Thermal conductivity tests

Woodside, W.; Wilson, A. G.

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/20338457
Technical Note (National Research Council of Canada. Division of Building Research); no. TN-263, 1958-09-01

NATIONAL RESEARCH COUNCIL OF CANADA

DIVISION OF BUILDING RESEARCH

No. 263

TECHNICAL NOTE

PREPARED BY W. Woodside and A.G. Wilson

CHECKED BY

APPROVED BY NBH

DATE September 1958
(revised May 1964)

PREPARED FOR General Distribution

SUBJECT Thermal Conductivity Tests

This note is intended as a guide to manufacturers of thermal insulating materials, and others who may require the thermal conductivity testing services of the Division of Building Research, National Research Council.

Thermal Conductivity

Thermal conductivity is defined as the time rate of heat flow under steady conditions, through unit area, per unit temperature difference across unit thickness in the direction perpendicular to the area. The units of thermal conductivity commonly used by heating and refrigeration engineers are Btu per (hr.) (sq. ft.) (°F. per in.). The thermal conductivity of a material is sometimes referred to as its k-value. It should be noted that the term can be applied only to materials that are essentially uniform in structure throughout.

Thermal Conductance

Thermal conductance is defined as the time rate of heat flow under steady conditions from one surface of a material to the other through unit area per unit temperature difference between the two surfaces. The units of thermal conductance commonly used are Btu per (hour) (sq. ft.) (°F.). The thermal conductance of a material is sometimes referred to as its C-value. The term is applied to specific materials for the stated thickness or construction, not per inch of thickness. It is applicable to specific arrangements of either uniform materials or combinations of materials.

Guarded Hot Plate Apparatus

The standard method of measuring the thermal conductivity of insulating materials is by means of the guarded hot plate apparatus. This method has been standardized by the American Society for Testing Materials (ASTM Designation C 177-45).

The apparatus consists of an electrically heated hot plate and two liquid-cooled cold plates, usually square, and all of the same size. The hot plate comprises a central test area and an outer guard ring, each heated independently. The guard ring is maintained at the same temperature as the test area to avoid lateral heat loss from the test area. Two identical specimens of the material under test are placed one on each side of the hot plate, and the two cold plates clamped against the other faces of the specimens. Constant temperature liquid is circulated through each of the cold plates and regulated current is passed through the heaters of the test area and guard ring of the hot plate, so that a temperature gradient is set up across each specimen. The symmetrical arrangement involving two identical samples and two cold plates, one on each side of a central heated plate, is an essential feature of the standard guarded hot plate in order to avoid the complication of unknown heat loss from the back of the heater plate when only one sample is used. When a steady-state temperature equilibrium has been established the average thermal conductivity of the two specimens may be calculated from the measured power input to the test area (Btu/hr.) the area of the test area (ft^2), the temperature difference between the hot and cold surfaces of the specimens (°F.) and the thickness of the specimens (in.).

Three sets of guarded hot plate apparatus are available at the Division of Building Research. The plate sizes of these are respectively 18 by 18 inches, 12 by 12 inches, and 8 by 8 inches. The 18-in. hot plate apparatus is the one normally used for commercial testing.

Test Specimens

The guarded hot plate is intended for determining the thermal conductivity of homogeneous materials in the form of flat slabs or plates. However, the thermal conductance of heterogeneous materials for which the thermal conductance is uniform over the whole area perpendicular to the direction of heat flow can be determined equally well. The apparatus is not suitable for arrangements containing discontinuities or large air spaces.

Specimens for test must be of uniform thickness and must have reasonably smooth, plane surfaces. It should be especially noted that in all cases two identical specimens are required for the determination of the thermal conductivity (or conductance) of a material by the guarded hot plate method.

To achieve a uniform specimen thickness, specimens of non-rigid materials such as batt or loose fill insulation are held in wooden or lucite frames having the same external dimensions as the plates of the apparatus.

For rigid materials with rough surfaces, pads of foam rubber or felt 1/8 in. thick are attached to the faces of the samples to improve the thermal contact with the plates. The temperature difference used to calculate the thermal conductivity of such specimens in such cases is measured by means of thermocouples attached to the faces of the specimens. Also the specimen thickness used to calculate the conductivity is the average of the thicknesses at the points where the thermocouples are attached, as measured by a dial indicator thickness gauge.

The sizes of specimens which may be tested depend upon the dimensions of the hot plate apparatus. The 18-in. hot plate apparatus accommodates specimens 18 in. square and of thickness up to 3 in. The 12-in. apparatus accommodates specimens 12 by 12 in. and of thickness 2 in. or less. The 8-in. apparatus accommodates specimens 8 by 8 in. of thickness 1 in. or less. In general, specimens suitable for the 18-in. hot plate apparatus are preferred since the other two sets of apparatus are intended primarily for research purposes.

Test Conditions

The thermal conductivity of most materials varies with mean temperature, density, moisture content and other factors. Moisture in a material provides a great complication in measurements of thermal conductivity. The effect of moisture is not one that can be determined by a few simple tests but is still the subject of much research. Therefore it is common practice on this continent to carry out thermal conductivity tests on dry materials so that results can be reported on a comparative basis.

Specimens are dried before test in a ventilated oven at 215°F. If it is thought that the material might suffer from this treatment, lower oven temperatures are used. The thermal conductivity obtained therefore applies to the dry material, although the material may not be in this state in use.

Tests may be performed readily in the hot plate apparatus at any mean temperature in the range between 30°F. and 150°F. Unless otherwise specified, tests are performed at a mean temperature of approximately 75°F. The temperature difference applied across the samples is usually approximately 40 F. degrees.

Besides the thermal conductivity (and/or thermal conductance) of the samples supplied, the following are also reported: (i) moisture content as received, expressed as a percentage of the dry weight, (ii) specimen thickness during test, (iii) dry density of specimen, (iv) mean temperature of test, (v) temperature difference applied across specimen, and (vi) moisture gain, if any, during test.

Further Information About Thermal Conductivity Tests

Tests are performed for the manufacturer of a material, or for any other interested party subject to the permission of the manufacturer if a particular product is in question. If it is possible to conduct the test the client will be requested to make application on special forms provided.

When no special preparation of the specimens or unusual test conditions are required the charge for each test is $50.00. If some special preparation of the specimens is necessary, or if pads and thermocouples must be provided because of nonuniformity of the surfaces, the charge for each test is $75.00. Please note that these charges are those in effect at the time of writing and are subject to change without notice.

General inquiries regarding thermal conductivity tests should be directed to:

Mr. L.P. Ruddy,
Division of Building Research,
National Research Council,
Ottawa, Ontario.

Specimens for test and any special inquiries regarding specimens, test conditions, and procedures should be directed to Mr. A.G. Wilson at the same address.

Test results are reported to and become the property of the client. A copy of the report is kept on file by the Council but is regarded as confidential.

It should be noted that the Council does not approve or endorse materials tested and the name of the Council must not be used in advertising.

NATIONAL RESEARCH COUNCIL OF CANADA

DIVISION OF BUILDING RESEARCH

No. 263

TECHNICAL NOTE

NOT FOR PUBLICATION — FOR INTERNAL USE

PREPARED BY W. Woodside and A.G. Wilson — CHECKED BY — APPROVED BY NBH

PREPARED FOR General Distribution — DATE September 1958

SUBJECT Thermal Conductivity Tests

This note is intended as a guide to manufacturers of thermal insulating materials, and others who may require the thermal conductivity testing services of the Division of Building Research, National Research Council.

Thermal Conductivity

Thermal conductivity is defined as the time rate of heat flow under steady conditions, through unit area, per unit temperature difference across unit thickness in the direction perpendicular to the area. The units of thermal conductivity commonly used by heating and refrigeration engineers are Btu per (hr.) (sq. ft.) (°F. per in.). The thermal conductivity of a material is sometimes referred to as its k-value. It should be noted that the term can be applied only to materials that are essentially uniform in structure throughout.

Thermal Conductance

Thermal conductance is defined as the time rate of heat flow under steady conditions from one surface of a material to the other through unit area per unit temperature difference between the two surfaces. The units of thermal conductance commonly used are Btu per (hour) (sq. ft.) (°F.). The thermal conductance of a material is sometimes referred to as its C-value. The term is applied to specific materials for the stated thickness or construction, not per inch of thickness. It is applicable to specific arrangements of either uniform materials or combinations of materials.

Guarded Hot Plate Apparatus

The standard method of measuring the thermal conductivity of insulating materials is by means of the guarded hot plate apparatus. This method has been standardized by the American Society for Testing Materials (ASTM Designation C 177-45).

The apparatus consists of an electrically heated hot plate and two liquid-cooled cold plates, usually square, and all of the same size. The hot plate comprises a central test area and an outer guard ring, each heated independently. The guard ring is maintained at the same temperature as the test area to avoid lateral heat loss from the test area. Two identical specimens of the material under test are placed one on each side of the hot plate, and the two cold plates clamped against the other faces of the specimens. Constant temperature liquid is circulated through each of the cold plates and regulated current is passed through the heaters of the test area and guard ring of the hot plate, so that a temperature gradient is set up across each specimen. The symmetrical arrangement involving two identical samples and two cold plates, one on each side of a central heated plate, is an essential feature of the standard guarded hot plate in order to avoid the complication of unknown heat loss from the back of the heater plate when only one sample is used. When a steady-state temperature equilibrium has been established the average thermal conductivity of the two specimens may be calculated from the measured power input to the test area (Btu/hr.) the area of the test area (ft^2), the temperature difference between the hot and cold surfaces of the specimens (°F.) and the thickness of the specimens (in.).

Three sets of guarded hot plate apparatus are available at the Division of Building Research. The plate sizes of these are respectively 18 by 18 inches, 12 by 12 inches, and 8 by 8 inches. The 18-in. hot plate apparatus is the one normally used for commercial testing.

Test Specimens

The guarded hot plate is intended for determining the thermal conductivity of homogeneous materials in the form of flat slabs or plates. However, the thermal conductance of heterogeneous materials for which the thermal conductance is uniform over the whole area perpendicular to the direction of heat flow can be determined equally well. The apparatus is not suitable for arrangements containing discontinuities or large air spaces.

Specimens for test must be of uniform thickness and must have reasonably smooth, plane surfaces. It should be especially noted that in all cases two identical specimens are required for the determination of the thermal conductivity (or conductance) of a material by the guarded hot plate method.

To achieve a uniform specimen thickness, specimens of non-rigid materials such as batt or loose fill insulation are held in wooden or lucite frames having the same external dimensions as the plates of the apparatus.

For rigid materials with rough surfaces, pads of foam rubber or felt 1/8 in. thick are attached to the faces of the samples to improve the thermal contact with the plates. The temperature difference used to calculate the thermal conductivity of such specimens in such cases is measured by means of thermocouples attached to the faces of the specimens. Also the specimen thickness used to calculate the conductivity is the average of the thicknesses at the points where the thermocouples are attached, as measured by a dial indicator thickness gauge.

The sizes of specimens which may be tested depends upon the dimensions of the hot plate apparatus. The 18-in. hot plate apparatus accommodates specimens 18 in. square and of thickness up to 3 in. The 12-in. apparatus accommodates specimens 12 by 12 in. and of thickness 2 in. or less. The 8-in. apparatus accommodates specimens 8 by 8 in. of thickness 1 in. or less. In general, specimens suitable for the 18-in. hot plate apparatus are preferred since the other two sets of apparatus are intended primarily for research purposes.

Test Conditions

The thermal conductivity of most materials varies with mean temperature, density, moisture content and other factors. Moisture in a material provides a great complication in measurements of thermal conductivity. The effect of moisture is not one that can be determined by a few simple tests but is still the subject of much research. Therefore it is common practice on this continent to carry out thermal conductivity tests on dry materials so that results can be reported on a comparative basis.

Specimens are dried before test in a ventilated oven at 215°F. If it is thought that the material might suffer from this treatment, lower oven temperatures are used. The thermal conductivity obtained therefore applies to the dry material, although the material may not be in this state in use.

Tests may be performed readily in the hot plate apparatus at any mean temperature in the range between 30°F. and 150°F. Unless otherwise specified, tests are performed at a mean temperature of approximately 75°F. The temperature difference applied across the samples is usually approximately 40 F. degrees.

Besides the thermal conductivity (and/or thermal conductance) of the samples supplied, the following are also reported: (i) moisture content as received, expressed as a percentage of the dry weight, (ii) specimen thickness during test, (iii) dry density of specimen, (iv) mean temperature of test, (v) temperature difference applied across specimen, and (vi) moisture gain, if any, during test.

Further Information About Thermal Conductivity Tests

Tests are performed for the manufacturer of a material, or for any other interested party subject to the permission of the manufacturer if a particular product is in question. If it is possible to conduct the test the client will be requested to make application on special forms provided.

When no special preparation of the specimens or unusual test conditions are required the charge for each test is $40.00. If some special preparation of the specimens is necessary, or if pads and thermocouples must be provided because of nonuniformity of the surfaces, the charge for each test is $75.00. In testing mineral wool insulations in accordance with CSA specification A101-1952 the charge for each thermal conductivity test is $37.00 and an additional charge of $13.00 is made for the determination of the thickness and density of batts or the density of fill. Please note that these charges are those in effect at the time of writing and are subject to change without notice.

General inquiries regarding thermal conductivity tests should be directed to:

Mr. L.P. Ruddy,
Division of Building Research,
National Research Council,
Ottawa, Ontario.

Specimens for test and any special inquiries regarding specimens, test conditions, and procedures should be directed to Mr. A.G. Wilson at the same address.

Test results are reported to and become the property of the client. A copy of the report is kept on file by the Council but is regarded as confidential.

It should be noted that the Council does not approve or endorse materials tested and the name of the Council must not be used in advertising.