Review of Literature 1989-1997:

Impacts of Forced Air Distribution Systems on Homes and Potential for Improvements

prepared by

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Background and Summary of Findings

This literature review is part of a duct efficiency pilot program co-sponsored by the Northwest Energy Efficiency Alliance [NEEA] and the Electric Power Research Institute [EPRI]. A literature search was conducted by Washington State University Cooperative Extension Service Energy Library. In addition to articles identified by the library, project staff in Oregon and Washington contributed a number of articles from their own collections. In all, approximately 107 articles or studies dating from 1989 to the present were collected and reviewed.

Duct literature supports several broad conclusions:

1) Deficiencies associated with forced air distribution systems cause large energy losses and can have other unintended effects on people and buildings. Reported energy losses range from 10-40% with 30-40% being typical. Other unintended effects include health, safety, air quality and building life issues.
2) Duct losses are influenced by housing characteristics and duct location within homes. Homes with a large percentage of ducts inside conditioned space—such as homes or multifamily buildings with conditioned basements, or new manufactured homes—experience losses at the lower end of the range: 10-20%. Homes with large portions of their ductwork outside heated space—homes built on crawlspaces--experience higher losses: 20-40%.
3) When distribution system components are accessible, various repairs/improvements can be cost effectively performed.

To place the energy losses from forced air distribution systems in perspective, annual efficiency losses in the range of 30% are of comparable magnitude to the total energy savings from all of the building envelope measures in Northwest utility sponsored energy efficient home programs [Palmiter, Francisco, 1994]. Regional housing programs focused on aggressive improvements to the building envelope such as increased insulation, thermally improved windows and doors, attention to air tightening and ventilation. In the absence of technical knowledge of duct system effects, ducts were under-appreciated and duct improvements under-emphasized.

Studies of duct system effects and repair benefits have been conducted in a range of housing types. Earlier studies focused on duct system impacts in site-built single family homes. Later studies broadened this focus to include duct impacts in manufactured homes, multi-family homes and small commercial buildings. We now have a better idea about comparative distribution system impacts in homes with ducts outside conditioned space [ducts in attics and crawlspaces] and homes with ducts inside conditioned space [typically homes with basements].

Studies have been conducted by researchers at federal laboratories and by private engineering consultants across the US. Duct systems in Minnesota, New York, Wisconsin, North Carolina, Tennessee, Florida, Arkansas, Arizona, California, Oregon, Idaho, Montana and Washington have been tested and are reported in the literature. In addition to the published record of such activities, duct improvement projects have been or are being carried out in many other states as well. Studies include homes utilizing electricity as well as natural gas for space conditioning. Distribution system effects in cooling climates as well as heating climates are documented.

Costs and energy savings benefits of duct improvements in existing homes have been extensively reported. Reports of duct improvement costs in new construction are relatively rare. In retrofit situations, reported costs have ranged from $200-$500 per home. It is presumed, but not clear from cost reports, that costs of performance testing by the repair technician have been included in these figures. One Northwest study that included average new construction costs placed duct sealing improvements at $301/home, and tracked other additional associated costs such as load calculations $75, and distributed returns and /or pressure relief $403. [Haskell 1995]

Studies report average decreases in annual energy use for homeowners in the range of 10-20% due to duct improvements. Where studies have examined costs of the energy savings to the utility, levelized costs have been in the range of 10-30 mills per kWh. Recent studies on large samples of Oregon and Washington homes report levelized costs of 13-17 mills/kWh. [Robison et. al 1997; Lerman 1997]

In addition, since space heating or cooling system run-times are greatest when outdoor temperatures place their heaviest demand on regional utility networks, several studies document reductions in peak demand to the utility system as well as annual energy savings to the homeowner. [Cummings, Tooley & Moyer 1991; Proctor 1991; Modera et. al. 1992; Vigil, Cummings, Moyer 1993; Horowitz, McGraw & Anderson 1994; Kolb & Ternes 1995]

About a third of the literature reviewed presents field procedures for implementing duct improvements or addresses associated technical issues of interest to people actually doing repair work. Technical literature of this sort includes testing and repair protocols, technical manuals and a range of other information about rapidly developing technologies and techniques. Technical literature attempts to fill a need for training that is universally recognized as a critical component in all serious attempts to implement wide-scale improvements to forced air distribution systems. It is important to note that most of the diagnostic techniques that help make duct repairs cost effective and safe are under 10 years old and, except in areas benefiting from aggressive utility sponsored duct programs, are virtually unknown to the mainstream hvac [heating, ventilating, air conditioning] industry. Because early efforts at duct repair adapted tests and equipment used for building envelope analysis, in many areas people doing building analysis in the weatherization/conservation community currently have more experience doing duct diagnostics and repairs than hvac technicians responsible for original duct installation.

As ducts received increasing attention, new equipment and testing techniques were rapidly introduced. In 1993, equipment for directly measuring air leakage in duct systems became readily available for the first time. Before that, neither the hvac industry nor the conservation community had the means to quickly evaluate air tightness of ducts. Once new equipment was placed in use, measurements showed air leakage to be much more extensive than anyone had previously imagined. Although conductive losses through ducts had been recognized as a contributor to space conditioning loads, the magnitude of losses due to duct air leakage were an unpleasant surprise. By late 1997, equipment that seals ducts “from the inside out” using a liquid sealant vapor [aerosol based duct sealing] was commercially available [Modera, Dickerhoff et. al.1996]. Although some national hvac professional associations are showing interest in duct improvements, most hvac professionals are not aware that this technology exists. Without broader recognition within the hvac industry of duct system diagnostic and repair techniques, energy savings and other benefits of duct repair efforts will not be achieved on a wide scale.

Although we have learned a great deal about ducts in the past 10 years, there are still gaps in our knowledge. For instance, a specific study of the prevalence of forced air systems in Northwest housing has yet to be undertaken, although it is known that a significant number of Northwest homes have forced air distribution systems. A 1993-1995 survey of builders participating in regional site-built energy efficient home programs,[Lubliner et. al., 1995] found that for 68% of builders, the most common hvac system is a forced air ducted system. Over two thirds homes built by these builders were found to be non-basement homes with ducts outside heated space. 61% of the builders install ducts and air handlers in unheated crawlspaces, attics and garages. While this estimate of forced air systems is helpful, it is biased towards builders in electric utility programs and may not account for Northwest homes built using natural gas forced air systems.

Measurements of heating system efficiency have been conducted in existing site-built and manufactured housing. But no comparable efficiency measurements have occurred on systems that were aggressively sealed and performance tested during initial installation. Consequently we do not currently know the upper limit of duct efficiency improvements in new construction. Only 1 study has currently been conducted to assess energy penalties /repair benefits associated with duct system leakage and system efficiency losses in commercial buildings. [Withers et.al. 1996]

On a national level, discussions continue about standardized methods for determining system efficiency based on field measurements or general system design information [Andrews 1996].

In spite of a decade of increasing attention to ducts, the industry involved in fabricating and installing ducted systems is largely uninformed about duct performance issues, as is virtually every other segment of the construction industry: homebuilders, Realtors, lenders, utilities, and home buyers. Major opportunities are being lost that could make our housing more comfortable, more affordable to operate, safer, healthier, and longer lasting.

Effects of Forced Air Distribution Systems on Homes

Higher Energy Use

During the 1985-86 heating season, 510 NW homes built in 1984 were metered to determine space heating energy use. This early large sample study provided important information about the energy implications of heating system choices and helped to stimulate much subsequent distribution system research. The sample included 220 new homes built to NW Model Conservation Standards [MCS] in the Residential Standards Demonstration Program sponsored by Bonneville Power Administration and regional electric utilities. In addition to the MCS homes, energy use was metered in 290 “control group” homes built according to typical current practice. Results of monitoring were analyzed in two 1989 studies. Both studies concluded that, homes with electric forced air furnace systems used more energy for space heating than homes with zonal electric systems. [Lambert & Robison 1989; and Parker 1989]

Control group homes with electric forced air systems used 22% more energy than control homes with zonal heat. MCS homes with forced air systems used 13% more space heat energy than MCS homes with zonal heat. [Parker 1989].

Blower door testing showed homes with electric forced air furnace systems were also leakier—had more building leakage area [ELA]--than homes with zonal systems. Control group forced air homes were 26% leakier than control group homes with zonal systems. MCS group forced air homes were 22% leakier than MCS homes with zonal systems. Measurements of leakiness using tracer gas methodology indicated that the average annual air infiltration rate in forced air homes was approximately 70% greater than in non-forced air homes. Air infiltration can have a large effect on space heating energy use, but the increased leakage area alone did not seem to account for the difference in space heat use.

Space Heat Energy Use by Heating System Type in Pacific NW Houses [Parker 1989]

Heating System Type	MCS kWh/ft2	Control kWh/ft2
Baseboard electric	3.19	5.28
Forced air electric	3.65	6.68
Heat pump	3.52	3.37

From a consumer perspective, the heating systems that were the most expensive to install were also the least efficient. Why was this happening? Subsequent research began to answer that question.

Mark Modera, a researcher at Lawrence Berkeley National Laboratory, describes 4 “deficiencies” of forced air distribution systems: 1) conductive heat transfer across duct system walls; 2) direct air leakage to and from ducts; 3) increases in uncontrolled air flow through building envelope leaks due to air flow imbalances and pressure imbalances caused by duct leakage and other aspects of distribution system design; and 4) a “thermal siphon effect” or “thermal bridging effect” that causes a portion of space conditioning energy to be drawn out of the home while the forced air system is off. [Modera 1989 and Modera & Jansky 1992]

Conduction: Heat Loss [or Gain] Through Duct Walls

The hvac industry and conservation community have long recognized the potential for conductive heat loss or gain through duct walls. Conduction occurs when the temperature of the duct is different from the temperature of the surrounding attic, basement or crawlspace. In cooling climates, when ducts pass through hot summer attics, conductive heat gain through duct walls significantly diminishes the ability of cooling equipment to maintain comfort inside the home. In heating climates, the reverse occurs: during heating season, ducts experience significant conductive heat losses to the surrounding unheated or partially heated zones. Conductive losses alone are estimated to reduce system output by 20-25%.[Andrews & Modera, 1992]

Conductive losses are generally addressed by increasing duct insulation. In many parts of the US, ducts are uninsulated or only minimally insulated [R-2-R-4]. Poorly insulated ducts are common in the Northwest, too, but weatherization specifications and many Northwest energy codes currently require R-8 duct insulation. Many estimates of losses due to conduction assume uninsulated or marginally insulated ducts as a baseline. Conductive losses may not be as serious when R-8 insulation is already in place [Palmiter & Francisco 1997]. However, it is safe to say that in general, the most highly conditioned air in homes –the air in the duct system—is the most poorly protected from conductive losses. In the Northwest, we protect buildings that contain 70 degree air with R-21 wall, R-30 floor and R-38-49 ceiling insulation; while we protect ducts containing 90-140 degree air with R2-R8 insulation.

Another strategy to improve system efficiency by reducing conductive losses is to keep duct runs inside conditioned space. If ducts are inside conditioned space, any losses they incur ultimately help meet building heating or cooling loads. Applying the same strategy to existing homes, conductive and other duct losses can sometimes be addressed by improving the building envelope around the duct rather than repairing the duct itself. This is called “bringing the ducts inside the building thermal and air pressure boundary” so that losses can contribute to indoor comfort, rather than detract from it.

How Ducts Affect Uncontrolled Air Flow

Operation of forced air systems was found to increase uncontrolled air flow in buildings in three ways: leakage directly to and from ducts; leakage through other openings in the building envelope due to air flow and pressure imbalances caused by duct leakage; and a thermal siphon effect when the system is off.

Researchers in Florida, Jim Cummings and John Tooley, have characterized forced air system operation as one of the largest driving forces of uncontrolled air flow in homes. Many other studies have supported their findings, reporting drastic increases [200-300%] in uncontrolled air flow when forced air systems operate. [Cummings & Tooley 1989]

<u>1) Leakage directly to and from ducts</u>.

When the air handler fan operates, ducts on the return side of the system are strongly depressurized, or negative with reference to surrounding air pressure, so leaks on the return side of the system bring unconditioned air into the return system from the area surrounding the duct. Ducts on the supply side of the system are strongly pressurized, or positive with reference to surrounding air pressure, so leaks on the supply side of the system lose highly conditioned air to the surrounding area.

Even though duct leaks typically account for only 10-20% of total building leakage area, because duct leaks are exposed to the furnace air handler fan or "blower," duct leaks are exposed to much higher forces [pressure differences] than leaks in the rest of the building. In 5 Florida homes that received extensive testing, infiltration caused by forced air system operation was 7 times greater than natural infiltration [Cummings and Tooley 1989].

Mark Modera of Lawrence Berkeley Laboratory drew the same conclusion: infiltration and ventilation impacts of duct system leakage are significantly larger than those for building envelope leaks because of the large pressure differentials driving flow through duct leaks. Measurements indicated that pressures across duct leaks—created by the air handler fan or "blower"--could be 10 times higher than pressures across holes in the building envelope caused by natural forces [Modera 1989].

2) Increased leakage through building envelope leaks, caused by forced air system operation.

Because of duct leakage, forced air system operation exposes the home to flow imbalances and pressure differences that –over and above direct losses through the ducts—is a strong driving force for leakage through the building envelope. This was "discovered" by Florida researchers [Tooley and Moyer,1989] when they measured pressures inside homes while forced air systems operated. If a system experiences return side leakage, large amounts of air will be sucked into the return system , will flow through the air handler and be delivered to the home as additional air. As return leakage is delivered to the home, home air pressure increases [home becomes pressurized] with respect to outside air pressure and air will flow from the home[high pressure] to the outside [lower pressure] through holes in the building envelope. If a system experiences supply leakage, large amounts of conditioned house air will be lost to the crawlspace. When this occurs, air pressure inside the home decreases [home becomes depressurized]with reference to outside air pressure and outside air [higher pressure] flows into the home [lower pressure] through holes in the building envelope. In general terms, the duct system is "interacting with the building envelope," increasing pressures that drive uncontrolled air flow across building leaks.

In a tightly sealed forced air distribution system, the amount of air flowing out of the home through the return grilles will be equal to the amount of air flow into the home through the supply registers. Therefore, system operation will not result in unbalanced flows or create the kind of unbalanced pressures that so strongly increase building envelope leakage. The same balance may be coincidentally attained when the return and supply leaks just happen to be equal. However, if either return or supply leaks are dominant, flow imbalance occurs, and pressures created by flow imbalance force rapid leakage through building envelope leaks.

In fact, researchers discovered , another circumstance causing increased building envelope leakage: interior door closure. When forced air systems are designed with only one or two central return grilles, closing interior doors causes return/supply flow imbalance. When doors are closed, supply air delivered to bedrooms can't flow back to return grilles in the hall. Bedrooms become pressurized [air is entering through supply registers faster than it can leave] and return zones become depressurized [air is leaving through the return grilles faster than it can be replaced]. The pressure imbalances caused by door closure result in increased leakage through holes in the building envelope. This effect does not occur when systems are designed with multiple, distributed return grilles. [Tooley & Moyer 1989].

Energy Penalties Associated with Forced Air Distribution Systems.

Annual Space Heating or Cooling Penalties

Most assessments of energy penalties are based on short term monitoring—usually several days to several weeks. In other cases, long term monitoring is used. In short term monitoring studies, energy use is measured with power meters and recorded by data loggers. Weather data is collected. Energy use is correlated to outdoor temperature. Energy use software is used to extrapolate short term results to the entire year using Typical Meteorological Year [TMY] weather data. In other studies field measurements are used to develop a "prototype home" whose energy use patterns over the year are simulated using software and observed . In other cases prototypes are used to assess effects of various repair strategies.

Based on short term studies prior to 1992, John Andrews, Brookhaven National Laboratory ,and Mark Modera, Lawrence Berkeley National Laboratory [Andrews & Modera 1992] estimated that the energy penalty due to direct duct leakage was approximately 7.5% of total system output, and that system impacts on building envelope air flow equaled about 9% of system output, for a combined effect of approximately 15-20% of output. Conduction losses were estimated at 20-25% of system output. Combining duct leakage, building envelope leakage due to supply/return imbalance and conduction, researchers estimated a "normal" efficiency loss in the range of 30-40% of system output.

Another method of quantifying losses associated with forced air distribution systems was used by Ecotope, Inc., a Seattle engineering firm, to field measure heating system efficiency in 24 electrically heated homes. The method meters energy used by the furnace to keep the house at a given temperature, and compares furnace energy use with the energy used by a battery of zonal heaters to maintain the same temperature. The method used by Ecotope is called an "alternating co-heat test." Zonal heaters are assumed to represent 100% efficiency because all of the heat they produce is delivered to the house. Two measures of efficiency were completed: "heat delivery efficiency": total useful heat delivered through the registers while the furnace fan is on divided by the power input to the furnace [including fan energy]; and "system efficiency": total useful heat delivered to conditioned space during the entire period of furnace cycling, divided by the power input to the furnace [including fan energy]. In this study, infiltration losses through the system while it is off and door closure effects are not included, so the real efficiency of these systems is probably somewhat lower than the measurements indicate. The home sample included 22 homes with at least 50% of the ductwork outside heated space and 2 homes with all ducts inside heated space.

Heat delivery efficiency averaged 56% for the base sample and 67% for homes with interior ducts. Due to recovery of cycling losses and offset of loads due to unintentional heating of buffer zones, system efficiency is higher. System efficiency for the base sample averaged 71%. Homes with interior ducts had a system efficiency of 98%. Efficiency losses due to ducts averaged 29% for the base sample and 2% for the homes with interior ducts. Power loss per cycle averaged 1276 watts for the base sample and 86.5 watts for the homes with interior ducts. Duct leakage to the outside for the base sample was 436 cfm @ 50 Pascals. For homes with interior ducts, leakage to outside measured 21cfm @50 Pascals. [Olson et. al. 1993]

Energy losses measured using the alternating co-heat method [29%] compare well to the energy losses calculated from short term monitoring studies by other researchers [30-40%].

Energy Savings Potential of Duct Repairs

Efficiency losses are a good way to describe the effect of duct system deficiencies, but an equally important question is, Can we effectively reduce those losses with duct repair efforts? Eight studies report reductions in either duct leakage area or duct leakage that lead to efficiency improvements and savings in annual energy use. A table summarizing these results is included at the end of this report. Early studies used different measurement techniques to quantify their results simply because duct testing equipment used in later studies hadn't been invented. However, fine points aside, it is typical to see repair efforts reduce duct leakage by 40-60% in homes w/basements [large portions of ducts inaccessible] and by 60-70% in homes with accessible ducts.

By reducing duct leakage 40-70% researchers were able to achieve 5-10% annual energy use reductions in homes with basements and 10-20% annual energy use reductions in homes on crawl spaces. 15% savings were produced with minimal repairs in 18 small commercial buildings. In rough numbers, with hand sealing approaches in use today, researchers are reducing typical 30-40% efficiency losses by a third to a half, depending on building type. It is important to note that new aerosol based sealing technology, available commercially in late 1997, could significantly improve our ability to deal with inaccessible ducts and improve our sealing percentage to the 70-80% range. Another important consideration is that all of the studies summarized here are based on repairs to existing homes. In new construction—that is, with maximum accessibility—leakage could be very low and efficiency very high. Currently the efficiency measurements by Bob Davis, [Davis et. al., 1996] on new energy efficient manufactured homes may provide a reasonable approximation of what could be achieved in new construction: 85% system efficiency. Aggressive duct repairs in 6 existing site built homes increased system efficiency by 16%, from about 70% before repairs to about 86% after. [Palmiter et.al. 1994] However, no alternating co-heat efficiency measurements have been reported for new homes whose duct systems were aggressively sealed and performance tested for leakage as part of initial installation.

Northwest researchers measured system efficiency as high as 98% in homes with ducts located inside heated space [Olson 1993]. In spite of efficiency advantages, cost and a long-standing and revered tradition of minimal practice represent significant barriers to this approach. Researchers at the National Home Builders Research Foundation [NHBRF] developed cost comparisons for several methods of bringing ducts inside new homes. These methods were competitive, but still involved cost increases over current practice. NHBRF staff strongly agreed with others around the country that if ducts are brought inside, they should be continuous and tightly constructed, that is, building cavities should not be used to transport air. [Lyons and Pesce 1996]

Costs of Duct Repairs

The 18% average reduction in annual energy use achieved in 160 Florida homes cost an average of $200 per home [Cummings 1990]. A 21.8% average reduction in 18 Arkansas homes cost $500 per home, including a materials cost of $39.65 [Davis 1991]. Duct repairs in 5 North Carolina homes were estimated to reduced cooling energy use by 12% or about 250 kWh/yr. and heating energy use by 600 kWh/yr. for an average cost of $200/system [Vigil et. al. 1993]. Ducts in 19 New York and Wisconsin homes with basements were sealed and insulated for a cost of $650 per home. Annual energy use was estimated to decrease 9% due to duct repairs [Strunk 1996]. Repairs to ducts in 25 multi-family buildings in New York resulted in 6-10% annual energy savings depending on basement tightness for a mean cost of $899/ building. Buildings contained 3-5 apartment units each. Mean cost of duct air sealing was $235; mean cost of duct insulation was $644 [Karins et. al. 1997]. Duct repairs in162 site-built homes in Washington achieved average energy savings of 1500 kWh at a cost of $450 per home. Utility administrative costs per home were $160 [Lerman, 1997]. Duct repairs in 387 Oregon manufactured homes averaged $228 per home and reduced annual space heating use by 1258 kWh or 13% [Robison et. al. 1997]. Based on results in 8895 homes, Florida Power Corporation reported average savings of 1000 kWh per customer at an average cost of $114 per home [Results Center 1993]. Costs reported for duct repairs in 25 existing Northwest homes averaged $335; costs of duct air sealing for 41 new Northwest homes averaged $301, although ducts in the new homes were twice as tight as ducts in the retrofit homes. Cost of pressure relief or distributed returns in new homes averaged $403. Cost of heat load calculations and minimal duct design averaged $75 [Haskell 1995].

Typically costs of duct sealing range from $200-$500 per home. Adding duct insulation increases duct repair costs significantly.

In some cases, duct repair costs were used to compute cost to a sponsoring utility of achieved energy savings, usually expressed in mills per kWh: Florida Power Corporation: 30 mills/kWh [Results Center 1993]; Tacoma Power and Light: 17 mills [Lerman 1997]; Eugene Water and Electric Board: 12 mills [Robison et. al. 1997].

In a study of 18 small commercial buildings, cooling energy use was reduced by an average of 15.1% at an average cost of $455. Annual energy savings were calculated at $195/yr for a simple payback of 3.1 years. According to the authors of this report, repairs and results were tightly constrained by project budget and do not represent the full costs or benefits available in these buildings [Withers et. al. 1996].

Effects on the Utility System: Peak Demand Reductions/Avoided Costs

Because forced air systems operate the most when weather conditions are at their worst, duct deficiencies can have an adverse effect on peak power demand. Several studies have estimated demand increases due to duct deficiencies, and several studies have measured demand reductions due to duct sealing programs.

Based on short term energy use monitoring before and after duct repairs in 160 Florida homes, researchers measured a 1.65 kW per house peak demand reduction. Extrapolating this result to the entire Florida housing stock, researchers estimated that reduction in peak demand could equal 13% of the state's generating capacity. Based on cost of repairs, researchers estimated that a statewide duct sealing effort would cost approximately $600 million dollars but would yield a $3.5 billion avoided cost to the utility system. [Cummings et.al. 1990 and 1991]

Based on field measurements in 31 California homes, researchers developed a prototype house and used an engineering model to simulate effects of duct repairs. Based on efficiency losses encountered in the field—30-40%--they estimated that duct deficiencies increased peak demand by 0.8 kW per home with an additional 0.2 kW peak demand increase due to door closure effects[supply/return imbalances]. [Modera et. al. 1992]

After duct repairs in 5 North Carolina homes, summer peak electrical demand decreased by an average of 250 watts/home, or a 12.8% reduction [Vigil et. al.1993].

Peak demand reductions were measured before and after duct repairs in 61 homes that were part of Florida Power Corporation's duct repair program. Peak demand was reduced 0.49 kW/home or 14% of air conditioning load .[Horowitz et. al. 1994]

Based on energy use and weather data for 96 Arizona homes, researchers calculated diversified demand savings of 0.23 kW or 5-7% of pre-repair demand. [Kolb and Ternes 1995]

Other Associated Effects/Benefits of Duct Repair and Improvement

Duct literature tends to concentrate on energy related effects of duct system deficiencies: air leakage, conductive losses, effects on the building envelope, quantified as system efficiency losses or unnecessary annual energy use. Benefits of repairs are likewise predominantly focused on reducing energy losses and improving efficiency of distribution systems. However, duct losses, and in particular the uncontrolled air flows caused by flow/pressure imbalance, can have other effects on buildings and people. [Cummings et. al., 1993]

Health Safety/Air Quality Issues

Homes with combustion devices present special challenges and opportunities for duct improvement efforts. Flow imbalances that depressurize a home, can make it more difficult for combustion appliances inside the home to draft properly. The relatively weak force of "draft" or "stack effect" in a chimney can be overcome by depressurization caused by mechanical system operation. When mechanical systems depressurize a home, outside air reacts by flowing down the chimney and into the home, bringing combustion by-products with it. Wood burning appliances that use house air for combustion are particularly vulnerable and are pervasive in NW housing. Appliances that use outside combustion air are potentially safer, but by no means immune to depressurization [Boe 1995]. Wood stoves that take combustion air from outside the home have backdrafted in negative pressure environments—specially as the fire dies down and draft weakens. [Tiegs and Bighouse 1994].

Newer induced draft , sealed combustion, direct vent gas and oil equipment is usually less vulnerable to depressurization, if the equipment is maintained in good repair. However natural draft equipment—the most vulnerable equipment—is far more common in existing housing.

Forced air systems are not the only appliances in homes that can cause depressurization related health and safety issues. Exhaust devices, dryer use, or a combination of systems operating simultaneously with the forced air system can cause a combustion device to spill potentially harmful combustion gases into living spaces. Combustion devices such as gas water heaters can experience “flame roll out” upon startup in a depressurized environment. Leading national duct repair training centers consistently emphasize combustion safety issues and potential health /safety benefits of properly conducted duct repairs. It may be fair to say that in a significant percentage of homes, the health /safety benefits may be much more important than any achievable energy savings.

Combustion safety issues pose a challenge to duct sealing programs, because for safety and liability reasons, repairs to ducts or to building envelope leaks should not be commenced until unsafe appliances are repaired. Enabling duct fixers to detect safety problems in the field and make appropriate decisions is a key element of training.

In cooling climates depressurization caused by forced air system operation brings humid outdoor air into the building, creating conditions that lead to deterioration of building materials and to growth of molds as well as increasing latent cooling load and cooling energy use.[Cummings et. al. 1991]

Duct leakage can affect air quality and pose health problems even when combustion devices are not present. Since return ducts often run in attics, and since return leaks suck attic air into the return air stream, and since attics contain dust and various types of insulation materials, return leaks can contribute to air quality problems by contaminating houses with particulates from attics. [Boe 1996]

When return leaks result in pressurization of homes or of zones within homes, combustion appliance problems go away—until the leaks are repaired. If this sort of situation is encountered in the field, untrained duct fixers can repair leaks and cause combustion appliance problems where none existed before. Pressurization inside homes drives moisture laden air into wall, floor and ceiling cavities on its way out of the home. As moisture accumulates inside building cavities, wetting of the building materials can lead to mold growth and structural decay. Siding and exterior finishes can be damaged as moist air is forced through wall cavities by pressurization. [Cummings et. al., 1993]

Training/Quality Control

Two recent studies of NW duct repair programs mention the impact trained, experienced, reliable duct fixers can have in achieving cost effective energy savings [Robison 1997 and Lerman 1997]. Trained duct fixers can minimize safety and liability problems because training enables duct fixers to detect safety problems before they start and to verify that repairs have been safely accomplished before they leave the job. Training proposed for the NEEA/EPRI project will enable/require trained technicians to fill out and submit a record of the tests they perform and test results they achieve. It is anticipated that test records will be used as the basis of a quality control review process and ultimately as the basis for contractor certification. In a large California project, quality control based on results of diagnostic tests was automated with software to more speedily review data and to collect/quantify overall program accomplishments. [Downey 1994]

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