EXPERIMENTAL DETERMINATION OF OXYGEN THERMAL CONDUCTIVITY IN THE GASEOUS PHASE (300-1000°K)

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UDC 536.23

Experimental values of oxygen thermal conductivity are presented for the temperature interval 300-1000°K at a pressure of $\sim 10^5$ Pa.

A number of studies of oxygen thermal conductivity has been published. The low temperature range has been studied in greatest detail. At higher temperatures the results of Schafer, Westenberg, and Saxena are available [1-3], with Saxena's values being somewhat lower than that of the others. Together with the experimental studies there have appeared theoretical studies on determination of oxygen thermal conductivity over a wide temperature range [4]. Sufficiently accurate data on oxygen viscosity [4] up to 2000°K have allowed use of a refined theory of thermal conductivity of multiatomic gases to calculate the Aiken factor and thermal conductivity up to the same temperatures to which viscosity has been determined. Thermal conductivity calculations by the Meison–Monchik method using the Aiken correction factor were performed by Saxena [3] and Lyusternik et al. [4]. The divergence between their results comprises more than 10%. Since the experimental data available as well as the theoretical do not agree sufficiently well, it is of interest to perform additional experiments to measure oxygen thermal conductivity.

Production of new experimental data is also desirable for the purpose of further generalizing all available results on oxygen thermal conductivity, both experimental and theoretical.

The present study will investigate the thermal conductivity of oxygen in the gaseous phase at temperatures of 300-1000°K at a pressure of $\sim 10^5$ Pa. The experiments were performed with equipment using the hot filament method. The working portion of the hot filament was located in a homogeneous temperature field. The quartz shell in which the measurement cell was located was joined to a molybdenum glass reservoir through a special transition fitting. The upper portion of the device (reservoir with eight electrical leads) was connected to a vacuum system.

The oxygen studied was 99.9% pure. Gas was admitted from its container into the apparatus through a special valve, in which a vacuum was first created. The temperature in the thermostatic chamber was monitored by three platinum–platinum/rhodium thermocouples. A detailed description of the experimental equipment was presented in [5].

The thermal conductivity of the test material was determined from the well-known expression

$$\lambda = \frac{\ln \frac{D}{d}}{2\pi l} \frac{Q}{\Delta t_g}. \qquad (1)$$

The length of the measurement section l = 162 mm, heater diameter d = 0.1 mm.

In the measurement process corrections were made for: 1) radiation from the heater; 2) heat loss to the ends of the heater; 3) temperature differential across the measurement cell wall; 4) temperature changes. Gas pressure was determined by a reference manovacuummeter.

Corrections for end effects were introduced by the generally used technique of [6]. To decrease the size of this correction the circuit for measuring the potential difference across the working portion of the heated filament used 0.05-mm leads. The correction was then 1.1%. The uncertainty introduced into the λ calculation by this correction was 0.11%.

Sergo Ordzhonikidze Aviation Institute, Moscow. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 49, No. 1, pp. 94-97, July, 1985. Original article submitted June 4, 1984.

 0022-0841/85/4901-0828 $09.50

TABLE 1. Experimental Data on Thermal Conductivity of Gaseous Oxygen

T, K	λ·10⁴, W/m·K	T, K	λ·10⁴, W/m·K	T, K	λ·10⁴, W/m·K
302,6	268	573,7	456	890,0	652
328,5	288	586,4	464	917,1	668
351,8	303	588,2	466	924,1	676
370,6	318	639,2	496	938,7	682
407,9	344	695,0	534	950,2	690
458,6	389	736,9	561		
524,7	425	829,1	614		

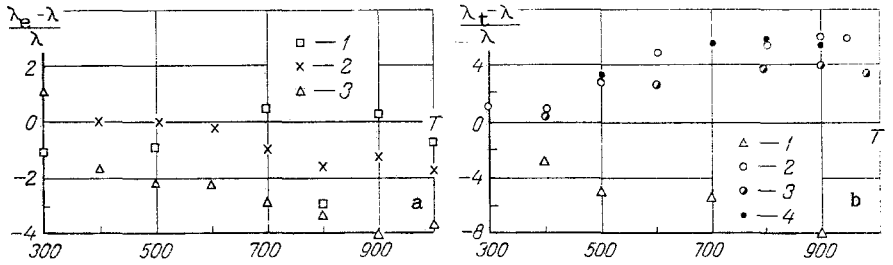

Fig. 1. Comparison of experimental λ_e (a) and calculated λ_t (b) data with results of present study: a) 1, (1); 2, (2); 3, (3); b) 1, (3); 2, (4); 3, (10); 4, (11). λ_e, λ_t, %; T, K.

The quantity of heat transferred by radiation was calculated with the Stefan–Boltzmann formula. The correction for radiation was 5%. The temperature differential across the wall of the quartz tube was in the range 0.01–0.1°K, or 0.08%. To determine the correction for temperature change experiments were performed at various gas pressures in the range (0.15–1.0)· 10^5 Pa. Using the function $\Delta T = f(P)$ the temperature change correction was calculated. At the highest experimental temperature (T ∿950°K) this correction to the measured λ value at a pressure of 10^5 Pa comprised 1%. At lower temperatures the effect of this correction decreases. The total uncertainty in λ determination was ∿2%.

The experimental results are shown in Table 1 and Fig. 1. It is evident from the graphs that there is a scattering among the experimental results of from 1% at 300°K to 4% at 1000°K.

The data of Westenberg [2], beginning at 700°K, lie 2% below the present results. Schafer's data [1] are close to those of Westenberg [2].

Jain and Saxena [3] studied the temperature range 400–1600°K using a thermodiffusion column with a relatively thick platinum heater wire 0.5 mm in diameter. It follows from Fig. 1 that Saxena's data are systematically lower than those of other experiments from 400 to 1000°K by 2–4%.

Using precise oxygen viscosity data Lyusternik et al. [4] calculated the thermal conductivity of oxygen with the Aiken correction using the Meison–Monchik method. The new viscosity data used agree within 0.65% with all known results on oxygen viscosity (Kestin, Clifford, Johnston, Metius) [4, 7, 8]. The quantity Z_c in the Meison–Monchik expression was taken from Parker's study [9]. It is evident from Fig. 1 that the calculated λ data lie above the present results from 500 to 950°K by from 2 to 6%.

Calculated data on oxygen thermal conductivity using Meison–Monchik theory were also obtained in [3]. These values are low relative to experiment. The calculated values in Saxena's study were taken from a graph, but were quite well defined (to an uncertainty of ∿1%). Saxena's calculated data lie from 3 to 8% below the present experimental data.

We also calculated oxygen thermal conductivity using the viscosity data of [4] and results for the coefficient f (Aiken factor) from Zhdanov [10]. Values of f in that study were obtained from experimental data on sound absorption in oxygen at temperature of 300–1200°K. The calculated data lie above our experimental results. The deviations from experimental data in this case are less than for the calculated results of [4], lying in the range 1–3.5%. This is within the limits of experimental and calculation uncertainty.

Thus, it has been shown that Saxena's data, both experimental and calculated, are significantly low in value. The data of [1, 2] agree with the experimental results of the present study within the limits of experimental uncertainty. Calculated values of λ using the viscosity data of [4] and the Aiken correction used in [4] and [10], as well as the results of [11] deviate from the experimental data by an average of 1-5% at T = 300-950°K. It would be of interest to perform an experimental study of oxygen λ at higher temperatures (to T $\sim$2000°K).

NOTATION

Q, heat flux from platinum heater wire; Δt_g, temperature difference in gas layer; D, tube outer diameter; l, length of measurement section; d, heater diameter.

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