

A MODEL FOR MASS TRANSFER IN BEDS OF WOOL FIBRES

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Abstract—The differential equations are given for mass transfer of water vapour in a bed of wool fibres during forced convection. Assumptions are made to simplify the problem, which is then solved numerically using the method of finite differences. The consequences arising out of this model of mass transfer are discussed, and predicted concentration and temperature profiles presented for absorption and desorption and for different concentration limits.

The wool–water system is characterized by a sigmoidal sorption isotherm and a concentration-dependent heat of sorption.

NOTATION

<p>A, B, constants in saturation vapour pressure relation (2b);</p> <p>c, specific heat of fibres [$\text{cal g}^{-1} \text{degC}^{-1}$];</p> <p>$C_p$, specific heat of air at constant pressure [$\text{cal g}^{-1} \text{degC}^{-1}$];</p> <p>$d$, packing densities of dry fibres in bed [g cm^{-3}];</p> <p>f_1, function describing isotherm of fibres, equation (1);</p> <p>f_2, function relating heat of sorption (or desorption) with regain;</p> <p>$F(x, t)$, function defined by equation (11);</p> <p>h, heat-transfer coefficient [$\text{cal sec}^{-1} \text{degC}^{-1} \text{cm}^{-1}$] (distance along bed);</p> <p>k, rate constant for mass transfer [$\text{g sec}^{-1} (\text{mm Hg})^{-1} \text{cm}^{-1}$] (distance along bed);</p> <p>$m_A(x, t)$, concentration of water vapour in air at position x and time t [g cm^{-3}];</p> <p>$m_w(x, t)$, concentration of water absorbed by fibres [g cm^{-3}] (unit volume bed);</p> <p>$p_A(x, t)$, vapour pressure of water in air at position x;</p> <p>$p_0(T)$, saturation vapour pressure of water at temperature T [mm Hg];</p> <p>$p_w(x, t)$, equilibrium vapour pressure of water sorbed by fibre [mm Hg];</p> <p>R, gas constant per g molecule, pressure</p>	<p>in mm Hg volume in cm^3, temperature degK;</p> <p>t, time [s];</p> <p>$T_A(x, t)$, air temperature at position x and time t [$^{\circ}\text{K}$];</p> <p>$T_w(x, t)$, temperature of wool at position x and time t [$^{\circ}\text{K}$];</p> <p>v, volume rate of air flow per unit gross bed area at right angles to air flow [cm sec^{-1}];</p> <p>x, distance from face of bed in direction of air flow [cm];</p> <p>y, relative humidity, equation (2a);</p> <p>λ, heat liberated or sorbed as water content of fibre changes [cal g^{-1}];</p> <p>ζ, density of air [g cm^{-3}].</p>
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INTRODUCTION

DRYING and reconditioning hygroscopic textile fibres is a process of wide industrial interest. The drying process frequently consists of two distinct phases, removal of free water by evaporation under conditions of forced convection and removal of physically absorbed water which has to diffuse from the interior of the fibres to their surface. The present investigation is concerned solely with the latter phase of the drying process and with the reverse situation of absorption of water vapour from air due to the hygroscopic nature of the fibres.

It was shown many years ago by Cassie [1, 2] that air flowing through a bed of hygroscopic fibres at a different water vapour pressure equilibrium would produce changes which manifest themselves in the propagation of two temperature fronts through the bed.† Both fronts were shown to travel at widely different but constant velocities. In typical cases the fast front might travel at approximately $\frac{1}{100}$ of the velocity of the air passing,‡ while the second front would travel at a velocity smaller by several orders.

Cassie's theory involved the assumptions of infinitely fast heat- and mass-transfer rates as well as a linear dependence of the water content of the fibres at equilibrium on concentration of water vapour in the air and on temperature. As a consequence of these assumptions, Cassie obtained linear partial differential equations which he was able to solve analytically for the steady state. The shape of the fronts was exactly the same as at the boundary and did not change as they passed through the bed.

Later experimental work [4, 7] on the rates of diffusion of water in single wool fibres indicated that the assumption of an infinitely fast mass transfer rate was not appropriate. The effect of a finite mass-transfer rate on the shape of the second front was subsequently calculated by McMahon and Downes [5] and their theoretical results were in closer agreement with experiment than the original work of Cassie. The assumptions employed by McMahon and Downes again led only to a steady-state solution of the differential equations.

The model which is developed here for forced convective mass transfer in beds of hygroscopic fibres, and in particular for wool fibres, is an attempt to reassess some of the assumptions made in previous treatments of the problem and to solve the resulting non-linear differential equations by the method of finite differences.

† Associated with these temperature fronts are two concentration fronts, of which the second is the greater.

‡ Cassie's original statement that the first front travelled at the velocity of air was a result of neglecting the contribution of the heat capacity of the fibres to the heat capacity of the textile-air mixture. However, this assumption was only introduced as an aid to the physical interpretation of the mathematical results.

This method gives numerical solutions of the problem not only for transient states but also in cases where analytical steady-state solutions have not been derived.

An additional purpose which led to the development of the present model arose out of recent work [8, 6] on forced convective heat transfer in beds of non-hygroscopic fibres. The suggestion was made that dispersion of air flow rather than film resistance plays the dominant role in the mechanism for overall heat transfer. Before a similar study could be undertaken for combined heat and mass transfer in the case of hygroscopic fibres a model had to be found as a basis for comparison which would permit calculation of the shape and movements of fronts for non-dispersed flow.

FORMULATION OF PROBLEM

Consider a bed of uniformly distributed fibres which will contain absorbed water when in equilibrium in air at a given humidity. The bed is of constant cross-section. It is assumed that the equilibrium between the concentration of water in the fibres (the regain m_w/d)§ and vapour in the air is a function of relative humidity only and invariant with temperature.

$$\text{Isotherm } y = f_1 \left(\frac{m_w}{d} \right) \quad (1)$$

where

$$\text{relative humidity } y = \frac{p_A}{p_0(T_A)} \quad (2a)$$

and

$$\text{saturation vapour pressure } p_0 = Ae^{-B/TA} \quad (2b)$$

Further, it is assumed that absorption (or desorption) of unit mass of water by the fibres liberates (or absorbs) a quantity of heat greater than the latent heat of water vapour at that temperature. This quantity is a differential heat and a function of regain only, independent of temperature

$$\lambda = f_2 \left(\frac{m_w}{d} \right) \quad (3)$$

§ Regain is (weight of fibres with sorbed water-weight of fibres when dry)/(weight of fibres when dry).

The rate at which the fibres change their water content at any given time and point in the bed is taken to be proportional to the difference between the vapour pressure of water in air at that point and the equilibrium vapour pressure which the water absorbed by the fibres exerts at the same point. The equilibrium vapour pressure of the fibres is expressed by

$$p_w(x, t) = f_1 \left[\frac{m_w(x, t)}{d} \right] \cdot p_v [T_w(x, t)] \quad (4)$$

where the numerical value of f_1 is given in Appendix I. Hysteresis has been neglected.

For the case of wool fibres this assumption represents a plausible simplification of the sorption kinetics [4, 7] which is too complex to be expressed analytically. It is a slight departure from the assumption employed by McMahon and Downes [5] and has been used here because it is formally equivalent to the situation where the mass-transfer rate is controlled by a film resistance similar to heat transfer. However, the rate constant for mass transfer used in the specific case discussed here is numerically different from the film coefficient for mass transfer.

The conservation and rate equations may be written as follows, considering unit section of bed:

Conservation of mass

$$v \frac{\partial m_A}{\partial x} + \frac{\partial m_w}{\partial t} = 0. \quad (5)$$

Conservation of heat

$$\zeta v C_p \frac{\partial T_A}{\partial x} + \lambda v \frac{\partial m_A}{\partial x} + cd \frac{\partial T_w}{\partial t} = 0. \quad (6)$$

Mass transfer

$$v \frac{\partial m_A}{\partial x} = k(p_w - p_A). \quad (7)$$

Heat transfer

$$\zeta v C_p \frac{\partial T_A}{\partial x} = h(T_w - T_A). \quad (8)$$

In formulating these equations a number of assumptions are involved which, however, do not appear to be of serious consequence. These are

- v, C_p, c are independent of temperature;
- ζ is constant for the range of temperature and pressure encountered;
- the product cd remains constant although it is strictly a function of the regain;
- the mass of vapour held in the inter-fibre space in the bed at any given time is negligible;†
- the total heat of the air-vapour mixture held in the inter-fibre space in the bed at any given time is negligible.‡

The latter two assumptions are only applicable at low temperatures when the saturation vapour pressure of water is a small fraction of the total pressure.

Using a finite difference solution of equations (5) to (8) the shape of the concentration front and first and second temperature fronts may be found for any time or position in the bed. However, because the two temperature fronts are propagated at vastly different velocities, very small finite difference intervals must be used, resulting in costly computations.

A considerable simplification of the problem can be achieved by two further assumptions. For the purpose of calculating the propagation of a change of humidity in the air stream entering the bed at constant temperature, the effects of the first front can be neglected, since the main concentration changes which take place are associated only with the second front.

If it is assumed that h in equation (8) is infinitely large, then to obtain a finite value for $\partial T_A / \partial x$, T_w must equal T_A and hence the first front is propagated through the bed at the velocity of the air stream. A further consequence is that the shape of the front is transmitted through the bed unchanged. This, in practice, is not strictly correct and hence the assumption amounts to a neglect of the first front in the sense that effects due to changes in its shape cannot be calculated.

† This assumption neglects the changing water content in the inter-fibre space as compared to that of the fibres. It avoids introduction of an additional term into equation (5).

‡ This assumption neglects the heat content of the inter-fibre air-water vapour mixture as compared to term 3 in equation 6, avoiding the introduction of an additional term.

The second assumption involves the term $cd(\partial T_w/\partial t)$ which gives the contribution of a change in the sensible heat of the wool in the heat balance equation (6). If this term is neglected compared with the other two terms, the error involved is only large when $\partial T_w/\partial t$ is large, i.e. when the first front passes. As the calculation of the first front is not included in the present treatment the assumption does not constitute a large error. We may now write in place of equation (6):

$$\zeta C_p \frac{\partial T_A}{\partial x} + \lambda \frac{\partial m_A}{\partial x} = 0. \quad (9)$$

Thus the problem of calculating changes in concentration and temperature inside a fibre bed as the conditions of the air entering the bed are changed has been reduced to a solution of equations (5), (7) and (9).

FINITE DIFFERENCE FORMULAE

Equation (7) may be written in the finite difference form

$$m_A(x+1, t) = m_A(x, t) + \frac{\Delta x}{v} F(x, t) \quad (10)$$

where

$$F(x, t) = k [p_w(x, t) - p_A(x, t)]. \quad (11)$$

Similarly equation (5) becomes

$$v [m_A(x+1, t) - m_A(x, t)] \Delta t + [m_w(x, t+1) - m_w(x, t)] \Delta x = 0$$

which when combined with equation (10) gives

$$m_w(x, t+1) = m_w(x, t) - \Delta t F(x, t) \quad (12)$$

and for equation (9) one finally obtains

$$T_A(x+1, t) = T_A(x, t) - \frac{\lambda \Delta x}{\zeta v C_p} F(x, t). \quad (13)$$

In order to evaluate $p_A(x+1, t)$ it is assumed that the water vapour in the air obeys the perfect gas law and that changes in air temperature are sufficiently small to permit the pressure to be evaluated at a constant temperature, i.e. the temperature of the air stream entering the bed of fibres. Thus it is assumed that

$$p_A(x, t) = \frac{RT}{M} m_A(x, t) \quad (14)$$

where T is always $T_A(0, t)$. It then follows from equation (10) that

$$p_A(x+1, t) = p_A(x, t) + \frac{RT}{Mv} \Delta x F(x, t). \quad (15)$$

Equations (10), (12), (13) and (15) together with the boundary conditions

$$\begin{aligned} m_w(x, 0) \\ T_A(0, t) \\ m_A(0, t) \end{aligned} \quad (14)$$

permit calculation of concentration, temperature and pressure distributions for any position in the bed at any time.

EVALUATION OF CONCENTRATION AND TEMPERATURE CHANGES IN A BED OF WOOL FIBRES

Numerical solutions for the mode of propagation of relative humidity changes in air passing through a bed of wool fibres were computed† using the numerical data given in Appendix I. Several boundary conditions were employed to cover the cases of absorption and desorption and of various concentration limits. In each case iteration was performed over 60 space and 102 time intervals. This number was just sufficient to demonstrate the phenomenological features of the model under discussion.

Absorption and desorption

The results for the case of absorption where air initially at 100 per cent relative humidity and at 20°C is blown through the bed initially at 0 per cent relative humidity is shown in Figs. 1(a), 2(a) and 3(a) while those for desorption are shown in Figs. 1(b), 2(b) and 3(b). In the latter case, the air is dry and at 20°C while the bed is initially at 100 per cent relative humidity (i.e. a saturation regain of 0.33).

Figure 1 is a plot of regain against time with bed position as parameter and thus depicts the change of concentration of water absorbed by the wool fibres with respect to time for successive positions in the bed. It is immediately obvious that absorption and desorption not only proceed

† "Silliac" digital computer of the Basser Computing Laboratory, University of Sydney.

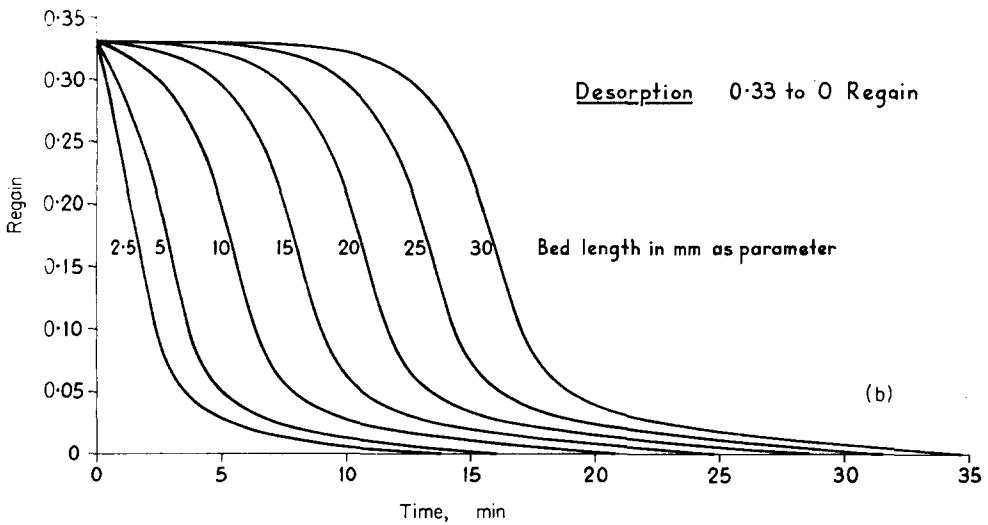
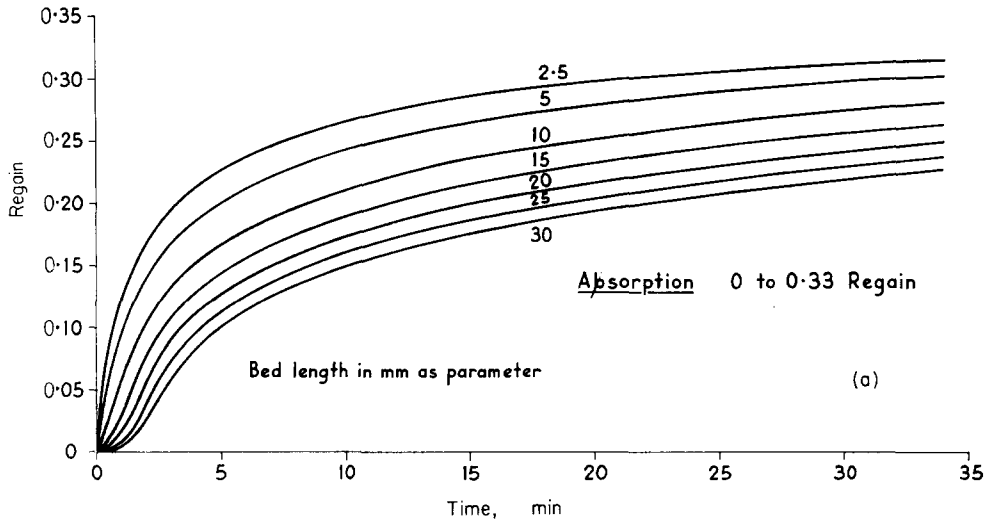


FIG. 1(a, b). Absorption and desorption. Concentration profiles with respect to time. Limits 0 and 100 per cent relative humidity.

at widely differing rates but also in a different manner. In the case of desorption a stable concentration front (in time) is established very soon and is displaced in time linearly with respect to distance. A similar behaviour is not observed for absorption. Although the calculation was not carried through for very large bed

depths, the conclusion that a stable front will never be formed appears likely.

The same information is expressed in a slightly different way in Fig. 2, where regain is plotted against distance with time as parameter and thus represents the spatial progress of the concentration front. Again, in the case of desorption a

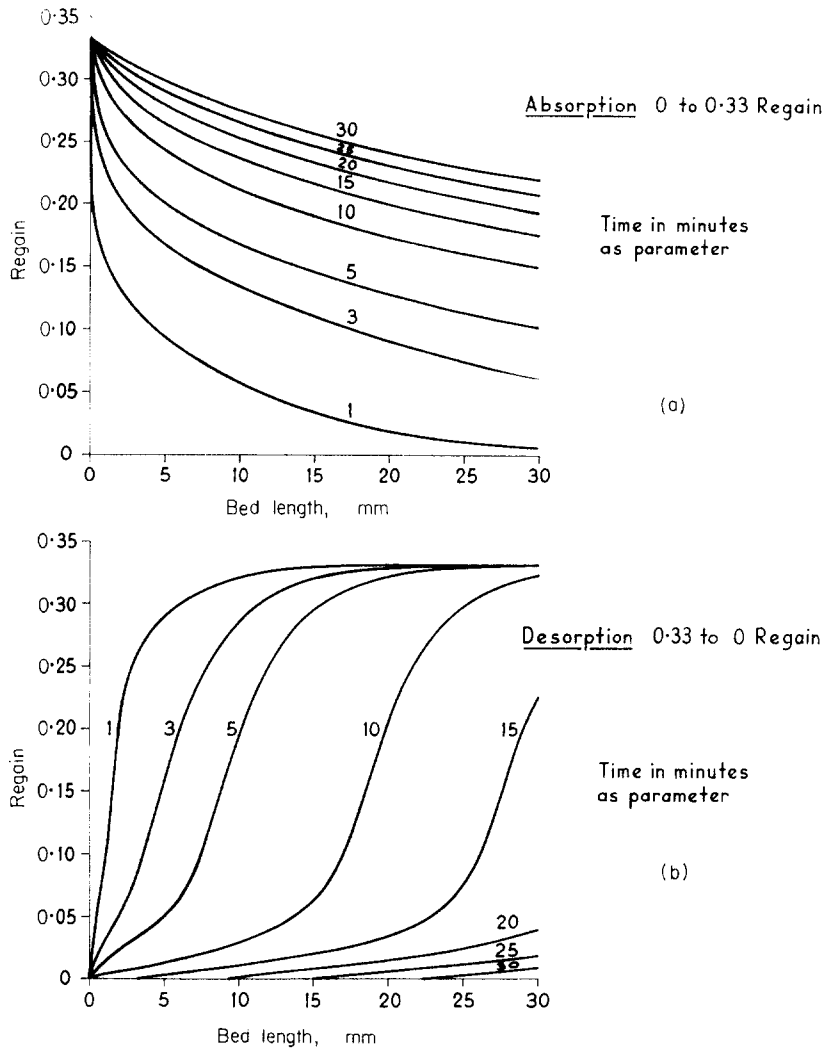


FIG. 2(a, b). Absorption and desorption. Concentration profiles with respect to distance. Limits 0 and 100 per cent relative humidity.

stable front which moves with uniform velocity is established (inferred from intermediate curves not shown in the figure), while absorption produces much smaller concentration gradients and does not lead to a front of constant shape.

The reason for the different mode of overall mass transfer in the wool bed for absorption and desorption is to be found in the exponential dependence of the saturation vapour pressure of water on temperature. Assume that at a given

point in the bed a small, given amount of water is transferred either by absorption or by desorption. Equal amounts of heat will be liberated or absorbed, producing an equal temperature rise or fall of the wool at that point. However, the resulting change in equilibrium vapour pressure of wool will not be the same in the two cases [see equation (4)] as p_0 is not linearly related to T_w .

The temperature rise produced by absorption

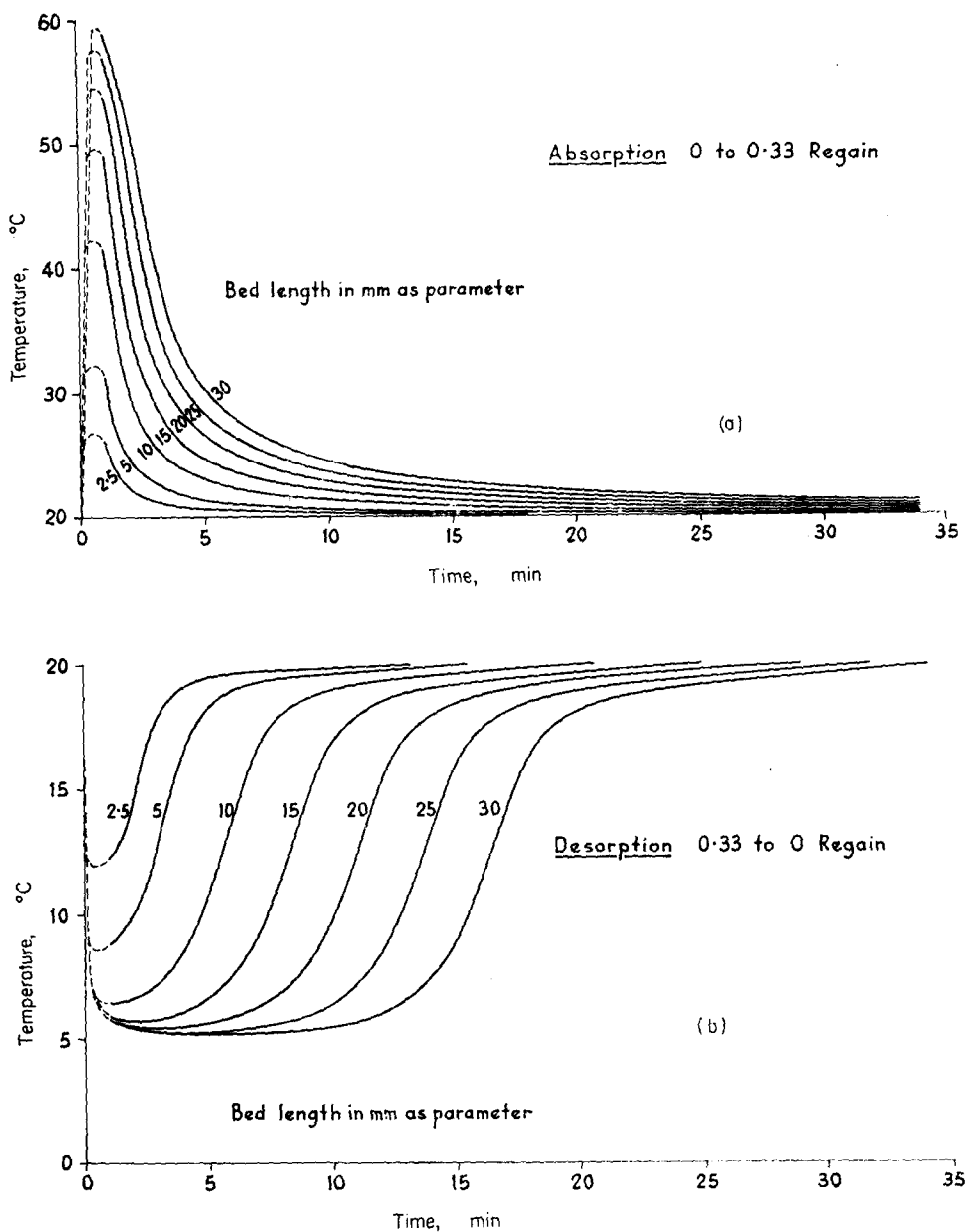


FIG. 3(a, b). Absorption and desorption. Temperature distributions with respect to time. Limits 0 and 100 per cent relative humidity.

results in a larger increase in the equilibrium pressure of the wool than the drop in equilibrium pressure due to the fall in temperature. Since the rate of mass transfer is proportional [equation

(7)] to the difference between the equilibrium pressure of the wool and the vapour pressure in the surrounding air, the subsequent rate of mass transfer is smaller for absorption than

desorption. The effects due to small changes are cumulative, resulting eventually in a completely different overall mode of transfer.

These differences can also be demonstrated by examining the appearance of the temperature fronts for the two cases which are shown in Fig. 3. The dotted lines represent the approximate courses of the first temperature fronts which are not covered by the present model. The full lines represent the second fronts which are associated with changes in concentration. They are the changes in temperature with respect to time as seen by thermocouples placed in the wool bed at various depths, and constitute a convenient basis by which the theory can be tested experimentally.

Here also the difference between absorption and desorption is most marked, with stable fronts being formed in the case of desorption. In absorption, after an initial rapid temperature increase and decay, a small but finite temperature difference is maintained for a long time while absorption proceeds.

A further feature of the concentration profiles requiring comment is the double inflection noticeable in the desorption curves at 3 and 5 min in Fig. 2(b). These can be shown to be due to the sigmoidal shape of the sorption isotherm (Fig. 7) which at low humidities is concave towards the r.h. axis. Although this concavity will influence the shape of all concentration profiles it only leads to a noticeable effect in the transient state.

It is also interesting to note the influence of the variable heat of sorption (Fig. 8) on the minimum temperature achieved by the wool during desorption as shown in Fig. 3(b). This temperature is lower than the temperature of adiabatic saturation for dry air at 20°C because of the heat changes involved. It is surprising, however, that the influence is not more severe than observed. The lowest temperature attained was 5.28°C, as compared with a temperature of adiabatic saturation of 5.88°C for free water as obtained from a similar computation in which the heat of sorption was taken to equal the heat of evaporation for free water. The main influence of the increased heat was to shift the curves in Fig. 3(b) further along the time axis without a pronounced effect on their shape.

Also included in the programme for the computation was the sum

$$\frac{1}{n \Delta x} \cdot d \sum_0^n m_w(n \Delta x, t) \quad (15)$$

which represents average regain at time t for beds of varying thickness $n \Delta x$, where n is an integer. This sum as a function of time gives the overall rate of drying during sorption of a bed of specified length. This relationship can be observed experimentally and is therefore of interest. A plot of the quantity given by (15) as a

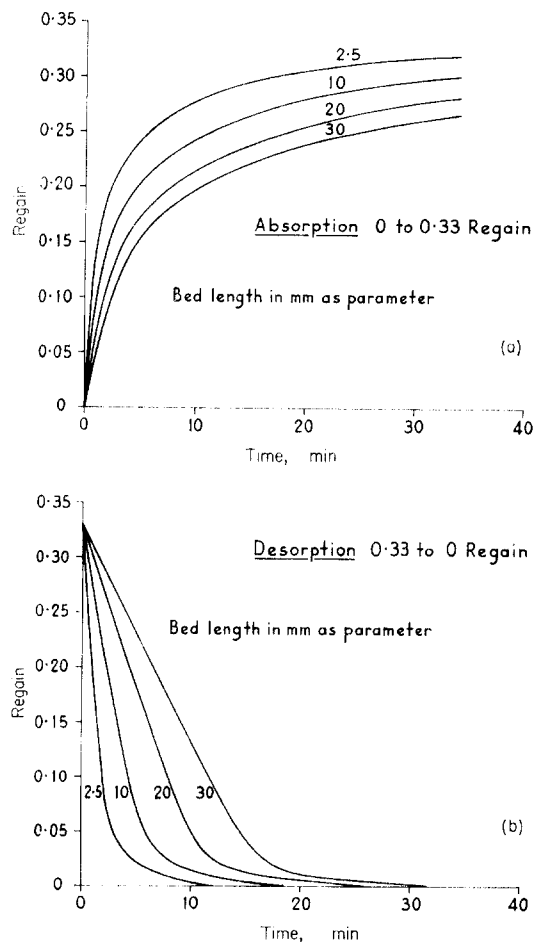


FIG. 4(a, b). Absorption and desorption. Overall changes for beds of differing thicknesses. Limits 0 and 100 per cent relative humidity.

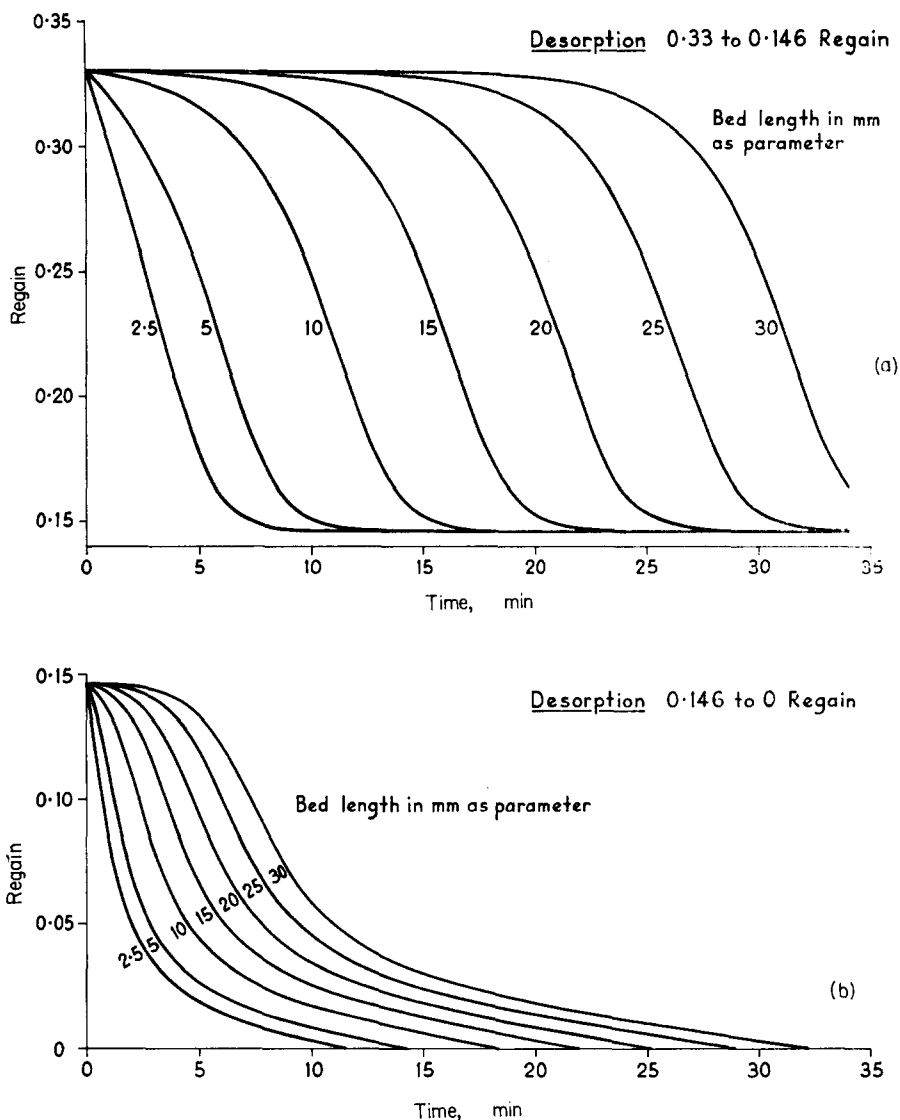


FIG. 5(a, b). Desorption. Concentration profiles. Limits 100 to 65 per cent and 65 to 0 per cent relative humidity.

function of time is shown in Figs. 4(a) and 4(b) for absorption and desorption respectively. Initially, the rates of absorption are larger than those of desorption, but due to rapid changes in the rates they soon become appreciably slower. The rates of desorption remain constant over most of the total change, due to the fact that until the concentration front emerges air leaves the bed in a saturated condition at a nearly constant temperature slightly lower than

that of adiabatic saturation.† As a consequence, when wool containing free water is dried, in which case air emerges saturated adiabatically, there is only a very small change in the rate at a time when all the free water has evaporated and desorption begins from the fibres near the end of the bed.

† The term adiabatic saturation is used here with the additional condition that free water and not sorbed water is used to saturate the air.

CONCENTRATION LIMITS

In order to assess the influence of the curvature of the isotherm (Fig. 7) on the shape of the desorption curves, an arbitrary division was made at 65 per cent relative humidity and desorption concentration and temperature profiles calculated for the ranges of 100–65 per cent and 65–0 per cent relative humidity. The concentration profiles are shown in Figs. 5(a) and 5(b) and the temperature profiles in Figs. 6(a) and 6(b) respectively. The general conclusion is that in both cases stable fronts are formed. In the 0.33 to 0.146 regain range (corresponding to 100–65 per cent r.h.) a stable concentration front is established close to the face of the bed which moves with a relatively slow velocity. In the 0.146 to 0 regain range the establishment of a stable profile takes place, only much deeper in the bed (it is, in fact, not obvious from Fig.

5(b) and only inferred) but the velocity of the profile is faster than in the previous case. The temperature profiles for the two ranges of concentration behave similarly and it is also interesting to note the similarity in shape between concentration and temperature profiles in each individual range. A like similarity is observed between the concentration and temperature profiles for the 0.33 to 0 regain range as shown in Figs. 1(b) and 3(b). For the absorption case, however [Figs. 1(a) and 3(a)], where a stable front is not established, the similarity is absent.

AIR VELOCITY AND RATE CONSTANT

The effect of changing the velocity of air passing through the bed in this model can be easily deduced by an inspection of the differential equations (5), (7) and (9).

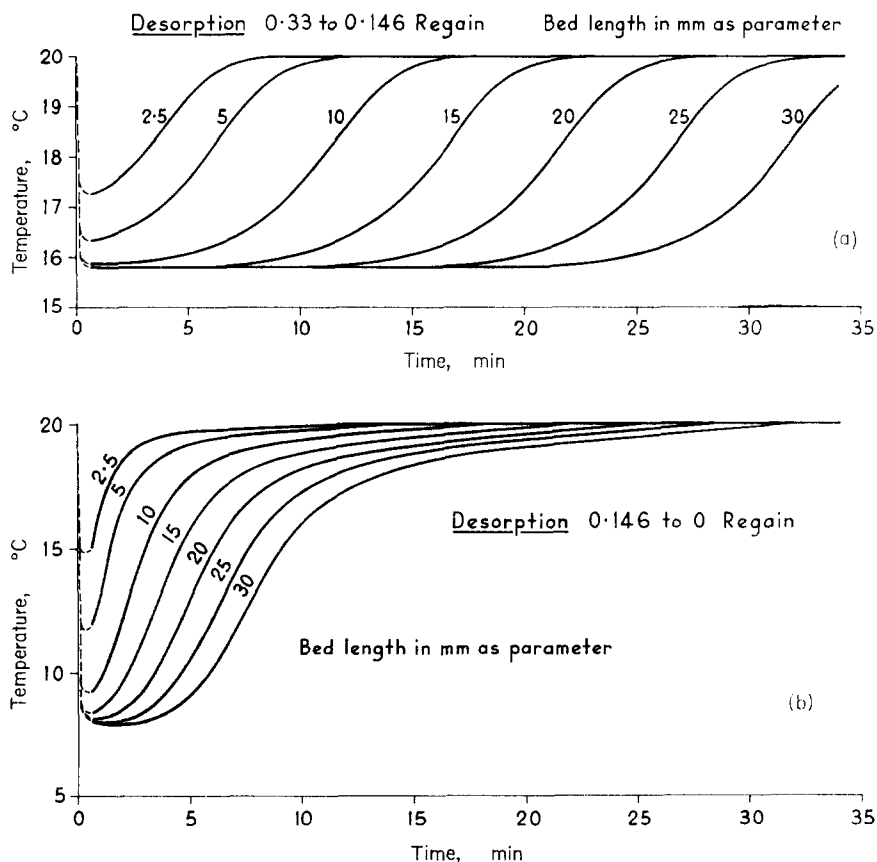


FIG. 6(a, b). Desorption. Temperature profiles. Limits 100 to 65 per cent and 65 to 0 per cent relative humidity.

If a change of variable

$$X = \frac{v}{x} \quad (16)$$

is made, the equations become

$$\frac{\partial m_A}{\partial X} + \frac{\partial m_w}{\partial t} = 0$$

$$\frac{\partial m_A}{\partial X} - k(p_w - p_A) = 0$$

$$\zeta C_p \frac{\partial T_A}{\partial X} + \lambda \frac{\partial m_A}{\partial X} = 0$$

and are independent of v . It may be concluded that if the velocity of the air, v , passing through the bed, is changed to nv , the results are the same as if the distance x is changed to x/n and the original air velocity retained. This means that the curves shown in Figs. 1 to 6 apply to any air velocity provided the corresponding change is made in the distance scale or distance parameter.

It can be demonstrated similarly that the effect of multiplying both x and t simultaneously by a number produces the same effect as dividing the rate constant, k , by the same number. Hence one may deduce the shapes of the various concentration and temperature profiles for other rate constants by means of the curves already given.

CONCLUSION

A model is presented which permits calculation of concentration and temperature changes in uniform beds of wool fibres under conditions of forced convection as humidity and temperature changes are made in the air stream. The most important assumption on which the model is based is that the rate of mass transfer is proportional to the difference between the pressure of water vapour in the air and the equilibrium pressure of the wool fibres. This assumption is probably quite good except at very low concentrations of water in the wool fibres, when diffusion within the fibres is extremely slow and when the value of the rate constant required to describe the changes probably needs adjustments. The assumption may also break down towards the end (in time) of any particular change where the wool may enter a second stage of

sorption behaviour [4, 7], which is also extremely slow.

The main predictions of the model are:

1. There is a vast difference in behaviour between absorption and desorption.
2. In desorption stable concentration and temperature fronts are formed.
3. Concentration and temperature fronts are similar in shape in desorption.
4. The lowest temperature attained in desorption will exceed the temperature of adiabatic saturation but only by a very small amount.
5. Drying of the bed as a whole shows a long "constant rate" period; this rate is only slightly smaller than the constant rate obtained when wool containing free water is dried.
6. The shapes and velocities of concentration and temperature fronts depend very much on the concentration limits over which desorption takes place.
7. In absorption stable fronts do not appear to be formed.
8. Concentration and temperature profiles in absorption are dissimilar in shape.
9. Overall absorption by the bed is initially faster than desorption, but finally slower.
10. Changes in air velocity are equivalent to changes in bed dimensions and vice versa.
11. Changes in the rate constant are equivalent to simultaneous changes in bed dimensions and time and vice versa.

A critical study of the behaviour of actual wool beds under conditions to which the calculations presented in this paper apply is in progress and will be reported later.

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APPENDIX I

The following is the numerical data used for the computations discussed in the paper.

$$f_1 = 1.02327 \exp \left[-4.81291 \exp \left(-16.191 \frac{m_w(x, t)}{d} \right) \right] \quad (\text{Fig. 7}) \quad (18)$$

$$\lambda = 1809 \left(\frac{m_w(x, t)}{d} - 0.3292 \right)^2 + 593 \text{ cal g}^{-1} (\text{H}_2\text{O sorbed}) \quad (\text{Fig. 8}) \quad (19)$$

The form of the isotherm follows closely that suggested by De Boer and Zwikker [3] and has been fitted to published data for wool [9]. The relation for heat of sorption or desorption is an empirical formula which also represents published data for wool [9].

- $A = 1.1858 \times 10^{10}$;
- $B = 5.2821 \times 10^3$;
- $v = 15 \text{ cm s}^{-1}$ unless stated otherwise;
- $c = 0.3 \text{ cal g}^{-1} \text{ degC}^{-1}$;

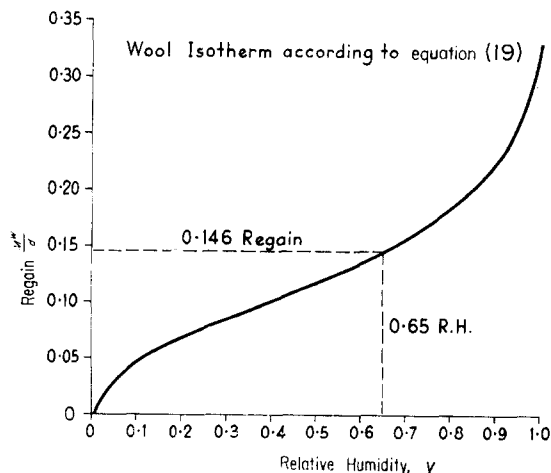


FIG. 7. The wool isotherm at 20°C as given by equation (18).

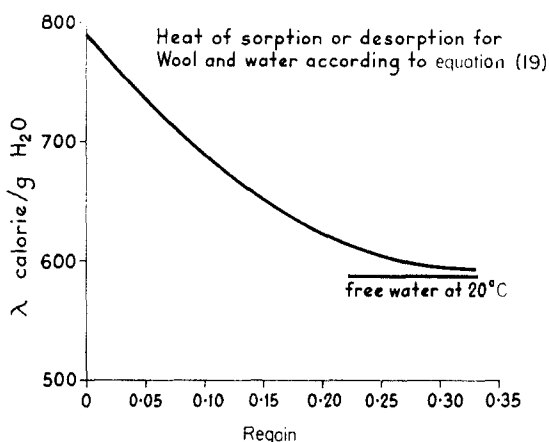


FIG. 8. Heat of sorption (or desorption) of wool at 20°C as given by equation (19).

- $d = 0.1 \text{ g cm}^{-3}$;
- $k = 2 \times 10^{-5} \text{ g s}^{-1} (\text{mm Hg})^{-1} \text{ cm}^{-1}$ (distance in bed);
- $T_A(0, t) = 293^\circ\text{K}$;
- $\Delta x = 0.05 \text{ cm}$;
- $\Delta t = 20 \text{ s}$.

APPENDIX II

Equations (5), (6), (7) and (8) may be expressed in the dimensionless form as follows:

$$\frac{\partial v}{\partial \xi} + \frac{\partial \mu}{\partial \tau} = 0 \quad (20)$$

$$\frac{\partial v}{\partial \xi} = (\pi_w - \pi_A) \quad (21)$$

$$\frac{\partial \theta_A}{\partial \xi} + \frac{\partial \theta_w}{\partial \tau} + \kappa \frac{\partial v}{\partial \xi} = 0 \quad (22)$$

$$\frac{\theta_A}{\partial \xi} = \left(\frac{\theta_w}{\sigma_w} - \frac{\theta_A}{\sigma_A} \right) \quad (23)$$

where

$$\xi = \frac{kp^*}{vm^*} x$$

$$\tau = \frac{kp^*}{m^*} t$$

$$\mu = \frac{m_w}{m^*}$$

$$\nu = \frac{m_A}{m^*} \qquad \kappa = \frac{\lambda k p^*}{h T^*}$$

$$\theta_A = \frac{C_p \zeta k p^*}{h T^* m^*} T_A \qquad \pi_A = \frac{p_A}{p^*}$$

$$\theta_w = \frac{c dk p^*}{h T^* m^*} T_w \qquad \pi_w = \frac{p_w}{p^*}$$

$$\sigma_A = \frac{C_p k \zeta p^*}{h m^*}$$

$$\sigma_w = \frac{c dk p^*}{h m^*}$$

The quantities p^* , m^* and T^* may be assigned arbitrary (non-zero) values. m^* , for example, may be made equal to the saturation value for m_w , while p^* and T^* may be given the boundary values for the particular calculation considered. π_A and π_w are not independent variables but functions of θ_A , ν and θ_w , μ respectively.

Résumé—On donne les équations différentielles pour le transport de masse de vapeur d'eau en convection forcée dans un lit de fibres de laine. On fait des hypothèses pour simplifier le problème, qui est alors résolu numériquement en utilisant la méthode des différences finies. Les conséquences provenant de ce modèle de transport de masse sont discutées et les profils prédits de concentration et de température sont présentés pour l'absorption et la désorption et pour différentes limites de concentration.

Le système laine-eau est caractérisé par une isotherme de sorption sigmoïdale et une chaleur de sorption dépendant de la concentration.

Zusammenfassung—Es werden die Differentialgleichungen für den Stofftransport von Wasserdampf bei Zwangskonvektion in einem Wollfaserbett aufgestellt. Nach vereinfachenden Annahmen wird das Problem numerisch nach der Methode endlicher Differenzen gelöst. Die aus diesem Modell des Stofftransports sich ergebenden Folgerungen werden diskutiert und Konzentrations- und Temperaturprofile für Absorption, Desorption und verschiedene Konzentrationsgrenzen angegeben.

Das Woll-Wassersystem wird von einer sigmaförmigen Sorptionsisotherme und von konzentrationsabhängiger Sorptionswärme charakterisiert.

Аннотация—Приводятся дифференциальные уравнения переноса массы водяного пара в слое шерстяных волокон при вынужденной конвекции. При определенных допущениях задача численно решается по методу конечных разностей. Рассматриваются результаты такого моделирования переноса массы, приводится расчет профилей концентрации и температуры при абсорбции и десорбции для различных значений концентрации.

Для системы шерсть-вода характерны сигмоидальная изотерма сорбции и зависящая от концентрации теплота сорбции.