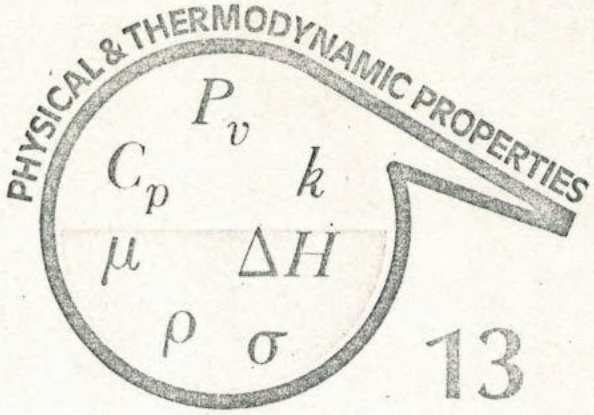


# Benzene and naphthalene

Property data for the aromatics benzene and naphthalene are summarized in a table and graphs for quick, easy access.

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☐ Aromatic compounds are important as feedstocks in the chemical process industries for the production of a variety of industrial chemicals. Benzene is used primarily for the production of the following major chemicals: styrene, phenol, cyclohexane, nitrobenzene, dodecylbenzene and maleic anhydride. Benzene is also a prevalent organic solvent. Naphthalene is principally a feedstock in the production of phthalic anhydride, insecticides, dyes, plasticizers and solvents.

## Critical Properties—Table 13—1 (T/13—1)

Experimental values for the critical constants have been determined for benzene [*2,3,4,15,415,417,473, 474,511,512,521*] and for naphthalene [*2,3,4,415,417, 473,474,518*]. The values reported are all within 1% deviation, except for the critical volume of benzene, 1.5%.

## Heat of Vaporization—Fig. 13—1(F/13—1)

The Watson correlation (Eq. 1—1) was used to augment experimental data to cover the entire liquid range. Deviations of the least-squares data fitting and correlated values are less than 1% for benzene and naphthalene.

See Part 1 of this series, *Chem. Eng.*, June 10, 1974, for equations starting with a boldfaced numeral "1", Part 2 for those with "2", etc. Part 2 appeared July 3, Aug. 19; Part 4, Sept. 30; Part 5, Oct. 28; Part 6, Nov. 25; Part 7, Dec. 23, 1974; Part 8, Jan. 20, 1975; Part 9, Feb. 17; Part 10, Mar. 31; Part 11, May 12; and Part 12, July 21.

## Vapor Pressure—F/13—2

Extensive data are available for the vapor pressure of benzene and naphthalene. The average deviation of reported values from the least-squares data fitting are 1.2% for benzene and 2.0% for naphthalene.

## Heat Capacity—F/13—3, F/13—4

Vapor heat-capacity data at constant atmospheric pressure for the ideal gas are available for both benzene and naphthalene. Results among investigators agree well, with average deviations being 2%, or less, in most cases.

Liquid heat-capacity data have been extended by means of the density extrapolation relation (Eq. 1—3, $n = 2$). Average deviations of extrapolated values and data are less than 1% for benzene and naphthalene.

## Density—F/13—5

Liquid densities for benzene are available over the entire liquid range, with deviations of less than 1% among reported values. For naphthalene, liquid densities were extended by a modified form of the Rackett correlation [*489*]:

$$\rho = \rho_1 Z_c^{[(1-T_r)^{2/7}-(1-T_r)^{2/7}]} \qquad (13—1)$$

In Eq. (13—1), $\rho$ = density at temperature $T$; $\rho_1$ =

(*Text continues on p. 115*)

## How To Use the Graphs

Each graph is outfitted with a key that lists references and explains just what part of the curve is determined experimentally, and what part is estimated from theoretical correlations.

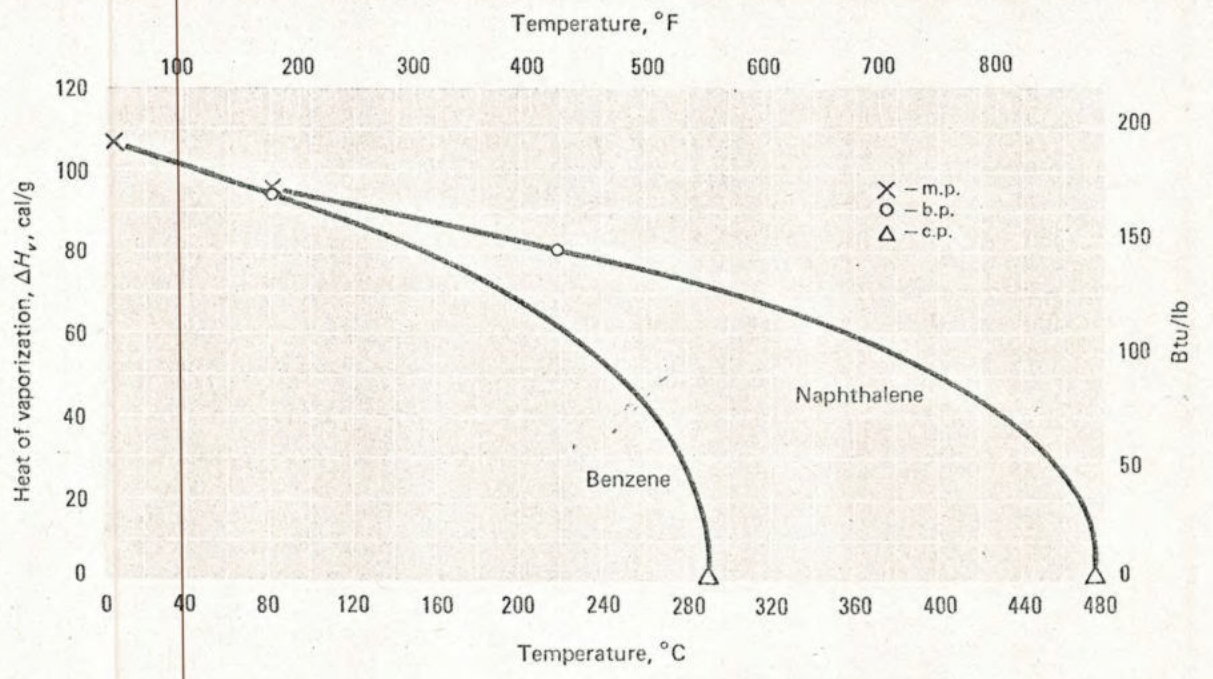
The shaded squares denote the following:

- Data in this region are experimentally known.
- Experimental and correlated data used.
- All data in this region are correlated.

The "regions" referred to are the temperature ranges between the melting, boiling and critical points (m.p., b.p. and c.p., respectively), or in some cases, the specific temperatures noted in the key.

## Physical properties of the cyclo-aromatics

| Identification | Benzene $C_6H_6$ | Naphthalene $C_{10}H_8$ |
|---|---|---|
| State (std. conditions) | Liquid | Solid |
| Molecular weight, $M$ | 78.11 | 128.17 |
| Boiling point, $T_b$, °C | 80.10 | 218.00 |
| Melting point, $T_m$, °C | 5.53 | 80.55 |
| Critical temp., $T_c$, °C | 288.94 | 475.02 |
| Critical pressure, $P_c$, atm | 48.30 | 39.59 |
| Critical volume, $V_c$, cm³/g-mol | 256.98 | 410.14 |
| Critical compressibility factor, $Z_c$ | 0.269 | 0.264 |

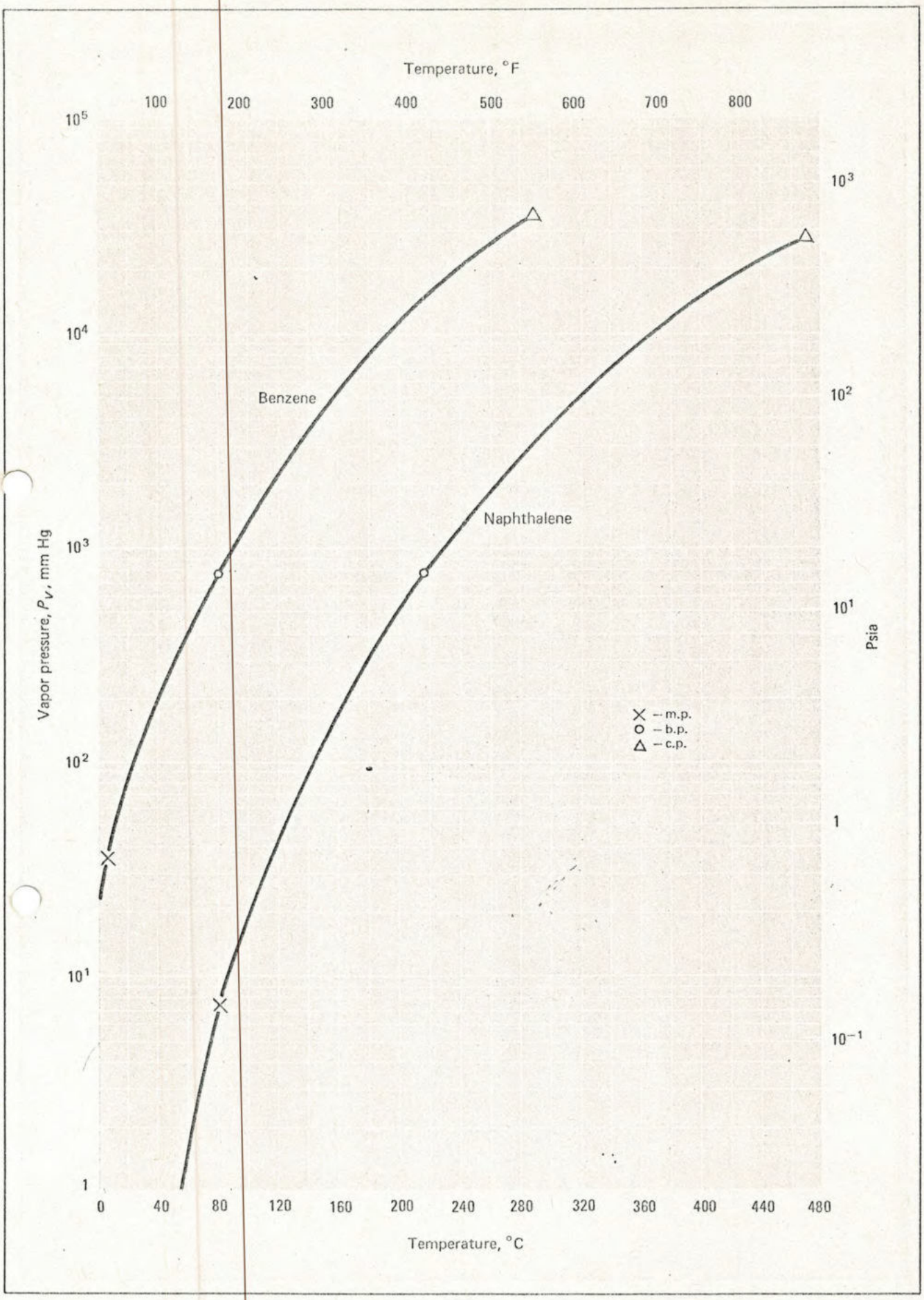


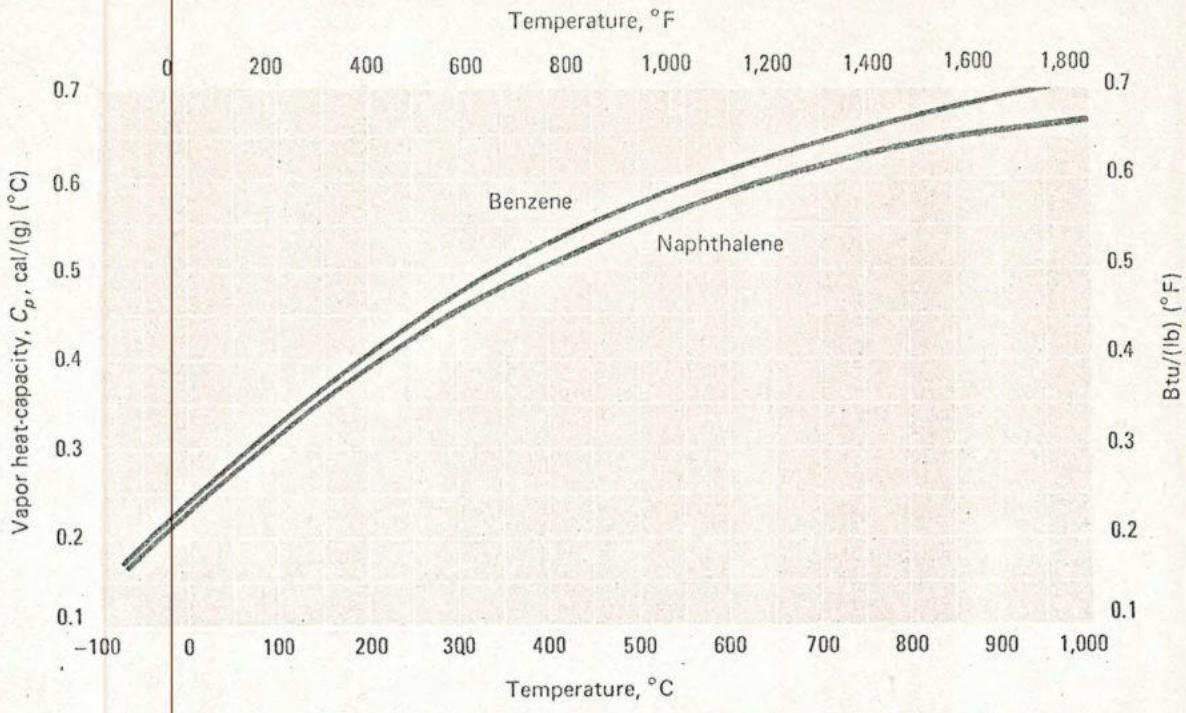

### Heat of vaporization

| Fig. 13–1 | Temperature Range | | References |
|---|---|---|---|
| | m.p.–b.p. | b.p.–c.p. | |
| Benzene | ◪ | ◪ | 3,4,15,309,415,417,419 |
| Naphthalene | ◪ | ◪ | 3,6,419 |

### Vapor pressure

| Fig. 13–2 | Temperature Range | | References |
|---|---|---|---|
| | m.p.–b.p. | b.p.–c.p. | |
| Benzene | ■ | ■ | 3,4,415,417,419,473 |
| Naphthalene | ■ | ◪ | 3,4,6,415,419,473,504,509 |


Temperature, °F
100
200
300
400
500
600
700
800
$10^5$
$10^4$
$10^3$
$10^2$
$10^1$
1
Vapor pressure, $P_v$, mm Hg
Benzene
Naphthalene
× – m.p.
○ – b.p.
△ – c.p.
$10^3$
$10^2$
$10^1$
1
$10^{-1}$
Psia
0
40
80
120
160
200
240
280
320
360
400
440
480
Temperature, °C

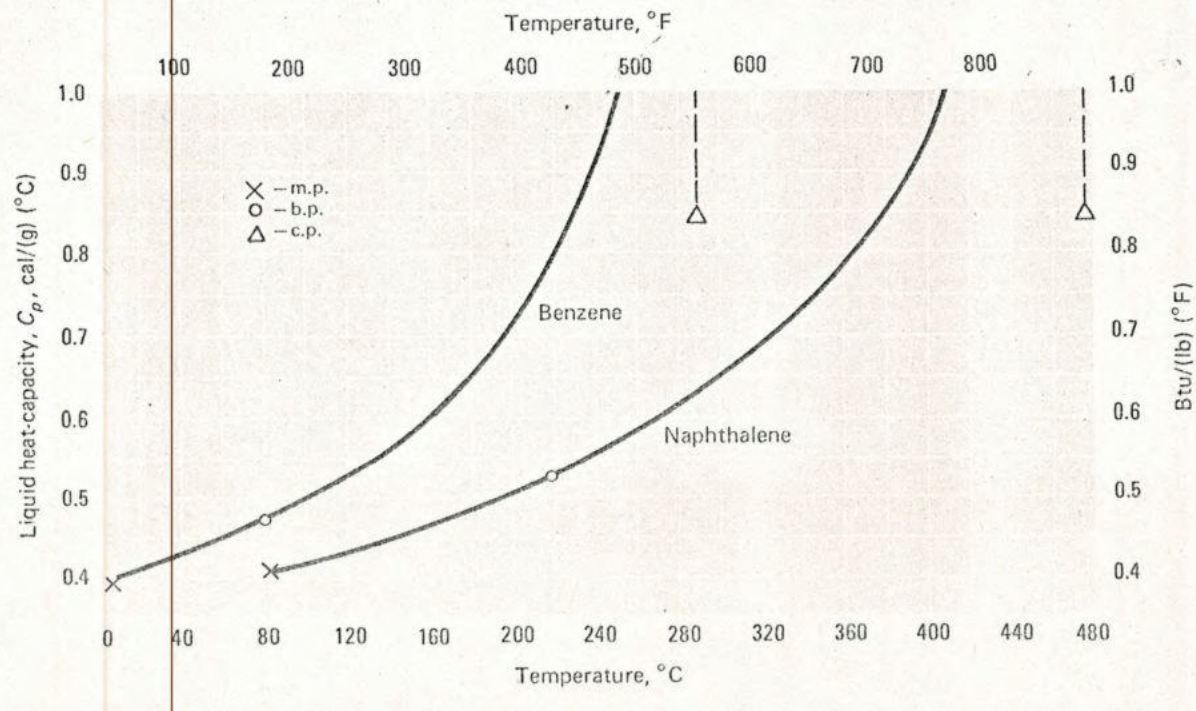


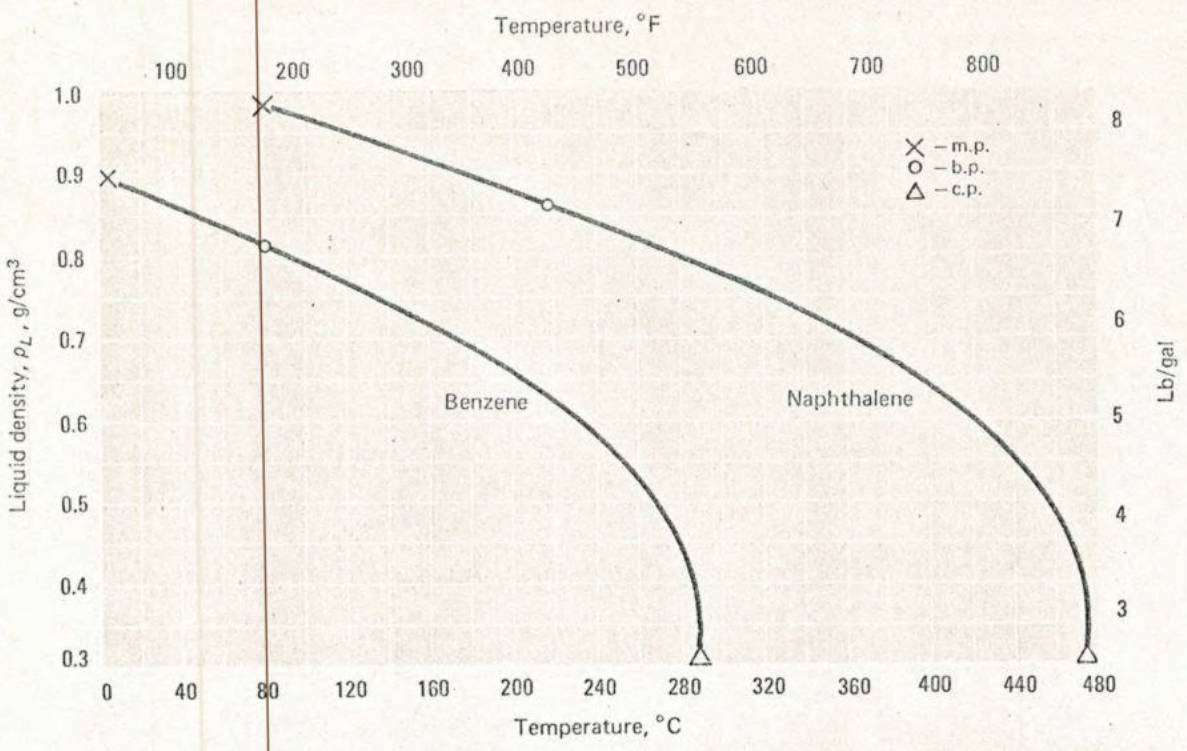

**Vapor heat capacity** F 3

| Fig. 13–3 | Temperature Range, C | | References |
|---|---|---|---|
| | 0–500 | 500–1,000 | |
| Benzene | ◪ | ◪ | 3, 15, 18, 19, 417, 484, 507, 512 |
| Naphthalene | ◪ | ◪ | 3, 6, 15, 415 |

**Liquid heat capacity** F 4

| Fig. 13–4 | Temperature Range | | References |
|---|---|---|---|
| | m.p.–b.p. | b.p.–c.p. | |
| Benzene | ■ | ◪ | 3, 19, 415, 481, 503 |
| Naphthalene | ◪ | □ | 415, 501, 510 |



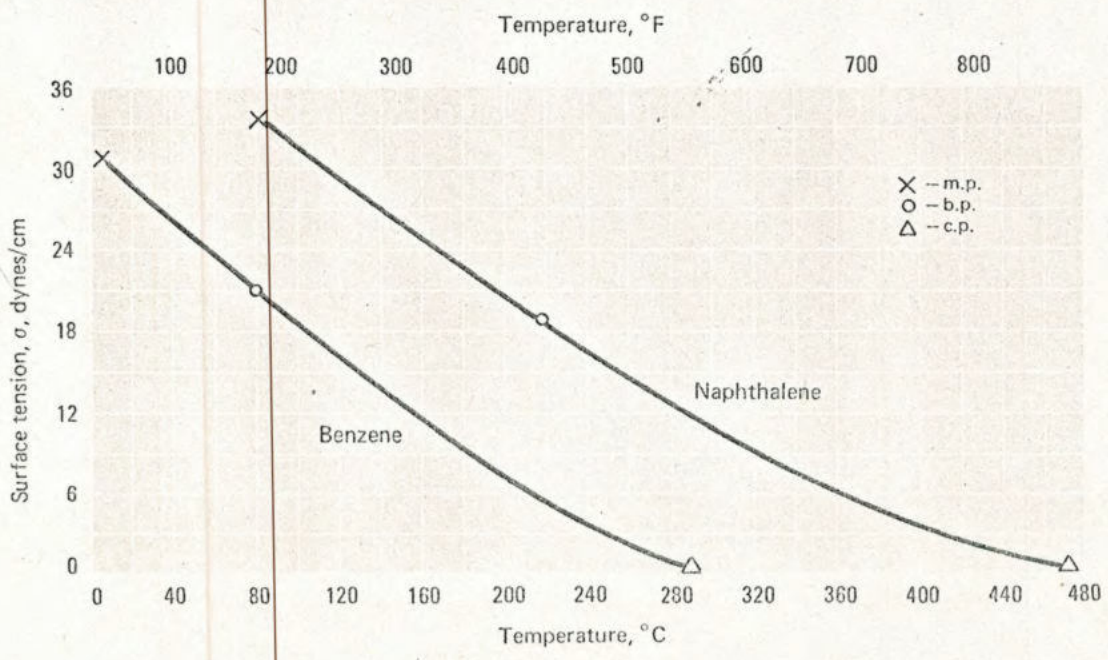


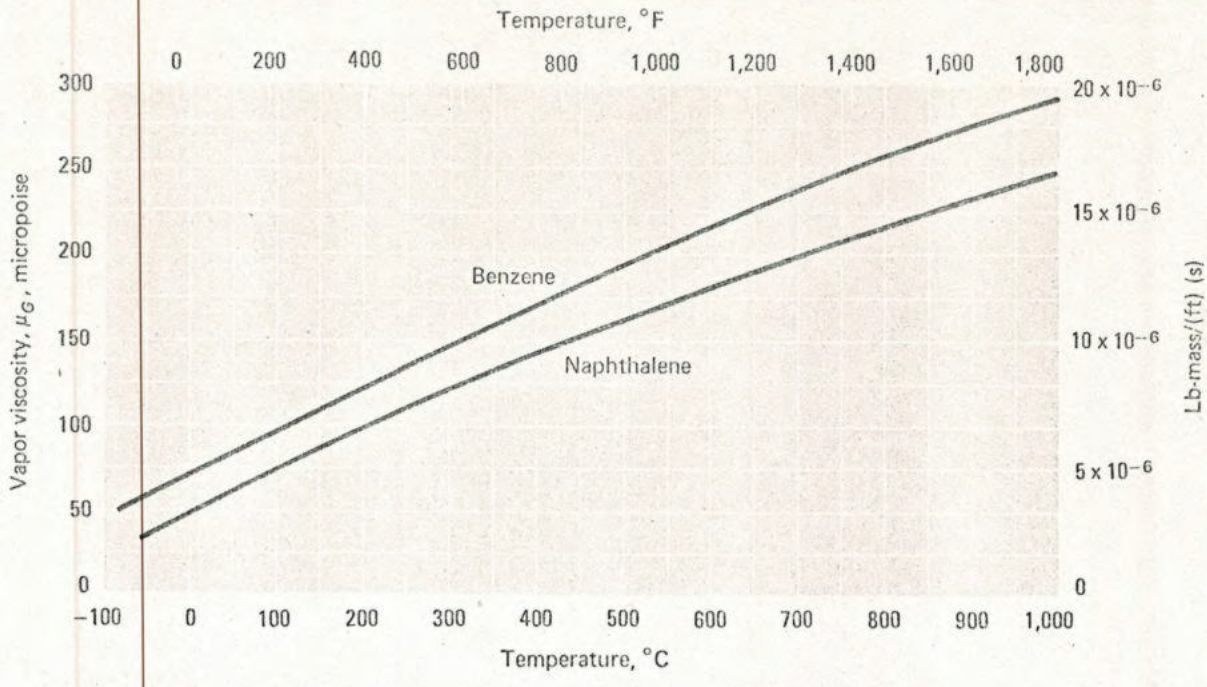

**Liquid density** F 5

| Fig. 13–5 | Temperature Range | | References |
|---|---|---|---|
| | m.p.–b.p. | b.p.–c.p. | |
| Benzene | ▩ | ▩ | 2,3,4,415,417,473,474,481,484,497 |
| Naphthalene | ◪ | ◪ | 4,417,473,474 |

**Surface tension** F 6

| Fig. 13–6 | Temperature Range | | References |
|---|---|---|---|
| | m.p.–b.p. | b.p.–c.p. | |
| Benzene | ◪ | ◪ | 3,4,79,415,417,495 |
| Naphthalene | ◪ | □ | 3,6,79 |



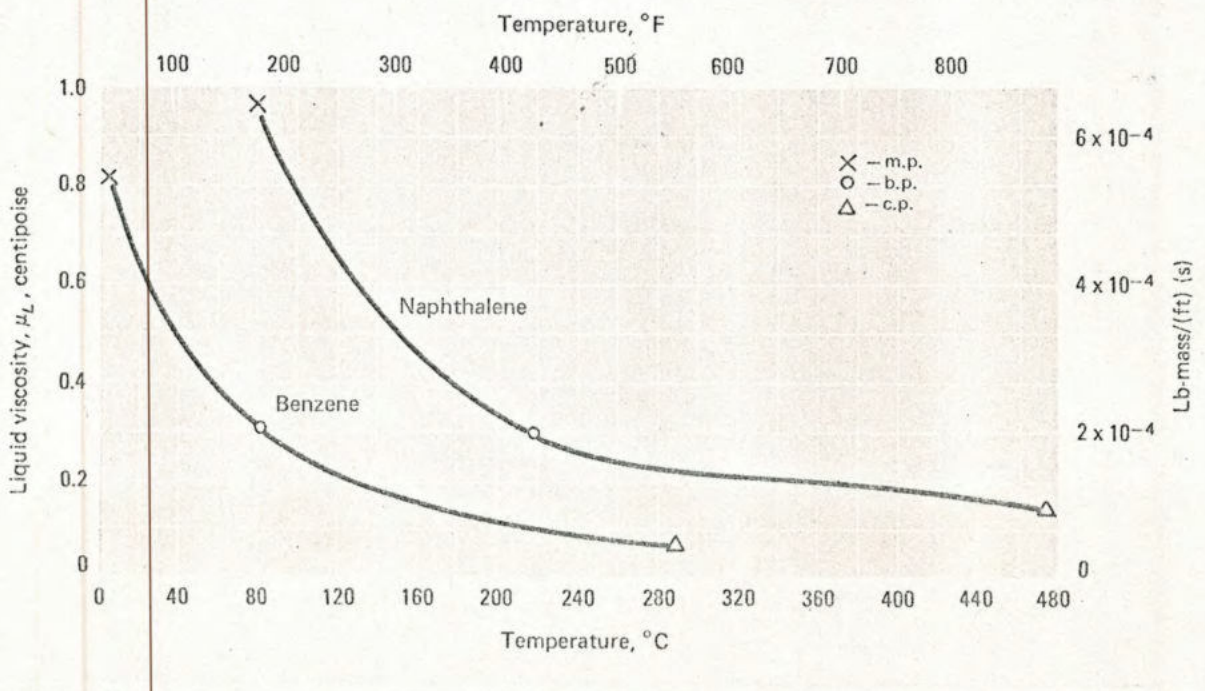


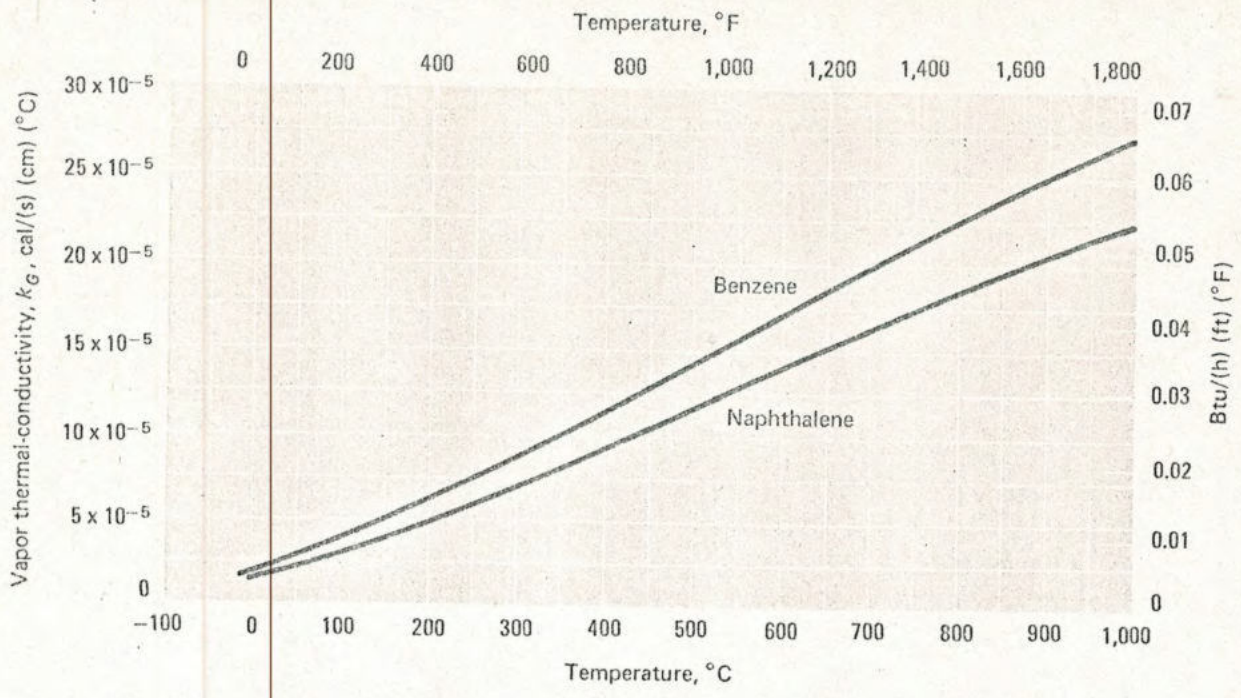

**Vapor viscosity** (F7)

| Fig. 13–7 | Temperature Range, °C: 0–500 | Temperature Range, °C: 500–1,000 | References |
|---|---|---|---|
| Benzene | ■ | ◪ | 14,18,242,442,467,484,500 |
| Naphthalene | □ | □ | 14,442 |

**Liquid viscosity** (F8)

| Fig. 13–8 | Temperature Range: m.p.–b.p. | Temperature Range: b.p.–c.p. | References |
|---|---|---|---|
| Benzene | ■ | ▩ | 3,4,415,417,484,506 |
| Naphthalene | ■ | ◪ | 3,6,484,505,506,511 |



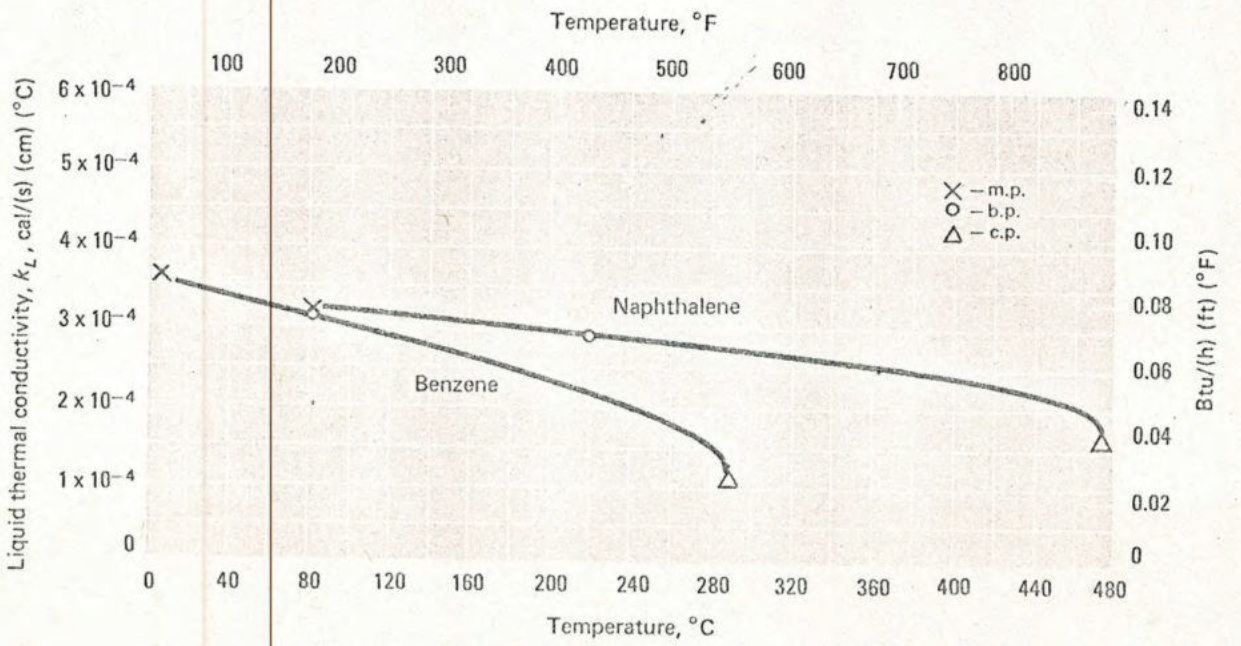


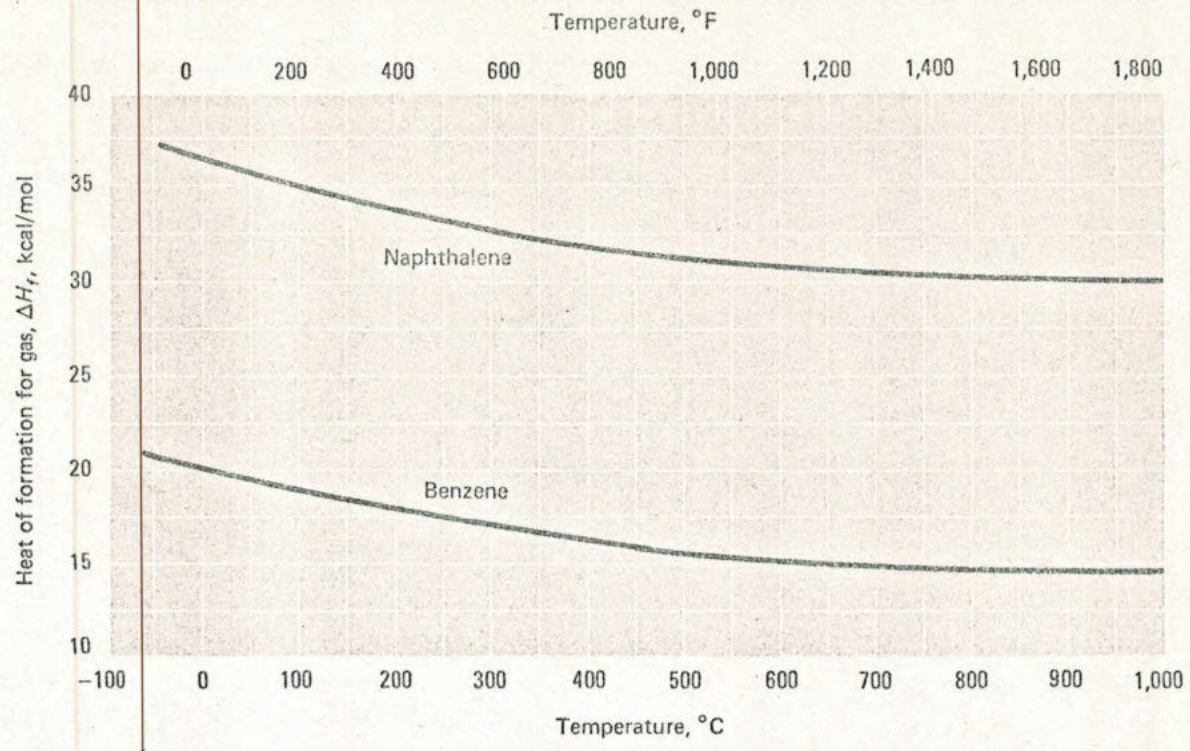

**Vapor thermal conductivity**

| Fig. 13–9 | Temperature Range, °C | | References |
|---|---|---|---|
| | 0–500 | 500–1,000 | |
| Benzene | ◪ | □ | 14, 18, 19, 443, 494, 515 |
| Naphthalene | □ | □ | 14, 443 |

**Liquid thermal conductivity**

| Fig. 13–10 | Temperature Range | | References |
|---|---|---|---|
| | m.p.–b.p. | b.p.–c.p. | |
| Benzene | ■ | ◪ | 14, 19, 443, 481, 484, 492, 493, 494, 514 |
| Naphthalene | ◪ | □ | 443, 496 |



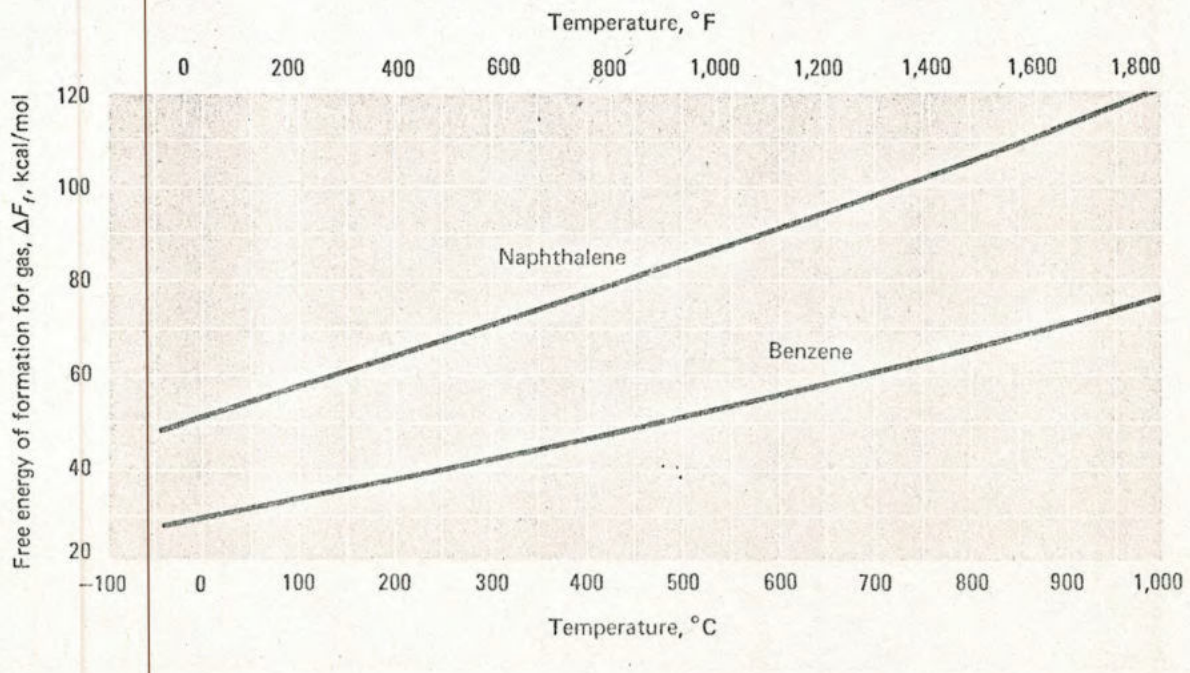



**Heat of formation for gas** (F11)

| Fig. 13–11 | Temperature Range, °C | | References |
|---|---|---|---|
| | 0–500 | 500–1,000 | |
| Benzene | ◪ | ◪ | 3,417,507 |
| Naphthalene | ◪ | ◪ | 4,15,501,502 |

**Free energy of formation for gas** (F12)

| Fig. 13–12 | Temperature Range, °C | | References |
|---|---|---|---|
| | 0–500 | 500–1,000 | |
| Benzene | ◪ | ◪ | 417,507 |
| Naphthalene | ◪ | ◪ | 4,15,502 |



density at reference temperature $T_1$; $Z_c$ = critical compressibility factor; $T_{r1} = T_1/T_c$; and $T_r = T/T_c$.

Deviations between correlated and experimental values for liquid densities of naphthalene were less than 1%, except at the critical temperature, where there was a maximum deviation of 3%.

## Surface Tension—F/13—6

To supplement experimental data, the Othmer linear relationship (Eq. 1—4) was used to determine surface tension over the entire liquid range. Deviations of correlated values and least-squares data fitting were less than 1% for both benzene and naphthalene.

## Viscosity—F/13—7, F/13—8

Vapor-viscosity data at atmospheric pressure were extended with the modified Flynn and Thodos correlation (Eq. 10—1) for hydrocarbon gases. The values obtained from the correlation and experimental data agree well, with an average deviation of 1.7%.

The Guzman-Andrade relation (Eq. 1—6) was used to cover the full liquid-phase. Deviations between data and relation values average about 2.5% for both benzene and naphthalene.

## Thermal Conductivity—F/13—9, F/13—10

Experimental data for gas-phase thermal conductivity at low pressure were extended with the modified Misic and Thodos correlation for hydrocarbon gases (Eq. 10—2). Deviations of correlated values and experimental data were less than 3% for benzene.

Liquid thermal-conductivity data were estimated with the modified Stiel and Thodos relation (Eq. 10—3). Results obtained with the relation agree well with the available data, with deviations less than 1% for benzene and naphthalene.

## Heat and Free Energy of Formation—F/13—11, 13—12

Values obtained from API Project 44 [*417*] were selected for the values of the heat and free energy of formation of the ideal gases. Available data for benzene and naphthalene agree well with selected values.

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## The authors


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**Carl L. Yaws**—For biography, See *Chem. Eng.*, May 12, 1975, p. 97.


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