AHRI GUIDELINE V:
RECOVERY EFFICIENCY RATIO (RER) AND COMBINED EFFICIENCY (CEF)

AHRI Guideline V (SI)

The **Recovery Efficiency Ratio (RER)** is an energy recovery metric developed within AHRI Guideline V to report the recovered space conditioning energy provided by and air to air energy recovery device divided by the power used to recover that energy. **It is a valuable metric for comparing energy recovery devices since it reflects the impact of pressure loss through the device as parasitic fan power.** RER\(_{\text{total}}\) reflects total recovery at cooling or heating design conditions. This value has units of BTUs/Watts. As a result, higher RER values produce higher energy savings delivered to the end user.

The **Combined Efficiency (CEF)** rating quantifies the efficiency of a packaged system which incorporates energy recovery to precondition the outdoor portion of the systems total airflow. The CEF metric reflects the combination of the packaged units cooling EER or heating COP with the RER of the recovery device to provide the combined system efficiency. **A system with a higher CEF reflects a more efficient system which provides greater energy savings to the end user.**

### Benefit of Higher RER: OEM Example

Assume a project located in Atlanta operates with 3,500 cfm of outdoor and exhaust airflow. A SEMCO UWCH-46 is compared against the OEMs current energy recovery wheel having the same dimensions and similar rated total energy performance, but a much higher pressure loss. The wheels would be installed within a 12.5 ton rooftop unit, operated 16 hours/day, 5 days per week serving a building that is charged $5.00/million BTU for gas and $.08/KWH for electricity.

The side by side performance values are listed within **Figure 1** below along with the calculated RER values for each of the two wheels.

**FIGURE 1.** Performance and RER comparisons - UWCH-46 wheel and competitive 46” diameter wheel*

<table>
<thead>
<tr>
<th>Performance Parameters</th>
<th>UWCH-46</th>
<th>Competitive Option*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Effectiveness</td>
<td>70%</td>
<td>71%</td>
</tr>
<tr>
<td>Supply Air Pressure Loss</td>
<td>0.68 inwg</td>
<td>1.10 inwg</td>
</tr>
<tr>
<td>Return Air Pressure Loss</td>
<td>0.67 inwg</td>
<td>1.10 inwg</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>RER(_{\text{total}}) Comparison</th>
<th>UWCH-46</th>
<th>Competitive Option*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling RER(_{\text{total}})</td>
<td>114.6</td>
<td>74.2</td>
</tr>
<tr>
<td>Heating RER(_{\text{total}})</td>
<td>141.2</td>
<td>91.4</td>
</tr>
</tbody>
</table>
The detailed methodology for calculating RER values is outlined within the AHRI Guideline V. The basic equations for calculating the cooling season RER values based upon total energy recovery performance are used below for our example. The 114.6 cooling season RER values based upon total recovery performance for the UWCH-46 wheel included within Figure 1 is calculated as follows:

$$\text{RER}_{\text{Total}} = \frac{\text{Net conditioning energy recovered}}{\text{Total electric power consumed}}$$

$$\text{RER}_{\text{Total}} = \frac{E_{\text{total}} \cdot \text{Flow}_{\text{supply}} \cdot (H_{\text{outdoor}} - H_{\text{return}})}{P_{\text{fan}} + P_{\text{comp}}} = \frac{.70 \cdot 3,500 \text{ cfm} \cdot 4.5 \cdot (41.4 \text{ BTU/lb} - 27.8 \text{ BTU/lb})}{591.7 \text{ watts} + 125 \text{ watts}} = 114.6 \text{ cooling RER total}$$

$$\text{Pwr}_{\text{fan}} = \frac{\text{Flow}_{\text{supply/return}} \cdot \text{Pressure loss}_{\text{supply/return}}}{8.52 \cdot \text{Eff}_{\text{fan/motor/drive}}} = \frac{3,500 \text{ cfm} \cdot .68^* \cdot \text{two fans at same flow and pressure}}{8.52 \cdot .472} = 591.7 \text{ watts}$$

$$\text{Eff}_{\text{fan/motor/drive}} = \text{Eff}_{\text{fan}} \cdot \text{EFF}_{\text{motor}} \cdot \text{EFF}_{\text{drive}} = 52.3^% \cdot 95^% \cdot 95^% = 47.2^%$$

Note that since the supply and return airflows are the same for this example, the calculated fan energy allocation for the supply fan is simply multiplied times two. Had the airflows been different, separate calculations of fan energy for the supply and return fans would have been required. The 125 watts used reflects the 1/6 horsepower wheel drive motor and is added to the fan energy allocation to provide the total electrical energy required for the energy recovery device.

The fan efficiency value of 52.3% was taken from the OEM customers fan data. This value changes somewhat depending upon the type of fan used, pressures involved and design point for a given manufacturer. Using the same calculation method shown above, the RER values for the heating season and competitive option can be easily confirmed.
Energy savings benefit of Higher RER: OEM Example

The benefit of integrating a recovery device with a higher RER rating is that the packaged system which has integrated the technology will operate with a higher EER (i.e. more cooling/heating output BTUs per watt of energy input). As importantly, higher RER values result in increased energy savings for the end user.

Utilizing the energy metrics provided for the OEM example (page 2) annual energy savings for the two wheel options can be easily compared. The results are shown within Figure 2. While the competitive option used for this example had a total recovery performance slightly better than that provided by the UWC-46 wheel, the increased pressure loss resulted in excess parasitic fan which offset much of the energy recovery savings provided.

As shown below, the UWCH-46 wheel having the higher RER and installed in Atlanta resulted in 17% more net energy savings than the competitive option. Had the same analysis been made using a location where far more free cooling hours existed or where electrical energy costs were higher, the increased energy savings would have been substantially greater.

FIGURE 2. Annual energy savings provided - UWCH-46 wheel vs. competitive 46” diameter wheel*

![Graph showing energy savings comparison]

- Cooling Energy Savings
- Heating/Humidification Savings
- Parasitic Fan Energy (less coil loss credit)
- Net Annual Energy Savings
Increased overall system operating efficiencies (EER) with Higher RER: OEM Example

The Combined Efficiency (CEF) rating can be calculated for both the cooling and heating performance of a packaged system which incorporates an air to air recovery device. If the recovery device is highly efficient and minimizes parasitic fan energy, it can make a significant impact on the combined system EER or CEF rating.

To continue the analysis of the sample project, we now assume that the 3,500 cfm processed by the UWCH-46 wheel is integrated into a packaged system rated at 12.5 tons of cooling output and which operates with a system EER rating of 11 before the incorporation of the total energy wheel. The increased combined system efficiency or CEF is calculated as follows:

$$\text{EER} = \frac{\text{Net cooling capacity}}{\text{Total electric power consumed}}$$

$$\text{CEF}_{\text{Cooling}} = \frac{\text{Net cooling capacity}_{\text{AAHX}} + \text{Net cooling capacity}_{\text{unitary}}}{\text{Electric power consumed}_{\text{AAHX}} + \text{Electric power consumed}_{\text{unitary}}}$$

As shown by the two equations above, the CEF provides the same performance metric as the more traditional EER but it integrates the free cooling and dehumidification (when total recovery is employed) provided by the recovery device and the parasitic energy consumed by the recovery device to provide a measure of combined efficiency.

The CEF calculation is configured to allow a direct calculation using RER values as shown below:

$$\text{CEF}_{\text{Cooling}} = \frac{1}{Y_c/RER_{\text{AAHX}} + (1-Y_c)/EER_{\text{unitary}}}$$

Where:

$$Y_c = \frac{\text{Net cooling capacity}_{\text{AAHX}}}{\text{Net cooling capacity}_{\text{combined system}}}$$
Using the information provided for the example, the CEF for the cooling season performance of the 12.5 ton packaged unit integrating the UWCH-46 total energy wheel can be calculated as follows:

\[ Y_c = \frac{.70 \times 3,500 \text{ cfm} \times 4.5 \times (41.4 \text{ BTU/lb} - 27.8 \text{ BTU/lb})}{(.70 \times 3,500 \text{ cfm} \times 4.5 \times (41.4 \text{ BTU/lb} - 27.8 \text{ BTU/lb}) + (12.5 \text{ tons} \times 12,000 \text{ BTU/ton})} \]

\[ = \frac{149,940}{299,940} = .50 \]

And the UWCH – 46 CEF calculated to be:

\[ \text{CEF}_{\text{Cooling}} = \frac{1}{(\frac{.50}{114.6}) + ((1-.50)/11)} = 20.1 \text{ for UWCH-46} \]

Completing the same CEF calculation for the competitive option can be easily done using the same methodology. Given the much lower RER value, the CEF value is substantially lower as well. The CEF for unitary system incorporating the UWCH-46 wheel is approximately 5% higher than the same system employing the competitive wheel.

\[ \text{CEF}_{\text{Cooling}} = \frac{1}{(\frac{.503}{74.2}) + ((1-.503)/11)} = 19.2 \text{ for competitive option} \]

Similar results are obtained when using the RER values to calculate the CEF during the heating season for a packaged system. The process is same as shown above with the energy recovery fraction \( Y_c \) reflecting the heating season load reduction, substituting the heating season RER and using COP rather than EER.
Conclusion: For the OEM

Original Equipment Manufacturers building packaged systems with integrated total energy recovery devices can substantially improve the combined system efficiency of their equipment by paying particular attention to the AHRI RER ratings of the components used.

The SEMCO UWC and UWCH products have been engineered to provide the highest RER values for a given cabinet size due to the combination of high total energy recovery performance and low parasitic pressure losses. SEMCO selection tools provide RER values as a standard output to simplify the process of choosing the most efficient and cost effective total energy recovery device for each project.

Typical example highlighting the importance of optimizing both total recovery and parasitic pressure loss

<table>
<thead>
<tr>
<th></th>
<th>Competition</th>
<th>SEMCO</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recovery Wheel Total Efficiency</td>
<td>71%*</td>
<td>70%</td>
<td>-1%</td>
</tr>
<tr>
<td>Recovery Wheel Total Efficiency</td>
<td>1.01</td>
<td>0.68</td>
<td>-33%</td>
</tr>
<tr>
<td>Cooling RER</td>
<td>74.2</td>
<td>114.6</td>
<td>54%</td>
</tr>
<tr>
<td>Combined Energy Efficiency (CEF)</td>
<td>19.2</td>
<td>20.1</td>
<td>5%</td>
</tr>
<tr>
<td>Annual Energy Savings</td>
<td>$990</td>
<td>$1,210</td>
<td>22%</td>
</tr>
</tbody>
</table>

*Slightly higher competitive total efficiency chosen intentionally for purpose of this analysis. SEMCO total effectiveness is typically the same or higher than the competition.
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