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FIELD MEASUREMENTS OF PERMEABILITY
OF NTS ALLUVIUM IN AREA 10

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FIELD MEASUREMENTS OF PERMEABILITY OF NTS ALLUVIUM IN AREA 10

ABSTRACT

We have completed a measurement of the permeability of NTS alluvium around hole U-10am-5. Tracer tests were also done using SF_6 to investigate the possible presence of cracks or highly permeable paths to the surface. This is the same hole used by Pasternak and McMullen for similar tests, but the region has since been subjected to shock from a nearby nuclear explosion.

Transient tests were conducted at a number of flowrates and included buildup and decay of downhole pressures for permeability calculations.

No significant gas leaks or paths were found. The permeability calculated is in the range 8 to 16 darcies and does not show any large change from that reported by Pasternak and McMullen.

INTRODUCTION

These measurements were made in support of the containment program.

In UCID-15895* we presented preliminary results of permeability and tracer gas tests of the region at U-9 ITS eXY30.5. After completion of our tests in that hole we moved the equipment to hole U-10am-5 and made similar tests on July 20, 21, and 22, 1971. In testing at U-10am-5 we were following up on an earlier test made in September 1969,[†] which indicated a permeability of 9.5 darcies based on steady-state approximations. Our purpose was to obtain additional permeability data emphasizing transient measurements and to search for movements of tracer gas with more sensitive equipment than had been used before. Since there had been a nearby nuclear shot in the meantime, we could also look for differences pre- and postshot, particularly cracking between the cement and casing.

This report presents preliminary results. Further consideration of the data including transient analyses is in progress.

The permeability of the alluvium at U-10am-5, calculated from new data assuming a radial cylindrical model and steady-state flow, is between 8.0 and 16.0 darcies.

*D. F. Snoeberger, C. J. Morris, and G. A. Morris, Field Measurements of Permeabilities in NTS Area 9, Lawrence Livermore Laboratory, Rept. UCID-15895 (1971).

[†]A. D. Pasternak and E. T. McMullen, Field Measurements of the Permeability of NTS Alluvium, Lawrence Livermore Laboratory, Rept. UCID-15727 (1970).

We found first indications of the tracer, SF_6 , at the wellhead and in the surface area 100 ft southeast of the well. Later we also found small amounts of SF_6 at the surface at other points 96 to 125 ft from the well. There was no convincing indication of cracks between the casing and cement under the test conditions we used.

THE EXPERIMENT AND RESULTS

Test Hole

Hole U-10am-5 is 454 ft deep and is cased to 400 ft with 10-3/4 in. casing grouted in a 17-1/2 in.-diam hole. The diameter of the uncased part of the hole varies from 10-1/2 to 18 in. This hole had been drilled with airfoam drilling fluid. Samples had been taken by undercutting at about 425 ft prior to the air test in 1969. Figure 1 is a reproduction from the caliper log of June 21, 1971, which shows the mean hole diameter and the sampled region in the uncased portion of the hole.

Equipment and Data Handling

The air supply system was described in UCID-15895. To obtain downhole measurements of air pressure and temperature we suspended a pressure transducer and a thermistor at 425 ft and connected them through the casing at the surface. We measured air temperature and pressure at the wellhead. Other measurements were made as before. Data were recorded at the test site with a Brush recorder and were simultaneously transmitted to Livermore. Figures 2 and 3 are photographs of the equipment at U-10am-5.

Tracer Sampling, Background, and Detection Limits

Somewhat randomly, we initially selected seven more sites for gas sampling in addition to the wellhead. At each we had a hole dug 2 ft deep and 2 ft in diameter. Each hole then was covered with a 20-ft square of 10-mil plastic held down at the edges by sandbags. We call these bagged ground areas (BGA). We exposed the joint between the cement and casing at the wellhead and shrouded the region to a radius of 2 ft with plastic also held down by sand bags. We sampled with 100-ml gas syringes through taped slits.

Teledyne Isotopes, Inc. personnel drilled three sampling holes for us to 50 ft. Each hole contained a 5/8-in.-i.d. sampling hose placed at the bottom with the annulus backfilled with alluvium. We sampled through the hoses by pumping out one hose volume and then filling the gas syringe through a hypodermic needle in each hose.

During the morning of July 21, 1971 we added supplemental bagged areas 4-A, 4-B, 4-C, and 4-D, 5A, and 6A.

Figure 4 shows the locations of the hoses and bagged areas.

Fig. 1. Caliper log of U-10am-5 below the casing (Birdwell, June 21, 1969).

Fig. 2. The air injector setup.

Fig. 3. Tracer gas analytical equipment.

Fig. 4. Locations of tracer test sampling places.

At the start we determined backgrounds for SF_6 and CCl_2F_2 at all sampling points around U-10am-5, at subsidence craters at U-10am-3 and -4 to the south, at the sampling tubes in U-10am-3 PS1A and U-10am-4 PS1A (postshot holes), and from the bottom of U-10am-5 (prior to installation of the downhole instruments). We detected a trace of CCl_2F_2 (~5 ppb) in the sample from the U-10am-3 crater and 8 ppm of CCl_2F_2 in the sample from the bottom of U-10am-5. At the latter location the gas is certainly a residue from the CCl_2F_2 injected during the 1969 test. At all other points we found neither SF_6 nor CCl_2F_2 .

Detection limits were 1.0 ppb for CCl_2F_2 and 0.01 ppb for SF_6 .

Air and Tracer Injection

We injected air at flows of 49,000 to 420,000 scfh (60°F, 1 atm) (see Table 1). Selected data and calculated air flows for permeability calculations are shown in Table 1. The values calculated range from 8.0 to 16.0 darcies. The higher values were obtained with lower flow rates. The low positive pressures downhole that result at these low flows are subject to more errors in reading. This may partly explain the range of permeability found. If we omit low-flow-rate tests, the range is 8 to 11 darcies. Table 2 lists the amounts and times for the air and tracers (SF_6 and CCl_2F_2), the injections, and the air flow rates.

Table 1. Data for permeability calculations.

Date	Flow rate (60°F, 1 atm) (cfh)	Downhole pressure (psia)	Downhole air temp (°F)
7/20	95,000	20.8	92
7/21	49,000	17.8	89
	90,000	21.7	92
	172,000	29.3	97
7/22	310,000	41.0	70
7/22	365,000	46.4	82
7/22	410,000	48.5	83
7/22	420,000	50.6	82

Table 3 shows the concentrations of SF_6 and CCl_2F_2 found in samples from various points on July 20, 21, and 22. Every location was sampled five or more times each day during these three days of testing. At the locations not mentioned in Table 3, the concentrations of SF_6 and CCl_2F_2 in the samples were less than the limits of detectability for these gases in our equipment.

On July 20 at 1500 hr, we injected 600 lb of SF_6 gas into the well. At 1616 hr, bagged ground area number 4 (BGA 4) 100 ft southeast of the well showed 5 ppb SF_6 , and at 1625 hr the area around the wellhead showed 0.5 ppb SF_6 . During July 20 and

Table 2. Air and tracer additions.

Starting time	Tracer added (lb)	Air pumping time (min)	Air flow rate (cfm)	Air added (ft ³)	Cumulative air addition (ft ³)
<u>7/20/71</u>					
1500	600 (SF ₆)				
1538		20	1583	31,660	31,660
<u>7/21/71</u>					
1133	145 (CCl ₂ F ₂)	28	817	22,876	54,536
1220		17	817	13,889	68,425
1447		26	1499	38,974	107,399
1527		22	2866	63,052	170,451
1630					
<u>7/22/71</u>					
0715	145 (CCl ₂ F ₂)				
0830		23	2866	65,918	236,369
0930	580 (CCl ₂ F ₂)	30	5166	154,980	391,349
1028					
1104		21	5249	110,229	501,578
1200		18	6083	109,494	611,072
1238		19	6833	129,827	740,899
1319		24	6999	167,976	908,875
1408		15	5333	79,995	988,870

Table 3. Tracer concentrations found.

Date	Time	Location	Concentration	Date	Time	Location	Concentration	
			SF ₆				SF ₆	CCl ₂ F ₂
7/20	1125	Wellhead	0.5 ppb	7/22	0810	BGA 7	10.0 ppb	
7/20	1616	BGA 4	5.0 ppb	7/22	0820	BGA 1	0.1 ppb	
7/20	1650	BGA 4	1.0 ppb	7/22	0930	BGA 7	0.3 ppb	
7/21	1005	Wellhead	2.0 ppb	7/22	1040	BGA 7	1.8 ppb	7 ppb
7/21	1310	Wellhead	0.08 ppb	7/22	1050	BGA 6A	0.2 ppb	
7/21	1323	Wellhead	5.0 ppb	7/22	1100	BGA 6	0.1 ppb	
7/21	1515	Wellhead	1.0 ppb	7/22	1115	BGA 7	0.2 ppb	
7/21	1600	BGA 4	2.0 ppb	7/22	1120	Wellhead	3.0 ppb	50 ppm ^a
7/22	0725	Wellhead	1.5 ppb	7/22	1135	BGA 6A	0.08 ppb	2 ppb
7/22	0735	BGA 4	0.2 ppb	7/22	1245	U-10am-3 crater		6 ppb
7/22	0800	BGA 6	0.1 ppb					
7/22	0800	BGA 6A	0.5 ppb	7/22	1335	Wellhead	0.08 ppb	5 ppb

^aProbably from a leak through the wellhead tracer transfer piping during addition.

21 we found SF₆ only at these sampling areas. On July 22, before starting to pump air into the hole, we found SF₆ at these two places and also at BGA 1 (125 ft to the north) and at BGA 6, 6A, and 7 (approximately 100 ft to the west). Later that day we again detected SF₆ at some of these locations.

We added CCl_2F_2 to the well as a liquid: 145 lb at 1630 hr on July 21, and 145 lb at 0715 hr and 580 lb at 1028 hr on July 22. Each time we allowed time for instrument warmup before resuming air flow.

On July 22 we found CCl_2F_2 at four locations: BGA 7 and 6A at 1040 hr and 1135 hr, respectively; at the U-10am-3 crater at 1245 hr; and at the wellhead.

At 11:30 a.m. on July 22, 1971, shortly after addition of CCl_2F_2 , we found approximately 50 ppm CCl_2F_2 at the wellhead. This apparently resulted from a slight leak during addition. We believe this was not seepage, i.e., flow through a crack between the casing and cement or through the ground, because

- (1) we did not detect CCl_2F_2 after every CCl_2F_2 addition—we found it this one time;
- (2) we did not detect a large concentration of SF_6 at the wellhead during its addition; and
- (3) the "high" concentration of CCl_2F_2 dissipated shortly after the addition was completed.

We did not detect either tracer gas in samples from the three hoses to 50 ft depth. This failure may be due to error in the way we sampled these hoses, i.e., by having pumped too much or too little air through the hoses before sampling. This error has seemed prevalent in other gas sampling of a similar nature at NTS.

The SF_6 found had to originate from the injections made during this test. However, the CCl_2F_2 found could have originated from either the 1969 or present injections.

When we compare the results of the tracer test portion of the experiment with the results of a similar set of tests at eXY30.5 we find large differences. At eXY30.5 we found larger concentrations (to 35 ppm) of tracer, both on the surface and in nearby holes, than we found at U-10am-5. The difference in casing length in the two holes may be significant. U-10am-5 had 400 ft of casing, and eXY30.5 had 77 ft of casing. We shall want to consider differences in the tests and the regions tested in more detail as we proceed with our computations.

CALCULATION

We calculated permeabilities of the alluvium in the region of hole U-10am-5 by use of the equation for steady state isothermal flow of compressible fluids in a radial (cylindrical) region.

The form of the following equation is described in UCID-15727 by Pasternak and McMullen. The expression is

$$Q_b = \frac{19.8 hKT_b}{\mu P_b T_h} \frac{P_h^2 - P_e^2}{\ln(r_e/r_h)},$$

where

Q_b = rate of flow at P_b and T_b (ft^3/day),

K = permeability (darcies),

h = length of uncased hole (ft),

μ = viscosity of air at T_h (0.0185 cp),

P_b = base pressure, 14.7 psia,

T_h = temperature of air at bottom of hole ($^{\circ}\text{R}$),

T_b = base temperature of air, 520°R ,

P_h = pressure of air at bottom of hole (psia),

P_e = pressure of air at radius of effect, 12.4 psia,

r_h = radius of uncased hole, 0.51 ft,

r_e = radius of effect (ft) assumed to be as done for 1969 tests, 425 ft.

Rearranging the radial flow equation to solve for permeability,

$$K = \frac{Q_b \mu P_b T_h}{19.8 h T_b} \frac{\ln(r_e/r_h)}{P_h^2 - P_e^2}.$$

CONCLUSIONS

Preliminary values for the permeability of alluvium at U-10am-5 for "steady state" radial (cylindrical) flow of air are in the range of 8 to 16 darcies. A value between 8 and 11 darcies appears less affected by experimental error.

Both SF_6 and CCl_2F_2 tracer gases reached the surface at concentrations in the parts per billion range during testing; dilution with atmospheric air may have occurred as samples were taken. We found no significant indications of cracks or major leak paths, i.e., paths allowing escape of tracer at higher concentrations than detected generally.

We detected SF_6 at most of the surface sampling points located up to 125 ft from U-10am-5, but not at any of the several more distant points sampled.

CCl_2F_2 added to U-10am-5 in 1969 may have moved to the subsidence crater at U-10am-3, 1000 ft to the south.

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