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Minimizing manganin/system noise for potential use in small geometry experiments

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Disclaimer

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1. INTRODUCTION

Manganin gauges are piezo resistive devices often used for pressure measurements on larger, planer impact experiments. These gauges function in this capacity as a result of their ability to change resistance in a consistent fashion relative to the pressure exerted against them. Pressures to 400 kbar have been reliably recorded (H.C. Vantine et al.[1]). Because the mini-manganin is significantly physically smaller than other types, there has been interest in our ability to place these gauges on small geometry (detonator) type experiments . Of primary concern is that the detonator shock front has significant curvature associated with it - especially at small geometries - and that this curvature will cause unknown distortion (stretching) of the manganin gauge and therefore may indicate erroneous data.

A problem encountered while configuring this experiment was noise as a result of the proximity and high current levels of the fireset to the manganin gauge. Initial results indicate noise on the order of 130 mV peak-to-peak (p-p) and running as long as the CVR signal from the ringdown charge voltage of 775 V. These noise problems significantly worsened while discharging the full charge voltage of 1500 V on the fireset through the chip slapper.

2. NOISE REDUCTION ATTEMPTS

Ordinarily, these gauges are used for pressure measurements involving significant quantities of high explosives. These experiment (gun tank) configurations allow for a large physical distance between the fireset and manganin gauges. This distance dramatically reduces noise pick-up by the gauge and associated hardware. In addition, because large quantities of HE are used, there are additional benefits in that any system noise generated is usually over by the time the gauge would see pressure. Finally, the geometries used in the gun tank allow for a near planer impact from the shock front into the gauge. There is a long history of papers written about the use and calibration of these gauges with near planer impacts.

We have investigated the potential use of manganin gauges on detonator-type geometries. Our firing tanks often include the entire experiment package (shot fixture and fireset) within inches of one another (Fig. 1).

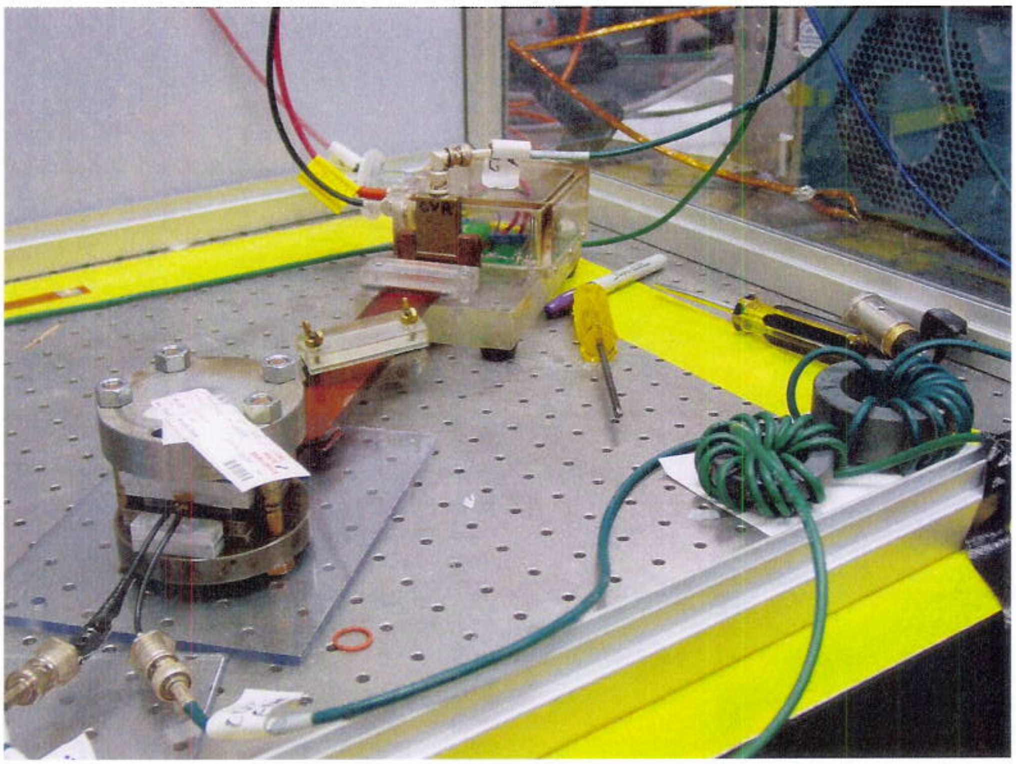

Figure 1. Photo of typical Tinyplate test fixture showing close proximity of test components (lower left) with the fireset. Ferrite rings were added to significantly reduce both the amplitude and duration of the noise generated as a result of the proximity of the manganin to the fireset and the chip slapper.

Figure 2 shows our original attempt at evaluating noise. We did not want to unnecessarily damage any of the gauges. In figure 2, we placed one of the larger "standard" gauges directly above the teflon (between the teflon and aluminum plates). In this case, the teflon was installed to protect the gauge from the flyer. Ultimately, we employed the method seen in figure 3 which more closely simulated the actual shot configuration.

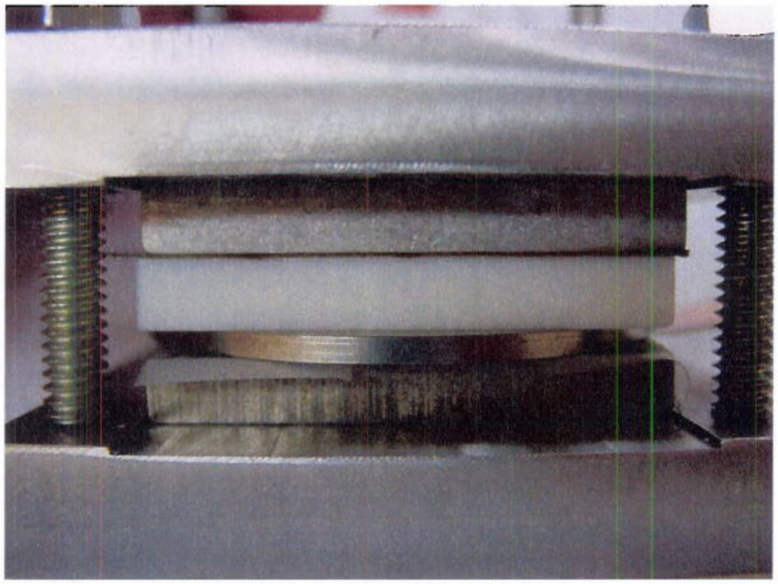

Figure 2. The original noise evaluation configuration - as seen through the side of the Tinyplate fixture. The manganin gauge (unseen) was placed between the teflon and aluminum block. This configuration placed the gauge further from the chip slapper (by the thinkness of the teflon) than should have been done.

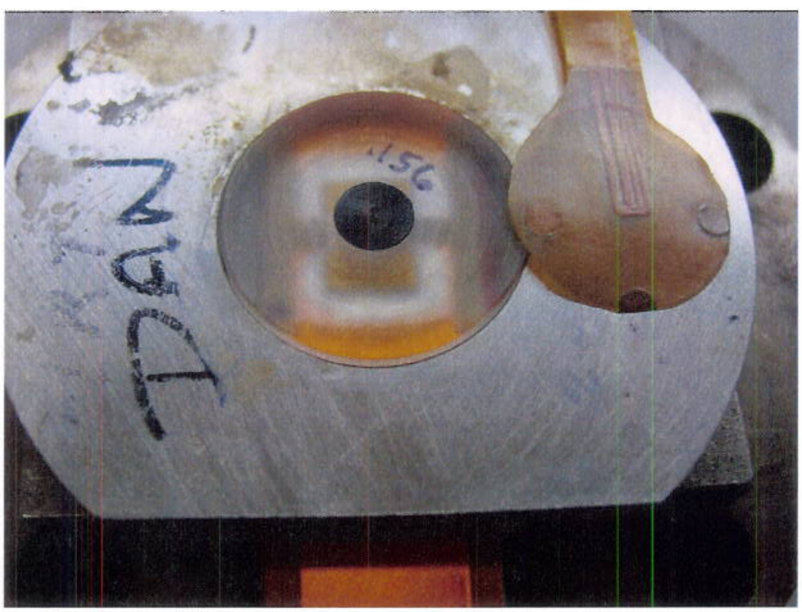

Figure 3. The corrected noise evaluation configuration. A piece of black delrin was placed in the position of the LX-16 pellets. The manganin gauge, seen to the side, was then placed directly over the center of the delrin pellet (simulating the HE pellet) and then covered by the two 0.258" think aluminum plates. This test configuration better simulated the geometry of the shot.

Three styles of manganin gauges were evaluated for noise (Fig. 4). These three were the "standard", a mini version of the stardard, and an "H" style gauge. Within these types of gauges, several modifications were made for noise suppression.

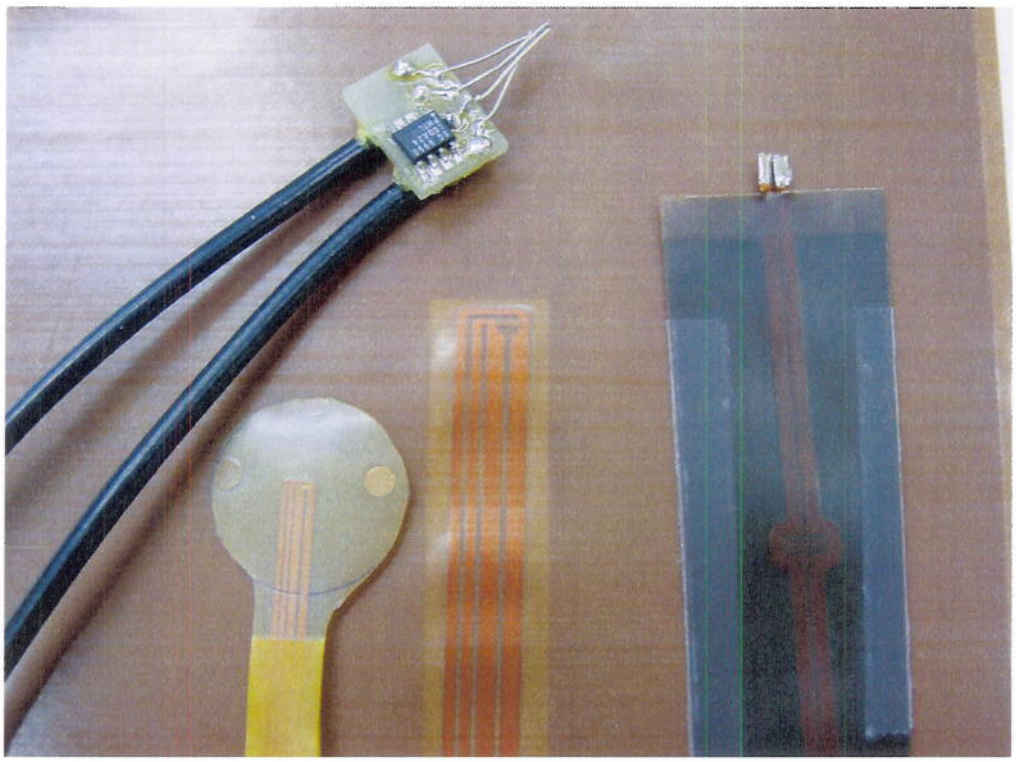

Figure 4. The various manganin gauges attached to the constant current source. The isolation "bug" is seen on the left. Note the gauges are wrapped in differing thicknesses of teflon. Teflon acts as "armor" to increase lifetime of the gauge under pressure.

System adjustments for noise suppression

- Various gauge geometries (see fig. 4)
- Physical location of the Tinyplate fixture relative to the fireset.
- Various lengths of coax cable connections.
- Within the confines of tinyplate fixturing, shortening of the manganin leads.
- The removal of the voltage suppressor "bug" from the manganin
- The direct soldering of coaxial cable to the manganin.
- Ferrite cores added to the signal transmission (V and I) coax cables (see fig. 1).

These modifications included the removal of the "bug" - IC LCDA24 - normally used as a voltage suppressor designed to protect electronics due to ESD or other voltage induced transients and as a connection interface to the constant current source and oscilloscope. Many of the modifications done to minimize noise were not, unfortunately, well documented. Over the course of several days, many configurations were attempted. These attempts included trying different gauges (fig. 4), reducing lead length on the gauges, removal of the bug, turning "off" the constant current source (with the use of manganin gauges, an obviously required piece of equipment), temporarily moving the shot fixture further from the fireset (this was effective with noise suppression - however, in our case, wasn't practical) and, ultimately, the installation of the ferrite cores on the current and voltage signal lines. Most of these modifications provided mixed results - occasionally providing some minor improvements. The largest improvement, by far, was the addition of the ferrite cores (fig.1) while using the mini-manganin gauge without the "bug" attached. For good measure, we also shortened the connection of the coaxial cable to the shortest lead length (of the mini manganin) possible with our test fixture. Figure 5 shows the extreme cases of our evaluation of noise. Viewing the top chart indicates peak-to-peak noise a bit over 400 mV. The middle chart indicates noise at ringdown voltage with all our noise reduction in place. At the 775 V ringdown voltage, there was no discernible noise. The bottom chart is actual shot data - the noise segment removed from the trace and magnified. It shows peak-to-peak noise of a bit over 150 mV - a reduction of nearly 1/3rd the original.

Duration of the noise signals was also considered. Not surprisingly, these signals coincided with the CVR signal recorded by the oscilloscope from the nearby fireset. Returning again to figure 5 (top and bottom), one can see that these signals occur for several hundred nanoseconds. Because the CVR, voltage, and current signals are recorded at the same time, we noted where, on the common time base, bridge burst occurred compared to the noise end point. We then noted the flyer flight time from the chip-slapper and the expected velocity of a 1.95 mm tall pellet of LX-16. These calculations pointed toward being able to run this experiment and expect pressure measurements just beyond the generated noise. To ensure that the voltage signal of interest would be well beyond any noise generated, we performed the first experiment with a total of 3.9 mm of LX-16 (two LX-16 pellets stacked on top of one another). At a detonation velocity of approximately 8.3 mm/us, this would push the signal of interest "out" almost 500 ns from flyer impact on the first pellet.

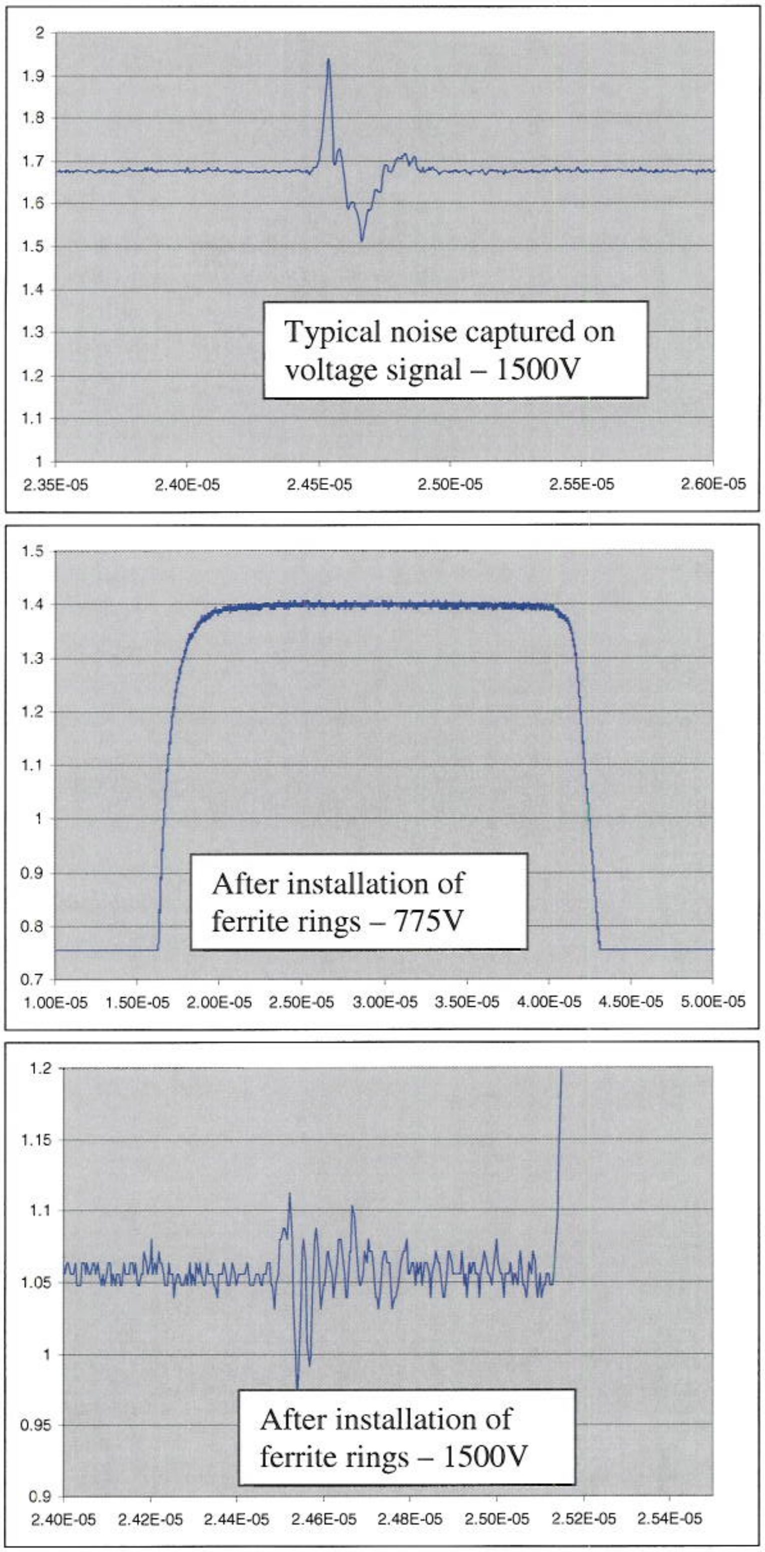

Figure 5. Typical noise files from multiple data sets. At the top is noise without the ferrite cores and with the LDCA24 "bug". The bottom two graphs are with "bug" removal and ferrite

cores installed on both the current and voltage coax connections to the system. Voltage on the Y-axis and time on the X-axis for all charts.

3. EXPERIMENT ASSEMBLY

APC2.5 glue, as seen in figure 6 was used in the assembly of these experiments. There is a long history of the use of this particular glue in gun tank operations. Care was taken to duplicate previous glue preparation. Specifically, the glue was mixed by hand for some two minutes and then put into a centrifuge for an additional two minutes to remove any possibility of trapped air bubbles. Air bubbles in the glue could dramatically affect gauge performance. The glue was applied below and above the manganin gauge and teflon 2mil armor.

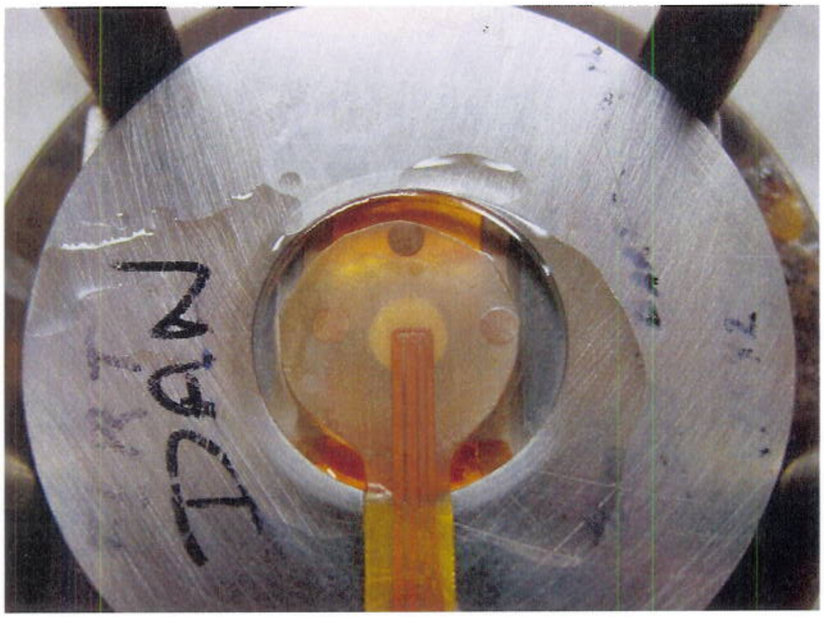

Figure 6. The mini-manganin gauge glued with APC 2.5 over the LX-16 pellets. APC2.5 was placed over the gauge and, before the glue was set-up, we placed two 0.258" thick aluminum plates directly over and centered on the pellets.

Immediately following the application of glue and gauge, we placed the two aluminum plates, the lid to the fixture, and very lightly tightened the 4 nuts holding the completed Tinyplate assembly together. It should be noted that figure 6 shows the quantity of glue originally applied for experiment #1. In fact, we had a failure on one of the tests (#3) because glue managed to seep into the chip slapper assembly immediately under the LX-16 pellet. After performing a post-shot evaluation, we determined too much glue was being applied in the assembly. Subsequent experiment assemblies were done with much less of the APC2.5 - using an artist's brush to "paint" the glue on the top of the HE pellet, both sides of the manganin armor, and the bottom of the plate (teflon or aluminum) above the gauge.

These experiments used a slightly modified "Tinyplate" fixture. One of the 5 bolts holding the assembly together was removed from the device to facilitate manganin gauge lead exits (fig.7). The shot assembly with the APC2.5 glue was then allowed to cure for a minimum of 24 hours.

4. EXPERIMENT RESULTS

The analysis of all the experiment records was done by Kevin Vandersall. In all, 3 HE experiments were done. Experiments #1 and #4 were intended to be duplicates of each other - each with two aluminum plates placed directly above the gauge (figure #7 and #9). The gauge was optimized in its placement directly over the LX-16 pellets. Test # 5 was identical to # 4 with the exception of the plate (teflon) placed directly over the gauge (figure 11).

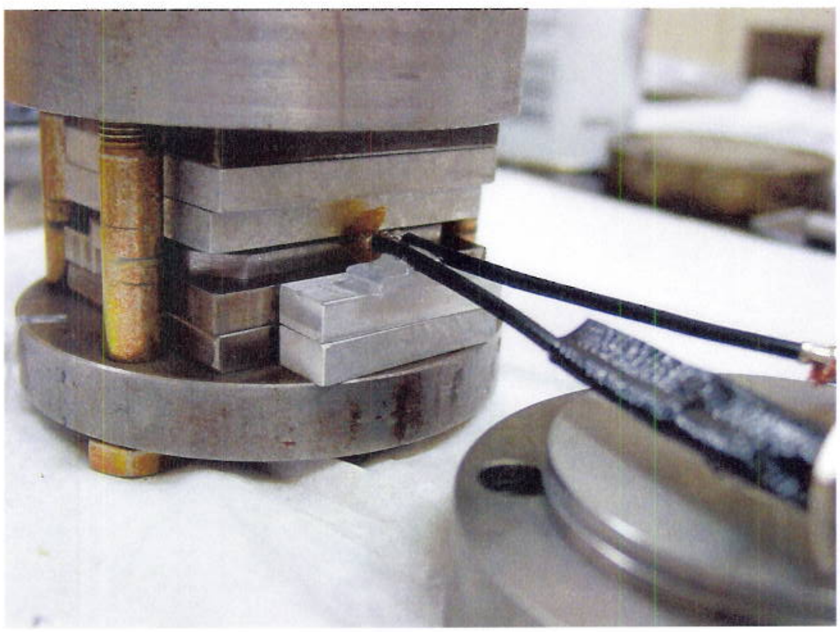

Figure 7. Experiment #1 assembly as fired. Note the direct connection of the coax (no "bug") to the trimmed manganin gauge leads.

As seen in figure 8, the gauge seems to indicate pressure from the double stacked LX-16 pellets at approximately 220 kbar (the peak of the red graph line at 25.2 us). Evaluation of manganin gauge data, generally speaking, and in its simplest form, is basically the application of ohm's law. As pressure is applied to the gauge, the resistance value changes (V=IR) causing a change in voltage. The actual transfer functions applied to the data are a bit more complicated than this and their application varies based on where on the rise in voltage (red graph line fig. 8) occurs. Zero to something less than 0.2 volts (from base line) has a linear function applied and

0.2 volts to the peak has a polynomial function applied. Data following the peak has yet another function applied to it (Vandersall [2]).

The apparent pressure seen in figure 8 does *not* agree with earlier pressure measurements via the PDV diagnostic system. That system has measured pressures in the 340 kbar region for a doubled LX-16 pellet system.

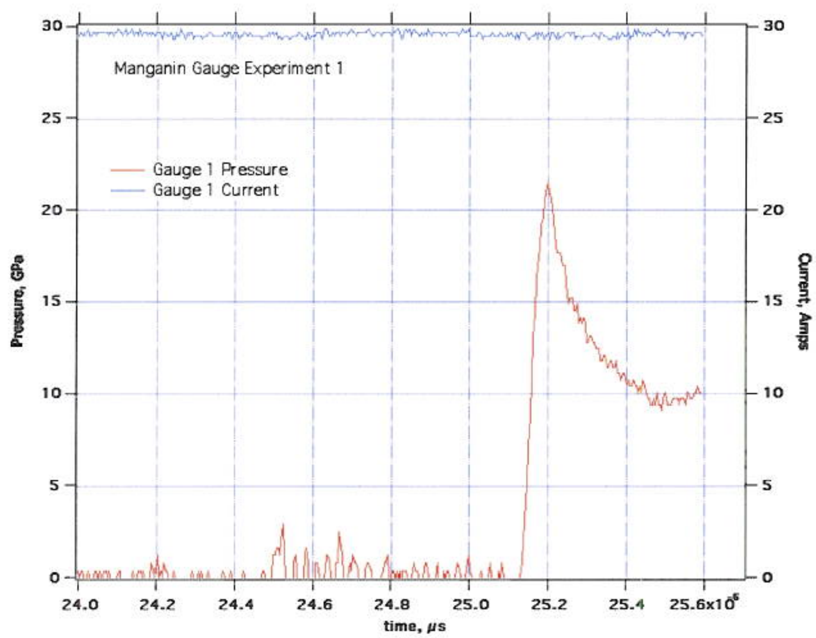

Figure 8. Experiment #1 reduced shot data. Noise can be seen starting at 24.5 us. The pressure recorded by the this gauge indicates 22 GPa (220 kbar)

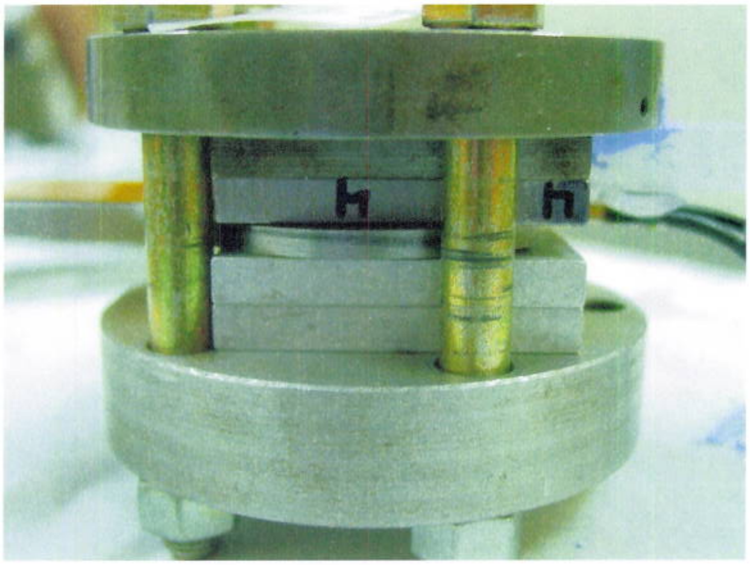

Figure 9. Experiment #4 assembly with two 0.28" thick (each) aluminum plates above the gauge.

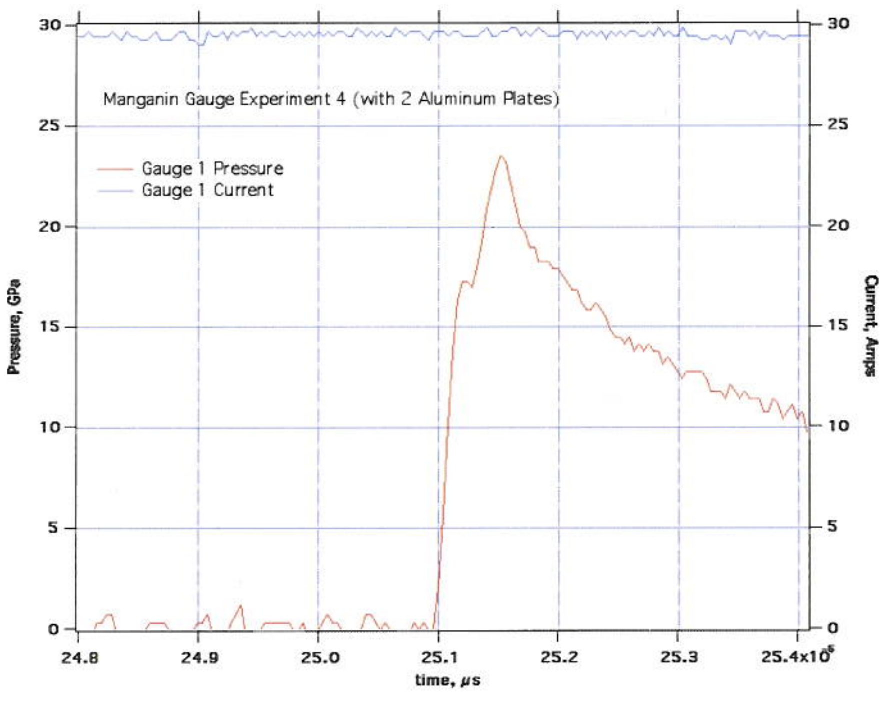

Figure 10. Experiment #4 (Identical configuration to experiment #1 - with two aluminum plates above the gauge) reduced data. The pressure recorded by this gauge indicates approximately 23.5 GPa (235 kbar). Note the cusp at approximately 17 Gpa - believed to be caused by shock reflections.

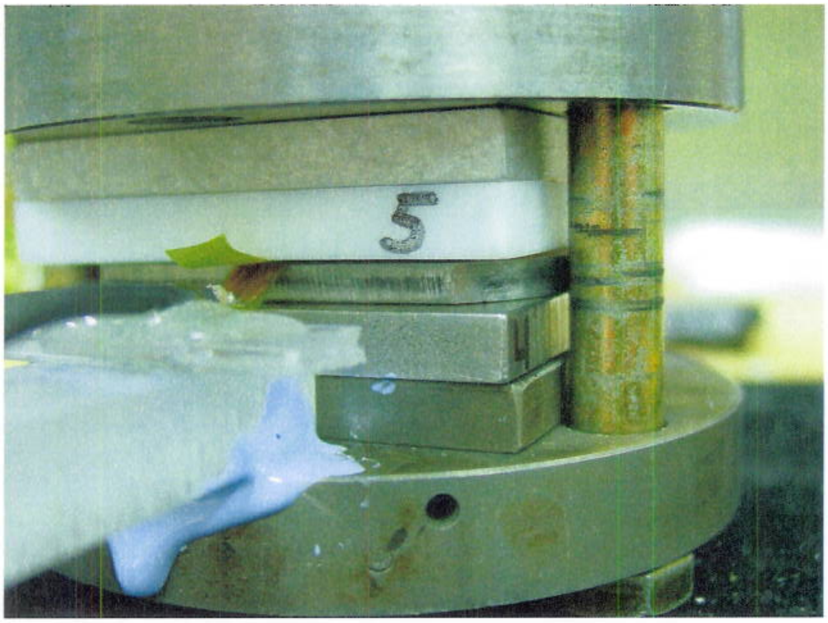

Figure 11. Experiment # 5 with one 0.266 inch thick Teflon and one 0.280 inch aluminum plate above the manganin gauge.

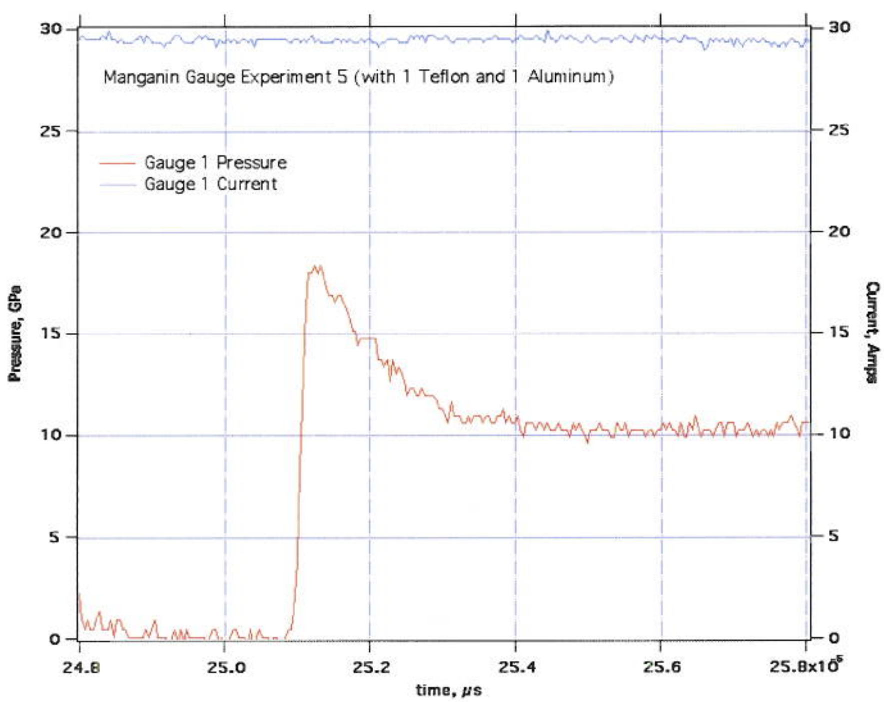

Figure 12. Experiment # 5 reduced data. Apparent peak pressure at approximately 18 GPa.

5. REFERENCES

[1] H.C Vantine, L.M. Erickson, J.M. Janzen, Hysteresis-corrected calibration of manganin under shock loading, Lawrence Livermore National Laboratory, 1979.
[2] K. Vandersall, *private communication*, Lawrence Livermore National Laboratory, 2008.

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