

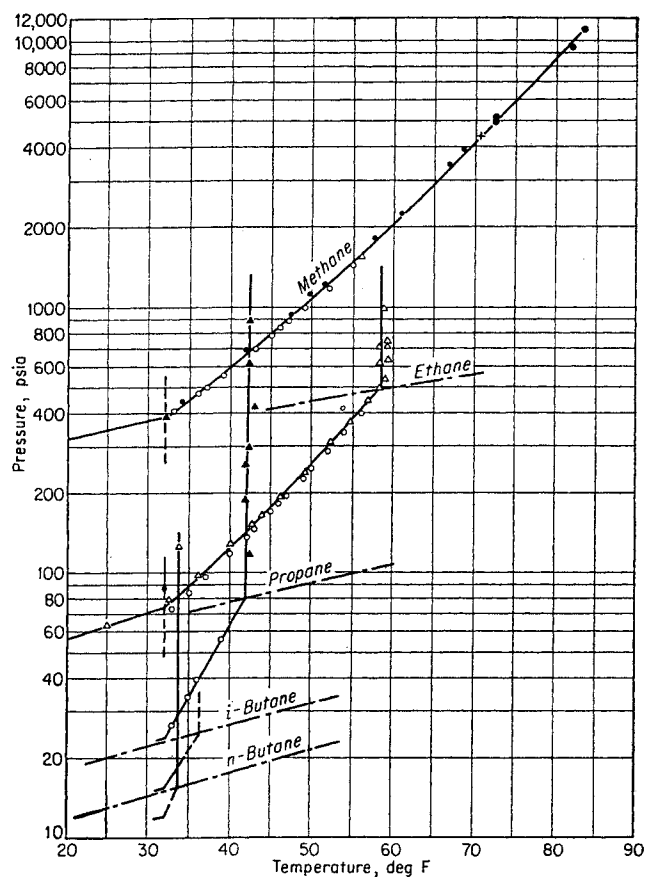


Fig. 5-37. Hydrate-forming conditions for paraffin hydrocarbons.

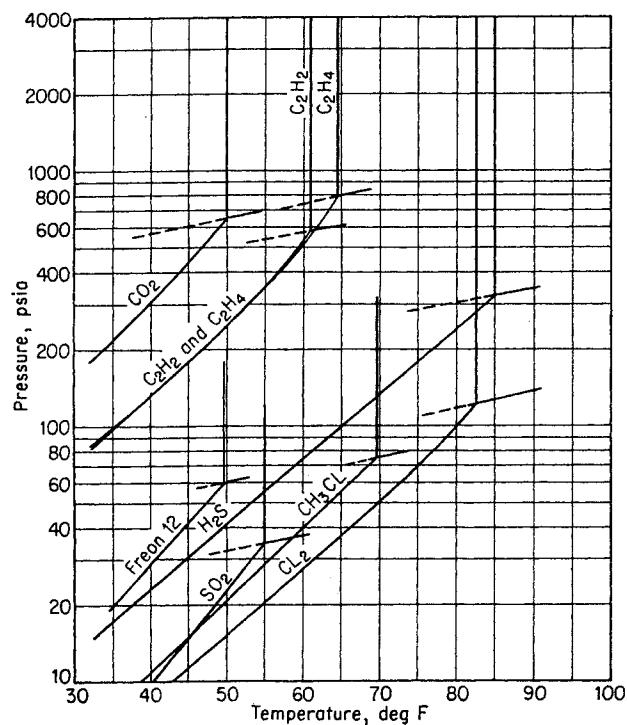


Fig. 5-38. Hydrate-forming conditions for miscellaneous substances.

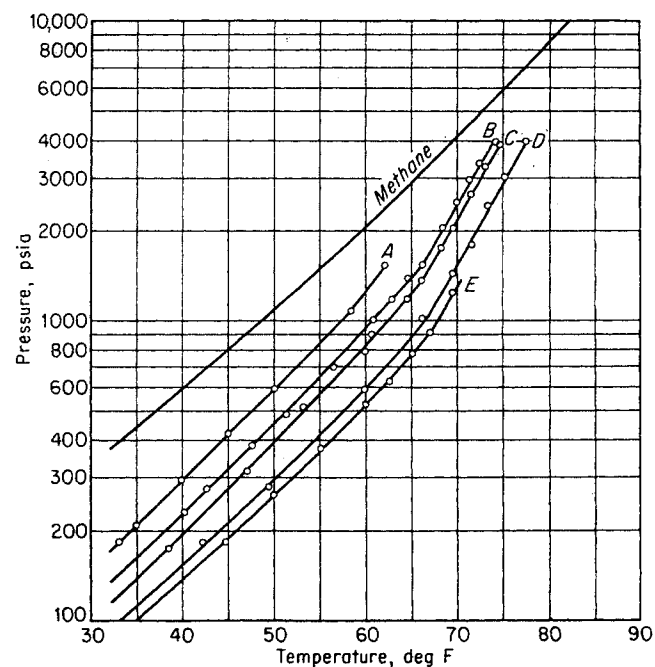


Fig. 5-39. Hydrate-forming conditions for natural gases. (Data of Refs. 5-21, 5-90, 5-42.)

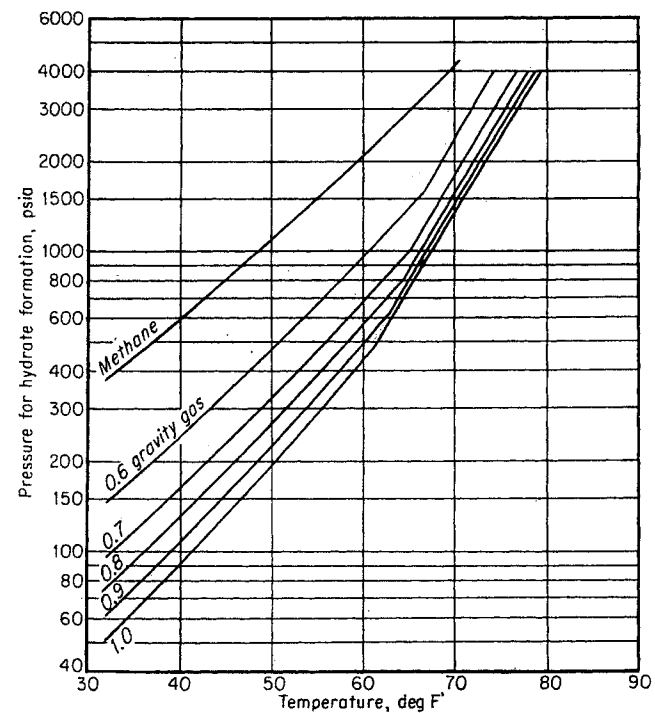


Fig. 5-40. Hydrate-forming conditions for natural gases with various gravities. (Katz, 5-38. Courtesy AIME.)

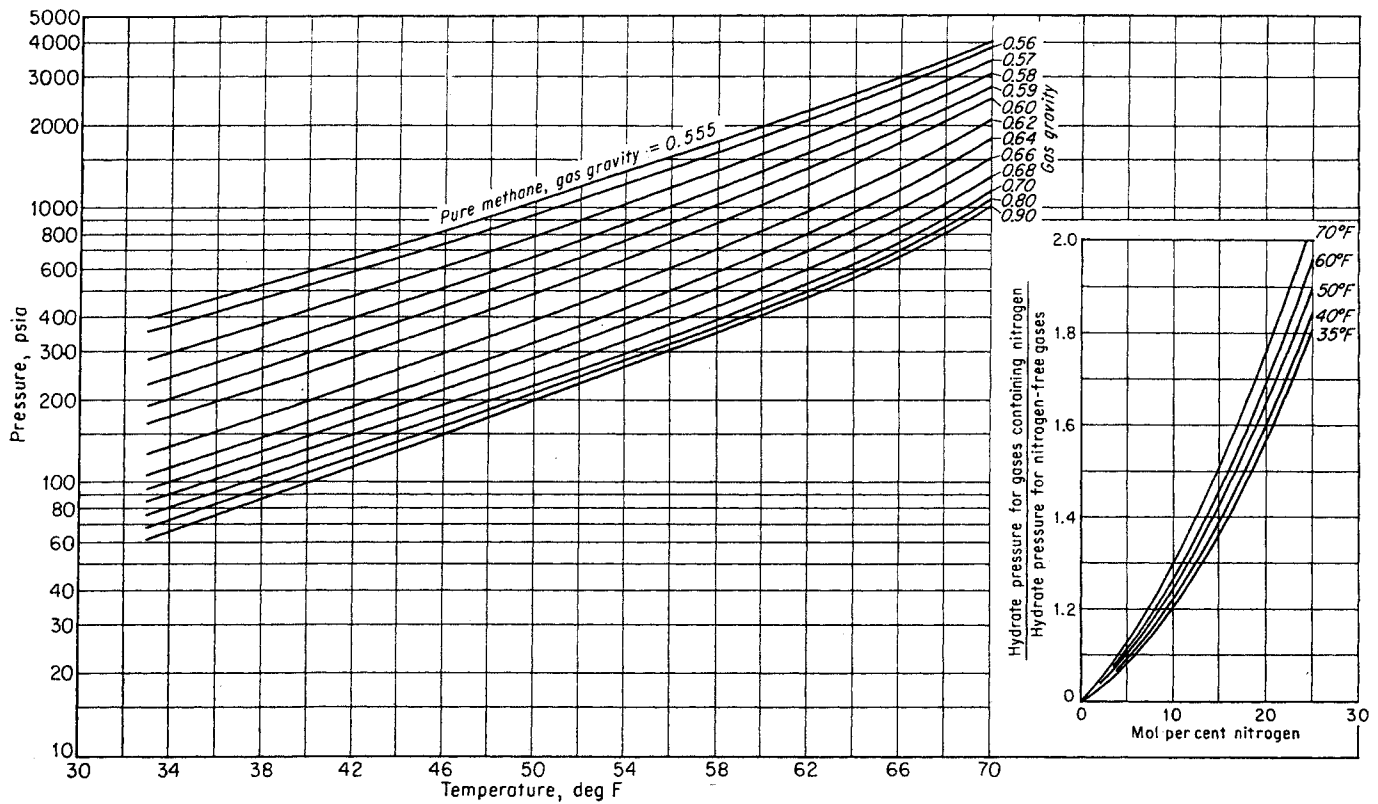


Fig. 5-41. Hydrate-formation conditions for natural gases, including effects of nitrogen.

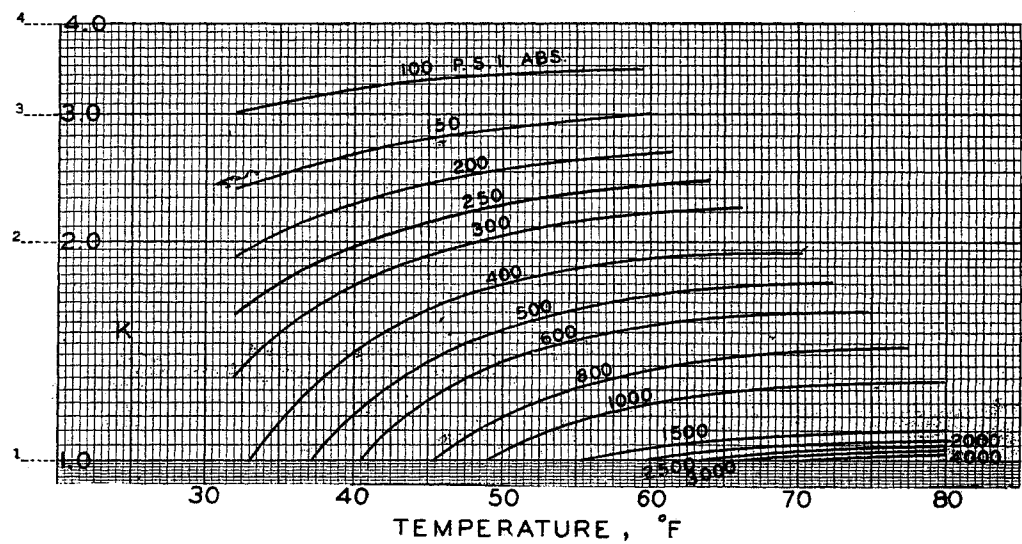


Fig. 5-42. Vapor-solid equilibrium constants for methane. (Carson and Katz, 5-12. Courtesy AIME.)

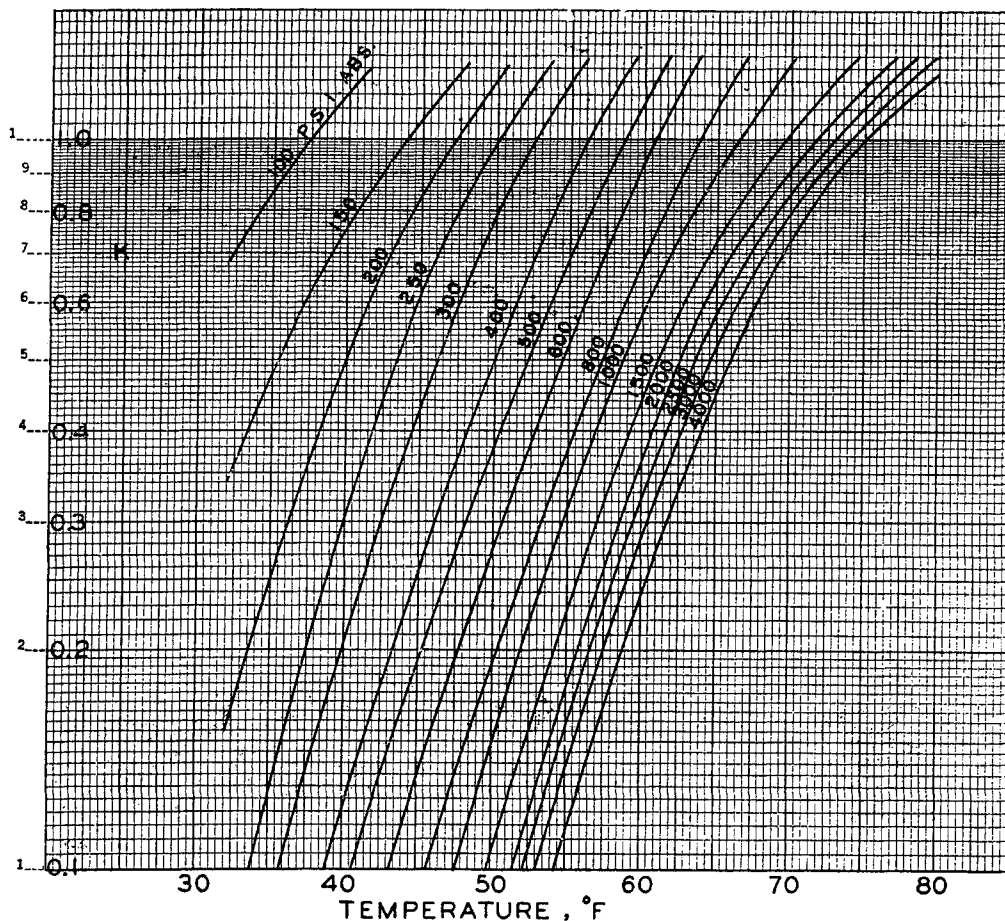


Fig. 5-43. Vapor-solid equilibrium constants for ethane. (Carson and Katz, 5-12. Courtesy AIME.)

Table 5-7. Calculation of Pressure for Hydrate Formation at 50°F

Component	Mole fraction in gas	At 300 psia		At 350 psia	
		<i>K</i>	<i>y/K</i>	<i>K</i>	<i>y/K</i>
Methane.....	0.784	2.04	0.3841	1.90	0.4126
Ethane.....	0.060	0.79	0.0759	0.63	0.0952
Propane.....	0.036	0.113	0.3185	0.086	0.4186
Isobutane.....	0.005	0.0725	0.0689	0.058	0.0862
<i>n</i> -Butane.....	0.019	0.79	0.0240	0.63	0.0301
Nitrogen.....	0.094	Infinity	0.0000	Infinity	0.0000
Carbon dioxide...	0.002	3.0	0.0007	2.3	0.0008
Total.....	1.000		0.8721		1.0435

Interpolating linearly, $y/K = 1.0$ at 337 psia.

The experimentally observed hydrate-formation pressure at 50°F was 325 psia.

SOURCE: (5-12).

present. The charts also give the temperature change upon expansion.

Prevention of Hydrate Formation

Hydrates form only when liquid water is present with the gas. The addition of a substance to the water can change its "freezing point." Methanol is a common substance used in industry. Much work has been done on hydrate prevention (5-5, 5-21, 5-34, 5-35, 5-43, 5-91).

Water-soluble substances inhibit or suppress hydrate formation; the hydrogen dipole may attack the water structure (5-81) or the solute may decrease the activity of the water (5-43). Ammonia inhibits the formation of hydrates by the first mechanism; salts such as sodium chloride reduce the activity of the water.

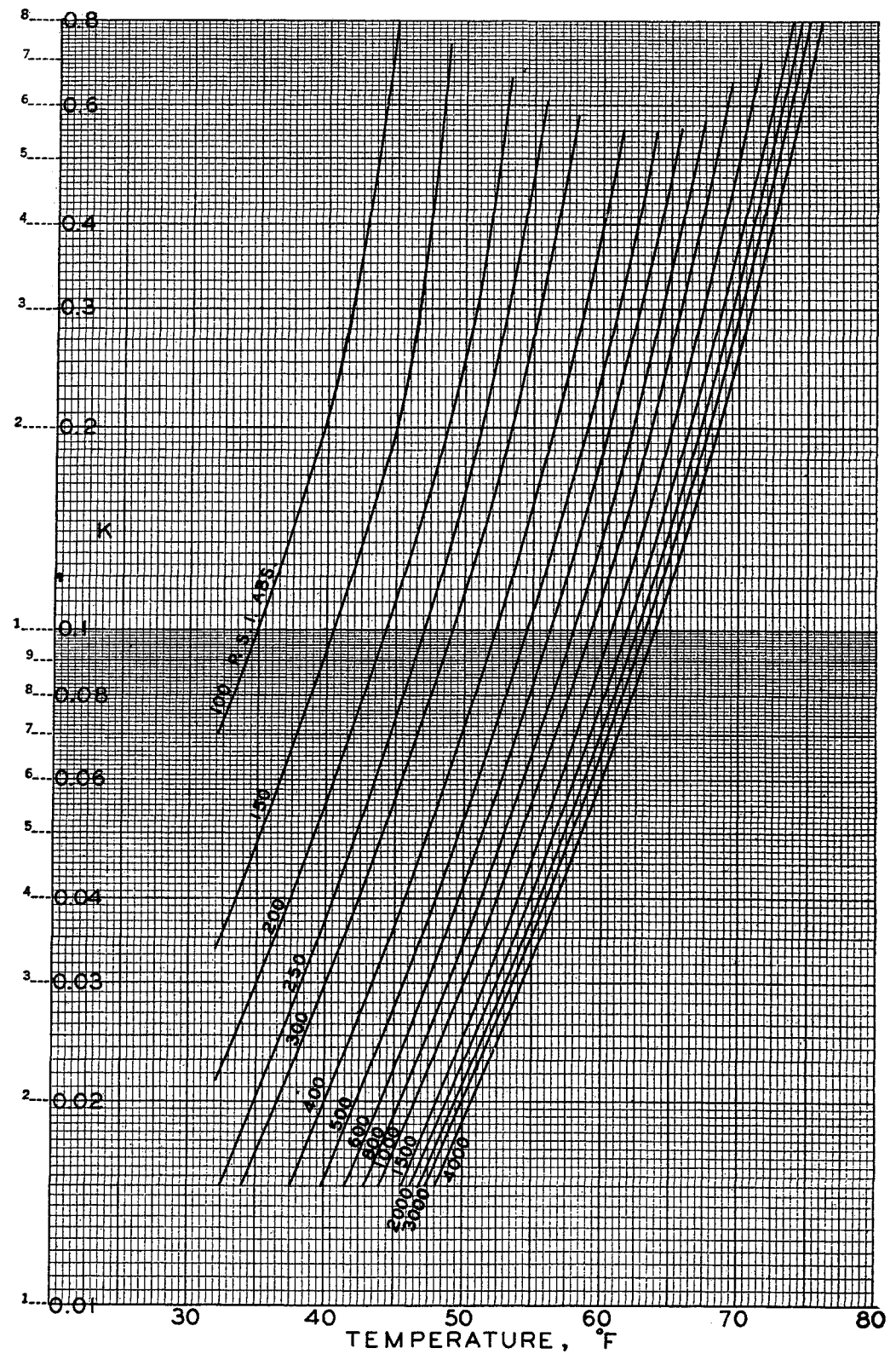


Fig. 5-44. Vapor-solid equilibrium constants for propane. (Carson and Katz, 5-12. Courtesy AIME.)

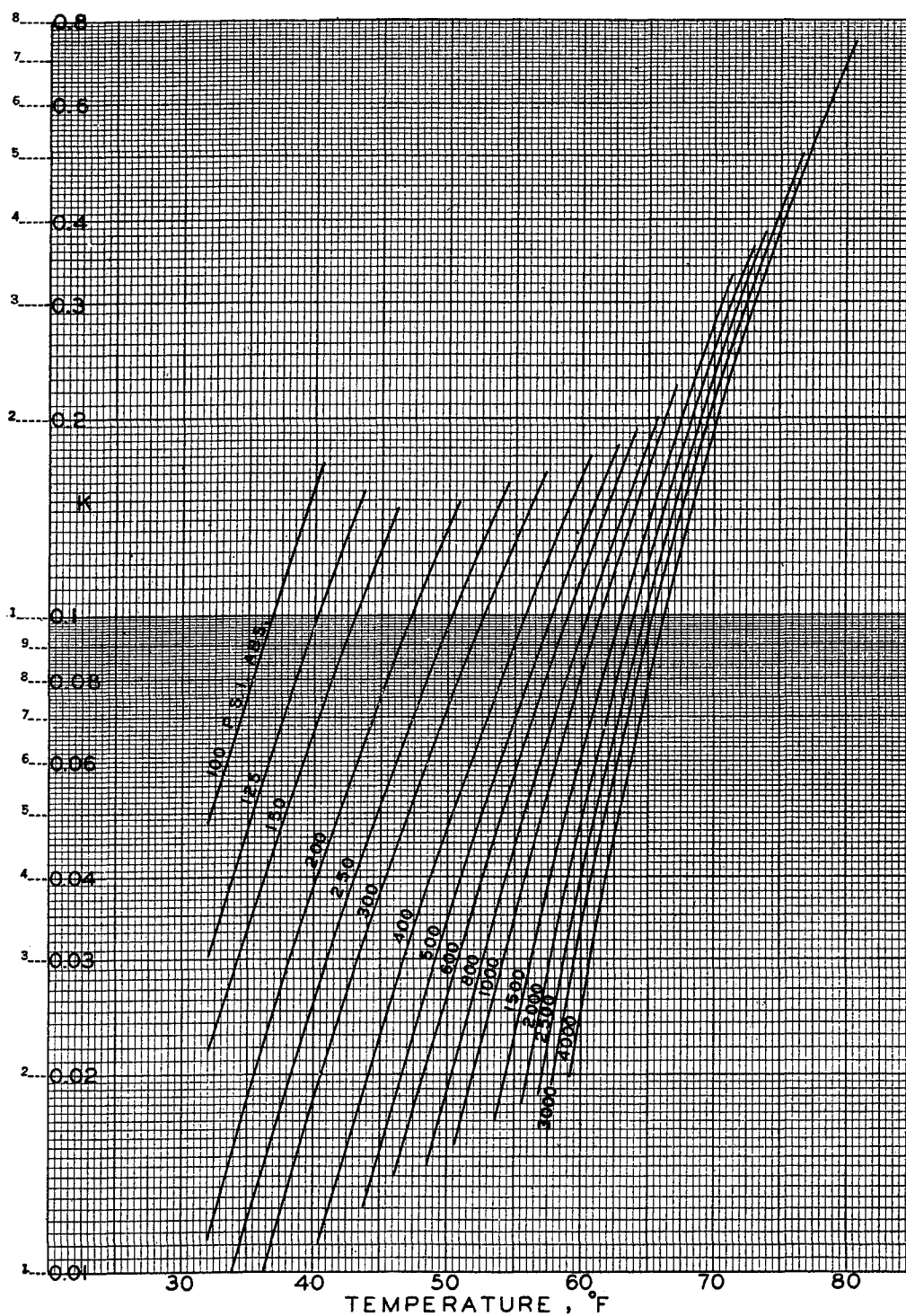


Fig. 5-45. Vapor-solid equilibrium constants for isobutane. (Carson and Katz, 5-12. Courtesy AIME.)

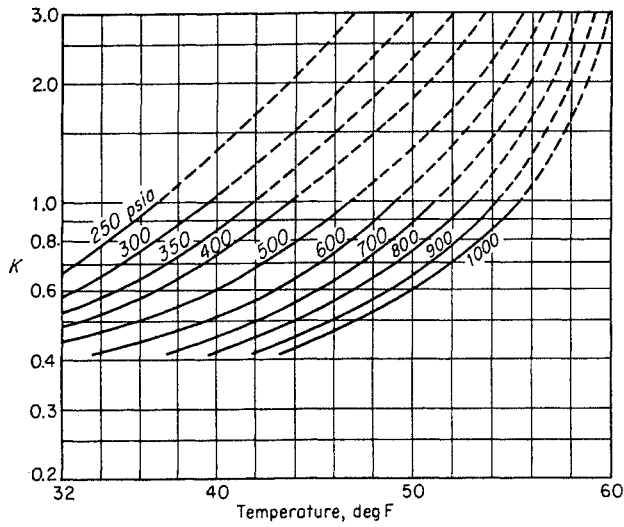


Fig. 5-46. Vapor-solid equilibrium constants for carbon dioxide. (Unruh and Katz, 5-84. Courtesy AIME.)

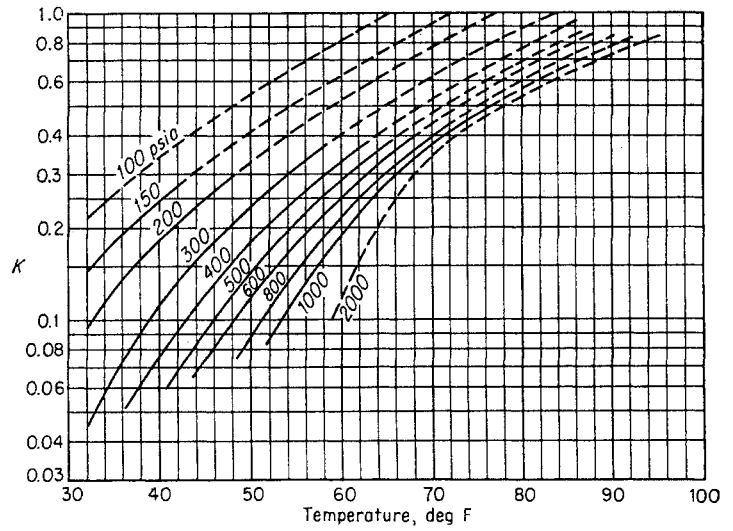


Fig. 5-47. Vapor-solid equilibrium constants for hydrogen sulfide. (Noaker and Katz, 5-55. Courtesy AIME.)

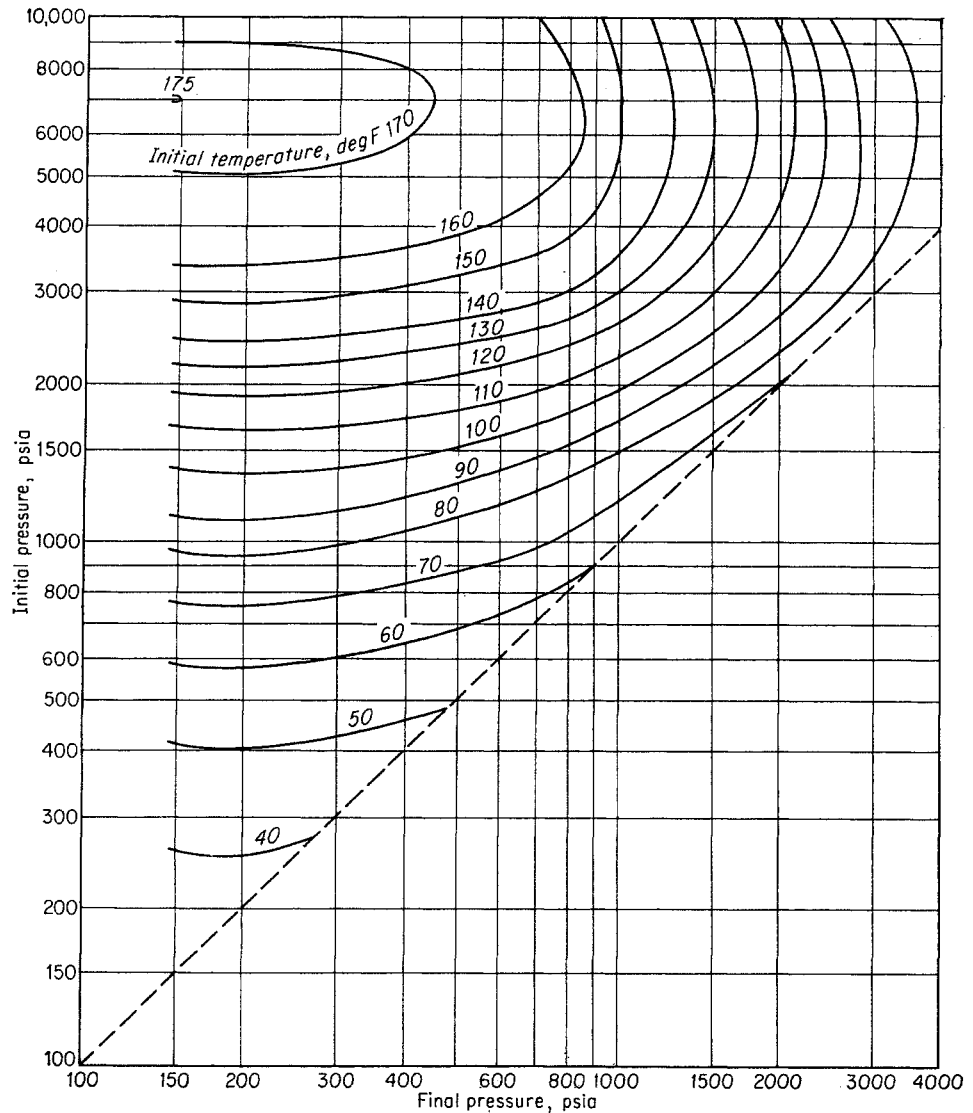


Fig. 5-48. Permissible expansion of 0.6 gravity gas without hydrate formation. (Katz, 5-38. Courtesy AIME.)

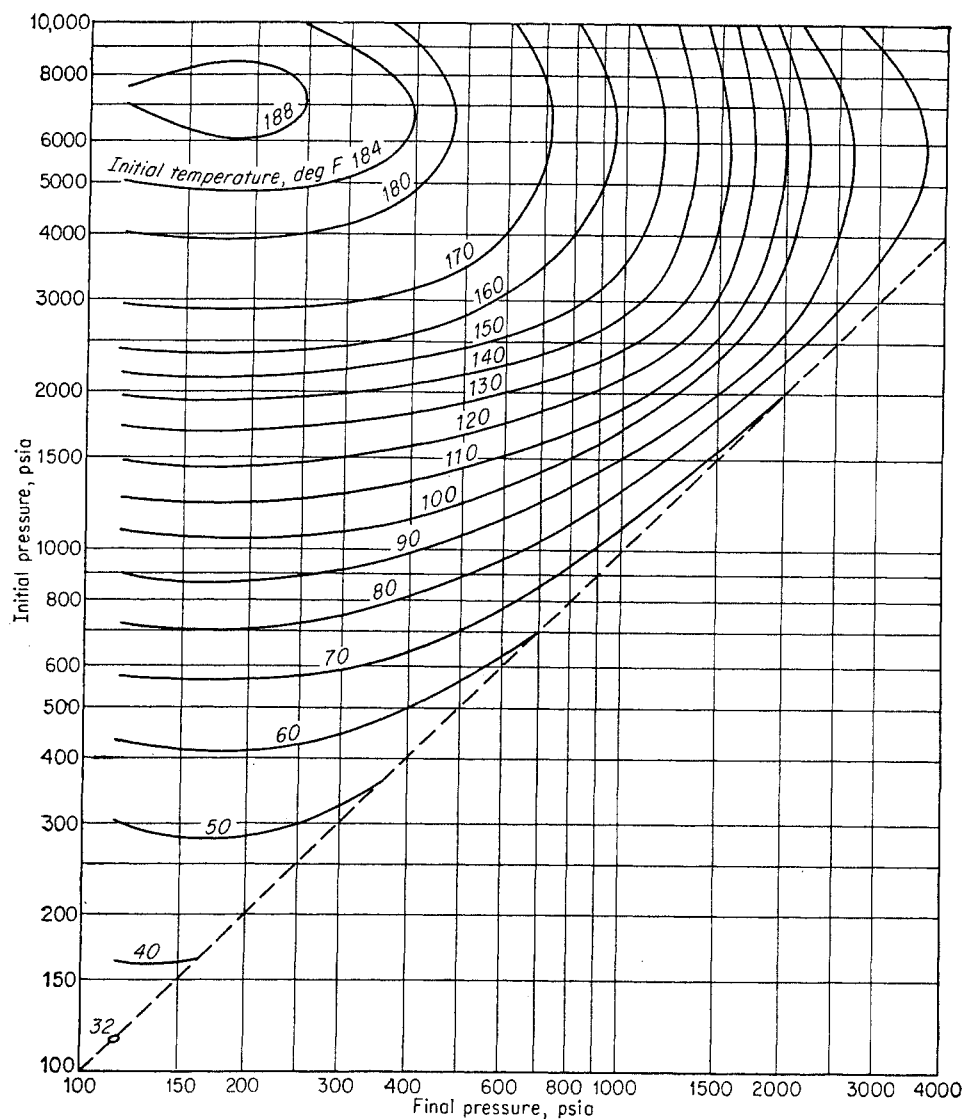


Fig. 5-49. Permissible expansion of 0.7 gravity gas without hydrate formation. (Katz, 5-38. Courtesy AIME.)

The suppression of hydrate formation by 10 wt % aqueous solutions of several inhibitors is shown in Fig. 5-51. The effectiveness of alcohols in preventing hydrate formation is in the order of their volatility: methanol, ethanol, then isopropanol. The effect of the concentration of various solvents on the hydrate-formation temperatures of a natural gas is plotted in Fig. 5-52, which neglects the slight dependence of the depression on pressure. The concentration shown is the actual concentration of the liquid in equilibrium with the natural gas. The effect of sodium chloride on propane hydrate is given in Fig. 5-53. The total amount of a volatile inhibitor required to produce a given depression is the sum of the amount required to produce a given liquid-phase composition and the

amount that has volatilized into the gas phase (5-34). For nonvolatile inhibitors, it may be possible to compute the effect of concentration on the extent to which the hydrate-formation temperature is depressed (5-43).

Di- and triethylene glycol are used for the inhibition of hydrate formation as well as in the dehydration of natural gases. Figure 5-54 gives the depression effect produced by various concentrations of diethylene glycol on a 0.595 gravity natural gas (5-73). The presence of oil with the glycol solution further depresses the hydrate-formation conditions, but the over-all depression is less than the sum of the depressions produced by the two solutions independently (5-73).

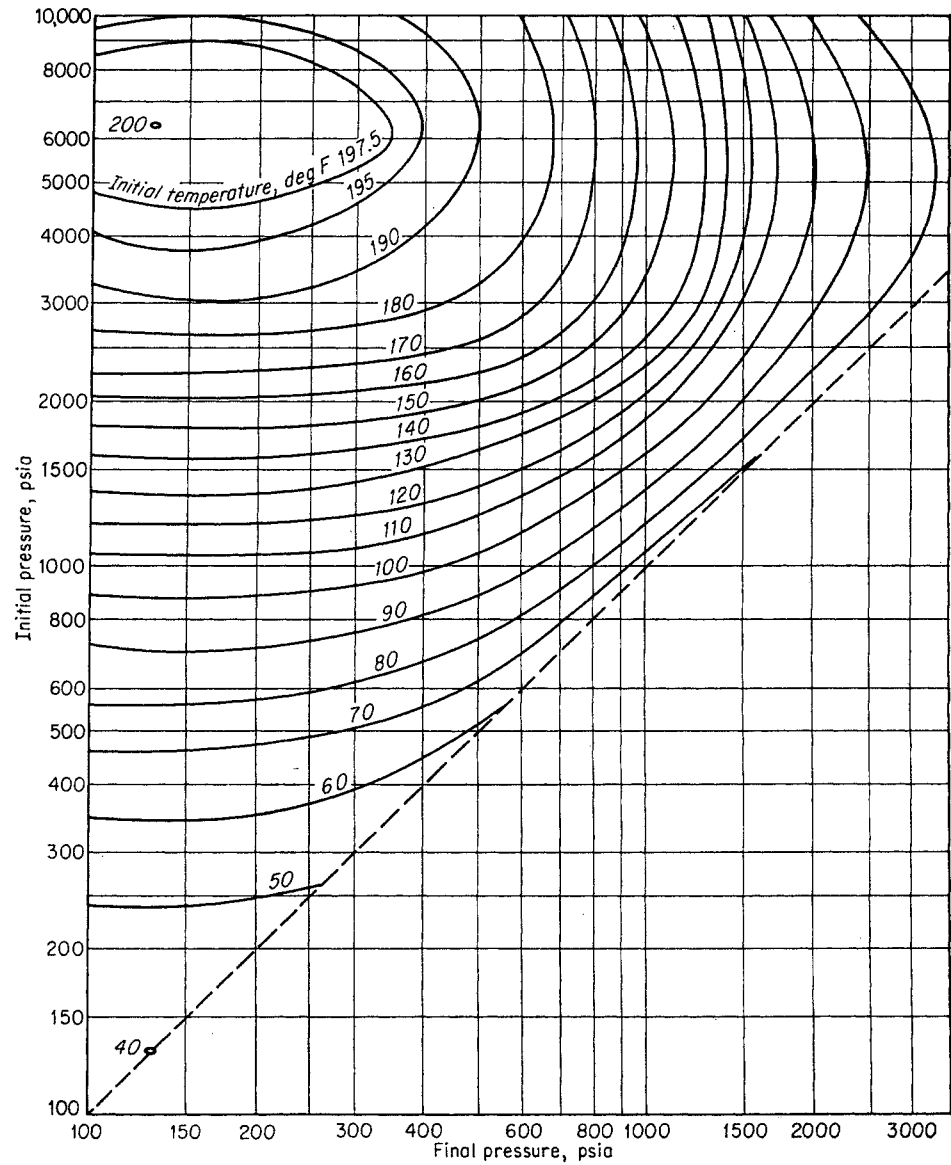


Fig. 5-50. Permissible expansion of 0.8 gravity gas without hydrate formation.
(Katz, 5-38. Courtesy AIME.)

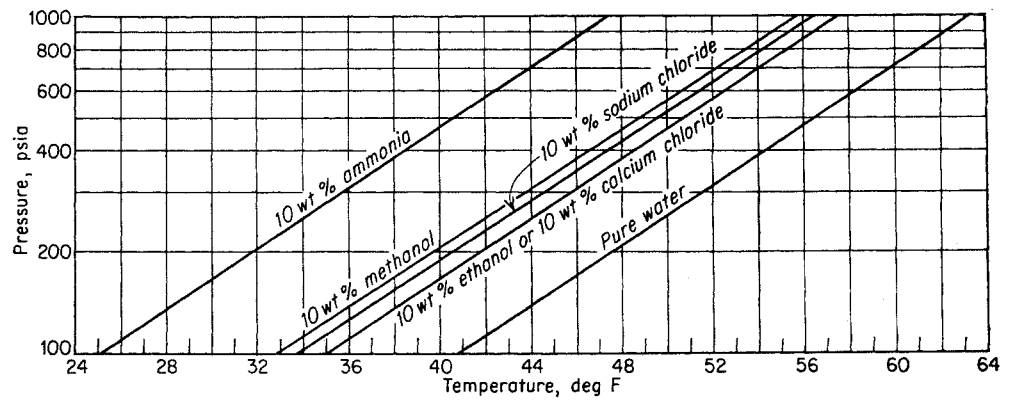


Fig. 5-51. Effect of dissolved substances in water on hydrate-formation conditions. (5-21.)