EXPERIMENTAL STUDY OF THERMAL CONDUCTIVITY OF HEAVY-WATER VAPOR AT TEMPERATURES OF 375-600°C AND PRESSURES TO 250 mPa

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Results are presented of an experimental study of the thermal conductivity of heavy water using the plane horizontal-layer method over the temperature range 375-600°C at pressures of 0.1-250 mPa. These are the first published heavy-water thermal-conductivity values at pressures above 100 mPa.

Heavy-water vapor has been studied much less thoroughly than normal water vapor. Only three studies have been performed in the high-pressure range. Vargaftik and Oleshchuk [1] used the heated-filament method to perform measurements up to 24.5 mPa pressure at temperatures to 500°C. The region near the saturation curve at temperatures to 330°C and pressures to 12.5 mPa was studied by Burry et al. [2] using the coaxial-cylinder method. Studies at 230-550°C and pressures to 80 mPa were performed by Tarzimanov and Zainullin [3] by the coaxial-cylinder method using an experimental apparatus previously employed for the study of the thermal conductivity of water vapor.

The development of thermoenergetics requires researchers to study the thermophysical properties of heavy water at high temperatures and pressures. For this purpose the authors have performed measurements using the plane horizontal-layer method in experimental apparatus previously used for study of the thermal conductivity of normal and heavy water [4, 5].

Heavy water at a concentration of 99.75% was used in the experiments. The thermal-conductivity studies were performed along isotherms.

A relatively high (0.4-1.8°C) temperature change was created across the layer during the experiments, which were performed in a 0.301-mm gap.

As is well known, values of the thermal-conductivity coefficient obtained for semitransparent substances depend on the method of considering radiative heat transfer. In our calculations, the correction for radiative heat transfer was treated in the same manner as in the case of a transparent medium, using the Stefan–Boltzmann formula.

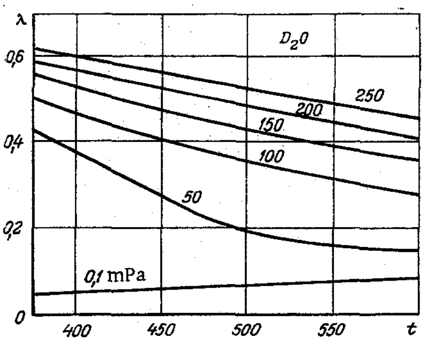

Fig. 1. Thermal conductivity of heavy-water vapor (isobars). λ, W/m·°K; t, °C.

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TABLE 1. Experimental Values of Heavy-Water-Vapor Thermal Conductivity (W/m · °K)

p, mPa	t, °C	Δt, °C	Q_{rad}/Q, %	$\lambda \cdot 10^3$	t, °C	Δt, °C	Q_{rad}/Q, %	$\lambda \cdot 10^3$
0,1	375,8	0,525	5,61	54	401,0	0,596	6,62	57
10	375,8	0,519	5,23	65	400,9	0,507	5,69	67
50	375,8	0,521	0,84	387	400,9	0,536	1,06	339
70	375,8	0,582	0,78	425	400,9	0,480	0,95	390
90	375,8	0,545	0,75	465	401,1	0,737	0,88	430
110	375,8	0,518	0,70	492	401,0	0,695	0,85	455
130	375,8	0,496	0,65	515	401,0	0,661	0,80	477
150	376,0	0,792	0,64	531	401,0	0,638	0,78	496
170	376,0	0,769	0,61	555	401,0	0,618	0,74	517
190	376,0	0,753	0,62	565	401,0	0,604	0,72	540
210	376,0	0,738	0,60	585	401,0	0,592	0,71	552
230	376,0	0,719	0,59	594	400,9	0,578	0,68	570
250	376,0	0,707	0,58	615	400,9	0,568	0,67	590
0,1	427,1	1,202	6,97	60	452,4	1,318	7,20	65
10	427,0	1,029	6,06	70	452,2	1,186	6,60	72
50	427,0	1,084	1,58	320	452,5	0,560	1,57	265
70	426,9	0,912	1,20	360	452,9	1,178	1,46	340
90	426,8	0,826	1,10	400	452,9	1,049	1,32	360
110	426,8	0,775	1,02	440	452,8	0,960	1,20	408
130	426,8	0,737	0,95	468	452,8	0,905	1,10	440
150	426,7	0,703	0,90	491	452,7	0,867	1,06	456
170	426,7	0,678	0,88	510	452,7	0,832	1,00	490
190	426,7	0,659	0,85	529	452,7	0,804	0,97	508
210	426,7	0,641	0,81	548	452,7	0,777	0,94	528
230	426,7	0,622	0,78	567	452,6	0,756	0,90	544
250	426,7	0,607	0,76	582	452,6	0,739	0,86	562
0,1	476,1	1,433	7,60	67	502,4	1,806	7,87	72
10	476,0	1,315	7,15	73	502,3	1,667	7,30	78
30	475,6	0,821	4,50	118	501,9	1,130	5,00	116
50	476,2	1,589	2,07	216	501,5	0,663	3,01	186
70	475,9	1,169	1,75	304	502,1	1,482	2,25	268
90	475,8	1,000	1,59	355	501,9	1,241	1,88	323
110	475,7	0,905	1,47	386	501,8	1,108	1,69	365
130	475,6	0,852	1,30	420	501,8	1,025	1,60	395
150	475,6	0,804	1,24	448	501,7	0,967	1,46	420
170	475,6	0,770	1.15	472	501,7	0,920	1,38	444
190	475,6	0,739	1,11	490	501,7	0,877	1,30	466
210	475,5	0,718	1,09	506	501,7	0,844	1,25	486
230	475,5	0,696	1,06	521	501,6	0,813	1,20	505
250	475,5	0,678	1,00	540	501,6	0,789	1,16	520
0,1	526,8	1,750	8,13	76	551,6	1,802	8,34	82
10	526,7	1,642	7,66	81	551,5	1,698	7,91	86
30	526,4	1,198	5,37	115	551,2	1,281	6,07	114
50	526,1	0,769	3,94	165	550,9	0,885	4.69	158
70	525,9	0,530	2,80	240	550,7	0,635	3,43	218
90	526,7	1,630	2,30	302	551,5	1,670	2,69	276
110	526,6	1,444	2,00	340	551,3	1,466	2,30	320
130	526,5	1,324	1,82	375	551,2	1,329	2,10	355
150	526,4	1,234	1,60	405	551,1	1,240	1,90	380
170	526,4	1,176	1,54	428	551,1	1,165	1,80	404
190	526,4	1,119	1,49	450	551,0	1,119	1,63	428
210	526,3	1,076	1,40	467	551,0	1,074	1,57	448
230	526,3	1,037	1,32	488	551,0	1,028	1,51	468
250	526,3	1,006	1,30	508	550,9	0,990	1,48	486
0,1	577,3	1,765	8,68	85	601,8	1,596	9,04	89
10	577,3	1,685	8,36	89	601,8	1,527	8,68	93
30	577,0	1,282	6,95	112	601,5	1,214	7,48	110
50	576,7	0,962	5,32	146	601,3	0,959	5,83	142
70	576,5	0,714	3,98	204	601,1	0,710	4,62	190
90	576,4	0,562	3,23	256	601,1	0,557	3,55	245
110	576,4	1,785	2,64	302	601,8	1,620	2,90	283
130	577,2	1,619	2,50	335	601,7	1,462	2,70	315
150	577,1	1,501	2,26	361	601,6	1,350	2,50	344
170	577,1	1,410	2,08	385	601,6	1,265	2,37	370
190	577,0	1,342	2,00	407	601,5	1,201	2,22	388
210	577,0	1,289	1,85	430	601,5	1,146	2,12	408
230	576,9	1,238	1,77	450	601,4	1,099	2,00	430
250	576,9	1,195	1,61	470	601,4	1,065	1,95	451

The emissivity of the radiating surface was taken as 0.32, which was confirmed by control experiments performed at a pressure of 0.1 mPa. The results of those experiments agree well with the data of [6].

The radiation correction comprised up to 9%.

The experimental results were used to construct curves of thermal conductivity as a function of temperature for various pressure values (Fig. 1).

Table 1 presents the experimental data on thermal conductivity of heavy-water vapor.

The accuracy of the experimental data is estimated to be 2.22%.

Comparison of the present data with the measurements of [1-3] shows good (within 1-3%) agreement.

The thermal-conductivity values obtained demonstrate that thermal conductivity always increases with increase in pressure.

NOTATION

t, mean vapor temperature; Δt, temperature difference across a vapor layer; Q_{rad}/Q, correction for radiative heat transfer, %; λ, thermal-conductivity coefficient with consideration of all corrections.

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