DETERMINATION OF THE RATIO OF SPECIFIC HEATS OF DRY AIR.

E. K. CHAPMAN.

The following method for determining the ratio of specific heats was suggested by some work in connection with an experiment in a fog chamber. It became necessary to know the temperature in a fog chamber on sudden expansion and consequent condensation of vapor. In order to measure this temperature a thermo-couple of Cu and Fe was introduced, and the deflection of a galvanometer connected in series with the couple was noted on the expansion of the saturated vapor. The couple was then graduated by keeping one junction at a constant temperature and noting the deflection of the galvanometer for a given change in temperature of the other junction. Knowing, then, the constant of the apparatus, the temperature in the fog chamber was easily determined.

The attempt was then made to use this method for finding the temperature in a chamber of air on sudden expansion, and thus determine the ratio of the specific heats.

To the stopper of a glass carboy was fitted a large valve that could readily be opened or closed by hand. One junction of the thermo-couple was introduced into the carboy through a rubber stopper fitted in a hole drilled in the side. The inner ends of the bent tube carrying the couple were then separated by twisting the tubes in the rubber stopper. The other junction was encased in a small glass bulb just outside the bottle and this kept at a temperature of the surrounding medium. Later in the work the entire apparatus, excepting the valve, was immersed in a bath which could be maintained at a constant temperature. Dry air was then pumped into the bottle and the whole was allowed to stand until it had regained the temperature of the surroundings. On opening the valve the temperature falls, due to the adiabatic expansion, and the galvanometer is deflected because of the difference in temperature of the two junctions of the couple. From this deflection it was hoped that the lowest temperature in the chamber might be calculated. A great deal of difficulty was experienced in trying to calibrate the couple, since the deflections due to a given difference in temperature varied considerably, and the degrees of accuracy desired

[19-26988]

necessitated a more consistent calibration. After repeated efforts to obtain a constant deflection for a given difference in temperature the method was abandoned as not being sufficiently accurate.

The following scheme was then adopted :



A battery of known E. M. F. was connected in series with two resistances, R_2 , which was approximately 100,000 ohms, and in later experiments kept constant, and R_1 was varied from one to eight ohms to suit the conditions of the particular observation. B is a carboy in the center of which one junction of the couple was located. A is a second junction which was kept at a constant temperature. G is a galvanometer in series with the couple and R_1 . The air in B was compressed as before and allowed to cool to the temperature of the bath. K_1 was then closed, then the valve was opened to the atmosphere and immediately K_2 was closed and the direction of the deflection of the galvanometer noted. This process was repeated, varying R_1 until a resistance was found such that on closing K_2 there was no deflection of the galvanometer, until the air began to warm after the adiabatic expansion. This balanced condition meant that the P. D. across R_1 just balanced that due to the difference in temperature of the two junctions of the thermo-couple.

In practice it was found better to set R_1 at a given place, e. g., 5 ohms, and then vary the original pressure until a balance was obtained. In some of the earlier observations R_2 was varied to secure a balance, but since it was not known to a sufficient degree of accuracy, the other method was used. It then remained to calibrate the thermo-couple. This was done by placing one junction, encased in a jacket, in a constant temperature bath, and the other, similarly encased, in a bath whose temperature was varied till a balance against a given resistance, R_1 , was obtained. The difference in temperature of the two junctions was then noted. R_1 was again varied and the temperature of the bath changed until another balance was found. In this way a number of balances were obtained for different values of R₄. By plotting R₄ against the difference in temperature of the two junctions a curve was obtained which gave the temperature for any resistance. The calibration was made with a number of different couples and the results were entirely consistent, no point being off the straight line thus found more than 1-20 of a degree centigrade.

The pressure in the bottle was measured by means of an oil manometer: as considerable time was consumed by the oil coming to a steady state, it was deemed desirable to place a stopcock between the manometer and the bottle, and after the pressure was determined cut off the manometer before expansion. The pressure for the following trial was adjusted approximately by an auxiliary mercurial manometer and the final adjustment was made with oil. The use of the oil manometer was necessary, as the errors introduced in the reading of the mercurial manometer were of a higher degree of magnitude than was permissible.

The delicacy of the apparatus was indicated by the fact that the observer could readily detect a difference in pressure of 2 mm. of oil, density .84.

The value of γ was determined as follows:—

From the adiabatic law, P V γ = a constant From the law of Charles, PV = RT

or
$$P_1V_1\gamma = P_2V_2\gamma$$

then $\left(\frac{V_2}{V_1}\right)^{\gamma} = \frac{P_1}{P_2}$
but $P_1V_1 = RT_1$
and $P_2V_2 = RT_2$
 $\frac{V_2}{V_1} = \frac{P_1}{P_2} \frac{T_2}{T_1}$
 $\left(\frac{V_2}{V_1}\right)^{\gamma} = \left(\frac{P_1}{P_2} - \frac{T_2}{T_1}\right)^{\gamma} = \frac{P_1}{P_2}$
therefore $\gamma = \frac{\log \frac{P_1}{P_2}}{\log \frac{P_1}{P_2} - \log \frac{T_1}{T_2}}$

P ₂	θ	R ₁	R ₂	A	В	A—B	P ₁	θ2 -	γ
74.14	294	2.2	100100	94.6	25	69.6	78.44	289.4	1.3888
75.20 74 72	294.05	2.2	109500	95.9 89.5	30 -	59.5	79.70	289.35	1.3910
74.5	293.9	2.1	103800	89.7	30	59.7	78.19	289.81	1.4802
75.19	293.95	2.1	103800	90.9	29.2	61.7	79	289.71	1.4160
75.49	293.1	3.2	100300	145	46.4	98.6	81.58	286.6	1.4042
74.99	293.7	3.2	100500	145	47	98	81.04	287.47	1.3872
74.99	293.5	3.2	100500	144.7	46.3	98.4	81.07	287.1	1,3945
75.06	293.6	4.7	101200	169	22.1	146.9	84.14	284.3	1.3927
74.84	294.1	4.7	100700	170	21.8	148.2	84.00	284.51	1.4027
75.52	293.8	4	100000	158.1	33.6	124.5	83.21	286.2	1.3704
74.76		5		174.2	18.2	156.2	84.41	283.89	1.3938
74.76		4		159.0	33.5	124.5	82.45	285.81	1.3921
74.76	**	3	· · ·	142.0	50	92	80.44	287.81	1.3911
74.71	4.6	6	6.6	195	7	188	86,33	281.96	1.3974
74.71		6		195	7	188	86.33	281.88	1.4013
74.57	4.6	5		178.5	29.3	154.6	84.12	283.86	1.4001
74.57	4.6	4	4.6	162.1	40.3	121.8	82.09	285.84	1.3997
74.57		3	6.6	146.5	57.3	89.2	80.08	287.84	1.4040
74.57	" "	2		132.5	73.7	58.8	78.20	289.83	1.4005
74.44	293.82	1	£ £	118.2	88.8	29.8	76.25	291.83	1.3925
									1 0077

The following table gives the results of the experiment:

 P_2 is the reading of the barometer. θ_1 is the original temperature of the bath. A and B readings of the oil manometer. $P_1 = P_2 (A - B) d_1/d_2$ where $d_1 = density$ of oil and $d_2 = density$ of mercury. θ_2 is the temperature as given by the thermo-couple required to secure a balance.

 $\gamma =$ ratio of specific heats.

DISCUSSION OF RESULTS.

The limits of precision seem to, be the precision of the resistance, the precision of the temperature reading as read by a thermometer, the precision of the temperature readings used to calibrate the couple, the consistency of the E. M. F. of the battery and the density of oil.

The precision of the resistance was none too good. The last ten observations were made with the best box available and R₂ kept constant so that errors due to R_2 were obviated. The maximum variation of the mean of these observations is less than $\frac{1}{2}$ per cent. and shows remarkable constancy.

A new storage battery "duro," made by the Chicago Battery Co., was used and showed no variations in E. M. F. during the entire time.

The density of the oil was determined by a specific gravity bottle and found to be .8370.

The temperatures were read on a standard thermometer graduated to 1-10 degree.

As to the question of the accuracy of the thermo-couple in registering the instantaneous temperature we have to consider the couple itself, its behavior under known conditions, and the results obtained.

The couple was of Fe-Cu, one millimeter in diameter, so its heat capacity was very small. In calibrating it a deflection was regularly noted when the change of temperature of the bath was less than 1-100 of a degree. It was found that for small changes in temperature considerable time, several seconds, elapsed before there was any heating due to radiation, etc. This was due largely to the size of the vessel. Using a smaller one the time required to warm up was small.

The experiment is now being repeated under vastly better conditions. The temperature of the bath is regulated by an electric thermostat, the resistances, barometer and thermometer, have been checked up by the Bureau of Standards at Washington and the voltage of the "duro" cell tested immediately before and after each observation, by means of a potentiometer of the Leeds Northrup type and a standard Weston cell. The results from the new determination will be published later.

Wabash College,

Crawfordsville, Ind.