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CONDENSATION IN BARNS**

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UNITED STATES DEPARTMENT OF AGRICULTURE  
FOREST SERVICE

In Cooperation with the University of Wisconsin

FOREST RESEARCH LABORATORY  
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INSULATION AND VENTILATION PREVENT  
CONDENSATION IN BARNS<sup>1</sup>

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Among the many problems that confront dairymen during severe cold weather is how to keep the cow barn warm, free from drafts, and reasonably dry; the air fresh, clean, and reasonably free from odors; how to prevent freezing of water pipes; and how to prevent excessive moisture from forming in drops on windows, walls, and ceilings. In a tightly constructed, uninsulated barn, with ventilators closed, the animals will throw off enough heat to keep the barn quite warm even in severe weather, but the atmosphere becomes humid and stale, and moisture condensation develops. Dripping ceilings and water running off of windows and walls make unsanitary working conditions, also paint peels off, and woodwork is liable to decay. Opening ventilators to relieve the conditions lowers the temperature below that best for steady high milk production, creates drafts that are unhealthy for the animals, and may cause freezing of water pipes. Most farmers, under such circumstances, cut off all ventilation or compromise by adjusting the dampers in the ventilators to reduce the inflow of cold air to avoid excessive chilling, even at the expense of inadequate removal of the moisture. Obviously, ventilation alone in such a barn is not the answer in correcting the troublesome conditions.

The animals produce the heat that raises the temperature inside the barn above that outside and also produce the moisture that supplies the source of the trouble. Heat is lost through the walls, windows, ceilings, and floors, and by ventilation. Where heat losses are high, less heat is available to warm the air used for ventilation and in consequence the ventilation is reduced below that adequate for moisture removal. If the heat losses can be reduced sufficiently, the heat saved becomes available to warm more air for ventilation without lowering the average temperature of the stable.

It is now possible to design and build a new cow barn with insulated walls and ceilings to minimize heat loss and with adequate ventilation to remove the

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<sup>2</sup>Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

moisture produced during cold weather while at the same time comfortable temperatures are maintained within the stable. Our purpose here, however, is to explain how the same advantages can be obtained in an existing barn.

Let us assume a cow barn in a zone where outside temperatures may drop to  $-20^{\circ}$  F. and where the dairyman wishes to maintain the inside temperature at about  $50^{\circ}$  F. It has been established by experience that to remove the moisture produced, the ventilation system should supply approximately 1,000 cubic feet of air per hour per animal when outdoor temperatures are  $-20^{\circ}$  F. and as much as 4,000 cubic feet per hour per animal when outdoor temperatures are  $30^{\circ}$  to  $35^{\circ}$  F. With this volume of fresh air the relative humidity in the stable will not exceed about 75 percent.

Enough heat must be supplied by the animals to raise the temperature of the incoming air to  $50^{\circ}$  F. and at the same time make up the heat loss through the various exposed parts of the structure. The animals do not supply enough to meet these requirements in an uninsulated barn or where the heat loss through the structure is high but they do supply enough heat to meet these requirements in barns that are adequately insulated.

It is common engineering practice to calculate the heat passage through a combination of materials that comprise a wall or roof and to express the result as the coefficient of transmission, or "U" value. These values make it possible to compare the rate of heat transmission through various combinations of materials and to select those best suited for the purpose. Since these values express heat losses the lower the "U" value the lower the heat loss.

To maintain the required ventilation and hold a temperature of  $50^{\circ}$  F., the "U" value for the walls and ceiling should not exceed about 0.15 and preferably should be less. This assumes average size cows in a barn with all stalls in use. The "U" value for most uninsulated barn walls is about 0.15. A number of typical wall types are shown in figures 1 and 2, and the "U" values are calculated for these walls as shown and with combinations of insulation. In each type of wall the "U" value of the uninsulated wall falls short of meeting the requirement as previously given but with insulation added the "U" value is well below the requirements established for a maximum, that is, below 0.15.

To prevent the sweating of moisture on the inner face of a wall, window, door, or similar exposed surface when the temperature and humidity conditions are as described here would require a "U" value of about 0.18. This value is, of course, below the values of the uninsulated walls. The "U" value commonly used for single sash windows is 1.13; for double (storm) sash windows the value is 0.45. Thus even with storm sash, sweating of moisture may be expected on the inner face of the glass when outdoor temperatures are low though much less than would develop on single sash windows. Doors likewise may have a "U" value higher than 0.18 and may also act as condensing surfaces. Since the objective is to reduce the overall heat loss from the stable as well as to prevent sweating, a lower "U" value than the minimum requirements as given for walls is desirable. This would permit an increase in the volume of air used for ventilation, thus lowering the relative humidity which in turn would reduce the amount of moisture formation on windows and doors.

Some exterior walls are combinations of wall types shown. For example, sometimes a concrete foundation wall will extend 3 or 4 feet above the stable floor so that the frame wall stands on top of the concrete wall. In such construction both walls should be insulated. Where there is a hayloft over the stable and hay over all portions of the stable during cold weather, the hay itself becomes a good insulating material. Ordinarily such a ceiling requires no additional insulation. For portions of the stable not covered with hay and also in one-story barns, the ceiling should be insulated. The equivalent of a 2-inch blanket of insulation will in most cases lower the heat transmission rate sufficiently to prevent moisture forming on the surface but 4 inches of blanket insulation is preferable to obtain minimum heat loss.

Since insulation can generally be forced into a stud space, the use of insulation in frame walls does not as a rule affect the total thickness of a wall. With masonry walls, however, it is necessary to apply the insulation over the interior face of the wall and this means some loss of stable space. One simple method is to attach to the inner face of the masonry wall 2- by 2-inch wood strips 16 inches apart and to install a 2-inch blanket-type insulation between the strips. Tongued and grooved lumber or other suitable materials may be used over the insulation to protect it and to serve as a sanitary wall covering.

Though moisture formation will not develop on the insulated surfaces under the conditions described here, it can collect within a wall not suitably protected with a vapor barrier. Most of the materials used in building construction are permeable to vapor and because of the warmer moist conditions inside the stable than outside, vapor tends to move outward through the lining of the side walls and ceiling. When it strikes the cold exterior sheathing or siding it condenses and gathers as frost during cold months. In warm weather, the frost melts and soaks into the wood and insulation and may lead to decay. Protective measures, fortunately, are both effective and inexpensive.

The most positive and least expensive method known at present is to install vapor barriers at or near the inner face of the wall. Figure 3 shows methods of installing vapor barriers in several types of walls. Vapor barriers should also be installed under the ceiling to prevent vapor passing up into the hayloft or into the roof of one-story barns. This barrier also should be protected by a suitable covering. As an added precaution against condensation in the loft and to keep the barn more comfortable during the summer, continuous screened vents below the eaves and in gable ends are desirable.

Details of workmanship in the installation of moisture barriers are extremely important to prevent water vapor leakage into insulated spaces. Barriers should be lapped only over solid supports and should be carefully fitted around braces and other parts of the structure. Damage to barriers during construction should be repaired before the covering is applied.

The Forest Products Laboratory has been making tests on 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: light weight asphalt roll roofing materials;

asphalt impregnated and surface coated sheathing paper, glossy surfaced, weighing 35 to 50 pounds per roll of 500 square feet; and double-faced reflective insulation mounted on paper. Polyethylene membrane, 2 or 4 mil thick can be used where covered as shown in A of figure 1, and A, B, C, and D in figure 2.

None of the materials listed is 100 percent resistant to vapor transmission, but each serves 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 so effective as the other barriers mentioned. Paint coatings, however, 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.

Many existing barns have wholly inadequate ventilating systems. Proper regulation of stable temperature and relative humidities means that the ventilation system must be of a type that also permits of proper regulation to suit the changing weather condition. Ventilation through open windows or openings through the side walls are generally unsatisfactory, particularly in cold weather. Natural circulation systems can be used if operated through a properly designed and dampered duct system for both fresh and exhausted air. The best results can be obtained where suitable forced-circulation methods are used, using either a motor with variable speed control and a fan of adequate capacity, or multiple fans and motors, to distribute the air through a duct system designed to avoid drafts on the animals. Thermostats can be used to make the system automatic and independent of changes in outside temperatures and wind velocities.

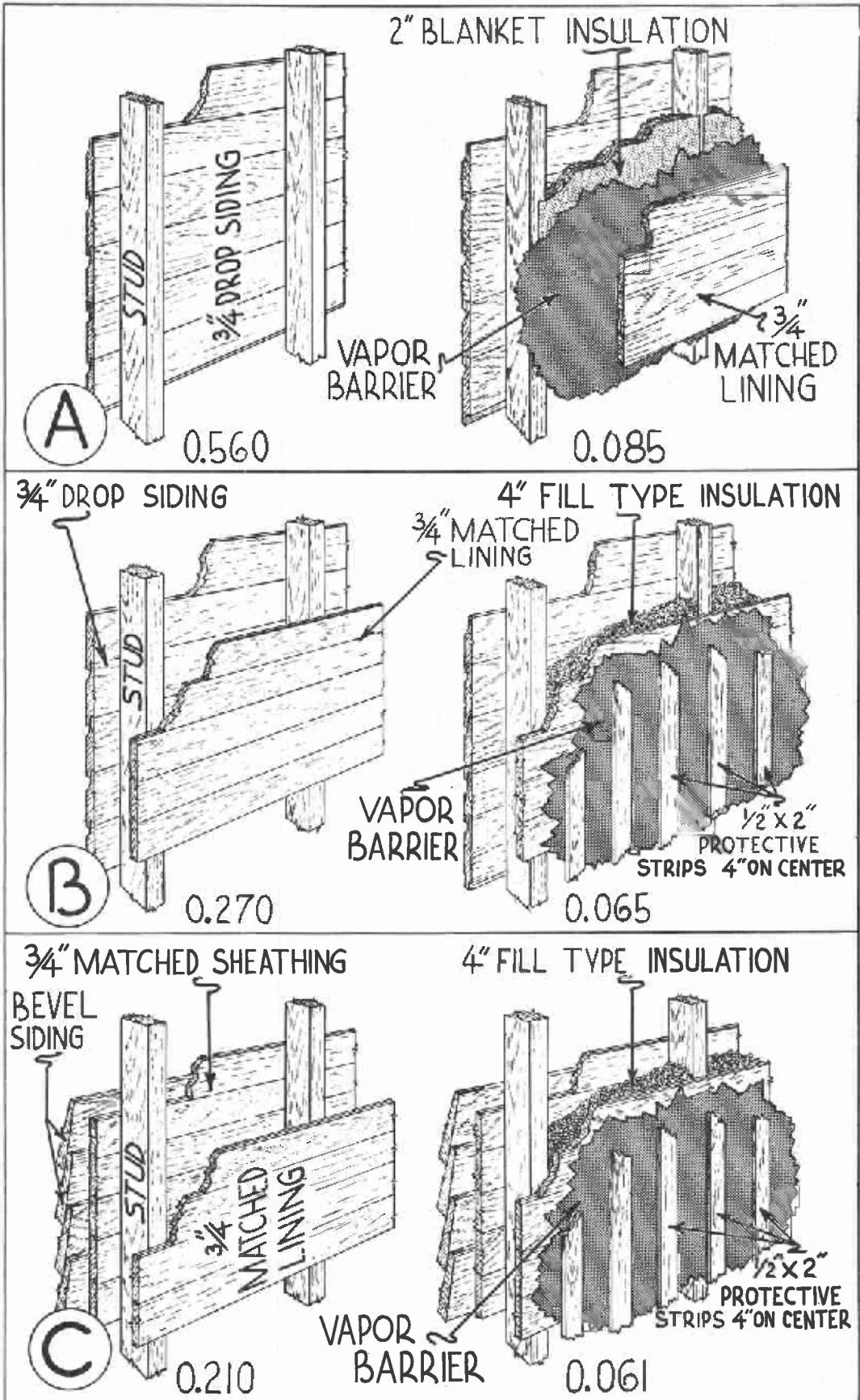


Figure 1.--Comparison of heat transmission values for three types of frame wall construction with and without thermal insulation. Values lower than 0.18 are required to prevent sweating on the inner face of a wall.

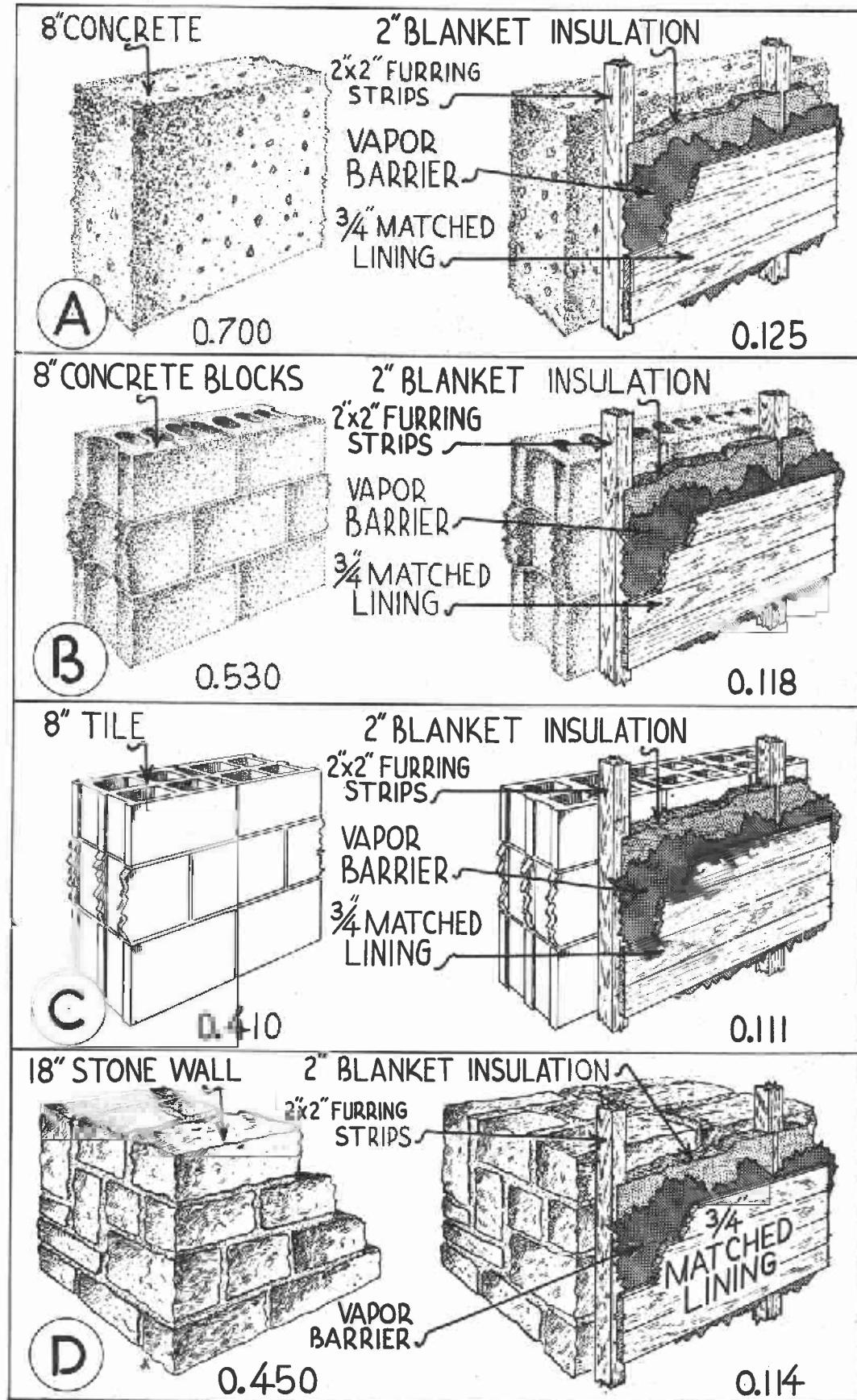
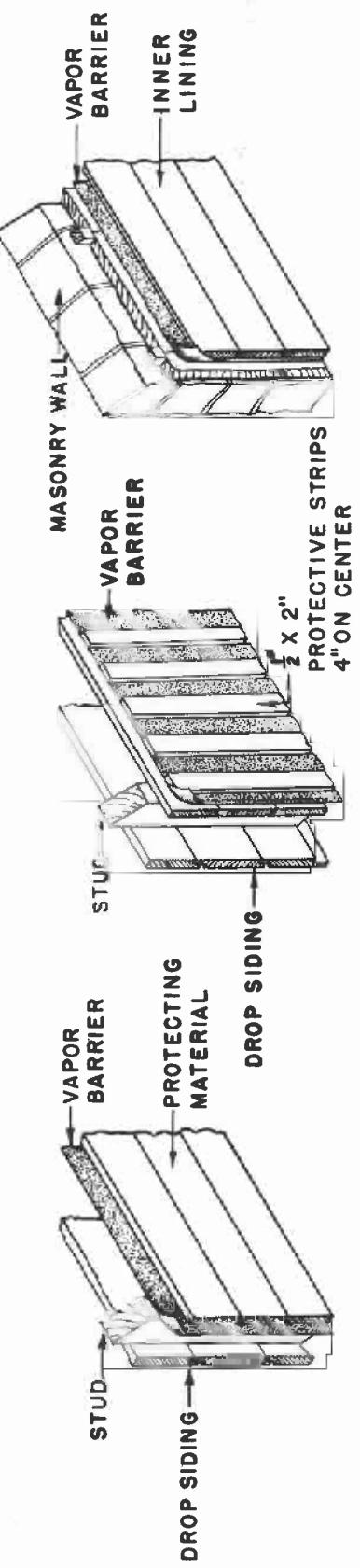


Figure 2.--Comparison of heat transmission values for several types of masonry wall construction with and without thermal insulation. Values lower than 0.18 are required to prevent sweating on the inner face of a wall.



**APPLICATION OF VAPOR BARRIER  
TO INSIDE FACE OF STUDS ON A  
WALL HAVING NO LINING**

**APPLICATION OF VAPOR BARRIER  
TO A WALL HAVING AN INNER  
LINING**

**APPLICATION OF VAPOR BARRIER  
OVER FURRING STRIPS AND  
INSULATION ON A MASONRY WALL**

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Figure 3.--Methods of installing vapor barriers on frame and masonry walls.

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