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## Abstract

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# BRIGHTNESS TEMPERATURE OF SHOCK WAVES IN XENON AND AIR

*(Presented by Academician Ya. B. Zel̓ dovich on 1 XI 1965)*

In observations of the glow of strong shock waves in gases it was found that the brightness temperature of the wave front is substantially lower than the calculated values. Thus, in a paper by one of the authors (⁀1), the temperatures of argon, krypton, and xenon measured photographically in a shock wave at a front velocity of 17 km/sec proved to be 2-3 times lower than the calculated ones. The explanation of this phenomenon, developed in the works of Ya. B. Zel' dovich and Yu. P. Raizer ([2-]6), consists in the screening of the glow by a layer of gas located ahead of the shock-wave front: the radiation flux emerging from the front, being absorbed in the gas layer adjacent to the front, heats it and makes it opaque.

Fig. 1
**Fig. 1.**

Fig. 2
**Fig. 2.**

**Fig. 1.** Dependence of the brightness temperature of the surface of the shock-wave front in air on the true temperature behind the front (for red light) ([5,]6)

**Fig. 2.** Diagram of the experiment for measuring the velocity and temperature of the shock-wave front in a gas (without observing the scale). 1 –charge of explosive substance with a flat detonation-wave front; 2 –plate (aluminum, 1.5 mm thick); 3 –chamber (spherical segment); 4 –diaphragm (mica, 15 $\mu$ thick); 5 –glass tube; 6 –reference marks; 7 –window (glass, 2 mm thick); 8 –mirror; 9 –SFR photorecorder (conventionally rotated by 90°); 10 –neutral light filter; 11 –red light filter

It follows from theoretical consideration that, as the amplitude of the wave increases, the increase of the brightness temperature, measured in the region of the spectrum in which the gas is transparent, lags behind the true temperature behind the front. After a certain amplitude is reached, the brightness

Fig. 3

Figure 1: Fig. 3

temperature decreases to a certain limiting value, and a further increase in the amplitude of the shock wave does not lead to a noticeable change in the brightness temperature. The form of the dependence of the brightness temperature of the shock-wave front in air on the true temperature behind the front, obtained from theoretical estimates ([5,6]), is shown in Fig. 1. It should be noted

**Fig. 3.** Streak photograph of the experiment

It may be assumed that for other gases as well the qualitative character of the dependence should have a similar form.

The aim of the present work is the experimental determination of the dependence of the brightness temperature on the wave amplitude. Xenon was chosen as one of the working gases, since behind the shock front in heavy inert gases, at the same wave velocity, a higher temperature is reached; and air was chosen because it is possible to compare the results obtained with theoretical estimates. To measure the temperature and velocity of the shock wave, a technique analogous to that described in (1) was used. The experimental arrangement is shown in Fig. 2. A large-amplitude shock wave was produced by means of a device developed by one of the authors (7). The plate 2, accelerated by the explosion products of charge 1, compresses the gas (hydrogen, $P_0 = 760$ mm Hg) contained in hemispherical chamber 3; this gas ruptures diaphragm 4 and excites, in the working gas filling tube 5, a strong shock wave. Different initial shock-wave velocities were achieved by changing the radius of curvature of chamber 3. The maximum shock-wave velocity is 37 km/sec when the tube is filled with xenon and 43 km/sec when filled with air ($P_0 = 760$ mm).

Registration was carried out with a slit photochronograph 9 of the SFR type (8), through a red KS-14 light filter, on Izopanchrom 180-unit GOST photographic film. In the field of view of the instrument were tube 5 and mirror 8, by means of which the luminosity of the front was observed through window 7. The axis of rotation of the mirror of the photochronograph was arranged parallel to the tube. A typical streak photograph of the process of shock-wave propagation is given in Fig. 3. The velocity of motion of the front at different instants of time was determined from the slope of curve $a$, which represents a time sweep of the propagation of the shock wave along the tube, and the temperature from the density of blackening of the photographic film at the corresponding points of band $b$, by comparison with the blackening of the photographic film from a standard source with known brightness temperature. As the standard source, a xenon lamp IFK-50 (9) was used, whose brightness temperature

**Fig. 4.** Dependence of temperature on shock-wave velocity in xenon and air ($P_0 = 760$ mm Hg): 1—temperature behind the front in xenon (theoretical); 2—brightness temperature of the front surface in xenon (experimental); 3—tem-

Fig. 4

Figure 2: Fig. 4

perature behind the front in air (theoretical); 4—brightness temperature of the front surface in air (experimental)

···in the spectral interval used ($\lambda_{\text{eff}} = 650$ mμ) was $6300 \pm 200^\circ$ K ([10]).

The measurement results are presented in Fig. 4. The temperature values behind the shock-wave front are also given there. The temperature in xenon was calculated from the equations of gas dynamics with allowance for ionization and radiation ([1]); the values for air were taken from the work of V. V. Selivanov and I. Ya. Shlyapintokh ([11]). Each experimental point in Fig. 4 is the arithmetic mean of four experiments. The root-mean-square error of the temperature measurement result is approximately ±15%.

For xenon it was possible to trace the transition of the brightness temperature through a maximum $T_{\max} \simeq 50\,000^\circ$ K at $D = 48$ km/sec* and a decrease to the temperature $T_{\text{pred}} \simeq 23\,000^\circ$ K with a further increase in the wave amplitude. The maximum brightness temperature of an air shock wave, $T_{\max} \simeq 72\,000^\circ$ K, recorded in our experiments, corresponds to a velocity $D = 43$ km/sec. Unfortunately, the devices used to create shock waves do not make it possible to obtain a higher velocity. Only in one of the experiments, which could not be reproduced, was a velocity of 55 km/sec attained. The brightness temperature corresponding to this velocity, approximately $25\,000^\circ$ K, agrees satisfactorily with the calculated estimate of Yu. P. Raizer.

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* The discrepancies between the temperature values at velocity $D = 48$ km/sec in the present work and in article ([1]) are explained by the use of windows made of different materials. As was found, the previously used windows made of organic glass lose transparency under the action of radiation emerging from the front, which leads to an underestimated measured temperature.

*Note: Figure translations are in progress. See original paper for figures.*