Designation: D6700 – 19

Standard Guide for
Use of Scrap Tires as Tire-Derived Fuel[1]

This standard is issued under the fixed designation D6700; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers and provides guidance for the material recovery of scrap tires for their fuel value. The conversion of a whole scrap tire into a chipped formed for use as a fuel produces a product called tire-derived fuel (TDF). This recovery guide has moved from a pioneering concept in the early 1980s to a proven and continuous use in the United States with industrial and utility applications.

1.2 Combustion units engineered to use solid fuels, such as coal or wood, or both, are fairly numerous throughout the U.S. Many of these units are now using TDF even though they were not specifically designed to burn TDF. It is clear that TDF has combustion characteristics similar to other carbon-based solid fuels. Similarities led to pragmatic testing in existing combustion units. Successful testing led to subsequent acceptance of TDF as a supplemental fuel when blended with conventional fuels in existing combustion devices. Changes required to modify appropriate existing combustion units to accommodate TDF range from none to relatively minor. The issues of proper applications and specifications are critical to successful utilization of this alternative energy resource.

1.3 This guide explains TDF's use when blended and combusted under normal operating conditions with originally specified fuels. Whole-tire combustion for energy recovery is not discussed herein, since whole-tire usage does not require tire processing to a defined fuel specification.

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 *This standard 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 to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D2013/D2013M Practice for Preparing Coal Samples for Analysis
D2361 Test Method for Chlorine in Coal (Withdrawn 2008)[3]
D2795 Test Methods for Analysis of Coal and Coke Ash (Withdrawn 2001)[3]
D3172 Practice for Proximate Analysis of Coal and Coke
D3173/D3173M Test Method for Moisture in the Analysis Sample of Coal and Coke
D3174 Test Method for Ash in the Analysis Sample of Coal and Coke from Coal
D3175 Test Method for Volatile Matter in the Analysis Sample of Coal and Coke
D3176 Practice for Ultimate Analysis of Coal and Coke
D3177 Test Methods for Total Sulfur in the Analysis Sample of Coal and Coke (Withdrawn 2012)[3]
D3178 Test Methods for Carbon and Hydrogen in the Analysis Sample of Coal and Coke (Withdrawn 2007)[3]
D3179 Test Methods for Nitrogen in the Analysis Sample of Coal and Coke (Withdrawn 2008)[3]
D3682 Test Method for Major and Minor Elements in Combustion Residues from Coal Utilization Processes
D4239 Test Method for Sulfur in the Analysis Sample of Coal and Coke Using High-Temperature Tube Furnace Combustion
D4326 Test Method for Major and Minor Elements in Coal and Coke Ash By X-Ray Fluorescence
D4749 Test Method for Performing the Sieve Analysis of Coal and Designating Coal Size

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[1] This guide is under the jurisdiction of ASTM Committee D34 on Waste Management and is the direct responsibility of Subcommittee D34.03 on Treatment, Recovery and Reuse.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

D5468 Test Method for Gross Calorific and Ash Value of Waste Materials (Withdrawn 2016)[3]

D5681 Terminology for Waste and Waste Management

D5865 Test Method for Gross Calorific Value of Coal and Coke

E873 Test Method for Bulk Density of Densified Particulate Biomass Fuels

F538 Terminology Relating to the Characteristics and Performance of Tires

2.2 *EPA Standards:*[4]

SW-846-5050 Bomb Preparation Method for Solid Waste

SW-846-9056 Determination of Inorganic Anions by Ion Chromatography

3. Terminology

3.1 *Definitions*—For definitions of general terms used in this guide, refer to Terminologies D5681 and F538 on waste management and tires, respectively

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bead wire, n*—a high-tensile steel wire, surrounded by rubber, which forms the bead of a tire that provides a firm contact to the rim.

3.2.2 *chip size, n*—the dimension of size-reduced rubber particles resulting from the processing of whole tires.

3.2.3 *combustion, n*—the chemical reaction of a material through rapid oxidation with the evolution of heat and light.

3.2.4 *combustion unit, n*—any number of devices to produce or release energy for the beneficial purpose of production by burning a fuel to include, but not limited to, units such as industrial power boilers, electrical utility generating boilers, and cement kilns.

3.2.5 *energy value, n*—the assignment of a value to the tire-derived fuel as measured in British thermal units per pound or calories per gram.

3.2.6 *fuel value, n*—the heat content, as measured in British thermal units (Btu)/lb or cal/g.

3.2.7 *new tire, n*—a tire that has never been mounted on a rim.

3.2.8 *relatively wire free, n*—TDF that has a bead wire content not greater than 1 % by weight, and a total wire content of 2 % or less by weight.

3.2.9 *rubber, n*—an elastomer, generally implying natural rubber, but used loosely to mean any elastomer, vulcanized and not vulcanized. By definition, rubber is a material that is capable of recovering from large deformations quickly and forcibly and can be, or already is, modified to a state in which it is essentially insoluble in a boiling solvent.

3.2.10 *scrap tire, n*—a rubber tire that is no longer used for its originally intended application.

3.2.11 *screen, n*—an apparatus for separating sizes of granules.

3.2.12 *standard size specification, n*—the size specifications with the broadest application when blending with other solid fuels and requiring minimal adjustments or retrofits to existing solid fuel combustion units.

3.2.13 *supplemental fuel, n*—a combustible material that displaces a portion of traditional fuel source. It refers to the product being used in conjunction with another conventional fuel but typically not as a sole fuel supply.

3.2.14 *tire-derived fuel (TDF), n*—a product made from scrap tires to exact specifications of a system designed to accept a tire-derived fuel as primary or supplemental fuel source.

3.2.15 *wire, n—in a tire,* high-tensile, brass-plated steel wire, coated with a special adhesion-promoting compound, used as tire reinforcement as belts, beads, or radial tire plies.

3.2.16 *wire free, n*—TDF that is free of all inherent wire.

3.2.17 *X minus, n*—a designation of sample particle size, with Dimension X indicating the upper limit or maximum size of particles passing through a sieve or screen opening upon which is cumulatively retained less than or equal to 1 % of the sample. For example, a sample designated as "2 in. (5 cm) minus" would pass a 2-in. screen opening with less than or equal to 1 % of the sample retained.

4. Significance and Use

4.1 When considering the specification of fuels for a boiler, issues to evaluate are the fuel's combustion characteristics, handling and feeding logistics, environmental concerns, and ash residue considerations. A thorough understanding of these issues is required to engineer the combustion unit for power and steam generation; however, TDF has demonstrated compatible characteristics allowing it to serve as a supplemental fuel in existing combustion units based on cumulative experience in many facilities originally designed for traditional fossil fuels, or wood wastes, or both. When used as a supplemental energy resource in existing units, TDF usage is generally limited to blend ratios in the 10 to 30 % range based on energy input. This limit is due to its high heat release rate and low moisture content, which differ significantly from other solid fuels such as wood, refuse-derived fuel, coal, and petroleum coke.

4.2 New combustion units dedicated to the use of TDF (or whole tires) as the sole fuel source are rare. The generation and availability of scrap tires are ultimately determined by market conditions for new tires and the depletion rate of scrap tire inventories (stockpiles). Scrap tires account for approximately 1 % of the municipal solid waste stream. Based on a national scrap tire generation rate, there are roughly 2.5 to 3 million tons (annually available for all uses to include fuel, crumb rubber, engineering projects, and so forth). Some dedicated combustion units have been built, however, competition for the scrap tires as other existing sources begin to use TDF will determine the ultimate viability of these facilities. Although most regions can supply TDF demand as a supplemental fuel, a dedicated boiler in the range of 500 000 lb/h (227 000 kg/h) steaming capacity would require over 66 000 scrap tires/day to meet its fuel demand. Such demand may strain a region's

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[4] Available from United States Environmental Protection Agency (EPA), William Jefferson Clinton Bldg., 1200 Pennsylvania Ave., NW, Washington, DC 20460, http://www.epa.gov.

ability to supply and put the fuel supply at risk. Some design projects have incorporated TDF as a supplemental fuel with wood, coal, coke, sludge, or some combination of multiple fuels where demand is consistent with supply availability.

4.3 It is important to understand what objectives may lead to TDF's choice as a supplemental fuel in existing power units. Several model objectives may be as follows:

4.3.1 To increase boiler efficiency in a co-fired boiler using wood, sludge, and coal;

4.3.2 To procure a competitively priced fuel;

4.3.3 To supplement limited supplies of an existing fuel;

4.3.4 To use a high-quality fuel;

4.3.5 To achieve environmental benefits by using a fuel with a relatively low sulfur content in comparison to certain coals or petroleum coke, and;

4.3.6 To provide a public and social benefit that solves a regional solid waste problem.

4.4 Boilers generally are engineered around fuels that will be available through the amortized life of the power unit. Boiler design discussions here are limited as TDF standard size specifications have been developed to ensure TDF's performance in existing systems. TDF is mined from the solid waste stream as a whole tire, then engineered via processing techniques to fit a new or existing combustion unit. A major modification or re-engineering of the combustion unit to accommodate TDF normally would make its use uneconomical as a supplemental fuel. TDF's use is economically dependent on the following two issues:

4.4.1 A combustion unit's existing ability to use the fuel without modification (other than minor operational changes in oxygen grate speed adjustments, and feed/material handling) and,

4.4.2 The ability of a supplier to economically collect, process, and transport TDF to the combustion unit.

4.5 Once an economic decision has been made to develop TDF as a fuel source for a particular unit, issues of fuel specifications including size, proximate and ultimate analysis, combustion characteristics, and environmental concerns must be evaluated properly to determine whether TDF is an appropriate supplemental fuel resource without major system modification.

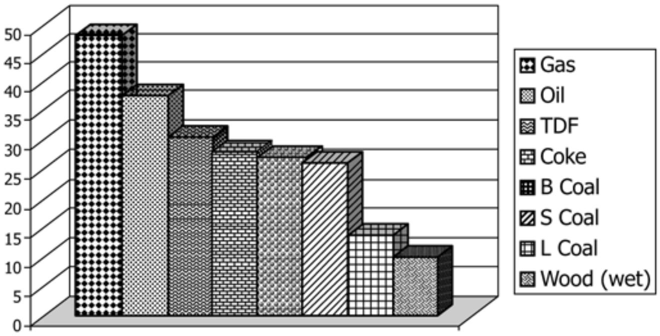


FIG. 1 Relative Energy Comparison of Fuels (Scale in Btu/ton)

5. Tire-Derived Fuel Analysis – General Description

5.1 TDF is defined as a fuel source derived from the processing of scrap tires into rubber chips with a range in size and metal content. Processing may include shredding, chopping, classification, recycling, granulation, wire/fabric separation, and other technologies. Size normally varies in a range from 1 in. (2.5 cm) to 4 in. (10.2 cm). Metal content ranges from wire free, to relatively wire free, to only bead wire removed, to no wire removed. TDF's tolerable wire content is determined by a combustion unit's design considerations. TDF's wire removal is determined by production process capabilities. Some combustion units such as cement kilns can tolerate all inherent wire, so no removal is necessary. In circumstances where no effort is made to remove wire, TDF must be cleanly cut with minimal exposed wire protrusion from the chips to facilitate mechanical handling.

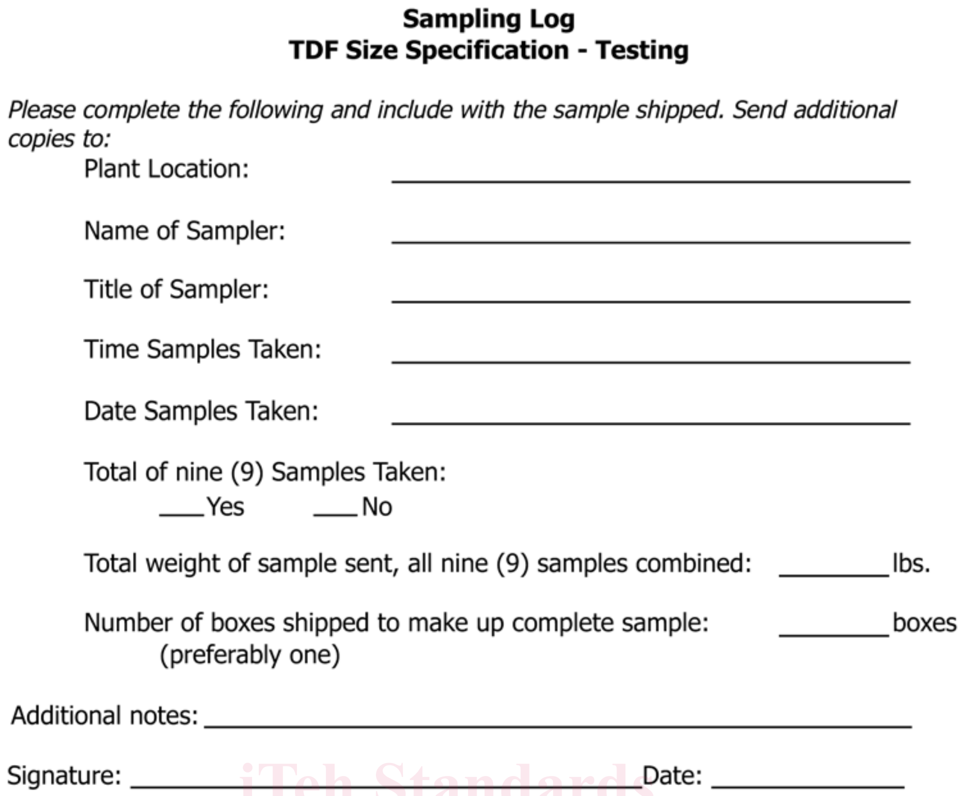
5.2 Unless temperatures in a combustion unit are sufficient to oxidize the wire, the energy contribution from the wire is nominal and will account for a lower product energy value than that of either a wire-free or relatively wire-free TDF product. Cement kilns typically burn at sufficient temperatures to oxidize the wire and benefit from both the energy release from oxidation and the resultant iron oxide that becomes a critical component in cement chemistry. Depending on the amount of wire removed, the TDF has an energy content ranging from 14 000 to 15 500 Btu/lb (7770 to 8600 cal/g).

5.3 Combustion efficiency for TDF generally is understood to be in the 80 % range. TDF represents an ideal fuel source in that its moisture content is low (1 to 3 %), and its energy value is high. Low moisture content uses less energy for moisture vaporization and lowers combustion gas mass flow rate. TDF has a volatile content of roughly 66 %, which indicates rapid heat release. Relatively low ash content (3 to 5 %) maximizes heat absorption and decreases ash disposal costs. As rubber is non-absorbent, moisture swings during seasonal periods of rainfall in ambient weather conditions are limited to a range of 1 to 8 %. The smaller the TDF chip size, the greater the storage pile surface area and its concomitant ability to hold moisture on its surface. Table 1 identifies the energy content of common fuel types currently used singularly or in some combination.

5.4 The specifications for TDF are somewhat customer specific, as this material will be fed into an existing combustion unit. A highly refined product with the wire removed is more expensive to produce, but provides more energy per ton and fewer operating problems in many units. Problematic areas to

TABLE 1 Energy Value

Fuel Type	Energy Value in million Btu/short ton (MBTU/ton)
Tire-derived fuel (TDF)	28–3
Petroleum coke (PC)	26–28
Bituminous coal (BC)	18–27
Subbituminous coal (SC)	17–25
Lignite coal (LC)	12–14
Wood fuel (WF)	8–17
Relative Comparison of Non-Solid Fuels	
Oil	34–38
Gas	42–48



Sampling Log
TDF Size Specification - Testing

Please complete the following and include with the sample shipped. Send additional copies to:

Plant Location: ______________________

Name of Sampler: ______________________

Title of Sampler: ______________________

Time Samples Taken: ______________________

Date Samples Taken: ______________________

Total of nine (9) Samples Taken:
____Yes ____No

Total weight of sample sent, all nine (9) samples combined: ________lbs.

Number of boxes shipped to make up complete sample: ________boxes
(preferably one)

Additional notes: ______________________

Signature: ______________________ Date: ____________

FIG. 2 Sampling Log

evaluate to determine true specification requirements are fuel feed system, grate maintenance, ash circulation/handling, and ash disposal systems. Since roughly 10 to 15 % of a tire is comprised of radial ply wire and bead wire, any TDF that is not relatively wire free will have a fuel value 10 to 15 % less than the values reported for TDF in Table 1. TDF specified to have a lower wire content is more expensive to produce. The increased cost is attributable to further refinement expense and ultimate disposal, or recovery cost for the wire residue generated from TDF production, or both.

5.5 In addition to steel wire, nylon and polyester may be used in tire construction. Nylon and polyester plies are found in both steel radial and non-steel radial tires, passenger, and truck tires. Approximately 3 % of a tire is made up of these types of non-steel plies. When a tire is processed into TDF, these synthetic plies will typically stay in the TDF. Both nylon and polyester are petrochemical products with an energy content similar to that of rubber. Due to their low ash content and high energy content, the fuel value of plies is relatively consistent with that of the rubber.

5.6 A representative analysis of TDF is presented in Table 2. This table identifies key combustion issues. The high amount of fixed carbon (29.96 %) suggests particulate concerns and ash (4.22 %) suggests solid waste concerns. Other elements of concern include sulfur (1.92 %) and zinc (1.52 %).

TABLE 2 Analysis of TDF (Relatively Wire Free)

NOTE 1—TDF produced from scrap tires with 96 % plus wire removed.

Description	Percent by Weight as Received
Proximate Analysis	
Moisture	0.474
Ash	4.22
Volatile matter	65.34
Fixed carbon	29.966
	Total 100.00
Ultimate Analysis	
Moisture	0.47
Ash	4.22
Carbon	89.51
Hydrogen	7.59
Nitrogen	0.27
Sulfur	1.92
Oxygen	. . .
Elemental Analysis	
Zinc	1.52
Calcium	0.378
Iron	0.321
Chlorine	0.149
Chromium	0.0097
Fluoride	0.0010
Cadmium	0.0006
Lead	0.0065
Others below detectable levels to include mercury, barium, silver, and so forth	
Theoretical air	3.362 kg/10000 Btu (2520 Kcal)
Wet gas from fuel	0.266 kg/10000 Btu (2520 Kcal)
H_2O from fuel	0.179 kg/10000 Btu (2520 Kcal)

6. Handling Considerations Conveying, Grate, and Ash

6.1 TDF can be produced with the wire left in or taken out. Either way, one must balance the trade-off(s). To remove a greater percentage of inherent wire the chip size must ultimately be smaller, in the ⅝-in. (1.6 cm) to 2-in. (5.08 cm) size range. Both smaller chip size and increased wire removal will