



## Project Summary

# Field Performance of Woodburning Stoves in Colorado During the 1995-96 Heating Season

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During the winter of 1995-96, the field performance of 13 EPA-certified woodburning stoves in Crested Butte and Curecanti National Park, CO, was evaluated. Measurements included particulate matter (PM), carbon monoxide (CO), and weekly average burn rates. Six non-catalytic Phase II stoves, six catalytic Phase II stoves, and one catalytic Phase I stove were monitored. The study adds to the existing database on the field emissions of newer and older certified stoves. Average non-catalytic stove PM and CO emission factors of the study were 9.8 and 93 g/kg, respectively. For the catalytic stoves the factors were 22.8 and 112 g/kg, respectively. The report compares these values with results from previous studies and suggests reasons that field performance is poor relative to what might be expected from certification test results.

*This Project Summary was developed by the National Risk Management Research Laboratory's Air Pollution Prevention Control Division, 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).*

### Objective

The purpose of this project was to quantify the field performance of EPA-certified woodstoves, both when stoves are relatively new and after stoves have been in service for an appreciable time. One-week averages of PM and CO emissions were measured for a variety of stoves, including both catalytic and non-catalytic EPA-certified models. The Virginia Polytechnic

Institute and State University (VPI) sampler was used for all measurements, and both PM and CO emissions are reported as measured by the sampler.

The report summarizes the measurement methods and the measured emission factors. The emission factors of the current study are compared with earlier data for PM and CO emissions of certified and uncertified (conventional) stoves.

### Introduction

Personnel from VPI measured woodstove emissions in Crested Butte, CO, during the winters of 1988-89, 1989-90, and 1991-92. The 1988-89 and 1989-90 measurements were intended to determine the effect of a town-wide changeover from conventional to EPA-certified (mostly Phase I) woodstoves. The 1991-92 study was intended to focus exclusively on Phase II stoves, but a limited number of Phase II stoves in Crested Butte and reluctance of owners to permit monitoring limited the Phase II data obtained. Both PM and CO emissions were measured during these studies. A fourth study, in the winter of 1992-93, involved only CO and carbon dioxide (CO<sub>2</sub>) measurements of catalytic stoves.

The 1995-96 study obtained additional data on the performance of Phase II stoves in Crested Butte and in Curecanti National Park, located outside of Gunnison, CO. The intention was to monitor each stove for four weeks to average the effects of weekly weather changes and other uncontrolled variables, but for some stoves fewer than four 1-week averages were obtained. Sampling in Crested Butte occurred from February 5 to March 4, 1996. Sampling in Curecanti National Park occurred from March 8 to April 13, 1996,

when warm weather ended the heating season.

Thirteen stoves were monitored: seven catalytic and six non-catalytic. Household profiles describing each site are in the full report. One of the catalytic stoves was Phase I certified and all other stoves were Phase II certified. The full report also contains a spreadsheet showing all measured values and calculated emissions data.

The previous studies created a large database of emissions from conventional and Phase I stoves, giving baseline data for comparison to Phase II models. Only one of the 1995-96 stoves was monitored in a previous study and can be directly compared with previous data. However, over the years, three Crested Butte stoves have been monitored for PM and CO during more than one season, and their data can be examined for long term performance changes. The 1988-1996 Colorado work also includes several catalytic stoves which were monitored for PM and CO (using the VPI sampler) during one season and also had short-term (approximately an hour) monitoring for flue gas temperature and CO and CO<sub>2</sub> concentrations under technician-controlled conditions during the winter of 1992-93. The 1992-93 CO, CO<sub>2</sub>, and temperature data can give a rough estimate of the PM and CO data that would have been obtained with the VPI sampler.

## Measurement Procedures

The hardware used for the measurements is known as the "VPI sampler." It

has been compared to the EPA reference method for woodstove PM and to the dilution tunnel method for CO measurement and has been found to be accurate. The methods for sampler preparation and workup are documented in earlier reports and are not repeated here.

Participants used their normal wood supply. Field personnel weighed a large part of the participant's woodpile at sampler deployment, marked the weighed part by replacing the wood on top of a bright red ribbon, and weighed any unused wood from the pre-weighed supply at sampler retrieval. Fuel moisture was measured gravimetrically, using chips generated by low speed drilling of representative logs.

## Results

Forty-seven deployments resulted in useful data on stove emissions. Eight blanks were also run and were used to correct the measured results and give an idea of the uncertainties of this season's measurements. Blanks were split equally between Crested Butte and the Curecanti National Recreation Area.

Table 1 compares the PM and CO factors for the current study with those of previous studies. The listed values represent the average factors for all datapoints for each type of stove in each study. The average PM catch of the study was 30.5 mg, and the highest level of uncertainty was 1.6 mg; thus, the average gravimetric uncertainty is 1.6/30.5, or 5%. As in previous studies the uncertainty in CO emis-

sions is estimated to be +/- 10% of reported value.

The average PM emission factor for the Phase II catalytic stoves in the 1995-96 study was 22.8 g/kg, approximately equivalent to that of conventional stoves and 133% greater than the average PM factor of Phase II non-catalytic stoves. The CO emission factors for catalytic stoves were 20% greater than for the non-catalytic stoves and effectively the same as for conventional stoves. The average PM emission factors for catalytic stoves increased by 30% from the 1991-92 study. The corresponding CO factors gained 45%.

The non-catalytic stoves, on average, show no definitive evidence of performance degradation over the course of the study. A strong dependence of emission factors on burn rate has been noted for non-catalytic stoves, and this dependence probably is the cause of the observed year-to-year fluctuations in average performance of these stoves.

Significant physical degradation has been noted in catalytic stove models over the course of this study. In some cases the cause of poor catalytic stove performance has been identified as mechanical failures. In other cases one can only assume that factors such as operator behavior or fuel variability are involved. In non-catalytic models, the operation, fueling and design of the stoves (as opposed to mechanical degradation) appear to be the most likely determiners of emission performance.

**Table 1.** Conventional and EPA Certified Woodstove Results

Year of Study	PM Factors, g/kg			CO Factors, g/kg			Avg. Burn Rate, kg/hr			#Stoves /# datapoints		
	Conv	CAT	NCAT	Conv	CAT	NCAT	Conv	CAT	NCAT	Conv	CAT <sup>a</sup>	NCAT <sup>b</sup>
1988-89	22.1	5.5	—	115	40	—	1.35	0.86	—	11/37	2/9	—
1989-90	22.2	11.1	9.9	111	52	76	1.64	0.93	1.10	7/27	12/72	5/29
1991-92	—	17.6	14.9	—	77	107	—	0.85	0.82	—	9/31	2/7
1995-96	—	22.8	9.8	—	112	93	—	0.77	0.98	—	7/27	6/20

Notes: \* 1988-1990 catalytic models were all Phase I certified.

1991-92 included 7 Phase I and 2 Phase II catalytics.

1995-96 included 1 Phase I and 6 Phase II catalytics.

\*\* All non-catalytic models tested were Phase II Certified.

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*The complete report, entitled "Field Performance of Woodburning Stoves in Colorado During the 1995-96 Heating Season," (Order No. PB98-106487; Cost: \$21.50, subject to change) will be available only from:*

*National Technical Information Service*

*5285 Port Royal Road*

*Springfield, VA 22161*

*Telephone: 703-487-4650*

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