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National Bureau of Standards
Gaithersburg, MD 20899

Prepared for:

General Services Administration
Public Buildings Service
18th and F Streest, NW
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U.S. DEPARTMENT OF COMMERCE, C. William Verity, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

ABSTRACT

Procedures were developed for limiting the release of fibers from fireproofing material during sprinkler hanger anchor installation on steel deck/concrete floor slab surfaces. These procedures were needed by the General Services Administration (GSA) for installation of sprinkler systems in buildings having fireproofing containing asbestos.

A prototype floor slab having spray-on friable mineral wool fireproofing was used in laboratory tests. The mineral wool fireproofing was used as a model system for fireproofing containing asbestos. The various combinations of mechanical anchoring procedures (use of drills or powder-actuated gun) and encapsulation procedures tested limited the fiber release to a range of values of 0.000 to 0.055 f/cc (fibers per cubic centimeter) as compared to a range of values of 0.26 to 0.82 f/cc for procedures without encapsulation. Encapsulation was shown to be effective as evidenced by much higher levels of fiber release during testing without encapsulation.

Because there is no known correlation between the release of mineral wool fibers and asbestos fibers, it was recommended that the procedures developed be evaluated by GSA in buildings having fireproofing containing asbestos. An air sampling protocol was developed for use by GSA in evaluating the procedures in the field. Subsequently, field tests were conducted by GSA.

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1. INTRODUCTION

1.1 Background

The General Services Administration (GSA) has determined that many of its buildings require retrofitting with fire sprinkler systems. Many of these buildings have spray-on fireproofing, containing asbestos fibers, applied to the structural members and decks where sprinkler systems are to be attached. Current asbestos abatement procedures regarding installation of sprinkler hangers involve the total removal of the fireproofing material. This is a costly procedure and the evaluation of alternative procedures for the installation of sprinkler systems on steel deck/concrete floor slab surfaces was needed by GSA. It is likely that significant cost savings can be obtained if the sprinkler systems can be installed by removing small amounts of fireproofing instead of total removal of the fireproofing.

GSA has determined that total removal is not necessary for buildings where the fireproofing is in acceptable condition and when an asbestos control management program is followed. For such buildings, only relatively small amounts of the fireproofing need be removed from the structural members or the steel deck/concrete floor slabs where the sprinkler hangers would be installed. In these cases, the sprinkler system installation must be carried out using procedures that limit the release of fibers from the fireproofing during and after installation. GSA was concerned that the removal of small amounts of fireproofing and induced vibrations in the structural system during installation of sprinkler hanger anchors might result in the release of fibers into the air. No recognized procedures exist for controlling the release of fibers during sprinkler hanger installation. Based on this need, GSA requested the National Bureau of Standards (NBS) to investigate installation techniques and to recommend procedures for installation of hanger anchors into steel deck/concrete floor slab surfaces containing spray-on, friable, fibrous fireproofing material.

In the NBS study, a mineral wool fireproofing material was used in laboratory tests as a model system for fireproofing containing asbestos. Since there was no known correlation between the release of mineral wool fibers and asbestos fibers, no conclusion could be drawn with respect to the performance of fireproofing containing asbestos.

Subsequently, field tests were conducted by GSA to evaluate the procedures developed in the NBS study and to measure asbestos fiber release during sprinkler hanger anchor installation. Comments pertaining to the field tests are given in Appendix A.

1.2 Objectives

The overall objectives of this study were (1) to evaluate alternative procedures to limit release of fibers from fireproofing during the installation of sprinkler hanger anchors on steel deck/concrete floor slab surfaces, (2) to evaluate these procedures by quantitatively determining the release of fibers from a model system of spray-on mineral wool fireproofing during sprinkler hanger anchor installation, and (3) to provide GSA with technical data based on the model system of mineral wool fireproofing for their use in field tests. GSA planned to develop procedures for limiting the release of fibers from asbestos-containing fireproofing materials into occupied areas of buildings during installation of sprinkler hangers.

1.3 Scope of the Study

The project involved NBS staff from the Center for Building Technology's Building Materials Division and Structures Division working with GSA. The NBS Center for Analytical Chemistry developed a protocol for air monitoring and fiber analysis. The NBS research consisted of four phases: (1) evaluation of mechanical anchoring procedures, (2) development of encapsulation and fireproofing core removal procedures, (3) development of a protocol for air monitoring and fiber analysis, and (4) evaluation of core removal/anchor installation methods with regard to fiber release. These tasks are referred to as Phases 1 through 4 of the project in the following text. GSA was responsible for the selection of an enclosure to be used in field testing and for performing field tests using the procedures developed by NBS. This report describes the work performed by NBS. At the request of GSA, NBS assisted GSA in making arrangements for an industrial hygienist contractor to work with GSA during the field tests. Brief outlines of the NBS phases (1 through 4) are given below.

Phase 1 - Mechanical Anchoring Procedures

The objective of this phase was to select mechanical anchoring procedures which cause only small disturbances from vibration and impact to the fireproofing material during sprinkler hanger anchor installation. Mechanical anchoring procedures refer to drilling holes needed for hanger anchors or installing a threaded anchor using a powder-actuated gun.

A series of laboratory tests was performed to evaluate existing procedures for limiting fiber release from fireproofing during installation of anchors for sprinkler systems in buildings. Test specimens were considered to be representative of the construction details in GSA buildings scheduled for evaluating sprinkler hanger installation procedures in the field. Mechanical anchoring devices and procedures were recommended for the prototype core removal/anchor installation tests in Phase 4.

Phase 2 - Fireproofing Core Removal

The objective of Phase 2 was to evaluate materials and procedures for encapsulation of spray-on friable, fibrous, mineral wool fireproofing material in order to minimize dislodgement of fireproofing during encapsulation, core removal, and sprinkler hanger anchor installation. Encapsulants and procedures for removal of wetted cores that minimize the release of fibers from the fireproofing were selected for inclusion in the prototype core removal/anchor installation tests in Phase 4. Encapsulants were used to penetrate, wet, and improve the cohesive strength of the friable fireproofing.

Phase 3 - Protocol for Fiber Monitoring and Analysis

The objective of Phase 3 was to develop a protocol for air sampling and analysis during Phase 4 and the GSA field tests. The protocol addresses factors such as the number of air samples to be taken, their locations, and the analytical procedure to be followed. The protocol presented in this report was recommended for use by GSA during their field tests.

Phase 4 - Prototype Core Removal/Anchor Installation Tests

The objective of Phase 4 was to carry out large-scale laboratory tests to evaluate the effect of sprinkler hanger anchor installation procedures on dislodgment of fibers from mineral wool fireproofing material. Apart from the use of fireproofing containing mineral wool, these prototype tests were intended to simulate the type of floor slab construction in GSA buildings scheduled for GSA's evaluation of sprinkler hanger anchor installation in the field. The mineral wool fireproofing material was applied to the underside of a steel deck/concrete floor slab. The mechanical anchoring devices selected in Phase 1 and the encapsulants and procedures for core removal recommended in Phase 2 were used in the Phase 4 prototype tests. The information gained in the Phase 4 tests was released to GSA for use in planning their field tests. The field tests were intended to determine if the release of fibers from fireproofing materials containing asbestos could be kept acceptably low when installing sprinkler hanger anchors.

This report describes the work performed by NBS in Phases 1 through 4. The report includes recommendations based on the results of this study for procedures that limit the release of mineral wool fibers from fireproofing on steel deck/concrete floor slab surfaces during sprinkler hanger anchor installation. Since there was no known correlation between the release of mineral wool fibers and asbestos fibers, it was not determined if the procedures developed would control the release of fibers from fireproofing containing asbestos. Subsequent field tests conducted by GSA provided information on asbestos fiber release during sprinkler hanger anchor installation. Comments on asbestos fiber release from fireproofing material during the field tests are included in Appendix A.

For the field tests, GSA selected an enclosure to seal the immediate work area during sprinkler hanger anchor installation. They intended that the enclosure be portable and easy to relocate within the building and provide adequate space for sprinkler hanger anchor installation. GSA conducted field tests based on the mechanical anchoring and encapsulation procedures developed by

NBS in Phases 1 through 4. The air sampling and analyses in the field tests were performed by an industrial hygienist contractor working in cooperation with GSA. The contractor's report on the field tests [1][1] was reviewed by NBS and comments about the report are presented in Appendix A. The comments pertain to the procedures used in the field tests for (1) air monitoring and analysis, and (2) for encapsulation and mechanical anchor installation. Comments are also presented in Appendix A on asbestos fiber release from sprinkler hanger anchor installation during the field tests as determined from analysis of air monitoring samples using phase contrast microscopy (PCM).

Sections 2, 3, 4, and 5 of this report describe Phases 1, 2, 3, and 4, respectively, of the NBS work.

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[1]Figures in brackets indicate references listed in Section 8.

2. MECHANICAL ANCHORING PROCEDURES (PHASE 1)

Vibrations induced in steel deck/concrete floor slabs during installation of sprinkler hangers may result in the release into the air of fibers from in-place fireproofing material. The objective of Phase 1 was to select procedures for sprinkler hanger anchor installation which cause only small disturbances from vibration and impact to the fireproofing material. Tests of conventional mechanical anchoring devices and anchor installation techniques were performed to determine their suitability for this application. Based on the results of these tests, procedures were selected for use in the Phase 4 laboratory tests.

The floor system recommended by GSA for the Phase 4 laboratory tests consisted of a lightweight concrete floor slab cast on top of a cellular steel deck sub-floor. Two methods for installing sprinkler hanger anchors on the underside of this floor system were studied:

(1) Threaded studs driven through the steel decking and embedded in the concrete floor slab using a powder-actuated gun (explosive-driven fastening tool).

(2) Expansive anchors installed in the concrete floor slab which required that a hole be drilled through the cellular steel decking and into the concrete floor slab.

In the first method, a 27-caliber, powder-actuated gun was used to install 3/8 in.-diameter threaded studs in a cellular steel deck/concrete test floor slab. A 2-7/8 in.-long steel stud (total length including threaded portion) was driven through the steel decking and embedded approximately 1-7/8 in. into the lightweight concrete floor slab, leaving the threaded portion (about 1 in.) of the stud protruding from the steel decking[2]. GSA requested that this method be tested in Phase 4 because of the ease of use and the one-step, rapid anchor (stud) installation.

Because of the difference between vibrations caused by impulse loading using a powder-actuated gun and mechanical vibrations induced by abrasive drilling, the two installation methods were not directly comparable. Therefore, no measurements were made of the magnitude and duration of vibrations caused by a powder-actuated gun, although vibration measurements were made to compare drilling methods.

In the second method, the installation of an expansive anchor required that a hole be drilled through the steel decking into the concrete floor slab. A variety of drills suitable for drilling into concrete were evaluated, including rotary drills and "hammer-drills". The purpose of this experimental program was to

[2]The stud anchorage should be of sufficient load carrying capacity for the appropriate installed sprinkler system, and should conform to applicable fire safety codes.

determine which drills and drilling techniques produced the least amount of vibration.

The drills which were selected for testing in Phase 1 are listed in table 1.

Table 1 - Drills Selected for Study in Phase 1

	Drill Designation	Speed (RPM)	Blows (BPM)	Current (Amps)
A	Rotary-drill	500	N/A	6.0
B	Light-duty hammer-drill	2500	50,000	4.5
C	Medium-duty hammer-drill	950	19,000	6.2
D	Medium-duty hammer-drill	520	3150	5.5
E	Heavy-duty hammer-drill	700	3750	10.0

Two different types of drill bits were used with the drills. The first was a masonry bit with a carbide tip designed specifically for drilling concrete or other masonry material. The second was a "hi-speed" twist drill bit specifically designed for drilling through steel or similar metal. This type is referred to in this report as a "steel bit" to distinguish it from a masonry bit.

Drilling of the steel deck/concrete slab floor system using either a rotary or "hammer-drill" causes vibration of the floor system. The response of the floor system may be characterized by its acceleration which is a measure of the amplitude of the vibrations. The average acceleration, as computed by the root-mean-square (RMS) procedure, was multiplied by the average time of drilling to produce a measure of vibration by which the various procedures could be compared.

Tests were conducted using various combinations of drill, drill bit, and drilling technique. Lightweight concrete slabs to which a single sheet of 18-gage steel decking was fastened were used to model the cellular deck sub-floor system. Accelerations were recorded using a processing digital oscilloscope and a piezoelectric type accelerometer with a range of 0 to 500 g. The "steel bit" was found to dull immediately upon penetration into the concrete and, therefore, a new steel bit was used for each test.

Drills D and E were found to produce much larger accelerations than Drills A, B, and C. For this reason they were eliminated from consideration. Results for drills A, B and C are summarized in tables 2 through 4.

Table 2 - Results for Drilling Through Two Sheets of 18-Gage Steel with a 5/8 in. "Steel Bit" using Rotary Action Only

Drill	RMS Accel. (g)	Drill Time (s)	Measure of Vibration (g x s)
A	2.5	55	138
B	6.0	9	54
C	5.3	23	122

Table 3 - Results for Drilling a 2 in. Deep Hole in a Concrete Slab with a 1/2 in. Masonry Bit Using Rotary Action Only

Drill	RMS Accel. (g)	Drill Time (s)	Measure of Vibration (g x s)
A	1.0	48	48
B	4.0	27	108
C	2.7	85	230

Table 4 - Results for Drilling a 2 in. Deep Hole in a Concrete Slab with a 1/2 in. Masonry Bit Using Rotary-Impact Action

Drill	RMS Accel. (g)	Drill Time (s)	Measure of Vibration (g x s)
B	6.7	14	94
C	5.8	18	104

If only a single drill type were to be used to drill both the steel and concrete, the smallest measure of vibration would be 148 g x s. This would be produced by Drill B using rotary action to drill through the steel deck (54 g x s) and rotary-impact action to drill a 2 in. deep hole in the concrete (94 g x s). Drill B produced similar vibration results (162 g x s) with rotary action alone. Drill A also produced fairly low vibrations (186 g x s). On this basis, Drills A and B were selected for use in Phase 4.

Based on the results from the comparative drill tests and tests with the powder-actuated gun, three methods for installing sprinkler hanger anchors were recommended to be tested in Phase 4:

(1) Threaded studs installed with a powder-actuated gun. The gun should be of sufficient capacity to install an anchor with a rated load-carrying capacity greater than or equal to that specified in the applicable fire safety codes (see footnote 2 previously noted in this chapter).

(2) Expansive anchors[3] requiring a hole drilled with a rotary drill (Drill A) using a "steel bit" to drill through the steel deck and a masonry bit to drill a hole approximately 2 in. deep in the concrete.

(3) Expansive anchors[2] requiring a hole drilled with a light-duty "hammer-drill" (Drill B) using a "steel bit" with only rotary action to drill through the cellular steel decking, and a masonry bit with rotary-impact action for drilling into the concrete.

Based on the information gained in Phase 1, the following procedures were recommended for use with Drills A and B when conducting the Phase 4 tests:

(1) A 5/8 in.-diameter or larger "hi-speed" twist drill bit should be used to drill through the cellular steel decking. The "steel bit" should be larger than the hole required for

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[3]The installed anchor should be of sufficient load carrying capacity for the appropriate installed sprinkler system, and should conform to applicable fire safety codes.

the expansive anchor to minimize the possibility of the masonry bit touching and vibrating the steel decking. Contact of the masonry bit with the steel decking during drilling was found to produce very high accelerations.

(2) A new "steel bit" should be used for each hole to be drilled through the cellular steel decking since the bit is dulled as soon as it penetrates into the concrete.

(3) A 1/2 in.-diameter masonry bit should be used to drill a hole approximately 2 in. deep in the concrete to accommodate a 1/2 in.-expansive anchor into which a 3/8 in.-diameter rod could be inserted (see footnote 2).

(4) A new masonry bit need not be used for each hole to be drilled in the concrete, but the bit should be replaced when wear becomes noticeable. It is noted that, for safety reasons, special masonry drill bits must be used with the "hammer-drills".

3. FIREPROOFING CORE REMOVAL (PHASE 2)

The objective of Phase 2 was to develop procedures for removing cores of sprayed-on fireproofing material from the underside of steel deck/concrete floor slabs before sprinkler hanger anchor installation.[4] The core removal procedure, which includes wetting with an encapsulant to stabilize the fireproofing material, is intended to minimize the risk of release of fibers from the fireproofing material. Encapsulation refers to an increase in resistance to fiber release while the fireproofing is wetted with an encapsulant and also after the encapsulant in the fireproofing has hardened. The definitions of encapsulants and the factors considered in their selection is this study are given in Sections 3.3 and 3.4. Encapsulants and procedures for removal of wetted cores were selected for testing in Phase 4.

3.1 Test Specimens

Specimens of a fibrous, friable, non-asbestos, spray-on fireproofing were prepared. Mineral wool fireproofing was chosen with the concurrence of GSA as a model system for fireproofing containing asbestos because mineral wool is commonly used for fireproofing. It was recognized that mineral wool fireproofing also has some important differences as compared to asbestos fireproofing (e.g, differences in fiber size and distribution, fiber aerodynamics, friability, and possibly different wetting characteristics). The

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[4]For reasons of fire safety, cored holes in fireproofing should be filled with a fireproofing material after installation of the sprinkler system.

fireproofing in the test specimens ranged from about 2 to 4 in. in thickness and had a friability between "low" and "moderate" in the terms described by EPA [2]. This level of friability was requested by GSA. The manufacturer of the mineral wool fireproofing material reported that this level of friability corresponded to a density of about 14 pcf. The moisture content in the mineral wool fireproofing ranged from about 2 to 3 percent when the Phase 2 tests were conducted.

Information about the mineral wool fireproofing prepared for NBS was provided by the manufacturer. The fireproofing, which consisted of mineral glass fibers with hydraulic binders, such as cements and plasters, was mixed with water and spray applied. Fiber sizes ranged, in general, from 4 to 8 micrometers in diameter and averaged 5 to 7 micrometers; the fiber lengths generally exceeded 1/4 in. The fibers were individual vitreous fibers, not bundles or nodules. The dry blend of materials had some spots rich in binder and others with clumps of fibers, but the product was fairly homogeneous when blended together as spray-applied fireproofing material.

3.2 Laboratory Tests of Encapsulants

Encapsulants were applied to the underside of a test frame having steel decking covered with spray-on mineral wool fireproofing material. In these tests, observations were made of the extent of wetting (surface of fibers coated by encapsulant) of the fireproofing material, and measurements were made of the depth of penetration (depth to which wetting was observed in cored fireproofing) of the encapsulants. The encapsulating materials to be included in the tests were selected based on recommendations from (1) GSA staff members having field experience with these materials, (2) a member of an ASTM technical committee on encapsulation, and (3) EPA staff.

Eight encapsulants were included in the tests. Preliminary tests involving spraying, injecting, and coring were performed. A two-gallon capacity garden-type sprayer (air compressed by hand pumping) was used which applied the encapsulants at a rate of 0.45 to 0.65 liters per minute. Because it was difficult to penetrate the total depth of fireproofing by spraying, encapsulant was injected into areas of fireproofing wetted by spraying to achieve total penetration. The encapsulant was injected using plastic, disposable syringes (Section 3.5). To determine the depth of encapsulant penetration, cores (1, 1-1/2, and 2-1/2 in. in diameter) were taken from areas which had been sprayed, or injected, or both. Based on these preliminary tests, a procedure for encapsulation of fibers in the fireproofing and for core removal was developed (Section 3.5).

3.3 Considerations for Encapsulant Selection

The following factors were considered in cooperation with GSA in selecting the encapsulants for the prototype tests (Phase 4).

(1) The encapsulant should penetrate deeply into the fireproofing and completely wet the surfaces of the fibers; total penetration of the depth of the fireproofing should be achievable by a combination of spraying and injection. They should be either "removal" or "penetrating" encapsulants[5] and should be able to wet fireproofing containing asbestos fibers, including amosite.

(2) The encapsulant should prevent the release of fibers from wetted (encapsulated) material, with resistance to fiber release being considerably increased after curing and hardening of the encapsulant.

(3) The encapsulant should harden in the fireproofing material in 7 days or less after application.

(4) The encapsulant should be commercially and readily available.

(5) The encapsulant should not be toxic or hazardous (e.g., not explosive, when used with a powder-actuated gun).

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[5]EPA has defined "removal" and "penetrating" encapsulants in a draft technical bulletin, dated May 27, 1987, addressing asbestos removal encapsulants. "Penetrating" encapsulants are those that penetrate into or wet the matrix and improve the cohesive strength of the friable material. "Removal" encapsulants are asbestos penetrating encapsulants designed specifically for removal of asbestos-containing material, rather than for in-place encapsulation.

(6) The encapsulant should not appreciably reduce the fire resistance of the fireproofing material.

(7) The encapsulant should be easy to work with (i.e., mixing, spraying, and injecting).

(8) The encapsulant should be applied as a single material rather than spraying with two different encapsulants, requiring two sprayer tanks.

3.4 Encapsulant Selection for the Phase 4 Tests

Based on the preliminary laboratory tests (Section 3.2) and considerations for encapsulant selection (Section 3.3), three of the eight encapsulants (designated as A, B, and C) were recommended for the Phase 4 tests for the following reasons. They provided 100 percent depth of penetration with injection and about 50 to 75 percent depth of penetration without injection (after about 5 minutes of spraying) for fireproofing from 2 to 4 in. thick. They were reported by their manufacturers to wet amosite asbestos fibers (the wetting ability of encapsulant B was documented by an independent testing laboratory). The encapsulant hardened in 7 days or less when sprayed on to fireproofing. The materials were reported by their manufacturers as nontoxic and nonhazardous when used as recommended. They were commercially available and were considered to be "removal" or "penetrating" encapsulants. They were easy to work with. It is noted that NBS did not test or evaluate the encapsulants with respect to being nontoxic, nonhazardous, or reducing the fire resistance of the fireproofing material.

Encapsulants A and B were one-component materials and were used as supplied. Encapsulant C was a two-component mixture (equal parts by volume) and the mixture was diluted with one part water by volume.

Because of the limited time available for identifying encapsulants, not all commercially available encapsulants were identified. Therefore, there may be additional encapsulants which would perform as well, or better, than those selected for Phase 4 testing. However, as will be seen in Section 5.2, those selected performed satisfactorily.

3.5 Procedure for Core Removal and Encapsulation

Based on the results of Phase 2, the following procedure (Steps 1 through 4) was recommended for use in Phase 4 to evaluate procedures for core removal and encapsulation of overhead fireproofing prior to sprinkler hanger installation. These steps were performed in a period of about 15 minutes (see Section 5.1.5.1).

(1) The location where the anchor was to be installed was marked with a thin application of spray paint along the circumferences of the 9 and 18 in.-diameter circles. As shown in figure 1, the anchor

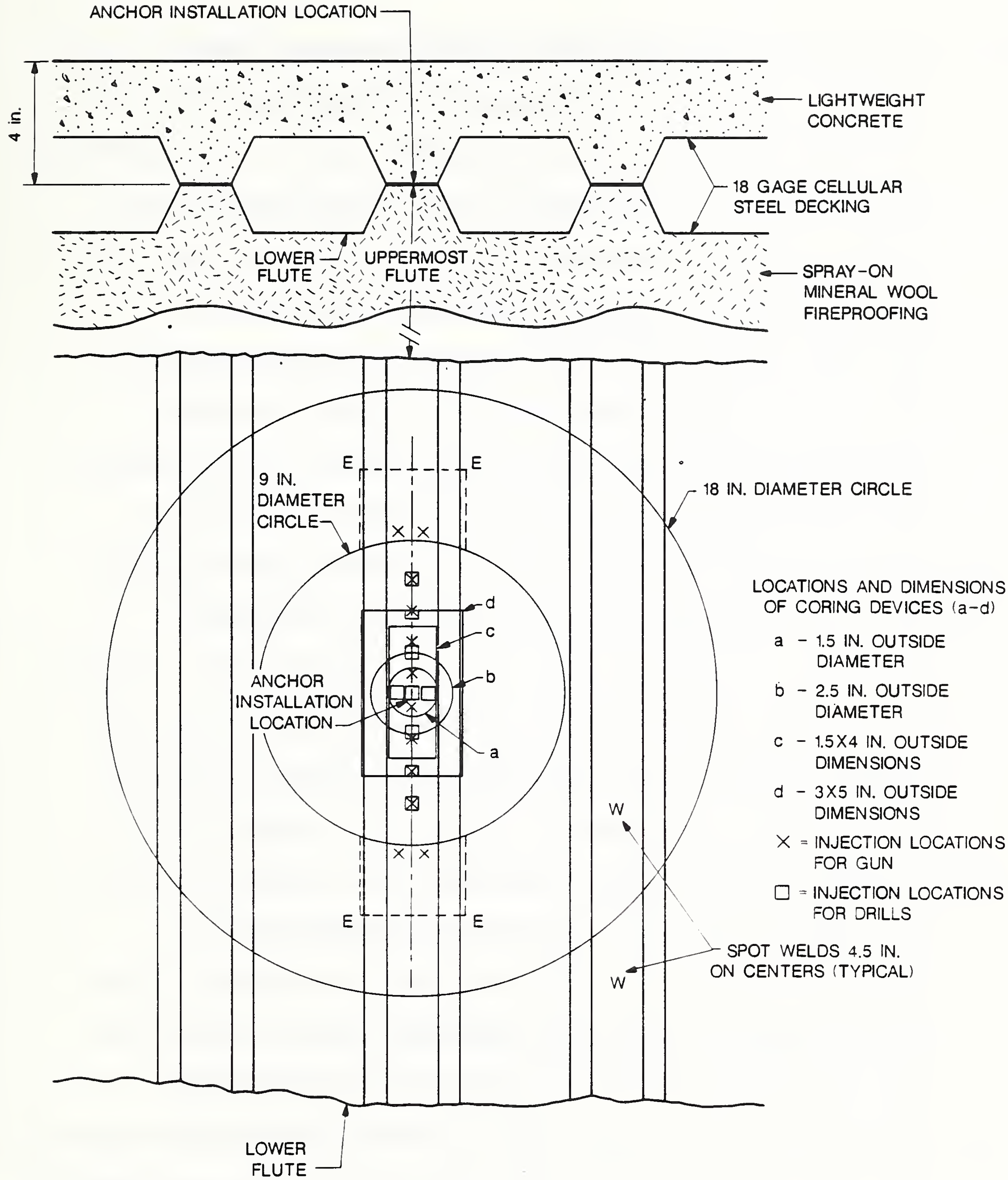

Figure 1. Sketch of typical test area of cellular steel deck/concrete floor slab and spray-on mineral wool. Locations of anchor installation, encapsulation, injection, and coring are shown. The "E" lines represent extended areas of encapsulation (Section 3.5).

installation location was at the uppermost flute (flute width 1.5 in.) of the cellular steel decking which was in direct contact with the concrete deck. An encapsulant was sprayed for 5 minutes on an area of fireproofing within the 9 in.-diameter circle (figure 1). When the powder-actuated gun was to be used, the area of spraying was extended about 2 in. beyond the edges of the 9 in.-diameter circle in the direction of the uppermost steel flute ("E" lines, figure 1). A garden-type sprayer was used which delivered 0.45 to 0.65 liters per minute of encapsulant when sprayed upwards onto the fireproofing. When excessive drippage occurred, the spraying was momentarily stopped. During the 5-minute interval, the encapsulant penetrated and wetted about 50 to 75 percent of the depth of the mineral wool fireproofing (2 to 4 in. thick). After spraying for 5 minutes, the location (figure 1) where the anchor was to be installed was determined by probing upward with a thin straight wire (e.g., 0.050 in. diameter) to find the uppermost flute adjacent to the concrete where the anchor was to be embedded (figure 1). The approximate thickness of the fireproofing was also measured at this time using a thickness gage for spray-on fireproofing materials. The flute where the anchor was to be installed was checked to assure that it was approximately centrally located within the 9 in.-diameter circle (figure 1).

(2) After spraying and locating the uppermost flute, encapsulant injections (each 20 ml) were made (nine injections for drills and twelve for the gun) to insure that the upper portion of fireproofing was completely wetted. When injecting, the tip of the injection needle was placed against the uppermost flute in the positions shown in figure 1. Disposable, plastic, 60 ml syringes were used with "Luer-lok"[6] tips fitted with reusable 13-gauge, 4 in.-long stainless steel, "Luer-lok"[6] needles.

(3) The next step was to take cores from the wetted 9 in.-diameter circular area where the anchor was to be installed. Two concentric circular cores were taken when a drill was to be used, and two rectangular cores (different sizes) were taken when the gun was to be used. Both of the circular coring devices were 12 in.-long brass tubes, with a 0.033 in. wall thickness and sharpened on the coring end. The rectangular coring

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[6] Certain manufacturer names, commercial equipment, instruments, or materials are identified in this report in order to adequately specify the experimental procedure. Such identification does not imply recommendation or endorsement by the National Bureau of Standards, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

devices were 10 in. long stainless steel tubes, with wall thickness of 0.040 in. The outer dimensions of the cutting edges were 1.5 x 4 in. and 3 x 5 in. for the smaller and larger rectangular coring devices, respectively.

When using the smaller circular coring device (1.5 in. outside diameter), it was positioned to be concentric with the 9 in.-diameter circle (figure 1) and was gently pushed vertically upward and simultaneously rotated until the end of the coring device contacted the uppermost flute. The fireproofing was removed completely up to the uppermost flute where the anchor was to be installed (figure 1). If the 1.5 in. outside diameter coring device contacted any steel surfaces other than the uppermost steel flute (figure 1), then the coring device was repositioned to the proper position. Then the larger coring device (2.5 in. outside diameter) was positioned such that it was concentric with the 1.5 in. diameter core hole. The coring device was then gently pushed vertically upward and simultaneously rotated until the end of the coring device contacted the sloped portions of the steel deck adjacent to the uppermost flute where the anchor was to be installed (figure 1). All of the fireproofing material in the cored area was then removed. Fireproofing remaining on the uppermost flute after coring, and other fireproofing not adequately removed by the coring devices, was removed with a knife having a blade with a square end.

The procedure used for the rectangular coring devices was similar to that used for the circular coring devices. The smaller rectangular coring device was gently pushed upward through the fireproofing until it contacted the uppermost flute. The 4 in. cutting edge of the coring device was oriented along the uppermost flute while the 1.5 in. cutting edge extended across the width of the uppermost flute (figure 1). Additional fireproofing material was removed by using the larger rectangular coring device to allow room for the gun to be positioned next to the uppermost flute. As previously noted, fireproofing not removed by the coring devices was removed with a knife. Adequate removal of fireproofing was important to assure that the powder-actuated gun was in contact with the uppermost flute.

Removable covers were placed on the lower ends of the coring devices to retain cored fireproofing material.

(4) After coring was completed, an encapsulant was sprayed for a total of 2 minutes. The inside of the cored hole was sprayed until drippage occurred. After that, spraying was continued over the area between

the 9 in.-diameter circle and the 18-in.-diameter circle, which was concentric with the 9 in.-diameter circle (figure 1). A small amount of encapsulant was also sprayed on the area inside the 9 in.-diameter circle.

4. PROTOCOL FOR FIBER MONITORING AND ANALYSIS (PHASE 3)

The protocol presented in this section of the report ("NBS Protocol") was developed by NBS. It was recommended to GSA for use in their field tests.

The "NBS Protocol" for field testing of sprinkler hanger anchor installation on surfaces with asbestos fireproofing included area samples taken (1) prior to any activity in the test zone, (2) during testing, and (3) after the test zone had been cleaned. Area samples also should be collected inside each work area along with personal samples. Personal samples refer to those worn by individuals performing abatement activities.

The EPA document "Interim Transmission Electron Microscopy Analytical Method and Field Sampling Protocol for the Clearance Testing of an Abatement Site," [3] or the most recent updated edition of this protocol, should be used for the sampling and analysis of the filter samples, except for the modifications listed below. The most recent edition of this EPA transmission electron microscopy (TEM) protocol [3], has been entered into the Federal Register under proposed rules, Vol. 52 #83; April 30, 1987.

NOTE: The "NBS Protocol" was designed to evaluate the asbestos fiber release during GSA's field tests of sprinkler hanger anchor installation. It was not designed to provide clearance monitoring for contractor release or area reoccupation. If GSA desires to use the post-installation sample set (see below) for this purpose, then the EPA TEM protocol [3] should be followed as written without any modifications. This will include the collection of five ambient air samples and the use of aggressive sampling during collection of the post-installation sample set.

4.1 The definitions of "test zone" and "work area" are given below.

4.1.1 Test Zone: A test zone is defined as a room or other area of the building which is being modified and is separated from other areas by walls, doors or appropriate containment barriers such as polyethylene sheeting. The test zone does not include work areas.

4.1.2 Work Area: The work areas are the areas inside the portable enclosures (barriers) and part of the air plenum where the anchor installation is being done.

4.2 If the sampling and analysis for the GSA field tests are not being conducted for the clearance of an abatement action, the following modifications should be made to the EPA TEM protocol [3]:

4.2.1 Eliminate section 7 of the EPA TEM protocol [3] on aggressive sampling.

4.2.2 Eliminate section of EPA TEM protocol [3] on ambient sampling.

4.2.3 In place of comparing abatement area samples to ambient samples, it is recommended that 15 area samples consisting of three sets of five samples each be collected for every test zone. The EPA TEM protocol [3] should be followed for locating the five sampling sites within the test zone. The three sample sets should be collected at the same locations and consist of the following samples:

4.2.3.1. Background set: This set of samples should be collected after the test zone has been cleaned with a high-efficiency particulate air (HEPA) vacuum and prior to any work activity with the heating, ventilating, and air conditioning (HVAC) system for the zone turned off the night before and the door(s) closed.

4.2.3.2. Installation test set: This set of samples should be started at the beginning of activity in the test zone and should run during all phases of the anchor installations within that test zone. This set should be terminated after all work and activity is completed in the test zone. For this set, the HVAC for the zone should be off.

4.2.3.3. Post-installation set: This set of samples should be collected immediately after all clean-up and activity has been completed in the test zone. For this set, the HVAC for the zone should be off.

NOTE: The above sampling protocol ("NBS Protocol") takes into account the time constraints imposed by GSA for completing the work during one weekend time period. As a result, sampling for this phase of the program will not provide a time-resolved analysis. It will only provide a comparison of the asbestos levels before, during, and after work is initiated in a given area. In addition, it is important to note that background asbestos levels inside a building containing friable asbestos may be highly variable.

4.3 In addition to the area samples described in 4.2.3, samples should also be collected inside the work area. For each work area, six filter samples, including five area samples and one personal sample, should be obtained inside the portable enclosure during each anchor-site installation in the test zone. The locations of the area samples should be as follows.

4.3.1 Three area samplers should be set on the ceiling tiles in the vicinity of the opening for access to the deck.

4.3.2 Two area samplers should be set inside the portable enclosure but at two different levels above the HEPA vacuum exhaust.

4.3.3 One personal sample should be obtained throughout the test procedure inside the portable enclosure.

4.4 In addition to the test-zone and work-area samples, area samples can be taken in areas of the building where no work is being done if the GSA coordinator of the field tests determines that they are needed.

4.5 A Fibrous Aerosol Monitor (FAM) or monitors may also be used to evaluate any phase of the program or any sampling location to provide a "real time" analysis. It is suggested, as a minimum requirement, that FAM data be collected inside the portable enclosure to obtain "real time" fiber loadings for this location. If possible, when sampling inside the portable enclosure, the sampling tube of the FAM (an extension of not more than 6 ft.) should be set at 5-6 ft. above the platform of the portable enclosure, and the FAM and its recorder should be set outside the portable enclosure.

4.6 Analysis of the filters must be done by transmission electron microscopy as described in the EPA TEM protocol [3].

4.7 The "NBS Protocol" presented in this section of the report should be used for any additional sampling required by GSA, such as during the installation of sprinkler system pipes.

NOTE: As mentioned above, if GSA intends to use any samples for clearance monitoring, the EPA TEM protocol [3] must be followed without modification.

4.8 If phase contrast microscopy (PCM) analysis is desired to be performed concurrently with TEM analysis of filter samples, the following sampling and analysis must be followed as shown in table 5:

4.8.1 Filter samples from all of the listed sampling locations are to be analyzed by the NIOSH PCM Protocol Method 7400 [4-6].

4.8.2 At 50 percent of the sampling locations listed, except those for clearance monitoring, separate TEM filter samples must be collected and analyzed by the EPA TEM protocol [3].

4.8.3 For all clearance sampling locations, TEM filter samples must be collected and analyzed by the EPA TEM protocol [3].

4.9 The filter sections analyzed by PCM are for information and comparison purposes only. GSA must evaluate fiber loadings based only on the results from the TEM analyses.

4.10 The industrial hygienist contractor who will perform the air sampling and analysis in the GSA's field tests may make minor modifications to this "NBS Protocol" provided they are acceptable to the GSA coordinator of the field tests.

Table 5. Collection and Analysis of Air Samples for GSA's Field Tests

Four buildings are included in the field tests. Tests will be conducted in four rooms in each of the buildings, and there will be two work areas in each room.

Number of Samples to be Collected and Analyzed

	Separate Samples	
	PCM	TEM
Background, each Room	5	2[a]
Working Samples, each Room	5	3[a]
Clearance Samples, each Room	5[b]	5
Working Samples, Work Area (A)	6	3
Working Samples, Work Area (B)	6	3
Total Samples, each Room	27	16

The following additional samples (provisional) are to be collected and analyzed immediately after testing or are to be stored for analysis at a later date if needed:

5 TEM background samples for each room (2 or 3 to be analyzed and 2 or 3 to be stored)

5 TEM "outside" (outdoor air) samples for each building (5 to be stored)

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[a] Number of samples will alternate between 2 and 3 for each room in a building to comply with requirement that 50 percent of the samples collected and analyzed must be by the TEM method.

[b] GSA will make interim clearance determination based on on-site PCM analysis. Final clearance will be based on TEM analysis results when they become available.

5. PROTOTYPE CORE REMOVAL/ANCHOR INSTALLATION TESTS (PHASE 4)

In Phase 4 of the study, laboratory tests were conducted to evaluate the influence of sprinkler hanger anchor installation on the release of fibers from the fireproofing material. These prototype tests were intended to simulate the type of floor slab construction in GSA buildings scheduled for evaluation of sprinkler hanger anchor installation in the GSA field tests. The mechanical anchoring procedures for hanger anchor installation recommended in Phase 1, and the encapsulants and procedures for stabilization and core removal of fireproofing material recommended in Phase 2, were used in the Phase 4 tests. The effectiveness of each mechanical anchoring device-encapsulant combination was determined from monitoring and analysis of airborne mineral wool fiber concentrations during core removal and sprinkler hanger anchor installation (either drilling a hole or installing a threaded anchor). An industrial hygienist contractor performed the air monitoring and fiber analysis during Phase 4 testing.

5.1 Test Specimens, Equipment, and Procedures

5.1.1 Mineral Wool Fireproofing

Spray-on mineral wool fireproofing was used for the Phase 4 tests. This material is described in Section 3.1. When the Phase 4 tests were conducted, the moisture content of the fireproofing, in most cases, ranged from 1 to 3 percent. This moisture content range was believed to be sufficiently low so as not to affect the fiber release. The dry density of the mineral wool fireproofing used in Phase 4 was about 11 pcf. The fireproofing had a friability of between "low" and "moderate" as described by EPA [2] and requested by GSA.

5.1.2 Encapsulants

The three encapsulants (denoted A, B, and C) selected in Phase 2 were used in the Phase 4 tests. Information regarding these encapsulants is given in Section 3.4.

5.1.3 Mechanical Anchoring Devices

Three mechanical anchoring devices were used in the Phase 4 tests. These devices were selected based on the Phase 1 tests. Information regarding the three devices is given in Sections 2 and 5.1.5.1.

5.1.4 Cellular Steel Decking/Concrete Floor Slab

Mineral wool fireproofing, about 2 to 4 in. thick, was sprayed on the underside of a cellular steel deck/concrete floor slab as shown in figure 1. The adjacent flutes of the cellular steel decking were spot welded every 4.5 in. (figure 1). Side laps for the cellular steel decking were made by overlapping the 3 ft. wide steel decking sections and attaching them together with screws spaced 20 in. apart. This type of cellular steel deck/concrete floor slab was requested by GSA. Prior to spraying the mineral wool fireproofing, the cellular steel decking surface to which the fireproofing was to be bonded was wiped with acetone to remove any contaminants, such as oil, which could reduce the bond between the fireproofing and the steel decking. The lightweight concrete in the floor slab had a density of 121 pcf and a compressive strength of 4400 psi. The floor slab, which measured approximately 8 x 15 ft., was supported on steel beams which were supported by a steel frame as shown in figure 2. The bottom of the fireproofing was elevated about 11 ft. above the laboratory floor. The flutes in the cellular steel decking ran in the 8 ft. direction.

5.1.5 Test Setup and Procedure

The space under the floor slab was enclosed with plastic sheeting attached to wood studs to prevent air disturbances inside the test enclosure. A test platform was used by personnel to apply the encapsulants and operate the mechanical anchoring devices. The temperature and relative humidity during the Phase 4 tests were about 74°F and 60 percent, respectively. Appropriate safety measures were followed during these tests (e.g., use of goggles, masks, and respirators; and safe operation of mechanical anchoring devices).

Prior to each test run, a test location was selected, air monitoring filters were positioned, the floor and a test platform in the test area were vacuumed, and a background air sample was

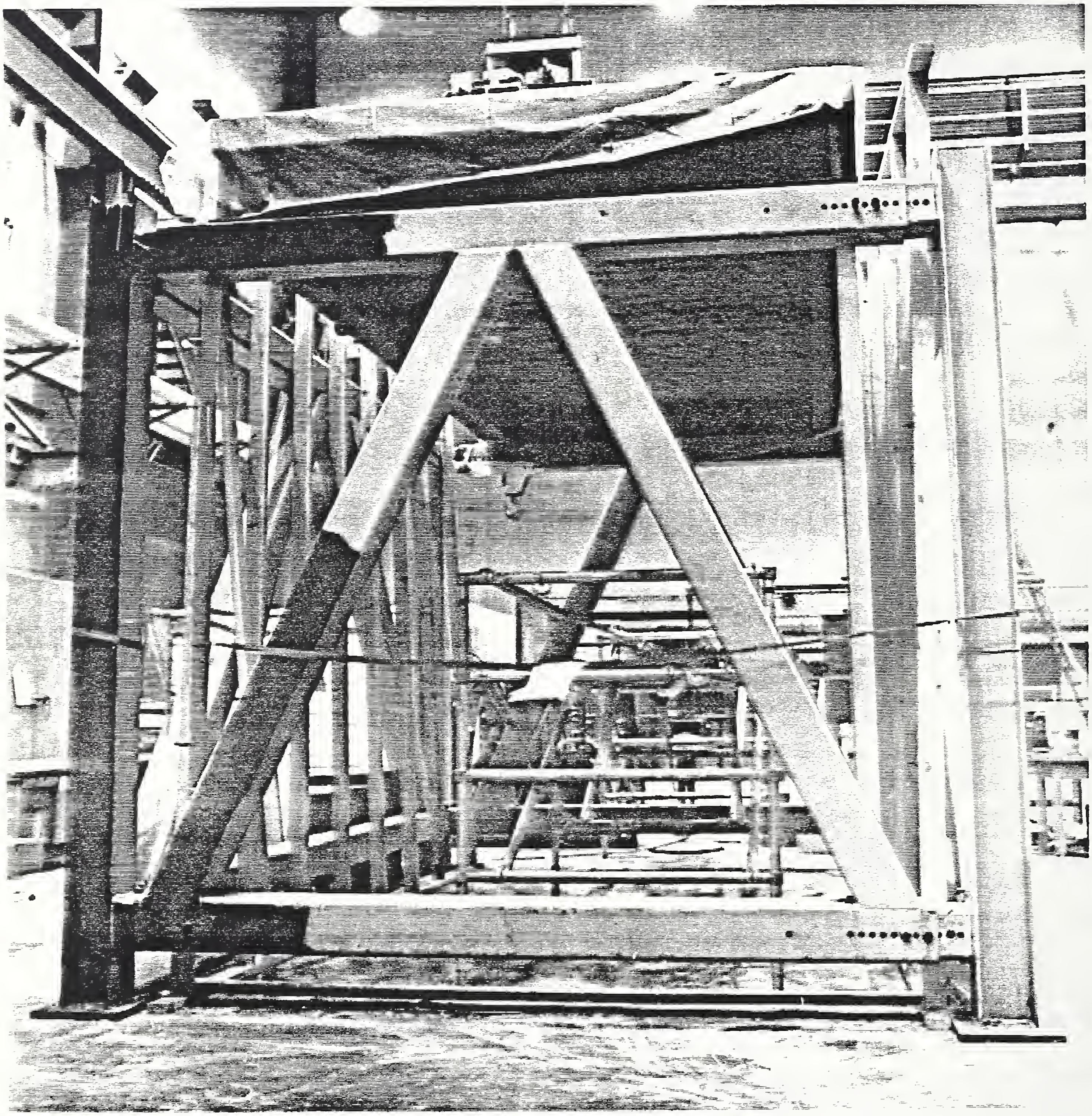

Figure 2. Test set-up for floor slab enclosure. The floor slab (approximately 8 x 15 ft.) was supported by steel beams which were supported by a steel frame as shown. Test area was enclosed with plastic sheeting (not shown) during testing.

taken. A test run consisted of (1) turning on the vacuum pumps[7] for the air monitoring filters, (2) spraying encapsulant, (3) injecting encapsulant, (4) coring encapsulated fireproofing material, (5) respraying encapsulant, (6) either drilling a hole or installing a threaded anchor stud using a powder-actuated gun, and (7) turning off the vacuum pumps for the air monitoring filters. The position and order of testing for each test run are shown in figure 3. As the tests were progressively run, more and more of the mineral wool fireproofing became encapsulated (see Section 5.2).

5.1.5.1 Tests with Encapsulation

From test run to test run, air monitoring Filter Nos. 1-6 did not appreciably change in their positions relative to the center of the cored hole in the encapsulated fireproofing as shown in figure 4. Because of the limited area in the enclosure, the positions and distances of air monitoring Filters Nos. 7-11 varied from test run to test run. The horizontal distances from the center of the cored hole in the fireproofing material to the air monitoring filters for Filters Nos. 7-11 are given in table 6. The vertical distance from Filter Nos. 7-11 to the bottom of the mineral wool fireproofing was about 66 in. The flow rates of the vacuum pumps used for each air monitoring filter are given in table 7. The air monitoring filters had a 25 mm (1 in.) nominal

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[7]Refers to Filter Nos. 4,5,7-11 and also for the personal pumps used with Filter Nos. 1,2,3 and 6.

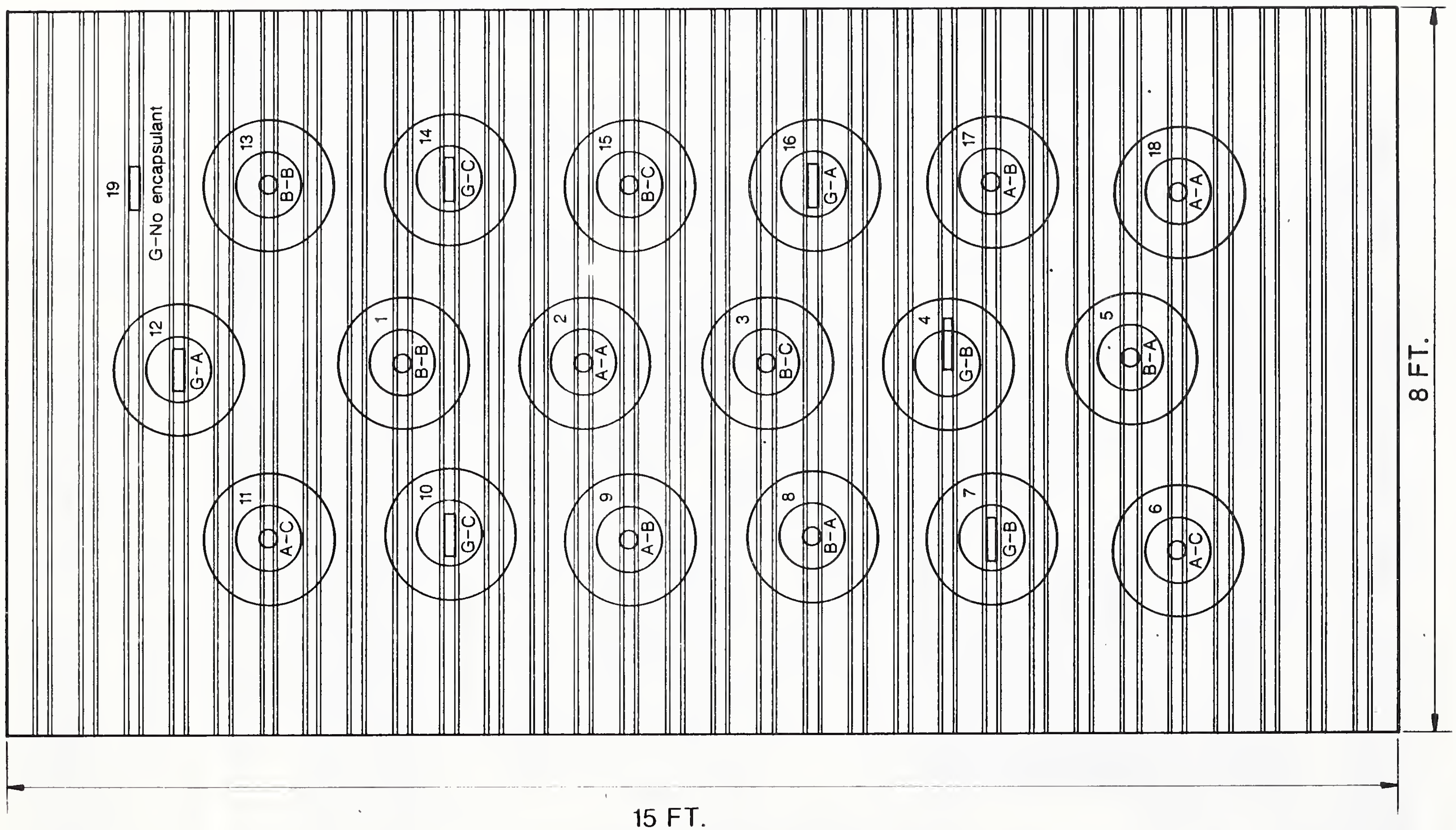

Figure 3. Sketch of the position and order of testing for each test run. Areas of encapsulation and coring are shown with respect to the position of the flutes. At each test location, the test run number is shown. The type of mechanical anchoring device is designated by the first letter, and the encapsulant type is designated by the cond letter (table 8).

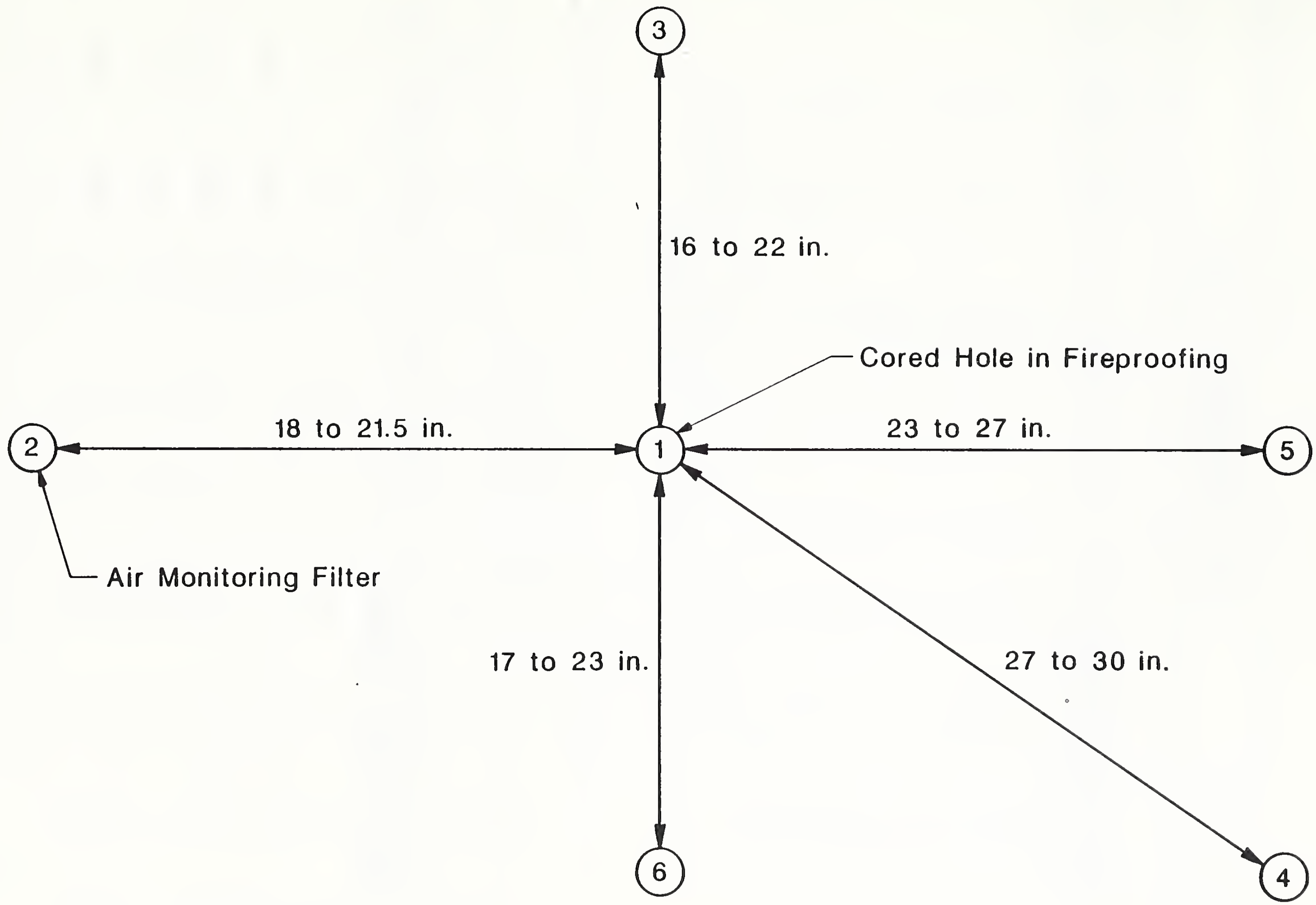

Figure 4. Horizontal distances from center of cored hole to air monitoring filters for Filter Nos. 1-6 and Test Run Nos. 1-18. Filter No. 1 was worn by the person who operated the mechanical anchoring devices. Vertical distance from air monitoring Filter Nos. 2-6 to the bottom of the mineral wool fireproofing was about 28 in.

Table 6. Horizontal Distances from Center of Cored Hole to Air Monitoring Filters for Filter Numbers 7-11 in Test Run Numbers 1-18.

	TEST RUN NUMBER								
	1	2	3	4	5	6	7	8	9
FILTER NUMBER	Horizontal Distance (in.) From Center of Cored Hole to Air Monitoring Filter								
7	56	56	56	56	56	62	56	56	56
8	69	69	60	40	69	69	39	40	40
9	40	40	40	40	40	45	40	40	40
10	21	21	21	21	21	35	21	21	21
11	34	49	49	49	49	56	69	69	65

Table 6. (Continued)

	TEST RUN NUMBER								
	10	11	12	13	14	15	16	17	18
FILTER NUMBER	Horizontal Distance (in.) From Center of Cored Hole to Air Monitoring Filter								
7	56	56	56	62	56	46	38	39	23
8	40	40	43	64	50	36	21	41	40
9	40	40	40	40	39	39	39	36	37
10	21	21	21	45	65	63	68	64	63
11	39	69	69	66	70	70	61	36	65

Table 7. Flow Rates of the Vacuum Pumps Used with each Air Monitoring Filter for Test Run Numbers 1-18

Air Monitoring Filter Number	Vacuum Pump Flow Rate(lpm)
1	2
2	4
3	4
4	10
5	4
6	2
7	10
8*	10
9	10
10	10
11	10

* In most cases, this filter position was also used for background readings ("BF", table 9).

diameter. The fibers collected on each filter were counted twice (once each by a different microscopist using phase contrast microscopy according to the NIOSH 7400 method [4-6]).

Background air monitoring samples were taken for 30-32 min. prior to starting each test run, with the exception of Test Run No. 1 (38 min.). All the background samples were taken at the Filter No. 8 position, except for Test Run No. 14 (Filter No. 10). The elapsed time between the ending of a background sample and the starting of a test run in most cases was 15 min. or less. Spraying of the encapsulant began about 1 to 5 min. after beginning a test run (starting of vacuum pumps).

After beginning a test run, the steps (given in detail in Section 3.5) used for spraying the encapsulant, injecting encapsulant, core removal, and spraying encapsulant on the fireproofing material after core removal were performed. The mechanical anchoring devices were then used to either drill an anchor hole or install a threaded anchor stud with a powder-actuated gun.

The equipment and procedures used for installing the mechanical anchoring devices are described as follows. Two drill types were used: a rotary drill (Drill A) and light-duty "hammer-drill" (Drill B). The details of the drills are given in Section 2. Prior to using both drills, a specially fabricated 12 in.-long center punch was used to mark the center of the hole to be drilled through the steel decking. A 5/8 in.-diameter x 12 in.-long "hi-speed" twist drill "steel bit" (designed for drilling through steel) was used to drill through the cellular steel decking. A new "steel bit" was used for each hole drilled through the steel. Then a 1/2 in.-diameter by 12 in.-long masonry bit was used to drill a hole in the concrete floor slab of sufficient depth (about 2 in.) to accommodate a 1/2 in.-expansive anchor (see footnote 2, Section 2). With Drill A, only rotary action was used for drilling both the steel and concrete. With Drill B, rotary action was used for drilling the steel and rotary action and hammer action were used for drilling the concrete. For safety reasons, special masonry drill bits designed for use with the hammer-drill (Drill B) must be used. With 5 of the 6 test runs using Drill A, the total drilling time (including changing of bits) ranged from 65 to 85 s (the average of five test runs was 72 s). The six test runs in which Drill B was used had similar total drilling times to those of Drill A (range of 55 to 90 s and an average of 68 s for six test runs). The person operating the drills indicated that Drill B was easier to use than Drill A.

A powder-actuated gun[8] with a special nose attachment so as to fit into the uppermost steel flute was used to install a 2-7/8 in.-long

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[8] A Hilti model DX 600 N powder-actuated gun with a 3/8 in. - 16 stud no. 3297211 W 10-30-42P10 and a 27-caliber-long safety booster no. 5/370 (purple - powder level 6). Also see footnote 6 in Section 3.5.

anchor stud (0.205 in. shank diameter and 1.25 in. thread length) using a 27-caliber-long charge. With one exception, the protrusion distance of the installed stud as measured from the bottom of the steel decking to the tip of the stud was about 1 in.

After either drilling a hole or installing an anchor stud in the concrete floor slab, there was in most cases an elapsed time of 2-4 min. before turning off the vacuum pumps for the air monitoring filters. The total elapsed time for each test run ranged from 18 to 20 min.

5.1.5.2 Test Without Encapsulation

In Test Run No. 19, the cored hole in the fireproofing was made without using any encapsulant and the powder-actuated gun was used to install an anchor stud. The positions and distances of the air monitoring filters used in Test Run No. 19 are given in figure 5. A vacuum pump flow rate of 10 lpm was used with Filter Nos. 2-6 and 2 lpm with Filter No. 1. A background air sample was taken for 15 min. prior to starting the vacuum pumps for the test run. The background filter was located 24 in. vertically beneath the bottom of the fireproofing material and 17 in. horizontally from the center of the cored hole. The total time for this test run was 12 min., which was somewhat less than the total time of Test Run Nos. 1-18 (18-20 min.).

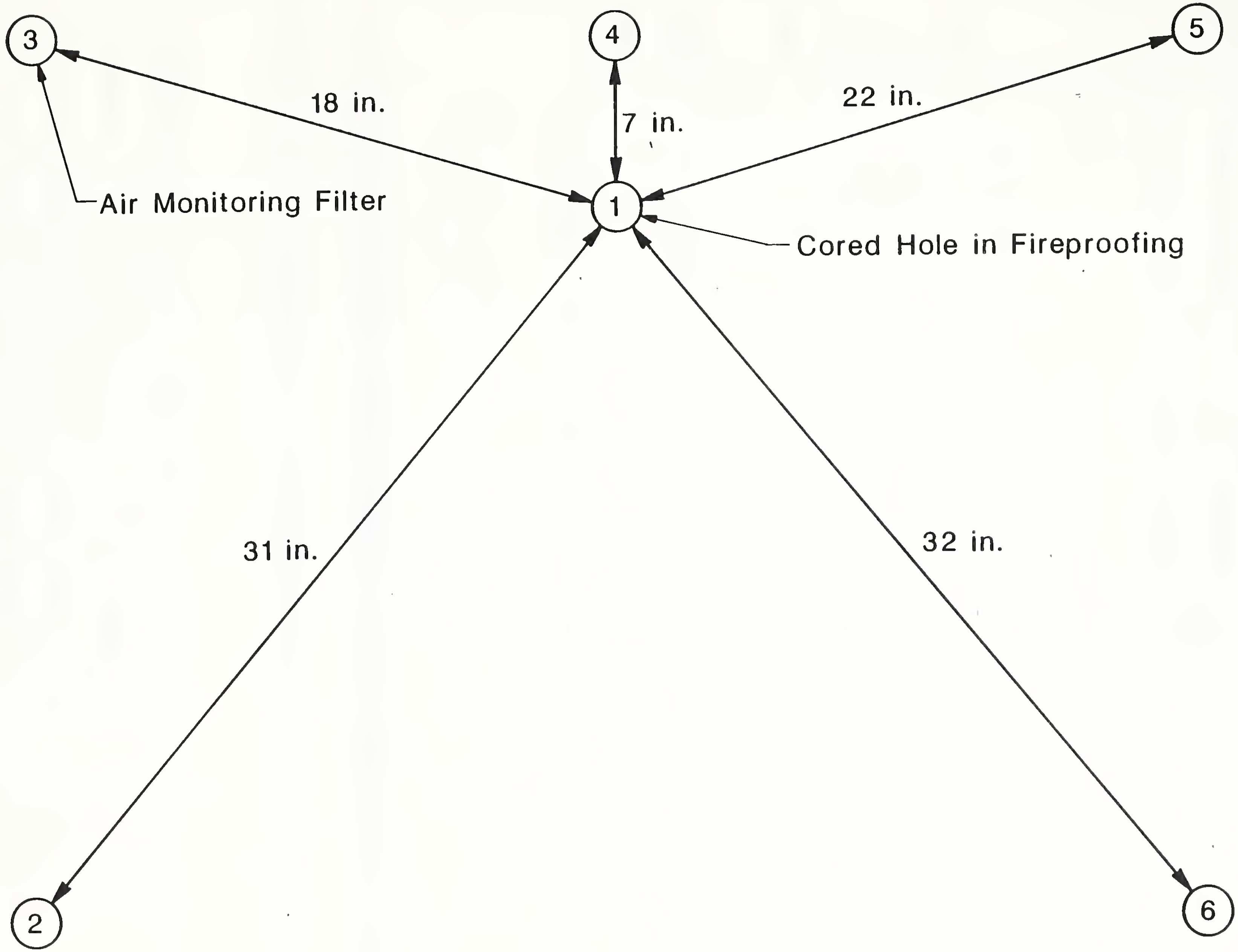

Figure 5. Horizontal distances from center of cored hole to air monitoring Filters Nos. 1-6 for Test Run No. 19. Filter No. 1 was worn by the person who operated the mechanical anchoring devices. Vertical distance from air monitoring Filter Nos. 2-6 to the bottom of the mineral wool fireproofing was about 24 in.

5.2 Test Results and Discussion

The nine mechanical anchoring device-encapsulant combinations and the two corresponding replicate test run numbers are shown in table 8. In addition to the 18 (9 combinations x 2 replications) test runs using encapsulants, there was one test run (Run No. 19) in which no encapsulant was used.

Table 9 shows the calculated fibers/cm^3 (f/cc) values (see equation below) for all air monitoring filters used in each of the 19 test runs, including the one background filter, "BF", located inside the enclosure. Another air monitoring filter was located outside the test enclosure and, for all test runs, the f/cc values for this filter were 0.000 (no fibers observed in 100 fields of view). During some test runs, one to three air monitoring filters were located vertically under fireproofing material which had been previously encapsulated; these filters are noted in table 9.

The f/cc values were calculated from the following equation:

$$f/cc = \frac{(\text{no. fibers counted}/100\ \text{fields})(\text{filter collection area})}{1000\ (\text{size of field of view})(\text{volume of air in liters})}$$

where: filter collection area = 385 mm^2
size (area) of field of view of microscope = 0.00785 mm^2

Figure 6 shows, for each test run in Run Nos. 1-18, the minimum, maximum, median, and approximate 25th and 75th percentile values based on the 11 f/cc values corresponding to Filter Nos. 1-11. Two data points (0.082 f/cc from Test Run No.6 and Filter No. 6,

Table 8. Mechanical Anchoring Device-Encapsulant Combinations and the Two Corresponding Replicate Test Run Numbers for Each Combination

Mechanical[a] Anchoring Device	Encapsulant[b]	Test Run Nos.	
		Replicate 1	Replicate 2
A	A	2	18
B	A	5	8
G	A	12	16
A	B	9	17
B	B	1	13
G	B	4	7
A	C	6	11
B	C	3	15
G	C	10	14
G	(no encapsulant used)	19	

[a] A = Drill A (rotary); B = Drill B (rotary-hammer); G = powder-actuated gun

[b] A, B, C = Encapsulants A, B, and C

Table 9. Calculated Values of Fibers Per Cubic Centimeter (f/cc) for All Test Runs

Test Run No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Encapsulant	B	A	C	B	A	C	B	A	B	C	C	A	B	C	C	A	B	A	None
Mechanical Anchoring Device[a]	B	A	B	G	B	A	G	B	A	G	A	G	B	G	B	G	A	A	G
Air Monitoring Filter Number[b] BF	0.005	0.002	NFO[c]	0.004	0.002	0.002	0.001	NFO	0.001	0.002	0.001	0.001	0.002	0.001	0.002	0.001	0.005	NFO	0.002
1	0.050	0.041	0.026	0.024	NFO	0.027	0.006	0.020	0.006	0.027	NFO	0.013	0.022	0.006	0.026	0.012	0.013	0.014	0.317
2	0.049	0.020	0.052	0.046	0.003	0.020	0.012	0.003	0.006	0.020	0.010	0.016[d]	0.003[d]	NFO[d]	0.022[d]	0.008[d]	0.016[d]	0.003[d]	0.566
3	0.040	0.014[d]	0.024[d]	0.021	0.015[d]	0.017	0.006	0.017	0.006	0.027	0.006	0.016	0.009	0.003[d]	0.018[d]	0.006[d]	0.010[d]	0.003[d]	0.349
4	0.027	0.008	0.013	0.023[d]	0.010	0.012	0.012[d]	0.003[d]	0.009[d]	0.008[d]	0.004[d]	0.012	0.004	0.011	0.013	0.005	0.004	0.006	0.260
5	0.021	0.020	0.009	0.014	0.007	0.037[d]	0.009[d]	0.003[d]	NFO[d]	0.041[d]	0.006	0.026	0.006	0.015	0.024	0.021	0.014	0.010	0.490
6	0.037	0.020	0.018	0.006	0.006	0.082	0.006[d]	0.006[d]	0.013[d]	0.102[d]	0.006[d]	NFO[d]	NFO	NFO	0.029	0.011	0.013	0.007	0.821
7	0.015	0.011	0.017	0.014	0.003	0.005	0.009	0.003	0.001	0.014	0.006	0.008	0.001	0.004	0.010	0.007	0.008	0.005	e
8	0.009	0.015	0.025	0.025	0.007	0.008	0.002	0.005	0.001	0.012	0.005	0.008	0.004	0.001	0.004	0.007	0.001	0.006	e
9	0.017	0.014	0.013	0.015	0.004	0.019	0.002	0.004	0.008	0.009	0.001	0.001	0.004	0.001	0.007	0.004	0.008	0.006	e
10	0.004	0.020	0.020	0.008	0.001	0.014	0.001	0.010	0.003	0.012	0.006	0.017	0.004	0.006	0.011	0.006	0.007	0.008	e
11	0.011	0.010	0.006	0.008	0.005	0.012	0.002	0.010	0.001	0.019	0.004	0.008	0.003	0.004	0.006	0.004	0.005	0.003	e

[a] G = Powder-actuated gun, A = Drill A, B= Drill B

[b] See tables 6 and 7 and figures 4 and 5 for filter locations and flow rates used. "BF" denotes the background filter readings taken inside the test enclosure prior to conducting a test run.

[c] NFO = no fibers observed on filter when using counting protocol

[d] Air monitoring filter under encapsulated area (from previous testing) during test run.

[e] Air monitoring filter not used.

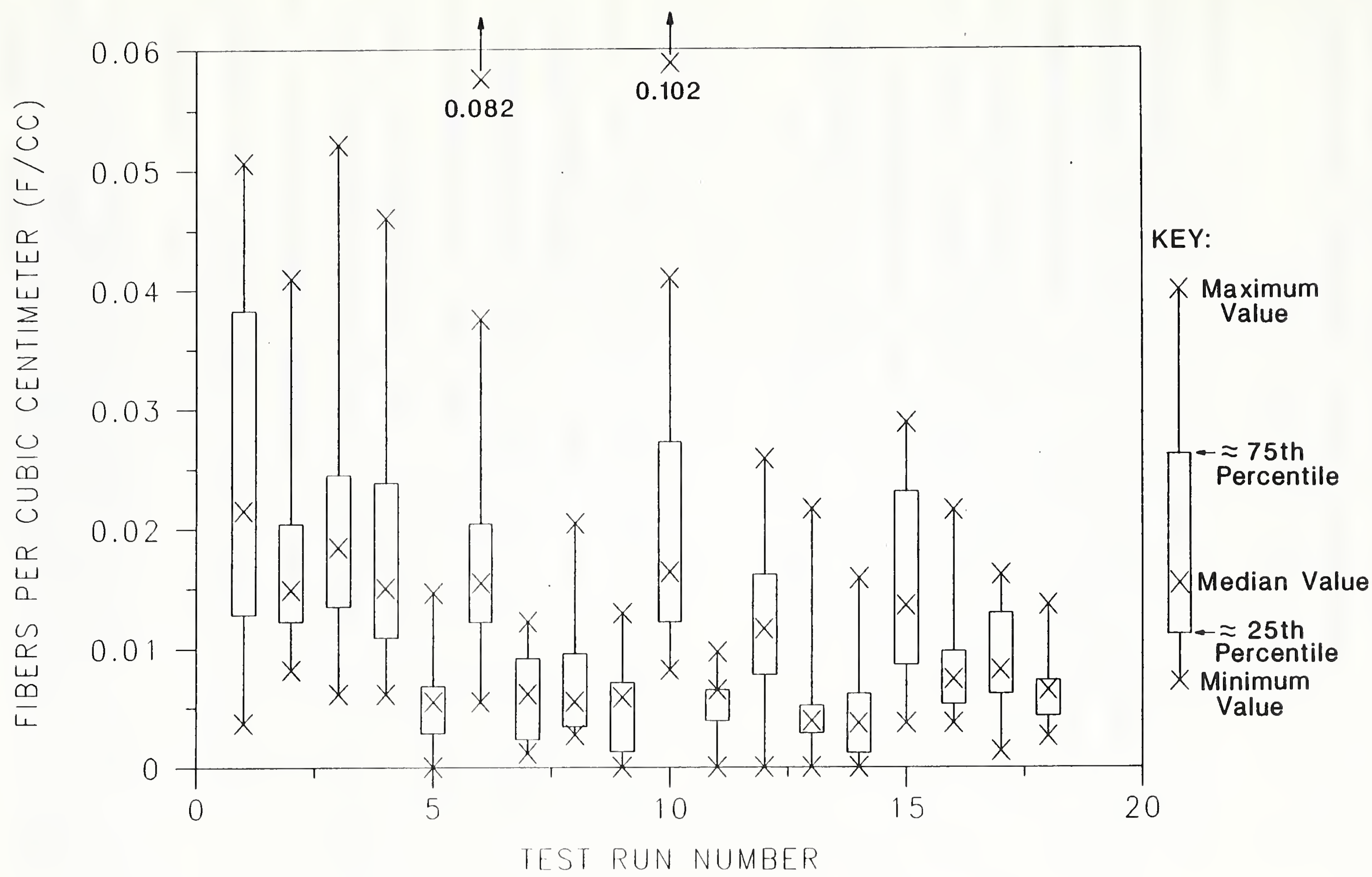

Figure 6. Plot of f/cc values for each test run in Run Nos. 1-18. The minimum, maximum, median, and approximate 25th and 75th percentile values are shown for the 11 f/cc values determined for each test run. Two data points (0.082 f/cc from Test Run No. 6 and Filter No. 6 and 0.102 f/cc from Test Run No. 10 and Filter No. 6) were excluded and were considered to be outliers. The range of f/cc values for the test run (No. 19) without encapsulation was 0.26 to 0.82.

and 0.102 f/cc from Test Run No.10 and Filter No. 6) were excluded and were considered to be outliers. With the exception of the two outliers, all the f/cc values were less than 0.055.

In most cases, the measured f/cc values in Test Run Nos. 1-18 were less than the "quantification limit"[9], which is defined [7] as the "limit of reliable quantification" using phase contrast microscopy. The f/cc values, however, were in almost all cases above the background values inside the test enclosure ("BF",table 9) and were considered to be meaningful in evaluating the encapsulant procedures investigated. In Test Run No. 19, the f/cc values for all six filters (Nos. 1-6) exceeded the background value and quantification limit.

The range of values of 0.000 - 0.055 f/cc (excluding the two outliers shown in figure 6) for test runs with encapsulants was substantially less than that for Test Run No. 19, which was run without an encapsulant, and which had a range of f/cc values of 0.26-0.82 for all six filters (table 9). Thus, in almost all cases the encapsulants were considered to have been effective in limiting the release of fibers during sprinkler hanger anchor installation to a relatively small value (0.055 f/cc). This f/cc

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[9] The quantification limit values were calculated using the equation in section M.1.4.2 of reference 6 using a filter collection area value of 385 mm^2 , a field of view value of 0.00785 mm^2, and a filter sampling volume value corresponding to that of the test run.

value was substantially less than those measured in the test run (Run No. 19) for which an encapsulant was not used.

Figure 6 indicates that there was a trend of decreasing f/cc values as the testing progressed (i.e., as the test run number increased). In particular, the first four test runs had generally higher readings than the remaining test runs. A possible explanation is that more loosely adhered fibers were dislodged in the earlier test runs. In addition, as more test runs were conducted, more test area was encapsulated and less non-encapsulated fibers were available to be released.

The trend of decreasing fiber release with increasing test run number is also illustrated in figure 7, where the f/cc values are shown in terms of the filter number. Each of the nine plots in figure 7 corresponds to a different mechanical anchoring device-encapsulant combination. In figure 7, the two replicate values and corresponding test run numbers for each filter number are shown. In most cases, the value of the second replicate (larger test run number, shown as "2" on the plots) was less than that of the first replicate (smaller test run number, shown as "1" on the plots), indicating that, as the testing progressed, the f/cc values decreased. Since the order in which the tests were run affected the f/cc values, figure 7 cannot be used to determine whether more or less fibers were released when the various mechanical anchoring devices, encapsulants, and mechanical anchoring device-encapsulant

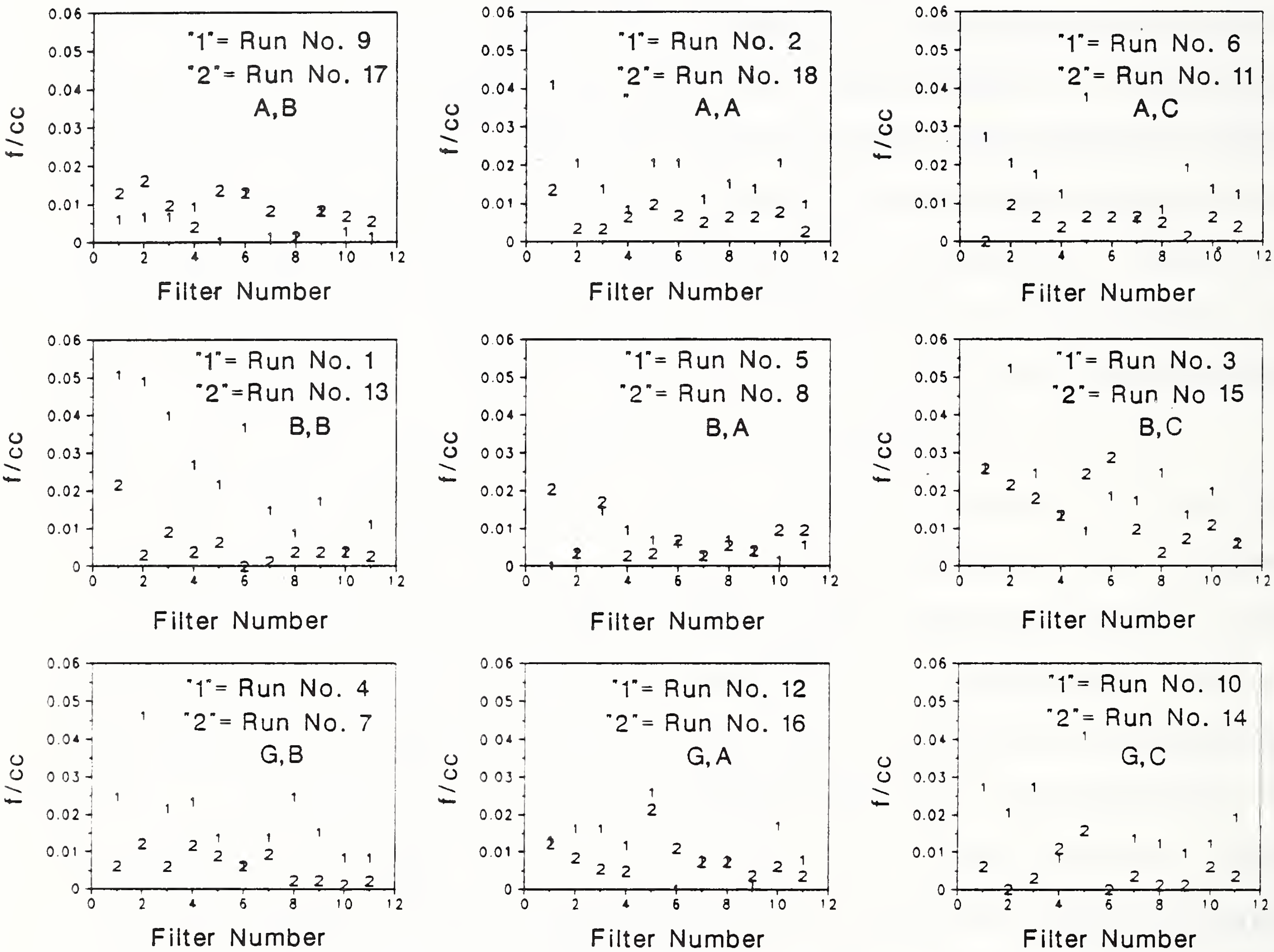

Figure 7. The first and second replicates, denoted by "1" and "2" respectively, are plotted for each of the 11 filter numbers. Each of the nine plots corresponds to a different mechanical anchoring device-encapsulant combination. For each plot, the type of mechanical anchoring device is designated by the first letter and the encapsulant type is designated by the second letter (see table 8).

combinations were used. For example, as shown in the plot on the left side of the middle row of figure 7, for the combination of Drill B and encapsulant B, the first replication in most cases clearly exceeded the second replication.

Because the f/cc values tended to decrease as the testing progressed, it was necessary to analyze each replication of the data separately. In figure 7, values of f/cc from the first replication ("1" entries) and second replication ("2" entries) are shown. Based on the first replication, mechanical anchoring device-encapsulant combinations of A,B and B,A (Test Run Nos. 9 and 5, respectively) appear to have the lowest f/cc values. Based on the second replication, however, all combinations except B,C (Test Run No. 15) appear to have roughly similar f/cc values. Thus, it was not possible to distinguish which of the nine mechanical anchoring device-encapsulant combinations was most effective in limiting fiber release. Similarly, based on the data from the first and second replications taken separately, it was not possible to distinguish among the three mechanical anchoring devices nor the three encapsulants. Therefore, the mechanical anchoring devices, encapsulants, and the mechanical anchoring device-encapsulant combinations having the lowest f/cc values could not be distinguished. However, even in the first replication, all combinations showed relatively small f/cc values (most below the "quantification limit"). All combinations gave much smaller values than the last test run without encapsulation.

5.3 Conclusions

(1) The encapsulation and mechanical anchoring procedures developed in this study limited the mineral wool fiber release to a range of 0.000 to 0.055 f/cc compared to procedures without encapsulation (range of fiber release 0.26 to 0.82 f/cc). The effectiveness of the procedures developed to limit asbestos fiber release from spray-on friable fireproofing needs to be evaluated, in order to establish a correlation between the release of mineral wool fibers and asbestos fibers from spray-applied fireproofing.

(2) The nine mechanical anchoring device-encapsulant combinations investigated were all considered to have performed equally well in limiting mineral wool fiber release during sprinkler hanger anchor installation. In particular, the use of the powder-actuated gun did not cause detectably greater release of fibers than the drilling methods.

The urgency of the project did not permit an extensive evaluation of encapsulants. Encapsulants other than those studied may perform as well as, or better than, those included in the prototype tests.

5.4 Recommendation

Prior to GSA's field tests it was recommended that the encapsulation and mechanical anchoring procedures used in the prototype tests prototype tests (Phase 4) be evaluated in the field tests on friable, asbestos fireproofing using the protocol for air sampling and fiber analysis given in Phase 3. It was also recommended that appropriate safety measures be followed when performing the field tests, including those pertaining to the powder-actuated gun, drills, encapsulants, and protection from airborne asbestos.

6. SUMMARY

At the request of the General Services Administration (GSA), procedures were developed that limited the release of mineral wool fibers from fireproofing material during sprinkler hanger anchor installation on cellular steel deck/concrete floor slab surfaces. The procedures were needed by GSA for installation of sprinkler systems in buildings having fireproofing containing asbestos. It was not practical to use fireproofing containing asbestos in laboratory tests because of safety requirements and the limited time available for completing the study. Tests were conducted using a model system of spray-on, friable, mineral wool fire-proofing on a cellular steel deck/concrete floor slab.

In the development of the procedures, tests were conducted to select mechanical anchoring devices (Phase 1) which caused only small amounts of disturbance to the fireproofing material. Testing was also performed to evaluate materials and procedures for encapsulation of mineral wool fireproofing material (Phase 2) in order to minimize dislodgement of fireproofing during encapsulation, core removal, and sprinkler hanger anchor installation. The selected methods and procedures for mechanical attachment of sprinkler hanger anchors, encapsulation of fireproofing material, and fireproofing core removal were used in prototype tests (Phase 4). Apart from the use of fireproofing containing mineral wool, these prototype tests were intended to approximate the conditions in buildings in which sprinkler hanger anchors were installed during the GSA field tests.

The effectiveness of the selected mechanical anchoring and encapsulation procedures from Phases 1 and 2 was evaluated based on air monitoring and analysis of air samples collected during the prototype tests (Phase 4). These selected procedures limited the release of mineral wool fibers during testing to a range of 0.000 to 0.055 f/cc as compared to a range of values of 0.26 to 0.82 f/cc for procedures without encapsulation. Encapsulation procedures were shown to be effective as evidenced by the much higher levels of fiber release during the test without encapsulation.

The encapsulation and mechanical anchoring procedures developed and the measured levels of fibers released apply only to the spray-on, fibrous, friable mineral wool fireproofing tested in this study. The effectiveness of the procedures developed to limit asbestos fiber release from spray-on friable fireproofing needs to be evaluated, in order to establish a correlation between the release of mineral wool fibers and asbestos fibers from spray-applied fireproofing.

Prior to GSA's field tests, it was recommended that the encapsulation and mechanical anchoring procedures used in the prototype tests (Phase 4) be evaluated in the field tests. Buildings having friable, fibrous fireproofing containing asbestos were included in the GSA field tests. A protocol for air sampling and fiber analysis was also developed by NBS for use by GSA in the field tests. The protocol addressed factors such as the number of air samples to be taken, their locations, and the analytical procedures to be used.

The laboratory and field studies provided GSA with an effective procedure, measurement method, and decision tool for installing sprinkler hanger anchors in steel/deck concrete floor slabs having fireproofing materials.

7. ACKNOWLEDGMENTS

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APPENDIX A - COMMENTS ON FIELD TESTS PERFORMED BY GSA

The contractor's report on the field tests [1] was reviewed by NBS and comments about the report requested by GSA are presented in this appendix. The comments pertain to the procedures used in the field tests for air monitoring and analysis, and for encapsulation and mechanical anchor installation. Comments are also presented in this appendix on fiber release from sprinkler hanger anchor installation during the field tests as determined from analysis of air monitoring samples using phase contrast microscopy (PCM).

1. Air Monitoring and Analysis

The NBS Center for Analytical Chemistry (CAC) reviewed the Contractor's report [1] for compliance of air sampling and analysis with the NBS recommended procedures and for consistency with NBS experience with fiber distributions in the air of buildings having asbestos containing fireproofing material. The CAC comments are given in this appendix.

Laboratory Study

In the laboratory study described in this report (Phase 4) to measure mineral wool fiber concentrations, the phase contrast microscopy (PCM) air sampling and analysis followed the NBS recommended procedures. Thus, the air monitoring and analysis data obtained were considered valid for the laboratory study.

Field Study - Phase Contract Microscopy Measurements (PCM)

Data reported in the Contractor's report [1] based on phase contrast microscopy (PCM) for the identification and estimation of asbestos content in the building air at the test sites were obtained using the NBS recommended air sampling and analysis procedures. Thus, the air monitoring and analysis data obtained were considered valid for the field tests. It is pointed out that the PCM method does not unambiguously identify asbestos mineral forms and only identifies fibers larger than 5 micrometers in length by the definition of the methodology.

Field Study - Transmission Electron Microscopy (TEM)

Data on asbestos contents of the air in buildings at the test sites were obtained by transmission electron microscopy and are included in the contractor's report [1]. Air sampling for the TEM analysis of airborne asbestos followed the NBS required procedures, except that the filter media were carbon coated after sampling.

However, the required procedures for analysis of the TEM samples were not followed. Thus, the TEM asbestos data were not valid for quantitative or semiquantitative correlation of the data.

2. Encapsulation and Mechanical Anchoring Procedures

The contractor's report [1] documents that the NBS recommended encapsulation and mechanical anchoring procedures were followed, except that two different encapsulants were used for some tests in one building because the recommended encapsulants were not available in the time required. This field modification represented no material deviation from NBS procedures.

3. Asbestos Fiber Release During Sprinkler Hanger Anchor Installation

The contractor's report [1] provided data from 268 air monitoring samples analyzed for asbestos fibers by the PCM method. Most of these samples (213) were taken either inside the work enclosure (118) or in the room where the work enclosure was located (95). Only 8 of these 213 samples had values of asbestos fibers per cubic centimeter (f/cc) of 0.01 or larger. The maximum value was 0.027 f/cc. All of the 8 samples which had values of 0.01 f/cc or larger were taken inside the work enclosure. Thus, all the air monitoring samples taken outside the work enclosure but in the room where the enclosure was located had values of asbestos fibers less than 0.01 f/cc. It is noted that the various combinations of mechanical anchoring procedures (use of drills or powder-actuated gun) and encapsulation procedures tested in the laboratory study (Phase 4) limited the measured value of mineral wool fiber release to a maximum of 0.055 f/cc. Since sampling and analysis methods using optical microscopy in the laboratory and the field were considered valid, the recommended procedures were sucessful in controlling fiber release both in the laboratory and in the field. The field tests showed no evidence that asbestos contamination occurred in the building air during anchor installation.

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10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant*

Procedures were developed for limiting the release of fibers from fireproofing material during sprinkler hanger anchor installation on steel deck/concrete floor slab surfaces. These procedures were needed by the General Services Administration (GSA) for installation of sprinkler systems in buildings having fireproofing containing asbestos.

A prototype floor slab having spray-on friable mineral wool fireproofing was used in laboratory tests. The mineral wool fireproofing was used as a model system for fireproofing containing asbestos. The various combinations of mechanical anchoring procedures (use of drills or powder-actuated gun) and encapsulation procedures tested limited the fiber release to a range of values of 0.000 to 0.055 f/cc (fibers per cubic centimeter) as compared to a range of values of 0.26 to 0.82 f/cc for procedures without encapsulation. Encapsulation was shown to be effective as evidenced by much higher levels of fiber release during testing without encapsulation.

Because there is no known correlation between the release of mineral wool fibers and asbestos fibers, it was recommended that the procedures developed be evaluated by GSA in buildings having fireproofing containing asbestos. An air sampling protocol was developed for use by GSA in evaluating the procedures in the field. Subsequently field tests were conducted by GSA.

The laboratory and field studies provided GSA with an effective procedure, measurement method, and decision tool for installing sprinkler hanger anchors in steel deck/concrete floor slabs having fireproofing materials.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

air sampling; asbestos; core removal; encapsulation; friable fireproofing; fiber analysis; mechanical anchoring devices; procedures; spray-on fireproofing; sprinkler system installation; steel deck/concrete floor slabs

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