The holdups can be used to explain the differences between gas-phase mass transfer rates obtained by vaporization and absorption techniques and to provide the limiting mass transfer rates for low and high absorbent concentrations when absorption is followed by an irreversible chemical reaction.

NOTATION

a = effective interfacial area, sq. ft./cu.ft.
D_p = diameter of sphere possessing the same surface area as a piece of packing, ft.
G = superficial gas rate, lb./(hr.)(sq.ft.)
h_o = operating holdup, cu.ft./cu.ft.
h_s = static holdup, cu.ft./cu.ft.
h_t = total holdup, cu.ft./cu.ft.
k_G = gas-phase mass transfer coefficient, lb. moles/(hr.)(sq. ft.)(atm.)
k_L = liquid-phase mass transfer coefficient, lb. moles/(hr.)(sq. ft.)(lb. mole/cu.ft.)
L = superficial liquid rate, lb./(hr.)(sq.ft.)
N = pieces of packing/cu.ft. of packing

Subscripts

vap = obtained by vaporization or absorption in very concentrated absorbents
abs = obtained by absorption in water or extremely dilute absorbents

Greek Letters

α = constant in Equantion (2)
β = constant in Equation (2)
γ = constant in Equation (3)
δ = constant in Equation (4)
ε = void fraction, cu.ft./cu.ft.
θ = constant in Equation (3)
λ = constant in Equation (4)

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II. Wetted and Effective-interfacial Areas, Gas - and Liquid-phase Mass Transfer Rates

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A study was made of separating the volumetric mass transfer coefficients, k_Ga and k_La, into their components k_G, k_L, and a so that the effects of variables might be determined separately for each component. Mass transfer rates for four packings, ½- and 1½-in. Raschig rings and ½-in. and 1-in. Berl saddles, made of naphthalene, were determined by vaporization into air at gas rates from 100 to 1,000 lb./(hr.) (sq. ft.).

The correlation for k_G was used to determine the wetted areas of those packings when irrigated with water and to calculate the effective interfacial areas, a, from Fellinger's data for ammonia absorption. These effective areas were then used to evaluate k_L from previously published k_La data, and a correlation was obtained for all packings.

The correlations for k_G and k_L and the effective-interfacial-area data make possible a more rigorous method for the design of packed columns than was heretofore available.

To predict the performance of columns employing ring and saddle packings for design purposes reliable data such as those of Fellinger(*4*) for volumetric gas-phase coefficients, k_Ga, and of Sherwood and Holloway(*8*) for volumetric liquid-phase coefficients, k_La, are used. Such coefficients can be estimated for aqueous systems from these sources of data and combined by the following relation to give for a limited number of packings the over-all mass transfer coefficients desired for design.

$$\frac{1}{K_Ga} = \frac{1}{k_Ga} + \frac{1}{Hk_La} = \frac{1}{HK_La} \quad (1)$$

Although these sources of data are

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considered reliable, they are of questionable value for predicting mass transfer rates for nonaqueous systems and for packings other than those for which data are reported. An examination of the data reveals no simple relation between packing size and performance even for one type of packing. For this reason the data must be presented in the form of plots or empirical equations which are of little value in predicting the performance of packings for which data are not available. The work of Surosky and Dodge(*11*) and Mehta and Parekh (*7*) on the vaporization of organic liquids and water in packed columns and that described in Part I of this paper, on total liquid holdup in carbon and porcelain packings, indicate that the effective interfacial area is a function of the properties of the liquids employed and the nature of the packing surface. Thus it is unlikely that data obtained with aqueous systems and a specific packing material can be used to estimate the performance in nonaqueous systems or even in aqueous systems when packing materials with different surface properties are used.

To overcome the limitations of the methods discussed, a more fundamental approach to the problem of mass transfer between phases in packed columns must be employed. As the first and most obvious step in this direction it would be desirable to separate the coefficients, k_G and k_L, from the effective interfacial area, a, in order to determine separately the effects of variables on each component of the volumetric coefficients, k_Ga and k_La.

Two attempts to separate a and k_G have been reported by Shulman and DeGouff(*9*) and Weisman and Bonilla(*14*). The methods used were equivalent to using k_G, obtained by vaporization of naphthalene or water from special Raschig rings of known transfer area, and various sources of k_Ga data to evaluate a, the effective interfacial area. As no liquid was used to irrigate the packing, no attempt was made to take into account the effect of the liquid flowing through the packing under practical operating conditions. Part I indicates that an appreciable portion of the void space in packing may be occupied by liquid, leaving a much smaller free space for gas flow than had been expected previously. In addition the recent work of Gamson(*5*), Evans and Gerald(*3*), McCune and Wilhelm(*6*), and Chu, Kalil and Wetteroth(*1*) has shown that the free space for gas flow, ϵ, is an important variable for correlating mass transfer data.

The present work was undertaken to separate k_G and k_L from a, to overcome the limitations of methods employed previously, and to obtain correlations for k_G and k_L in terms of all pertinent variables in order to make possible the prediction of the performance of packings for which data are not available. The method employed is outlined as follows.

1. Naphthalene packings (0.5- and 1.5-in. Raschig rings and 0.5- and 1.0-in. Berl saddles) were used to obtain k_G data which could be combined with previous work to obtain a single k_G correlation for all ring and saddle packings which would take into account the effect of liquid in the packing on k_G.
2. The k_G correlation was used in conjunction with Fellinger's(*4*) extensive k_Ga data for ammonia absorption to calculate the effective interfacial areas, a, for the five packings, 0.5-, 1.0-, and 1.5-in. Raschig rings and 0.5- and 1.0-in. Berl saddles, for which total holdup data were available.
3. The effective interfacial areas were applied to the k_La data of several investigators to obtain k_L values for the five packings which could be correlated by a single equation.

TABLE 1.—PROPERTIES OF NAPHTHALENE PACKINGS

	Raschig rings			Berl saddles	
Nominal size, in.	0.5	1.0*	1.5	0.5	1.0
Height, in.†	0.50	1.0	1.5	....	....
Outside diameter, in.†	0.50	1.0	1.5	....	....
Wall thickness, in.†	0.0938	0.125	0.250	....	....
Void fraction, dry	0.630‡	0.758†	0.688‡	0.660†	0.695†
No. of pieces/cu. ft.	10,700‡	1,220‡	366‡	15,000†	1,810†
Surface area/piece, sq. ft.	0.0105‡	0.0430‡	0.0955‡	0.00888**	0.0346**
Surface area, sq. ft./cu. ft.‡	113	52.5	35.0	133	62.6
Diam. of equivalent sphere, ft.*	0.0578	0.1167	0.174	0.0532	0.105

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* From data of Shulman and DeGouff (*9*)

† From measurements

‡ Calculated

** From data of Maurice A. Knight, Akron, Ohio

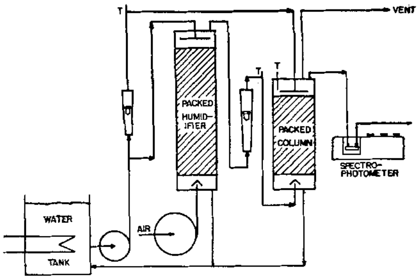

FIG. 1. SCHEMATIC DIAGRAM OF APPARATUS.

4. The correlations for k_G and k_L were tested and found satisfactory for extension to larger packings, 2.0-in. rings and 1.5-in. saddles, for which incomplete data were available.

In addition to the studies outlined, work was done on the wetted area in ring and saddle packings to supply data which may be of value in developing a method for predicting the behavior of nonaqueous liquids in packings.

APPARATUS AND PROCEDURE

The apparatus, a schematic diagram of which is given in Figure 1, has been described in detail by Shulman and DeGouff(*9*) except for several minor changes, which will be discussed. To improve control a water-storage tank with a circulating pump was installed and the air orifice meters were replaced by two calibrated rotameters. A new technique was developed to analyze the air for naphthalene. The optical density of air containing naphthalene, as measured in 10-cm. quartz cells in a Beckmann model DU photoelectric quartz spectrophotometer, was found to be proportional to the naphthalene partial pressure. This provided a very rapid and simple method of analysis for the naphthalene.

The naphthalene Raschig rings, which were prepared by means of special molds on a fast-acting hydraulic press, were held to close tolerances by weighing the feed for each 1.5-in. ring and by using a calibrated feed measure for the 0.5-in. rings. The 0.5- and 1.0-in. naphthalene Berl saddles, prepared by Maurice A. Knight, have the same dimensions as do the porcelain Berl saddles supplied commercially by this company. The characteristics of the naphthalene packings used are tabulated in Table 1. The naphthalene used for all the work was crushed refined Polar naphthalene obtained from the Barrett Division of Allied Chemical and Dye Corporation.

To determine k_G and wetted areas for a naphthalene packing the 3-ft. by 10-in. diam. Pyrex column was packed with 6 in. of porcelain packing followed by 3 to 6 in. of naphthalene packing of the same type and another 6 in. of porcelain packing. The porcelain packing above and below the naphthalene provided the gas and liquid distribution which was characteristic of the packing used. Air and water temperatures were adjusted to the 20° to 23°C. range and held constant to within ±0.1°C. for each run. To determine k_G with a dry packing the air rate was set at the desired value and inlet and outlet air temperatures were checked for constancy for a minimum of 10 min. When equilibrium was established, a copper air-sampling line at the top of the column, which operated at a pressure slightly above atmospheric, was opened and a 10-cm. quartz cell was flushed for about 1 min. with the outlet air. The cell stopcocks were closed and the cell was placed in the spectrophotometer for analysis. The optical density of the air-naphthalene mixture was determined at three naphthalene ultraviolet absorption peaks, 221.75, 258.75, and 268.75 $m\mu$. The optical densities of air saturated with naphthalene had been measured previously at these three wavelengths at several temperatures in the 15° to 25°C. range. The k_G for the run was calculated by an equation employing these optical densities, which was derived as follows. As the inlet air was free of naphthalene and a logarithmic mean driving force was applicable because the partial pressure of naphthalene never exceeded 0.1 mm. Hg, one can write

$$k_G A \frac{[(p_s) - (p_s - p_o)]}{\ln\left[\dfrac{p_s}{p_s - p_o}\right]} = \frac{GSp_o}{M_M P} \qquad (2)$$

and as the optical density, α, as measured by the spectrophotometer, is proportional to the partial pressure of naphthalene

$$k_G = \frac{GSp_o}{AM_M P} \, \frac{\ln\left[\dfrac{p_s}{p_s - p_o}\right]}{p_o} = \frac{GS \ln\left[\dfrac{\alpha_s}{\alpha_s - \alpha_o}\right]}{AM_M P} \qquad (3)$$

The term containing the optical densities was evaluated for the readings at the three wavelengths and an average value was used for each run. In addition each run was duplicated, and each k_G value reported is the average value for two or more runs at the same conditions. An attempt was made to keep the outlet air naphthalene concentration in the neighborhood of 50 to 60% saturated. This was not always possible with the smaller packings at lower air rates, and these date scattered as a result. The naphthalene concentrations could be duplicated within 2%.

To determine the wetted area of the naphthalene packings when they were irrigated with water, a similar procedure was used except that Equation (3) was rearranged so that $k_G A$ was evaluated for the dry area. The corresponding k_G was calculated from the correlation of the data obtained with the dry packing so that the dry area, A, might be calculated and the wetted area found by the difference from the total surface area.

EXPERIMENTAL RESULTS

Mass Transfer in Dry Naphthalene Packings. The data obtained with the dry naphthalene packings are shown in Figure 2 with the data of Shulman and DeGouff(*9*) for 1.0-in. rings as a plot of the mass transfer factor, j_D, vs. a modified Reynolds number. The equation for the best line through the points is

$$j_D = \left[\frac{k_G M_M P_{BM}}{G}\right]\left[\frac{\mu_G}{\rho_G D_V}\right]^{2/3} = 1.195\left[\frac{D_P G}{\mu_G(1-\epsilon)}\right]^{-0.36} \qquad (4)$$

Other methods of correlation were tested, such as those suggested by Gamson(*5*) and Taecker and Hougen(*11*), but the one used was found to represent the data best. The correlation includes the void fraction, ϵ, which makes it possible to take into account the effect of liquid in the packing when the total holdup is known under operating conditions. In Figure 3 the data are compared with the extensive data of Chu, Kalil, and Wetteroth(*1*) on fixed and fluidized beds of a variety of particles coated with naphthalene. The agreement is good, with the best line for Chu's data (not shown on Figure 3) lying slightly below the line recommended by the authors. The broken line on Figure 3 represents the equation

$$j_D = 1.77\left[\frac{D_P G}{\mu_G(1-\epsilon)}\right]^{-0.44} \qquad (5)$$

which Chu obtained as the best line representing his data and those of numerous previous investigators of fixed and fluidized beds.

Figure 4 compares the authors' line with the data of Taecker and Hougen(*11*) obtained by vaporizing water from porous packings. There is good agreement for the Berl saddle data, but each series of data for the rings shows increasing disagreement at the higher Reynolds numbers corresponding to

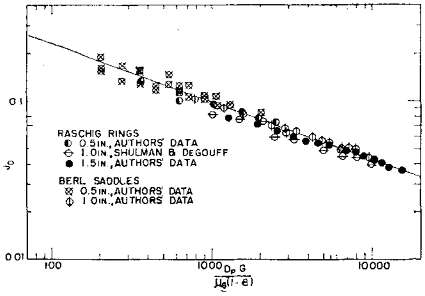

FIG. 2. MASS TRANSFER FACTORS FOR NAPHTHALENE PACKING.

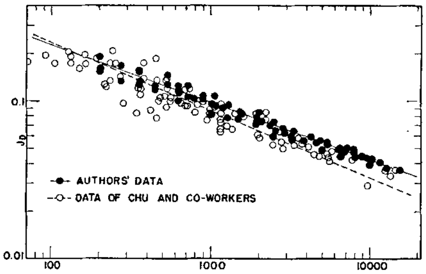

FIG. 3. COMPARISON OF AUTHOR'S DATA WITH DATA OF CHU AND CO-WORKERS.

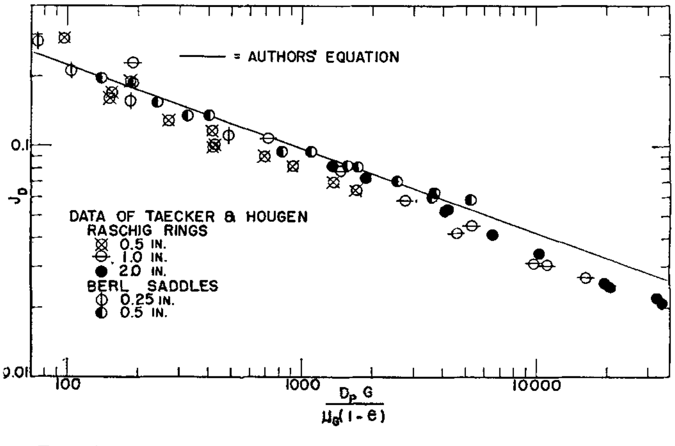

FIG. 4. COMPARISON OF AUTHOR'S EQUATION WITH DATA OF TAECKER AND HOUGEN.

high gas rates. A possible explanation of this type of behavior for wetted porous rings may be an incompletely wetted surface brought about by the inability of the water to migrate to the surface fast enough to keep the surface completely wetted. It is interesting to note that the Berl saddles used by Taecker and Hougen(*11*) were prepared by Maurice A. Knight by molding and the Raschig rings were prepared by the authors by extrusion. The differences in preparation may have resulted in porous materials with different properties. The good agreement with the Berl saddle data and the Raschig ring data at the lower gas rates is an indication that the Schmidt number to the 2/3 power is capable of correlating data of different systems.

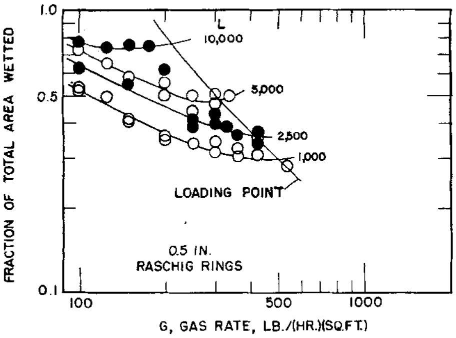

FIG. 5. WETTED AREA FOR 0.5-IN. NAPHTHALENE RASCHIG RINGS.

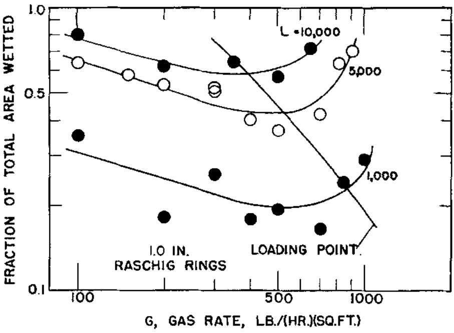

FIG. 6. WETTED AREA FOR 1.0-IN NAPHTHALENE RASCHIG RINGS CALCULATED FROM DATA OF SHULMAN AND DEGOUFF.

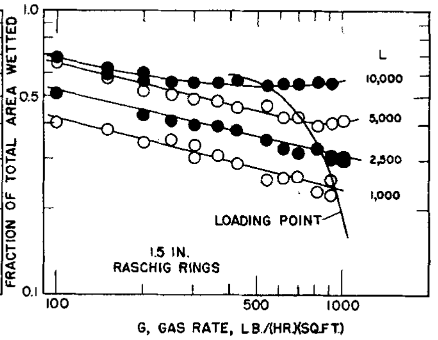

FIG. 7. WETTED AREA FOR 1.5-IN. NAPHTHALENE RASCHIG RINGS.

Wetted Area in Naphthalene Packings. The wetted areas for irrigated naphthalene packings were divided by the total surface areas, listed in Table 1, and are presented in Figures 5, 7, 8, and 9 as the fraction of the total area wetted. Figure 6 shows the data of Shulman and DeGouff(*9*) for 1.0-in. Raschig rings recalculated by means of Equation (4) for k_G and the total holdup data obtained in Part I. The loading points shown in these figures are obtained from the work of Tillson(*12*). For all the packings the wetted areas increase with increasing liquid rate and decrease with increasing gas rate usually until the loading point is reached when the lines tend to become horizontal or even to show an increase in wetted area at still higher gas rates. The unusual effect of gas rate was first reported by Shulman and DeGouff(*9*) and was found again for the four packings used in this work. The explanation of this phenomenon as offered in the earlier work seems to be valid. It will be shown later that the effective interfacial areas also decrease at increasing gas rates for low liquid rates.

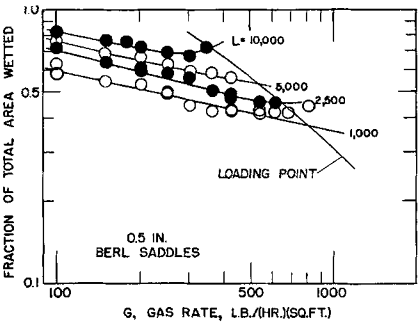

FIG. 8. WETTED AREA FOR 0.5-IN. NAPHTHALENE BERL SADDLES.

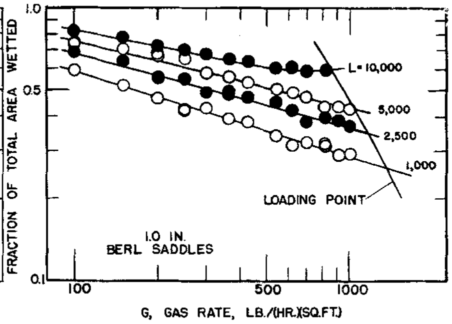

FIG. 9. WETTED AREA FOR 1.0-IN. NAPHTHALENE BERL SADDLES.

The wetted-area data obtained in this work can be correlated by a line for each type of packing, as shown in Figure 10. For some unknown reason the data of Shulman and DeGouff(*9*) for the 1.0-in. rings scatter badly on this type of plot. The equations of the two lines in Figure 10 are

$$\frac{a_w}{a_t} = 0.35\left[\frac{L}{G}\right]^{0.20} \qquad (6)$$

for Berl saddles and

$$\frac{a_w}{a_t} = 0.24\left[\frac{L}{G}\right]^{0.25} \qquad (7)$$

for Raschig rings.

EFFECTIVE INTERFACIAL AREA

A correlation for k_G, such as is given by Equation (4), makes it possible to calculate the effective interfacial area, a, from reliable sources of k_Ga data. The data of Fellinger(*4*) for ammonia absorption in water obtained by use of nine ceramic packings seem to be the most complete and reliable source of data. Part I of this paper explains the reason for the large differences between k_Ga obtained by vaporization and absorption techniques on the basis of total and operating holdups. On the basis of this explanation it should be emphasized that the effective interfacial areas reported here are valid for absorption work. For vaporization of water the effective area is greater by a factor equal to 0.85 times the ratio of total to operating holdup at the liquid and gas rates employed.

Fellinger's(*4*) data were corrected for liquid-phase resistance by means of the Sherwood and Holloway(*8*) correlation and divided by the corresponding k_G obtained from Equation (4) and the

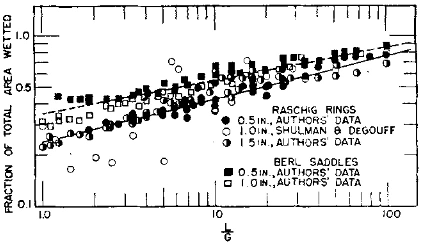

FIG. 10. CORRELATION OF FRACTION WETTED FOR NAPHTHALENE PACKINGS.

holdup data of Part I. Figures 11, 12, 13, 15, and 16 present the effective interfacial areas for the packings for which both absorption and holdup data are available. Figures 14 and 17 present these areas for 2.0-in. rings and 1.5-in. saddles employing holdups estimated by means of correlating equations given in Part I. The loading-point line on each figure was obtained from the data of Tillson(*12*).

An examination of these plots shows that the effective interfacial area increases with increasing liquid rate and is fairly independent of gas rate although in general it increases with gas rate at high liquid rates, decreases at the lower liquid rates, and is independent at the intermediate liquid rates. The behavior at low liquid rates is similar to that of the wetted area. A comparison of wetted and effective areas reveals some important differences. Wetted areas increase as packing size decreases. The effective area, however, is smallest for the smallest packings in spite of the fact that they possess the largest total surface and wetted area. The effective area seems to go through a maximum for the 1.0-in. rings and saddles although the larger packings have almost as much effective area. It may be possible to explain these results by the holdup studies in Part I. The small packings were found to have very large static holdups which exist in the packing as pockets of almost stagnant water. This water can account for the large wetted area, but it is practically useless for absorption because it comes to equilibrium with the gas very rapidly. The water which runs through the packing, corresponding to the operating holdup, flows through the numerous crevices at the points of contact in the small packing, exposing a relatively small surface area. In the larger packings there are fewer points of contact and resulting crevices, and so the water must spread out over the surface and the effective area is more closely related to the wetted area.

CORRELATION OF k_L FOR RINGS AND SADDLES

Sherwood and Holloway(*8*) have obtained k_La data for nine ceramic packings by desorption of slightly soluble gases from water. Some of this work has been checked by other investigators, for instance, Deed, Schutz, and Drew(*2*) and Vivian and Whitney(*13, 15*), with good agreement. As was pointed out earlier, there is no way to correlate the k_La data for the different packings. With the effective interfacial areas for absorption, as shown in Figures 11 to 17 inclusive, it is a simple matter to extract k_L and attempt a generalized correlation. Figure 18 shows the best correlation that could be obtained from the three sources of data cited above. For some of the packings it was possible to extrapolate with confidence the effective interfacial areas to liquid rates well above those shown in Figures 11 to 17. The line drawn in Figure 18 is the best line through the points for 0.5-, 1.0-, and 1.5-in. rings and 0.5- and 1.0-in. saddles.

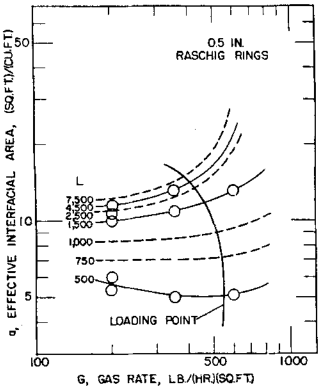

FIG. 11. EFFECTIVE INTERFACIAL AREA FOR 0.5-IN. RASCHIG RINGS BASED ON DATA OF FELLINGER.

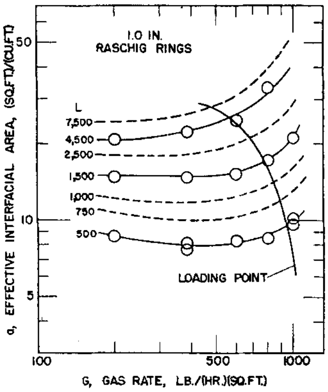

FIG. 12. EFFECTIVE INTERFACIAL AREA FOR 1.0-IN. RASCHIG RINGS BASED ON DATA OF FELLINGER.

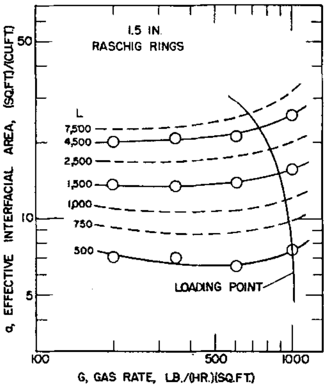

FIG. 13. EFFECTIVE INTERFACIAL AREA FOR 1.5-IN. RASCHIG RINGS BASED ON DATA OF FELLINGER.

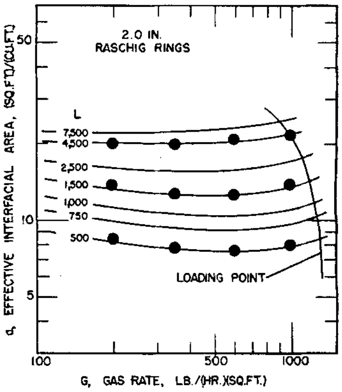

FIG. 14. EFFECTIVE INTERFACIAL AREA FOR 2.0-IN. RASCHIG RINGS BASED ON DATA OF FELLINGER USING ESTIMATED HOLDUPS.

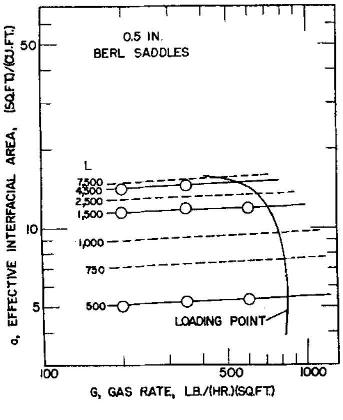

FIG. 15. EFFECTIVE INTERFACIAL AREA FOR 0.5-IN. BERL SADDLES BASED ON DATA OF FELLINGER.

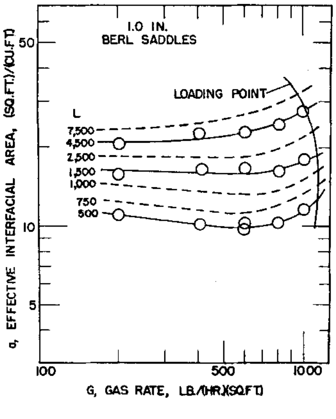

FIG. 16. EFFECTIVE INTERFACIAL AREA FOR 1.0-IN. BERL SADDLES BASED ON DATA OF FELLINGER.

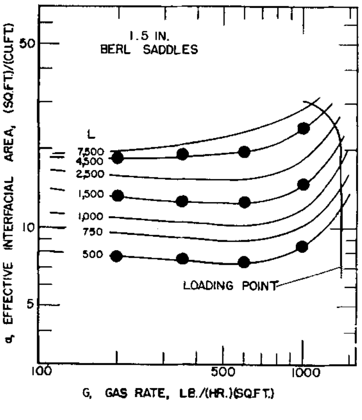

FIG. 17. EFFECTIVE INTERFACIAL AREA FOR 1.5-IN. BERL SADDLES BASED ON DATA OF FELLINGER USING ESTIMATED HOLDUPS.

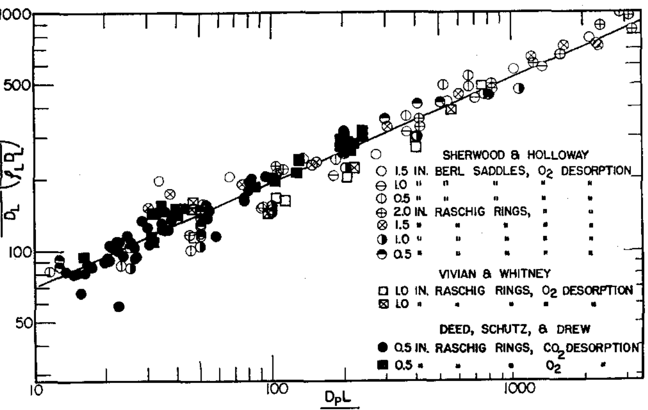

FIG. 18. CORRELATION OF LIQUID-PHASE DATA.

The points for 2.0-in. rings and 1.5-in. saddles, which are based on effective interfacial areas calculated from Fellinger's (*4*) data, Equation (4) for k_G, and estimated holdups, are also in good agreement with this line. This indicates that the correlations for k_G, k_L, and holdup can be used to predict the performance of packings for which complete data are not available.

The equation for the line in Figure 18 is

$$\frac{k_L D_P}{D_L} = 25.1\left[\frac{D_P L}{\mu_L}\right]^{0.45}\left[\frac{\mu_L}{\rho_L D_L}\right]^{0.5} \tag{8}$$

It can be seen that k_L is independent of gas rate, and so $k_L a$ can be expected to vary with gas rate as a does, as shown in Figures 11 to 17 inclusive. This observation seems to contradict that of Sherwood and Holloway (*8*), who found $k_L a$ to be independent of gas rate up to loading. Their statement, however, seems to be based on data obtained with 1.5-in. rings at a liquid rate of 2,000 lb./(hr.)(sq.ft.). As an examination of Figure 13 shows a to be just about independent of gas rate at this liquid rate, $k_L a$ should also be independent. It should be noted that it would not be serious to neglect the effect of gas rate with large packings, but some of the small packings do show an appreciable effect at the high and low liquid rates.

Equation (8) will predict the effects of temperature and diffusivity as found by Sherwood and Holloway (*8*). If further work on effective interfacial areas makes possible predictions for nonaqueous systems, it will be possible to use Equations (4) and (8) to predict the performance of ring and saddle packing for all systems.

RESULTS AND CONCLUSIONS

For Raschig ring and Berl saddle packings mass transfer rates can be predicted for the gas phase by

$$j_D = \left[\frac{k_G M_M P_{BM}}{G}\right]\left[\frac{\mu_G}{\rho_G D_V}\right]^{2/3} = 1.195\left[\frac{D_P G}{\mu_G(1-\epsilon)}\right]^{-0.36} \tag{4}$$

and for the liquid phase by

$$\frac{k_L D_P}{D_L} = 25.1\left[\frac{D_P L}{\mu_L}\right]^{0.45}\left[\frac{\mu_L}{\rho_L D_L}\right]^{0.5} \tag{8}$$

The effective interfacial areas, a, for absorption and desorption are given for seven packings in Figures 11 to 17 inclusive, and those for vaporization can be estimated from these by applying a factor equal to 0.85 times the ratio of total holdup to operating holdup.

The wetted areas for five packings, Figures 5 to 9 inclusive, are not related in any simple manner to the effective interfacial areas.

NOTATION

A = total dry surface area, sq.ft.
a = effective interfacial area, sq.ft./cu.ft.
a_w = wetted area, sq.ft./cu.ft.
a_t = total surface area, sq.ft./cu.ft.
D_L = diffusivity of solute in liquid, sq.ft./hr.
D_P = diameter of sphere possessing the same surface area as a piece of packing, ft.
D_V = diffusivity of solute in gas, sq.ft./hr.
G = superficial gas rate, lb./(hr.)(sq.ft.)
H = Henry's law constant, lb. moles/(cu.ft.)(atm.)
j_D = mass transfer factor
K_G = over-all mass transfer coefficient, lb. moles/(hr.)(sq.ft.)(atm.)
k_G = gas-phase mass transfer coefficient, lb. moles/(hr.)(sq.ft.)(atm.)
K_L = over-all mass transfer coefficient, lb. moles/(hr.)(sq.ft.)(lb. moles/cu.ft.)
k_L = liquid-phase mass transfer coefficient, lb. moles/(hr.)(sq.ft.)(lb. moles/cu.ft.)
L = superficial liquid rate, lb./(hr.)(sq.ft.)
M_M = mean molecular weight of gas, lb./(lb. mole)
P = total pressure, atm.
p_{BM} = mean partial pressure of inert gas in the gas phase, atm.
p_o = partial pressure of naphthalene in outlet air, atm.
p_s = vapor pressure of naphthalene, atm.
S = column cross-sectional area, sq. ft.

Greek Letters

α = optical density
α_o = optical density of outlet air
α_s = optical density of air saturated with naphthalene
ϵ = void fraction, cu.ft./cut.ft.
μ_G = gas viscosity, lb./(hr.)(ft.)
μ_L = liquid viscosity, lb./(hr.)(ft.)
ρ_G = gas density, lb./cu.ft.
ρ_L = liquid density, lb./cu.ft.

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