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NOTATION

A = area of heating surface
B = film thickness
C_1 = numerical constant
C_2 = numerical constant
c_p = specific heat at constant pressure
D = diameter ($d = D$ in figures)
g = acceleration due to gravity
h = mean heat transfer coefficient, 1 W./(°K.)(sq. cm.) = 1,761 B.t.u./(sq. ft.)(hr./°F.)
k = heat conductivity of vapor
L = length of test section ($l = L$ in figures)
m = exponent of empirical correlation
n = empirical exponent
$N_{Gr} = D^3 \cdot \rho^2 \beta g \, \Delta T/\mu^2$
$N_{Gr}^* = \dfrac{D^3 g \rho(\rho_v - \rho)}{\mu^2}$ modified Grashof number
$N_{Nu} = hD/k$
$N_{Pr} = c_p \mu/k$
q = rate of heat flow
R = electrical resistance
R_{273} = electrical resistance at ice point
$R_{4.2}$ = electrical resistance at liquid-helium temperature
T = absolute temperature
T_m = mean temperature of vapor
ΔT = temperature difference

Greek Letters

β = Coefficient of thermal expansion
β^* = Modified coefficient of thermal expansion
ρ = density of vapor
ρ_L = density of saturated liquid
ρ_v = density of saturated vapor
μ = viscosity of vapor
λ = latent heat of vaporization
λ' = effective heat of vaporization

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COMMUNICATIONS TO THE EDITOR

The Uselessness of Raffinate Reflux

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The theory behind the separation of liquid mixtures into their constituents by solvent extraction is based on the relatively simple, exact, material-balance calculation which may be done graphically for a two-component system. In this operation a feed stream is separated into two streams by contact with a partially miscible solvent in a countercurrent cascade (*1*, *2*). Ideally one component is extracted into a solvent rich phase and the other is obtained in a solvent poor or raffinate phase. The separation is complete when the solvent is recovered from each stream. In a finite cascade each constituent is contaminated by a certain portion of the other constituent, which can be made as small as desired if the solvent is partially miscible with each component. Even so, to achieve this degree of separation the cascade must be modified by feeding into an intermediate stage and refluxing a portion of the product recovered from the extract.

A number of expositions of this theory show a countercurrent cascade which also includes reflux from the raffinate phase as a useful method of operation. This mode of operation is a needless generalization of the reflux concept, as it cannot achieve any degree of separation which cannot be obtained in its absence. The number of theoretical stages required for a desired separation is the same with or without raffinate reflux. In addition the use of raffinate reflux requires an extra solvent mixing stage. The saturation of the solvent that is achieved in this mixing stage can in no way aid the possible degree of separation. That the number of theoretical stages other than the mixing stage depends only on the degree of separation and an extract reflux ratio great enough to avoid a pinch point at any stage along the cascade is shown by locating the operating points and stepping off stages starting from the raffinate end. Alternately it can be seen that the number of stages is exactly the same when the material balances are started from the extract end and the reflux ratio is adjusted by trial and error until an integral number of stages is achieved. This latter condition is in reality the only situation in which the solution is exact mathematically. The nonintegral number of stages generally obtained for an arbitrary reflux ratio is only an approximation.

The lack of usefulness of raffinate reflux applies also in the case of extraction with a solvent that is immiscible with only one of the constituents of a binary system. In this case extract reflux may or may not be used. Without extract reflux, raffinate reflux achieves with an extra mixing stage only that separation which an adequate solvent-to-feed ratio already assures. Extract reflux can improve the degree of separation by a considerable amount if a solvent of low selectivity must be used but will not greatly aid the separation if a highly selective solvent is available.

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