BURZET

Containment Data Report

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National
Laboratory

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BURZET Instrumentation Summary

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

(a) Description only.

(b) SLIFER in emplacement and satellite holes.

(c) CLIPER in emplacement and satellite holes.

(d) Emplacement pipe load.

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1. Event Description

1.1 Site

The BURZET event was detonated in hole U4ai of the Nevada Test Site as indicated in figure 1.1. The device had a depth-of-burial (DOB) of 450 m in the Alluvium of area 4, about 50 m above the standing water level and 500 m above the Paleozoic formation, as shown in 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 08:07:30 PDT on August 3, 1979, and about 1 hour, 55 minutes later a surface collapse occurred leaving a crater with mean radius of 86.1 m and maximum depth of 11.8 m.

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

1.2 Emplacement

One strain station (84) was fielded on the emplacement pipe to monitor the load during installation and stemming. During these procedures, output of this station was recorded by hand in the stemming log maintained by Holmes & Narver⁽²⁾.

The two stemming plugs were composed of coal-tar epoxy (LAE 59, denoted CTE), each about 3.5 m thick. A gas seal layer of soft coal-tar and aggregate (LAE 59MY, denoted CTA) was poured above a layer of foam cubes resting on the top of the top plug. About 3.5 m of the surface casing extended below the top plug. 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 for its full length. See figure 1.4.

Figure 1.5 is a schematic layout of the instrumentation designed to monitor the emplacement procedures and performance of the BURZET event. Figure 1.6 is a schematic layout of the instrumentation designed to monitor the free-field motion and stress associated with the BURZET event in the satellite hole Ue4ah.

Vertical motion (acceleration and velocity) was monitored at ten stations in the satellite hole, 32.3 m from the emplacement hole, and in the ground surface, 15.24 m from SGZ. Being in the satellite hole and grouted in place with "rock-matching" grout, the data from these stations are considered free-field measurements. Each of the eight deepest motion stations was accompanied by a "paddle" type Ytterbium stress transducer oriented to be in the plane of the shock front.

D-cable information was used for quality assurance during the stemming operations and was recorded post-shot to monitor cavity collapse as were the outputs of CLIPER gauges in both the emplacement hole and the satellite hole.

Data from the motion stations, stress transducers and D-cable were transmitted to the recording trailer by an analog system and recorded on magnetic tape.

Results of the yield measurements are reported elsewhere⁽³⁾.

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

Figure 1.1 Map of the Nevada Test Site indicating the location of hole U4ai.

Figure 1.2 North-South geologic cross sections through hole U4ai.

Figure 1.3 East- West geologic cross sections through hole U4ai.

Figure 1.4 As-built stemming plan for the event BURZET in Hole U4ai.

Figure 1.6 As-built containment instrumentation plan for the satellite hole (Ue4ah) on the BURZET event.

2. Free-Field Motion

2.2 Explosion Induced Motion

Wave forms of the motion derived from the satellite hole Ue4ah and the ground surface are shown in figures 2.1 - 2.11. Arrivals and peak values of the motion are given in table 2.1 with the transducer characteristics in tables 2.2 and 2.3.

Signals from stations 41, 42, and 43 (figures 2.1, 2.2, and 2.3) were lost shortly before 0.3 s while the remaining stations yielded information until recording was stopped when the tapes reached their respective ends; no tapes were reloaded for later recording. On the high-speed (60 ips) tapes the active data recording time is about 30 minutes and on the low-speed (3.75 ips) tapes, the recording time is about 3 hours.

The signals from stations 44 - 48 were corrupted by off-sets and noise during a period of about 100 ms around 0.3 s. Visual inspection of the records suggested that at least a portion of the noise may be common to all the data and that it might be possible to remove it. The partially successful removal attempt is detailed in the appendix and resulted in the data displayed in figures 2.4-2.8 and listed in table 2.1. Stations 49, 50, and 61 (figures 2.9 -2.11) were either not bothered by the noise or were ranged such that the noise level was too small to be of consequence. There is evidence (see the appendix) that the noise was caused by a grounding problem in the transmission cables at about the location of station 48, at a depth of around 270 m. In view of the corrections required, the correlation between the accelerometer-derived and the velocimeter-derived wave forms is remarkable.

A brief oscillation of the accelerometer records of stations 48, 49 and 50 at about 0.8 s (figures 2.8, 2.9 and 2.10) is likely due to strain relief in the fiber glass pipe on which the gage canisters were hung before grouting in place. Such behavior has been noted on several events⁽⁶⁾ and is attributed to the ground going into dilatation from passage of the surface-reflected relief wave.

Station 61, 0.9 m in the ground surface and at a distance of 10.7 m from the satellite hole, was unaffected by the noise seen down-hole and the resulting data are displayed in figure 2.11. The signal cable of this station was on the ground surface and independent of the down-hole system.

Figure 2.1 Explosion-induced vertical motion at station 41 in the satellite hole (depth 330.0 m). The signals from this station were lost shortly before 0.3 s. When there is more than one trace in a plot, the lighter was derived from the accelerometer.

Figure 2.2 Explosion-induced vertical motion at station 42 in the satellite hole (depth 312.0 m). The signals from this station were lost shortly before 0.3 s. When there is more than one trace in a plot, the lighter was derived from the accelerometer.

Figure 2.3 Explosion-induced vertical motion at station 43 in the satellite hole (depth 294.5 m). The signals from this station were lost shortly before 0.3 s. When there is more than one trace in a plot, the lighter was derived from the accelerometer.

Figure 2.4 Explosion-induced vertical motion at station 44 in the satellite hole (depth 276.0 m). When there is more than one trace in a plot, the lighter was derived from the accelerometer.

Figure 2.5 Explosion-induced vertical motion at station 45 in the satellite hole (depth 251.5 m). When there is more than one trace in a plot, the lighter was derived from the accelerometer.

Figure 2.6 Explosion-induced vertical motion at station 46 in the satellite hole (depth 232.3 m). When there is more than one trace in a plot, the lighter was derived from the accelerometer.

Figure 2.7 Explosion-induced vertical motion at station 47 in the satellite hole (depth 199.9 m). When there is more than one trace in a plot, the lighter was derived from the accelerometer.

Figure 2.8 Explosion-induced vertical motion at station 48 in the satellite hole (depth 170.1 m). When there is more than one trace in a plot, the lighter was derived from the accelerometer.

Figure 2.9 Explosion-induced vertical motion at station 49 in the satellite hole (depth 120.0 m). When there is more than one trace in a plot, the lighter was derived from the accelerometer.

Figure 2.10 Explosion-induced vertical motion at station 50 in the satellite hole (depth 49.2 m). When there is more than one trace in a plot, the lighter was derived from the accelerometer.

Figure 2.11 Explosion-induced vertical motion at station 61 in the ground surface (at a depth of 0.9 m and horizontal range of 10.7 m from the satellite hole). When there is more than one trace in a plot, the lighter was derived from the accelerometer.

Table 2.1 Summary of Free-Field Motion

Gauge	Slant Range (m)	Arrival Time (ms)	Acceleration Peak (g)	Velocity Peak (m/s)	Displacement Peak (cm)	Displacement Residual (cm)
41av	122.8	50	26	12.5	a	a
41uv		-	-	10.0	a	a
42av	140.2	59	9(b)	5.3	a	a
42uv		-	-	7.5	a	a
43av	157.2	66	5(b)	1.0	a	a
43uv		-	-	3.0	a	a
44av	175.5	75	5.0	2.0	43	16
44uv		-	-	2.4(b)	54	18
45av	199.6	87	4.1	0.8	29	11
45uv		-	-	1.2(b)	29	11
46av	218.6	97	3.8	1.2	35	17
46uv		-	-	1.2	34	12
47av	250.6	114	2.1	0.6	20	8
47uv		-	-	0.6	24	0
48av	280.2	132	2.7	0.72	31	40
48uv		-	-	0.55	22	5
49av	330.0	162	1.8	0.70	24	25
49uv		-	-	0.75	24	3
50av	400.6	214	1.4	0.85	23	-1
50uv		-	-	0.85	24	-1
61av	447.9	270	2.8, 3.9(c)	0.70	26	5
61uv		-	-	1.00	22	3

(a) Chanel lost before this value attained.

(b) Approximate

(c) Slap down.

Table 2.2 Containment-Related Accelerometer Characteristics

Gauge	Natural Frequency (Hz)	Damping Ratio	System Range (g's)
41av	1800	0.65	1600
42av	1950	0.65	800
43av	1500	0.65	500
44av	1600	0.65	350
45av	1100	0.65	150
46av	800	0.65	100
47av	540	0.75	50
48av	540	0.75	40
49av	330	0.65	16
50av	200	0.65	8
61av	350	0.55	25

Table 2.3 Containment-Related Velocimeter Characteristics

Gauge	Natural Frequency (Hz)	Time to 0.5 Amplitude (s)	Calibration Temperature (°C)	Operate Temperature (°C)	Stop-Stop Range (m/s)	System Range (m/s)
41uv	3.9	22.6	23.88	32.55	294	70
42uv	3.64	23.5	23.94	21.72	119	45
43uv	3.50	11.5	24.00	29.94	77	30
44uv	3.10	7.4	24.00	22.33	51	20
45uv	3.10	7.3	24.28	27.17	50	12
46uv	3.30	7.0	24.17	26.00	53	9
47uv	3.30	11.4	24.17	26.5	50	8
48uv	3.50	7.6	23.78	24.11	52	6
49uv	3.0	8.3	23.61	21.39	57	5
50uv	3.0	9.8	24.11	21.39	53	3.2
61uv	3.4	9.4	23.39	29.68	55	8

2.3 Collapse phenomena

Stations 41 - 43 were lost at early time and are thus not represented in the collapse phase; the accelerometer at station 44 failed before collapse time and is also not represented. Evident noise interference was profound in stations 44 - 50 so only the acceleration and velocity wave forms are shown for these stations in figures 2.12 - 2.18 (no integrals were computed). Fine-structure similarity in the acceleration wave forms around 6986 s is evident in figures 2.13-2.16 and in the velocity wave forms displayed in figures 2.12-2.17. The presence of noise in the motion signals during the collapse strongly suggests that the source of the noise was the cabling and not the electronics in the recording trailer. This was also suggested by the beginning of discrepancies between the velocimeter and integrated accelerometer data occurring before the first motion could reach the trailer, as described in the appendix.

Collapse motion of the ground surface (station 61) is shown in figure 2.19. The accelerometer went beyond its system limits of 25 g's for a brief time (less than 15 ms) and the wave form was augmented by a triangular acceleration pulse to bring the integral (velocity) to the required zero-level base line at late time. A total augmentation of about 55 g's was required. Inserted in figure 2.19 "velocity" is a plot of the uncorrected wave form of the velocity transducer indicating a rotation of the sensor. If there were no rotation, the final level would be zero velocity. (This class of sensor has a 13 degree paddle rotation stop-to-stop.) The jump in the velocimeter wave form during the free fall period is an artifact of the gauge response correction⁽⁷⁾.

Figure 2.20 is a composite plot of all the velocity records during the collapse as functions of both time and initial depth. Collapse is seen to progress smoothly in the satellite hole. There were no CLIPER data surviving to the "turn-on-time" following the EMP. This is usually about +0.2 s. The D-cable was similarly lost at early time and afforded no collapse data.

Figure 2.12 Vertical acceleration and velocity signals during the collapse phase recorded at station 44 in the satellite hole (depth 276.0 m).

Figure 2.13 Vertical acceleration and velocity signals during the collapse phase recorded at station 45 in the satellite hole (depth 251.5 m).

Figure 2.14 Vertical acceleration and velocity signals during the collapse phase recorded at station 46 in the satellite hole (depth 232.2 m).

Figure 2.15 Vertical acceleration and velocity signals during the collapse phase recorded at station 47 in the satellite hole (depth 199.9 m).

Figure 2.16 Vertical acceleration and velocity signals during the collapse phase recorded at station 48 in the satellite hole (depth 170.1 m).

Figure 2.17 Vertical acceleration and velocity signals during the collapse phase recorded at station 49 in the satellite hole (depth 120.0 m).

Figure 2.18 Vertical acceleration and velocity signals during the collapse phase recorded at station 50 in the satellite hole (depth 49.2 m).

Figure 2.19 Vertical collapse motion of the ground surface at a distance of 10.6 m from the satellite hole (station 61). When there is more than one trace in a plot, the lighter was derived from the accelerometer. The insert in the velocity portion of the figure is the uncorrected wave form of the velocimeter history.

Figure 2.20 Composite of collapse velocity signals showing the progression of the collapse in the satellite hole

3. Free-field Stress Measurements

Associated with each of the deepest eight motion stations was a flat-pack stress gauge. The active elements of these devices (built by Pulsar, Inc.) were Ytterbium grids oriented to be in the plane of the stress front. Stations 41, 42 and, 43 were lost before 30 ms and figures 3.1 -3.4 display the first 30 ms of wave form obtained from all of the stress gages. Data for the first 5 s from stations 44-48 are shown in figures 3.5 and 3.6. The "common" noise discussed in the appendix also affects the stress transducer output but can not be removed as the stress does not necessarily return to a zero base line at late time. In these records the "noise" becomes a major part of the data.

Figure 3.1 The first 30 ms of record obtained from stress gages 41 and 42 at depths of 331.2 and 313.2 m, respectively, in the satellite hole.

Figure 3.1 The first 30 ms of record obtained from stress gages 43 and 44 at depths of 295.8 and 277.2 m, respectively, in the satellite hole.

Figure 3.2 The first 30 ms of record obtained from stress gages 45 and 46 at depths of 252.6 and 233.4 m, respectively, in the satellite hole.

Figure 3.1 The first 30 ms of record obtained from stress gages 47 and 48 at depths of 201.1 and 171.4 m, respectively, in the satellite hole.

Figure 3.2 The first 5 s of record obtained from stress gages 44, 45, and 46 at depths of 277.2, 252.3, and 233.4 m, respectively, in the satellite hole.

Figure 3.2 The first 5 s of record obtained from stress gages 47 and 48 at depths of 201.1 and 171.4 m, respectively, in the satellite hole.

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Appendix. Data processing considerations

The data were recorded redundantly on four analog tapes for the BURZET event, two tapes at high-speed (at 60 ips) and two at low speed (3.75 ips). Upon re-entry to the recording trailer it was found that the supply reel lock-down of one of the high-speed tapes was insufficient to keep the tape in position when the ground shock reached the trailer. As a result, the tape moved outward on the hub, automatically stopping that recorder. The loss of the CLIPER and D-cable at early time also suggests a higher than expected ground shock at the recording trailer. Signals from the deepest three motion stations were lost before 0.3 s and the wave forms from all but the three shallowest stations (49, 50 and 61) showed large permanent shifts in the base-lines beginning at about that time. Figure A.1 displays the first 5 s of the "as-digitized" wave forms from station 45 acceleration and velocity. The insets include only the first 0.5 s of the records. Observation of the wave forms in the region of 0.3 to 0.4 s also shows large, random, short duration offsets of the records which are not common to all channels.

A common, non-data signal may be eliminated by the following procedure. Say the record is composed of three components $S(t)$ (the transduced signal), $N(t)$ (the common noise signal), and $n(t)$ (the channel dependent noise). Thus, the accelerometer channel produces the record;

$$A(t) = S_a(t) + n_a(t) + N(t) \quad (1)$$

and the velocimeter channel yields

$$U(t) = S_u(t) + n_u(t) + N(t). \quad (2)$$

Now, the integral of the acceleration portion of the accelerometer channel record is proportional to the velocity portion of the velocimeter channel: $K \int S_a(\tau) d\tau = S_u(t)$. Subtracting equation (2) from the scaled integral of equation (1) results in the integral equation for the common noise;

$$K \int N(\tau) d\tau - N(t) = [K \int A(\tau) d\tau - U(t)] - f(t) \quad (3)$$

Here $f(t) = K \int n_a(\tau) d\tau - n_u(t)$ is a term combining the non-common, channel dependent noise (hopefully small) from the accelerometer and velocimeter records which must be removed by other means as discussed below and the term in brackets on the right-hand-side is derivable from the measured data.

Figure A.1 Acceleration and velocity records, as digitized, from station 45 (at 232 m depth in the satellite hole). The inserts display the first 0.5 s of each record delineating a region of high-level short-time shifts and drop-outs.

The upper plot in figure A.2 is an overlay of the output of the velocimeter channel with the integral of the accelerometer channel multiplied by the empirically determined scale factor 47.9 (The term K in equation 3). Good agreement between the scaled integral of the acceleration and the velocity is seen until a time of about 120 ms. This is approximately the time that the explosion-induced stress front reached a position between stations 47 and 48, a range between 250 and 280 m, substantially earlier than first arrival at the recording trailer (estimated to be about 290 ms).

The lower plot in figure A.2 is $N(t)$, the solution of equation 3 (assuming that $f(t)$ is negligible or all noise is common) with the first 0.5 s insert accentuating the likely contributions of $f(t)$ (that were clearly not absent) beginning around 290 ms.

Subtraction of $N(t)$ of figure A.2 from the acceleration record of station 45 yields a wave containing the acceleration, a combination of the noise contributions from the acceleration ($n_a(t)$), and additions to $N(t)$ from non-negligible contributions of $f(t)$. The base line of the resulting "acceleration" is, perforce, on zero at late time; however, its integral (or velocity) is not, due to contributions from the remaining noise terms. Single datum drop-outs and brief shifts in the record occurring between times of 0.29 and 0.4 s are eliminated by hand until the base line of the integral is zero at late time in an attempt to reduce the effects of non-common noise. Such a procedure is applicable only to the acceleration records since the base line at late time of the integral of the velocimeter is never necessarily zero (there may be a residual displacement). The same reasoning applies to the stress records (which may show residual stress) and they were thus not altered from the as-digitized form except to be converted to engineering units.

Acceleration records from stations 44, 45, 46, 47, and 48 all were processed individually in this fashion. Although the acceleration and velocity channels from each station were recorded on different tracks (in different VCO groups), they were recorded at the same multiplex center-band frequency. This affords the most likely situation of having common noise across the station, although not necessarily across the entire data suite. The plots of the velocimeter-derived records in figures 2.1 through 2.11 were generated shortly after the event was conducted in 1979 and were not referenced until the above accelerometer processing was performed in 1997. The agreement between the velocity transducer data and the velocity histories as derived from the accelerometers is remarkable.

Figure A.2 The smooth curve in the top figure is the integral of the acceleration from station 45 scaled to the magnitude of the velocimeter output from the same station (the non-smooth trace). They agree for the first 120 ms. The lower plot is the solution to equation 3 with the insert being the first 0.5 s of the solution.

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