# Combustion Safety Simplified Test Procedure

2016 Building Technologies Office Peer Review

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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# Project Summary

**Timeline**:

Start date: 6/15/2013

Planned end date: Completed 9/30/2015

Key Milestones

1. Test Plan; 11/1/2013
2. Field Data Collection Complete; 9/1/2015

## Budget:

**Total Project $ to Date**:

- DOE: $375,775
- Cost Share: $94,000

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**Key Partners**:

| | |
|---|---|
| University of Illinois | Midwest Energy Efficiency Alliance |
| Center for Energy and the Environment | Utilization Technology Development |
| Seventhwave | National Associations of State Community Service Providers |
| NorthernSTAR | |

**Project Outcome**:

Develop a simplified combustion safety test procedure that results in fewer false positives in order to increase the number of home energy upgrades.

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# Purpose and Objectives

**Problem Statement**: (MYPP: Residential Buildings Integration, Strategy 1, Building America, Combustion Appliance Zone Test.) This project addresses the challenge of upgrading existing homes where a "worst-case" depressurization test will cause a combustion safety failure in approximately 10% of the homes. Data suggests that failures under standard operating conditions are far fewer. Failure of the test may require costly remediation.

**Target Market and Audience**: Target market is 80 million existing single family homes. Target audience is home inspectors, state weatherization agencies, and the home improvement industry that need better tools and methods.

**Impact of Project**: A significant reduction in combustion safety false positives that stop home energy upgrades from proceeding.
Final products: the simplified test method transferred to the Building Performance Institute's ANSI/BPI-1200-S-2015 Standard Practice for Basic Analysis of Buildings.
In the near, mid, and long-term the project contributes to the goal to reduce energy consumption in existing homes by 40% relative to the 2010 baseline by permitting more homes to be upgraded.

# Approach

**Approach**: The approach to the project is to develop a simplified test procedure starting with the Building Performance Institute current practice and modifying the worst case conditions to those that are more predictive of persistent failure. The approach includes:

- Survey state weatherization teams to collect data on the actual frequency of field failures and the approach taken when a failure occurs.
- Perform a pilot study of the procedure in existing homes and collect longer-term data to determine if the procedure accurately predicts failure (frequent excessive spillage events).

**Key Issues**: Availability of homes that fail the test; difficult to find without testing many homes.

**Distinctive Characteristics**: First extensive field data collection project of its kind attempting to correlate a test failure with field data over time. First survey of state weatherization agencies attempting to quantify false positives.



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# Simplified Test Procedure

| | Test Procedure | | |
|---|---|---|---|
| | Worst Case | BPI 2015 | Simplified |
| Dryer & Kitchen | On | On | On |
| Next Largest Exhaust Fan | On | On | On |
| Other Exhaust Fans | On | On | Off |
| CAZ Door | Check | Check | Closed |
| Other Doors | Check | Open= exhaust fan or return register in room | Open= exhaust fan or return register in room |
| Air Handler | Check | Check | Check |

*Check= which ever produces lowest CAZ pressure*

Source: CEE

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# Survey

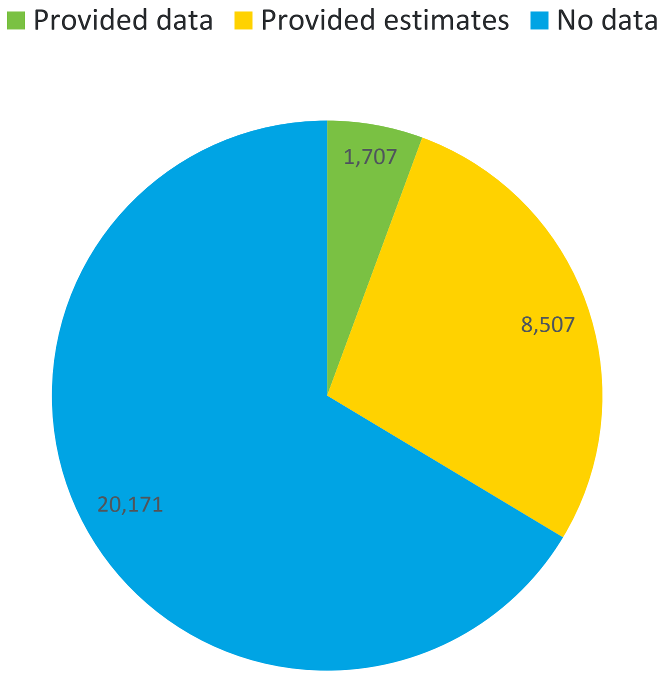
- How common are combustion safety failures?
- NASCSP Disseminated – National Association for State Community Services Programs


- Asked questions about housing (last program year)
  - How many homes treated?
  - How many use fossil fuels?
  - How many have natural draft appliances in the pressure boundary?
- Asked about test procedure – BPI, other?
- For those that failed:
  - How many due to air handler operation?
  - How many due to exhaust operation, including dryer?
  - How many had a new appliance installed to address the issue?
  - How many had a Power Vent kit installed to address the issue?
  - How many were deferred because of the issue?

# Survey Results – Failure Rates

## 30,385 homes sampled

- States with data (4 states)
  - 4.3% (74 of 1,707 homes) got remediation due to EXPECTED failures
  - 5.4% (92 of 1,707 homes) got remediation due to OBSERVED spillage
- States with estimates (5 states)
  - 6% (~513 of 8,507 homes) got remediation due to EXPECTED failures
  - 16% (~1,351 of 8,507 homes) got remediation due to OBSERVED spillage
    - AK said 40-50%
    - Excluding AK, about 8%

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# Survey Results – Failure Causes

- States with data
  - 4% (73 of 1,707 homes) failed because of air handler operation
  - 4% (39 of 967 homes) failed due to exhausts (including dryers)
- States with estimates
  - 6.5% (~374 of 5,757 homes) failed because of air handler operation
  - 18% (~1,043 of 5,757 homes) failed due to exhausts (including dryers)

> Combustion safety failures not as common as expected

> Combustion safety failures not often due to exhaust fans alone
>
> – Leaky ducts, dryers, then exhaust fans. Vent system defects likely cause persistent events.

> Some states volunteered that many/most failures due to:
>
> – Improper flue sizing
>
> – Crushed roof cap
>
> – Air handler operation
>
> – Dryer operation



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# Field Testing

- 11 homes in MN and WI; 1500 days of data
- Field testing
  - Simplified test procedure
    - Fixed door positions
    - Air handler on if it reduces indoor pressure
    - Clothes dryer on
  - Sites selected based on
    - Must fail criteria – Kitchen fan on high; next largest fan on; continuous spillage after set time
    - Must pass criteria – Kitchen fan on high or low; next largest fan on or off; no spillage after set time
- Test for spillage - beyond
  - 2 minutes for water heaters and furnaces in heating mode
  - 5 minutes for furnaces not in heating mode
- Check CO against ANSI certification standards

| | Minimum | Maximum | Average |
|---|---|---|---|
| Air Leakage (ACH50) | 3.9 | 11.1 | 6.2 |
| Kitchen Fan (cfm), [10/11] | 121 | 276 | 219 |
| Bathroom Fan (cfm), [11/11] | 30 | 130 | 65 |
| 2nd Bath Fan (cfm), [7/11] | 20 | 72 | 41 |
| CAZ Depress (Pa) | -1.9 | -13.7 | -6.9 |


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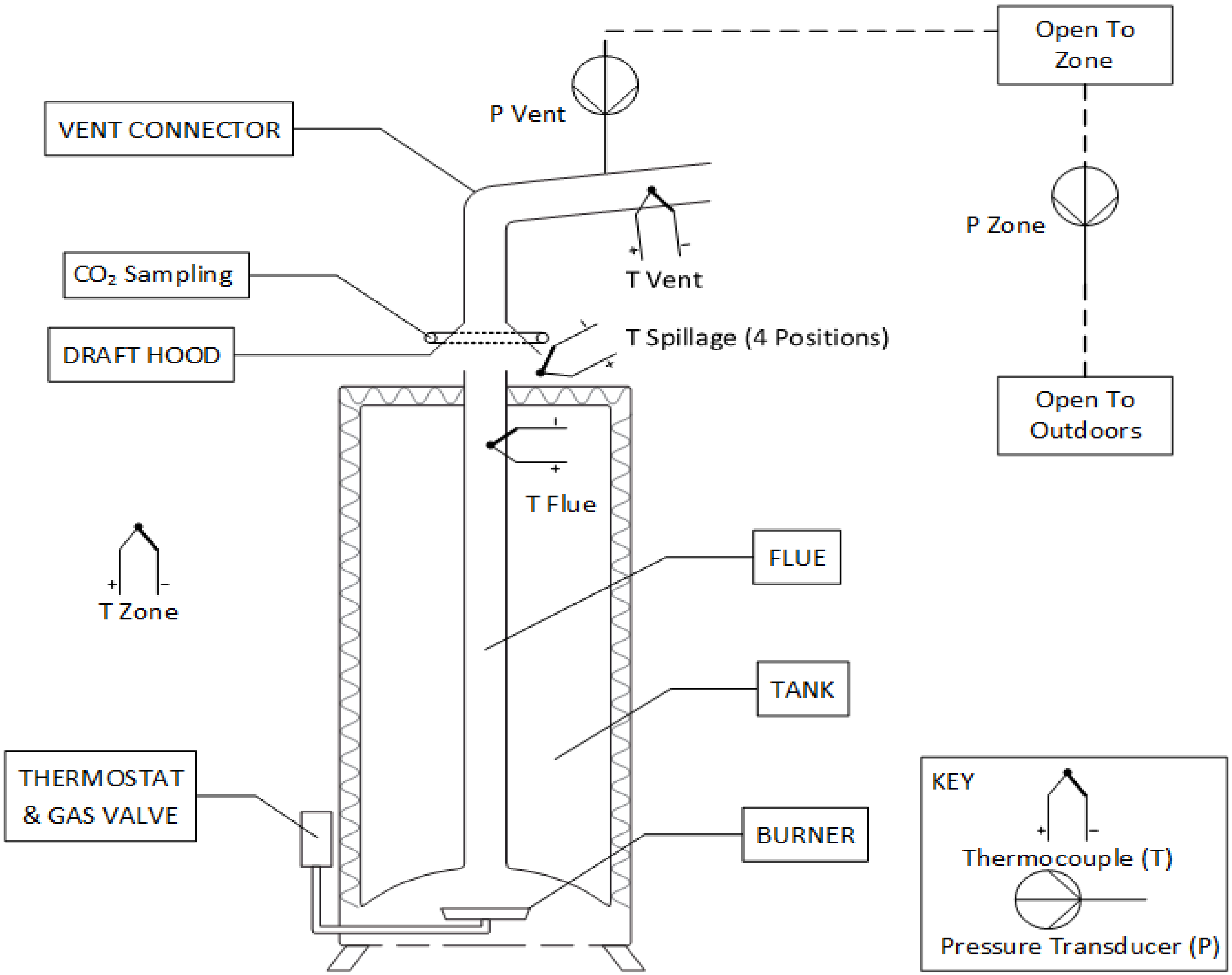
# Monitoring setup - *CO2 near vent used to identify spillage*




Source: Seventhwave



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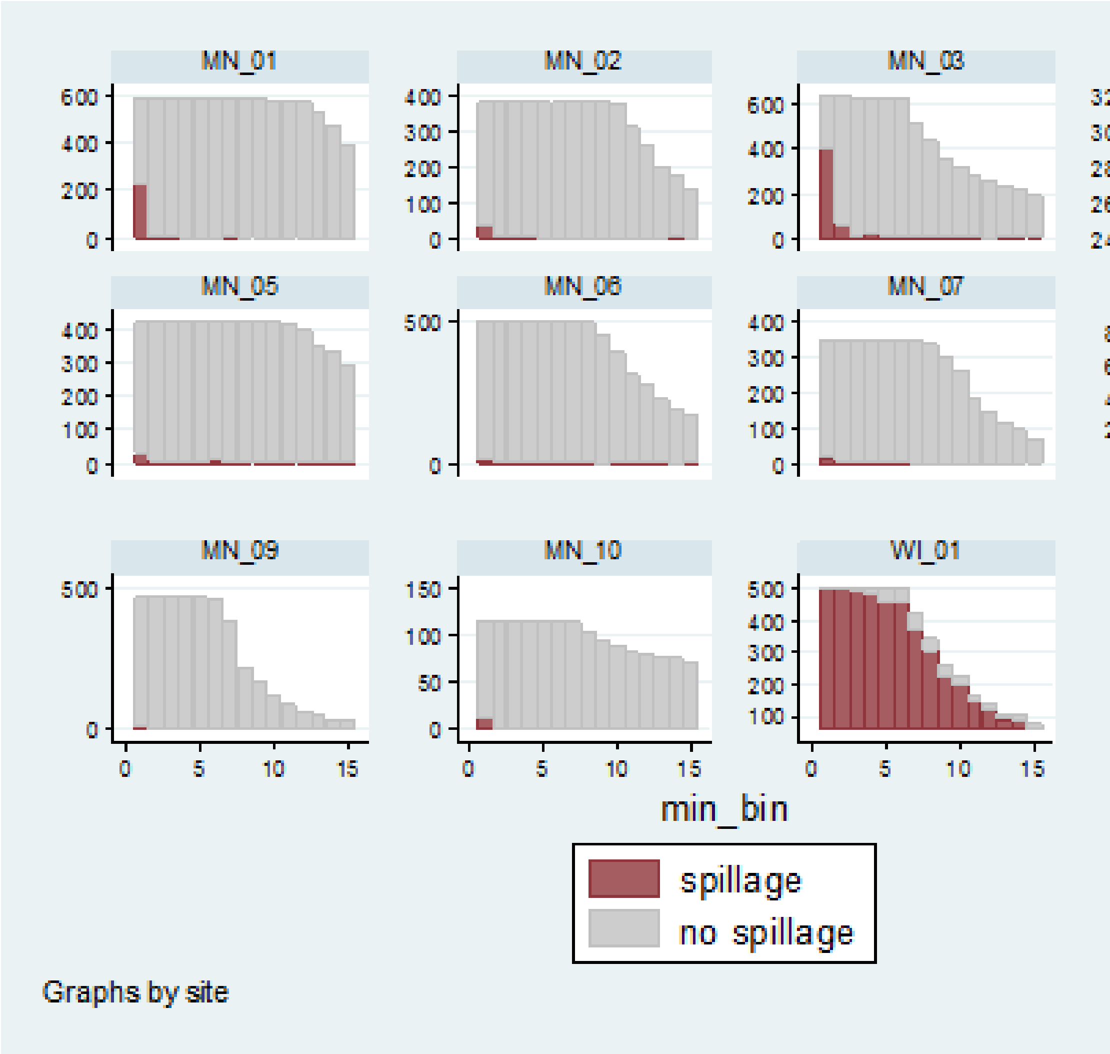
# Spillage by minute of operation, by site




What caused this?

Source: Seventhwave



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# Two sites showed excessive spilling - *had venting defects*

- MN_04 had an undersized water heater vent (vent capacity = 75% of burner input)

- WI_01 had a large opening downstream of the water heater (unused, partially repaired connection for a furnace)


3” vent, 6’ run, 4 elbows

Water heater and unused furnace vent

*Images courtesy CEE*

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# Conclusions/Accomplishments

- Weatherization survey data indicates frequency of failure from the existing procedure near the expected 10% value.
  - Approximately half of the failures are related to air handler operation and half are related to exhaust appliances.
- Minnesota field data indicates close correlation between homes with persistent events and vent systems that were not installed to code.
  - Simplified test procedure easier to implement but still fails many houses that don’t have persistent events.
- Typical systems as monitored don’t spill excessively

*Vent defects are an important cause, perhaps the largest cause, of excessive spillage. Vent inspection is critically important in evaluating safe operation.*



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# Progress and Accomplishments

**Accomplishments**: See prior slide.

**Market Impact**: Informed ANSI/BPI-1200-S-2015 Standard Practice for Basic Analysis of Buildings. Used in the training materials for BPI certified professionals, specified by over 110 weatherization and utility programs nationwide.

**Awards/Recognition**: Recognition by BPI for assistance in upgrading the worst-case depressurization test to the simplified procedure.

**Lessons Learned**: Field test houses with acceptance criteria that are too narrow are difficult to find. Homeowners are wary of safety-related testing. Clear failures must be flagged for remediation.

# Project Integration and Collaboration

**Project Integration**: BPI was brought into the discussion of the simplified test procedure early and was open to replacing the worst-case approach that was a barrier to upgrading houses. Team members participated in the BPI-1200 Combustion Safety Task Group.

**Partners, Subcontractors, and Collaborators**: Partners: University of Illinois, Midwest Energy Efficiency Alliance (PARR team members). NorthernSTAR team members: University of Minnesota, Minnesota Center for Energy and Environment, Seventhwave. BPI was also a partner. The National Association of State Community Services Programs (NASCSP) that oversees state Weatherization Assistance Programs, LBNL, NREL.

**Communications**: Building America Webinar (12/16/15), ASHRAE 2016 Winter Conference (1/25/16), Duluth Energy Design Conference (2/22/16), Seventhwave Better Buildings Better Business Conference (3/4/16).

# Next Steps and Future Plans

**Next Steps and Future Plans**:

This project is complete.  Additional data would be valuable to verify the result in a broader array of houses:

1. Additional archetypes
2. Construction practices
3. Geographic diversity
4. Climate diversity



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# REFERENCE SLIDES

# Project Budget

**Project Budget**: $375,775 over 2 budget years
**Variances**: Additional funds were added in 2014/2015 to expand the number of houses in the study.
**Cost to Date**: 100% of the project budget was spent
**Additional Funding**: $94,000 in cost share from Utilization Technology Development, a consortium of natural gas utilities

| Budget History | | | | | |
|---|---|---|---|---|---|
| 6/15/13– FY 2015 (past) | | FY 2016 (current) | | FY 2017 – End (planned) | |
| DOE | Cost-share | DOE | Cost-share | DOE | Cost-share |
| $375,775 | $94,000 | $0 | $0 | $0 | $0 |

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# Project Plan and Schedule

- See below for schedule and milestones
- No slipped milestones or slips in schedule – additional funds added in FY15 to increase the quantity of field data collected
- Project complete – no planned future work

| Project Schedule | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Project Start: 5/15/2013 | | Completed Work | | | | | | | | | | |
| Projected End:9/30/2015 | | Active Task (in progress work) | | | | | | | | | | |
| | | Milestone/Deliverable (Originally Planned) | | | | | | | | | | |
| | | Milestone/Deliverable (Actual) | | | | | | | | | | |
| | FY2013 | | | | FY2014 | | | | FY2015 | | | |
| Task | Q1 (Oct-Dec) | Q2 (Jan-Mar) | Q3 (Apr-Jun) | Q4 (Jul-Sep) | Q1 (Oct-Dec) | Q2 (Jan-Mar) | Q3 (Apr-Jun) | Q4 (Jul-Sep) | Q1 (Oct-Dec) | Q2 (Jan-Mar) | Q3 (Apr-Jun) | Q4 (Jul-Sep) |
| **Past Work** | | | | | | | | | | | | |
| Test Plan | | | | | | | | | | | | |
| Draft Technical Report - Test Method | | | | | | | | | | | | |
| Final Technical Report - Test Method | | | | | | | | | | | | |
| Draft Technical Report - Pilot Study | | | | | | | | | | | | |
| Final Technical Report - Pilot Study | | | | | | | | | | | | |