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Heat Pump Study: Tricks of the Trade That Can Pump Up Efficiency

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by Virginia Jenkins

Heat pumps can be highly efficient devices for heating or cooling indoor air. Yet all too often, poor service can result in costly operation. A study in California shows how the right installation, maintenance, and troubleshooting techniques for the whole system can make the heat pump a valuable part of a home.

Many of you are already familiar with the sad story of the heat pump. Its energy efficiency looks great on paper, but once installed, it often earns a bad reputation. In 1983 one researcher found that residents of a retirement community disliked their heat pumps so much that they used their kitchen ranges for space heating. They, like many other consumers, complained the heat pumps blew cold air and were noisy and expensive.[1]

Two years ago, many homeowners in an area near Auburn, Calif. were unhappy with their heat pumps. The local utility, Pacific Gas & Electric (PG&E), received unusually large numbers of complaints from them of high electricity bills and poor system operation. PG&E wanted to know whether correctable mechanical problems were to blame. It hired John Proctor, then of Building Resources Management Corp., to design and implement a study to address the heat pump customers' complaints. The Pacific Gas & Electric Heat Pump Efficiency and Super Weatherization Pilot Project[2] was the result.

The first objective of the Pilot Project was to identify the major problems and their prevalence in the existing residential heat pump installations. The second was to design a correction strategy that would cost PG&E $400 or less per site. Participating homeowners would also share some of the costs. (See Table 1.) Project goals were improved homeowner comfort and satisfaction, increased energy efficiency of mechanical systems, and 10–20% space heating energy savings. By improving system operations, the project wished to increase customer acceptance of heat pumps in general.

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Table 1. Heating Energy Savings and Cost Estimates for Individual Retrofit Measures

Retrofit Measure	Average Heating Energy Savings %	Estimated Cost per Site $	Net Owner Lifecycle Benefit	Net Utility Lifecycle Benefit
Duct and House Diagnostics		60		
Heat Pump Diagnostics		30		
Repair Disconnected Ducts	15	35	1638	562
Repair Diffuse Duct Leaks	8	150	952	147
Install Thermostat Cutout	10	100	462	82
Correct Low Air Flow	6	50	312	52
Install Fan "Off Time" Delay	4	50	167	23
Repair Leaks and Correct Refrigerant Charge (approx. 30% of units)	18	200	777	215
House Medic (alone)	15	530	1281	470
House Medic (after duct repairs are already done)	8	430	612	194

Methods: Testing, Repairs, Feedback

To attain its goals, the Pilot Project employed initial testing, system modifications, repairs and retrofits, and final testing. The project borrowed two experienced technicians from a local heating contractor. They recorded data at every step of the process. Proctor used these data to evaluate the condition of the heat pump system and of the house, the technician's performance, and the merits of the testing and retrofit methods used.

Homeowners included in the study used an average of over 30 kWh of heating energy per winter day, high even in this snow-blanketed Sierra climate. They all heated with their heat pumps. These homeowners also all had high total electricity usage (more than 14,600 kWh annually), and had complained to PG&E about high bills between December 1988 and December 1989. The Pilot program included 51 heat pumps at 48 residences which were serviced by several different heating contractors. Work began on the first house on November 30, 1989.

A heat pump technician visited each home, testing and repairing. The tests determined the problems with the heat pump and the building shell, and their frequency. The technician measured heat-pump air flow, heat output, and apparent electrical input (from which the coefficient of performance (COP) was determined)[3], tested the unit control cycle, and inspected insulation and ductwork. He measured house leakage with a blower door test. Homeowners were interviewed as to their heat pump problems and possible causes. Proctor later reviewed the data collected, and if he determined that the unit needed additional work, the technician returned to complete the assignment.

Many participants, in their own words, "hate heat pumps" due to high bills, poor comfort, or especially a combination of the two. One resident complained that his house remained cold whenever the outside temperature dropped below 40°F. Pilot project technicians found that the resident's auxiliary strip heat had never been connected, despite two previous service calls. Two months later he was happy, exclaiming, "This works great! I can get heat!"

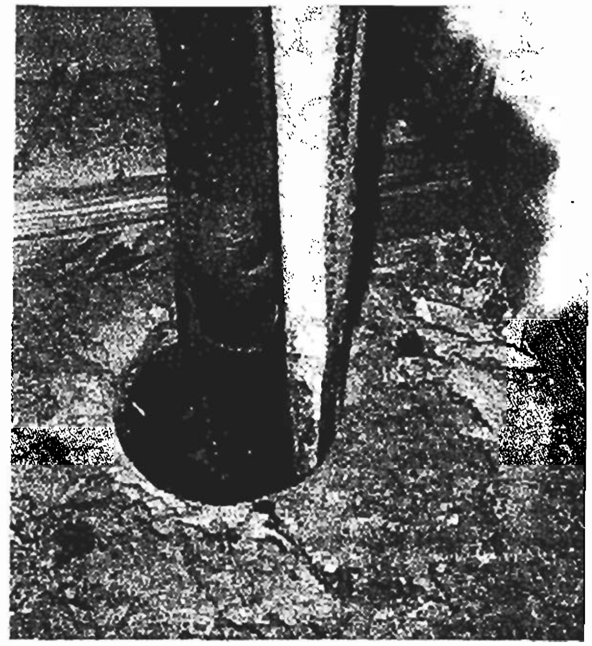
The Culprits

The study found that *all* of the houses studied had at least one major problem. (Of course, these were all houses with high numbers of heat-bill-complaints.) Problems occurred in the heat pump, its controls, or the house ductwork or shell. Seventy percent of the houses had two or more major problems. Table 2 summarizes the problems found. Most of these houses had high "diffuse" supply duct leakage and return duct leakage (>150 cubic feet per minute), or "catastrophic" duct leaks such as disconnected ducts. Over half had low air flow to the inside coils or air recirculation at the outside coils. Refrigerant leaks or incorrect charges were also very common. Control problems included manual setbacks and "disagreeing managers," both of which caused excessive strip heat use. Shell problems included substandard insulation and houses leakier than 0.75 air changes per hour (ach), derived from the Lawrence Berkeley Laboratory air infiltration model.

Table 2. Problems Identified in Pilot Project Sites
(48 Houses, 51 Heat Pumps)

	Number of Houses with Problem	Problems Solvable through Program
HEAT PUMP PROBLEMS		
Diffuse Duct Leakage > 150 cfm	33	25
Low Air Flow	24	19
Incorrect Charge	16	16
Disconnected Ducts	16	14
Refrigerant Leaks	10	10
Recirculation Through Outside Coil	9	0
Other Major Problems	6	5
Auxiliary Heat On First	3	3
CONTROL PROBLEMS		
Manual Thermostat Setback	23	23
"Dueling Managers"	8	8
SHELL PROBLEMS		
House Leakier than 0.75 ach	15	15*
Less than R-19 Ceiling	5	5*
No Floor Insulation	2	2*

*Building shell retrofits are an optional component of the program.



Bruce Davis

Openings for service lines like this can open the way for unwanted air flow.

Hot Air Flow

Correct air flow is critical in heat pump systems. While a 10% reduction in air flow will increase fossil fuel furnace use by 1.2%, it will increase heat pump use by about 7%—over five times as much. In this study, low air flow was the most prevalent heat pump problem. The primary cause of low air flow was dirty inside coils. Correct filter cleaning and replacement is crucial to help keep coils clean. Once coils are dirty, however, the only option is to clean them. Often, though, the coils were nearly inaccessible. In the houses studied, filter maintenance patterns varied widely, from replacing them monthly to yearly to not at all.

Low air flow was also the most likely problem to go unrepaired. This is because service technicians do not regularly test air flow or duct work, often because of indoor coil inaccessibility. In one house, the technician found a return duct closed off in the attic, which resulted in an air flow of only 61% of design. The homeowner asked, "Why hasn't anyone else found this? I've had contractors and PG&E out here for five years. All they could ever tell me was, 'heat pumps just work that way.'" The project corrected 56% of the houses with low air flow problems, for an average estimated heating savings of 5.6% per unit corrected.

High air flow is a problem in heat pump systems, too, but for different reasons. With high air flow, the unit operates efficiently, but homeowners often complain of "cold air from the registers." In addition, higher duct pressures increase loss through duct leakage.

Heat Pump Training Seminars

Most heat pump manufacturers provide training seminars which are specific to their equipment, but teach techniques that could be generalized to other brands. These seminars are offered once or more per year, through distributors or by the company directly, and often in many locations throughout the U.S. and Canada. Training calendars usually run from September to May, so few manufacturers had 1991 schedules ready when this list went to press. In addition, several associations offer heat pump training seminars. These are sometimes restricted to association members. This list may not be exhaustive. It is grouped by heat pump type.

Air-to-Air Heat Pumps

Montgomery Community College Heat Pump Skills Center/ North Carolina Alternative Energy Corp., P.O. Box 12699, Research Triangle Park, NC 27709. (Tel: 919/361-8000). Heat Pump Servicing Topics: Field testing, performance optimization. This one-week course is only available to experienced service technicians who live in North Carolina, as it is supported by the local utilities. The $195 price includes all materials and lodging for the week. This hands-on course emphasizes techniques for keeping all equipment, regardless of manufacturer, near their specifications. Call for a current schedule.

Oregon State University Extension Energy Program, Batchellor Hall, Rm. 344, Corvallis, OR 97331. (Tel: 503/737-3004). This program has, in the recent past, offered several courses of interest, such as a 2-day, $375 course on heat pumps for homes and another on air-to-air heat pumps. Courses are usually supported by associations such as Air Conditioning Contractors Association or the Northwest Public Power Association, so entrance is sometimes restricted to members. Call for current plans.

Rheem Air Conditioning, 5600 Old Greenwood Road, Fort Smith, AR 72903. (Tel: 501/646-4311). Heat Pump Seminar School Topics: Complete basics, including installation, servicing, electrical, charging. This two-day training is only available through local Rheem distributors; costs are determined by them. A manual is included. Dates are determined according to requests by distributors.

The Trane Company, Troup Highway, Tyler TX 75711. (Tel: 903/581-3659). Heat Pump Service School. Topics: Complete installation and service. This 4½ day course is given several times a year, at the Texas plant or in other locations. Course materials and lunches are included. The 1990 price was $200; call for dates and prices for 1991.

Bard Manufacturing Company, P.O. Box 607, Bryan, OH 43506. (Tel: 419/636-1194). Topic: Heat pump servicing and trouble shooting. This five-day training is limited to 12 people per class. It is given at the Ohio factory, or other locations on request. The cost of $210 includes all course materials. 1991 dates are April 1–5, June 3–7, plus more after August (not yet scheduled).

Lennox Industries, P.O.Box 79900, Dallas TX 75379. (Tel: 800/654-DAVE (3283)). Topics: Heat pump design, installation, maintenance, trouble-shooting. This four-day course is given in Calgary, Toronto, Sacramento, Marshalltown, Iowa, Atlanta, Columbus, or Fort Worth, plus elsewhere on request. The $435 cost includes manuals and hands-on experience. Call for 1991 dates.

Carrier Corp., P.O. Box 4808, Syracuse, NY 13221. (Tel: 315/432-6000). Tech-2 course. Topics: Complete principles of heat pump operation and servicing. This five-day course is given at the company laboratory in Syracuse as well as six other scheduled locations. Its cost of $600 includes all materials and hand-on practice. 1991 starting dates are: Chicago, San Francisco, and Syracuse Oct. 7; Minneapolis, April 15; Portland, April 8; Phoenix, April 22.

Ground-Source Heat Pumps

Carrier Corp., P.O. Box 4808, Syracuse, NY 13221. (Tel: 315/432-6000). Topics: Design, applications, control, and ventilation of commercial water source heat pump systems. This 4½ day workshop is usually given in Syracuse and costs $500. Call for 1991 dates.

National Rural Electric Cooperative Association/AHP Systems Inc., 3333 Quebec Street, Suite 8100, Denver, CO 80207. (Tel: 303/388-0935). Contractor training and advanced contractor training workshops. Topics: The first, a two-day course, covers installation, maintenance, and troubleshooting for Ground Source Heat Pump systems. The second lasts three days and is more advanced, assuming prior experience with these systems. Both of these courses cost $175, and include manuals and lunches. The basic course is taught as needed all over the U.S., while the advanced is taught in Marietta, Okla. 1991 schedules not yet available.

WaterFurnace International, Inc., 4307 Arden Drive, Fort Wayne, Indiana 46804. (Tel: 219/432-5667). Geothermal Servicing, Level 1. Topics: Design, installation, and servicing of closed-loop geothermal heat pumps. This course runs five days. It costs $300 for the first person from a company and $200 for each additional employee. It is given monthly in Fort Wayne, and includes manuals, take-home videos (with $300 fee only), some meals, hands-on lab work, and field experience at a local job site. Class size is 10-20. Call for 1991 dates.

Climate Master, P.O. Box 25788, Oklahoma City, OK 73125. (Tel: 415/745-6000). Geothermal Training. Topics: Complete designing, installation, trouble-shooting. This two-day seminar is given all over the U.S. and Canada. An optional certification exam is given at the end of the course. Call for 1991 dates.

Oklahoma State University College of Engineering, Architecture and Technology, 101 Industrial Building, Stillwater, OK 74078. (Tel: 405/744-5175). Topics: Complete system design and troubleshooting. This two-day course costs $225 for International Ground Source Heat Pump Association (GSHPA) members and $300 for others. It is given in Stillwater, and includes participation in an actual GSHP-system installation. 1991 dates are March 13–14, April 10–11, plus others to be announced.

Retrofit Heat Pump and Duct Sealing Training

Proctor Engineering Group, 45 Massasoit Street, Suite 102, San Francisco, CA 94110. (Tel: 415/647-5052). Topics: Duct leakage, and heat pump and air conditioner servicing.

Natural Florida Retrofit Inc., P.O. Box 301, Montverde, FL 32756. Contact John Tooley. (Tel: 407/469-2173 or 407/841-4376). Topics: Class and field training on mechanical air distribution and interacting relationships (mad-air) to eliminate the main causes of heat pump failure such as installation and air distribution systems. Classes nationwide.

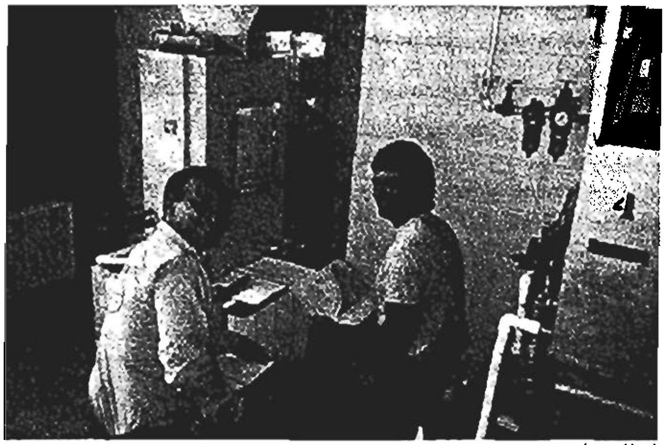
Jim Fitzgerald Contracting, 4225 Columbus Avenue South, Minneapolis, MN 55407. Contact Jim Fitzgerald (Tel: 612/823-0498). Topics: Advanced weatherization techniques such as dense-packed cellulose.

The North Carolina Alternative Energy Corporation, P.O. Box 12699, Research Triangle Park, NC. Contact Leon Neal. (Tel: 919/361-8000). Topics: For experienced service technicians for central air and heat pumps. This five-day course is a unique approach emphasizing field measurement of capacity and efficiency to recognize impact of service improvements. Cost: $195, includes motel and meal allowance.

The Energy Conservancy, 5158 Bloomington Avenue South, Minneapolis, MN 55417. Contact Gary Nelson. (Tel: 612/827-1117). Topics: Training on a house as a system, which includes looking at duct leakage, interaction of forced-air distribution systems, and house tightness.

Alabama Power Company, Heat Pump Training Center, 2388 Chilton Road 93, Verbena, AL 36091. (Tel: 800/634-0154). Topics: Duct design training, heat pump application, installation, marketing, and service for both retrofit and new construction. Certifies heat pump specialists in Alabama.

Sunpower Consumer Association, 5160 Parfet, Unit A3, Wheat Ridge, CO 80033. Contact Margie Figgins. (Tel: 303/467-0521). Topics: Overall training in heating systems, including heat pumps and ductwork, weatherization on houses and mobile homes, and emphasis on technical aspects and accurate documentation of field work.



Leon Neal

Manufacturer's psychrometric chart—in technician's hand, right—is an indispensable tool for determining a heat pump's capacities.

A Charged Problem

Improper refrigerant charge was the second most common problem, found in 31% of the units. All 16 units were repaired, with an estimated resulting energy savings of 18% each. Service technicians typically guess at charge levels. One participant commented that the previous technician "didn't even use gauges." He said he didn't find any leaks but he would "fill it up." This unit had leaks at both Schrader valves and moisture in the system. Moisture or overcharge can lead to compressor failure. Many heat pumps in this study were older (average age was 13 years) and had no manufacturers' refrigerant test charts which specify operative parameters at given indoor and outdoor temperatures. Overcharge is difficult to determine in the winter without charts.

Duct Blinds

Catastrophic duct leaks (such as totally disconnected ducts and air returns open to the attic) appeared in 31%

John Proctor

Catastrophic attic ducts leaks—easy to find, yet undiscovered by service personnel—compromised efficiency in a third of the houses studied.

of the houses. They could have been discovered by anyone willing to crawl the length of the ducts. All catastrophic duct leaks were repaired.

Diffuse duct leaks, found in 70% of the houses, accounted for 8% of total house leakage after the catastrophic leaks had been repaired. Each of these small leaks was by itself inconsequential, but together were much more important than the 8% figure would suggest because of higher pressures in the ductwork.

Diffuse duct leaks accounted for 16% of total house infiltration in the affected houses (heating season average). As a result, the total heat loss due to diffuse duct leakage was 13% of the annual heating use. This occurred because supply leaks dumped air, warmer than house temperature, to the outside. (Proctor has done a study similar to this one, on heat pump efficiency in the cooling mode.[4] But supply leaks had an additional energy penalty beyond their effect on infiltration. The Pilot Project determined that, with only four hours, experienced crews could achieve a 65% reduction in diffuse duct leaks. Savings estimates were 15% for catastrophic leaks repaired and 7% for diffuse leaks repaired.

Controls

PG&E first thought that the homeowners' high thermostat settings were responsible for their high electricity bills. This study found that not to be true. These houses in fact had low thermostat settings. Nevertheless, the thermostat was a problem in most houses. In 17% of these houses, two adults fought over the thermostat settings, one turning the heat up while the other often turned it all the way down. In 48% of the houses, the thermostat was set back manually at night or when the house was empty. In either case, the electric resistance strip heat came on whenever the thermostat was turned back up, whether it was actually needed or not. Monitoring data from one house showed that the participants tried avoiding strip heat in the manner suggested by the energy auditors. Every morning they carefully turned up the heat only a few degrees at a time in intervals of several minutes. Even this conscientious technique was not successful in avoiding strip heat use.

The pilot program attempted two control retrofits. About half the houses received a new digital, programmable thermostat with a gradual ramp-up feature. This thermostat solved the strip heat problem, but was not well accepted by program participants because it seemed more complicated than their old one. Many people never learned to operate it and instead manually overrode it.

Ninety-four percent of the houses with control problems received a thermostat cut-out which disconnected the strip heat altogether whenever the outside temperature exceeded 40° F. Above this temperature a heat pump alone is generally sufficient to comfortably warm a house. In one typical case, 38% of an entire heating load was provided by the strip heater when the outside temperature averaged 53° before the cut-out was installed. After retrofitting, no strip heat was used on a similar day. The cut-out system was well accepted because it was invisible to the homeowner and required no behavioral changes. Potential savings from this retrofit were 16% for each of the

Measuring Heat Pump Efficiency

Measuring heat pump efficiencies in the field is often thought to be difficult because measuring air conditioner efficiencies certainly is. But a little trick—using the backup heat—greatly simplifies the measurement. You can actually get an accurate efficiency measurement with equipment as minimal as two thermometers and a stopwatch.

The presence of backup heat (or strip heater) facilitates air flow (cfm) measurement. For air conditioners, air flow is "the hardest thing to measure in the field," according to Bruce Hunn, head of the Building Energy Systems Program at the University of Texas. But for heat pumps, it is possible to measure the air temperature rise between the return and supply air (ΔT, in °F), and the back-up heat plus fan power draw (BW + FW, in watts). This allows the cfm to be calculated.

$$\text{cfm} = \left(\frac{BW + FW}{\Delta T}\right) \times 3.16$$

Measuring air temperatures requires care. It is important that the air be well mixed and critical that the thermometer not be in the line of sight of the backup heaters to avoid radiant heating errors. This usually means taking readings a small distance from the heat pump, beyond at least one duct elbow. Longer distances lead to other measurement errors because duct air leakage and heat losses can become significant.

The building's kWh meter is the best way to measure the backup heat plus fan power. Simply time the revolutions with a stop watch, and use the kh factor on the meter to determine power drawn by the equipment as follows:

$$\text{Watts} = kh \times 3600 \times \frac{\#\text{ revolutions of meter disk}}{\#\text{ seconds}}$$

Subtract the power draw when the equipment is not running, and ensure that nobody turns on a microwave oven during the measurements! (John Proctor, President of Proctor Engineering Group, suggests cutting power to the rest of the building at the circuit breakers—with the owners' permission of course.) Take one measurement with the fan and heat on—i.e., set the heat pump control so that only the backup heat and the fan run (BW + FW)—and one with the fan only (FW). The difference between the two is the backup heat only (BW), which will be used in the COP calculation as well.

With the air flow rate, the heat pump efficiency can now be measured. Run the equipment in heat pump mode, with the backup heat on, and again measure the air temperature rise (ΔT). Also measure the total equipment power draw (EW, in watts). (The degree of error from leaving back-up heat on proves to be negligible.

The heat pump coefficient of performance (COP) is:

$$\text{COP} = \frac{((\text{cfm} \times \Delta T \times 1.00) - (BW \times 3.41))}{(EW \times 3.41)}$$

This equation subtracts the backup heat capacity (BW x 3.41) in order to calculate the COP of the heat pump without the backup heat.

To compare the field COP to manufacturers' ratings, one must also measure the indoor and outdoor temperatures, because heat pump efficiency varies greatly with air temperature. If the equipment isn't rated, John Proctor's report provides a good generic chart.

In order to make it easy enough to use in the field, a few minor simplifications have been made in this technique. This technique assumes that:

- air properties such as density are constant (again, for our purposes, leaving on backup heat makes only a minor difference),
- all fan power is converted into heat (some of it is actually still in the form of air pressure where measurements are taken),
- the system is at steady state,
- and—in the case of a heat pump added to an existing furnace—fan power draw of the furnace motor is the same as that of fan coils used in equipment rating.

These simplifications result in errors of less than 1–2% of the final COP calculation.

A simple way to check for air mixing is to move the thermometer around within the duct, waiting at each position for the reading to stabilize. Averaging thermometers are also available. The temperature should be fairly uniform.

For all the measurements, run the equipment for at least 10 minutes before taking readings to allow some stability. However, perfect stability is impossible unless it's in the middle of winter and the building heat load is equal to equipment capacity! To ensure accuracy, double-check measurements with any secondary means available. For example, a wattmeter can be used to check the building meter power measurement. Also, Bruce Hunn reports measuring cfm using both a pitot traverse and a flow hood, with some success. Finally, to avoid erratic readings, consider taking a few measurements and averaging them.

31 houses that received it, but variability in actual cut-out temperatures lowered estimated average real savings to 8%.

Decks and Defrosters

Other frequent heat pump problems included leaks in the refrigerant lines, frequent defrost cycles, and air recirculation to outside coils. Leaks had sometimes been introduced by previous repairs. Project technicians repaired all leaks. Time between defrost cycles was corrected in all affected units (defrost cycles occurring every 90 minutes are sufficient in this climate). Air recirculation usually was caused by the placement of the outside coils in a restricted area, such as under a deck. In one case, the trapped air was 10° F below the ambient temperature. This unit's efficiency was lowered by 11%. Not surprisingly, no one could be convinced to tear down their deck for the sake of lower heating bills.

Overall Savings

The Pilot Project results showed that, if the full program were to be applied to houses of this type, homeowners could expect an average heating-energy savings of 27%. These savings were well above the original goal of 10–20%. The program also projected an average cooling savings of 22%. Under the plan, the utility would pay $400 per site, while it would regain a calculated net life cycle benefit of $459. The program would cost participants from $50 to $350, and would save them an average calculated net lifecycle benefit of $2,597. The lifetime of the duct repair work is considered 15 years. That of the heat pumps is only five years, owing to the likelihood of replacement. Costs and savings for individual retrofits are summarized in Table 1. Because not all the retrofits were needed in each house, the sum of the savings for each of the individual retrofits added up to a higher number than the 27% average savings for the package of retrofits.

"But I've Tried Before!"

Three-quarters of the project participants had already tried to discover the source of the poor system performance by calling in a heating contractor or PG&E. These service visits had not found nor repaired the above problems. In many cases, heating technicians blamed their inability to find problems on the heat pump itself. They often had made such comments as, "I'm sorry, this heat pump is doing the best it can. If you would like, I can install an efficient propane furnace for you." Comments like these reinforced participants' negative attitudes towards heat pumps.

The existing contractor infrastructure is just not equipped to satisfactorily address many heat pump problems. This study was more successful because it used an integrated approach to diagnosing and servicing problems. Even though the Pilot Project employed only experienced technicians, many of the tests and testing devices used were initially unfamiliar to them. Due to technician error, 39% of the program sites had to have return visits. The project provided them the additional training and feedback necessary to assure quality repairs and retrofits.

Recommendations

This study found that installed heat pumps did not perform up to expectations due to numerous system problems. But according to John Proctor, there is an even more basic issue which allows the problems to remain unsolved. "The contractor business is built on a low-bid/least-cost system that precludes you from spending the time to find out what's really wrong with the unit," he says. "It's economically almost impossible to do the job right. The field technicians may have been trained to do the job properly in a good school, but the workplace pressure is to do it fast and dirty."

"It's a major economic mistake for a customer to make the hiring decision based on cost instead of quality. But, of course, everybody does just that all the time, and so you see bad work."

Proctor suggests several steps to build up the contractor infrastructure. Contractors should have an economic incentive for doing good work. They should use a system that accomplishes the desired goals and that provides workers with feedback and training. Technicians should have adequate time to accomplish needed tasks. Finally, everyone must be held accountable to the system.

In new heat pump installations Proctor recommends that several strict criteria be employed. The measured air flow of the system should be between 5% below and 15% above the manufacturer's specification. The installed Energy Efficiency Ratio (EER)[5] or COP must be tested on site and be within 5% of specification. Duct leakage should be tested, and be less than 150 cfm at 50 Pa house pressure. Ductwork must be sealed at every joint with mastic tape. Coils and filters must be accessible for cleaning.

Bruce Davis

Clogged fan blades can result from duct leaks somewhere between filter and fan, severely limiting heat pump efficiency.

Heat pump installers and maintenance workers can glean some valuable information from the results of this study alone. Installers should ensure that the outside coils are not located under a deck or in a similar area of restricted air flow. Similarly, inside coils must be easily accessible for cleaning. It is crucial that the ductwork joints are mechanically secured and sealed with mastic. The ducts must not restrict proper air flow.

When maintaining heat pumps, it is important to clean the coils, if necessary, as well as replace the filters. Technicians should test the air flow and COP or EER on the units. Personnel working on units in the winter must use the hot gas discharge temperature method to determine charge. This method requires the manufacturers' charts. In the absence of such charts, a low COP with adequate air flow should be checked for charge by pumping down and recharging by weight. Care must be taken when repairing refrigerant lines to leave no leaks, and to fix any existing ones. Ductwork is an important component of the heat pump system, which needs to be checked along with the heat pump itself.

Technicians could clearly benefit from specific training in heat pump installation and maintenance, as well as in ductwork repair. This training must be accompanied by adequate time to complete each job properly and feedback on the work that is done. Improved installation and maintenance quality are essential, in order to assure that heat pumps are effective and accepted in the field. ■

Endnotes

1. Richard C. Diamond, "Energy Use Among the Low-Income Elderly: A Closer Look," LBL-17593, Lawrence Berkeley Laboratory, Applied Science Division, Univ. of Calif., Berkeley, July 1984.
2. Available from the Proctor Engineering Group, 45 Massasoit St., Suite 102, San Francisco, CA 94110.
3. The Coefficient of Performance is the measure of instantaneous heating or cooling efficiency under constant test conditions. It is the number of Btus a heat pump can supply to or remove from the conditioned space per Btu of energy consumed.
4. PG&E Appliance Doctor Pilot Project, Jan. 1991, available from the Proctor Engineering Group, 45 Massasoit St., Suite 102, San Francisco, CA 94110.
5. The Energy Efficiency Ratio is the measure of instantaneous cooling efficiency under constant test conditions. It is the number of Btus a heat pump can remove from the conditioned space per watt-hour of electricity consumed.