TABLE 1. COMPARISON OF EXPERIMENTAL AND CALCULATED DATA

System	Re_{pm}	Experimental j_D	Calculated j_D Equation (1)	Calculated j_D Equation (2)
2-naphthol, water	140	0.171	0.0415	0.171
2-naphthol, water	2 820	0.061	0.009	0.065
Succinic acid, aq. acetone	263	0.225	0.175	0.184
Succinic acid, *n*-butanol	510	0.143	0.029	0.143

Hughmark (1972) presented a correlation for mass transfer data in packed beds that also represented heat transfer data. The heat transfer data were obtained with simultaneous mass transfer

$$\frac{kD_e}{\mathfrak{D}} = 0.22 \left(\frac{D_e u_e}{\nu}\right)^{2/3} (N_{Sc})^{1/3} \qquad (2)$$

Galloway and Sage (1970) used an instrumented copper sphere, 3.8 cm diameter, which was provided with a small calorimeter to obtain heat transfer to flowing air in a packed bed of uniform diameter spheres. Lindauer (1967) obtained heat transfer data for particles to air in a packed bed with the cyclic temperature method. Figure 1 shows the Galloway and Sage data and the Lindauer data for 0.048 cm tungsten spheres and 0.32 cm steel spheres for comparison with Equation (2). Good agreement is observed. This agreement of heat and mass transfer data confirms that particle-to-particle transfer is negligible in the turbulent region because the mass transfer correlation represents data without particle-to-particle transfer.

The Bhattacharyya and Pei data for 0.32 and 0.76 cm are also shown by Figure 1. It is apparent that these data, which are claimed to represent fluid-to-particle heat transfer, are inconsistent with the fluid-to-particle mass transfer correlation and the apparent fluid-to-particle heat transfer data.

NOTATION

Ar = Archimedes number, $D^3 g\rho(\rho_s - \rho)/\mu^2$
D = diameter of solids
D_e = equivalent diameter of channel
$\mathfrak{D}$ = molecular diffusivity
G = superficial mass velocity of fluid
g = acceleration due to gravity
j_D = Colburn mass transfer factor
j_h = Colburn heat transfer factor
k = mass transfer coefficient
N_{Pr} = Prandtl number
N_{Sc} = Schmidt number
Re_{pm} = modified Reynolds number, $DG/\mu(1 - \epsilon)$
u_e = actual velocity in packing channels

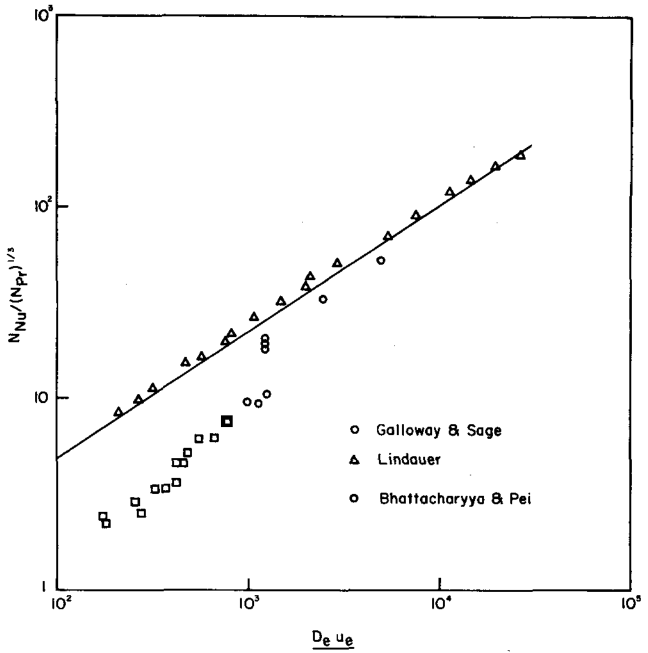

Fig. 1. Packed bed heat transfer.

Greek Letters

ϵ = packing void fraction
μ = fluid viscosity
ν = fluid kinematic viscosity
ρ = fluid density
ρ_s = solids density

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Manuscript received July 24, 1975; revision received November 6, and accepted November 7, 1975.

Miscibility Considerations in the System Propane-Hexatriacontane

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Rowlinson's discovery of the partial miscibilities of lower paraffinic hydrocarbons with their higher homologues has resulted in a large number of systems being studied, in which the prime cause of immiscibility seems to be the difference in size of the two components. With the discussion restricted primarily to paraffinic components, the following is known: methane is immiscible with *n*-hexane across a narrow temperature range, though it is completely miscible with all paraffinic components C_5 and lower in chain size (Davenport and Rowlinson, 1963). In an inter-

TABLE 1. PHASE DATA FOR THE SYSTEM PROPANE-HEXATRICONTANE

Temperature (°C)	Pressure (mega pascals)		Temperature (°C)	Pressure (mega pascals)	
140.7	9.71	Gas-liquid	24.9	0.945	Solid-liquid-gas
138.1	9.37	Gas-liquid	25.9	1.21	Solid-liquid-gas
135.6	9.14	Gas-liquid	46.6	1.51	Solid-liquid-gas
134.2	8.92	Gas-liquid	56.1	1.68	Solid-liquid-gas
132.6	8.76	Gas-liquid	61.3	1.57	Solid-liquid-gas
131.4	8.65	Gas-liquid	65.4	1.17	Solid-liquid-gas
130.1	8.45	Gas-liquid	69.3	0.800	Solid-liquid-gas
129.2	8.39	Gas-liquid			
127.2	8.16	Gas-liquid			
120.9	7.45	Gas-liquid			
111.2	6.15	Gas-liquid			

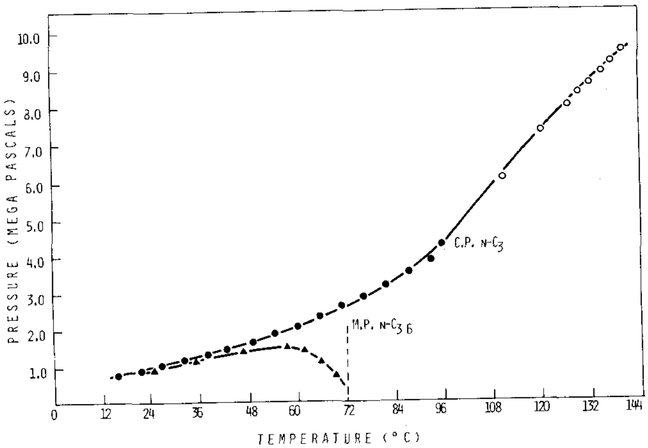

Fig. 1. Projection of the critical locus of binary mixtures of propane and hexatriacontane.

esting variation (Guy et al., 1967), a methane (80 mole %)-nitrogen (20 mole %) mixture was found to be immiscible with C_5 paraffins, and a separation of n- and isopentane was effected.

When methane is replaced by ethane as the lower boiling component, it becomes necessary to go as high as n-$C_{19}H_{40}$ (Kohn et al., 1966) before liquid-liquid immiscibility is noticed. It has also been pointed out that structural changes (that is, branching) play an important role in the formation of these liquid-liquid immiscibilities (Rowlinson, 1969). Thus, branched structures are more soluble than straight chain, and cyclic ones less so.

When the lower boiling component is propane, the n-paraffin, which would first show liquid-liquid immiscibility, has not been determined. Rowlinson and Freeman (1961) studied the solubility in propane of a series of pure liquid hydrocarbons with between twenty-four and thirty-seven carbon atoms. Based on their observations, they concluded that the first paraffin hydrocarbon immiscible with propane must lie above C_{37}. However, the C_{37} structure studied was 18-ethylpentatriacontane, a slightly branched structure. It had earlier been pointed out that branched structures were more soluble than straight chain, and hence the possibility for a liquid-liquid immiscibility in the propane-n-C_{37} system could not categorically be excluded. Actually, there is no basis for discounting the possibility of a liquid-liquid immiscibility in the propane-n-C_{36} system. As the correct order of progression is essential for developing a theoretical basis for understanding such immiscibilities, we thought it necessary to screen such systems for onset of immiscibility.

We have studied the propane-n-C_{36} system and, within the limits of our observations, we have found no region of liquid-liquid immiscibility. Thus, the likelihood increases that n-C_{37} is the lowest possible normal paraffin which could display liquid-liquid immiscibilities in binary mixtures with propane.

A high-pressure sight glass equipped with two tempered borosilicate windows was fitted with a magnetic stirrer. Stirring action was obtained by two flat paddles attached to a stainless steel shaft which screwed into the main magnedrive shaft. Immersion of the entire sight glass assembly into a constant temperature bath provided accurate temperature control (± 0.1°C). For the high temperature studies, a transparent high boiling hydrocarbon fluid (for example, Exxon's Primol 355) was used. In the low temperature studies, methanol was used as the circulating fluid. Pressure was read on a Heiss gauge to $\pm(7KN/m^2)$. The propane used was Matheson C. P. Grade (99.4% C^0_3, 0.50% i-C_4, 0.05% $C_3^=$, 0.05% C^0_2), and the n-C_{36} was analyzed as 99 wt. % n-C_{36}; 0.4 wt. % n-C_{35}, and 0.6 wt. % n-C_{37}.

The hexatriacontane was added as a liquid and the propane introduced at the highest temperature via a compressor. The L-G critical locus was obtained by studying the vanishing meniscus. The composition was adjusted by venting the sight glass, after which more propane was introduced. The L-G critical locus was indicated by the meniscus disappearing in the center of the sight glass. A large number of observations were made at very close temperature intervals, and some of the results are tabulated in Table 1 and plotted in Figure 1. A solid-liquid-gas line very similar to that reported for the system ethylene-p-dichlorobenzene (Diepen and Scheffer, 1948) was observed. However, no region of three phase liquid-liquid-gas immiscibility was noticed in the region of the L-G critical locus.

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Manuscript received August 7, 1975; revision received October 15, and accepted October 16, 1975.