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CALIBRATION OF THE HOPKINS BLASTMETER

BY

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CALIBRATION OF THE HOPKINS BLASTMETER

Abstract

This report gives the results of calibration measurements made on the Hopkins Blastmeter and also a brief discussion of the accuracy of these measurements.

Mr. Kent, in Ballistic Research Laboratory Report No. 176, has developed the theory of the Hopkins Blastmeter. Under his direction the same instrument has been calibrated.

The theory gives us

$$(1a) \qquad I = \frac{\left(K + \gamma\, p_o \frac{A^2}{v_o}\right)}{-2\, A \frac{d\varphi}{dx}} \frac{J}{F} R\, \theta_{max} .$$

Here I is the impulse of the explosion and θ_{max} is the observed deflection in the ballistic galvanometer. The definition of the other constants and the procedures for measuring them are both given in the aforementioned report. This report gives the results of such measurements together with a brief discussion of their accuracy.

In (1a) "Θ_{max}" is in radians. As "d_{max}", the number of scale divisions, is more convenient to observe we shall write

$$(1b) \qquad I = \frac{(K + \gamma\, p_o \frac{A^2}{v_o})}{-2\, A \frac{d\varphi}{dx}} \cdot \frac{J}{F} R \cdot \frac{d_{max}}{L}$$

where "L" is the number of scale divisions per radian.

Two ballistic galvanometers were avilable. One is a Leeds and Northrup mirror-telescope type; the other is an aluminum pointer type designed by Dr. Hopkins. J, F, and L were determined for both galvanometers. In the L & N type it is easily seen that $L = 2\ell$ where ℓ is the scale distance is centimeters.

Under different conditions "R", the total circuit resistance will vary. Since the other quantities are constant, we shall write finally -

$$(1c) \qquad I = B\, R\, d_{max}$$

where

$$B = \frac{(K + \gamma\, p_o \frac{A^2}{v_o})}{-2A \frac{d\varphi}{dx}} \cdot \frac{J}{F}$$

The determined values of "B" are -

For L & N Galvanometer	For Hopkins Galvanometer
$B = 1.97 \frac{\text{dyne}}{\text{cm}^2}$ sec per ohm per div.	$B = 1600 \frac{\text{dyne}}{\text{cm}^2}$ sec per ohm per div.
$= 2.01 \times 10^{-3} \frac{\text{gm}}{\text{cm}^2}$ sec per ohm per div.	$= 1.63 \frac{\text{gm}}{\text{cm}^2}$ sec per ohm per div.
$= 2.86 \times 10^{-5} \frac{\text{lbs}}{\text{in}^2}$ sec per ohm per div.	$= 2.32 \times 10^{-2} \frac{\text{lbs}}{\text{in}^2}$ sec per ohm per div.
$= 1.95 \times 10^{-6}$ Atmos sec per ohm per div.	$= 1.58 \times 10^{-3}$ Atmos sec per ohm per di

It is seen that the L & N galvanometer would be about 800 times as sensitive as the Hopkins galvanometer if the circuit resistances were equal. For accurate readings, however, this resistance must be larger (see p. 18, BRL Report No. 176) when the L & N galvanometer is used and this, of course, reduces its comparative sensitivity. For instance, if 500 ohms are used in the L & N circuit, to obtain the same accuracy ($\frac{D}{J}$ Hopkins = $\frac{D}{J}$ L & N) with the Hopkins galvanometer, only 14.4 ohms need be used. Thus in this case, the L & N galvanometer is 23 times as sensitive as the Hopkins instrument.

Three sets of measurements were made, one on the blastmeter proper and one each on the two galvanometers.

I

The Measured Values of the Blastmeter Constants

"γ" is taken as 1.4

"p_o", the atmospheric pressure, is taken as 1033 $\frac{\text{gram}}{\text{cm}^2}$

$K = 1820 \text{ gm/cm}^2$

$A = 317 \text{ cm}^2$

$V_o = 484 \text{ cm}^3$

$\frac{d\varphi}{dx} = 1.61 \times 10^{-2} \frac{\text{volt sec}}{\text{cm}}$.

"A" and "V_o" should be accurate to within a few percent. Although "K" could not be determined very accurately (about 50% possible error) due to the friction present, this is not serious as the following will show.

$$\frac{\gamma\, p_o \frac{A^2}{v_o}}{K} \approx 165$$

That is to say, the restoring force due to the compressed air is over one hundred times as great as that due to the spring. If appreciable air leaks out, even in the short time in which the blast is acting upon the blastmeter,

$$\gamma\, p_o \frac{A^2}{v_o}$$

will not represent the compressed air component of the restoring force accurately. This may cause an appreciable error in the value for "B".

"$\frac{d\varphi}{dx}$" is assumed to be constant. The error in the measurement is around five percent.

II

The Measured Values of the L & N Galvanometer Constants

T_a = 5.46 seconds

R_c = 177 ohms

λ_a = .103

f = $.111 \times 10^6$ radians/amp.

F = 2.68×10^{-3} volt sec/radian

J = .182 gm cm^2

$\frac{J}{F}$ = 6.80×10^{-6} coulomb sec/radian

L = 100 scale divisions per radian

"T_a" and "L" are accurate to within one percent. The probable errors for "λ_a" and "f" are about two or three percent while that for R_c is somewhat larger.

"F" is determined by the formula

$$F = \frac{R_c\ T_g}{\pi\ f}\left(1 - \frac{\lambda_a}{\pi}\right)$$

"$\frac{J}{F}$" is determined by $\frac{J}{F} = \frac{T_g^{\ 2}}{4\pi^2 f}$.

"J" is the product of these two reduced to the proper units. "T_g" is assumed to be equal to T_a. This must be true since the air damping is small. Luckily, it is "$\frac{J}{F}$" that enters into "B" and it is more accurate than either "J" or "F" taken separately.

III

<u>The Measured Values of the Hopkins Galvanometer Constants</u>

L = 6.93 divisions per radian

T_a = 3.08 seconds

λ_a = .329

f = 4.36×10^3 divisions per amp. or (using L)

= $.629 \times 10^3$ radians per amp.

for r = 11 ohms

T_r = 3.10 sec.

λ_r = .775

F = 2.40×10^{-3} volt sec/radian

J = 9.17 gm cm^2

$\frac{J}{F}$ = 3.82×10^{-4} coulomb sec/radian

L, T_a, f, r, & T_r are accurate to within one percent. The error in λ_a and especially λ_r is larger.

F is calculated by

$$F = \frac{T_a(\lambda_r \frac{T_a}{T_r} - \lambda_a)\ r}{\pi^2\ f}$$

"J" and $\frac{"J"}{F}$ are calculated as above.

Again the very accurate $\frac{"J"}{F}$ alone enters into the determination of "B".

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ABSTRACT:
Calibration measurements were made on the Hopkins Blastmeter and a brief discussion is given of the accuracy of these measurements. This instrument is an aluminum pointer type galvanometer; a Leeds and Northrup mirror-telescope type of galvanometer was available for check. Three sets of measurements were made, one on the blastmeter proper and one each on the two galvanometers. The measured values of the constants are stated for each set of measurements.

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