TECHNICAL INFORMATION ON BUILDING MATERIALS

FOR USE IN THE DESIGN OF LOW-COST HOUSING

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THE NATIONAL BUREAU OF STANDARDS
UNITED STATES DEPARTMENT OF COMMERCE
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THERMAL INSULATION

Summary and Conclusions

This is a summary and brief presentation of conclusions, pertaining to thermal insulating qualities of various types of building walls, commercial insulating materials, and application of insulating materials to building walls, derived from tests conducted by the National Bureau of Standards.

Complete details regarding materials and walls tested, methods of testing, and results are given in Bureau of Standards Circular No. 376, "Thermal Insulation of Buildings", (October 17, 1929);[1] Research Paper No. 291, "Heat Transfer Through Building Walls", (August 6, 1930),[2] by M. S. Van Dusen and J. L. Finck; and Letter Circular No. 421, "Thermal Insulation", (July 13, 1934).[3]

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[1] Available from Superintendent of Documents, Government Printing Office, Washington, D. C. (Price 5 cents)

[2] Available from Superintendent of Documents, Government Printing Office, Washington, D. C. (Price 15 cents)

[3] Available from National Bureau of Standards, Washington, D. C. (Free)

various types of the same size, in the same locality, unless air leakage around doors and windows or through very poorly constructed walls is excessive.

The difference between insulating values of the poorest and the best wall tested (representing extremes in ordinary uninsulated construction) is equal to the insulating value of approximately 3/4 inch of good insulating material.

Commercial Thermal Insulating Materials

Light Fibrous or Cellular Materials: Differences in respective insulating values of light fibrous or cellular insulating materials are not very great. Less than 1 1/2 inches of the poorest material is equivalent in insulating value to 1 inch of the best. In general, the lighter the material per unit total volume the better its insulating value per inch thickness.

Stiff Fibrous Insulating Boards: Stiff fibrous insulating boards having considerable structural strength are somewhat poorer insulators than lighter and looser materials.

Dense Highly Compressed Wallboards: Dense highly compressed wallboards made of wood or other organic fibre are not as good insulators as less compressed boards of the same general character.

Heavy Plaster Wallboards: Heavy wallboards containing plaster in one form or another are relatively poor insulators, although they are very useful building materials.

Metal Foil: Aluminum foil is used to increase the insulating value of air spaces by reducing heat transfer by radiation, therefore, it is of value only when used in conjunction with air spaces, and has no value when placed in continuous contact with solid material on both sides, except insofar as it may act as a building paper in preventing air leakage.

Paper with aluminum foil glued to both sides or a sheet of bright tin plate would produce the same thermal insulating effect. Sheet material coated with aluminum paint can also be used as thermal insulation, but it is considerably less effective than actual metal foil.

Paint: As a film of paint is relatively thin, it can offer but slight resistance to heat flow by conduction. However, the color of external paint has considerable effect on absorption of heat from the sun. Light-colored paints absorb less heat from the sun and are therefore more desirable from a thermal insulation standpoint. The reradiation of heat from the underside of a hot roof may be reduced by coating the underside with paint containing metallic flakes, such as aluminum paint.

Building Walls

Hollow Tile Walls: Of the types of 8" hollow tile walls tested (single unit--6 cell; double shell unit--3 cell; and two 4" units back to back--3 cell) the differences in insulating values are negligible.

Brick Walls: According to tests conducted on two kinds of brick (very hard burned brick; and rather porous, dry-pressed brick), representing approximately the two extremes in common brick manufacture; the kind of brick used in a brick wall is of little importance from an insulation standpoint alone.

Temperature of Wall: The insulating value of all walls tested increased as temperatures decreased; the increase, in general, being more rapid in hollow walls than in solid walls.

Air Infiltration: Investigations carried out elsewhere indicate that air infiltration through complete walls is usually so small as not to materially increase heat loss from buildings. There is a possibility, however, that an individual hollow type wall may be subject to air penetration effects of considerable import.

Air Spaces: Although air is a very poor conductor of heat, the insulating value of an ordinary air space is rather small because of the large transfer of heat by radiation and convection; for the same reason the insulating value of an air space is not proportional to its width (thickness), as would be the case with a slab of uniform solid material.

Insulating values of air spaces in excess of about 3/4 inch remain practically constant regardless of the width. Narrower air spaces have less insulating value. Insulating values of air spaces less than 1/2 inch are approximately proportional to the width.

Under average conditions, the insulating value of vertical air spaces commonly found in building walls is equivalent to approximately 1/4 to 1/3 inch of average insulating material (about 1 Btu per hour, per square foot, per temperature difference of 1°F).

Furring: Furring materially increases the insulating value of ordinary types of walls.

Choice of a Building Wall or Roof: A great many types of walls and roofs are to be found in present day dwelling-house construction. Tests show that the insulating value of one type may vary considerably from that of another. From an insulation standpoint, in an actual building, it has been demonstrated that heat losses through and around windows and doors tend to level out the effect of differences in the properties of the walls themselves. Thus, it follows that there are no wide variations in the amounts of fuel required to heat houses of

Application of Thermal Insulation

Type vs. Thickness: From an insulation viewpoint only, the most important question is the thickness of insulating material to be applied, rather than which material to select.

Cost: The real cost of an insulating material is not the cost per square foot of commercial thickness, but the cost per unit insulating value of the commercial thickness.

Effectiveness: The percentage increase in the insulating value of a building wall through the application of thermal insulation depends (1) upon the original insulating value of the wall without insulation, and (2) upon the amount of glass surface and air leakage around windows and doors. A somewhat greater percentage saving in fuel may be obtained by insulating a solid masonry wall than by applying the same insulation to a frame or hollow tile construction.

Insulating Air Spaces: Application of 1/2 inch of insulation in the middle of a frame wall air space is equivalent to applying slightly more than 3/4 inch at some other place in the wall, as the insulating layer not only furnishes its own insulating value, but it also divides the air space into 2 parts, each of which has approximately the same insulating value as the original air space. Application of a sheet of aluminum foil in the middle of an air space in excess of 1 1/2 inches across, dividing the original air space into 2 parallel spaces, increases the insulating value of the original air space by an amount equivalent to about 1 1/4 inches of insulating board.

If one interior surface of an air space in excess of about 3/4 inch across is lined with aluminum foil, the insulating value of the air space will be increased by an amount roughly equivalent to that of 1/2 inch of insulating board. Little additional insulating value is gained by lining the opposite interior surface with foil.

Aluminum Foil Insulation

(The following transcript of National Bureau of Standards Letter Circular No. 465, dated June 4, 1936, contains additional information concerning Aluminum Foil Insulation.)

At the time Circular C376 of the National Bureau of Standards was prepared (1929), insulating materials of the reflective type had not come into prominence. This letter circular is to be considered as a supplement to Circular C376 pending its revision.

In Circular C376 it is stated: Commercial insulating materials can be divided into two general groups -

(1) fibrous materials either in loose form or fabricated into soft flexible quilts confined between relatively thin layers of paper or textile, and

(2) more or less rigid boards in which the components are bonded together in some way.

To this classification must now be added a new and distinctive group, as follows:

(3) reflective materials such as aluminum foil, deriving their insulating properties from the fact that they reflect radiant heat.

Since the principles involved in the use of aluminum foil or other bright metal sheet as thermal insulation are not generally understood, a brief discussion will be given here. Aluminum foil is used to increase the insulating value of air spaces by reducing heat transfer by radiation. It is of value only in conjunction with air spaces, and has no value when placed in continuous contact with solid material on both sides, except in so far as it may act as a building paper in preventing air leakage.

Clean metallic surfaces in general are good reflectors and poor emitters of radiant heat. Since a large proportion of the heat transfer across air spaces bounded by non-metallic materials takes place by radiation, the use of aluminum as one or both boundaries of a space will materially reduce the heat transfer across the space. It will be evident that the insulating effect does not depend on the thickness of the metallic foil, while the insulating value of ordinary types of insulating materials depends mainly on their thickness. The insulating value of air spaces bounded on one or both interior surfaces with aluminum foil increases with increasing width of space up to about 3/4 inch width. Spaces wider than about 3/4 inch have substantially the same insulating value, regardless of width.

There is little definite information on the permanency of the reflective surfaces of aluminum under various conditions of use over long periods. Installations are reported where no appreciable deterioration of the aluminum has occurred over a considerable period of years. Thin layers of dust readily visible to the eye do not cause any very serious lowering in the reflecting power. If aluminum is wetted over considerable periods of time, there is possibility of corrosion. The reflectivity is not appreciably reduced until the aluminum is covered by an easily visible layer of corrosion products (Gregg, Refrigerating Engineering, May, 1932).

The use of lacquer to resist possible corrosion under severe conditions of use reduces the reflecting power to a greater or lesser extent. The effect of a very thin coat of lacquer is small, but relatively thick lacquers, even though they are almost invisible to the eye, may seriously reduce the effectiveness of the foil.

The effect of reduced reflectivity on heat transfer across an air space is less marked the narrower the space, since heat transfer by conduction and convection plays a more important role than radiation in the case of narrow air spaces.

The available data in the literature on the insulating value of aluminum foil used in various ways show considerable variation. The numerical data in the following table are therefore necessarily only approximate, but are sufficiently accurate for practical purposes in connection with house insulation. In this table the data in Column 1 on clean aluminum foil are calculated from test results. The data in the other columns are calculated from the figures in Column 1, assuming that the reflecting power of clean aluminum is 95 percent. All air spaces are assumed to be 3/4 inch or more in width. The figures given represent the number of inches of insulating material having a thermal conductivity of 0.3 Btu/hr sq ft (deg F/inch) to which each combination of reflective material is equivalent.

A material having a conductivity of 0.3 Btu has been selected as a basis for comparison because this figure is about the average of insulating materials now being sold.

The figures in the table represent the total insulating values of the air-space combinations described. Since the original single air-space bounded by ordinary materials such as paper has insulating value equivalent to about 1/4 inch of insulating material (Column 4), the insulating value which is actually added by the use of reflective material is about 1/4 inch less than the figures given in the table.

There are a number of ways in which insulating value may be expressed. The method of expressing insulating value in the table has been chosen as being most readily intelligible to persons not familiar with the technical side of the subject. Anyone who wishes to have the results expressed in terms of heat transfer in Btu per hour per square foot and per degree F temperature difference, may do so by dividing 0.3 (the conductivity of an average insulating material) by the numbers given in the table. For example, the number 1.5 represents 0.3/1.5 or 0.2 Btu per hour per square foot and per degree F temperature difference.

Aluminum foil is also applied in a crumpled form so that it is self-spacing. If two or three crumpled sheets are hung in the air space of a frame wall, there is so little contact between the sheets that the insulating values are essentially the same as those given for the spaced sheets.

Combination	Insulating value in inches of insulating material			
	Clean aluminum (95% reflecting)	Reflecting surface (85% reflecting)	Aluminum paint (65% reflecting)	Ordinary paper (10% reflecting)
1 Space, reflective material on one side	0.75	0.61	0.45	0.26
1 Space, reflective material on both sides	.80	.70	.54	.26
2 Spaces, formed by dividing wide space by 1 reflective sheet	1.50	1.21	.90	.53
3 Spaces, formed by dividing wide space with 2 reflective sheets	2.30	1.90	1.43	.79
4 Spaces, formed by dividing wide space with 3 reflective sheets	3.10	2.61	1.97	1.05