BRIE Containment Data Report

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BRIE Instrumentation Summary

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

(a) Emplacement pipe; strain converted to load weight.

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1. Event Description

1.1 Containment summary

BRIE was detonated occurred on June 18, 1987, at 08:20 PDT. All phenomena appeared normal with a chimney collapse breaching the ground surface about 17 minutes later. The mean radius of the resulting crater was 54.1 m and its maximum depth was 10.3 m.

No radiation arrivals were detected above ground and containment was satisfactory.

1.2 Site

The third in a series of experiments in close proximity, BRIE was located in hole U10cc in area 10 of the Nevada Test Site (NTS) as shown in figure 1.1. The first experiment (JARLSBERG) was conducted about four years earlier while the second experiment (NORMANNA) was detonated about three years earlier. Figures 1.2 and 1.3⁽¹⁾ are geologic cross sections through hole U10cc. The diameter of the emplacement hole was 2.18 m and the depth-of-burial of 203 m placed the working point in alluvium about 100 m above the Paleozoic contact and nearly 300 m above the static water level.

1.3 Instrumentation

Stemming of the emplacement hole was designed to follow the plan of figure 1.4. No post-shot measurements were taken from the emplacement hole, however, quality assurance systems consisting of conductivity probes and thermistors were fielded in each of the five stemming plugs. These are shown in the instrumentation plan (figure 1.5) where the positions of each of the transducers are tabulated. All of the rigid plugs were composed of gypsum aggregate concrete. Strain gages, bonded to the emplacement pipe, were used to monitor the load on the pipe during emplacement and stemming. A log of the stemming procedures was maintained by Holmes & Narver⁽²⁾.

Hole Ue10aa was instrumented for JARLSBERG with both stress and motion as shown in figure 1.6. The gage stations were emplaced on a fiber glass pipe and the 0.31 m diameter hole was grouted to about 36 m of the surface with the remainder of the hole being plugged with two-part epoxy (TPE). This system was activated for the BRIE event.

A lightning strike, shortly after the satellite hole instrumentation was installed for JARLSBERG destroyed several transducers and possibly damaged others. The only transducers in the satellite hole remaining operational for BRIE (about four years after installation) were the motion gauges. The satellite hole motion channels that were inoperative pre-shot were 41at, 44at, 44ut, 45ur, 46ur, 46at, 47at, 48ur, 49ar, and all of stations 42 and 43. Channel 44ur malfunctioned for unknown reasons. Further details on the installation and operation of the instrumentation are given in reference 3.

The array of six vertical and six triaxial motion stations were placed as shown in figure 1.7 at a depth of 0.61 m in the ground surface. Station locations were dictated by the desire to measure the effects on the surface ground motion of the craters and chimneys produced by JARLSBERG and NORMANNA. "Control" stations were also fielded 0.61 m in the ground surface that was left relatively unperturbed by those shots. Four of the data channels, namely 64uv, 67uv and 161ut were lost due to EMP. Further details of the instrumentation fielding and behavior are given in reference 4.

Figure 1.1 Map of the Nevada Test Site indicating the location of hole U10cc.

Geologic Cross Section U10cc A-A'

- EXPLANATION
- QTma - Mixed Alluvium
 - QTla - Basal Tuffaceous Alluvium
 - Tp - Paintbrush Tuff
 - Tbg - Grouse Canyon Member
 - Tt - Tunnel beds Tuff
 - Tbt - Tut Spring member
 - Pz - Paleozoic rocks
 - - - - - Bend in Section
 - - - - - Gravity and/or Seismic inferred fault
 - SWL - Standing Water Level

Figure 1.3 Plan view of the region near Hole U10cc with an East-West geologic cross section through the hole.

Figure 1.4 As-built stemming plan for hole U10cc.

Figure 1.6 As-built instrumentation plan for the satellite hole (Ue10aa).

Figure 1.7 Plan view of the BRIE surface array.

2. Emplacement

2.1 Pipe strain

The strain on the emplacement pipe was monitored during emplacement and stemming by transducers bonded to the emplacement pipe near its top and just above the device canister (stations 87 and 81, respectively). Figure 2.1 shows the strain (load) history of the emplacement pipe during stemming.

2.2 Plug level and temperature

Both the slurry level and the curing temperature of the stemming plugs were monitored by a string of thermistors and conductivity probes placed at 5 foot vertical intervals in each of the five plugs. The depths of these probes are listed in figure 1.5. Three thermistors were mounted in each of the long plugs while the two short plugs were instrumented with four thermistors each. Figures 2.2 through 2.6 show the plug quality assessment measurements taken during the stemming of BRIE.

All plugs were emplaced as planned.

Figure 2.1 Emplacement pipe strain history at stations 81 (near the bottom of the pipe just above the device canister) and 87 (on the load collar at near top of the pipe) during stemming.

Figure 2.2 Sanded gypsum emplacement for the first plug. In the upper figure, the upper and lower plug boundaries were determined with a tag line (open circles); solid symbols indicate the presence of a thermistor. Identification of the various plug temperature histories is not available.

Figure 2.3. Sanded gypsum emplacement for the second plug. In the upper figure, the upper and lower plug boundaries were determined with a tag line (open circles); solid symbols indicate the presence of a thermistor. Identification of the various plug temperature histories is not available.

Figure 2.4. Sanded gypsum emplacement for the third plug. In the upper figure, the upper and lower plug boundaries were determined with a tag line (open circles); solid symbols indicate the presence of a thermistor. Identification of the various plug temperature histories is not available.

Figure 2.5. Sanded gypsum emplacement for the fourth plug. In the upper figure, the upper and lower plug boundaries were determined with a tag line (open circles); solid symbols indicate the presence of a thermistor. Identification of the various plug temperature histories is not available.

Figure 2.6. Sanded gypsum emplacement for the fifth plug. In the upper figure, the upper and lower plug boundaries were determined with a tag line (open circles); solid symbols indicate the presence of a thermistor. Identification of the various plug temperature histories is not available.

3. Satellite hole (Free-Field) Measurements

3.1 Motion

Wave forms of the motion recorded and derived from stations in the satellite hole are presented in figures 3.1 through 3.21. Arrival times and peak values of the first motion are included in table 3.1. Characteristics of the associated transducers are given in tables 3.2 and 3.3.

Very high noise levels in the early portions of some of the records lead to invalid first motions on those channels. In particular, see the transverse velocity records and the derived displacement histories from stations 47 and 48 in figures 3.15 and 3.18.

3.2 Stress

None of the stress transducers installed in the satellite hole were recorded on this event.

Figure 3.1 Explosion-induced vertical motion at a depth of 384 m in hole Ue10aa (station 41). Traces annotated with "A" are derived from the accelerometer.

Figure 3.2 Explosion-induced radial-horizontal motion at a depth of 384 m in hole Ue10aa (station 41). Traces annotated with "A" are derived from the accelerometer.

Figure 3.3 Explosion-induced horizontal-transverse motion at a depth of 384 m in hole Ue10aa (station 41).

Figure 3.4 Explosion-induced vertical motion at a depth of 304 m in hole Ue10aa (station 44).

Figure 3.5 Explosion-induced radial-horizontal motion at a depth of 304 m in hole Ue10aa (station 44). Traces annotated with "A" are derived from the accelerometer.

Figure 3.6 Explosion-induced vertical motion at a depth of 251m in hole Ue10aa (station 45). Traces annotated with "A" are derived from the accelerometer.

Figure 3.7 Explosion-induced radial-horizontal motion at a depth of 251 m in hole UE10aa (station 45).

Figure 3.8 Explosion-induced horizontal-transverse motion at a depth of 251 m in hole Ue10aa (station 45). Traces annotated with "A" are derived from the accelerometer.

Figure 3.9 Explosion-induced vertical motion at a depth of 198m in hole Ue10aa (station 46). Traces annotated with "A" are derived from the accelerometer.

Figure 3.10 Explosion-induced radial-horizontal motion at a depth of 198 m in hole Ue10aa (station 46).

Figure 3.12 Explosion-induced horizontal-transverse motion at a depth of 198 m in hole Ue10aa (station 46).

Figure 3.13 Explosion-induced vertical motion at a depth of 173 m in hole Ue10aa (station 47). Traces annotated with "A" are derived from the accelerometer.

Figure 3.14 Explosion-induced radial-horizontal motion at a depth of 173 m in hole Ue10aa (station 47). Traces annotated with "A" are derived from the accelerometer.

Figure 3.15 Explosion-induced horizontal-transverse motion at a depth of 173 m in hole Ue10aa (station 47).

Figure 3.16 Explosion-induced vertical motion at a depth of 113 m in hole Ue10aa (station 48). Traces annotated with "A" are derived from the accelerometer.

Figure 3.17 Explosion-induced radial-horizontal motion at a depth of 113 m in hole Ue10aa (station 48).

Figure 3.18 Explosion-induced horizontal-transverse motion at a depth of 113 m in hole Ue10aa (station 48). Traces annotated with "A" are derived from the accelerometer.

Figure 3.19 Explosion-induced vertical motion at a depth of 56m in hole Ue10aa (station 49). Traces annotated with "A" are derived from the accelerometer.

Figure 3.20 Explosion-induced radial-horizontal motion at a depth of 56 m in hole Ue10aa (station 49).

Figure 3.21 Explosion-induced horizontal-transverse motion at a depth of 56 m in hole Ue10aa (station 49).

Table 3.1.
Summary of Satellite Hole Motion Data

<u>Gage</u>	Slant Range (m)	TOA (ms)	Acceleration	Velocity	Displacement	
			Peak (g's)	Peak (m/s)	Peak (m)	Resid. (mm)
41av	321.6	156	-0.122	-0.057	-0.0051	7
41uv	321.6	156	--	-0.062	-0.060	-2
41ar	321.6	128	0.11	0.045	0.0043	-8
41ur	321.6	--	--	0.12	0.0109	2
41at	321.6		not recorded			
41ut	321.6	--	--	0.05	0.004	0
44av	280.3		malfunction			
44uv	280.3	175	--	-0.09	-0.0075	-3
44ar	280.3	150	0.36	0.136	0.024	3
44ur	280.3		malfunction			
44at	280.3		not recorded			
44ut	280.3		not recorded			
45av	270.1	152	-0.17	-0.035	-0.0019	4
45uv	270.1	--	--	-0.04	-0.0037	-5
45ar	270.1	145	0.52	0.24	0.031	-4
45ur	270.1		not recorded			
45at	270.1	155	-0.21	-0.095	-0.0098	-4
45ut	270.1	--	--	-0.3	-0.017	-4
46av	265.8	170	0.20	0.13	0.0229	4
46uv	265.8	170	--	0.13	0.0195	2
46ar	265.8	149	0.45	0.263	0.0335	12
46ur	265.8		not recorded			
46at	265.8		not recorded			
46ut	265.8		malfunction			
47av	267.5	159	0.92	0.040	0.020	8
47uv	267.5	--	--	0.040	0.018	3
47ar	267.5	154	0.52	0.260	0.032	13
47ur	267.5	--	--	0.275	0.034	7
47at	267.5		not recorded			
47ut	267.5	--	--	(a)	0.10	12
48av	280.6	174	0.145	0.087	0.0186	0
48uv	280.6	--	--	0.084	0.0165	3
48ar	280.6	148	0.32	0.181	0.0269	5
48ur	280.6		not recorded			
48at	280.6	149	-0.13	-0.050	-0.0037	20
48ut	280.6	--	--	-0.060	(a)	15
49av	303.8	163	0.111	0.110	0.0160	4
49uv	303.8	--	--	0.110	0.0161	-3
49ar	303.8		not recorded			
49ur	303.8	162	--	0.20	0.0366	0
49at	303.8	162	-0.090	-0.040	-0.0036	17
49ut	303.8		not recorded			

(a) Too noisy to estimate.

Table 3.2
Satellite Hole Accelerometer Characteristics^(a)

<u>Gauge</u>	<u>Natural Frequency (Hz)</u>	<u>Damping Ratio</u>	<u>System Range (g's)</u>
41av	182	0.70	1.6
41ar	138	0.65	1.6
41at	175	0.70	1.6
44av	180	0.70	2
44ar	122	0.75	2
44at	158	0.85	2
45av	170	0.65	2
45ar	117	0.65	2
45at	132	0.65	2
46av	174	0.70	2
46ar	170	0.65	2
46at	145	0.70	2
47at	175	0.60	2
47ar	175	0.75	2
47at	145	0.65	2
48av	184	0.65	2
48ar	169	0.70	2
48at	145	0.75	2
49av	170	0.65	2
49ar	120	0.65	2
49at	152	0.65	2

(a) All transducers are variable reluctance accelerometers.

Table 3.3
Satellite Hole Velocimeter Characteristics

<u>Gauge</u>	<u>Natural Frequency (Hz)</u>	<u>Time to .5 ampl. (sec)</u>	<u>Calibration Temperature °C</u>	<u>Operation Temperature °C</u>	<u>System Range (m/s)</u>
41uv	3.566	8.89	23.89	24.65	1.4
41ur	3.594	9.38	24.07	24.65	1.4
41ut	3.600	9.39	24.17	24.65	1.4
44uv	3.543	8.82	25.80	22.81	2.0
44ur	3.518	9.94	22.54	22.81	2.0
44ut	3.556	9.17	24.08	22.81	2.0
45uv	3.657	8.61	25.90	20.93	2.0
45ur	3.502	9.38	24.24	20.93	2.0
45ut	3.384	9.28	24.55	20.93	2.0
46uv	3.518	9.74	26.06	18.76	2.0
46ur	3.444	9.30	24.34	18.76	2.0
46ut	3.624	9.50	22.73	18.76	2.0
47uv	3.551	9.22	25.46	17.67	2.0
47ur	3.685	9.36	22.82	17.67	2.0
47ut	3.577	9.20	23.06	17.67	2.0
48uv	3.640	8.38	25.63	15.60	2.0
48ur	3.452	8.82	24.46	15.60	2.0
48ut	3.362	9.76	22.77	15.60	2.0
49uv	3.396	10.32	25.72	14.59	2.0
49ur	3.512	9.21	22.39	14.59	2.0
49ut	3.464	9.27	22.40	14.59	2.0

4. Surface Motion

The measured and derived histories of the surface motion obtained on the event BRIE are displayed in figures 4.1–4.22. The "gv" gages on stations 60 and 61 had extremely large noise components lasting for about 170 ms after the detonation. This noise lasted well into the motion signals and precluded meaningful integrals of the data from these gages. When both an "av" and a "gv" gage were present, appeared valid, and yielded significantly different wave forms, both are presented. The "gv" gages are denoted by "B" on the wave forms. Arrival times and peaks of the first motions are included in table 4.1.

Four channels were lost at zero-time due to the EMP, also a circuit breaker controlling twelve channels from the six triaxial surface motion stations opened at the time of slap-down. Since this represents two channels from each station, no triaxial explosion-induced data were obtained on any surface station at times later than 0.6 seconds after detonation.

Station 163, placed in the ground surface at the trailer park, contained a geophone and a vertical accelerometer. The accelerometer was ranged to capture the expected surface vertical motion at the trailer park and the results are shown in figure 4.23. The companion geophone waveform is shown in figure 4.24 for both the detonation and the collapse time frames. These wave forms are "as digitized" and have not been transformed to engineering units.

Collapse reached the surface about 17 minutes after detonation and was recorded on all tapes. Only the vertical motions due to collapse are represented in figures 4.25–4.32. The collapse-induced motions at stations 62, 69, 161, and 162 are too low to yield meaningful integrals and are thus not shown.

Figure 4.33 shows a scatter plot of the effective sound speed (slant range divided by the time of arrival) as a function of the azimuth of propagation obtained from all three experiments in the study. JARLSBERG was conducted in an undisturbed medium, NORMANNA had one propagation path across the chimney of JARLSBERG while BRIE included propagation rays through the chimneys of both of the previous experiments. There may be a slight correlation of the arrival times with azimuth while nearly no effect of the chimneys is apparent.

5. Other measurements

The barometric pressure in the recording trailer, (station 71), was the only gas pressure measured (figure 4.34). A major perturbation in the recording occurred between 1.9 and 2.0 seconds: any signal during that period should be ignored.

Figure 4.1

Explosion-induced vertical motion of the ground surface at a horizontal range of 101.8 m and azimuthal angle of 116.7° from SGZ (station 60). Traces annotated with "A" were derived from a variable reluctance accelerometer. In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.2 Explosion-induced vertical motion of the ground surface at a horizontal range of 15.7 m and azimuthal angle of 305.8° from SGZ (station 61). Traces anotated with "A" were derived from a variable reluctance accelerometer. In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.3 Explosion-induced vertical motion of the ground surface at a horizontal range of 280.0 m and azimuthal angle of 115.1° from SGZ (station 62). Traces annotated with "A" were derived from a variable reluctance accelerometer while those annotated with "B" were derived from a piezoresistive accelerometer. In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.4 Explosion-induced vertical motion of the ground surface at a horizontal range of 53.5 m and azimuthal angle of 312.8° from SGZ (station 63). Traces annotated with "A" were derived from a variable reluctance accelerometer while those annotated with "B" were derived from a piezoresistive accelerometer. In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.5 Explosion-induced vertical motion of the ground surface at a horizontal range of 90.9 m and azimuthal angle of 355.8° from SGZ (station 64). Traces anoted with "A" were derived from a variable reluctance accelerometer. In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.6 Explosion-induced vertical motion of the ground surface at a horizontal range of 171.2 m and azimuthal angle of 355.9° from SGZ (station 65). Traces anoted with "A" were derived from a variable reluctance accelerometer. In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.7 Explosion-induced horizontal-transverse motion of the ground surface at a horizontal range of 15.7 m and azimuthal angle of 355.9° from SGZ (station 65). The signal was terminated at about 0.6 s due to a circuit breaker loss. In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.8 Explosion-induced vertical motion of the ground surface at a horizontal range of 171.1 m and azimuthal angle of 322.0° from SGZ (station 66). Traces anoted with "A" were derived from a variable reluctance accelerometer. In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.9 Explosion-induced horizontal-radial motion of the ground surface at a horizontal range of 171.1 m and azimuthal angle of 322.0° from SGZ (station 66). The signal was terminated at about 0.6 s due to a circuit breaker loss. In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.10 Explosion-induced horizontal-transverse motion of the ground surface at a horizontal range of 171.1 m and azimuthal angle of 322.0° from SGZ (station 66). In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.11 Explosion-induced vertical motion of the ground surface at a horizontal range of 91.8 m and azimuthal angle of 288.5° from SGZ (station 67). Traces annotated with "B" were derived from a piezoresistive accelerometer. In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.12 Explosion-induced vertical motion of the ground surface at a horizontal range of 163.0 m and azimuthal angle of 261.5° from SGZ (station 68). Traces annotated with "A" were derived from a variable reluctance accelerometer. In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

ACCELERATION (G)

ACCELERATION NOT RECORDED

VELOCITY (M/SEC)

DISPLACEMENT (M)

TIME (SECONDS)

Figure 4.13 Explosion-induced horizontal-radial motion of the ground surface at a horizontal range of 171.1 m and azimuthal angle of 261.5° from SGZ (station 68). In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.14 Explosion-induced horizontal-transverse motion of the ground surface at a horizontal range of 163.0 m and azimuthal angle of 261.5° from SGZ (station 68). The signal was terminated at about 0.6 s due to a circuit breaker loss. In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.15 Explosion-induced vertical motion of the ground surface at a horizontal range of 265.3 m and azimuthal angle of 261.5° from SGZ (station 69). Traces anotated with "A" were derived from a variable reluctance accelerometer. In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.16 Explosion-induced horizontal-radial motion of the ground surface at a horizontal range of 265.3 m and azimuthal angle of 261.5° from SGZ (station 69). The signal was terminated at about 0.6 s due to a circuit breaker loss. In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.17 Explosion-induced horizontal-transverse motion of the ground surface at a horizontal range of 265.3 m and azimuthal angle of 261.5° from SGZ (station 69). The signal was terminated at about 0.6 s due to a circuit breaker loss. In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.18 Explosion-induced vertical motion of the ground surface at a horizontal range of 265.4 m and azimuthal angle of 288.3° from SGZ (station 161). Traces anoted with "A" were derived from a variable reluctance accelerometer. In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.19 Explosion-induced horizontal-radial motion of the ground surface at a horizontal range of 265.4 m and azimuthal angle of 288.3° from SGZ (station 161). The signal was terminated at about 0.6 s due to a circuit breaker loss. In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.20 Explosion-induced vertical motion of the ground surface at a horizontal range of 265.7 m and azimuthal angle of 303.0° from SGZ (station 162). Traces anoted with "A" were derived from a variable reluctance accelerometer. In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.21 Explosion-induced horizontal-radial motion of the ground surface at a horizontal range of 265.7 m and azimuthal angle of 303.0° from SGZ (station 162). In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

ACCELERATION (G)

ACCELERATION NOT RECORDED

VELOCITY (M/SEC)

DISPLACEMENT (M)

TIME (SECONDS)

Figure 4.22 Explosion-induced horizontal-transverse motion of the ground surface at a horizontal range of 265.7 m and azimuthal angle of 303.0° from SGZ (station 162). The signal was terminated at about 0.6 s due to a circuit breaker loss. In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.23 Explosion-induced vertical motion of the ground surface in the trailer park at an approximate horizontal range of 225 m (station 163).

Figure 4.24 Explosion- and collapse-induced response of a geophone mounted in the ground surface of the trailer park at station 163.

Figure 4.25 Collapse-induced vertical motion of the ground surface at a horizontal range of 101.8 m and azimuthal angle of 116.7° from SGZ (station 60). Traces annotated with "A" were derived from a variable reluctance accelerometer. In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.26 Collapse-induced vertical motion of the ground surface at a horizontal range of 15.7 m and azimuthal angle of 305.8° from SGZ (station 61). Traces annotated with "A" were derived from a variable reluctance accelerometer while those annotated with "B" were derived from a piezoresistive accelerometer. In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.27 Collapse-induced vertical motion of the ground surface at a horizontal range of 53.5 m and azimuthal angle of 312.8° from SGZ (station 63). Traces anotated with "A" were derived from a variable reluctance accelerometer. In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.28 Collapse-induced vertical motion of the ground surface at a horizontal range of 90.9 m and azimuthal angle of 355.8° from SGZ (station 64). In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.29 Collapse-induced vertical motion of the ground surface at a horizontal range of 171.2 m and azimuthal angle of 355.9° from SGZ (station 65). In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.30 Collapse-induced vertical motion of the ground surface at a horizontal range of 171.1 m and azimuthal angle of 322.0° from SGZ (station 66). In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.31 Collapse-induced vertical motion of the ground surface at a horizontal range of 91.8 m and azimuthal angle of 288.5° from SGZ (station 67). In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters from JARLSBERG and NORMANNA are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.32 Collapse-induced vertical motion of the ground surface at a horizontal range of 163.0 m and azimuthal angle of 261.5° from SGZ (station 68). In the upper map, surface stations are indicated by circles, drill holes by squares, and the approximate size of the collapse craters are shown as shaded regions. Filled symbols show the active elements of this figure.

Figure 4.33 Effective sound speed (slant range divided by time-of-arrival) as a function of the azimuth of propagation. The two previous experiments are also shown.

Figure 4.34 Air pressure measured by a transducer in the recording trailer, ported outside through the wall.

Table 4.1
Summary of Surface Motion Data

Gauge	Slant Range (m)	Azimuth Angle ^(a) (degrees)	TOA (ms)	Acceleration Peak (g's)	Velocity Peak (m/s)	Displacement Peak (m)	Resid. (mm)
60av	227.1	116.7	146	1.2, 14.7 ^(b)	0.76	0.108	-140
60gv			(c)	1.1	(b)	(b)	(b)
60uv			--	--	0.80	0.118	-10
61av	203.6	305.8	149	2.0, 42 ^(b)	1.35	0.247	-108
61gv			(c)	2.0	(c)	(c)	(c)
61uv			--	--	1.50	0.283	-40
62av	296.6	115.1	197	0.41	0.162	0.0201	-10
62gv			197	0.42	0.164	0.0204	-6
62uv			--	--	0.150	0.0174	-3
63av	209.9	312.8	142	1.7, 11.1 ^(b)	1.35	0.251	-170
63gv ⁺			143	3.2, 23.7 ^(b)	2.50	0.458	-200
63uv			--	--	1.42	0.260	-70
64av	222.5	355.8	158	1.15, 3.7 ^(b)	1.00	0.172	-15
64gv			155	1.14, 3.7 ^(b)	1.00	0.174	8
64uv			malfunction				
65gv	265.6	355.9	165	0.49, 1.6 ^(b)	0.41	0.110	10
65uv			--	--	0.48	0.116	10
65ur			malfunction				
65ut			185	--	0.32	(c)	(c)
66gv	265.5	322.0	203	0.398	0.206	0.022	-6
66uv			205	--	0.230	0.026	(d)
66ur			210	--	0.49	(d)	(d)
66ut			210	--	0.062	0.005	25
67av	222.8	288.5	147	0.93	0.76	0.121	-170
67gv			147	0.92	0.76	0.121	-120
67uv			malfunction				
68gv	260.3	261.5	190	.71, 8.3 ^(b)	0.45	0.058	-32
68uv			179	--	0.50	0.067	(d)
68ur			180	--	0.53	0.083	-33
68ut			--	--	0.53	0.098	(d)
69gv	334.1	261.5	212	0.35	0.16	0.017	-8
69uv			--	--	0.15	0.014	-18
69ur			273	--	0.44	0.0595	(d)
69ut			222	--	0.4	(d)	(d)
161gv	334.1	288.3	253	0.193	0.08	0.0055	12
161uv			--	--	0.10	0.0070	(d)
161ur			273	--	0.189	(d)	(d)
161ut			malfunction				
162gv	334.1	303.0	256	0.228		0.011	6
162uv			272	--	0.175	0.012	(d)
162ur			--	--	0.140	0.072	-10
162ut			278	--	0.080	0.0079	(d)
163qv			(c)	0.80	(c)	(c)	(c)

- (a) Horizontal, counter clockwise angle of propagation; zero = East.
(b) Late-time peak at about +2.5 seconds.
(c) Early noise precludes accurate values
(d) Channel malfunctions after slap-down
+ amplitudes appear to be a factor of 2 too high

Table 4.2
Ground Surface Accelerometer Characteristics

<u>Gage</u>	<u>Natural Frequency (Hz)</u>	<u>Damping Ratio</u>	<u>System Range (G's)</u>	<u>Type*</u>
60av	350	.75	15	vr
60gv	NA	NA	10	pr
61av	580	.75	30	vr
61gv	NA	NA	10	pr
62av	165	.65	5	vr
62gv	NA	NA	5	pr
63av	585	.75	30	vr
63gv	NA	NA	10	pr
64av	360	.75	20	vr
64gv	NA	NA	10	pr
65gv	NA	NA	5	pr
66gv	NA	NA	5	pr
67av	420	.65	20	vr
67gv	NA	NA	10	pr
68gv	NA	NA	10	pr
69gv	NA	NA	5	pr
161gv	NA	NA	5	pr
162gv	NA	NA	5	pr

• vr = variable reluctance; pr = piezoresistive
NA = no data available

Table 4.3
Ground Surface Velocimeter Characteristics

<u>Gage</u>	<u>Natural Frequency (Hz)</u>	<u>Time to .5 ampl. (sec)</u>	<u>Calibration Temperature °C</u>	<u>Operation Temperature °C</u>	<u>System Range (m/s)</u>
60uv	3.690	7.52	25.59	20.15	6.0
61uv	3.506	9.62	25.80	19.42	8.0
62uv	3.635	8.26	25.82	18.75	2.0
63uv	3.415	10.41	25.10	19.30	8.0
64uv	3.439	10.11	24.97	18.48	6.0
65uv	3.482	9.38	25.11	18.36	2.4
65ur	3.841	8.70	25.26	18.36	2.0
65ut	3.714	8.91	25.00	18.36	1.6
66uv	3.649	8.19	25.05	18.94	1.4
66ur	3.632	8.88	25.25	18.94	2.0
66ut	3.670	9.37	25.02	18.94	1.6
67uv	3.688	8.48	25.04	16.50	6.0
68uv	3.624	8.95	25.08	20.13	2.4
68ur	3.827	9.16	25.48	20.13	2.0
68ut	3.887	9.05	25.32	20.13	1.6
69uv	3.704	7.58	25.31	19.27	2.0
69ur	3.817	9.28	25.94	19.27	2.8
69ut	3.738	9.76	25.57	19.27	1.2
161uv	3.693	8.21	25.08	18.50	2.0
161ur	3.651	9.17	25.39	18.50	2.8
161ut	3.744	9.30	25.78	18.50	1.2
162uv	3.669	7.84	25.39	18.76	2.0
162ur	3.707	9.57	25.36	18.76	2.8
162ut	3.746	8.79	25.73	18.76	1.2

References

1. Gayle Pawloski and Casey Schmidt, "U10cc, Preliminary Site Characteristics Summary", CP 86-96, Lawrence Livermore National Laboratory, Livermore, CA, January 30, 1987
2. Alfred E. Burer, "Containment Report for U10cc", Holmes & Narver, NTS:A2:87-64
3. Richard A. Spilsbury, "Special Measurements Physics/Instrumentation for BRIE, U10cc", EG&G, Energy Measurements, Las Vegas, NV, SM:87E-143-16, 14 July, 1987.
4. Richard A. Spilsbury, "Special Measurements Final Engineering Report for BRIE, U10cc", EG&G, Energy Measurements, Las Vegas, NV, SM:87E-143-17, 23 December, 1987.

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