Swedish Test Hut Research Program
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SWEDISH TEST HUT RESEARCH PROGRAM

(Värme- och Fuktproblem i Ladugårdar)
("Heat and Moisture Problems in Barns")

by

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This is the seventh of the series of translations prepared for the Division of Building Research.

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PREFACE

The Division of Building Research is privileged to have a close link with the Swedish State Committee for Building Research. Through Mr. Boris Blomgren, Secretary to this Committee, the Division was put into touch with two Swedish organisations which had in operation research programs involving the use of test huts. These were of special interest to the Division in view of its own test hut program, now being initiated.

This translation describes one of the Swedish test hut projects and the reasons for it. The Division is glad to be able to arrange for publication of this interesting record, especially since it shows that building research problems in Canada and Sweden are similar. This is a translation of a reprint from Teknisk Tidskrift 1948, number 5.

Robert F. Legget,
Director.

SWEDISH TEST HUT RESEARCH PROGRAM

("Heat and Moisture Problems in Barns")

The control of heat and moisture conditions is one of the major technical problems in the construction of barns. Cattle like humans produce both heat and water vapour. The amounts depend to a certain extent on temperature and moisture conditions in the surrounding air, the animals' size, milk production, feeding and many other factors, but under all circumstances they are considerable. According to investigations carried out by the Swedish Research Committee on Farm-buildings (SFL), in some Norrland barns during the years 1944-45 [1] the output of heat averages approximately 20,000 kcal. over a 24-hour period. In these investigations it was found that 26 per cent of this quantity is emitted in the form of water vapour. This corresponds to 9 kg. every 24 hours. If it were necessary to take into account only the quantities of heat produced by the animals, then the whole problem of barns would be fairly simple, since as a rule the quantities of heat emitted are entirely adequate to balance the heat losses through boundary areas (floor, roof, wall), even when the temperature is very low. The matter becomes somewhat complicated, however, because it is necessary to neutralize the effects of the large quantities of water by some means or other. If no special measures are taken the automatic result will be a gradual increase in the relative humidity. Eventually it becomes so high that water vapour condenses on the surfaces (walls and roof), which generally have a lower temperature than the air. Usually nothing can prevent these quantities of condensed water from being absorbed by the materials of the roof and walls. This in turn gradually increases their moisture content and causes their structural elements to deteriorate rapidly, thus gravely jeopardizing the balance of heat in the barn. According to conventional methods removal of the water vapour is all that is necessary. Formerly the ventilation was considered adequate if the carbon dioxide content of the air did not exceed a certain limit beyond which the effects might be biologically harmful. Research during the last ten years has shown, however, that this is only of secondary concern in connection with the ventilation of barns. The removal of the excess moisture, not the carbon dioxide, constitutes the main problem. When this is done, the carbon dioxide content of the air is automatically adjusted and at the same time most of the odours are removed.

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1) Seth, E. and Holmquist, N. : Några undersökningar rörande norrlandsladugårdar. Stat. Forskn.-Komm. Lantmannabyggn. no. 5 (1945)

However, this process fails entirely to solve the problem of heat conservation since approximately 26 per cent of the total heat is retained in the water vapour. Furthermore, very large quantities of heat are consumed in order to heat the outside air which replaces the evacuated air masses. In all, not more than about 30 per cent of the 20,000 kcal. mentioned above is left to heat the air. Incidentally, it may be mentioned that last year investigations were started into the possibility of causing the water vapour inside the barn to condense in another way on surfaces where it can do no damage. By this means advantages might be gained, partly in the utilization of the quantities of heat retained and partly in the reduction of ventilation, thereby greatly diminishing the heat losses. However, these investigations have not yet produced useful results, and it is necessary, therefore, to attempt a solution by the traditional method. (It has been possible to apply the system described above in potato-storage plants with good results.)

While most of the heat produced within the barn is used up for ventilation purposes, the remainder serves to keep the building warm. There is the usual balance between the amount of heat supplied and that transmitted to the outside air, mainly through roof, floor and walls. In barns of conventional design but not attached to the house, the mutual heat losses between the sections are approximately equal.

With regard to the roof, the possibilities of restricting the heat losses depend to some extent on the type of construction. In barns of the low-roof type, to which, for example, most of the Norrland barns belong, it is possible at small expense to obtain great thermal resistance together with protection against moisture in the framework, thereby greatly reducing the heat losses through the roof. However, in conventional barns with more than one storey the problems involved are not so simple, since the framework has a supporting function in addition to its insulating properties. At times this supporting framework does not provide any insulation at all unless the hay stored in the loft is sufficiently heat-insulating. This is true as long as there is actually hay left, but after February or March most of it may already have been consumed, so that large sections are often completely bare. As a rule this is the coldest period of the winter and at the end of February, therefore, it becomes increasingly difficult to maintain an even balance of heat in barns of this type. If, on the other hand, the height of the framework is utilized to accommodate the filling in the usual manner, more stable conditions are obtained. However, apart from the question of heat balance, this has no great bearing on the construction of the roof. Its importance in this connection will rather depend mainly on the arrangement of the barn as a whole according to the personal requirements of the owner.

The other great heat loss may be attributed mainly to the floor, the usual types being unsatisfactory from the point of view of insulation. In the Norrland investigations it was found that the degree of insulation is of fundamental significance to the total heat losses through the floor. More comprehensive tests in this field, however, are planned by the SFL next year. The purpose of these tests is to examine three insulations: that for the construction of the foundation itself, that of the various parts of the floor requiring different degrees of insulation and, in particular, that for the manger. The investigations are planned with a view to analysing the conditions of the heat losses of buildings as a whole, i.e., in conjunction with the balance of heat in barns, and of the direct heat transfer from the recumbent animal to the manger and its importance from the physiological point of view for various cases.

However, the problem most frequently investigated, yet the most difficult to solve, is that associated with the walls. The walls, of course, have two functions, a supporting one and a heat-insulating one, and therefore their construction is more complicated than that of other parts of a building. Possible penetration by moisture may greatly affect both the bearing capacity and the heat-insulating properties of a wall, and, therefore, as has been proved, the construction of the walls largely determines the life of the whole barn. Careful study of the most suitable wall construction is thus of prime importance for agriculture from the economic point of view. Following the above preliminary investigations, which were carried out in certain Norrland barns, the SFL began full-scale tests in 1946 (Fig. 1). In one and the same barn the external walls have been divided into 12 sections, each representing one type of wall. In this barn, in so far as the method of measurement permits, the heat and moisture properties are investigated with respect to both transmission and capacity. This winter's test results indicate that much valuable information will be obtained in this barn, particularly on conditions of heat transmission and the significance of heat capacity for different walls. It need only be pointed out in this connection that the heat capacity is perhaps not so important a problem for farm buildings as for dwellings. In fact, the even production of heat in barns continues day and night. Hence only certain variations in the outside temperature can be balanced. In dwellings, on the other hand, even a smaller heat capacity which will balance the variations in intensity of the fire for day and night is greatly desired.

Penetrating water from driven rain is another condition which, however, cannot be investigated in the barn for testing walls, but probably it is often very important for the balance of heat. In the latter part of the summer and during the autumn rain water is being absorbed by the external walls, often in large quantities. Its evaporation removes a certain amount of heat. These heat losses add to those caused by the normal heat transmission through the walls. This behaviour is of special interest for Central Sweden and particularly for the most southerly parts of the country. Here heat insulation in barns is normally chosen for temperatures in the neighbourhood of 0°C. or immediately below it, for which these additional heat losses due to evaporation of rain water can, for the most part, be estimated and added to those previously calculated for the barns. For conditions in Norrland these additional heat losses are probably less important. The estimated heat balances of Norrland barns are based on outside temperatures of the order -10 to -15°C. Therefore, the evaporation from the external surface of a wall ceases when the wall's external temperature drops below 0°C., i.e., the temperature which is critical only in this one respect must be above approximately -3°C. This behaviour has been observed in Norrland too, and it can be surprisingly difficult to maintain an indoor temperature which is neither too high nor too low without excessive humidity in the air, particularly in cases where the temperature fluctuates about 0°C. However, at this outside temperature conditions in Norrland are seldom so severe that they cannot be overcome. However, should such a situation arise difficulties would result only when the outside temperature was at its lowest, because the barn then obviously could not have been properly designed by conventional standards of calculation.

Since these difficulties are particularly pronounced in the southwestern part of the country, a test with half-scale models was started during the summer of 1947 by the SFL in order to investigate the significance of these conditions in detail.

On the basis of principles discussed with civil engineer Emrik Lindman, Stockholm, Professor Hjalmar Granholm, Göteborg, and several other experts. the SFL thought it appropriate to carry out tests in huts especially built for the purpose. These are shown in Figures 2 and 3. Each hut has an inner floor space 1 x 1 m. and external walls of the design and material to be investigated. The floors and roofs are provided with such good insulation that the extent of the heat transmission through floor and roof is considerably lower than that of the heat transmission through the walls. Insulation of both floor and roof consists of a 21-cm. layer of glass-wool matting. Its proportion of the total heat losses is estimated at approximately three per cent. In order to avoid "corner effect" the hut has been so finished that the wall elements only touch at the corners. The latter have been especially insulated with wood shavings and a layer of moisture- and water-resisting cardboard. The additional quantities of heat which escape in the corners of huts of this construction are relatively small and can be estimated. In order to be able to measure directly the differences in heat loss between the case where the rain water is permitted to evaporate and that where this additional heat loss does not exist, two huts having exactly the same shape and wall construction have been erected. As is evident from one of the wall sections shown in Figure 3, one of these huts has been covered with aluminium sheets fastened down on top of the ordinary walls by means of bolts. This aluminium layer has been finished in such a manner that the radiation will be as nearly equal as possible for each of the twin huts. However, even in this hut there is an additional heat loss due to evaporated rain water, but it is slight compared with that of the other hut. Furthermore, absorption through small holes in the sheet, which prevents the penetration of rain water, may permit the free passage of moisture escaping through the wall from within. The additional heat resistance of the aluminium sheet to the uniform layer of air can be calculated theoretically with some accuracy. Moreover, it is possible to check this during the periods when the temperature of the surface layer of the walls drops below 0°C. On these occasions the evaporation is very slight. In order to utilize this opportunity of supervision it would be necessary to verify the fact that the moisture content of the material is fairly equal for both walls. Firstly a large container with saturated brine is placed inside the test hut so that the relative humidity is maintained constant at a level corresponding approximately to conditions in a barn (70 to 80 per cent). Then, thermostatically controlled electric heating elements are installed inside the hut and connected with an ordinary power meter. Hence, by setting the thermostat for a normal barn temperature of +15°C., conditions which, practically speaking, correspond in all respects to those in a barn can be reproduced. The heat transmissions or heat losses are measured directly by the power meter. These values can be reduced so as to apply to a square metre of wall area after allowing for losses through floor and roof and making adjustments with respect to the effect of the aluminium sheet and the remaining corner effects, including the effects from the corners between the floor and the walls. The diffusion of water vapour, which in fact is brought about by the walls themselves, is measured directly by checking the quantity of brine at regular intervals. It is necessary to keep adding brine so as to maintain a constant level in the container.

Since the test station has access to daily reports of precipitation, wind velocity and wind direction, it is obviously possible to obtain valuable data, apart from the effect of rain water, on the heat transmission coefficient of the different walls and the effect of their heat capacity along with their resistance to diffusion. These values can be directly compared with those obtained from the previously mentioned barn for testing walls. Moreover, experiments are being made with seven different wall materials, most of which are also being tried in the barn for testing walls. The following types are included in the tests:

(i) a masonry wall consisting of two withes separated by a 12-cm. cavity filled with sawdust;

(ii) a concrete block wall, type Nopsa II, consisting of three wall withes, with the blocks laid on edge and with its inner 12-cm. cavity filled with sawdust;

(iii) a siporex wall, 25 cm. thick, a wall of rendered concrete, 25 cm. thick (according to investigations by the research institute rendered concrete and siporex have practically the same thermal conductivity value but may have somewhat different properties with respect to conditions of absorption and evaporation);

(iv) a wall of vibro blocks, type L-15, 25 cm. thick;

(v) a wall of wood fibre slabs, 10 cm. thick, type Nike and Serponit;

(vi) a wooden wall with framework of 4" posts and insulation of 25-mm. glass-wool matting (an SFL wall like this one has been erected in the barn of the low-roof type)[2].

All these walls have been plastered outside and inside, except the wooden and the masonry wall; the latter, however, will be plastered 1 side at a later date.

This test is primarily intended to investigate the manner in which the evaporation of rain water affects the heat losses through a roof. Here, it need only be pointed out that the first aim is to determine the order of magnitude of the additional heat losses during short periods of time (one or two periods of twenty-four hours). These losses are assumed to apply to all the walls of a barn. They may, at least in Southern Sweden, be of decisive importance for the construction of buildings with respect to the heat balance. On the other hand, the test affords certain opportunities of adding to what is already known about the theoretical process, in particular the origin of these additional heat losses. The problem here consists in determining the relationship between three factors: the quantities of rain which are supplied to the different walls in the form of driven rain (according to Professor Jacob Holmgren, Trondheim, the rain which impinges upon a vertical surface), the amount of rain which is absorbed by the wall and the manner of evaporation. Here is an opportunity of utilizing all the

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[2] Holmquist, N.: Ett försök med ladugård av låghustyp.
Stat. Forskn.-Komm. Lantmannabyggn. no. 6 (1945)

experience gained from the test made by Holmgren and Dr. Tuomola, Finland, regarding the amounts of rain which can be absorbed by a wall under various conditions. In the test outlined above no measurements are made in connection with this intermediate part of the theory.

As mentioned above, the test huts were erected at the beginning of September 1947. It is fairly usual for barns (and even dwellings, to which some of the experience gained might be applied) to be constructed at this time of the year, and as a result the walls are not properly dry before the fall rains commence. The values thus obtained do not correspond to normal conditions but to those which generally prevail during the first winter after construction. It is obvious that it is of the utmost interest to obtain information on these conditions. However, in order to obtain results for the normal state as well, the tests are to continue for at least two more winters.

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Fig. 1: Barn for testing walls.

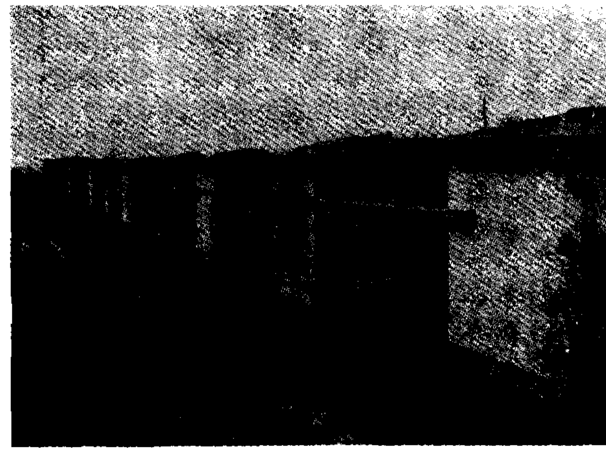

Fig. 3: The finished 14 test huts.

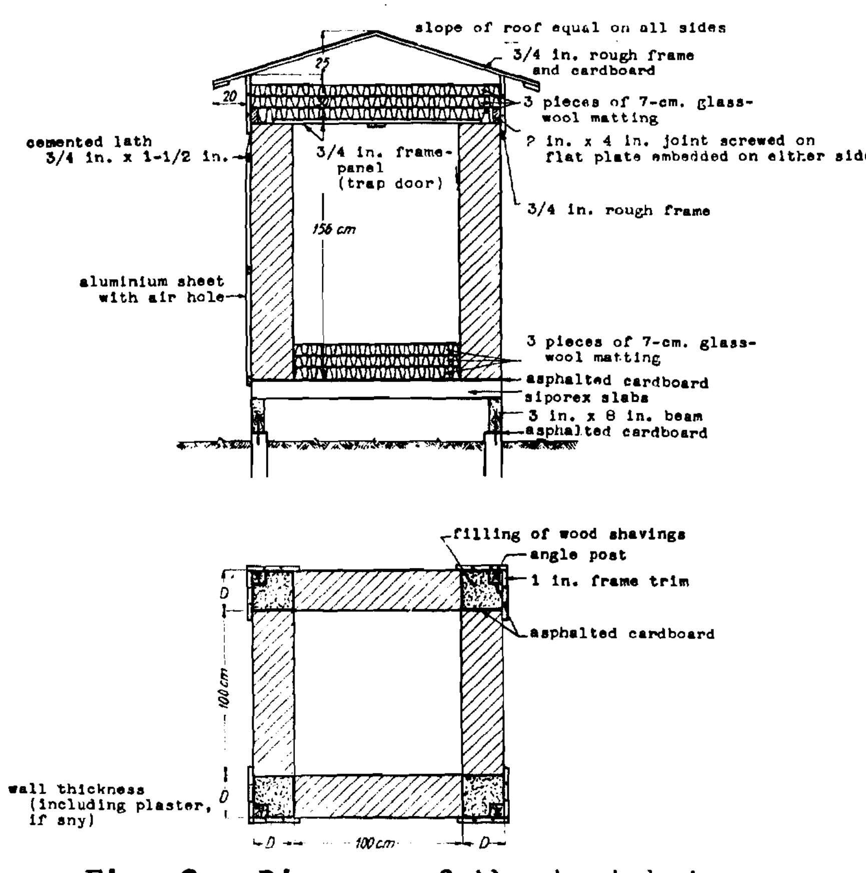

Fig. 2: Diagram of the test hut.