# INSULATION IN HOME CONSTRUCTION

Senior Thesis

Walter A. Gustafson '32

Grade A.

Decidedly worth while.
A study worth going
into more extensively.
Well arranged and
well presented

1932

P.W.P.

TABLE OF CONTENTS

Introduction Page 1.

Why insulation should be used in home construction Page 4.

How insulation materials are tested Page 10.

How Fir-Tex is made Page 14.

Insulation as a plaster base Page 18.

How to make the simple calculation of the insulating value of a wall Page 20.

How various types of wall construction may be compared Page 24.

Summary and Observations Page 29.

Bibliography Page 31.

# INSULATION IN HOME CONSTRUCTION

## Introduction

Twenty years ago the insulation of a home against heat and cold was possible only at a very high cost. Since that time many inventions and discoveries have been made which have added to our comfort and decreased the cost of insulation. At present there are some forty insulating materials offered on the market for building construction, ranging in price from moderate to very expensive fire-proof insulators. With the introduction of the cheaper insulating materials a change in the form of building construction has evolved. The old idea in construction was to build a wall as wide as possible in order to cut down the heat loss. With the application of scientific principles to construction, the new form of construction is to build a wall that will give the highest insulation value at the lowest cost.

A great many men in the lumber industry seem to think that insulating materials are competitors to the industry. On the contrary, the use of insulating materials in wall construction requires more lumber than do walls uninsulated and consisting of brick, stucco, or some other material. The lumber interests must unite with the insulation interests in order to further the cause of each. If the industry wishes to buck insulation, its results will prove fruitless, because insulation is based on scientific principles. Lumbermen should understand these principles and adopt merchandising methods that will further lumber and insulation interests.

Let us look to nature and see a few insulation principles. Nature has provided so many forms of insulation, the more remarkable because we have become so accustomed to them that we never think of them as insulation. Trees are insulated by means of their covering of bark which constains millions of tiny air cells. In northern climates these air cells protect the tree from destructive frosts. In tropical climates these same air cells prevent the hot sun from drying out the life-giving sap so necessary to the tree's existence.

A polar bear dives into icy, cold water to catch fish and seals for food. He enjoys his swim because the cold does not bother him. Nature has given him a wonderful coat of fur which insulates his body against the deadly cold and keeps his body heat within. Every single hair in his great shaggy fur coat is in reality a tiny hollow tube containing many minute air cells. It is these tiny cells which prevent the passage of heat and cold and enable him to live comfortably in the frozen wastes of the far north.

We see the same principle applied by nature for the protection of sheep and goats and other animals which must survive in cold climates.

The Eskimo lives in an igloo built from blocks of packed snow which is full of tiny air cells, and he wears a suit of furs.

In equatorial countries, the natives roof their huts with a heavy thatch of cane and fibrous grasses which provides air cell insulation, and the traveler in the tropics wears a sun helmet made from pith or cork to insulate his head and prevent sunstroke.

In modern communities we find insulation being discussed in relation to every building, from the modest bungalow to the mighty skyscraper. The retail lumberman, the architect, the contractor, and the prospective home builder should have a knowledge of the principles of insulation and should be able to compare different types of wall construction as to insulating values.

This thesis is presented with the intention to give the principles of insulation as to testing, manufacture, application, and the calculation of insulation values of walls.

## WHY INSULATION SHOULD BE USED IN HOME CONSTRUCTION

Protection from heat and cold is attained through the use of materials having a structure composed of millions of minute air pockets. Where nature stopped in providing inexpensive materials with good insulating properties, human ingenuity has carried on, until today there are forty or more prepared products for use in building construction.

These man-made heat resisting products are built into the walls, floors, and roofs of modern homes either as structural parts of the building or as materials added purely for their insulating value. Although generally they may be installed more easily and economically at the time of building they may also be applied to houses already erected. In fact, insulation has come to play an important part in making comfortable those homes which originally were not constructed to take sufficient account of heat leakage.

If materials with poor insulating properties are used, greater attention must be given to heating the home than otherwise, and more fuel is required. Not only are comfort and health promoted by the proper use of materials with high insulating values, but appreciable savings are made possible. Even in the insulated house however, considerable heat may pass through glass and leak through cracks around openings. Obviously such heat loss is not affected by insulation in walls and roofs. To obtain maximum protection against such conditions, storm windows and doors, as well as calking and weather stripping around all windows and doors, will be found effective.

Although the value of insulation is obvious, the problem for the home builder or home owner is how to obtain maximum effectiveness from the wide assortment of materials available for insulating purposes. He is looking for a product that will give adequate protection with a minimum cost of material and labor.

Methods of application are equally as important as the selection of the material itself.

Economy and comfort are the two outstanding reasons for installing insulation in a home. On cold days uniform, comfortable temperatures are obtained at minimum expense and effort if the house is adequately insulated. On summer days insulation keeps rooms comparatively cool and comfortable.

In cold climates economy is affected through lowered fuel costs and smaller heating plants.

Comfort, although it can not be measured in terms of dollars and cents, is equally important, because frequently it is directly related to health. In the well-insulated house comfort is more readily assured through uniform temperatures and decreased drafts. In winter months the need for frequent furnace firing is lessened. Since insulation enhances the comfort and desirability of a home, it naturally follows that well-insulated homes should represent greater loan and resale values.

### 1. Lower Fuel Costs

When the heating plant of a home is functioning at its very best, only 50 to 75% of the available heat in the fuel is actually transmitted to those parts of the house to be warmed. Some of the heat escapes through the chimney, and some is lost through poor firing.

Other things being equal, the house protected with effective insulation will require less fuel to maintain the same degree of comfort than the house which is without insulation. This fuel saving over a period of a few years usually will pay for the insulating material. Factors that determine the length of this period are (1) the net cost of the material installed and (2) the value of the fuel saved. In localities where the winters are long and severe or where the fuel is expensive, the cost of insulation may be repaid in a comparatively short time - in many instances from two to four years. In climates only moderately cold, however, or where cheap fuel is used, this period will be considerably longer.

The U.S. Bureau of Standards gives the following approximate yearly savings in fuel from insulating the ordinary dwelling. These savings are expressed in percentage of fuel which would have been required for a similar house without insulation or weather stripping, and are based on the assumption that the insulation is applied to both walls and roofs, and that it is not used to replace any other material in the uninsulated structure.

Adding ½ inch layer of insulation saves 20 to 30 %.

Adding 1 inch of insulation saves 30 to 40 %.

2. Smaller Heating Systems

Since insulation reduces the amount of heat needed to maintain comfortable living conditions, it follows that a smaller heating system will suffice in an insulated structure. In the event a hot-water, steam, or vapor system is used, smaller or fewer radiators, and possibly a smaller boiler , may reasonable represent a substantial saving on the part of the owner. This initial saving, which often is applied toward the cost of the insulation, may represent approximately 5 to 15% of the cost of the heating equipment.

With a warm-air system, however, the initial cost of which is usually less than that of the other types, considerably smaller savings will result from a reduction of size of furnace and piping.

In homes where the heating equipment is too small, insulation in the walls and roofs will serve as an effective means of conserving heat, thereby tending to offset the inadequacy of the system.

3. Winter Comfort

Bodily comfort which depends so much upon proper room temperature and proper humidity, may be more readily assured when the walls and roofs of the home are protected with an efficient heat-resisting material. By retarding the escape of heat, insulation makes possible uniform temperatures throughout. Large temperature variations frequently found in the rooms of an uninsulated house are practically eliminated in a well-insulated structure. Moreover, when the house is adequately insulated, properly humidified air may be maintained with little danger from condensation and the consequent marring of walls and ceilings.

Tests made recently at the University of Illinois indicate that with the same room temperature in two houses - one with walls insulated and windows storm-proofed, and the other without such protection - the body would have a greater sensation of comfort in the insulated house. This is explained by the fact that the walls and glass in the insulated house, with their consequent higher inside surface temperature, have a less chilling effect upon the body than the colder surfaces of the uninsulated structure.

4. Summer Comfort

Just as in winter the use of insulation retards the passage of heat from the inside to the outside of the house, so in summer it resists the inward flow of heat. That is why it is easier to maintain comfortable temperatures in the well-insulated house during hot summer days than in the non-insulated structure. Numerous experience records show that the adding of insulation has, in many cases, resulted in reducing room temperatures from 10 to 15 degrees below those of the uninsulated house.

5. Air conditioning

The prediction has been made that within a few years the homeowner will make his own weather the year round, furnishing heat and properly moistened air to his home in winter, and cool, refreshing air during the hot summer months. When this time arrives, walls and roofs having high resistance to heat passage will be essential for the economical operation of the cooling equipment. With this in mind, therefore, home owners should seriously consider effective insulation.

6. Reduced Fire Hazard

A cold spell customarily leads to unusual demands on heating facilities. Fires are given full draft and furnaces pushed to the utmost. Unless care is taken, overheating with its consequent danger of setting fire to the house may result. In an uninsulated structure, such hazards are reduced since a sudden drop in outside temperature does not effect correspondingly sudden inside variation.

A few of the insulating materials offered on the market are fire-proof, but they are very expensive. A few are advertised as fire-resistant, but this property should be regarded with skepticism. I have burned several fire-resistant insulation materials with comparative ease.

Types of Insualting Materials

The various insulating materials commonly used in building construction fall into four general classes, namely, (1) rigid, (2) semirigid, (3) flexible, and (4) fill. The names of these types are descriptive of the materials themsleves. A description of the various insulating materials offered on the market would perhaps take volumes, and in this thesis I wish to present just the principles of insulating materials.

## HOW INSULATION MATERIALS ARE TESTED*

The heat losses of a building are of two kinds: (1) the transmission losses through the walls, floors, roof, ceiling and windows, and (2) the infiltration losses through the cracks, crevices, etc., around doors and windows and through solid materials. No concern will be paid to (2).

Coefficients may be determined experimentally by test, or they may be computed with sufficient accuracy when certain physical constants are known. Two test methods shall be discussed briefly.

### 1. Hot-Box Method

The standard method of testing built-up wall sections is by means of the guarded hot-box. It consists of an insulated outer box of about 5' x 5' x 5', and an inner box of 3' x 3' x 3', also insulated. The wall specimen is clamped to the open side of the outer box and in this position must come in firm contact with the edges of the open side of the inner box. The air in the inner box is heated by means of a resistance coil wound on a cubical frame, and the temperatures in the two boxes controlled thermostatically to maintain the same temperature in each. Fans are installed to maintain uniform temperatures in these two spaces with a minimum circulation of air.

The heat transferred through the wall specimen is readily estimated from the heat input of the inner box, and the air to air coefficient of the specimen for still-air conditions determined by dividing this heat loss by the area of

* See Bibliography #1.

the specimen through which the heat passes, the temperature difference of the air on the two sides of the specimen and the number of hours of the test.

2. Nicholls Heat Meter

The Research Laboratory of the American Society of Heating and Ventilating Engineers has developed an apparatus known as the Nicholls heat meter for the determination of the heat transmission coefficients of any type of construction under natural weather conditions. It consists essentially of a plate of bakelite, 2' square and 1/8 inch thick. This plate is equipped with thermocouples which are so constructed as to operate as differential pyrometers. A difference in temperature between the two surfaces of the plate produces a difference in electrical potential between the thermocouples.

The plate is calibrated so that this difference in potential, when measured, can be converted into terms of heat transmission through the plate. In connection with this plate, it is also necessary to use several other thermocouples to give the temperature of the air within the building, the temperature of the inner surface of the wall or roof, the temperature of the plate itself, the temperature of the exterior of the wall or roof and the temperature of the exterior air.

Tests have been conducted with the Nicholls heat meter on many types of wall construction, and the results obtained are in close agreement with the computed values for these same constructions.

If the hot-box method is used, tests are usually run under still-air conditions, which means there was no wind movement during the test over the surfaces of the wall. In practice, some wind movement over the exterior surface of the wall should always be allowed for; hence, still-air coefficients cannot be used in actual work as they do not provide for the normal wind movement over the outside of the building in the locality in question during the heating season. Moreover, still air transmission coefficients can not be corrected to provide for moving-air conditions by multiplying by a constant factor.

It would obviously be impossible to determine the air-to-air transmission coefficients of every type of wall construction in use with the heat meter or the hot-box on account of the great amount of time involved. Hence, the method of computing the coefficients from fundamental constants must be resorted to in most cases, but heat-meter and the hot-box tests can be used to good advantage in checking the accuracy of the computed values.

The Celotex Company uses a flat plate conductimeter a device which measures conductivity most accurately, but I was unable to get a description of the device.

Next to heat resistance, the most important quality of an insulaion material is tensile strength. A motor driven tensile test machine is generally used for this purpose. Two clamps grip a piece of insulation. The lower clamp is geared to a motor, by means of which a load or pull is applied. The upper clamp is attached to a highly sensitive measuring device which accurately records the load required to produce a failure (or break) in tension.

One minor test which is generally performed and which is getting increased importance is the moisture absorption test. Due to the inherent nature or principle of insulation, that of air cells, the capillarity absorption is rather high. The Fir-Tex Company adds a sizing of rosin to lower the moisture absorption of their product. They advertise their product as 99.8 % fibre, and the other .2 of 1 % is accounted for in the sizing.

Practically all insulation manufacturers have completely equipped laboratories for testing and research.

Sound absorption property is the selling point of several of the vegetable fibre insulation materials.

## How FIR-TEX is Made

During Easter vacation it was my privilege to visit the Fir-Tex plant at St. Helens, Oregon. A very courteous guide was sent with me through the plant who explained the various processes to me. However, I was not allowed to take any pictures with my camera. I then proceeded to take a few notes, and the guide informed me that note-taking was not permitted. The description following of the manufacture of Fir-Tex will serve to give the reader a general idea of the process and the principles involved.

Before beginning this description let me go back a moment and review a few fundamentals.

Nature makes the primary or first provision for man's existence. Man has arisen though the ages by improving on nature,and this improvement is the discovery of laws of the universe. The discovery and use of these laws is known as science.

Nature has fabricated the organic chemicals of the earth into a fibrous, strong, useable tree, which man converted first into lumber to house himself against changes of climate and weather.

But Science has gone further now than merely to shape the raw timber as Nature furnished it.

Science has recognized the valuable elements in the texture of wood and has taken them apart from the primitive in which nature has placed them, and put them together into an insulation that carries to a higher degree of effectiveness møany of the qualities of the natural wood, for which the tree was first selected as a superior lumber making material. The fiber of Douglas fir is separated first and then assembled into an insulation of more useable form than was possessed in the first place by the materials that entered the recreative process. The manufacture of Fir-Tex insulation is essentially mechanical, and it is the first step, I believe, into the field of changing wood into a more useable form through mechanical means. Preswood  is now offered on the market - a wood fiber board which has qualities far superior in some particulars to the original wood. We have just started in the field of changing wood by mechanical means into a better product. In the field of changing wood by chemical means we are taking tremendous strides.

Wood fiber insulation evolved through the necessity of finding a use for waste material. Sawmills of the Columbia river region have had a problem concerning the utilization of slabwood. They have looked upon slabwood as a waste and were quite contented and pleased if they could receive some remuneration for it as a fuel. The utilization of slabwood in the manufacture of insulation has provided an economic use for a material which was almost a waste.

The Fir-Tex Company has invested two and a half million dollars in a plant at St. Helens, Oregon for the manufacture of insulation from slabwood. It is an experience of keenest interest to follow the movement of the raw fir material through the big plant, from the moment the conveyor lifts it from the barge, to the time it emerges at the loading shed, 1700 feet away, a finished product.

The Fir-Tex plant is situated on the Multnomah channel of the Willamette slough near St. Helens. Slabwood used is hogged at the Clark-Wilson Lumber Company near Linn. The chips are loaded on barges and pulled by tugs to the Fir-Tex plant, a distance of about 25 miles.

A clamshell derrick lifts the cargo onto a belt conveyor which carries the material into the overhead gallery above a battery of six huge digesters. These digesters are perfectly round in shape and they are continually revolving. They are about 24 feet in diameter and are made of riveted steel plates approximately $\frac{3}{4}$ inch in thickness. They are heated by steam pressure of about 90 pounds pressure and a temperature of 150 degrees Fahrenheit is maintained. Chips are cooked for about 20 hours. Caustic soda and soda ash are used in the cooking process. When the chips are released from the digesters they are little changed in form, the cooking being done to soften the fiber.

The chips are dumped and caught on a screw conveyor which carries them to the hammer shredders. Here the initial process of reducing the chips to their component fiber is begun, and continues without pause - pumping into a new shredder for finer reduction, into a second for still further shredding and finally emerging from the fourth shredder. Then the material goes through two machines which look exactly similar to Jordan machines in the paper making process.

The prepared pulp of fiber is pumped into a head box. The pulp is a mass of interwoven fiber - not parallel and of varying qualities of hardness and softness as in the original wood, but meshed and interwoven. (The complete process is similar to paper manufacture except for the preceding fact.) The pulp enters a machine similar to a paper machine and having a Foudrinier wire. As the pulp flows over the wire it is kept to a thicknesssof about two and a half inches. Then suction pumps begin to work and extract the moisture from the pulp. When sufficient moisture has been removed so that the pulp has a body it goes through a series of roller presses until the material is one-half inch in thickness.

I found a very ingenius rig used for cutting the Fir-Tex into proper sizes. The material is constantly moving. A stationary I beam is placed at an angle across the Fir-Tex , the angle being dependent upon the speed of the material. A suspended saw at right angles to the edge and face of the material travels along the "I" beam and cuts the material without stopping the material. Another very ingenius rig was used for tripping the saw. As the material moves along it moves a roller. When this roller reaches the edge of a piece of Fir-Tex it drops down and tips a small vial of mercury. The tipping of the mercury vial makes an electrical contact wich starts the suspended saw moving along the "I" beam. As the saw finishes its cut it is jigged back automatically and ready for the next cut.

The Fir-Tex then enters a drier. This drier is much like a progressive kiln, lower temperatures at first with a high temperature of about 150 degrees Fahrenheit. Three large retorts supply the heat for the driers. No attention is paid to keeping a correct humidity.

The material emerges from the driers as a dry, full inch thick, insulation and sound deadener. It is then cut into standard or special order sizes, packed in cartons and loaded for shipment. Freight cars are loaded within the warehouse.

The Fir-Tex plant turns out 150,000 square feet of inch thick insulation per day. Thirty men are required per shift, a total of ninety men to run the entire plant. Approximately ten men are skilled and twenty men unskilled. Order, cleanliness, and efficiency characterize the plant.

## INSULATION AS A PLASTER BASE

In the past six or eight years, various insulation materials have been offered on the market which may also be used as a plaster base. Advantages claimed for these products are that they provide insulation as well as a base for plaster. The best sellers in this field are the insulating plaster bases offered by the Celotex Company and the Fir-Tex Company.

Both products are offered in the same size, 18" x 48". Celotex lath is 7/16" thick and Fir-Tex is ½" thick. Both products have beveled shiplap joints.

Most people are skeptical as regards the adhesiveness of plaster to these insulating materials. It truly is surprising how well plaster will adhere to such materials. Scientific tests prove that plaster applied to this type of lath forms a bond of amazing strength and tenacity. As an example, a disc may be set in the wet plaster of about five inches in diameter. When the plaster has thoroughly dried, the disc will support a dead weight of 800 pounds. Both Celotex and Fir-Tex use samples of plaster applied to a piece of insulation material to sell the public on the adhesive property of their products and plaster. Both companies insist on the use of galvanized wire mesh bent into the angles on all interior angles, and on all exterior angles metal corner bead should be used, both to be secured by nailing or stapling.

The advantages of insulation as a plaster base over wood lath are as follows:

1. Plaster does not crack, loosen, or fall.
2. Lath marks never can appear.
3. No heat leakage as between wood lath.
4. Lath covers a wall area of six feet with one lath making for less labor cost.
5. Joints need not be stripped.
6. Increased insulation.
7. Frequent redecoration is not required.

The insulation value of an insulator used as a plaster base is not as high as if the insulation were not in direct contact with the plaster. I do not know of studies along this line, but I do know that companies do not make a strong selling point of the insulation property of this type of lath.

I believe the strong point of these products is that lath marks, common to wood lath walls, do not appear. Every homeowner knows that periodically it is necessary to redecorate walls of plaster over wood lath to cover up the marks which washing cannot remove. These marks indicate non-uniform temperature of wall surfaces caused by heat loss through the spaces between the lath, resulting in the deposit of a greasy film upon the surface plaster. Since heat does not seep through an insulated wall in this way, such marks never appear, and frequent redecoration is not required.

p.20-23 not supplied.

## HOW VARIOUS TYPES OF WALL CONSTRUCTION MAY BE COMPARED

The National Lumber Manufacturers Association has published a handbook entitled the"Cost of Comfort". This handbook is for the use of the architect, retail lumberman, contractor, and prospective home builder. It consists of computations made for the various types of wall construction and their relative heating costs.

I happened upon this book some time ago, and was quite surprised to see how definite cost figures and computations had been made for the various types of wall construction. It was the desire to underatand these computations that caused me to choose insulation as the subject for my thesis.

The Annual Cost of Comfort consists of three figures:

1. Interest on the cost of the wall at 6%.
2. Interest cost of 6%, depreciation cost of 2% on the radiation or heat necessary, a total of 8% for radiation to heat the home.
3. Cost of fuel to offset the heat loss.

In the handbook "Cost of Comfort" the U. S. Department of Commerce figures for retail prices f.o.b. job are used. All heating computations and data are taken from the American Society of Heating and Ventilating Engineers Guide for 1928-1929. All types of construction are compared on exactly the same basis.

I shall give an example for a home in Portland, Oregon to show how the annual cost of comfort may be computed. This home is to have standard lumber construction, and shall be lumber insulated. This means that the construction shall consist of shingles, building paper, sheathing, studding, sheathing, furring strips, wood lath and plaster.

The detailed costs per 100 square feet is as follows:

| ITEM | Quantity | Unit | Cost Unit | Cost Total |
|---|---|---|---|---|
| Materials | | | | |
| Studs | .068 | M bd.ft | $42.67 | $2.90 |
| Outside sheathing(1"x6"shiplap) | .120 | " | 49.11 | 5.89 |
| Inside sheathing(1"x4" D&M) | .120 | " | 37.41 | 4.49 |
| Shingle strips and furring1"x2" | 225. | ft. | .01 | 2.25 |
| Shingles | 1. | sq. | 5.92 | 5.92 |
| Nails | 13.3 | lbs. | .04 | .53 |
| Building Paper | 110. | sq.ft. | .003 | .33 |
| Wood lath | .161 | M | 8.86 | 1.43 |
| Gypsum Plaster | 151. | lbs. | .01 | 1.51 |
| Sand | .133 | cu.yds. | 3.00 | .40 |
| Hydrated lime | 32. | lbs. | .01 | .32 |
| Keene's cement | 17. | " | .02 | .34 |
| Shingle stain | 1. | gal. | 1.87 | 1.87 |
| LABOR | | | | |
| Carpemter's time | 10.1 | hr. | .96 | 9.70 |
| Carpenter's helper | 3.47 | " | .47 | 1.63 |
| Lather's time | .9 | " | 1.22 | 1.10 |
| Lather's helper | .16 | " | .47 | .08 |
| Plasterer's time | 2.8 | " | 1.45 | 4.06 |
| Plasterer's helper | 1.9 | " | .73 | 1.39 |
| Painter's time | 1.9 | " | .97 | 1.84 |
| Foreman's time | 1.57 | " | 2.50 | 3.93 |
| TOTAL | | | | $51.91 |

Assume that this home has 2,000 square feet of wall.
Then, interest on the cost of 2,000 sq. ft. of wall equals 20 x $51.91 x .06 equals $62.29 (Number 1 of annual cost)

Heat loss per square foot per hour, per degree difference according to the Guide(1928) of American Society of Heating and Ventilating Engineers for wood shingles over exterior siding, studs, interior sheathing, wood lath and plaster is .122 B. T. U.s.

Cost of hot water radiation needed to offset heat loss through 2,000 sq. ft. of wall area during extreme weather conditions (80 degrees temperature difference) at $1.00 per square foot of radiation installed, estimating radiator efficiency at 150 B.T.U.s per hour per square foot is:

$$\frac{2{,}000 \times .122 \times 80 \text{ degrees} \times \$1.00}{150} = \$130.13$$

8% times $130.13 = $10.41 (No. 2 of annual cost)

Before the third computation can be made we must consult tables covering temperatures for Portland for the past ten years in order to determine the total hour degrees temperature difference. The table found in the Heating and Ventilating Guide gives us the following information:

For Portland:

| | | |
|---|---|---|
| Average temperature Oct.1 to May 1. | 45.9 | (1) |
| Aver. temp. waking hours (70 degrees minus (1) ) | 24.1 | (2) |
| Hr. degrees temp. dif. waking hors. (3,604 times (2) ) | 86,856 | (3) |
| Av. temp. dif. sleeping hors (60 degrees - (1)) | 14.1 | (4) |
| Hr. degrees temp. dif. sleeping hrs. (1,484 times (4)) | 20,924 | (5) |
| Total hr. degrees temp. dif. ( (3) plus (5)) | 107,780 | (6) |

From step six we shall use the figure 107,780 for the total hour degrees tmperature difference for this problem.

Then we may proceed with the third step:

(I was unable to obtain the average cost of sawdust or slabwood and their calorific content so we shall use coal as a fuel.)

The cost of coal needed to offset heat loss through 2,000 sq. ft. of wall area during heating season (107,780 hour degrees of temperature difference) at $12.00 per ton at a 50% heating efficiency or 6,000 B. T. U.s per lb. of coal is,

$$\frac{.122 \times 2,000 \times 107,780}{6,000 \times 2,000} = 2.1915 \text{ tons or } \$26.30. \quad (3)$$

Adding the three calcualtions:

| | |
|---|---|
| Interest on cost of wall at 6% | $62.29 |
| Interest and depreciation on radiation at 8% | 10.41 |
| Cost of fuel to offset heat loss at $12.per ton | 26.30 |
| Total annual charges | $99.00 |

<u>Observation</u>:

Among forty-four different types of walls, standard lumber construction - lumber insulated walls are the cheapest from a standpoint of annual charges. This type of wall has but three competitors in its own class. These three consist of flexible insulation materials which provide double air space, thus accounting for their high insulating value or low conductivity value. The lumber insulated type of wall provides a rigidity in construction far above those consisting of flexible materials. The lumber industry has a selling point here which can not possibly be over-estimated in new merchandising methods, methods which must be employed by the industry.

On the calculations in "Cost of Comfort" the annual charges for a standard lumber construction - lumber insulated are $112.42. An 8" concrete, stucco, plaster on masonry wall has an annual cost of $262.71. There is a saving of $150.29 in annual charges. This annual saving may be capitalized by the capitalization formula $\frac{e}{.0p}$.

$$\frac{e}{.0p} = \frac{150.29}{.06} \text{ (assuming money is worth 6\%)} = \$2,504.83$$

This calculation shows that there is an economic saving of $ 2,504.83 by building a lumber insulated wall over that of an 8" concrete, stucco, plaster on masonry wall.

## SUMMARY AND OBSERVATIONS ON INSULATION

1. The placing of a layer of semi-rigid or rigid insulation halfway between the studding in wall construction increases the insulation value by the added air space. Therefore I would recommend that manufacturers cut their insulation material to a size accordingly. Studding is generally placed with 12", 16" or 24" centers, and the corresponding widths of insulation material should be 10¼", 14¼" and 22¼". Furring strips must be nailed to the studding and insulation nailed to the strips. The added cost of the furring strips is easily offset by the increased insulation value.

2. To determine whether or not the expenditure for insulation is justified, when considered purely as a financial investment, weigh the fuel savings against the cost of insulating. Net insulation cost, like fuel savings is dependent upon a number of factors. Briefly these are: insulation thickness, labor for installing the material, the savings resulting from a reduction in size of the heating equipment, and the savings resulting from the replacement of structural materials with insulation.

3. The use of insulation in increasing thicknesses follows the law of diminishing returns. That is, doubling the thickness does not double the comfort and fuel savings. From an investment standpoint this usually means that ½ inch materials, for example, show a larger percentage of return than thicker ones which cost more. This does not mean that thick insulation is uneconomical. In fact, in many instances,

the additional fuel saving resulting from the use of thicker material is sufficient to justify the additional expenditure.

4. The lumber industry can sell the public on the insulation value of lumber plus the resulting stronger construction. The annual cost for walls of standard lumber construction - lumber insulated is cheaper than all others but two. These two are flexible insulation known on the market as Balsam Wool and Cabot's Quilt. Lumber used as an insulator should be made a strong selling point in the new methods of merchandising which the lumber industry is adopting.

# BIBLIOGRAPHY

1. The American Society of Heating and Ventilating Engineers Guide. 1930.
2. The Cost of Comfort. National Lumber Manufacturers Association, Washington D. C.
3. House Insulation. National Committee on Wood Utilization. U. S. Department of Commerce.
4. Thermal Insulation, April 19, 1927. Bureau of Standards. U. S. Department of Commerce.
5. Cane Fiber Insulation. Celotex Company, Chicago, Illinois.
6. Facts About the Economy of House Insulation. Celotex Company, Chicago, Illinois.
7. Insulating the House. J.L.Finck. U.S. Bureau of Standards. Reprint by Fir-Tex from Good Housekeeping Jan, 1930.
8. The Insulation of the Age. Fir-Tex Company.