Combination space and water heating systems

Energy & Environmental Building Alliance
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Gas Technology Institute (GTI)
Learning Objectives for Combis

> Technology and market landscape
> System performance in lab
> System performance in-field
> What is next for the technology
Vintage Combi

Baseline!
Forced-air Combi Technology

> Condensing water heaters
> Combined loop DHW/SH

> Pump timer needed
> DHW priority naturally
> Flow switch protects pump
Combi Boiler Technology

- Condensing water heaters
- Isolated SH loop from DHW
- No pump timer needed
- DHW priority by water heater
- Typically designed for higher temperatures than tankless
- Incorporate outdoor reset
- Residential and Commercial models
- Separate from AC system
Condensing Combi Landscape

> Packaged combis (dual/triple integrated appliances)
  – Rheem, Dettson, Rinnai/First Co, Heat Transfer Products (storage)

> Mix-and-match condensing tankless water heaters
  – Rheem, Rinnai, Takagi, Navien, Bosch, Grand Hall, Quietside, etc.

> Mix-and-match condensing storage water heaters
  – AO Smith, American, Bradford White

> Mix-and-match FAUs
  – First Company, Enerzone, Comfort-Aire, SunTherm, Rheem, Dettson, etc.

> Combi Boilers
  – Rinnai, Navien, Laars, Triangle Tube, Heat Transfer Products, etc.
Tankless-FAU Benefits/Challenges

> Tankless/FAU Benefits
  ─ Lowest cost combi option
  ─ High efficiency and capacity
  ─ Easy forced-air integration
  ─ Space savings, no floor space, outdoor, attic

> Tankless/FAU Challenges
  ─ Sizing dilemma (SH/DHW)
  ─ Inconsistent condensing
  ─ Typical tankless issues
  ─ Pump timer
  ─ Contractor unfamiliarity

  ─ Complexity/field engineering
  ─ System tweaking to achieve high efficiencies.
Tankless vs. Storage Combis in Lab

- Mid-80% to low-90%
- Big eff. drop at low loads
- Systems “fine-tuned”
- Tankless combis had slightly better efficiencies
- Costs for condensing storage vs tankless similar
Tankless vs. Storage Combis in Lab

> Tankless: very consistent heat loop water temp
  – +/-2°F from set point
  – Consistent supply air temp

> Storage: temperature stratification in tank
  – Within 10°F to 15°F of setting
  – Inconsistent supply air temp
  – Using side taps for htg loop
  – Maybe better with top taps
Cold Water Sandwich

- No control measure
- 27°F sandwich
- Drops below 90°F (cool)
- ¼-gal manifold (low-cost)
- 15°F sandwich (still ~100°F)
- 44% improvement
- 5-gal electric water heater
- Higher cost ($350)
- 6°F sandwich
- 81% improvement
GTI Tankless-FAU Combi Field Work

> Combi field demos: 10 units in NY
  - All 10 homes monitored for 1 year

> Combi pilots: 36 units in IL, CA, and CT
  - Nicor: 5 homes monitored for 1 year
  - SoCal: 30 homes, 5 will be monitored
  - UIL: 3 homes monitored for ~5 months so far

> Combi laboratory testing and development
  - Combi enhancements and guidelines
  - Advanced FAU development (with Auburn)
NYSERDA/Nicor Demo/Pilot Scopes

> Determine performance attributes of tankless-FAU combis

> 12 months of in-field monitoring (weather normalization)

- Trained contractors
- Recruited host-sites
- Analyzed gas bills
- Contractor load calcs
- Manufacturer approvals
- Contractor installed w/o GTI intervention
- GTI commissioned
- Data collected/reduced
Code Misperception and a Barrier Broken Down

> Major distributor in Illinois service territory had perception that combi systems were prohibited

> Past installations in the region were sited with specific code violations and ingrained in the trade
  - There must be provisions that prohibit potable water from standing in the heat transfer unit when not in use
  - Units must bear a statement on the rating plate indicating suitability for potable water heating and space heating

> Manufacturers had long since resolved those issues

> Code misperception alleviated through training
## NYSERDA/Nicor Performance Results

<table>
<thead>
<tr>
<th>Host Site</th>
<th>Cumulative Data</th>
<th>Therm Savings Combi Versus Baselines</th>
<th>Percent Savings 0.59 DHW 80% SH</th>
<th>Percent Savings 0.59 DHW 90% SH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nicor</td>
<td>127.5</td>
<td>0.59 80% SH</td>
<td>0.59</td>
<td>0.59</td>
</tr>
<tr>
<td>NYSERDA</td>
<td>129.5</td>
<td>0.59 90% SH</td>
<td>0.59</td>
<td>0.59</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Nicor</th>
<th>Site-System</th>
<th>1B</th>
<th>2B</th>
<th>3B</th>
<th>4B</th>
<th>5B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cumulative Eff.</td>
<td>82.8%</td>
<td>88.0%</td>
<td>86.4%</td>
<td>85.6%</td>
<td>82.8%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NYSERDA</th>
<th>Site-System</th>
<th>1G</th>
<th>2A</th>
<th>3A</th>
<th>4B</th>
<th>5C</th>
<th>6B</th>
<th>7D</th>
<th>8E</th>
<th>9F</th>
<th>10A</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Cumulative Eff.</td>
<td>74.4%</td>
<td>77.3%</td>
<td>90.3%</td>
<td>82.0%</td>
<td>72.0%</td>
<td>82.4%</td>
<td>92.2%</td>
<td>93.0%</td>
<td>91.7%</td>
<td>87.4%</td>
</tr>
</tbody>
</table>

- Systems D, E, and F used third-party AHUs designed specifically for use with condensing water heaters (maximized thermal transfer across hot water coils)
Field Data Observations

- **Seasonal Impacts**
- **Third-party AHUs**
- **Return Water Temperatures**
- **Efficiencies**

Corresponds with CEE research
Pump Timer Problem

- Why heating loads in the summer?
- AHU manufacturers incorporate pump timers to circulate water every 6 hours (Legionella)
- Circulates for ~30 seconds even in the summer… and the burner comes on
- Heats air conditioned supply air briefly ~85°F
- Pump timer for combi forces 199k btuh burner on for ~2 minutes per day
  - ~6k btu per day just to circulate AHU water
- For reference: storage WH standby losses might use 40k to 50k btu per day
- Need a better solution!
  - Part of GTI’s upcoming laboratory work with Auburn University
DHW/Space Heating Mismatch

Typical Flow Rates
- Dishwasher: 0.5 - 1.0 gpm
- Sink: 0.5 - 2.0 gpm
- Washing Machine: 2.0 - 2.5 gpm
- Shower: 1.5 - 2.5 gpm
- Body Shower: 1.75 - 2.0 gpm ea.
- Bath Tub: 2.5 - 4.0 gpm

More than 10:1 turndown for typical space heating
Sizing Recommendations for Tankless-FAU Combis

> Water heater objectives
  ─ Size water heater based on DHW demands
  ─ Avoid tendency to oversize tankless based on unrealistic DHW demand scenarios
    > Install low-flow fixtures (old houses)

> Hydronic FAU objectives
  ─ Size FAU based on heating/cooling load calcs (e.g. Manual J)
    > Best to use an FAU with integrated hydronic/refrigerant coils
  ─ Maximize heat transfer across the FAU hot water coil
    > Adjust air flow to maintain min 110°F supply air
    > Adjust water flow to maintain max 105°F water return to FAU
  ─ Outside 15-60kBtuh - maybe not suitable for condensing combi

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Load Calculations from Field

> Typical ~2,000 sq-ft, 3 tons cooling

> Readily available hydronic FAUs well-matched with typical homes
  – 30 to 60 MBH

> Condensing tankless plenty of capacity for space heating and DHW
  – 120 to 199 MBH

> What about ZNE homes?
  – 15 to 30 MBH heating?
  – Combi system product gap?
Installation Guidelines

A) Shutoff with thermal expansion (ASSE-rated)
B) Mixing valve with certified check valves
C) Shutoff with manual bleed at low point
D) Shutoff with automatic air vent at high point
E) 2” dia. by 12” long manifold
   • For cold-water sandwich
F) Min ¾” hard copper tubing
   • Plastic harbors Legionella
G) Insulate SH loop and DHW supply
H) Minimize distance between FAU-tankless, and minimize all piping pressure losses
I) Flow switch protects FAU pump from min flow (DHW priority happens naturally)
J) Snorkel vent raises vent opening above snow-line in cold climates
K) Check valve prevents back flow during DHW draws, prevents thermal siphoning
Looking Ahead

- Widespread contractor education is key to market expansion
- Installed costs need to come down by about 15% to 25% to make combis marginally acceptable in terms of utility total resource cost
  - Average of 130 therms saved per year
  - Average of 11.5% DHW and SH gas saved per year
  - Compared to conventional furnace at 80% AFUE and water heater at 0.59 EF
  - Combi cost $5,750 vs. $3,500 to $3,800 for traditional equipment
- Maximize opportunities for better efficiencies through better system integration and advanced system/product design
- Better understand how well combis compare to other heating systems
Triple Integrated Appliances

- Auburn University Advanced AHU
  - Cooling, Heating, DHW
  - EHP/Gas WH integration
  - Improve coil thermal transfer
  - Eliminate pump timer?
  - Reduced installation cost

- AO Smith (Takagi 120kBtuh tankless water heater)

- Carrier electric heat pump

- 5-unit demo (NYSERDA)

- Pretesting in lab through UTD

- Field demos in 2015

Maximize opportunities for better efficiencies (High and low loads)
24-Hour Profile Testing in Laboratory

- Have field results for combis, but how do they compare to traditional equipment?

- Lab test methodology
  - SH loads and thermostat calls
  - DHW draws and flows
  - Outdoor air temperatures
  - Municipal water inlet temperatures

- Simulates as-installed field conditions in controlled lab setting

- Can compare performances of different systems on equal footing
As-Installed Controlled Conditions
Competitive Performance

- Test systems against as-installed space and water heating loads typical to residential applications.
- Conduct tests under controlled conditions in the laboratory where as-installed conditions can be consistently replicated.

<table>
<thead>
<tr>
<th>System</th>
<th>Type</th>
<th>Space Heating</th>
<th>Water Heating</th>
</tr>
</thead>
<tbody>
<tr>
<td>BL</td>
<td>Gas</td>
<td>Conventional Forced-air Furnace</td>
<td>Conventional Storage Water Heater</td>
</tr>
<tr>
<td>1</td>
<td>Gas</td>
<td>Condensing Forced-air Furnace</td>
<td>E-star Storage Water Heater</td>
</tr>
<tr>
<td>2</td>
<td>Gas</td>
<td>Tankless* + Hydronic Furnace</td>
<td>Tankless* Water Heater</td>
</tr>
<tr>
<td>3</td>
<td>Gas</td>
<td>Absorption GHP + Hydronic Furnace</td>
<td>Tankless* Water Heater</td>
</tr>
<tr>
<td>4</td>
<td>Gas/Electric</td>
<td>Hybrid EHP + Tankless* + Hydronic Furnace</td>
<td>Tankless* Water Heater</td>
</tr>
<tr>
<td>5</td>
<td>Electric</td>
<td>Traditional EHP</td>
<td>Resistance Water Heater</td>
</tr>
<tr>
<td>6</td>
<td>Electric</td>
<td>Traditional EHP</td>
<td>EHP Water Heater</td>
</tr>
</tbody>
</table>
Zero Energy Ready Homes

➢ Technology solution
  – High efficiency space and DHW
  – Minimizes fossil fuel
  – Can integrate solar thermal

➢ Business solution
  – Some gas utilities no longer offering residential, high efficiency, stand-alone water heater incentives because TRCs too low
  – Combi systems can raise water heating efficiencies along with space heating efficiencies
  – Builders need only install one system – saves space and installation costs
Questions?