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AGRINI

Containment Data Report

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Laboratory

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AGRINI 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	yes	yes	yes
Cavity	no	-	-
Atmospheric	no	-	-
<u>Motion</u>			
Free Field	no	-	-
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>	no	-	-
<u>Strain (c)</u>	yes	yes	yes
<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) Strain in Gypsum Concrete Plugs

Event Personnel

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Contents

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1. Event Description

1.1 Site

The AGRINI event was detonated in hole U2ev of the Nevada Test Site as indicated in figure 1.1. A plan view map of the local region around hole U2ev indicating the inferred faults and drill holes is shown in figure 1.2. The device had a depth-of-burial of 320 m in the alluvium of Area 2, about 260 m above the standing water level (SWL) and almost 550 m above the Paleozoic formation, as shown in figure 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⁾.

Hudson et. al. analyzed, in detail, much of the data presented here⁽³⁾.

Detonation time was 06:30 PST on March 31, 1984 and about 104 minutes later an unusual chimney collapse reached the surface with an attendant small release of radiation.

1.2. Emplacement

AGRINI was the first event on which coarse gypsum aggregate (GFA) in a gypsum cement slurry was used as containment plug material. The bottom plug (15.2 m thick), in the region of expected maximum permanent compressive stress (the "containment cage"), served as a barrier to the rapid arrival of radioactivity in the column while the top plug (3.5 m thick) was installed to experimentally test the efficacy of the gypsum aggregate and gypsum cement as a containment member. To simulate the loss of stemming below the top plug, it was poured on a layer of low density foam blocks^(2,3).

Two additional GFA stemming platforms were included in the stemming plan. Each of the four GFA plugs was monitored during emplacement with arrays of conductivity probes, thermistors and Metritapes[®]. An additional two plugs were soft, coal tar aggregate (CT/A) gas seal membranes having a thickness of about 3.3 m sandwiched between layers of fines material. A seventh 5.5 m thick, rigid, coal-tar epoxy (CTE) plug was fielded, starting about 1 m below the bottom of the surface casing. A layer of CT/A was poured on the top of the two stemming platforms and the CTE plug to act as impediments to gas flow. A topping of CT/A was thought to be of little use on both the bottom, thick plug and the top, experimental plug.

The emplacement of each of the four gypsum concrete plugs was monitored with an array conductivity probes , thermistors and Metritape®. The locations of the probes are tabulated in figure 1.5. The upper and lower boundary positions of the plugs were determined by tag lines. Figure 1.6 contains plots of the arrival times of the GFA slurry as a function of depth (as determined from the conductivity probes and tag lines). Thermistor readings were monitored in the stemming trailer to assure that the required set-up temperature was reached and the Metritape output was monitored but not shown in figure 1.6. See reference 1.3 for a display of the Metritape records. These data indicate that all plugs were emplaced as planned.

1.3 Instrumentation

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

A 15 m thick gypsum-filled aggregate concrete plug (GFA) was emplaced near the region of expected maximum permanent compressive stress (the "containment cage"). Pressure and radiation challenging this plug were monitored through a hose (a braided wire rope) penetrating the plug to near the diagnostics canister. The bottom portion of this hose (about 24 m) was stripped of its protective gas barrier to act as a sieve over the entire region of coarse stemming between the diagnostics canister and the plug. The upper portion of the hose (retaining its protective coating) extended up for about 52 m to a depth of 228.3 m, the location of the transducers.

Pressure and radiation were monitored in the coarse stemming on either side of a thin coal-tar aggregate (CT/A) layer emplaced to act as a gas impedance. A standard station transmits the data as an analog signal which may be multiplexed and recorded in the trailer; accompanying the standard stations on either side of the CT/A layer were two experimental stations from which the data were multiplexed down-hole.

Vertical motion was monitored in the top three GFA plugs, on the surface casing, on the top of the emplacement pipe, and at 0.61 m depth in the ground surface, 15.24 m from SGZ. Displacement between the surface casing and the top plug was monitored by a Vernitech® "fishing reel" type extensometer.

Strain was monitored by an array of four "dumbbell" transducers in each of the top three GFA plugs.

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

Two CLIPER sensors were fielded, one on the emplacement pipe and the other on the instrumentation pendant, 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⁽⁴⁾.

A history of the fielding operations of the instrumentation, including the emplacement pipe strain measurements, is outlined in reference 5. Details of the instrumentation are given in reference 6.

Figure 1.1 Map of the Nevada Test Site indicating the location of hole U2ev.

Figure 1.2 East-West geologic cross section through hole U2ev.

Figure 1.3 North-South geologic cross section through hole U2ev.

Figure 1.4 As-built stemming plan for the event AGRINI in Hole U2ev.

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

Figure 1.6 Emplacement diagnostics data at the GFA plugs. The upper and lower boundaries of the plug were determined with a tag line. Solid symbols indicate the elevation of the probes and the open symbols are at the tag depths. Metritape data tend to confirm the conductivity probe information⁽³⁾. Start time for each plug pour is arbitrary.

2. Stemming Performance

2.1 Radiation and Pressure

Pressure and radiation histories from a few seconds before detonation until 6500 s later are shown in figures 2.1–2.5. Signal was lost at all stations upon collapse at about 6240 s (104 minutes).

Challenge pressure and radiation were monitored at station 31 (figure 2.1) through a 76 m length of gas sample hose. The transducers were at a depth of 228 m, 92 m above the working point, to insure their survival. This "hose" was a braided wire rope that penetrated the deep plug and was terminated on its lower end with a 24 m length of screen (the rope with gas-seal protective coating removed). A rapid (within the first 100 s) pressure jump of about 40 psi was seen followed by a gradual increase to around 155 psia at 5200 s. This was followed by a fairly rapid decrease in pressure to near ambient at collapse at around 6240 s when the signal was lost. A radiation arrival at near 4000 s was observed in the hose. The radiation level rose rapidly until the time that the maximum in pressure was attained when a more gradual radiation increase prevailed until the signal was lost at collapse.

The output of station 32, located in the coarse stemming within 3 m above station 31, is seen in figure 2.2. This station monitored the coarse stemming between the deep, rigid plug and the first soft, gas-seal CT/A membrane. A rapid (within the first 100 s) pressure increase of about 7 psi was seen followed by a gradual decrease to near ambient at collapse time, when the signal was lost. A radiation arrival was seen at about 4600 s, 10 minutes after the arrival in the hose assembly of station 31. Station 33 (figure 2.3), paired in elevation with station 32, was nearly identical in output to station 32. It was at the deeper elevation of two experimental multiplexed stations.

Station 34 (figure 2.4) monitored the coarse stemming above the first soft, gas-seal CT/A membrane and about 9 m above station 32. A rapid jump of about 1.3 psi which likely was due to ground compaction occurred near detonation time and decayed to ambient at collapse. No radiation arrival was seen above the deep soft plug before collapse. Station 35 (figure 2.5), paired in elevation with station 34, was nearly identical in output to station 34. It was at the shallower elevation of two experimental multiplexed stations.

2.2 Motion

Explosion-induced motion histories obtained from the AGRINI experiment are shown in figures 2.6-2.11. Characteristics of the motion and of the motion transducers are given in tables 2.1-2.3.

The vertical motion detected on AGRINI was unremarkable except for the station 22 acceleration (figure 2.7), in the stemming platform at a depth of 75.6 m. This signal contained a large noise component which apparently led to very low velocity and displacement amplitudes. Comparing the velocity and displacement data derived from the velocimeter at this station with the data from the other stations, we conclude that the accelerometer data are incorrect.

Note that the data from stations 23 and 24 (figures 2.8 and 2.9) are almost identical suggesting that, during the explosion, the top GFA plug remained intact and bonded to the surface casing. The final relative displacement between the two stations as determined by their respective velocity transducers is less than 1.0 cm.

Figure 2.1

Pressure challenging the deepest GFA plug at a depth of 277 m. Gas pressure was sensed through a section of wire rope (gas sample hose). Transducer station was emplaced within the coarse stemming below the deepest soft gas seal plug at a depth of 228.3 m (station 31). Radiation was also monitored through this "hose". The first 20 s of data are displayed in the inserts.

Figure 2.2 Pressure and radiation measured in the coarse stemming below the deepest soft gas seal plug (Station 32 at a depth of 225.7 m). Standard transmission was employed. The first 20 s of data are displayed in the inserts.

Figure 2.3 Pressure and radiation measured in the coarse stemming below the deepest soft gas seal plug (Station 33 at a depth of 225.7 m). This was one of two multiplexed stations.

Figure 2.4 Pressure and radiation measured in the coarse stemming above the deepest soft gas seal plug (Station 34 at a depth of 216.4 m). Standard transmission was employed. The first 20 s of data are displayed in the inserts.

Figure 2.5 Pressure and radiation measured in the coarse stemming above the deepest soft gas seal plug (Station 35 at a depth of 216.4 m). This was one of two multiplexed stations.

Figure 2.6 Vertical motion of the second GFA plug at a depth of 115.8 m (station 21). When there is more than one trace in a plot, the lighter is derived from the accelerometer.

Figure 2.7 Vertical motion of the third GFA plug at a depth of 75.6 m (station 22). When there is more than one trace in a plot, the lighter is derived from the accelerometer. The very high level of noise in the accelerometer record tends to cast suspicion on its validity.

Figure 2.8 Vertical motion of the top GFA plug (station 23 at a depth of 8.4 m). When there is more than one trace in a plot, the lighter is derived from the accelerometer.

Figure 2.9 Vertical motion of the top of the surface casing (station 24). When there is more than one trace in a plot, the lighter is derived from the accelerometer.

Figure 2.10 Vertical motion of the top of the emplacement pipe (station 1). When there is more than one trace in a plot, the lighter is derived from the accelerometer.

Figure 2.11 Vertical motion of the ground surface (station 61 at a horizontal range of 15.24 m and a depth of 0.9 m). When there is more than one trace in a plot, the lighter is derived from the accelerometer.

Table 2.1 Summary of Motion

Gauge	Slant Range (m)	Arrival Time (ms)	Acceleration Peak (g)	Velocity Peak (m/s)	Displacement Peak (cm)	Displacement Residual (cm)
1av	321	100	120(a)	11.5(a), 7.8	85	110
1uv		100	-	10.5(a), 7.1	81	57
21av	204.2	47(a), 93	1.1, 2.8(b)	0.50	7.6	-5.3
21uv		93	-	0.50	7.6	-5.4
22av(c)	244.4	(e)	0.2(d)	0.18(c)	2.9(c)	-0.8(c)
22uv		121	-	0.43	7.0	-6.5
23av	311.6	98(a), 160	3.0(d), 12.2(b)	0.53	7.4	-8.7
23uv		103(a), 160	-	0.55	7.9	-8.0
24av	320.0	98(a), 160	5(d), 15(b)	0.60	8.5	-4.8
24uv		10(a), 160	-	0.52	7.0	-7.3
61av(f)	319.5	185	0.11, 3.35(b)	0.65	10.5	-23
61uv		192	-	0.54	8.4	-9.0

(a) Pipe-induced motion.

(b) Slap-down (termination of first negative phase of motion).

(c) Large off-set at ZIP followed by extreme noise. Data are highly questionable.

(d) Approximate.

(e) Could not estimate - data too noisy.

(f) Data amplitude questionable

Table 2.2 Accelerometer Characteristics

Gauge	Natural Frequency (Hz)	Damping Ratio	System Range (g's)
1av	1500	0.65	1200
21av	275	0.75	6
22av	260	0.65	5
23av	340	0.70	16
24av	360	0.65	16
61av	620	0.60	30

Table 2.3 Velocimeter Characteristics

Gauge	Natural Frequency (Hz)	Time to 0.5 Amplitude (s)	Calibration Temperature (°C)	Operate Temperature (°C)	System Range (m/s)
1uv	3.868	30.69	25.36	34.64	80
21uv	4.000	9.63	25.10	82.66	4
22uv	3.578	9.37	25.08	88.29	3.2
23uv	3.349	10.42	25.12	84.08	16
24uv	3.700	8.09	25.07	41.06	16
61uv	3.603	8.68	24.37	51.56	16

3 Collapse phenomena

3.1 Radiation and Pressure

Records of pressure and radiation during the 20 s spanning the collapse at 6240 s obtained from the four stations surrounding the deepest soft gas impedance layer are shown in figures 3.1 - 3.5. Station 31 monitored a long hose representing a wide section of stemming between the deep GFA plug and the device canister. The collapse data from this station were difficult to interpret but are shown in figure 3.1.

The pressure records from stations 32 and 33 were identical (figures 3.2 and 3.3), showing the effect of a stemming drop starting at 6228 s and maintaining a low pressure for about 4 s at which time the cabling to the transducer was damaged. The radiation wave forms of the two stations were similar during this time: almost an order-of-magnitude, nearly monotonic decrease in dose rate during the constant low pressure phase.

Above the soft layer, stations 34 and 35 (figures 3.4 and 3.5) also show an identical pressure history beginning about 1 s later than the lower stations and lasting for about 3 s. The radiation histories of the two stations, however, suggest that there was a slight dose rate increase associated with the low pressure phase just before the signals were lost.

3.2 Motion

Collapse motion histories are shown in figures 3.6-3.11. All stations below the top plug were lost at collapse at around 6240 s. All stations in and above the top plug survived collapse. Motion was detected at only stations 21 and 22, in the GFA stemming platforms (figures 3.6 and 3.7) and on the emplacement pipe (figure 3.10). The other three stations recorded just the occurrence and the outputs from the accelerometers and velocimeters are shown only for completeness (figures 3.8, 3.9, and 3.11). The character of all of the surviving motion records suggests a grounding problem beginning at or shortly after 6237 s. The sole exception to this was the velocity record from station 22 (figure 3.7). Credence to the postulate that the signals were due to electronic problems is given by the similarity of the trace from station 61 (figure 3.11) which was not directly involved in the collapse.

Data were received from both CLIPER cables (stations 91 and 92, figure 3.12) giving the lower position of each cable end as a function of time during the cavity collapse. Station 91, mounted on the emplacement pipe failed to transmit properly due to a coaxial relay⁽⁵⁾. However, a final break at 68.9 m (near the top of the upper GFA stemming platform) at a time of about 6240 s was registered. The data from station 92, fielded on the instrumentation pendant is shown in figure 3.12 along with pressure wave forms from stations 33 and 35 and velocity wave forms from stations 21 and 23.

An extensometer was mounted to the surface casing and connected to the top GFA plug to detect relative displacement between the two. The output of this device (station 89) is shown in figure 3.13. It is suspected to have failed.

3.2 Crater

Based upon the data presented above, it would be reasonable to conclude that AGRINI was a normal, benign event without a surface crater (stations 23 and 61 show no net displacement at collapse time). There was, in fact, an unusual collapse crater which broached the ground surface about 104 minutes after detonation. Figure 3.13 is a drawing of the feature as determined by observation with a down-hole television camera. Associated with the cratering event there was a series of six or seven dust "burps" emitted from the crater at regular intervals. These were interpreted to have been the results of side-wall caving and may have been associated with sonic resonance in the crater.

About 9 hours after detonation, low levels of radioactive gas seeped into the atmosphere. This was contained to the test site.

Figure 3.1 Collapse epoch pressure and radiation challenging the deepest GFA plug at a depth of 277 m as sensed through a section of wire rope (gas sample hose). Transducer station was emplaced within the coarse stemming below the deepest soft gas seal plug at a depth of 228.3 m (station 31).

Figure 3.2 Collapse epoch pressure and radiation measured in the coarse stemming below the deepest soft gas seal plug (Station 32 at a depth of 225.7 m). Standard data transmission was employed.

Figure 3.3 Collapse epoch pressure and radiation measured in the coarse stemming below the deepest soft gas seal plug (Station 33 at a depth of 225.7 m). This was one of two multiplexed stations.

Figure 3.4 Collapse epoch pressure and radiation measured in the coarse stemming above the deepest soft gas seal plug (Station 34 at a depth of 216.4 m). Standard data transmission was employed.

Figure 3.5 Collapse epoch pressure and radiation measured in the coarse stemming above the deepest soft gas seal plug (Station 35 at a depth of 216.7 m). This was one of two multiplexed stations.

Figure 3.6 Collapse motion of the second GFA plug (station 21 at a depth of 115.8 m). When there is more than one trace in a plot, the lighter is derived from the accelerometer.

Figure 3.7 Collapse motion of the third GFA plug (station 22 at a depth of 75.6 m). When there is more than one trace in a plot, the lighter is derived from the accelerometer.

Figure 3.8 Collapse signal at the top GFA plug (station 23 at a depth of 8.4 m).

Figure 3.9 Collapse signal at the top of the surface conductor (station 24).

Figure 3.10 Collapse motion of the top of the emplacement pipe (station 1). The accelerometer record is shown only for timing.

Figure 3.11 Collapse signal at the ground surface (station 61 at a horizontal range of 15.24 m and a depth of 0.9 m).

Figure 3.12 Progression of collapse in stemming column as indicated by CLIPER data (station 92). Also shown are selected wave forms of velocity and pressure (not to vertical scale) .

Figure 3.13 Output of the Vernitech® "fishing reel" type extensometer mounted between the surface casing and the top GFA plug. These data should probably be disregarded.

Figure 3.14 The AGRINI crater profile as determined by observation with a down-hole camera⁽³⁾.

4. Other Measurements: Strain

Since AGRINI was the first event on which gypsum cement with gypsum aggregate was used for containment plug material and was considered for future use, it was desired to have as complete a description of the performance of these members as possible. In addition to the usual measurements relative to the plug emplacement and motion, an array of earth-strain gauges was installed in each of the top three GFA plugs. Recognizing the tensor nature of stress, each array consisted of three gauges oriented along three perpendicular axes with a fourth oriented in the direction of the vector sum of the other three (the "oblique" gauge). Outputs from these three arrays are shown in figures 4.1 - 4.3. The transverse and oblique transducers on station 37 were lost during the stemming operation.

Load on the emplacement pipe was monitored as one of the standard stemming operations measurements and was also recorded post-shot. Data from this gauge are shown over three different time intervals in figure 4.4. The top plot gives the behavior during the detonation, the middle shows its output during collapse to the same time scale as figure 3.12 for ease of comparison, and the bottom time interval includes collapse and about 4 additional minutes. The initial load is recorded to be about 246 Klbs, about 4% higher than that quoted in figure 1.5 and reference 2. The gauge appears to go to lower band edge (zero or negative load) shortly after time zero and stay there until collapse when it takes about 5 s to reach upper band edge of 400 Klbs (equivalent to 3,000 μ strains). Between 3 and 4 minutes later further unexplained occurrences are evident.

Figure 4.1 The first 10 s of strain measured in the deepest stemming platform (station 36 at a depth of 111.5 m). The transverse and "oblique" components were lost pre-shot. Positive strain implies extension.

Figure 4.2 The first 10 s of strain measured in the second stemming platform (station 37 at a depth of 72.5 m). The transverse and "oblique" components were lost pre-shot. Positive strain implies extension.

Figure 4.3 The first 10 s of strain measured in the top plug (station 38 at a depth of 5.2 m). The transverse and "oblique" components were lost pre-shot. Positive strain implies extension.

Figure 4.4 Load seen on the emplacement pipe during three time intervals. The central plot is to the same time scale as figure 3.12.

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