§ 434.402 Building envelope assemblies and materials.

The building envelope and its associated assemblies and materials shall meet the provisions of this section.

402.1 Calculations and Supporting Information.

402.1.1 Material Properties. Information on thermal properties, building envelope system performance, and component heat transfer shall be obtained from RS-4. When the information is not available from RS-4, (incorporated by reference, see § 434.701) the data shall be obtained from manufacturer's information or laboratory or field test measurements using RS-5, RS-6, RS-7, or RS-8 (incorporated by reference, see § 434.701).

402.1.1.1 The shading coefficient (SC) for fenestration shall be obtained from RS-4 (incorporated by reference, see § 434.701) or from manufacturer's test data. The shading coefficient of the fenestration, including both internal and external shading devices, is SCX and excludes the effect of external shading projections, which are calculated separately. The shading coefficient used for louvered shade screens shall be determined using a profile angle of 30 degrees as found in Table 41, Chapter 27 of RS-4 (incorporated by reference, see § 434.701).

402.1.2 Thermal Performance Calculations. The overall thermal transmittance of the building envelope shall be calculated in accordance with Equation 402.1.2:

\[
U_o = \frac{\sum U_i A_i}{A_o} = \left(\frac{U_1 A_1 + U_2 A_2 + \ldots + U_n A_n}{A_o}\right)
\]  

(402.1.2)

Where:

U_o = the area-weighted average thermal transmittance of the gross area of the building envelope; i.e., the exterior wall assembly including fenestration and doors, the roof and ceiling assembly, and the floor assembly, Btu/(h·ft²·°F)

A_o = the gross area of the building envelope, ft²

U_i = the thermal transmittance of each individual path of the building envelope, i.e., the opaque portion or the fenestration, Btu/(h·ft²·°F)

U_i = 1/R_i (where R_i is the total resistance to heat flow of an individual path through the building envelope)

A_i = the area of each individual element of the building envelope, ft²

The thermal transmittance of each component of the building envelope shall be determined with due consideration of all major series and parallel heat flow paths through the elements of the component and film coefficients and shall account for any compression of insulation. The thermal transmittance of opaque elements of assemblies shall be determined using a series path procedure with corrections for the presence of parallel paths within an element of the envelope assembly (such as wall cavities with parallel paths through insulation and studs). The thermal performance of adjacent ground in below-grade applications shall be excluded from all thermal calculations.

402.1.2.1 Envelope Assemblies Containing Metal Framing. The thermal transmittance of the envelope assembly containing metal framing shall be determined from one of three methods:

(a) Laboratory or field test measurements based on RS-5, RS-6, RS-7, or RS-8 (incorporated by reference, see § 434.701).

(b) The zone method described in Chapter 22 of RS-4 (incorporated by reference, see § 434.701) and the formulas on page 22.10.

(c) For metal roof trusses or metal studs covered by Tables 402.1.2.1a and b, the total resistance of the series path shall be calculated in accordance with the following Equations:

\[
U_i = \frac{1}{R_i}
\]  

Equation 402.1.2.1a

\[
R_i = R_i + R_e
\]

Where:

R_i = the total resistance of the envelope assembly

R_i = the resistance of the series elements (for i = 1 to n) excluding the parallel path element(s)

R_e = the equivalent resistance of the element containing the parallel path (R-value of
710

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Values for \( F_c \) and equivalent resistances shall be taken from Tables 402.1.2.1a or b.

**Table 402.1.2.1a—Parallel Path Correction Factors—Metal Roof Trusses Spaced 4 ft. O.C. or Greater That Penetrate the Insulation**

<table>
<thead>
<tr>
<th>Effective framing cavity R-values</th>
<th>Correction factor ( F_c )</th>
<th>Equivalent resistance ( R_e )</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-0</td>
<td>1.00</td>
<td>R-0</td>
</tr>
<tr>
<td>R-6</td>
<td>0.96</td>
<td>R-4.8</td>
</tr>
<tr>
<td>R-10</td>
<td>0.92</td>
<td>R-9.2</td>
</tr>
<tr>
<td>R-15</td>
<td>0.88</td>
<td>R-13.2</td>
</tr>
<tr>
<td>R-20</td>
<td>0.85</td>
<td>R-17.0</td>
</tr>
</tbody>
</table>

1 Based on 0.66-inch-diameter cross members every one foot.

**Table 402.1.2.1b—Parallel Path Correction Factors—Metal Framed Walls With Studs 16 Ga. or Lighter**

<table>
<thead>
<tr>
<th>Size of members</th>
<th>Spacing of framing, in.</th>
<th>Cavity insulation R-Value</th>
<th>Correction factor ( F_c )</th>
<th>Equivalent resistance ( R_e )</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 \times 4</td>
<td>24 O.C.</td>
<td>R-11</td>
<td>0.50</td>
<td>R-5.5</td>
</tr>
<tr>
<td>2 \times 4</td>
<td>24 O.C.</td>
<td>R-13</td>
<td>0.46</td>
<td>R-6.0</td>
</tr>
<tr>
<td>2 \times 6</td>
<td>16 O.C.</td>
<td>R-11</td>
<td>0.43</td>
<td>R-6.4</td>
</tr>
<tr>
<td>2 \times 6</td>
<td>24 O.C.</td>
<td>R-13</td>
<td>0.60</td>
<td>R-6.6</td>
</tr>
<tr>
<td>2 \times 8</td>
<td>16 O.C.</td>
<td>R-15</td>
<td>0.55</td>
<td>R-7.2</td>
</tr>
<tr>
<td>2 \times 8</td>
<td>24 O.C.</td>
<td>R-19</td>
<td>0.52</td>
<td>R-7.8</td>
</tr>
<tr>
<td>2 \times 8</td>
<td>24 O.C.</td>
<td>R-21</td>
<td>0.37</td>
<td>R-7.1</td>
</tr>
<tr>
<td>2 \times 8</td>
<td>24 O.C.</td>
<td>R-25</td>
<td>0.35</td>
<td>R-7.4</td>
</tr>
</tbody>
</table>

402.1.2.2 **Envelope Assemblies Containing Nonmetal Framing.** The thermal transmittance of the envelope assembly shall be determined from laboratory or field test measurements based on RS-5, RS-6, RS-7, or RS-8 (incorporated by reference, see §434.701) or from the series-parallel (isothermal planes) method provided in page 23.2 of Chapter 23 of RS-4 (incorporated by reference, see §434.701).

402.1.2.3 **Metal Buildings.** For elements with internal metallic structures bonded on one or both sides to a metal skin or covering, the calculation procedure specified in RS-9 (incorporated by reference, see §434.701) shall be used.

402.1.2.4 **Fenestration Assemblies.** Determine the overall thermal transmittance of fenestration assemblies in accordance with RS-18 and RS-19 (incorporated by reference, see §434.701) or by calculation. Calculation of the overall thermal transmittance of fenestration assemblies shall consider the center-of-glass, edge-of-glass, and frame components.

(a) The following equation 402.1.2.4a shall be used.
Where:

\[ U_{gr} = \sum_{i=1}^{n} \left[ \frac{U_{f,1} \times A_{cg,1} + U_{f,2} \times A_{cg,2} + \ldots + U_{f,n} \times A_{cg,n} + U_{f,1} \times A_{eg,1} + U_{f,2} \times A_{eg,2} + \ldots + U_{f,n} \times A_{eg,n} + U_{f,1} \times A_{f,1} + U_{f,2} \times A_{f,2} + \ldots + U_{f,n} \times A_{f,n}}{\sum_{i=1}^{n} (A_{cg,i} + A_{eg,i} + A_{f,i})} \right] \]

Equation 402.1.2.4a

(3) Calculations based on the actual area for center-of-glass, edge-of-glass, and frame assemblies and on the thermal transmittance of components derived from 402.1.2.4a, 402.1.2.4b or a combination of the two.

402.1.3 Gross Areas of Envelope Components.

402.1.3.1 Roof Assembly. The gross area of a roof assembly shall consist of the total surface of the roof assembly exposed to outside air or unconditioned spaces and is measured from the exterior faces of exterior walls and centerline of walls separating buildings. The roof assembly includes all roof or ceiling components through which heat may flow between indoor and outdoor environments, including skylight surfaces but excluding service openings. For thermal transmittance purposes when return air ceiling plenums are employed, the roof or ceiling assembly shall not include the resistance of the ceiling or the plenum space as part of the total resistance of the assembly.

402.1.3.2 Floor Assembly. The gross area of a floor assembly over outside or unconditioned spaces shall consist of the total surface of the floor assembly exposed to outside air or unconditioned space and is measured from the exterior face of exterior walls and centerline of walls separating buildings. The floor assembly shall include all floor components through which heat may flow between indoor and outdoor or unconditioned space environments.

402.1.3.3 Wall Assembly. The gross area of exterior walls enclosing a heated or cooled space is measured on the exterior and consists of the opaque walls, including between-floor spandrels, peripheral edges of flooring, window
areas (including sash), and door areas but excluding vents, grilles, and pipes.

402.2 Air Leakage and Moisture Mitigation. The requirements of this section shall apply only to those building components that separate interior building conditioned space from the outdoors or from unconditioned space or crawl spaces. Compliance with the criteria for air leakage through building components shall be determined by tests conducted in accordance with RS–10 (incorporated by reference, see § 434.701).

402.2.1 Air Barrier System. A barrier against leakage shall be installed to prevent the leakage of air through the building envelope according to the following requirements:

(a) The air barrier shall be continuous at all plumbing and heating penetrations of the building opaque wall.

(b) The air barrier shall be sealed at all penetrations of the opaque building wall for electrical and telecommunications equipment.

---

**Table 402.2.1—Air Leakage for Fenestration and Doors Maximum Allowable Infiltration Rate**

<table>
<thead>
<tr>
<th>Component</th>
<th>Reference standard</th>
<th>cfm/lin ft Sash crack or cfm/ft² of area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fenestration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminum:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operable</td>
<td>RS–11*</td>
<td>0.37 cfm/lin ft.</td>
</tr>
<tr>
<td>Jalousie</td>
<td>RS–11*</td>
<td>1.50 cfm/ft².</td>
</tr>
<tr>
<td>Fixed</td>
<td>RS–11*</td>
<td>0.15 cfm/ft².</td>
</tr>
<tr>
<td>Poly Vinyl Chloride (PVC):</td>
<td>RS–12*</td>
<td>0.37 cfm/ft².</td>
</tr>
<tr>
<td>Prime Windows</td>
<td>RS–12*</td>
<td>0.25 cfm/ft².</td>
</tr>
<tr>
<td>Wood</td>
<td>RS–13*</td>
<td>0.15 cfm/ft².</td>
</tr>
<tr>
<td>Sliding Glass Doors:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminum</td>
<td>RS–11*</td>
<td>0.37 cfm/ft².</td>
</tr>
<tr>
<td>PVC</td>
<td>RS–12*</td>
<td>0.37 cfm/lin ft.</td>
</tr>
<tr>
<td>Doors—Wood:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential</td>
<td>RS–14*</td>
<td>0.34 cfm/ft².</td>
</tr>
<tr>
<td>Light Commercial</td>
<td>RS–14*</td>
<td>0.25 cfm/ft².</td>
</tr>
<tr>
<td>Heavy Commercial</td>
<td>RS–14*</td>
<td>0.10 cfm/ft².</td>
</tr>
<tr>
<td>Commercial Entrance Doors</td>
<td>RS–10*</td>
<td>1.25 cfm/ft².</td>
</tr>
<tr>
<td>Residential Swinging Doors</td>
<td>RS–10*</td>
<td>0.50 cfm/ft².</td>
</tr>
<tr>
<td>Wall Sections Aluminum</td>
<td>RS–10*</td>
<td>0.06 cfm/ft².</td>
</tr>
</tbody>
</table>

*Note: The “Maximum Allowable Infiltration Rates” are from current standards to allow the use of available products.*

402.2.2 Building Envelope. The following areas of the building envelope shall be sealed, caulked, gasketed, or weatherstripped to limit air leakage:

(a) Intersections of the fenestration and door frames with the opaque wall sections.

(b) Openings between walls and foundations, between walls and roof and wall panels.

(c) Openings at penetrations of utility service through, roofs, walls, and floors.

(d) Site built fenestration and doors.

(e) All other openings in the building envelope.

Exceptions are as follows: Outside air intakes, exhaust outlets, relief outlets, stair shaft, elevator shaft smoke relief openings, and other similar elements shall comply with subsection 403.

402.2.2.2 Building Assemblies Used as Ducts or Plenums. Building assemblies used as ducts or plenums shall be sealed, caulked, and gasketed to limit air leakage.

402.2.2.3 Vestibules. A door that separates conditioned space from the exterior shall be equipped with an enclosed vestibule with all doors opening into and out of the vestibule equipped with self-closing devices. Vestibules shall be designed so that in passing through the vestibule, it is not necessary for the interior and exterior doors to open at the same time. Exceptions are as follows: Exterior doors need not be protected with a vestibule where:

(a) The door is a revolving door.

(b) The door is used primarily to facilitate vehicular movement or material handling.

(c) The door is not intended to be used as a general entrance door.

(d) The door opens directly from a dwelling unit.

(e) The door opens directly from a retail space less than 2,000 ft² in area, or from a space less than 1,500 ft² for other uses.

(f) In buildings less than three stories in building height in regions that have less than 6,300 heating degree days base 65 °F.

402.2.2.4 Compliance Testing. All buildings shall be tested after completion using the methodology in RS–11, (incorporated by reference, see § 434.701) or an equivalent approved method to determine the envelope air leakage. A standard blower door test is an acceptable technique to pressurize the building if the building is 5,000 ft² or less in...
area. The building's air handling system can be used to pressurize the building if the building is larger than 5,000 ft². The following test conditions shall be:

(a) The measured envelope air leakage shall not exceed 1.57 pounds per square foot of wall area at a pressure difference of 0.3 inches water.

(b) At the time of testing, all windows and outside doors shall be installed and closed, all interior doors shall be open, and all air handlers and dampers shall be operable. The building shall be unoccupied.

(c) During the testing period, the average wind speed during the test shall be less than 6.6 feet per second, the average outside temperature greater than 59°F, and the average inside-outside temperature difference is less than 41°F.

402.2.2.5 Moisture Migration. The building envelope shall be designed to limit moisture migration that leads to deterioration in insulation or equipment performance as determined by the following construction practices:

(a) A vapor retarder shall be installed to retard, or slow down the rate of water vapor diffusion through the building envelope. The position of the vapor retarder shall be determined taking into account local climate and indoor humidity levels. The methodologies presented in Chapter 20 of RS-4 (incorporated by reference, see §434.701) shall be used to determine temperature and water vapor profiles through the envelope systems to assess the potential for condensation within the envelope and to determine the position of the vapor retarder within the envelope system.

(b) The vapor retarder shall be installed over the entire building envelope.

(c) The perm rating requirements of the vapor retarder shall be determined using the methodologies contained in Chapter 20 of RS-4 (incorporated by reference, see §434.701) and shall take into account local climate and indoor humidity level. The vapor retarder shall have a performance rating of 1 perm or less.

402.3 Thermal Performance Criteria.

402.3.1 Roofs; Floors and Walls Adjacent to Unconditioned Spaces. The area weighted average thermal transmittance of roofs and also of floors and walls adjacent to unconditioned spaces shall not exceed the criteria in Table 402.3.1a. Exceptions are as follows: Skylights for which daylight credit is taken may be excluded from the calculations of the roof assembly U₀ if all of the following conditions are met:

(a) The opaque roof thermal transmittance is less than the criteria in Table 402.3.1b.

(b) Skylight areas, including framing, as a percentage of the roof area do not exceed the values specified in Table 402.3.1b. The maximum skylight area from Table 402.3.1b may be increased by 50% if a shading device is used that blocks over 50% of the solar gain during the peak cooling design condition. For shell buildings, the permitted skylight area shall be based on a light level of 30 foot candles and a lighting power density (LPD) of less than 1.0 w/ft². For speculative buildings, the permitted skylight area shall be based on the unit lighting power allowance from Table 401.3.2a and an illuminance level as follows: for LPD <1.0, use 30 foot-candles; for 1.0 <LPD <2.5, use 50 foot-candles; and for LPD ≥2.5, use 70 foot-candles.

(c) All electric lighting fixtures within daylighted zones under skylights are controlled by automatic daylighting controls.

(d) The U₀ of the skylight assembly including framing does not exceed 0.70 Btu/(h·ft²·°F) [Use 0.70 for ≤8000 HDD65 and 0.45 for >8000 HDD65 or both if the jurisdiction includes cities that are both below and above 8000 HDD65.]

(e) Skylight curb U-value does not exceed 0.21 Btu/(h·ft²·°F).

(f) The infiltration coefficient of the skylights does not exceed 0.65 cfm/ft².

402.3.2 Below-Grade Walls and Slabs-on-Grade. The thermal resistance (R-value) of insulation for slabs-on-grade, or the overall thermal resistance of walls in contact with the earth, shall be equal to or greater than the values in Table 402.3.2.

402.4 Exterior Walls. Exterior walls shall comply with either 402.4.1 or 402.4.2.
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402.4.1 Prescriptive Criteria. (a) The exterior wall shall be designed in accordance with subsections 402.4.1.1 and 402.4.1.2. When the internal load density range is not known, the 0–1.50 W/ft² range shall be used for residential, hotel/motel guest rooms, or warehouse occupancies; the 3.01–3.50 W/ft² range shall be used for retail stores smaller than 2,000 ft² and technical and vocational schools smaller than 10,000 ft²; and the 1.51–3.00 W/ft² range shall be used for all other occupancies and building sizes. When the building envelope is designed or constructed prior to knowing the building occupancy type, an internal load density of 3.0 W/ft² shall be used. [Use 3.0 W/ft² for HDD65 <3000, 2.25 W/ft² for 3000 <HDD65 <6000, and 1.5 W/ft² for HDD65 >6000.]

(b) When more than one condition exists, area weighted averages shall be used. This requirement shall apply to all thermal transmittances, shading coefficients, projection factors, and internal load densities rounded to the same number of decimal places as shown in the respective table.

402.4.1.1 Opaque Walls. The weighted average thermal transmittance (U-value) of opaque wall elements shall be less than the values in Table 402.4.1.1. For mass walls (HC ≥5), criteria are presented for low and high window/wall ratios and the criteria shall be determined by interpolating between these values for the window/wall ratio of the building.

402.4.1.2 Fenestration. The design of the fenestration shall meet the criteria of Table 402.4.1.2. When the fenestration columns labeled “Perimeter Daylighting” are used, automatic daylighting controls shall be installed in the perimeter daylighted zones of the building. These daylighting controls shall be capable of reducing electric lighting power to at least 50% of full power. Only those shading or lighting controls for perimeter daylighting that are shown on the plans shall be considered. The column labeled “VLT >= SC” shall be used only when the shading coefficient of the glass is less than its visible light transmittance.

APPENDIX A

§ 434.402 System Performance Criteria.

The cumulative annual energy flux attributable to thermal transmittance and solar gains shall be less than the criteria determined using the ENVSTD24 computer program in Standard 90.1–1989, or the equations in RS–1, (incorporated by reference, see § 434.701) Attachment 8–B. The cumulative annual energy flux shall be calculated using the ENVSTD24 computer program or the equations in RS–1. (incorporated by reference, see § 434.701) Attachment 8–B.
TABLE 402.4.2—EQUIP DEFAULT VALUES FOR ENVSTD24

<table>
<thead>
<tr>
<th>Occupancy</th>
<th>Default equipment power density</th>
<th>Default occupant load adjustment</th>
<th>Default adjusted equipment power density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly</td>
<td>0.25</td>
<td>0.75</td>
<td>1.00</td>
</tr>
<tr>
<td>Health/Institutional</td>
<td>1.00</td>
<td>−0.26</td>
<td>0.74</td>
</tr>
<tr>
<td>Hotel/Motel</td>
<td>0.25</td>
<td>−0.33</td>
<td>0.00</td>
</tr>
<tr>
<td>Warehouse/Storage</td>
<td>0.10</td>
<td>−0.60</td>
<td>0.00</td>
</tr>
<tr>
<td>Multi-Family High</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rise</td>
<td>0.75</td>
<td>N/A</td>
<td>0.00</td>
</tr>
<tr>
<td>Office</td>
<td>0.75</td>
<td>−0.35</td>
<td>0.40</td>
</tr>
<tr>
<td>Restaurant</td>
<td>0.10</td>
<td>0.07</td>
<td>0.17</td>
</tr>
<tr>
<td>Retail</td>
<td>0.25</td>
<td>−0.38</td>
<td>0.00</td>
</tr>
<tr>
<td>School</td>
<td>0.50</td>
<td>0.30</td>
<td>0.80</td>
</tr>
</tbody>
</table>

1 Defaults as defined in Section 8.6.10.5, Table 8–4, and Sections 8.6.10.6 and 13.7.2.1, Table 13–2 from RS–1 (incorporated by reference, see § 434.701).

402.4.2.1 Equipment Power Density (EQUIP). The equipment power density used in the ENVSTD24 computer program shall use the actual equipment power density from the building plans and specifications or be taken from Table 402.4.2 using the column titled “Default Adjusted Equipment Power Density” or calculated for the building using the procedures of RS–1. (incorporated by reference, see § 434.701). The program limits consideration of the equipment power density to a maximum of 1 W/ft².

402.4.2.2 Lighting Power Density (LIGHTS). The lighting power density used in the ENVSTD24 computer program shall use the actual lighting power density from the building plans and specifications or the appropriate value from Tables 401.3.2a, b, c, or d.

402.4.2.3 Daylighting Control Credit Fraction (DLCF). When the daylighting control credit fraction is other than zero, automatic daylighting controls shall be installed in the appropriate perimeter zone(s) of the building to justify the credit.

§ 434.403 Building mechanical systems and equipment.

Mechanical systems and equipment used to provide heating, ventilating, and air conditioning functions as well as additional functions not related to space conditioning, such as, but not limited to, freeze protection in fire projection systems and water heating, shall meet the requirements of this section.

403.1 Mechanical Equipment Efficiency. When equipment shown in Tables 403.1a through 403.1f is used, it shall have a minimum performance at the specified rating conditions when tested in accordance with the specified reference standard. The reference standards listed in Tables 403.1a through 403.1f are incorporated by reference, see § 434.701. Omission of minimum performance requirements for equipment not listed in Tables 403.1a through 403.1f does not preclude use of such equipment.

TABLE 403.1A—UNITARY AIR CONDITIONERS AND CONDENSING UNITS, ELECTRICALLY OPERATED, MINIMUM EFFICIENCY REQUIREMENTS

<table>
<thead>
<tr>
<th>Equipment type</th>
<th>Size category</th>
<th>Subcategory or rating condition</th>
<th>Minimum Efficiency</th>
<th>Test procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Conditioners, Air Cooled.</td>
<td>&lt;65,000 Btu/h</td>
<td>Split system</td>
<td>10.0 SEER</td>
<td>ARI 210/240</td>
</tr>
<tr>
<td></td>
<td>&gt;65,000 Btu/h</td>
<td>Single Package</td>
<td>9.7 SEER</td>
<td>ARI 210/240</td>
</tr>
<tr>
<td></td>
<td>&gt;135,000 Btu/h</td>
<td>Split System and Single Package</td>
<td>9.3 SEER</td>
<td>ARI 210/240</td>
</tr>
<tr>
<td>Air Conditioners, Water</td>
<td>&lt;65,000 Btu/h</td>
<td>Split System and Single Package</td>
<td>8.9 EER</td>
<td>ARI 340/360</td>
</tr>
<tr>
<td>and Evaporatively Cooled.</td>
<td>&gt;135,000 Btu/h</td>
<td>Split System and Single Package</td>
<td>7.5 IPLV</td>
<td>ARI 340/360</td>
</tr>
<tr>
<td>Condensing Units, Air Cooled.</td>
<td>135,000 Btu/h</td>
<td>Split System and Single Package</td>
<td>7.5 EER</td>
<td>ARI 340/360</td>
</tr>
</tbody>
</table>

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