MEASUREMENT OF VELOCITY OF SOUND IN FREONS

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This paper gives experimental data in a fairly wide region of state variables, including the saturation line, and the sub- and supercritical regions. To determine the behavior of $c = f(p, T)$ we chose Freon-12 (CF_2Cl_2) and Freon-142 ($C_2H_3F_2Cl$). These Freons have relatively low critical temperatures and, hence, are suitable for investigation of the supercritical region. In addition, there are no data on the speed of sound in these Freons.

The measurements were made by the standing-wave method at frequencies of 1000–3000 Hz in a resonator on the apparatus described in [1]. A special feature of these measurements was that at temperatures below room temperature (up to 233° K) the autoclave with the resonator was placed in a specially equipped refrigerator. This made the work easier and allowed accurate temperature regulation. The Freon-12 was analyzed on a mass spectrometer. No impurities were detected in it. The Freon-142 was subjected to chromatographic analysis, which revealed the following impurities: Freon-12, 0.28%; 1,1-difluoroethane + 1,2-fluorochloroethylene, 0.06%; Freon-141, less than 0.01%.

Work with Freon-12 showed good agreement between the p–T relationship on the saturation line and tabulated data. Work with Freon-142 showed a deviation of the saturation pressure from the tabulated value [2], and this deviation increased with approach to the critical temperature. In view of this we give no data for Freon-142 in the immediate vicinity of the critical point. For the presented values of the speed of sound the deviation of the saturation pressure from the tabulated value did not exceed 0.4%; this deviation did not lead to a significant increase in the error of the results.

From the formula

$$c^\circ = \left(g \frac{C_p^\circ}{C_v^\circ} RT\right)^{1/2}$$

we calculated the speed of sound in the two Freons at zero pressure, and in the treatment of the results we extrapolated the isotherms of the speed of sound to zero pressure. The initial data for the calculation were taken from [3]. The results of sound velocity measurements in superheated vapor on the isotherms and saturation line are given in Figs. 1 and 2, where P_s is the saturation curve and the figures correspond to the following temperatures:

Freon-12

	1	2	3	4	5
T [°K] =	576.16	513.16	473.16	433.16	413.16
	6	7	8	9	10
T [°K] =	394.16	385.16	352.36	304.26	233.16

Freon-142

	1	2	3	4	5
T [°K] =	473.16	441.16	423.96	410.08	399.16
	6	7	8	9	
T [°K] =	363.16	330.36	272.51	233.46	

The speed of sound in Freon-12 was investigated at temperatures of 233–576° K and pressures of 0.01–100 bar, and in Freon-142 at 233–473° K and the same pressures. The temperature was measured with a platinum resistance thermometer, and the pressure with a MP-60 piston pressure gauge of accuracy class 0.05 and a standard 4 kg/cm^2 manometer of accuracy class 0.35. During the measurements the temperature was kept constant to within 0.1–0.2° K at low temperatures, to within 0.03° K in the temperature range 293–510° K, and to within 0.1–0.2° K in the range 510–590° K.

In addition to direct measurement, the distance between the membranes was determined by measurements of the speed of sound in dried air. The reference error did not exceed 0.1% in the whole

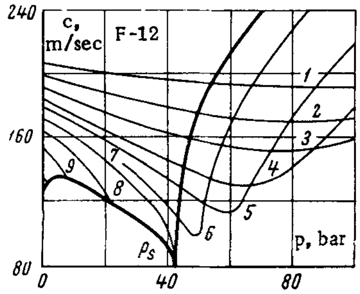

Fig. 1

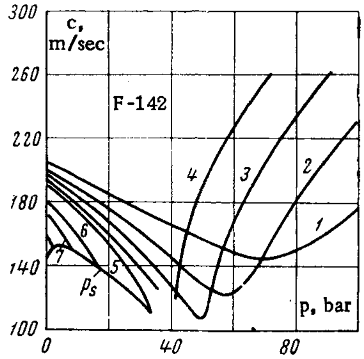

Fig. 2

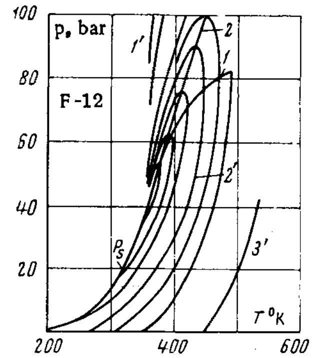

Fig. 3

range of investigated state variables, except in the critical region, where this error was a little higher. At temperatures of 233–400° K the divergence between the experimental values of the speed of sound and the values extrapolated to zero pressure did not exceed 0.2–0.3%. At higher temperatures this difference increased, reaching 0.6–0.7%. A correction for thermal expansion of the resonator was introduced. The correction for friction on the resonator wall was negligibly small. The over-all error of the results was estimated as 0.5–0.8%.

The speed-of-sound measurements in Freon-12 and Freon-142 in this investigation and earlier measurements in Freon-21 [1] revealed certain features of the lines of constant speed of sound in the critical region. Figure 3, where k is the critical point and P_s is the saturation curve, shows the lines of constant speed of sound (1', 270.3 m/sec;

2', 150.9; 3', 189.7) in coordinates p, T for Freon-12. Line 1 connects points of minimum sound velocity, which are also points of maximum temperature on the curves c(p, T) = const.

As the graph shows, with increasing distance from the critical point line 1 deviates from a straight line in the direction of lower pressures. Line 2, which connects points of maximum pressure on the lines c(p, T) = const, is a straight line. As a comparison with p-v-T data [4] shows, in this region line 2 is very close to the critical isochor. A similar picture is observed in the case of Freon-142 and Freon-21.

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