THE ELCAP RSDP AND BASE RESIDENTIAL SAMPLES:
SUMMARY OF CONDUCTIVE UA CALCULATIONS

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1.0 INTRODUCTION

As part of the Residential Standards Demonstration Program (RSDP), new homes have been constructed to either the proposed Model Conservation Standards (MCS) or to a characterization of current building practice. A sample of 114 of these homes has been subjected to audits to determine the actual building characteristics as a part of the End Use Load and Conservation Assessment Program (ELCAP). ELCAP has also collected characteristics data for a base sample of 343 previously existing Pacific Northwest homes, to which the RSDP homes can be compared. These data have been used to calculate the thermal integrity of the homes.

The analysis of the RSDP homes has focused on a comparison of the insulating values actually in the RSDP homes with the values targeted by the RSDP study. Thus it is possible to determine whether the MCS homes were built to the MCS standards and if the "Control" homes were built to the "Current Code". If the two samples of buildings differ significantly from their target characteristics, then RSDP conclusions concerning the MCS energy savings would be called into question.

A secondary goal of the UA analysis was a comparison the MCS and Control buildings with existing residences in the Northwest, as represented by the ELCAP sample. For the Control buildings this permits determination of the extent to which the RSDP control group of buildings is typical of the houses currently being built in the region. The comparison also permits placing the MCS homes in the context of the existing residential stock.

This paper summarizes the conclusions of our UA analysis, particularly as it affects the interpretation of the RSDP study. A detailed report on this work, including a full description of the method of calculation, is in preparation.

2.0 CALCULATIONS OF THE UA VALUES FROM THE CHARACTERISTICS DATA

The standard measure of thermal integrity (or the tendency to lose heat) for a building is the "UA". The UA of a specific component is a product of the heat conductance (the U-value) and the area (A), and is thus a measure of that component's steady state heat loss rate for any given inside-outside temperature difference. (A material's resistance to heat flow is often given as an R-value, which is 1/U.) A higher UA implies a higher expected rate of heat loss. The total UA of a building is simply the sum of the component UAs for all the building's exterior surface components. This total UA is a quantity which can be compared across structures as a measure of thermal integrity.

The conductive UA of each residence was calculated using the data collected in on-site surveys. Each survey was conducted by an experienced auditor who visited the house and reported the physical characteristics of the building based on actual inspection and measurement. Each section of each building component (wall, window, door, etc.) was separately evaluated for its construction type, insulation and area. For instance a typical building included ten separate entries describing the different wall sections. Gaps in
the reported data were filled with default assumptions about construction. In cases where a significant part of a building's audit data was missing or in error and no reasonable default was available, that building was removed from the analysis. Although it represents a mechanism for heat loss, infiltration into the conditioned zones is not included in the UA calculation described here because it varies over time. Attic and crawl space infiltration is included in the UA as a constant. The equations and constants used to calculate the conductive UA are primarily based on the 1985 ASHRAE Fundamentals Handbook.

2.1 THE SAMPLES

There are four samples for which we have calculated UA values: the MCS and Control houses from the ELCAP sample of RSDP homes, and the Post-78 and the Residential Base samples from the ELCAP data base. The Residential Base sample from the ELCAP database is a subset of the PNWRES sample and is roughly representative of the Pacific Northwest electrically-heated single-family housing stock. The size of each sample is shown in Table 1 below. The table is divided into the three climate zones defined in the MCS. The climate zones are defined by the number of base 65°F heating degree days: Zone 1 is 4000 to 6000, Zone 2 is 6001 to 8000, and Zone 3 is over 8001. As the table shows, 86 of single-family detached RSDP homes with data are in the ELCAP database. The conclusions in this report assume that the ELCAP subset is roughly typical of the full RSDP sample.

<table>
<thead>
<tr>
<th>Climate</th>
<th>RSDP MCS</th>
<th>Control</th>
<th>Post 78</th>
<th>Res Base</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
<td>34</td>
<td>14</td>
<td>17</td>
<td>167</td>
<td>232</td>
</tr>
<tr>
<td>Zone 2</td>
<td>20</td>
<td>3</td>
<td>15</td>
<td>71</td>
<td>109</td>
</tr>
<tr>
<td>Zone 3</td>
<td>9</td>
<td>6</td>
<td>9</td>
<td>17</td>
<td>41</td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>23</td>
<td>41</td>
<td>255</td>
<td>382</td>
</tr>
</tbody>
</table>

The average UAs for each sample are given in Table 2. Because the MCS houses average 22% larger than the Control houses, the floor area and UA/floor area for each sample is also given. The MCS houses have the smallest average UA/floor area, as expected.
Table 2: Average UA and Floor Area by Sample

<table>
<thead>
<tr>
<th>Sample</th>
<th>Average UA</th>
<th>Floor Area</th>
<th>UA/Floor Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>btu/(hr/°F)</td>
<td>sq ft</td>
<td>btu/(hr/°F/ft²)</td>
</tr>
<tr>
<td>MCS</td>
<td>295</td>
<td>1833</td>
<td>0.17</td>
</tr>
<tr>
<td>Control</td>
<td>326</td>
<td>1499</td>
<td>0.22</td>
</tr>
<tr>
<td>Post-78</td>
<td>486</td>
<td>1962</td>
<td>0.25</td>
</tr>
<tr>
<td>Res Base</td>
<td>552</td>
<td>1737</td>
<td>0.34</td>
</tr>
</tbody>
</table>

2.2 COMPARISON OF SAMPLE IN RSDP STUDY WITH TARGET CHARACTERISTICS

To draw the correct conclusions from the RSDP experiments, it is necessary to understand the relationship between the MCS and the Control samples as built and the same samples as planned. The analysis described in the following paragraphs demonstrates that the ELCAP subsample of the MCS homes was built essentially to the MCS standard, and that the ELCAP subsample of the Control homes was built to the intended "Current Code" target. Some variation from the exact targets is expected. For instance, the MCS builders were allowed to exceed the MCS standards if they desired. At times the MCS builders failed to meet the MCS standards, as the ELCAP auditors reported. The key concern was that the buildings in the RSDP sample were similar enough to their target characteristics to draw valid conclusions concerning the MCS energy savings from the homes in the RSDP sample.

The residential MCS and Current Code primarily define insulating values for a building shell. That is, they specify insulation R values for each component and the number of window glazings. They do not limit the area allowable for each component, except windows. Therefore, for each building there is a target UA specific to that building which is a function of the building's design. Each building must be compared to its own target MCS or Current-Code UA.

To permit this comparison, three UAs were calculated for each building. All three UAs are calculated using the physical dimensions of the buildings components measured by the auditors, but differ in the insulating values assumed. The "As-Built" UA is calculated using the insulating values of the house as it exists, using the measured insulation levels recorded by the auditor. (Table 2 above gives the As-Built UAs.) The "Standard" UA is computed by replacing the existing insulation values with those specified by the MCS. The "Current Code" UA assumes insulation values equal to the estimates of current building practice determined by the Northwest Power Planning Council.

In order to determine if a house was built as expected in the RSDP study, each home's As-Built UA was compared to its target UA. For the MCS houses, the As-Built UA was compared to the Standard UA. For the Control homes the comparison was to the home's Current-Code UA. Since heat loss through a building shell should be correlated with the total building UA for any of the types of UAs, this analysis did the comparison using a total UA for each building rather than a component by component UA.
2.3 COMPARISON OF THE MCS HOMES TO THE STANDARD

The MCS builders were given the option of following one of four different types of compliance paths. Depending on when and where a house was built, the values allowed by a particular version of the MCS varied somewhat. This analysis assumes that the different paths produce similar buildings in terms of overall heat energy used. Prescriptive Requirements Method - Path A of the MCS was picked as the reference standard for the results contained in this report.

Figure 1 compares the MCS buildings with the Prescriptive Path-A standard. Each point represents one MCS house. Figure 1 shows that the ELCAP buildings were near the UA required by Path A, that is, the points were near the line. There was some scatter around the Path-A standard. There was also a tendency for the MCS home UAs to be slightly over the UA allowed by the MCS. Still, in the aggregate the ELCAP MCS buildings are similar to the MCS requirements. The average As-Built UA is 10% in excess of that allowed by the Path A limit for the 63 homes in the ELCAP MCS sample. (For comparison, on the average the As-Built UAs were only 3% in excess of that allowed by another MCS method, the Component Performance Method.) The tendency for MCS homes to have UAs slightly in excess of the Path A requirements is reasonable because some MCS methods had requirements (like heat pumps or properly oriented glazing) which were not reflected in the UA, but were compensated for by allowing a higher UA. To the extent that ELCAP MCS homes are representative of all the RSDP MCS homes, the thermal integrity of the MCS portion of the RSDP study was roughly as targeted in the Model Conservation Standards.

2.4 COMPARISON OF THE CONTROL HOMES TO CURRENT CODE

Unlike the MCS homes, where there were several possible targets in the MCS, the Control homes had only one target, the Current-Code UA. Figure 2 compares the Control homes As-Built UA to their Current-Code UA. Although the Control homes show some variation from the Current Code UA, the points are generally grouped around the line. In fact the average values of the Control home As-Built UA and the Control home Current-Code UA are almost equal. Therefore, as represented by the ELCAP Control homes, the Control homes in the RSDP study are a good representation of the Current Code targeted by the RSDP study.

Figure 3 compares the As-Built UA for non-RSDP homes built after 1978 in the ELCAP sample with the Current-Code UA for the same homes. Most of the points group around the vertical line where the two UAs would be equal. The tendency for the Post-78 As-Built UAs to be similar to Post-78 Current-Code UAs suggests that the Current-Code UA is indeed representative of the UA for new construction and therefore a reasonable description of the RSDP control group.

2.5 VINTAGE DEPENDENCE OF CONDUCTIVE UA

Figure 4 compares the non-RSDP homes in the ELCAP sample with the MCS by vintage (year built). The vertical axis shows the difference between the As-Built UA and Standard UA, that is the amount the As-Built UA would have to be reduced to achieve the MCS. This reflects insulation levels reported by the auditor and therefore will include any retrofit improvement in insulation since the
homes were built. This figure shows a clear trend of improving insulation levels with vintage. However, this graph also shows the newer buildings are clearly below the MCS. (For comparison, on the average the difference between the Standard UA and the Current-Code UA is 148 (btu/hr/°F).

3.0 CONCLUSIONS

In summary, we have reached several conclusions, as follows:

- The UAs of the RSDP sample of MCS buildings are reasonably representative of the targets set in the Model Conservation Standards.
- The UAs in the RSDP sample of Control buildings are representative of the targets set for the control group by the Current Code.
- The Current Code approximately describes the newer homes in the Region, and therefore is a reasonable description of a control group for the RSDP study.
- Although the thermal integrity of newer homes is improving, the Model Conservation Standards define UA requirements significantly more stringent than represented by the newer homes in the Region.

Each of these conclusions is contingent on the reasonable assumption that the various ELCAP samples are roughly representative of the Pacific Northwest populations from which they were drawn.
Figure 1 compares the MCS homes' As-Built UA to the Standard UA. The horizontal axis is the As-Built UA. The vertical axis is the Path-A UA. Any points falling on the diagonal line represent buildings whose As-Built UA exactly equaled its Path-A UA. Points above the line represent buildings which have lower UAs than required by Path A. Houses below the line have UAs higher than Path A allows. Although there is some scatter and a tendency towards UAs above those allowed by Path A, in general the ELCAP MCS houses roughly met the Path A standard.
Figure 2 compares the Control homes' As-Built UA to their Current-Code UA. The horizontal axis is the Control home As-Built UA. The vertical axis is the Current Code UA. Points on the line represent homes whose As-Built UA exactly equals the targeted Current-Code UA. Although the Control homes show some variation from the Current-Code UA, the points are generally grouped around the line, with the average of the As-Built and Current-Code UA being almost equal. Therefore, as represented by the ELCAP Control homes, the Control homes in the RSDP study are a good representation of the Current Code targeted by the RSDP study.
Figure 3 compares the As-Built UA for non-RSDP ELCAP homes built after 1978 with the Current-Code UA for the same homes. The horizontal axis is the Post-78 home As-Built UA. The vertical axis is the Current-Code UA. Points on the line represent homes whose As-Built UA exactly equals the targeted Current-Code UA. Most of the points group around the vertical line where the two UAs would be equal. The tendency for the Post-78 As-Built UAs to be similar to Post-78 Current-Code UAs suggests that the Current-Code UA is indeed representative of the UA for new construction in the region.
Figure 4 compares the non-RSDP homes in the ELCAP sample with the Path A standard by vintage (year built). The vertical axis shows the difference between the As-Built UA and Standard UA, that is the amount the As-Built UA would have to be reduced to achieve the MCS. Points at zero would represent houses at the MCS standard. One-half of each vintage's houses will fall inside each box. There is a clear trend of improving insulation levels (decreasing UA) with vintage. However, this graph also shows that the newer buildings clearly do not meet the MCS.