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Project Summary

Woodstove Durability Testing Protocol

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Woodstove field studies during seven heating seasons have shown that new technology woodstoves designed to have low particulate emissions have frequently shown rapid degradation in emission control. This degradation has been documented both by measurement of particulate emission factors with an in-home automated emission sampler (AES) and by observable physical damage to the woodstove components. Most of the damage appears to occur when the woodstove is allowed to operate at exceptionally high temperatures. A method to test the long-term durability of woodstove models in the laboratory in a 1- to 2-week time frame has been developed and has come to be referred to as a stress test.

Two avenues of research have been taken in developing the stress test protocol. First, the performance of woodstoves while in actual in-home use has been observed during two heating seasons in three communities: Medford and Klamath Falls, OR, and Glens Falls, NY. Eight models of stoves in 13 homes were studied. The field studies permitted records of woodstove operating temperatures, particulate emission levels, and (in some cases) physical degradation to be followed in a real world setting. The second line of research was the laboratory "stressing" of various woodstove models under high temperature operation. This laboratory research has been conducted on six stoves (five models) and, as with the in-home research, changes in particulate emission rates were measured and physical degradation documented. Both catalytic and noncatalytic stove models, including EPA Phase 2 certified stoves, were represented in the tests.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Recently, there has been much concern by regulatory agencies and stove manufacturers about long-term physical degradation of woodstoves and elevated air pollutant emissions due to this degradation. In the past, such degradation could be observed only in the field after one or more heating seasons of use**,** after a particular model had been widely introduced to the market. Consequently, improvement in the manufacturing and design of woodstoves in response to degradation has been slow.

The development of an accelerated test to simulate in-home woodstove aging and degradation over a short period of time in the laboratory is reported here. Because stoves are aged under extreme conditions, the process is termed a "stress test." The goal of the project was to develop a protocol by which a woodstove could be operated in the laboratory for a short period of time (about 1 week) to simulate one heating season in the field. The short turnaround time has been deemed necessary

to evaluate a stove's long-term performance and durability so that stove design and manufacturing can be modified while the stove model is being developed.

Development of a Stress Test

Stress testing was done to subject target stoves to a cyclic pattern of high temperature exposures. To maintain consistency, a protocol was developed to specify all parameters of woodstove burning, including fuel type, moisture, size, and configuration; loading density; woodstove air settings; startup method; length of time doors and bypasses are open; stack height; and criteria for refueling.

Throughout the development of a stress testing protocol, many of the above parameters were held constant, while others were varied to determine the combination of factors that would lead to the most extreme burning condition. The parameters held constant were the following:

Fuel Type
Split lodgepole pine, as free of knots as possible.

Fuel Moisture
10 to 20% (dry basis).

Fuel Length
Five-sixths of the longest firebox dimension.

Fuel Configuration
Fuel in center of firebox, packed tightly with smaller fuel on bottom.

Air Settings
Stove settings set to maximize burn rate and firebox temperatures.

Kindling Load
Maximum of 15 minutes in duration.

Length of Bypass Opening
For catalytic stoves only, bypass open for additional 7 minutes after stove door is closed.

Stack Draft
Minimum of 17.4 Pa (0.07 in. H_2O) for 90% of the burn cycle.

Refueling
A temperature threshold was empirically determined for each stove model by putting fuel wood loads into operating stoves. The temperature that corresponded to the conditions when there was first enough space (from the burndown of the previous load) to put the full wood load into the stove was later used as a reloading prompt for each stove model.

Four parameters were varied throughout protocol development, and the effects on temperature were analyzed:

Fuel Size
Two different fuel sizing regions were used: (1) 70% "large," 30% "small," and (2) 100% "small." Wood was considered large if it fit through a 20-cm (8-in.) diameter hole but not through a 13-cm (5-in.) diameter hole. Wood was considered small if it fit through a 13-cm (5-in.) diameter hole but not through an 8-cm (3-in.) diameter hole.

Loading Density
Loading densities used were 48, 112, and 160 kg/m^3 (3, 7, and 10 lb/ft^3) of firebox volume.

Length of Door Openings
Stove door was left open between 3 and 45 minutes after fuel was loaded.

Stack Height
Two stack heights were used: (1) 6.1 m (20 ft) and (2) 8.2 m (27 ft).

Results

Five stoves were stress-tested using protocol 6. Data for one stove used in the development of the final stress test protocol (Blaze King Royal Heir #1) are presented in the report and represent the effect of protocols 2 through 5. Each stove was emissions-tested prior to stressing and once again afterwards. Some stoves underwent extended stress testing. The physical degradation is summarized in Table 1. Particulate emissions and a more detailed description of physical degradation (in both homes and the laboratory) are provided in the report by stove model.

Conclusions

Considerable variation in woodstove degradation has been observed in home usage. For some, degradation was observed to be more severe than that produced by the in-laboratory stress test protocol. For others, little in-home degradation was observed even after two heating seasons. Such variability is not surprising in light of the differences in installation, use habits, and fuel types seen with woodstoves. The research presented here shows that deterioration similar to that caused by 10 days (240 hours) of stressing a stove following protocol 6 is a reasonable predictor of the deterioration that may be seen under the more extreme in-home usage conditions after one heating season. Each of the protocol variables has been quantified so that the protocol can be standardized and used in a reproducible manner. This protocol can be used as a tool to estimate particulate emissions of a population of aging stoves. It can also be used by stove manufacturers during the design stage to ensure that a durable stove with low emissions over a long period of use is produced.

Table 1. *Observations of Physical Damage Due to Stressing*

Duration of Stressing (days)	Blaze King Royal Heir #1[1]	Blaze King Royal Heir #2	Country Flame BBF-6	Regency R3/R9	Quadrafire 3100	Earth Stove 1003C
4	Some oxidation and warpage					
7	Continued oxidation and warpage Catalyst tested; still fully active		None			
10		Bypass gap of 0.64 cm		Baffle plate oxidized and moderately warped (matches Y20, Y24)	Minor warping and oxidation of baffle and secondary air tubes	Some warping and oxidation of catalyst holder
14	Bypass gap of 0.64 cm	Test complete	Catalyst holder oxidized and slightly warped (similar toY14)			
20 [2]	Test complete			Extensive baffle warpage	Major warping and oxidation of baffle and secondary air tubes	Failure of bypass mechanism (stuck open) Severe oxidation and warping of catalyst holder Warped door frame (not airtight)
25			Catalyst holder oxidized and warped (identical to Y14 after two seasons)	Test complete	Test complete	Test complete
35			Still no bypass gap			

[1] *Protocols 2 through 5 were used with the Blaze King Royal Heir #1; all others used protocol 6.*
[2] *Observation after 18 days of stressing for the Regency R3/R9 stove.*

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The complete report, entitled "Woodstove Durability Testing Protocol," (Order No. PB95-136164; Cost: $19.50, subject to change) will be available only from
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