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Progress On Improved Testing and Rating Standards for Combination Space and Domestic Water Heating

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Definition:

- **Combined space and water heating system ("combo")** — a product or a group of individual components that form an integrated system that is designed to provide space heating and water heating.
- **Note:** We discourage the use of "Combos" based on non-condensing tank water heaters + fan coils.

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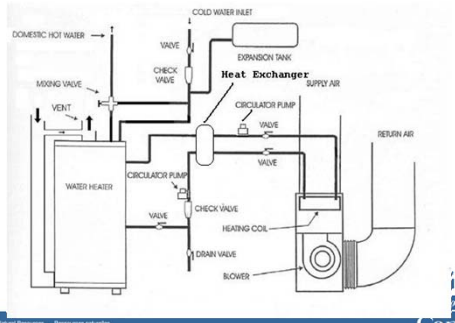
Combination System Layout

- Segregated Space & DHW Heating



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Why Build a Combination System?

- **Integrating the space & water heating functions can lead to synergistic efficiency benefits.**
- **As space heating loads drop, the water heating load becomes more significant; with EE housing, overall the two loads become comparable**
- **The combination and flexibility offered with the two loads can allow for the technology to be suitable for low energy or near net-zero housing.**
- **Venting & gas/fuel connections are simplified resulting in a compact, potentially lower cost, installation.**

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Test Methods Available

In North America there are two* test Methods Available:

- ASHRAE 124 – 2007
  - Covers Gas, Oil & Electric, Forced Air & Hydronic.
  - Yields a Combined Annual Efficiency (CAE)
- CSA P.9 – 2011
  - Covers Gas & Oil, Forced Air only.
  - Yields a Thermal Performance Factor (TPF)

* There is also ASHRAE 206.

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Differences Between the Two Test Methods

With ASHRAE 124 :

- there is no way to assess the combined performance, i.e. Testing a combo as an operating system, not individual components.
- Combo may be rated under unrealistic conditions.
- Test does not evaluate the complete system and recognize performance interactions and synergies
  - Smart integration
  - Advanced controls

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Differences Between the Two Test Methods

With CSA P.9 :

- Doesn't force set points, which allow manufacturers to be creative with controls.
- Tests and rates at the conditions in which the system operates, as opposed to being tested to current test methods that are strictly applicable to that component.
- Two Part load efficiencies in space heating mode (plus maximum input rate).
- Separate combined duty test.

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The CSA P.9 in More Detail

System Categories:

- **Type A System**: a combo with a fixed capacity for space heating;
- **Type B System**: a combo equipped with controls that automatically adjust the space heating capacity based on the space heating load; and
- **Type C System**: a combo with a thermal storage tank or equivalent that decouples the space heating load from the burner control.

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The CSA P.9 in More Detail

Currently does not apply to:

- Hydronic distribution (Future work for P.9)
- Electric and solar-based combo systems;
- Not test-verified for oil yet.
- solid-fuel-based combo systems; and
- multi-family dwellings with a central heating plant

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The CSA P.9 in More Detail

- Overall performance factor needs to aggregate performance in each operating condition
- Consistent set-ups required and equipment functions need to be fully operational during all tests
- Controls need to be operational during performance testing
- Space heating needs to include (weighted) part-load fractions

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P.9 Performance Descriptors

- Thermal Performance Factor (TPF)
- Composite Space Heating Efficiency (CSHE)
- Water Heating Performance Factor (WHPF)
- 1 hr Water Delivery Rating (OHR)

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Space Heating Performance

- Input-Output air enthalpy approach
- Part load testing and rating based on load-weighted performance measurements
- Part load space heating cyclic tests
  15%, 40% and Full load output,
- CSHE =0.1xEff(100%)+0.6xEff(40%)+0.3xEff(15%)
- Takes into account the energy input delivered to the airstream (excludes casing/pipe losses)

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Water Heating Performance

- Water enthalpy method (energy out / energy In)
- 24 hr simulated use test and recovery efficiency
- Combo capacity as a water heater determined and reported as a one (first) hour rating
- Additional capacity testing done with and without concurrent calls for space heating (Combined operation)
- Same as CSA P.3, ASHRAE 118.2, or US DOE EF test.

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Overall Performance Rating

Thermal Performance Factor (TPF)

$$TPF = \frac{2000H_{CAP} + 4400}{[2000H_{CAP}/CSHE] + [4400/WHPF]}$$

2000 = an annualized aggregate rating of the number of full-load operating hours of the combo in space heating mode, h

HCAP = full-load space heating system output, kW (Btu/h)

4400 = annual domestic hot water draw load based on the standardized water heating simulated use test (SUT), kWh (Btu)

CSHE = composite space heating efficiency

WHPF = water heating performance factor

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The ASHRAE 124 in a Nutshell

- Uses ASHRAE 103 to test Hot Water Generator as a boiler to get $Effy_{hs}$ = space-heating seasonal efficiency (%) under fixed test conditions.
- Tests at minimum and maximum heat input.
- Uses ASHRAE 118.2 (or 118.1) to establish water heating efficiency (EF).
- Uses weighting factors based on: the temp. base for HDD = 65° F, US ave. outdoor temp. over heating season = 42° F, US ave. outdoor heating design temp. = 5° F, oversize fraction = 0.7 and the ratio of energy delivered in hot water to the maximum possible energy use per day.

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The ASHRAE 124 in a Nutshell

Combined Annual Efficiency, CAE

$$CAE = \frac{[(SHF \times Effy_{hs}/100) + (WHF \times Effy_{ss}/100) + (R \times NHF \times EF)]}{[(SHF) + (WHF) + (R \times NHF)]}$$

Where:
SHF = Space Heating Factor
WHF = Heating Season Water Heating Factor
NHF = Non-Heating Season Water Heating Factor
EF = Water Heater Energy Factor
$Effy_{hs}$ = Space-Heating Seasonal Efficiency
$Effy_{ss}$ = Steady State Space-Heating Efficiency
R = ratio of non-heating-season days to heating-season days

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Technologies tested?

- **Combo 1:** Power vented non-condensing storage WH coupled with (48,000 Btu/h) air handler with ECM motor. (40 MBtu/h input / 50 US Gal.)
- **Combo 2:** Power vented condensing commercial storage WH coupled with same air handler as Combo 1. (76 MBtu/h input / 50 US Gal.)
- **Combo 4:** Manufactured unit, Condensing low mass boiler / 25 to150 MBtu/h input plus fan coil with ECM motor, Modulating, and DHW Priority.

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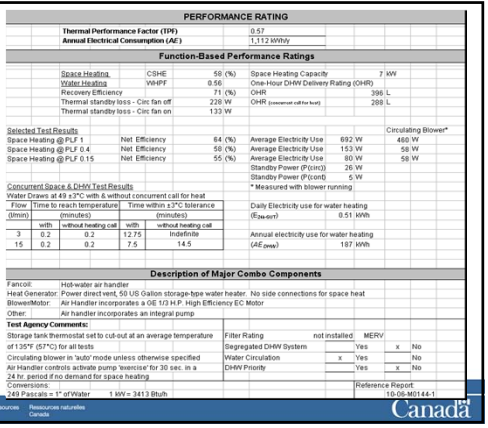

PERFORMANCE RATING

Thermal Performance Factor (TPF)			0.57			
Annual Electrical Consumption (AE)			1,112 kWh/y			
Function-Based Performance Ratings						
Space Heating	CSHE	59 (%)	Space Heating Capacity		7 kW	
Water Heating	WHPF	0.56	One-Hour DHW Delivery Rating (OHR)			
Recovery Efficiency		71 (%)	OHR		396 L	
Thermal standby loss - Circ fan off		228 W	OHR (concurrent call for heat)		288 L	
Thermal standby loss - Circ fan on		133 W				
Selected Test Results					Circulating Blower*	
Space Heating @ PLF 1	Net Efficiency	64 (%)	Average Electricity Use	692 W	460 W	
Space Heating @ PLF 0.4	Net Efficiency	59 (%)	Average Electricity Use	153 W	58 W	
Space Heating @ PLF 0.15	Net Efficiency	55 (%)	Average Electricity Use	80 W	58 W	
			Standby Power (P(circ))	26 W		
			Standby Power (P(cont))	5 W		
			* Measured with blower running			
Concurrent Space & DHW Test Results						
Water Draws at 49 ±3°C with & without concurrent call for heat						
Flow (l/min)	Time to reach temperature (minutes)		Time within ±3°C tolerance (minutes)			
	with	without heating call	with	without heating call		
3	0.2	0.2	12.75	Indefinite		
15	0.2	0.2	7.5	14.5		
				Daily Electricity use for water heating (E_{Dd-SHT})	0.51 kWh	
				Annual electricity use for water heating (AE_{DHW})	187 kWh	
Description of Major Combo Components						
Fancoil:	Hot-water air handler					
Heat Generator:	Power direct vent, 50 US Gallon storage-type water heater. No side connections for space heat					
Blower/Motor:	Air Handler incorporates a GE 1/3 H.P. High Efficiency EC Motor					
Other:	Air handler incorporates an integral pump					
Test Agency Comments:						
Storage tank thermostat set to cut-out at an average temperature of 135°F (57°C) for all tests			Filter Rating	not installed	MERV	
			Segregated DHW System		Yes x No	
Circulating blower in 'auto' mode unless otherwise specified			Water Circulation	x	Yes No	
Air Handler controls activate pump 'exercise' for 30 sec. in a 24 hr. period if no demand for space heating			DHW Priority		Yes x No	
Conversions:					Reference Report	
249 Pascals = 1" of Water	1 kW = 3413 Btu/h				10-06-M0144-1	

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PERFORMANCE RATING

Thermal Performance Factor (TPF)		0.68	
Annual Electrical Consumption (AE)		813 kWh/y	

Function-Based Performance Ratings

Space Heating	CSHE	67	(%)	Space Heating Capacity	7	kW
Water Heating	WHPF	0.72		One-Hour DHW Delivery Rating (OHR)		
Recovery Efficiency		85	(%)	OHR	548	L
Thermal standby loss - Circ fan off		129	W	OHR (conserver coil for heat)	491	L
Thermal standby loss - Circ fan on		108	W			

Selected Test Results				Circulating Blower*
Space Heating @ PLF 1	Net Efficiency	76	(%)	456 W
Space Heating @ PLF 0.4	Net Efficiency	69	(%)	54 W
Space Heating @ PLF 0.15	Net Efficiency	61	(%)	49 W

Average Electricity Use	591	W	
Average Electricity Use	117	W	
Average Electricity Use	57	W	
Standby Power (P(circ))	24	W	
Standby Power (P(cont))	4	W	

* Measured with blower running

Concurrent Space & DHW Test Results

Water Draws at 49 ±3°C with & without concurrent call for heat

Flow (l/min)	Time to reach temperature (minutes)		Time within ±3°C tolerance (minutes)	
	with	without heating call	with	without heating call
3	0.2	0.2	Indefinite	Indefinite
15	0.2	0.2	6.7	11.1

Daily Electricity use for water heating (E_{DH-OUT}) 0.3 kWh

Annual electricity use for water heating (AE_{DWH}) 110 kWh

Description of Major Combo Components

Fancoil:	Hot-water air handler
Heat Generator:	Power vent, condensing, 50 US Gallon storage-type water heater. Side connections for space heat.
Blower/Motor:	Air Handler incorporates a GE 1/2 H.P. High Efficiency EC Motor
Other:	Air handler incorporates an integral pump

Test Agency Comments:

Storage tank thermostat set to cut-out at an average temperature of 135°F (57°C) for all tests

Circulating blower in 'auto' mode unless otherwise specified

Air Handler controls activate pump 'exercise' for 30 sec. in a 24 hr. period if no demand for space heating

Filter Rating	not installed		MERV	
Segregated DHW System		Yes	x	No
Water Circulation	x	Yes		No
DHW Priority		Yes	x	No

Conversions: 249 Pascals = 1" of Water 1 kW = 3413 Btu/h

Reference Report: 10-06-M0144-2

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PERFORMANCE RATING

Thermal Performance Factor (TPF)	0.83
Annual Electrical Consumption (AE)	1173 kWh/y

Function-Based Performance Ratings

Description of Major Combo Components

Commercially available packaged combo system

GE 3/4 H.P. High Efficiency EC Motor

Grundfos UP15-42 Pump

Honeywell AM-1 Series Thermostatic Mixing Valve

Test Agency Comments:

All tests performed at 'Heat Profile 1' (PF1) setting on Fan Control

Fan Control 'Storage Feature Timer' set to OFF

Circulating blower in 'auto' mode unless otherwise specified

Venting: Intake - 27 equivalent feet, 3" ABS pipe + terminal

Exhaust - 30 equivalent feet, SW36' pipe + terminal

Conversions: 249 Pascals = 1" of Water 1 kW = 3413 Btu/h

Filter Rating	not installed		MERV	
Segregated DHW System	x	Yes		No
Water Circulation		Yes		No
DHW Priority	x	Yes		No

Reference Report: 10-06-M0144-3

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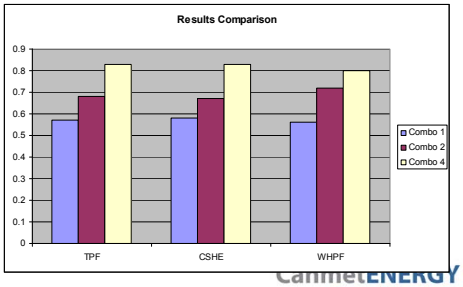
Lab. Test Results



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Combination System Performance

Lets Look at Some Field Test Results

The Canadian Centre For Housing Technology (CCHT)

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Combination System Performance

Testing at the CCHT

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Combination System Performance

Rating Performance

ASHRAE 124 CAE Values

Reference System (Estimated) = 85 %

Combo 1 = 74%

Combo 2 = 85%

Combo 3 = 76%

The ASHRAE 124 is currently being revised

Note that the CAE is weighted heavily towards the space heating efficiency and in this case it does not accurately reflect the superior performance of the Condensing Furnace for space heating.

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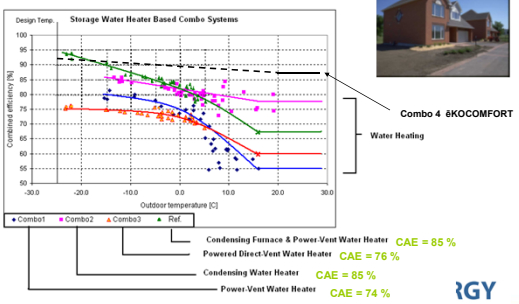
Combination System Performance

Testing at the CCHT



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Combination System Performance

P.9 Results

Testing on 3 combination systems has been conducted:

(1) A combination system based on a water Heater having a recovery efficiency of 71 % - Similar to Combo 1;
TPF = 0.57

(2) A combination system based on a water Heater having a recovery efficiency of 90 % - Similar to Combo 2; and
TPF = 0.68

(4) A packaged eKocomfort combination system with a steady state efficiency of 95%.
TPF = 0.83

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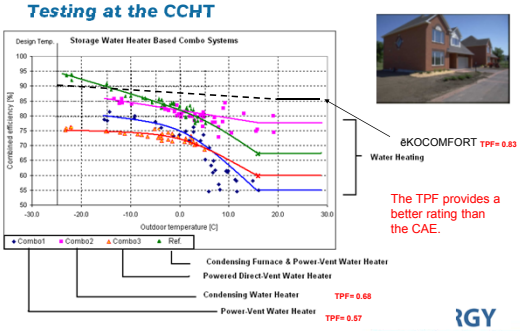
Combination System Performance

Testing at the CCHT



The TPF provides a better rating than the CAE.

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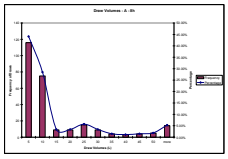
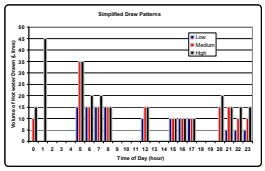
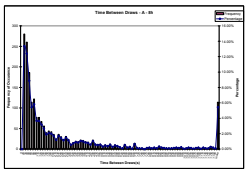
Combination System Performance





Next Steps

The water heating portion of the test needs to be revised to reflect current "Real Use".



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Combination System Performance

Next Steps

(1) The ASHRAE 124 is currently being reviewed with a view to making some improvements

(2) It is possible that we could take elements from the CSA P.9 and incorporate them into the ASHRAE 124 and also develop a suitable test for under-floor or radiator based hydronic heating systems, that could be added to the CSA P.9

(3) We are also considering modifying the draw schedule for water heating to more properly reflect today's reality of hot water use (in CSA P.3 & ASHRAE 118.2).

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Next Steps

- Further testing of different heat generators:
  - Tankless water heater
  - Condensing tankless water heater
  - Boilers, including Oil
  - Oil storage water heaters
- Inclusion of test for hydronic distribution systems

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QUESTIONS

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