MARIBO Containment Data Report

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MARIBO Instrumentation Summary

Instrumentation	Fielded	Data Return	Present in this Report
<u>Plug Emplacement</u>	yes	yes	yes
<u>Radiation</u>	yes	yes	yes
<u>Pressure</u>			
Stemming	yes	yes	yes
Challenge	yes	yes	yes
Cavity	no	-	-
Atmospheric	no	-	-
<u>Motion</u>			
Free field	no	-	-
Surface	yes	yes	yes
Plug	yes	yes	yes
Stemming	yes	yes	yes
Surface casing	yes	yes	yes
Emplacement pipe	yes	yes	yes
Recording trailer	yes	yes	yes
<u>Hydroyield^(a)</u>	yes	yes	no
<u>Collapse^(b)</u>	yes	yes	yes
<u>Stress</u>	yes	yes	yes
<u>Strain^(c)</u>	yes	yes	no
<u>Other Measurements^(d)</u>	yes	yes	yes

- (a) CLIPER/CORRTEX in emplacement hole.
(b) CLIPER measurement in emplacement hole.
(c) Emplacement pipe and instrumentation pendant load.
(d) Gauge development of stress & strain transducers.

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1. Event Description

1.1 Containment summary

The MARIBO event was detonated in hole U2cs of the Nevada Test Site (figure 1.1). Detonation time was 6:03 PM PST on June 26, 1985 and evidence of a subsurface subsidence to below the top plug was observed about 76.3 minutes later. No radiation due to the detonation of MARIBO was detected above ground at any time.

Containment of the MARIBO event was satisfactory.

1.2 Site.

A magnified geologic map showing some of the surface features near the U2cs site is shown in Figure 1.2. The device had a burial depth of 361 m in Area 2 tuffs about 200 m above the static water level (SWL), as shown in the geologic cross sections of figure 1.3⁽¹⁾.

Stemming of the 2.44 m diameter emplacement hole followed the plan shown in figure 1.4. A log of the stemming operations was maintained by Holmes & Narver⁽²⁾.

1.3 Instrumentation

Figure 1.5 is a schematic layout of the instrumentation in hole U2cs, designed to monitor the stemming emplacement procedures and performance on the MARIBO event.

For quality assurance during emplacement, each of the three gypsum filled aggregate (GFA) plugs was monitored with arrays of conductivity probes and thermistors.

The coarse stemming below each of the five plugs was instrumented with pressure and radiation stations. A pair of stations was mounted on a section of gas sample hose to monitor the pressure challenging the bottom plug. There was no instrumentation in the stemming above the top GFA plug.

Vertical motion was monitored in the stemming at the each of the standard pressure and radiation stations, in the top pressure and radiation station on the section of gas sample hose, in the top two GFA plugs, on the surface casing, on the top of the emplacement pipe, and at 0.61 m depth in the ground surface, 15.24 m from SGZ. During stemming, the acceleration channel at station 36 (below the third GFA plug) was lost suggesting possible problems with that station. Triaxial motion of the recording trailer was also monitored. Relative displacement of the top plug and the surface casing was monitored by a set of proximity switches mounted in the plug next to the bottom of the casing.

Data from each of the transducers above (with the exception of the sensitive pressure stations) were transmitted to the recording trailer by an analog system and recorded on magnetic tape.

Hydrodynamic yield of the device and cavity subsidence was monitored by an EXCOR/CORRTEX cable (labeled "CLIPER/CORRTEX" in figure 1.5) fielded in the emplacement hole. Results of the hydrodynamic yield measurements are reported elsewhere⁽³⁾.

A brief history of the fielding operations of the instrumentation (including the emplacement pipe strain measurements) is given in reference 4. Further details of the instrumentation are given in reference 5.

Figure 1.1 Map of the Nevada Test Site indicating the location of hole U2cs.

Figure 1.2 Geologic Map of the region near hole U2cs.

Figure 1.3 Geologic cross section through hole U2cs.

Figure 1.4 As-built stemming plan for hole U2cs.

Figure 1.5 As-built containment instrumentation plan for the MARIBO event emplacement hole U2cs.

2. Emplacement

2.1 Plug levels and temperature

Emplacement of each of the three GFA plugs was monitored with an array of conductivity probes and thermistors. The locations of the probes are tabulated in figure 1.5. Figure 2.1 shows plots of the GFA emplacement history. Open circles indicate the upper and lower boundary positions of the plugs as measured with tag lines while solid circles indicate the positions of the probe stations and the times at which the conductivity probes were activated. The contact times for probe C in plug 1 and probe B in plug 5 are fictional: only the probe elevation is accurate. Those probes which included temperature sensors are noted in each figure caption. Curing temperature histories are not available.

All plugs were emplaced as planned.

Figure 2.1 Emplacement histories of the three GFA plugs. The upper and lower plug boundaries were calculated or determined with a tag line (open circle). Solid symbols indicate the probe elevations and shaded symbols represent only the elevations of non-reporting probes; the contact times are fictitious. Probe C included a temperature sensor on the deepest plug and probes B included temperature sensors for both shallower plugs.

3. Stemming Performance

3.1 Radiation and Pressure

All pressure and radiation data are consistent with satisfactory containment.

As indicated in Figure 1.5, the region around each of the five stemming plugs was monitored by pressure and/or radiation stations, as was the ground surface, 15.24 m from SGZ. Signals from these stations were transmitted to the recording trailer in analog form and recorded on magnetic tape.

Pressure and radiation histories, from a few seconds before detonation until 80 minutes after detonation (collapse was at about 76 minutes) or until recording was terminated (at about 3.6 hours) are displayed in Figures 3.1–3.7.

Pressure challenging the deepest GFA plug was monitored at stations 31 and 33 (figures 3.1 and 3.3) were mounted at different positions on the same section of gas sample hose extending through the deepest GFA plug to the coarse stemming below it. Station 31 was located in the plug, 2.1 m above its bottom while station 33 was at the top of the hose, in the coarse stemming 36.4 m above the top of the plug. These two wave forms are approximately the same except for a slight difference in amplitude and the increase in pressure just before collapse at station 33. This increase may be due to stretching of the gas sample hose caused by motion of the stemming material around it. (If this conclusion and the data from stations 31 and 33 are correct, then the GSH was closed to the outside environment with some blockage between these stations)

The character of the pressure and radiation records from station 36 (figure 3.6) tend to cast doubt on the data from this station. Station 37 (figure 3.7, below the top plug) was the only station to survive past collapse time (about 76 minutes) and the pressure and radiation are shown to a time of 220 minutes.

No radiation was seen in the coarse stemming before collapse at about 76 minutes and station 37 (figure 3.7, below the top plug) indicates a stemming fall and some slight radiation arrival at collapse.

Figure 3.1 Pressure challenging the deepest GFA plug (station 31 at 325 m depth, within the plug). Data originate from a location at a depth of 334 m, below the deepest GFA plug. Signal was terminated by collapse at about 76 minutes after detonation.

Figure 3.2 Pressure and radiation measured in the coarse stemming above the deepest GFA plug (station 32 at 292 m depth). Signals were terminated by collapse at about 76 minutes after detonation.

Figure 3.3 Pressure challenging the deepest GFA plug (station 33 at 276 m depth, within the coarse stemming above the plug). Data originate from a location at a depth of 334 m, below the deepest GFA plug. Signal was terminated by collapse at about 76 minutes after detonation.

Figure 3.4 Pressure and radiation measured in the coarse stemming below the deepest CT/A gas seal plug (station 34 at 270 m depth). Signals were terminated by collapse at about 76 minutes after detonation.

Figure 3.5 Pressure and radiation measured in the coarse stemming above the deepest CT/A gas seal plug (station 35 at 239 m depth). Signals were terminated by collapse at about 76 minutes after detonation.

Figure 3.6 Pressure and radiation measured in the coarse stemming below the fourth (GFA) plug (station 36 at 125 m depth). Signals were terminated by collapse at about 76 minutes after detonation. These data are suspect both because of their wave forms and the fact that the accelerometer at this location (within the instrumentation canister) was lost during stemming.

Figure 3.7 Pressure and radiation measured in the coarse stemming below the top (GFA) plug (station 37 at 45 m depth). Note that this station survived the collapse at about 76 minutes after detonation. Radiation at about 3 times background is seen immediately after collapse.

3.2 Motion

Characteristics of the motion and of the motion transducers are given in tables 3.1–3.3.

Vertical acceleration of the stemming was monitored at each of the pressure and radiation stations (except the deepest, station 31). The top two GFA plugs, the surface casing, the top of the emplacement pipe, and the ground surface, at a depth of 0.91 m and a horizontal range of 15.24 m from SGZ, were instrumented for vertical acceleration and velocity. Explosion-induced data derived from these stations are shown in figures 3.8–3.17. Wave forms of triaxial motion of the recording trailer are shown in figures 3.18–3.20.

Station 33 was mounted to the top of a section of gas sample hose, a relatively competent member, thus the motion recorded there (figure 3.9) is not necessarily that of the surrounding stemming. The accelerometer at station 35 (above the deepest CT/A gas seal plug) malfunctioned and the resulting record is shown for completeness (figure 3.11). The accelerometer at station 36 was lost during stemming and was not recorded. Comparing the data from stations 21, 37, and 23 (figures 12, 13, and 15) it would appear that the calibration of the accelerator of station 22 (figure 14) is low by about a factor of 2.

A geophone and sensitive accelerometer were fielded 0.91 m deep in the ground surface near the recording trailer (station 70). Data from these instruments are seen in figure 3.21. Although the acceleration exceeds the dynamic ranges of both instruments, the accelerometer yielded useful information.

Table 3.1 Summary of Motion

Gauge	Slant Range (m)	Arrival Time (ms)	Acceleration Peak (g)	Velocity Peak (m/s)	Displacement Peak (mm)	Displacement Resid. (mm)
32av	88.6	38	12.5	6.1	500	120(a)
33av	105	48	4.4	0.90	160	100
34av	111.2	40	4.5	0.62	95	-160(a)
35av(b)	141.6					
37av	336.4	95, 167	1.0	0.23, 0.38	41	-60(a)
21av	265.2	68, 127	2.05	0.26	29	-20
21uv	-	-	-	0.34	38	-35
22av(e)	346	171	0.8, 6.6(c)	0.28	32	-60
22uv	-	-	-	0.48	56	-35
23av	381	100,190(b)	1.5(b), 4.7(c)	0.38	50	(f)
23uv	-	-	-	0.40	52	-20
24av	382	99	9(d), 5.5(c)	0.33	41	-50(a)
24uv	-	-	-	0.40	51	-35
61av	381.3	203	2.0, 15.4(c)	0.36	45	23
61uv	-	-	-	0.48	56	-30
71ar(g)	426	247	(f)	-0.21, 0.20	-42	-95
71ur(g)	-	-	-	-0.25(d), 0.30(d)	-48	-48
71at	426	232	(f)	0.17	20	-10
71ut	-	-	-	0.18	24	-15
71av	426	232	3.5	0.80	70	-23
71uv	-	-	-	1.25	57	-60

(a) Approximate.

(b) Gauge malfunctioned.

(c) Slap-down peak.

(d) Noisy - value questionable

(e) Calibration may be a factor 2 too low.

(f) Can not estimate.

(g) Polarity appears reversed.

Table 3.2 Accelerometer Characteristics

Gauge	Natural Frequency (Hz)	Damping Ratio	System Range (g's)
32av	(a)	(a)	625
33av	(a)	(a)	625
34av	(a)	(a)	625
35av	(a)	(a)	250
36av	(a)	(a)	62.5
37av	(a)	(a)	62.5
21av	185	0.75	10
22av	276	0.75	20
23av	272	0.75	20
24av	800	0.56	100
61av	560	0.63	50
71ar	235	0.75	4
71at	240	0.70	4
71av	230	0.75	4

(a) Manufacturer's specifications are: natural frequency > 2000 Hz; damping ratio unspecified.
Gauges are Endevco 2260 or 2262, depending on range.

Table 3.3 Velocimeter Characteristics

Gauge	Natural Frequency (Hz)	Time to 0.5 Amplitude (s)	Calibration Temperature (°C)	Operate Temperature (°C)	System Range (m/s)
21uv	3.319	9.89	25.53		6
22uv	3.519	8.18	26.04		8
23uv	3.518	11.40	25.24		30
24uv	3.545	9.16	25.69		8
61uv	3.445	11.02	25.67		8
71ur	4.711	10.72	25.77		3
71ut	4.835	10.58	26.89		3
71uv	2.999	17.82	23.99		3

Figure 3.8 Explosion-induced vertical motion in the coarse stemming of the emplacement hole at a depth of 292 m (station 32, above the deepest GFA plug).

Figure 3.9 Explosion-induced vertical motion of the top of the section of gas sample hose used to measure challenge pressure (station 33 at a depth of 276 m). Motion station was about 35 m above the bottom GFA plug.

Figure 3.10 Explosion-induced vertical motion of the coarse stemming below the deepest CT/A gas seal plug (station 34 at a depth of 270 m).

Figure 3.11 Explosion-induced vertical motion measured in the coarse stemming above the deepest CT/A gas seal plug (station 35 at a depth of 239 m). This gauge apparently malfunctioned and the resulting data are shown for completeness.

Figure 3.12 Explosion-induced vertical motion of the fourth (GFA) plug (station 21 at a depth of 116 m). Traces annotated with "a" are derived from the accelerometer.

Figure 3.13 Explosion-induced vertical motion of the coarse stemming below the top (GFA) plug (station 37 at a depth of 45 m).

Figure 3.14 Explosion-induced vertical motion of the top (GFA) plug (station 22 at a depth of 36 m). Traces annotated with "a" are derived from the accelerometer. The calibration of the accelerometer may be in error by a factor of 2.

Figure 3.15 Explosion-induced vertical motion of the top of the surface casing (station 23).
Traces annotated with "a" are derived from the accelerometer.

Figure 3.16 Explosion-induced vertical motion of the top of the emplacement pipe (station 24).
Traces annotated with "a" are derived from the accelerometer.

Figure 3.17 Explosion-induced vertical motion of the ground surface near the emplacement hole (station 61 at a depth of 0.91 m and a horizontal range of 15.2 m). Traces annotated with "a" are derived from the accelerometer.

Figure 3.18 Explosion-induced vertical motion of the recording trailer. Traces annotated with "a" are derived from the accelerometer.

Figure 3.19 Explosion-induced horizontal-radial motion of the recording trailer. Traces annotated with "a" are derived from the accelerometer.

Figure 3.20 Explosion-induced horizontal-transverse motion of the recording trailer. Traces annotated with "a" are derived from the accelerometer.

Figure 3.21 The first ten seconds of vertical data from a geophone and sensitive accelerometer placed in the ground surface near the recording trailer (station 70). The amplitude of the geophone is given in digitizer units since this sensor went substantially beyond its dynamic range. Since the accelerometer also went beyond its dynamic range, no further processing of this unit was deemed useful. The records during the collapse phase are also presented.

3.3 Collapse Phenomena

Collapse-induced motion detected in the emplacement hole is shown in figures 3.22-3.30. At only stations 33, 21, and 37 (figures 3.23, 3.26, and 3.27) were the data of sufficient quality to allow a second integration to displacement and station 37 (figure 3.27) required such an extensive amount of manipulation that the displacement is not to be believed. The top GFA plug, the surface casing and the emplacement pipe showed no motion during the subsurface collapse as evidenced by figures 3.28, 3.29, and 3.30. As is shown, the motion data from these three locations were not processed beyond digitization except for the collapse acceleration data captured at station 22 (figure 3.28) which were reduced to engineering units.

The progression of the collapse as taken from the loss-times of the pressure and motion gauges is shown in figure 3.31. Included are a few pressure records showing the usual pressure drop just before signal loss.

Pressure and radiation measured at station 37 during a ten minute interval around collapse are shown in figure 3.32 (see figure 3.7 for the full recording time). Shortly after 76 minutes, the pressure undergoes a drop characteristic of a stemming fall in a competent emplacement hole. The pressure then partially recovers and slowly approaches ambient, presumably due to diffusion from the surrounding formation. At the same time as the pressure drop there is a rise in the radiation to about 3 times background. The radiation stays at this level for about 3.5 minutes and then begins a slow decay toward background. A 30 second interval covering this collapse indication is shown in figure 3.33 along with the acceleration record from the same station..

Loss of signal at station 21 (in the GFA plug 4 at a depth of 116 m) and the suggestion that the surrounding formation at station 37 (at a depth of 45 m) was still competent after collapse places the upper limit of the chimney collapse between these two locations. Also, since station 37 showed only slight collapse motion (the motion at station 37 was not seen by the geophone, figure 3.21), the top plug was probably not challenged by the collapse and likely was not required to be a stemming platform.

A vertical array of seven proximity switches was mounted in the top GFA plug at the bottom edge of the surface casing to detect relative motion of the plug and casing. None of the switches changed state at any time indicating that no relative motion occurred between the top GFA plug and the surface casing.

Figure 3.22 Collapse-induced vertical motion in the coarse stemming of the emplacement hole at a depth of 292 m (station 32, above the deepest GFA plug). Displacement was not derived because of the high noise level in the acceleration signal.

Figure 3.23 Collapse-induced vertical motion of the top of the section of gas sample hose used to measure challenge pressure (station 33 at a depth of 276 m). Motion station was about 35 m above the bottom GFA plug.

Figure 3.24 Collapse-induced vertical motion of the coarse stemming below the deepest CT/A gas seal plug (station 34 at a depth of 270 m). Displacement was not derived because of the high noise level in the acceleration signal.

Figure 3.25 Collapse-induced vertical motion measured in the coarse stemming above the deepest CT/A gas seal plug (station 35 at a depth of 239 m). Although this gauge apparently malfunctioned, the time of signal loss due to collapse is available.

Figure 3.26 Collapse-induced vertical motion of the fourth (GFA) plug (station 21 at a depth of 116 m). Traces annotated with "a" are derived from the accelerometer.

Figure 3.27 Collapse-induced vertical motion of the coarse stemming below the top (GFA) plug (station 37 at a depth of 45 m). A significant amount of manipulation of the base line was required to obtain an integral of the acceleration. The shown displacement is not to be believed.

Figure 3.28 Collapse-induced vertical motion of the top (GFA) plug (station 22 at a depth of 36 m). Only the acceleration was reduced to engineering units during the collapse period. No motion was detectable.

Figure 3.29 Collapse-induced vertical motion of the top of the surface casing (station 23). No motion was detectable.

Figure 3.30 Collapse-induced vertical motion of the top of the emplacement pipe (station 24).
No motion was detectable.

Figure 3.31 Progression of the chimney collapse as indicated by the loss of signal from the pressure and motion transducers. Motion signal loss is indicated by filled diamonds, pressure collapse indication is represented by (connected) circles. Also included are the pressure histories from three stations (34, 35 and 37) showing that the pressure dropped before the signals were lost on those stations that did not survive. (Station 37 survived collapse).

Figure 3.32 Pressure and radiation measured in the coarse stemming below the top GFA plug (station 37 at a depth of 45 m). A 10 minute period including the collapse episode is shown.

Figure 3.33 Pressure and radiation measured in the coarse stemming below the top GFA plug (station 37 at a depth of 45 m). A 30 second period including the beginning of the collapse episode is shown. Also shown is the acceleration measured at the same location.

4. Other Measurements

4.1 Stress and strain within the bottom two plugs.

As part of a continuing effort to develop a bi-axial in-situ stress gauge⁽⁶⁾, a set of five transducers were fielded in the bottom two plugs on MARIBO. Two different parameters were investigated: the first was the matrix material in which the active elements were imbedded and the second was the electronic coupling to the transmission line. Each gauge consisted of an active element mounted on kapton film embedded in a fluid cavity. The elements were interlaced grids of Ytterbium and Constantan oriented in both the radial and transverse directions with respect to the explosive source. For stations 53 and 55 the cavity was constructed of a flattened copper tube while stations 1, 2, and 3 had cavities of fiber glass-epoxy composite. Stations 1 and 53 had two-arm completion elements within the gauge themselves, thus allowing each gauge output to be transmitted via multiplex circuitry.

Outputs from the five stations are seen in figures 4.1 - 4.5. Amplitudes are presented as percent of resistance change.

Figure 4.1 Stress and strain measured at a depth of 316.93 m within the bottom GFA plug (station 1). Fiber glass encased cavity and two-arm bridge completion within gauge.

Figure 4.2 Stress and strain measured at a depth of 316.93 m within the bottom GFA plug (station 53). Copper encased cavity and two-arm bridge completion within gauge.

Figure 4.3 Stress and strain measured at a depth of 313.94 m within the bottom GFA plug (station 2). Fiber glass encased cavity.

Figure 4.4 Stress and strain measured at a depth of 313.94 m within the bottom GFA plug (station 55). Copper encased cavity.

Figure 4.5 Stress and strain measured at a depth of 245.36 m within the bottom CT/A gas seal plug (station 3). Fiber glass encased cavity.

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