One of the Problems of The Air-Conditioning Engineer

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After many years of development, air-conditioning for the home, the office, or the factory is an accepted fact. Within recent years this industry has been expanding rapidly; in the movie, the restaurant, the hotel, the store, the train, the office, the factory, and now in the home. This discussion relates principally to a problem arising from the faulty design and construction of winter air-conditioned homes which is causing much grief and needless expense for the home owner.

By adding special types of heat insulating materials to the outside walls and ceiling or roof structures, and by the use of weather strips, storm windows and doors, and a tighter construction to minimize the infiltration of air, houses are being constructed to better keep the heat out during hot weather and keep it in when outside temperatures are low. Moisture is also added for comfort and health.

A few elementary facts relating to the physics of heat and of water vapor are necessary for a correct understanding of the problem.

Heat tends to flow from higher to lower temperature areas and seek a common temperature level. It does this in one or all of three ways, by radiation, by convection, and by conduction. Suitable types of heat insulating materials tend to impede the flow of heat by conduction and convection, while other types of materials reflect the radiated heat. Loose, fibrous, or granular insulating materials, and such materials in the form of a blanket or insulating board, will impede the flow of heat by conduction and convection, and certain insulating materials having polished surfaces reflect radiated heat as a mirror reflects light.

Air tends to flow from higher to lower pressure areas carrying with it the heat of the agitated air molecules, unless prevented by an effective barrier.

Water vapor, like water, also tends to seek its level and, like water, will flow from higher to lower levels or pressures unless prevented from doing so by an effective barrier.

Many kinds of materials that will prevent the flow of air will not materially impede the flow of heat, and what is even more important, many kinds of materials that act as effective barriers to the flow of air and of heat will not stop the flow of water vapor.

Water vapor is always present in the atmosphere. Room air in a dwelling will usually have a higher vapor content and pressure than the outside air due to evaporation from water pans over radiators and from cooking and body moisture.

Adding heat to air containing water vapor, without the addition of vapor, will reduce the relative humidity. Removing heat will have the opposite effect, increasing the relative humidity until the air has become saturated and its temperature has fallen to the dewpoint temperature. As the temperature is caused to fall below the dewpoint temperature, precipitation of moisture from the air will take place and will continue so long as temperatures below the dewpoint temperature are maintained.

Adding water vapor to unsaturated air without changing the temperature will increase the relative humidity and the dewpoint temperature, and removing it will reduce them.

Air containing a certain amount of water vapor can be brought to the saturation point or 100 per cent relative humidity in either of two ways, by adding water vapor or by reducing the temperature.

When the temperature of water vapor is reduced below the dewpoint temperature, which is the saturation point of 100 per cent relative humidity, condensation and precipitation of moisture takes place. During fairly cold weather some of the materials in wall, ceiling or roof structures will have temperatures below the dewpoint temperature of the inside air. Unfortunately, ordinary construction methods do not prevent the infiltration of moisture through walls and ceilings to those materials having temperatures below the dewpoint where the vapor will be condensed, often forming frost and ice, staining walls and ceilings and causing rot and decay at the same time making relatively ineffective the heat insulating qualities of wall and ceiling materials.

Vapor condensation does not often take place in the walls, ceilings and roof structures of buildings of ordinary construction, having no air conditioning, as the relative humidity of the inside air is usually low, seldom more than 15 per cent in cold weather, and wall and ceiling structures permit leakage of heat that keeps the temperatures of structure materials above the dewpoint temperature, and allows some infiltration of air and ventilation that carries off water vapor that otherwise would be precipitated.

Air at ordinary room temperature of 70° F. and relative humidity of 40 per cent, frequently attained in winter air-conditioning, has a relatively high dewpoint temperature.

Heat insulation added to walls and ceilings of ordinary construction will raise the temperatures of the inside wall and ceiling surfaces and lower the temperatures of the outside surfaces with the result that the dewpoint temperature will often lie within the wall structure and sometimes within the heat insulating material itself with resulting condensation of moisture. A recent experience with this problem will be referred to.

In January of this year one of a number of modern air-conditioned homes in East Lansing, Michigan, built within the last two or three years, was inspected. It was a six room two-story house of wood frame and stucco exterior and wall board and plaster interior, of ordinary construction except for rock wool insulation above the ceilings of the second floor rooms and between the studs of the outside walls. The house was equipped with storm windows and doors and with weather strips, and was tightly and snugly built to prevent the loss of heat from the infiltration of air through walls and window and door frames. Room temperature of 70° F. and relative humidity of 40 per cent were maintained.

But the architect had failed to provide against the flow of water vapor through the wall and ceiling structures into the insulating materials. Condensation was taking place and ceilings of the second floor rooms and the lower parts of the outside walls of the first floor were wet; so wet that the ceilings were warped and sagging and stained, and in places had pulled loose from the ceiling joists. The first floor walls were badly stained. The house was rapidly deteriorating. The owner had complained to the architect who could suggest no remedy.

The situation just described is typical of all too many modern, insulated, air-conditioned homes built in recent years. It represents a problem generally prevalent in the northern states where winters are severe and bring low temperatures of long duration. The subject within the last few years has received considerable attention by investigators of college and other research laboratories, and particularly by Mr. L. V. Teesdale, Senior Engineer of the Forest Products Laboratory of Madison, Wisconsin, in cooperation with the University of Wisconsin.

The solution of the problem appears to be a comparatively simple one; stop the flow of vapor into the walls and ceiling structures. To accomplish satisfactory winter air-conditioning in the homes requires not only that air flow and heat flow be minimized or prevented, but as is evidenced by experiences such as has been described, the vapor flow must be stopped.

This cannot be accomplished with such porous insulating materials as rock wool, mineral wool and other types of loose or packaged insulation or with the various kinds of fibre board insulation.

Reflective insulations represent positive correctives of moisture condensation, and at the same time furnish the necessary resistance to heat leakage and air infiltration. This form of heat insulation can best be applied in the outside walls between the studs and under the attic floor between the ceiling joists.

Where other forms of heat insulations are used it will be necessary to place the vapor seal inside of the heat insulation as near as practicable to the inner wall surfaces. A good grade of building paper will tend to impede the flow of vapor but not nearly so effectively as the reflector types of heat insulation. Vapor which readily flows through ordinary plaster will be retarded somewhat by paint or other like surface treatments. For the homes originally built without special heat insulation and later insulated with rock wool or similar fibrous or granular insulation blown into the walls between the studs and over the ceilings between the ceiling joists, two coats of aluminum paint applied to the inside surfaces of outside walls and ceilings has proven to be most practicable and permits of usual methods of wall decoration.

Experience has not yet shown a perfect vapor seal. Reflective types of insulation seem to be the most nearly perfect. Ventilation of attic and wall spaces outside of the heat insulation should be provided to carry off any vapor that might get through the insulation and otherwise condense, form frost and ice and ultimately cause all of the troubles resulting from a leaky roof.

Heat insulation and air-conditioning are fine, but the effective vapor seal is a necessary concomitant.