



## **BTEC Standard 100 - 2016**

### **Test Method for Measurement of Heating Efficiency and Emissions Performance of Commercial, Biomass-fired, Hydronic Boilers**

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# Why a new standard for commercial, biomass-fired, hydronic boilers?

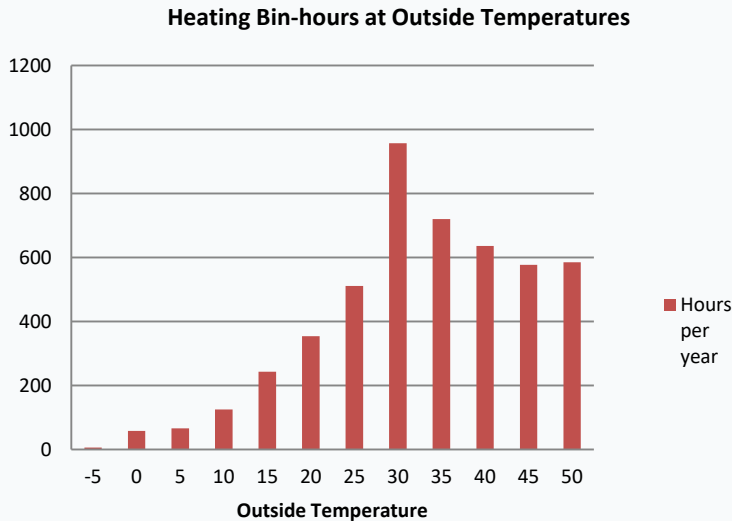
**Existing U.S. commercial boiler standards only address full-load performance**

**Most building operation hours are at part-load during heating season**

**Uniform basis for comparison of annual product performance of new boilers**

**Documentation of expected benefits and savings of new, biomass-fired boiler systems compared to existing, fossil fuel-fired boiler systems**

**Build customer confidence in making investments in new, biomass-fired, hydronic boiler systems**



# Scope

**Builds upon ASTM E2618-13 (Standard Test Method for Measurement of Particulate Emissions and Heating Efficiency of Solid Fuel-fired Hydronic Appliances) which is authorized test method under USEPA New Source Performance Standards for new residential, hydronic heaters**

**Single or multiple boiler systems with manual (cordwood) or automatic (pellets/chips) feed**

**OPEN PLATFORM TESTING APPROACH:**

**With or without external thermal storage**

**Allows for use of manufacturer-specified operating principles for boiler temperature control, including continuous modulation of firing rate, slumber modes, and “stay alive” combustion air cycling strategies during off-cycle periods, so long as manual reset of the boiler control is not required**

## **Other Referenced Documents**

**ASTM E2515-11 Test Method for Determination of Particulate Matter Emissions Collected by a Dilution Tunnel**

**CSA B415.1-2010 Performance Testing of Solid-fuel-burning Heating Appliances (Stack Loss Method)**

**ASHRAE Standard 155P Method of Testing for Rating Commercial Space Heating Boilers Systems (Gas and Oil-fired)**

**ASHRAE Weather Data Viewer – bin hour data during heating season**

**European Standard EN 303-5 Heating Boilers – Part 5: Heating Boilers for Solid Fuels, Manually and Automatically-stoked, Nominal Heat Output up to 500 kW – Terminology, Requirements, Testing and Marking**

## **New Terminology**

**Multiple Boiler System** – a system consisting of two or more boilers, installed with automatic valves or pumps that can prevent hydronic circulation through such boilers when not firing

**Stack Loss Method (SLM) Delivered Efficiency** – overall efficiency per CSA B415.1-10 minus the jacket loss (%) of a boiler

**Total Boiler-plus-Thermal Storage System Standby Loss (Btu/hr)** – sum of boiler plus thermal storage system standby losses (Btu/hr)

**Application Seasonal Efficiency** – calculated seasonal thermal efficiency of single or multiple boiler system based on performance from zero load to full load, capacity of boiler relative to peak load, and distribution of temperature bin hours

# **Summary of BTEC Commercial Boiler Test Method**

**Modified Stack Loss Method (SLM) for all boilers over 300,000 Btu/hr capacity**

**Direct BTU metering allowed only for boilers under 300,000 Btu/hr to allow for use of previous USEPA NSPS testing results for residential applications**

**Boiler jacket loss measurements in accordance with ASHRAE 155P for commercial, gas and oil-fired boilers at 180 deg F except for thermal post-purge (140 deg F) or condensing (120 deg F)**

**Fuel input vs output graph in accordance with ASHRAE 155P over range of 0 to 100 percent of rated boiler capacity**

# **Summary of BTEC Commercial Boiler Test Method**

## **Cont'd**

**Annex A1 Modified Test Method for Wood-fired Hydronic Appliances that Utilize Full Thermal Storage with added requirement to include standby loss of both boiler and thermal storage tank**

**Annex A2 Modified Test Method for Wood-fired Hydronic Appliances that Utilize Partial Thermal Storage with added requirement to include standby loss of both boiler and thermal storage tank plus same efficiency calculation procedures as for Annex A1**

**Annex A3 (Informative) includes optional calculation procedures for estimating annual efficiency and total annual fuel consumption for single boiler systems**

**Annex A4 (Informative) includes optional calculation procedures for estimating annual efficiency and total annual fuel consumption for multiple boiler systems**

# Testing of Boilers Without Thermal Storage

Same burn categories (15/25/50/100 percent) as ASTM E2618-13

Boiler may use on/off operation rather than continuous 15% or 25% burn rate.

Boiler jacket loss measurements in accordance with ASHRAE 155P for commercial, gas and oil-fired boilers at 180 deg F except for thermal post-purge (140 deg F) or condensing (120 deg F)

If boiler does not incorporate positive shutoff of combustion air during standby mode, then standby jacket plus draft loss test must be performed

Measurement of efficiency and emissions during firing mode when boiler is in standby (zero load) operating mode

Fuel input vs output graph in accordance with ASHRAE 155P over range of 0 to 100 percent of rated boiler capacity



# **Testing of Boilers With Thermal Storage**

**Use full or partial thermal storage procedure in ASTM E2618-13**

**Boiler operation not required at firing rates lower than manufacturer specifications.**

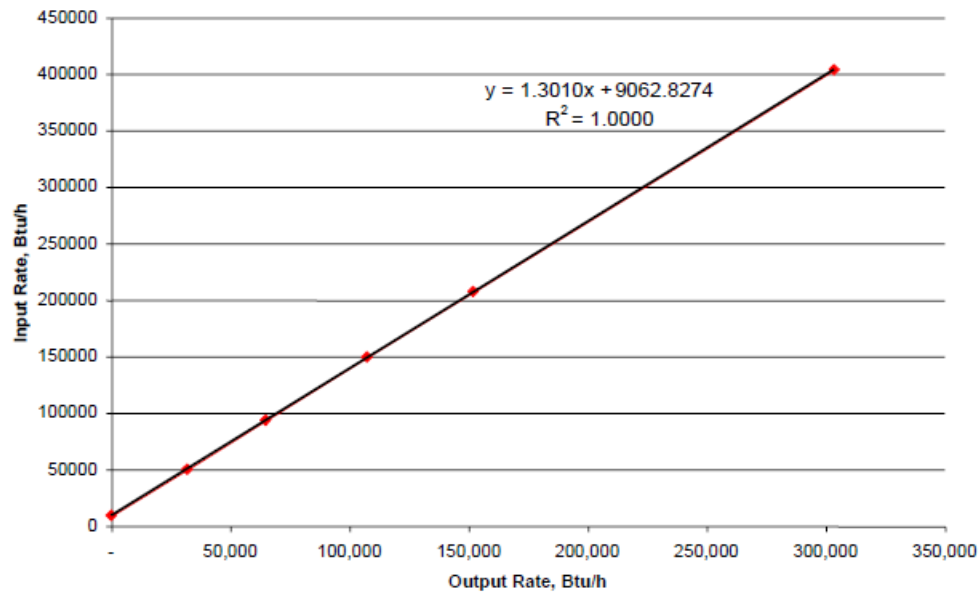
**Combined thermal storage plus boiler operation to meet part-load requirements in accordance with manufacturer specifications**

**Measure thermal storage heat content and jacket loss plus boiler standby loss to determine capacity and efficiency for 4 and 8 hour periods**

**If boiler does not incorporate positive shutoff of combustion air during standby mode, then standby jacket plus draft loss test must be performed**

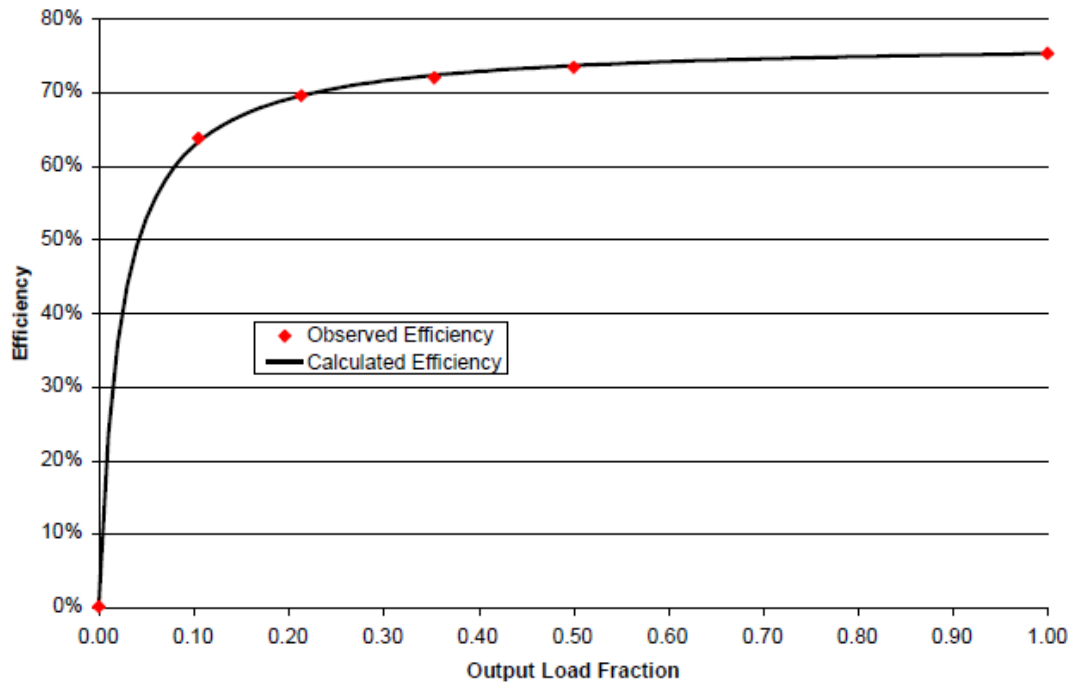
**Measure efficiency and emissions when boiler is firing to re-charge thermal storage tank then divide fuel consumption and emissions over length of time from start of firing cycle through end of “rest” cycle**

# Input vs Output Graph for Boiler



**Y-intercept represents fuel input for jacket loss and draft loss under zero load condition**

# Efficiency Curve for Boiler



Based on data from Input vs Output Graph

# Annex A3 Efficiency and Fuel Input Table Single Boiler System

**Boiler Capacity = Peak Load**

Boiler capacity Btu/hr	300000													
Boiler standby fuel input Btu/hr	9063													
Outdoor temperature deg F	-10	-5	0	5	10	15	20	25	30	35	40	45	50	55
Percent peak heating load	100	92.4	84.7	77	69.3	61.6	53.9	46.2	38.5	30.8	23.1	15.4	7.7	0
Heating output Btu/hr in temp bin	300000	277200	254100	231000	207900	184800	161700	138600	115500	92400	69300	46200	23100	0
Fuel input Btu/hr in temp bin	399363	369700.2	339647.1	309594	279540.9	249487.8	219434.7	189381.6	159328.5	129275.4	99222.3	69169.2	39116.1	9063
Number of hours in temperature bin	10	21	52	86	141	222	346	453	636	798	669	540	427	299
Annual output in temperature bin	3000000	5821200	13213200	19866000	29313900	41025600	55948200	62785800	73458000	73735200	46361700	24948000	9863700	0
Annual fuel input in temperature bin	3993630	7763704	17661649	26625084	39415267	55386292	75924406	85789865	101332926	103161769	66379719	37351368	16702575	2709837
Efficiency in temperature bin	0.751196	0.749797	0.748129	0.746138	0.743719	0.740718	0.736893	0.731856	0.72491739	0.7147532	0.698432	0.6679273	0.59055	0
Annual heating output Btu/yr	4.59E+08													
Annual fuel input Btu/yr	6.4E+08													
Annual efficiency %	71.74975													

**Table uses data from Input vs Output Graph plus heating load information and ASHRAE weather data**

**Combines individual fuel inputs and heating outputs to produce seasonal performance estimate**

# Annex A3 Efficiency and Fuel Input Table Single Boiler System

**Boiler Capacity = 200% of Peak Load**

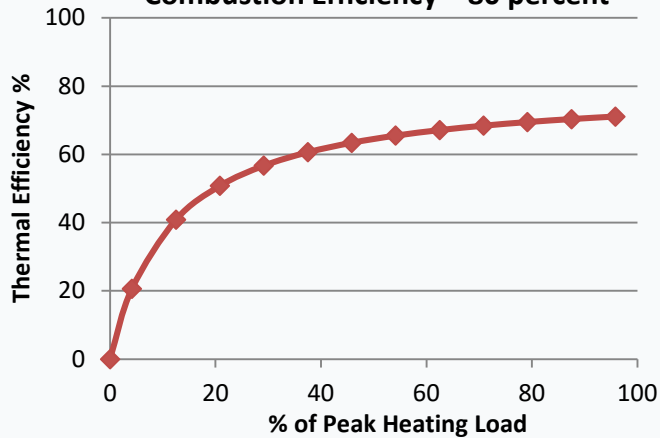
Boiler capacity Btu/hr	600000													
Peak heating load Btu/hr	300000													
Boiler standby fuel input Btu/hr	18000													
Outdoor temperature deg F	-10	-5	0	5	10	15	20	25	30	35	40	45	50	55
Percent peak heating load	100	92.4	84.7	77	69.3	61.6	53.9	46.2	38.5	30.8	23.1	15.4	7.7	0
Heating output Btu/hr in temp bin	300000	277200	254100	231000	207900	184800	161700	138600	115500	92400	69300	46200	23100	0
Fuel input Btu/hr in temp bin	408300	378637.2	348584.1	318531	288477.9	258424.8	228371.7	198318.6	168265.5	138212.4	108159.3	78106.2	48053.1	18000
Number of hours in temperature bin	10	21	52	86	141	222	346	453	636	798	669	540	427	299
Annual output in temperature bin	3000000	5821200	13213200	19866000	29313900	41025600	55948200	62785800	73458000	73735200	46361700	24948000	9863700	0
Annual fuel input in temperature bin	4083000	7951381	18126373	27393666	40675384	57370306	79016608	89838326	107016858	110293495	72358572	42177348	20518674	5382000
Efficiency in temperature bin	0.7347539	0.732099	0.728949	0.725204	0.720679	0.715102	0.708056	0.698875	0.68641522	0.66853625	0.6407216	0.5915023	0.4807182	0
Annual heating output Btu/yr	459340500													
Annual fuel input Btu/yr	682201991													
Annual efficiency %	67.332037													

**Annex A3 can also be used to estimate performance of oversized boilers**

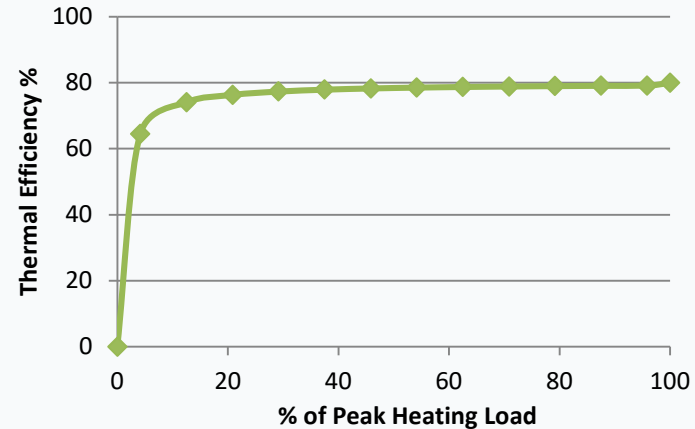
# Efficiency Curves

## Old Oil-fired Boiler vs New Pellet-fired Boiler

Thermal Efficiency vs Heating Load  
Oil-fired Boiler - 6 MMBTU/hr Capacity  
Peak Heating Load = 2 MMBTU/hr  
Jacket Loss = 4 percent  
Combustion Efficiency = 80 percent



Thermal Efficiency vs Heating Load  
Pellet-fired Boiler - 2 MMBTU/hr Capacity  
Peak Heating Load = 2 MMBTU/hr  
Jacket Loss = 1 percent  
Combustion Efficiency = 80 percent



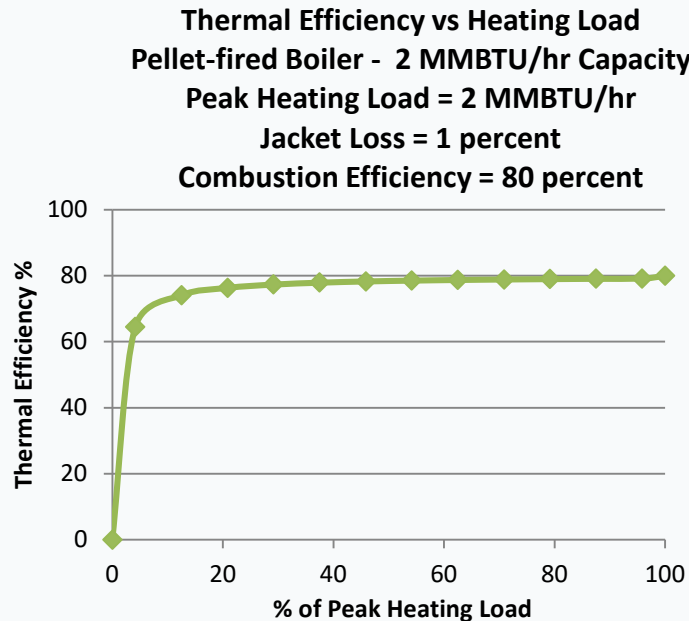
**Difference in efficiency curves represents potential energy savings**

**Two boilers each with 80% combustion efficiency can have 30% difference in annual fuel consumption**

**Key to success: Low jacket loss and standby draft loss**

# Annex A4 Efficiency and Fuel Input Table

## Multiple Boiler System



**Annex A4 under further development**

**Two or more boilers can be evaluated as a system using the same type of table in Annex A3**

**Inflection point on efficiency curve will get pushed up and to the left in a high-efficiency, multiple boiler system**

## **EN 303-5-based Alternate Testing Option**

**To be developed further**

**Input vs output graph to be based on efficiency testing at 30-50% load plus 100% load under EN 303-5**

**Jacket loss (Btu/hr) to be used with boiler/water mass to calculate frequency and duration of firing cycles during zero load conditions**

**Efficiency of firing cycle during zero load conditions to be extracted from performance data at beginning of two-hour test cycle**

**Emissions from firing cycle during zero load conditions to be determined using real-time PM 2.5 monitoring during start phase with duration of calculated firing cycle length compared to average two-hour steady state emissions rate**



# **BTEC Commercial Boiler Test Protocol**

## **Future activities:**

**Validation testing with small commercial size, pellet-fired boiler**

**Development of EN 303-5 alternate test option**

**Revisions and clarifications to text of BTEC standard**

**Publication as BTEC standard for interim use**

**Further development and promulgation by accredited standards organization**



**Thank You!**

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