QUESO

Containment Data Report

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QUESO 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
Challenge	no	-	-
Cavity	no	-	-
Atmospheric	no	-	-
<u>Motion</u>			
Free Field	yes	yes	yes
Surface	yes	yes	yes
Plug	yes	yes	yes
Stemming	no	-	-
Surface Casing	yes	yes	yes
Emplacement Pipe	yes	yes	yes
<u>Hydroyield (a)</u>	yes	yes	no
<u>Collapse (b)</u>	yes	yes	yes
<u>Stress</u>	yes	yes	yes
<u>Strain(c)</u>	yes	no	-
<u>Other Measurements (d)</u>	yes	yes	yes

- (a) CORTEX or SLIFER in emplacement hole.
 (b) EXCOR or CLIPER in emplacement hole.
 (c) Emplacement pipe.
 (d) Motion across an intersecting fault.

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1. Event Description

1.1 Site

The QUESO event was detonated in hole U10bf of the Nevada Test Site as indicated in figure 1.1. The device had a depth-of-burial (DOB) of 216 m in the alluvium of Area 2, about 460 m above the Paleozoic and about 360 m above the standing water level, as shown in figures 1.2 and 1.3⁽¹⁾. Stemming of the 1.63 m diameter emplacement hole followed the plan shown in figure 1.4. A 1.22 m diameter liner was grouted inside the emplacement hole between depths of 202 and 222.5 m. An additional exploratory hole (Ue2bf) was drilled 15 m to the west of the emplacement hole. This hole was grouted from depth to 24 m below the surface and filled with naive backfill to the surface. A log of the stemming operations was maintained by Holmes & Narver⁽²⁾.

Detonation time was 08:00 PDT on August 11, 1982 and about 25.5 minutes later a subsurface collapse to a little greater than half the DOB occurred. Slight pressure change activity was detected about 54 hours later.

No radiation arrivals were detected above the ground surface and the QUESO 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 QUESO event.

The four stemming plugs were composed of coal-tar epoxy (LAE 59, denoted CTE). A soft layer of coal-tar and aggregate (LAE 59MY, denoted CTA) was poured on the top of the bottom and the top plugs to act as a gas seal.

Pressure and radiation was monitored in the coarse stemming about 6 m beneath the bottom surfaces of each of the four stemming plugs. A similar station was fielded about 1.5 m above the deepest plug.

Vertical motion was monitored in each of the four plugs in the emplacement hole on the surface casing, on the emplacement pipe, at three locations in the satellite hole corresponding to the top three stemming plugs in the emplacement hole and in the ground surface, 15.24 m from SGZ. A dual set of reel- type displacement transducers were fielded in the bottom three stemming plugs in the emplacement hole to monitor the relative displacement between each plug and the underlying stemming. Another pair monitored the surface casing - stemming relative displacement and the emplacement pipe - surface casing relative displacement.

As part of a continuing effort to develop an in-situ stress transducer, two elevations were instrumented with stress and strain transducers in the emplacement hole and one in the satellite hole.

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

D-cable information was used for quality assurance during the stemming operations.

One CLIPER/CORRTEX sensor was emplaced in the emplacement hole and one in the satellite hole, as indicated in figures 1.5 and 1.6, 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⁾.

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.

1.3. Emplacement

A single strain station (93) was fielded near the top of the emplacement pipe to monitor the load during installation and stemming. This station was monitored randomly during these procedures and was recorded by hand during the device installation only. Emplacement was detailed by Holmes & Narver⁽²⁾. The stemming plugs consisted of four "LAE 59" coal-tar epoxy (CTE) plugs. The bottom three were about 4 m thick while the top was about 6 m thick. The bottom and the top plugs were capped with about 1.8 m of soft coal-tar-aggregate "LAE 59MY" epoxy (CTA) to act as a gas sealant. 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. See figure 1.4. The emplacement pipe was coated with hydoseal in the region of the plugs to allow free movement through the plugs and the inside of the pipe was grouted to near the surface.

All motion and stress stations in the satellite hole were hung on a fiberglass pipe which also carried a compass. The pipe was rotated until the correct orientation of the stress gauges was obtained and then the hole was grouted.

Figure 1.1 Map of the Nevada Test Site indicating the location of hole U10bf.

Figure 1.2 North-South geologic cross sections through hole U10bf.

Figure 1.3 Southwest-Northeast geologic cross sections through hole U10bf.

Figure 1.4 As-built stemming plan for the event QUESO in Hole U10bf.

ALL DIMENSIONS ARE REFERENCE

Figure 1.5 As-built containment instrumentation plan for the emplacement hole (U10bf) on the QUESO event.

2. Stemming Performance

2.1 Radiation and Pressure

As seen in figure 1.5, pressure and radiation was monitored in the coarse stemming at a total of five stations. Four stations were placed about 6 m beneath the bottom surfaces of each of the four stemming plugs. A similar station was fielded in the coarse stemming 1.5 m above the bottom plug.

Figure 2.1 shows the pressure and radiation detected in the coarse stemming below the deepest stemming plug. This station was lost at about 1533 s, the time of subsurface collapse. This is the only pressure and radiation station that did not survive indefinitely. Figures 2.2, 2.5, 2.8 and 2.9 show the pressure and radiation histories obtained at stations 32, 33, 34 and 35 for a period lasting about 55 hours after detonation. The data were recorded on magnetic tape with the maximum recording time per tape being less than 6 hours. Ten tapes were processed for this report and the gaps in the records are due to the requirement to manually change the tapes.

Only the stations in the loose stemming between plugs 1 and 2 (stations 32 and 33) show any pressure or radiation activity and this occurred after subsurface collapse to the region of the bottom plug. The first 8000 s of pressure and radiation histories obtained from stations 32 and 33 are displayed in figures 2.3 and 2.6. Figure 2.3 (station 32) indicates a radiation arrival coinciding with the pressure drop of the collapse followed by gradual increase with a maximum increase rate occurring at about 1 hour. There is no abrupt collapse-induced radiation arrival at station 33 (figure 2.5) and the maximum radiation increase rate at that station occurs about 20 minutes after the maximum of station 32. In general, the radiation wave forms at stations 32 and 33 are the same (figures 2.2 and 2.5) but are different in magnitude by about a factor of 10 with station 32 registering the lower level. Since station 32 is nearer the source than station 33, the levels are contrary to intuition and the gauge calibrations are suspect.

Details of the pressure changes seen at stations 32 and 33 are shown in figures 2.4 and 2.6. The character of the collapse-induced pressure drop at about 1533 s is similar for both stations 32 and 33 suggesting that both were exposed to a similar collapse phenomenon, likely a stemming fall. The pressure histories seen at about 193,400 s at both stations are unexplained.

All pressure and radiation data are consistent with satisfactory containment.

Figure 2.1 Pressure and radiation measured in the coarse stemming at 136m depth, below the deepest stemming plug 1 (Station 31). Signals were lost at subsurface collapse time (1533 s).

Figure 2.2 Pressure and radiation measured in the coarse stemming at 122 m depth, above the deepest stemming plug 1 (Station 32). Gaps in the records occurred when the magnetic tape required manual replacing.

Figure 2.3 Pressure and radiation measured in the coarse stemming at 122 m depth, above the deepest stemming plug 1 (Station 32). The first 8000 s includes the subsurface collapse pressure drop and radiation arrivals. Radiation arrives as a direct result of collapse.

Figure 2.4 Station 32 pressure histories at subsurface collapse (at about 1533 s) and at later at about 193,400 s. Depth is 122 m.

Figure 2.5 Pressure and radiation measured in the coarse stemming at 94.5m depth, below stemming plug 2 (Station 33). Gaps in the records occurred when the magnetic tape required manual replacing.

Figure 2.6 Pressure and radiation measured in the coarse stemming at 94.5m depth, below stemming plug 2 (Station 33). The first 8000 s includes the subsurface collapse pressure drop and radiation arrivals. There is no radiation jump at subsurface collapse.

Figure 2.7 Station 33 pressure histories at subsurface collapse (at about 1533 s) and at later at about 193,400 s. Depth is 94 m.

Figure 2.8 Pressure and radiation measured in the coarse stemming at 59.1 m depth, below stemming plug 3 (Station 34). Gaps in the records occurred when the magnetic tape required manual replacing.

Figure 2.9 Pressure and radiation measured in the coarse stemming at 40 m depth, below the top stemming plug (Station 35). Gaps in the records occurred when the magnetic tape required manual replacing.

2.2 Motion

Explosion-induced histories of the containment related motion measured on the QUESO event are shown in figures 2.10-2.19. Characteristics of the associated motion and transducers are given in tables 2.1–2.3.

Acceleration measured at station 62 (figure 2.15) went beyond the system limits (4 g's) and it was necessary to augment the single peak that went out of band to force the integral history (velocity) to be zero at late time. This required only a small increment to the velocity. The acceleration peak is expected to be nearly correct and the velocity within the experimental error of 5%.

Both the acceleration and velocity signals from station 1 (figure 2.16) exceeded the system limits precluding the presentation of any integral of the acceleration and only the first integral of the velocity (displacement). Only the first peak of the velocity record is out of band and is of a very short duration suggesting that the displacement recorded, although greater than shown, is approximately correct.

Noise spikes visible on the acceleration records from stations 41, 42 and 43 (figures 2.17-2.19) at about 200 ms are postulated to arise from stress relief of the fiberglass pipe on which the stations were hung as the relief wave from the surface passes the stations.

Figure 2.20 is a composite plot of the velocity wave forms comparing the histories at equivalent slant ranges. This indicates that the motion measured in the solid plugs is a good representation of the free-field motion, as measured in the grout of the satellite hole. Two sets of arrivals are noted on the records. The first, traveling at about 5 Km/s, is postulated to arise from motion in the emplacement pipe while the second arrival, traveling at about 2 Km/s, is close to the sound speed of the medium⁽¹⁾.

Table 2.1 Summary of Containment-Related Motion

Gauge	Slant Range (m)	Arrival Time (ms)	Acceleration Peak (g)	Velocity Peak (m/s)	Displacement Peak (cm)	Displacement Residual (cm) ^(e)
1av	217	50(a)	(b)	(b)	(b)	(b)
1uv		-	-	0.44(c)	49(d)	48(d)
21av	88.6	19(a), 40	8.0	0.44	2.8	0.2
21uv		-	-	0.45	2.8	0.4
22av	127.6	27(a), 57	3.8(f), 5.9	0.2	1.42	-0.25
22uv		-	-	0.21	1.45	-0-
23av	164.5	34(a), 85	2.4(f), 13.5(g)	0.14	1.29	0.1
23uv		-	-	0.14	1.21	0.2
24av	181.1	42(a), 95	1.5(f), 11.9(g)	0.23	1.87	0.6
24uv		-	-	0.20	1.50	0.1
41av	127.5	60	2.0(f), 3.2	0.24	1.34	0.1
41uv		-	-	0.24	1.48	-0-
42av	164.5	82	1.5(f), 8.9	0.20	1.17	-0.2
42uv		-	-	0.21	1.23	0.1
43av	181.0	94	1.3(f), 11.4(g)	0.23	1.65	0.6
43uv		-	-	0.20	1.40	-0.2
61av	215.6	127	2.6(f), 11.0(g)	0.37	2.24	-1.8
61uv		-	-	0.35	2.05	-1.0
62av	215.1	52(a), 114	1.2(f), 4.2(g)	0.30	1.72	-0.6
62uv		-	-	0.34	1.97	-0.6

(a) Pipe-induced motion.

(b) Channel is driven out of band with first 140 ms unusable.

(c) First peak is out of band.

(d) Lower limit.

(e) Estimate.

(f) Precursor.

(g) Slap-down.

Table 2.2 Containment-Related Accelerometer Characteristics

Gauge	Natural Frequency (Hz)	Damping Ratio	System Range (g's)
1av	550	0.65	16
21av	331	0.55	16
22av	350	0.65	8
23av	179	0.75	4
24av	182	0.55	4
41av	210	0.65	8
42av	170	0.65	4
43av	170	0.75	4
61av	180	0.75	4
62av	620	0.65	4

Table 2.3 Containment-Related Velocimeter Characteristics

Gauge	Natural Frequency (Hz)	Time to 0.5 Amplitude (s)	Calibration Temperature (°C)	Operate Temperature (°C)	System Range (m/s)
1uv	3.85	14.25	24.77	26.26	8
21uv	3.62	8.10	25.06	29.13	4
22uv	3.70	7.20	26.06	25.05	2
23uv	3.70	8.40	26.06	27.65	3
24uv	3.60	8.60	25.94	36.56	3
41uv	3.57	8.90	25.00	17.95	2
42uv	3.50	111.48	24.94	17.28	2
43uv	3.50	11.55	25.33	17.39	3
61uv	3.44	10.25	25.17	27.45	8
62uv	3.41	19.56	25.06	26.46	4

Figure 2.10

Explosion-induced vertical motion of the bottom stemming plug at a depth of 127 m (station 21). Traces annotated with "a" are derived from the accelerometer.

Figure 2.11 Explosion-induced vertical motion of stemming plug 2 at a depth of 88.4 m (station 22). Traces annotated with "a" are derived from the accelerometer.

Figure 2.12 Explosion-induced vertical motion of stemming plug 3 at a depth of 51.5 m (station 23). Traces annotated with "a" are derived from the accelerometer.

Figure 2.13 Explosion-induced vertical motion of the top stemming plug at a depth of 34.9 m (station 24). Traces annotated with "a" are derived from the accelerometer.

Figure 2.14 Explosion-induced vertical motion of the surface casing (station 62). Traces annotated with "a" are derived from the accelerometer.

Figure 2.15 Explosion-induced vertical motion of the emplacement pipe (station 1). The signal was beyond the dynamic range of the accelerometer as was the initial peak for the velocimeter. The derived displacement should be considered a lower limit to the true value.

Figure 2.16 Explosion-induced vertical motion of the ground surface at a horizontal range of 15.24 m and a depth of 0.9 m (station 61).

Figure 2.17 Explosion-induced vertical motion in the satellite hole (station 41 at a depth of 89.4 m). This station was emplaced at a slant range equivalent to that of station 22, in the emplacement hole. Traces annotated with "a" are derived from the accelerometer.

Figure 2.18 Explosion-induced vertical motion in the satellite hole (station 42 at a depth of 89.4 m). This station was emplaced at a slant range equivalent to that of station 23, in the emplacement hole. Traces annotated with "a" are derived from the accelerometer.

Figure 2.19 Explosion-induced vertical motion in the satellite hole (station 43 at a depth of 89.4 m). This station was emplaced at a slant range equivalent to that of station 24, in the emplacement hole. Traces annotated with "a" are derived from the accelerometer.

Figure 2.20 Comparison of velocity wave forms measured in the emplacement hole with those measured in the satellite hole. When there is more than one trace at a given elevation, the heavier is associated with the emplacement hole. The ground motion is seen to propagate at a speed of about 2 Km/s while motion attributed to the emplacement pipe travels at about 5 Km/s.

2.3 Collapse phenomena

Figure 2.21 shows the collapse motion histories obtained from station 21 in the bottom stemming plug. The accelerometer was lost at 1533.4 s while the velocity gauge remains on line for about an additional 50 s. The accelerometer and velocimeter are in agreement as long as they last, while the velocity record suggests that the station rotated during collapse. The resulting displacement is shown for completeness and is clearly not valid.

Collapse motion of the top of the emplacement pipe is shown in figure 2.22. This station was lost at about 1570 s and suggests a total displacement of about 23 cm at that time.

The CLIPER cables in the emplacement hole (stations 91) and in the satellite hole (station 51) performed as expected, giving the lower position of the cable end as a function of time during the cavity collapse. The cable of station 91 was attached to the device canister and emplacement pipe. These data are shown in figure 2.23 along with pressure wave forms (not to vertical scale) from stations 32 and 33 and the velocity history of the bottom plug (station 21). Collapse is seen to progress to about the upper surface of the bottom stemming plug (a depth of about 123 m) while the satellite hole registers collapse to a depth of about 148 m at about 1532 s. An additional, final, single collapse in the emplacement hole to a depth of 119 m (not shown) was registered at 4150 s.

The two pressure wave forms shown in figure 2.23 suggest that the collapse progressed up the emplacement hole beyond the upper limits indicated by the CLIPER data.

Pairs of Celesco® displacement transducers (reel-type extensometers) were fielded near the bottom of each of the bottom three CTE plugs to monitor separation of the plugs and the stemming below them. An additional pair was placed between the surface casing and the emplacement pipe and the stemming at the top of the hole. The down-hole stations were initially mounted on stand-off brackets on the emplacement pipe. When the stemming and plug material enveloped them, the stations were freed from the brackets by the detonation of explosive bolts. Results of the measurements are shown in figures 2.24 - 2.27.

To estimate the relative vertical separation between the emplacement pipe and the top plug, the difference between the displacement histories of the surface casing and the top plug was computed from the motion data. The resulting wave form is shown in figure 2.28. Comparison of these data with those of figure 2.27 suggests a compaction of the stemming above the top plug of more than 1 m (about 1 %).

Figure 2.21 Collapse-induced vertical motion of stemming plug 1 (station 21 at a depth of 127.4 m). The velocimeter signal lasted substantially longer than the accelerometer signal and suggests rotation of the station.

Figure 2.22 Collapse-induced vertical motion of emplacement pipe (station 1).

Figure 2.23 Progression of the collapse as determined from the CLIPER records (stations 51, and 91). The upper limit of the subsurface collapse in the emplacement hole is indicated to be at a depth of about 126 m, in or near the bottom plug (a later, single collapse in the emplacement hole to a depth of 119 m occurred at 4150 s). Included are the collapse-induced pressure changes seen at stations 32 and 33 and the velocity history of the bottom plug (station 21). The pressure change seen at about 193,400 s did not register on the CLIPER instrumentation.

Figure 2.24 Relative displacement between plug 1 and the stemming below it.

Figure 2.25 Relative displacement between plug 2 and the stemming below it.

Figure 2.26 Relative displacement between plug 3 and the stemming below it.

Figure 2.27 Relative displacement between the surface casing and the stemming (station 36) and the relative displacement between the emplacement pipe and the surface casing (station 2).

Figure 2.28 Relative displacement between the surface casing and the top plug (the difference between the displacement histories of station 62 and station 24). Due to the expected experimental errors and those inherent in integration, these data are consistent with zero net displacement.

3. Stress measurements

As part of a continuing effort to develop a transducer to measure in-situ stress, a composite stress and strain transducer (the internal structure of which is shown in figure 3.1) was developed by Dynasen, Inc⁽⁶⁾. Figures 3.2 - 3.5 show the output from four of the composite transducers at two locations in coarse stemming of the emplacement hole. Both strain elements of station 14 (figure 3.4) were lost pre-shot. Stations 11 and 14 were configured to sense the radial stress and strain produced by the explosion while stations 12 and 15 sensed hoop stress and strain.

Four additional single element (flat-pack) stress transducers developed by SRI were also fielded in both the emplacement hole and the satellite hole. The internal structure of these is schematically shown in figure 3.6. A flat pack gauge accompanied each of the two composite stress gauge locations in the emplacement hole and two were fielded at approximately the depth of working point in the satellite hole. In the satellite hole the stress gauges were oriented to sense the radial and the hoop stress. Both flat-pack gauges in the emplacement hole (stations 13 and 16) sensed hoop stress.

The outputs from the flat-pack gauges are shown in figures 3.7-3.9 wherein the amplitudes are given in units of percent resistance change. All elements (Yb, C, and Constantan) of the composite gauges are assumed to have an unstressed resistance of $350 \pm 70 \Omega$ while the SRI flat-pack transducer elements are assumed to have a 50Ω resistance.

Figure 3.1 Structure of composite gauge showing the two piezoresistive elements (Ytterbium and carbon) and the strain transducers. The strain grids were installed in both parallel and transverse orientations.

Figure 3.2 Output of composite radial stress-strain gauge station 11 at a depth of 194.5 m (22 m from explosive source). Each element is assumed to have an original resistance of 350Ω .

Figure 3.3 Output of composite hoop stress-strain gauge station 12 at a depth of 194.5 m (22 m from explosive source). Each element is assumed to have an original resistance of 350 Ω .

Figure 3.4

Output of composite radial stress-strain gauge station 14 at a depth of 166.4m (50.1 m from explosive source). The strain elements (Constantan) were inoperative pre-shot. Each element is assumed to have an original resistance of 350 Ω .

Figure 3.5 Output of composite hoop stress-strain gauge station 15 at a depth of 166.4m (50.1 m from explosive source). Each element is assumed to have an original resistance of 350 Ω .

Figure B1. The flat-pack gage featuring an ytterbium grid.

Figure 3.6 Structure of Ytterbium flat-pack stress gauge developed at SRI.

Figure 3.7 Output of Ytterbium flat-pack hoop stress transducer mounted at a depth of 194.5 m in the emplacement hole (station 13). The Yb element is assumed to have an original resistance of $50\ \Omega$.

Figure 3.8 Output of Ytterbium flat-pack hoop stress transducer mounted at a depth of 166.4 m in the emplacement hole (station 16). The Yb element is assumed to have an original resistance of 50 Ω .

Figure 3.9

Output of Ytterbium flat-pack stress transducers mounted at a depth of 200.5 m in the satellite hole and oriented to sense radial and transverse stress (stations 52 and 53). The Yb elements are assumed to have original resistances of 50 Ω .

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