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DRYING OF PEAT INSULATING SLABS BY THE PRESSURE RELIEF METHOD

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Results of studies of peat insulating slabs dried by the pressure relief method are presented. Data on the influence of the process parameters on the expulsion of moisture in the liquid phase are given.

Drying of materials by the pressure relief method [1] is of great interest because of the possibility of significantly accelerating the moisture expulsion process, without deterioration in the technological properties of the material, and the substantially reduced heat consumption. Intensification of drying is conditioned by the "thermomechanical expulsion" effect, manifested in the removal of moisture from the material in the liquid phase under the influence of an intense molecular flow of vapor.

The violent vaporization that takes place throughout the volume of the solid being dried upon pressure relief is attributable to the heat accumulated in the material in the preheating period during pressure increase.

On the basis of the general theory of heat and mass transfer in capillary-porous bodies, equations have been obtained [2] relating the parameters of heat and moisture transfer in pressure relief drying.

In the work reported below, the process of drying peat insulating slabs by the pressure relief method was studied. Circular slabs, prepared in a laboratory press by the "wet method" [3] from upland peat of 5% degree of decomposition, were subjected to drying. The average initial moisture content of the slabs in all experiments was 7.5 kg/kg. The slabs were 100 mm in diameter and 40 mm thick.

The experiments were carried out in a special autoclave* (Fig. 1), with an internal volume of 5 l. The slabs, placed on a flat metal grid, were heated by an upper and a lower heater. In order to prevent condensation on the walls of the apparatus, a special auxiliary heater was used. In the course of the experiment we continuously recorded the temperature inside the material (in the middle of the slab and at a distance of 2 mm from the surface), the surface temperature of the upper and lower heaters using a shielded thermocouple to determine the temperature of the gaseous medium. The vapor pressure inside the apparatus was measured by a pressure gauge. A valve, fitted with a vacuum-rubber gasket, was used to vary the rate of pressure relief.

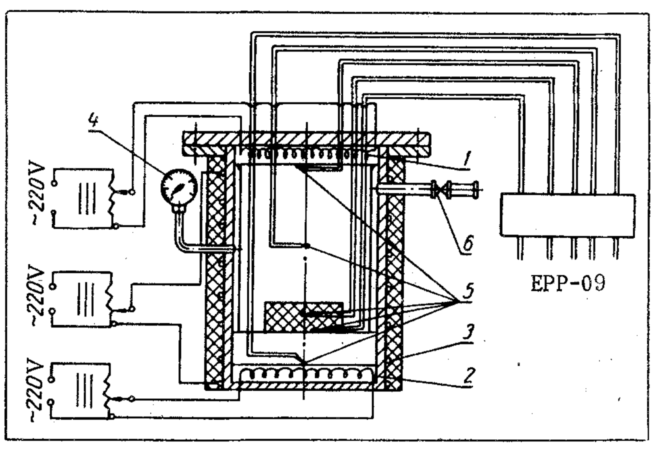

Fig. 1. Diagram of experimental equipment. 1, 2, 3) Heaters; 4) pressure gauge; 5) thermocouples; 6) valve.

The valve outlet was connected to a tube of thick vacuum-rubber fitted with a capillary. During pressure relief this capillary was immersed in a tall measuring cylinder filled with cold water, in which, owing to the high dispersion, practically all the vapor was condensed.

From the change in the level of the water in the cylinder, and from the free volume of the autoclave, the quantity of water and vapor removed from the slab in the drying process was completely determined. The quantity of vapor re-

*U. A. Berman assisted in developing the apparatus; the drawings were made by E. A. Skobolev.

moved from the free volume of the autoclave was calculated from thermodynamic tables for superheated steam. The quantity of moisture transferred from the material in the vapor phase was determined from the heat balance equation using data on the cooling of the slab in the relief process. The specific heat of the peat was calculated from the known equation for the specific heat of materials with a high moisture content; the specific heat of the water in the peat was taken to be equal to that of unbound water, since in the range of moisture content studied these quantities are practically equal [4, 5]. In separate experiments the removal of water in drop form was checked by calculation from the change of temperature in the condensate cylinder. In all the experiments the temperatures of the upper and lower heaters were maintained in the range 300-350°C and were chosen so that the temperature of the material close to the upper and lower surfaces of the slab was the same.

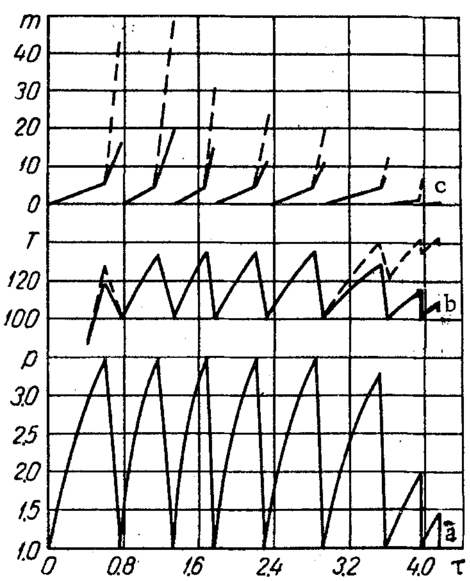

Fig. 2. Variation of the drying parameters of slabs dried by the pressure relief method: a) Pressure in autoclave; b) temperature in middle of slab (solid line) and at 2 mm from surface of slab (broken line); c) calculated moisture loss without allowance for thermomechanical effect (solid line) and actual moisture loss (broken line).

Drying proceeds in the following way (Fig. 2). In the moisture content range 7.5-1 kg/kg the temperatures in the center of the slab and near the surface are the same and increase and decrease synchronously with the rise and fall in pressure, the temperature of the material in the middle of the slab and close to the surface being 3-4°C lower than the temperature of water in equilibrium with saturated vapor at gauge pressure. After reduction of the moisture content to 1 kg/kg, heat transfer inside the slab slows down as a result of a natural decrease in the heat and mass transfer coefficients [6].

As a result, on the surface of the material there appears a dry zone, the role of which is, on the one hand, to prevent further heat transfer inside the slab during the process of increase in pressure and, on the other, to trap drops of water entrained by the molecular flow of vapor from the moist core of the material when the pressure is relieved.

Because the pressure in the apparatus was raised very slowly, pressure equalization over the thickness of the slab was not accompanied by any significant expulsion of water from the material during increase in pressure. In the rare cases, when water trickled onto the heated surface of the lower heater, the pressure gauge indicator jumped sharply.

Moisture transfer in droplet form during the pressure relief process was determined both by calculation (see above) and by direct experiment. For this purpose, to the water with which the peat was saturated in forming the slab a nonvolatile dye (methyl orange) was added. After raising the pressure, with the aid of a simple device installed inside the autoclave, we adjusted a framed sheet of filter paper under the slab; upon pressure relief, numerous tracks – spots of dye picked up by drops of water – were clearly seen on the paper.

Figure 2 also presents the results of experiments showing how much moisture, in the liquid and vapor phases, is expelled from the material in the process of raising and reducing the pressure. For comparison, the same figure presents graphs illustrating the calculated moisture outflow (in the vapor phase) without allowance for the thermomechanical expulsion effect. From the graphs it is clear that the transfer of moisture in droplet form exceeds by several times transfer in the vapor phase, up to the appearance of a dry zone near the surface of the material. With the appearance of a dry zone, the thermocouple located in the vicinity of the surface of the slab begins to show a temperature different from that in the middle of the slab (Fig. 2b). In order to avoid undesirable changes in the physicochemical properties of the surface layer of material (wet charring, etc.) one is obliged progressively to reduce the pressure preceding relief and, finally, to discontinue the experiment.

In the period of pressure increase preceding the first pressure relief, when a significant quantity of air remains in the free volume of the autoclave, and the partial pressure of water vapor in it is significantly less than that registered by the pressure gauge, the temperature inside the slab is correspondingly lower than before subsequent reliefs. In this period we get insignificant overheating of the surface layer in comparison with the center of the slab, which is apparently connected with the nonuniform rate of drying over the thickness of the material. However, even in the first relief, the molecular flow of vapor from inside the slab transfers moisture from the moist core to the drier surface layer, which serves to equalize the moisture content over the thickness of the material. This is confirmed by a layer-by-layer moisture content analysis of slabs taken from the autoclave before the moisture content reaches ω = 2-2.5 kg/kg.

Figure 3 presents experimental and calculated (without allowance for thermomechanical expulsion) curves for slabs dried under the conditions described in Fig. 2. It may be seen from the graphs that, under the conditions described above, the thermomechanical expulsion effect is such as to accelerate very significantly the drying process in comparison with what would have taken place if there had been no removal of moisture in dispersed from.

In course of the work a series of experiments was carried out, the object of which was to clarify the influence of the pressure before relief on the drying rate. By appropriate regulation of the outlet valve, pressure relief was accomplished in such a way that the law of pressure decrease in the autoclave was approximately linear and the relief time in all experiments was the same (τ_{rel} = 7 min). The following values of the vapor pressure were taken: 1. 6; 2. 0; 3. 0; 3. 5 ($9.8 \cdot 10^4$ N/m^2) for which the drying rate is, respectively: 0. 540; 0. 565; 0. 584; 0. 611; 0. 625 (10^{-3} kg/m^2 · sec) with change in moisture content from 7. 5 to 1 kg/kg.

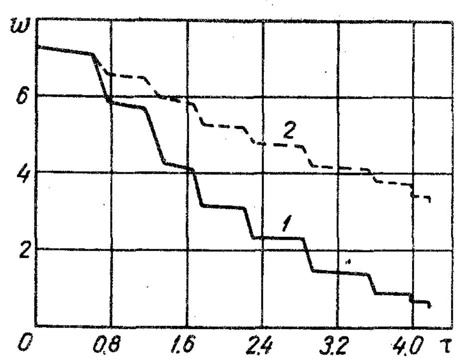

Fig. 3. Drying curves for peat slabs: 1) Experimental; 2) calculated (without allowance for thermomechanical effect).

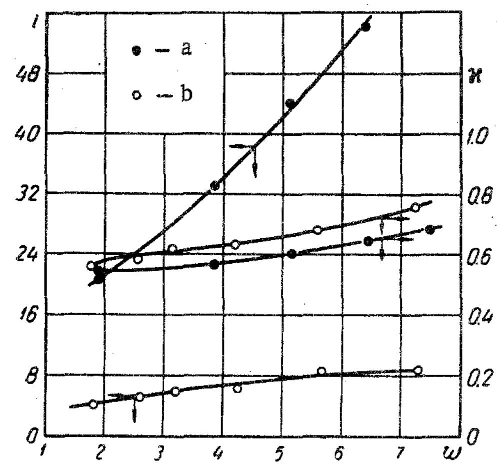

Fig. 4. Dependence of the drying rate in kg/m^2 · hr during pressure relief and the thermomechanical expulsion coefficient $\varkappa$ on the moisture content of the material for Δp = 24.5 N/m^2: τ_{rel} a) 1 min; b) 7 min.

The weak dependence of the above-mentioned quantities (in all the experiments described the pressure was reduced to atmospheric) is explained by the fact that simultaneously with the quantitative increase in the removal of moisture in the liquid and vapor phases during pressure relief, with increase in the pressure in the autoclave before relief the time necessary to attain this pressure increases. The design of the device utilized in the present work was not such as to permit changes in the free volume of the autoclave; however, it can be assumed that as it decreases, the drying rate will increase considerably more rapidly with increase in the pressure before relief. Analogous results can be expected if the pressure in the autoclave is raised by vapor supplied from an external source.

In the course of investigating the drying of slabs an attempt was made at qualitative determination of the effect of the rate of pressure relief on the drying rate in the pressure relief process. Shortening the relief time causes more vigorous vaporization in the thickness of the material and hence a higher rate of moisture loss from the material during pressure relief (Fig. 4).

Increase in the drying rate in the pressure relief process with decrease in its duration does not mean, however, that it is necessary to reduce the relief time indefinitely to obtain maximum removal of moisture from the material. The effectiveness of drying material by the method examined may be judged from the value of the thermomechanical expulsion coefficient $\varkappa$ or the ratio of the rate of removal of moisture in droplet form to the over-all rate of moisture removal from the material in the liquid and vapor phases.

In practice it is convenient to use the average (over the relief period) value of $\varkappa$ calculated as the ratio of the quantity of moisture removed in the liquid phase to the total amount of moisture removed (Fig. 4). From a comparison of the curves it may be concluded that in each specific case there is an optimum value of the relief time, for which $\varkappa$ will be a maximum.

The appearance at a certain stage in the process of a dry zone limiting the drying rate permits the conclusion that drying by the method examined is expedient up to some specific moisture content of the material.

On the other hand, the advantages of the method can be fully utilized if the appearance of a dry zone near the surface of the material can be excluded. Thus, for example, it is probable that heating with high-frequency current in conjunction with pressure relief would permit intensive drying over practically the entire range of moisture contents.

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