MEMBRANES IMPROVE INSULATION EFFICIENCY

Christopher A. Bullock
Caddo Parish Magnet High School

ABSTRACT

It has been determined from extensive tests involving test models and home attics that loose fill and fiber batt insulation does not function as expected by the industry. The reason for this deficiency is current test methods do not accurately predict the magnitude of air infiltration into fiber insulation as used in home attics, radiant heat infiltration into the insulation during summer, or radiant heat loss through the insulation during winter conditions.

The use of (1) moisture permeable membranes over the insulation, and (2) layered membranes between fiber batts to form closed cells in the insulation both dramatically improve the efficiency of the fiber insulation.

The efficiency of this insulation will be improved to an even greater degree if these membranes reflect radiant heat as well as reduce convection air currents.

Extensive tests have also been conducted which show that if moisture permeable membranes are used over fiber insulation, the moisture content of the insulation will be reduced.

MEMBRANES IMPROVE INSULATION EFFICIENCY

Christopher A. Bullock
Caddo Parish Magnet High School

INTRODUCTION

This research study of insulation is unorthodox in that it was started as a science fair project when this researcher was in the fourth grade and knew nothing of insulation other than that the thermal efficiency of glass fiber insulation was supposed to be 1/3 that of polyurethane foam insulation. It was found that this is not the case.

The project took on a more serious nature when as an eighth grade student, this researcher's work was reviewed for approximately one year by a group of seven engineers with a local public utility company at which time research was supported in the form of reviews and a research grant by the utility company.

AIR INFILTRATION

The original test in this study was an attempt to show that one inch of polyurethane was thermally equal to three inches of fiberglass insulation. One box was built of each insulation with no backing using two inch by two inch wood around the edges to make the boxes structurally sound. Twenty-five ice cubes were placed in each box. The two boxes were placed in a garage near an electric clothes dryer outlet. The dryer was turned on and temperatures were measured inside each box using dial type photographic thermometers. The temperature inside the box with polyurethane ranged between 52 °F to 58 °F while the temperature inside the box with fiberglass ranged between 81 °F to 88 °F. This showed that the insulations were not equal.

The next phase in this project was to measure temperature in and under insulation in houses. Hundreds of measurements were made on several homes and typical examples are discussed below. One of the tests was conducted when the outside air temperature was 30 °F, the attic temperature was 33 °F, and the temperature above the sheet rock and ten inches deep in the insulation was 42 °F. The temperature inside the home near the sheet rock ceiling was 80 °F which is a 38 °F drop through the one-half inch sheet rock. This proved that the sheet rock was doing most of the insulating and the ten inches of insulation in the attic was of very little benefit.

A two mil membrane of polyethelene was installed between two rafters of this home over the existing insulation. Temperatures were checked at various depths with a digital trendicator. There was a substantial improvement in the efficiency of the insulation when a membrane was installed. During the following summer, temperatures were checked when the attic temperature was 125 °F. Without a membrane over the insulation, the temperature next to the sheet rock was 114 °F or an 11 °F drop through the insulation. The temperature next to the sheet rock inside the room was 82 °F or a 32 °F drop through the sheet rock, again showing that the insulation was of very little benefit and only 1/3 as effective as sheet rock. Between the rafters, under the insulation with a membrane, the temperature was checked and found to be 92 °F next to the sheet rock or a 33 °F drop through the insulation and a 10 °F drop through the sheet rock, showing that the insulation with a membrane was three times as effective as sheet rock.

In order to more accurately measure temperature in and through the attic insulation, a home simulator was constructed. The top of the simulator was divided into four 15 inch by 19 inch cells in order to compare various insulation systems with and without membrane. In all cases the efficiency of the insulation was improved as membranes were placed over the insulation and horizontally through the insulation.

The increase in efficiency of the insulation which is protected by membranes is due to a decrease in heat induced natural convection in the fiber insulation. This phenomenon is contrary to current accepted concepts of insulation but was observed by Kenneth E. Wilkes, Ph.D. of Owens Corning Technical Center and is described in his report entitled Thermal Performance of Residential Attic Insulation. This convection was indicated by heat flux transducers under the insulation, a lack of uniform temperature at the top of the insulation as measured by an array of thermocouples, and actual convection currents above the insulation photographed with an infrared camera. Dr. Wilkes states that many of these conditions are contrary to theory and that theories have not been found which apply to the open top surface such as fiber insulation. This study, even more than Dr. Wilkes' study, indicates that the convection currents and air infiltration into fiber insulation is much more serious than previously expected.

RADIATION

In mid January, 1985, several perforated polyethelene films became available for tests. This material uses TiO_2 as the white pigment. The unique advantage of this is that the titanium in the pigment reflects radiant heat. Three tests were conducted to evaluate this new membrane. Tests number 1 and 2 used the home simulator used in previous tests to compare the white material to the clear membrane. These data clearly showed an improvement if the white material is used. It is hypothesized that radiant heat was being reflected back into the insulation, thus addressing radiant heat loss as well as convection heat loss.

Test number 3 was conducted using four-six inch square, three-1/2 inch deep cells with 1/2 inch sheet rock under the insulation. This test used 3-1/2 inches of "R" 11 insulation in each cell with no membrane over one cell; clear two mil polyethelene over one cell; white perforated polyethelene over another cell; and aluminum foil over the fourth cell. The temperature in each cell next to the top of the sheet rock was observed throughout this test and, in all cases, the temperature under the white material and the aluminum foil was the same ± 1 °F while the temperature under the clear membrane and the insulation only was significantly lower. It was determined from these tests that:

1. The white perforated polyethelene material is as effective in reducing convection heat loss as the clear material.

2. The white perforated material is as effective in reducing the radiant heat loss as aluminum foil.

DERIVATION OF THERMAL CONDUCTIVITY (K) AND THERMAL RESISTANCE (R)

To conduct tests to determine (R) and (K) values, the simulator described earlier was modified. A 110 volt thermostat was placed inside the simulator. The thermostat was attached to a two outlet plug. To this plug was attached a calibrated 4750 Btu electric heater and a clock. The heater remained inside the simulator and the clock was placed outside the simulator so as to measure the time the heater was on over a period of days. The outside walls and bottom of the simulator were then insulated with four (4) inches of spray applied polyurethane foam insulation. This test equipment was then placed inside a 35 °F food cooler. The temperature inside the box was 72 °F. The recorded data and the "R" and "K" derivation calculations are presented on Table I.

As can be seen, the energy usage reduction and economic savings are substantial if membranes are used in conjunction with fiber insulation. In fact, only one-third as much heat is lost through an attic if insulation and two membranes are used as there is using our current technology. However, the tests do need to be repeated using: (1) larger test boxes; (2) various thicknesses of insulation; (3) more membranes; and (4) at various differential temperatures.

Derivation Of In Place "R" And "K" Values

		Units	7 Inches Insulation Only, No Sheet Rock	7 Inches Insulation Over Sheet Rock	1 Membrane Insulation Over Sheet Rock	2 Membranes Insulation Over Sheet Rock
①	Time Heater On For 7 Days	Hr.	9.5	6.82	6.07	5.82
②	Time Heater On For Loss Through Insulation ① - 5.33 Hrs. *1	Hr.	4.17	1.49	.74	.49
③	Heat Loss Through Insulation ② x 4750 Btu	Btu / 7 Days	19807	7077	3515	2327
④	Heat Loss Through Insulation ③ /(168 Hr. x 7.8 Ft²)	Btu / Hr x Ft²	15.16	5.40	2.68	1.77
⑤	In Place Thermal Conductivity "K" (④ x 7 in.)/35°F	Btu x In. / Hr. x Ft² x °F	3.03	1.08	.53	.35
⑥	In Place Thermal Resistance 7 inches/ ⑤	In. / K	2.3 *2	6.48	13.05	19.7

*1 5.33 hr. = time heater on for heat loss through walls and bottom of box.
*2 Published "R" Value = 22.

Table I