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BORATE

Containment Data Report

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<u>Classification Guide</u>	<u>Topic Number</u>	<u>Subject</u>
COK-88-024	1.5.6	Event announcement
NV-89-18		Event announcement
TCG-WT-1	1113	Contractor identification
TCG-WT-1	1121	Personnel identification
TCG-WT-1	1210	Geology
TVG-WT-1	1260	Crater (map)
TCG-WT-1	1413	Statement concerning venting
TCG-WT-1	1452	Event announcement
TCG-WT-1	1831	Depth of burial
TCG-WT-1	1843	Stemming material, amount,etc
TCG-WT-1	1925	Diagnostic canister dimensions
TCG-WT-1	3542.3	Ground motion
TCG-WT-1	4810	Radiation measurement
TCG-WT-1	4820	Acceleration, pressure, temperature measurement

Event Name: . . . BORATE

Instrumentation	Fielded on this Event	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
Cavity	no	-	-
Atmospheric	yes	yes	yes
<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
<u>Hydroyield (a)</u>	yes	yes	no
<u>Collapse (b)</u>	yes	no	no
<u>Stress</u>	no	-	-
<u>Strain (c)</u>	yes	yes	yes
<u>Other Measurements (d)</u>	yes	yes	no

- (a) CORRTX in emplacement hole.
(b) EXCOR in emplacement hole.
(c) Emplacement pipe.
(d) Thermistors in and near the top plug.

Event Personnel

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1. Event Description

1.1 Site

The BORATE event was detonated in hole U2ge of the Nevada Test Site as indicated in Fig. 1.1. The device had a depth-of-burial of 468 m in the Rainier Mesa Member of the Timber Mountain Tuff, as shown in Fig. 1.2.⁽¹⁾ Note that sixteen other experiments had been conducted within two depths of burial (DoB) of U2ge. Detonation time was 07:00 PST on the morning of October 23, 1987. Collapse reached the ground surface about two hours and 34 minutes later with an asymmetric crater having a mean radius of 105 m and a maximum depth of 26.4 m.

Stemming of the 2.44 m diameter emplacement hole followed the plan shown in Fig. 1.3. A log of the stemming operations was maintained by Holmes & Narver⁽²⁾.

Neither down-hole radiation nor pressure arrivals were detected and containment of BORATE was considered satisfactory.

1.2 Instrumentation

Figure 1.4 is a schematic layout of the instrumentation designed to monitor the emplacement procedures and stemming performance of the BORATE event.

A history of the fielding operations of the instrumentation, including the emplacement pipe strain measurements, is detailed in Reference 3. Details of the instrumentation are given in Reference 3 and 4.

Each of the six sanded gypsum concrete (SGC) plugs was monitored during emplacement with arrays of conductivity probes and thermistors. The coarse stemming beneath each of the SGC plugs (except the deepest) was instrumented for motion, pressure and radiation. Data from each of the transducers in the region of each plug were transmitted up-hole in analog form and recorded on magnetic tape.

Atmospheric pressure was monitored by a sensor mounted inside the recording trailer, ported through the trailer wall. Because the length of recording time (about 3 hours) was too short to register gross weather trends these data are not shown.

An CORTEX/EXCOR cable was emplaced as indicated in Fig. 1.4 to measure the hydrodynamic yield of the device, and monitor cavity collapse and chimney formation. Results of the yield measurements are not reported here.

Motion on this event was monitored at eleven locations, including the five stemming stations. Behavior of the top SGZ plug was monitored with vertical motion stations (acceleration and velocity) within the plug, on the surface casing, and on the emplacement pipe. The ground surface near the trailer held a station containing a geophone and an accelerometer. The recording trailer itself was instrumented for triaxial acceleration and velocity.

Figure 1.1 Map of the Nevada Test Site indicating the location of hole U2ge.

Figure 1.2 Geologic cross section through hole U2ge.

Figure 1.3 As-built stemming plan for hole U2ge.

Figure 1.4 As-built Containment instrumentation plan for the BORATE event.

2. Emplacement

2.1 Pipe strain

The emplacement pipe was equipped with a strain gage located on the final pipe section just below the load collar (Station 87) to monitor pipe load during the emplacement and final stemming operations. Figure 2.1 shows the time dependence of the emplacement pipe load as read from the stemming log⁽²⁾.

2.2 Plug levels and temperature

The emplacement of each of the six SGC plugs was monitored with an array of conductivity probes and thermistors. The locations of each of the components of these arrays are given in Figure 1.4. The upper and lower boundary positions of the plugs were determined by tag lines. Figures 2.2 through 2.7 contain plots of the arrival times of the SGC as a function of depth (as determined from the conductivity probes and tag lines) and SGC temperature as a function of time.

These data indicate that all plugs were emplaced as planned.

Figures 2.1 Strain on the emplacement pipe near its top (Station 87) during the stemming. Points were read from the stemming log⁽²⁾.

Figure 2.2. Emplacement diagnostics data at SGC plug #1. The upper and lower boundaries of the plug were determined with a tag line. Solid symbols indicate the elevation of the probes, the open symbols are at the tag depths. Probes annotated with "T" included a temperature sensor.

Figure 2.3. Emplacement diagnostics data at SGC plug #2. The upper and lower boundaries of the plug were determined with a tag line. Solid symbols indicate the elevation of the probes, the open symbols are at the tag depths. Probes annotated with "T" included a temperature sensor.

Figure 2.4. Emplacement diagnostics data at SGC plug #3. The upper and lower boundaries of the plug were determined with a tag line. Solid symbols indicate the elevation of the probes, the open symbols are at the tag depths. Probes annotated with "T" included a temperature sensor. Lack of identification of the individual temperature histories in the original data precludes labeling them.

Figure 2.5. Emplacement diagnostics data at SGC plug #4. The upper and lower boundaries of the plug were determined with a tag line. Solid symbols indicate the elevation of the probes, the open symbols are at the tag depths. Probes annotated with "T" included a temperature sensor. The dip in temperature at about 24 hours is due to grout poured in the emplacement pipe.

Figure 2.6. Emplacement diagnostics data at SGC plug #5. The upper and lower boundaries of the plug were determined with a tag line. Solid symbols indicate the elevation of the probes, the open symbols are at the tag depths. Probes annotated with "T" included a temperature sensor.

Figure 2.7. Emplacement diagnostics data at SGC plug #6. The upper and lower boundaries of the plug were determined with a tag line. Solid symbols indicate the elevation of the probes, the open symbols are at the tag depths. Probes annotated with "T" included a temperature sensor.

3. Stemming Performance

3.1 Radiation and Pressure

As seen in Fig. 1.4, the region beneath each SGC plug, except the deepest, was monitored by pressure, radiation, and motion sensors. Signals were transmitted to the recording trailer in analog form.

Pressure and radiation histories, from a few seconds before detonation until station failure, are displayed in Figures 3.1 - 3.5. All down-hole stations in the stemming that survived the first few seconds after detonation failed upon collapse at about two hours, thirty four minutes.

Both pressure and radiation channels of Station 33 appear to have been damaged at or near zero time (Figure 3.3). Both pressure and radiation channels of Station 34 appear to have been lost at collapse (Figure 3.4). The radiation channel of Station 35 was damaged during installation and the corresponding pressure channel was lost at collapse (Figure 3.5).

3.2 Motion

Motion of the stemming caused both by the explosion and the subsequent collapse are presented in Figures 3.6 - 3.13. Judging by the character of the records, it is questionable whether Stations 31, 32, and 33 survived beyond the first second after detonation (see Figures 3.1 - 3.3 and 3.6 - 3.9). Arrival times and peaks of the explosion-induced motion are given in Table 3.1 while the characteristics of the transducers employed are given in Tables 3.3 and 3.3.

Motion of the top plug and its environment was monitored by stations in the plug, on the surface conductor, the emplacement pipe, and the ground surface 15.24 m from SGZ. Explosion induced histories are presented in Figures 3.6 - 3.14. Station 21 was not properly weighted and floated in the grout out of vertical orientation. Thus the velocimeter was inoperative and the accelerometer laboratory calibration was not applicable. Engineering units for the acceleration channel were obtained by assuming that the period of "free-fall" was at -1.0 g. Note that the motion of the plug (Station 21), the surface casing (Station 22), and the ground surface (Station 61) were all quite similar. Those traces in Figures 3.11 - 3.14 that are annotated with "a" were derived from the associated accelerometer history.

Figure 3.1 Pressure and radiation data in the coarse stemming below SGC plug #2 (Station 31 at 406 m depth). Both transducers appear to have failed at about 0.1 second.

Figure 3.2 Pressure and radiation measured in the coarse stemming below SGC plug #3 (Station 32 at 325 m depth). The pressure channel appears to have failed at about 0.24 seconds while the radiation transducer is forced out-of-band by the EMP during this time and never recovers.

Figure 3.3 Pressure and radiation signals in the coarse stemming below SGC plug #4 (Station 33 at 244 m depth). Both channels, displayed to post collapse time (9420 s), appear to have been damaged at or near zero-time. The pressure channel shows a trace smoothly dipping below a value of absolute zero, indicating a channel malfunction.

Figure 3.4 Pressure and radiation measured in the coarse stemming below SGC plug #5 (Station 34 at 160 m depth). Both channels were lost at collapse (about 9240 seconds).

Figure 3.5 Pressure and radiation measured in the coarse stemming below the top SGC plug (Station 35 at 45 m depth). The pressure channel was lost at collapse (about 9240 seconds). The radiation channel was damaged during installation.

Figure 3.6 Explosion-induced vertical motion of the stemming below SGC plug #2 (Station 31 at 406 m depth). This channel appears to have been lost at about 0.1 second.

Figure 3.7 Explosion-induced vertical motion of the stemming below SGC plug #3 (Station 32 at 325 m depth). This channel appears to have been lost at about 0.17 second.

Figure 3.8 Explosion-induced vertical motion of the stemming below SGC plug #4 (Station 33 at 244 m depth). This channel appears to have been lost at about 0.25 second.

Figure 3.9 Explosion-induced vertical motion of the stemming below SGC plug #5 (Station 34 at 160 m depth).

Figure 3.10 Explosion-induced vertical motion of the stemming below the top SGC plug (Station 35 at 45 m depth).

Figure 3.11 Explosion-induced vertical motion of the top of the emplacement pipe (Station 1). The traces annotated with "a" are derived from the accelerometer history.

Figure 3.12 Explosion-induced vertical motion of the top SGC plug (Station 21). The data are suspect and should not be used after the initial slap-down. See text.

Figure 3.13 Explosion-induced vertical motion of the surface casing (Station 22). The traces annotated with "a" are derived from the accelerometer history.

Figure 3.14 Explosion-induced vertical motion of the ground surface (Station 61 at 15.24 m from SGZ and .61 m depth). The traces annotated with "a" are derived from the accelerometer history.

3.3 Collapse

Motion induced by the cavity collapse is shown in Figures 3.15-3.21. Station 21 was not properly weighted and floated in the grout out of vertical orientation. Thus the velocimeter was inoperative and the accelerometer laboratory calibration was not applicable. Engineering units for the acceleration channel were obtained by assuming that the period of "free-fall" was at -1.0 g. Note that the motion of the plug (Station 21), the surface casing (Station 22), and the ground surface (Station 61) were all quite similar. Station 33 was lost at about 0.25 second, however, a signal was received on this channel at collapse time and is thus reported in Figure 3.15.

A cavity collapse history may be constructed from the times at which the stemming motion records were lost. This is shown in Figure 3.22. The EXCOR system returned only one datum occurring between 0.1 and 1.0 second after detonation and thus did not provide collapse information.

Figure 3.15 Collapse-induced record from the vertical motion transducers in the stemming below SGC plug #4 (Station 33 at 244 m depth). This channel appears to have been lost at about 0.25 second (Figure 3.8). These data are shown only for completeness. The recording does, however, indicate the time of collapse.

Figure 3.16 Collapse-induced vertical motion of the stemming below SGC plug #5 (Station 34 at 160 m depth).

Figure 3.17 Collapse-induced vertical motion of the stemming below the top SGC plug (Station 35 at 45 m depth).

Figure 3.18 Collapse-induced vertical motion of the top of the emplacement pipe (Station 1). The traces annotated with "a" are derived from the accelerometer history.

Figure 3.19 Collapse-induced vertical motion of the top SGC plug (Station 21). The data are suspect and should not be used after the slap-down. See text.

Figure 3.20 Collapse-induced vertical motion of the surface conductor (Station 22). The traces annotated with "a" are derived from the accelerometer history.

Figure 3.21 Collapse-induced vertical motion of the ground surface (Station 61 at 15.24 m from SGZ and .61 m depth). The traces annotated with "a" are derived from the accelerometer history.

Figure 3.22 Progression of the cavity collapse as constructed from the times at which the motion channels were lost in the stemming. Times are taken from Figures 3.6, 3.7, 3.8, 3.16, and 3.17. Stations 31 - 33 were lost at or near zero time; 34 and 35 were lost as a result of collapse to the surface at 2 hours and 34 minutes after detonation.

Table 3.1 Summary of Motion

Gage	Slant Range (m)	Arrival Time (ms)	Acceleration Peak (g)	Velocity Peak (m/s)	Displacement Peak (cm)	Displacement Resid. (cm)
1av	542.1	155(a)	70	5.18	40, 65(b)	80
1uv	-	-	-	5.22	40, 56(b)	17
21av	510	147(a), 254	0.42, 7.7(c)	1.10	22	(e)
21uv(d)	-	-	-	-	-	-
22av	542	175(a), 274	1.1, 5.3(c)	1.10	19.2	-5
22uv	-	-	-	1.12	19.3	-21
31av	136	26(a), 42	(e)	(e)	(e)	(e)
32av	217	46(a)	6.8	(e)	(e)	(e)
33av	298	66(a), 128	1.8	0.5	(e)	(e)
34av	382	92(a), 180	1.2	0.35, 0.8	11.5	-27
35av	497	141(a), 248	0.75	0.26, 0.78	12.1	-13
61av	542.1	286	1.3, 20(c)	1.14	19.0	-40
61uv	-	-	-	1.42	24.0	-20

(a) Pipe motion-induced arrival.

(b) Pipe and ground motion composite peak.

(c) Slap-down peak.

(d) Gage inoperative due to faulty installation.

(e) Indeterminate value.

Table 3.2 Accelerometer Characteristics

<u>Gage</u>	<u>Natural Frequency (Hz)</u>	<u>Damping Ratio</u>	<u>System Range (g's)</u>
1ava	800	0.65	100
1avb	355	0.75	12
21av	350	0.75	16
22av	280	0.65	16
31av	na	na	250
32av	6440	na	125
33av	na	na	125
34av	na	na	25
35av	na	na	25
61av	350	0.65	16

Table 3.3 Velocimeter Characteristics

<u>Gage</u>	<u>Natural Frequency (Hz)</u>	<u>Time to 0.5 Amplitude (s)</u>	<u>Calibration Temperature (°C)</u>	<u>Operate Temperature (°C)</u>	<u>System Range (m/s)</u>
1uv	3.20	10.03	25.02	10.59	8.0
21uv	3.519	10.05	23.83	31.88	8.0
22uv	3.450	9.95	24.69	11.59	8.0
61uv	3.606	8.04	24.70	15.74	8.0

4. Motion at the Recording Trailer Park

A triaxial acceleration array captured the motion of the recording trailer both during the explosion and subsequent collapse periods.

Histories of the trailer motion are shown in Figures 4.1 through 4.6 and a summary of the arrivals and peak motions is included in Table 4.1. Tables 4.2 and 4.3 give the characteristics of the accelerometers and velocity transducers used in the recording trailer on BORATE.

Another station (Station 62, in the ground surface near the recording trailer) included a geophone & accelerometer with system ranges set too low (0.2 g's) to capture the peaks of the explosion and collapse motion. The data, although recorded and displayed, (Figure 4.7) have not been converted to engineering units.

Figure 4.1 Explosion-induced vertical motion of the recording trailer (Station 71). The traces annotated with "a" are derived from the accelerometer history.

Figure 4.2 Collapse-induced vertical motion of the recording trailer (Station 71). The traces annotated with "a" are derived from the accelerometer history.

Figure 4.3 Explosion-induced horizontal-radial motion of the recording trailer (Station 71). The traces annotated with "a" are derived from the accelerometer history.

Figure 4.4 Collapse-induced horizontal-radial motion of the recording trailer (Station 71). The traces annotated with "a" are derived from the accelerometer history.

Figure 4.5 Explosion-induced horizontal-transverse motion of the recording trailer (Station 71). The traces annotated with "a" are derived form the accelerometer history.

Figure 4.6 Collapse-induced horizontal-transverse motion of the recording trailer (Station 71). The traces annotated with "a" are derived from the accelerometer history.

Figure 4.7 Motion history recorded at the geophone station, (Station 62). The records extend from before detonation to several minutes after collapse. The wave forms were "cleaned up" by low-pass filtering them at 75 Hz. No attempt was made to convert them to engineering units.

Table 4.1 Recording Trailer; Summary of Motion

Gage	Slant Range (m)	Arrival Time (ms)	Acceleration Peak (g)	Velocity Peak (m/s)	Displacement Peak (cm)	Displacement Resid. (cm)
71av	606(a)	327	1.7,6(b)	1.60	29	-40
71uv	-	-	-	1.85	33	-20
71ar	606(a)	333	0.38, 0.95(b)	0.41, 0.96	67	65
71ur	-	-	-	0.49,1.04	56.5	18
71at	606(a)	334	-0.3	-0.11, 0.29	-3.8, 7.3	-8
71ut	-	-	-	-0.15, 0.36	-2.6, 13.7	-5

(a) Station in recording trailer about .5 DoB from SGZ.

(b) Slap-down peak.

Table 4.2 Recording Trailer Accelerometer Characteristics

Gage	Natural Frequency (Hz)	Damping Ratio	System Range (g's)
71av	325	0.65	20
71ar	325	0.65	15
71at	355	0.65	15

Table 4.3 Recording Trailer Velocimeter Characteristics

Gage	Natural Frequency (Hz)	Time to 0.5 Amplitude (s)	Calibration Temperature (°C)	Operate Temperature (°C)	System Range (m/s)
71uv	2.999	23.50	24.24	15.78	7.0
71ur	4.711	11.11	24.43	15.78	5.0
71ut	4.835	11.80	24.88	15.78	5.0

References

1. Steven R. Clark and Larry McKague, "U2ge Site Characteristics Report", CP 87-36, Lawrence Livermore National Laboratory, Livermore, CA, April 14, 1987.
2. Scott. L. Doney, "Containment Report for U2ge", Holmes & Narver, NTS:A2:87-98, October 21, 1987.
3. W. G. Webb, "Special Measurements Physics/Instrumentation for BORATE, U2ge, Revision 'A'", EG&G, Energy Measurements, Las Vegas, NV, SM: 87E-146-25, March 13, 1988.
4. W. G. Webb, "Special Measurements Final Engineering Report, BORATE, U2ge", EG&G, Energy Measurements, Las Vegas, NV, SM:87E-146-24, March 31, 1988.