SALUT Containment Data Report

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May 1995

Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

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SALUT Instrumentation Summary

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	no	-	-
Emplacement Pipe	no	-	-
<u>Hydroyield (a)</u>	yes	yes	no
<u>Collapse (b)</u>	yes	yes	yes
<u>Stress</u>	no	-	-
<u>Strain (c)</u>	yes	yes	yes
<u>Other Measurements (d)</u>	yes	yes	no

- (a) CORRTEX or SLIFER in emplacement hole.
- (b) EXCOR or CLIPER in emplacement hole.
- (c) Emplacement pipe.
- (d) Permeability pressure measurements.

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Contents

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1. Event Description

1.1 Site

The SALUT event was detonated in hole U20ak of the Nevada Test Site as indicated in Fig. 1.1. The device had a depth-of-burial of 607 m in the Scrugham Peak rhyolite of Area 20, about 15 m above the standing water level (SWL), as shown in Figures 1.2 and 1.3.⁽¹⁾ Stemming of the 2.44 m diameter emplacement hole followed the plan shown in Fig. 1.4. A log of the stemming operations was maintained by Holmes & Narver⁽²⁾.

Detonation time was 08:15 PDT on June 12, 1985 and about 10 hours, 17 minutes later a sub-surface collapse progressed upwards to a depth between 200 and 270 m.

No radiation arrivals were detected in the emplacement hole and the SALUT containment was considered successful.

1.2 Instrumentation

Figure 1.5 is a schematic layout of the instrumentation designed to monitor the emplacement procedures and stemming performance of the SALUT event.

A history of the fielding operations of the instrumentation, including the emplacement pipe strain measurements, is outlined in reference 4. Details of the instrumentation are given in reference 5.

Three of the five stemming plugs (the first, fourth and fifth) were composed of coarse gypsum aggregate in a gypsum cement slurry. Each of the three gypsum filled aggregate (GFA) plugs was monitored during emplacement with arrays of conductivity probes and thermistors. The remaining two plugs were soft, coal tar aggregate (CT/A) gas seal membranes having a thickness of about 1.5 m. Such a membrane was poured on the top of the top GFA plug.

Two CLIPER/CORRTEX sensors were emplaced, as indicated in figure 1.5, to measure the hydrodynamic yield of the device and to monitor cavity collapse and chimney formation. Results of the yield measurements are reported elsewhere⁽³⁾.

In the emplacement hole, vertical motion was monitored at each of the five pressure-radiation stations in the coarse stemming and at four separate motion stations. Three of the motion stations were mounted in the top three stemming plugs and one in the coarse stemming. See figure 1.5. Additionally, four motion stations were fielded in the ground surface and one in the recording trailer. The surface array stations were approximately equally spaced on a line extending from the emplacement hole for a distance of 915 m in a direction 3° east of south.

SALUT was the first event on which LLNL fielded instruments to measure the effect of a nuclear event on the permeability of the geologic medium. Two stations, one in the ground surface near the emplacement hole and another at a depth of 56.4 m in the emplacement hole, were fielded.

SALUT

Figure 1.1 Map of the Nevada Test Site indicating the location of hole U20ak.

SYMBOLS USED ON THE GEOLOGIC MAP AND CROSS SECTION

Quaternary Unit

Qac Alluvium

Tertiary Units

Ttt Trail Ridge Member, Thirsty Canyon Tuff
 Tts Spearhead Member, Thirsty Canyon Tuff
 Ttr Rocket Wash Member, Thirsty Canyon Tuff
 Ttsr Spearhead and Rocket Wash Members, undifferentiated
 Tat Ash-fall and reworked tuff
 Tma Ammonia Tanks Member, Timber Mountain Tuff
 Tmr Rainier Mesa Member, Timber Mountain Tuff
 Tp(Tb) Bedded tuff associated with Paintbrush Tuff
 Trpq Quartz-bearing rhyolite lavas; Lavas of Schrugum Peak Quadrangle
 Tpc Tiva Canyon Member, Paintbrush Tuff
 Tpt Topopah Spring Member, Paintbrush Tuff
 Trab Bedded and ash-flow tuff; Tuffs and rhyolites of Area 20
 Trau Upper rhyolite lavas, Tuffs and rhyolites of Area 20

Figure 1.2 Surface geology at the U20ak site.

DOWNHOLE WT. 182.3K

STEMMING WT. 327.0K

TOTAL 509.3K SURFACE -40.0'

SALUT

U20ak

Figure 1.4 As-built stemming plan for the event SALUT in Hole U20ak.

Figure 1.5 As-built containment instrumentation plan for the SALUT event.

2. Emplacement

2.1 Pipe strain

Figure 2.1 is the strain history measured on the emplacement pipe during stemming of the SALUT experiment. The emplacement pipe was instrumented with a strain gage station on the final pipe section just below the load collar (Station 88) and another station on the emplacement pipe just above the diagnostics canister (Station 82).

2.2 Plug levels and temperature

The emplacement of each of the three gypsum concrete plugs was monitored with an array of conductivity probes and thermistors. The locations of the probes are tabulated in figure 1.7. The upper and lower boundary positions of the plugs were determined by tag lines. Figure contains plots of the arrival times of the GFA slurry as a function of depth (as determined from the conductivity probes and tag lines). Temperature sensors were located at the locations indicated in the caption of figure 2.2 but the GFA temperature histories are not available. All plugs were emplaced as planned.

Figures 2.1 Strain measurements during the stemming at stations 89 (near the top of the pipe), and 82 (above the diagnostics canister near the bottom of the pipe).

Figure 2.2. Emplacement diagnostics data for the GFA plugs. The upper and lower boundaries of each plug were determined with a tag line. Solid symbols indicate the elevation of the reporting probes. The open symbols are at the tag depths and the shaded symbols represent only the elevations of probes that did not report depths (the contact times are fictitious). A temperature sensor was located at probe "E" in the deepest plug and at "D" in the other two plugs. Temperature histories are not available.

3. Stemming Performance

3.1 Radiation and Pressure

As seen in figure 1.5, the region near each GFA plug (except the deepest) was monitored by pressure and radiation stations. The signals were transmitted to the recording trailer in analog form and recorded on magnetic tape for later processing.

Pressure and radiation histories, from a few seconds before detonation until station failure or recording termination, are displayed in Figures 3.1 through 3.4. Cavity collapse at about 10 hours destroyed only stations 31, 21, and 22, with the recording being maintained for more than two days after the event.

No radiation above ambient was observed at any station in the emplacement hole. Station 32 radiation recording was interrupted about one day after the event for unknown reasons and never recovered.

The slow decay of pressure observed at station 31 (figure 3.1) may be due to the influence of cavity gasses. However, the lack of radiation at that station suggests that the formation was relatively impermeable up to the time of collapse, when the station was lost.

The large pressure drop upon subsurface collapse observed at station 32 (figure 3.2) is characteristic of a stemming fall, while the slow increase in pressure after collapse suggests restricted communication with the chimney region. Figure 3.5 compares the pressure histories of station 32 (below plug 4) with that of station 33 (above plug 4). The amplitude of station 33 is amplified by a factor of 40 with the amplitude scale shown to the right of the plot. Although the signal from station 33 is noisy, less than a thirty second delay is observed in transmitting the pressure drop signal through the GFA plug.

All pressure and radiation data are consistent with complete containment.

3.2 Motion

Explosion-induced motion histories obtained from the SALUT emplacement hole are shown in figures 3.6-3.12. Station 21 was mounted in the soft CT/A plug 3, stations 23 and 24 were in the top GFA stemming plugs while the rest were in the coarse stemming material. Elevations of these stations are shown in figure 5. The accelerometer mounted in station 31 failed pre-shot and is not reported.

Arrivals and peaks of the motion are given in table 3.1 while characteristics of the motion transducers are given in tables 3.2 and 3.3.

3.3 Collapse phenomena

Both CLIPER cables (station 91 and 92) performed as expected, giving the lower position of each cable end as a function of time during the cavity collapse. These data are shown in figure 3.13 along with information on station loss, motion and pressure gleaned from figures 3.1, 3.2, and 3.14 -3.16.

Collapse motion signals are shown in figures 3.14-3.21. All times discussed below are relative to +37,000 s after detonation.

Station 21 (in the CT/A plug 2, figure 3.14) begins collapse motion at about -1 second and both acceleration and velocity channels are lost at about +0.8 s. Station 22 (in the coarse stemming, figure 3.15) shows the beginning of collapse motion at about +4 seconds with the acceleration channel being lost at about +6 seconds and the velocity channel dying at about +10 seconds. The disparity in the channel loss times, coupled with the oscillatory nature of the velocity signal suggests that this station (which was connected via a stretch cable) was suspended in free space for the few seconds before it was lost.

Although the high noise level of station 32 (in the coarse stemming, figure 3.16) precludes more than a first integration, there is a clear motion signal at +14.5 seconds. This suggests that stemming fall could have proceeded to plug 4 which then acted as a stemming platform. No collapse motion signals are seen during the time period displayed at either of the two stations in the coarse stemming below the top plug (stations 33 and 34, figures 3.18 and 3.19). Signals seen in the GFA plugs at stations 23 and 24 (figures 3.17 and 3.20), beginning at the time of collapse of station 21, are most probably due to the motion of the emplacement pipe.

Motion signals seen at station 61 (15.25 m from SGZ at a depth of 0.91 m) are shown in figure 3.21. The timing phasing, and amplitude of these data tend to make them highly suspect. They are shown for completeness.

Table 3.1 Summary of Motion

Gauge	Slant Range (m)	Arrival Time (ms)	Acceleration Peak (g)	Velocity Peak (m/s)	Displacement Peak (m)	Displacement Residual (m)
21av	263.6	110	9.8	3.9, 5.1(a)	2.1	2.3(b)
21uv		-	-	3.7, 4.6(a)	1.65	1.0
22av	317.7	75(c), 114	17.3	5.75	2.75	2.9
22uv		-	-	5.75	2.14	1.3
23av	415.23	160	9.0	2.84, 3.45(a)	1.43	1.35
23uv		-	-	2.35, 2.85(a)	1.15	0.54
24av	537.2	236	6.8, 8.2(d)	1.35, 3.98(a)	1.75	0.6
24uv		-	-	1.4, 4.1(a)	1.8	0.35
32av	406.1	98(c), 157	9.5	3.6, 4.4(a)	1.8	1.2
33av	425.9	113(c), 165	14.2	3.2, 4(a)	1.56	0.60
34av	528.0	230	8.2, 18(d)	1.6, 4.2(a)	1.86	0.9

(a) Maximum value.

(b) Approximate.

(c) Early arrival.

(d) Slap-down peak.

Table 3.2 Accelerometer Characteristics

Gauge	Natural Frequency (Hz)	Damping Ratio	System Range (g's)
21av	1550	0.70	600
22av	820	0.70	160
23av	420	0.85	50
24av	410	0.75	30
32av	(a)	(b)	625
33av	(a)	(b)	62.5
34av	(a)	(b)	62.5

(a) Piezoresistive element: mounted resonance ≥ 2000 Hz.

(b) Manufacturer's specification: damping ratio = 0.7.

Table 3.3 Velocimeter Characteristics

Gauge	Natural Frequency (Hz)	Time to 0.5 Amplitude (s)	Calibration Temperature (°C)	Operate Temperature (°C)	System Range (m/s)
21uv	4.255	16.70	22.59	23.72	32.0
22uv	3.726	29.24	22.78	19.71	30.0
23uv	3.559	9.19	24.63	30.01	16.0
24uv	3.357	10.43	24.61	32.14	8.0

Figure 3.1 Pressure and radiation measured in the coarse stemming below CT/A plug 2 (Station 31 at 431 m depth). Station signals were lost upon collapse at about 37,000 s (10 h, 17 m).

Figure 3.2 Pressure and radiation measured in the coarse stemming below GFA plug 4 (Station 32 at 201 m depth). Subsurface collapse to about 270 m occurred at about 37,000 s (10 h, 17 m). When the analog tape was changed (at about +20 hours) the radiation channel became unstable, with a large voltage offset and oscillations which persisted for about another day. Thus the data for this time period are not shown.

Figure 3.3 Pressure and radiation measured in the coarse stemming above GFA plug 4 (Station 33 at 181 m depth). The slight drop in pressure is due to the subsurface collapse which occurred at about 37,000 s (10 h, 17 m).

Figure 3.4 Pressure and radiation measured in the coarse stemming below GFA plug 5 (Station 34 at 79 m depth).

Figure 3.5 Comparison of pressure wave forms seen at stations 32 and 33 during the subsurface collapse. Note the two different amplitude scales for the two histories.

Figure 3.6 Vertical motion of CT/A plug 3 (Station 21 at 344 m depth). Traces annotated with "a" are derived from the accelerometer history.

Figure 3.7 Vertical motion in the coarse stemming between CT/A plug 3 and GFA plug 4 (Station 22 at 289 m depth). Traces annotated with "a" are derived from the accelerometer history.

Figure 3.8 Vertical motion in the coarse stemming below GFA plug 4 (Station 32 at 201 m depth).

Figure 3.9 Vertical motion of GFA plug 4 (Station 23 at 192 m depth). Traces annotated with "a" are derived from the accelerometer history.

Figure 3.10 Vertical motion in the coarse stemming above GFA plug 4 (Station 33 at 181 m depth).

Figure 3.11 Vertical motion in the coarse stemming below GFA plug 5 (Station 34 at 79 m depth).

Figure 3.12 Vertical motion of top GFA plug (Station 24 at 70 m depth). Traces annotated with "a" are derived from the accelerometer history.

Figure 3.13 Progression of collapse in stemming column as indicated by CLIPER (stations 91 and 92). Also shown are the collapse signals obtained from stations 21, 22 and 32.

Figure 3.14 Collapse motion of CT/A plug 3 (Station 21 at 344 m depth). Traces annotated with "a" are derived from the accelerometer history.

Figure 3.15 Collapse motion in the coarse stemming between CT/A plug 3 and GFA plug 4 (Station 22 at 289 m depth). Velocimeter and accelerometer give the same records until 37006 s, when the accelerometer is lost. The velocity gauge behaves as if it were "springing" on its stretch cable in the absence of stemming material. Traces annotated with "a" are derived from the accelerometer history.

Figure 3.16 Collapse motion in the coarse stemming below GFA plug 4 (Station 32 at 201 m depth). Although the accelerometer can not be integrated to displacement, there is a clear motion signal at about 37,015 s.

Figure 3.17 Collapse motion of GFA plug 4 (Station 23 at 192 m depth). Traces annotated with "a" are derived from the accelerometer history.

Figure 3.18 Collapse motion in the coarse stemming above GFA plug 4 (Station 33 at 181 m depth).

Figure 3.19 Collapse motion in the coarse stemming below GFA plug 5 (Station 34 at 79 m depth).

Figure 3.20 Collapse motion of top GFA plug (Station 24 at 70 m depth). Traces annotated with "a" are derived from the accelerometer history.

Figure 3.21 Collapse motion of the ground surface 15.24 m from Surface Ground Zero (station 61, at a depth of 0.91 m). These data are highly suspect because of the phasing, timing and amplitude: they are shown for completeness.

4. Other Measurements

4.1 Surface motion

Explosion-induced motion histories obtained from the ground surface and the recording trailer are shown in figures 4.1-4.6. Transverse motion of the trailer was not recorded.

Arrivals and peaks of the motion are given in table 4.1 while characteristics of the motion transducers are given in tables 4.2 and 4.3.

4.2 Permeability pressure measurements

The barometric pressure data from stations 32, 33, 34, and 35 are not available.

Table 4.1 Summary of Motion

Gauge	Slant Range (m)	Arrival Time (ms)	Acceleration Peak (g)	Velocity Peak (m/s)	Displacement Peak (m)	Displacement Residual (m)
61av	607.4	305	8.3, 35(a)	4.4	2.16	0.30
61uv		-	-	4.3	2.06	0.15
62av	(b)	-	-	-	-	-
62uv	697.5	345	7.4(c), 6.8(a)	2.25	0.46	0.08
63av	860.4	380	4.23, 11.8(a)	1.75	0.26	0.075
63uv		-	-	1.75	0.255	-0.10
64av	1097.7	470	5.03, 31(a)	1.42	0.205	-0.03
64uv		-	-	1.40	0.205	-0.02
71av	679(d)	351	3.8, 6(a)	2.5	0.59	0.09
71uv		-	-	2.3	0.52	-0.08
71ar	679(d)	360	0.55	0.60	0.43	-0.13
71ur		-	-	0.65	0.40	-0.16

(a) Slap-down peak.

(b) This channel was lost pre-shot.

(c) Obtained from derivative.

(d) Range is approximate: station is in recording trailer.

Table 4.2 Accelerometer Characteristics

Gauge	Natural Frequency (Hz)	Damping Ratio	System Range (g's)
61av	480	0.65	30
62av	470	0.75	50
63av	270	0.75	25
64av	790	0.85	20
71av	350	0.65	20
71ar	420	0.85	15

Table 4.3 Velocimeter Characteristics

Gauge	Natural Frequency (Hz)	Time to 0.5 Amplitude (s)	Calibration Temperature (°C)	Operate Temperature (°C)	System Range (m/s)
61uv	3.539	8.05	22.92	16.49	12.0
62av	3.420	9.68	23.20	18.72	12.0
63uv	3.515	8.59	24.80	17.17	10.0
64uv	3.438	9.46	24.50	17.28	10.0
71uv	3.515	9.28	24.33	18.72	7.0
71ur	3.334	9.39	24.48	18.72	5.0

Figure 4.1 Explosion-induced vertical motion of ground surface at a depth of 0.91 m and horizontal range of 15.24m from SGZ on a line extending 83° east of south (station 61). Traces annotated with "a" are derived from the accelerometer history.

Figure 4.2 Explosion-induced vertical motion of ground surface at a depth of 0.91 m and horizontal range of 305.4m from SGZ on a line extending 3° east of south (station 62). The accelerometer at this station was lost pre-shot and the acceleration data were obtained from the velocity history.

Figure 4.3 Explosion-induced vertical motion of ground surface at a depth of 0.91 m and horizontal range of 610.8m from SGZ on a line extending 3° east of south (station 63). Traces annotated with "a" are derived from the accelerometer history.

Figure 4.4 Explosion-induced vertical motion of ground surface at a depth of 0.91 m and horizontal range of 914.4m from SGZ on a line extending 3° east of south (station 64). Traces annotated with "a" are derived from the accelerometer history.

Figure 4.5 Explosion-induced vertical motion of recording trailer (station 71). Horizontal range is approximately 679 m. Traces annotated with "a" are derived from the accelerometer history.

Figure 4.6 Explosion-induced horizontal-radial motion of recording trailer (station 71). Horizontal range is approximately 679 m. Traces annotated with "a" are derived from the accelerometer history.

References

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