the Energy to Lead

High-Efficiency Heating Rooftop Units (RTUs) – The Final Frontier for Condensing Gas Furnaces

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gti

Presenter

- Douglas Kosar
  Senior Institute Engineer
  Gas Technology Institute
- 30+ years experience introducing new technologies to buildings
- Last 5 years working to introduce condensing heating RTUs through
  - product R&D w/manufacturers
  - national account/other end user pilots
  - Consortium for Energy Efficiency (EE) & utility EE Program deployments

Source: GTI

Presentation Goals

- Recognize the diversity in a given commercial building of individual RTU heating runtime/gas use
- Apply higher efficiency heating RTUs in the most cost effective commercial building applications
- Review the latest pilot project issues and results
- Understand handling of RTU combustion condensate, especially in cold climates
- Recognize other commercial heating product categories with emerging condensing options

Presentation Agenda –
35 minute presentation/10 minute Q&A

- Individual RTU heating runtimes on a building
- Initial ventilation markets for condensing heating
  - Dedicated Outside Air Systems (DOAS), for example
- Condensing DOAS pilot in big-box retail stores
  - Net operating energy and cost savings, w/fan penalty
  - Added neutralizer maintenance cost, if code required
  - Condensing heating equipment cost premiums
  - Combustion condensate system installation and costs
  - Combustion condensate management practices
- More condensing heating products in our future

Setting the Stage for Condensing RTUs

- High efficiency, condensing heating RTUs are entering the commercial marketplace, BUT …
- Lack of non-condensing RTU heating load data on which to base savings & paybacks for condensing
  - Conflicting DOE & ASHRAE building modeling results
  - No RTU by RTU datasets for given building types
- So monitoring undertaken of 107 RTUs/11 buildings
  - Current switch/logger timestamps gas valve runtime, nameplate rating provides gas use
  - 1 small office, 3 restaurants, 3 drug stores, 3 clothing & home goods stores, & 1 “big box” retail store

GTI Baseline Monitoring in the Field of Non-Condensing RTUs

- **1 small office**
- 3 quick service restaurants
- **3 drug/convenience stores**
- 3 clothing/home goods stores
- **1 retail "super" store**

Source: GTI

Heating Runtime & Gas Use Diversity

- Perimeter RTUs w/longer runtimes while core RTUs w/shorter runtimes (in general, excess core RTU capacity increases w/area of building)
- HI heat sees limited use – can benefit from 2 stage fan to reduce fan energy penalty in LO heat

Perimeter RTUs (1, 2, 3, & 5)
Core RTUs (4 & 6)

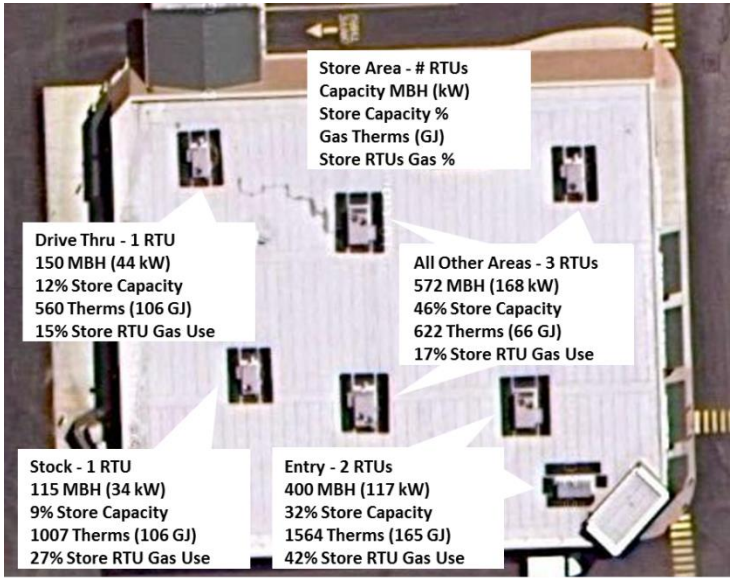
SMALL OFFICE

Source: GTI

Usage Pattern & Excess Capacity

- Entry, stock, & drive-thru RTUs see high use pattern that is repeated across “identical” stores
- One “identical” store halved its installed heating capacity and had no HI heat use increase

DRUG STORE



Source: GTI

Dedicated Outside Air System (DOAS)

- Condition 100% OA for building ventilation
- DOAS in retail stores (open 24/7) exhibit highest heating loads & longest runtimes for RTUs
- Focus of follow-on condensing RTU demo

"BIG BOX" RETAIL STORE

Source: GTI

Key Takeaways So Far

- Very diverse heating runtimes for RTUs on a given building, but patterns emerge
  - Perimeter zone RTUs see longer runtimes and interior zone RTUs see shorter runtimes
  - RTU layouts in “identical” buildings show consistency in RTU runtime patterns with opportunity for selective higher efficiency heating upgrades for high runtime RTUs
- DOAS (or other high ventilation/make-up air fraction RTUs) exhibit highest heating/gas loads and present the most promising early market entry point for condensing RTUs

Condensing Heating DOAS Pilots in Big Box Retail Stores in IL and MN

- Nicor Gas ETP
  - Baseline Winter 2010/2011 tests at IL store led to DOAS focus
  - Condensing DOAS tests Winter 2012/2013 with annual savings of ~2400 therms per DOAS
- GTI NA ETP Collaborative
  - Condensing DOAS tests began 3/2013 at MN store and continue through Winter 2013/2014
  - Projected annual therm savings are similar but smaller due to differences in control schemes

Source: GTI

Pilot Project Installations

- 3 step condensing heating module retrofit process early Oct 2012 (Nicor Gas ETP)/Mar 2013 (NA ETP)
  1. Installation of condensate piping with neutralizer
  2. Replacement of non-condensing heating modules
  3. Completion of data acquisition system

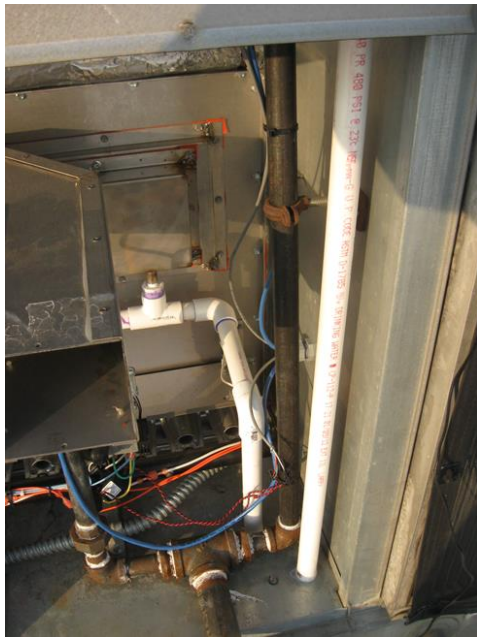
Source: GTI

Combustion Condensate System – *from DOAS …*

- Plumbing slope minimum between condensate ports of heating module
- Then vertical drop thru RTU base to conditioned space
- Trap inside the conditioned space before run to sanitary drain

To heat tape
or
not to heat tape …
that is the question!

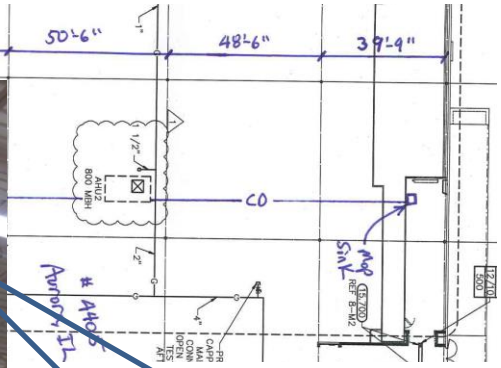
Ensure heating module design avoids standing condensate and maintains water tight gasket connections!



Source: GTI

Combustion Condensate System – *… to Sanitary Drain*

- Long runs to code required sanitary drain disposal
- Acidic condensate neutralization is limited local code issue presently
  - Well established neutralizers from condensing boilers
  - Annual/2 year maintenance



Take advantage of roof deck plumbing slope for condensate line!

Replenish neutralizer calcium carbonate when outlet pH drops below 5.5!

Source: GTI

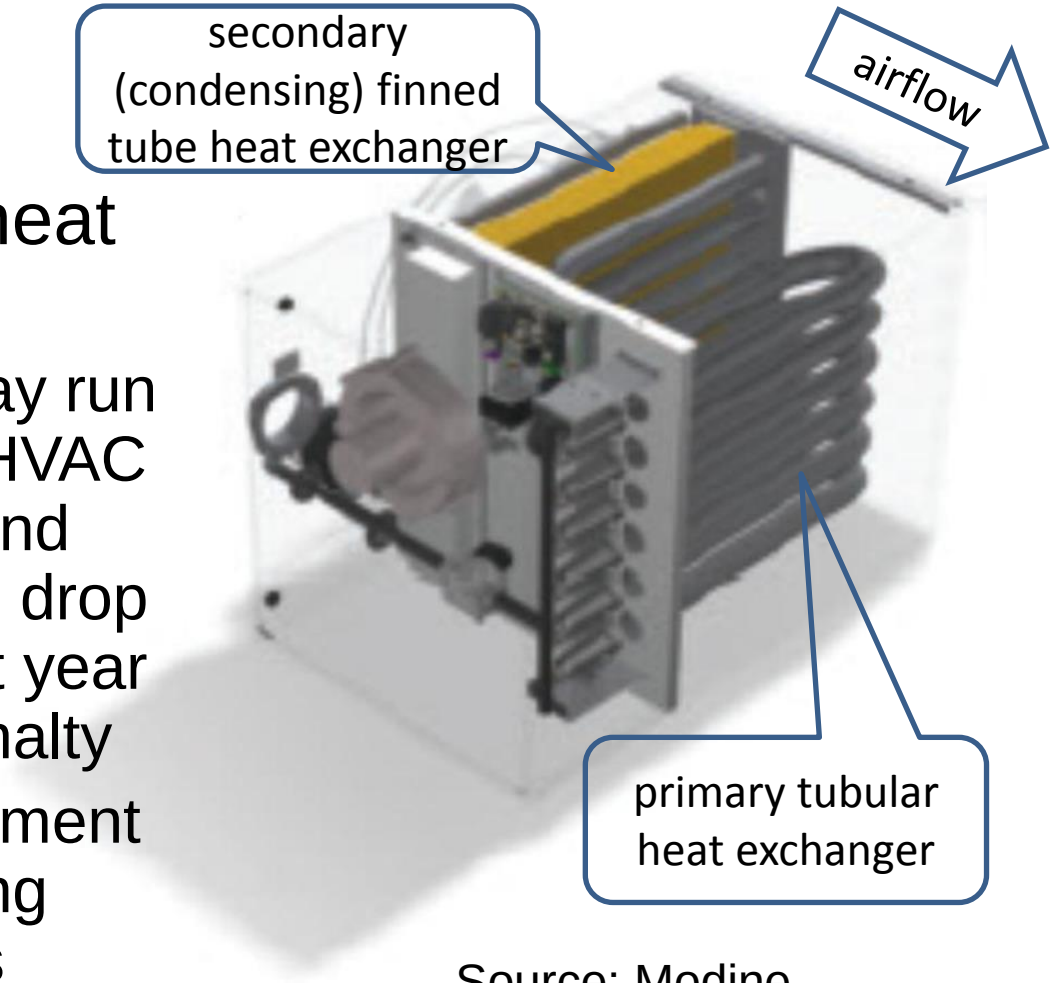
DOAS Heating Module Retrofit

> Two (2) DOAS with two (2) heating modules each

Source: GTI

Condensing Heating Module

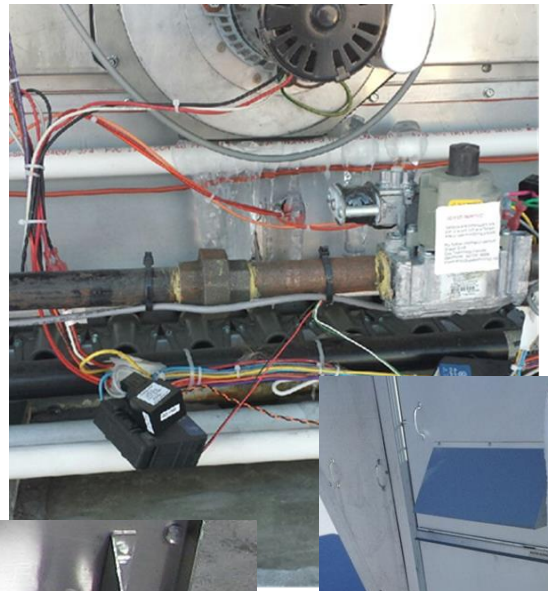
- RTUs fundamentally scale up residential condensing furnace heat exchangers, but
  - RTUs supply fans may run continuously during HVAC operating schedule and incremental pressure drop can create significant year round fan energy penalty
  - Condensate management must consider freezing rooftop environments

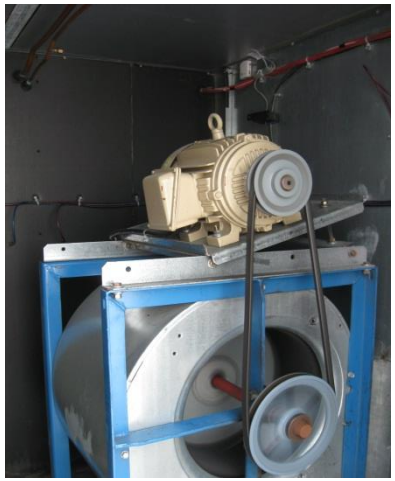


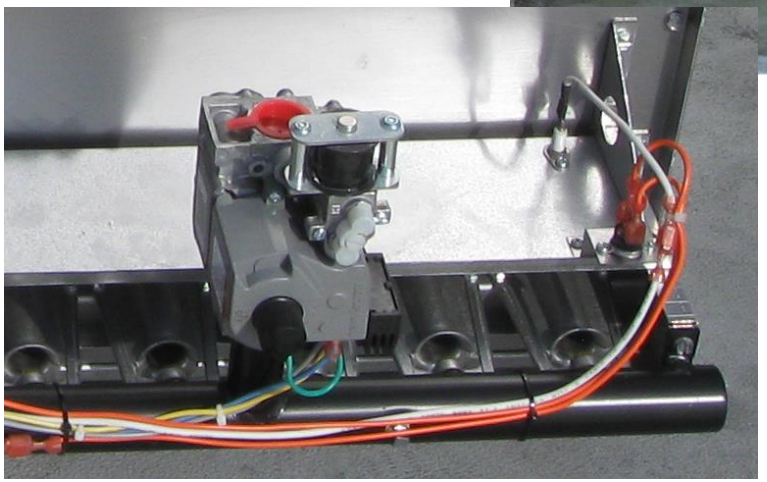
Source: Modine

MN Store Pilot Issues this Winter

- **Condensate leakage**
- **Flue icing buildup**
- Burner flame rollout fault
- Supply fan kWh increase (slipping belt replacement)







Source: GTI

Condensate Leakage

- Combustion fan gasket leakage detected & DOAS shutdown 12/16-18/13
- Gasket replaced 1/13/14 and no further leakage has been detected since
- Even w/OA temperatures below design conditions drain line has not frozen even though no external heat applied to PVC pipes

Source: GTI

Icing at Flues is Typical in Operation

Residential Condensing
Furnace Flue in MN

Big Box Retail Store Condensing
DOAS Flues in MN

Source: GTI

DOAS Operating Cost Savings – *MN Store 7/23/13 – 3/31/14*

Per **RAW** data, gas savings 1800 therms (11%) with 940 kWh added fan electricity for net energy savings of $1084 @ $0.65/therm gas & $0.08/kWh electricity

Condensing Heating RTU Retrofit of DOAS (Munters HCU) at Target Store, Medina, MN | input cells | update cell range

Cumulative

Usage Date			Gas Heat		Supply Fan Electricity		Gas Usage Decrease		Electricity Increase		Net Savings
7/23/2013	through	3/31/2014	Cumulative		Cumulative		Cumulative		Cumulative		Cumulative
		HDD	ft3	therms	kWh		therms	$	kWh	$	$
		7925	1419804	14397	8812		1800	1163.26	940	78.76	1084.50

Daily

								Gas Usage Decrease from Baseline TE		Electricity Increase @ cfm of 6000 fan/motor η 0.6 @ΔP of 0.15		
			KMIC	Gas	@	Supply Fan	Fan Runtime	80%				
Reading Date	Reading Time	Usage Date	Crystal Airport	Heat Daily	1014 Btu/ft^3	Electricity Daily	Fraction Daily	to Condensing TE 90%	$0.6464 $/therm	$0.0838 $/kWh		Net Savings
MM/DD/YYYY	HH:MM:SS	MM/DD/YYYY	HDD65	ft3	therms	kWh	0.00 to 1.00	therms	$	kWh	$	$
3/25/2014	0:00:00	**3/24/2014**	43.0	7733	78.41	45.58	1.00	9.80	$6.34	4.23	$0.35	$5.98
3/26/2014	0:00:00	**3/25/2014**	47.9	8015	81.27	46.28	1.00	10.16	$6.57	4.23	$0.35	$6.21
3/27/2014	0:00:00	**3/26/2014**	37.9	7334	74.37	45.54	1.00	9.30	$6.01	4.23	$0.35	$5.65
3/28/2014	0:00:00	**3/27/2014**	28.9	6159	62.45	42.94	1.00	7.81	$5.05	4.23	$0.35	$4.69
3/29/2014	0:00:00	**3/28/2014**	33.9	7111	72.11	44.82	1.00	9.01	$5.83	4.23	$0.35	$5.47
3/30/2014	0:00:00	**3/29/2014**	32.7	7129	72.29	44.72	1.00	9.04	$5.84	4.23	$0.35	$5.49
3/31/2014	0:00:00	**3/30/2014**	17.9	3180	32.25	43.82	1.00	4.03	$2.61	4.23	$0.35	$2.25
4/1/2014	0:00:00	**3/31/2014**	16.4	3222	32.67	43.47	1.00	4.08	$2.64	4.23	$0.35	$2.29

Source: GTI

DOAS Net Operating Cost Savings – *for IL Store Annually*

Gas savings 2400 therms (11%) with 1285 kWh of added fan electricity for an annual net energy savings of $1444 @ $0.65/therm gas and $0.09/kWh electricity

High Efficiency DOAS Net Operating Cost Savings

Assumptions		inputs		Net Annual Energy Cost Savings		positive		negative								
						Electricity										
Heating Module						($/kWh)										
Capacity Btu/hr Out	640,000	187.6	kw			**0.05**	**0.06**	**0.07**	**0.08**	**0.09**	**0.10**	**0.11**	**0.12**	**0.13**	**0.14**	**0.15**
Base AFUE/TE	80%			**Gas Cost**	**0.50**	1,135.74	1,122.89	1,110.04	1,097.18	1,084.33	1,071.48	1,058.63	1,045.77	1,032.92	1,020.07	1,007.22
Base Btu/hr In	800,000	234.5	kw	**($/therm)**	**0.55**	1,255.74	1,242.89	1,230.04	1,217.18	1,204.33	1,191.48	1,178.63	1,165.77	1,152.92	1,140.07	1,127.22
High Efficiency AFUE/TE	90%			X	**0.60**	1,375.74	1,362.89	1,350.04	1,337.18	1,324.33	1,311.48	1,298.63	1,285.77	1,272.92	1,260.07	1,247.22
High Efficiency Btu/hr In	711,111	208.4	kw	9.479	**0.65**	1,495.74	1,482.89	1,470.04	1,457.18	1,444.33	1,431.48	1,418.63	1,405.77	1,392.92	1,380.07	1,367.22
Heating Full Load Operating Hours/Yr	2700			($/GJ)	**0.70**	1,615.74	1,602.89	1,590.04	1,577.18	1,564.33	1,551.48	1,538.63	1,525.77	1,512.92	1,500.07	1,487.22
					0.75	1,735.74	1,722.89	1,710.04	1,697.18	1,684.33	1,671.48	1,658.63	1,645.77	1,632.92	1,620.07	1,607.22
Base therms/yr	21,600	2278.8	GJ/yr		**0.80**	1,855.74	1,842.89	1,830.04	1,817.18	1,804.33	1,791.48	1,778.63	1,765.77	1,752.92	1,740.07	1,727.22
High Efficiency therms/yr	19,200	2026	GJ/yr		**0.85**	1,975.74	1,962.89	1,950.04	1,937.18	1,924.33	1,911.48	1,898.63	1,885.77	1,872.92	1,860.07	1,847.22
Site Gas Savings therms/yr	2,400	253	GJ/yr		**0.90**	2,095.74	2,082.89	2,070.04	2,057.18	2,044.33	2,031.48	2,018.63	2,005.77	1,992.92	1,980.07	1,967.22
Source Savings MMBtu/yr	245	258	GJ/yr		**0.95**	2,215.74	2,202.89	2,190.04	2,177.18	2,164.33	2,151.48	2,138.63	2,125.77	2,112.92	2,100.07	2,087.22
		(x 1.02 site to source)			**1.00**	2,335.74	2,322.89	2,310.04	2,297.18	2,284.33	2,271.48	2,258.63	2,245.77	2,232.92	2,220.07	2,207.22
Supply Fan					**1.05**	2,455.74	2,442.89	2,430.04	2,417.18	2,404.33	2,391.48	2,378.63	2,365.77	2,352.92	2,340.07	2,327.22
Fan CFM	5000	2360	L/s		**1.10**	2,575.74	2,562.89	2,550.04	2,537.18	2,524.33	2,511.48	2,498.63	2,485.77	2,472.92	2,460.07	2,447.22
Added Fan Δ P inch WG	0.15	37.35	Pa		**1.15**	2,695.74	2,682.89	2,670.04	2,657.18	2,644.33	2,631.48	2,618.63	2,605.77	2,592.92	2,580.07	2,567.22
Fan&Motor Efficiency	0.6				**1.20**	2,815.74	2,802.89	2,790.04	2,777.18	2,764.33	2,751.48	2,738.63	2,725.77	2,712.92	2,700.07	2,687.22
Added kW	0.15				**1.25**	2,935.74	2,922.89	2,910.04	2,897.18	2,884.33	2,871.48	2,858.63	2,845.77	2,832.92	2,820.07	2,807.22
Fan Operating Hours/Yr	8760				**1.30**	3,055.74	3,042.89	3,030.04	3,017.18	3,004.33	2,991.48	2,978.63	2,965.77	2,952.92	2,940.07	2,927.22
					1.35	3,175.74	3,162.89	3,150.04	3,137.18	3,124.33	3,111.48	3,098.63	3,085.77	3,072.92	3,060.07	3,047.22
Site Added Fan kWh/yr	1285				**1.40**	3,295.74	3,282.89	3,270.04	3,257.18	3,244.33	3,231.48	3,218.63	3,205.77	3,192.92	3,180.07	3,167.22
Source Added MMBtu/yr	14	15	GJ/yr		**1.45**	3,415.74	3,402.89	3,390.04	3,377.18	3,364.33	3,351.48	3,338.63	3,325.77	3,312.92	3,300.07	3,287.22
		(x 3.16 site to source)			**1.50**	3,535.74	3,522.89	3,510.04	3,497.18	3,484.33	3,471.48	3,458.63	3,445.77	3,432.92	3,420.07	3,407.22

Source: GTI

DOAS Payback Economics – *for IL Store*

Based on installed cost premium of $6085 for condensing DOAS and condensate system, plus a projected annual neutralizer maintenance cost of $65 for calcium carbonate replenishment, a simple payback of 4.4 years is estimated

High Efficiency Heating Module DOAS Paybacks

Assumptions			Payback in Years											
Condensing Heating Module and Condensate Piping and Nuetralizer					Electricity ($/kWh)									
					0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15
			Gas Cost	0.50	5.7	5.7	5.8	5.9	6.0	6.0	6.1	6.2	6.3	6.4	6.4
New Contruction Installed Equipment Cost	$	6,069	($/therm)	0.55	5.1	5.2	5.2	5.3	5.3	5.4	5.4	5.5	5.6	5.6	5.7
				0.60	4.6	4.7	4.7	4.8	4.8	4.9	4.9	5.0	5.0	5.1	5.1
Annual Neutralizer Maintenance Cost	$	65		0.65	4.2	4.3	4.3	4.4	4.4	4.4	4.5	4.5	4.6	4.6	4.7
				0.70	3.9	3.9	4.0	4.0	4.0	4.1	4.1	4.2	4.2	4.2	4.3
				0.75	3.6	3.7	3.7	3.7	3.7	3.8	3.8	3.8	3.9	3.9	3.9
				0.80	3.4	3.4	3.4	3.5	3.5	3.5	3.5	3.6	3.6	3.6	3.7
				0.85	3.2	3.2	3.2	3.2	3.3	3.3	3.3	3.3	3.4	3.4	3.4
				0.90	3.0	3.0	3.0	3.0	3.1	3.1	3.1	3.1	3.1	3.2	3.2
				0.95	2.8	2.8	2.9	2.9	2.9	2.9	2.9	2.9	3.0	3.0	3.0
				1.00	2.7	2.7	2.7	2.7	2.7	2.8	2.8	2.8	2.8	2.8	2.8
				1.05	2.5	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.7	2.7	2.7
				1.10	2.4	2.4	2.4	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
				1.15	2.3	2.3	2.3	2.3	2.4	2.4	2.4	2.4	2.4	2.4	2.4
				1.20	2.2	2.2	2.2	2.2	2.2	2.3	2.3	2.3	2.3	2.3	2.3
				1.25	2.1	2.1	2.1	2.1	2.2	2.2	2.2	2.2	2.2	2.2	2.2
				1.30	2.0	2.0	2.0	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
				1.35	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
				1.40	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	2.0
				1.45	1.8	1.8	1.8	1.8	1.8	1.8	1.9	1.9	1.9	1.9	1.9
				1.50	1.7	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8

Source: GTI

More Key Takeaways

- Higher RTU runtimes key to generating high net operating cost savings for high efficiency payback
- DOAS provides best early market payback scenario
  - "big box" retail accounts with established DOAS vendors
  - high heating degree day (HDD)/heating load locations
- Mainstream condensing RTU transition hinges on
  - Progressing incremental pressure drop below 0.15"WG
  - Broadening RTU use of staged blowers
  - Achieving consensus on building heating loads

Condensing RTU Market Situation

- Non-major, second tier HVAC companies introducing product lines and provide early market entry point
  - Dedicated outside air systems (DOAS)
  - Applied by some key “big box” retail accounts
- Major HVAC companies on the sidelines for now, but introducing staged blowers that are improving their general outlook on condensing RTU economics
- GTI baseline/pilot testing supports targeting DOAS … but other technologies competing for OA roles
  - Direct fired vs. indirect fired condensing heating
  - Demand control ventilation (DCV)
  - Energy recovery ventilation (ERV)

Current Active Manufacturers

Manufacturer	Availability	Heating Module Specifications w/Hot Link (subject to change)
Engineered Air	now	90%TE, 100 – 1,400 MBH input, 15:1 turndown, 1,000 to 44,000 CFM www.engineeredair.com/index.php/our_products/category/indirect-fired#djx-series (DJX Series products)
Modine	now	90%TE, up to 500 MBH input, 7:1 turndown, up to 12,000 CFM www.modinehvac.com/web/Commercial-HVAC/Commercial-Ventilation-1.htm (Atherion products)
Reznor	now	up to 93% TE, up to 600 MBH package (400MBH split),up to 10:1 from 500 to 11,500 cfm package (6000 cfm split). www.rezspec.com/en/me/all-products (YDMA, YDHA, & YDSA products)
Munters	now	90%TE, up to 800 MBH input, 10:1 turndown, up to 16,000 CFM www.munters.us/en/us/Products--Services/Dehumidification/Energy-Recovery/Packaged-Energy-Recovery1/?Product=87392AFD-C031-4BC7-AED9-65E508651504 (DryCool product literature does not currently show condensing option)

Source: GTI

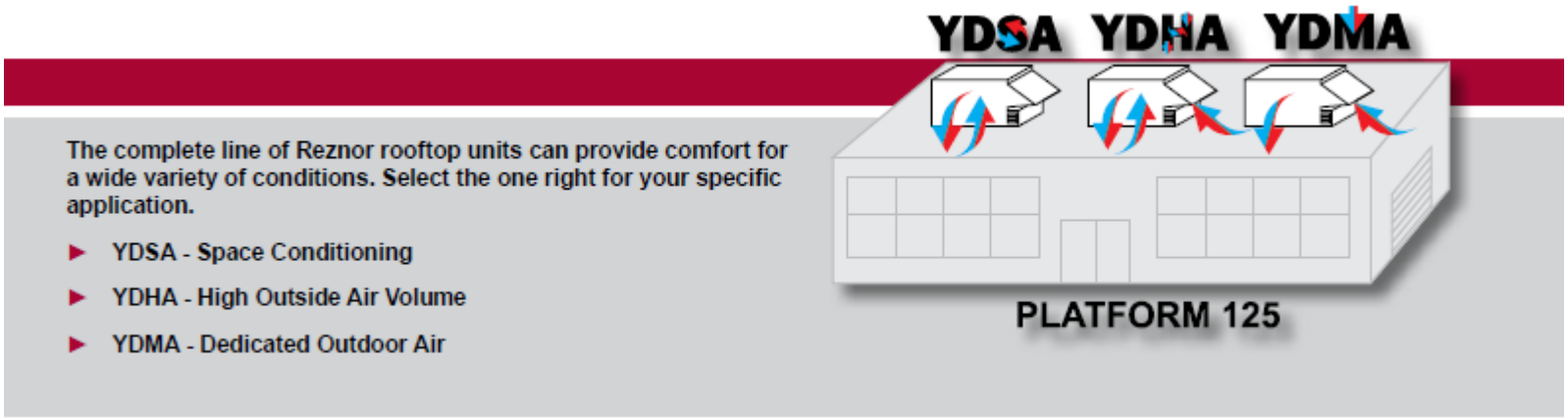
What the Future Holds …

- Condensing heating RTUs
  - challenging market development from 100 to 30% OA
    - with current high equipment cost premiums
    - and low natural gas prices in US/Canada
  - logical market development will see progression in cost effectiveness to lower %OA RTUs over time
  - ≤ 30% OA will need to be competitive w/low-cost, mass-produced, non-condensing efficiency RTUs
- Other commercial (including multi-family) heating products are also going condensing heating
  - even with sustained, lower natural gas prices
  - steady increase in product categories ≥90% AFUE/TE

...

Expanding Condensing RTU Offerings

- One manufacturer responding to the lower OA% challenge by providing condensing heating RTU product lines for the full (100 to 0) %OA spectrum
  - YDMA (~100 to 60% nominally)
  - YDHA (~60 to 30% nominally)
  - YDSA (~30 to 0% nominally)



Source: Reznor

...
Other Condensing Product Offerings

- Duct furnaces
  - stand-alone or
  - furnace for RTU

Source: Heatco

- Unit heaters
  - Manufacturing, warehousing, automotive, retail buildings

Source: Modine

- Wall furnaces/hearths
  - multifamily (rentals), home additions

Source: Empire

- Thru-the-wall furnace/AC
  - multifamily (condos), senior living facilities

Source: Suburban

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Bibliography

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- Kosar, Douglas, et al. 2013. 1001: High Efficiency Heating Rooftop Units (RTUs) Public Project Report. Nicor Gas Emerging Technology Program. www.nicorgasrebates.com/emerging.
- **Look for upcoming *ASHRAE Journal* article on condensing DOAS field test**

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Sponsor Acknowledgements

> Utilization Technology Development (UTD)

www.utd-co.org

> Nicor Gas Emerging Technology Program

www.nicorgasrebates.com/emerging

> GTI North American Emerging Technology Program Collaborative

http://www.gastechnology.org/Expertise/Pages/Emerging-Technology-Program.aspx

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