Security-Related Information – Withheld Under 10 CFR 2.390

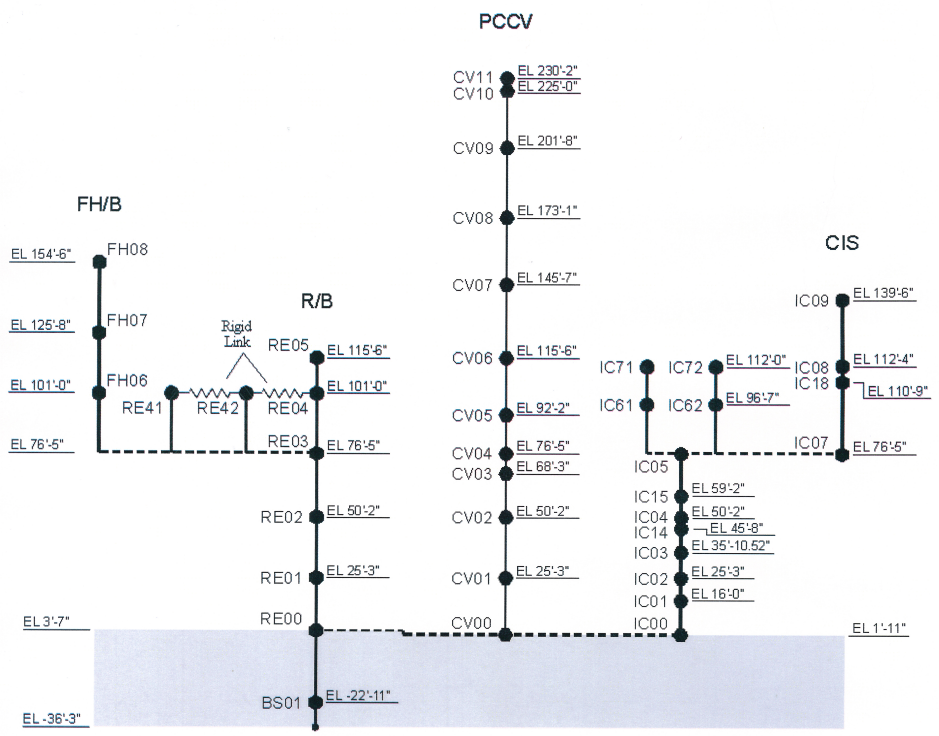
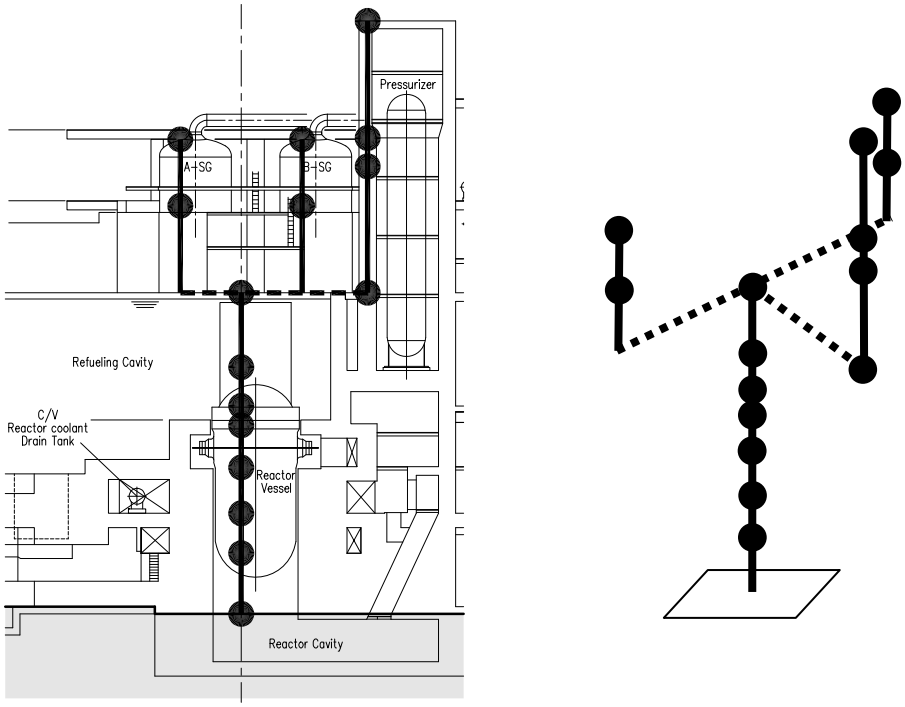



**Figure 5.3.1-2 (sheet 1 of 2) Lumped Mass Stick Model for Buildings (R/B, PCCV, CIS)**

Security-Related Information – Withheld Under 10 CFR 2.390




Note: Upper portion of this sheet shows the zoning above the operating floor at elevation 76'-5" and the lower portion shows conceptual stick model with respect to configuration of the CIS.

**Figure 5.3.1-2 (Sheet 2 of 2) Lumped Mass Stick Model for Buildings (R/B, PCCV, CIS)**

#### 5.3.1.3 Lumped-Mass-Stick Models of Major Equipment and Piping

The RCL lumped mass stick model represents the dynamic properties of RV, SG, RCP, main coolant piping (MCP), and component supports, as applicable, for each of the four loops. The RCL piping and support system is modeled as three-dimensional model representing the stiffness of components, pipes, and supports as beam elements and springs and the mass inertia with mass lumped at selected node locations.

The RCL of the US-APWR has four loops, which are modeled as combination of RV, SG, RCP and MCP. These combined system models include both the translational and rotational stiffness, mass characteristics of the RCL piping and components, and the stiffness of supports. The RCL lumped mass stick model considers the stiffnesses and mass of those auxiliary line piping that affect the dynamic response of the RCL system. Table 5.3.1-11 through Table 5.3.1-22 present the mass, material properties and stiffness characteristics of the individual components of the RCL such as the RV, the SG and RCP and MCP.

The RV support system consists of eight steel support pads which are integrated with the inlet and outlet nozzle forgings. The support pads are placed on brackets, which are supported by an embedded steel structure on the primary shield wall. The supports allow radial thermal growth of the RCS and RV. Details of the RV supports and their relationship with the primary shield wall are presented in Section 3.8 of the US-APWR DCD.

The SG support system consists of an upper shell support structure, an intermediate shell support structure and a lower support structure. The upper and intermediate shell supports are lateral restraints (snubbers) attached to structural steel brackets, while the lower support structure is constructed entirely of structural steel and provides both vertical and lateral support. Four pinned-end columns to the slab support the vertical loads of the SG.

The RCP support system consists of a lateral support structure, and three pinned-end structural columns to the slab. Both support structure are designed considering thermal expansion of connected piping.

Figure 5.3.1-5 presents the analytical model of the entire RCL including the individual components of the four loops and the support representation. Figure 5.3.1-6 and Table 5.3.1-22 identify the connectivity between the RCL nodes and the building nodes. Typically, the fixed end nodes of the RCL support springs are attached to the nodes associated with the internal concrete by rigid beam elements. For example, the nodes which represent the ends of the RV support springs at the RV inlet and outlet nozzle are all connected by rigid beams to IC03 of the CIS at that elevation.

**Table 5.3.1-11 Lumped Mass of RV Model**

| Symbol | Description | Location | | | Weight | | |
|---|---|---|---|---|---|---|---|
| | | X (ft) | Y (ft) | Z (ft) | Wx (kip) | Wy (kip) | Wz (kip) |
| RV09 | Top Head CG | 3.33 | 0 | 49.94 | 426.6 | 426.6 | 397.5 |
| RV08 | Upper Core Support Flange | 3.33 | 0 | 46.79 | 241.0 | 241.0 | 241.0 |
| RV07 | Core Ridge of Core Barrel | 3.33 | 0 | 45.36 | 672.9 | 672.9 | 108.2 |
| RV06 | Center of Nozzles | 3.33 | 0 | 40.39 | 246.3 | 246.3 | 241.8 |
| RV05 | Upper Core Plate | 3.33 | 0 | 35.88 | 154.3 | 154.3 | 149.7 |
| RV04 | Division Point | 3.33 | 0 | 30.51 | 159.6 | 159.6 | 154.3 |
| RV03 | Division Point | 3.33 | 0 | 24.57 | 165.3 | 165.3 | 159.8 |
| RV02 | Radial Support Key | 3.33 | 0 | 18.8 | 566.4 | 566.4 | 82.5 |
| RV01 | Bottom Head CG | 3.33 | 0 | 15.25 | 113.1 | 113.1 | 117.1 |
| RV11 | UCI | 3.33 | 0 | 42.08 | 0 | 0 | 271.8 |
| RV12 | LCI | 3.33 | 0 | 42.08 | 0 | 0 | 1129 |

**Table 5.3.1-12 Lumped Mass of SG Model**

| Symbols | Description | Location | | | | | Mass Inertia | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | X (ft) | | Y (ft) | | Z (ft) | Weight (kip) | Jyy (kip-ft$^2$) | Jxx (kip-ft$^2$) | Jzz (kip-ft$^2$) |
| | | A&D Loop | B&C Loop | A&B Loop | C&D Loop | | | | | |
| S(A/B/C/D) 12 | Steam Outlet Nozzle | -10.62 | 17.29 | 33.69 | -33.69 | 113.76 | - | - | - | - |
| S(A/B/C/D) 11 | Upper Shell/Upper Head | -10.62 | 17.29 | 33.69 | -33.69 | 108.06 | 152.0 | 4,527 | 4,527 | 6,850 |
| S(A/B/C/D) 10 | Upper Shell Support | -10.62 | 17.29 | 33.69 | -33.69 | 96.58 | 241.0 | 8,710 | 8,710 | 13,095 |
| S(A/B/C/D) 09 | Feed Water Nozzle | -10.62 | 17.29 | 33.69 | -33.69 | 90.84 | - | - | - | - |
| S(A/B/C/D) 08 | Transition Cone Upper Side | -10.62 | 17.29 | 33.69 | -33.69 | 86.87 | 163.6 | 4,987 | 4,987 | 7,509 |
| S(A/B/C/D) 07 | Tube Support Plate(#8) Pt. | -10.62 | 17.29 | 33.69 | -33.69 | 80.74 | 51.57 | 769.0 | 769.0 | 1,473 |
| S(A/B/C/D) 06 | Transition Cone Lower Side | -10.62 | 17.29 | 33.69 | -33.69 | 79.38 | | | | |
| S(A/B/C/D)05 | Middle Shell Support | -10.62 | 17.29 | 33.69 | -33.69 | 75.42 | 156.8 | 2,790 | 2,790 | 4,237 |
| S(A/B/C/D)04 | Lower Shell/Middle Shell | -10.62 | 17.29 | 33.69 | -33.69 | 64.72 | 188.4 | 4,984 | 4,984 | 4,546 |
| S(A/B/C/D)03 | Adjustment Point | -10.62 | 17.29 | 33.69 | -33.69 | 54.71 | 108.4 | 1,725 | 1,725 | 2,567 |
| S(A/B/C/D)02 | Leg Point of Intersection | -10.62 | 17.29 | 33.69 | -33.69 | 49.5 | 97.7 | 1,254 | 1,254 | 2,370 |
| S(A/B/C/D)01 | Lower Support | -10.62 | 17.29 | 33.69 | -33.69 | 45.64 | 101.5 | 1,377 | 1,377 | 2,199 |

**Table 5.3.1-13 Lumped Mass of RCP Model**

| Symbols | Description | Location | | | | | Weight (kip) |
|---|---|---|---|---|---|---|---|
| | | X (ft) | | Y (ft) | | Z (ft) | |
| | | A&D Loop | B&C Loop | A&B Loop | C&D Loop | | |
| P(A/B/C/D)14 | Top of RCP | -29.62 | 36.29 | 25.09 | -25.09 | 63.21 | - |
| P(A/B/C/D)13 | Motor Mass Point | -29.62 | 36.29 | 25.09 | -25.09 | 57.13 | 105.82 |
| P(A/B/C/D)12 | Upper Bracket | -29.62 | 36.29 | 25.09 | -25.09 | 56.84 | - |
| P(A/B/C/D)11 | Lower Bracket | -29.62 | 36.29 | 25.09 | -25.09 | 53.52 | - |
| P(A/B/C/D)10 | Motor Stand Upper Side | -29.62 | 36.29 | 25.09 | -25.09 | 50.51 | - |
| P(A/B/C/D)09 | Motor Stand Opening Upper Side | -29.62 | 36.29 | 25.09 | -25.09 | 49.86 | - |
| P(A/B/C/D)08 | Motor Stand Opening Lower Side | -29.62 | 36.29 | 25.09 | -25.09 | 46.58 | - |
| P(A/B/C/D)07 | Motor Stand Lower Side | -29.62 | 36.29 | 25.09 | -25.09 | 45.09 | - |
| P(A/B/C/D)06 | Casing Upper Side | -29.62 | 36.29 | 25.09 | -25.09 | 43.78 | - |
| P(A/B/C/D)05 | Lower Support Point | -29.62 | 36.29 | 25.09 | -25.09 | 42.61 | - |
| P(A/B/C/D)04 | Pump Mass Point | -29.62 | 36.29 | 25.09 | -25.09 | 42.26 | 149.47 |
| P(A/B/C/D)03 | Cold Leg Point of Intersection | -29.62 | 36.29 | 25.09 | -25.09 | 40.39 | - |
| P(A/B/C/D)02 | Transition Point | -29.62 | 36.29 | 25.09 | -25.09 | 36.38 | - |
| P(A/B/C/D)01 | Cross Over Leg Intersection Point | -29.62 | 36.29 | 25.09 | -25.09 | 35.29 | - |

**Table 5.3.1-14 Lumped Mass of MCP Model (Sheet 1 of 3)**

Concentrated Mass of MPC Hot Leg Model

| Symbols | Description | Location | | | | | Mass Inertia | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | X (ft) | | Y (ft) | | Z (ft) | Weight (kip) | Jxx (kip-ft$^2$) | Jyy (kip-ft$^2$) | Jzz (kip-ft$^2$) |
| | | A&D Loop | B&C Loop | A&B Loop | C&D Loop | | | | | |
| M(A/B/C/D)01 | RV Outlet Nozzle | -1.81 | 8.48 | 12.43 | -12.43 | 113.76 | - | - | - | - |
| M(A/B/C/D)11 | Hot Leg Piping | -4.21 | 10.88 | 18.21 | -18.21 | 40.39 | 17.66 | 215.9 | 64.57 | 247.2 |
| M(A/B/C/D)02 | | -5.82 | 12.49 | 22.1 | -22.1 | 108.06 | - | - | - | - |
| M(A/B/C/D)03 | | -5.87 | 12.54 | 22.22 | -22.22 | 96.58 | - | - | - | - |
| M(A/B/C/D)41 | | -7.62 | 14.29 | 26.45 | -26.45 | 40.82 | 9.273 | 28.89 | 21.95 | 28.38 |
| M(A/B/C/D)04 | SG Inlet Nozzle | -8.4 | 15.06 | 28.32 | -28.32 | 90.84 | - | - | - | - |

**Table 5.3.1-14 Lumped Mass of MCP Model (Sheet 2 of 3)**

Concentrated Mass of MPC Crossover Leg Model

| Symbols | Description | Location | | | | | Mass Inertia | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | X (ft) | | Y (ft) | | Z (ft) | Weight (kip) | Jxx (kip-ft$^2$) | Jyy (kip-ft$^2$) | Jzz (kip-ft$^2$) |
| | | A&D Loop | B&C Loop | A&B Loop | C&D Loop | | | | | |
| M(A/B/C/D)05 | SG Outlet Nozzle | -16.4 | 23.07 | 33.13 | -33.13 | 86.87 | - | - | - | - |
| M(A/B/C/D) 06 | Crossover Leg Piping | -23.63 | 30.3 | 29.14 | -29.14 | 80.74 | - | - | - | - |
| M(A/B/C/D) 71 | | -17.67 | 24.33 | 33.01 | -33.01 | 40.65 | 7.973 | 20.64 | 21.06 | 16.19 |
| M(A/B/C/D) 72 | | -17.93 | 24.60 | 32.98 | -32.98 | 36.82 | 4.405 | 7.548 | 7.548 | 8.208 |
| M(A/B/C/D)73 | | -19.03 | 25.69 | 32.25 | -32.25 | 31.36 | 15.22 | 77.22 | 90.54 | 66.05 |
| M(A/B/C/D)74 | | -23.78 | 30.45 | 29.04 | -29.04 | 30.04 | 5.183 | 9.900 | 10.193 | 10.437 |
| M(A/B/C/D)75 | | -28.53 | 35.20 | 25.83 | -25.83 | 31.36 | 15.22 | 77.22 | 90.54 | 66.05 |
| M(A/B/C/D) 07 | RCP Inlet Nozzle | -29.62 | 36.29 | 25.09 | -25.09 | 79.38 | - | - | - | - |

**Table 5.3.1-14 Lumped Mass of MCP Model (Sheet 3 of 3)**

Concentrated Mass of MPC Cold Leg Model

| Symbols | Description | Location | | | | | Mass Inertia | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | X (ft) | | Y (ft) | | Z (ft) | Weight (kip) | Jxx (kip-ft$^2$) | Jyy (kip-ft$^2$) | Jzz (kip-ft$^2$) |
| | | A&D Loop | B&C Loop | A&B Loop | C&D Loop | | | | | |
| M(A/B/C/D) 81 | Cold Leg Piping | -18.74 | 25.41 | 14.03 | -14.03 | 40.39 | 28.44 | 510.9 | 495.8 | 954.0 |
| M(A/B/C/D) 82 | | -10.58 | 17.25 | 5.86 | -5.86 | 40.39 | 5.505 | 10.49 | 10.26 | 9.97 |
| M(A/B/C/D) 09 | | -23.4 | 30.06 | 18.76 | -18.76 | 64.72 | - | - | - | - |
| M(A/B/C/D) 10 | | -21.1 | 27.77 | 16.43 | -16.43 | 54.71 | - | - | - | - |
| M(A/B/C/D) 11 | | -20.5 | 27.17 | 15.82 | -15.82 | 49.5 | - | - | - | - |
| M(A/B/C/D) 12 | RV Inlet Nozzle | -9.09 | 15.76 | 5.15 | -5.15 | 45.64 | - | - | - | - |

**Table 5.3.1-15 Material Properties of RV Stick Model**

| Element Node | | Material (ASME) | Temperature (°F) | Young's Modulus (ksi) | Poisson's Ratio |
|---|---|---|---|---|---|
| Start | End | | | | |
| RV09 | RV08 | SA508, Gr.3, Cl.1 | 583.9 | 25,280 | 0.3 |
| RV08 | RV07 | | | | |
| RV07 | RV06 | | | | |
| RV06 | RV05 | | | | |
| RV05 | RV04 | | | | |
| RV04 | RV03 | | | | |
| RV03 | RV02 | | | | |
| RV02 | RV01 | | | | |

**Table 5.3.1-16 Element Properties of RV Stick Model**

| Element Nodes | | Axial Area ($ft^2$) | Shear Area ($ft^2$) | Moment of Inertia ($ft^4$) | |
|---|---|---|---|---|---|
| Start | End | | | Torsion | Bending |
| RV09 | RV08 | 41.26 | 21.86 | 2303 | 1152 |
| RV08 | RV07 | 69.19 | 36.66 | 5719 | 2859 |
| RV07 | RV06 | | | | |
| RV06 | RV05 | | | | |
| RV05 | RV04 | 48.61 | 25.76 | 3858 | 1929 |
| RV04 | RV03 | | | | |
| RV03 | RV02 | | | | |
| RV02 | RV01 | 25.90 | 13.72 | 1357 | 678.6 |
| Start | End | Vertical Stiffness (kip/ft) | | | |
| RV07 | RV11 | 122,073 | | | |
| RV07 | RV12 | 651,829 | | | |

**Table 5.3.1-17 Element Properties of SG Stick Model**

| Element Nodes | | Pipe Cross Section | |
|---|---|---|---|
| **Start** | **End** | **Outer Diameter (ft)** | **Thickness (ft)** |
| S(A/B/C/D)11 | S(A/B/C/D)12 | 16.62 | 0.36 |
| S(A/B/C/D)10 | S(A/B/C/D)11 | | |
| S(A/B/C/D)09 | S(A/B/C/D)10 | | |
| S(A/B/C/D)08 | S(A/B/C/D)09 | | |
| S(A/B/C/D)07 | S(A/B/C/D)08 | 14.89 | 0.37 |
| S(A/B/C/D)06 | S(A/B/C/D)07 | 12.74 | 0.37 |
| S(A/B/C/D)05 | S(A/B/C/D)06 | 12.20 | 0.29 |
| S(A/B/C/D)04 | S(A/B/C/D)05 | | |
| S(A/B/C/D)03 | S(A/B/C/D)04 | | |
| S(A/B/C/D)02 | S(A/B/C/D)03 | | |
| S(A/B/C/D)01 | S(A/B/C/D)02 | Rigid | |

**Table 5.3.1-18 Material Properties of RCP Stick Model**

| Element Node | | Material (ASME) | Temperature (°F) | Young's Modulus (ksi) | Poisson's Ratio |
|---|---|---|---|---|---|
| Start | End | | | | |
| PX13 | PX14 | SA283 | 120.0 | 29,230 | 0.3 |
| PX12 | PX13 | | | | |
| PX11 | PX12 | | | | |
| PX10 | PX11 | | | | |
| PX09 | PX10 | | | | |
| PX08 | PX09 | | | | |
| PX07 | PX08 | | | | |
| PX06 | PX07 | SA540 Gr.B24 Cl.4 | (335.4*) | 26,490 | |
| PX05 | PX06 | SA351 CF8 | 550.6 | 25,550 | |
| PX04 | PX05 | Infinity | | | |
| PX03 | PX04 | | | | |
| PX02 | PX03 | | | | |
| PX01 | PX02 | SA351 CF8 | 550.6 | 25,550 | 0.3 |

**Table 5.3.1-19 Element Properties of RCP Stick Model**

| Element Nodes | | Pipe Section | | Beam Area | | Beam Moment of Inertia | | |
|---|---|---|---|---|---|---|---|---|
| **Start** | **End** | **Outer Diam. (ft)** | **Thick. (ft)** | **Axial ($ft^2$)** | **Shear ($ft^2$)** | **Izz ($ft^4$) Torsion** | **Iyy ($ft^4$) NS** | **Ixx ($ft^4$) EW** |
| P(A/B/C/D)13 | P(A/B/C/D) 14 | - | - | 0.66 | 0.36 | 5.20 | 2.60 | 2.60 |
| P(A/B/C/D)12 | P(A/B/C/D)13 | 6.56 | 0.08 | - | - | - | - | - |
| P(A/B/C/D)11 | P(A/B/C/D)12 | - | - | 2.52 | 2.52 | 39.32 | 19.66 | 19.66 |
| P(A/B/C/D)10 | P(A/B/C/D)11 | - | - | 3.01 | 2.00 | 21.97 | 10.99 | 10.99 |
| P(A/B/C/D)09 | P(A/B/C/D)10 | 7.04 | 0.13 | - | - | - | - | - |
| P(A/B/C/D)08 | P(A/B/C/D)09 | - | - | 1.95 | 1.66 | 23.87 | 16.28 | 7.60 |
| P(A/B/C/D)07 | P(A/B/C/D)08 | 7.04 | 0.13 | - | - | - | - | - |
| P(A/B/C/D)06 | P(A/B/C/D)07 | - | - | 2.44 | 2.16 | 19.93 | 9.96 | 9.96 |
| P(A/B/C/D)05 | P(A/B/C/D)06 | 6.70 | 1.05 | - | - | - | - | - |
| P(A/B/C/D)04 | P(A/B/C/D)05 | Rigid | | | | | | |
| P(A/B/C/D)03 | P(A/B/C/D)04 | | | | | | | |
| P(A/B/C/D)02 | P(A/B/C/D)03 | | | | | | | |
| P(A/B/C/D)01 | P(A/B/C/D)02 | 3.09 | 0.26 | - | - | - | - | - |

## Table 5.3.1-20 Specification of MCP Model

| | Unit | Hot Leg (Straight) (31 ID) | Hot Leg (50°Elbow) (31 ID) | Crossover Leg (Straight) (31 ID) | Crossover Leg (40°,90°Elbow) (31 ID) | Cold Leg (Straight) (31 ID) | Cold Leg (22°59'Elbow) (31 ID) |
|---|---|---|---|---|---|---|---|
| **Outer Diameter** | **in** | 37.126 | 39.110 | 37.126 | 39.110 | 37.126 | 39.110 |
| **Thickness** | **in** | 3.063 | 4.055 | 3.063 | 4.055 | 3.063 | 4.055 |
| **Material (ASME)** | **–** | SA182 F316 or SA366 F316LN | SA182 F316 or SA366 F316LN | SA182 F316 or SA366 F316LN | SA182 F316 or SA366 F316LN | SA182 F316 or SA366 F316LN | SA182 F316 or SA366 F316LN |
| **Young's Modulus** | **ksi** | 25,220 | 25,220 | 25,550 | 25,550 | 25,550 | 25,550 |
| **Poisson's Ratio** | **–** | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| **Temperature** | **°F** | 617.0 | 617.0 | 550.6 | 550.6 | 550.6 | 550.6 |
| **Pressure** | **ksi** | 2.2350 | 2.2350 | 2.2350 | 2.2350 | 2.2350 | 2.2350 |
| **Maximum Temperature** | **°F** | 649.4 | 649.4 | 649.4 | 649.4 | 649.4 | 649.4 |
| **Maximum Pressure** | **ksi** | 2.4888 | 2.4888 | 2.4888 | 2.4888 | 2.4888 | 2.4888 |

**Table 5.3.1-21 Support Stiffness of RV, SG and RCP**

| | Support Name | Location | | | | | Support | Stiffness x $10^3$ (kip/ft) |
|---|---|---|---|---|---|---|---|---|
| | | x (ft) | | y (ft) | | z (ft) | | |
| | | A&D Loop | B&C Loop | A&B Loop | C&D Loop | | | |
| RV | Inlet Nozzle Support | -6.93 | 13.60 | 4.25 | -4.25 | 40.39 | Krh | 1,002 |
| | | | | | | | Krv | 1,086 |
| | Outlet Nozzle Support | -0.92 | 7.59 | 10.27 | -10.27 | | Krh | 1,002 |
| | | | | | | | Krv | 1,086 |
| SG | Upper Shell Support | -10.62 | 17.29 | 33.69 | -33.69 | 96.58 | Kux | 76.93 |
| | | | | | | | Kuy | 78.07 |
| | Intermediate Shell Support | | | | | 75.42 | Kmx | 83.39 |
| | | | | | | | Kmy | 80.46 |
| | Lower Support | -13.80 | 20.47 | 28.40 | - | 45.64 | Kℓ5y (1) | 33.43 |
| | | -15.91 | 22.55 | 36.87 | - | | Kℓ6y (1) | 69.38 |
| | | -7.44 | 14.11 | 30.98 | -30.98 | | Kℓ7y (2) | 484.0 |
| | | -5.33 | 12.00 | 30.51 | -30.51 | | Kℓ8y (2) | 675.9 |
| | | - | 22.58 | - | -36.87 | | Kℓ6x (3) | 555.6 |
| | | - | 14.11 | - | -38.98 | | Kℓ7x (3) | 745.8 |
| RCP | Lower Support | -33.13 | 39.80 | 28.66 | -28.66 | 42.61 | Kpt | 221.8 |

**Table 5.3.1-22 Node Connectivity between RCL and CIS**

| No. | Item | CIS Location | | RCL Node | | RCL Location | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | EL. (ft) | x (ft) | | y (ft) | |
| | | El. (ft) | Node | | | | A & D | B & C | A & B | C & D |
| 1 | Base Floor of SG,RCP Columns | 25.25 | IC02 | PartD | S(A/B/C/D)C1 | 25.68 | -13.80 | 20.47 | 28.40 | -28.40 |
| | | | | | S(A/B/C/D)C2 | | -15.91 | 22.58 | 36.87 | -36.87 |
| | | | | | S(A/B/C/D)C3 | | -7.44 | 14.11 | 38.98 | -38.98 |
| | | | | | S(A/B/C/D)C4 | | -5.32 | 12.00 | 30.51 | -30.51 |
| | | | | PartE | P(A/B/C/D)S1 | 25.68 | -33.13 | 39.80 | 28.66 | -28.66 |
| | | | | | P(A/B/C/D)S2 | | -24.50 | 31.17 | 24.94 | -24.94 |
| | | | | | P(A/B/C/D)S3 | | -29.67 | 36.33 | 20.09 | -20.09 |
| | *) Rigid connection between IC02 and base plates of SG or RCP Columns. | | | | | | | | | |
| 2 | RV Support | 35.88 | IC03 | PartF | RV(A/B/C/D)S1 | 40.39 | -5.68 | 12.35 | 7.28 | -7.28 |
| | | | | | RV(A/B/C/D)S2 | 37.11 | -6.93 | 13.60 | 4.25 | -4.25 |
| | | | | | RV(A/B/C/D)S3 | 40.39 | 2.11 | 11.52 | 11.52 | -11.52 |
| | | | | | RV(A/B/C/D)S4 | 37.11 | -0.92 | 10.26 | 10.27 | -10.27 |
| | *note) Rigid connection between IC03 and RV. | | | | | | | | | |
| 3 | SG(RCP) Lower Support | 45.67 | IC14 | PartC | S(A/C)L1 | 45.64 | -16.83 | 23.49 | 27.14 | -27.14 |
| | | | | | S(A/C)L2 | | -18.95 | 25.61 | 35.61 | -35.61 |
| | | | | PartG | P(A/B/C/D)S4 | 42.61 | -35.10 | 41.77 | 26.04 | -26.04 |
| | *) Rigid connection between IC14 and SG or RCP Lower Supports. | | | | | | | | | |
| 4 | SG Intermediate Support | 76.42 | IC05 | PartB | S(A/B/C/D)M1 | 75.42 | -11.88 | 18.54 | 36.72 | -36.72 |
| | | | | | S(A/B/C/D)M2 | | -13.65 | 20.32 | 32.43 | -32.43 |
| | *) Rigid connection between IC05 and SG Intermediate Supports. | | | | | | | | | |
| 5 | SG Upper Support | 97.00 | IC61 & IC62 | PartA | S(A/B/C/D)T1 | 96.58 | -11.88 | 18.54 | 36.72 | -36.72 |
| | | | | | S(A/B/C/D)T2 | | -13.65 | 20.31 | 32.43 | -32.43 |
| | *) Rigid connection between IC61 and IC62 and SG Upper Supports. | | | | | | | | | |
| | * SGs of Loop A and B connected to IC62, and SGs of Loop C and D connected to IC61 | | | | | | | | | |

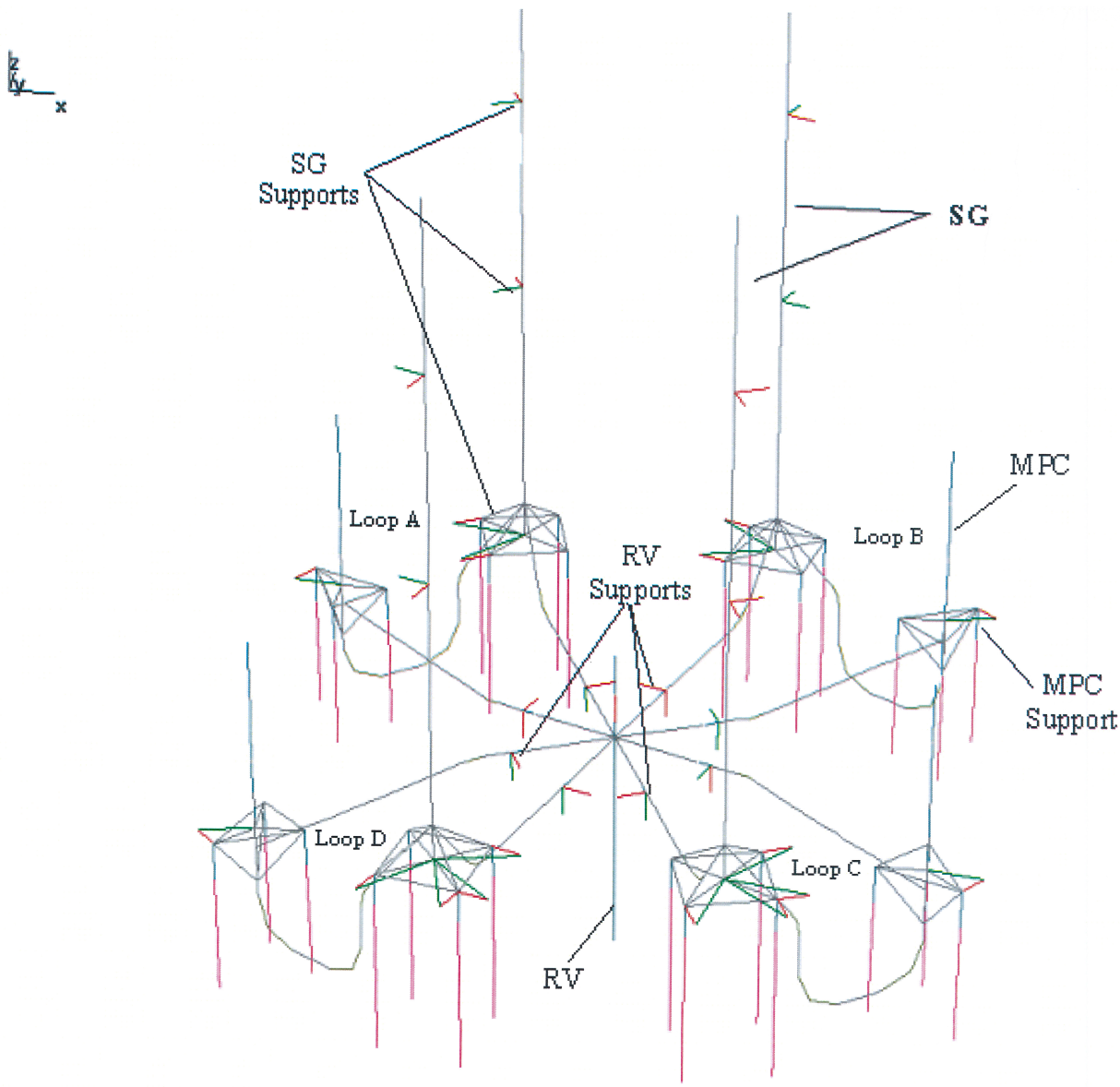
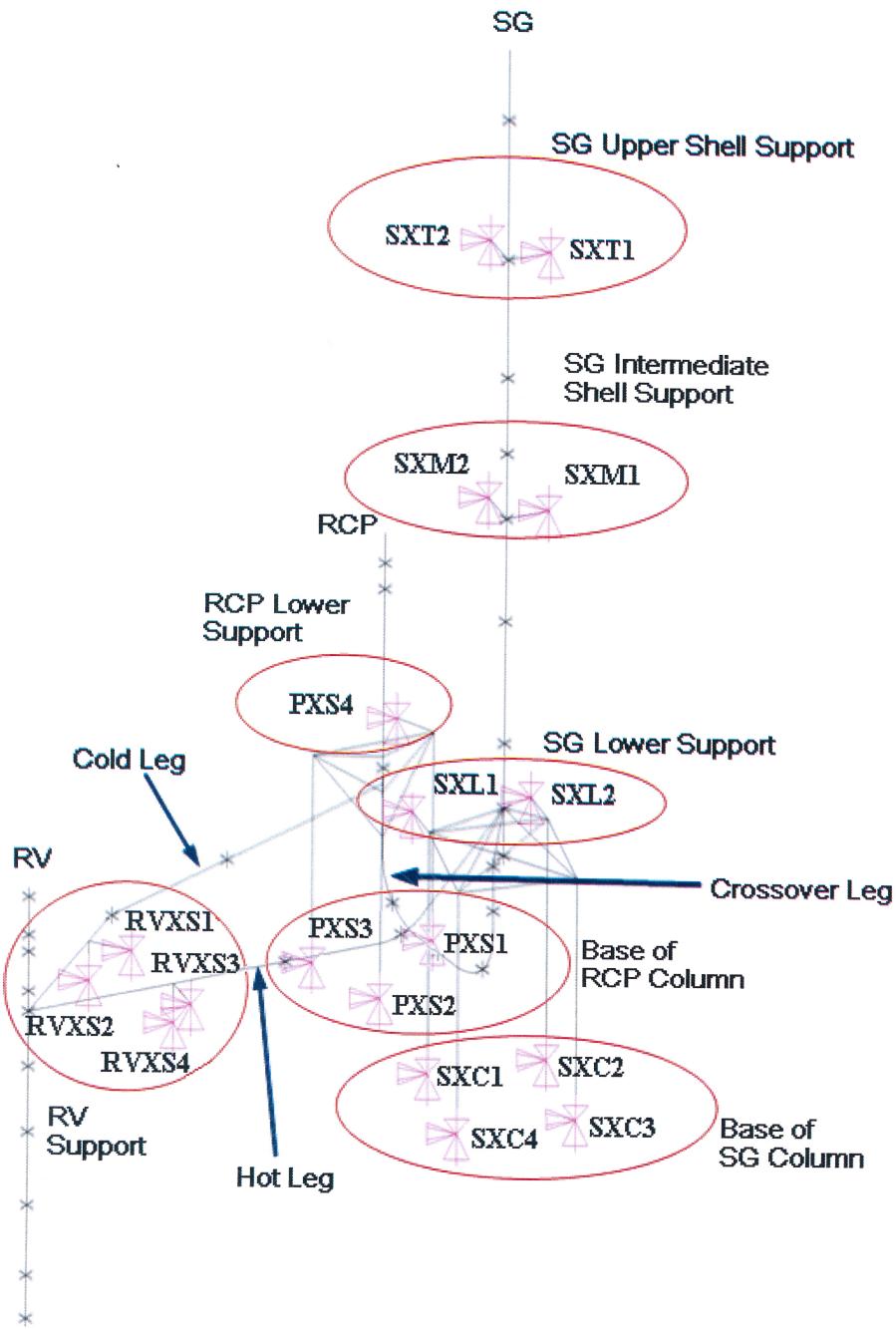



**Figure 5.3.1-3 Stick Mass Spring Model for Reactor Coolant Loop**




Note:

Connectivity of each support groups to building nodes are presented in Table 5.3.1-22.

**Figure 5.3.1-4 Connectivity between RCL and Buildings**

### 5.3.2 Reactor Building Basemat Model

The ANSYS program (Reference 12) is used to develop the 3-D FE model of the R/B building basement. The model is developed with reference to the Cartesian coordinate system with origin located at the center of the PCCV foundation, at a point 2'-7" below the ground elevation and Z-axis oriented upward. The overall footprint of the PCCV, CIS and R/B common foundation is 309 feet in the NS direction and 210 feet in the EW direction, resulting in an area of 64,890 square feet. The SASSI model of the basement is simplified by neglecting the pits in the basemat.

The positive X and Y axes of the Cartesian coordinate system are oriented northward and westward, respectively. Table 5.3.2-1 present the model main vertical coordinates, and Tables 5.3.2-3 and 5.3.2-4 present the model main horizontal coordinates. The radii coordinates of the PCCV foundation are presented in Table 5.3.2-5. The coordinates of the external basement walls are set at the outer wall surface in order to accurately model the overall dimensions of the basement. The coordinates of interior basement walls are set at the wall centerline. The ANSYS input files also use a cylindrical coordinate system to create the central portion of the Basemat foundation under the PCCV. Table 5.3.2-4 lists the major radial coordinates used in the development of the R/B basement. Table 5.3.2-5 presents the groups of finite elements used to model different structural members of the basement.

The resulting model of the basement is shown in Figure 5.3.2-1 through Figure 5.3.2-5. These figures are generally arranged in order of ascending elevation. The model is comprised of solid brick type elements, plate elements, and rigid beam elements.

The material properties of the components of the model are based on the concrete properties given in Table 5.3.2-1 below.

**Table 5.3.2-1 Input Material Properties**

| Structural Component | Concrete Compressive Strength (psi) | Young's Modulus ($x10^5$ ksf) | Poisson's Ratio | Damping | |
|---|---|---|---|---|---|
| | | | | OBE | SSE |
| PCCV | 7,000 | 6.86 | 0.17 | 3% | 5% |
| R/B, FH/A and Basement | 4,000 | 5.191 | 0.17 | 4% | 7% |
| CIS | 4,000 | 5.191 | 0.17 | 4% | 5% |

SASSI 3-D shell elements are used to model the basement shear walls, and the R/B slabs at ground floor elevation. The elastic modulus material property assigned to the shell elements of the shear walls is adjusted to accurately model the wall's shear stiffness, and account for the reduction of wall stiffness at the openings as described in Section 4.5.2. Table 5.3.2-7 presents the properties of the Shell elements modeling the walls with openings.

At the basemat solid elements located at the tendon gallery floors, Young's modulus and the density are reduced to account for the reduced thickness of the concrete at these locations. The 3-D beam elements are used to connect the shell elements at the top of the shear walls of the 3-D SASSI FE model of the R/B basement to the lumped-mass stick model representing the above ground portion of the R/B and FH/A.

The basemat solid elements are shown in Figure 5.3.2-1.

The material properties assigned to the FE are adjusted to accurately model the actual bending stiffness and mass inertia of the basemat. Figure 5.3.2-2 shows the part of the FE model that represents the upper part of the thick portion of the Basemat under the PCCV. Flexible shell elements are used to account for additional bending stiffness of the thick central part of the basemat. The thickness and material properties assigned to these elements are presented in this figure.

Figure 5.3.2-3 shows the FE model components located below the PCCV and CIS. The rigid shell and beam elements connect the basemat with the rest of the model at ground elevation. Figure 5.3.2-5 shows the FE model shell elements of the floor slabs and the basemat at ground elevation. The thicknesses of the shells and the input material properties are also presented in the figure.

Figure 5.3.2-4 presents the shell elements used to model the shear walls of the R/B and FH/A basement. The material properties assigned to the shell FE are adjusted to model accurately the shear stiffness and mass inertia of the walls. The plate and beam elements shown in Figure 5.3.2-3 fit inside the center area of the shear wall element to complete the portion of the basement model that is located below the floor slabs at the ground elevation.

Figure 5.3.2-5 shows the FE model shell elements of the floor slabs and the basemat at ground elevation. The thicknesses of the shells and the input material properties are also presented in the figure.

**Table 5.3.2-2 Basement Model Z-Coordinates (Down to Up)**

| Z (ft) | Elevation (ft) | Description |
|---|---|---|
| -37.420 | 782.00 | Basemat Bottom |
| -24.083 | 795.34 | Bottom of Basemat under Reactor |
| 2.583 | 822.00 | Ground Elevation |

**Table 5.3.2-3 Basement Model X-Coordinates (South to North)**

| X (ft) | Column Line | Description |
|---|---|---|
| -161.67 | LR | South Exterior Wall |
| -139.33 | K1R | R/B South Basement Wall |
| -127.00 | KR | R/B South Basement Wall |
| -106.00 | J1R | E-W Interior Wall R/B South Basement |
| -94.00 | JR | Reactor Basemat South End |
| -73.92 | H0.5R | R/B South Basement Wall |
| -39.08 | GR - G2R | Reactor Basement South Edge |
| 0.00 | FR | Reactor E-W Centerline |
| 39.08 | D1R - ER | Reactor Basement North Edge |
| 76.42 | C0.5R | R/B North Interior Wall |
| 94.00 | CR | North Interior Wall |
| 106.8 | BR | Reactor Basemat North End |
| 117.9 | A1R | Basement Exterior Wall under FH/A Surface Mat |
| 115.83 | A2R | R/B North Interior Wall |
| 147.25 | AR | Basement North Exterior Wall |

**Table 5.3.2-4 Basement Model Y-Coordinates (East to West)**

| Y (ft) | Column Line | Description |
|---|---|---|
| -116.42 | 12R | Basement East External Wall (Short) |
| -106.67 | 11R | Basement East External Wall |
| -92.167 | 10R | Reactor Basemat East End |
| -85.667 | 9bR | R/B Basement N-S Interior Wall |
| -70.00 | 9R | R/B Basement N-S Interior Wall |
| -66.25 | 8bR | R/B Basement N-S Interior Wall |
| -48.75 | 8aR & 8R | Reactor Basement East Edge |
| -43.917 | 8R | N-S External Wall under F/HB Surface Mat |
| -38.833 | 7R | R/B Basement N-S Interior Wall |
| -8.5 | 6aR | R/B Basement N-S Interior Wall |
| -21.70 | 6bR | R/B Basement N-S Interior Wall |
| -31.70 | 7a1R | R/B Basement N-S Interior Wall |
| 0.00 | 6R | Reactor N-S Centerline |
| 17.833 | 5aR | Tendon Gallery Access Exterior Wall |
| 39.333 | 4bR | Tendon Gallery Access West Wall |
| 38.83 | 5R | R/B Basement N-S Interior Wall |
| 59.58 | 4aR | Reactor Basement West Edge |
| 61.50 | 4R | F/HB N-S Interior Wall |
| 70.000 | 3R | R/B Basement N-S Interior Wall |
| 86.583 | 2aR | FH/A and R/B N-S Interior Wall |
| 92.167 | 2R | Reactor Basemat West End |
| 106.67 | 1R | Basement West External Wall |

**Table 5.3.2-5 Basement Model Radial Coordinates**

| R (ft) | Description |
|---|---|
| 0.00 | Reactor Center |
| 46.00 | Reactor Pit Radius |
| 71.83 | Tendon Gallery Inner Radius |
| 80.42 | Tendon Gallery Outer Radius |
| 93.50 | Reactor Foundation Radius |

**Table 5.3.2-6 Finite Element Properties of R/B Basement Model**

| Structural Member | Element Type | Mass | Stiffness |
|---|---|---|---|
| Upper Portion of Reactor Mat | Shell | Weightless | Concrete fc=4000psi |
| FH/A Surface Basemat | Shell | Weightless | Concrete fc=4000psi |
| NS Exterior Walls | Shell | Concrete | Concrete fc=4000psi (adjusted) |
| EW Exterior Walls | Shell | Concrete | Concrete fc=4000psi (adjusted) |
| NS Basement Inner Shear Walls | Shell | Weightless | Concrete fc=4000psi (adjusted) |
| EW Basement Inner Shear Walls | Shell | Weightless | Concrete fc=4000psi (adjusted) |
| Connecting Shells | Shell | Weightless | Rigid |
| Ground Floor Slabs | Shell | Weightless | Concrete fc=4000psi |
| Basemat | Solid | Concrete | Concrete fc=4000psi (adjusted) |
| Fill Concrete | Solid | Concrete | Concrete fc=3000psi |
| Rigid Rim at top of Reactor Mat | Beam | Weightless | Rigid |
| PCCV stick Rigid Connection | Beam | Weightless | Rigid |
| CIS stick Rigid Connection | Beam | Weightless | Rigid |
| R/B-FH/A stick Rigid Connection | Beam | Weightless | Rigid |
| BS01 Lumped Mass Rigid Connection | Beam | Weightless | Rigid |

**Table 5.3.2-7 Adjusted Material Properties of Basement Shear Walls with Openings (Sheet 1 of 3)**

| Wall Location | Wall Dimensions (ft) | | | Openings Dimensions (ft) | | Stiffness Ratios | | Adjusted |
|---|---|---|---|---|---|---|---|---|
| | Thick. | Width | Height | Width | Height | Outplane | Inplane | E ($x10^5$ ksf) |
| CL-11R segment A1R-CR (-26'-4") | 3.33 | 21.833 | 15.92 | 9.0 | 8.33 | .593 | .468 | 2.428 |
| CL-1R segment CR-JR<br>CL-11R segment CR-JR | 3.33 | 188.00 | 15.92 | 8.0 | 8.33 | .958 | .879 | 4.562 |
| CL-1R segment JR-KR<br>CL-11R segment JR-KR | 3.33 | 33.0 | 27.25 | 9.0 | 9.0 | .758 | .676 | 3.508 |
| CL-2R segment H1R-GR (-26'-4")<br>CL-10R segment H1R-GR (-26'-4") | 2.67 | 40 | 15.52 | 3,6.6 | 6.83,10 | .764 | .677 | 3.514 |
| CL-2R segment C1R-ER (-26'-4")<br>CL-10R segment C1R-ER (-26'-4") | 2.67 | 40 | 15.52 | 3,6.6 | 6.83,10 | .764 | .677 | 3.514 |
| CL-2R segment H1R-JR (-26'-4")<br>CL-10R segment H1R-JR (-26'-4") | 3.33 | 19 | 16.5 | 9 | 16 | .520 | .106 | 0.550 |
| CL-2R segment C1R-CR (-26'-4")<br>CL-10R segment C1R-CR (-26'-4") | 3.33 | 19 | 16.5 | 9 | 16 | .520 | .106 | 0.550 |
| CL-2R segment C1R-ER (-8'-7")<br>CL-10R segment C1R-ER (-8'-7") | 3.33 | 40 | 8.83 | 3.0 | 6.83 | .925 | .888 | 4.609 |

**Table 5.3.2-7 Adjusted Material Properties of Basement Shear Walls with Openings (Sheet 2 of 3)**

| Wall Location | Wall Dimensions (ft) | | | Openings Dimensions (ft) | | Stiffness Ratios | | Adjusted |
|---|---|---|---|---|---|---|---|---|
| | Thick. | Width | Height | Width | Height | Outplane | Inplane | E ($x10^5$ ksf) |
| CL-2R segment GR-H1R (-8'-7")<br>CL-10R segment GR-H1R (-8'-7") | 3.33 | 40 | 8.83 | 3.0 | 6.83 | .925 | .888 | 4.609 |
| CL-CR segments 1R-2R & 10R-11R (-26'-4") | 3.33 | 12.83 | 15.92 | 6.67 | 8.5 | .488 | .393 | 2.040 |
| CL-CR segments 1R-2R & 10R-11R (-8'-7") | 3.33 | 12.83 | 8.83 | 3 | 6.83 | .763 | .545 | 2.829 |
| CL-J1R segments 2aR-3R & 9bR-9R | 2.67 | 16.58 | 25.92 | 3 | 6.83 | .866 | .798 | 4.142 |
| CL-J1R segments 3R-5R & 7R-9R | 1.67 | 31.17 | 25.92 | 6.67 | 8.5 | .816 | .741 | 3.846 |
| CL-J1R segments 5R-6R & 6R-7R | 1.67 | 38.83 | 25.92 | 6.67 | 8.5 | .853 | .794 | 4.121 |
| CL-K1R segments 1R-2aR & 11R-9bR | 2.00 | 35 | 25.92 | 3 | 6.83 | .939 | .898 | 4.66 |
| CL-BR segment YCMwest-YTGeast (-26'-4") | 4.0 | 64.9 | 15.92 | 7,7 | 8.5,8.5 | .789 | .772 | 4.007 |
| CL-BR segment 4R-YTGwest (-8'-7") | 4.0 | 77.1 | 8.83 | 3,3 | 6.83,6.83 | .922 | .874 | 4.536 |
| CL-A1R segment 2aR-4R (-8'-7" & above, no foundation @ EL -26'-4") | 3.17 | 21.1 | 9.5 | 3.0 | 6.83 | .857 | .761 | 3.950 |
| CL-A1R segment 8aR-11R (-26'-4") | 2.67 | 40.58 | 17.75 | 6.0 | 8.5 | .858 | .827 | 4.292 |

**Table 5.3.2-7 Adjusted Material Properties of Basement Shear Walls with Openings (Sheet 3 of 3)**

| Wall Location | Wall Dimensions (ft) | | | Openings Dimensions (ft) | | Stiffness Ratios | | Adjusted |
|---|---|---|---|---|---|---|---|---|
| | Thick. | Width | Height | Width | Height | Outplane | Inplane | E ($x10^5$ ksf) |
| CL-4R segment AR-CR (-26'-4") | 4.0 | 54.99 | 15.92 | 3,7 | 6.83,8.5 | .823 | .733 | 3.804 |
| CL-4R segment AR-CR (-8'-7") | 4.0 | 54.99 | 9.5 | 5 | 6.83 | .908 | .870 | 4.515 |
| CL-YCMwest segment AR-CR (-26'-4") | 4.0 | 54.99 | 14.58 | 7 | 8.5 | .874 | .850 | 4.412 |
| CL- YCMwest segment AR-CR (-8'-7") | 4.0 | 45.17 | 8.83 | 3.33 | 8.83 | .924 | .787 | 4.085 |
| CL-YTGwest segment AR-CR (-8'-7") | 5.92 | 54.99 | 8.83 | 9.83 | 6.83 | .822 | .787 | 4.085 |
| CL-8R segment AR-CR (-26'-4") | 4.0 | 53.25 | 15.92 | 3,5 | 6.83,8.5 | .854 | .776 | 4.027 |
| CL-8R segment AR-CR (-8'-7") | 4.0 | 55 | 8.83 | 5 | 8.83 | .907 | .769 | 3.991 |
| CL-9bR segment AR-A1R (-26'-4") | 2.67 | 33.18 | 26.58 | 6.0 | 8.5 | .848 | .774 | 4.017 |