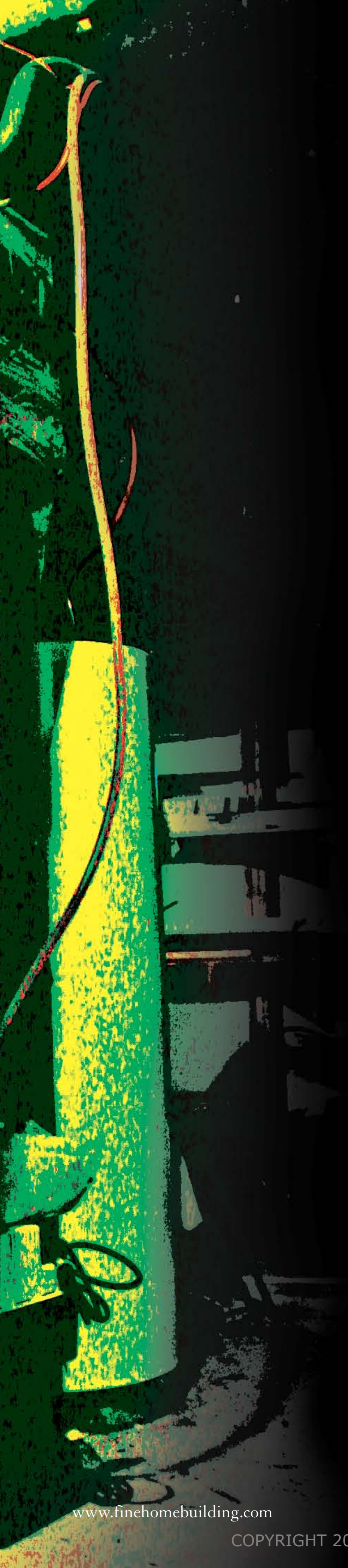
Photo: Justin Fink



Getting to Know

The Beast in Your Basement

A forced-air heating system isn't as scary as it seems

BY MARTIN HOLLADAY

Many different appliances can be used to heat a house, including boilers, water heaters, heat pumps, and woodstoves. According to the Department of Energy (DOE), however, most homes in the United States are heated by forced-air furnaces.

A forced-air furnace is connected to ducts that deliver heated air to registers throughout the house. Different types of furnaces are manufactured to burn a variety of fuels, including natural gas, propane, oil, and firewood. The most common furnace fuel in the United States is natural gas.

Even though the smallest available furnaces are often too big for a high-performance home (see "Heating Options for a Small Home," *FHB* #217), furnaces still have virtues that are hard to ignore. They are inexpensive, widely available, and easily serviced by local HVAC contractors. For many North American homes, they are a logical way to supply space heat.

A furnace is only as good as its installation, though, and research has shown that new furnaces and their distribution systems (ducts) often aren't sized correctly. According to a 2013 report prepared for the DOE, the problem is even more widespread when it comes to replacement furnaces. An oversize furnace often costs more than a right-size furnace, and improper duct installation results in reduced operating efficiency.

Efficiency drives the decision

When it comes to fuel efficiency, furnaces are grouped based on their annual fuel-utilization efficiency, or AFUE. These efficiency ratings are calculated using a laboratory method that tells you how much of the fuel going into the furnace is being converted to usable heat. AFUE is expressed as a percentage, and higher is better. Residential furnaces in the United States are divided into just two main categories: medium-efficiency furnaces (80% to 82% AFUE) and high-efficiency furnaces (90% to 97% AFUE). The

CHOOSE AN **EFFICIENCY**

Understanding AFUE

The efficiency of a furnace is calculated using a laboratory procedure that measures an appliance's annual fuel-utilization efficiency, or AFUE. This calculation tells you what percentage of the energy in the fuel is being converted to heat, so higher is better.

What's calculated

- Heat losses up the chimney
- Heat losses through the appliance jacket
- Heat losses due to on-and-off cycling

What's not calculated

- Electricity use (energy required to run fans and controls)
- Heat losses through ductwork connected to the furnace

Efficiency categories

75% 80% 85%

LOW

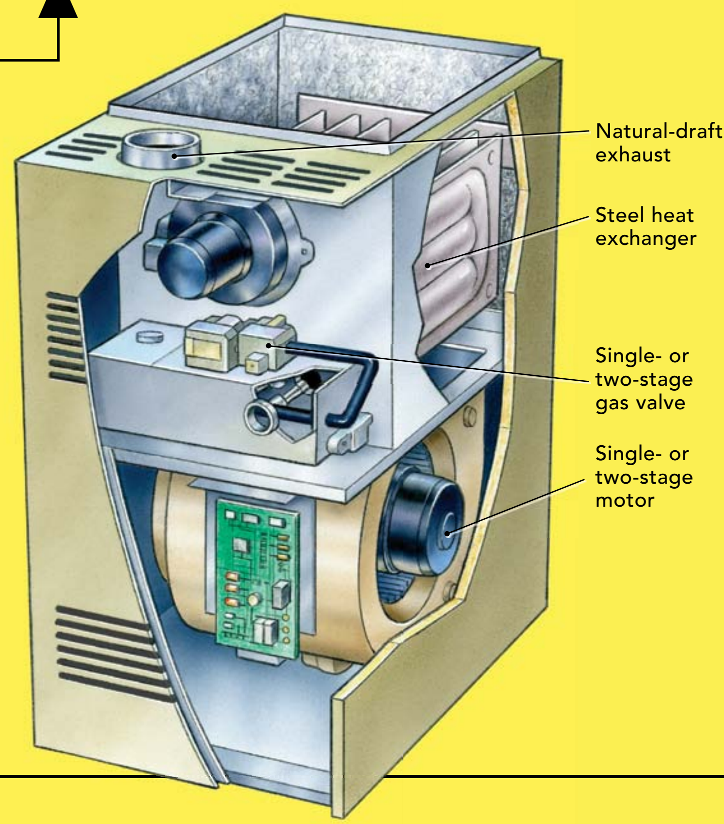
LESS THAN 75%

Although a low-efficiency furnace has traditionally been any model less than 75% efficient, the technology used in these older furnaces is now considered obsolete. The new minimum AFUE, mandated by the federal government, is 80%. Even though furnaces operating at low efficiency are no longer being manufactured, many are still in use throughout the country.

MEDIUM

80% TO 82%

Single- or two-stage (sometimes called "standard") furnaces can be equipped with either a single- or a variable-speed blower. They usually have a steel heat exchanger and rely on a natural draft to create a flow of exhaust gases up a chimney.



CHOOSE A **TYPE**

Single-stage These are the simplest furnaces because they only have one heat-output setting. If a furnace is rated with an output of 60,000 Btu/hr, that is the furnace's output whenever it is running, regardless of exterior temperature or differences in temperature in different parts of the house.

reason that you can no longer buy a low-efficiency furnace is that the federal government now requires residential gas-fired furnaces to have a minimum efficiency of 80%.

The line between medium- and high-efficiency furnaces isn't arbitrary or driven by marketing campaigns; it's a function of the inner workings of those furnace types. Medium-efficiency furnaces are designed to keep flue gases hot enough to avoid condensation of flue-gas moisture, while high-efficiency furnaces deliberately encourage this condensation. Furnaces with an efficiency of at least 90%, sometimes known as condensing furnaces, draw so much heat out of the flue gases that the furnace exhaust can be vented through PVC pipe. PVC costs less than the stainless-steel pipe that would have to be used to vent hotter flue gases at risk of depositing corrosive condensate.

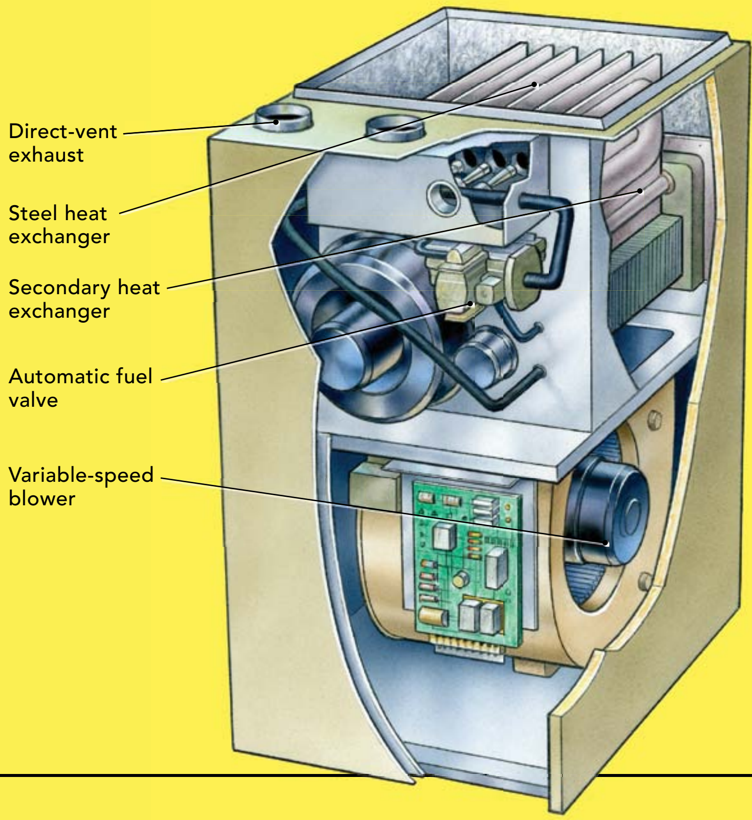
Single-stage, two-stage, and modulating furnaces

The simplest furnaces are single-stage models with single-speed blowers; they're either on or they're off. By contrast, two-stage furnaces can operate at two different output

Drawings: Don Mannes

WHAT ABOUT 83% TO 89%?

From a technological standpoint, it's difficult to manufacture a furnace with an efficiency rating between 83% and 89%, so none are available in that range. A furnace with this rating would have sporadic condensation of flue gases, which would lead to corrosion problems. You either want dependable condensation (so that it can be dealt with and the thermal benefits of it can be harvested) or no condensation at all (to avoid the need for a condensate drain). Any condensation requires expensive features, including a method of collecting and disposing of the condensate; if the efficiency gains are small, the investment in these features isn't worth it. Also, very-high-efficiency furnaces with dependable levels of condensation lower the temperature of the flue gases to the point where PVC can be used as a flue; intermediate levels of condensation result in hotter flue gases, and hotter flue gases require a stainless-steel flue pipe, which costs more than PVC.



HIGH
90% TO 98%

These furnaces can be either single-stage or two-stage models, but most have a variable-speed blower. Also, in addition to the standard steel-tube heat exchanger, high-efficiency furnaces have a secondary heat exchanger, which condenses the moisture in the escaping flue gases, turning it from vapor to liquid and squeezing out even more available heat in the process. These furnaces require a drain hookup to dispose of the condensate from this process. So much heat is drawn out of the flue gases that the exhaust can be vented safely through a PVC pipe going out the wall.

Two-stage A bit more sophisticated than single-stage models, these furnaces can operate at two different output levels. Most of the time, they operate at a lower Btu/hr output—typically around 65% of full capacity. The higher output is needed only on the coldest days of the year.

Modulating These furnaces include an automatic fuel valve that varies the amount of fuel delivered to the burner. Since modulating furnaces can match the heating demand precisely, they provide heat more evenly than single-speed furnaces, which operate with a stop-and-go jerkiness.

levels—either a high or a low Btu/hr setting depending on the demand. This is helpful because most of the time, a furnace only needs to operate at a low Btu/hr output to do its job. The higher output is needed only on the coldest days of the year.

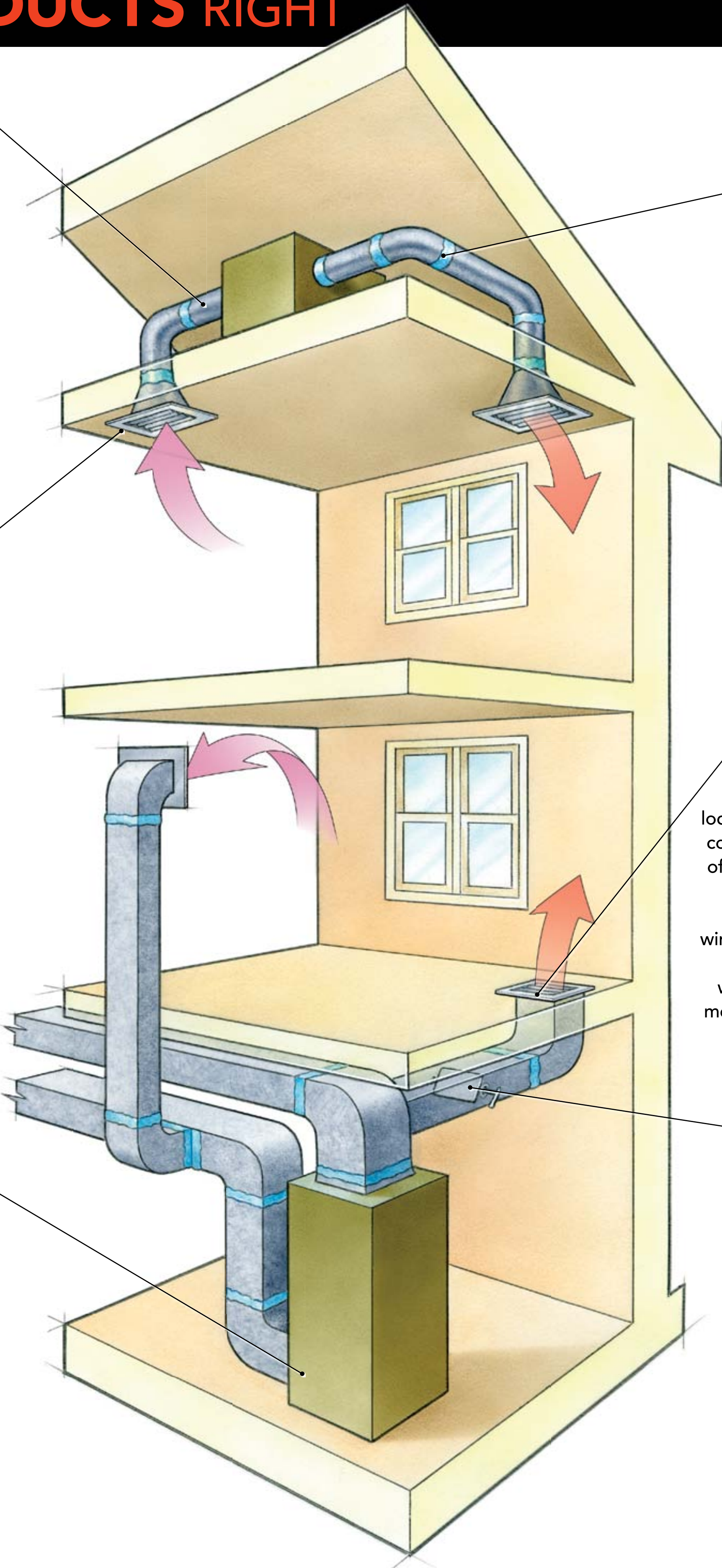
Slightly more sophisticated than two-stage furnaces, modulating gas furnaces include an automatic fuel valve that varies the amount of fuel delivered to the burner. Many modulating furnaces also include a variable-speed blower motor—usually an electronically commutated motor (ECM)—that, like the automatic fuel valve, adjusts the airflow of the warmed air up and down in response to heating demand.

While it's fairly easy to design a gas valve that varies the amount of fuel delivered to the burner, it's harder to design such a valve for delivering oil, so these furnaces are usually optimized for a single firing rate at a fixed Btu/hr output. That's why oil furnaces are usually single-stage furnaces.

Efficiency leads to direct venting

Condensing furnaces are power-vented, so they include at least two fans: an air-handler

GET YOUR DUCTS RIGHT



Choose the right ducts

Use rigid galvanized ducts wherever possible, and keep runs as short and straight as possible to enhance airflow. Flexible duct is hard to support and to keep straight, and its corrugations can cause turbulence that reduces airflow. Never use stud bays or other framing cavities as plenums to move supply air or return air. It's not only bad practice because it allows air to leak through miscellaneous gaps and cracks; it's also a code violation.

Plan for return air

Return air has to have a path from every conditioned room back to the furnace's return plenum. You can ensure this either by including grilles in every room that are connected to the return-air duct system, or by installing jumper ducts or transfer grilles to connect rooms without a return to those with a return. Avoid a single, central return-air grille, which can cause bedrooms with closed doors to become pressurized, forcing conditioned air into walls and ceilings. Size return-air ducts to be as large as or larger than supply-air ducts. When in doubt, make them bigger.

A central location is best

To make sure that duct runs are as short as possible, locate the furnace in the center of your basement or in a mechanical room near the center of your house. Both the furnace and the ductwork should be located inside of the thermal envelope, not in an unconditioned attic or crawlspace.

Seal everything

It's crucial to seal duct seams with mastic to prevent leakage, and you should apply foil tape or mastic to the plenum seams, too. If your furnace is located inside your home's conditioned space, these leaks may not matter very much, but if your furnace is located in a garage or vented attic, it can mean a substantial energy loss. Once sealed, the airtightness of the entire system should be evaluated with a Duct Blaster or similar duct-leakage tester.

Reconsider register placement

Although traditionally located near exterior walls to counteract the chilling effect of windows, supply registers can be placed on interior walls if high-performance windows have been specified and the house is tight and well insulated. This method means shorter duct runs that operate more efficiently.

Include dampers

Balancing dampers should be included on every branch duct running to a register to allow for airflow adjustments, a critical portion of the commissioning process.

Photo facing page: Rodney Diaz

fan that distributes warm air through the home's ductwork, and a power-vent fan to move exhaust gases through the flue pipe.

Most condensing furnaces are sealed-combustion furnaces, which means that the burners pull outside air into the combustion chamber through plastic ducts to feed the fire's needs. Sealed-combustion furnaces don't use any indoor air for combustion. The main advantage of a sealed-combustion furnace (compared to an old-fashioned atmospherically vented furnace) is that it is much less likely to suffer from backdrafting problems. Backdrafting occurs when a powerful exhaust fan—for example, a range-hood fan—depressurizes a house enough to draw combustion fumes down the chimney and back into the house. (For more information on this issue, see "How to Provide Makeup Air for Range Hoods," *FHB* #232.)

Sizing matters

The most accurate method for determining the required size of a furnace is to do what's called a Manual J calculation. In its simplest form, a Manual J calculation takes into account the shape and orientation of a house, its insulation levels and airtightness, its square footage and surface area, and the various amounts of heat lost through all of the exterior surfaces. This information is then plugged into a Manual D calculation, which helps determine duct sizing.

Sounds easy, right? Well, it isn't. It can be difficult to find a residential HVAC contractor who is willing to perform Manual J, Manual D, or code-compliant alternative calculations, even though they're required by code. You should not assume that an HVAC contractor who agrees to do a "heat-loss calculation" will perform an actual Manual J calculation. (When in doubt, ask to see the paperwork.) Because heat loss and heat gain through building envelopes is governed by many factors, an accurate Manual J calculation requires many inputs, as well as dedicated computer software. Those who do perform the calculation need to be diligent and accurate about the details, because taking any guesses about building components and other fudge factors used to cover unknown defects in construction will push heat-loss estimates higher, leading to furnaces that are oversize.

You could argue that a pinpoint-accurate Manual J isn't necessary when furnace-size options aren't that numerous, but it's not uncommon for rule-of-thumb calculations to miss the mark by more than a little. Even if you aren't sold on the idea of conducting an accurate Manual J calculation to size a furnace, you should consider one for the room-by-room calculations it provides, which are necessary to perform a Manual D calculation. Failure to take Manual J seriously means that Manual D calculations suffer.

The dos and don'ts of ductwork

During the 1950s and 1960s, fuel was so inexpensive that most heating contractors routinely installed ductwork without much attention to airtightness. In many areas of the country, contractors still install ductwork in vented crawlspaces or vented attics. These locations are outside of a home's conditioned envelope, and any air that escapes from leaky ductwork running through these areas is money wasted.

In the 1980s, energy-efficiency advocates responded to this issue with training programs to encourage HVAC installers to seal duct seams. After three decades of training, these programs are beginning to bear fruit in some areas of the United States. Unfortunately, the gospel of airtight ductwork hasn't reached every corner of the country, and many HVAC contractors are still installing ductwork the way their grandfathers did.

To make up for the fact that leaky duct systems waste large amounts of energy, many HVAC contractors install oversize furnaces with huge blowers. According to the DOE, 40% of contractors in one large-scale survey indicated that they purposefully oversized equipment, citing reasons such as "To reduce callbacks," "To allow for future expansion," or "Customers demanded it."

Designing a duct system properly and installing it carefully costs more than doing sloppy work, but it provides two important benefits to homeowners: better comfort and lower energy bills. □

Martin Holladay is a senior editor.

A low thermostat setting may void your furnace warranty

Energy columnists routinely advise owners of vacation homes to turn down their thermostats when the homes are unoccupied. As it turns out, homeowners following this advice not only are at risk of damaging their furnace; they are also at risk of voiding their furnace warranty.

If you read the fine print on the installation instructions for Carrier condensing furnaces, to take one example, you'll find this statement: "This furnace is designed for continuous return-air minimum temperature of 60°F ... or intermittent operation down to 55°F ... such as when used with a night setback thermometer [thermostat]. Failure to follow these return air limits may affect reliability of heat exchangers, motors and controls."

When I asked the Carrier Corp. whether setting one's thermostat to 50°F would void the warranty, the company had this response: "For optimal performance, Carrier Corp.'s 58MXB gas condensing furnace should be operated with return-air temperatures no lower than 60°F and no higher than 80°F. To support appropriate return-air temperatures, Carrier recommends that the 58MXB furnace be set within the range of 55°F to 80°F. Return-air guidelines and detailed operating instructions are included in the 58MXB owner's manual. Failure to operate the furnace according to the owner's manual could affect the furnace's reliability and void the factory warranty."

The bottom line: Condensing furnaces are more efficient than noncondensing furnaces, but their efficiency comes with the added risk that low return-air temperatures can contribute to the condensation of corrosive flue gases in the primary heat exchanger.