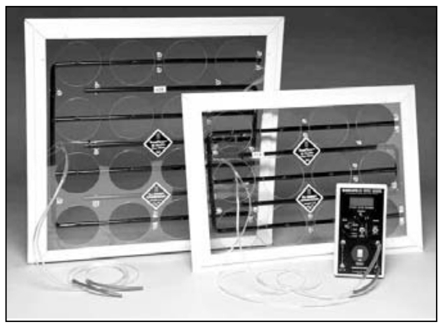
Flow Control Gains in Accuracy

A new flow meter is easier to use than a Duct Blaster, and more accurate than the temperature rise method.

by Paul W. Francisco and Larry Palmiter

The air flow rate through residential air handlers is an important measurement for a variety of reasons. One of the most important uses of this measurement is in assessing the adequacy of flow across a heat pump or air conditioning coil. Another is for the accurate estimation of the thermal efficiency of duct systems. Yet another use of air flow measurement is in diagnosing comfort problems in homes; such problems can be caused by too little flow for the size of the house and ducts, even if the thermal efficiency of the ducts is good and the flow over the coil is sufficient.

However, the primary method of estimating the air handler flow rate, which is the temperature change across the equipment, can be troublesome (see "Checking an Installation," *HE* Jan/Feb '02, p. 10). This is called the temperature rise method. This method combines the temperature difference between the supply and return air as measured near the air handler (for example, in the plenums) and the output capacity of the equipment to estimate air flow. For furnaces, the temperature in the supply plenum is usually extremely nonuniform, and the air flow estimate can vary by more than a factor of two, depending on exactly where the temperature is measured within the supply plenum. For heat pumps and air conditioners, one of the biggest problems with using the temperature rise method is that the actual operating compressor efficiency must be known in order to make an accurate estimate of flow rate.



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Using the external static pressure with the manufacturer's fan curve to estimate air handler flow can also be problematic. Pressures within the supply and return plenums can also be highly variable, and can be strongly affected by the inlet conditions. Manufacturer's data are based on a specific set of fan inlet conditions, and they do not always state whether the results include filters or coils. Also, in many cases, the manufacturer's data are not available, especially for older equipment.

Another method of measuring the air handler flow uses a calibrated fan (such as a Duct Blaster) installed at the air handler cabinet with the return isolated from the rest of the system. Research has shown that this method works well in residential systems, and it is one of the primary approved methods for estimating air handler flow for proposed ASHRAE Standard 152P, but it is time-consuming and somewhat difficult to do. A simple flow-measuring device that was accurate and easy to use would make evaluating HVAC systems and diagnosing comfort problems easier. And that translates into less time spent and fewer callbacks for HVAC contractors.

A New Tool to Measure Air Flow

In 1997, the U.S. Department of Energy (DOE) sponsored a project to develop a device that would meet the need for a more accurate, yet simple, method for estimating air handler flow. The outcome of this project was a new device called the TrueFlow Air Handler Flow Meter (hereafter referred to simply as the Flow Meter). It has been commercially available from the Energy Conservatory since the beginning of 2001. (For instructions on its use, see "Using the Flow Meter.")

The Flow Meter is inserted into the HVAC unit's filter slot. It consists of an active plate and spacers that are added to the active plate to make the required filter slot size. The active plate has a set of 3-inch-diameter holes in it. A pressure manifold averages the upstream total pressures in these holes, while a second pressure manifold averages the static pressures on the downstream side (see photos above). A small tube comes out of each of these pressure manifolds for

This Flow Meter is installed in a manufactured home heat pump. Tubes coming from the two manifolds allow for pressure measurements.

Using the Flow Meter

Calculating the flow across a coil using the Flow Meter involves six steps:

1. Insert a pressure measurement device at an acceptable location in the distribution system, such as a static pressure probe in the supply plenum.

2. With filter in place, turn the air handler on and measure the pressure between the distribution system and the house.

3. Replace the filter with the Flow Meter, bringing the small plastic hoses that measure the pressures up- and downstream of the flow plate through the air handler/duct system to the pressure gauge. To improve accuracy, seal gaps that would cause air to bypass the Flow Meter.

4. Turn on the air handler and measure the distribution system pressure at the same location as when the filter was in place (see steps 1 and 2).

5. Measure the pressure drop across the Flow Meter and use this to calculate the flow.

6. Calculate the correction factor and multiply it by the measured flow to get the flow that was moving through the system with the filter in place.

attachment to a pressure gauge. The difference between these two pressures is used with a calibration to provide an estimate of the flow. This calibration uses the same form as that used to convert a blower door fan pressure into an air flow rate for determining house leakage.

The Flow Meter active plate has a combination weatherstripping and H-channel on all four sides. The weatherstripping provides a seal around the plate when it is inserted into the filter slot, while the H-channel allows easy attachment of the spacers. The spacers have the weatherstripping and H-channel combination on all sides except for the side that is attached to the active plate. There are two sizes of active plate: 14 inch x 20 inch and 20 inch x 20 inch. The spacers are sized to cover about 90% of residential filter slots. For sizes that are not covered by the spacers, cardboard can be used to cover the slots, as the clear plastic material used for the plates and spacers is about the same thickness as standard cardboard.

One might question whether the Flow Meter changes the flow characteristics through the air handler, because the meter is either more or less restrictive than the filter. The device was designed to match approximately the pressure drop across a standard new 1-inch fiberglass filter. It also accurately matches the pressure drop in an electronic air cleaner (electronic air cleaners and standard 1-inch fiberglass filters have similar pressure drops). Measuring the duct pressure with respect to the house with the filter in place as normal, and measuring again with the Flow Meter installed, allows for any necessary correction. The ratio of the pressure under normal operation to the pressure with the Flow Meter is calculated, and the square root of the result is the correction factor.

The user's guide for the Flow Meter describes the best locations in the HVAC system for measuring this pressure. The supply plenum is often the best place to measure the pressure. When the supply plenum is unavailable, other locations, such as supply registers or return ducts, can be used. When using the return duct, it is important to measure pressure well away from the filter slot, because the Flow Meter can significantly change the flow pattern near it, even if the flow rate itself is virtually unchanged.

Performance in the Field

In order to investigate the performance of the Flow Meter under a variety of real-world settings, we performed a field study in collaboration with Washington State University. We tested the device in residential equipment in the Pacific Northwest. We tested electric furnaces, gas furnaces, and heat pumps, with air handlers in basements, in crawlspaces, in garages, and indoors. In all, we measured flow rates in 79 air handlers.

We used the Duct Blaster, or calibrated fan method, to establish a benchmark. This is simply a calibrated fan installed at the air handler cabinet with the return isolated from the rest of the system. In order to make the results from this method as accurate as possible, we used a Duct Blaster that had been specially calibrated by the manufacturer. In addition, we performed the standard temperature rise method for comparison to the Flow Meter.

The main results from the field tests are shown in Figure 1, which plots the results for the Flow Meter and the temperature rise method, expressed as ratios to the Duct Blaster method results. Only 74 tests are included here, since the graph is restricted to those cases where all three methods of flow measurement were done. The line through the middle of the box indicates the median, and the lower and upper boundaries of the boxes represent the 25th and 75th percentiles respectively. The line at 1 indicates perfect agreement with the Duct Blaster method.

The results show that the Flow Meter measurements are nearly unbiased, and that there is less scatter evident when Flow Meter measurements are compared to the temperature rise method measurements. In fact, the Flow Meter gives results that are about 4.5 times more accurate than the temperature rise method results. Note that the entire range of results using the Flow Meter fits within the box portion from the temperature rise method.

We also compared the performance of the Flow Meter to that of the temperature rise method in a different way (see Figure 2). In this graph, the horizontal axis is the percentage difference of the flow estimate relative to the Duct Blaster method, with no distinction made between estimates that are too low or too high. More than half of the Flow Meter results (referred to as flow plate in the figure) are within 5% of the Duct Blaster method results, while only about 20% of the estimates from the temperature rise method are within 5%. The Flow Meter results are within 10% of the Duct Blaster method results in 86% of cases, while only 30% of the temperature rise estimates meet that standard. All of the Flow Meter results are within 20% of the Duct Blaster method, whereas the temperature rise method

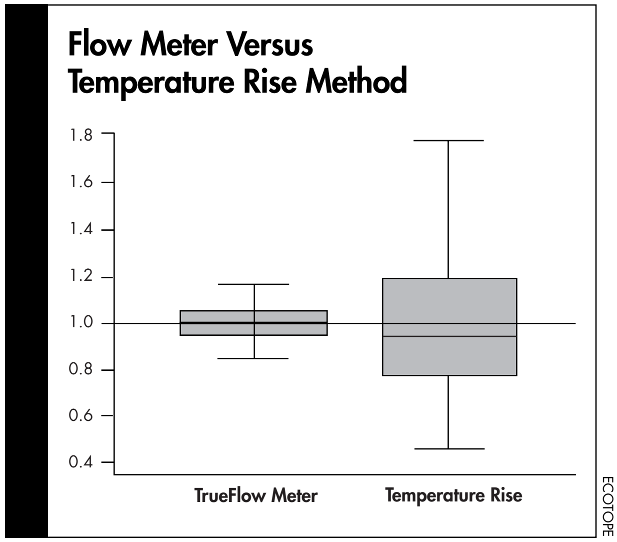

Figure 1. The Flow Meter device proves to be accurate in this comparison of the Flow Meter to the temperature rise method, expressed as a ratio to the flow measured using the Duct Blaster method.

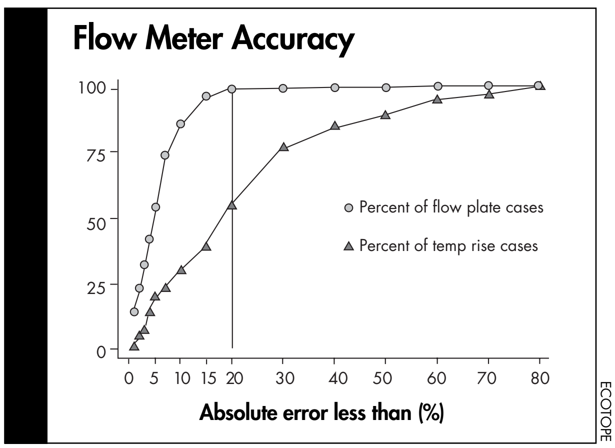

Figure 2. There is a closer correlation between the Flow Meter and the Duct Blaster measurements than between the temperature rise and the Duct Blaster measurements.

results are within 20% in slightly over half of the cases.

Ease of Use

Making measurements with the Flow Meter required the same amount of time as making measurements with the temperature rise method, including the measurement of output capacity. Output capacity needs to be measured when one uses the temperature rise method, since the nominal rated value is often incorrect. For example, electric-resistance elements may be burnt out, or a gas furnace may be dirty, compromising combustion efficiency. For an experienced user, measuring flow with the Flow Meter will take about 15 minutes.

In several houses, the temperature rise method could not be used, whereas the Flow Meter could. The most common reason why the temperature change method could not be used was that the output capacity of the equipment could not be measured. In some cases, heat pumps were not wired for resistance-only operation, and without the compressor efficiency it was not possible to use power measurements to obtain the output capacity. Our prior experience suggests that using the manufacturer's rated compressor efficiency leads to poor results, and that for an accurate estimate of flow the actual efficiency needs to be measured. Oil furnaces created a different problem. Even if combustion efficiency could be measured, there was no way to measure the input rate of consumption. Another reason why the temperature rise method could not be used was that some supply plenums were not easily accessible—for example, when the air handler sat on a garage floor and the supply plenum was in a crawlspace.

We found only two situations where the Flow Meter could not be used. In one case, the air handler filter slot did not have at least one dimension of a minimum of 20 inches. In the other case, in a downflow gas furnace, the flue pipe prevented access to the filter slot. Another situation that would make it impossible to use the Flow Meter would be one where there is no filter slot, as is the case when the filters are at the return grilles and no filter slot was placed at the air handler. It is not necessary that the filters actually be located at the air handler, only that a filter slot exist; but there may be some systems that do not have

The Flow Meter has a spacer to fit most filter slots. This one fits in a 20 inch x 30 inch filter slot in a manufactured home.

filter slots at the air handler at all. In cases such as this, flows could be measured at the grilles, but this would not capture any return leakage and hence would likely not be the actual air flow through the air handler. Of course, this return leakage would also be unfiltered air, so one could argue that the first thing that should be done is to install a filter slot.

Our field tests confirmed that in most cases the flow through the air handler with the Flow Meter in place was essentially the same as that with the filter in place. Thus, the correction factors derived from the auxiliary plenum pressure measurements were generally small. However, in a few cases these corrections were fairly large. More than half of the houses required less than a 10% pressure correction, which corresponds to a 5% or less correction to the flow. In a few cases, a large correction was necessary, though the required correction was rarely greater than 25% (corresponding to about a 12% flow change). One common cause of a large correction was a very dirty filter. In these cases, the Flow Meter was significantly less restrictive than the filter.

Paul W. Francisco and Larry Palmiter are researchers at Ecotope, a Seattle-based consulting firm specializing in the evaluation and design of energy conservation in buildings.