chart and calculation of dewpoints and bubble-points using Raoult's law—topics common to practically all initial chemical engineering courses—are not considered.

Undoubtedly, many mechanical engineers reviewing this book would find that some of their favorite topics have been omitted or treated with brevity and, conversely, some topics have been covered more extensively than is usually the case.

The book is well written and the level of mathematics—some partial differential equations are used—such that the second year, or certainly the first semester third year, student should have no trouble. If a student cannot learn the the principles of thermodynamics from this book, it should certainly not be due to the mathematics used. Each chapter is concluded with a number of problems which appear to offer the user a reasonable choice; i.e. some difficult ones and some not so difficult. Apparently, the problems were selected so a slide rule is the only type of computer necessary.

The usage of this book by chemical engineers depends upon how our programs develop over the next few years. If we move to more common core courses—and thermodynamics is one of the prime areas where such movement is possible—this book "Engineering Thermodynamics," should be seriously considered for use.

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ChE problems for teachers

The following solutions to thermodynamics problems published in CEE Spring quarter, pp. 95-96, 1968, were prepared by Professors R. K. Irey and J. H. Pohl at the University of Florida. We continue to solicit questions on subjects of general engineering or scientific interest to be presented in this department.

1. (a) Consider u as $u(s,x_i)$,

$$du = \left(\frac{\partial u}{\partial s}\right)_{\vec{x}_i} ds + \sum_{j=1}^{N} \left(\frac{\partial u}{\partial \vec{x}_j}\right)_{s,\vec{x}_i} \cdot d\vec{x}_j$$

By analogy with

$$du = T ds - \sum_{j=1}^{N} \vec{F}_j \cdot d\vec{x}_j$$

$$\left(\frac{\partial u}{\partial s}\right)_{\vec{x}_i} = T \quad \text{and} \quad \left(\frac{\partial u}{\partial \vec{x}_j}\right)_{s,\vec{x}_i} = -F_j \text{ , (N+1 eqs.)}$$

(b) The Maxwell relations are

$$\left(\frac{\partial T}{\partial \vec{x}_j}\right)_{s,\vec{x}_i} = -\left(\frac{\partial \vec{F}_j}{\partial s}\right)_{\vec{x}_j \vec{x}_i}$$

$$\left(\frac{\partial \vec{F}_i}{\partial \vec{x}_j}\right)_{s,\vec{x}_i} = \left(\frac{\partial \vec{F}_j}{\partial x_i}\right)_{s,\vec{x}_j}$$

(c) i) N+1, for a total of 4(N+1) eqs.

ii) $\frac{3N(N+1)}{2}$, for a total of 2N(N+1) eqs.

iii) Take the derivative of ψq and substitute du into the equation

$$d\psi q = -s dT - \sum_{j=1}^{N} \vec{F}_j \cdot d\vec{x}_j \ .$$

Consider the total derivative of $\psi q = \psi q(T, x_i)$, $i=1,\cdots,N$.

$$d\psi q = \left(\frac{\partial \psi_q}{\partial T}\right)_{\vec{x}_i} dT + \sum_{j=1}^{N} \left(\frac{\partial \psi_q}{\partial \vec{x}_j}\right)_{T,\vec{x}_i} \cdot d\vec{x}_j \ .$$

thus, $\left(\frac{\partial \psi_q}{\partial T}\right)_{\vec{x}_i} = -s$ and $\left(\frac{\partial \psi_q}{\partial \vec{x}_j}\right)_{T,\vec{x}_i} = -\vec{F}_j$.

Since

$$\frac{\partial^2 \psi_q}{\partial T \partial \vec{x}_j} = \frac{\partial^2 \psi_q}{\partial \vec{x}_i \partial T}$$

we have

$$\left(\frac{\partial \vec{F}_j}{\partial T}\right)_{\vec{x}_j,\vec{x}_i} = \left(\frac{\partial s}{\partial \vec{x}_j}\right)_{T,\vec{x}_i}$$

2. (a) Consider $s = s(T,\vec{x}_i)$ and $s = s(T,\vec{F}_i)$. Then

$$ds = \left(\frac{\partial s}{\partial T}\right)_{\vec{x}_i} dT + \sum_{j=1}^{N} \left(\frac{\partial s}{\partial \vec{x}_j}\right)_{T,\vec{x}_i} \cdot d\vec{x}_j \qquad \text{(i)}$$

and

$$ds = \left(\frac{\partial s}{\partial T}\right)_{\vec{F}_i} dT + \sum_{j=1}^{N} \left(\frac{\partial s}{\partial \vec{F}_j}\right)_{T,\vec{F}_i} \cdot d\vec{F}_j \qquad \text{(ii)}$$

$$C_{\vec{F}_i} = \left(\frac{\partial \psi_u}{\partial T}\right)_{\vec{F}_i} = T\left(\frac{\partial s}{\partial T}\right)_{\vec{F}_i} \quad \text{and}$$

$$C_{\vec{x}_i} = \left(\frac{\partial u}{\partial T}\right)_{\vec{x}_i} = T\left(\frac{\partial s}{\partial T}\right)_{\vec{x}_i} \qquad \text{(iii)}$$

Use the Maxwell relations,

$$\left(\frac{\partial s}{\partial \vec{x}_j}\right) = \left(\frac{\partial \vec{F}_j}{\partial T}\right)_{\vec{x}_i,\vec{x}_j} \quad \text{AND} \quad \left(\frac{\partial s}{\partial \vec{F}_j}\right)_{T,\vec{F}_i} = -\left(\frac{\partial \vec{x}_j}{\partial T}\right)_{\vec{F}_i,\vec{F}_j}$$

and the relations (iii) in (i) and (ii). Then set the right of (ii) equal to the right of (i).

$$C_{\vec{F}_i} - C_{\vec{x}_i} = T\left\{\sum_{j=1}^{N}\left(\frac{\partial \vec{F}_j}{\partial T}\right)_{\vec{x}_i,\vec{x}_j} \cdot \frac{d\vec{x}_j}{dT} + \sum_{j=1}^{N}\left(\frac{\partial \vec{x}_j}{\partial T}\right)_{\vec{F}_i,\vec{F}_j} \cdot \frac{d\vec{F}_j}{dT}\right\}$$

If $\vec{F}_j$ is constant,

$$C_{\vec{F}_i} - C_{\vec{x}_i} = T\sum_{j=1}^{N}\left(\frac{\partial \vec{F}_j}{\partial T}\right)_{\vec{x}_i,\vec{x}_j} \cdot \left(\frac{\partial \vec{x}_j}{\partial T}\right)_{\vec{F}_i,\vec{F}_j}$$

If $\vec{x}_j$ is constant, the result is the same.

(b) From (i) above

$$ds = \left(\frac{C_{\vec{x}_i}}{T}\right) dT + \sum_{j=1}^{N}\left(\frac{\partial \vec{F}_j}{\partial T}\right)_{\vec{x}_i,\vec{x}_j} \cdot d\vec{x}_j$$

From the exactness of this equation

$$\left(\frac{\partial C_{\vec{x}_i}}{\partial \vec{x}_j}\right)_{T,\vec{x}_i} = T\left(\frac{\partial^2 \vec{F}_j}{\partial T^2}\right)_{\vec{x}_i,\vec{x}_j}$$

Hold T constant in this equation and integrate with respect to all $\vec{x}_j$. The lower limit is a reference value, $C_{\vec{x}_j^*}$. The upper limit is variable.

$$C_{\vec{x}_j} - C_{\vec{x}_j}^* = T\sum_{j=1}^{N}\int_{\vec{x}_j^*}^{\vec{x}_j}\left(\frac{\partial^2 \vec{F}_j}{\partial T^2}\right)_{\vec{x}_i,\vec{x}_j} \cdot d\vec{x}_j$$