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DATA SUMMARY OF GAS PRESSURE MEASUREMENTS ON THE LOS ALAMOS LEDOUX EVENT

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Prepared for:

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I. Introduction

Several sets of gas pressure measurements were fielded on the LEDOUX event to evaluate the experiment room pressure history and the horizontal pressure gradient in the alluvium due to the detonation. The pressure measurements in the zero room and diagnostic drift consisted of fluid filled high pressure tubing running from each of these areas up to pressure transducer packages in their respective cable holes. The pressure gradient in the alluvium was sensed at several locations adjacent to the main drift and at a gravel filled section of the drift stemming. Fluid filled high pressure tubes were also used in this set to transmit the pressure from the sensing location to a transducer package located between the end of drift stemming and the U1-a shaft.

The measurements resulted in limited success. Two very useful data records were obtained in the pressure gradient measurements adjacent to the main drift. The two remaining measurements in that set yielded no data: one suffered an electronic failure in the data transmission system, and the other sensed no pressure increase. The measurement of the diagnostic drift pressure history showed that the pressure transmission tubes were either closed off by backflow restrictor valves (containment features) or the pressure did not rise high enough to burst a diaphragm in the tubing string. This measurement did, however, indicate the point in time when the pressure in the room returned to ambient. The zero room pressure measurements were rendered unreadable due to severe noise on the data records.

This summary report provides the details of the measurement installations and the measured data.

II. Description of the Measurement Installations

The layout of the original LEDOUX drift complex is shown in Figure 1. (A second access drift was mined back into the diagnostic drift, parallel and to the right of the original drift when facing the working point. The stemming design of the second drift was identical to that of the original drift.) The diagnostic drift and zero room pressure history measurements were located at the bottom of cable holes number 1 and 2. The pressure profile measurements were located in existing holes off the main access drift.

A. Zero room and diagnostic drift pressure history measurements

The pressure histories in the zero room and diagnostic drift were configured as shown in Figure 2. The sensing point in each case was a quartz gravel filled steel mesh box, 1 ft. by 1 ft. by 2 ft. long, in which 0.25 in. OD (0.15 in. ID) stainless steel high pressure tubing terminated. This tubing, which was filled with a mixture of water and antifreeze, passed through the bulkhead and up to the instrumentation packages in the cable hole stemming. To minimize the chance of ground motion shearing the tubes at the steel bulkheads, the 0.25 inch tubes transitioned to 9/16 in. OD (0.16 in. ID) high pressure tubes for the feedthrough, then back to 0.25 in. for the remainder of the run to the instrumentation packages. To prevent the fluid from draining, a loss-of-fluid seal was installed in each tubing string at the bottom of the cable hole. This seal consisted of a vinyl diaphragm, strong enough to sustain the hydrostatic head of the fluid filled tube but weak enough to burst with an overpressure of several hundred psi. Gas seal rings

(4 in. diameter steel disks) were epoxied to the tubing at the indicated locations to impede gas flow along the tubing/grout interface in the grout stemming regions.

The instrumentation packages were modified versions of the standard LANL/EG&G backfill monitors, incorporating the pressure transducers and data transmission components to multiplex the signals and transmit them to surface recording facilities. The pressure transducers were manufactured by Precise Sensors to LANL J Division specifications for backfill monitors, requiring 10 VDC excitation and a 0-10 VDC output. To cover the anticipated range of possible pressures in the experiment drifts, high and low range pressure transducers were used with the low range transducer protected from overpressurization by a gauge guard (Fairchild Industrial Products). A redundant package was installed higher in cable hole #1, with a single high pressure transducer.

If the tubing failed at a location high in the hole, such as at the connection to the instrumentation package, cavity gas could potentially flow up the tube into the cable hole stemming. To prevent this, a backflow restrictor was installed in each tubing string as a containment feature, at the locations indicated in Figure 2. The backflow restrictor (Figure 3) allows unimpeded pressure communication to the instrument package as long as there is insignificant flow up the tubing. A steel ball seats against an O-ring if flow up the tubing is of sufficient velocity to lift the ball. It is critical to the performance of this system that the tubing string above the backflow restrictor remain completely fluid filled. A gas void in this region greater than the volume inside the restrictor could result in sufficient flow to raise the steel ball and seal the system, if the fluid pressure is high enough. The void in the flow restrictor allows about 0.1 cubic inch of liquid flow before the ball seats on the O-ring seal at the top of the valve. For the 0.25 in. tubing (0.15 in. ID) the length of tubing with a volume equal to the volume of the restrictor is about 5 inches. A gas void could form above the restrictor if noncondensable gas evolved from the water/antifreeze mixture and collected at the top of the tubing string. We attempted to minimize this by degassing the water under slight vacuum before filling the tubes, and filling under vacuum. A much greater threat is a leak in the tubing string. A water vapor void would form if a leak occurred somewhere in the tubing string, drawing down the fluid level and evolving water vapor at the top of the fluid column. The minimum distance from the instrumentation package to the bottom end of the tubing strings was 70 feet. This water head is sufficient to evolve water vapor until the water column height is about 30 feet, leaving potentially tens of feet of void in the tubing string.

If the tubing remained intact and fluid filled, the compression of the water/antifreeze mixture at the maximum possible pressure would not be sufficient to close the restrictor.

This is being discussed at length because the pressure traces recorded for these measurements suggest that closure of the restrictors may have occurred. In the design of the system we did not anticipate that the tubing strings would be in place for roughly a year and a half before the event was executed (emplacement was completed in March 1989 and LEDOUX was executed in September of 1990). Consequently, an extremely small leak or very slow gas evolution could result in closure of the restrictors.

B. Pressure gradient adjacent to the main access drift

Early in the construction of the LEDOUX drift complex a series of

permeability measurements was conducted in holes drilled out from the drift walls. Each hole was nominally 20 ft. long, 2 inch in diameter. Three of these holes were used for emplacement of pressure measuring tubes to sense the air pressure gradient resulting from detonation. A fourth tube was terminated in a gravel filled void in the drift stemming. The tubing, backflow restrictors, and gas seal rings were the same as those used for the experiment drift pressure measurements. The locations of these measurements are shown in Figure 4 (the approximate plan view is also shown in Figure 1). The nominal installation configuration of the tubes installed in the boreholes is depicted in Figure 5. A thermocouple was also located in the gravel-filled section of the drift at RS175' (type K, 0.25 in. OD metal clad, magnesium oxide filled, Omega Engineering). The instrumentation and data transmission package was located at the end of the drift stemming. A single coaxial cable carried the multiplexed signals up the partially stemmed shaft to the surface.

III. Results Discussion

A. Zero room and diagnostic drift pressure history measurements

The two instrumentation packages in cable hole #1, intended to sense the zero room gas pressure, suffered electronic noise which masked any pressure response. The package at 888' incurred the interference at zero time, and the package at 798' was noisy before and after with a general shift in the signal at zero time.

The package in cable hole #2, located at 887' and sensing the pressure in the diagnostic drift, recorded pressure out past two hours. The recorded data clearly do not reflect the actual pressure in the zero room, since the pressure observed rises from just below 14 psia to about 16.5 psia (see Figures 6, 7, and 8 for different time spans). Two characteristics of the pressure history are notable. First, the initial recorded pressure is 13.7 psia. This is approximately the ambient pressure of the LEDOUX drift. If the tubing string extending up to the instrument package was full of liquid, or even if only 30 feet of it contained liquid, the pressure sensed in the instrument package would be the vapor pressure of water at the ambient cable hole temperature, or about 0.5 psia. The tubing was possibly either partially or completely drained of fluid. Another credible scenario is that enough noncondensable gas evolved from the liquid to form a void at the top of the tubing string pressurized to ambient. One of two circumstances would result: a) the void is long enough to cause the backflow restrictor to shut when the diagnostic drift pressure increased, or b) the diagnostic drift pressure was not sufficient to break the loss-of-fluid seal (which required several hundred psi to fail in lab tests). Either of these cases is plausible, and the effect on the measurement similar, leading to the next point. The second notable feature is that the magnitude of the pressure response is clipped at 16.5 psia. At approximately 350 seconds the pressure starts to drop back to ambient. This would be the response if the flow in the tube (due to pressurization of a gas or vapor void) is sufficient to close off the back flow restrictor, or the loss-of-fluid seal did not burst. The restrictor would then open up again, or the vinyl diaphragm in the loss-of-fluid seal would relax, when the drift pressure dropped below the pressure in the tube. The data record suggests that the drift pressure returned to ambient in the 350 to 440 second time frame. While this is not the complete cavity pressure history, it is a useful result for porous flow calculations.

B. Pressure gradient adjacent to the main access drift

Two excellent records were obtained at the measurement locations of RS168' and RS205' (see Figures 9, 10, and 11). At RS168' the pressure rose from ambient to 28.5 psia by 200 seconds. The RS205' measurement rose to 17.8 psia in slightly less than a half hour. Both of these histories, combined with RAMS measurements, can be compared with calculated pressure responses.

The measurement at RS285' suffered an electronics failure before the event execution. The thermocouple in the gravel volume at RS175' showed some sporadic increases in temperature but it is difficult to separate real temperature effects from the probable noise inherent in long thermocouple lead lengths. The pressure record at that location showed no increase. It is possible that the increase was so small as to not appear on the digitized data (this was a 0-1000 psia gauge).

IV. Summary and Recommendations

The experiment room pressure measurements located in the two cable holes were unable to sense the complete pressure histories of interest. In the cable hole nearest to the zero room, the packages suffered electronic interference which masked any pressure history record. The measurement farther away, in cable hole #2, did well electronically but the pressure magnitude appeared to be clipped. To improve the chance of success in these measurements in the future several aspects of the design need to be changed. If liquid fill of the tubing is necessary, the liquid should be something like a silicone oil with much less tendency to evolve noncondensable gases. The loss-of-fluid seal needs to be a proven long term device with no chance of leakage or material degradation over time. If at all possible, the instrumentation packages should be located so low in the cable holes that backflow restrictors are not necessary (but not so low to risk damage by ground shock or EMP).

The measurements adjacent to the main access drift were quite successful. Several excellent records were obtained. The system design seemed to have no serious flaws, although using a silicone oil fill fluid would probably be useful in this configuration also. The temperature measurement showed no gross failure, but probably needs to be evaluated more before being used again.

Figure 1. Drift layout and stemming plan.

Figure 2. Zero room gas pressure measurement, Cable hole #1. A single tube system is emplaced in Cable hole #2, similar in configuration to the system shown here, with the instrument package at 271 m depth (887 ft.).

Figure 3. Backflow restrictor to prevent flyid flow in case of line failure.

Figure 4. Gas flow pressure and temperature measurements (emplaced in holes in drift left rib).

Figure 5. Typical gas pressure measurement location in hole off of main drift..

HOLE #2 TEST
 SQ: 118
 VR: 200 T1/06/DR/02
 DIG. RATE: 0.020 KHZ
 FILTER : 10.000000 HZ
 MAX RANGE: 500.000 PSIA
 TOT. TIME CORR. = 0.000 MSEC

TIME (SECONDS)
 SEA-2 -887' DRIFT PRESS 500 PSIA

OFF-SET CORR. = 0.000 PSI PCFSC: 100.0 % T.S.C.: NO

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Figure 7. Diagnostic drift pressure record, zero time.

HOLE #2 TEST
 SQ: 118
 VR: 100 T1/06/DR/02
 DIG. RATE: 0.100 KHZ
 FILTER : 10.000000 HZ
 MAX RANGE: 500.000 PSIA
 TOT. TIME CORR. = 0.000 MSEC

TIME (SECONDS)
 SEA-2 -887' DRIFT PRESS 500 PSIA

OFF-SET CORR. = 0.000 PSI PCFSC: 100.0 % T.S.C.: NO

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12 PRESSURE (PSIA)

HOLE #2TEST
SD:118 T1/06/DR/02
VR:300
DIG. RATE: 6.020 KHZ
FILTER: 10.000000 HZ
MAX RANGE: 500.000 PSIA
TOT. TIME CORR. = 0.000 MSEC
SEA-2 -887' DRIFT PRESS 500 PSIA
TIME (SECONDS)
OFF-SET CORR. = 0.000 PSI PCFSC: 100.0 % T.S.C.: NO

U-1-A SEA-3-A 50# & 100#

Figure 10. RS168' pressure record, short time window.

HOLE #2TEST
 SQ: 12E
 VR: 200 T1/08/DR/05
 DIG. RATE: 0.020 KHZ
 FILTER: 10.000000 HZ
 MAX RANGE: 100.000 PSIA
 TOT. TIME CORR. = 0.000 MSEC

TIME (SECONDS)
 SEA-3-DRIFT WP+165' FLOW PRESS 100 PSIA

OFF-SET CORR. = 0.000 PSI PCFSC: 100.0 % T.S.C.: NO

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Figure 11. RS205' time record, short time window.

HOLE#2TEST
 SO:12C T1/08/DR/03
 VR:200
 DIG. RATE: 0.020 KHZ
 FILTER: 10.000000 HZ
 MAX RANGE: 50.000 PSIA
 TOT. TIME CORR. = 0.000 MSEC

TIME (SECONDS)
 SEA-3-DRIFFT WP+200' FLOW PRESS 50 PSIA

OFF-SET CORR. = 0.000 PSI PCFSC: 100.0 % T.S.C.: NO

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