INVITATION TO SUBMIT A RESEARCH PROPOSAL ON AN ASHRAE RESEARCH PROJECT

1910-TRP, Evaluation of Standard 103 Transient Components and Thermostat Cycle Times on the Resulting AFUE (re-bid)

Attached is a Request-for-Proposal (RFP) for a project dealing with a subject in which you, or your institution have expressed interest. Should you decide not to submit a proposal, please circulate it to any colleague who might have interest in this subject.

Sponsoring Committee: TC 6.03, Residential and Light Commercial Forced Air Heating and Cooling Systems

Budget Range: $235,000 may be more or less as determined by value of proposal and competing proposals.

Scheduled Project Start Date: **April 1, 2025** or later.

All proposals must be received at ASHRAE Headquarters by 8:00 AM, EST, December 16, 2024. NO EXCEPTIONS, NO EXTENSIONS. Electronic copies must be sent to rpbids@ashrae.org. Electronic signatures must be scanned and added to the file before submitting. The submission title line should read: 1910-TRP, Evaluation of Standard 103 Transient Components and Thermostat Cycle Times on the Resulting AFUE and *"Bidding Institutions Name"* (electronic pdf format, ASHRAE's server will accept up to 10MB)

If you have questions concerning the Project, we suggest you contact one of the individuals listed below:

For Technical Matters
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Contractors intending to submit a proposal should so notify, by mail or e-mail, the Manager of Research and Technical Services, (MORTS) by December 1, 2024 in order that any late or additional information on the RFP may be furnished to them prior to the bid due date.

All proposals must be submitted electronically. Electronic submissions require a PDF file containing the complete proposal preceded by signed copies of the two forms listed below in the order listed below. **ALL electronic proposals are to be sent to rpbids@ashrae.org.**

All other correspondence must be sent to ddaniel@ashrae.org and shammerling@ashrae.org. In all cases, the proposal must be submitted to ASHRAE by 8:00 AM, EST, December 16, 2024.
NO EXCEPTIONS, NO EXTENSIONS.

The following forms (Application for Grant of Funds and the Additional Information form have been combined) must accompany the proposal:

(1) ASHRAE Application for Grant of Funds (electronic signature required) and
(2) Additional Information for Contractors (electronic signature required) ASHRAE Application for Grant of Funds (signed) and

ASHRAE reserves the right to reject any or all bids.

State of the Art (Background)

The current ASHRAE 103 standard combines steady-state, heat-up, cool-down, condensate cycle, tracer gas, and jacket loss test procedures and employs a complicated calculation procedure to determine the final AFUE. The standard was developed in the 1970s at a time when state-of the art furnaces and boilers had steady-state efficiencies that were significantly higher than the cyclic efficiency. The standard was used by the Department of Energy to regulate and drive product minimum efficiency to higher levels for energy conservation (Kelly 1978). The result, after several decades, is that modern heating appliances now have cyclic efficiencies (AFUE) that are very close to the steady-state efficiency to the extent that the complexity of the test procedure may no longer be necessary.

The results of the literature review show that off-cycle losses are high where there is flow through the heat exchanger driven by buoyancy, frequent cycling occurs to keep heat exchangers warm, and jacket losses are high. Fan-assisted combustion systems have little buoyancy-driven heat loss due to the presence of the fan and the smaller passages in the heat exchanger, furnaces and boilers now have more jacket insulation, and other improvements have been made so the expected cycling losses are small.

The data showing the impact of the six parts of the test procedure on AFUE is not itemized with the reported appliance rating, so there is a gap in our knowledge of the impact of the parts of the test procedure.

Regarding thermostat influence, the AFUE energy descriptor for furnaces and boilers use thermostat cycle response assumptions for the cycle test component of the standard. The cycle times are based on a thermostat behavior with a 50% load response of 5-cycles per hour for furnaces and 2-cycles per hour for boilers. For the load condition selected by the standard, the cycle times for 1-stage furnaces is 3.87-min on, and 13.3-min off. A furnace that uses modulating controls (two-stage and step-modulating) is assigned 10-min on and 10-min off cycle in the standard which aligns with a 3-cycle per hour response at 50% load (Kelley 1978, Kweller 1982, also see References). This project will test those assumptions.

Justification and Value to ASHRAE

ASHRAE standards drive industry test practices and federal government labeling practices in this area. The project will bring together the best experts in the field in TC 6.03 and qualified researchers to reduce the complexity of the AFUE test procedure and to evaluate the interaction of the equipment in this study and new electronic thermostats. The standard will be improved with this new information and the research and manufacturing communities will have a peer-reviewed dataset for making decisions on design improvements and expected performance levels.

Objectives

The primary project objectives are:

(1) to determine if ASHRAE Standard 103 can be simplified by eliminating one or more of the six sub-tests without significant impact to the measured AFUE, and

(2) to determine if the AFUE calculation from the ASHRAE 103 standard still reflects equipment performance when used with cycling rates from newer electronic “smart” thermostats.

Secondary objectives are:

1. Determine the impact of each of the sub-tests on the calculated AFUE.
2. Identify how accurate each of the sub-tests are compared to the accuracy of the overall AFUE.
3. Obtain a clear objective recommendation on the future of the standard to either maintain the current complexity, or to reduce the complexity and by what amount.
4. Determine the operating behavior and cycle rates for current thermostats at different heating loads, with different equipment sizes.
5. Determine the customization and variations allowed by the consumer and identify the norm or mean for the population for the country(s).
6. Identify how sensitive the tested efficiency is for different thermostat types.

A longer-term objective outside of the scope of this Work Statement is to identify what national average or nominal cycling behavior should be used for the furnace standard so the standard is a better predictor of field performance. TC6.3 is the cognizant TC for ASHRAE 103 and will apply research results to the next update of the standard.

Scope:
Task A

1. Review the six parts of the AFUE standard to determine how the parts influence the measured AFUE
2. Identify major heat exchanger design differences for products on the market and evaluate against expected outcome from the six parts of the standard
3. For furnaces, select several designs for testing – single stage condensing and non-condensing, two-stage condensing and non-condensing, step-modulating condensing, and non-condensing. Two types of heat exchangers should be evaluated as well: clamshell and tubular. The table below is a proposed set of tests for furnaces and includes a potential list of manufacturers who produce those types of units. The bidder will verify the results and propose a test plan that will yield the desired results.
4. For boilers, select designs having both "high mass" (i.e. cast iron/fire tube) and "low mass" (i.e. water tube) heat exchangers as well as fan-assisted and atmospheric combustion systems. The table below is a proposed set of tests for boilers
5. Obtain samples of each furnace and boiler control type and design type; a minimum of 13 furnaces and 7 boilers should be tested. TC 6.3 will assist in getting equipment donated. The team believes some equipment will need to be purchased; estimated cost $6,000.
6. Measure the performance of each appliance by control type and design type. Quantify, and document the outcomes
7. Make comparative analyses
8. Summarize results and make recommendations to the committee to update ASHRAE 103.

Milestones –

1. Test plan developed – after task A4.
2. Spreadsheet calculator to perform the calculations developed or obtained – after task A5.
3. Furnaces tested and results calculated – after task A6.
4. Boilers tested and results calculated – after task A6.
5. Comparative analysis and recommendations to update ASHRAE 103 – after task A8.

Notes -

- Collect data from each of six parts of the standard for each unit and record. Determine the significance of each test point on the AFUE for the furnace/boiler
- Adjust burner input rate in accordance with the manufacturer's instructions
- Prime the trap for the condensing units
- For furnaces, adjust blower speed to test at the midpoint of the temperature rise range

See preliminary furnace and boiler test plan below. Only one unit is required per test, a list of manufacturers who make that type of unit is provided. Contractor shall confirm the test plan or propose an alternative.

Furnaces - non-condensing					
Heat Exchanger	Tubular	Clam Shell	Tubular	Clam Shell	Tubular
Burner	Single Stg	Single Stg	2-Stg	2-Stg	Mod
Steady State	1	1	2	2	2
Heat Up	1	1	2	2	1
Cool Down	1	1	2	2	1
Condensate Cycle					
Dp (Tracer Gas)	1	1	1	1	1
Jacket Loss	1	1	1	1	1
Suggested Manufacturers	Trane	Lennox	Trane	Lennox	Rheem
	Rheem	Carrier	Rheem	Carrier	
	York		York		
	Goodman		Goodman		

Furnaces - condensing								
Heat Exchanger	Tubular	Clam Shell	Tubular	Clam Shell	Tubular	Tubular	Clam Shell	Clam Shell
Burner	Single Stg	Single Stg	2-Stg	2-Stg	Mod	Mod	Mod	Mod (CT2)
Steady State	1	1	2	2	2	2	2	2
Heat Up	1	1	2	2	1	1	1	1
Cool Down	1	1	2	2	1	1	1	1
Condensate Cycle	1	1	1	1	1	1	1	1
Dp (Tracer Gas)	1	1	1	1	1	1	1	1
Jacket Loss	1	1	1	1	1	1	1	1
Suggested Manufacturers	Trane	Lennox	Trane	Lennox	Rheem	York	Lennox	Lennox
	Rheem	Carrier	Rheem	Carrier	Trane		Carrier	
	York		York		Goodman			
	Goodman		Goodman					
Preliminary # of furnaces	13							
Preliminary # of tests	90							

Boilers - non-condensing					
Heating Medium	Hot Water	Hot Water	Hot Water	Hot Water	Steam
Heat Exchanger	Cast Iron	Cast Iron	Copper Water Tube	Copper Water Tube	Cast Iron
Input Rate Control	Single Stg	Single Stg	Single Stg	Single Stg	Single Stg
Burner/draft type	Atmospheric	Fan Assisted	Atmospheric	Fan Assisted	Atmospheric
Steady State	1	1	1	1	1
Heat up	1	1	1	1	1
Cool Down	1	1	1	1	1
Condensate Cycle					
Dp (tracer gas)		1		1	
(no jacket loss)					
Suggested Manufacturers	Burnham Holdings	Burnham Holdings	Laars	Laars	Burnham Holdings
	Weil Mc-Lain	Weil Mc-Lain		Raypak	Weil Mc-Lain
	ECR Int'l	ECR Int'l			ECR Int'l
	PB Heat	PB Heat			PB Heat

Boilers - condensing		
Heating Medium	Hot Water	Hot Water
Heat Exchanger	Water Tube	Fire Tube
Input Rate Control	Modulating	Modulating
Burner/draft type	Pre-mix	Pre-mix
Steady State	2	2
Heat up	1	1
Cool Down	1	1
Condensate Cycle	1	1
Dp (tracer gas)	1	1
(no jacket loss)		
Suggested Manufacturers	Burnham Holdings	Burnham Holdings
	Weil Mc-Lain	Weil Mc-Lain
	ECR Int'l	Triangle Tube
	PB Heat	Heat Transfer Products
	Lochinvar	Lochinvar
	NTI	
	Navien	
	Heat Transfer Products	
Preliminary # of boilers	7	
Preliminary # of tests	29	

Task B

1. Survey the smart thermostat market and obtain data or samples for testing from the top 5 products by volume.
2. If manufacturers data is available, determine the cycle rate vs. load curve for single stage and two stage furnaces and boilers for each thermostat. Identify the cycling rate under several part load conditions (see notes) for step 4. Confirm using a proposed benchtop experiment.
3. If manufacturers data is not available, conduct a controlled experiment in a psychometric room or similar load-based test environment to obtain cycling rate vs. load curves. Provide details of the test procedure.
4. Using the ASHRAE 103 standard, calculate the efficiency with representative single stage and two stage condensing and non-condensing gas furnace and boilers using the part load cycling rates from step 2 or 3. Task A data will be needed for this step.
5. Propose representative cycle rate vs load curves for the following general cases and calculate the AFUE:
    a. Single stage furnace
    b. Single stage boiler
    c. Two stage furnace
    d. Two stage boiler
6. Propose a single load vs. cycling rate curve for furnaces and another one for boilers to be used for the AFUE test procedure. Perform a second set of AFUE calculations with the proposed curves. A total of 2 curves:
    a. Furnace
    b. Boiler

Summarize results and make recommendations to the committee to update ASHRAE 103.

Milestones –

1. Survey results and report - after task B1
2. Cycle rate and load curve for single and two-stage thermostats – after task B3
3. Confirmation with benchtop testing or psychometric room testing – after task B3

4. Calculated efficiency for two types of furnaces and boilers (total of 4) – after task B5
5. Calculated efficiency for furnaces and boilers (total of 2) – after task B6
6. Results and recommendations – after task B6

Notes -

- Part load conditions (percent of capacity)
    - For single stage furnaces and boilers and 2-stg at high fire - 20-25%, 50%, 70-80% of output capacity
    - For 2-stg at low fire, divide ranges above by the capacity fraction at low stage

No testing on modulating systems

Deliverables

Progress, Financial and Final Reports, Technical Paper(s), and Data shall constitute the deliverables ("Deliverables") under this Agreement and shall be provided as follows:

a. Progress and Financial Reports

Progress and Financial Reports, in a form approved by the Society, shall be made to the Society through its Manager of Research and Technical Services at quarterly intervals; specifically, on or before each January 1, April 1, June 10, and October 1 of the contract period.

The deliverables shall be provided to the Project Monitoring Subcommittee (PMS) as described in the Scope/Technical Approach section above, as they are available.

Furthermore, the Institution's Principal Investigator, subject to the Society's approval, shall, during the period of performance and after the Final Report has been submitted, report in person to the sponsoring Technical Committee/Task Group (TC/TG) at the annual and winter meetings, and be available to answer such questions regarding the research as may arise.

b. Final Report

A written report, design guide, or manual, (collectively, "Final Report"), in a form approved by the Society, shall be prepared by the Institution and submitted to the Society's Manager of Research and Technical Services by the end of the Agreement term, containing complete details of all research carried out under this Agreement, including a summary of the control strategy and savings guidelines. Unless otherwise specified, the final draft report shall be furnished, electronically for review by the Society's Project Monitoring Subcommittee (PMS).

Tabulated values for all measurements shall be provided as an appendix to the final report (for measurements which are adjusted by correction factors, also tabulate the corrected results and clearly show the method used for correction).

The final report shall contain:

1. Findings related to the impact of thermostat cycling on efficiency.
2. Recommended changes in language that can be inserted into the standard re: thermostat cycling changes
3. Findings related to the impact of eliminating parts of the test on the accuracy of the measured efficiency.
4. Recommendations on which sections of the standard can be removed to reduce complexity.

Following approval by the PMS and the TC/TG, in their sole discretion, final copies of the Final Report will be furnished by the Institution as follows:

-An executive summary in a form suitable for wide distribution to the industry and to the public.
-Two copies; one in PDF format and one in Microsoft Word.

c. *Science & Technology for the Built Environment* or ASHRAE Transactions Technical Papers

One or more papers shall be submitted first to the ASHRAE Manager of Research and Technical Services (MORTS) and then to the "ASHRAE Manuscript Central" website-based manuscript review system in a form and containing such information as designated by the Society suitable for publication. Papers specified as deliverables should be submitted as either Research Papers for HVAC&R Research or Technical Paper(s) for ASHRAE Transactions. Research papers contain generalized results of long-term archival value, whereas technical papers are appropriate for applied research of shorter-term value, ASHRAE Conference papers are not acceptable as deliverables from ASHRAE research projects. The paper(s) shall conform to the instructions posted in "Manuscript Central" for an ASHRAE Transactions Technical or HVAC&R Research papers. The paper title shall contain the research project number (1910-RP) at the end of the title in parentheses, e.g., (1910-RP).

All papers or articles prepared in connection with an ASHRAE research project, which are being submitted for inclusion in any ASHRAE publication, shall be submitted through the Manager of Research and Technical Services first and not to the publication's editor or Program Committee.

d. Presentations

TC 6.3 will propose a seminar or conference paper session for a future ASHRAE technical program to present results and field questions and answers from the community. The contractor will prepare 2 presentations for the program.

e. Data

Data is defined in General Condition VI, "DATA"

f. Project Synopsis

A written synopsis totaling approximately 100 words in length and written for a broad technical audience, which documents 1. Main findings of research project, 2. Why findings are significant, and 3. How the findings benefit ASHRAE membership and/or society in general shall be submitted to the Manager of Research and Technical Services by the end of the Agreement term for publication in ASHRAE Insights

The Society may request the Institution submit a technical article suitable for publication in the Society's ASHRAE JOURNAL. This is considered a voluntary submission and not a Deliverable. Technical articles shall be prepared using dual units; e.g., rational inch-pound with equivalent SI units shown parenthetically. SI usage shall be in accordance with IEEE/ASTM Standard SI-10.

Level of Effort
Project Duration in Months: 36
Professional-Months: Principal Investigator: 24
Professional-Months: Total 30

Estimated Dollar Value
Total cost for the project: $325,000
Cost share: ($90,000)
DOE cost share anticipated: $50,000
AHRI cost share anticipated: $25,000
In-kind cost share for 15 donated furnaces and boilers: $15,000 with shipping
Net ASHRAE Cost: $235,000

It is expected that furnaces and boilers for testing will be provided by donations from the manufacturers and can be excluded from the cost proposal. Parts I and II may be funded sequentially by ASHRAE.

Other Information for Bidders

Bidders with unique knowledge or facilities preferred. Teaming between an accredited lab and a research team is encouraged.
Task A data is needed for Task B.
AHRI and DOE cost share may require additional contracting, program management, and reporting for AHRI and DOE.

Proposal Evaluation Criteria:

No.	Proposal Review Criterion	Weighting Factor
1	Furnace and boiler testing lab is accredited (Task A)	10
2	Principals have experience with the ASHRAE 103 or DOE AFUE standard	30%
3	Principals have experience with the design of the equipment being evaluated	15%
4	Principals are familiar with load testing and have a psychometric room or equivalent as needed (Task B)	15%
5	Principals have strong analytical capabilities	20%
6	Proposed cost (below budget)	10%

Milestones

Project Milestones:

No.	Major Project Completion Milestone	Deadline Month
A1	Test plan developed	Month 2
A2	Spreadsheet calculator to perform the calculations developed or obtained	Month 4
A3	Furnaces tested and results calculated	Month 10
A4	Boilers tested and results calculated	Month 16
A5	Comparative analysis and recommendations to update ASHRAE 103	Month 18
B1	Survey results and report	Month 20
B2	Cycle rate and load curve for single and two-stage thermostats	Month 22
B3	Confirmation with bench top testing or psychrometric room testing	Month 30
B4	Calculated efficiency for two types of furnaces and boilers with	Month 32
B5	Calculated efficiency for furnaces and boilers with proposed cycle rate	Month 34
B6	Results and recommendations	Month 36

References

1. ASHRAE 103-1988
2. ASHRAE 103-1993
3. ASHRAE 103-2007
4. ASHRAE 103-2017
5. Chi, J., G.E. Kelly. 1978. A Method for estimating the seasonal performance of residential gas and oil-fired heating systems. ASHRAE Transactions 84(1)
6. Kelly, G.E, J. Chi, and M.E. Kuklewicz. 1978. Recommended Testing and Calculation Procedures for Determining the Seasonal Performance of Residential Central Furnaces and Boilers. Report No. NBSIR 78-1543, National Bureau of Standards, Gaithersburg, MD.
7. Kweller, E. 1983. An Analysis of Burner On and Off Periods and Their Effect on Part-Load Efficiency for Furnaces and Boilers Equipped with Modulating Controls. National Bureau of Standards, Gaithersburg, MD.
8. Liu, S.T. 2002. Proposed Revisions of Part of the Test Procedures for Furnaces and boilers in ASHRAE Standard 103-1993. Report No. NISTIR 6913, National Institute of Standard and Technology, Gaithersburg, MD.
9. Wise, R.A. and E.R. Kweller. 1986. Part-load seasonal efficiency test procedures evaluation of furnace cycle controllers. ASHRAE Transactions 92(2).
10. Kweller, E. 1987. A Study of Three Measures for Energy Efficiency of Fossil Fueled Furnaces and Boilers. Report No. NBSIR 87-3645, National Bureau of Standards, Gaithersburg, MD.
11. Kweller, E., and R.L. Palla. 1982. A Test Method and Calculation Procedure for Determining Annual Efficiency for Vented Household Heaters and Furnaces Equipped with Modulating-Type Controls. Report No. NBSIR 82-2497, National Bureau of Standards, Gaithersburg, MD.
12. Park, C. and G.E. Kelly. 1989. A Study on the Performance of Residential Boilers for Space and Domestic Hot Water Heating. Report No. NIST IT894104, National Institute of Standards and Technology, Gaithersburg, MD.