

SHOCK DYNAMICS LABORATORY
Department of Physics
Washington State University

INTERNAL REPORT

74-02

Y. M. Gupta

July, 1974

MEMORANDUM

TO: Shock Dynamics Group

FROM: Y. M. Gupta

DATE: July 15, 1974

The attached internal report is for your information only and PLEASE do not reference any material without consulting me.

YMG/ms

INTRODUCTION

In an earlier report (SDL Internal Report 73-03), response and use of quartz gauges under shock loading were reviewed.¹ Various modes of operation and possible designs for different experiments were described.² It was pointed out that shunted gauges are experimentally difficult to use, when non-metallic solids are being studied. The shorted gauges, while experimentally simple to use, do not have a universal behavior and each gauge design has to be individually calibrated. Since the bulk of experimentation in this laboratory is done on non-metallic crystals, it was decided to investigate the feasibility of using a modified shorted gauge. The intent was to combine the experimental ease of operation of a shorted gauge and universal response features of the shunted mode. This is achieved by removing almost all of the gold plating on the side of the shorted gauge. The motivation for this is governed by the fact that conductivity originating at lateral edges appears to cause deviations from one dimensional behavior in shorted gauges.^{2,4} Hence minimizing gold plating on the side may allow for elimination of conductivity effects. In the following sections we describe the procedure, results and conclusions of this study.

PROCEDURE

Experiments consisted of quartz on quartz impact with recording gauges being 1/2 in. in diameter and 1/8 in. thick. They were subjected to long stress pulses.⁵ Detailed accounts of technique and care involved in these experiments are not described here and can be seen elsewhere.^{1,6} We merely describe the quartz gauge design used here.

Five recording gauges were used. One consisted of a 1.5 mm x 1.5 mm gold tab on the side which was connected to plating on the -ve electrode. This is obtained by rubbing off gold from the rest of the region on the lateral edges.

The tab served to provide a ground connection. This design is fabricated analogous to a shunted gauge. The other four gauges had gold plated faces and a thin tab on the side which connected the two faces. The width of this tab varied between 0.5 mm and 3.0 mm. The plating resistance between the faces increased with decreasing tab width and varied between 2 and 5 ohms. The gauges were bought as such from the supplier. In Fig. 1 we show the two designs.

RESULTS AND ANALYSIS

Five shots were fired and pertinent details are presented in Table I. In Fig. 2 we present quartz gauge outputs of shots 73-023, 045, 052 and 058. No meaningful quartz gauge output was obtained in shot 73-014, which had a small square gold tab connected to the -ve electrode. This was attributed to a loss of ground connection at the tab.

The other four quartz records are shown in Fig. 2 and display intermittent breakdown and high frequency noise. This is attributed to possible break in tab plating from lateral rarefactions. All results were reduced using the piezoelectric response equation⁸

$$i = KAv_s \sigma / \ell \quad (1)$$

where the symbols have the usual meaning. K-values deduced from our data are shown in column 7 of Table I. In the same column we have given in parentheses K-values obtained from Graham's calibration for shunted gauges.⁹ It is emphasized that these values are applicable for the initial current jump only. While the two sets of K-values are within 2.5% of each other, it is interesting to note that ΔK (as defined by $K_{\text{Graham}} - K_{\text{present}}$) increases with increasing gold plating on the side of the gauge. Thus for a gauge fully plated on the side, this difference could be indeed large. This observation agrees very well with Graham's work on shorted and shunted gauges.⁴ The present experiments provide a more direct confirmation of

Graham's hypothesis that plating on lateral edges is mainly responsible for two dimensional field effects due to conductivity at lateral edges.⁴

Another feature of shorted quartz gauge behavior, i.e. increase in current with time after impact (referred to as "ramping") is also caused by plating on lateral edges. This is easily seen by examining Fig. 2, and noticing that for thinner gold tabs, the current initially stays nearly constant and then increases non-linearly. For wider tabs the non-linear increase starts fairly early in time. The amount of ramping displayed by gauges in the present work lies in between that displayed by shunted and shorted gauges.

CONCLUSIONS

The conclusions of this study are summarized below.

- (a) Current-time profiles have been obtained from modified shorted gauges. These show intermittent breakdown and high frequency noise, possibly due to plating breakdown at lateral edges from rarefactions.
- (b) Initial current output decreases with increasing amounts of gold on the side and this is reflected in ΔK (defined by $K_{\text{shunted}} - K_{\text{present}}$) increasing at the first jump.
- (c) At later times behavior is reversed and non-linear increase in current (ramping) goes up with increasing gold plating on the side.
- (d) The response of a modified shorted gauge with a narrow gold tab (0.5 mm) is similar to a shunted gauge.

The decrease in initial current jump can be understood by recognizing that due to plating at the edges, there are charges of the plated surface. In the quartz itself there are no charges and this causes very large fields to be set up which may induce breakdown at the edge.⁴ These large lateral fields can distort the one dimensional fields in the central region, thereby giving the

observed changes in current at the initial jump. The increase in ramping with increased gold plating is not so easily understood.

The present experiments provide a direct confirmation of Graham's hypothesis that conductivity at the edges is responsible for differences in shorted and shunted gauge outputs.⁴ The narrow tab modified shorted gauge should be looked at more carefully for that may provide the design which is theoretically simple to analyze and experimentally easy to use.

TABLE I

Shot No. and Configuration	Proj. Velocity (mm/ μ sec)	Impact Stress (kbar)	d_1 (mm)	d_2 (mm)	Current (amp)	$10^8 \times K$ (coul/cm ² /kbar)	Comments
73-014 1.5 mm x 1.5 mm gold tab connected to -ve x electrode	0.281	21.29	3.602	3.75 (2.209)	Ground contact broke down
73-023 3.5 mm thick gold tab connecting both faces	0.287	21.68	3.58	3.691	0.089	2.17 (2.213)	Gauge output ramps non-linearly
9 73-045 0.5 mm thick gold tab connecting both faces	0.402	30.44	3.537	3.662	0.1415	2.31 (2.298)	Intermittent signal with very little ramping
73-052 1.5 mm thick gold tab connecting both faces	0.3283	24.887	3.341	3.513	0.101	2.221 (2.244)	Output signal has noise and constant linear ramping for about 200 nsec.
73-058 3.0 mm thick gold tab connecting both faces	0.357	27.07	3.568	3.712	0.111	2.22 (2.265)	Output signal very noisy with change in slope of ramping after 200 nsec

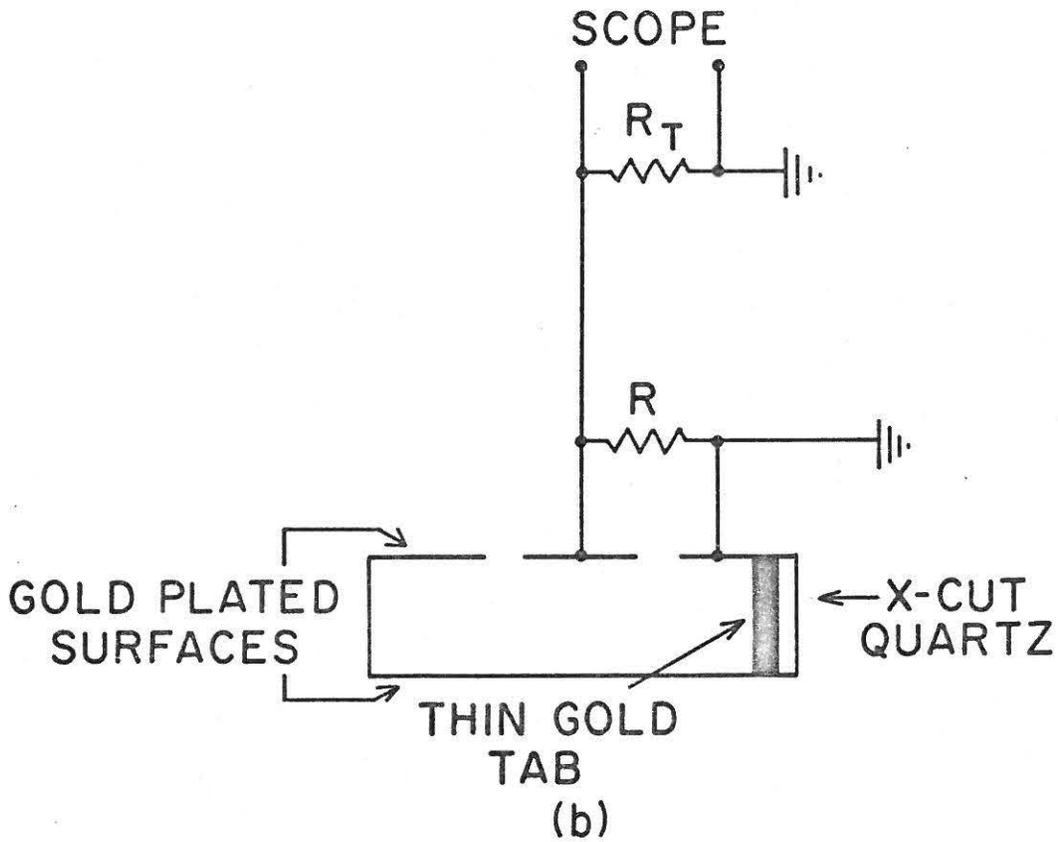
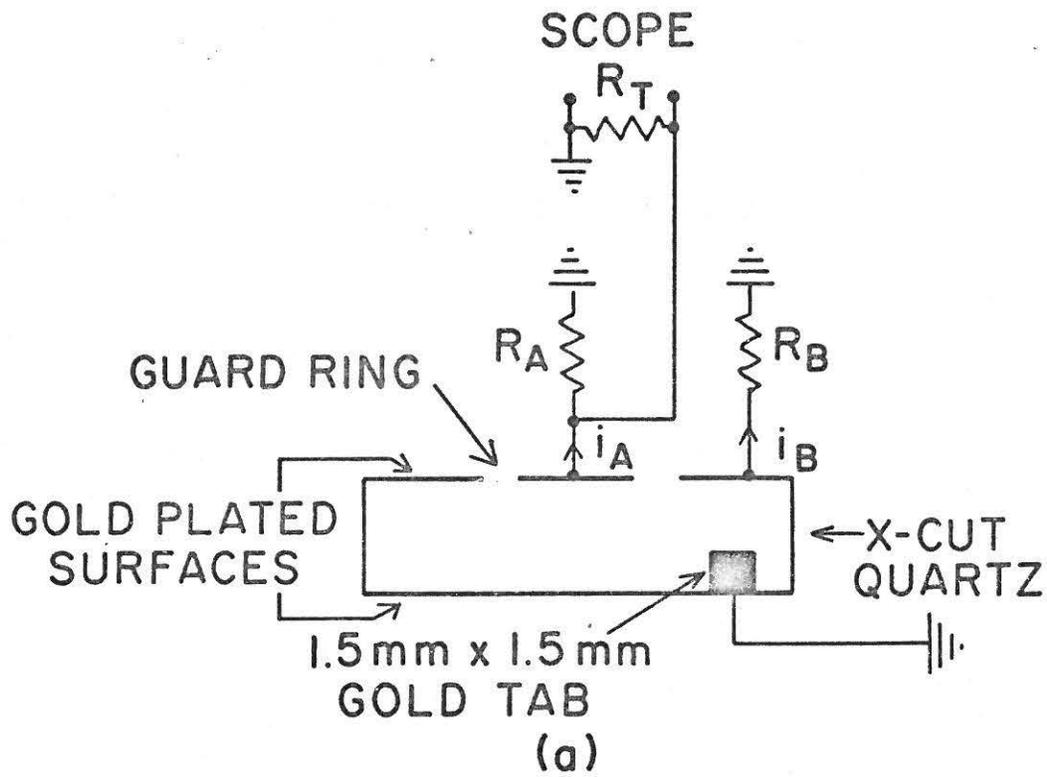
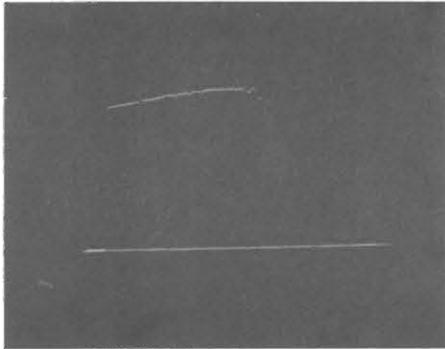


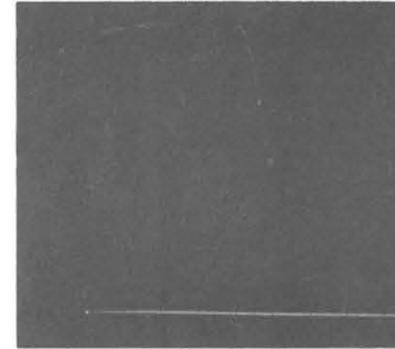
Figure 1. Modified shunted and shorted gauge designs.

Fig. 2 Current-time profiles from quartz gages. Blanked out spaces on base line give one division. See Table I and text for details.

(a) 73-023: 0.1 μ sec per division (approx.)

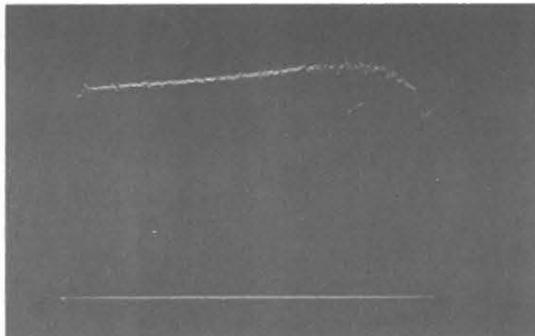


(b) 73-045: 0.1 μ sec per division (approx.)

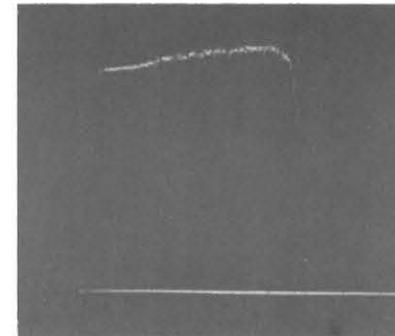


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(c) 73-052: 0.05 μ sec per division (approx.)



(d) 73-058: 0.1 μ sec per division (approx.)



REFERENCES

1. Y. M. Gupta, "Response and Use of a Quartz Gauge," SDL Internal Report, 73-03.
2. All the nomenclature used in this report is fairly standard and has been described in Reference 1.
3. R. A. Graham, "Conductivity in Shock-Loaded X-cut Quartz," SC-R-72-2877, (Dec. 1971).
4. R. A. Graham, private communication and APS meeting in Denver, (1972).
5. R. A. Graham and G. E. Ingram, J. Appl. Phys. 43, 826 (1972).
6. G. E. Ingram and R. A. Graham, "Quartz Gauge Technique for Impact Experiments," Fifth Symposium on Detonation, Pasadena, Ca. (1970).
7. Valpey-Fisher Corporation, Mass.
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9. R. A. Graham, latest calibration (private communication).

KCI

#. Hoys Gupta constants in both programs

QUARTZ	— Proper finite strain
QUART	Ad hoc

→ XBY points must lie within

Yogi has always used QUART program.

QUARTZ is apt to have errors due to vice time

Use calibration given in internal report (latest)
uses internal diameter.



Set Yogi know about jobs

INTERNAL REPORTS - 1975

1. G.E. Duvall, "Plastic Strain in LiF Compressed Uniaxially in a $\langle 100 \rangle$ Direction", Internal Report 75-01, June 1975.