A Review of Field Testing

Tom Butcher

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@BrookhavenLab

Introduction

Scope

- Only residential-sized equipment
- Wood stoves, wood hydronic heaters, wood warm air furnaces
- Systems typical of equipment in North America, Europe
- Not including cooking but some systems are hybrid

Goals of Field Testing

- Obtain information on extent of wood use, types of appliances.
- Obtain information on operating practices;
- Obtain information on types of wood used, moisture, size, source;
- Compare efficiency and emission factors to those developed in certification testing;
- Improve emission factors for inventory purposes;
- Develop improvements to test methods to improve real world relevance;
- Evaluate impact of change-outs or retrofit devices;
- “Beta-test” new products and concepts;
- Compare technologies;
- Detailed emissions characterization under real-world conditions;

Surveys

Relatively low cost way to get broad range of data

Example – U.S. Census, Residential Energy Consumption Survey (RECS/ U.S. DOE) distribution of wood use for heating but no details on equipment or performance;

Example – CEC Residential Wood Use Survey 2019 [1]. Some good detail on appliance types and use in the U.S. but limited response rate.

Example – On-line, detailed questions about how wood heating appliances are used. 1,980 responses from 16 European countries [2].

Field Studies with Basic Measurements

Example – Logging stack temperature data to get data on operating frequency, cold starts. Four Outdoor Hydronic Heaters and 20 wood stoves [3].

Example – Australia, 2011 – wood stoves -impact of education and/or an in-chamber catalyst device. 224 households with different combinations of measures. Performance based on visual assessment of smoke by carefully trained observers [4].

Example – Australia, 2016 – wood stoves, impact of an in-chamber catalyst device. Application to 80% of stoves in a defined region (283 homes). Impact of this intervention on ambient PM2.5 was studied using a regional monitoring network [5].

U.S. Field Testing 1980-early 2000's

A large amount of work was done during this time period both on field test measurement development and field testing in Klamath Falls, Oregon; Portland Oregon; Whitehorse Yukon; Glens Fall, New York; and Crested Butte, Colorado and other locations. [6,7,8,9]

Example – Automated Wood Stove Emission Sampler (AWES): Heated filter followed by an XAD-2 trap. Calibrated orifice for constant sampling rate. Integrated sampler in the home.

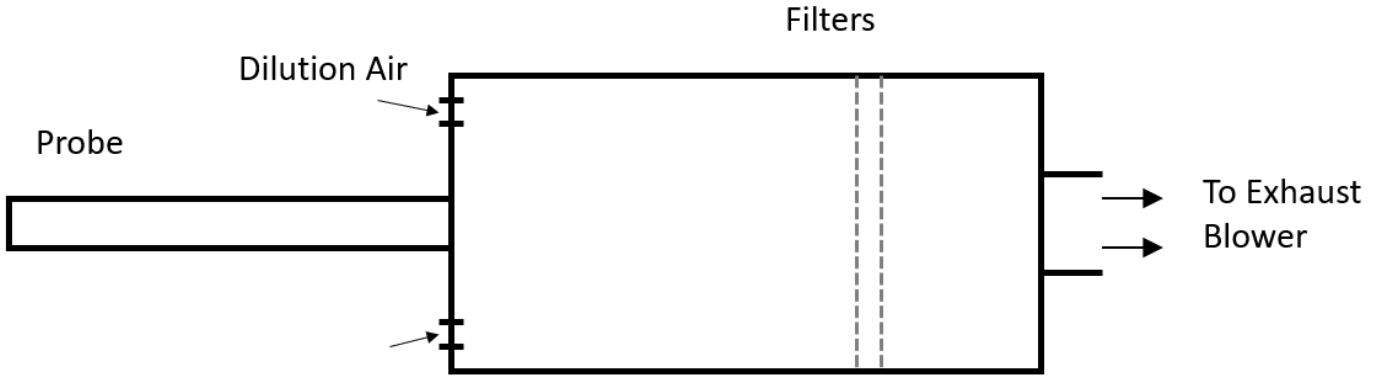
Example – Virginia Polytechnic Institute (VPI) sampler. Glass trap followed by two filters. Pre-evacuated tank to draw sample. Automatic control of system on/off. Integrated sampler in the home.

Condar Sampler

Sampler combining a large, fixed ratio diluter and filter. A blower provides needed suction. Simple tunnel diluter. No filtering, temperature control or humidity control of dilution air.

Developed since late 70's. OMNI Lab., Condar Company, Paul Tiegs, S.G Barnett among others. Adopted by Oregon as a measurement standard.

Example: A field study in New Zealand used the Condar sampler and demonstrated good agreement with standard certification test methods [10]



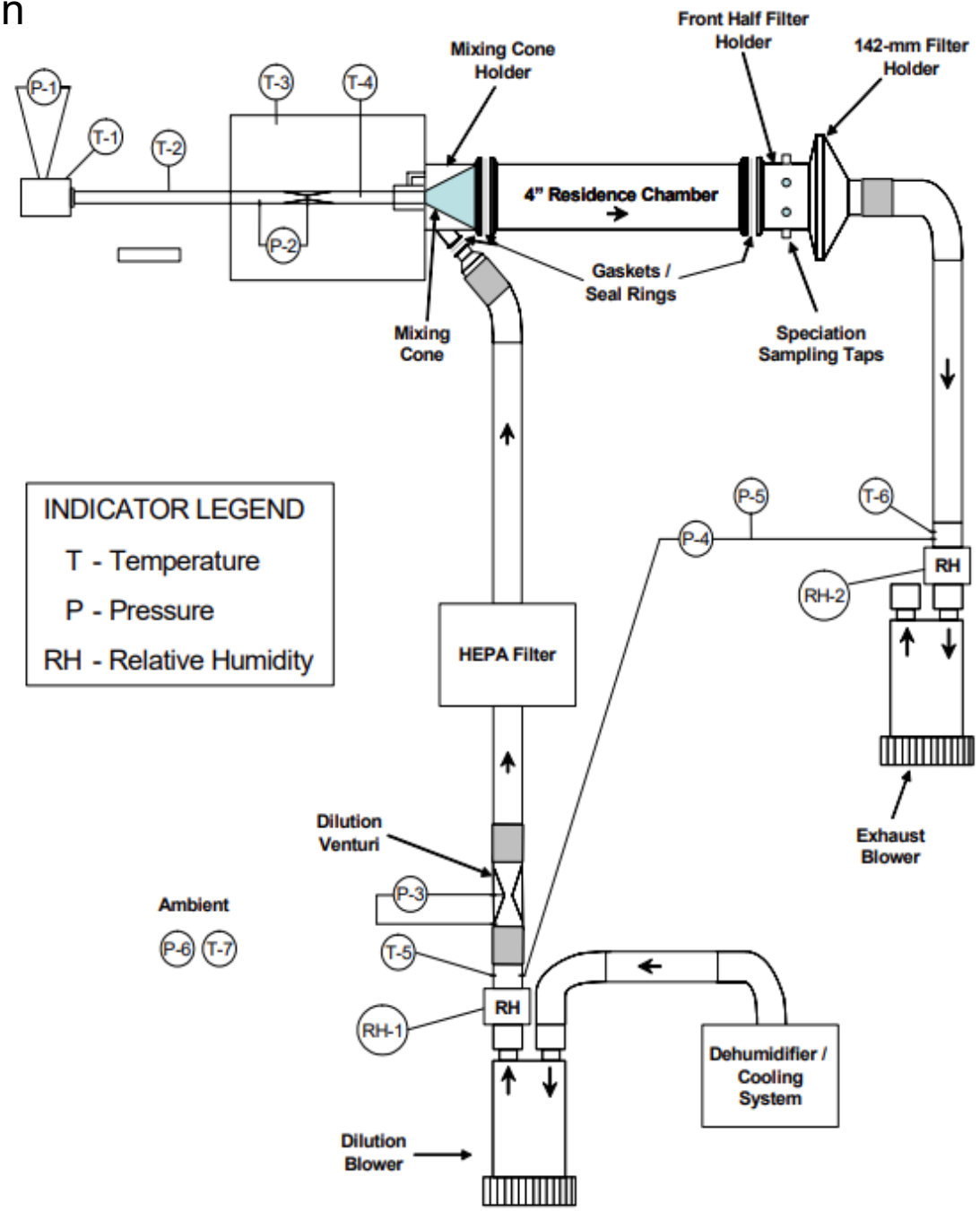
EPA CTM-039 – Dilution Sampling

A dilution sampling method defined by the U.S. EPA [11] as a conditional test method. Large equipment set suitable for industrial sources. Uses a mixing cone and residence chamber. Filtered dilution air with temperature and humidity control. Final measure is a filter – providing an integrated PM value.

Example – Wang et al [12] used this method on a residential wood pellet boiler (in-field).

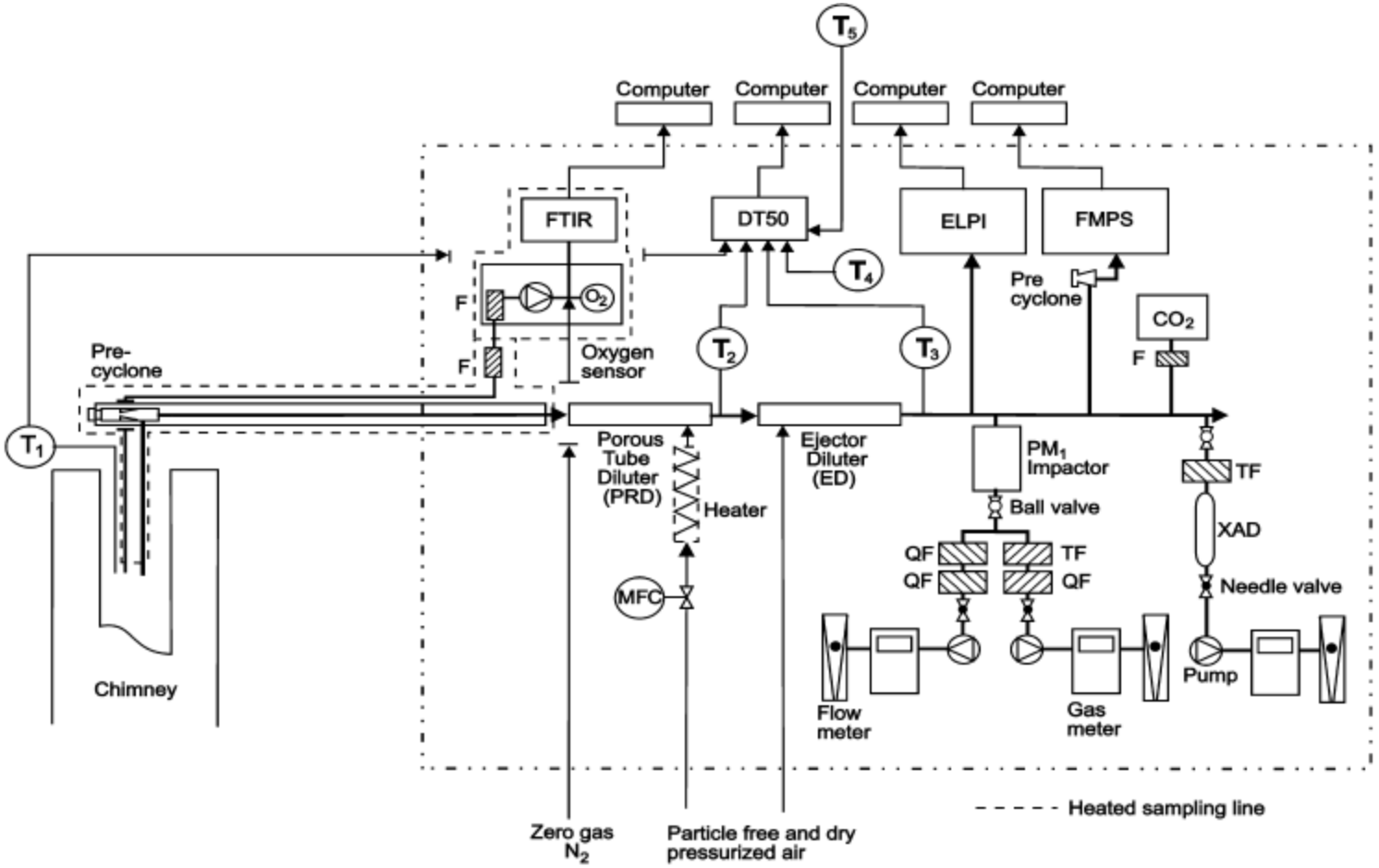
Example – McDonald et al. [13] used this method on a residential wood pellet stove (in-lab).

CTM 039 Dilution Sampler



Finland Study – 2007 [14]

Seven appliances in the field.
Dilution sampling system including a hot pre-cyclone, porous tube diluter, and ejector diluter.
Instrumentation and control in a mobile lab;
Sampling head raised to the chimney top and lowered in (avoids challenging issue of sampling equipment in the home).
Total integrated PM filter plus real-time size distributions (ELPI, FMPS);
CO_2 before and after dilution used to determine dilution ratio.



Source: Tissari et al. Ref. 14

Austria “Clean-Air by biomass” -2019 [15]

15 appliances tested in the field;
6 stoves, 6 hydronic heaters, 3 tile stoves;
“hot filter”, porous tube diluter, “condensables” filter;
Integrated cycle measurements
Analysis of BaP

Swiss field study, 2001 [16]

14 appliances tested in the field;
Stoves, cordwood hydronic heaters, pellet heaters;
Integrated filter for total PM;
SMPS for real-time size distribution;
Rotating disk diluter.

TEOM – Type Instruments

TEOM – Tapered Element Microbalance – uses changes in inertial forces to determine real-time PM emissions;
In Europe – two instruments of this type have been developed as portable devices for field checking of home appliances. These determine that the system meets the requirement in a short, steady state test, but has limited applicability as an accurate instrument under transient and very clean operation;
Lab-type TEOM instruments are currently of great interest for real time measurements;
In prior Wood Stove Design Challenges BNL and NESCAUM have used these types of instruments as part of the measurement efforts.

Source: testo.com/en-US/testo-380/p/0632-3801

Summary of Points

- There is a lot of interest, a lot of history, and a lot of options in field testing;
- The approach, of course, links directly to the goals;
- Technical approaches are trending toward small dilution samplers feeding multiple instruments, real time PM measurements (mass-based with other supplemental) and adding more detailed characterization of pollutants.

Citations

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