Physical Properties of Hydrocarbons

Part 1—Methane-Ethane-Propane-Butane
Part 2—C_2 to C_4 Monoolefins
Part 3—C_2 to C_4 Alkynes
Part 4—C_2 to C_4 Diolefins

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As a STARTING RAW MATERIAL for many petrochemical products, the monoolefins are unsurpassed. In 1964, approximately 8 billion pounds of ethylene will be used in making such products as polyethylene, ethylene glycol, vinyl chloride, etc. Propylene usage as a starting compound for polypropylene, propylene oxide, isopropanol, cumene, and a variety of other products will reach 3.5 billion pounds. The butenes, although dwarfed by these two giants, continue to increase in value as stereospecific C_4 polymers grow in usage. Probably every engineer, at one time or another, uses one of these hydrocarbons in his process.

The presentation of the physical properties for the monoolefins is essentially the same as in Part 1. As much as possible, reference is made to the sources of data for those who may be interested in reviewing the sources or in gathering more detailed information. Physical properties are not as easily available for the monoolefins, especially the butenes. A considerable amount of estimation was necessary to present butene data over a wide range.

Vapor Pressure. The vapor pressures of all five compounds have been fairly extensively explored. The best sources are the three earlier mentioned ones of Stull,[16] Hachmuth,[17] and Maxwell.[7] For the butene compounds, Hachmuth is the best source available from the temperature range of −73° C to the critical pressure. He has carefully reviewed the literature and, where data were lacking, calculated the values.

Thermal Properties. Maxwell[7] presents data for the heat of vaporization to the critical point for ethylene and propylene. Data for the butenes are mostly in the −60 to +25° C range and so the low and high temperature range data are largely extrapolated using the method of Watson, which relates the heat of vaporization to the reduced temperature. This method appears to be highly

accurate. Comparison with four experimental points gave a maximum error of 0.9 percent and an average error of 0.5 percent.

The vapor heat capacities were drawn largely from the compilation of Kobe.[19] Once again, liquid heat capacity data are almost nil for the monoolefins and these data have been calculated by the method of Schiff.

Liquid Density. Maass and Wright[23] present density data for ethylene and propylene. Maxwell[7] presents data over a wide temperature range for all five compounds. The equations presented by Francis[24] were also used to calculate the densities for ethylene, propylene, 1-butene, and trans-2-butene. Agreement among the various sources was excellent.

Liquid and Vapor Viscosity. The vapor viscosity of ethylene is available in several of the handbooks.[2,3] Data for propylene, and especially the butenes, are rather limited. However, Flynn and Thodos[34] presented in 1961 an improved method of accurately calculating the vapor viscosity for hydrocarbons in the pressure range of 5 psia to 75 psia. The only properties needed are the molecular weight, critical pressure, and critical temperature. The method gives an average error of 2.2 percent, well within the accuracy needed for most engineering calculations. This method has been used here for propylene and the butenes. Because pressure affects the viscosity so little up to 100 psia, these results could be used for pressures from atmospheric to 100 psia and still be within the experimental error.

Liquid viscosity data for ethylene, propylene, and 1-butene are available in Reid and Sherwood's book[12] in the low temperature range. This has been extrapolated by the method of plotting the log of the viscosity versus the reciprocal of the absolute temperature. The liquid viscosity for cis- and trans-2-butene was calculated by the

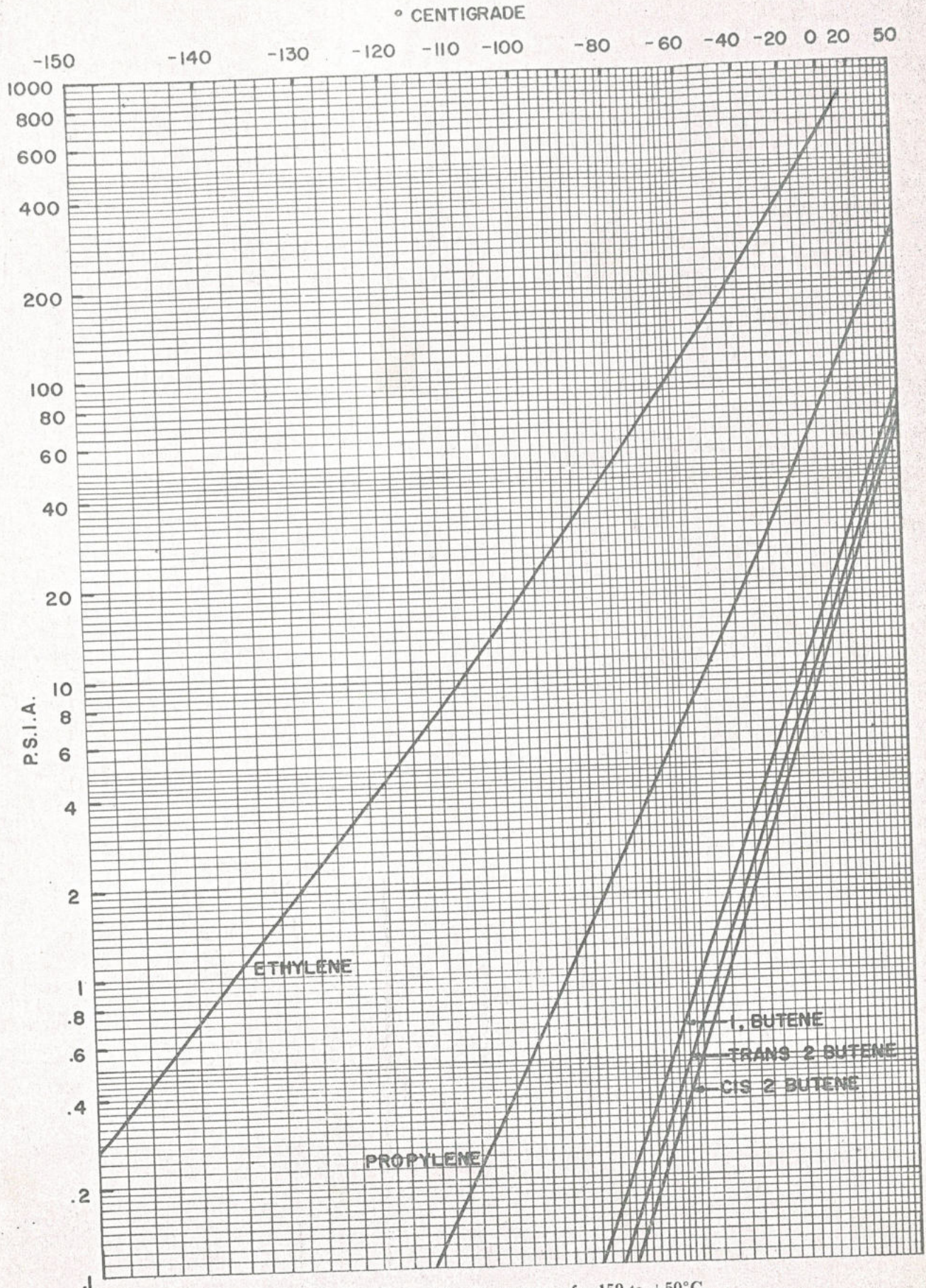PHYSICAL PROPERTIES OF HYDROCARBONS . . .

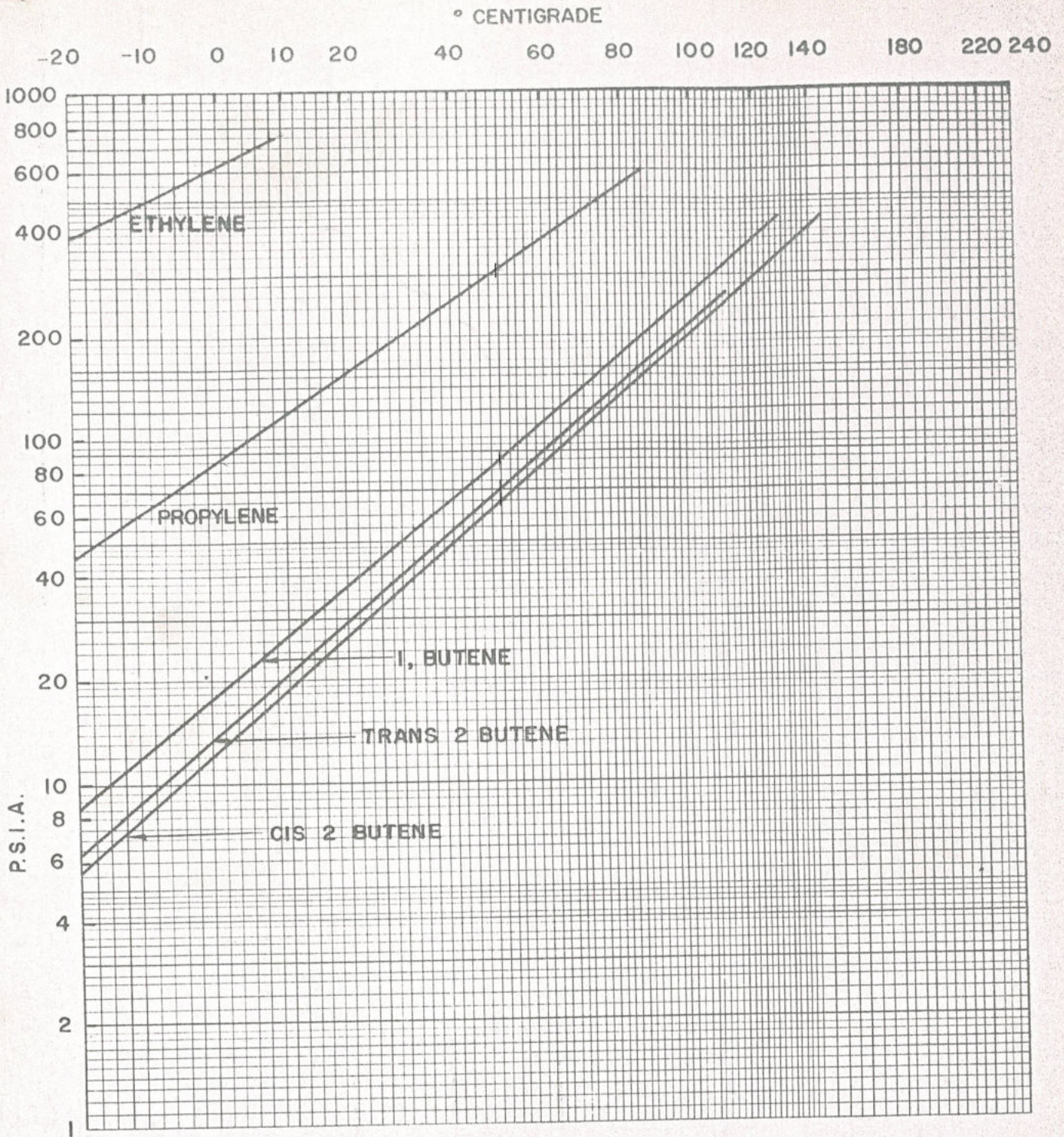Fig. 2-1—Vapor pressure over a range of —150 to +50°C.

Fig. 2-2—Vapor pressure over a range of −20 to +160°C.

method of Thomas, which relates the liquid viscosity to the reduced temperature, molecular structure of the compound, and liquid density. The error is probably 10-20 percent by this method. No more reliable method is known at this time.

Surface Tension. Maass and Wright have presented data for ethylene and propylene in the low temperature range.[23] Data for the butenes were taken from Project 44 of the API.[9] The data were extrapolated to the wider temperature range by the method of Othmer.

TABLE 2-1—C₂ to C₄ Monoolefins

| Compound | Boiling Point °C | Freezing Point °C | Molecular Weight | Critical Properties | | |
				°C tc	psi Pc	g/ml dc
Ethylene	−103.7	−169.1	28.052	9.90	742	0.21
Propylene	−47.7	−185.2	42.078	91.9	667	.233
1-Butene	−6.3	−185.35	56.104	146	583	.233
Cis-2-Butene	3.7	−138.9	56.104	160	610	.238
Trans-2-Butene	0.9	−105.4	56.104	155	595	.238

LITERATURE CITED

³¹ Flynn, L. W. and Thodas, G., "Viscosity of Hydrocarbon Gases at Normal Pressures," *Journal of Chemical and Engineering Data* 6, pp 457-9 (1961).

See Part 1 for earlier references.
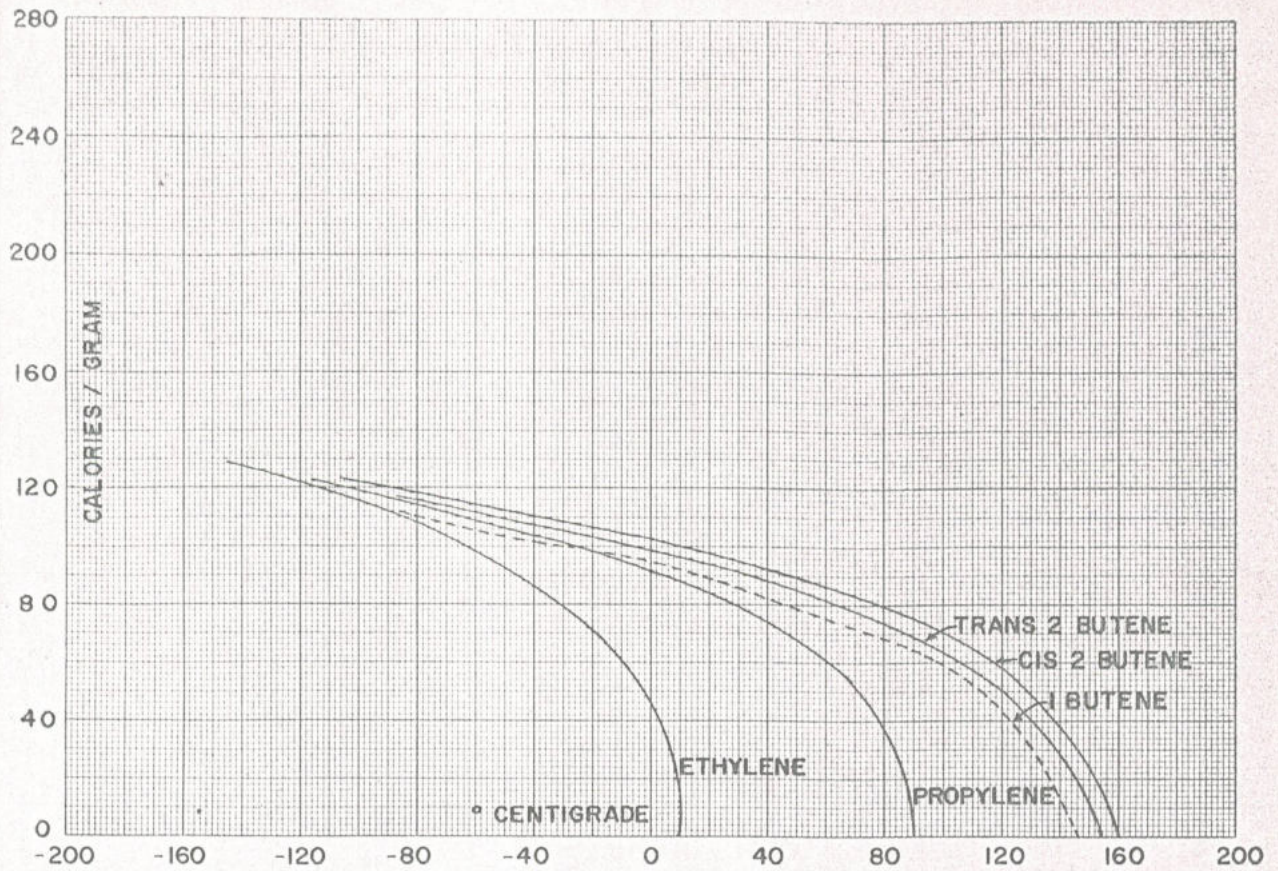
Fig. 2-3—Heat of vaporization over a range of −150 to +160°C.
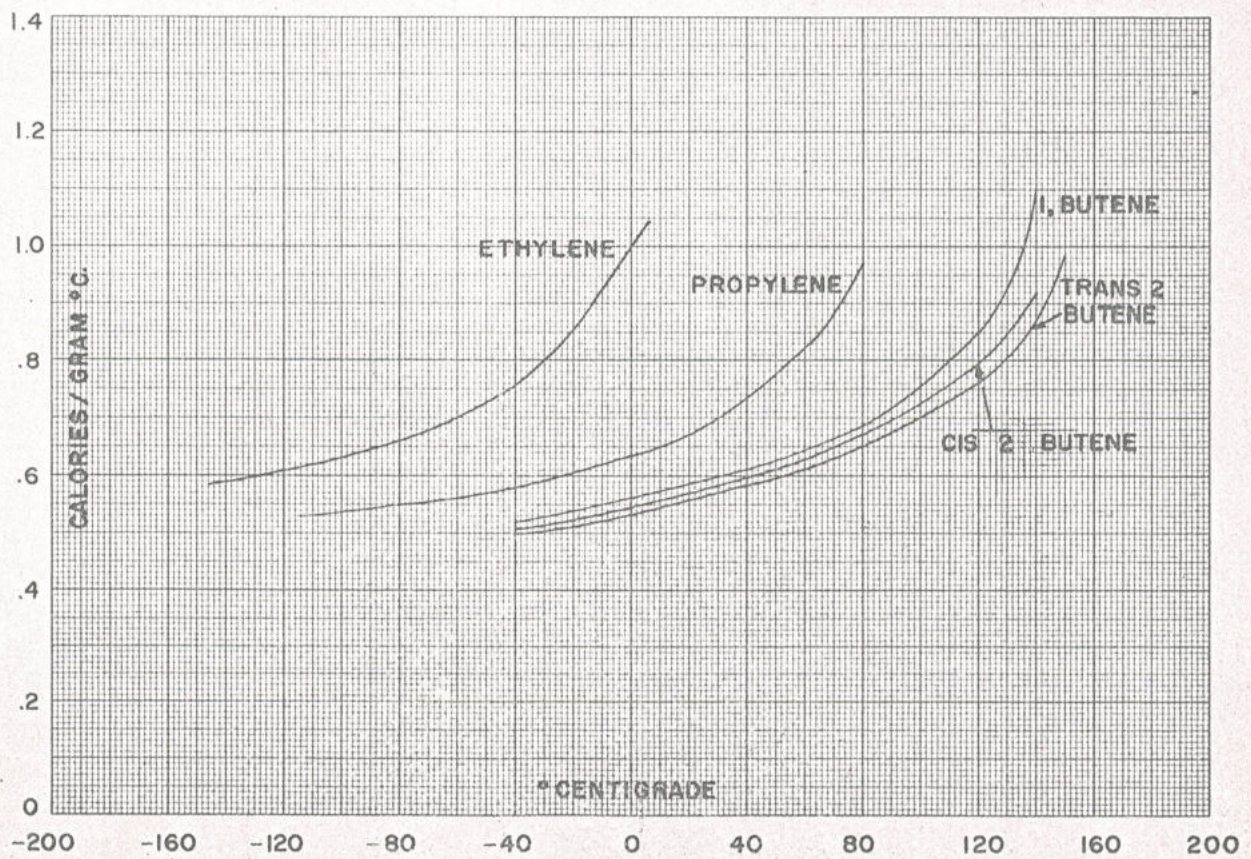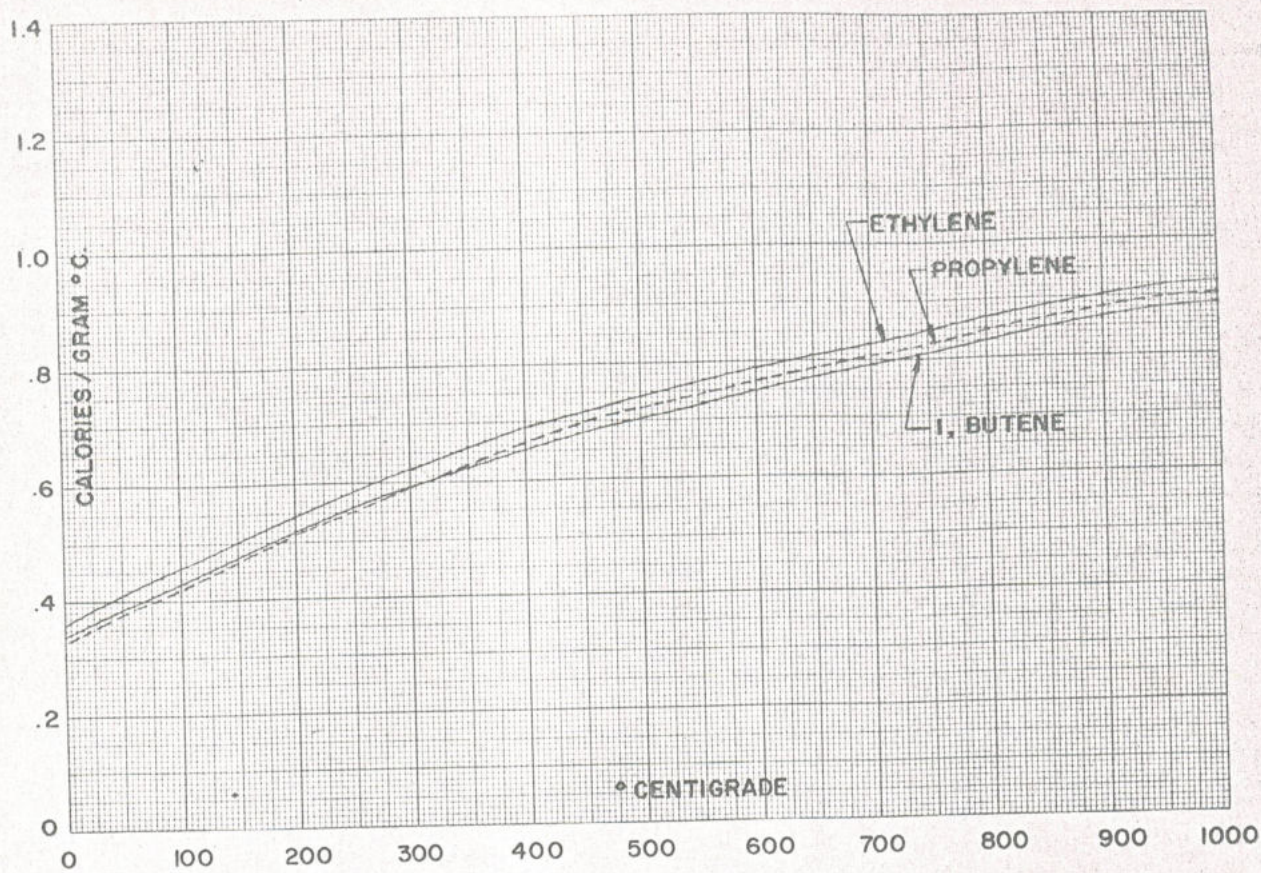

Fig. 2-4—Liquid heat capacity over a range of −150 to +160°C.

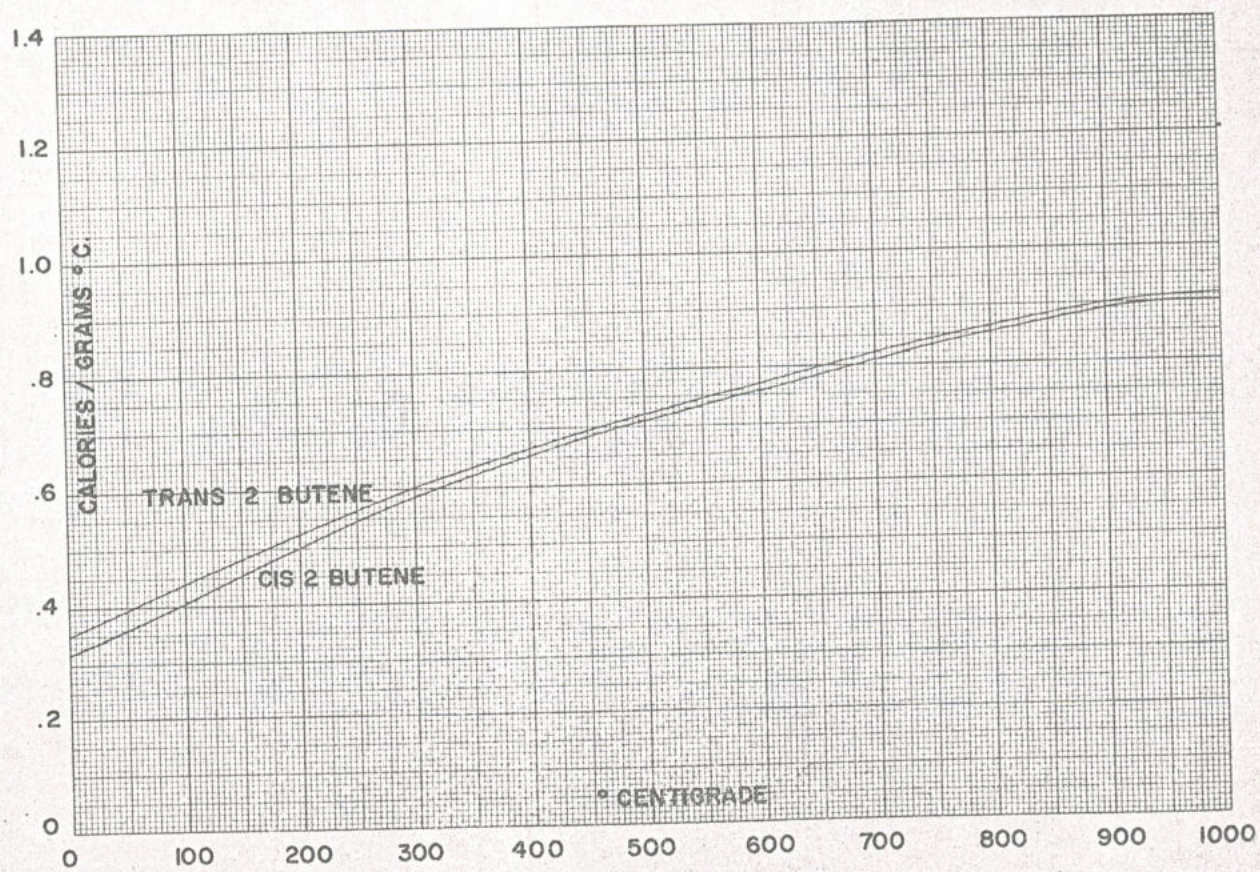Fig. 2-5A—Vapor heat capacity over a range of 0 to +1,000°C.

Fig. 2-5B—Vapor heat capacity over a range of 0 to +1,000°C.
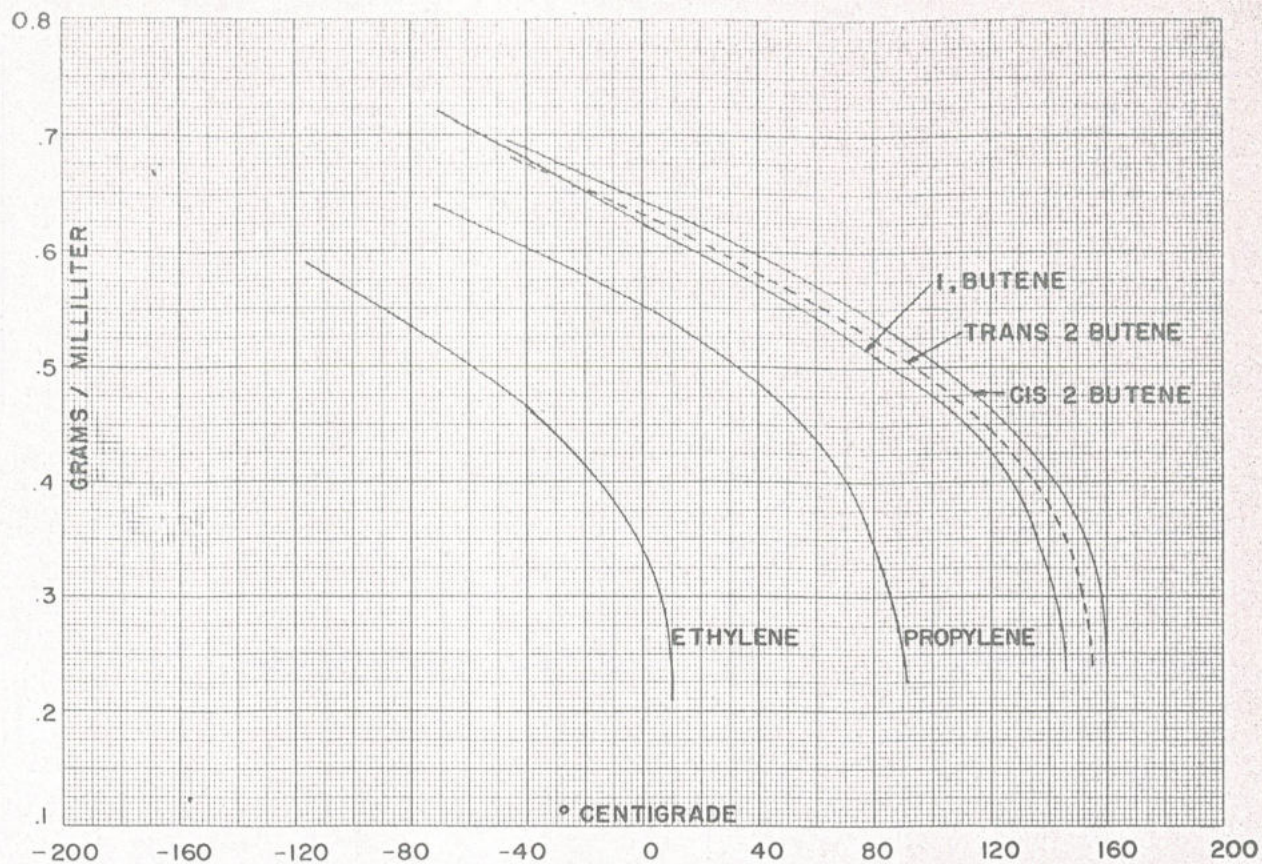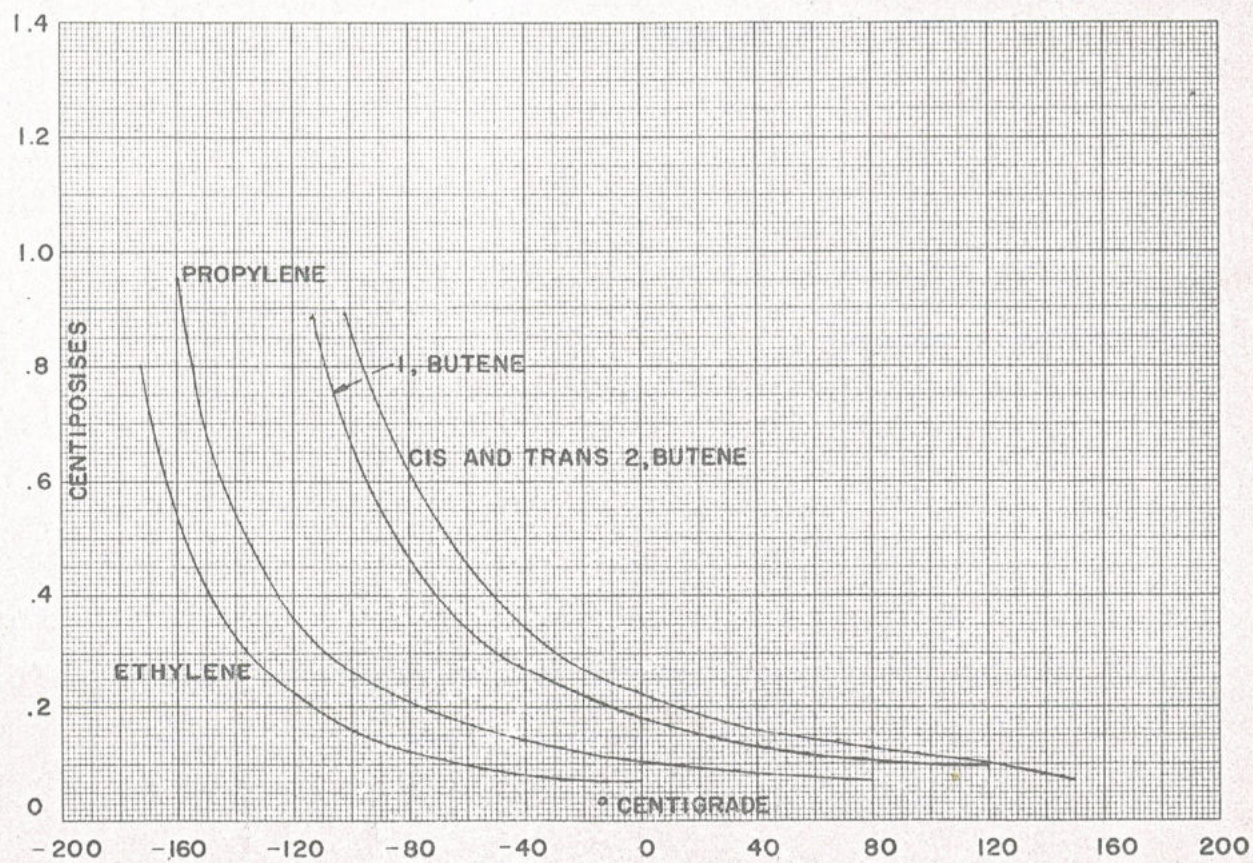
Fig. 2-6—Liquid density over a range of −120 to +160°C.

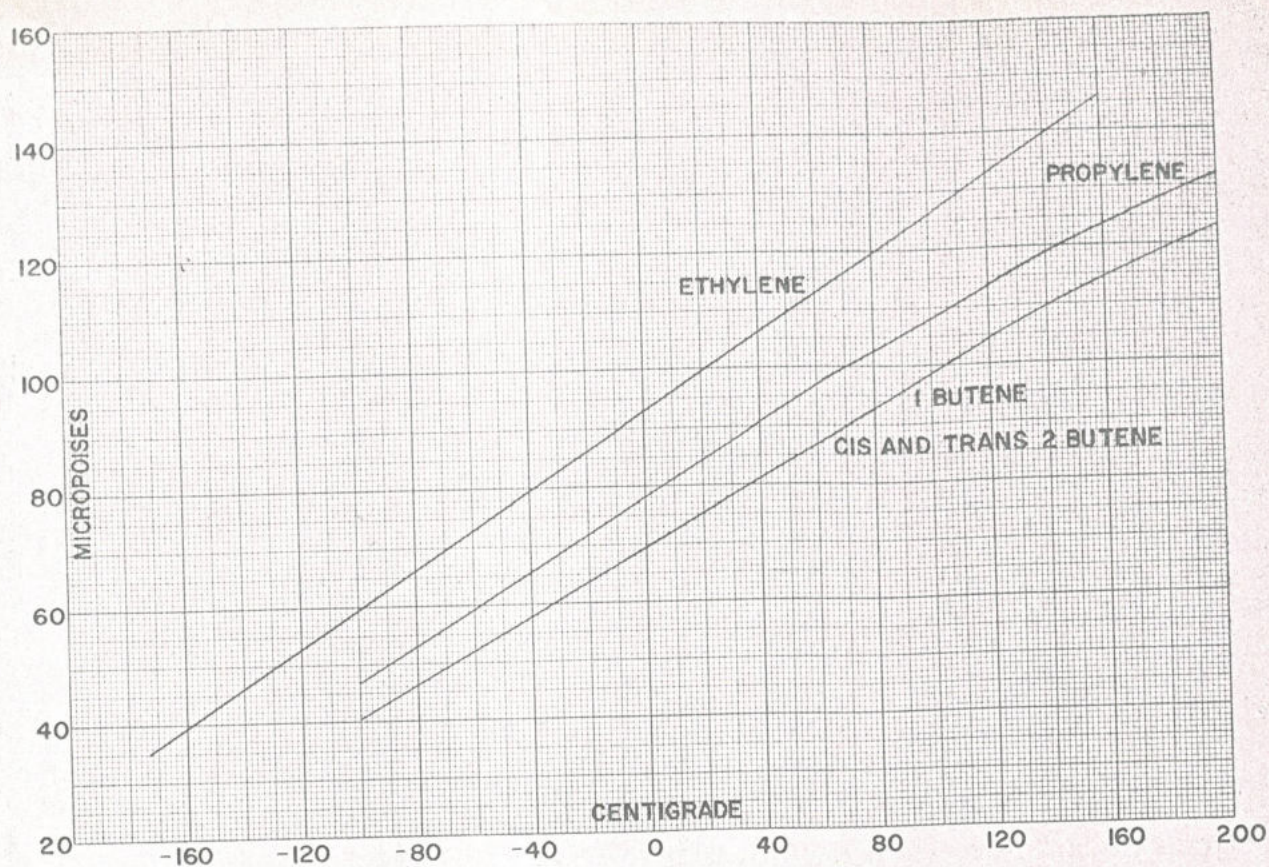

Fig. 2-7—Liquid viscosity over a range of −180 to +150°C.

Fig. 2-8—Vapor viscosity over a range of −180 to +200°C.

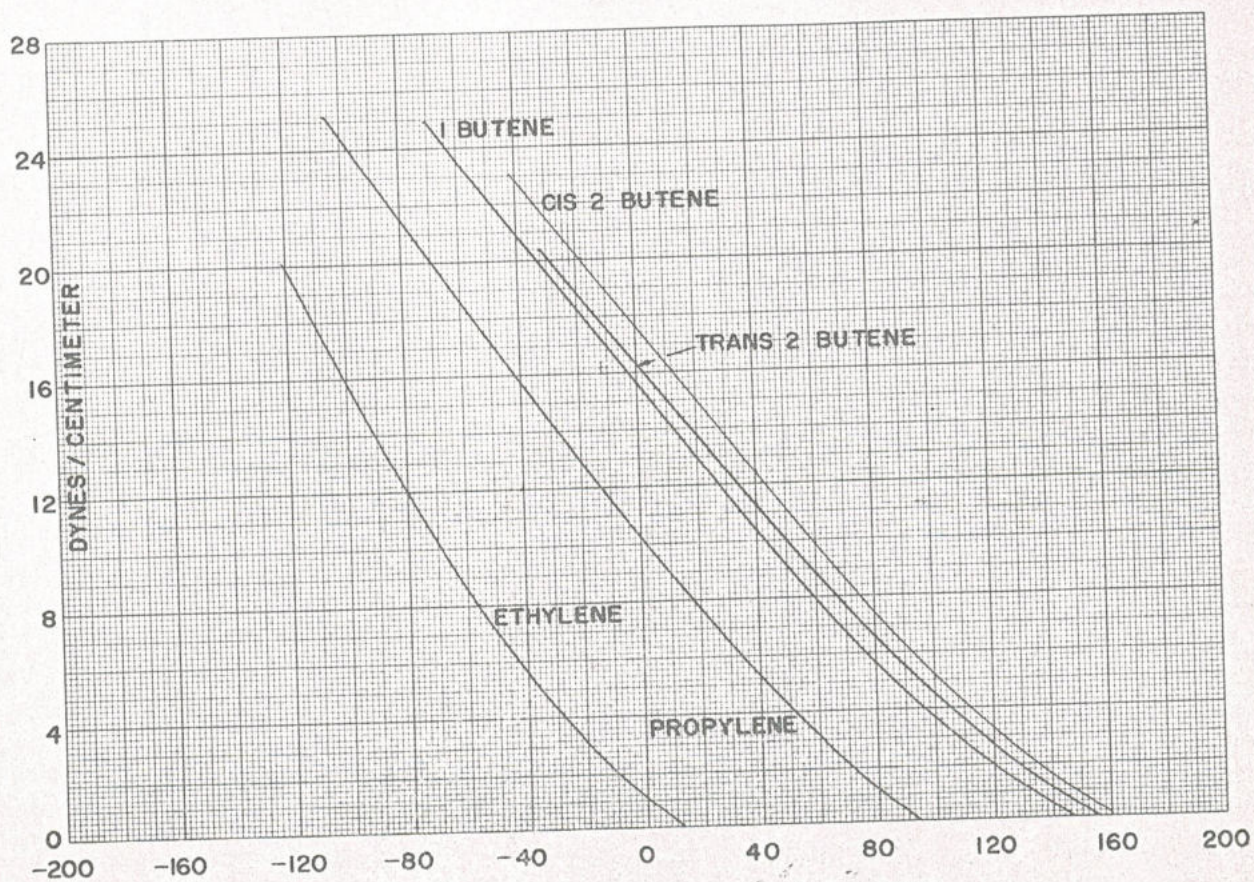Fig. 2-9—Surface tension over a range of −120 to +160°C.

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