist degradation caused by shipping and handling.
- 3.1.15 *Simple Acceptance* – A conformity statement decision rule as defined by ILAC-G8 whereby a Testing Laboratory result is directly compared with a specified limit for determining pass or fail.
- 3.1.16 *Woody Biomass* – Biomass originating from trees, brush and shrubs.

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**TABLE 1 PFI Fuel Grade Requirements**

Fuel Property	Residential/Commercial Densified Fuel Standards		
	See notes 1-5		
	PFI Premium	PFI Standard	PFI Utility
<b>Normative Information - Mandatory</b>			
Material Type	Woody Biomass	Woody Biomass	Woody Biomass
Additives, %	≤ 2.0	≤ 2.0	≤ 2.0
Bulk Density, lb./cubic foot	40.0 - 48.0	38.0 - 48.0	38.0 - 48.0
Diameter, inches (mm)	0.230 - 0.305 (5.84 – 7.75)	0.230 - 0.305 (5.84 – 7.75)	0.230 - 0.305 (5.84 – 7.75)
Length, Weight % greater than 1.50 inches	≤ 1.0	≤ 1.0	≤ 1.0
Pellet Durability Index	≥ 96.5	≥ 95.0	≥ 95.0
Fines, % (at the mill gate)	≤ 0.50	≤ 1.0	≤ 1.0
Inorganic Ash, % (As-Received)	≤ 1.0	≤ 2.0	≤ 6.0
Moisture, % (As-Received)	≤ 8.0	≤ 10.0	≤ 10.0
Chloride, ppm (As-Received)	≤ 300	≤ 300	≤ 300
Heating Value, BTU/lb (As-Received)	7800	N/A	N/A
Arsenic (As), mg/kg (Dry Basis)	≤ 1	≤ 1	≤ 1
Cadmium (Cd), mg/kg (Dry Basis)	≤ 0.5	≤ 0.5	≤ 0.5
Chromium (Cr), mg/kg (Dry Basis)	≤ 10	≤ 10	≤ 10
Copper (Cu), mg/kg (Dry Basis)	≤ 10	≤ 10	≤ 10
Lead (Pb), mg/kg (Dry Basis)	≤ 10	≤ 10	≤ 10
Mercury (Hg), mg/kg (Dry Basis)	≤ 0.1	≤ 0.1	≤ 0.1
Nickel (Ni), mg/kg (Dry Basis)	≤ 10	≤ 10	≤ 10
Zinc (Zn), mg/kg (Dry Basis)	≤ 100	≤ 100	≤ 100
<b>Informative Only - Not Mandatory</b>			
Ash Fusion	N/A	N/A	N/A

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## Table 1 Notes:

1. It is the intent of these fuel grade requirements that failure to meet any fuel property requirement of a given grade does not automatically place a fuel in the next lower grade unless it meets all requirements of the lower grade.
2. Raw materials and/or additives used shall exclude chemically treated materials and prohibited fuel types as defined in sections 4.2 & 4.3 of the *PFI Residential/Commercial Densified Fuel QA/QC Handbook*.
3. Additive type shall be disclosed to the Certification Body.
- 4.NA – Not Applicable; No value has been established.
5. Fines content is to be determined at the production facility by the fuel producer. The fines determination shall reflect the amount of fines at the mill gate as product is shipped. This is to be done by measuring the fines content of bagged product and/or through bulk load outs (refer to Sections 8.1.4 or 8.1.5 for further information).

## 4. Conformance Requirements

- 4.1 The various grades of densified fuel shall conform to the limiting requirements shown in Table 1.
- 4.2 For purposes of determining conformance with the fuel grade, all properties reported by the Testing Laboratory must fall at or within the specified limits listed for a particular grade whereby “Simple Acceptance” decision rules are applied – see ILAC-G8.
- 4.3 Reported values obtained from Testing Bodies shall be rounded to the nearest unit in the last right-hand place of the figures used in expressing the limit in accordance with ASTM E 29 *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*.

## 5. Equipment and Supplies

- 5.1 Caliper – A caliper capable of measuring fuel diameter and length to within 0.001 in. (0.025 mm). Shall meet the calibration requirements specified in 9.1.
- 5.2 Analytical Balance – A balance with a resolution of 0.1 grams or better. Shall meet the calibration requirements specified in 9.2.
- 5.3 Measuring Block – A 1.5 inch (38 mm) long gauge block used for screening fuel pieces for length. Shall meet the requirements specified in 9.3.
- 5.4 Scale – A scale with resolution of 0.05 kilograms or better. Shall meet the calibration requirements specified in 9.2.
- 5.5 Balance – A balance with a resolution of 0.01 kilograms or better. Shall meet the calibration requirements specified in 9.2

## 6. Sampling and Sample Handling

- 6.1 The reader is strongly advised to review all intended test methods and sampling requirements prior to sampling in order to understand the importance and effects of sampling technique and special handling required for each method.

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## 7. Sample Preparation

- 7.1 A sample preparation schematic is shown in Annex B.1 to illustrate how a bag of pelletized material may be subdivided to perform the analysis procedures. All sample subdividing shall be conducted utilizing a sample splitter with a slot width that ranges from 3.0 +/- 0.5 inches (64 – 89 mm) and meeting the requirements specified in ASTM C 702. For all instances in which samples are split, use the split closest to the intended weight.

## 8. Test Methods

- 8.1 The requirements enumerated in this specification shall be determined in accordance with the referenced test method(s) except where modifications are noted or in accordance with the test procedures specified.
  - 8.1.1 Bulk Density – Determine in accordance with ASTM E 873 except this method shall be revised to utilize a 1/4 cubic foot container that is dropped 25 times from 1 inch. In order to ensure that an adequate sample quantity is available for this revised method, a minimum sample size of 12 pounds (5.44 kilograms) is recommended.
  - 8.1.2 Diameter - Select 5 pellets randomly out of the pellet sample being evaluated and measure the diameter of each pellet with the caliper specified in 5.1. Each measured pellet diameter shall be recorded to the nearest 0.001 inch. .
  - 8.1.3 Pellet Durability Index (PDI) – Pellet durability shall be determined by using the method specified in Annex A.1. It should be noted that the pellets remaining after performing the fines determination as specified in 8.1.4 may be used without further preparation to conduct the durability test.
  - 8.1.4 Fines – Determined using the following procedure that incorporates the use of a 1/8-inch (3.18 mm) wire screen sieve. All weight measurements shall be recorded to the nearest 0.1 gram.
    - 8.1.4.1 Secure a representative fuel sample.
    - 8.1.4.2 Reduce the sample size down to an intended weight of 2.5 pounds (1,134 grams) using a sample splitter as specified in section 7.1. Larger sample sizes may be used.
    - 8.1.4.3 Using the analytical balance specified in 5.2, weigh the sample and record as the initial sample weight to the nearest 0.1 grams.
    - 8.1.4.4 Weigh the receiving pan and record the weight to the nearest 0.1 grams.
    - 8.1.4.5 Attach a 1/8-inch (3.18 mm) screen to the receiving pan and place the pellet sample on the screen using care not to overload the screen. The maximum load on the screen should not exceed 1 pound (453 grams) of pellets per 100 square inches (645 square centimeters) of screen surface area. Smaller screens may require the sample to be screened in increments.
    - 8.1.4.6 Screen the sample by tilting the screen side to side 10 times.
    - 8.1.4.7 If the sample is being screened in increments, after the first portion has been screened remove the 1/8-inch (3.18 mm) screen from the base pan and empty the pellets off the screen.
    - 8.1.4.8 Repeat 8.1.4.5 through 8.1.4.7 until the entire sample has been screened.

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8.1.4.9 Remove the 1/8-inch (3.18 mm) screen and weigh and record the weight of the base pan with the fines to the nearest 0.1 grams.

8.1.4.10 Calculate and report the percent of fines to the nearest 0.01% as follows:

$$\% \text{ Fines} = \frac{[(\text{Weight of Base Pan} + \text{Fines}) - (\text{Weight of Base Pan})]}{\text{Initial Sample Weight}} \times 100$$

8.1.5 Inorganic Ash – Determine in accordance with ASTM D 1102.

8.1.6 Length - Starting with an intended weight of 2.5 pounds (1.13 kilograms) of pellets as developed by sample splitting as outlined in section 7.1, hand sort to identify pellets over 1.50 inches (38 mm) in length. Use the caliper specified in 5.1 or a certified measuring block as specified in 5.3 to confirm that a pellet exceeds the specified length. The weight percent of all pellets exceeding the specified length shall be reported.

8.1.7 Moisture – Determine in accordance with ASTM E 871.

8.1.8 Chloride – Determine in accordance with ASTM D 4208 or ASTM D 6721 or ISO 16994.

8.1.9 Ash Fusion - Determine in accordance with ISO 21404.

8.1.10 Heating Value – Determine in accordance with ISO 18125.

8.1.11 Heavy Metals – Determine in accordance with ISO 16968.

## 9. Calibration and Standardization

9.1 Caliper – Before each test, audit the caliper by measuring one NIST traceable gauge block that corresponds to between 80 percent and 120 percent of the anticipated fuel diameter and by measuring the length of the measuring block specified in 5.3. If the caliper cannot reproduce the calibration gauge dimensions within 1%, the caliper may not be used.

9.2 Balances and Scales - Perform an initial calibration using NIST or other recognized national standards in accordance with the manufacturer’s instructions. Before each test, verify the balance or scale by using at least one calibration weight that corresponds to 50 to 150 percent of the weight of the fuel sample to be measured. If the balance or scale cannot reproduce the value of the calibration weight to within 1% of the mass, recalibrate before use.

9.3 Measuring Block – The length of the block shall be traceable to NIST and demonstrate accuracy of ±0.01 in. from length specified in 5.3. The block manufacturer’s certification documents are sufficient for this purpose.

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## Annex A.1

### Pellet Fuels Institute Standard Operating Procedure for: Durability Testing – Residential/Commercial Pellet Fuels

Produced by: PFI Standards Committee

The Pellet Fuels Institute has adopted the test procedure outlined by Kansas State University (See Kansas State University - *Mechanical Durability of Feed Pellets*, Call Number: LD2668 .T4 1962 Y68) for assessing the durability of residential/commercial densified fuel products, with the exception that the screen size used in determining durability has been modified to be a 1/8-inch (3.17 mm) wire screen sieve.

The durability tester consists of a dust tight box. The box shall be made of a rigid material with smooth and flat surfaces (e.g., stainless steel plate). The inner dimensions of the box shall be  $305 \pm 3$  mm long by  $140 \pm 3$  mm wide by  $305 \pm 3$  mm deep. It shall rotate about an axis which is perpendicular to and centered in the nominal 305 mm by 305 mm sides. A  $230 \pm 3$  mm long baffle is affixed symmetrically to a diagonal of one nominal 305 mm by 305 mm side of the box. The baffle extends  $50 \pm 1$  mm into the box and is securely fastened to the back of the box. The edges of the baffle shall not be sharp, but rounded to avoid any cutting effect. A door may be placed on any side of the box. Projections, such as rivets and screws, shall be kept to a minimum and well rounded (alternatively, flat head screws may be used). An illustration of the tester is shown in Fig 1.

The procedure is outlined as follows:

1. Secure a representative pellet fuel sample. The minimum recommended representative sample weight is 1100 grams.
2. Screen the representative sample with a 1/8-inch (3.18 mm) wire screen sieve to remove fines. Obtain the initial test sample from the portion of the representative sample retained on the screen.
3. Using the analytical balance specified in 5.2, weigh  $500 \pm 10$  grams of the initial test sample and record as the initial weight to the nearest 0.1 grams (IW).
4. Tumble the pre-weighed initial test sample in the durability tester at  $50 \pm 2$  rotations per minute for a total of 500 rotations.
5. Re-screen the tumbled test sample weigh the portion retained on the 1/8-inch (3.18 mm) sieve, and record as the whole pellet sample weight to the nearest 0.1 grams (WPW).



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6. Compute Pellet Durability Index (PDI) by dividing the whole pellet sample weight (WPW) by the initial weight (IW) of the sample and multiply by 100. Report to one decimal place.

$$PDI = \frac{WPW}{IW} \times 100$$

7. Repeat steps 2-6 on a second portion of the representative fuel sample.

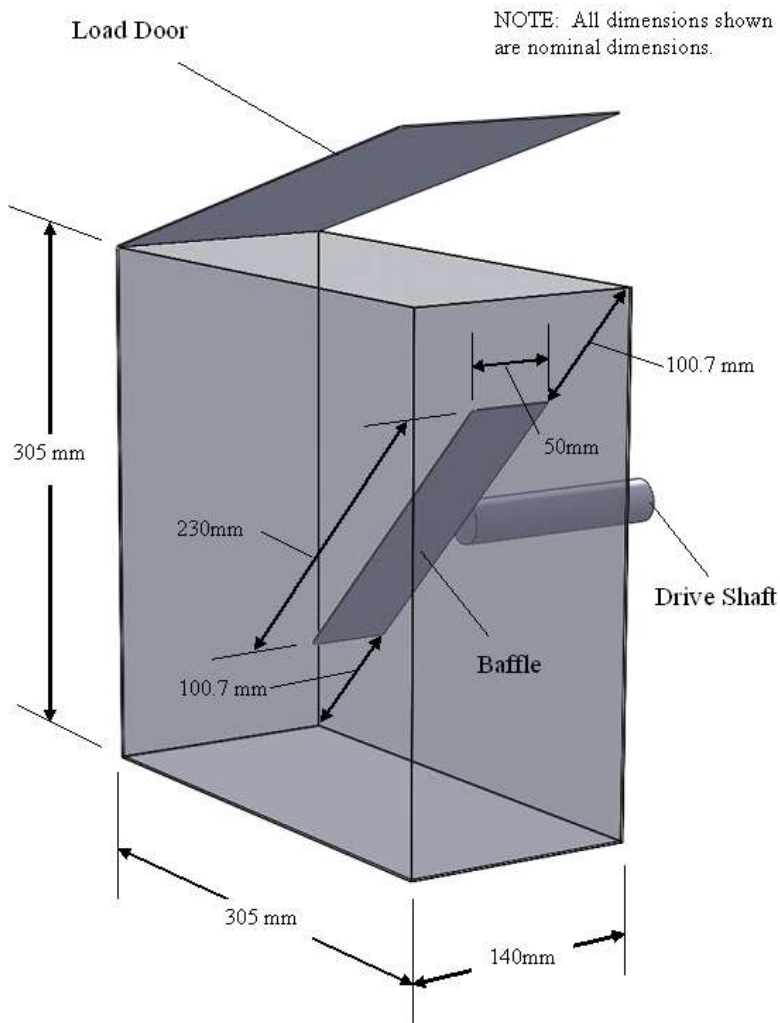
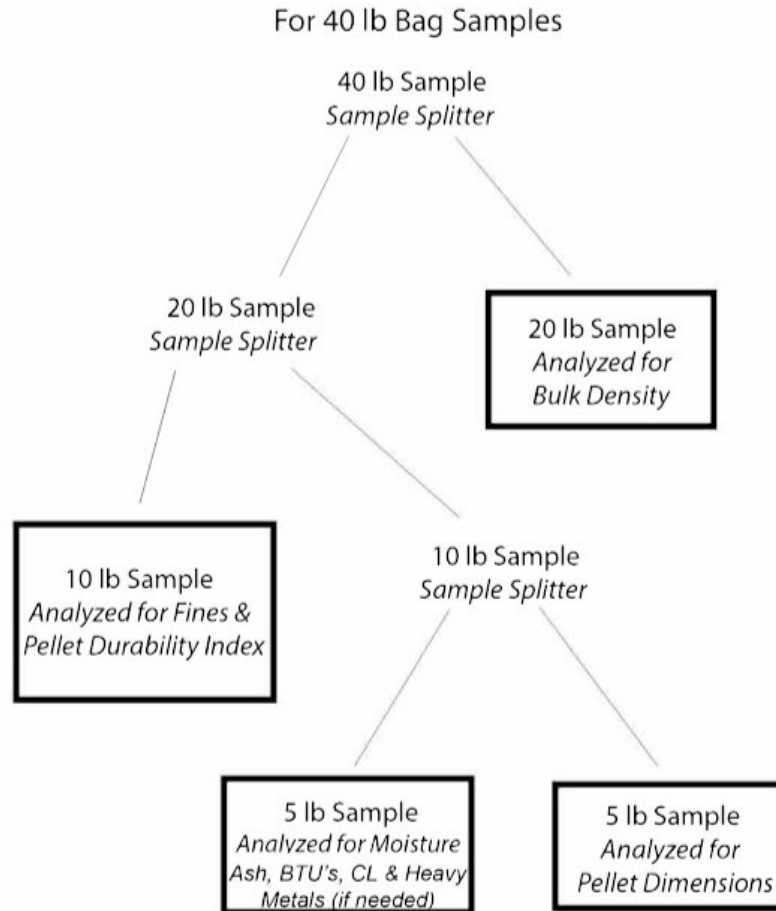


FIG 1. Pellet Durability Tester

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**Annex B.1 Sample Preparation and Analysis Flow Chart**



*\*Sample Splitters should have a slot width of 3.0 in (76 mm) +/- 0.5 in (13mm) and meet the requirements specified in ASTM C702 (e.g Gilson SP-Sample Splitter)*

*\*Additional sample splitting may be necessary to analyze some parameters*

*\*All sample weights are approximate*