MANTECA Containment Data Report

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MANTECA 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	-	-
Emplacement Pipe	yes	yes	yes
<u>Motion</u>			
Free Field	no	-	-
Surface	yes	yes	yes
Plug	yes	yes	yes
Stemming	yes	yes	yes
Surface Casing	no	-	-
Emplacement Pipe	yes	yes	yes
<u>Hydrofield (b)</u>	yes	yes	no
<u>Collapse (c)</u>	yes	yes	yes
<u>Stress</u>	no	-	-
<u>Strain(d)</u>	yes	yes	no
<u>Other Measurements</u>	no	-	-

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

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1. Event Description

1.1 Site

The MANTECA event was detonated in hole U4a1 of the Nevada Test Site as indicated in figure 1.1. The MANTECA device had a depth-of-burial (DOB) of 412 m in the alluvium of area 4, about 320 m above the Paleozoic formation and 120 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 07:20 PST on December 10, 1982, and collapse progressed to the surface at about 1.1 hour after detonation. The resulting crater had a mean radius of 82.2 m and a maximum depth of 14.1 m

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

1.2. Emplacement

Part of the device diagnostics of the MANTECA experiment was a mechanical neutron Pinex fielded within the emplacement pipe. This required that the emplacement pipe be left open except for a series of pressure barriers between the region of the bottom rigid plug (the formation-coupling plug) and the pinhole. The emplacement pipe was suspended from a break-away beam (to assure alignment of the enclosed neutron Pinex experiment) and held in place by explosive bolts. These bolts were detonated shortly after the execution of the MANTECA event. A section of the top of the pipe, enlarged to accommodate the mechanism required to recover the Pinex detector, it was removed from the pipe to a position outside of the potential collapse crater shortly after the experiment. The pipe below this region was closed by a ball valve to preclude gas leakage up the pipe.

The top three stemming plugs above the MANTECA event were composed of rigid two-part- epoxy (TPE) These plugs were about 7 m thick except for the middle which was about 3 m thick. A soft (about 1.8 m thick) layer of coal-tar and aggregate (LAE 59MY, denoted CTA) was poured on the top of each of the rigid plugs to act as a gas seal. A drag ring was mounted to the emplacement pipe at the position of the bottom rigid plug (below the position of the Pinex detector) and the emplacement pipe was coated with hydroseal in the regions of the upper two plugs to allow free motion of the pipe. 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 except for the top 3 m which was left open. See figure 1.4.

1.3 Instrumentation

A description of the containment instrumentation and its purpose is given in reference 3. Figure 1.5 is a schematic layout of the instrumentation designed to monitor the stemming performance of the MANTECA event. The wire-line pendant supporting the containment-related instrumentation and cables was hung from a bracket on the top of the emplacement pipe and offset from the pipe by about 0.7 m.

Fifteen stations were fielded in the stemming to monitor pressure and radiation. Two groups of three stations were fielded to define the horizontal distribution of gas flow in the stemming column, midway between each of the two bottom plugs. The stemming in the regions surrounding each of the trios was fines material and the cables (both device diagnostics and containment instrumentation) were fanned out through this region to reduce the possibility of open gas flow paths. One member of each trio was mounted on the emplacement pipe within the device diagnostics cable bundle. The remaining two were hung on the containment instrumentation pendant with one of the pair within the containment instrumentation cable bundle and the remaining member in the stemming material outside the bundle. No attempt was made to orient the pendant: it is thus unknown which of the two stations was the closer to the emplacement pipe. The radiation monitor in each of these stations was fitted with lead shielding/collimation to reduce the radiation from sources other than the stemming. Pressure and radiation stations spanned all of the plugs but the top, beneath which was a single station. Two additional stations were fielded in the stemming at the approximate elevations of the intermediate pressure domes in the emplacement pipe between the pin hole and the neutron detector.

The internal gas pressure and temperature of each of the four sealed sections of the emplacement pipe was monitored just below the corresponding pressure dome defining the section. Pressure and radiation inside the emplacement pipe was monitored near the top of the pipe midway between the top plug and the ground surface.

Motion of the emplacement pipe was monitored at each of the four pressure and temperature stations, at the location of the neutron detector plate and on the top of the pipe below the ball valve

Standard LLNL vertical motion canisters, containing variable reluctance velocity and acceleration transducers, were emplaced in all three of the rigid stemming plugs, the ground surface, 15.24 m from SGZ, and on the top of the emplacement pipe. An additional pair of motion stations spanned the bottom CTA plug.

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

Two CLIPER/CORTEX sensors, one attached to the emplacement pipe and one to the instrumentation pendant, were fielded to estimate device yield and to monitor cavity collapse and chimney formation. Results of the yield measurement are reported elsewhere⁽⁴⁾. A "D-cable" was fielded on the instrumentation pendant to monitor the stemming emplacement and was recorded post-shot to sense collapse.

After emplacement, but before stemming, it was found that station 21 (in the deepest rigid plug) was compromising the trailer electronics and it was decided to disconnect this station.

A history of the fielding operations of the instrumentation is outlined in reference 5. Details of the instrumentation are given in reference 6.

Figure 1.1 Map of the Nevada Test Site indicating the location of hole U4al.

Figure 1.2 East-West geologic cross section through hole U4a1.

2. Stemming Performance

2.1 Radiation and Pressure

Pressure and radiation stations were fielded on the MANTECA at fifteen locations as indicated in figure 1.5. Wave forms of the data recorded at these locations between a few seconds before detonation of MANETCA to 1000 s, shortly after collapse at 9830 s are shown in figures 2.1-2.15.

Early time structure (the first 300 seconds) of the wave forms of pressure and radiation measured at station 32 are shown in figure 2.16. An immediate arrival of both pressure and radiation is evident with a second arrival of radiation at about 60 s. Referring back to figure 2.1, a third radiation arrival might be inferred prior to 1000 s. The radiation measured at station 33, (figure 2.2) above the soft, gas seal plug, is low and does not show the early arrival but does show arrivals at about 300 s and prior to 1000 s seen at station 32. A significant, decaying pressure difference was maintained across the soft plug as seen in figure 2.17 suggesting that the gas seal plug operated as expected. The pressure wave form of station 34 (figure 2.3) is the same as that of station 33 but the change is about a factor of 3 less in magnitude. Radiation measured at station 34 has nearly the same peak as that at station 32, but with only one arrival at about 600 s.

Cable fan-outs, both on the emplacement pipe and the wire line pendant were located in a fines layer of stemming centered at a depth of about 256 m. A trio of pressure and radiation stations was fielded in this region with one station in the pipe cable fan-out, banded to the pipe and the other two hung on the pendant with one station in the pendant fan-out and the other outside the pendant fan-out. It is unknown which of this pair was closer to the emplacement pipe. Figures 2.4 - 2.6 show the data received from this trio. Radiation measured at station 51 (figure 2.4) shows an immediate arrival, probably shine from the emplacement pipe, another at about 500 s with a third at around 4000 s with a greater magnitude than that seen at station 32. Station 52 shows a radiation arrival between 2000 and 2500 s. A radiation arrival at around 2200 s is observed at station 53 (figure 2.6) and an earlier arrival is suggested around 1000 s. At the station at the elevation just below the upper intermediate pressure dome in the emplacement pipe (station 35, figure 2.7), radiation is seen to arrive at about 8800 s, just prior to collapse. Radiation was not detected at any station above this elevation.

The radiation data in figures 2.2 - 2.8 suggest that there was a path of radiation flow that bypassed the elevation of station 33, entering the stemming column at or just below the region of the fines layer containing the lower cable fan-out. It is suspected that the path was the emplacement pipe, implying loss of at least the first two pressure domes. The pipe was constrained by drag plates in the deepest rigid plug (the formation coupling plug) and was expected to fail below that containment element.

Pressure wave forms from all standard pressure and radiation stations above the formation coupling plug at a depth of about 190 m can be explained as resulting from ground motion (figures 2.9-2.15). However, the long time that the pressure takes to decay for stations 54 and 56 at 152 m depth (figures 2.10 and 2.12) is unexplained. These stations were two members of a trio of pressure and radiation stations fielded at this elevation with one station (station 55) banded to the pipe and the other two hung on the pendant with one station in the pendant fan-out and the other outside the pendant fan-out. It is unknown which of this pair was closer to the emplacement pipe.

No radiation arrival was detected above the formation coupling plug before collapse, when all radiation signals were lost (at about 9830 s). This includes station 12, mounted to sense radiation and pressure within the top of the emplacement pipe (figure 3.5) The radiation data are consistent with satisfactory containment.

Figure 2.1 Pressure and radiation measured in the coarse stemming below the soft plug and 0.3 m below the elevation of the pin hole (station 32 at a depth of 321.0 m).

Figure 2.2 Pressure and radiation measured in the coarse stemming above the soft plug and 19.5 m above the elevation of the pin hole (station 33 at a depth of 310.3 m).

Figure 2.3 Pressure and radiation measured in the coarse stemming at the elevation of the first intermediate pressure dome in the emplacement pipe (station 34 at a depth of 277.7 m).

Figure 2.4 Pressure and radiation measured in fines stemming midway between the soft plug and the deepest rigid plug (station 51 at a depth of 256.0 m). This shielded station was strapped to the emplacement pipe inside of the associated cable bundle.

Figure 2.5 Pressure and radiation measured in fines stemming midway between the soft plug and the deepest rigid plug (station 52 at a depth of 256.0 m). This shielded station was hung on the pendant and mounted inside of the associated cable bundle.

Figure 2.6 Pressure and radiation measured in fines stemming midway between the soft plug and the deepest rigid plug (station 53 at a depth of 256.0 m). This shielded station was hung on the pendant and mounted outside of the associated cable bundle.

Figure 2.7 Pressure and radiation measured in the coarse stemming at the elevation of the second intermediate pressure dome in the emplacement pipe (station 35 at a depth of 234.4 m).

Figure 2.8 Pressure and radiation measured in the coarse stemming below the deepest rigid plug (station 36 at a depth of 201.2 m).

Figure 2.9 Pressure and radiation measured in the coarse stemming above the deepest rigid plug (station 37 at a depth of 179.8 m).

Figure 2.10 Pressure and radiation measured in fines stemming midway between the deepest rigid plug and the middle rigid plug (station 54 at a depth of 152.5 m). This shielded station was strapped to the emplacement pipe inside of the associated cable bundle.

Figure 2.11 Pressure and radiation measured in fines stemming midway between the deepest rigid plug and the middle rigid plug (station 55 at a depth of 152.5 m). This shielded station was hung on the pendant and mounted inside of the associated cable bundle.

Figure 2.12 Pressure and radiation measured in fines stemming midway between the deepest rigid plug and the middle rigid plug (station 56 at a depth of 152.5 m). This shielded station was hung on the pendant and mounted outside of the associated cable bundle.

Figure 2.13 Pressure and radiation measured in the coarse stemming below the middle rigid plug (station 38 at a depth of 121.9 m).

Figure 2.14 Pressure and radiation measured in the coarse stemming above the middle rigid plug (station 39 at a depth of 100.6 m).

Figure 2.15 Pressure and radiation measured in the coarse stemming below the top plug (station 40 at a depth of 49.0 m).

Figure 2.16 The first 300 s of pressure and radiation measured in the coarse stemming below the soft plug and 0.3 m below the elevation of the pin hole (station 32 at a depth of 321.0 m).

Figure 2.17 Pressure difference maintained across the soft plug.

2.2 Motion

Explosion-induced histories of the motion measured in the stemming column and on the ground surface during the MANTECA event are shown in figures 2.18–2.23. Characteristics of the associated motion and transducers are given in tables 2.1–2.3.

The data are unremarkable except that the accelerometer and velocity gauges for stations 24 and 25 yielded velocity magnitudes that had a discrepancy of about a factor of 1.5. The source of this discrepancy remains unknown.

Figure 2.18 Explosion-induced vertical motion of the stemming below the soft plug (station 21 at a depth of 319.4 m). The traces annotated with "a" are derived from the acceleration while the velocimeter-derived signals are shown as heavy traces.

Figure 2.19 Explosion-induced vertical motion of the stemming above the soft plug (station 22 at a depth of 310.3 m). The traces annotated with "a" are derived from the acceleration while the velocimeter-derived signals are shown as heavy traces.

Figure 2.20 Explosion-induced vertical motion of the bottom rigid plug (station 23 at a depth of 192.0 m). The traces annotated with "a" are derived from the acceleration while the velocimeter-derived signals are shown as heavy traces. This plug incorporated a drag plate, coupling the emplacement pipe to the formation.

Figure 2.21 Explosion-induced vertical motion of the middle rigid plug (station 24). The traces annotated with "a" are derived from the acceleration while the velocimeter-derived signals are shown as heavy traces.

Figure 2.22 Explosion-induced vertical motion of the top plug (station 25 at a depth of 35.8 m). The traces annotated with "a" are derived from the acceleration while the velocimeter-derived signals are shown as heavy traces.

Figure 2.23 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.

2.3 Collapse phenomena

Collapse-induced histories of the motion measured in the stemming column on the MANTECA event are shown in figures 2.24–2.29. Collapse reached the ground surface about 9830 s after detonation with slap-down occurring about 1.5 s later.

Peak acceleration at collapse of the ground surface exceeded the 40 g system limits for a brief time as shown in figure 2.29. The integral of the acceleration (velocity) was shifted during this brief time period to bring the subsequent history to the zero base-line at late time. The acceleration slap-down signal at station 25 also exceeded the 15 g system limits (figure 2.28) and the same data manipulation was applied. At both stations, the system limits were also exceeded for the velocimeters. An estimate of the collapse displacement was obtained by extending the velocity on the same slope the wave form had just prior to truncation to the time at which the acceleration indicates the "fall" should terminate. Shaded traces in figures 2.28 and 2.29 are the results of these extrapolations: they are not reported in table 2.2.

Progression of the collapse is shown in figure 2.30 by the depth of the broken end of the CLIPER cables and representative histories of displacement derived from the motion gauges in the emplacement hole. CLIPER station 91 was mounted on the emplacement pipe while station 92 was mounted with the containment instrumentation pendant. D-cable information is not in a form that is usable to investigate the progression of the cavity collapse.

U4al

acceleration not available

Figure 2.24 Collapse-induced vertical motion of the stemming below the soft plug (station 21 at a depth of 319.4 m). The explosion-induced signal damaged the accelerometer at this station.

Figure 2.25 Collapse-induced vertical motion of the stemming above the soft plug (station 22 at a depth of 310.3 m). The traces annotated with "a" are derived from the acceleration while the velocimeter-derived signals are shown as heavy traces.

Figure 2.26 Collapse-induced vertical motion of the bottom rigid plug (station 23 at a depth of 192.0 m). The traces annotated with "a" are derived from the acceleration while the velocimeter-derived signals are shown as heavy traces. This plug incorporated a drag plate, coupling the emplacement pipe to the formation.

Figure 2.27 Collapse-induced vertical motion of the middle rigid plug (station 24). The traces annotated with "a" are derived from the acceleration while the velocimeter-derived signals are shown as heavy traces.

Figure 2.28 Collapse-induced vertical motion of the top plug (station 25 at a depth of 35.8 m). The traces annotated with "a" are derived from the acceleration while the velocimeter-derived signals are shown as heavy traces. The faint trace is the result of the extrapolation of the velocimeter record during the time it was out-of-band, as explained in the text.

Figure 2.29 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. The faint trace is the result of the extrapolation of the velocimeter record during the time it was out-of-band, as explained in the text.

Figure 2.30 Progression of collapse as shown by the position of the break in the CLIPER cables. Station 91 was attached to the device canister and the emplacement pipe while station 92 (heavy trace) was on the instrumentation pendant. Also shown are representative displacement traces derived from the motion stations. Station 25 survived collapse, presumably because it was protected by the surface casing and the data from station 21 are omitted for clarity.

Table 2.1 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)
13av	414	135	6, -11	0.1, -7.7, 0.9	-54, 9.7	-2
13uv		-	-	0.1, -9.1, 0.66	-65, 102	3
21av	92.6	35, 100	220	3(a), 27	440	(b)
21uv		-	-	2(a), 26	420	350
22av	101.7	40, 105	105	23.3	400	440
22uv		-	-	20.0	330	280
23av	220	50, 105	5.4	0.7, 7(c)	24	5
23uv		-	-	0.75	23	5
24av	297.7	150	2.3	0.50	16	-4
24uv		-	-	0.31	10	-1
25av	376.2	210	1.3, 0.68(d)	0.74	16	0.5
25uv		-	-	0.52	11	-2
61av	413	248	2.6, 1.8(d)	0.90	10	3.5
61uv		-	-	1.02	14	0

(a) Precursor.

(b) Could not estimate.

(c) Noise interference: either explosive release of strong-back or pipe interaction.

(d) Slap-down.

Table 2.2 Containment-Related Accelerometer Characteristics

Gauge	Natural Frequency (Hz)	Damping Ratio	System Range (g's)
13av	350	0.75	8
21av	1575	0.65	400
22av	(a)	(a)	400
23av	402	0.75	15
24av	255	0.65	4.5
25av	350	0.60	15
61av	590	0.65	40

(a) Not available.

Table 2.3 Containment-Related Velocimeter Characteristics

Gauge	Natural Frequency (Hz)	Time to 0.5 Amplitude (s)	Calibration Temperature (°C)	Operate Temperature (°C)	System Range (m/s)
13uv	3.424	9.63	24.30	4.12	5
21uv	3.789	26.42	24.16	19.02	50
22uv	3.783	27.95	23.21	20.59	50
23uv	3.624	9.32	24.22	36.48	10
24uv	3.494	10.08	24.13	52.68	10
25uv	3.618	8.29	24.46	46.07	5
61uv	3.754	6.70	24.32	8.20	10

3. Emplacement Pipe Measurements

A mechanical neutron Pinex experiment was fielded as part of the device diagnostics on MANTECA and the line-of-sight was included in the bottom sections of the emplacement pipe. The detector was fielded above the bottom rigid stemming plug and mechanically recovered shortly after the experiment by pulling it up to a recovery section at the top of the pipe, which was then detached and transported to a location beyond the potential crater area. To afford a greater probability of recovery, the emplacement pipe was coupled to the formation at the bottom rigid plug by incorporating large drag rings within the plug thus ensuring that the pipe (and detector) moved with the medium at that elevation. The pipe was "greased" with hydroseal in the regions of the two rigid plugs at higher elevations to allow free motion within these members. As a result of the drag rings, it was not expected that the pipe below the coupling plug would survive. Below the coupling plug effort was made to prevent cavity gasses from flowing up the emplacement pipe while keeping the line-of-sight open to neutrons. This effort included a series of three pressure domes separating the pipe into four regions below the coupling plug. Locations just below each of the top of each of the pipe sections were instrumented with transducers that monitored motion, pressure and temperature within the pipe. It was the intent to observe the gas flow within the pipe (if it existed) and the motion of the pipe near the pressure domes to detect pipe failure.

3.1 Pressure, Temperature and Radiation

Figures 3.1 - 3.4 show the pressure and temperature history of the gas within the emplacement pipe. Only the bottom two sections indicate the presence of gas. The pressure at station 6 (figure 3.1), which is initially open to the cavity, appears to suggest failure at about 120 ms while the temperature transducer continues to read until almost 200 ms. Gas pressure and temperature at station 8, the lowest intermediate pressure dome (figure 3.2) remain at a low level while the station appears to fail at about 200 ms. The remaining stations monitoring pressure and temperature in the pipe below the detector plate (figures 3.3 and 3.4) sensed no pressure change except for a brief drop-out at around 0.7 s. If there was a failure of the emplacement pipe these data suggest it occurred below the second intermediate pressure dome at an elevation of 234 m. Figure 3.5 shows the pressure and radiation detected within the emplacement pipe at its top. No radiation was detected within the pipe at any time and the pressure jumped about 0.5 psi at detonation time and stayed at that level for about 6000 s and then slowly decayed toward ambient

Figure 3.1 Pressure and temperature measured in the emplacement pipe below the Tau can (station 6 at an elevation of 325.28 m). This is in the evacuated section between the device canister and the pin hole.

Figure 3.2 Pressure and temperature measured in the emplacement pipe 1.65 m below the first intermediate pressure dome (station 8 at an elevation of 279.35 m). This is in the first evacuated section above the pin hole.

Figure 3.3 Pressure and temperature measured in the emplacement pipe 1.65 m below the second intermediate pressure dome (station 9 at an elevation of 236.07 m). This is in the second evacuated section above the pin hole.

Figure 3.4 Pressure and temperature measured in the emplacement pipe 1.65 m below the third intermediate pressure dome (station 10 at an elevation of 191.57 m). This is in the third evacuated section above the pin hole and above the drag rings on the pipe.

Figure 3.5 Pressure and radiation measured in the emplacement pipe just below the ground surface (station 12 at an elevation of 15.3 m). This was placed in the region of the back-fill to protect it from the detonation of the explosive bolts holding the break-away beams at experiment time and the detachment of the Pinex recovery equipment a few minutes later.

3.2 Shock Motion

Explosion-induced vertical motion histories of the emplacement pipe are shown in figures 3.6–3.12. Characteristics of the associated motion and transducers are given in tables 2.1–2.3. Note that on the acceleration records of stations 6, 7, 8 and 9 (figures 3.6 - 3.9) the first motion is downward, but propagating outward at a speed around 4.7 km/s, the propagation speed commonly seen in the steel of the emplacement pipe. A composite of the acceleration obtained from these four stations below the coupling plug is shown in figure 3.13.

The record from station 6 (below the Tau can) is probably not believable much beyond 30 ms while the integrated accelerometer and velocimeter records from stations 7 and 8 yield internally consistent wave forms for times up to 120 ms. Loss of signal from stations 6, 7, and 8 suggest that the pipe was damaged in the region below station 9, at the second intermediate pressure dome. This is consistent with the stemming radiation data discussed in section 2.

All stations above an elevation of 277 m survived until collapse although acceleration records from stations 9, 10, and 11 appear suspect. The data from stations 10 and 11 (figures 3.10 and 3.11, both associated with the formation coupling plug) showed wave forms of motion consistent with that of the plug (station 23, figure 2.20).

The emplacement pipe was held in place during and after stemming by a break-away beam. Tension on the pipe was released when explosive bolts holding the pipe to the beam were ignited at about 135 ms after detonation of the MANTECA device. Station 13, mounted on a flange near the top of the emplacement pipe, shows an initial downward motion (figure 3.12) which was probably caused by this release of tension in the pipe.

Figure 3.6 Explosion-induced motion of the emplacement pipe measured below the Tau can (station 6 at an elevation of 325.28 m). The velocimeter-derived signals are shown as heavy traces.

Figure 3.7 Explosion-induced motion of the emplacement pipe measured 12 cm below the pin hole (station 7 at an elevation of 320.74 m). The velocimeter-derived signals are shown as heavy traces.

Figure 3.8 Explosion-induced motion of the emplacement pipe measured 1.65 m below the first intermediate pressure dome (station 8 at an elevation of 279.35 m). The velocimeter-derived signals are shown as heavy traces.

Figure 3.9 Explosion-induced motion of the emplacement pipe measured 1.65 m below the second intermediate pressure dome (station 9 at an elevation of 236.07 m). The velocimeter-derived signals are shown as heavy traces.

Figure 3.10 Explosion-induced motion of the emplacement pipe measured 1.65 m below the third intermediate pressure dome (station 10 at an elevation of 191.57 m). The velocimeter-derived signals are shown as heavy traces. The defective accelerometer record is shown for completeness.

Figure 3.11 Explosion-induced motion of the emplacement pipe measured on the pressure plate (detector) coupling (station 11 at an elevation of 184.13 m). The velocimeter-derived signals are shown as heavy traces. The defective accelerometer record is shown for completeness.

Figure 3.12 Explosion-induced motion of the emplacement pipe measured 2.13 m above the ground surface and below the ball valve (station 13). The velocimeter-derived signals are shown as heavy traces.

Figure 3.13 Composite plot of the first 50 ms of emplacement pipe acceleration measured at the four stations below the formation coupling plug. The first motion is toward the source (downward) and propagating outward at about 4.7 km/s.

3.3 Collapse phenomena

Collapse signals retrieved from the motion stations on the emplacement pipe are shown in figure 3.14 - 3.18. Although station 8 was thought to have been lost about 120 ms after detonation, the accelerometer channel reported a signal at collapse time which is shown in figure 3.14. The accelerometer data from stations 9 and 10 (figures 3.15 and 3.16) could not be meaningfully integrated.

Station 13 (figure 3.18) shows the collapse motion of the top of the pipe. Both the accelerometer and the velocimeter were driven beyond their respective system limits, however, comparison of the velocity history as derived from the velocimeter with the integral of the acceleration suggests that the velocimeter was only slightly over ranged so the displacement history derived from the velocimeter is a good approximation.

Comparison the displacement history of the top of the pipe with that of the formation coupling plug (station 23) and the top plug (station 25) suggests that the pipe began falling with the coupling plug, halted briefly and completed its fall with the top plug. See figure 3.19. this suggests that the pipe remained intact above the coupling plug.

Figure 3.14 Collapse-induced motion of the emplacement pipe measured 1.65 m below the first intermediate pressure dome (station 8 at an elevation of 279.35 m).

Figure 3.15 Collapse-induced motion of the emplacement pipe measured 1.65 m below the second intermediate pressure dome (station 9 at an elevation of 236.07 m). Acceleration data were not integrated; displacement history is derived from the velocimeter.

Figure 3.16 Collapse-induced motion of the emplacement pipe measured 1.65 m below the third intermediate pressure dome (station 10 at an elevation of 191.57 m). Acceleration data were not integrated; displacement history is derived from the velocimeter.

Figure 3.17 Collapse-induced motion of the emplacement pipe measured on the detector pressure plate coupling (station 11 at an elevation of 184.13 m). The velocimeter-derived signals are shown as heavy traces.

Figure 3.18 Collapse-induced motion of the emplacement pipe measured 2.13 m above the ground surface and below the ball valve (station 13). The velocimeter-derived signals are shown as heavy traces.

Figure 3.19 Displacement history of the top of the emplacement pipe compared with that of the top plug and the formation coupling plug.

Table 3.1 Summary of Emplacement Pipe Motion

Gauge	Slant Range (m)	Arrival Time (ms)	Acceleration Peak (g)	Velocity Peak (m/s)	Displacement Peak (cm)	Displacement Residual (cm)
6av	86.5	16.5	-910	-6	(a)	(a)
6uv		-	-	4.6	(b)	(b)
7av	91.3	18	-220	-2.6	(a)	(a)
7uv		-	-	-2.3	(a)	(a)
8av	132.6	26.5	-67	-1.1	(a)	(a)
8uv		-	-	-1.1	4	(a)
9av	175.9	35	-18, 148	-0.4, 1.76	20	(b)
9uv		-	-	-0.37, 1.50	20	13
10av	220.4	50	5.9	-13(a)	(c)	(c)
10uv		-	-	0.88	22	2
11av	227.9	52	(d)	-	-	-
11uv		70	-	0.75	20	4
13av	414	135	6, -11	0.1, -7.7, 0.9	-54, 9.7	-2
13uv		-	-	0.1, -9.1, 0.66	-65, 102	3

(a) Signal out-of-band before this value reached.

(b) Extreme noise; signal is out of phase with acceleration integral.

(c) Could not estimate.

(d) Channel appears to be bad.

Table 3.2 Emplacement Pipe Accelerometer Characteristics

Gauge	Natural Frequency (Hz)	Damping Ratio	System Range (g's)
6av	1550	0.57	4000
7av	1540	0.56	4000
8av	1525	0.58	1500
9av	1700	0.62	1000
10av	1675	0.55	600
11av	310	0.65	8
13av	350	0.75	8

Table 3.3 Emplacement Pipe Velocimeter Characteristics

Gauge	Natural Frequency (Hz)	Time to 0.5 Amplitude (s)	Calibration Temperature (°C)	Operate Temperature (°C)	System Range (m/s)
6uv	3.763	36.29	24.01	17.91	60
7uv	3.990	30.38	23.99	18.09	60
8uv	3.464	37.20	24.30	16.33	40
9uv	3.740	27.83	24.28	15.11	24
10uv	3.709	8.03	24.24	46.37	20
11uv	3.587	9.37	24.44	20.23	15
13uv	3.424	9.63	24.30	4.12	5

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