NATIONAL BUREAU OF STANDARDS REPORT

10 961

FIELD INVESTIGATION OF THE NATURAL GAS PIPELINE ACCIDENT AT CANTERBURY WOODS, ANNANDALE, VIRGINIA

Report to

National Transportation Safety Board
Department of Transportation
Washington, D. C. 20591

NBS

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

NATIONAL BUREAU OF STANDARDS

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16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

On the morning of March 24, 1972, in Annandale, Virginia, two homes were destroyed and a third home damaged by gas explosions and fires resulting from a construction accident that caused the gas main leak. The National Transportation Safety Board is responsible for investigating this accident and requested that the National Bureau of Standards assist them with their investigation by conducting a field test at the accident site.

The objective of the test was to determine how the natural gas entered the homes and the paths the gas followed from the leak to the homes. The premise of the NBS test was that if an air-tracer mixture could be detected at locations where natural gas was known to have escaped, then the original underground gas paths may still exist. A detailed test plan was developed to determine gas escape locations and paths. This plan included a simulation of the underground gas movement, excavation of various utility trenches, soil tests, and dismantling of the foundation wall of one of the destroyed homes. The equipment used to introduce the tracer into the ground near the original leak consisted of an air compressor, a tracer source (harmless refrigerant R-12), air flow measuring, piping and control valves. Electronic catalytic leak detectors were used to detect the tracer in homes and elsewhere on the test site.

The test results substantiated the basic test premise, and tracer was detected in the basements of the two destroyed homes and the damaged home, but not in the undamaged homes. From the results, it is concluded that gas traveled through rock rubble on the site and used as backfill in utility trenches containing the individual water and sewer lines to the destroyed/damaged homes and entered the homes through leaks in their concrete block foundations. Further study is recommended to develop means to prevent similar incidents in the future.

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Annandale; field test; gas explosion; leak detection

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Abstract

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The test results substantiated the basic test premise, and tracer was detected in the basements of the two destroyed homes and the damaged home, but not in the undamaged homes. From the results, it is concluded that gas traveled through rock rubble on the site and used as backfill in utility trenches containing the individual water and sewer lines to the destroyed/damaged homes and entered the homes through leaks in their concrete block foundations.

Keywords: Annandale; field test; gas explosion; leak detection.

1. INTRODUCTION

The National Bureau of Standards (NBS) was requested by the National Transportation Safety Board (NTSB) to conduct a field investigation at the site of the natural gas pipeline accident that occurred at the Canterbury Woods Subdivision, Annandale, Virginia on March 24, 1972, as part of their overall investigation of the accident. The objective of the investigation was to determine how the natural gas entered the homes and the path the gas followed from the leak to the homes. The basic approach used to reach the objective was to simulate natural gas flow underground by introducing a harmless mixture of air and refrigerant R-12 (tracer) in the vicinity of the underground gas leak and checking for the tracer within homes and other locations.

The strategy for the NBS test plan was approved by the NTSB at a meeting held at NBS on April 26, 1972. Representatives from the Washington Gas Light Company and the American Gas Association were also present at this meeting. NTSB made arrangements for NBS personnel to inspect the accident site at Magdalene Court on March 28, 1972. At that time arrangements were also made to confer with Washington Gas Light Company officials in regard to the accident.

NTSB requested that NBS attend a public hearing concerning the accident. The hearing was held all day on April 5th and 6th in Room 2008, Federal Office Building No. 7, Washington, D. C. The hearing was called by NTSB under the authority of Section 5 of the Transportation Act of 1966 and was conducted as part of the overall investigation of the March 24th natural gas pipeline accident in Fairfax County, Virginia involving a pipeline owned and operated by the Washington Gas Light Company.

The purpose of the investigation was to determine the cause or probable cause of the accident, to report the facts, conditions, and circumstances relating to the accident, and to assist NTSB in making recommendations that would tend to prevent such accidents in the future.

NTSB made arrangements for NBS to meet with Fairfax County officials on May 2, 1972. At that time, Mr. George H. Alexander, Director, Fire/Rescue Services, Fairfax County was designated coordinator of NBS field test activities because these activities related to county functions. The county subsequently performed the following functions.

a. Delivered a *Notice of NBS Field Test* to residents of South Magdalene Court, Annandale, Virginia where the NBS test was to take place. This notice stated the purpose of the test, the name of the Fairfax County Coordinator, the type of test results expected, and that the test would be performed by using a harmless air-tracer mixture introduced into the ground near where the natural gas leak occurred. The notice stated that NBS personnel might need to have access to the following homes in order to perform the test. The complete notice is presented in Appendix 7.1 of this report.

    4907 South Magdalene Court
    4908 South Magdalene Court
    4909 South Magdalene Court
    4910 South Magdalene Court
    4911 South Magdalene Court
    8601 Queen Elizabeth Boulevard.

b. Placed barricades around the NBS test equipment.

c. The County Plumbing Department flushed debris from the building drains in the destroyed buildings so that NBS could test these drains for indication of the tracer (refrigerant R-12).

d. Furnished what drawings were available showing sewer and water main locations. Five drawings were furnished. They are listed in Appendix 7.2.

e. Furnished *REPORT OF ANALYSIS OF SOIL* for the road sub-base.

f. The water authority furnished "as-built information" for Canterbury Woods showing the water mains.

g. The county furnished equipment and manpower as required to make excavations during the NBS test.

The Washington Gas Light Company furnished a site drawing showing their utility lines. The company furnished manpower to dig by hand as required to assist in the installation of the NBS test setup over the 2-inch-diameter gas main on South Magdalene Court.

The Federal Highway Administration, Fairbanks Laboratory, Soils Group took soil samples as required from South Magdalene Court.

The names of individuals who participated in this investigation are listed in Appendix 7.1.

In view of the limited funding available to NTSB for conducting this study and because of the interest of the Center for Building Technology in it, a substantial portion of the support for this investigation was provided by NBS to complement NTSB contract number CB 20169 dated 5/11/72.

2. BACKGROUND

Unfortunately, certain of the events which took place on March 24, 1972 at South Magdalene Court, Canterbury Woods Subdivision, Annandale, Virginia will never be known. However, the principal events relating to the fatal pipeline accident as found by hearing officials, are as follows:

a. At 7:55 a.m., during the process of excavating for storm sewer pipe replacement for Queen Elizabeth Boulevard, a contractor's back hoe hooked a 2-inch, schedule 40, steel gas main serving five houses on South Magdalene Court, as indicated in Figure 1.

b. Approximately 22 feet downstream from where the gas line was hooked, a compression coupling in the 2-inch gas main separated by 2 1/2 inches. The coupling was located 42 inches below finished road grade.

c. Natural gas entered homes at 4907, 4909, and 4911 South Magdalene Court, and subsequent explosions occurred before the gas was shut off.

d. At about 8:55 a.m. an explosion occurred in the home at 4911. A woman and child escaped without injury.

e. Shortly after the explosion at 4911, an apparently more severe explosion occurred at 4909 killing two children, fatally injuring their mother, and severely injuring a gas company employee.

f. A third explosion, at 4907, occurred about the same time as the explosion at 4909. This explosion occurred in the west basement wall. No one was injured at 4907.

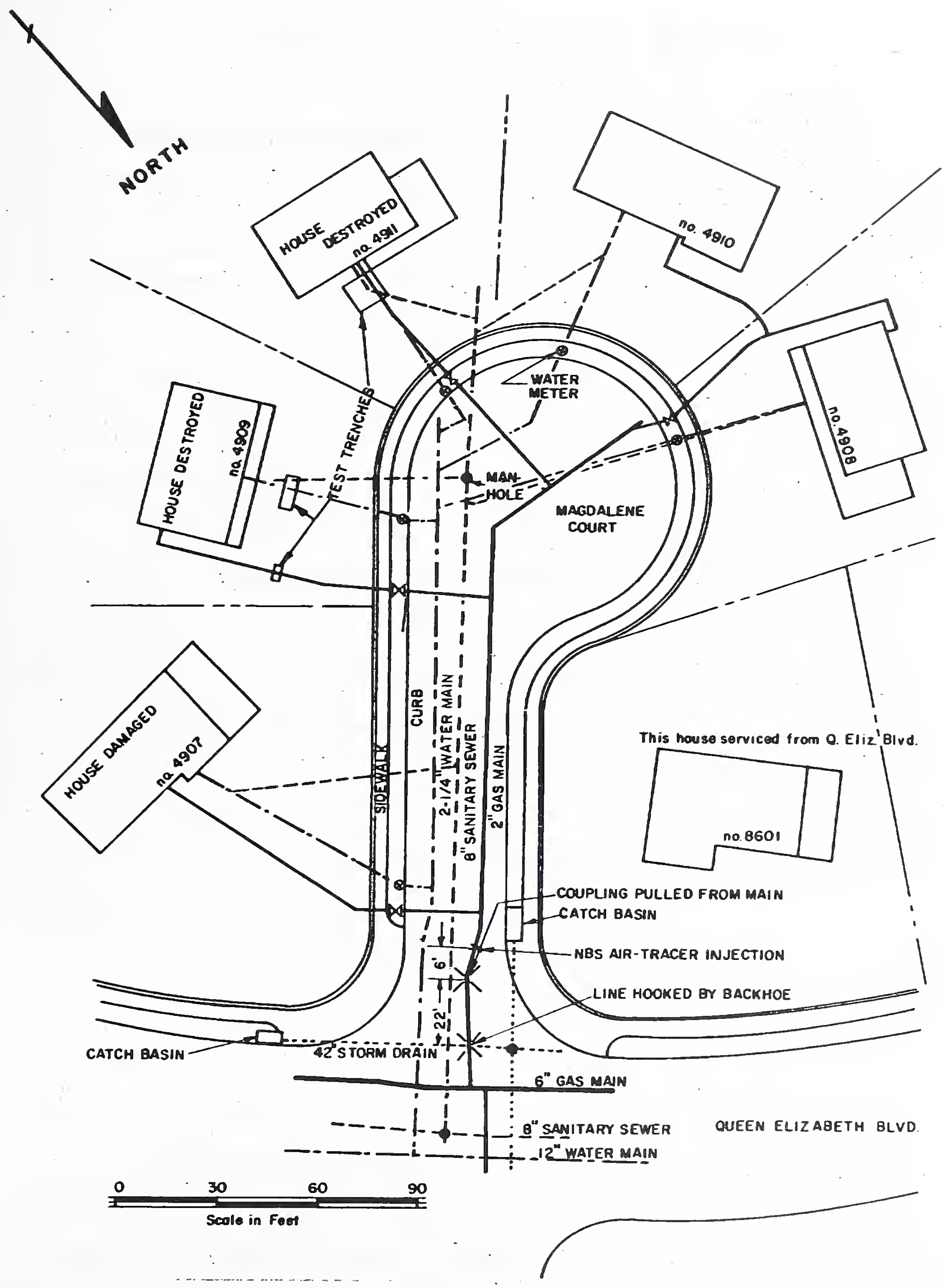

Figure 1. Accident Site.

g. The gas was turned off at about 9:52 a.m.

A video tape was made by the Fairfax County Fire and Rescue Service during the time that they were fighting the fires. This tape shows gas escaping from the following locations.

a. Expansion joint between driveway and carport concrete slabs at 4907.

b. Crack in the concrete gutter in front of the water meter box at 4909.

c. Blacktop and concrete gutter interface located about three feet north of the catch basin adjacent to 8601 at the corner of South Magdalene Court and Queen Elizabeth Boulevard.

3. DESCRIPTION OF THE TEST SETUP AND TEST PROCEDURE

3.1. Overall Test Plan

The premise of the NBS test was that if the tracer could be detected at locations where natural gas was known to have escaped, then the underground paths followed by the natural gas at the time of the accident may still be intact. It is assumed that the tracer would follow the same paths as the natural gas even though certain characteristics of the two gases are different because pressure is the main driving potential. The test plan developed to determine existing gas escape locations and paths consisted of four basic phases sequenced as follows:

a. Test of Simulation. The purpose of this phase, once the test setup had been installed and checked out, was to test the air-tracer injection strategy by determining whether this mixture could be detected at points where natural gas was known to have escaped during the accident.

b. Leakage Patterns on Site. The purpose of the second phase was to comb the site, particularly the basements, foundation walls, and grounds of all the homes on the site to attempt to reconstruct the pattern of the natural gas leakage that occurred downstream of the separated pipe coupling during the accident.

c. Tests in Utility Trenches. The first purpose of the third phase of the investigation was to pinpoint the paths followed by the natural gas to the homes destroyed in the accident. The second purpose of this phase was to obtain quantitative estimates of gas flow to these homes.

d. Examination of Foundation Wall. The purpose of the last phase of the study was to attempt to determine the means by which natural gas entered the basement of one of the homes (4911) destroyed in the accident.

3.2. Test Setup

Figure 2 shows the air-tracer test setup which consisted of the following major pieces of equipment:

a. Air compressor connection.

b. A source of refrigerant, R-12 (tracer).

c. A needle valve for controlling air flow input.

d. An air flow measuring section.

e. Meters and manometers for measuring air pressure.

f. A vertical section of piping (injection piping) for introducing air and refrigerant R-12 into the ground above the gas line.

g. A section designed to introduce a harmless smoke tracer.

In order to simulate the leak from the gas main beneath the road surface, air under controllable pressure was fed to the gas main location through a 2-inch steel pipe as shown in Figure 3. A hole, approximately 12 inches square, was dug in the street down to the bottom of the gas main. The air-injection pipe was placed in this hole with the pipe outlet just above the gas main. A six-inch-deep layer of large crushed stone (1 1/2 to 2 inches) was placed in the bottom of the hole around the injection pipe and a 1/4-inch pipe used to transmit cavity pressure as shown in Figure 2. Above these large stones a 2-inch-deep layer of 3/4-inch maximum size crushed stone concrete aggregate was placed. A 10-inch layer of damp, stone free clay, brought in from Maryland for this purpose, was well-tamped in three layers over the concrete aggregate layer. The hole was then filled to the bottom of the asphalt pavement with the clay taken from the hole. The top of the hole was sealed with an asphalt cold patch to slightly above the street surface. This hole was located

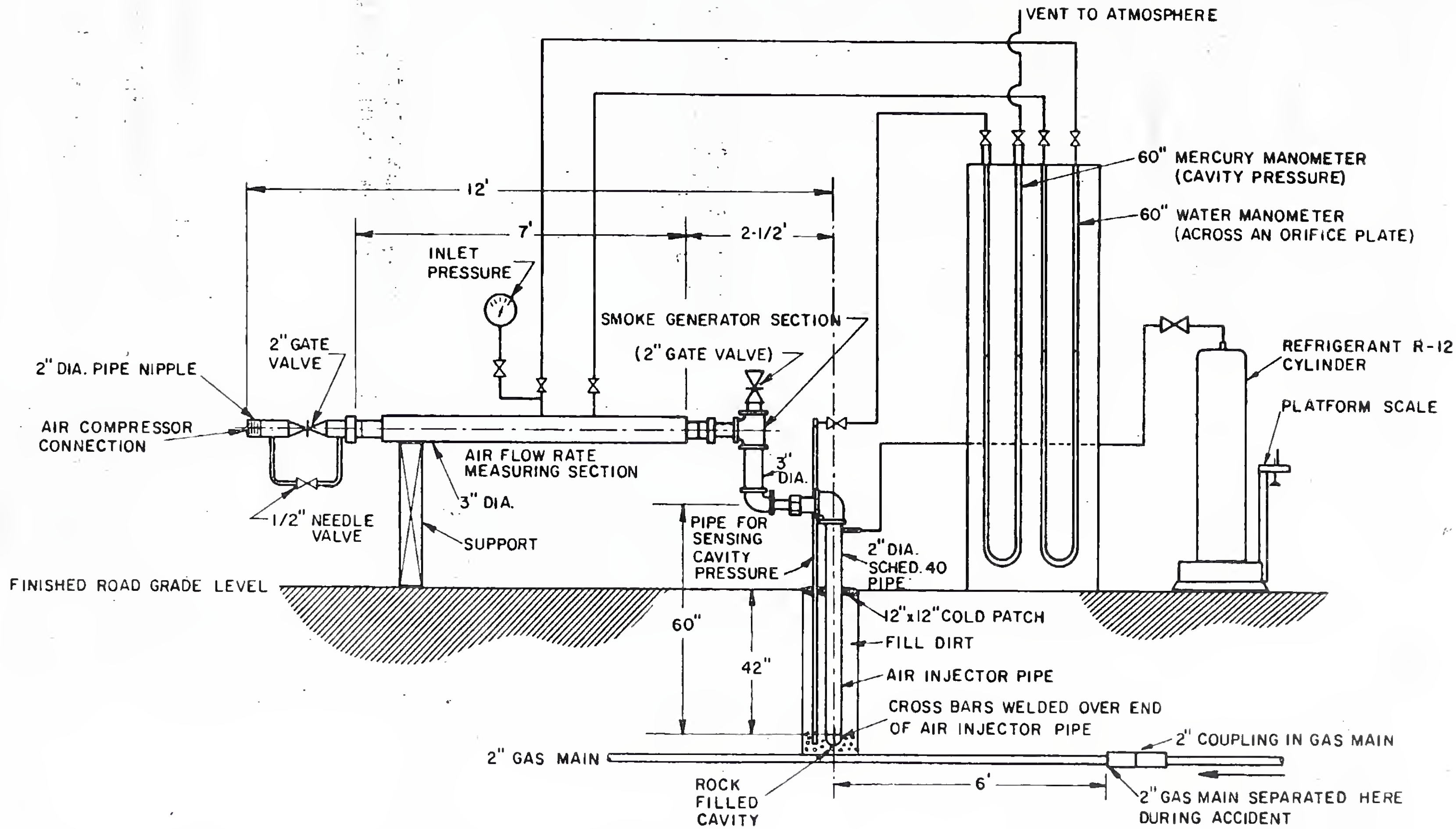

Figure 2. Air-tracer test setup.

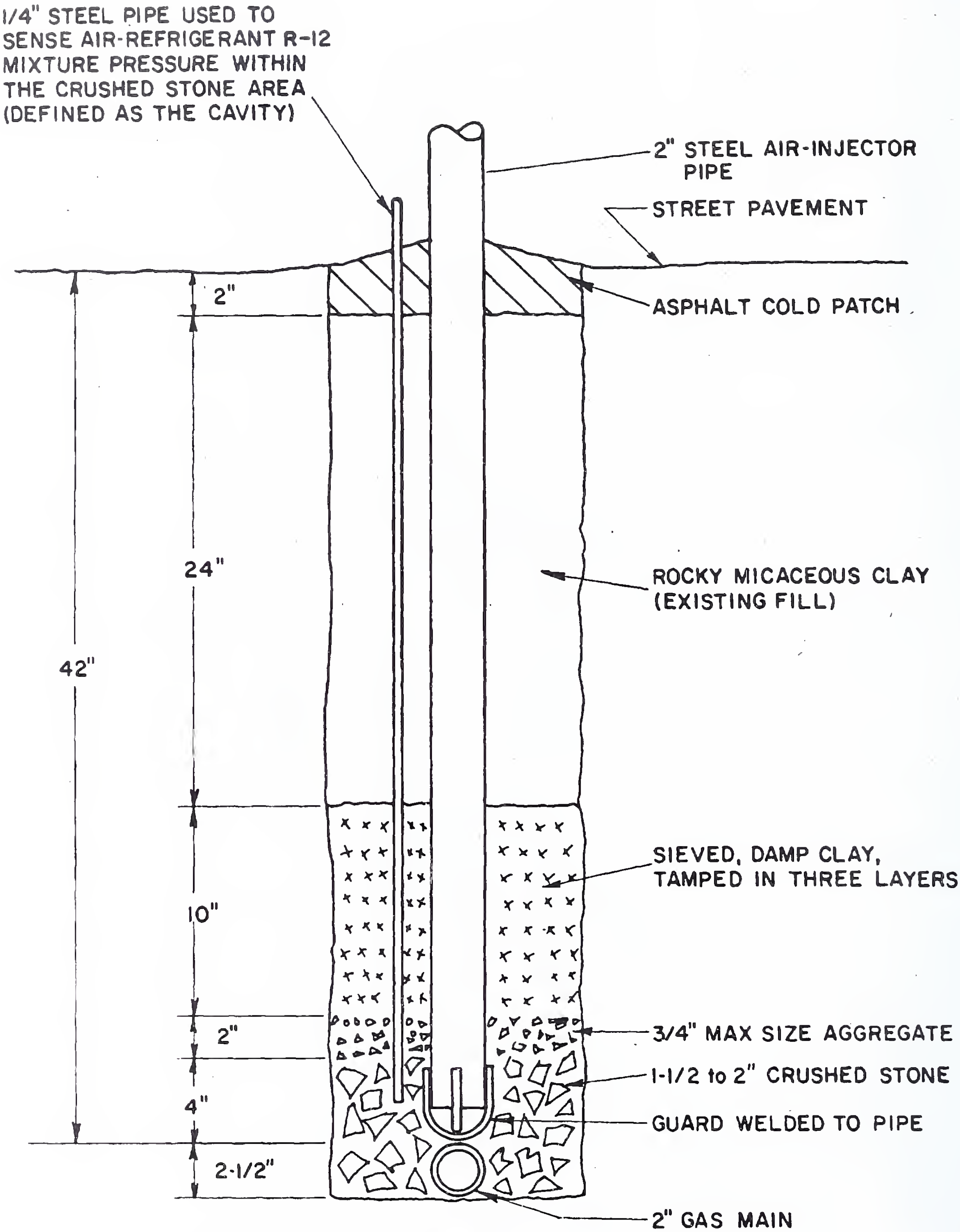

Figure 3. Air-tracer injector pipe installation

approximately six feet downstream from the natural gas leakage position because the soil had been disturbed in the leakage area when the trench was dug to repair the gas leak (see Fig. 1).

3.2.1. Air Compressor

A diesel engine driven air compressor supplied air to the test setup shown in Figure 2. This compressor supplied air at 100 psi pressure and had a capacity of 600 cfm of free air.

3.2.2. Air-Tracer Detectors

In addition to the test setup shown in Figure 2, an electronic catalytic leak detector, as shown in Figure 4, was used to detect the refrigerant R-12 tracer. This detector, which operates on 110V AC, was powered from portable electric generators.

3.2.3. Air Flow Measurement at Test Trenches

A quantitative air flow test was conducted in a test trench using the test setup shown in Figure 5. The vacuum pump shown in this test setup was powered by the generators mentioned above.

3.2.4. Pavement Deflection Measurement

A precision level was used to monitor road surface deflection (lift) during the first two phases of the test to permit air flow control to insure against excessive road surface lift.

Figure 4. The electronic catalytic leak detector.

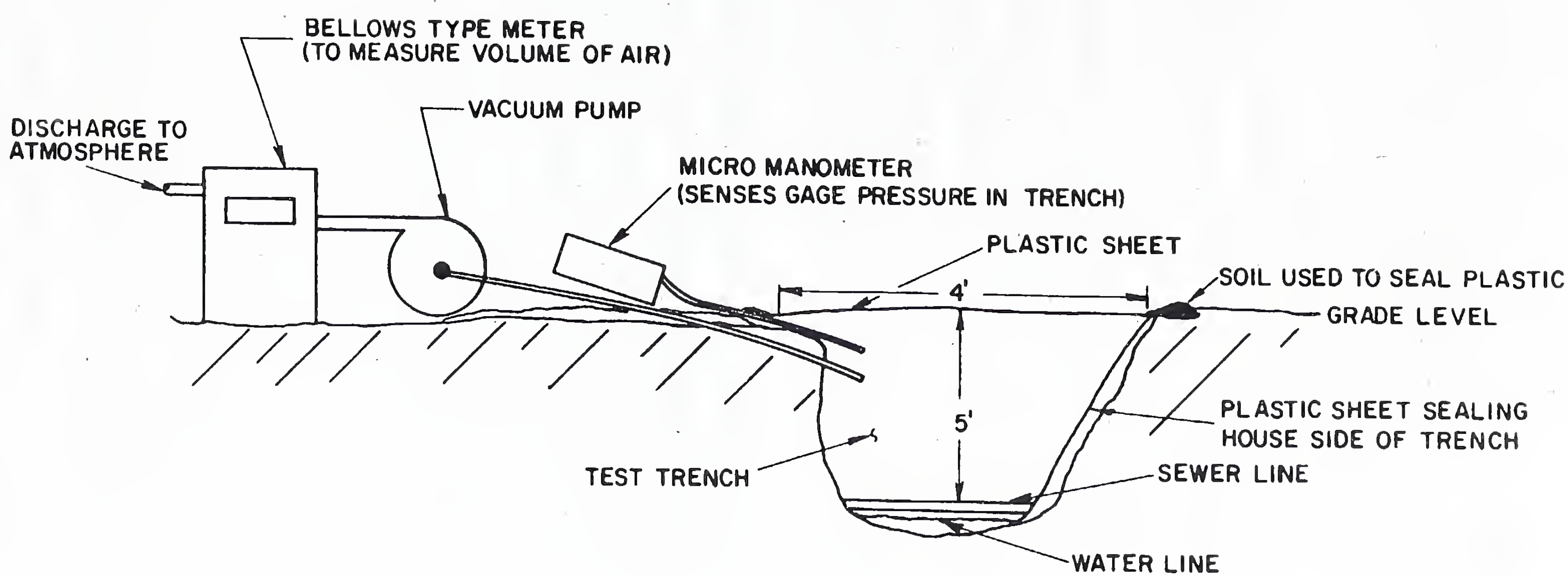

Figure 5. Test setup for determining air flow rate in the test trench at 4909.

3.3. Test Procedure

The following is the test procedure used.

3.3.1. Test of Simulation

The first day of the test, May 16, 1972 was devoted to determining how much air could be pumped into the ground and to validating on-site the tracer detection technique. It was believed that a cavity pressure equal to that of the gas main (22 psig) would rupture the asphalt road surface; therefore, the elevation of the pavement was monitored at 31 reference points with a precision level while the cavity pressure was slowly increased. The intent was to adjust the cavity pressure to a value high enough to obtain a workable air flow without disturbing the pavement.

a. The injection piping and piping used to transmit pressure in the rock fill cavity as shown in Figures 2 and 3 had been installed by NBS and the Washington Gas Light Company personnel prior to the first day of the test. On May 16, the test setup was assembled to the injection piping.

b. The compressor rental company connected their air compressor to the test setup connection as shown in Figure 2 and operated the compressor as directed by NBS.

c. Air was allowed to enter the test setup by way of the 1/2-inch-diameter needle valve shown in Figure 2. This valve was used to control cavity pressure. Cavity pressure was regulated while observing for road deflection with the precision level.

d. Air flow was measured in the orifice meter section of the test setup shown in Figure 2. It was hoped that adequate flow would be established so that soil could be seen blowing up from the ground as had been observed during the accident and at the locations noted from the aforementioned videotape. These positions are (1) the blacktop and concrete gutter interface near the catch basin, (2) the driveway and carport concrete slab expansion joint at 4907, and (3) the joint in the concrete curb in front of the water meter box at 4909. See Figure 1.

e. The refrigerant R-12 was introduced into the injection piping test setup as shown in Figure 2. The rate of R-12 injection was measured by periodically monitoring the weight of the R-12 tank using a platform scale.

f. At the end of the test each day (at about 4:00 p.m.) the test setup was disassembled and barricades were positioned around the injection piping and air compressors.

3.3.2. Leakage Patterns on Site

The second day of the test, May 17, was devoted to determining if R-12 tracer could be detected at the locations noted on the videotape. The test procedure for this day consisted of the following:

a. The test setup was assembled to the injection piping, and the compressor connected to the test setup.

b. Air and refrigerant R-12 (tracer) were introduced into the injection system as explained for phase 1 above and the road surface level was monitored with the precision level.

c. Electronic leak detectors were used to check for tracer escaping from positions inside the test homes and selected site locations.

d. At the end of the day smoke tests were attempted using smoke candles in the test setup as shown in Figure 2.

e. The phase 2 test was concluded at 4:00 p.m.

3.3.3. Tests in Utility Trenches

The third and fourth days of the test were used to determine how the natural gas got from the leak position to the homes. The test procedure for these two days was as follows:

a. The test setup was assembled as explained for phases 1 and 2.

b. On the third day, at NBS request, a Fairfax County Department of Public Works employee used a backhoe to dig two test trenches across utilities located in the front yard at 4909. The location of these trenches is shown in Figure 1. One trench was dug for the gas line (two feet deep) and the second trench was dug for the sewer and water lines (five feet deep). Also, as shown in Figure 1, a trench was dug (10 feet deep) across the combined utilities (gas, water and sewer) in the front yard at 4911. This trench was completed on the morning of the fourth day.

c. A check for tracer was made in these test trenches using an electronic leak detector. An electric fan was used to ventilate the trenches and prevent the tracer from accumulating so that the exact positions of leakage could be noted.

d. A soil expert from the Federal Highway Administration took samples of the soil in these trenches and at the tree belt in front of 4908.

e. On the morning of the fourth day, approximate quantitative air flow measurements were taken in the test trench containing the water and sewer lines for 4909. The test procedure used was to cover the trench, as shown in Figure 5, with a 2-mil sheet of plastic which was sealed around the top of the trench with soil. The face of the trench on the house side was covered with plastic. The purpose of this test was to determine the quantity of air pumped to the trench through the rock fill passages from the injection setup. At the same time, a vacuum pump was used to remove air from the trench to maintain atmospheric pressure in the trench. The manometer shown in Figure 5 was used to observe the pressure in the trench. A laboratory grade, bellows-type gas meter (conventional residential gas flow meter) was used to determine volume rate of air flow being drawn from the trench.

f. A Washington Gas Light Company employee drilled a network of holes approximately one-inch diameter and two-feet deep throughout the right-of-way at South Magdalene Court. Also, holes were drilled in the lawn and driveway in front of 4907. See Figure 6.

g. The tracer portion of the test was terminated at 4:00 p.m. on the fourth day, May 19. The drilled holes in the right-of-way were filled by the Washington Gas Light Company. The trenches were filled by Fairfax County. The NBS test setup was disassembled.

3.3.4. Examination of Foundation Wall

On June 4, 1972 additional information and soil samples were obtained from the site. The procedure involved the following:

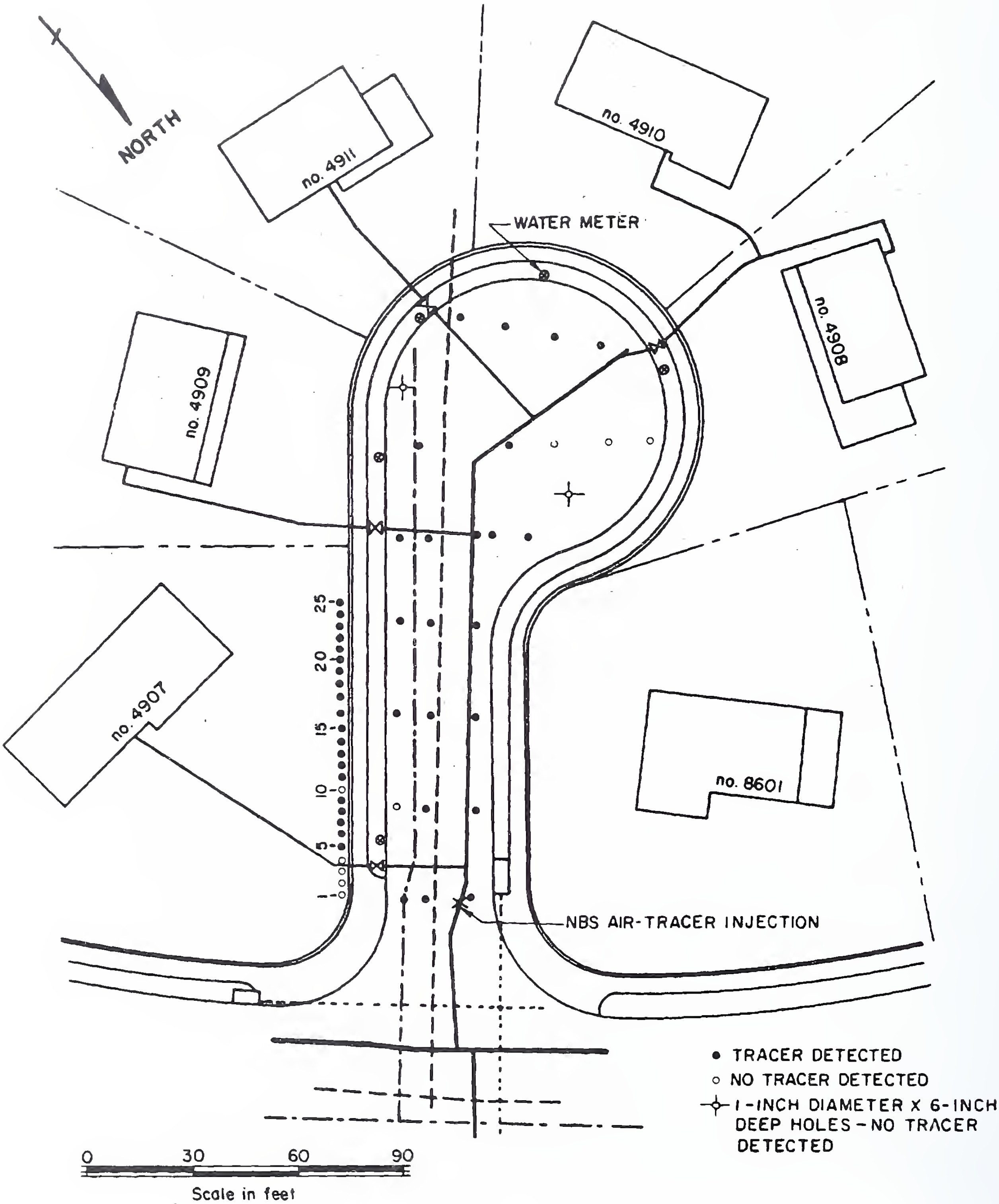

Figure 6. Network of drilled test holes.

a. A section of the front basement wall at 4911 containing the gas and water lines was dismantled by removing one concrete block at a time. The purposes of this work were to determine soil condition at the outside face of the front wall, and to examine the condition of the wall and the utility pipe seals.

b. The soil expert from the Federal Highway Administration took soil samples from the front yard at 4907 and from the wall area at 4911.

4. TEST RESULTS

The following paragraphs describe the results of the various phases of the test.

4.1. Test of Simulation

When air was first introduced into the test setup to check for air leaks in the test setup and to obtain familiarity with the test procedure, a cavity pressure of 6 psig was observed for about 30 seconds. At this time a section of the road surface on the south side of the test setup lifted appreciably, and the air was shut off. Maximum lift appeared to have occurred in the center of a circular section of road surface estimated to have an area of approximately 6-foot diameter. Although elevation of the lift area was not monitored by use of the precision level, the maximum lift was estimated visually to have been several inches. Perceptible lift appeared to have settled down over a period of about two minutes after the air was shut off. Subsequent examination of the road surface showed that the lift did not break up the surface. Thereafter air and refrigerant R-12 tracer were introduced for about two hours into the cavity at pressures starting at 0.5 inches W.G. (water gage) and increasing gradually to about 51 inches W.G. (1.8 psig). This was done to determine the on-site functioning of the electronic detector technique and to observe the road lift at different pressures. At cavity pressure of 1.8 psig the road lift was negligible. The maximum cavity pressure during the time that the tracer detection technique was being checked on the first day of the test was 0.8 psig. Based on subsequent measured air-tracer flows at higher cavity pressures, the combined air-tracer flow at 0.8 psig cavity pressure was about 11 cfm, including a measured flow of 1.1 cfm of refrigerant tracer. At these relatively low injection pressures and flow rates, positive traces were observed at curb cracks adjacent to the injection point and at the patch surrounding the injection tube, indicating that the air-tracer detection technique was functioning.

4.2. Leakage Pattern on Site

On May 17, an average measured air-tracer flow rate of 29.2 cfm (including 3.6 cfm of refrigerant tracer) at an average cavity pressure of 2.2 psig was maintained during the four-hour period when trace detection measurements were being made at many points on the site. The measured road lift during this period also was negligible. Using the electronic detector (see Fig. 4) tracer was detected at the following locations:

a. Blacktop and concrete gutter interface near the catch basin at the corner of South Magdalene Court.

b. Driveway/carport concrete slab expansion joint at 4907.

c. Crack in the concrete gutter and curb in front of 4909 water meter box. (See Fig. 7.)

d. At the front inside basement walls of 4907, 4909, 4911, where the water lines enter.

e. Within concrete blocks at the front basement wall next to the utility trench for water, sewer, and gas at 4911 and within the same area for the utility trench serving water and sewer at 4909.

f. Within the rock rubble located below the carport and adjacent to the fireplace foundation wall at 4907. (See Fig. 8.)

g. At the gas line where it penetrates the concrete block wall in the basement of 4911.

Figure 7. Joint in the concrete gutter in front of 4909.

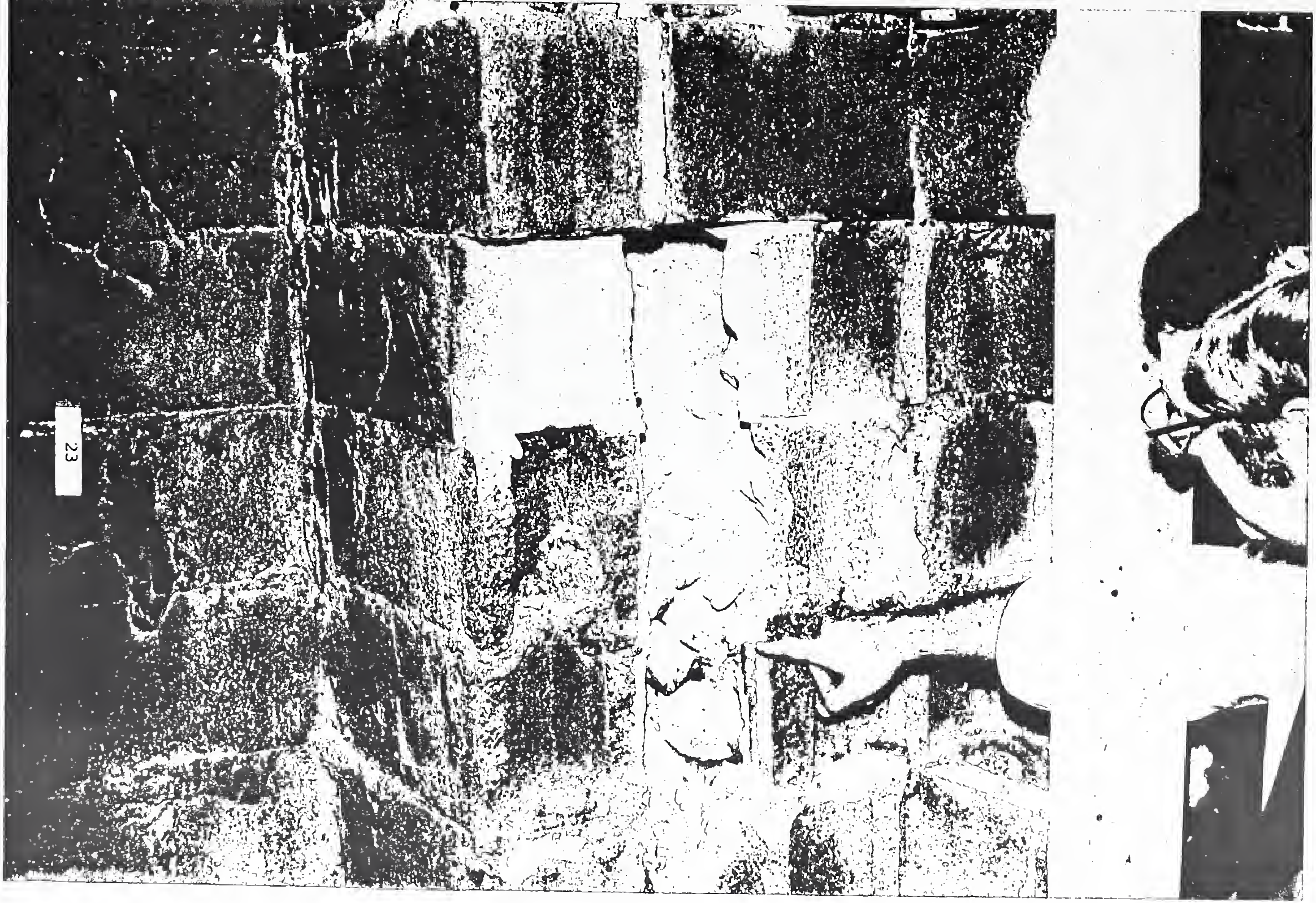

Figure 8. Rock rubble against the foundation wall at 4907.

h. In all water meter boxes located on South Magdalene Court.

i. In the gas curb box for 4911. (This curb box had been dug up for repairs so this indication of tracer does not necessarily mean natural gas was in the box at the time of the accident.)

j. At many positions along concrete gutter and curb, including curb joints near several water boxes, and curb joints adjacent to driveways at 4907 and 4911.

k. At the interface between the sanitary sewer manhole rim and surrounding blacktop located in the South Magdalene Court cul-de-sac.

l. In catch basins located at (a) Queen Elizabeth Boulevard in front of 4907 South Magdalene Court, (b) Queen Elizabeth Boulevard in front of 8526 (at the corner of North Magdalene Court), and (c) the north corner of South Magdalene Court and Queen Elizabeth Boulevard.

Air tracer was not detected at the following locations:

a. Interior of homes at 4908 and 4910 South Magdalene Court and the home at 8601 Queen Elizabeth Boulevard. The slab on grade home at 8601 was not entered but was judged to be free of tracer because a check for tracer at the front foundation wall, the gas curb box, and the water meter box at 8601 did not reveal tracer.

b. The gas curb box for 4908 and 4910. It was not possible to check the gas curb box at 4907 since it had been removed by the gas company when gas was shut off to 4907 after the accident.

c. Gas line at the point of basement entrance and gas curb box at 4909.

d. Gas line at the point of basement entrance at 4907.

e. Water and gas valve boxes located in the right-of-way at the intersection of North Magdalene Court and Queen Elizabeth Blvd.

f. The sanitary sewer in 4907, 4909, 4911, and street manholes. At 4907 normal water seals were in all traps. At 4909 and 4911, measurements were made in the open basement commode drain line. The commodes had been removed and there were no water seals. No tracer was detected either in or around the sanitary drain lines.

g. Two one-inch holes, six inches deep, drilled in cul-de-sac surface. (See Fig. 6.)

h. Curb joints adjacent to driveways at 4908 and 4910.

Smoke was generated in the air-tracer injector system through the special valve shown in Figure 2 to give visual indication of leakage path. Although preliminary tests at NBS demonstrated that the smoke would pass through wet sand, there was insufficient air flow on the site for this test and no smoke traces were observed.

4.3. Tests in Utility Trenches

The test trenches in front of 4909 and 4911 contained much rock rubble. See Figures 9 and 10. This rock rubble consisted of loosely-placed rock backfill. The Federal Highway Administration's report containing results of rock-soil samples is attached as Appendix 7.3. This report shows that the trench at 4909 containing the water and sewer lines had fine soil to a depth of 0.4 of a foot, course angular rock

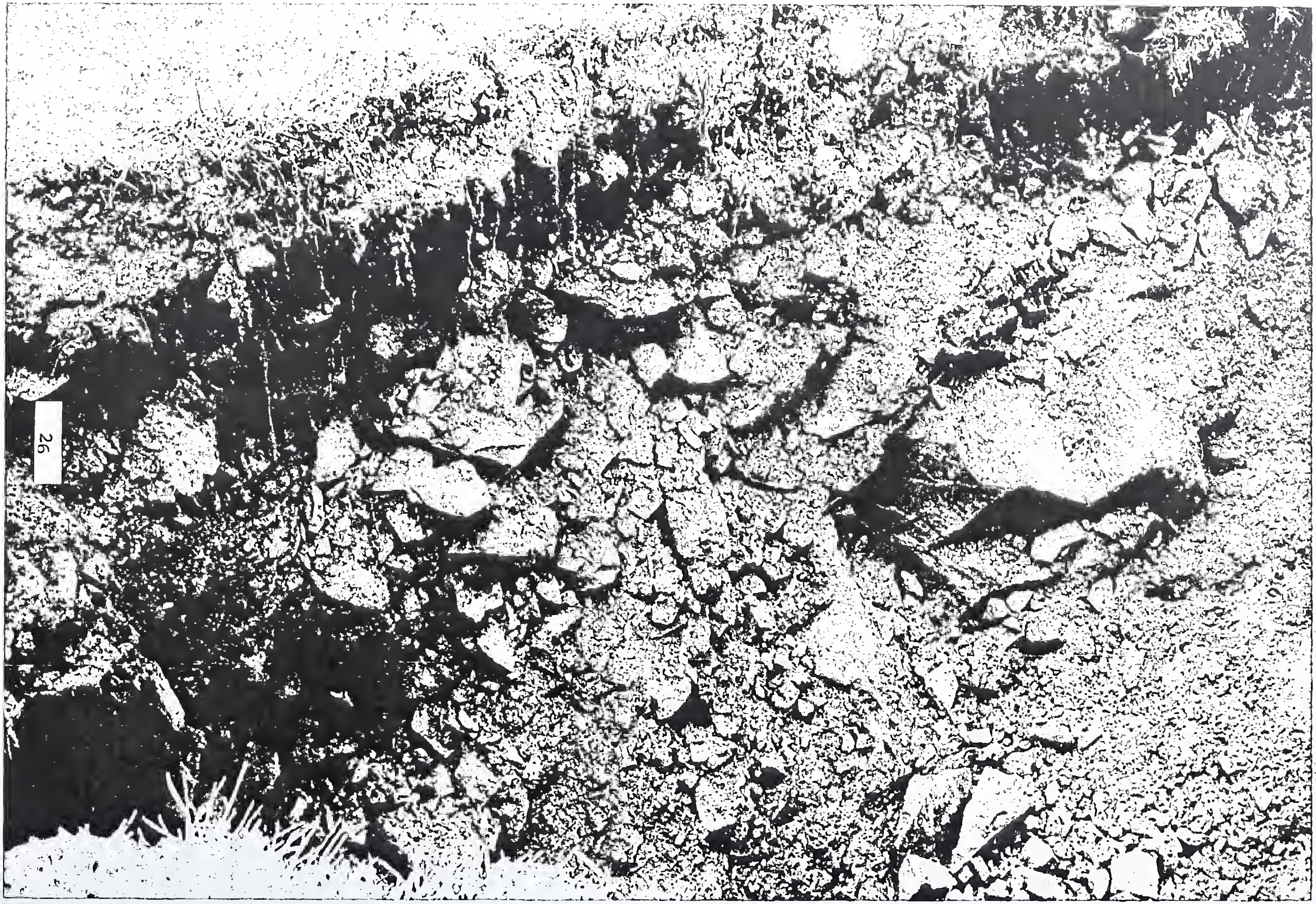

Figure 9. Rock rubble in the water and sewer service trench at 4909.

Figure 10. Rock rubble bed for water and sewer services at 4909.

fragments loosely placed as backfill between 0.4 and 5.8 foot depths, and at 6.8 foot depth a fine soil existed. In other words, the rock fill of five inches or greater sieve-size was sandwiched between layers of fine soil material in the 4909 water and sewer line trench. The water/sewer lines were covered by about six inches of rock-free fill in this trench but rested directly on rock fill. No tracer was detected in the immediate vicinity of the water/sewer lines. The water line was beside and below the sewer line.[1] (See Fig. 10.) Water line depth was 69 inches below grade and sewer line depth was 63 inches. No tracer was detected in the gas line trench at 4909. Appendix 7.3 shows that this trench contained a mixture of fine soil and angular rock fragments. The gas line was bedded in rock-free fill and covered with rock-free fill about eight inches deep. The gas line depth was about 24 inches.

Throughout the digging process on May 18, tracer was detected in the trench at 4911. Rocky fill was found in direct contact with water, sewer, and gas lines.[2] Appendix 7.3 shows that coarse angular rock fragments, five inches or greater sieve size, were loosely placed around the water line.

During this day's testing, the air flow was increased to a maximum of 49.3 cfm at a cavity pressure of 2.9 psig. No refrigerant tracer was added because measurements during the excavation process could be made from residual trace. No road lift was observed during the period.

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[1]Federal Housing Authority Minimum Property Standards (FHA 300), November 1966, para. 1006-4.5d, page 214, "(Water) service pipe may be laid in same trench with sewer pipe provided it is laid on a shelf of solid earth at least 1 foot above the sewer pipe. Service trenches shall be filled with earth free of . . . . rocks."

[2]Ibid.

On May 19 (the 4th day of the test) three principal tests were performed.

a. Refrigerant trace detection checks were made in the excavations at 4909 and 4911 for verification of checks made on May 18 during excavation.

b. A quantitative air-tracer flow measurement was made at the sewer/water excavation at 4909.

c. Refrigerant trace detection checks were made in a series of one-inch holes, 24-inches deep, drilled in the street and along the front edge of the lawn at 4907.

During these tests, a maximum air-tracer flow rate of 65.5 cfm free air rate (including 2.7 cfm of refrigerant) was obtained with a maximum cavity pressure of 4.2 psig.

Positive refrigerant-tracer detection was made at the rock-fill face of the sewer/water trench at 4909 and at the sewer/water/gas trench at 4911. No tracer was detected in the gas line trench at 4909. Shoring was needed in the trench at 4911 because of the depth (∿10 feet) and because the rock fill kept falling into the excavation.

In the quantitative air flow test at 4909, with the vacuum pump off, air tracer entered the trench through the rock fill and caused the plastic cover sheet to be forced up. With the vacuum pump operating at a measured maximum capacity of 15.0 cfm, this capacity was not sufficient to cause the plastic cover to collapse. A micromanometer indicated a varying positive pressure of up to 0.02 inches W.G. (water gage) in the trench with the pump running. To determine if a slight wind was affecting this observation, the vacuum pump and the air supply to the street cavity were turned off. The plastic cover sagged into the trench within one minute. See Figure 11. The air supply was turned on and within ten seconds the plastic cover began to rise and was taut within one minute. See Figure 12.

This test indicates that the air-tracer flow into the trench was in excess of 15 cfm. Also, this air flow test showed that the air-tracer readily passed through voids in the rock rubble from the injection point 150 feet away to the front of the foundation wall at 4909. Air flow at the injection point was 41 cfm and cavity pressure was 3.5 psig at the time of this test.

The 2-foot-deep drilled holes in the Magdalene Court right-of-way showed that tracer existed under most of the right-of-way surface at or above a depth of two feet. Tracer was not detected in the drilled holes in the portion of the cul-de-sac in front of the undamaged home at 4908, as shown in Figure 6. Tracer was detected in most of the drilled holes next to the sidewalk in the front lawn of 4907, and was detected in the drilled hole in the concrete driveway ramp of 4907.

4.4. Examination of Foundation Wall

The dismantling/examination of the foundation wall at 4911 produced the following observations:

a. Coarse rock fill existed against the front wall surface in the utility trench. Analysis of rock-soil fill is contained in Appendix 7.3.

b. The gas line and water line were laid on top of rock fill. There was no evidence that either of these lines had been bedded in soil.

Figure 11. Sagging plastic cover over 4909 test trench.

Figure 12. Taut plastic cover over 4909 test trench.

c. The water line and gas line did not have good seals at the penetrations in the concrete block. Both showed evidence of having been sealed prior to the accident. It is likely that the foundation wall was moved by the explosion-fire.

d. The street side of the concrete block foundation wall had a protective coating to prevent water penetration.

e. One shortened (cut) concrete block located in the center of the wall did not have a mortar seal between its cut/shortened end and the adjacent block. Appendix 7.3 shows the analysis of the soil samples taken from the front yard of 4907 at the positions of the drilled holes shown in Figure 6. The gas test holes referenced by number in Appendix 7.3 are these holes numbered from left to right in the front of 4907. Figure 6 shows that tracer was not detected in holes numbered 1, 2, 3, 4, and 10. All of these holes were located in the lawn area except hole number 16 which was located in the concrete ramp of the driveway. Soil samples were taken near gas test hole 2, between gas test holes 10 and 11, and near gas test hole 18. No tracer was detected in hole 10 and this may be because of the red-brown dense clayey silt sampled between holes 10 and 11.

5. DISCUSSION OF RESULTS

The repair work on 4907 prior to the NBS test reduced the usefulness of tracer simulation results for this home because

a. The concrete carport slab had been completely broken up. The expansion joint between this slab and the driveway slab was considered an important simulation point where natural gas was seen burning in the videotape.

b. During the process of repairing the house, a hole had been made in the side of the house above the carport slab area which exposed the entire void space under the first floor fireplace where an explosion had occurred.

The basements of 4909 and 4911 had been cleaned of debris prior to the tracer test. The equipment used to clean up the basement at 4909 appeared to have

a. Bent the gas line.

b. Made a hole approximately 4 feet by 2 feet in that portion of the front foundation wall containing the water line penetration.

The equipment used to clean up the basement at 4911 appeared to have

a. Punched several holes, judged to be about one foot long and two inches wide, in the front foundation wall.

b. Caused cracks around water and gas line penetrations in the front foundation wall.

For these reasons, the detection of tracer at water and gas lines where they penetrate the walls of these homes does not necessarily indicate that the natural gas entered the homes by way of these penetrations. Since the water line in 4907 did not appear to have been damaged, it is judged that tracer detected at this line at its penetrative position on the concrete block wall is good simulation of one possible natural gas entrance into 4907.

The Fairfax County soil analysis sheets for Magdalene Court show only sub-base soil condition (approximate depth 10 inches) and do not show soil or fill condition beneath the sub-base. The drill hole pattern showed that tracer existed generally under the entire right-of-way surface at or above a depth of 2 feet. If a record of type of fill materials used in each utility trench and the depth below the right-of-way that these materials are located had been available, a better judgment could be made concerning the probable distribution paths of tracer in light of the tracer pattern recorded over the plan view of the right-of-way.

6. CONCLUSIONS

The following are concluded from the results of the field investigation.

a. The air-tracer traveled through soil and rock rubble located in the utility trenches containing the individual water and sewer lines for the destroyed homes at 4909 and 4911.

b. The investigation showed that tracer did not flow on the outside of any particular pipe, per se, but rather, traveled through soil and rock fill. It was not possible to determine precisely how gas actually entered the houses through their foundations from the rock-rubble-fill that was found in the utility trenches. The water lines, gas lines, and concrete block walls had been disturbed by the explosions, fires, and fire-fighting and clean-up activities in the homes. Repair work carried out on 4907 prior to the tests further altered the test simulation in this home. As a result it is surmised that the gas entered 4909 and 4911 through the front walls by way of piping penetrations and/or through the mortar and asphalt coated concrete block construction. Because tracer was detected at the apparently undisturbed water line at its penetration in the front wall and at the fireplace foundation wall under the carport of 4907, it is assumed that gas entered this building in the same manner. Soil tests and drilled hole tracer tests at 4907 indicated that possibly more than one rock fill path exists between the injection area and the house.

c. The undamaged homes at 4908 and 4910 South Magdalene Court and the home at 8601 Queen Elizabeth Boulevard did not experience explosion or fire during the accident and did not receive tracer during the air-tracer test.

d. Natural gas could flow again into or to the same homes if another natural gas leak were to occur in the vicinity of the leak of March 24 unless the rock rubble paths are eliminated.

e. In the tests conducted, it was not possible to duplicate enough conditions to pinpoint the time required for natural gas to travel from the leak to the homes at the time of the accident. However, it was established, based on the following two facts, that the gas could have traveled to the homes in less than 30 minutes. It was documented at the public hearing that the odor of natural gas was detected by residents of 4909 and 4911 in their homes at about 8:30 a.m. on the day of the accident, and air tracer traveled from the injection point to the front wall of 4909 in less than 30 minutes during the tests on May 17. Secondly, during the test, air tracer injection began at 11:00 a.m. and tracer was detected inside the front wall of 4909 in the vicinity of the water line at 11:31 a.m. Further, because this wall position had not been monitored before 11:31 a.m., the tracer could have arrived at the wall in less than 30 minutes.

f. The quantitative air flow test at 4909 showing more than 15 cfm of air tracer flowing from the point of break on the gas main to the trench in front of the foundation wall with a source (cavity) pressure of 3 1/2 psig indicates that gas flow at the time of the break through this same path could easily have been considerably in excess of that required (12 cfm) to form an explosive mixture (5% by volume) in one half hour in an unventilated volume of 7200 cubic feet, the approximate volume of the 4909 basement, if the cavity or source pressure was sufficiently high. The source pressure at the time of break could possibly have approached 22 psig, far in excess of the 3.5 psig source pressure used in the quantitative air flow test. The actual volume of the 4909 home is not known, nor is the ventilation/infiltration rate existing at the time of the explosion.

g. Although tracer was detected in the storm sewer, tracer was not detected in the sanitary sewer. The storm and sanitary sewers are not interconnected. It is concluded that natural gas did not enter the sanitary sewer because tracer was not detected in sanitary manholes servicing South Magdalene Court or in sanitary sewer connections within the homes. If natural gas had existed in the storm sewer at the time of the accident, the gas in the storm sewer could not have contributed to the accident since the storm sewer does not extend up the Court.

Examination of drawing no. 4, as listed in Appendix 7.2, shows that the home at 4907 is built on fill and also that the entire front yard of this home is fill. It is concluded from test results that the tracer must have traveled through this fill to the home. The rest of the houses on the site, including the destroyed homes at 4909 and 4911, were built on excavated land and not on fill. Except for the utility trenches, little or no fill exists in the front yards of the destroyed homes. The middle of the cul-de-sac area is about 14 feet lower than the original land grading indicating that considerable material had been removed. It may be that the removal of this material exposed bed rock since the service trenches at 4909 showed the existence of solid rock. It appears that some blasting must have taken place in order to form the trenches. The rock rubble found as fill in the trenches at 4909 and 4911 was probably produced by the blasting.

7. APPENDIX

7.1 - Names of Individuals Who Participated in the NBS Test Program

Because concern for building systems in general is within the scope of the mission of the NBS, Center for Building Technology, Building Service Systems Section, and because of section participation on the National Fuel Gas Code, ANSI Z223, Dr. Jack Snell, Chief, Building Service Systems Section, requested that Robert W. Beausoliel, Mechanical Engineer for the section, determine if anything could be learned from the Annandale pipeline accident that might contribute to Z223 work. Discussion with Mr. Barry M. Sweedler, Chief, Pipeline Safety Division, National Transportation Safety Board disclosed that NTSB was investigating the accident but did not know how the natural gas entered the homes. Subsequently, NTSB requested that NBS determine how the gas entered. In order to assist with the investigation, Robert W. Beausoliel attended the public hearing concerning the accident, visited the accident site, and developed the test plan and test organization presented in this report.

On April 26, a meeting was held at NBS for concerned parties to discuss and approve the basic test plan. The meeting was attended by the following individuals:

Mr. Barry M. Sweedler, Chief, Pipeline Safety Division, National Transportation Safety Board

Mr. Lance F. Heverly, Assistant Chief, Technical Division, Office of Pipeline Safety

Mr. Paul R. Achenbach, Chief, Building Environment Division, (462.00) NBS

Dr. Jack E. Snell, Chief, Building Service Systems Section (462.03), NBS

Mr. Frank J. Powell, Chief, Thermal Engineering Systems Section (462.01), NBS

Mr. Clinton W. Phillips, Engineer, (462.01) NBS

Mr. Robert W. Beausoliel, Engineer, (462.03) NBS

Dr. Charles M. Hunt, Engineer (462.02) NBS

Mr. Keith H. Fellows, Assistant Superintendent, Transmission & Distribution Department, Washington Gas Light Company

Mr. Kenneth G. Behrens, Field Engineer, Transmission & Distribution Department, Washington Gas Light Company

Mr. Richard G. Little, Junior Staff Engineer, American Gas Association.

On May 2, a meeting was held at the Massey Building, Fairfax County to brief the County officials concerned with the test and to outline the assistance that NBS requested from the County in order to conduct the tests. The following persons were present at the meeting.

Mr. Barry M. Sweedler, Chief, Pipeline Safety Division, NTSB

Capt. John Wahl, Fairfax County Police

Mr. George H. Alexander, Director, Fairfax County Fire/Rescue Services

Mr. George H. Williams, Chief Plumbing Inspector, Fairfax County

Mr. Rudolf Schroeck, Assistant Chief Plumbing Inspector, Fairfax County

Mr. Winford Atkins, Field Supervisor, Fairfax County Plumbing Department

Mr. Jack Liedl, Director, Office of Capital Facilities, Department of Public Works, Fairfax County

Mr. Joseph E. Sunday, Chief of Planning Programs, Program Administration Division, Fairfax County

Mrs. Audrey Moore, Fairfax County Supervisor for the Annandale District

Mr. Clinton W. Phillips, Engineer (462.01) NBS

Mr. Robert W. Beausoliel, Engineer (462.03) NBS

It was agreed during this meeting that Mr. George H. Alexander would act as coordinator between the concerned Fairfax County functions and NBS. Also, Mr. Alexander would make arrangements to notify the residents of South Magdalene Court of the test. The written notice, which was subsequently prepared, read as follows:

NOTICE OF NATIONAL BUREAU OF STANDARDS FIELD TEST

FOR

THE NATIONAL TRANSPORTATION SAFETY BOARD

"The purpose of this notice is to provide you with detailed information on the tests to be conducted by the National Bureau of Standards (NBS) at South Magdalene Court, Annandale, Virginia during the week of May 15, 1972.

Chief George H. Alexander, Director, Fire and Rescue Services, Fairfax County, Virginia, has been designated coordinator of this test for Fairfax County and for making arrangements with the residents of South Magdalene Court to facilitate the work of the NBS engineers.

As you may be aware, the National Transportation Safety Board (NTSB) is responsible for investigating the gas explosion which occurred at this location on March 24, 1972. NTSB has requested that the NBS conduct a field test on the site to determine (a) how the gas entered the homes, and (b) the path or paths the gas followed from the leak to the homes. This test may help us in improving the safety of such installation.

The test will be performed by introducing a harmless tracer-air mixture into the ground at the position where the natural fuel gas leak occurred. Hopefully, this harmless mixture will be detected at various locations in the area by use of special electronic indicators.

To do this, NBS personnel must have access to the following homes (outside yards and basement areas primarily):

4907 South Magdalene Court
4908 South Magdalene Court
4909 South Magdalene Court
4910 South Magdalene Court
4911 South Magdalene Court
8601 Queen Elizabeth Boulevard.

"Residents may remain in their homes during the tests; however, as an added precaution during the test, the Washington Gas Light Company will turn off the gas supply to each of these houses and will restore service in the evenings and at the end of the test.

The present schedule calls for preparations and test set up on Monday, May 15, and the tracer air mixture tests on Tuesday and Wednesday, May 16 and 17. Three large air compressors will be required on these dates to inject the mixture into the ground. The residents should be advised that these machines are quite noisy.

You will be advised promptly if it becomes necessary to alter this plan or schedule.

Again, thank you for your cooperation in this experiment. Chief Alexander will be happy to provide any additional information you may require."

Mr. Liedl made arrangements for equipment and men to dig the test trenches across the utility services at 4909 and 4911 and supplied drawings showing sewer mains, plot plans, and grading at South Magdalene Court.

Mr. George H. Williams made arrangement for plumbing assistance as required to locate and clean building drains and building sewers at 4909 and 4911.

Mr. John W. Peck, Engineer, Fairfax County Water Authority, supplied drawings of the water service main for South Magdalene Court.

The injector pipe hole was hand dug by Washington Gas Light Company (WGLC) employees under the supervision of Mr. Kenneth Behrens, WGLC engineer. The one-inch-diameter by 24-inch deep test holes were drilled in the South Magdalene Court right of way by WGLC employees. WGLC supplied a drawing showing their distribution and service piping.

Mr. Jerome R. Blystone, Highway Research Engineer, Materials Division, Federal Highway Administration, took soil samples at South Magdalene Court.

Mr. John L. Stecklen, Representative, Washington Air Compressor Rental Co. supplied the air compressor services during the NBS test.

The following NBS personnel participated during the test:

1. Dr. Jack Snell, 462.03, Chief of the Building Service Systems Section, was responsible for overall test supervision.

2. Mr. Robert W. Beausoliel, Engineer, 462.03, was responsible for overall test planning, test organization, supervision of activities during the test, reduction of test data, and the final report.

3. Mr. Clinton W. Phillips, Engineer, 462.01, was responsible for development of the tracer techniques, air flow measurement in the test trench at 4909, data reduction, and the final report.

4. Dr. Jim Shaver, Mr. Robert G. Mathey and Mr. Tom Reichard, engineers, 461.01, were responsible for injection tube bedding and road lift monitoring.

5. Mr. Jim Melvin, engineer, 213.06, was responsible for air flow measurement at the injection setup.

6. Mr. Raymond J. Mele, Visual Information Specialist, and Mr. Franklin K. Mackley, Engineering Draftsman, 463.03, were responsible for the photographs taken during the test.

7. The following technicians served to install and operate the test equipment:

   a. Mr. Julius T. Cohen, 462.03
   b. Mr. John W. Grimes, 462.01
   c. Mr. Lymus Payton, 461.01
   d. Mr. Boyd L. Shoemaker, 462.01

8. The piping systems were fabricated and assembled by:

   Mr. Joseph Clem, pipefitter, 126.07
   Mr. Thomas S. Fisher, pipefitter, 126.03

The number shown after each name indicates NBS Division and Section. That is:

OFFICE OF THE ASSOCIATE DIRECTOR FOR ADMINISTRATION (120.00)

126 Plant Division
03 Piping Shop

INSTITUTE FOR BASIC STANDARDS (200.00)

213 Mechanics Division
06 Fluid Meters Section

INSTITUTE FOR APPLIED TECHNOLOGY (400.00)
Center for Building Technology (460.00)

461 Structures, Materials & Life Safety Division
01 Structures Section

462 Building Environment Division
01 Thermal Engineering Systems Section
02 Building Service Systems Section

Appendix 7.2 - List of Drawings Furnished by Fairfax County

1. Plan and Profile, MAGDALENE COURT, Section 5, Canterbury Woods, Falls Church Magisterial District, Fairfax County, Virginia. Drawing by Greenhorne, O'Mara, Dewberry and Nealon, Civil Engineers, Land Surveyors, Arlington, Virginia. (Drawing Sheet 6 of 8). This drawing shows views of the sanitary and storm sewer system including the water mains.
2. Plan and Profile drawing with the same title as in (1) above, and sheet 6 of 8 also. The drawing was made by the same company.
3. Plan and profile QUEEN ELIZABETH DRIVE, 1OF2, Section 5, Canterbury Woods, Falls Church Magisterial District, Fairfax County, Virginia (drawing sheet 3 of 8). Similar to drawing mentioned in (1) above. The drawing was made by the same company.
4. DRAINAGE PLAN, Section 5, Canterbury Woods, Falls Church Magisterial District, Fairfax County, Virginia (sheet 2 of 8). This drawing shows land contours before and after construction.
5. Drawing titled FAIRFAX shows the location of building lots by number and street.

Appendix 7.3 - Federal Highway Administration's Description of Soil and Aggregate Materials at the Canterbury Woods Subdivision

June 20, 1972

Description of Soil and Aggregate Materials at the
Canterbury Woods Subdivision
Fairfax County, Virginia

By Jerome R. Blystone, Highway Research Engineer
Materials Division, Federal Highway Administration

Profile of the waterpipe and sewage trench in front of Building 4909

0.0 to 0.4 ft. - Fine soil with some coarse angular fragments. (S. No. 47344)

0.4 to 5.8 ft. - Coarse angular rock fragments. Loosely placed as backfill Had large continuous voids. Extremely porous. (S. No. 47340)

5.8 to 6.8 ft. - Fine soil with some coarse angular fragments. (S. No. 47343)

Profile of the gas line trench front of Northeast Corner of Building 4909

0.0 to 2.4 ft. - Mixture of fine soil and angular rock fragments (S. No. 47341)

Aggregate Material Around the Gas Pipe front of Building No. 4911

2.0 to 3.0 ft. - Mixture of coarse angular rock fragments and fine soil. Was loosely placed and contained large continuous voids. (S. No. 47342)

Back fill against side wall of 4907 Magdolene Court, and under parking slab

Coarse angular rock fragments with large voids. This material was not sampled.

Backfill around water pipe in front of front wall of 4911 Magdalene Court

Coarse angular rock fragments loosely placed with large continuous voids. (S. No. 47345)

Data from shallow drill holes

Hole No.	Location	Depth, ft.	Description of Material
1	Front of 4908 Magdalene Court	0.0 to 2.0 (stopped by rocks)	Mixture of fine soil and coarse angular fragments of micaceous schist (not sampled)
2	N. end of gas line trench 4909 Magdalene Court	0.0 to 1.5	Mixture of soil and angular particles of micaceous schist. (S. No. 47346)
3	Near gas test hole 18	0.0 to 0.6	Fine soil and coarse angular particles of micaceous schist (not sampled)
		0.6 to 2.2	Fine soil - some coarse angular particles of micaceous schist. (S. No. 47347)
		2.2 to 2.8	Coarse angular particles of micaceous schist. Some soil. (not sampled)
4	Between gas test holes 10 and 11	0.0 to 0.7	Mixture of fine soil and some coarse angular particles. (not sampled)
		0.7 to 4.0	Red brown clayey silt, dense. (S. No. 47348)
5	Near gas test hole 2	0.0 to 1.5	Mixture of fine soil and coarse angular rock fragments (S. No. 47349)

FORM PR-202
(REV. 8-65)

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

DATE: June 19, 1972

REPORT ON SAMPLES OF Soil and Soil Aggregate Mixtures

STATE: Virginia

PROJECT: Gas Explosion Site, Centerbury Woods Subdivision

DATE SAMPLED: May 19, 1972

RECEIVED: May 19, 1972

SAMPLED FROM: Backfill in water pipe and gas line trenches

TESTED FOR USE IN: Identification of materials

SUBMITTED BY: J. R. Blystone

IDENTIFICATION

B. P. R. Report No.	S 47340	S 47341	S 47342	S 47343
Field No.				
~~Station or Station No.~~ Location	1/	2/	3/	1/
~~Elevation or~~ depth (below surface)	1.0' to 4.0'	0.0' to 2.4'	2.0' to 3.0'	4.8' to 5.8'
Soil description				

CLASSIFICATION TEST RESULTS

Mechanical analysis: Percentage passing—				
6"	100			
5"	78		100	
4"	62		86	
3"	57		86	
2-inch sieve	43	100	62	
1½-inch sieve	34	92	54	
1-inch sieve	23	80	49	100
¾-inch sieve	19	74	45	98
⅜-inch sieve	14	63	38	97
No. 4 sieve (4.7 mm.)	12	58	33	96
No. 10 sieve (2.0 mm.)	10	54	29	94
No. 40 sieve (0.42 mm.)	7	50	23	88
No. 60 sieve (0.25 mm.)	--	--	--	--
No. 200 sieve (0.074 mm.)	5	33	16	58
Percentage smaller than—				
0.050 mm	4	29	14	51
0.020 mm	3	18	10	36
0.005 mm	2	10	5	20
0.002 mm	1	7	4	11
0.001 mm	1	6	4	10
Liquid limit (LL)	32	32	30	38
Plasticity index (PI)	5	6	6	7
Classification				

REMARKS:
1/ Front of house - 4909 Magdalene Court.
2/ Front of N. E. corner of house - 4909 Magdalene Court.
3/ Front of house - 4911 Magdalene Court.

Woodrow J. Halstead, Chief, Materia
Divisio

Per

USCOMM-DC 26126-P66

FORM PR-202
(REV. 8-65)

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

DATE: June 19, 1972

REPORT ON SAMPLES OF Soil and Soil Aggregate Mixtures

STATE: Virginia	**PROJECT**: Gas Explosion Site, Canterbury Woods Subdivision
DATE SAMPLED: May 19 and June 7, 1972	**RECEIVED**: May 19 and June 7, 1972
SAMPLED FROM: Backfill in water pipe and gas line trenches	
TESTED FOR USE IN: Identification of materials	**SUBMITTED BY**: J. R. Blystone

IDENTIFICATION

B. P. R. Report No.	S 47344	S 47345		
Field No.	---	---		
~~Boring or Station and~~ Location	1/	2/		
~~Elevation or~~ depth (below surface)	0.0' to 0.4'			
Soil description				

CLASSIFICATION TEST RESULTS

Mechanical analysis: Percentage passing—				
6"		100		
5"		74		
4"		59		
3"		27		
2-inch sieve				
1½-inch sieve	100	17		
1-inch sieve	97	9		
¾-inch sieve	96	8		
⅜-inch sieve	94	6		
No. 4 sieve (4.7 mm.)	92	5		
No. 10 sieve (2.0 mm.)	88	4		
No. 40 sieve (0.42 mm.)	81	2		
No. 60 sieve (0.25 mm.)	--	-		
No. 200 sieve (0.074 mm.)	51	1		
Percentage smaller than—				
0.050 mm	45	1		
0.020 mm	33	1		
0.005 mm	18	0		
0.002 mm	14	0		
0.001 mm	11	0		
Liquid limit (LL)	34	30		
Plasticity index (PI)	6	7		
Classification				

REMARKS: 1/ Front of house - 4909 Magdalene Court.

2/ Sample from area immediately above water pipe - front wall of building No. 4911.

Woodrow J. Halstead, Chief, Materials Division

Per ....

FORM PR-202
(REV. 8-65)

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

DATE: June 19, 1972

REPORT ON SAMPLES OF Soil and Soil Aggregate Mixtures

STATE: Virginia	PROJECT: Gas Explosion Site, Canterbury Woods Subdivision
DATE SAMPLED: June 7, 1972	RECEIVED: June 7, 1972
SAMPLED FROM: Auger holes	
TESTED FOR USE IN: Identification of materials	SUBMITTED BY: J. R. Blystone

IDENTIFICATION

B. P. R. Report No.	S 47346	S 47347	S 47348	S 47349
Field No.	-	-	-	-
Location	1/	2/	3/	4/
Elevation or depth (below surface)	0.0' to 2.0'	0.5' to 2.0'	0.7' to 4.0'	0.0' to 1.5'
~~Soil description~~				

CLASSIFICATION TEST RESULTS

Mechanical analysis: Percentage passing— 3"	100	100		
2-inch sieve	89	99		
1½-inch sieve	89	--		
1-inch sieve	69	94		
¾-inch sieve	62	90	100	100
⅜-inch sieve	45	77	98	91
No. 4 sieve (4.7 mm.)	35	68	93	85
No. 10 sieve (2.0 mm.)	24	59	91	80
No. 40 sieve (0.42 mm.)	21	53	83	74
No. 60 sieve (0.25 mm.)	--	--	--	--
No. 200 sieve (0.074 mm.)	16	38	74	52
Percentage smaller than— 0.050 mm	11	32	68	46
0.020 mm	7	21	55	35
0.005 mm	4	12	35	22
0.002 mm	3	9	24	16
	3	9	20	14
Liquid limit (LL)	30	31	37	34
Plasticity index (PI)	5	5	13	9
Classification				

REMARKS: 1/ North end of gas line trench, 4909 Magdalene Court
2/ Near gas test hole 18
3/ Between test holes 10 and 11
4/ Near gas test hole 2

Per L. Smith

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