



# *Emerging Technology Unplugged Smart Flue Damper Systems*

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ACEEE Hot Water Forum  
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# Unplugged Systems

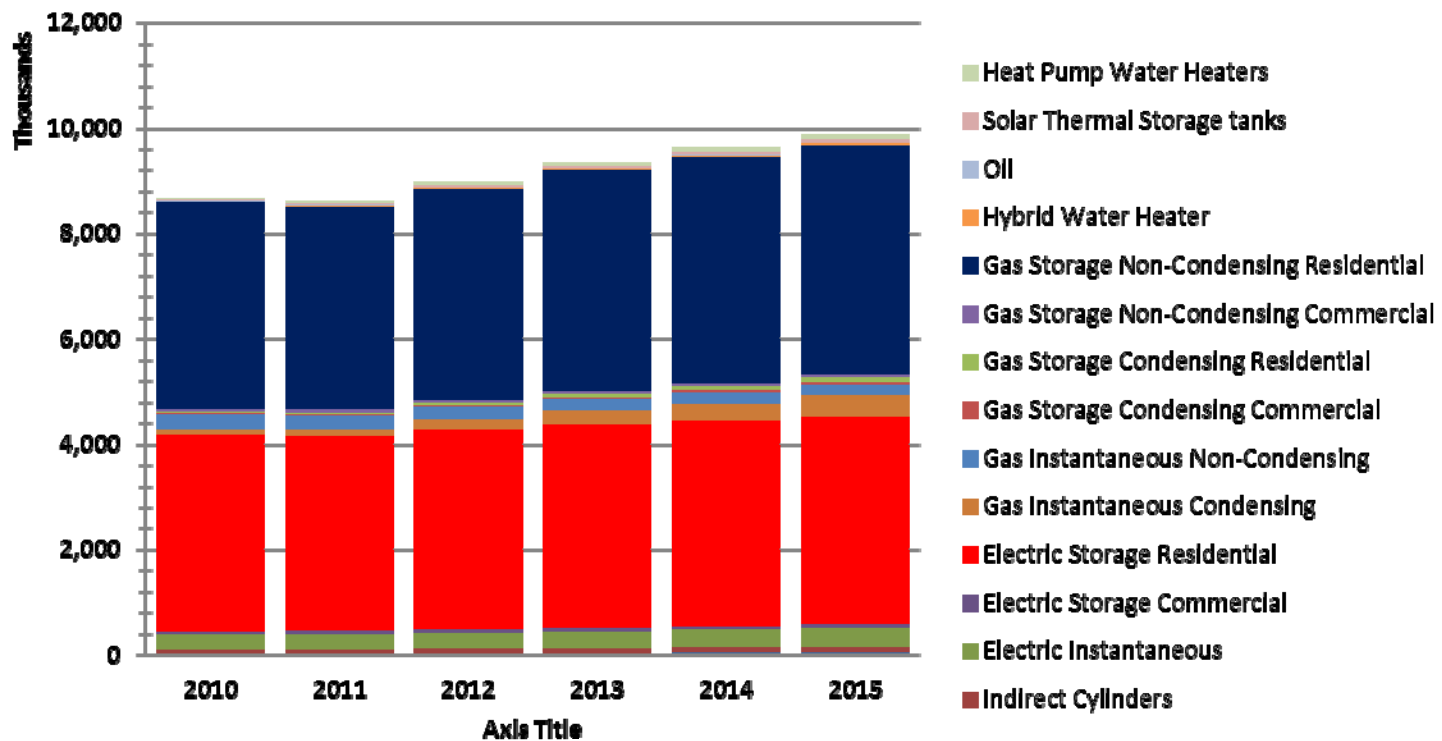
This details a self-powered flue/valve system for residential water heaters. The system provides an opportunity for higher efficiency in continuous pilot water heaters.

The development program was completed by the Gas Technology Institute (GTI) and the technology is under license to Field Controls.

The technology is further covered under Field Controls patent 6,257,871.

# Water Heater Market

## VOLUME SALES OF WATER HEATERS



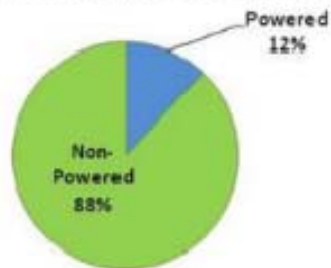
Source: M. Parker May 2011 ACEEE Hot Water Forum

2010: 8.7 Million valued at \$1.3 Billion

## Industry Need/Business Value

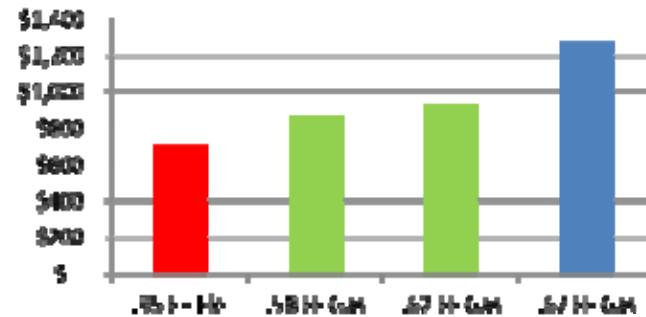
- **Need** - Higher efficiency drop-in storage water heater replacements that require no powered connection
- **Value** - Unplugged systems have an installation cost advantage over competing technologies.

Natural Gas Water Heaters  
(63.5 Million in U.S. & Canada)



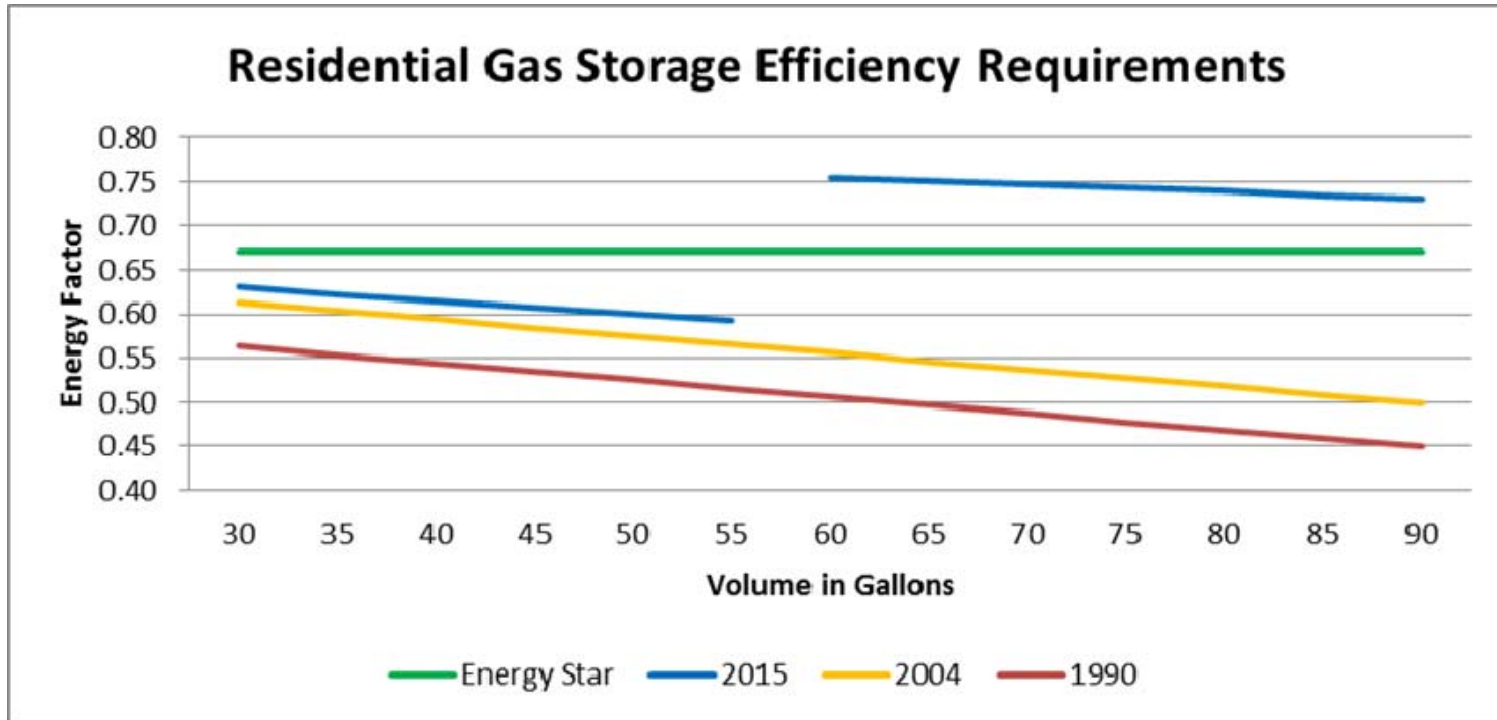
Unplugged is 88% of in-situ gas water heaters.

Water Heater Installed Costs



Powered connections can add \$150 or more.

# Efficiency Change 2015



EFs will be replaced by UEFs. Current products are undergoing modifications in an effort to maintain or increase their efficiency ratings. These modifications will make it harder for drop-in replacements for a number of gas storage water heaters.

## Utility Study 2000

	Single Family	Multi- Family
Percent of Customers Unable to Accommodate a Larger Size Water Heater	13%	22%
Breakdown by Location		
Basement	42%	17%
Appliance Closet	24%	43%
Laundry/Kitchen /Utility Room	14%	30%
Garage	17%	9%
Other	2%	2%

### Replacement Opportunity

A 2000 Gas Utility Survey of 15 U.S. companies with service territories covering 24 states and Wash D.C. estimated 13 percent of water heaters in single family homes in their service territory could not accommodate a larger water heater or did not have easy access to power grid without significant cost.

## Why bother with Unplugged

- > Eliminates the need for a powered connection – Installation costs are reduced
- > Delivers efficiency options where no options previously existed – Higher efficiencies are maintained and promoted
- > Continued hot water supply in power outages – Consumer confidence in gas water heating is maintained
- > Allows higher efficient water heaters to be installed in space/location constrained installation - Higher efficiency opportunities are expanded

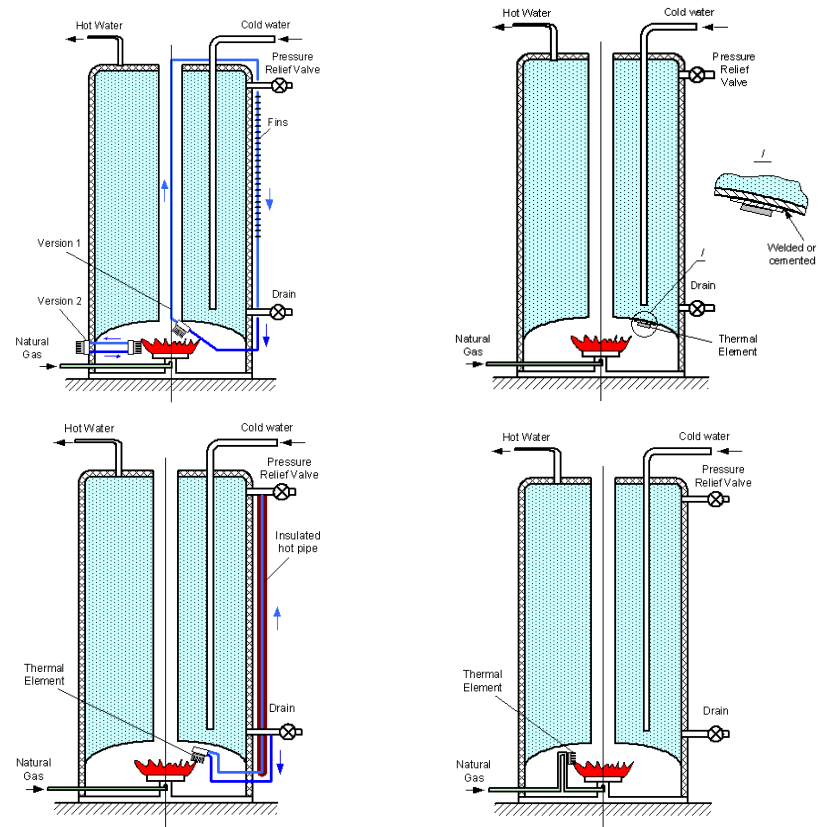
## Prior GTI Work

- > Conceptual analysis of low-power ignition systems for natural gas appliances
- > Design of thermo-electric concepts for water heater integration (Evaluate the most promising concept)
- > Develop and test a low-power control valve
- > Develop and test a low-power pilotless burner ignition and control circuit
- > Integrate and demonstrate an unplugged system



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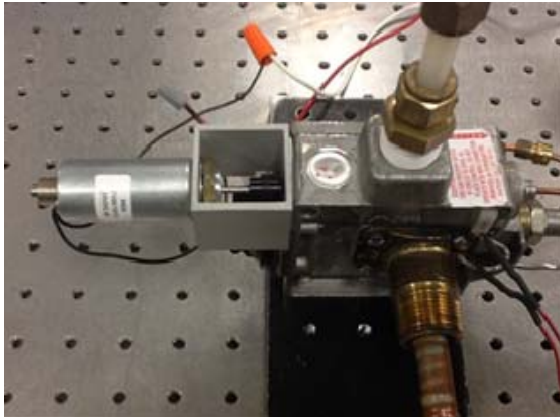
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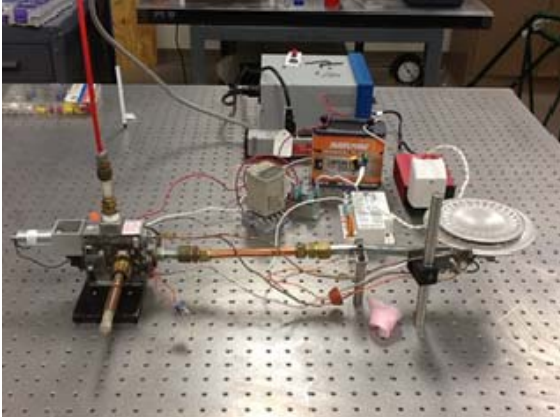


Available spark igniters were identified but not optimized

- Developed and demonstrated a low-power control valve



An available flue damper was identified but not optimized.



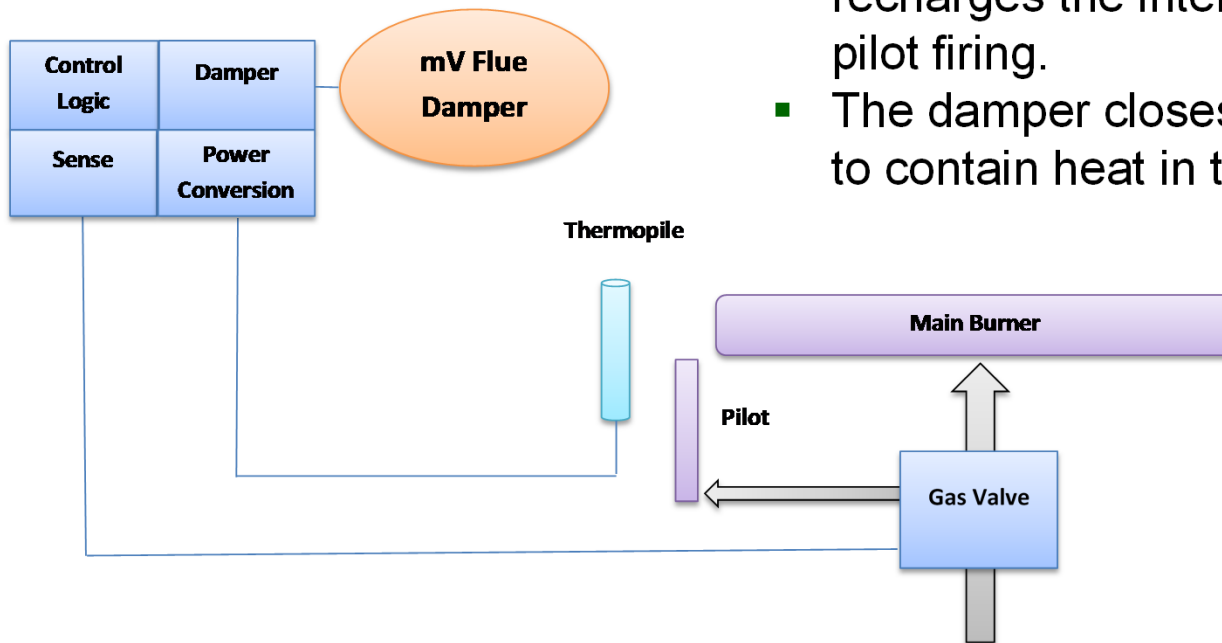
## Objective

- > Develop a cost effective unplugged “smart” flue damper that can operate with a modified thermally-actuated gas valve for use in residential water heaters with standing pilots.
- > Determine the operational characteristics of a thermally-actuated gas valve to determine placement, timing, and requirements of a signal switch to operate a unplugged “smart” flue damper.
- > Modify and test an unplugged “smart” flue damper to verify safe gas valve and burner operation.

# Unplugged “Smart” Flue Damper

## HOW IT WORKS

- The on-board power and system control manages damper operation.
- The thermopile/power conversion system recharges the internal power source via pilot firing.
- The damper closes during stand-by mode to contain heat in the tank.



# Thermally-Actuated Gas Valve



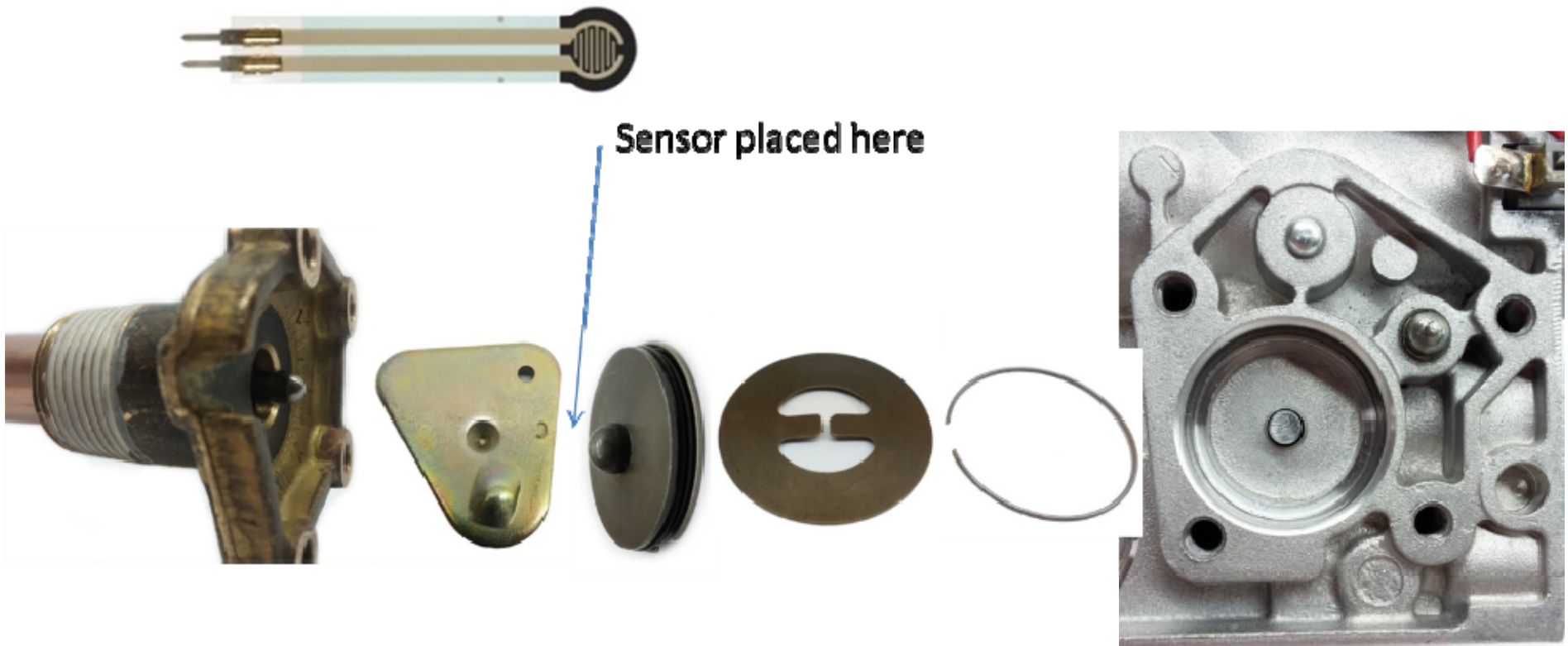
## Advantages

- Thermal mechanical activation
- High safety
- Self-powered; no electrical connections;
- Proven reliability
- Low cost
- Established history on water heaters

## CHALLENGE

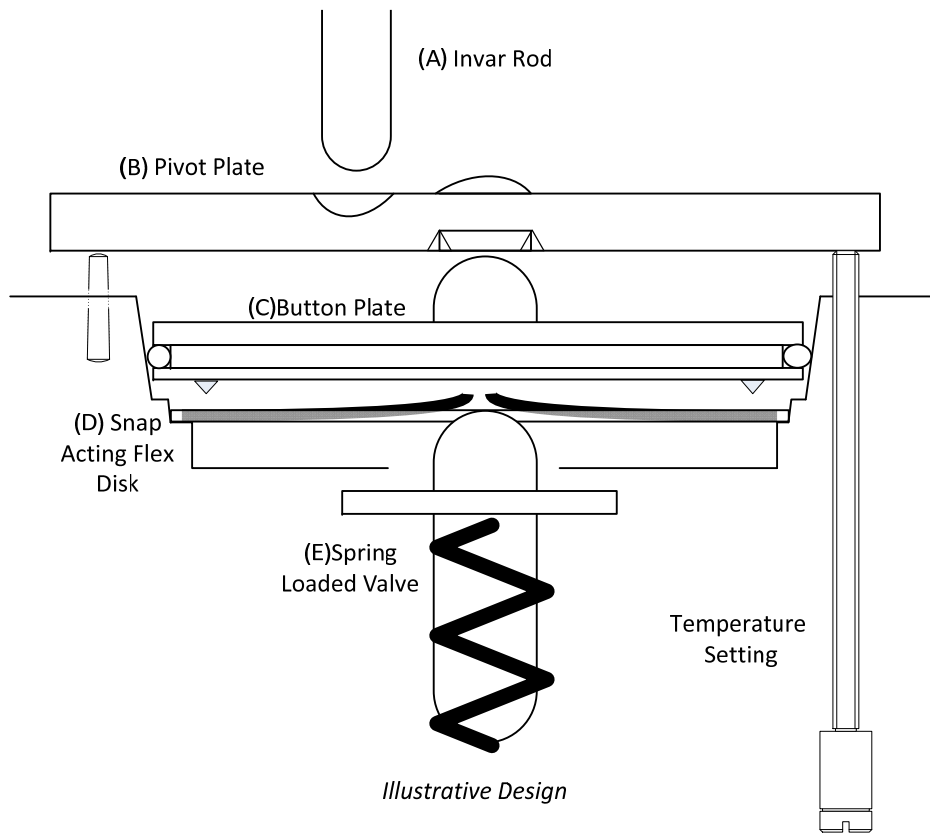
- Limit modifications so re-certification of the gas valve is simplified, and allow for smart flue damper operation without compromise to current safety and reliability.

# Force Sensitive Resistor (FSR) Approach

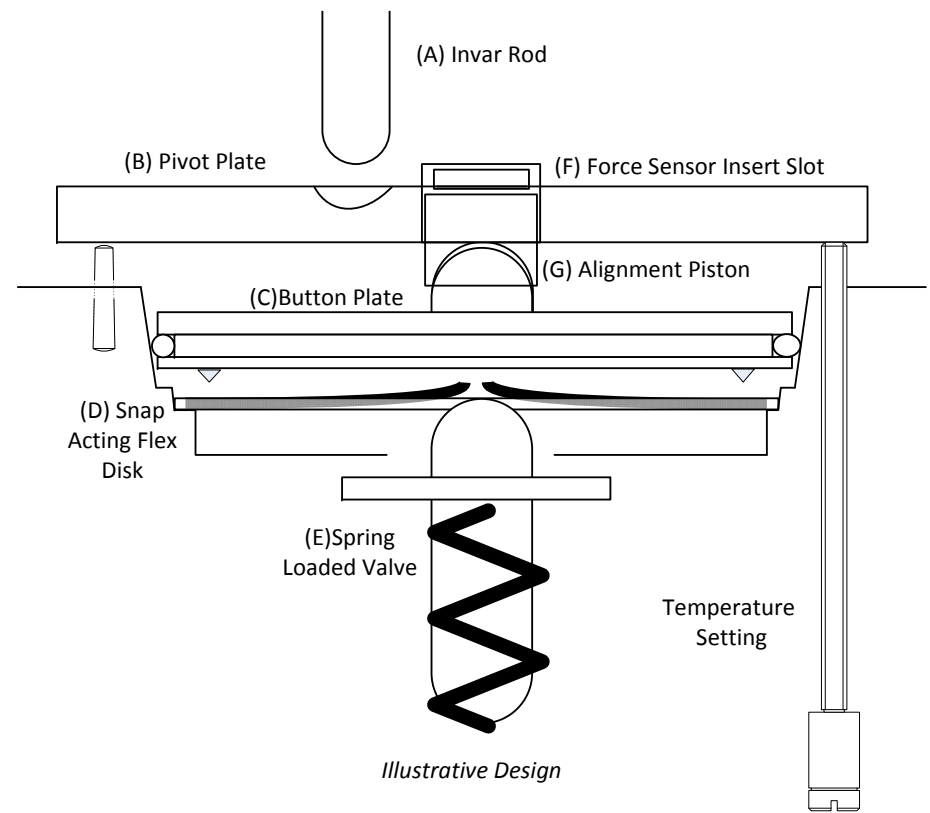


# Gas Valve Mechanism

Original



Modified Prototype

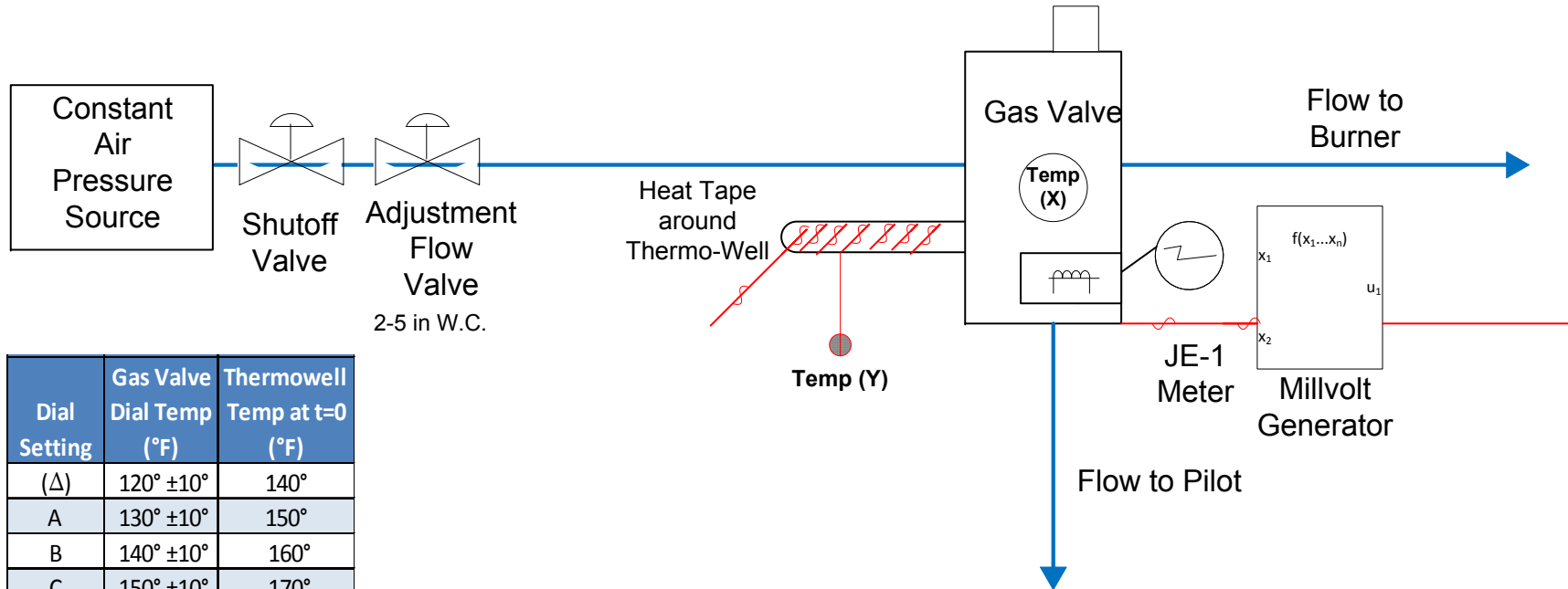


# Pivot Plate Modification and Placement





# Benchtop Characterization Test

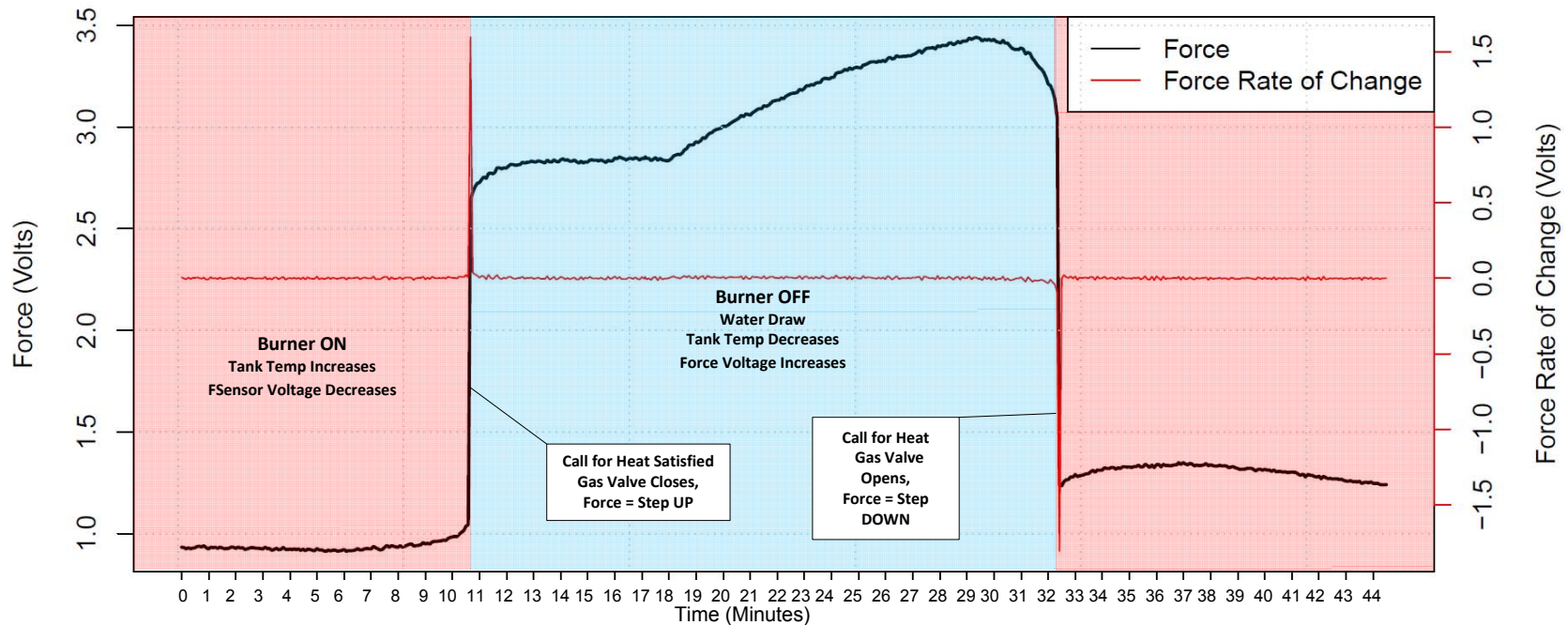


Dial Setting	Gas Valve Dial Temp (°F)	Thermowell Temp at t=0 (°F)
(Δ)	120° ±10°	140°
A	130° ±10°	150°
B	140° ±10°	160°
C	150° ±10°	170°
VERY HOT	160° ±10°	180°

- > Objective: Measure and record the force voltage applied to the opening/closing mechanism of a thermally-actuated gas valve while cycling the gas valve at selected dial temperature setting

# Force Sensor Signal

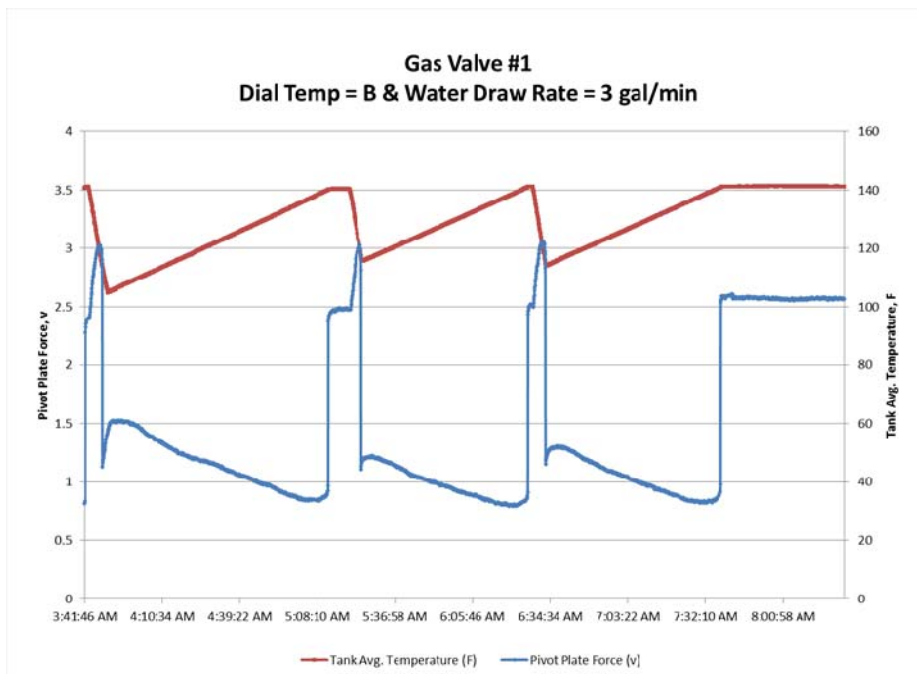
GTI 21813 Unplugged Valve Test – Temp Setting @ 130F



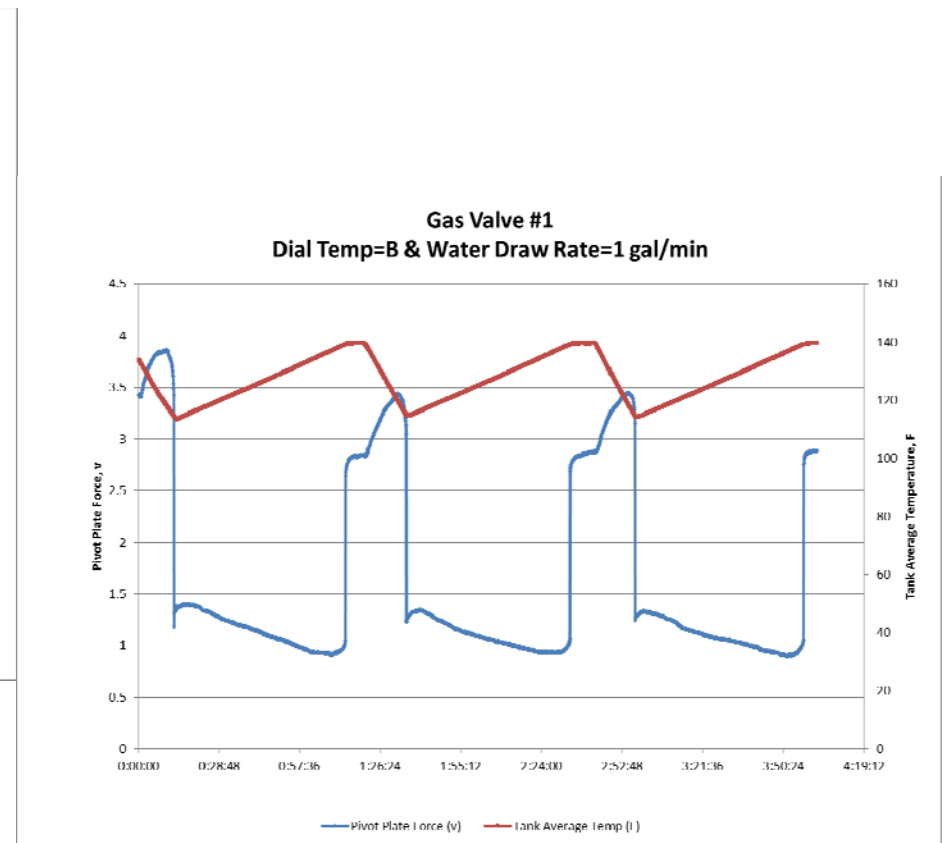
## > Measurements of Interest

- Force
- Force Rate of Change

# In-Water Heater Draw Test – Multiple Cycles, High, Low Draw Rates

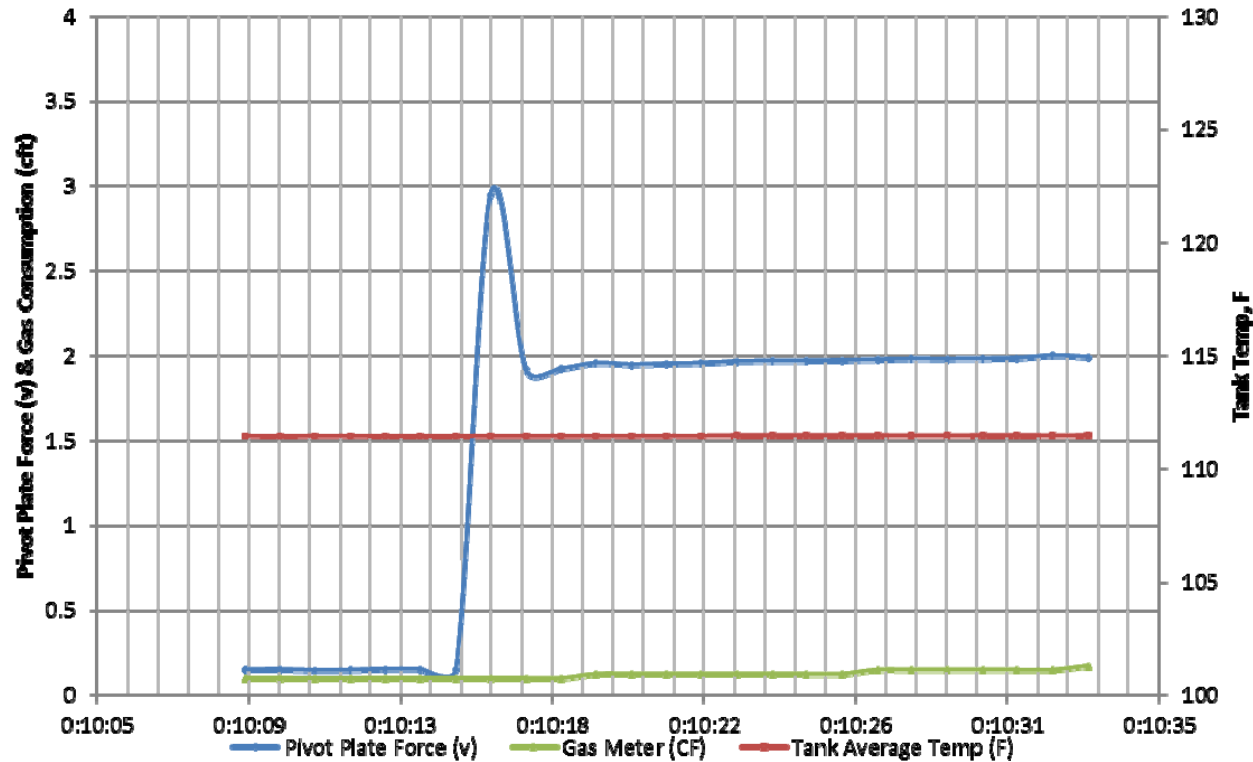


- Repeatabile signal output at high and low draw rates.



# In-Water Heater Shot Test – 1 Cycle

## Shot Test From Pilot Lighting to VERY HOT - Run #1

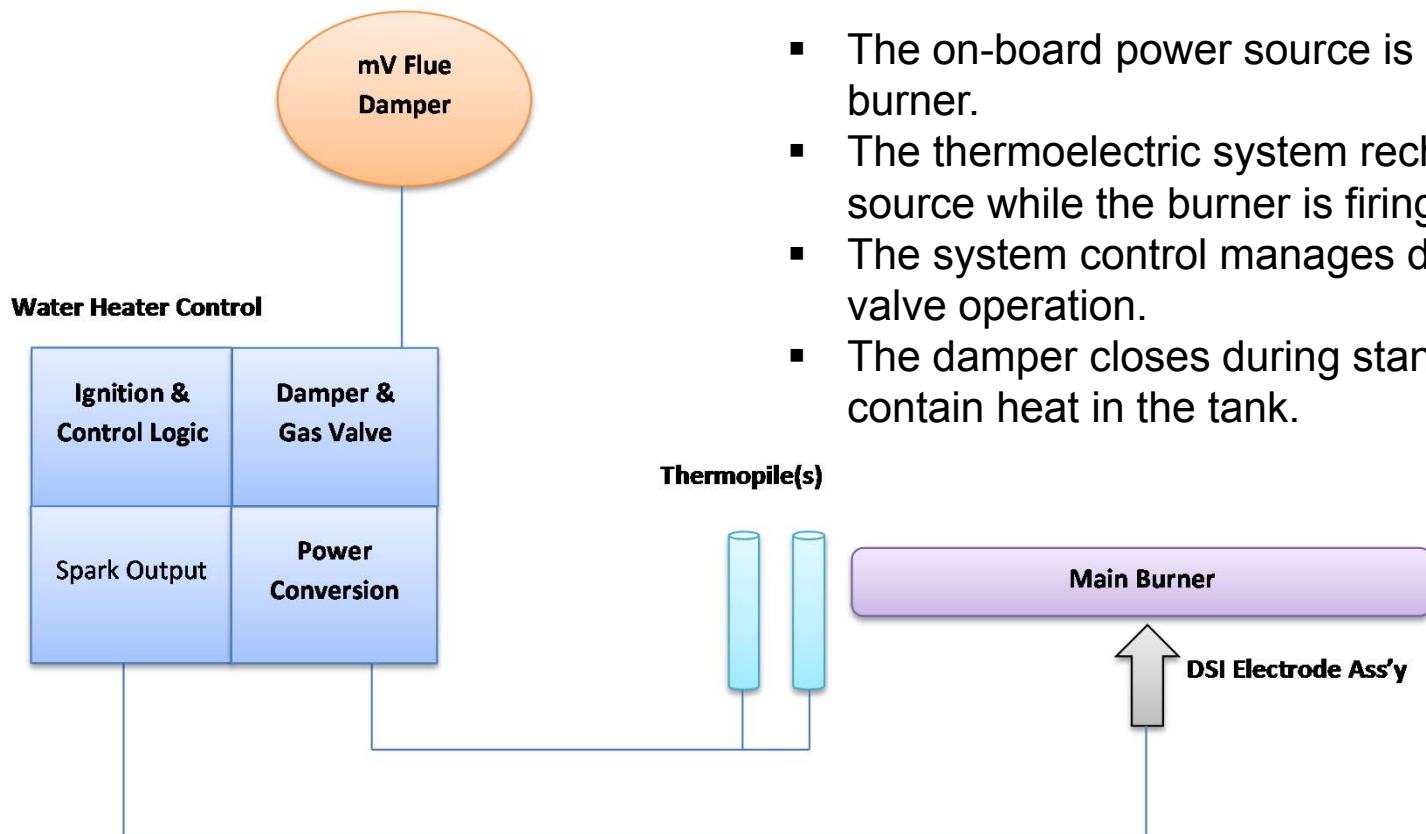


- A flue damper must be able to either open or be partially venting within 4 seconds should a mechanically-induced call-for-heat occur.

# Unplugged “Energy Star” System

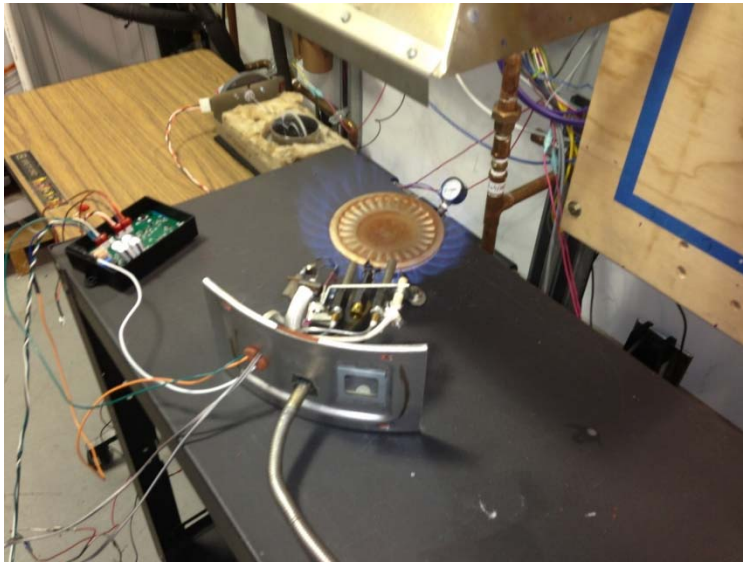
## HOW IT WORKS

- The on-board power source is used to ignite burner.
- The thermoelectric system recharges the power source while the burner is firing.
- The system control manages damper and gas valve operation.
- The damper closes during stand by mode to contain heat in the tank.



# Unplugged “Energy Star” System

## FEATURES

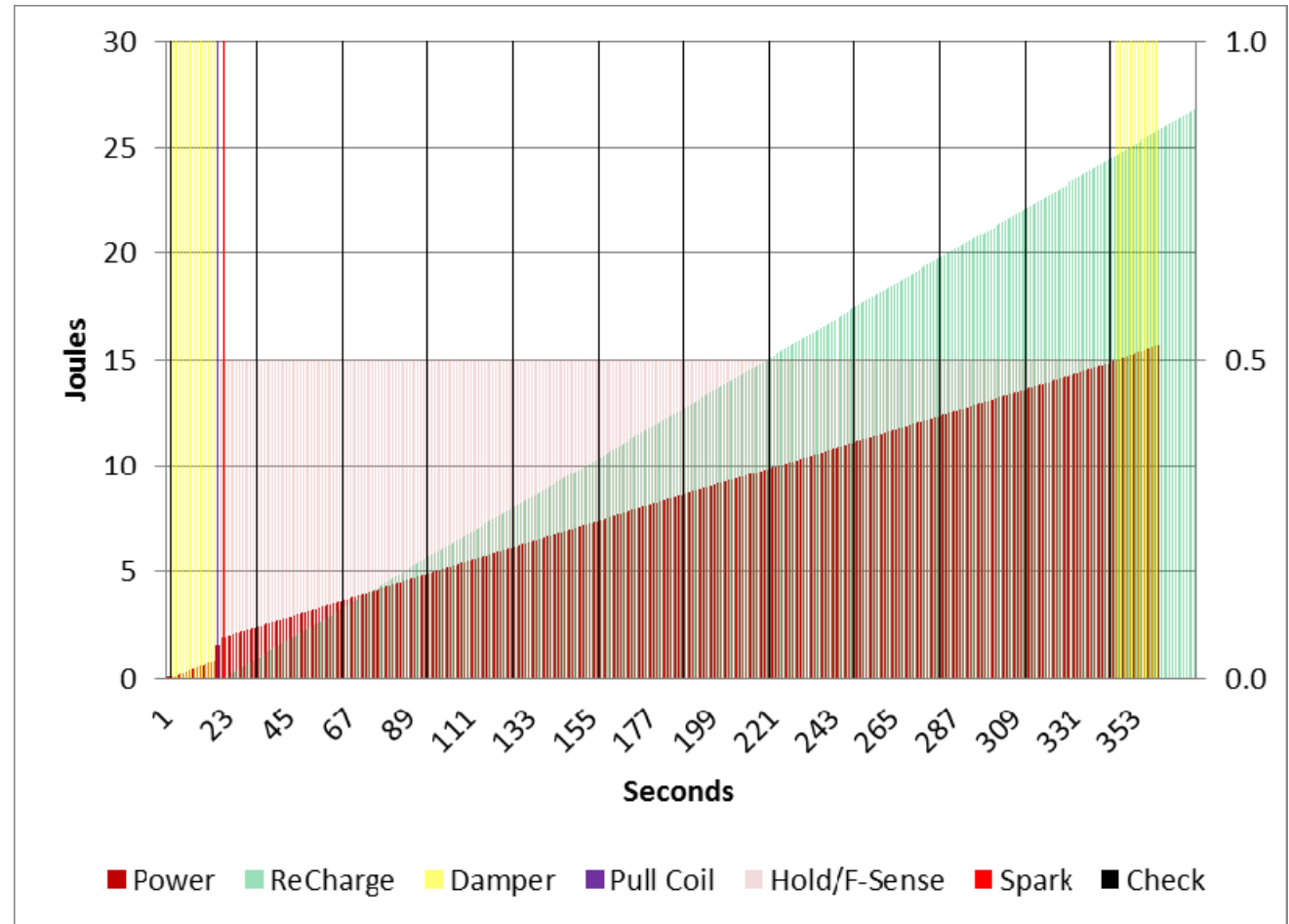


- Requires no external power.
- Requires no standing pilot.
- Damper closes during stand-by mode to contain heat in the tank improving EF significantly.
- Minimal changes to water heater required.
- Patent Pending.
- Simple and Cost Effective.

## 6-Minute Burner Cycle Test

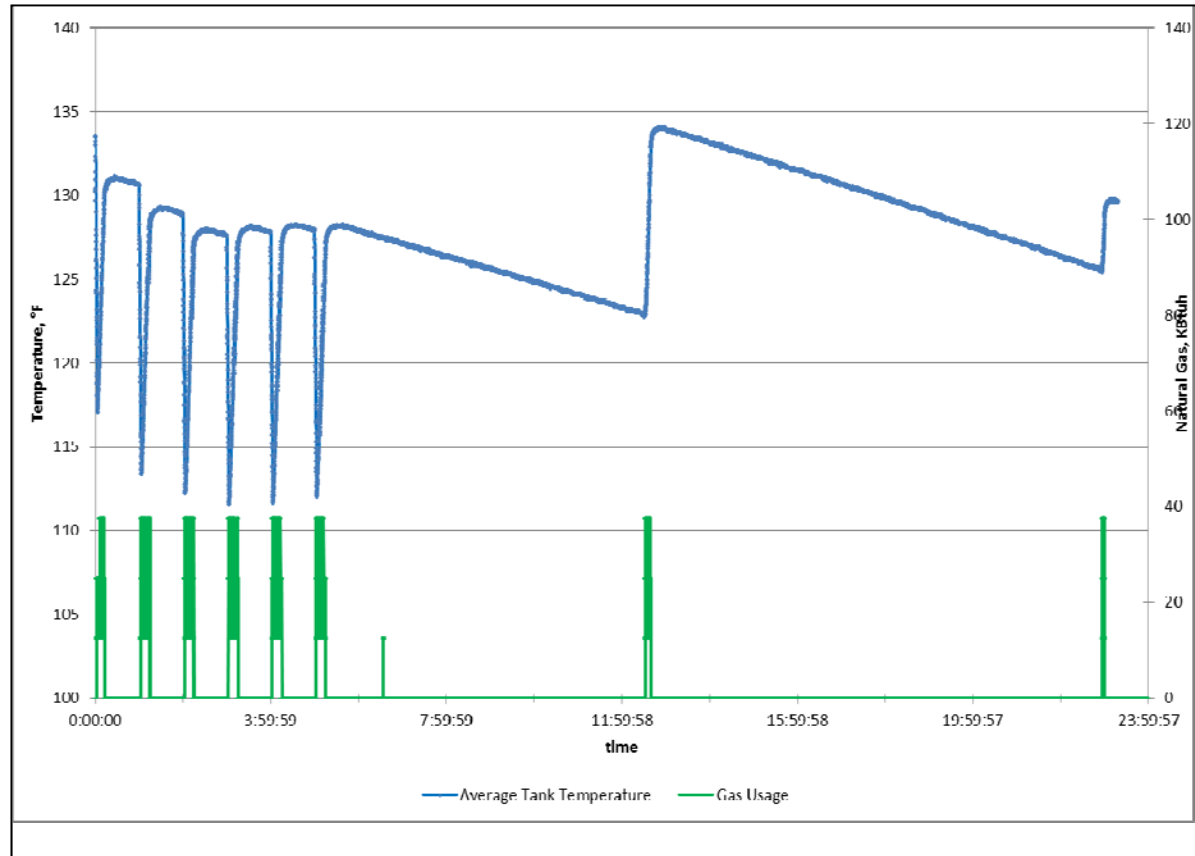
In a 6 minute Cycle Test of Components:

- Energy Consumed = 15.7J.
- Energy Harvested = 25.8J+
- System in Recharge State after 1.5 minutes of burner operation.
- Fully charged after 3-4 minutes



## Baseline 24hr Test

- The Unplugged E-Star system was installed in an E-Star Water Heater and subjected to the 24 Hr Test.
- The water heater maintained E-Star Efficiency





## Next Steps

- Evaluating the Unplugged Smart Flue Damper and Unplugged E-Star System with manufacturers
- Continued technology transfer and testing to optimize for current product integration
- Seek input from end users on the value of these systems.