Ductless Heat Pumps

by Jerry Sutherland

These easily installed units offer flexible sizing and high efficiency at moderate cost

I'm an hvac system designer in Vancouver, Wash., just across the Columbia River from Portland, Ore. We install a wide variety of heating and air-conditioning systems, but in recent years our best-selling products have been super-efficient small-to-medium-sized ductless heat pumps (DHP), most of which are retrofitted into existing homes.

That trend has been helped along by now-expired federal and state tax credits and an ongoing rebate program sponsored by the Northwest Energy Efficiency Alliance, or NEEA. The NW Ductless Heat Pump Project, as it's called, helps eligible homeowners cover the cost of converting from existing electric resistance heat — which the regional utilities call "zonal heat" — to more energy-efficient heat pumps. Even before the program took effect, though, we'd already been putting in quite a few ductless systems; in fact, we've installed more than 600 DHPs in the past few years. They go in quickly and easily, and have proven to be extremely reliable. We almost never have any quality issues with the equipment, and customer satisfaction has been very high.

Heat-Pump Basics

As most people know by now, heat pumps are refrigeration-cycle devices that use electricity to move and concentrate heat energy. During cold weather, the system collects diffuse heat energy from the outdoors and releases it indoors; and during the cooling season, it does the opposite. Although electricity is required to run a compressor, the energy needed to deliver a given quantity of heat with a heat pump is typically a fraction of what it would take to provide the same amount of heat with resistance baseboard heaters or wall-hung units.

Air-source vs. ground-source systems. The NW Ductless Heat Pump Project rebates apply only to air-source heat pumps, which draw heat energy from the ambient outdoor air. In the past, our company has installed some ground-source systems (also known as geothermal systems), which extract heat from soil or groundwater by circulating fluid through a closed loop of buried or submerged tubing. Ground-source systems are at their best under extreme environmental conditions, so they can be a good choice in regions with long, blazing-hot summers or winters that feature long periods of subzero cold.

But in our area, temperatures are quite moderate throughout the year. The design temperature for heating-load calculations, for example, varies from 18°F to 22°F, depending on elevation, while cooling-load design temperatures are in the 85°F to 88°F range. Air-source heat pumps operate very efficiently here, and offer much more bang for the buck than ground-source systems, which must be individually engineered and often cost tens of thousands of dollars to install. As a result, our company now offers air-source systems exclusively.

Figure 1. Ductless heat pumps deliver cooled or heated air with one or more indoor fan-coil units. For this home's single-zone system, the surface-mounted indoor unit has been placed in a central area of the living space to distribute the conditioned air as widely as possible.

Going ductless. The output from any heat-pump system — whether ground- or air-source — can be distributed by way of a conventional duct system served by a central air handler. But the ductless systems I'll be talking about in this article consist of an outdoor unit — made up of a coil, a fan, and an inverter-driven variable-speed compressor — connected by refrigerant lines to one or more indoor fan-coil units, each of which is equipped with a filter, a coil, and a multispeed blower to distribute the conditioned air (**see Figure 1**).

These kinds of systems are often called mini-splits, to distinguish them from through-the-wall "motel units" that combine the compressor and fan coils in a single package, as in a conventional room air conditioner. But to avoid confusing consumers, we follow NEEA's lead and refer to them as ductless heat pumps.

Measuring efficiency. One standard measure of efficiency for heat pumps while in heating mode is their coefficient of performance, or COP. A heat pump that is operating with a COP of 2, for example, is delivering twice as much heat as a resistance heater that's drawing the same wattage (**Figure 2, next page**).

Many consumers and contractors will be more familiar with heating seasonal performance factor (HSPF) and seasonal energy-efficiency ratio (SEER) ratings, which in effect average the instantaneous COP figure over an entire heating or cooling system. Some of the ductless systems we install have SEER ratings of more than 20, and HSPF ratings of 12 or more — far exceeding the minimum federal SEER and HSPF standards of 13 and 7.7. Very few ducted heat-pump systems can come anywhere near this level of efficiency.

Sizing Strategies

In some respects, the ideal ductless heat-pump configuration is a zoned multihead system. By putting an indoor fan-coil unit in each room or area to be heated, you get the same sort of control over each zone that you would with conventional zoned electric resistance heat. Each indoor unit comes equipped with its own remote control, allowing the residents to tailor the temperature of the main living space and bedrooms to suit their individual preference (**Figure 3, page 4**).

Displace, don't replace. That approach is standard practice in much of Europe and Asia. In the U.S., however, such systems are less familiar, and many customers balk at the cost and the thought of having to look at a fan coil in

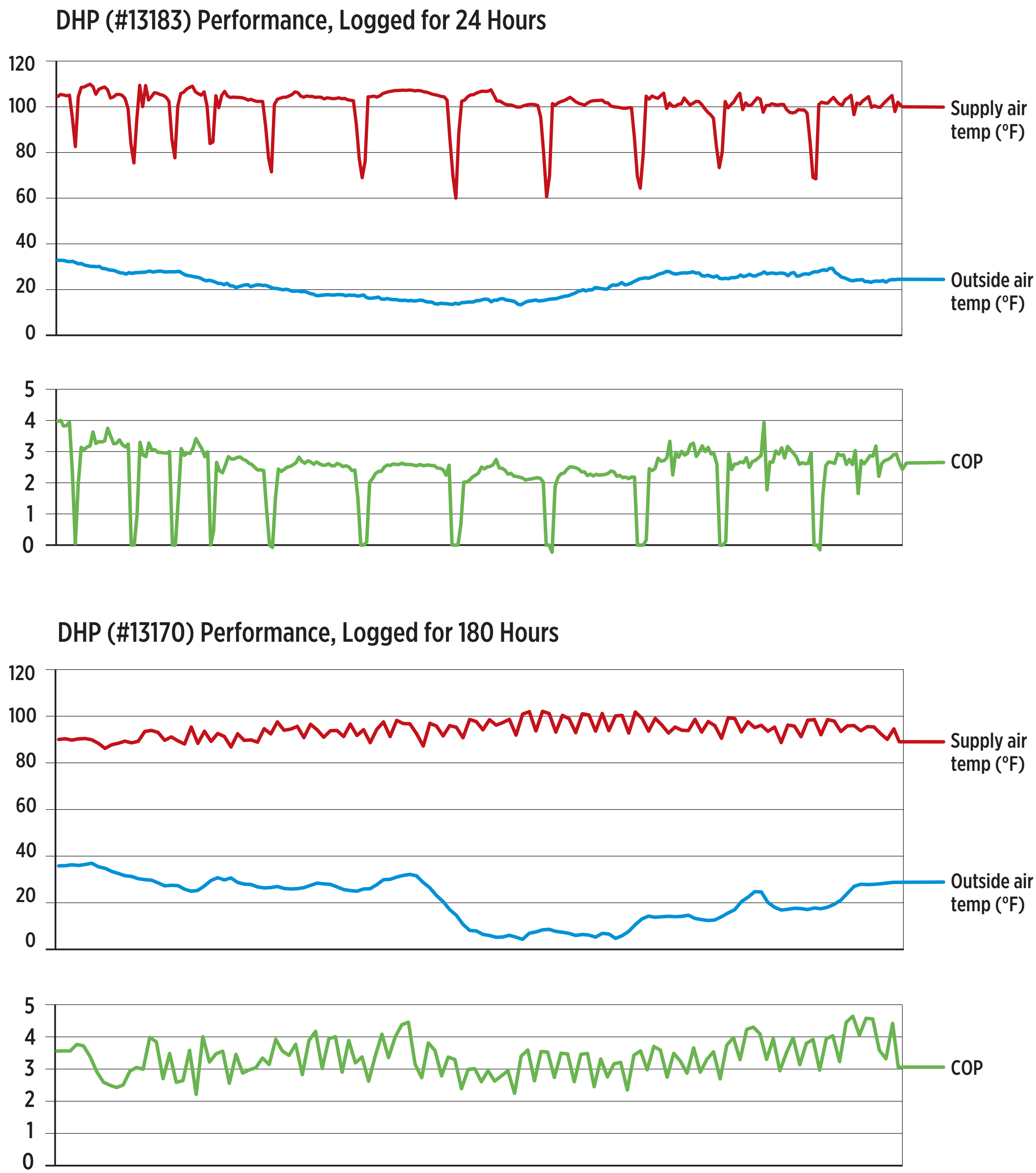


Figure 2. The graphs above show some of the data collected from two of the many ductless heat pumps monitored in operation by Ecotope, a Seattle-based consulting firm that specializes in renewable resources and energy efficiency. The dips in supply air temperature and COP visible in the top graph show what happens when this unit, monitored for one day, kicks into a periodic defrost cycle to clear the outdoor condenser coil of accumulated ice. The bottom graph shows the operation of a different unit — specifically designed for cold-weather operation — during a week in which outdoor temperatures dipped below 10°F; despite the cold the DHP maintained an average 3.4 COP.

Figure 3. Unlike most hvac equipment, which cycles on and off as a thermostat calls for heating or cooling, inverter-driven ductless heat pumps ordinarily run continuously, adjusting their output as needed to maintain a constant indoor temperature. A remote supplied with each indoor unit controls temperature, blower speed, and the position of the vent louvers.

every room. Although we do install some multizone systems, single-zone systems — in which one fan-coil indoor unit is placed in an area of the main living space where it can distribute conditioned air across a wide area — are by far our biggest seller.

In this application, the centrally located indoor unit is responsible for the baseline heating load, and the existing zonal electric heaters provide additional heat to outlying rooms as needed. Energy-use data collected from homes in the NEEA program show that the DHP typically provides all the heat needed during the swing seasons of the year, with the resistance heat coming into play only during the coldest months. This is known as the "displace, not replace" strategy, since the intent is to shift as much of the heating load to the heat pump as possible, without removing the resistance units entirely. Customers who really hate the appearance of their wall or baseboard heaters may be able to remove them from rooms served by a fan coil large enough to handle the worst-case heating load, but I always recommend that they hold off on doing so until they've lived with the DHP through at least one severe winter.

Cost and capacity. Today's homeowners are very cost-conscious. As a result, a lot of contractors will try to keep the upfront cost to a minimum by specifying a DHP system just large enough to heat and cool the main living area where the indoor unit will be installed.

We too will do that, if the room layout makes it impractical to move heated or cooled air to other parts of the house, or if that's what the customer wants. But if we can use the blower on the indoor unit to provide significant airflow to outlying areas that would otherwise be heated by the resistance heaters, we usually recommend going with a larger unit. Most of the systems we install are rated at 15,000 to 24,000 Btu. Increasing the size of the DHP does carry a higher cost, but a lot of extra capacity is available for a relatively small price bump. In our area, for example, the installed cost of a 12,000-Btu DHP — including state sales tax — is about $4,000. Going with a 24,000-Btu unit would

Figure 4. Although indoor units are most often mounted high on a wall, some models are designed to be concealed in a soffit (above) or mounted flush in a dropped ceiling (right). Floor-mounted low-wall units (far right) are also available.

increase that figure by only about a thousand dollars.

Of course, the by-the-book approach to sizing conventional hvac equipment (the "book" in this case being the ACCA's Manual J) is to perform a heating- or cooling-load calculation for the conditioned space, then choose a unit just large enough to handle the resulting design figure. But with a DHP powered by an inverter-driven compressor — the only kind we sell — there's no need to closely match output and load, because it's designed to operate continuously over a wide range of speeds. Rather than shortening its operating cycle in response to reduced demand for heating or cooling, the unit simply increases or decreases output as needed, like cruise control in a car.

And remarkably, as a DHP slows down, its overall efficiency actually improves. An oversized unit that's loafing along, in other words, will use less energy per Btu of output than a smaller one running at near capacity.

In short, when it comes to sizing a DHP, bigger is usually better. A larger model not only operates more efficiently, but the added heat it provides reduces the need for the costly zonal resistance heat that would otherwise pick up the slack. The inherent flexibility in a DHP system is also useful if the homeowner later adds to the heating load by adding on, or subtracts from it by improving the building envelope or beefing up the insulation.

Planning the Installation

There's a variety of great DHP products on the market today, and we've installed quite a few brands over the years. But we rely mostly on Mitsubishi, Daikin, and Fujitsu, all of which offer multiple sizes and models with different features. In deciding which DHP to use for a given installation, we base our choice on the specific combination of features needed, not the nameplate.

Planning the layout. In zoned systems with a fan coil in every room, placement of the units can be fairly flexible. But in a single-zone system, it's critical to put the indoor unit where it will best distribute conditioned air to the desired rooms. Ideally, it should go fairly high on a wall so furniture and other obstructions don't interfere with circulation of the conditioned air, and in as central a location as possible. Recessed-ceiling and low-wall units are also available for applications where a high wall location isn't possible, or for customers who just prefer their appearance (**Figure 4, previous page**).

All indoor fan coils have adjustable louvers to direct the flow of conditioned air as needed. Some models allow the user to choose an oscillating setting that will sweep the airflow back and forth or set the louvers in one position

Figure 5. After the mounting bracket of a wall-mounted indoor unit is screwed to the studs (top), the unit itself is hung on the bracket, with the stubs for refrigerant lines, a condensate drain, and an electric line passing through a hole in the exterior wall (center). The $2\frac{9}{16}$-inch hole is later filled with canned closed-cell foam and waterproofed with caulk (above).

Figure 6. Concrete riser blocks — which elevate the outdoor unit to provide drainage — are fastened to the pad with construction adhesive (top). Then the outdoor unit itself is put in position (center) and fastened to the risers with Tapcon screws (above).

(so they blow air in the direction of a hallway, for example, to help heat or cool outlying areas of the house). This feature can usually be operated with a remote.

Some DHPs from Mitsubishi include a feature the company calls “i-see,” which uses a roaming infrared sensor to locate the coldest or hottest part of the room and then adjust the louvers to blow conditioned air in that direction. That sounds good, and we find that it can work well in a system with a fan coil in every room. But we recommend against using this feature in single-zone systems, because the sensor tends to direct the airflow continuously toward a window or other localized cold spot, defeating the goal of moving as much conditioned air as possible to other rooms in the house.

Installing the Units

It ordinarily takes two technicians half a day to complete a single-zone installation. After confirming the system design with the homeowner, the installers unpack and install the indoor fan coil while the electrician roughs in the power supply for the outdoor unit. The indoor unit is secured to a mounting bracket that’s screwed to the wall studs; an opening in the sheet metal provides a template for the hole that allows the line set to pass through the wall. After drilling the required $2\frac{9}{16}$-inch hole, the installers unfold the short lengths of wiring, refrigerant tubing, and condensate line that come attached to the unit, push them through the wall, and secure the unit to the wall bracket. The hole is later filled with closed-cell spray foam and weatherproofed on the outside with caulk (**Figure 5, previous page**).

For the sake of appearance, we try not to put the outdoor unit on the front of the house. If the indoor unit is mounted on a back or side wall, it’s often possible to locate the outdoor unit directly below the wall penetration, which keeps the line set as short as possible. The maximum allowable length varies from 33 to 100 feet, depending on model and manufacturer, so the site layout often has some bearing on the product we’ll specify for a particular installation.

In most cases, we place the outdoor unit on a lightweight 16-by-36-inch mounting pad that looks like concrete but is actually made from polyurethane foam wrapped in fiberglass (diversatech.com). To make sure defrost water won’t refreeze in the drain pan and back up into the unit — which could damage the fan — we provide extra drainage space by attaching two concrete riser blocks to the pad with construction adhesive. Then we place the outdoor unit on the blocks and

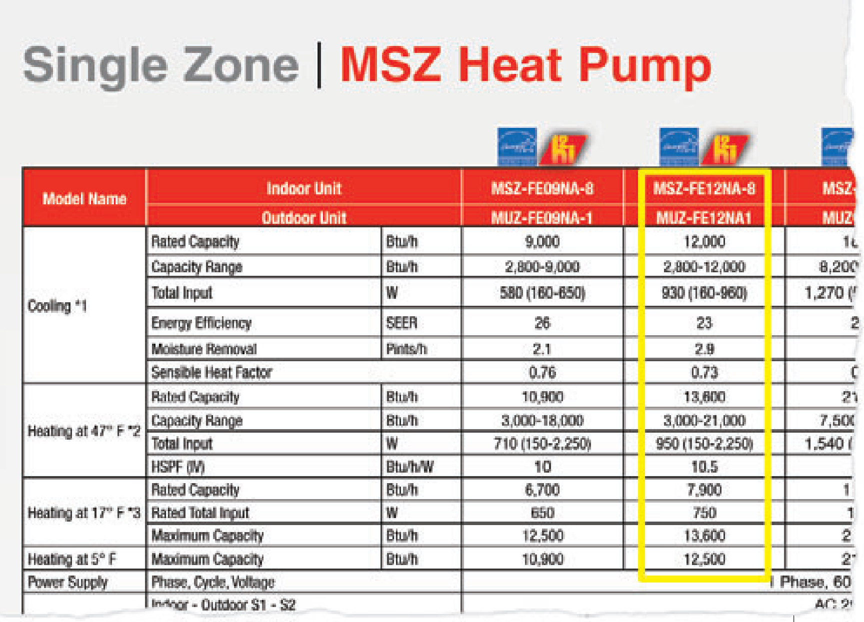
Understanding Ductless Heat-Pump Sizing

When the flexible "displace, don't replace" strategy outlined in this article is followed, it's easy to select a right-sized ductless heat pump. But in applications where the unit will serve as the sole heating source, the selection process gets a little trickier.

As an example, look at the partial spec sheet for a single-zone heat pump shown below. Note that performance figures are listed for four separate categories: cooling; heating at 47°F; heating at 17°F; and heating at 5°F. In every case, says Mitsubishi engineer Joe Cefaly, the "rated capacity" figure is relatively unimportant; it simply represents the manufacturer's best guess at where the efficiency "sweet spot" lies within each unit's range of operation.

More important is the "capacity range," which gives the high and low output figures at which the unit will operate continuously. When operating in cooling mode, for example, the highlighted model can provide from 2,800 to 12,000 Btu of cooling, or anywhere from a small fraction of a ton up to about 1 ton. If less cooling is required, the unit will begin to cycle on and off, like a conventional single-speed air conditioner, rather than running continuously.

When operating in heating mode at an outdoor temperature of 47°F, the unit's range is even wider. At that relatively warm temperature, the heat pump can deliver a maximum of 21,000 Btu or throttle back to 3,000 Btu.



Single Zone | MSZ Heat Pump

Model Name	Indoor Unit		MSZ-FE09NA-8	MSZ-FE12NA-8	MSZ-
	Outdoor Unit		MUZ-FE09NA-1	MUZ-FE12NA1	MUZ
Cooling *1	Rated Capacity	Btu/h	9,000	12,000	1(
	Capacity Range	Btu/h	2,800-9,000	2,800-12,000	8,200
	Total Input	W	580 (160-650)	930 (160-960)	1,270 (
	Energy Efficiency	SEER	26	23	2
	Moisture Removal	Pints/h	2.1	2.9	
	Sensible Heat Factor		0.76	0.73	(
Heating at 47° F *2	Rated Capacity	Btu/h	10,900	13,600	2
	Capacity Range	Btu/h	3,000-18,000	3,000-21,000	7,500
	Total Input	W	710 (150-2,250)	950 (150-2,250)	1,540 (
	HSPF (IV)	Btu/h/W	10	10.5	
Heating at 17° F *3	Rated Capacity	Btu/h	6,700	7,900	1
	Rated Total Input	W	650	750	1
	Maximum Capacity	Btu/h	12,500	13,600	2
Heating at 5° F	Maximum Capacity	Btu/h	10,900	12,500	2
Power Supply	Phase, Cycle, Voltage		1 Phase, 60		
	Indoor - Outdoor S1 - S2		AC 2		

When sizing a ductless heat pump in a mixed or heating climate, it's important to match the "maximum capacity" spec at the design temperature to the expected load.

But as the outdoor temperature falls, the heat pump's ability to extract usable heat falls with it, and a second figure — the "maximum capacity" listing — becomes critical. At 17°F, the unit can no longer provide the 21,000 Btu it delivered at 47°F; instead, its new maximum is 13,600, a decline of 30 percent.

At an ambient temperature of 5°F, the maximum capacity falls still further, to 12,500 Btu. (The product we're considering here — one of Mitsubishi's "Hyper Heat" models — is designed to operate at unusually low temperatures; many DHPs aren't configured to heat effectively much below 20°F or so.)

In other words, the colder it gets outside — and the more heat is needed to keep the indoor temperature at a comfortable level — the less heat a DHP can actually deliver. If its output declines to the point where it can no longer heat the space on its own, some additional heat will be required.

In an energy-efficient new home, the best choice may be to install low-cost electric strip heating as a backup. Although operating costs will be high when the resistance heat is running, it will be needed for such a limited amount of time — perhaps only a few hours each year — that the total expense will be low. (Be sure to check your local code; some jurisdictions may prohibit the use of backup resistance heat.)

A woodstove is another possible source of low-cost backup heat. And while it doesn't make economic sense to install a new furnace or boiler to back up a heat pump, an existing heating system can sometimes provide backup in a retrofit situation. "A lot of people will install a heat pump to lower their energy costs and add air conditioning," says Cefaly. "If they have functional heating equipment that's not at the end of its service life, they can hang onto it and use it on the rare occasion where they need to." — *Jon Vara*

Figure 7. If no suitable position for a ground mount is available, the unit can be wall-mounted on a manufactured bracket.

Figure 8. Refrigerant lines and wiring on the exterior wall are protected with a vinyl or sheet-metal cover. Condensate drain tubes are visible at lower right.

secure its mounting feet to the blocks with Tapcon screws (**Figure 6, page 6**).

If there's no suitable flat ground available, we install the outdoor unit on a manufactured wall-hung mounting bracket that keeps it well off the ground and a suitable distance from the wall (**Figure 7**). We've learned from experience not to put brackets over an outdoor deck, though, because it really bothers customers to see its surface wetted by defrost water, even though the entire deck may be soaked with rain for much of the year. We also avoid putting an outdoor unit directly on a deck, both because of the drainage issue and because we're concerned that vibration of the deck structure could lead to cracking of welds or other unforeseen long-term problems.

Refrozen defrost water is a potential hazard, too, if an outdoor unit is mounted above a sidewalk or hard-surfaced patio (or — again — a deck). The only time we'll place it in that type of location is if there's no better option available, there's no regular foot traffic in the area, and the customers sign off on the contract saying that they've approved it.

Line Set and Cover

Once both units are in place, they're connected with copper refrigerant line. If an exposed horizontal run is necessary, we ordinarily route it low along the wall, where it will be relatively inconspicuous. The paired refrigerant lines — which come wrapped along their length with insulation — are secured to the siding with two-hole pipe straps. Once the line set is secure, the electrician runs the cable from the outdoor unit to the indoor fan coil, zip-tying it to the line set. This is required under our state code — elsewhere it may be possible to use line sets that come with the required cable bundled with the refrigerant lines.

After the refrigerant lines have been pressurized with nitrogen and tested for leaks, we install a protective cover over the line set, which helps prevent physical damage and deterioration from the UV in sunlight. Depending on the situation and the customer's preference, we'll use either manufactured vinyl "line hide" covers or 26-gauge aluminum covers that we make up as needed in our own sheet-metal shop (**Figure 8**). These are reversible and prepainted white on one side and brown on the other, allowing us to use whichever side looks best with the siding. The owner can then paint over it for a more exact match later, if desired.

Jerry Sutherland *is an estimator and hvac system designer with MetFab Heating in Vancouver, Wash.*