CODES AND STANDARDS ENHANCEMENT REPORT

2005 Title 24 Building Energy Efficiency Standards Update

Duct Sealing Requirements upon HVAC or Duct-System Replacement

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Overview

Description

This Code Change Proposal encompasses two changes to the existing California Building Energy Efficiency Standards: 1) a requirement that duct systems be sealed and tested at the time that an air-conditioner, heat-pump, or furnace is replaced or installed in an existing building, and 2) a requirement that new or replacement duct systems in existing buildings have an insulation level of R-8 as well as be sealed and tested. The proposed requirements are triggered either by installation of a furnace, an indoor-air heat-exchanger coil, an outdoor condensing unit for a heat-pump or air conditioner, or by installation of a new or replacement duct system in an existing structure.

If triggered by HVAC equipment installation, the requirement would be that ducts be sealed such that the measured leakage is less than 10% of fan flow for the supply and return ductwork combined, including the HVAC equipment cabinet and plenums. Acceptable alternatives to duct sealing and testing include increasing the insulation level of the duct system and the efficiency of the equipment being installed, or increasing the efficiency of both the heating and cooling equipment in that structure. The accepted alternatives depend upon the climate zone. When the ducts are not replaced and the insulation alternative is chosen, the duct insulation level in all unconditioned spaces must be increased by at least R-5, and the equipment efficiencies must be increased to the values specified in Table 1-AA in the Proposed Standards Language section below. Alternatively, the ducts do not need to be addressed at all if the HVAC equipment is brought up to the set of efficiency levels specified in that same table for non-insulation alternatives.

If triggered by the installation of a new or replacement duct in an existing building, the requirements would be that that ducts be sealed such that the measured leakage is less than 10% of fan flow for the supply and return ductwork combined, including the HVAC equipment cabinet and plenums, and that the new ducts must have a rated insulation level of R-8 or higher.

These requirements will apply to all single-family homes, either attached or detached. All installations that include duct sealing shall be self-certified by the installing contractor, including leakage testing, and shall be submitted to a verification program by a third-party special inspector or building inspector. The verification program shall follow a set of procedures that are functionally equivalent to those used for new-construction duct sealing requirements.

The existence of the proposed requirements for duct sealing shall be publicized on the CEC and other public interest web sites, as well as through campaigns such as the Flex-Your-Power campaign. These requirements should also be publicized on a voluntary basis by HVAC equipment distributors.

Benefits

California, through the Title-24 California Building Energy Efficiency Standards, has made tight ducts an integral part of low-rise residential new construction in California. These changes to the Standards, enacted over the past 5 years, were based upon favorable cost-benefit analyses. The benefits of sealing ducts in existing homes are larger on both an absolute and percentage basis, the former due to higher baseline consumption, and the latter due to somewhat higher initial leakage levels. This is true for both energy-use and demand reduction. The options of increasing insulation and equipment efficiencies, rather than sealing ducts, are included because of the fact that sealing may not always be practical, and the proposed alternatives are essentially equivalent to duct sealing in terms of energy savings achieved.

Another reason to address energy efficiency in existing buildings is that more air conditioners and furnaces are installed in existing homes as compared to new construction, both in California and nationwide. In California, a little more than 60% of this equipment is installed in existing homes (Source: Carrier Corporation Data), or in other words, 50% more equipment goes into existing homes as opposed to new construction each year. The proposed change makes the standards apply to all duct systems, no matter what type of HVAC installation is involved—new construction, addition/alteration or replacement.

In addition to providing energy and peak-demand savings, both duct sealing and duct insulation provide significant improvements in comfort. In the case of duct sealing, a survey of customers who had their ducts sealed (conducted for SMUD by an outside survey firm) indicated that less than 10% of the customers were very satisfied with their HVAC systems before sealing, versus more than 80% of customers being very satisfied after sealing. Similarly, a study by LBNL indicated that homeowners were much more comfortable after sealing and insulation of their duct systems, and were particularly pleased with the improvements in heating uniformity. These reported comfort improvements were supported by measurements of register temperatures before and after insulating the ducts, which showed significant improvements in temperature uniformity (Modera and Jump, 1995).

Duct sealing also can improve indoor air quality and safety, principally by reducing entry of outdoor pollutants into the living-space, including reduced ozone entry during smog alerts, reduced entry of car exhaust, pesticide and other toxic fumes from garages, reduced entry of dust, soil gasses, or pesticide fumes from crawlspaces.

On a statewide level, there are somewhat more than 300,000 furnaces, air conditioners, or heat pumps installed in existing homes each year (Source: Carrier Corporation Data). According to data collected on 1000 houses by Aeroseal Inc. in Sacramento for SMUD, approximately 85% of these system installations would require duct sealing. Assuming that all 85% of the installations receive duct sealing or an alternative at the time of equipment installation, the estimated annual statewide savings added each year that the proposed change is in effect are: 200 GWh, 20 million therms, and 160 MW. The details behind these estimates are included in the Appendix.

Environmental Impact

This change does not have any adverse environmental impacts. The only materials used are commonly used materials: building sealants, tapes, and fiberglass duct insulation.

Type of Change

The proposed changes are Prescriptive Measures that must be met whenever a residential furnace, evaporator coil condensing unit, or packaged unit is installed in an existing single-family residence, or whenever a duct system is added to or replaced in an existing single-family residence. The measures also become the basis for the "existing plus alteration" performance approach. The proposed changes do not expand the scope of the standards, but augment the current requirement to check refrigerant charge, install a Thermostatic Expansion Valve, or increase equipment efficiency at the time of equipment replacement.

The proposed change encompasses small changes to both the Standards and the ACM. In both cases, the changes are relatively minor, as outlined in the section below.

Measure Availability and Cost

The principal suppliers of this measure are the HVAC contractors who normally install HVAC equipment in existing residences. The methodology and supplies required by these contractors for accomplishing the proposed changes are provided by a range of suppliers. These include duct sealant manufacturers, manufacturers of duct leakage test equipment, companies that supply training to HVAC technicians, and manufacturers of duct insulation products. There are multiple suppliers in each of these categories, and there already exist hundreds of contractors and technicians who have been trained to test tight ducts through utility training programs. Many of these contractors already own the equipment required to test for duct tightness. Sealing supplies are available from multiple manufacturers.

There exists adequate capacity to meet the expected increase in demand for training, duct sealants, sealing equipment and duct insulation. In addition to the training staff and facilities at utilities, there are several companies that sell duct-improvement training and diagnostic/sealing equipment for contractors and technicians, including Advanced Energy, Carrier-Aeroseal, Comfort Institute/Retrotec, The Energy Conservatory, and Honeywell/Enalysis. The means by which training and sealing equipment are distributed include direct sales of

equipment, complete diagnostic/sales systems, and franchises that provide one-stop shopping for training, sealing/diagnostic equipment and diagnostic/sales tools.

The baseline condition that this measure is attempting to change is simple replacement of HVAC equipment without any change to the energy efficiency of the duct system to which it is connected. Currently, less than 10% of duct systems receive verified sealing or additional insulation at the time of equipment replacement, and the current standard does not require these measures. The other significant aspect of the baseline condition is that a significant number of HVAC replacements are performed without a building permit being issued.

The costs for this change are time and materials for sealing and leakage testing of existing ducts in existing dwellings, or the incremental costs of sealing and testing replacement duct systems combined with the incremental cost of using R-8 instead of R-4.2 replacement ducts. Sealing- costs are estimated to be $660, based upon duct testing/sealing costs in the DEER Update Study (Xenergy, 2001) of $630, combined with a $30/system incremental cost associated with third-party verification services. Duct replacement with tested and verified -tight R-8 ducts is estimated to cost $768, based upon a combination of sealing and testing costs plus $108 in incremental duct costs (Source: Owens-Corning Fiberglas). The duct sealing costs include self-verification measurement costs on every job, and third-party verification costs that correspond to current cost of field verification on one in every five jobs. Maintenance costs are not an issue for these technologies.

Useful Life, Persistence and Maintenance

For all cost-effectiveness analyses, the useful life of duct sealing and insulation was assumed to be 30 years, consistent with the values used for new construction within the current Title-24 Standards and ACM.

Performance Verification

The proposed change includes three alternatives, one of which requires a third-party verification program, and two of which do not. The testing protocol for the duct sealing alternatives is similar to that used for new construction, which is already outlined in Appendix F of the Residential ACM Manual. In addition to the testing protocol, the third-party verification mechanisms also need to be specified. In this case, the proposed change will utilize the HERS rater mechanism and some equivalent alternatives.

The key issue with respect to enforcement of this change in the Standards is the significant fraction of HVAC equipment that is installed without building permits. This proposal does not address that issue directly, but rather proposes several alternatives for helping to increase the use of permits, and therefore the degree of enforcement of the proposed change. These alternatives include publicity of the change on CEC and other public interest web sites, publicity through campaigns such as the Flex-Your-Power campaign, and publicity on a voluntary basis by HVAC equipment distributors.

Cost Effectiveness

The cost effectiveness of the proposed change was evaluated based upon savings calculated using the Micropas TDV version that implements the calculation procedures in Appendix F of the Residential ACM, as well as the Time Dependent Valuation analysis procedures and time-dependent duct efficiency calculation model developed by Berkeley Solar Group for the Pacific Gas & Electric company. The energy consumption levels to which these savings were applied were generated by applying the compliance program to a 1978 prototype house, and then were reduced by 25% to account for some non-operation of HVAC systems in less efficient construction. Duct sealing cost values were obtained from the DEER Update Study (Xenergy, 2001). Cost effectiveness was evaluated for every climate zone for duct sealing, while energy consumption values were computed for the various alternatives to duct sealing. The details of these analyses are presented in the Appendix, and the statewide average results are presented below:

Measure	Consumer Cost	Discounted Lifetime Energy Cost Savings	Discounted Lifetime Time Dependent Valuation Savings
Attic Duct Sealing	$ 660	$ 2,197	$ 2,784
Crawlspace Duct Sealing	$ 660	$ 2,101	$ 2,658
Attic Duct Replacement w/tight R-8	$ 768	$ 2 ,731	$ 3,444
Crawlspace Duct Replacement w/tight R-8	$ 768	$ 2,549	$ 3,197

Analysis Tools

This change does not require the use of any analysis tools, as what is proposed is a set of prescriptive requirements.

Relationship to Other Measures

This change will not have any significant impacts on other measures. One beneficial interaction that should occur is a reduction in the costs of third party verification of refrigerant charge and airflow or Thermostatic Expansion Valve installation, as duct leakage verification is likely to be performed in conjunction with those existing verification requirements.

Methodology

The lack of requirements for duct efficiency improvements at the time of HVAC replacement has been recognized as an area for improvement since 1998, and was identified by the California Energy Commission as a topic for this proceeding during the AB970 effort. Research consisted of reviewing the standards language to identify a strategy to incorporate replacement duct sealing or the equivalent in the standard. The methodology used to analyze this code change proposal is based upon the analysis techniques and assumptions described in the Appendix and the Cost Effectiveness sections of this report.

Results

See proposed standards language below.

Recommendations

Proposed Standards Language

The proposed changes to the Standards are as follows:

Section 152 (a) shall be modified to read as follows:

EXCEPTION 4 to Section 152 (a): When heating and/or cooling will be extended to an addition from the existing system(s), the existing heating and cooling equipment need not comply with Title 24, Part 6. Existing ducts shall be upgraded to meet the requirements of section 152(b)1.D ii, or the addition shall meet the requirements of Section 152(a)2. The heating system capacity must be adequate to meet the minimum requirements of UBC Section 310.11.

The following text shall be added to Section 152 (b) 1.:

Section 152 (b)1 shall be modified to read as follows:

B. New or replacement space-conditioning systems or components shall:

i. ……

ii. …….; and

iii. Have their existing duct system sealed, as confirmed through diagnostic testing and field verification in accordance with procedures set forth in the Residential ACM manual.

D. New or replacement space-conditioning ducts shall:

i. Either be in conditioned space or be insulated to a minimum installed level of R-8 and constructed to meet the requirements of Section 150(m); and

ii. Be sealed, as confirmed through diagnostic testing and field verification in accordance with procedures set forth in the Residential ACM manual.

EXCEPTION to Section 152 (b)1B: The alternatives in Table 1-AA can be substituted for the field-verified duct sealing in Section 152 (b)1B iii.

TABLE 1-AA –
ACCEPTABLE ALTERNATIVES TO VERIFIED DUCT SEALING FOR ALTERATIONS

	Duct Insulation + HVAC Measure		HVAC Measure Only	
	Minimum SEER/EER	Minimum AFUE	Minimum SEER/EER	Minimum AFUE
CZ1		90		
CZ2	14 / 13		14 / 13	90
CZ3		90	14 / 12	90
CZ4	14 / 13		14 / 11	90
CZ5		90	14 / 12	90
CZ6	14 / NR		14 / NR	90
CZ7	14 / NR		14 / NR	90
CZ8	14 / NR		14 / NR	90
CZ9	14 / 12		14 / 12	90
CZ10	14 / 12		14 / 13	90
CZ11	14 / 13		14 / 13	90
CZ12	14 / 13		14 / 13	90
CZ13	14 / 12		14 / 12	90
CZ14	14 / 13		14 / 13	90
CZ15	14 / 13		14 / 13	90
CZ16		90		

Note: Duct Insulation requires the addition of insulation having an installed value of R-5 over and above the existing insulation level of the duct system.

EXCEPTION to Section 152 (b)1D: Replacements or additions of ductwork serving existing spaces comprising less than 25% of the total duct system surface area are exempt from this section.

Proposed ACM Language

The proposed changes to the ACM are as follows:

The following text shall be added to Section 7-4:

7.4.4 Procedures for Alterations That Require Field Verification

In the case of alterations that require field verification, contractors and HERS raters shall follow the procedures in Chapter 7, with the following exceptions in the case of duct sealing field verification pursuant to Section 152 (b)1.B. or Section 152 (b)1.D. of Title 24, Part 6,:

7.4.4.1: The contractor shall submit a signed statement identifying the entity that will be providing the field verification to the building department at the time that the permit application is submitted. The contractor shall also provide at final inspection a confirmation by the entity providing field verification that field verification has been provided or that the installation is part of a sample pursuant to section 7.4. Sampling will be done for all space-conditioning equipment installations and replacements in existing low-rise residential buildings that are completed by the same contractor in a maximum 90-day period (the period may be shorter at the option of the contractor). All installations and replacements in the sampling period form the group for which sampling, resampling, full testing and corrective action applies. Initial Field Verification and Testing will be done for the first installation or replacement in each 90 day period and whenever the entity completing field verification changes for a particular contractor.

7.4.4.2: The Commission may approve Data Collection and Validation Entities which collect data on all installations and replacements for a particular contractor, do error checking, and initiate corrective action on installations and replacements in a sampled group where errors are found. These Data Collection and Validation Entities may be approved to be alternative mechanisms for field verification that allow the HERS rater sampling percentage to be reduced as specified by the Commission. Data Collection and Validation Entities shall meet the conflict of interest requirements specified for HERS raters in Title 20, Chapter 4, Article 8, Sections 1670 - 1675.

The language in Section 7.4 of the ACM will be further clarified to make the treatment of duct leakage for HVAC installations in existing buildings practical but still as consistent as possible with new-construction installations.

The following text will be added to Section 4 of Appendix F:

4.3.8.2.1.1 Leakage Testing for Existing Duct Systems

When the diagnostic leakage test is performed for existing duct systems pursuant to Section 152 (b)1.B. or Section 152 (b)1.D. of Title 24, Part 6, the measured total duct leakage shall be less than 10% of the total fan flow, where the total fan flow shall be determined pursuant to section 4.3.7.

This language may require additional modification in light of other changes proposed for the ACM and the HERS process in the proceedings leading up to the 2005 standards.

Proposed Residential Manual Language

Chapter 7 of the Residential Manual will also need to be modified to make it consistent with the proposed changes to the Standard and the Residential ACM. For example, the treatment of duct systems in additions (section 7.2.3) needs to be modified to use 10% instead of 28% minimum leakage for the existing ductwork when calculating the target leakage when new or replacement space conditioning equipment or a new or replacement duct system is installed.

Bibliography and Other Research

Papers and standards used to complete this report include:

ASHRAE Standard 152P: Method of Test for Determining the Energy Efficiency of Residential Thermal Distribution Systems under Seasonal and Design Conditions. Second Public Review Draft 08/01.

2001 DEER Update Study Final Report, Prepared by Xenergy Inc. August 2001.

Life Cycle Cost Methodology, Prepared by Eley and Associates, March 11, 2002.

D.A. Jump and M.P. Modera, Energy Impacts of Attic Duct Retrofits in Sacramento Houses, Proceedings of ACEEE Summer Study, 1994.

M.P. Modera and D.A. Jump, ‘‘Field Measurements of the Interactions between Heat Pumps and Duct Systems in Residential Buildings’’, Proceedings of ASME International Solar Energy Conference, March, 1995, Lawrence Berkeley Laboratory Report, LBL-36047.

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Robert Raymer (California Building Industry Association) Mr. Raymer provided the perspective of new construction builders

Dave Ware (Owens Corning) Mr. Ware provided cost data for using R-8 ducts instead of R-4.2 ducts.

Appendix

Savings Estimates

The statewide savings estimates are based upon the following assumptions

- 250,000 furnaces and/or air conditioners are installed in existing homes with duct leakage above 10% each year;
- all installations are addressed (i.e., 250,000 efficiency improvements);
- all installations have central A/C;
- all installations have base-case efficiency levels of AFUE-80 and SEER-12 (the federal air conditioner standards will be either SEER 13 (adopted by the Clinton Administration) or SEER 12 (adopted by the Bush Administration) in 2006 depending on the outcome of a suit by California and other parties brought against U.S. DOE);
- electricity savings from furnace fans and elevated savings associated with heat pumps or electric furnaces are excluded;
- the improvements are split 70%/30% between sealing and replacing ducts;
- 70% of the houses have attic ducts, versus 30% with crawlspace ducts;
- improvements split uniformly between climate zones (data was not available of the distribution of existing houses by climate zone);
- 30-year life for duct sealing and duct insulation measures;
- $14.21 value per annual therm savings, and $2.06 per annual KWh savings for 30-year-lifetime measures (Eley Associates);
- $0.145 value per KBtu for TDV savings estimates (Time Dependent Valuation (TDV) Economics Methodology, John McHugh, HMG, http://www.h-m-g.com/TDV/index.htm)
- Peak demand reduction calculated based upon average unit draw of 4.1 KW, corresponding to 3.4 tons at EER 10.
- Peak demand reduction based upon percentage reduction estimates calculated with Second Public Review draft of ASHRAE Standard 152P.
- Percentage peak demand reduction estimate from ASHRAE 152P reduced by 40% to account for lack of thermostat operation and take-back in improved comfort.

The discounted measure-lifetime energy cost savings estimates (in dollars) calculated with the Time-Dependent Valuation methodology by climate zone and improvement type are as follows:

Change	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Sealing (Attic)	1,389	2,319	966	1,431	1,051	720	723	1,154	1,960	2,917	3,912	2,957	3,885	5,661	9,446	4,059
Sealing (Crawl)	1,353	2,228	936	1,380	1,022	693	697	1,112	1,875	2,783	3,732	2,836	3,709	5,376	8,868	3,931
Replace R-8/seal (Attic)	1,776	2,978	1,229	1,812	1,328	913	882	1,399	2,385	3,562	4,821	3,648	4,763	6,958	11,421	5,225
Replace R-8/seal (Crawl)	1,728	2,775	1,173	1,696	1,267	844	810	1,294	2,197	3,278	4,476	3,408	4,405	6,436	10,378	4,983

The discounted measure-lifetime energy cost savings estimates (in dollars) (based upon Eley & Associates report) by climate zone and improvement type are as follows:

Change	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Sealing (Attic)	1,400	1,892	848	1,149	933	537	508	793	1,336	2,008	3,101	2,277	3,135	4,168	7,261	3,805
Sealing (Crawl)	1,364	1,822	822	1,114	909	517	489	765	1,281	1,916	2,965	2,186	2,991	3,967	6,818	3,687
Replace R-8/seal (Attic)	1,790	2,429	1,079	1,462	1,186	682	626	969	1,636	2,462	3,840	2,828	3,855	5,156	8,786	4,906
Replace R-8/seal (Crawl)	1,741	2,288	1,037	1,385	1,143	638	579	902	1,516	2,276	3,584	2,656	3,569	4,787	7,982	4,700

Cost Estimates

The statewide cost estimates are based upon the following assumptions

- Duct sealing costs are from the DEER study, augmented to include third-party testing cost of $30/system, which corresponds to an effective inspection rate of one in five systems installed;
- Incremental costs for duct replacement are the cost of sealing, as well as increased material cost associated with installing R-8 instead of R-4.2 ducts (Material Cost Data obtained from Dave Ware, Owens Corning Fiberglas).