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LAWRENCE LIVERMORE LABORATORY

University of California/Livermore, California

DATA AND RESULTS, NUCLEAR CHIMNEY PERMEABILITY—TEST 3

D. F. Snoeberger
C. J. Morris
J. Baker

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ABSTRACT

We have conducted tests at a third nuclear chimney site in alluvium at the Nevada Test Site. The indicated value of pressure diffusivity is in the range of 0.5 to 1.0 m^2/s. We used previously described methods based on atmospheric pressure change and obtained an improved fit of calculated to measured pressure-time curves by superposition analysis.

INTRODUCTION

We have made permeability measurements at a third nuclear chimney site in alluvium at the AEC Nevada Test Site. The purposes were to obtain additional data on chimneys in alluvium, and to further develop the test method. The location is in area 2, Yucca Flat, and is designated DH-6. This work is in support of the containment program.

This report gives initial results obtained by fitting calculated curves to measured curves of chimney pressure versus time for a depth of 340 m. We obtained the calculated pressure by superposition analysis for a semi-infinite slab with time-varying surface pressure. The indicated value of pressure diffusivity is in the range of 0.5 to 1.0 m^2/s. Results obtained at previous sites are in this order of magnitude.

We are preparing a more detailed report on analysis of these and prior data using solutions obtained by superposition.

EXPERIMENT

The chimney site is similar to those previously described.[1] The uncased post-shot drill hole enters the chimney at an estimated vertical depth of 340 m. The following considerations, related to the hole, may also bear on interpretation of the results.

For the first time, the 73-mm gas sampling tube had been emplaced with a 3-m-long packer to close the annulus 40 m short of the chimney. This may have improved accuracy of pressure sensing through the tube. During previous use for gas sampling in September 1973, the tube was perforated at a vertical depth of 317 m and then flushed with 16 m^3 of water to reopen a gas flow path to the chimney.

The instrumentation and data transmission system are the same as those used in the last of the previous test except that thermistors with linear output were used to monitor temperatures in place of a nonlinear type of thermistor.

Measurements of atmospheric and chimney pressure used in this report are for the period November 23 to December 22, 1973. The interval between measurements was 1.5 h. A few data points were missed due to various causes, but can be interpolated.

Pressure data in this report and as recorded during measurement are in volts dc. The range of 0 to 10 V represents 632 to 662 mm Hg (84.3 to 88.3 kPa) linearly. Figures 1 and 2 are graphs of the atmospheric (surface) and chimney (340-m depth) pressures in volts dc. Figure 2 also shows the calculated pressures as explained in the next section. Accuracy and precision of data are as previously stated.[1] Instruments were calibrated with a mercury barometer.

CALCULATIONS AND RESULTS

As described by Carslaw and Jaeger,[2] a solution to the heat conduction equation for a semi-infinite slab with zero initial temperature and varying surface temperature can be generated from the solution for the case with constant surface temperature. The technique is also known as superposition.[3]

The differential equation is

$$\frac{\partial P}{\partial t} = \alpha \frac{\partial^2 P}{\partial x^2}$$

$$\alpha = \frac{kP}{\epsilon\mu}$$

The expression for calculating the pressure variation, v, in the chimney (assumed homogeneous) from the surface pressure data, V, is

$$v_\ell(x) = V_0 \operatorname{erfc}\left(\frac{x}{2\sqrt{\alpha \ell \Delta t}}\right) + \sum_{n=1}^{n=\ell-1} (V_n - V_{n-1}) \times \operatorname{erfc}\left[\frac{x}{2\sqrt{\alpha(\ell - n)\Delta t}}\right]$$

where

v_ℓ = pressure at ℓth time interval,
x = depth in meters,
Δt = time interval (1.5 h),
α = permissivity in m^2/s, and
V = surface pressure; V_0 is the initial value.

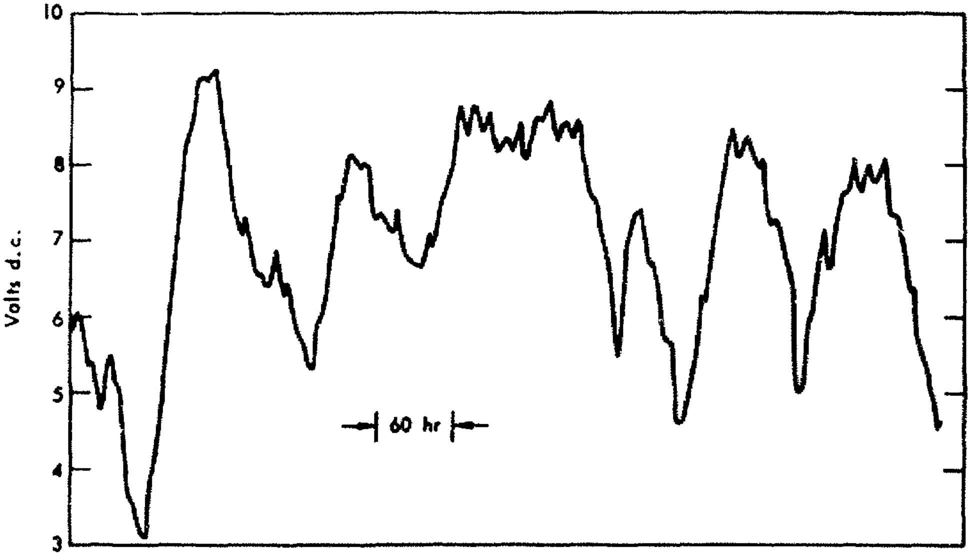

Fig. 1. Surface pressure (atmospheric).

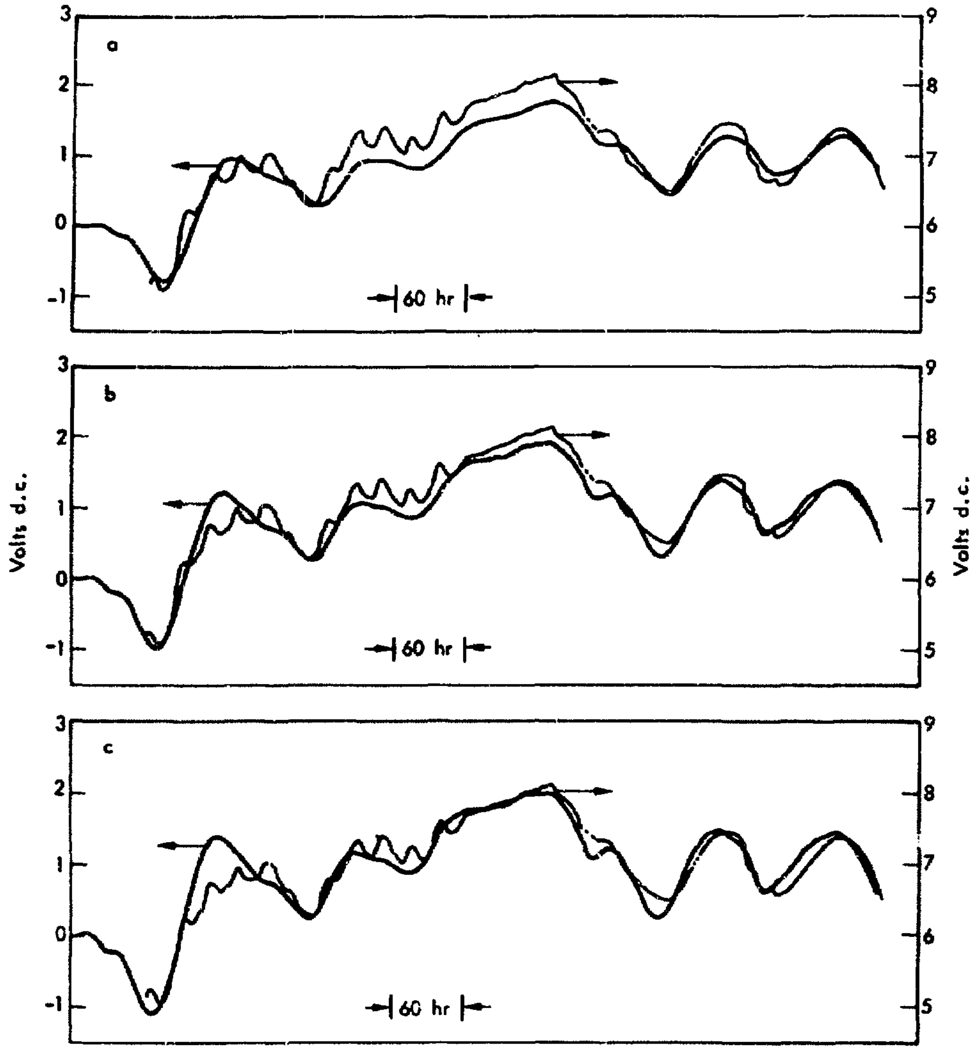

Fig. 2. (a) Calculated pressure, diffusivity = 0.5 m^2/s, and measured pressure for 340-m depth. (b) Calculated pressure, diffusivity = 0.75 m^2/s, and measured pressure for 340-m depth. (c) Calculated pressure, diffusivity = 1.0 m^2/s, and measured pressure for 340-m depth.

The initial value of pressure (volts) was subtracted from each data point to obtain surface pressure variation about this value as zero. The first term on the right side of the above equation therefore drops out.

We calculated and graphed pressure for a depth of 340 m and values of pressure diffusivity, α, for a range indicated by previous results. Graphs for $\alpha = 0.5$, 0.75 and 1.0 m^2/s are in Fig. 2. The fit of these curves to the data has been arbitrarily chosen, and is much better than found in prior work. The indicated pressure diffusivity is in the range of $\alpha = 0.5$ to 1.0 m^2/s. The ratio of effective permeability, k, to porosity, ϵ, is for a mean chimney pressure $\bar{P}$ of 0.1 MPa (1 atm) and air viscosity, μ, of 0.02 mPa·s (0.02 centipoise),

$$\frac{k}{\epsilon} = \alpha \frac{\mu}{\bar{P}} = (2 \times 10^{-10}\ s^{-1})\ \alpha\ m^2/s = 1 \times 10^{-10} \text{ to } 2 \times 10^{-10}\ m^2.$$

The data show a delay time of 15 to 20 h from the arrival of a weather system front (pressure increase) to its detection 340 m underground. Calculations (for a depth of 340 m and $\alpha = 0.75\ m^2/s$) of the time delay of underground pressure response to a step function change in surface pressure show that at 15 h the underground pressure has risen to 25% (50% at 45 h, 75% at 200 h) of the surface pressure.

REFERENCES

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