AN EXPERIMENTAL STUDY OF THE SPEED OF SOUND IN SATURATED AND SUPERHEATED VAPORS OF DIFLUOROCHLOROMETHANE

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Results are given on the speed of sound in difluorochloromethane along the saturation line from 293° K to the critical temperature and also for the superheated vapor for the isotherms at 293, 313, 333, 353, 363, 369, and 373° K.

This compound, $CHClF_2$, is the compound most widely used in refrigeration, and it now appears promising as a heat carrier in power engineering. The data on the compound are not complete even for low temperatures. Here we present the first systematic measurements on the speed of sound in the vapor from 293° K up to a point beyond the critical temperature.

The speed of sound in a substance is an important thermodynamic parameter that not only gives evidence on the molecular structure but also is of purely practical interest, since it may be used with the density to construct the entropy diagrams needed to calculate thermal processes in power systems [1].

The apparatus provided simultaneous measurement of the speed of sound and the density. An acoustic interferometer [2] was used in the speed measurement. The source was an X-cut quartz plate. The reaction of the standing wave on the plate varies as the reflector is displaced, being maximum or minimum when the separation is an integral number of half-wavelengths.

The power was supplied to the crystal via an amplifier from a type-121a oscillator calibrated to 0.015%; the voltage at the crystal was measured with a VKS-7B vacuum-tube voltmeter, whose output was presented on a milliammeter in series with a standard resistor. The dc component of the potential difference across this resistor was balanced with a PMS-48 potentiometer, while the ac component was passed to an F-16 galvanometer. The response of the crystal was recorded by an N16 chart recorder. The recording was processed to give the wavelength with an error not exceeding 0.2%, apart from points near the critical temperature, where the error was somewhat larger. The known frequency ν and wavelength λ give the speed of the ultrasound as $c = \nu\lambda$. The gas temperature was measured with a calibrated platinum resistance thermometer, whose resistance was measured with a class A potentiometer of the PMS-48 type. This system provided measurement of the temperature to 0.02-0.04° K.

The interferometer was set up in a thermostat, in which the oil was kept at a temperature constant to ±0.02° K by a contact thermometer and electronic relay.

The pressure was measured with a class-0.05 calibrated piston gauge of the MP-60 type. Contamination with oil vapor was avoided

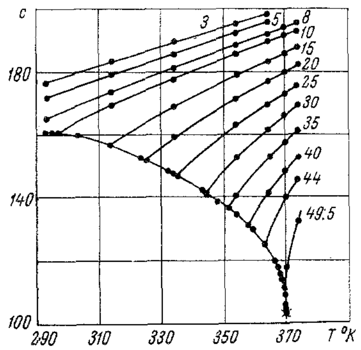

Fig. 1

by separating the interferometer volume from the gauge volume by a tube from a Bourdon gauge of class 0.35, $0.98 \cdot 10^5$ N/m^2. The tube was placed in a thick-walled vessel connected to the pressure source of the piston gauge and thus operated as a differential manometer. In

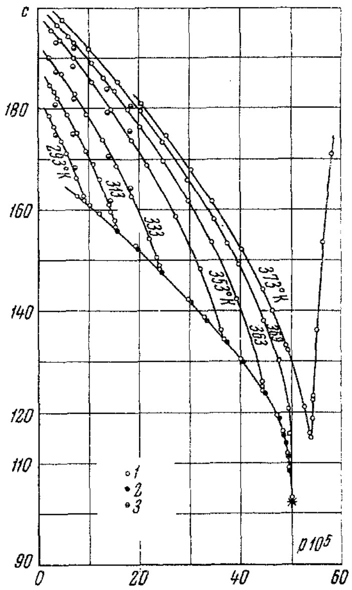

Fig. 2

every case, the differential readings were close to zero, so the Bourdon tube introduced only a little additional error in the pressure measurement (over-all error 0.05-0.07%). The freon-22 was of All-Union State Standard quality and contained 0.2% by volume of freon-21 and traces of other substances. The boiling point was given as 232.2° K at 760 mm Hg and the change in boiling point on distillation as 0.06° K.

Impurities have large effects on c, so an apparatus was built for further purification of the freon (drying, triple distillation at 195° K, and freezing). The product contained no impurities detectable by a MKh1303 mass spectrometer (limit 0.05%). The measuring apparatus was checked on CO_2, and then c was measured on the freon. The overall error from all sources did not exceed 0.25%.

The measurements along the saturation line (Table 1) were made at 500 and 1500 kHz.

The unsaturated vapor was used at 500 kHz at 293, 313, 333, 353, 363, 369, and 373° K (Table 2); c on the saturation line was independent of frequency, while the isotherms were smooth over a wide pressure range, so dispersion was absent and the measured c could be taken as the thermodynamic value. Figure 1 shows c in m/sec as a function of T for the pressures p given in 10^5 N/m^2 on the curves; the critical point is denoted by an asterisk.

The observed values were compared with ones calculated [3] from the equation of state proposed in [4]. Figure 2 shows the pressure dependence of c, with experimental values at: 1) 500 kHz, 2) 1500 kHz. Points 3 are the calculated [3] ones, which deviate from the observed ones by 0.7% in the worst case. The slopes of the calculated isotherms differ from the observed ones, and so the calculated c differ more substantially from the observed ones near the saturation line. This arises because the data used in [4] were restricted and not very accurate.

The check measurements with CO_2 gave good agreement with the calculated values, which indicates that our values for $CHClF_2$ are reliable for the ranges 293-373° K and $2 \cdot 10^5$ to $60 \cdot 10^5$ N/m^2.

Table 1

Results on c (at 500 kHz) and c' (at 1500 kHz) for the Saturated Vapor of $CHClF_2$

T, °K	$p\ 10^{-5}$, N/m^2	c m/sec	c', m/sec	T, °K	$p\ 10^{-5}$, N/m^2	c, m/sec	c', m/sec
287.47	7.505	162.6	—	357.89	40.310	130.0	130.0
294.68	9.780	160.8	—	363.15	44.365	124.0	123.8
303.16	11.900	159.6	159.6	366.12	46.921	119.1	119.3
313.18	15.273	155.9	156.4	367.07	47.739	117.1	117.4
303.23	11.884	159.4	—	367.65	48.269	115.3	115.2
322.69	19.180	152.7	152.4	367.98	48.533	115.4	115.8
333.04	24.161	147.8	148.3	368.28	48.790	114.0	114.0
333.19	24.204	147.6	147.6	368.61	49.150	111.2	111.1
343.02	29.802	141.9	141.8	368.75	49.298	110.0	110.1
347.88	32.933	138.4	138.5	369.00	49.514	108.8	109.0
353.05	36.460	134.0	134.3	369.27	49.779	102.6	102.6

Table 2

Results on c for Superheated Vapor of $CHClF_2$

T, °K	$p\ 10^{-5}$, N/m^2	c, m/sec	T, °K	$p\ 10^{-5}$, N/m^2	c, m/sec	T°, K	$p\ 10^{-5}$, N/m^2	c, m/sec
	293° K			353° K				
293.17	2.003	178.3	353.15	2.499	195.6	369.28	19.879	179.5
293.15	3.008	176.4	353.16	3.965	193.5	369.29	24.649	173.2
293.12	4.179	173.1	353.14	7.487	188.9	369.27	29.490	165.9
293.21	5.392	170.9	353.14	10.268	185.3	369.29	34.427	158.5
293.16	7.366	166.0	353.12	14.337	179.8	369.28	39.310	149.5
293.14	8.729	162.3	353.14	18.466	173.8	369.27	44.348	138.4
293.16	8.899	162.1	353.15	21.579	169.1	369.29	47.177	129.9
			353.15	27.168	158.9	369.28	49.098	120.9
	313° K		353.15	27.170	158.5	369.28	49.581	115.8
313.16	2.023	184.6	353.16	31.581	148.1			
313.18	3.057	183.0	353.16	36.130	136.1		373° K	
313.16	3.530	181.9				373.17	20.287	180.6
313.18	5.405	178.5		363° K		373.19	25.072	174.8
313.16	7.495	174.3	363.16	3.629	196.3	373.14	29.968	168.1
313.15	9.003	171.3	363.16	5.994	194.1	373.17	34.433	161.6
313.16	10.573	168.0	363.16	6.906	193.2	373.16	40.060	152.1
313.19	11.728	165.5	363.17	10.097	188.8	373.15	44.253	144.3
313.14	13.669	160.7	363.15	12.857	185.9	373.16	46.301	140.0
313.17	14.797	157.6	363.16	14.834	183.2	373.17	47.060	132.9
	333° K		363.16	17.769	179.5	373.13	49.415	132.2
			363.14	20.123	176.3	373.10	52.363	121.1
333.16	2.009	190.2	363.16	24.650	169.7	373.16	52.649	119.6
333.18	4.120	187.1	363.15	29.682	161.6	373.12	53.054	116.0
333.16	4.297	186.8	363.15	34.356	153.1	373.12	53.288	115.1
333.16	6.989	182.7	363.15	39.238	142.4	373.20	53.557	115.4
333.13	9.499	178.8	363.15	44.097	125.4	373.12	53.848	118.5
333.16	12.454	173.8	363.16	44.183	125.1	373.12	54.121	122.7
333.17	15.347	168.6		369° K		373.19	54.190	122.9
333.15	18.203	162.6				373.20	55.070	135.2
333.18	21.854	154.1	369.28	4.477	197.8	373.15	56.352	153.2
333.15	23.269	150.4	369.28	9.609	191.4	373.20	58.456	171.0
333.15	23.964	148.2	369.28	15.378	185.2			

REFERENCES

1. I. I. Novikov and Yu. S. Trelin, "A new method for constructing thermodynamic diagrams for working substances," Teploenergetika, no. 2, 1962.

2. Yu. S. Trelin, "A study of the speed of ultrasound in CO_2 in the liquid and gaseous states," Application of Ultrasound to the Examination of Materials [in Russian], Mosk. Obl. Ped. Inst., no. 13, 1961.

3. R. C. Downing and L. I. Long, "Velocity of sound in some fluorocarbon refrigerants," ASHRAE Journal, vol. 5, 41–46, 1963.

4. Benning and McHarness, "Thermodynamic properties of fluorochloromethanes and fluorochloroethanes," Ind. Engng. Chem., vol. 32, no. 5, 698–700, 1940.

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