R-Value and Thermal Conductivity of PEX and PE-RT

TR-48/2014

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Foreword

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The purpose of this technical report is to provide the thermal conductivity of cross-linked polyethylene (PEX) and PE-RT tubing materials.

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This Technical Report was first published in August 2014.

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1.0 BACKGROUND

Thermal conductivity, through a homogeneous material such as the wall of a PEX tube, is a measurement of the rate at which heat transfers by conduction. It is defined as the amount of heat, in BTU's per hour, that will conduct through one square foot of one inch thick material when the temperature differential across the material is one degree Fahrenheit.[1] Thermal conductivity is often denoted as ***k*** or ***k factor*** and is expressed as (BTU•in)/(ft^2•hr•°F). It can be converted to SI units as Watts per meter per degree Kelvin or W/(m•°K), where 1 (BTU•in)/(ft^2•hr•°F) = 0.1442279 W/(m•°K). [2]

Thermal resistance, or R-value, is a measurement used to compare the relative thermal resistance of materials used in the construction industry. For a flat surface, R-value is the reciprocal of ***k***, thus a lower R-value means greater heat conduction and vice versa. The letter "R" is placed before the numerical value, as in R19 or R-19. [3]

In the process of designing a plumbing system, radiant heating / cooling system, or other application where PEX tubing is to be used, it is sometimes necessary to know the R-value of PEX. In order to provide this information to interested parties, the Building and Construction Division of the Plastics Piping Institute undertook a test program to determine the thermal conductivity and R-value of PEX.

2.0 OBJECTIVE

The objective of the test program was to determine the thermal conductivity of various PEX tubing materials. For completeness and comparison purposes, PE-RT was also tested.

Samples were submitted of PE-RT and PEX. The PEX samples included specimens representing all three common manufacturing methods and two colors of PEX. The samples were flattened into disk form to accommodate the testing equipment.

3.0 TESTING

The tests were conducted in the summer of 2012 by The Dow Chemical Company.

The equipment used was a Hot Disk AB model TPS 2500 S which meets ISO Standard ISO/DIS 22007-2.2. ISO/DIS 22007-2.2 utilizes the "Transient Plane Source Method" to determine a material's thermal conductivity. The data is comparable to that generated in compliance with ASTM D5930 which utilizes the "Transient Line Source Method".

The test protocol includes tests at three temperatures: 23, 60, and 82.2°C. Samples were provided to the laboratory without brand or type identification (blind).

4.0 CONCLUSIONS:

Using the average of all samples at each temperature, the ***k factor*** results of 2.89, 2.88, and 2.82 (BTU•in)/(ft^2•hr•°F) were obtained. This is a narrow range, and the average ***k factor*** of 2.86 was used in the calculations of R-value.

The wall thickness of PEX is less than 1" and varies by its nominal size. To provide additional information specific to nominal (SDR-9) PEX sizes, the following table shows the R-value by nominal size:

Tubing size:	**1/2"**	**3/4"**	**1"**	**1-1/4"**	**1-1/2"**	**2"**
R-value:	0.028	0.038	0.049	0.060	0.072	0.093

Note: The R-value was calculated based on the ***k factor*** for PEX at 23, 60, and 82.2 °C and dimensions found in ASTM F876. The following equation was used:

R = r2•ln(r2/r1)/k (see footnote 4) Where:

r1 = inside radius (in.)
r2 = outside radius (in.)
k = thermal conductivity (BTU•in)/(ft^2•hr•°F)
ln = natural logarithm

Two colors of PEX were tested and little difference was noted. Therefore the color of PEX appears to be insignificant in determining ***k factor*** and R-value.

For reference and comparison purposes, the following table lists the thermal conductivity of PEX (from above), PE-RT (also tested as part of this project)[6], and copper [7]

Material	Thermal Conductivity BTU•in/(ft^2•hr•°F)	Thermal Conductivity W/(m•°K)
PEX	2.86	0.41
PE-RT	3.15	0.46
COPPER	196	28

Footnotes

1. Olin, Schmidt, Lewis, revised Simmons, *CONSTRUCTION PRINCIPLES, MATERIALS, AND METHODS*, (New York: VAN NOSTRAND REINHOLD, 1994) p. 948.
2. Taylor, *Guide for the Use of International System Units (SI) Special Publication 811,* (Gaithersburg, MD: National Institute of Standards and Technology, 1995) p. 46.
3. Olin p. 949.
4. The simple relation for flat sheet conductivity does not hold true when looking at cylindrical pipe. For cylindrical geometry, heat flow is not the simple straight through heat flow found in flat surface material, but rather radial heat flow. This reasoning is based on the fact that the inner radius surface area is much smaller that the outer radius surface area.
5. Sample 2 was omitted from the results because it had been prepared in a different manner and might not be representative.
6. There was variation between PE-RT and PEX from various sources. Actual thermal conductivity values may vary from the average values reported by +/- 5%.
7. Copper Development Association Inc., *Properties of Wrought and Cast Copper Alloys – Physical Properties,* Alloy C12200, http://www.copper.org/resources/properties/db/CDApropertiesselectionservlet.jsp?mode=basic, July 2013.

Appendix

Results of the testing at each of the three temperatures are detailed in the following tables[5]:

Sample	Material	Temperature (°C)	Thermal Conductivity BTU•in/(ft^2•hr•°F)	Thermal Conductivity W/(m•°K)	Std. Deviation
1	PEX	23	3.029	0.437	2.59E-03
3	PEX	23	2.821	0.407	6.19E-04
3a	PEX	23	2.994	0.432	3.57E-04
5	PEX	23	2.792	0.403	2.84E-04
5a	PEX	23	2.830	0.408	4.55E-04
6	PE-RT	23	3.266	0.471	3.88E-04
6a	PE-RT	23	3.050	0.440	8.52E-04

PEX Avg. 2.893

Sample	Material	Temperature (°C)	Thermal Conductivity BTU•in/(ft^2•hr•°F)	Thermal Conductivity W/(m•°K)	Std. Deviation
1	PEX	60	3.004	0.433	4.64E-04
3	PEX	60	2.841	0.410	7.49E-04
3a	PEX	60	2.937	0.424	3.36E-04
5	PEX	60	2.789	0.402	1.14E-03
5a	PEX	60	2.830	0.408	6.02E-04
6	PE-RT	60	3.266	0.471	3.88E-04
6a	PE-RT	60	3.163	0.456	3.55E-04

PEX Avg. 2.880

Sample	Material	Temperature (°C)	Thermal Conductivity BTU•in/(ft^2•hr•°F)	Thermal Conductivity W/(m•°K)	Std. Deviation
1	PEX	82.2	2.968	0.428	1.55E-04
3	PEX	82.2	2.760	0.398	3.35E-04
3a	PEX	82.2	2.864	0.413	1.44E-04
5	PEX	82.2	2.740	0.395	1.82E-03
5a	PEX	82.2	2.754	0.397	1.97E-03
6	PE-RT	82.2	3.227	0.465	1.02E-03
6a	PE-RT	82.2	2.949	0.425	2.43E-04

PEX Avg. 2.817