Once Heated, Twice Used

By David Bohac

A single appliance can efficiently supply hot water for both domestic use and space heating in cold climates, so say test results from multifamily units in Minneapolis. While the price of a "dual-integrated appliance" rivals a separate high-efficiency furnace and a water heater, convenience may be its winning virtue.

Dual-integrated appliances—water heaters used to provide both domestic hot water and space heating—have seen increased use in recent years, primarily in the warmer climates of the mid-Atlantic states. We at the Center for Energy and the Urban Environment (CEUE), along with our local gas utility (Minnegasco), felt that there were appropriate applications in cold climates and carried out a two-year field study of these systems installed in multifamily buildings. We measured the energy savings of dual-integrated appliances while gaining some experience with their use in cold climates.[1]

How Do Dual Appliances Work?

In the systems we installed, the hot water outlet from the heater not only supplies domestic hot water, but also water to an airspace heating coil (see Figure 1).[2] When the thermostat calls for space heat, a pump circulates hot water through the heating coil and returns it to either the cold water inlet or a separate heater inlet. A check valve on the heating coil supply pipe prevents cold water from entering the heating coil when there is a domestic hot water draw in the building. The space heating coil can be located near the heater or in a remote location, and is available in vertical, horizontal, and wall-recessed units.[3] The building thermostat typically activates the space heat blower and circulation pump simultaneously. A time-delay relay can be incorporated in the blower control to reduce the short length of time that cool air is supplied to the heating registers. The heater burner is controlled as it would be for a typical heater, by an aquastat inside the tank. This control scheme differs from that used in a typical boiler system where the pump and burner are both activated by a thermostat. A dual system controls these two components independently, since the water in the heater must always be kept warm for domestic hot water use.

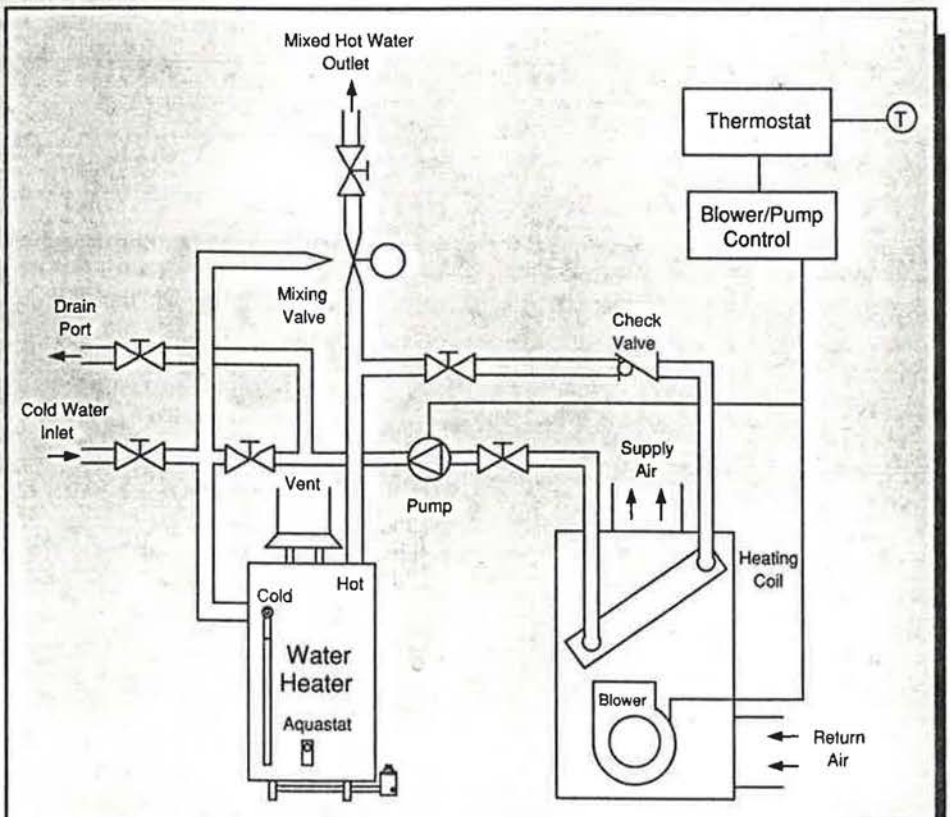


Figure 1. Schematic of typical Dual-Integrated Appliance system.

David Bohac is director of research at the Center for Energy and the Urban Environment in Minneapolis.

This system has the advantage of having off-cycle losses for only one appliance and can operate at a potentially higher energy efficiency than similar yet separate systems. Apart from energy considerations, it has many other advantages compared to separate appliances:

- Side venting and sealed combustion—features that are hard to find in water heater and space heating appliances—are easier to accomplish with a single appliance.
- A horizontally mounted air handler reduces the floor area, or "footprint," required for the mechanical system.
- The heating supply system is easier to zone, and zones are easier to add after the initial installation.
- There is only one combustion appliance to maintain or replace.

Dual-integrated systems, however, are still relatively new and prone to the disadvantages of a new technology: fewer experienced contractors, higher equipment failure rates, and hesitant acceptance by some code officials (see box, "Modernizing Codes").

The systems are generally best suited for buildings with relatively high domestic hot water loads. In these situations, it may not be necessary to significantly increase the heater size from the level that would have been used if it were independent of the water heater. Larger loads on the heater will also usually make it cost-effective to use a more efficient heater.

Availability

Five manufacturers produce 56 heaters that are approved for dual appliances. Of these 56, we found that local distributors stocked only 19. For new and retrofit applications it may be all right to wait four weeks for delivery, but it certainly would not be acceptable to someone whose heater just broke down.

We also wanted to select models that would be at least as efficient as the least efficient separate domestic water heaters and furnaces. Since the minimum Annual Fuel Utilization Efficiency (AFUE) standard for furnaces is now 78%, we felt that the installed heaters should have recovery efficiencies of at least 78%.[4] Of the 56 heaters, 15 feature recovery efficiencies of 78% or above. Only four of these have inputs greater than 40,000 Btu/hr and six are stocked locally.

It is also interesting to note that the majority of the dual appliances have atmospheric burners and require vertical venting. Only 14 of the heaters can be side-vented and six of these have sealed combustion. Of the 15 units with a recovery efficiency over 78%, four can be side-vented and two are power-vented.

Matchmaking: Dwellings and Heaters

Dual-integrated units were installed in five apartments to replace the existing conventional domestic hot water tank heaters and forced air furnaces. We selected these units because they could be heated with commonly sized water heaters and had clean gas-use data. All of the units are in a single, two-story, eight-plex built in the early 1980s. The two larger, three-bedroom apartments (units A and B) have floor areas of 930 ft² and design heat loss rates of 27,000 Btu/hr. The three two-bedroom apartments

Modernizing Codes

When we began our research project, only a few dual-integrated appliance systems had been installed in the Minneapolis metropolitan area, but they were not allowed in the city of Minneapolis itself. This is not an unusual situation. Resistance by code officials to allowing water heaters for space heating can be found in other parts of the United States and in Canada.[1] For example, State of Delaware Department of Public Safety officials initially stated that only appliances meeting the more restrictive American Society of Mechanical Engineers Boiler and Pressure Vessel Code could be used for hydronic space heating. The State of Delaware later rescinded this notice and amended regulations to specifically allow the use of water heaters in dual systems.[2]

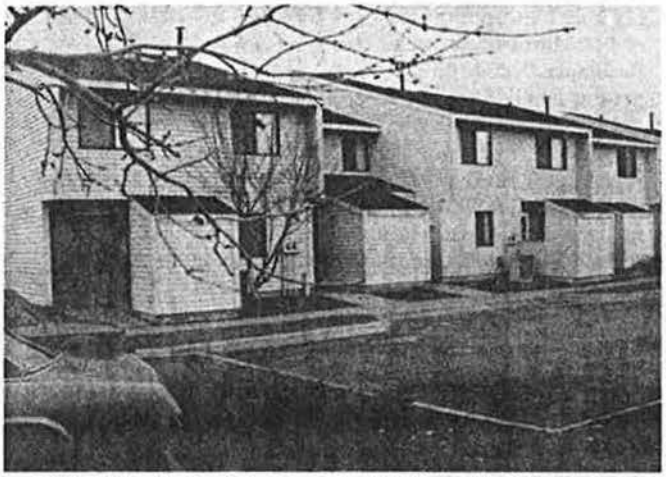
At the heart of this debate are the criteria used to define an appliance as either a water heater or a boiler. One side argues that adding the space heating load to a water heater establishes that the heater is being used as a boiler and must meet boiler specifications. The other side—water heater manufacturers and others—argues that the operating parameters of the appliance (that is, maximum temperature and pressure) define whether the appliance is a water heater or a boiler. They note that, since the operating parameters of the water heater have not changed, the heater should continue to be treated as a water heater. Thus far, the courts have sided with the manufacturers and ruled that heaters used in dual systems do not have to meet boiler specifications.[3]

These systems have become somewhat more acceptable in Minnesota thanks to a recent amendment to the State of Minnesota plumbing code that includes several dual system design guidelines.[4] One of these guidelines requires a drainage port and isolation valves or an automatic purge control on the heating coil loop. This was incorporated to address concerns that Legionella pneumophila could breed in the stagnant water of the heating coil loop (although there have been no reported cases of Legionnaire's Disease involving dual systems). The Minnesota code also requires a mixing valve, which allows the occupant to adjust the domestic hot water supply temperature separate from the tank temperature (see Figure 1).

Another concern was that the increased burner operation would reduce the heater life span. However, field studies conducted in Southern California and Canada have found no evidence of this.[5] In fact, the additional water circulation through the tanks may actually reduce scaling, sediment deposits, and degradation of heater anodes.

Endnotes

1. "Utah Appeals Court Reverses Ruling, *Air Conditioning, Heating & Refrigeration News*, Sept. 23; 1991, p.23. "Water Heater Usage for Space Heating Approved in Wisconsin," *Energy Design Update*, June 1989, p.3; and Thrall, R. and Mayhew, W.J. "Final Report for Field Investigation of Domestic Hot Water Tanks as Space Heating Appliances," Canada Mortgage and Housing Corp., April 25, 1989.
2. State of Delaware Rules and Regulations for Boilers, Pressure Vessels, and Nuclear Installations, 1989. Section XIX.
3. "Utah Appeals Court Reverses Ruling, *Air Conditioning, Heating & Refrigeration News*, Sept. 23, 1991, p.23.
4. State of Minnesota Plumbing Code, 1990. Section 4715.2190.
5. BR Laboratories, "Lemoore Tank Analysis: Multipurpose Appliance." BR Laboratories, Inc., P.O. Box 1249, Huntington Beach, CA 92647, February 20, 1986; and Thrall, R. and Mayhew, W.J., see above.



Mark Hancock

This eight-plex built in the early 1980s provided five apartments for research. Researchers selected these units because they all had clean data on gas use and they could be heated with standard-size water heaters.

(units C, D, and E) have floor areas of 675 ft² and design heat loss rates of 20,000 Btu/hr. All of the units had used the same makes and models of furnaces and water heaters. The furnaces had inputs and outputs of 55,000 and 42,000 Btu/hr, respectively, all with AFUEs of 60.3%. They appeared to be greatly oversized for the building design heat loss, but were probably the smallest furnaces readily available in the Minneapolis metropolitan area at the time they were installed. The water heaters had inputs of 36,000 Btu/hr, storage capacities of 40 gal, and energy factors (EFs) of 0.49.

Selection of the heaters posed somewhat of a dilemma. On one hand, we wanted to match the size of the existing equipment in order to obtain a valid comparison of energy use. Conversely, the existing equipment was obviously oversized, so matching sizes might not have provided a fair test of the savings potential of the new equipment. We settled on a compromise whereby the systems for two of the units, A and B, were designed to approximately match the size of the existing equipment and the other three systems using the design heat loss as a guide.

The systems installed in units A and B are manufactured by Apollo Hydro Heat & Cooling. They feature atmospheric burners vertically vented through the existing chimney. The output of both heating coils closely matches the output of the existing furnace. The output of the heater installed in unit B is about 120% greater than the coil output, but the output for the heater in unit A is slightly less than the coil output (see "Equipment Sizing"). The size for the heater in unit A was smaller than it should have been and somewhat of an oversight. However, we felt that this design would be acceptable due to the greatly oversized heating coil. The installed cost of each of the systems was $2,212. As a comparison, the heating contractor estimated that it would cost approximately $1,750 to install a furnace with an AFUE of 80% and water heater with an EF of 0.5.

We decided to test two, recently available, Mor-Flow Integra systems in units C and D. The heaters have recovery efficiencies of 83%, power-draft burners, and are vented out the side wall. The heating coil outputs are 25% greater than the design heating load and 133% greater than the heater output. The Integras are specifically designed for these applications. The air handler/heating coil is factory-wired and -plumbed and is stacked on top of the heater to minimize the system footprint. The stacked design proved to be a significant advantage for these locations. Previously, a contractor had cut a hole in the hallway wall in order to replace the water heater. Another advantage of the Integra is that side venting in multifamily buildings typically costs less than vertical venting, especially in multiple-story buildings where the furnace closet is next to an outside wall. Unfortunately, in these particular buildings, side venting turned out to be a disadvantage. A vertical vent was already available and side venting required cutting open a portion of the living room ceiling. (Minnesota does not require side-venting, but the original Integra design does.) The installed cost for each system was $2,809. This higher cost is due to the higher equipment cost and the added materials and labor for side-venting the heater.

In unit E we installed a system similar in size to the Integra, but with a separate heater and air handler to allow a comparison between unitary and split water heating systems. The heater input and storage capacity are the same as the Integra's, but the recovery efficiency, heater output, and coil output are all slightly higher. This heater is manufactured by Apollo and features a recovery efficiency of 85%, atmospheric burner, and use of the existing vertical vent. The installed cost of the system was $2,067, the least expensive of the five systems.

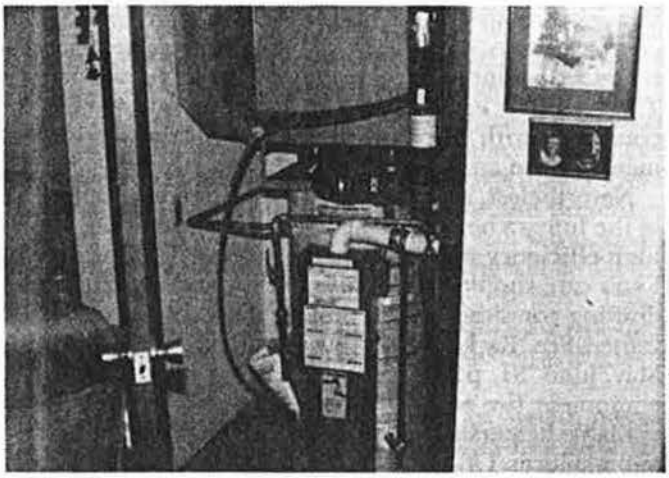
Equipment Sizing

Since dual appliance water heating technology is relatively new, few guidelines exist for equipment sizing and design. To design a system, a contractor needs to determine the correct heating coil energy output, water heater output, and heater storage capacity. The standard practices used for other systems to determine the heat output (that is, the design heat loss, safety factor, and pick-up load) can also be used for sizing the heating coil output.

ASHRAE Transactions recently published a report that uses a simplified model of system operation to recommend guidelines for sizing dual systems for multifamily and single-family applications.[1] The authors assume that an adequately sized integrated system should be able to "recover from a large hot water draw in one hour or less, while also supplying the space heat load." They recommend a "rule of thumb" that heater output should typically be 1.2 times the rated coil output. In addition, the storage capacity should be 3–4 times the peak hot water draw. For locations without clothes washers, this means heaters should have a storage capacity of 40–50 gal, but 50–75 gal may be required when there is a clothes washer.

In general, the integrated appliances in our study followed the guideline of having heater outputs at least a factor of 1.2 times the heating coil output.

1. Pietsch, J. and Talbert, S., "Equipment Sizing Procedures for Combination Space-Heating/Water-Heating Systems," *ASHRAE Transactions*, Vol. 95, part 2, 1989. Atlanta, Ga.



Mark Hancock

A Mor-Flow Integra, a system specifically designed for dual applications, is visible in this apartment. The water heater is the bottom component, with the air handler above.

Gas Use, Measured and Estimated

We used a pre- and post-test procedure to estimate the energy savings of the water heating systems. The PRInceton Scorekeeping Method (PRISM) analyzed one year of pre- and one year of post-installation gas-use data to compute the change in the normalized annual consumption (NAC) of each unit. PRISM also compared pre- and post-installation summer non-heating use, heating slope, and reference temperature.[5]

(A preferable method would have been to alternate weeks of operation between existing and dual-integrated systems. In fact, we tested systems using alternating weekly time intervals in small commercial settings. The measured results were not far from the estimated gas use.)

The dual-integrated appliances were installed in early February 1990. The NACs of units A, C, D, and E for the post-installation period range from 591 to 890 therms/year. These results represent savings of 113–231 therms/year or 11.3–27.5%, and average 149 therms/year or 18%. The savings for all of these units are highly statistically significant. A change in occupants in unit B invalidated the energy savings estimate. The two post-installation data points collected while the original occupant still lived in the unit show a decrease in use of 13% and 16%. However, the NAC for the new occupants increased by 5% and the reference temperature increased by 8.7°F.

The Integra system installed in unit D achieved the greatest savings—27.5%. It is possible the relatively high base use of unit D (which was predominantly domestic hot water) was responsible for some of the additional savings.

Table 1. Results of PRISM Gas-Use Analysis

Unit	Pre-installation NAC *therms*	Post-installation NAC[1] *therms*	NAC Savings (%)	NAC Savings *therms*
A	1,003	890	11.3 (2.5)	113 (25)
E	705	591	16.2 (2.3)	114 (16)
C	808	670	17.1 (4.0)	138 (33)
D	839	608	27.5 (2.6)	231 (21)
B[2]	895	960	-5.2 (2.3)	-45 (29)
		Average[3]	18	149

NAC values assume therm = ccf.
1 February 1990–February 1991.
2 Change of occupant, March 1990, post-installation results for second occupant.
3 Average savings without site B.

However, the post-installation period results for unit D were not as stable as those for the other three units and probably not as reliable.

Given the low efficiency ratings of the existing furnaces and water heaters, it is not surprising that the new systems obtained such high savings. We would have preferred to have compared the dual-integrated systems to heaters and furnaces that meet the present national appliance efficiency standards. After gathering information from 25 different sites, we found that it was impossible to find units that had efficient equipment and met our other requirements for the study. So, we decided to rely upon model estimates of energy use for the comparison of the dual systems to more efficient equipment. Interested readers should consult our report for details on the methodology of this comparison.[1]

Experiences with Installed Systems

A staff member who frequently spoke with the occupants during the field visits to collect gas use data turned up no complaints of inadequate space heat at any of the locations. He gathered this feedback during periods of time when the outdoor temperature dropped below design conditions. No one complained of continuous space heating

Table 1. Comparison of Two Systems

	DUAL-INTEGRATED APPLIANCE SYSTEM					EXISTING SYSTEM					SAVINGS		
Building	Water Heater Output[1] (Btu/h)	Coil Output (Btu/h)	Recovery Efficiency (%)	Energy Factor	CAE (%)	Water Heater Output (Btu/hr)	Furnace Output (Btu/hr)	AFUE (%)	Energy Factor	CAE (%)	Savings Estimated (%)	Savings Measured (%)	Base Use (%)
A	39,900	41,500	76.0	0.54	68.2	27,792	42,000	60.3	0.49	56.1	17.7	11.3	37.0
E	34,000	30,000	85.0	0.61	78.4	27,792	42,000	60.3	0.49	56.9	27.4	16.2	29.9
C	33,200	25,000	83.0	0.64	78.4	27,792	42,000	60.3	0.49	56.9	27.4	17.1	30.0
D	33,200	25,000	83.0	0.64	73.7	27,792	42,000	60.3	0.49	54.4	26.1	27.5	52.0
Average	35,075	30,375	81.8	0.61	74.7	27,792	42,000	60.3	0.49	56.1	24.7	18.0	37.2

1. Computed from (heater input) (recovery efficiency)
Installed costs: Buildings A and B, $2,212; building E, $2,067; buildings C and D, $2,809.
CAE = Approximate Combined Annual Efficiency
AFUE = Annual Fuel Utilization Efficiency

demand causing low domestic hot water temperatures, either. It appears that all the heating coils and heater outputs were adequately sized for the space heating loads.

Overall, there were few occupant complaints. However, immediately after the installation of the new systems, many tenants complained of large fluctuations in the indoor temperature. One or two weeks of monitored data from temperature strip chart recorders placed near the thermostat in each of the apartments revealed short-term fluctuations no greater than a few degrees. It is possible that the tenants were responding to the brief period when cool air comes out of the register when the air handlers first switch on. The complaints didn't continue beyond the first month.

No repairs had to be performed on either of the two atmospheric-burner, vertically vented dual-integrated appliances. The original vent terminations of the three side-vented, Mor-Flow Integra heaters had to be modified and have since worked without failure (see box, "A Solution to Vent Icing"). Both Integra heaters have been replaced due to high concentrations of carbon monoxide and a destroyed burner. We intermittently measured the carbon monoxide levels in the combustion gas of the heaters throughout the study. The levels were quite high compared to typical values for other types of heaters, but remained within state guidelines for atmospheric burners. The problems encountered with the Integra systems are consistent with the experiences from other Twin City metropolitan area installations of these heaters.

Nevertheless, we believe that the design characteristics of the Integra heaters make them ideally suited for use in high-efficiency dual-integrated systems. [Editor's note: Extra care should be taken to test for and alleviate backdrafting conditions, even though the systems are power-vented. See "Backdrafting Causes and Cures," *Home Energy*, May/June '91, p. 30–35.] As is often the case with new equipment (we acquired some of the first commercially available heaters), they have a disturbing trend of equipment failures. On the other hand, manufacturers are typically quick to modify the heater design, hopefully resulting in more reliable heaters. I should add that one of the systems had problems during the past heating season.

Conclusions

Albeit in a small number of cases, we were able to show that dual-integrated systems could be successfully used in multifamily units in a cold climate. Along with increasing levels of insulation placed in new and existing multi-

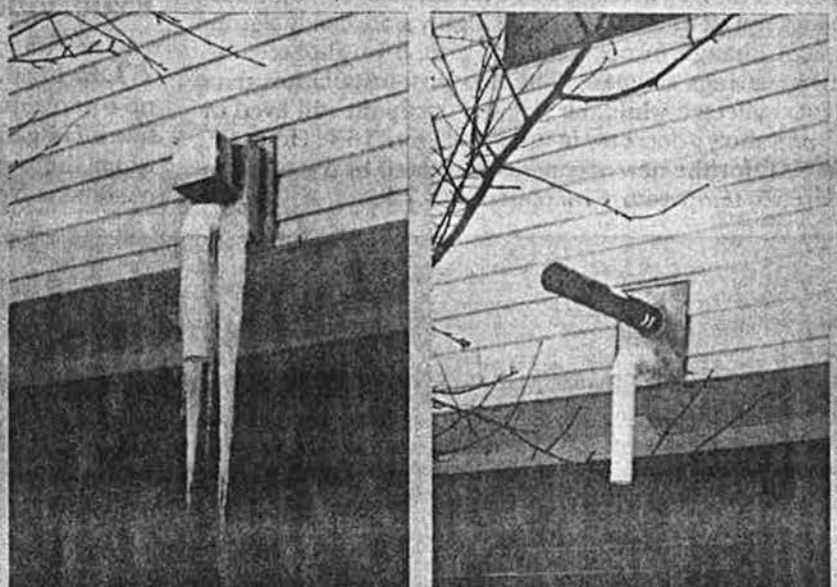
A Solution to Vent Icing

We encountered numerous venting problems with the Mor-Flo Integra heaters. The Integras contain power-draft burners and, when used with the standard termination kit, must be vented through a side wall. All the problems were corrected and could have been avoided by using vent terminations more suitable to the 8,000 heating degree-day climate of Minneapolis.

The problems first started during an extended period of sub-freezing weather, shortly after the heaters were installed. The water vapor in the exhaust was condensing on the upper part of the sheet metal termination kit and dripping down to the lower portion used for the inlet air. This condensate soon turned into a huge icicle which partially closed the combustion air inlet. Since the heaters have a flow-proving switch, the burners would not operate—leaving the occupants without hot water and heat. The icing (flow restriction) problem also occurred on an Integra heater installed in a small commercial building.

We modified the standard vent terminations by placing a PVC pipe, a 90° elbow, and 1 ft-long pipe pointed towards the ground on the inlet-air portion of the vent termination. No more failures occurred, but the residents still had to chop off the ice in the winter and were not too happy about the condensate that dripped off the termination in the summer time. To solve this problem, the original terminations were removed, an 18-in. horizontal section of high temperature vent pipe was connected to the exhaust pipe, and a 90° elbow followed by a 12-in. vertical pipe was connected to the inlet air pipe. These terminations performed well during periods of –10°F weather, causing no heater failures.

Mor-Flo now provides an optional coaxial termination for the Integra that can be used for side or vertical venting. The coaxial termination has performed successfully on another Integra heater installed in the Twin Cities metropolitan area. However, the factory-supplied termination was modified by extending the exhaust pipe and removing the cap covering the end of the pipe. The occupant (an energy consultant familiar with these problems) did this because he was concerned about possible ice build-up on the exhaust cap and about eddies in the inside corner of the house causing re-entry of the exhaust gases.



Ted Staller

Ice formed on the first modified vent termination for an Integra system, *left*. The final termination design, *right*, is even more effective, since the extended exhaust pipe helps alleviate condensation close to the unit.

family buildings, the percentage of units that can use dual-integrated systems is on the rise. At the same time, code officials are becoming more knowledgeable about the systems and lowering their resistance to them.

We found that it was more expensive to install these heating systems than separate hot water and space heat systems with 80% AFUE furnaces and that the savings from the dual systems may not be very significant. For the present, it appears that factors such as the ability to vent through side walls, a small footprint, and ease of zoning will be a more important factors in the decision when to use them. While dual system costs are stabilizing as their volume on the market grows, the price of installation is sure to fall as this technology becomes more commonplace.

The sizing guidelines we followed for system design seemed to work well. Few occupants complained about the operation of the systems, but we did have a number of equipment failures of the newer Integra heaters. However, the manufacturer has modified the design to address these system failures and the new models should be more reliable in the future. ■

Endnotes

1. Bohac, D.; Hancock, M.; Dunsworth, T.; Hewett, M.; and Staller, T. "Retrofit Savings for Dual-Integrated Appliances in Small Commercial and Multifamily Buildings," CEUE/TR90-5-MF, CEUE, 510 First Ave. N. Suite 400, Minneapolis, MN 55403.
2. According to ASHRAE, the three types of dual-integrated appliance systems differ according the primary function of the appliance—supplying space heat, domestic hot water, or both.
3. If the proper materials are used, fin-tube baseboards can be used in place of a fan coil; however most manufacturers don't recommend finboards. This is because it is more likely that materials incompatible with potable water can mistakenly be used with baseboards, and they usually require higher supply water temperatures.
4. The National Appliance Energy Conservation Act (Public Law 100-12, March 17, 1987) has established a minimum AFUE standard of 78% for furnaces with inputs less than 225,000 Btu/hr manufactured after 1991.
5. "PRISM: a Tool for Tracking Retrofit Savings," *HE*, Nov/Dec '87, pp. 27–35; "Now that I've Run PRISM, What Do I with the Results," *HE* Sept/Oct '90, pp. 27–34.

Nelson

I learned one thing. The Btu loss from a tent in a Russian winter is incalculable.