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BALLISTIC RESEARCH LABORATORIES

REPORT NO. 734

August, 1950

RESPONSE OF AIR BLAST GAUGES OF VARIOUS SHAPES AS A FUNCTION OF PRESSURE LEVEL

Spence T. Marks

Project No. TB3-0112J of the Research
and Development Division, Ordnance Corps

ABERDEEN PROVING GROUND, MARYLAND

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⑭ BRL-734

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S. T. Marks/emj
Aberdeen Proving Ground, Md.

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ABSTRACT

The nonlinear pressure response of tourmaline air-blast gauges of various shapes has been investigated by comparing peak pressures recorded by the gauges, based upon the extrapolated values of the effective dynamic calibrations at zero peak pressure, with absolute pressures obtained from velocity measurements of shock-front propagation. A similar comparison has been made based upon the static calibrations. Small ~~"bare"~~ charges were employed in ~~"free air."~~

The principal errors involved have been calculated from theoretical considerations at peak pressures of 14 and ~~29 lb/in²~~, and the totals of these errors compared with the over-all errors actually recorded.

bare

free air

29 psig

INTRODUCTION

One of the specifications for an air-blast gauge is that its response should be as linear as possible over the range of peak pressures for which it is designed.

The shock tube provides a method for air-blast gauge calibration which essentially duplicates field conditions,[1] and tests run in shock tubes up to 5 inches in diameter have shown that a progressive reduction in the response of air-blast gauges occurs as peak pressures are increased from 3 to 15 lb/in^2. Moreover, discrepancies between static and shock tube calibrations have been observed,[2, 3] the latter being in reasonable agreement with the dynamic calibrations obtained in the field when large charges are employed.

This reduced response in the shock tube has been attributed to a "flow effect," that is, a reduction of the average hydrostatic pressure effective on the sensitive element of the gauge due to its finite size when mounted edge-on to the flow.[3] This is essentially a Bernoulli effect; consequently, it is believed that this error can be reduced by equipping air-blast gauges with baffles which are designed to reduce the perturbation of the flow behind the shock front to a minimum.

A "gauge-size error" is also introduced in field work,[4] being a function of the relationship between the diameter of the sensitive element of the gauge and the shock duration. The shock duration varies with the charge weight and with the distance from the charge. For a given shock duration, the smaller the diameter of the gauge element, the less the error. Unfortunately, sensitivity requirements make the use of small diameter tourmaline elements impractical at low peak pressure levels.

In addition, what may be termed "high frequency amplifier response error" is present in field work.[4] The magnitude of this error is a function of the frequency at which the response of the amplifier is down to 70 per cent of its midband response for the attenuator setting being

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[1] "Final Report on the Shock Tube," J. C. Fletcher, W. T. Read, R. G. Stoner, and D. K. Weimer, NDRC A-356, OSRD-6321, 1946.

[2] "Characteristics of Air Blast Gauges, II: Response as a Function of Pressure Level," C.W. Tait and W.D. Kennedy, NDRC, Div. 2, AES-11c, OSRD-5271c, 1945.

[3] "Characteristics of Air Blast Gauges: Response as a Function of Pressure Level," A. B. Arons, C. W. Tait, G. K. Fraenkel, and K. M. Doane, NDRC, Div. 2, AES-8a, OSRD-4876a, 1945.

[4] "Design and Use of Piezoelectric Gauges for Measuring Large Transient Pressures," A.B. Arons and R.H. Cole, Review of Scientific Instruments, Jan. 1950.

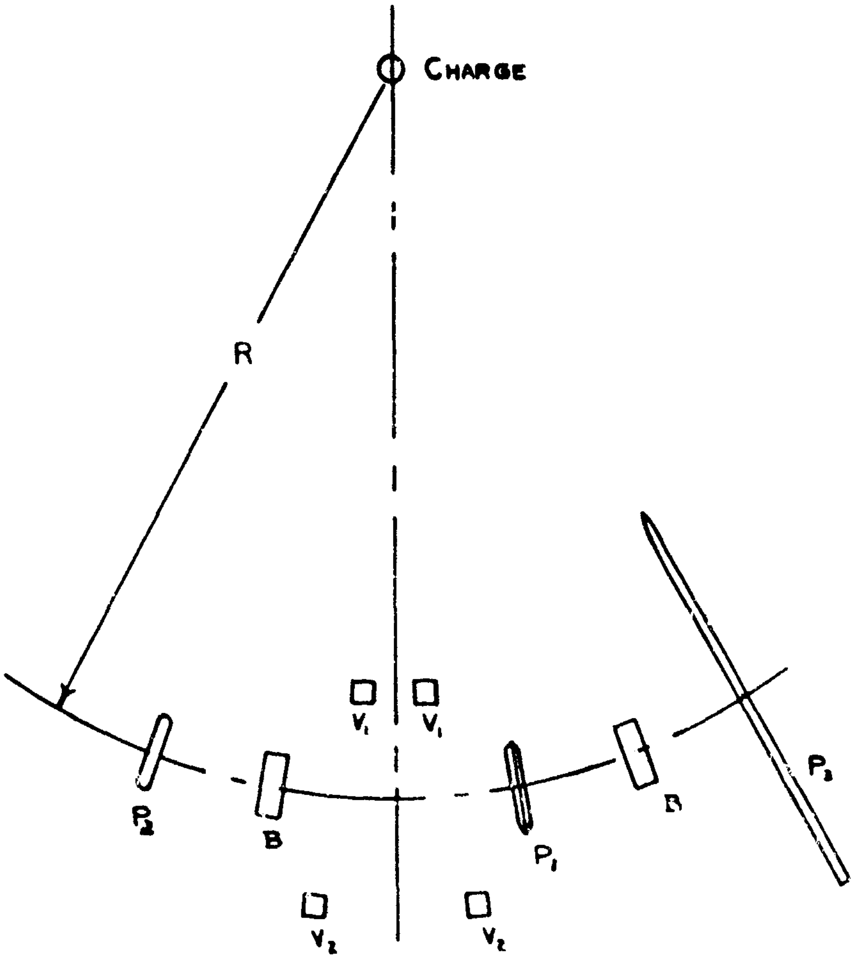

FIG. 1. EXPERIMENTAL TEST SETUP.

V_1, V_2: Velocity Gauges. B: BRL Gauges

P_1, P_2: Pancake Gauges. P_3: Pencil Gauge used, and the frequencies that are recorded by the gauge. Obviously, employing an amplifier whose response is linear to a very high frequency will reduce this error.

An effort was made to evaluate these errors by testing air-blast gauges in a 5-inch shock tube. However, equipping air-blast gauges with baffles increases their over-all dimensions to such an extent that their responses cannot be determined accurately in a shock tube of this size, since correction factors to compensate for the large diameters of the gauges are not available. Moreover, the peak pressures that can be covered with this shock tube is limited to the range from 3 to 15 lb/in^2.

It was therefore necessary to resort to field tests in order to obtain air-blast gauge response data needed in connection with the development of air-blast gauges that are relatively free from flow effects up to Mach 1 (peak pressure of 57 lb/in^2).

EXPERIMENTAL PROCEDURE

The experimental procedure consisted of firing one-eighth pound bare spherical pentolite charges at a series of predetermined distances from the group of air-blast gauges being tested, these distances having been selected from the Pressure Versus Scaled Distance graph so as to produce the desired series of peak pressures at the gauge positions (Figures 1 and 2). It was assumed that the shock waves produced were spherical at the gauge positions. A prerequisite for firing was that the resistances of the cables and gauges had to be 500 megohms or more.

The group of air-blast gauges being tested were equipped with a variety of baffles, two BRL gauges, two experimental pancake-shaped gauges, and an experimental pencil-shaped gauge having been included in the test setup (Figure 3).

Both the charge and the gauges were supported at a height of five feet above level ground, this elevation having been selected as being high enough to prevent ground reflections from affecting the recorded trace and at the same time low enough to permit necessary adjustments of the gauge positions. The distances from the charge to the gauge positions were measured with a steel scale to 0.01 inch, and in order to avoid additional calculations all blast gauges were made equally distant from the charge by adjusting their positions before each charge was fired.

Two pairs of Rochelle Salt velocity gauges were also included in the test setup, one gauge of each pair being placed one foot closer to the charge than the group of air-blast gauges while the other gauge of each pair was placed one foot farther away from the charge than the blast gauges.

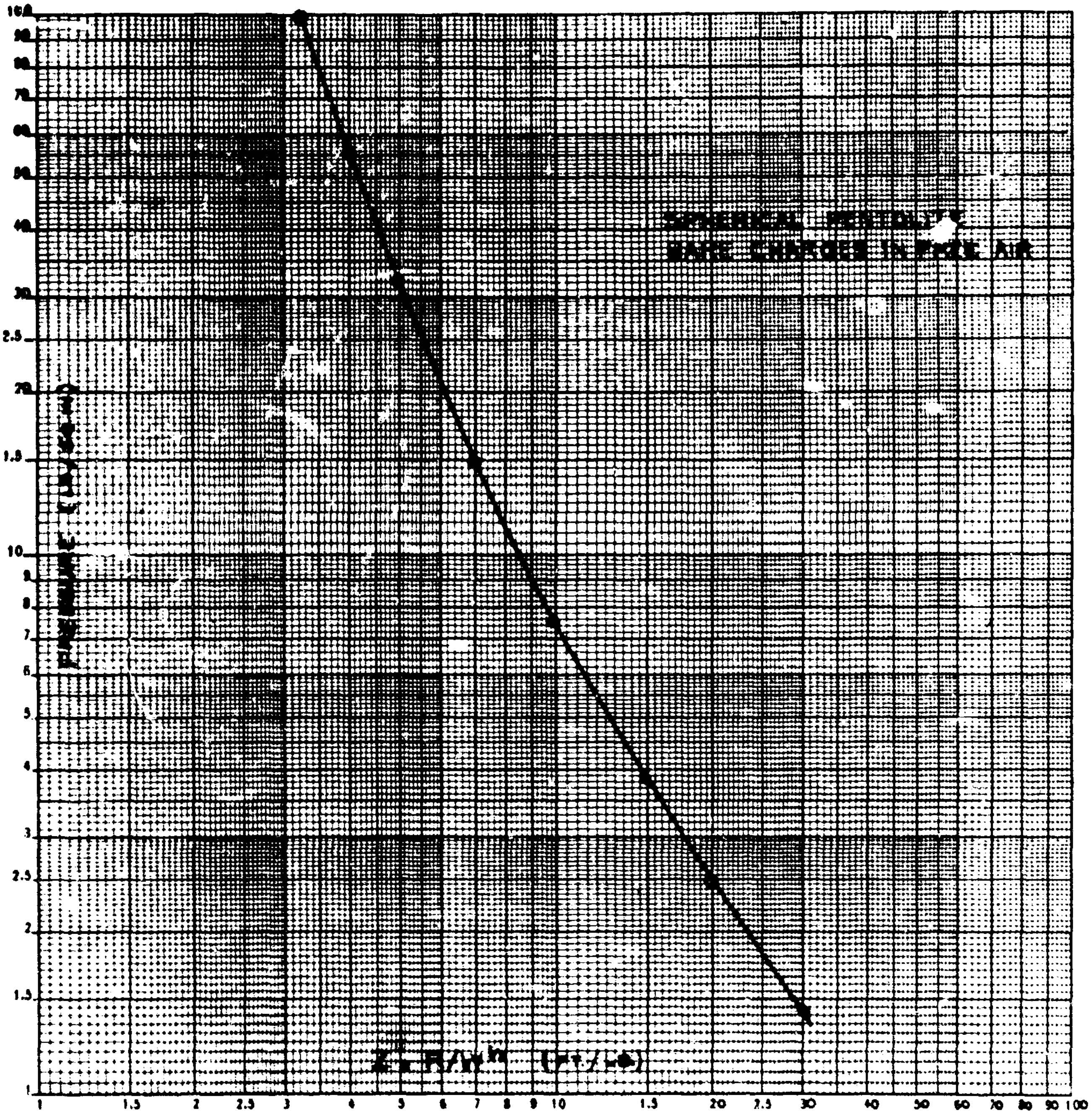

FIG. 2. PRESSURE VERSUS SCALED DISTANCE

R = DISTANCE FROM CHARGE W = WEIGHT OF CHARGE

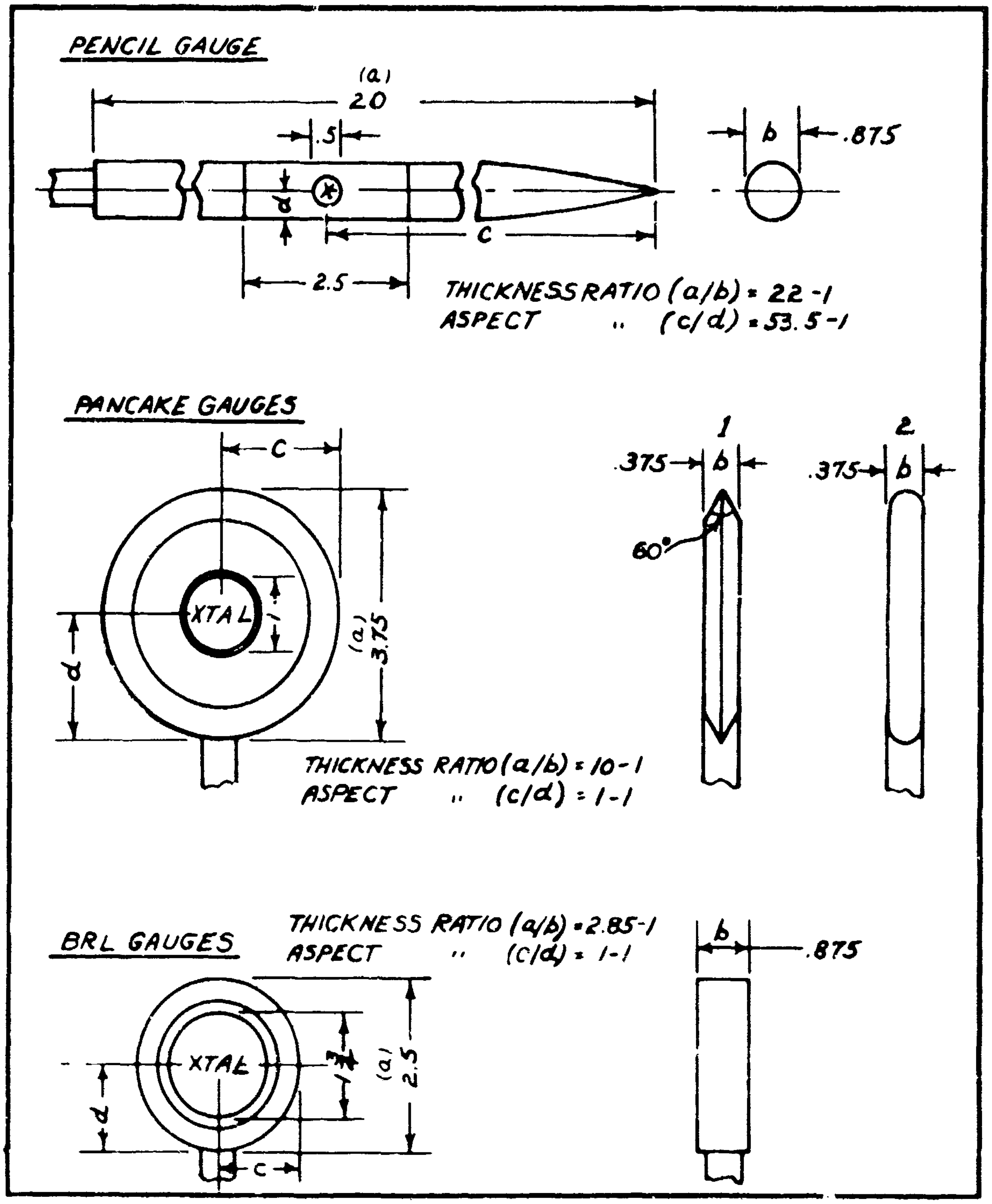
PENCIL GAUGE
(a)
20
.5
d
c
2.5
b
.875
THICKNESS RATIO (a/b) = 22-1
ASPECT " (c/d) = 53.5-1
PANCAKE GAUGES
C
XTAL
1
(a) 3.75
d
1
2
.375
b
60°
THICKNESS RATIO (a/b) = 10-1
ASPECT " (c/d) = 1-1
BRL GAUGES
THICKNESS RATIO (a/b) = 2.85-1
ASPECT " (c/d) = 1-1
XTAL
1 3/4
(a) 2.5
d
c
b
.875

FIG.3

The outputs of the group of air-blast gauges were fed into an oscilloscope bank and the deflections recorded on 35mm film moving at approximately 20 ft/sec. A series of calibration steps were also impressed upon this film before each charge was fired.

The arrival times of the shock-front at the velocity gauges were recorded simultaneously on 35mm film moving at 40 ft/sec in the form of pips on a 10 kc sawtooth trace supplied by a crystal controlled oscillator. A harmonic of the oscillator was checked against radio station WWV before each group of charges was fired and adjustments made, if necessary, to insure timing accuracy.

The atmospheric pressure was recorded with a calibrated and temperature compensated aneroid barometer located at the firing site and placed at the same height as the group of air-blast gauges being tested.

The velocity of sound was obtained by recording the temperature of the air at the firing site with a calibrated thermometer, making relative humidity measurements with a sling psychrometer and employing the relation[1]

$$C_o = 1088 \sqrt{1 + \frac{t}{273}} \left[1 + 0.149 \frac{P_w}{P_a} \right] ,$$

where C_o is the velocity of sound in air ahead of the shock,
t^o is the air temperature (Centigrade),
P_w is the partial pressure of water vapor in air, and
P_a is the partial pressure of the air.

Wind effects were held to a minimum by restricting firing to calm days or to days when a slight cross wind prevailed.

The peak pressures were obtained from the shock-front velocity measurements by the application to air of the Rankine-Hugoniot ideal gas relation

$$\frac{P_s}{P_o} = \frac{2\gamma}{\gamma + 1} \left(\frac{U^2}{C_o^2} - 1 \right) ,$$

where P_s is the peak pressure,
P_o is the atmospheric pressure ahead of the shock,
U is the velocity of shock-front propagation,
C_o is the velocity of sound in air ahead of the shock, and
γ is 1.40 (ratio of specific heats for air).

Over the peak pressure range covered by this report, the results obtained from this equation are in close agreement with the calculations of Brinkley, Kirkwood, and Richardson.[2]

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[1] "Final Report on the Shock Tube," J. C. Fletcher, W. T. Read, R. G. Stoner, and D. K. Weimer, NDRC A-356, OSRD-6321, 1946.

[2] "Tables of the Properties of Air along the Hugoniot Curve and the Adiabatics Terminating in the Hugoniot Curve," S.R. Brinkley, Jr., J.G. Kirkwood, and J.M. Richardson, NDRC, OSRD-3550, 1944.

The distances from the charge at which these peak pressures apply ($P_s < 17$ lb/in^2) were calculated from the approximate relation[1]

$$R_v \cong R_m \left[1 - \frac{n+1}{24} \left(\frac{\Delta r}{R_m}\right)^2 \right] ,$$

where R_v is the distance from the charge at which the average shock velocity measured over interval Δr is equal to the instantaneous shock velocity,
R_m is the distance from the charge of the mid-point of the velocity interval,
n is the exponent in the distance-decay law when approximated by a power function, and
Δr is the length of the velocity measurement interval.

The distances from the charge at which these peak pressures apply ($P_s > 17$ lb/in^2) were calculated from the relation[2]

$$R_v = R_m \left\{ 1 - \frac{\left(\frac{\Delta r}{R_m}\right)^2 R_m^n}{16K} \left[\frac{3n-2}{2} + \left(\frac{2-n}{3}\right) \frac{K}{R_m^n} \right] \right\} ,$$

where R_v, R_m, n, and Δr are the same as above,

K is equal to $\frac{6A}{7P_o}$,

A is equal to $\frac{P_s}{r^n}$, and

r is the distance from the center of the charge to the center of the gauge element.

The peak pressures at the air-blast gauge positions were then calculated from the relation

$$\frac{P_1}{P_2} = \left(\frac{r_2}{r_1}\right)^n ,$$

where P_1 is the peak pressure at the position where the average shock velocity over interval Δr is equal to the instantaneous shock velocity,
P_2 is the peak pressure at the gauge position,
r_1 is the distance from the center of the charge to the position where the average shock velocity over interval Δr is equal to the instantaneous shock velocity,
r_2 is the distance from the center of the charge to the center of the air-blast gauge element, and
n is the exponent in the distance decay law when approximated by a power function.

[1, 2] "Apparatus for Measurement of Air Blast by Means of Piezoelectric Gauges," G. K. Fraenkel, NDRC A-373, OSRD-6251, 1946.

The effective dynamic gauge responses were then calculated, employing the relation[1]

$$KA = \frac{d_p E_o C_s}{d_o P_s}$$

where KA is the effective dynamic gauge response ($\mu\mu$Coul/lb/in^2),
d_p is the deflection resulting from P_s,
P_s is the peak pressure at the gauge position,
E_o is the calibration voltage,
d_o is the deflection resulting from E_o, and
C_s is the standard capacitance ($\mu\mu f$).

EXPERIMENTAL RESULTS

In Figures 4 to 8 are plotted the effective dynamic KA's as a function of peak pressure level for the gauges and the amplifiers included in the tests (for shock durations produced by one-eighth pound spherical pentolite charges).

BRL gauges T-63 and T-66 are round unbaffled gauges of identical construction and dimensions (Figure 3), consisting of a four-crystal stack, made of one and three-quarter inch diameter tourmaline discs cemented to a steel housing, and sensitive on one side only. The ratio of the diameter to thickness of these gauges is approximately 3:1.

These gauges showed approximately linear reductions in response between peak pressures of 5 and 15 lb/in^2. Above this pressure level, the reductions in their responses began to level off, and the response of gauge T-63 increased above 25 lb/in^2 peak pressure. Both of these gauges recorded erratically above the 30 lb/in^2 peak pressure level.

Pancake gauges Nos. 1 and 2 are round baffled gauges of similar construction and dimensions except for their edge shape, No. 1 having a pointed edge and No. 2 having a rounded edge (Figure 3). The sensitive elements of these gauges consists of two two-crystal stacks made of one-inch diameter tourmaline discs soldered to opposite sides of a central brass tab, which is an integral part of the brass baffle. These gauges are sensitive on both sides. The ratio of the diameter of the baffle to the thickness of these gauges is 10:1, a ratio which, in conjunction with the edge shape of gauge No. 1, should hold the flow effect error to a maximum of 5 per cent up to Mach 0.8 (peak pressure of 35 lb/in^2), according to the predictions of MacDonald and Schaaf.[2]

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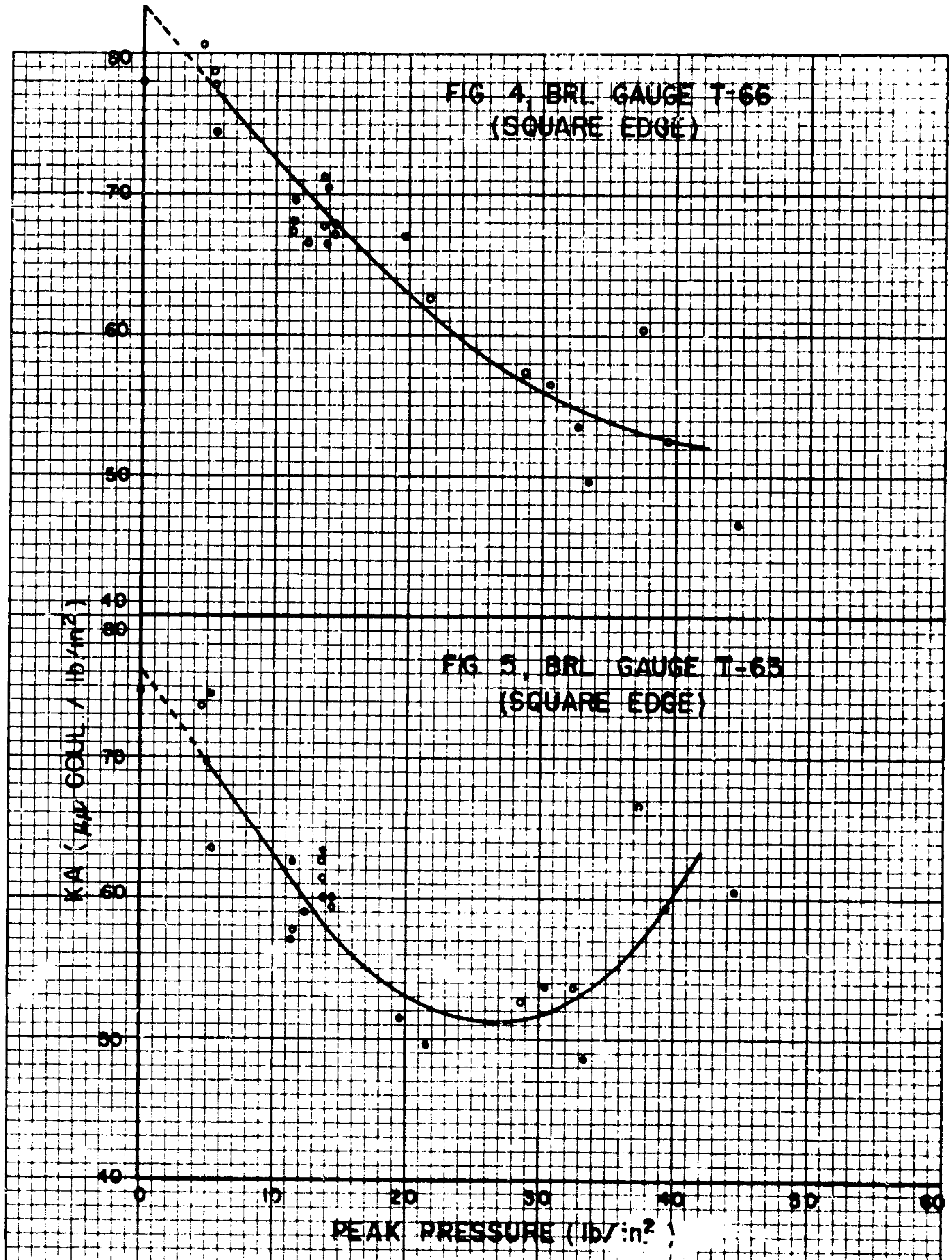
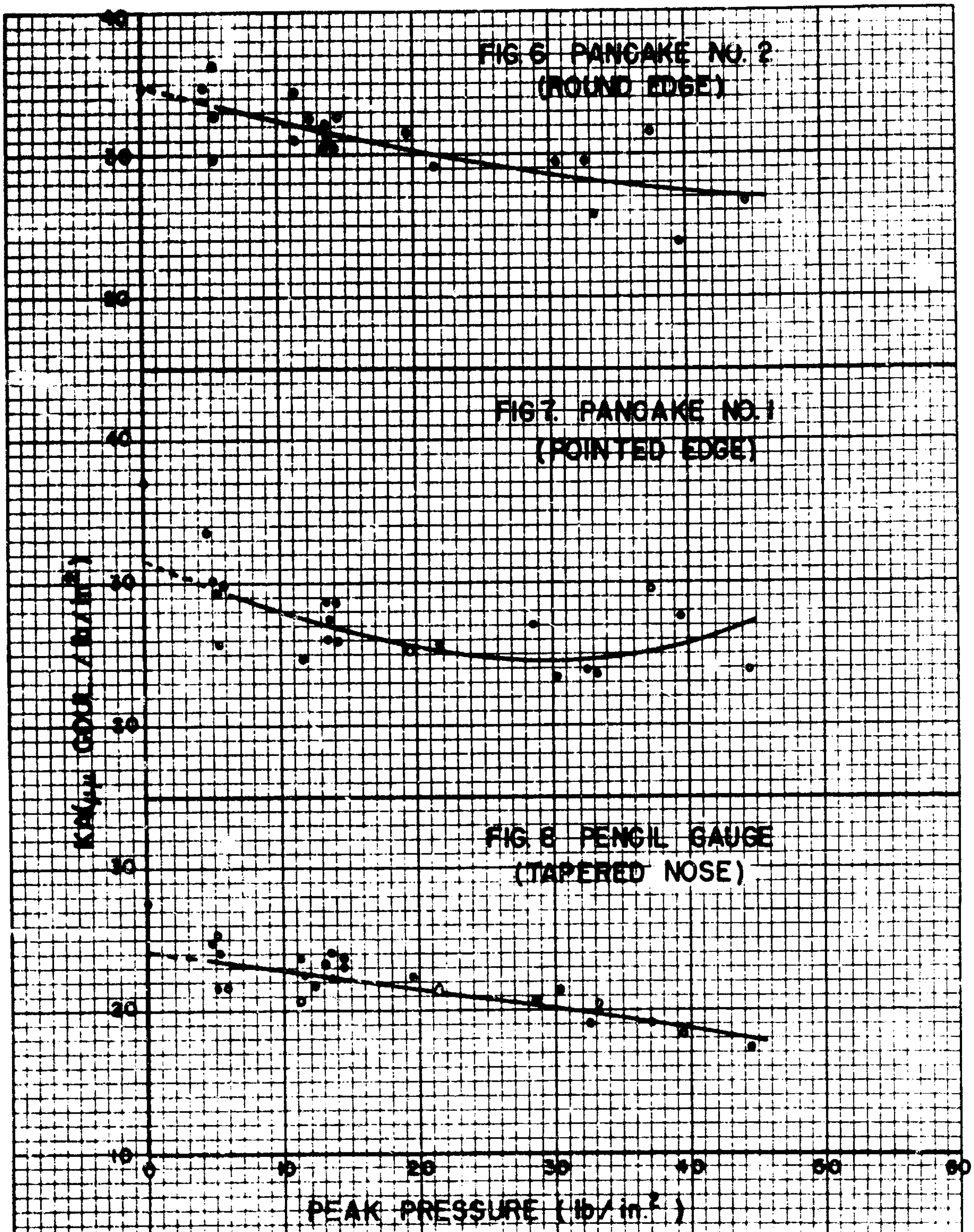
[1] "Design and Use of Tourmaline Gauges for Piezoelectric Measurement of Air Blast," A. B. Arons and C. W. Tait, NDRC A-372, OSRD-6250, 1946.

[2] "On the Estimation of the Perturbations due to Flow Around Blast Gauges," J. K. L. MacDonald and S. A. Schaaf, AMP Note 22, AMG-NYU 136, 1945.



FIGS. 4-5 GAUGE KA AS A FUNCTION OF PEAK PRESSURE

LEGEND:
STATIC KA .... ●
DYNAMIC KA .... ○
EXTRAPOLATED DYNAMIC KA ----



FIGS. 6-8 GAUGE KA AS A FUNCTION OF PEAK PRESSURE

LEGEND:

STATIC KA .... •

DYNAMIC KA .... •

EXTRAPOLATED DYNAMIC KA ....

The reductions in the responses of the pancake gauges were approximately linear between peak pressures of 5 and 15 lb/in^2. Above this pressure level, the reductions in their responses began to level off, and the response of pancake gauge No. 1 increased above 30 lb/in^2 peak pressure. Both pancake gauges were considerably less subject to reductions in response than the BRL gauges, pancake gauge No. 2 (rounded edge) being superior to pancake gauge No. 1 (pointed edge) in this respect. Moreover, the recordings of the pancake gauges were somewhat less scattered than those of the BRL gauges.

The pencil gauge is an air-blast gauge of new design,[1] shaped like a pencil, with two six-crystal stacks made of one-half inch diameter tourmaline discs inserted into openings on opposite sides of the pencil at its mid point (Figure 3). The ratio of the length of the pencil gauge to its thickness is approximately 20:1, which should hold the flow effect error to 4 per cent up to Mach 0.8, assuming that the predictions of MacDonald and Schaaf apply.[2]

The reductions in the responses of the pencil gauge were linear between peak pressures of 5 and 40 lb/in^2, being slightly less than those of the pancake gauges and considerably less than those of the BRL gauges. Moreover, the responses of the pencil gauge were much more uniform above peak pressures of 30 lb/in^2 than were those of the pancake and BRL gauges (Figures 4 to 8).

In Figures 9 and 10, the percentage errors in effective gauge KA's as a function of peak pressure for all three types of air-blast gauges are presented. The calculations of Figure 9 are based upon the extrapolated values of the effective dynamic KA's at zero peak pressure, while those of Figure 10 are based upon the conventional static calibrations.

An additional comparison of these percentage errors for the respective air-blast gauges is given in Tables I and II.

Table I

Errors in Effective Gauge Response Versus Peak Pressure

Gauge	5 lb	10 lb	15 lb	20 lb	30 lb	40 lb
Pencil	2.5%	5.0%	8.3%	11.2%	17.0%	22.4%
Pancake 2	3.7%	7.7%	11.1%	13.4%	18.5%	22.0%
Pancake 1	5.4%	11.1%	15.2%	18.7%	22.8%	18.1%
BRL T-66	8.3%	15.1%	21.2%	26.0%	34.4%	37.6%
BRL T-63	7.5%	17.5%	25.0%	30.6%	32.0%	24.0%

Note: Extrapolated effective dynamic KA used as the reference point.

---

[1] "A Pencil-Shaped Piezoelectric Air Blast Gauge," J. W. Hanna, BRL Technical Note No. 275, 1950.

[2] "On the Estimation of the Perturbations due to Flow Around Blast Gauges," J.K.L. MacDonald and S.A. Schaaf, AMP Note 22, AMG-NYU 136, 1945.

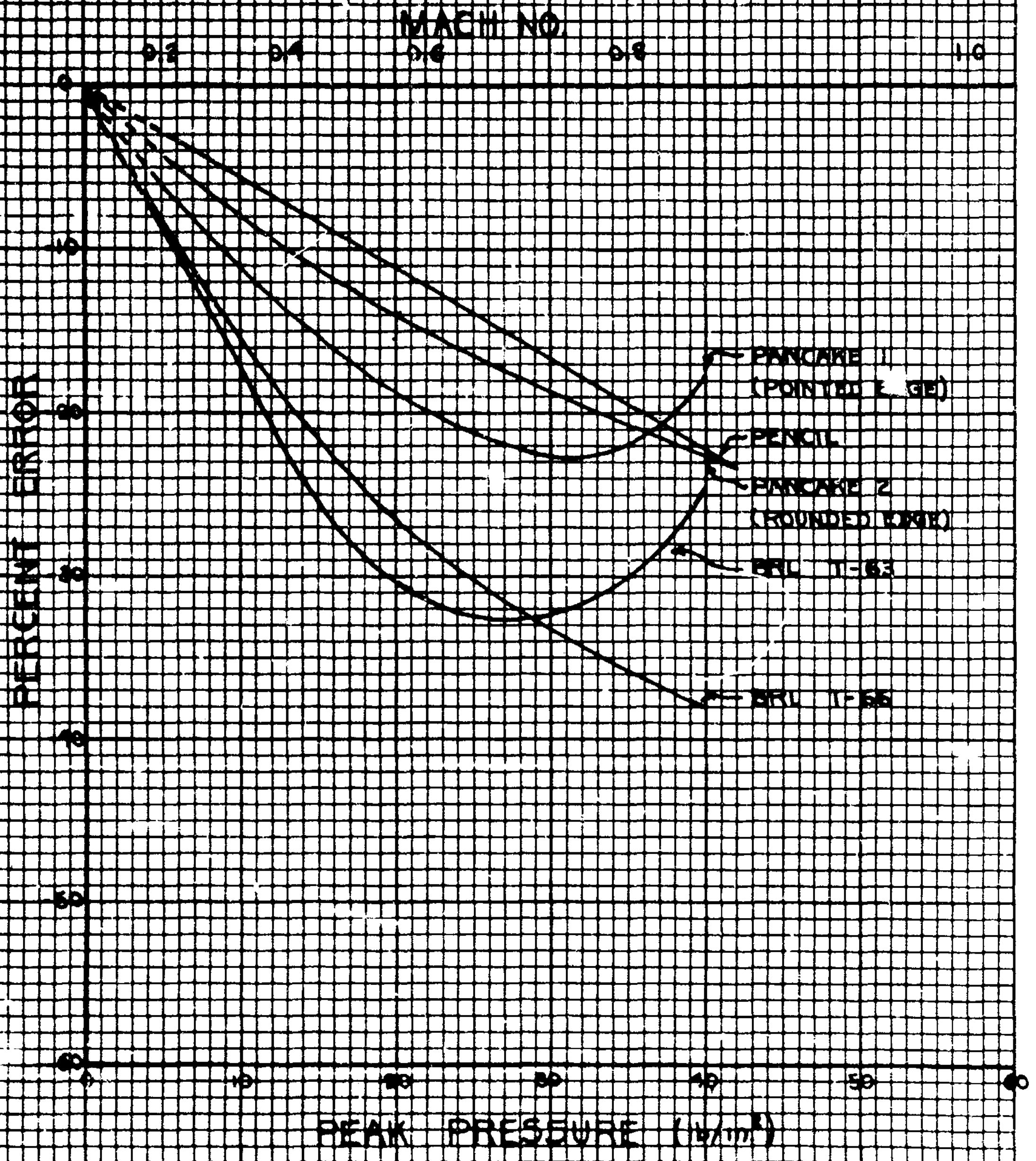


FIG 9 ERROR IN GAUGE KA AS A FUNCTION OF PEAK PRESSURE

NOTE: EXTRAPOLATED DYNAMIC KA USED AS THE REFERENCE POINT

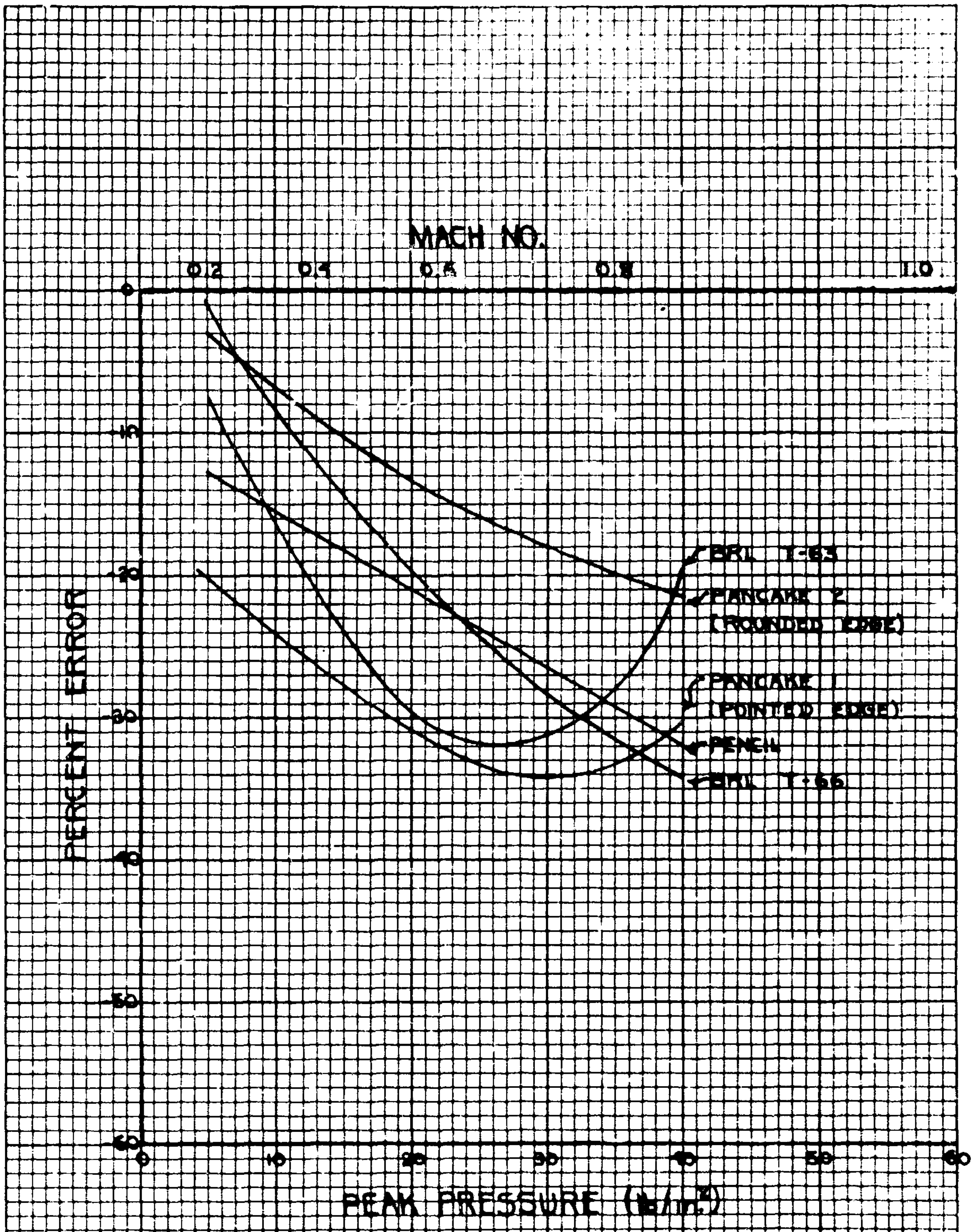


FIG 10 ERROR IN GAUGE KA AS A FUNCTION OF PEAK PRESSURE

NOTE: STATIC KA USED AS THE REFERENCE POINT

ARMY—OS—ABERDEEN PROVING GROUND, MD—[illegible]

Table II

Errors in Effective Gauge Response Versus Peak Pressure

Gauge	5 lb	10 lb	15 lb	20 lb	30 lb	40 lb
Pencil	12.8%	16.2%	18.0%	21.2%	27.0%	31.8%
Pancake 2	2.9%	6.9%	10.4%	13.4%	17.9%	21.3%
Pancake 1	19.5%	24.4%	27.8%	30.4%	34.3%	30.3%
BRL T-66	1.0%	7.8%	14.0%	19.2%	28.2%	34.2%
BRL T-63	7.2%	15.8%	23.8%	29.9%	31.2%	19.5%

Note: Static KA used as the reference point.

INTERPRETATION OF EXPERIMENTAL RESULTS

Figures 4 to 8 reveal the discrepancies which exist between the static and the effective dynamic gauge calibrations when the latter are extrapolated to zero peak pressure. Some of the response curves extrapolate to points above the static calibration, while others extrapolate to points considerably below the static calibration.

It might possibly be thought that these discrepancies reflect the inaccuracy of the velocity measurements at low peak pressures. However, it should be noted that the data were obtained by recording all five gauges on the same film, and similar results were obtained from individual runs at low peak pressures.

These discrepancies are further emphasized in Figures 9 and 10, the response curves showing a good relation to the reference point in Figure 9 and a poor relation in Figure 10.

It would therefore appear that the discrepancies which exist between the static and the extrapolated effective dynamic gauge calibrations are of such a nature as to make the use of the latter preferable.

It should be understood that the effective dynamic KA's are not absolute values. However, an improvement in these KA's represents an improvement in the recording characteristics of the gauges.

The response curves of Figure 9 would indicate that, while the pancake gauges represent a substantial improvement over the BRL gauges from the standpoint of freedom from response errors, the pencil gauge is slightly superior between peak pressures of 5 and 40 lb/in^2.

The pencil gauge is also superior from the standpoint of linearity of reductions in response with increasing peak pressure level, the reductions in the responses of this gauge being linear between 5 and 40 lb/in^2 peak pressure.

From the standpoint of uniformity of response, the pancake gauges are somewhat of an improvement over the BRL gauges; however, the pencil gauge is decidedly superior to both of the other types tested in this respect, being subject to considerably less scatter above peak pressures of 25 lb/in^2 (Figures 4 to 8).

It is logical to assume that gauges of the same physical dimensions containing the same size sensitive elements should be subject to the same over-all response errors. Figure 9 shows that the response curves of the two BRL gauges are in general agreement with this hypothesis up to peak pressures of 25 lb/in^2, but that above this pressure level disagreement exists, with BRL gauge T-63 showing an increase of response above 25 lb/in^2 peak pressure, while BRL gauge T-66 shows a continued reduction.

The response curves of the pancake gauges (Figure 9) are also in general agreement with this hypothesis up to 30 lb/in^2 peak pressure, disagreement existing above this pressure level. The causes of these effects are not known at this time.

Pancake gauge No. 2 (rounded edge) appears to be somewhat less subject to reductions in response than pancake gauge No. 1 (pointed edge), but in view of the BRL gauge response curves it is not certain that the edge shape makes a significant difference.

It should also be noted that the data on the pencil gauge were taken using both 8- and 12-inch nose sections and that no discernible difference in the response of the gauge occurred. The ratio of the length of the pencil to its thickness is 20:1 using the 8-inch nose, and 30:1 using the 12-inch nose. Obviously, there is no advantage in using the longer nose section, and it may be that a nose section somewhat shorter than the 8-inch length could be used without affecting the response of the gauge materially.

The question arises as to whether the differences between the response curves of Figure 9 could be attributed to the differences in the degree to which the respective air-blast gauges are subject to flow effect.

One of the principal errors involved, in addition to that due to flow effects, is the "gauge-size error." This error can be expected to be large when small charges are used, since the shock durations are greatly reduced. Because of the differences in the diameters of the sensitive elements employed in these gauges, this error will be least in the case of the pencil gauge, somewhat more for the pancake gauges, and greatest in the case of the BRL gauges. Thus the "gauge-size error" should have the effect of spreading the response curves of Figure 9 apart.

The other principal error involved, in addition to that due to flow effect, is the "high frequency amplifier response error." This error, while probably not large, will be greatest for the pencil gauge, somewhat less for the pancake gauges, and least for the BRL gauges. Thus this error should have the effect of moving the response curves of Figure 9 closer together and counteracting the effect of the "gauge-size error" to some extent.

The possibility of one other major source of error should be mentioned. Tourmaline is subject to what is known as a "pyroelectric effect." This refers to a volume polarization caused by distortion of the crystal lattice when the geometrical shape of the crystal is changed by uniform heating. A change of 1°C has the same effect as a pressure of 200 lb/in^2, the effects being of opposite sign.[1]

This effect can be avoided by insulating the sensitive elements of air-blast gauges against the temperature rise in blast waves, and this has been done in the case of the gauges included in these tests. While the type and thickness of the insulating coatings varies with the respective gauges, it is believed to be sufficient in all cases to eliminate this effect as a source of error.

It must therefore be concluded that the differences in the response curves of Figure 9, while representing the "over-all" differences in the responses of the respective air-blast gauges, do not represent the flow effect differences alone. This would be true only if all of the gauges contained the same diameter sensitive elements, had identical insulation, and were equipped with baffles of the same dimensions.

CALCULATION OF PRINCIPAL ERRORS

Since flow effect data were unobtainable from the response curves of Figure 9, it was believed that it would be of interest to calculate the values of the principal errors involved from theoretical considerations and then compare the totals of these calculated errors with the average over-all errors recorded, based on both the extrapolated effective dynamic calibrations and the static calibrations. Thus, it could be determined whether flow effect data might be obtained indirectly. Accordingly, this has been done for two runs, one at 13.86 lbs peak pressure and the other at 28.86 lbs peak pressure.

The "flow effect errors" were calculated using the relation employed by Schaaf[2]

$$\delta_p = \frac{70\,M^2}{\sqrt{1 - M^2}} \cdot C_{p,o} \quad ,$$

where δ_p is the percentage flow effect error,

M is the Mach number behind the shock-front, and

$C_{p,o}$ is the mean pressure coefficient over the gauge surface.

(The application of this equation to a pencil shape is a doubtful procedure).

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[1] "Blast Pressures and Momenta from Some Large Bombs," E. B. Wilson, Jr. and W. D. Kennedy, NDRC, OSRD-3046, 1943.

[2] "Estimation of Perturbations due to Flow around Blast Gauges with Spheroidal Shapes," S. A. Schaaf, AMG-NYU 144, 1946.

The peak pressures at the blast-gauge positions, as obtained from the two-point velocity measurements, were then reduced by the "flow effect error" percentages in order to obtain the peak pressures acting upon the respective blast-gauge sensitive elements.

Next the "gauge-size errors" were calculated using the relation[1]

$$\frac{a}{c\theta}$$

where a is the radius of the sensitive element,
c is the velocity of shock-front propagation, and
θ is the initial decay time of the trace.
(This relation applies when the ratio of half the gauge-crossing time to the initial decay time of the recorded trace is less than 1/5).

The "high frequency amplifier response errors" were then calculated from the relation[2]

$$\Delta = \beta \ln \left[1 + (1 - \epsilon^{-\alpha/\beta}) / \alpha \right] ,$$

where Δ is the fractional error recorded by the amplifier,
β is equal to K/θ,
K equals RC equals $1/2\pi f_o$
R_o is the time constant of the input circuit,
f_o is the frequency at which the amplifier response is down to 70 per cent of its mid-band response,
θ is the initial decay time,
ϵ is the constant 2.71828
α is γ/θ, and
γ is the gauge crossing time.

The peak pressures effective upon the respective blast-gauge sensitive elements were then reduced by the sums of the "gauge-size error" and the "high frequency amplifier response error" percentages so as to obtain the peak pressures which the respective blast-gauges should have recorded.

The percentage differences between the peak pressures at the blast-gauge positions, as determined by the two-point velocity method, and the peak pressures which the respective blast-gauges should have recorded were then calculated.

The results of these calculations are presented in Table III, along with the average over-all errors actually recorded, based upon both the extrapolated effective dynamic calibrations and the static calibrations.

[1, 2] "Design and Use of Piezoelectric Gauges for Measuring Large Transient Pressures," A. B. Arons and R. H. Cole, Review of Scientific Instruments, January, 1950.

Table III

Calculated Principal Errors Versus Over-all Errors Actually Recorded

Type of Gauge	Flow Effect Errors	Gauge-Size Errors	Freq. Response Errors	Total Calc. Errors	Over-all Errors Dyn. Cal.	Over-all Errors Stat. Cal.
		$13.86\ lb/in^2$ (Mach .448)				
Pencil	1.3%	4.5%	2.2%	7.9%	7.8%	17.6%
Pancake 1	2.6%	7.5%	1.4%	11.2%	12.3%	26.8%
Pancake 2	2.6%	7.8%	1.6%	11.6%	11.0%	10.0%
BRL T-63	7.2%	12.4%	1.1%	19.6%	23.0%	22.0%
BRL T-66	7.2%	13.0%	1.3%	21.6%	20.0%	13.0%
		$28.86\ lb/in^2$ (Mach .723)				
Pencil	4.2%	6.9%	3.7%	14.8%	15.8%	26.0%
Pancake 1	8.4%	11.7%	2.5%	21.5%	20.8%	33.0%
Pancake 2	8.4%	-	-	-	-	-
BRL T-63	23.8%	15.8%	1.5%	36.9%	32.6%	31.8%
BRL T-66	23.8%	15.2%	1.6%	36.5%	33.1%	27.1%

INTERPRETATION OF CALCULATED PRINCIPAL ERROR RESULTS

At the 13.8 lb/in^2 peak pressure level, the totals of the principal errors, as calculated, are in reasonably good agreement with the over-all errors actually recorded, as based upon the extrapolated effective dynamic calibrations, but are not in good agreement with the errors actually recorded when based upon the static calibrations.

The totals of the calculated principal errors and the over-all errors actually recorded at 28.8 lb/in^2 peak pressure, when based upon the extrapolated effective dynamic calibrations, also compare favorably, although the totals of the calculated errors are slightly in excess of the errors actually recorded in several instances. Again, the agreement with the over-all errors actually recorded, as based upon the static calibrations, is not good.

The fact that the totals of the calculated principal errors are in good agreement with the over-all errors actually recorded, when based upon the extrapolated effective dynamic calibrations, indicates that the residual errors are small at these zero peak pressure positions. Of course, this has not been proven.

These results also indicate that the respective error calculations have some validity. On this basis, it would appear that the "flow effect errors" range from about 1 to 8 per cent at the 13.8 lb/in^2 peak pressure level, varying with the gauge employed, and are less than 3 per cent for the pancake and pencil gauges. At the 28.8 lb/in^2 peak pressure level, the indicated range is from 4 to 24 per cent, being about 4 per cent for the pencil gauge.

In Table IV, a comparison is made between the calculated "flow effect errors" and the baffle diameter to thickness ratios of the respective gauges.

Table IV

Flow Effect Errors as a Function of Baffle Dimensions

Type of Gauge	Diameter to Thickness	Calculated Errors 13.8 lb/in^2	Calculated Errors 28.8 lb/in^2
Pencil	20:1*	1.3%	4.2%
Pancake	10:1	2.6%	8.4%
BRL	3:1	7.2%	23.8%

*Length to thickness

This table indicates that the baffle diameter to thickness ratio should range between 10:1 and 20:1 if the "flow effect errors" are to be held to low values.

The data presented in this report represents Phase I of an air-blast gauge "flow effect" program. Larger charges will be employed in Phase II, and the gauges tested will be subjected to peak pressures ranging up to 100 lb/in^2. These tests are now under way.

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Spence T. Marks.

Spence T. Marks

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1. References:

a. Ballistic Research Laboratory Memorandum Report No. 397, "An Improved Tourmaline Air Blast Gage", by T. D. Carr and M. A. Bakinowski, October 1945, AD number 494667, UNCLASSIFIED, enclosed.

b. Ballistic Research Laboratories Memorandum Report No. 1778, "Detonation Pressure Measurements in TNT and OCTOL", by R. Jameson and A. Hawkins, August 1966, AD number 802251, UNCLASSIFIED, enclosed.

c. Ballistic Research Laboratory Memorandum Report No. ARBRL-MR-03115, "Blast Computations over a Hemicylindrical Aircraft Shelter", by J. Wortman, July 1981, AD number B058960, UNCLASSIFIED, enclosed.

d. Ballistic Research Laboratory Memorandum Report No. ARBRL-MR-03125, "Combinatorial Geometry Computer Models of Sitting and Standing Crew Personnel" by L. R. Kruse and C. H. Lee, August 1981, AD number B060185, UNCLASSIFIED, enclosed.

e. Ballistic Research Laboratories Report No. 734, "Response of Air Blast Gauges of Various Shapes as a Function of Pressure Level", by S. T. Marks, August 1950, AD number 801219, UNCLASSIFIED, enclosed.

f. Ballistic Research Laboratories Report No. 775, "Response of Air Blast Gauges of Various Shapes to One-Pound Spherical Pentolite Charges as a Function of Pressure Level", by S. T. Marks, September 1951, AD number 801726, UNCLASSIFIED, enclosed.

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BENJAMIN E. BRUSO
Team Leader, Security/CI Office

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