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VERIFICATION OF ENERGY EQUIVALENCE OF DOMESTIC WATER DISTRIBUTION SYSTEM COMPARING EMBEDDED PRE-SLEEVED AQUAPEX TO INSULATED, OVERHEAD COPPER

CSI Section:
22 11 16 Domestic Water Piping

1.0 RECOGNITION

The total energy usage (heat and pressure losses) of two types of domestic water distribution systems were compared employing TRNSYS software. Using the TRNSYS software, the pre-sleeved AquaPEX embedded in a concrete slab was modeled as a Detailed Radiant Floor (Type 993) and the insulated Copper system installed overhead was modeled as Bi-Directional Nodded Pipe (Type 604). The Copper systems are insulated as required by the 2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings produced by the California Energy Commission (BEES) and its total energy consumption is compared to the pre-sleeved AquaPEX embedded in a concrete slab to document energy equivalence as allowed in Section 10-109 of the BEES.

The equivalence analysis is based on Section 10-109 of the 2016 BEES.

It was shown that under optimized conditions AquaPEX installed embedded in a concrete slab had a lower energy usage than overhead insulated copper tubing.

2.0 LIMITATIONS

Use of the pre-sleeved AquaPEX embedded in a concrete slab recognized in this report is subject to the following limitations:

2.1 The AquaPEX shall be installed in accordance with the applicable code, the manufacturer's published installation instructions, IAPMO UES evaluation report ER-253, and this report. Where there is a conflict, the most restrictive requirements shall govern.

2.2 UPONOR's AquaPEX tubing is recognized for code compliance in ER-253 and R&T File 3558.

2.3 Field verification shall be made to determine the ratio of the proposed AquaPEX installation versus the proposed copper tubing installation for each installation.

2.4 The AquaPEX shall be installed in a slab located within a conditioned space.

2.5 UPONOR's AquaPEX shall be manufactured in locations noted in ER-253.

3.0 PARAMETERS

The engineering study evaluated the associated energy losses of the UPONOR pre-sleeved AquaPEX® and provided parameters noted in Sections 3.1 through 3.6 that achieved energy losses less than the overhead insulated copper configuration.

3.1 UPONOR AquaPEX/Cu Length Ratio – UPONOR AquaPEX embedded in the slab is run directly to the fixtures and it is assumed the copper tubing total lengths will be longer since it is typically run along the structure.

3.2 Pipe / Tubing Diameter - Increasing pipe diameter results in increasing heat losses for both UPONOR PEX and overhead insulated copper configurations. Heat losses for UPONOR pre-sleeved AquaPEX are higher than insulated copper. Above 1 inch. (25.4 mm) of diameter, the difference between the UPONOR pre-sleeved AquaPEX heat losses and insulated copper losses increases due to the insulation recommendations from BEES. Pressure losses per foot are the same for UPONOR PEX and insulated copper.

3.3 Water Temperature - Heat losses increase with the change in water temperature in both cases with the same percentage of increase. An increase of 20°F (-7 °C) results in an increase of 43%-44% of heat losses due to the temperature difference between space and surface temperature. Therefore, there is little difference due to water temperature configuration when using UPONOR PEX instead of copper. Using lower water temperature will reduce heat losses for both cases. Each simulation case conducted modeled the water temperature at 120 °F (49 °C).

3.4 Slab Thickness and Conductivity - The slab thermal resistance represents only 20% of the overall thermal resistance, while the air gap is approximately 75%. Therefore, variations of the slab properties must be high to significantly influence heat losses. Consequently, doubling the slab thickness is only reducing heat losses by 2%. For each simulation case the slab thickness was modeled as 7-$^{7}/_{8}$ inches (200 mm). Slab conductivity has a greater impact, with the minimum conductivity of 0.0578 BTU/(hr•ft •°F) (0.328 W/(m^2 • K)) instead of 0.298 BTU/(hr•ft •°F) (1.69 W/(m^2 • K)), heat losses can be reduced by 117%. The slab conductivity values used are for light to medium concrete.

3.5 Air Gap Thickness - Air gap thickness is the distance between the pre-sleeve inner wall and UPONOR PEX pipe outer wall. This is a main parameter that reduces heat losses. Convection heat transfer is happening in large air gaps, which is increasing heat transfer. There is no spacer in the UPONOR PEX so due to gravitation, there is an eccentricity that can influence heat losses. The eccentricity is increasing downward losses since the PEX pipe is directly in contact with the HDPE sleeve. Therefore, considering eccentricities heat losses can decrease by only 51% (0.93 in) (23.6 mm) or 57% (0.128 in) (3.25 mm) compared to a configuration with no air gap.

3.6 Fluid Velocity - Fluid velocity influences heat losses minimally due to the surface temperature of the outer pipe being close to fluid temperature for both 5 ft/s and 8 ft/s velocity. The impact is on pressure losses, as the fluid velocity increases from 5 ft/s to 8 ft/s (1.52 m/s to 2.44 m/s), the pressure losses increase by more than 73%.

3.7 Cases Considered

The following cases were presented in the analysis:

Case 1: UPONOR AquaPEX ½- inch (12.7 mm) diameter, see Table 1 for details.

Case 2: UPONOR AquaPEX ½- inch (12.7 mm) diameter, all parameters the same as Case 1 except the slab conductivity was reduced.

Case 3: UPONOR AquaPEX ¾- inch (19 mm) diameter, all other parameters the same as Case 1.

Case 4: UPONOR AquaPEX ¾ -inch (19 mm) diameter, all parameters the same as Case 3 except the slab conductivity was reduced.

Case 5: UPONOR AquaPEX ½ -inch (12.7 mm) diameter, decreasing the slab conductivity and increasing the Air Gap / overall outside diameter, otherwise the same as Case 1.

3.8 Minimum Parameters for Energy Equivalence

Under the conditions noted in Table 3 for ½-inch diameter piping and Table 4 for ¾-inch diameter piping, UPONOR pre-sleeved AquaPEX's total energy losses (including heat losses and pressure losses) are similar to the Overhead Insulated Copper's total energy losses. Key parameters are:

- PEX/CU length ratio,
- Slab conductivity and,
- Air gap thickness.

4.0 PRODUCT DESCRIPTION

IAPMO UES ER-253 recognizes AquaPEX as conforming to ASTM F876, as well as conforming to NSF 61 and NSF 14. The pre-installed sleeve is made from HDPE materials and provides a shield for embedment in concrete slabs.

5.0 IDENTIFICATION

Products recognized in this report are identified by the Listing Report Holder's name and or trademark, product identifier, evaluation report number (UES ER253), and the identification required by IAPMO R&T File 3558. The IAPMO Uniform Evaluation Service Mark of Conformity may be used as shown below:

IAPMO UES UEL-5036

6.0 SUBSTANTIATING DATA

6.1 Engineering study and analysis of data generated by the TRNSYS software with the cases noted dated 2020-01-21.

6.2 IAPMO R&T Listing File 3558 for UPONOR Cross-linked Polyethylene Water Distribution System (PEX).

7.0 STATEMENT OF RECOGNITION

This evaluation listing describes the results of research carried out by IAPMO Uniform Evaluation Service on UPONOR's pre-sleeved AquaPEX tubing to assess conformance to the codes shown in Section 1.0 of this report and serves as documentation of the product certification. Products are manufactured at locations noted in ER-253 under a quality control program with periodic inspection under the supervision of IAPMO UES.

For additional information about this evaluation listing please visit www.uniform-es.org or email us at info@uniform-es.org

TABLE 1
UPONOR AquaPEX Parameters Used in the Simulation for the following Acceptable Configurations

CASE	Nominal Diameter (inches)	Pipe Inside Diameter (inches)	Pipe / Tubing Outside Diameter (inches)	Air Gap Thickness (inches)	HDPE Sleeve Thickness (inches)	Overall Outside Diameter (inches)	Slab Connectivity (BTU/ft·h·°F)	Maximum Length of Aqua PEX to generate Energy Values Shown (feet)	Simulated Annual		
									Heat Energy Losses (kBTU)	Pressure Energy Losses (kBTU equivalent)	Total Energy Losses (kBTU equivalent)
1	½	0.475	0.625	0. 0.093	0. 0.095	1.0	0.289	28	2,709	374	3,082
2	½	0.475	0.625	0.093	0.095	1.0	0.173	33	2,621	440	3,062
5	½	0.475	0.625	0.093	0.095	1.071	0.173	36	2,556	480	3,037
3	¾	0.671	0.875	0.128	0.115	1.360	0.289	31	3,248	540	3,788
4	¾	0.671	0.875	0.128	0.115	1.360	0.173	36	3,134	627	3,762

1. 1 inch = 25.4 mm, 1ft = 304.8 mm
2. 1 BTU/ft·h·°F = 5.678263 W/ ($m^2 \cdot K$)
3. For each simulation the following parameters are constant:
   a. Water temperature at 120 ˚F (48.9 °C)
   b. Water Velocity at 8 feet per second (2.44 m/s)
   c. Slab Thickness 7-$^7/_8$" (200 mm)

TABLE 2
Overhead Insulated Copper Tubing
Parameters Simulated and Resulting Annual Energy Loss

Nominal Diameter (Inches)	Inner Pipe Diameter (Inches)	Outer Pipe Diameter (Inches)	Insulation Thickness (Inches)	Water Temperature (°F)	Water Velocity f/s	Pipe Length Feet	Simulated Annual		
							Heat Energy Losses (kBTU)	Pressure Energy Losses (kBTU equivalent)	Total Energy Losses (kBTU equivalent)
½	0.545	0.625	1.000	120	8	60	2,206	878	3,084
¾	0.785	0.875	1.000	120	8	60	2,632	1,166	3,800

1. 1 inch = 25.4 mm, 1ft = 304.8 mm
2. 1 BTU/ft·h·°F = 5.678263 W/(m^2 · K)
3. For each simulation the following parameters are constant:
   a. Water temperature at 120 ˚F (48.9 °C)
   b. Water Velocity at 8 feet per second (2.44 m/s)
   c. Slab Thickness 7-7/8" (200 mm)

TABLE 3
Parameters for UPONOR AquaPEX ½"
which yield similar total losses as the
Overhead Insulated Copper Configuration Shown in Table 2

Parameters	Case 1	Case 2	Case 5
UPONOR AquaPEX to Copper Pipe Length Ratio	0.470	0.550	0.600
Slab Conductivity BTU/ft·h°F	0.289	0.173	0.173
Air Gap Thickness (inches)	0.093	0.093	0.128

TABLE 4
Parameters for UPONOR AquaPEX ¾"
which yield similar total losses as the
Overhead Insulated Copper Configuration Shown in Table 2

Parameters	Case 3	Case 4
UPONOR AquaPEX to Copper Pipe Length Ratio	0.520	0.600
Slab Conductivity BTU/ft·h°F	0.289	0.173
Air Gap Thickness (inches)	0.128	0.128