Condensation of moisture in farm buildings that house livestock has always been a problem in the winter in the colder portions of the country and is responsible for much of the upkeep expense on these structures. The problem is due to the high humidity (high moisture content) of the air in structures housing animals. Tightly constructed well-built structures are most likely to be affected, since they allow less exchange of outside air for the warm moist inside air than would occur in loosely built structures. The condensation of the atmospheric moisture on and in the walls of barns and other structures in cold weather can and does constitute a nuisance that frequently leads to serious consequences, most damaging of which is the rotting of the wall structure.

The bodily functions of the animals themselves account for the high moisture content of the air in livestock barns. In dairy barns, for example, the animals contribute a large amount of water vapor to the air through their pores and by breathing, and there are numerous other sources, such as manure, urine, drinking water, and feed. It has been estimated that a milch cow of average weight will give off 12 to 18 pounds of moisture per day or 1/2 to 3/4 pound per hour. As saturated air at 45° F. (to take a temperature commonly considered to be best in the dairy barn in winter) will hold only about 1/2000 of a pound of water vapor per cubic foot it can be seen that a few cows could very quickly saturate the air in a barn if there were no means of escape for the moisture and if this temperature were maintained.

Since it is the added humidity in the barn that creates the conditions causing condensation, obviously all possible means of lowering indoor humidities should be considered. Ventilation of the spaces where animals are housed lowers the humidity, but inasmuch as it lowers the temperature as well, it has its limitations. Preheating the air used for ventilation helps when and if this is practicable.

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1Original report published 1940.
2Maintained at Madison, Wis., in cooperation with the University of Wisconsin.
Ventilation of the wall structure itself by special construction helps to remove moisture entering the wall, but this has not always proven a practicable measure.

On the basis of present information, the most positive and least expensive method of preventing condensation within the wall structures is the use of vapor resistant barriers at or near the inner face of the wall. Vapor barriers, however, will not prevent condensation upon the inside surface of a barn wall.

The Forest Products Laboratory has been making tests on the vapor resistance of various materials used in building construction and also on many materials that might be used for vapor barriers. Although these tests are still under way and have not covered all possibilities, enough information is available to permit the selection of a number of materials that are highly resistant to the passage of water vapor. Among these are: (1) light weight asphalt roll roofing materials; (2) asphalt impregnated and surface coated sheathing paper, glossy surfaced, weighing 35 to 50 pounds per roll of 500 square feet; (3) laminated paper made of two or more sheets of kraft paper cemented together with asphalt, 30-60-30 grade; and (4) double-faced reflective insulation mounted on paper.

None of the materials listed are 100 percent resistant to vapor transmission, but they serve to reduce the amount of vapor entering the wall to the point where any that does enter can escape outward through the outer sheathing without causing damage. Painting the inner lining of the wall with two or more coats of asphalt or aluminum paint will also be helpful, though these coatings are not as effective as the other barriers mentioned. Furthermore, paint coatings do not offer protection where numerous cracks or crevices occur in the surface of the inner lining. Coatings would be more effective on plywood or similar sheet materials that have few joints than on standard lumber.

Barriers as suggested for the side walls should also be considered for installation in the ceiling over the stalls, because of the inevitable collection of moisture at this point if this part of the barn is at all tight.

In most cases installation of vapor barriers in walls can best be done when the wall is constructed.

In barns already constructed with simple walls that have only studs with sheathing or sheathing and siding nailed on the outside the vapor barrier should be placed on the inner face of the studs. (See fig. 1.) Barriers installed on the inner face of the sheathing between the studs would result in condensation on the surface of the barrier paper, which would run down and add to the decay hazard at the plate. Installation of barriers on the inner face of the studs, which is proper in this case, calls for some form of protection of the barrier paper, such as a lining of boards or sheet material to prevent tearing of the barrier, which would, of course, nullify its moisture stopping properties. The barriers should be installed under such protective boards or sheet materials as shown in figure 1.
In barns already constructed with an inner lining in place the barrier would have to be placed on the exposed face of the inner lining boards. (See fig. 2.) Thus exposed the vapor barrier would be subject to tearing and some resultant loss of effectiveness. It might be protected by nailing wooden strips 1/2 by 2 inches about three inches apart (on centers) over the exposed barrier.

In new walls provided with sheathing or sheathing and siding plus inner lining boards with or without insulation, the vapor barrier should be installed under the lining, as shown in figure 3. It should be pointed out again that an insulated wall has the most need of moisture barriers because of the lower temperatures within the structure of such a wall, and of the moisture holding tendency of the insulating materials.

The functions of vapor barriers and sheathing paper should not be confused. Vapor barrier paper should never be installed over or under the exterior sheathing. The use of sheathing paper on the outer sheathing of a wall is up to the builder, but if used the sheathing paper should be waterproof (to withstand rain driven under the sheathing or siding), windproof (to fulfill its function of keeping out drafts), and permeable to moisture vapor (to allow moisture to escape through the outer wall). The use of a sheathing paper impermeable to moisture vapor will seriously reduce the effectiveness of a good vapor barrier installed in the same wall. Slater's felt and tar paper make good sheathing papers.

Certain seemingly paradoxical facts about atmospheric moisture and its behavior may help to an understanding of the condensation problem:

Vapor movement in an enclosed structure is independent of general air movement, and vapor tends to move to cold surfaces; the greater the difference between the air temperature and enclosing surfaces the greater the pressure of the movement.

Many materials, such as wood, brick, concrete, plaster, etc., are permeable to vapor, even though resistant to liquid water.

Adding insulation to a wall tends to decrease condensation of moisture on inner wall surfaces by decreasing heat loss through the wall and thereby raising the temperature of such surfaces. However, the insulation has the effect of reducing the temperature of the inner face of the outside sheathing and tends to increase the amount of condensation that may collect within wall structures unprotected by vapor barriers.

Insulation does not "draw" water as is sometimes suggested, but it can become wet if condensation develops in the wall. Some kinds of commercial insulation are relatively resistant to water absorption; others are treated to make them resistant to wetting by water. This property, while desirable, does not make these materials resistant to the passage of vapor. Also, water can still collect between the fibers, filaments, or particles of the insulation.
Complete elimination of condensation on windows is more or less impractical. It may be minimized by maintaining lower humidities and by using storm sash, but even these provisions will not entirely prevent condensation in extremely cold weather. Window frames and sills should be designed to drain rapidly to dispose of any condensation.

If you are interested in a more detailed and technical discussion of moisture in farm buildings, write to the Forest Products Laboratory, Madison, Wis., for a copy of Mimeograph 11186, "Condensation Problems in Farm Buildings," a paper presented before the American Society of Agricultural Engineers.
VAPOR BARRIER

PROTECTING MATERIAL (PLYWOOD OR LUMBER)

FIG. 1
APPLICATION OF VAPOR BARRIER TO INSIDE FACE OF STUDS ON A WALL HAVING NO LINING

FIG. 2
APPLICATION OF VAPOR BARRIER TO AN EXISTING WALL HAVING AN INNER LINING OVER THE STUDS

IF SHEATHING PAPER IS USED IT SHOULD BE PERMEABLE TO VAPOR BUT RESISTANT TO WATER. USE SLATERS FELT OR TAR PAPER.

FIG. 3
APPLICATION OF VAPOR BARRIER TO NEW CONSTRUCTION OF WALLS HAVING INNER LINING

APPLICATION OF VAPOR BARRIER TO NEW CONSTRUCTION OF WALLS HAVING INNER LINING

If sheathing paper is used, it should be permeable to vapor but resistant to water. Use Slaters felt or tar paper.
The following are obtainable free on request from the Director, Forest Products Laboratory, Madison 5, Wisconsin:

- List of publications on Box and Crate Construction and Packaging Data
- List of publications on Chemistry of Wood and Derived Products
- List of publications on Fungus Defects in Forest Products and Decay in Trees
- List of publications on Glue, Glued Products, and Veneer
- List of publications on Growth, Structure, and Identification of Wood
- List of publications on Mechanical Properties and Structural Uses of Wood and Wood Products
- Partial list of publications for Architects, Builders, Engineers, and Retail Lumbermen

- List of publications on Fire Protection
- List of publications on Logging, Milling, and Utilization of Timber Products
- List of publications on Pulp and Paper
- List of publications on Seasoning of Wood
- List of publications on Structural Sandwich, Plastic Laminates, and Wood-Base Aircraft Components
- List of publications on Wood Finishing
- List of publications on Wood Preservation
- Partial list of publications for Furniture Manufacturers, Woodworkers and Teachers of Woodshop Practice

Note: Since Forest Products Laboratory publications are so varied in subject no single list is issued. Instead a list is made up for each Laboratory division. Twice a year, December 31 and June 30, a list is made up showing new reports for the previous six months. This is the only item sent regularly to the Laboratory's mailing list. Anyone who has asked for and received the proper subject lists and who has had his name placed on the mailing list can keep up to date on Forest Products Laboratory publications. Each subject list carries descriptions of all other subject lists.