Measure Information Template – Revise ACM Distribution System Multipliers (Table RG-2) and Eligibility Requirements

2008 California Building Energy Efficiency Standards

Proposer: Oak Ridge National Laboratory and Davis Energy Group, Inc
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CONTENTS

Purpose

This document proposes changes to the Distribution System Multiplier (DSM) and eligibility requirements for various residential hot water distribution systems under the Title 24 Residential Building Standards. Current multipliers do not accurately reflect the performance of hot water distribution systems and can therefore encourage the use of less efficient systems. Changes in eligibility requirements reflect improved knowledge of systems performance since the 2005 Standards.

Overview

Description	The proposed changes modify the distribution system multipliers (DSM) for hot water distribution systems. Parallel pipe system and demand controlled recirculation system multipliers have been revised. New multipliers are proposed for pipe systems buried in soil and pipe systems buried in soil and insulated. The remaining DSMs have been rounded to the nearest tenth. Modifications have been made to several eligibility requirements to add new knowledge or correct the previous standards wording. These changes would apply to single-family residences regulated by the California Building Energy Efficiency Standards.
Type of Change	The proposal represents a change in the distribution system multiplier (DSM) and eligibility requirements for hot water distribution systems in the Residential ACM modeling rules. Appendix RG of the ACM Manual would need to be modified to reflect the proposed changes.
Energy Benefits	The benefit would be increased accuracy in the selection of hot water distribution systems within the Title 24 Standards. This increased accuracy would improve the selection of the more energy efficient systems.
Non-Energy Benefits	Non-energy benefits include the potential reduction of water consumption and sewage production by the residences impacted.
Environmental Impact	The proposed change/measure has no potential adverse environmental impacts. It will reduce water consumption and sewage produced as well as natural gas and electric consumption used in heating water. Air quality benefits would accrue from reduced gas and electric consumption.
Technology Measures	Not applicable.
Performance Verification	Not applicable.
Cost Effectiveness	Not applicable.
Analysis Tools	The proposed changes can be easily implemented in the ACM.
Relationship to Other Measures	None identified.

Methodology

These recommendations stem from the review and evaluation of information and analyses prepared by the proposers for the Commission as part of previous work.

A numerical model for residential hot water distribution systems was developed by ORNL that allows analysis of various types of pipe, with and without insulation. The pipe segments may be exposed to a convective environment with known conditions (either forced or natural convection), buried in attic insulation, or buried beneath a floor slab in the soil. The distribution system model is Windows-based and versatile. The model simulates one-dimensional energy transport in the axial direction of the piping system with lateral heat losses to the pipe wall. The temperature distribution in the pipe wall and insulation is computed using two-dimensional calculations, coupled to the one-dimensional pipe solution through a heat transfer coefficient.

The following are the assumptions used in the analysis of the various hot water distribution systems and options.

- Average Attic Temperature – 76^{o}F.
- Average Crawl Space Temperature – 68^{o}F.
- Average Under-Slab Temperature – 64^{o}F.
- Shower Flow Rate - 2.25 GPM.
- Bath Faucet Flow Rate - 1.25 GPM.
- Kitchen and Laundry Faucet Flow Rate - 2.5 GPM.

There is little data available on actual hot water usage patterns in California or elsewhere. The project initially computed all houses and system configurations with the assumption that each draw was a "cold start" – meaning that the water had cooled down to the ambient temperature surrounding the pipe before each subsequent use. This approach provided an unambiguous, standard reference point that could be used to compare one system against another.

However, this approach has two significant drawbacks. First, the cold start assumption would only be valid for the first draw of the day, and for other draws during the day when a long enough time elapsed between draws for the water in the piping to go cold. Using such an approach for closely spaced draws would largely negate the effect of insulation around the piping. Second, one of the systems being evaluated is a continuous recirculation system, and there is no such thing (except when the system is first installed and turned on) as a "cold start" for that system.

The cold start approach may overstate the total energy and water waste and tends to discount the value of insulation. An all-cold start use pattern probably represents the "worst case" for potential water and energy waste.

A subsequent decision was made to modify the model to allow approximate calculations of scenarios where draws occurred near each other in time ("clustered"). In these calculations, the extent to which water in the piping cooled down between draws was calculated, rather than assumed. In these cases, a set of draws was assumed in the morning, and then a second set in the evening, with a nine-hour gap between them. This pattern might be typical of a family that spends the middle of the day away from the house. The clustered use represents the likely "best case" regarding water and energy waste.

In the clustered approach, for the first draw of the day (early morning) water in the pipe was assumed to be at ambient temperature. All subsequent draws were based on the calculated temperature of the water remaining in the pipe for each of the segments between the water heater and the end-use fixture. These cool down temperatures were calculated based on the number of minutes between draws. The second cluster of uses occurred nine hours after the first cluster and the water in the pipes had reached ambient temperatures. A similar set of cool down temperatures was calculated for the second cluster of draws. After the second cluster, the delay before use the next day was assumed to be sufficient for the water temperatures to reach ambient.

Certain approximations had to be made in calculating the cool down for the clustered draw cases. The most rigorous approach would have been to take the entire profile of temperatures through the water, pipe, insulation and surrounding material (soil or attic insulation) and use these as initial conditions for the calculation of the cooling that occurs between the draws. Time and cost did not permit this much rigor.

In 2004 ORNL, using this model, completed a numeric simulation evaluation of the five houses used in the 2005 Standards and compared a broad range of systems types and options. This simulation effort forms the basis of the proposed changes to Table RG-2.

Work accomplished by DEG for the Title 24, 2005 and 2008 revisions was reviewed and evaluated using current fuel costs and building practices. This evaluation forms the basis of the proposed changes to both Table RG-2 and the Proposed Eligibility Requirements.

Measures proposed as mandatory or prescriptive have life-cycle cost analyses that demonstrate the measures are cost effective. Cost effectiveness was calculated at the residential natural gas rate of $.24374 per TDV, or $24.374 per therm. Cost effectiveness is discussed in the Analysis and Results section below.

Analysis and Results

DEG updated their analysis of the cost effectiveness of insulating the hot water line between the water heater and kitchen sink/dish washer. This analysis (table below) showed that insulating this line is cost effective at both DEG's and ORNL's estimate of the cost of installing pipe insulation. This situation is applicable to all pipe sizes including those <3/4". Insulating the kitchen hot water supply line (all sizes) should also be considered for a mandatory item in the 2008 Standards.

Summary of Kitchen Pipe Insulation Savings and Economics

Kitchen Lines Insulated			
Plan	Therms/yr	PV$	Cost
960	3.6	$88	$64
1384	12.6	$307	$80
2010	7.6	$186	$114
2811	2.2	$53	$68
3080	6.3	$155	$74
Total		$789	$403

Overall using DEG's $1.54/ft installed: PV$/Cost = 789/403 = 2.0
Overall using ORNL's $2.57/ft installed: PV$/Cost = 789/673 = 1.2

ORNL updated their 2004 analysis of the energy savings and cost effectiveness of insulating the hot water line buried in soil between the water heater and end use points. This analysis (table below) showed that insulating these lines is cost effective at both DEG's and ORNL's estimate of the cost of installing pipe insulation. The analysis used CPVC pipe which is less conductive than copper—the results for copper would show a greater benefit. Insulating the in-soil hot water supply line (all sizes) should also be considered for a mandatory measure in the 2008 Standards.

Summary of In-Soil Pipe Insulation Savings and Economics

	In-Soil Lines Insulated		
Plan	Therms/yr	PV$	Cost
580	35.6	$958	$133
960	39.3	$868	$202
2010	78.1	$1901	$338
2811	79.0	$1923	$464
3080	74.8	$1824	$494
Total		$7474	$1631

Overall using ORNL's $2.57/ft installed: PV$/Cost = 7474/1631 = 4.6
Overall using DEG's $1.54/ft installed: PV$/Cost = 7474/979 = 7.6

Note: The ORNL HWDS simulation model has undergone initial validation with in-air experimental data and has shown a high degree of agreement. In-soil experimental data has not yet become available (due in May 2006) to validate the in-soil simulation capabilities. However, given the large benefits predicted with the current version, it is not expected that changes due to validation would change the overall outcome that this proposal is cost effective.

The changes proposed to Table RG-2 are based on ORNL's update of their 2004 analysis for CEC of the energy savings of various types of hot water distribution systems in various sizes of houses.

Parallel Piping –The parallel piping DSM will be rounded to 1.0. Additional mandatory measure requirements are being proposed by DEG in a separate template requiring that the distribution manifold be located within 10 pipe feet of the water heater and that the entire pipe between the water heater and manifold be insulated. Finally we propose dropping the reference to the ¾" and larger pipe to the kitchen since the earlier description states that ½" is to be the maximum pipe size for the individual runs in this system.

Recirculation + demand control - From our modeling the DSM in attics ranged from 0.39 to 0.98 and in soil from 0.10 to 0.42. Based on this we feel the current DSM of 1.31 is too large. In none of our simulations was a demand control system worse than a conventional system – so the DSM should be not be >1.0. A study by DEG monitored a demand system in Livermore and the data showed that motion dectors had an adverse impact on system performance due to significant "false" signals (70% of pump activation signals did not result in hot water being used.) ORNL did a study in Palo Alto of demand recirculation system retrofit into existing homes and found that there was little energy savings but perhaps 10% water savings from the use of the system. We propose that the DSM be reset to 1.0 for the demand control system. We further propose that the eligibility requirements for this system exclude both motion detection and flow detection as a means of control and require that push button controls be provided at the kitchen and all full bathrooms in the house.

The other changes proposed for Table RG-2 involve rounding to the nearest tenth. The current hundredth level reflects an accuracy that simply cannot be substantiated. The performance of all of these systems varies widely with house size and configuration, pipe material, system location, insulation, and the hot water use pattern.

We have shown DSMs for in-soil piping with and without insulation in Table RG-2. These reflect the energy losses associated with piping in the soil compared with the same piping in the attic (the alternative location). The DSM for the various houses evaluated ranged from 2.7 to 5.0 for uninsulated copper pipe and from 2.3 to 4.3 for uninsulated CPVC pipe. The average of these uninsulated systems was 3.8. When insulation was added the DSM ranged from 1.0 to 1.1 for both copper and CPVC with an average of 1.0. These DSMs would be unnecessary if insulating in-soil piping was made mandatory.

Recommendations

Proposed Revisions to Table RG-2

Measure	~~DSM Now~~	DSM Proposed
PIA	~~0.90~~	0.9
PS*	------	3.8
PSI**	------	1.0
POU	~~0.00~~	0.0
STD	~~1.00~~	1.0
SNI	~~1.19~~	1.2
PP	~~1.04~~	1.0
RNC	~~4.52~~	4.5
RTm	~~3.03~~	3.0
RTmp	~~3.73~~	3.7
RTmTmp	~~2.49~~	2.5
RDmd	~~1.31~~	1.0

* PS is piping system buried in soil – delete this entry if made mandatory
** PSI is piping system buried in soil with insulation – delete this entry if made mandatory

Proposed Eligibility Requirements Changes:

RG.3.2.1 Pipe Insulation Eligibility Requirements

Pipe insulation on the first five feet of hot and cold water piping from storage gas water heaters, recirculating sections of domestic hot water systems, all in-soil hot water piping, and the hot water line from the water heater to the kitchen sink and dish washer (regardless of pipe size) is a mandatory measure as specified in Section 150 (j) of Title 24, Part 6. Note that exceptions 3, 4 and 5 to Section 150 (j) apply to all pipe insulation that is required to meet the mandatory measure requirement or that is eligible for compliance credit.

Pipe insulation credit available if all remaining hot water lines are insulated. Insulation shall meet mandatory minimums in Section 150 (j). Pipe insulation must be installed in a manner to avoid future material shrinkage. During insulation, pipe insulation should be compressed along its length and sealed from one length to the next. Pipe elbows shall be insulated, taped, and sealed to adjacent pipe sections.

Add the following if not made mandatory—Pipe insulation credit is available if all hot water lines buried in soil are insulated. Insulation shall meet mandatory minimums in Section 150 (j).

Overhead Plumbing for Non-Recirculation Systems. All plumbing located in attics with a continuous minimum of 4 in. of blown insulation coverage on top of the piping will be allowed to claim the "all lines" pipe insulation credit, provided that:

1. Piping from the water heater to the attic, and
2. Piping in floor cavities or other building cavities are insulated to the minimum required for pipe insulation credit.

RG.3.2.2 Point of Use Water (POU) Water Heaters Eligibility Requirements

Current requirements apply. All hot water fixtures in the dwelling unit, with the exception of the clothes washer, must be located within 8' (plan view) of a point of use water heater. To meet this requirement, most houses will require multiple POU units.

RG.3.2.3 Recirculation Systems Eligibility Requirements

All recirculation systems must have minimum nominal R-4 pipe insulation on all supply and return recirculation piping. Recirculation systems may not take an additional credit for pipe insulation.

As a general rule, the recirculation loop should be laid out to be within 8 feet (plan view) of all hot water fixtures in the house (with the exception of the clothes washer). The plumbing layout should be focused on minimizing the total volume in the recirculating loop. Remote hot water use points should have longer runouts than 8 feet to avoid overextending the loop.

Approved recirculation controls include "no control", timer control, time/temperature control, and demand control. Time/temperature control must have an operational timer initially set to operate the pump no more than 16 hours per day. Temperature control must have a temperature sensor with a minimum 20°F deadband installed on the return line.

Demand recirculation systems shall have a pump (maximum 1/8 hp), control system, and a timer or temperature sensor to turn off the pump in a period of less than 2 minutes from pump activation. Acceptable control systems include push buttons~~, occupancy sensors, or a flow switch at the water heater~~ for pump initiation. At a minimum, push buttons ~~and occupancy sensors~~ must be located in the kitchen, ~~and in~~ the master bathroom, and all additional full bathrooms.

RG.3.2.4 Parallel Piping Eligibility Requirements

Each hot water fixture is individually served by a line, no larger than ½ in., originating from a central manifold located no more than ~~8~~ 10 pipe feet from the water heater. The entire pipe from water heater to manifold must have minimum nominal R-4 pipe insulation. Fixtures, such as adjacent bathroom sinks, may be "doubled up" if fixture unit calculations in Table 6-5 of the California Plumbing Code allow.

Acceptable piping materials include copper and cross-linked polyethylene (PEX), depending upon local jurisdictions.

3/8 in. lines are ~~acceptable~~ encouraged, pending local code approval, provided minimum required ~~pressures~~ flow rates listed in the California Plumbing Code (Section 608.1) can be maintained.

~~Piping to the kitchen fixtures (dishwasher and sink(s)) that is equal to or greater than ¾ inch in diameter must be insulated to comply with Section 151(f)8D.~~

Material for Compliance Manuals

Not included

Bibliography and Other Research

Wendt, R., Baskin, E., Durfee, D., “Evaluation of Residential Hot Water Distribution Systems by Numeric Simulation, Final Report”, ORNL for CEC, March 2004

2002 DEG SFDHW Final Report that I previously sent you (add to Biblio).

Progress Report on Building America Residential Water Heating Research – DEG report to Steven Winter Associates, Nov 14, 2003.

M. R. Ally, J. J. Tomlinson, and B. T. Ward, "Water and Energy Savings using Demand Hot Water Recirculating Systems in Residential Homes: A Case Study of Five Homes in Palo Alto, California," Oak Ridge National Laboratory, Oak Ridge, TN ORNL/TM-2002/245, October 21, 2002. <http://www.ornl.gov/~webworks/cppr/y2001/rpt/115441.pdf>

Appendices

None