MEASUREMENT OF THE THERMAL CONDUCTIVITY OF WATER VAPOR AT 375-600°C AND PRESSURES UP TO 250 mPa

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UDC 536.23

Results are presented on the thermal conductivity of water vapor measured by the planar-layer method for the range 375-600°C and pressures of 0.1-250 mPa. Results are also given on the thermal conductivity of water vapor above 147.1 mPa.

In 1964, the International Skeletal Table for the thermal conductivity of water and water vapor was adopted (IST-1964). This table covers pressures up to 50 mPa.

Development prospects in thermal power engineering involve research on the thermophysical parameters of water and steam at high pressures and temperatures.

Researches have been published for the region above 50 mPa; nonstationary thermal conditions have been used [1] to examine water vapor up to 660°C and 147.1 mPa. Also, the planar-layer method has been used [2] to examine the region 20-100 mPa at 350-450°C. A table of smoothed values has been published [3] for the thermal conductivity of water and steam, which are derived from monotonic heating at 10-100 mPa and 350-700°C. Coaxial cylinders have also been used [4] to examine the thermal conductivity of steam at pressures up to 100 mPa. Vargaftik et al. [5, 6] have examined steam up to 900°C. A heated filament was used in that case. The planar-layer has been chosen [7] to examine the thermal conductivity of water in the critical region, and results were reported for the range 20-30 mPa and 208-406°C.

We have used a planar horizontal layer to examine the thermal conductivity of water vapor up to 250 mPa.

The temperature difference across the layer was comparatively small (0.4-1.6°C).

The experiments were performed with a gap thickness 0.301 mm.

A check was made for the absence of convection by performing measurements with several different temperature differences.

The result obtained for the thermal conductivity of a semitransparent medium is dependent on the method of correcting for the radiative heat transfer. No data have been published on the absorption coefficient of water vapor at high pressures. The radiation correction was therefore performed as for a transparent medium, namely, via Stefan's formula.

The blackness of the radiating surface was taken as 0.32, which was verified in measurements on the thermal conductivity of nitrogen, and also with water vapor at 0.1 mPa. The radiation correction was 10% at low pressures, whereas it did not exceed 4.5% above 50 mPa.

A check was made for systematic errors by using the equipment to measure the thermal conductivities of air, ethanol (96%), and water at room temperature and atmospheric pressure. We also measured the thermal conductivity of nitrogen on the 75°C isotherm at pressures up to 100 mPa. Good agreement with published data [9] was obtained.

Allowance was made for the errors quoted in [8] in calculating the thermal conductivity, in addition to the errors in temperature correction at constant pressure and in pressure correction at constant temperature.

Dagestan Branch of the Institute of Physics, Academy of Sciences of the USSR, Makhachkala. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 34, No. 2, pp. 217-220, February, 1978. Original article submitted July 20, 1976.

TABLE 1. Measured Thermal Conductivities for Water Vapor (W/ m·°K)

P, mPa	t, °C	Δt, °C	Q_{rad}/Q, %	λ·10³	t, °C	Δt, °C	Q_{rad}/Q, %	λ·10³
0,1	375,8	0,520	6,68	52	401,5	0,704	7,03	55
10	375,7	0,400	5,20	65	401,4	0,569	5,85	67
50	375,7	0,457	0,74	488	401,5	0,680	0,96	444
70	375,8	0,583	0,66	535	401,5	0,670	0,82	498
90	375,8	0,544	0,62	575	401,5	0,608	0,76	530
110	375,8	0,516	0,58	600	401,4	0,567	0,71	562
130	375,8	0,494	0,57	624	401,9	1,168	0,68	590
150	375,8	0,480	0,56	643	401,9	1,127	0,65	616
170	375,8	0,466	0,53	663	401,8	1,092	0,64	634
190	376,1	0,894	0,53	678	401,8	1,068	0,62	650
210	376,1	0,881	0,51	693	401,8	1,043	0,60	665
230	376,1	0,857	0,50	708	401,8	1,019	0,58	684
250	376,0	0,845	0,49	725	401,7	0,999	0,57	698
0,1	426,0	0,825	7,59	58	452,2	1,450	7,95	61
10	425,9	0,672	6,25	67	452,0	1,235	6,88	68
50	425,9	0,720	1,30	380	451,6	0,723	1,68	320
70	425,9	0,603	0,96	450	451,5	0,561	1,29	406
90	425,8	0,543	0,90	500	451,5	0,496	1,12	460
110	425,8	0,502	0,85	540	452,0	1,250	1,04	504
130	425,8	0,473	0,79	558	452,0	1,173	0,95	538
150	425,7	0,451	0,76	588	451,9	1,118	0,90	550
170	426,3	1,158	0,75	603	451,9	1,064	0,86	571
190	426,2	1,123	0,72	620	451,9	1,032	0,84	595
210	426,2	1,092	0,70	637	451,9	0,996	0,82	615
230	426,2	1,061	0,69	655	451,8	0,970	0,79	632
250	426,2	1,033	0,66	672	451,8	0,948	0,76	650
0,1	476,4	0,818	8,47	64	501,4	1,110	8,72	67
10	476,3	0,681	7,13	72	501,3	0,959	7,64	74
30	476,1	0,395	4,32	119	501,1	0,592	4,82	115
50	476,3	0,724	2,35	260	501,4	1,028	3,06	208
70	476,2	0,510	1,63	355	501,1	0,694	2,02	318
90	476,7	1,149	1,38	420	501,0	0,578	1,66	380
110	476,6	1,037	1,22	470	501,5	1,182	1,40	433
130	476,5	0,966	1,14	500	501,4	1,078	1,33	470
150	476,5	0,909	1,08	515	501,4	1,012	1,24	484
170	476,4	0,861	1,00	542	501,3	0,954	1,18	510
190	476,4	0,825	0,98	566	501,3	0,907	1,12	536
210	476,4	0,796	0,94	588	501,2	0,870	1,07	560
230	476,3	0,773	0,90	605	501,2	0,835	1,02	580
250	476,3	0,754	0,88	628	501,2	0,808	0,99	600
0,1	527,4	1,574	9,01	68	551,9	1,486	9,33	72
10	527,2	1,372	7,94	78	551,7	1,305	8,29	82
30	526,9	0,907	5,42	112	551,4	0,892	5,90	111
50	526,6	0,563	3,60	181	551,2	0,608	4,14	170
70	527,5	1,699	2,53	263	551,5	0,997	3,00	252
90	527,2	1,374	2,00	336	551,3	0,790	2,32	308
110	527,1	1,212	1,77	378	551,3	0,681	2,03	340
130	527,0	1,108	1,59	418	551,2	0,615	1,88	398
150	527,0	1,026	1,46	454	551,2	0,573	1,70	428
170	526,9	0,966	1,38	478	551,1	0,536	1,58	456
190	526,9	0,911	1,29	510	551,8	1,373	1,48	483
210	526,9	0,878	1,23	536	551,7	1,314	1,40	510
230	526,8	0,839	1,20	557	551,7	1,254	1,31	536
250	526,8	0,807	1,15	583	551,7	1,203	1,29	558
0,1	576,5	1,695	9,62	76	602,1	1,398	9,96	80
10	576,7	1,518	8,70	85	602,0	1,273	9,10	88
30	576,4	1,075	6,61	116	601,7	0,933	7,06	114
50	576,2	0,768	4,76	160	601,5	0,700	5,44	151
70	576,1	0,556	3,58	220	601,4	0,509	4,10	206
90	576,9	1,692	2,77	280	602,0	1,314	3,25	264
110	576,7	1,428	2,38	330	601,9	1,132	2,80	306
130	576,6	1,284	2,13	370	601,8	1,008	2,46	347
150	576,5	1,183	1,96	405	601,7	0,929	2,28	379
170	576,4	1,104	1,86	430	601,7	0,864	2,12	408
190	575,4	1,046	1,74	458	601,6	0,812	1,97	438
210	576,4	0,994	1,69	485	601,6	0,767	1,86	466
230	576,3	0,947	1,55	511	601,6	0,729	1,77	490
250	576,3	0,905	1,47	536	601,5	0,701	1,68	515

Table 1 gives the results on the thermal conductivity of water vapor (Fig. 1).

The precision of the experimental results is estimated to be 2.22%.

These values show that the thermal conductivity increases with pressure throughout the range used.

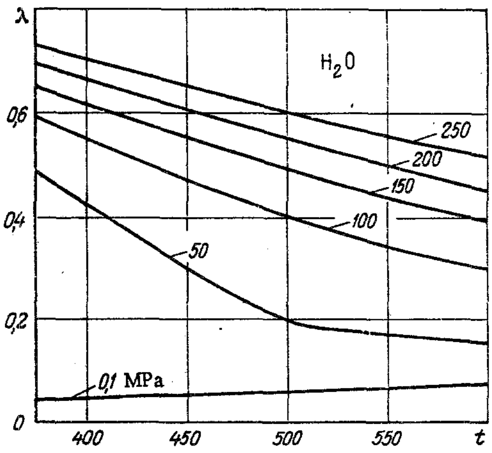

Fig. 1. Thermal conductivity of water vapor (isobars); λ in W/m · °K, t in °C.

The results agree well with IST-1964; there is also agreement within 1-3% with the data of [4]. The results of [1-3] are much lower for pressures above 50 mPa.

NOTATION

t	is the mean vapor temperature;
Δt	is the temperature difference across vapor layer;
Q_{rad}/Q	is the correction for radiant heat transfer, %;
λ	is the corrected thermal conductivity.

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