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Thermal Insulation of Dwelling Houses

I. Introduction

In preparing a letter circular on insulation with the hope that it will be useful to the householder, it appears reasonable, first, to answer those questions which arise most frequently and then to discuss the subject in general and furnish some reference for those who desire to make a fuller investigation.

Our answers to the more ordinary questions on this subject are as follows:

(1) It is possible to save heat by insulating a house. Application of insulation to exposed elements such as roofs or ceilings and exposed walls and of storm- or double windows can reduce the heat requirement by more than 50 percent in many cases.

(2) Partial insulation, that is, insulation of some parts and not others is worthwhile. For instance, the heat loss through the ceiling or roof of some houses is one-third or more of the total. The ceiling or roof loss can be reduced 75 percent or more which will result in a saving of 25 percent or more of the total heat requirement.

(3) It is improper to speak of one insulating material as more "efficient" than another. Insulating materials do differ from each other in conductivity for heat but it is only necessary to install a correspondingly greater thickness of one with a higher conductivity in order to attain a given insulating effect.

(4) Rock wool and glass wool are both known to the trade as mineral wool, and about the same effects are expected of them if they are installed in the same thickness.

(5) Prices change from time to time and differ from place to place. Information on prices of insulating materials is not available at the National Bureau of Standards.

(6) It happens that the insulating values of many fibrous materials such as mineral wool, shredded wood, cotton or other vegetable fiber, paper or cellulose insulation are about the same, so that, for the same thickness, the material with the lowest installed cost can well be chosen in many cases.

(7) For the same thickness, the same insulating effect is expected of fibrous materials whether they are installed as batts or blankets or as a fill, either by hand or by the blowing-in process. Batt and blanket materials usually are furnished with a vapor barrier on one side in which event separate application of such a barrier is not required.

A vapor barrier is a membrane or coating designed to prevent the passage of water vapor. As used in building construction, it usually consists of: a strong paper saturated and coated with asphalt; two plies of strong paper cemented together with a heavy layer of asphalt; or of a metal foil sheeting cemented to paper or building board.

(8) Use of vapor barriers is recommended on the warm side of insulation, especially in the side walls and roofs of houses, to prevent condensation of water vapor in the insulation or on timbers adjacent to it. Although vapor barriers are desirable, they have been omitted from many older houses insulated by the blowing-in process, and yet the results appear to be satisfactory in most cases.

(9) A vapor barrier is not usually necessary under insulation on a ceiling, especially if the attic above the insulation is ventilated by means of louvres or otherwise.

(10) Insulation should not be placed in contact with roof boards. When insulation is installed in a roof, an air space of several inches should be provided between the insulation and the roof boards. Ventilation of this space, with air from the outside, is desirable in order to prevent condensation, and a vapor barrier should be used on the warm side of the insulation.

(11) Some light-weight granular, fibrous and cellular insulating materials, such as straw, excelsior, sawdust, etc., are excluded from general use in dwelling houses, unless suitably treated, because of the necessity of providing for resistance to fire, rot and vermin infestation. Such materials often serve satisfactorily in barns, animal houses, etc., and are sometimes given inexpensive treatments against vermin infestation for such purposes.

(12) Some granular materials, including some commercially available expanded vermiculites, have conductivities greater than ordinarily expected of fibrous materials. Very often, such granular materials must be installed one- and one-half times as thick as a typical fibrous material to attain equal insulating effect.

(13) Cotton, treated for fire resistance etc., is a satisfactory insulating material. The thermal conductivity of the material as supplied on the market is likely to be approximately equal to that of other typical fibrous materials.

(14) Sheep's wool and animal hair have good insulating qualities. Such materials are likely to be relatively expensive, and treatment of them against moths and other insects is necessary.

(15) Metal or other reflective sheets may be able to compete commercially with other types of insulation after the war.

(16) Double or storm windows reduce window heat loss by somewhat more than one-half.

(17) Weather stripping saves heat by reducing the air leakage around window sash. The amount of saving for particular windows cannot be precisely estimated because the original amount of air leakage is unknown.

(18) Insulation assists in keeping a house cool in summer because it reduces the flow of heat into the house during the warmer part of the day. Cooling by night ventilation or otherwise of an insulated house is therefore made more effective in this manner.

(19) The insulation of houses or other structures by means of vacuum, as is done with thermos bottles, has not proved practical.

(20) Wooden, cement and composition shingles, roofing paper, other tar papers and building papers are not ordinarily considered to be thermal insulators. Such materials may reduce the heat lost by air leakage, but their effect on the heat lost by conduction is not great. Wooden shingles have about the same insulating effect as wooden plank or boards of the same average thickness, but 3 or 4 inches of wood are required to equal one inch of typical commercial insulating material. Either cement or composition shingles have less insulating effect than wooden shingles. Paper is too thin to have much effect as insulation although it may greatly reduce air leakage. Tar or roofing paper, if used, should be installed on the inner or warm side of the insulation, to serve as a vapor barrier.

II. Units of Measurement

In heating, air conditioning and refrigerating work, the unit of heat is the British thermal unit, abbreviated Btu, and defined as the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit.

The conductivity of a material (Symbol k) is defined as the amount of heat, in Btu, which will flow in one hour through one square foot of the material one inch thick when the temperature difference between opposite surfaces of the slab is one degree F.

Resistivity is the reciprocal of conductivity. It can be regarded as the temperature difference in degree F. required to force one Btu per hour through one square foot of the material one inch thick.

Conductance (symbol C) is distinct from conductivity in that conductance applies to a wall or other heat barrier which may be composed of a number of different materials or elements. Conductance is expressed in Btu per hour for each square foot and for each degree F temperature difference through the wall or other heat barrier.

Resistance, symbol R, is the reciprocal of conductance.

The symbol U, often called the transmittance, denotes the heat flow in Btu per hour, through each square foot of a wall or other heat barrier due to each degree F in temperature difference of the air on the two sides. This factor is useful when the air temperature inside and that outside of a house are known or assumed.

III. Computations

Resistance is important because it is proportional to the thickness of a material, and because resistances are additive when heat flows through a number of materials in series. For instance, consider a wall or heat barrier composed of two materials, A with a conductivity, k = 0.3 and a thickness of 2-inches and B, with a conductivity, k = 2.5 and a thickness of 1/2-inch. Then for material A,

Conductivity = 0.3; Resistivity = 1/k = 3.33

Resistance, R_A = 2 x 3.33 = 6.66

And for material B

Conductivity = 2.5; Resistivity = 1/k = 0.40

Resistance, R_o . 1/2 x 0.40 = 0.20

Combined resistance of A and B, R = 6.66 + 0.20 = 6.86

Conductance is the inverse of resistance. Therefore

Conductance = 1/R = 1/6.86 = 0.146

This means that 0.146 Btu per hour will flow through each square foot of this wall when the one surface is one degree F warmer than the other surface.

In addition to the resistance of a wall, there is also a resistance at the surface where heat must pass from the air to or from the wall. For still air, such as that inside a house, the film or surface resistance is approximately 0.61. For the outside, a wind velocity of 15 miles per hour is usually assured, and the corresponding outside film resistance is approximately 0.17.

The transmittance, U, can be found from the sums of the wall and surface resistances.

$$R = 6.86 + 0.61 + 0.17 = 7.64$$

$$U = 1/R = 1/7.64 = 0.13 \text{ nearly}$$

This means that about 0.13 Btu per hour will flow through each square foot of this wall when the air on the two sides differs in temperature by one degree F.

If the outside temperature is 0°F while that inside a structure with such a wall is 70°F, the heat loss will be about

70 x 0.13 = 9.1 Btu per hour for each square foot of wall.

Transmittances of most simple walls can be satisfactorily estimated in this way. Complicated walls, especially those involving metal in their construction, require testing.

IV. Types of Insulating Materials

All light-weight granular, cellular and fibrous materials have insulating properties, attributable to the insulating property of air. The materials themselves serve mainly to retard convective or other air currents in spaces filled with them and to interrupt the transfer of heat by radiation across such spaces.

An example of a granular insulating material is vermiculite, a mica-like mineral, which is expanded by heat and sold under various trade names. Samples of commercial vermiculite have conductivities averaging around k = 0.48. It is therefore necessary to install this material thicker than a typical fibrous material in the ratio of about one and one-half to one, to attain the same insulating effect. Vermiculite is not much used in the side walls of structures. Observation indicates that it is a satisfactory material for use in a thickness of several inches on horizontal surfaces such as ceilings.

A typical cellular material is cork, the traditional insulator in the refrigeration industry. Cork is not in general use for insulating houses, probably on account of its cost and limited availability. The conductivity of typical cork board is likely to be from 0.28 to 0.32.

Fibrous materials in common use are rock wool, slag wool and glass wool, (all known to the trade as mineral wool), cotton, paper or cellulose fiber and shredded wood or bark in various forms. The conductivity of materials of this class is likely to be between 0.25 and 0.30. Heat loss estimates, satisfactory for many purposes, can be made by assuming $k = 0.27$ for fibrous materials. If precision is required in estimating, reference should be made to some source such as those listed in Section IX below, or to test data.

Insulation boards are relatively strong, rigid sheetings, composed of vegetable fibers. Their conductivity is usually in the range 0.33 to 0.40; hence the insulating effect of such boards is somewhat less than that of typical fibrous materials of equal thickness. However, use of board insulation is advantageous in many instances on account of its form and strength which permit it to be used as structural elements such as lath, sheathing and interior wall finish. Material so used serves two purposes: that of insulation and that of structural elements.

An air space such as the stud space in a wall has a considerable inherent insulating effect. If such a space is faced with a reflecting surface, such as a metal foil, the insulating effect is greatly increased because such a surface is capable of arresting a large part (about 95 percent) of that portion (about half) of the heat which would ordinarily cross the space by radiation. Sometimes, reflecting sheets are installed in such spaces in tandem, one behind the other, thus dividing the space into several small spaces. Such an arrangement interferes with air currents and thus reduces heat flow by convection as well as by radiation.

Reflective insulation usually has the advantage that it acts also as an effective vapor barrier. Otherwise, the choice between a reflective and another insulation is purely one of economics. Reflective sheets probably require more care and skill in handling than other materials, thus increasing the cost of installation.

Reflective insulation is not as effective for reducing heat flow upward as it is in reducing heat flow horizontally or downward, because convection currents are exceptionally effective in conveying heat upward.

Double windows and double doors are to be regarded as insulating means. Their effect is mainly attributable to the air space between the two window sash or between the two doors, although the infiltration usually is also reduced by the use of either.

If double windows are installed, the saving of heat is likely to be 50 percent or more of the previous window heat loss provided the space between the panes is 3/4-inch or more.

Thermos bottles and Dewar flasks are very effectively insulated by means of a vacuum in conjunction with reflective surfaces, and the insulation of houses or other structures in the same way is occasionally proposed. Design of suitable vacuum-space walls for large structures has not been found practicable, however, chiefly on account of the magnitude of the atmospheric pressure. This pressure amounts to about one ton per square foot.

V. Condensation

The basic cause of condensation in buildings is the evaporation or boiling of water, usually incident to cooking, washing, and bathing operations. Such processes liberate water vapor, but they are, of course, necessary to living in a house.

Water vapor is invisible like air, being unlike "steam" at the spout of a kettle. When visible, the steam has already condensed and the resulting water exists as fine droplets, or mist, suspended in the air. From its source, water vapor will spread through a house and condense into water on any surface, such as a cold window, which is cooler than the dew point temperature.

In addition to other sources of water vapor, it should be remembered that much water vapor is generated by the combustion of any fuel containing hydrogen. For this reason, if no other, any gas or oil burning device should be vented to the outside either by means of a suitable chimney or flue or by opening a window in the room containing it. Also, potted plants are sometimes unsuspected causes of excessive humidity in houses. Water, poured around the roots of such plants, is carried up to the leaves by a process necessary to the plant's life. The water evaporates and thereby increases the humidity in the house. Plants kept indoors in winter should, therefore, be limited in number and size and none should be so kept if the humidity is known to be excessive.

Water vapor in ordinary concentrations is not harmful to either persons or furniture. In fact, some people consider their homes too dry for comfort and install humidifiers at some expense. The first evidence of excessive humidity is usually condensation or "fogging" on windows. If the condensation is slight or if the resulting water quickly evaporates, no harm is done; but, in bad cases, the water may run down from the window and damage the wall, the floor or any furniture in its way.

Water vapor is capable of permeating plaster, paper and most insulating materials, if unprotected, and of condensing on cold surfaces within the wall. In this way, the insulation may be damaged or, the house timbers, the weather boarding and paint may be adversely affected.

Three preventatives for condensation are suggested. (1) Reduce the generation of water vapor in the house; vent gas burning devices to the outside; cook with a lower flame; dry clothing out of doors; etc.

(2) Ventilate the house. The surrounding atmosphere in winter contains very little water vapor, so that outdoor air allowed to pass through the house, by the opening of windows or otherwise, will carry out considerable vapor.

(3) Raise the temperature of surfaces in contact with the air. When double windows are installed, condensation on the inner window does not occur because it is relatively warm. Installation of a vapor barrier prevents contact of moist air from the house with cold surfaces within the wall.

In the past, the condensation problem was not widely recognized, probably because most houses were sufficiently well ventilated by accidental air leakage or infiltration. The problem is more serious in the well insulated, and therefore more nearly air-tight, house, and the necessity of artificially providing ventilation in well insulated houses is likely to be recognized in the future. However, if it is attempted to prevent condensation by ventilation alone, much of the saving due to the insulation is likely to be wasted. Therefore, vapor barriers, consisting of vapor proof or vapor resistant sheets or layers, on the warm side of insulating material appear to be essential. A higher humidity can be maintained in a house so treated, which may favor comfort. Moreover, less ventilation, and therefore less heat loss, will be necessary to keep the humidity below a tolerable limit.

When used on the warm side of the insulation, a barrier is advantageous, on the cold side it is disadvantageous. The placing of moisture-proof sheathing paper on the cold side of an insulated wall causes an accumulation of moisture within the wall even when an excellent vapor barrier is used on the warm side. When a moisture repelling protective sheet is used on the cold side, it is essential to have a sheet of considerably greater - usually several times greater - vapor resistance on the warm side. The use of vapor barriers of equal resistance on the two sides of an insulated wall, is worse than using no barrier at all unless the barriers are perfectly vapor proof.

It is a fact that few troublesome cases have been reported from the great number of frame houses known to have been insulated by the blowing-in process. The stud spaces in such houses are filled with loose material and there is usually no vapor barrier. This fact appears to warrant taking a chance, on an existing uninsulated house, that a vapor barrier will not be necessary or that damage, if it does occur, can be corrected later. It must be that the accidental ventilation or infiltration is sufficient in most such houses to dispel the excess water vapor. If storm windows are installed in addition to the blown-in insulation, condensation may occur, especially in the severe climates. The above fact does not justify insulating the side walls of new houses without vapor barriers. Furthermore, Rowley and Jordan recommend precautions against wall condensation in all insulated houses north of the 35°F January isotherm. (See References, Section IX, University of Minnesota Bulletin No. 22). These authors cite test data to show that some paints and varnishes can be used as vapor barriers on the interior walls of existing houses when the use of other vapor barriers is impracticable.

Two special cases of condensation deserve consideration. Sometimes, in double windows, condensation occurs on the inner surface of the outside glass. This is caused by the leakage of warm and moist air from the house into the space between the windows. The remedies are (1) stop the leaks in the inside window or sash, (2) ventilate the space between the windows with outdoor air by boring holes or otherwise. Only a slight amount of such ventilation should be required, so that the heat loss need not be significantly increased. (3) Reduce the humidity in the house, as discussed above.

Condensation sometimes occurs in unexpected places when humid air is unintentionally conveyed to a cool region. For instance, a case is known in which the carpenters left a continuous opening, from the basement to the attic, around the soil pipe. Water vapor from the basement ascended through this opening and condensed on the roof boards, resulting in rot. Such condensation can be prevented, of course, by stopping the opening. Basements should, of course, be ventilated, in some way in winter to provide air for burning the fuel in the heating device.

VI. Insulation and Summer Comfort

A house can be kept cooler in summer if insulation is installed, but it must not be imagined that insulation has any inherent cooling effect. Insulation can only reduce the flow of heat through walls, ceiling or roof etc., and in this way assist whatever cooling means is used, be this simple night ventilation or a more complicated means such as a mechanical air conditioner.

Double windows reduce heat gain from the air outside the house but they do not greatly reduce the heat gained from sunlight entering windows. For this reason, the shading of windows, including double windows, by awnings or by trees or otherwise is beneficial in keeping a house cooler.

VII. Estimating Savings

Estimates of fuel consumption in houses and of savings due to insulation are seldom if ever exact. Various methods of computation, all based on assumptions about wind and weather, have been proposed and several are now practiced. An estimate within 10 percent of actual fuel consumption or of saving due to insulation would be considered good.

For many purposes a rough approximation, such as the following, is sufficient.

Assume that the walls, windows and the ceiling or roof each lose 25 percent of the heat supplied to a house and that the remaining 25 percent is lost by air leakage or infiltration. Houses differ in size and shape; some are one-story, others two-story or multi-story so that these assumed percentages do not apply exactly to any house. However, a house to which they apply is possible, and they probably represent the proportionate losses in average houses closely enough for purposes of rough estimation.

Reference to the American Society of Heating and Ventilating Engineers' "Guide"* indicates that, for typical construction, wall heat losses can be reduced 50 percent by one inch of insulation, 64 percent by 2 inches of insulation, 70 percent by 3 inches of insulation, etc. Ceiling or roof insulation can be expected to have a comparable effect. Window heat loss is reduced 50 percent or more if double windows are installed.

On these considerations, insulation of the house elements indicated should save heat or fuel approximately in the percentages shown below:

Insulation	Saving: Computation	Saving: Percent
1-inch in ceiling or roof	50% of 25% loss	12.5
2-inch in ceiling or roof	64% of 25% loss	16.0
3-inch in ceiling or roof	70% of 25% loss	17.5
1-inch in exposed walls	50% of 25% loss	12.5
2-inch in exposed walls	64% of 25% loss	16.0
3-inch in exposed walls	70% of 25% loss	17.5
Storm Windows	50% of 25% loss	12.5
Weather Strips**		4.0

*See reference, Section IX

**From the book "Building Insulation" by P. D. Close (See Section IX).

These percent savings are additive if more than one house element is insulated. For instance, if 3 inches of insulation are installed in the ceiling, 3 inches in the side walls and if storm windows are put on, the indicated saving is

$$17.5 + 17.5 + 12.5 = 47.5\%$$

Figures on infiltration are not included in the above tabulation (except the reference to weather strips) because the effect of insulation on air leakage is indefinite. Insulation, however, is expected to reduce infiltration in many cases. Storm windows will reduce infiltration in practically all cases.

Those interested in closer estimates of fuel saving can use either average heating season temperature or degree days as a basis. Data for the computations are contained in some of the references below such as "Building Insulation" by Close, and the American Society of Heating and Ventilating Engineers' "Guide".

VIII. Tests

The most generally accepted apparatus for testing insulating material is the hot plate apparatus, described in the paper "The Thermal Conductivity of Heat Insulation", by M. S. Van Dusen, listed in the references in Section IX. This apparatus consists essentially of a hot plate and two cold plates. For a test, two similar specimens of a material in the form of slabs are used, one on each side of the hot plate. The cold plates are then placed against the outside of the specimens. The cold plates are usually water cooled, being either cored or provided with a coil of tubing, soldered on, for the purpose. The hot plate is electrically heated and this plate is divided into two parts: an outer or guard section or "ring" and an inner "measuring" section. The energy supplied to the measuring section is measured and the amount, together with the temperature difference through the specimens and their thickness and area indicates the conductivity of the material tested. The guard ring is kept at the same temperature as the measuring section and serves to diminish any error due to edge effect. The hot plate apparatus now in use at the National Bureau of Standards has plates 8-inches square, and the measuring section is 4-inches square. This apparatus accommodates specimens 8-inches square and up to 1-1/4-inch thick.

Larger apparatus, with plates up to 3-feet square, has been used at the National Bureau of Standards and in other laboratories.

The apparatus and test conditions are described in "The Thermal Conductivity of Insulating Materials" and in "Standard Method of Test for Thermal Conductivity of Materials by Means of the Guarded Hot Plate", both of which are referred to in Section IX. The latter paper was sponsored by a joint committee representing the American Society of Heating and Ventilating Engineers, the American Society for Testing Materials and the American Society of Refrigerating Engineers.

Composite walls are tested in the shielded hot box apparatus. This apparatus accommodates specimens of walls 5-feet wide, 8-feet high and up to a foot or more in thickness. The apparatus consists essentially of three boxes, each with one side open to be placed against the test wall. The cold box, cooled by a refrigerating machine, is placed against one side of the wall and the hot box, containing the metering box, is placed against the other side. The metering box is heated electrically and the energy flow required is measured and, with the area and the temperature difference through the specimen, indicates the conductance of the specimen. The hot box is heated electrically and kept at the same temperature as the metering box to prevent heat transfer to or from the metering box except through the specimen wall.

Tests of insulating materials are ordinarily undertaken at the National Bureau of Standards at the request of Government agencies interested in making purchases, and the test results on particular makes of material are reported only to the requesting agencies. Research, other than that made at the request of Government agencies, is undertaken only when suitable facilities are not available elsewhere because the Bureau does not enter into competition with private laboratories.

IX. References

The following publications contain information of possible interest on insulation and fuel saving.

"The Thermal Conductivity of Insulating Materials" by M. S. Van Dusen, Transactions of the American Society of Heating and Ventilating Engineers, Volume 26, 1920, page 385.

The "Guide", handbook of the American Society of Heating and Ventilating Engineers of 51 Madison Avenue, New York, N. Y.

"Building Insulation" by P. D. Close, published by The American Technical Society of Chicago, Illinois.

"Thermal Conductivity of Building Materials" by Frank B. Rowley and Axel B. Algren, Bulletin No. 12, University of Minnesota, Minneapolis, Minnesota.

"Heat Transmission Through Building Materials" by Frank B. Rowley and Axel B. Algren, Bulletin No. 8, University of Minnesota, Minneapolis, Minnesota.

"Mechanism of Heat Flow in Fibrous Materials", by J. L. Finck, National Bureau of Standards Research Paper No. 243, available from Superintendent of Documents, Washington, D. C. at 5 cents each, (stamps not accepted).

"Fiber Boards; Their Manufacture and Use" by Charles G. Weber, Industrial and Engineering Chemistry Magazine, 27, 896-898 (1935). (Reprints obtainable from the author, National Bureau of Standards, Washington, D. C.)

"Thermal Conductivity of Wood" by J. D. MacLean, (ASHVE Transactions Vol. 47, 1941, p. 323).

"Heat Transfer Through Single and Double Glazing", by M. L. Carr, R. A. Miller, Leighton Orr, and Alan C. Byers, (ASHVE Journal Section "Heating, Piping and Air Conditioning" 1938).

"Aluminum Foil Insulation", National Bureau of Standards Letter Circular No. 535.

"Thermal Test Coefficients of Aluminum Insulation for Buildings", by Gordon B. Wilkes, F. G. Hechler, and E. R. Queer, (ASHVE Transactions Vol. 46, 1940).

"Reflective Insulation" by Gordon B. Wilkes, "Industrial and Engineering Chemistry" Volume 31, No. 7, p. 832, July, 1939.

"Air Infiltration Through Windows", by E. F. Coleman and R. H. Heald, National Bureau of Standards Report BMS 45, Available from Superindentent of Documents, Washington, D. C. Price 10 cents. (Stamps not accepted).

Federal Specification LLL-F-321b "Fiberboard; Insulating" Available from Superintendent of Documents, Washington, D. C., Price 5 cents. (stamps not accepted).

"Standard Method of Test for Thermal Conductivity of Materials by means of the Guarded Hot Plate" (Tentative) Published by the American Society of Heating and Ventilating Engineers of 51 Madison Avenue, New York, N. Y.

"Heat Insulation as Applied to Buildings and Structures" by Professor E. A. Allcut, College of Mechanical Engineering, University of Toronto, Toronto, Canada.

"Insulating Farm Buildings" by W. J. Promersberger, Bulletin 325, Agricultural Experiment Station, North Dakota Agricultural College, Fargo, North Dakota.

"Moisture Condensation in Building Walls" by Harold W. Woolley, National Bureau of Standards Report BMS 63, Available from the Superintendent of Documents, Washington, D. C. at 10 cents each, (stamps not accepted).

"Accumulation of Moisture in Walls of Frame Construction During Winter Exposure" by C. G. Weber and R. C. Reichel, National Bureau of Standards Report BMS 93, Available from Superintendent of Documents, Washington, D. C. Price 10 cents (stamps not accepted).

"Simultaneous Heat and Vapor Transfer Characteristics of an Insulating Material" by F. G. Hechler, E. R. McLaughlin and E. R. Queer, (ASHVE Journal Section, "Heating, Piping and Air Conditioning", September 1942, p. 574.)

"Vapor Transmission Analysis of Structural Insulating Board" by Rowley and Lund, Bulletin No. 22, University of Minnesota Engineering Experiment Station, Minneapolis, Minnesota.

"Treatment of Sawdust Insulation for Protection against Decay, Insects, Animals and Fire", Forest Products Laboratory, Madison, Wisconsin.

"Notes on Domestic Fuel Oil Conservation", National Bureau of Standards Letter Circular No. 738.

"Conservation of Fuel" by Frank B. Rowley, Richard C. Jordan, and Clarence E. Lund, Bulletin No. 20, University of Minnesota, Minneapolis, Minnesota.

"Home Insulation with Mineral Products -- Conservation of Fuel for War" - U. S. Bureau of Mines, Information Circular No. 7220.

"Domestic Heating and Air Conditioning", National Bureau of Standards Letter Circular No. 649.

"Solar Heating of Various Surfaces" by H. V. Cottony and R. S. Dill, National Bureau of Standards Report BMS 64, Available from the Superintendent of Documents, Washington, D. C. Price 10 cents each, (stamps not accepted).

"Effect of Ceiling Insulation Upon Summer Comfort" by T. D. Phillips, National Bureau of Standards Report BMS 52, Available from the Superintendent of Documents, Washington, D. C. Price 10 cents each, (stamps not accepted).

"Policy of the National Bureau of Standards with Regard to Tests for Agencies Outside the Bureau", National Bureau of Standards Letter Circular No. 544.