ARMADA Containment Data Report

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ARMADA Instrumentation Summary

Instrumentation	Fielded on this Event	Data Return	Present in this Report
<u>Plug Emplacement</u>	yes	yes	yes(a)
<u>Radiation</u>	yes	yes	yes
<u>Pressure</u>			
Stemming	yes	yes	yes
Challenge	no	-	-
Cavity	no	-	-
Atmospheric	no	-	-
<u>Motion</u>			
Free Field	no	-	-
Surface	yes	yes	yes
Plug	yes	yes	yes
Stemming	no	-	-
Surface Casing(b)	yes	yes	yes
Emplacement Pipe(b)	yes	yes	yes
<u>Hydroyield (c)</u>	yes	yes	no
<u>Collapse (d)</u>	yes	no	-
<u>Stress</u>	no	-	-
<u>Strain(e)</u>	yes	yes	no
<u>Other Measurements</u>	no	-	-

- (a) Description only.
(b) Extensometer between element and stemming.
(c) CORTEX and/or SLIFER in emplacement hole.
(d) EXCOR or CLIPER in emplacement hole.
(e) Strain load on emplacement pipe.

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Contents

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1. Event Description

1.1 Site

The ARMADA event was detonated in hole U9cs of the Nevada Test Site as indicated in figure 1.1. The ARMADA device had a depth-of-burial (DOB) of 265 m in the Paintbrush Tuff of area 9, about 400 m above the Paleozoic formation and 310 m above the standing water level, as shown in the geologic cross-sections of figures 1.2 and 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⁾.

Detonation time was 05:53 PDT on April 22, 1983, and collapse progressed to the surface at about 0.4 hour after detonation. The resulting crater had a mean radius of 72.9 m and a maximum depth of 7.7 m

No radiation arrivals were detected above ground and the ARMADA containment was considered successful.

1.2 Instrumentation

Figure 1.5 is a schematic layout of the instrumentation designed to monitor the stemming performance of the ARMADA event.

Eleven stations were fielded in the stemming to measure pressure and radiation of which six monitored a new foam cable fanout (FFO) design at two elevations. At each elevation above and below the FFO one station was mounted on the emplacement pipe with two stations hung on the instrumentation pendant; one near the hole wall and one near the cable bundle. The horizontal separation of the two was about 0.22 m and the pendant was on a bracket and horizontally offset from the emplacement pipe about 0.93 m. No attempt was made to orient the pendant: the position of the gauges with respect to the emplacement pipe is unknown. The radiation monitor in each of these stations was fitted with lead shielding/collimation to insure that only stemming radiation was detected. Two stations were fielded on either side of the bottom plug, two across the fines layer at a depth of about 74 m and one station below the top plug.

Standard LLNL vertical motion canisters, containing variable reluctance velocity and acceleration transducers, were emplaced in both of the stemming plugs as well as the ground surface, 15.42 m from SGZ. The performance of the standard LLNL motion system was compared with that of two stations supplied by LANL, each including a multiplexed pair of piezoresistive accelerometers. The LANL stations were installed in the plugs at the same elevations as the LLNL stations.

Displacement transducers (reel-type extensometers) were mounted between the surface casing and the backfill above the top plug, between the surface casing and the top plug, and between the emplacement pipe and the backfill above the top plug to obtain a direct measure of the relative motion between these elements.

Data from each of the above instruments were transmitted to the recording trailer by an analog system and recorded on magnetic tape.

One CLIPER/CORTEX sensor, attached to the device canister and emplacement pipe was fielded to estimate device yield and to monitor cavity collapse and chimney formation. Results of the yield measurement are reported elsewhere⁽³⁾. A "D-cable" was fielded to monitor the stemming emplacement and was recorded post-shot to sense collapse.

A history of the fielding operations of the instrumentation is outlined in reference 4. Details of the instrumentation are given in reference 5.

1.3. Emplacement

Both of the stemming plugs above the ARMADA event were composed of rigid two-part-epoxy (TPE). The top plug was about 4.6 m thick while the bottom was about 3.1 m thick. A soft (about 1.8 m thick) layer of coal-tar and aggregate (LAE 59MY, denoted CTA) was poured on the top plug to act as a gas seal. Stemming between the plugs consisted of layers of fines and coarse gravel. The top of the hole (above the top plug) was filled with ground surface derived backfill and the inside of the emplacement pipe was grouted to a depth of 142 m and then filled with overton sand. See figure 1.4.

During stemming the top pressure and radiation station was lost as was the accelerometer associated with the standard LLNL motion instrumentation in the bottom plug. Neither of these two will be reported.

Figure 1.1 Map of the Nevada Test Site indicating the location of hole U9cs.

Figure 1.3 North-South geologic cross section through hole U9cs.

DOWNHOLE WT. — 614.0K(566K)
STEMMED WT. — 955.0K(874K)

ARMADA — U9cs

Figure 1.4 As-built stemming plan for the event ARMADA in Hole U9cs.

Figure 1.5 As-built containment instrumentation plan for the emplacement hole (U9cs) on the ARMADA event.

2. Stemming Performance

2.1 Radiation and Pressure

Pressure and radiation stations were fielded on the ARMADA at eleven locations as indicated in figure 1.5. Station 41, below the top plug was lost during stemming and is not reported: stations 31 and 34 (mounted on the emplacement pipe) were lost shortly after detonation and are also not reported. The surviving measurements are shown in figures 2.1-2.8.

Pressures measured on both sides of the FFO (figures 2.1-2.4) showed an early peak of about 3 psi above ambient. At stations 32 and 33, below the FFO, this peak dropped quickly by about 1 psi and held for about 40 s. It then decayed to about 0.5 psi above ambient at the time of collapse, when the station signals were lost. Above the FFO the pressure peak decayed monotonically to near ambient at collapse time. Pressure behavior at all the other stations is explainable by ground motion.

Above the fanout (stations 35 and 36, figures 2.3 and 2.4) the radiation wave forms are identical in magnitude and shape. This indicates that both stations were in the same radiation field. There is a suggestion of a second radiation arrival at about 200 s. Below the FFO the wave forms are nearly the same in shape but of quite different magnitudes, suggesting that the two stations sensed the radiation as shine from a localized source. Furthermore, the maximum radiation magnitude below the FFO is at least a factor of four less than that above the fanout.

At station 37, below the bottom plug (figure 2.5), there was only a brief shock-induced pressure change, but radiation arrivals were recorded with a wave form that mimicked that of the lower stations but with a much reduced magnitude and a second arrival superimposed. Table 2.1 lists the arrivals at each elevation.

Table 2.1 Radiation arrivals

station	elevation (m)	arrival (s)
33, 33	180	42
35, 36	167	44.5, 200
37	140	52, 550

No radiation arrival was detected above the bottom plug before collapse, when all radiation signals were lost (figures 2.6-2.8). The radiation data are consistent with satisfactory containment.

2.2 Motion

Explosion-induced histories of the motion measured on the ARMADA event are shown in figures 2.9–2.12. Characteristics of the associated motion and transducers are given in tables 2.2–2.4.

The standard variable reluctance accelerometer at station 21 was disconnected pre-shot as it was causing considerable electrical system interference. Figure 2.9 is a composite of all the explosion-induced motion data measured at stations 21 and 22 (in the bottom plug at a depth of 132.6 m). Figure 2.10 shows the motion data measured at the standard LLNL station 23 in the top plug while figure 2.11 displays the motion of the top plug as measured by LANL station 24. Also included for comparison in this figure are the velocity and displacement of the top plug derived from the LLNL accelerometer at station 23.

The motion of the ground surface is shown in figure 2.12. The peak acceleration at "slap-down" exceeded the system limits of 20 g's for a brief time and was extrapolated to about 50 g's by augmenting the truncated as-recorded peak by a triangular pulse that brought the integral (velocity) to the zero base-line at late time.

Comparison of the two measurement systems is shown in greater detail in figure 2.13 where one second of all of the velocity data (measured and derived) from both plugs are plotted. A high noise level in the velocimeter record of the bottom plug (station 21) precludes a meaningful comparison of the standard LLNL motion transducers to the piezoresistive accelerometers. However, it is seen from the top plug (stations 23 and 24) that the Piezoresistive accelerometer data are consistently lower than the variable reluctance data (both the velocimeter and accelerometer data are shown to overlay each other).

The displacement wave forms output by the extensometers at the top of the emplacement hole are shown in figure 2.14. Station 1, mounted between the emplacement pipe and the top of the stemming suggests that the pipe had about a 50 cm upward excursion with respect to the stemming, induced by the detonation. This is followed by a permanent downward offset of about 10 cm with respect to the stemming within 5 s.

Comparing station 2 (the relative motion of the surface casing and top plug) with station 3 (the relative displacement of the surface casing and the top of the stemming) suggest that the detonation induces the top plug to settle out of the casing by about 30 cm while the top of the stemming drops about 40 cm, further suggesting that the bond between the plug and the casing was compromised. The greater excursion of the stemming transducer is consistent with slight shock-induced compaction of the loose stemming material above the top plug.

2.3 Collapse phenomena

Collapse-induced histories of the motion measured on the ARMADA event are shown in figures 2.15–2.18. Collapse reached the ground surface 1430 s after detonation with slap-down occurring about 1.3 s later. All of the acceleration data of station 22 and the velocity data of station 21 are shown in figure 2.15. The velocity exceeded the 8 m/s system limit on station 23 (figure 2.16) and all the acceleration transducers in the top plug are represented in figure 2.17.

The collapse motion of the ground surface is shown in figure 2.18. The peak acceleration at collapse exceeded the system limits of 20 g's for a brief time and the same procedure applied used for the "slap-down" was applied to the collapse acceleration history.

The displacement wave forms output during collapse by the extensometers at the top of the emplacement hole are shown in figure 2.14. The data suggest that the top plug ended about 2 m below its initial position relative to the surface casing.

CLIPER available indicate that the sensor cable broke at a depth of about 11 m within 1.5 s after detonation with no further activity during the period before collapse. D-cable information is not in a form that is usable to investigate the progression of the cavity collapse.

Figure 2.1 Pressure and radiation measured in the coarse stemming below the bottom cable fan-out and near the hole wall (station 32 at a depth of 180.4 m).

Figure 2.2 Pressure and radiation measured in the coarse stemming below the bottom cable fan-out, near the emplacement pipe and separated horizontally 0.22 m from station32, (station 33 at a depth of 180.4 m).

Figure 2.3 Pressure and radiation measured in the coarse stemming above the bottom cable fan-out and near the hole wall (station 35 at a depth of 167 m).

Figure 2.4 Pressure and radiation measured in the coarse stemming above the bottom cable fan-out and toward the emplacement pipe (station 36 at a depth of 167 m).

Figure 2.5 Pressure and radiation measured in the coarse stemming below the bottom plug (station 37 at a depth of 140 m).

Figure 2.6 Pressure and radiation measured in the coarse stemming above the bottom plug (station 38 at a depth of 111 m).

Figure 2.7 Pressure and radiation measured in the coarse stemming at a depth of 92 m (station 39).

Figure 2.8 Pressure and radiation measured in the coarse stemming at a depth of 56 m (station 40).

Figure 2.9 Explosion-induced vertical motion of the bottom plug (stations 21 and 22) The accelerometer normally associated with station 21 was missing so all accelerometer-derived information came from station 22.

Figure 2.10 Explosion-induced vertical motion of the top plug (station 23) The traces annotated with "a" are derived from the acceleration while the velocimeter-derived signals are shown as heavy traces.

Figure 2.11 Explosion-induced vertical motion of the top plug (stations 23 and 24). The velocity and displacement plots include the acceleration-derived information from both stations 23 and 24 for comparison; the acceleration plot includes only the two accelerometers of station 24.

Figure 2.12 Explosion-induced vertical motion of the ground surface at a depth of .9 m and horizontal range of 15.24 m (station 61). The traces annotated with "a" are derived from the acceleration while the velocimeter-derived signals are shown as heavy traces.

Figure 2.13 One second of comparison of the Variable reluctance motion transducers used by LLNL to the piezoresistive accelerometers used by LANL. Stations 21 and 23 comprise the LLNL transducers while the LANL transducers are represented by stations 22 and 24. There was no accelerometer at station 21 and the measured and derived velocity data from station 23 overlay each other.

Figure 2.14 Extensometer readings from stations 1, 2, and 3.

Figure 2.15 Collapse-induced vertical motion of the bottom plug (stations 21 and 22) The accelerometer normally associated with station 21 was missing so all accelerometer-derived information came from station 22. Both accelerometers of station 22 are represented

Figure 2.16 Collapse-induced vertical motion of the top plug (station 23) The traces annotated with "a" are derived from the acceleration while the velocimeter-derived signals are shown as heavy traces.

Figure 2.17 Collapse-induced vertical motion of the top plug (stations 23 and 24). The velocity and displacement plots include the acceleration-derived information from both stations 23 and 24 for comparison; the acceleration plot includes only the two accelerometers of station 24.

Figure 2.18 Collapse-induced vertical motion of the ground surface at a depth of .9 m and horizontal range of 15.24 m (station 61). The traces annotated with "a" are derived from the acceleration while the velocimeter-derived signals are shown as heavy traces.

Table 2.2 Summary of Containment-Related Motion

Gauge	Slant Range (m)	Arrival Time (ms)	Acceleration Peak (g)	Velocity Peak (m/s)	Displacement Peak (cm)	Displacement Residual (cm)
21uv	132.5	82	-	1.63	22.6	11
22ava	132.5	30(a), 78	6.8	0.60(b), 1.31	18.2	10.5
22avb	132.5	30(a), 77	6.7	0.62(b), 1.40	18.8	11.5
23av	230.7	52(a), 148	1.6, 4.1(c)	1.15	19.8	0.5
23uv	230.7	-	-	1.13	19.0	-2.0
24ava	230.7	51(a), 148	1.23, 3.0(c)	0.90	15.2	-1.5
24avb	230.7	50(a), 148	1.30, 2.9(c)	0.94	15.8	-1.5
61av	265	188	3, 7, 51(c,d)	1.21	20.5	-3(e)
61uv	265	190	-	1.3(e)	20.5	-3.0

(a) Pipe-induced motion.

(b) Precursor .

(c) Slap down.

(d) Extrapolated.

(e) Extremely noisy.

Table 2.3   Containment-Related Accelerometer Characteristics

<u>Gauge</u>	<u>Natural Frequency (Hz)</u>	<u>Damping Ratio</u>	<u>System Range (g's)</u>
22ava	550	.71	10
22avb	800	.71	10
23av	420	0.65	15
24ava	500	0.71	10
24avb	250	0.71	10
61av	400	0.65	20

Table 2.4   Containment-Related Velocimeter Characteristics

<u>Gauge</u>	<u>Natural Frequency (Hz)</u>	<u>Time to 0.5 Amplitude (s)</u>	<u>Calibration Temperature (°F)</u>	<u>Operate Temperature (°F)</u>	<u>System Range (m/s)</u>
21uv	3.544	9.68	25,24	45.28	6.0
23uv	3.43	9.46	24.19	50.62	6.0
61uv	3.515	8.95	24.55	10.41	8.0

References

1. Nancy Howard, "U9cs Preliminary Site Characteristics Summary", DM 82-66, Lawrence Livermore National Laboratory, Livermore, CA, November 22, 1982.
2. George Kronsbein, "Containment Report for U9cs," Holmes & Narver, NTS:A2:83-39, April 21, 1983.
3. LLNL contacts for additional information: R. A. Heinle (CORTEX and SLIFER data)
4. William G. Webb, "Special Measurements Final Engineering Report ARMADA, U9cs", EG&G, Energy Measurements, Las Vegas, NV, SM:823E-105-19, 5 April, 1983.
5. William G. Webb, "Special Measurements Physics/Instrumentation Package for ARMADA, U9cs, , Revision 'A' ", EG&G, Energy Measurements, Las Vegas, NV, SM:83E-105-18, 15 May, 1983.

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