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Mobile Home Smoke Detector Siting Study

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Center for Fire Research
Institute for Applied Technology
National Bureau of Standards
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U.S. DEPARTMENT OF COMMERCE, Elliot L. Richardson, ***Secretary***

James A. Baker, III, ***Under Secretary***
Dr. Betsy Ancker-Johnson, ***Assistant Secretary for Science and Technology***

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, ***Acting Director***

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MOBILE HOME SMOKE DETECTOR SITING STUDY

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Abstract

An investigation was conducted to evaluate the significance of smoke detector locations to response time for a specific set of fire conditions in a mobile home. Parameters having the potential of affecting response time include: the physical location within a mobile home such as inside wall vs outside wall or wall vs ceiling installations; the impact of air circulation resulting from the operation of the heating, ventilating, and air-conditioning system; and the basic detector parameter of smoke detector alarm threshold. For the study only photoelectric-type smoke detectors were used. These detectors utilize the Tyndall Effect in their sensing mechanism. This limitation was imposed to limit the number of variables. Detector response was evaluated for fires in both smoldering and flaming modes. The results of the study provide a case for wall installations as opposed to ceiling installations. Further, inside wall installations may be marginally superior to outside wall installations. The most significant finding of the study suggests that, when in operation, the forced-air circulating system has a major delaying effect on detector response time to a given fire size.

Key words: Detector sensitivity; fire detectors; mobile homes; photoelectric smoke detectors; smoke detector installation; smoke detector placement; smoke detectors.

1. INTRODUCTION

The 1973 edition of the National Fire Protection Association's (NFPA) Standard for Mobile Homes, NFPA No. 501B (ANSI A119.1-1974) [1][1] required, for the first time, the installation of a smoke detector immediately outside of each separate sleeping area. A sleeping area was defined as a

[1] Bracketed numbers refer to references located at the end of this paper.

bedroom or group of bedrooms not separated by a common-use area. But in some cases, bedrooms adjoin a common corridor, which may be as long as 6.1 m (20 ft).

Specific guidance was not provided as to the precise location for the smoke detector, other than to state it should be on or near the ceiling. Reports from the field indicate that mobile homes in the marketplace have detectors: installed on ceilings; on inside walls; on outside walls; at either end of the common corridor; or somewhere in between. In one case, it was noted that the requisite detector was installed in one of the bedrooms.

The location of the smoke detector may have a significant effect on its ability to detect a fire in the shortest possible time. The location is further conditioned by the fact that the objective of the smoke detector requirement was to give a measure of early warning to the sleeping occupants of a mobile home from fires occurring in the common-use areas.

In an effort to determine the optimum location for a smoke detector of the photoelectric type, a series of fire tests was conducted in a mobile home comparing the response times of a number of detectors in various locations to fires in the common-use area. Two additional parameters were studied concurrently. These included detector sensitivity, that is, alarm threshold, and the effect of the air circulation portion of the heating, ventilating and air conditioning system (HVAC). The specific objectives of this study were:

1. to evaluate smoke detector response time based on location in the hallway of a mobile home,

2. to observe the effect of the HVAC system on the response time of a smoke detector,

3. to evaluate the relative merits of inside wall vs outside wall installation,

4. to evaluate the relative merits of ceiling vs wall installation, and

5. to examine the significance of detector sensitivity to response time for a specific set of fire conditions.

The study involved only photoelectric-type smoke detectors which utilize the Tyndall Effect in the sensing mechanism. All detectors were manufactured by the same corporation and were the same model. The intent was to eliminate a variable which could be introduced by the use of more than one type of smoke sensing mode.

2. DESCRIPTION OF TEST SETUP

2.1. Test Enclosure

The mobile home used in this study was a two-bedroom model with sleeping and common-use areas at opposite ends of the unit (see fig. 1). The home was obtained from the Department of Housing and Urban Development. It had been occupied by a family which was displaced during serious flooding in Pennsylvania following Hurricane Agnes of 1972. The mobile home contained the usual furnishings, appliances and draperies normal to a mobile home. The exterior of the home may be seen in figure 2.

In those tests where air circulation was desired the blower of the HVAC system was used. No attempt was made to alter the internal temperature of the mobile home with the system. In addition, it was assumed that the airflow patterns of the HVAC system met the requirements of ANSI A119.1, "Mobile Homes."

2.2. Smoke Detectors

2.2.1. Smoke Detector Type

All smoke detectors used were of the photoelectric-type. These units are listed by Underwriters' Laboratories, Inc. and are commercially available through normal retail outlets. The detector utilizes the Tyndall Effect in sensing smoke (see fig. 3). Specifically, smoke enters the sensing chamber of the detector after traveling through a specially designed labyrinth which serves to trap light from sources external to the detector. Between the labyrinth and the sensing chamber is a foamed plastic filter. The sensing chamber contains a light source at one side which projects a narrow beam of light across the chamber into a light trap at the other side. A photocell is located approximately halfway across and to one side of the chamber and is directed toward the void space through which the light beam passes. The angle of intersection between the axis of the photocell and light beam path was a nominal 135° in the smoke detector used in the tests. When smoke aerosols enter the sensing chamber, those smoke particles having diameters larger than 0.3 micrometres scatter light in all directions. A portion of the scattered light impinges on the photocell resulting in the generation of a minute current. As the smoke concentration increases, the intensity of the scattered light increases with a corresponding change in the output of the photocell. When the output of the photocell reaches a predetermined point, an alarm is triggered.

2.2.2. Smoke Detector Sensitivity

Apparent smoke detector sensitivity is a function of five parameters: sensing mechanism, smoke characteristics (such as particle size), velocity of the medium carrying the smoke, alarm set-point of the detector circuitry, and detector entry characteristics. The sensing mechanism and smoke characteristics are related. Generally, photoelectric-type smoke detectors are more responsive to smoke from smoldering fires than from flaming fires due to the larger mean particle size in the smoke aerosol from a smoldering fire. A smoldering fire generates a greater quantity of particulate in the size range of 0.3 micrometer or larger, the size range in which the photoelectric-type smoke detector operates [2].

Another factor affecting apparent sensitivity is the smoke entry characteristic of the detector. The effect of this parameter is directly related to the velocity of the medium carrying the smoke particles. Essentially, this characteristic describes the degree of difficulty which the smoke experiences in traveling from the area immediately outside the detector housing to the interior of the sensing chamber. Every detector model has its own entry characteristic. Differences between characteristics are most noticeable at low air velocities, in the range developed by slow smoldering fires. Therefore, a single model detector was used in an effort to standardize this variable.

The actual alarm threshold of each detector used in this study was determined in a small-scale, closed test chamber (see fig. 4). The detectors are placed in the chamber in an energized condition. Two smoldering punk sticks are introduced into the chamber and air laden with smoke is circulated past the detector by means of a blower. Air velocity in the vicinity of the detector and total smoke concentration are carefully monitored. The smoke concentration is allowed to increase continually until the detector reaches its alarm threshold; the time and optical density of the smoke at alarm are recorded. This procedure allows determination of the alarm threshold of a specific detector with a reasonable degree of reproducibility. The sensitivities of the detectors used in this siting study are shown in the following table. Values are given in percent obscuration per foot, optical density per foot, and optical density per meter.

Detector No.	Alarm Threshold Percent Per Foot	Optical Density Per Foot	Optical Density Per Meter
1	2.3	0.010	0.033
2	1.1	0.004	0.015
3	2.3	0.010	0.033
4	3.0	0.013	0.043
5	1.9	0.008	0.027
6	1.7	0.007	0.024

Note that the sensitivities of the detectors vary between the samples. A number of detectors having precisely the same alarm threshold were not available at the outset of the study although this would have made interpretation of the data more straight forward. The variance noted above has been taken into consideration and the results of the test series were examined for trends rather than searching for specific conclusions from a specific test.

2.2.3. Smoke Detector Locations

In all tests, smoke detectors were located in the hallway serving the two bedrooms and bath (see fig. 1). The requirements contained in NFPA No. 501B [1] specify the location of a smoke detector as immediately outside the sleeping areas. The configuration of rooms in this mobile home plan provides some latitude with respect to specific detector location. For example, no instructions are provided with regard to inside versus outside wall versus ceiling installations, or precise location in the corridor. The various test series which follow explore the relative merits of a number of possible locations. In accordance with the objectives of this program, comparative tests were conducted which provided an evaluation of ceiling versus wall installations, inside wall versus outside wall installations and installations at opposite ends of the hallway. The significant point to be noted about installations at opposite ends of the hallway is that the air intake for the HVAC system is at the approximate midpoint of the hallway. That is, the HVAC intake has the potential of affecting performance at one end of the hallway significantly more than at the other by the intakes influence on the flow of smoke along the corridor.

3. TEST PROCEDURES

3.1. Test Fires

3.1.1. Smoldering Fires

A small, wood (pine) crib was used in each test in which a smoldering fire source was desired. The crib was square and nominally 20.3 cm (8 in) on a side. It contained three layers of sticks, 1.9 cm (3/4 in) square. Two layers contained eight sticks each, evenly spaced, so that the space between the sticks was approximately 0.7 cm (9/32 in). The top layer contained nine sticks, evenly spaced, approximately .64 cm (1/4 in) apart.

The crib used was chosen from a variety of different designs previously examined. Since a truly smoldering fire source was desired, the construction needed to be such that the convected ventilation of the crib during combustion was restricted. It was found that designs with larger spaces between the crib members provided sufficient ventilation to allow reradiating surfaces to reach auto-ignition temperature and to convert to flaming. The overall size of the crib was kept to a minimum to ensure that interior finish materials within the mobile home would not be ignited inadvertently. A photograph of the crib may be seen in figure 5.

A radiant heat source was used to sustain smoldering combustion in the crib at a controlled rate. Care was taken to ensure that a flaming mode did not occur on the underside of the crib by observing the bottom through a mirror placed adjacent to the crib. The heat source was a radiant furnace of the type used in the National Bureau of Standards smoke chamber [3] (see fig. 6). The crib was suspended horizontally in such a manner that the bottom surface was approximately 2.5 cm (1 in) above the heater element. A nominal 78 volts AC was applied to the element. The time of each test was recorded from the moment the voltage was applied.

The typical test setup is shown in figure 7. An example of the smoke generated by the crib is shown in figure 8. Note that a sheet metal pan 1.2 m (4 ft) square was placed under each of the test fires to prevent ignition of the carpeting.

3.1.2. Flaming Fires

A number of tests were also conducted in which the smoke was generated by a flaming source. In each of these tests, gasoline was used as a fuel. The fuel was placed in a metal container which was 10.2 cm (4 in) in diameter and 14 cm

(5-1/2 in) high. A total of 500 ml of gasoline was placed in the container prior to each test. (This resulted in the container being approximately half full.) The gasoline was ignited with a match. The time of the test was recorded from ignition.

3.1.3. Fire Location

In each test, the fire was located in the living room in a corner formed by two outside walls as shown in figures 1 and 8. This location was used for both smoldering and flaming sources.

3.1.4. Weather Condition

The weather conditions during the tests are summarized as follows:

Test Series A, Test Nos. 1 to 8	- Clear, temperature 27-29 °C (80-85 °F)
Test Series B, Test No. 9	- Partly cloudy, 27 °C (80 °F)
Test Series B, Test Nos. 10-11	- Overcast, 27 °C (80 °F)
Test Series B, Test Nos. 12-13	- Clear, 24 °C (70 °F)
Test Series C, Test Nos. 14 to 21	- Clear, 29-35 °C (85-95 °F)
Test Series D, Test Nos. 22 to 26	- Partly cloudy, 21-27 °C (70-80 °F)

3.2. Test Series

The tests conducted in this study are organized into four test series. A discussion of each of these series is contained in the following sections. See table 1 for a recapitulation of all of the test series.

3.2.1. Series A

In this series, which consisted of eight tests, detectors were all located at the same end of the corridor, immediately outside the master bedroom at the rear of the mobile home (see fig. 1). Each test employed a total of three detectors. This series examined a total of five positions of installation which are shown in figure 9. Specific location with respect to the master bedroom is identical to that shown in figure 16.

Table 1. Test Series Data

Test Series	Test Numbers	Detector Location in Hall	Specific Detector Location	Type of Fire	HVAC
A	1 to 6	Bed. End	A-B-C*	S††	Off
	7	Bed. End	A-D-E	S	Off
	8	Bed. End	A-B-C	S	On
B	9-10-13	Kit. End	A-B-C-D-E**	S	Off
	11-12	Kit. End	A-B-C	S	Off
C	14 to 18	Bed. End & Kit. End	IR-CR-OR &*** IF-CF-OF	S	Off
	19 to 21	Bed. End & Kit. End	IR-CR-OR & IF-CF-OF	S	On
D	22 to 25	Bed. End & Kit. End	IR-CR-OR &† IF-CF-OF	F	Off
		Bed. End & Kit. End	IR-CR-OR & IF-CF-OF	F	On

*See figure 9 for code.

**See figure 14 for code.

***See figure 18 for code.

†See figure 18 for code.

††S = Smoldering and F = Flaming

Each test fire in this series was a smoldering wood crib. In Tests 1 to 7, the HVAC circulating system was not in operation. In Test 8, the system was operating continuously throughout the test.

Detector response time vs sensitivity and location are illustrated in figures 10 to 13.

3.2.2. Series B

In this series, consisting of five tests (Nos. 9 to 13), detectors were located at the same end of the corridor, immediately outside the kitchen. Each test employed a total of five detectors. Detector positions are shown in figure 14. Location with respect to the kitchen is identical to that shown in figure 18.

In each test, a three-layer wood crib of the type used in Test Series A was utilized to produce smoldering combustion. The HVAC system was not in operation during this test series.

Detector response time vs sensitivity and location are illustrated in figures 15-17.

3.2.3. Series C

In this series, consisting of eight tests (Nos. 14 to 21), detectors were located at both ends of the corridor. A total of six detectors were used in each test; three were installed at each end of the corridor. Specific installation locations are shown in figure 18. Designations are OR (outside wall, rear), CR (ceiling, rear), IR (inside wall, rear), OF (outside wall, front), CF (ceiling, front) and IF (inside wall, front).

In each test, a three-layer wood crib of the type used in the previous test series was used to provide a smoldering fire. In Tests 14 to 18, the HVAC circulating system was not in operation. In Tests 19 to 21, the system was operating continuously during the test.

Detector response time vs sensitivity and location are illustrated in figures 19 to 26.

3.2.4. Series D

In this series, consisting of five tests (Nos. 22 to 26), detectors were located at both ends of the corridor. A total of six detectors were used in each test; three were installed at each end of the corridor. Specific installation locations are shown in figure 18. Designations are the same as those used in Test Series C.

In each test smoke was generated from the flaming gasoline source. Time was recorded from the ignition of the gasoline.

In Tests 22 to 25, the HVAC circulating system was not in operation. In Test No. 26, the system was operating continuously during the test.

Detector response time vs sensitivity and location are illustrated in figures 27 to 31.

4. DISCUSSION OF TEST RESULTS

4.1. Test Series A

One might assume that detector sensitivity is a major factor in response time. Examination of the test data bears this out. When one compares the mean response times of the detectors of different sensitivities for the first seven tests, the results are as follows:

Detector Sensitivity (percent per foot)	Mean Response Time (minute:second)
1/2	16:15
1	18:30
2	22:15

When one compares mean response times for detectors in location A vs C (inside ceiling vs outside ceiling), the following is observed:

Tests 1 - 5

Mean Response Time (Minute:Second)

A	C
15:00	16:40

These results seem to indicate that an inside ceiling installation is slightly superior to an outside ceiling installation. (Tests 6 to 8 were not included because these employed a two-percent detector on an inside wall without data for a corresponding outside wall installation.)

It should be noted that response times were substantially increased by the operation of the HVAC circulation system in Test No. 8. The significance of the effect is apparent when comparing mean response time for all detectors for Tests 1 to 6 with the mean response time for Test No. 8.

Condition	Mean Response Time (Minute:Second)
HVAC off	19:00
HVAC on	32:00
	13:00 - Difference

Note that the system air return grille is located between the detectors and the fire. It appears that the blower tended to intercept the smoke before reaching the detectors and distributed it homogenously throughout the volume of the mobile home. The result was that a substantially greater total volume of smoke was needed to be generated in order to bring the entire volume to a high enough density to reach alarm threshold.

4.2. Test Series B

When examining the data for Tests 9, 10 and 12, and comparing the response times of detectors A and B (inside wall) with D and E (outside wall) no significant difference can be noted. In this test series, there does not appear to be any significant advantage to inside wall vs outside wall installation.

If one compares response time for wall installation vs ceiling installation, the following is noted:

Location	Mean Response Time* (Minute:Second)
Wall	16:20
Ceiling	20:00
	3:40 - Difference

*For Tests 9 and 10.

Thus, it appears that the wall installation results in more rapid detection than the ceiling installation in this test series. Test No. 11 was not included because the crib went to the flaming mode of combustion at approximately 4 minutes and the test was terminated shortly thereafter. Test No. 12 was not included because, inadvertently detectors D and E were not energized prior to the test. However, of the detectors which did alarm, the ceiling installation had the longest response time by 2 minutes. In Test No. 13, no alarm was experienced by the ceiling mounted detector at 30 minutes and the test was terminated. All other detectors had been in alarm for at least 5 minutes.

Also, it was noted in this test series that there was no appreciable difference in response time between those detectors installed 7 cm (18 in) from the ceiling and those installed 3.5 cm (9 in). Apparently, in this smoldering fire test series, the smoke layer had sufficient depth below the ceiling to reach both the upper and lower detectors simultaneously.

4.3. Test Series C

With a fire occurring in a common-use area of the mobile home and detectors installed at a variety of locations in the corridor, one would anticipate that those detectors closest to the fire would alarm first. This assumption is borne out by the data from the smoldering fires in this test series. Mean response times for installations at the opposite ends of the corridor is as follows:

Location	Mean Response Time (Minute:Second)
Kitchen end	22:30
Bedroom end	26:45
	4:15 - Difference

In Test Series A, data seemed to indicate that an inside wall installation would be somewhat superior to an outside wall installation. This does not seem to be confirmed in this test series. Data comparing these two locations follows:

Location	Mean Response Time (Minute:Second)
Inside Wall	23:50
Outside Wall	23:40
	0:10 - Difference

This data does not indicate an advantage to either location. It should be noted, however, that these tests were conducted under summer conditions with interior temperatures approximately equal to outside temperatures. The result was that temperatures of inside walls and outside walls were approximately the same.

It is of interest to compare the results of ceiling vs wall installation. The following mean response time comparison shows that a wall installation is substantially superior to a ceiling installation for a slow, smoldering fire.

Location	Mean Response Time (Minute:Second)
Wall	23:45
Ceiling	26:20
	2:35 - Difference

Finally, note the effect of the HVAC circulating system in this test series with that experienced in Test No. 8 described earlier. The following table compares the effect of the HVAC system on response time:

Condition	Mean Response Time (Minute:Second)
HVAC off	21:40
HVAC on	29:20
	7:40 - Difference

In general, this data confirms the experience from the earlier test series.

4.4. Test Series D

In this test series, which were all flaming gasoline fires with black smoke, comparison of response times for locations at each end of the hallway, indicate an apparent anomaly. It appears as though the detectors at the far (bedroom) end of the corridor had a shorter mean response time than those at the kitchen end. In this case, it is apparent that detector sensitivity may be more important than location within the limits of the test parameters. Additionally, the velocity of the smoke was greater because of the greater thermal energy of the flaming fire. This greater velocity would serve to minimize the effect of distance between locations.

When a comparison is made of response times for inside wall locations vs outside wall locations, it appears as though the inside wall provides slightly superior response times than does the outside wall. The following shows a comparison between the two.

Location	Mean Response Time (Minute:Second)
Inside wall - front and rear	14:00
Outside wall - front and rear	15:05
	1:05 - Difference

The performance of ceiling vs wall installations for a flaming as opposed to a smoldering fire can be compared next. In the flaming case, the ceiling installation is superior apparently because sufficient thermal energy is available to break through the boundary layer near the ceiling. Additionally, boundary layer conditions tend to be minimized under higher velocity conditions. A comparison of these two locations follows:

Location	Mean Response Time (Minute:Second)
Wall	14:30
Ceiling	12:05
	2:25 - Difference

Finally, it is again possible to examine the effect of the HVAC ventilating system on the performance of the detectors, this time with a flaming fire. As in earlier tests, the effect of the system was dramatic in the manner which detector response times were increased. A comparison of the data gathered in this test series follows:

Condition	Mean Response Time (Minute:Second)
HVAC off	12:20
HVAC on	19:20
	7:00 - Difference

If one examines the mean response times of detectors at opposite ends of the corridor with the HVAC system on, one finds that those units at the kitchen end of the corridor had substantially shorter response times than those at the bedroom end when the HVAC system was in operation, as indicated in the following table:

Location	Mean Response Time (Minute:Second)
Kitchen end	16:10
Bedroom end	22:05
	5:55 - Difference

Note also that the detectors at the kitchen end had a substantially longer mean response time than that for all detectors without the HVAC in operation. This would seem to indicate that the response of all detectors is delayed when the HVAC system is in operation, regardless of location of installation.

Finally, of all the parameters examined, the circulating system had the most significant effect on detector performance. The data also indicates that the results were reasonably consistent.

4.5. Weather Conditions

It is interesting to compare the response characteristics of detectors based on location with general weather conditions at the time of the test. For example, Test Nos. 12-21 were conducted during a period of generally clear weather. In examining the data, note that with the exception of Tests 20 and 21, the response times of the ceiling mounted detectors were longer than that of the wall mounted detectors. Conversely, in Tests 9-11 and 22-26, the weather was generally cloudy and it may be observed that the ceiling mounted detectors generally performed better than wall mounted units.

Evaluation of weather as a test parameter was not planned at the outset of the investigation. Accordingly, the test series was not structured so that definitive conclusions could be drawn from the results. However, the effect of the sun's heating of the roof/ceiling assembly may be the major reason for the poorer performance of the ceiling detectors with respect to the wall detectors.

5. CONCLUSIONS

In line with the objectives of this siting study, the following conclusions have been reached from an examination of the data presented in this report.

1. In mobile homes employing a floor plan similar to the one used in this study, it appears as though the best general location for a smoke detector is at the end of the corridor entering the common-use areas of the home. Generally, this location appears to offer the shortest response time to fires originating in the living room area and perhaps the dining/kitchen areas as well.

2. The effect of the HVAC circulating system was more significant than anticipated prior to this study. In each case, the system delayed the response of the smoke detectors, regardless of location within the corridor. Even those detectors installed between the incipient fire and the intake for the HVAC system, i.e. the kitchen end of the corridor, will have their response times increased by operation of the HVAC system. The conclusion is that

an incipient fire which occurs during the operation of the system is a more serious hazard than one which occurs when the system is not in operation. (In addition to the alarm delay, there is a more rapid distribution of smoke and potentially toxic combustion products throughout the home.) It is not possible to predict precisely the effect of a HVAC system having a location other than in the corridor, as in this test program. It is likely, however, that any HVAC system, if in operation, will have a similar delaying effect on the response of smoke detector in the event of a fire in the mobile home.

3. When examining the results of Test Series A with Test Series B, it appears that in one case an inside wall installation is marginally superior to an outside wall installation. In the other case, the opposite seems true. Considering all data, however, it does not appear that this report can demonstrate that one location is consistently superior to the other. Again, it should be noted that these tests were conducted under summer conditions with the result that temperatures of internal walls and external walls were approximately the same. Unpublished test data from another source [4] for tests conducted under winter time conditions indicate that under winter conditions smoke detectors installed on exterior walls are slower to respond than smoke detectors on interior walls.

4. It appears that in the case of ceiling vs wall installation, relative performance relates to the type of fire. Slowly developing, smoldering fires seem to be detected more easily by detectors installed on a wall a short distance below the ceiling. Flaming fires have more thermal energy and appear to be more easily detected by a ceiling installation. Since some evidence has been presented by other studies which indicates that a higher percentage of fires in the home start in the smoldering rather than in the flaming mode, a wall installation would seem preferable.

5. It was anticipated prior to the study that more sensitive detectors would have a shorter response time to a given fire than less sensitive ones. This was particularly evident during the smoldering fire test series. This difference in response times would be amplified during the operation of the HVAC circulating system since smoke is mixed somewhat homogenously during its operation. It would appear

then for the earliest alarm indication of fire, smoke detectors with the highest degree of sensitivity should be used. However, the sensitivity of the detector will have to be balanced against a possible increase in false alarms. What this balance is or how to arrive at this balance, particularly for photoelectric-type smoke detectors as used in this test series, has not been satisfactorily determined at the present time.

6. REFERENCES

[1] National Fire Protection Association's (NFPA) Standard No. 501B, Standard for Mobile Homes, 1973 Edition. Also American National Standards Institute Standard ANSI No. A119.1-1974.

[2] Scheidweiler, A., New Research in Fire Detection Technology. International Symposium (1968).

[3] Lee, T. G., Interlaboratory Evaluation of Smoke Density Chamber, Nat. Bur. Stand. (U.S.), Technical Note 708 (Dec. 1971).

[4] Private communication, G. Rork, Honeywell.

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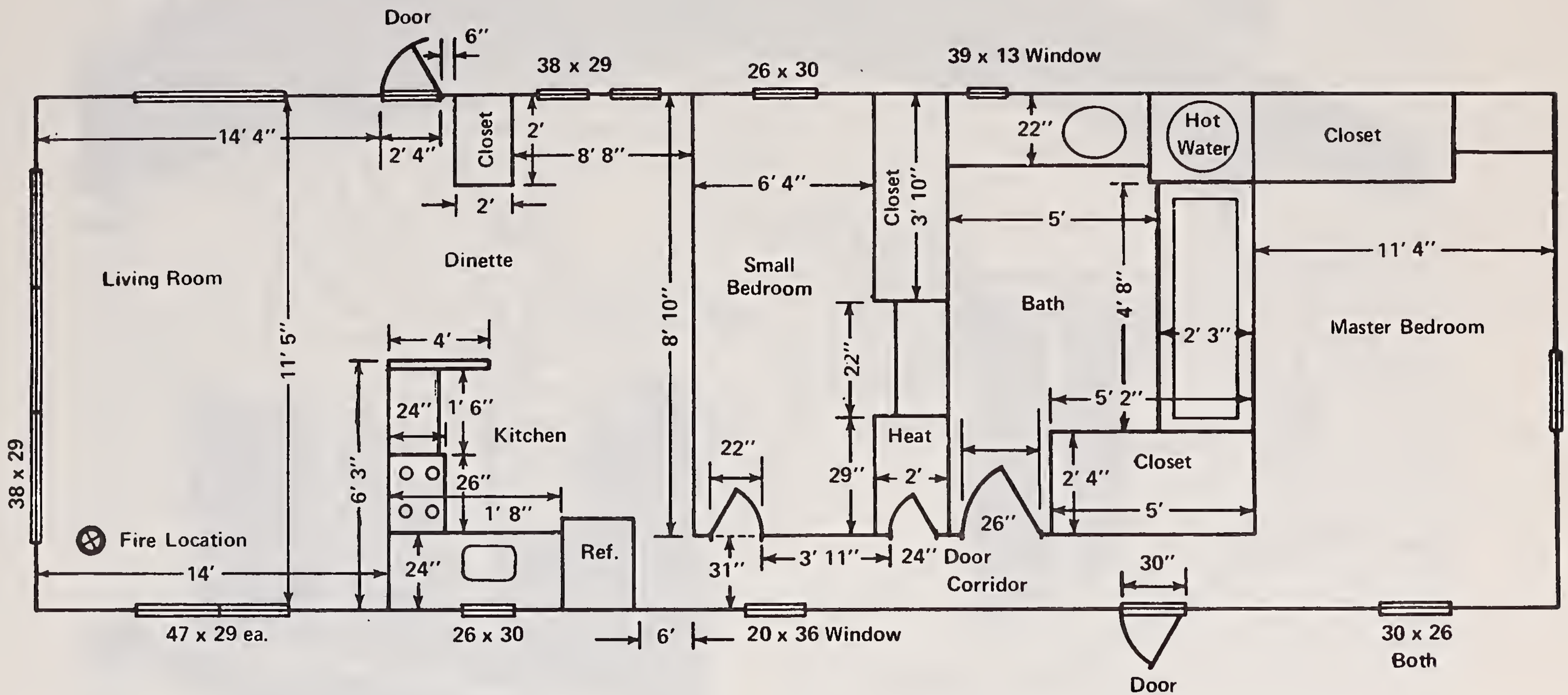

Figure 1. Return Air Vent in Heater Compartment

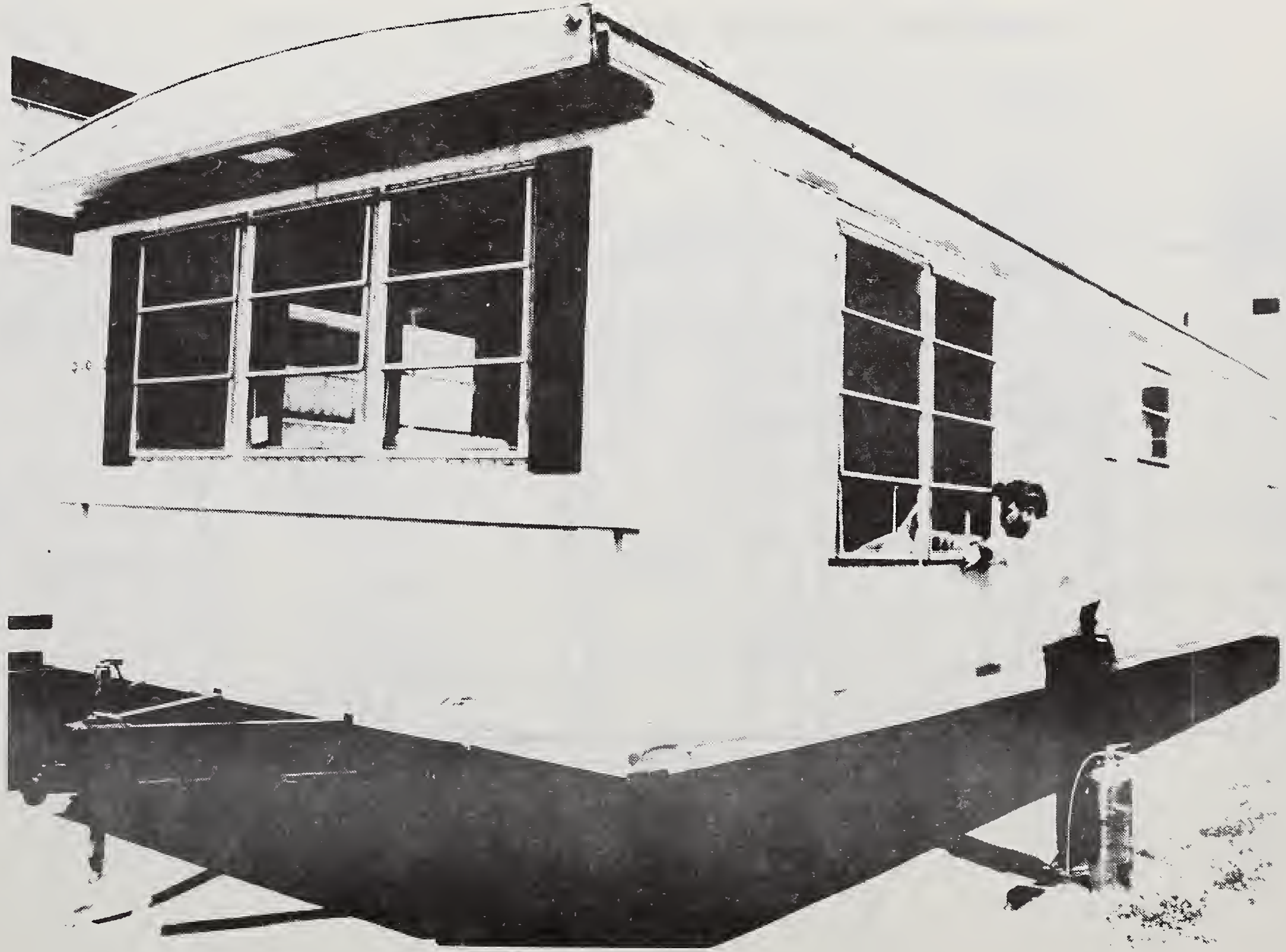

Figure 2. Exterior of Mobile Home (Living Room End)

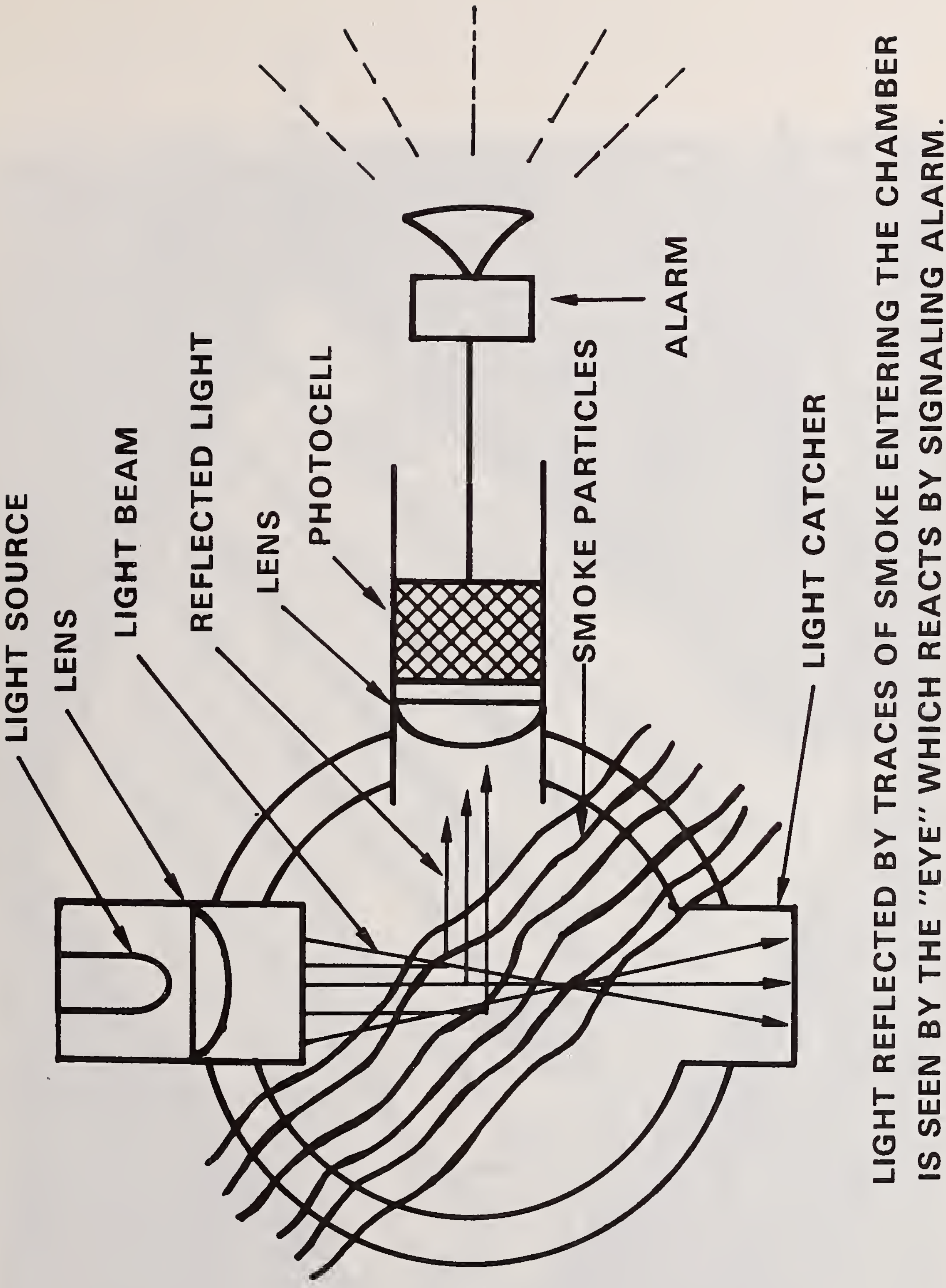

Figure 3. Photoelectric Smoke Detector Chamber

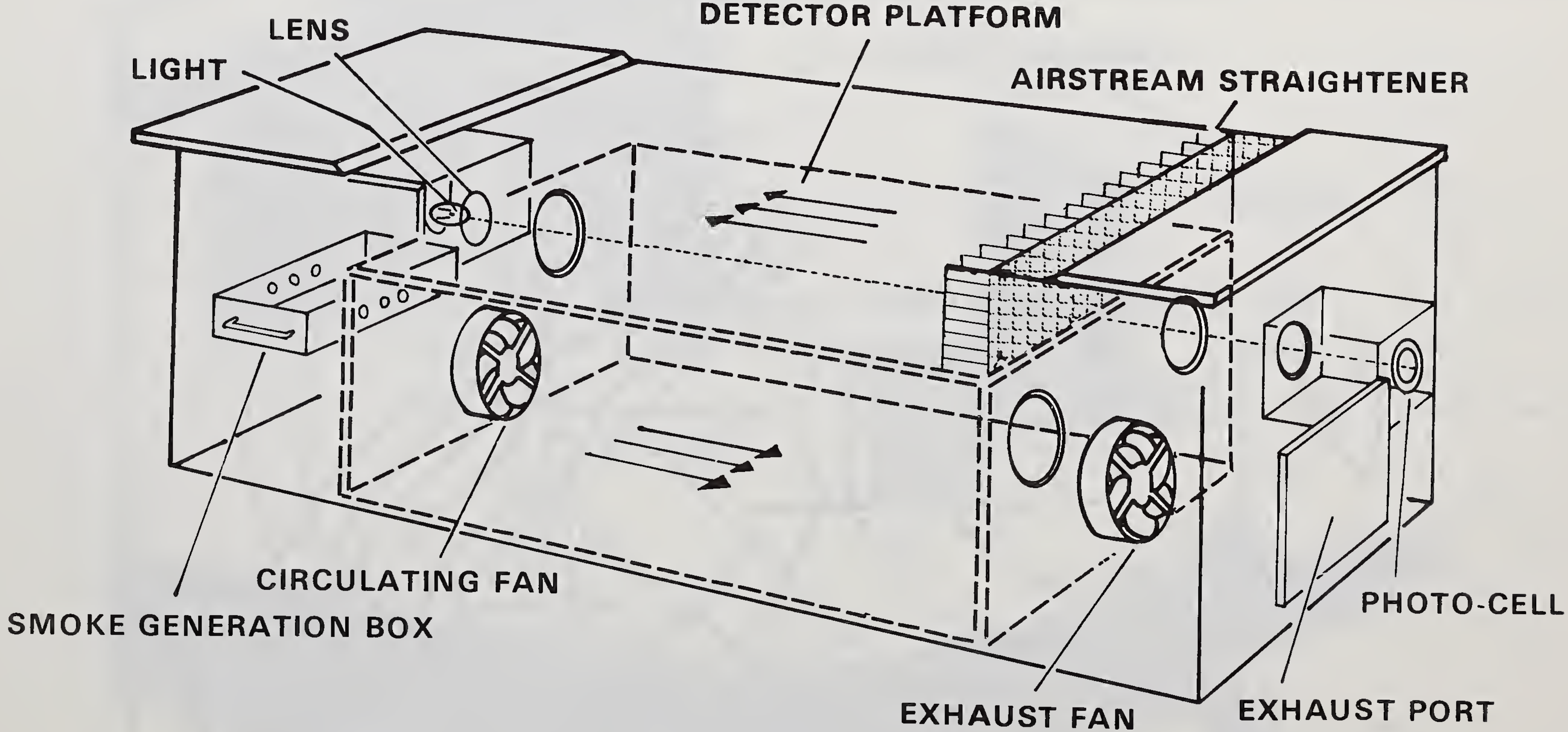

Figure 4. Smoke Detector Test Chamber

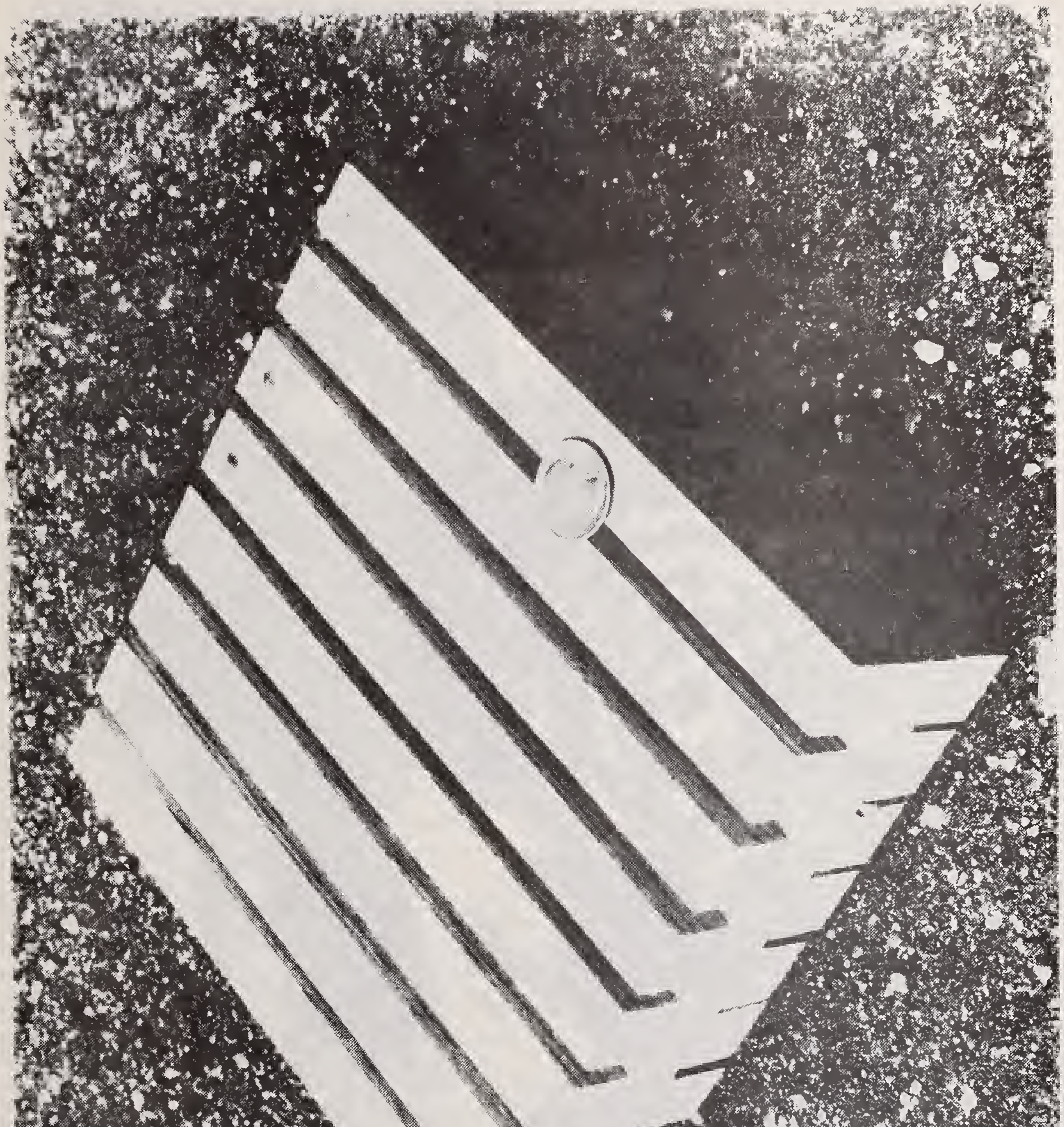

Figure 5. Wood Crib

Figure 6. Radiant Furnace

Figure 7. Wood Crib Test Setup

Figure 8. Smoldering Wood Crib Fire Test

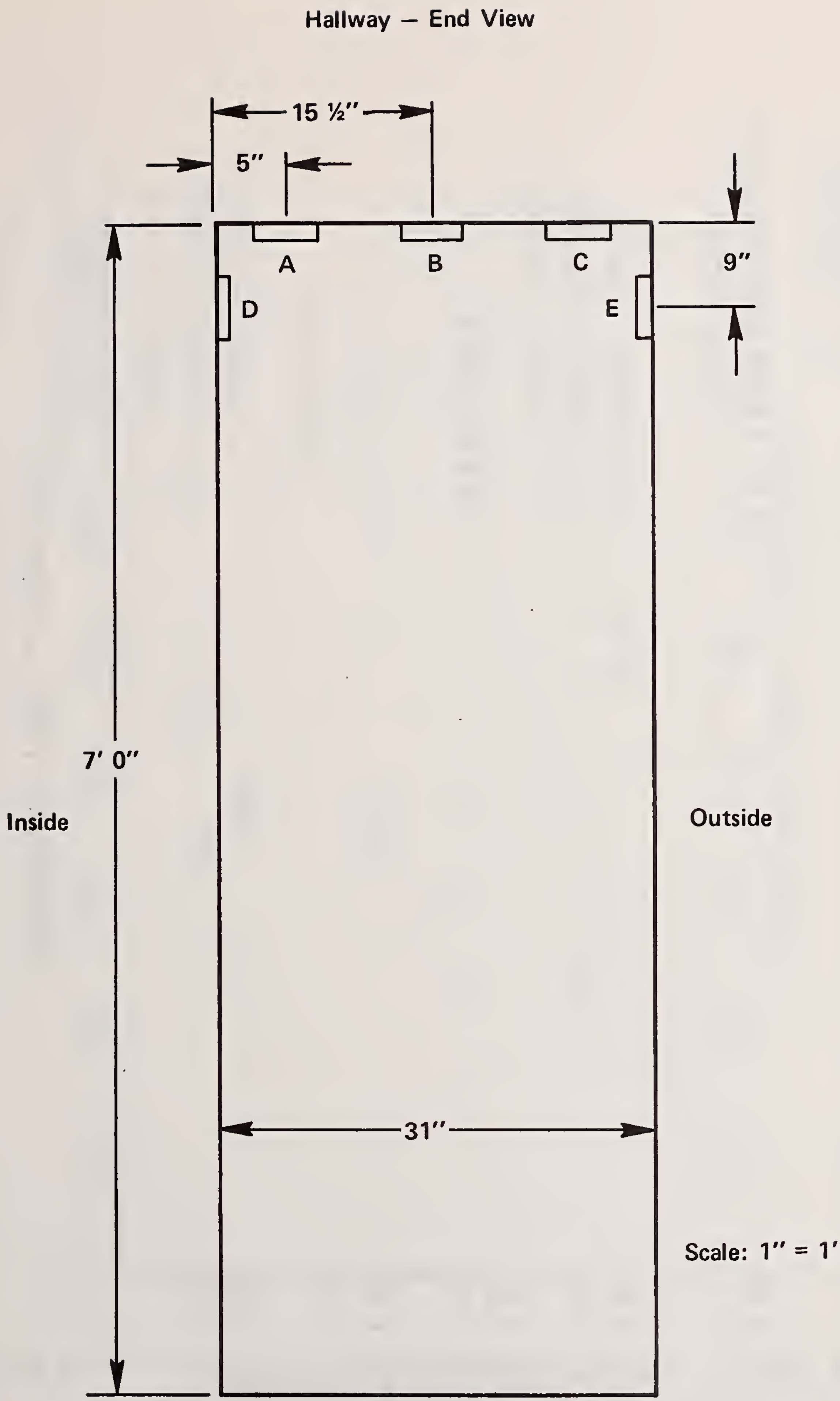

Figure 9. Detector Locations — Test Series A

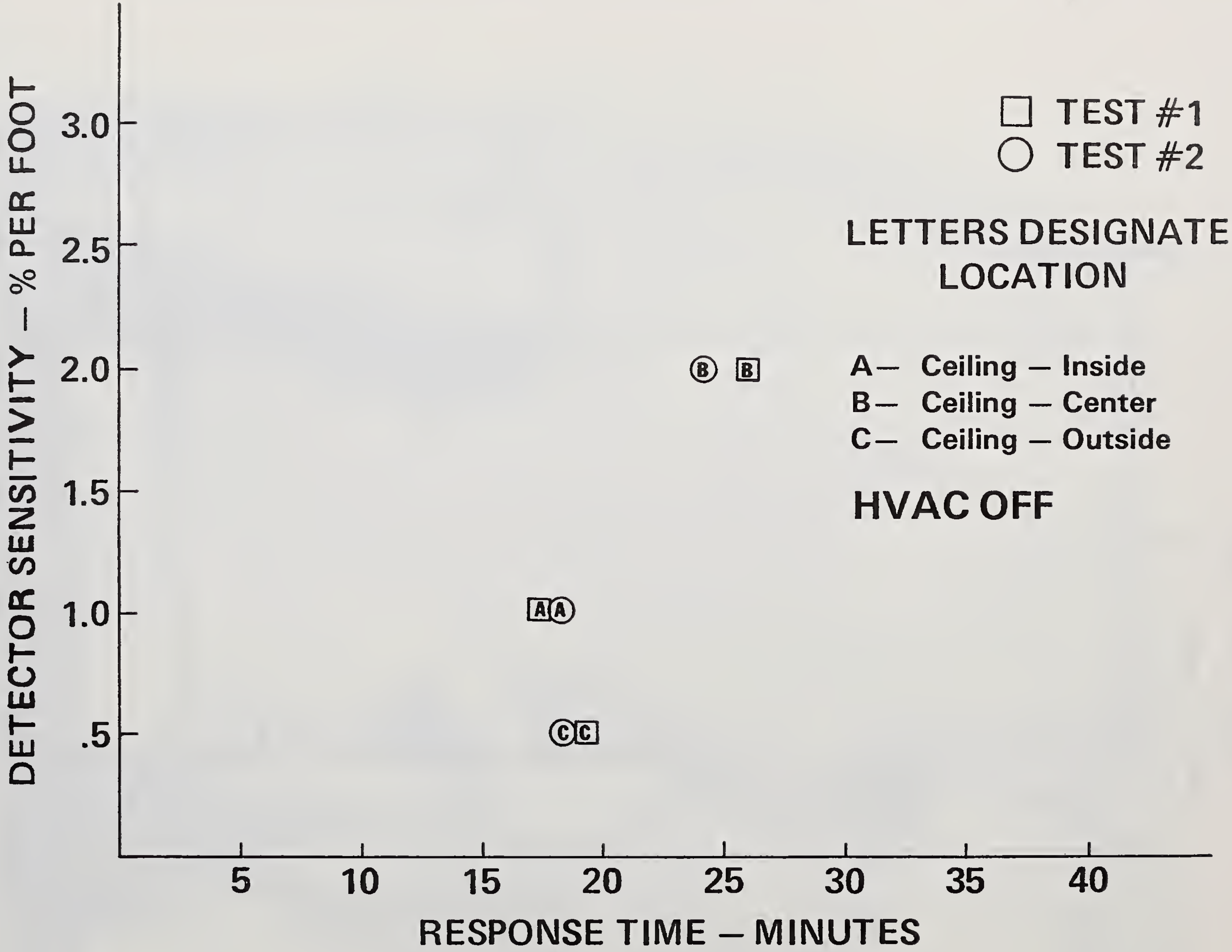

Figure 10. Detector Response Time vs Sensitivity — Test Series A, Tests 1 and 2

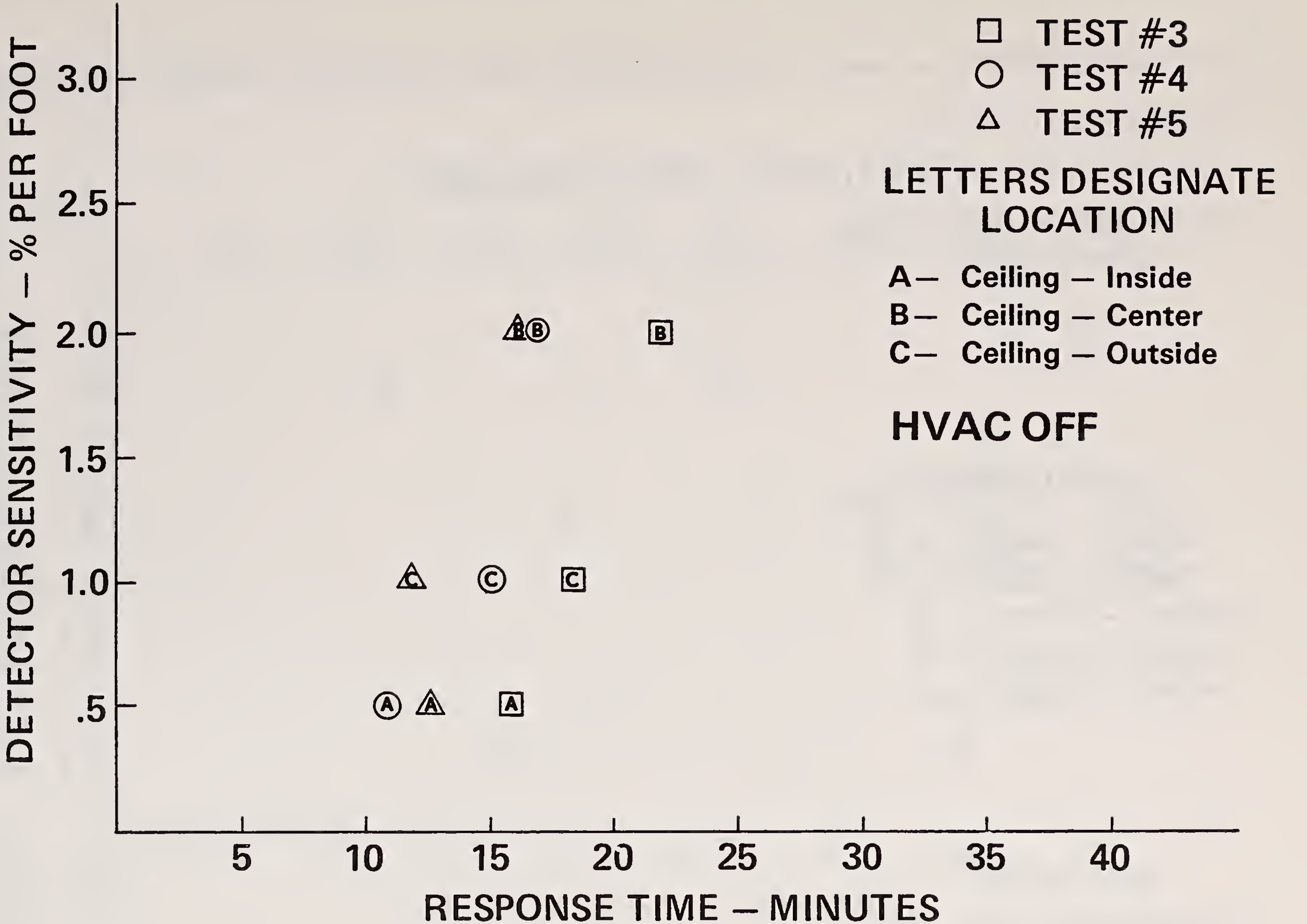

Figure 11. Detector Response Time vs Sensitivity — Test Series A, Tests 3, 4 and 5

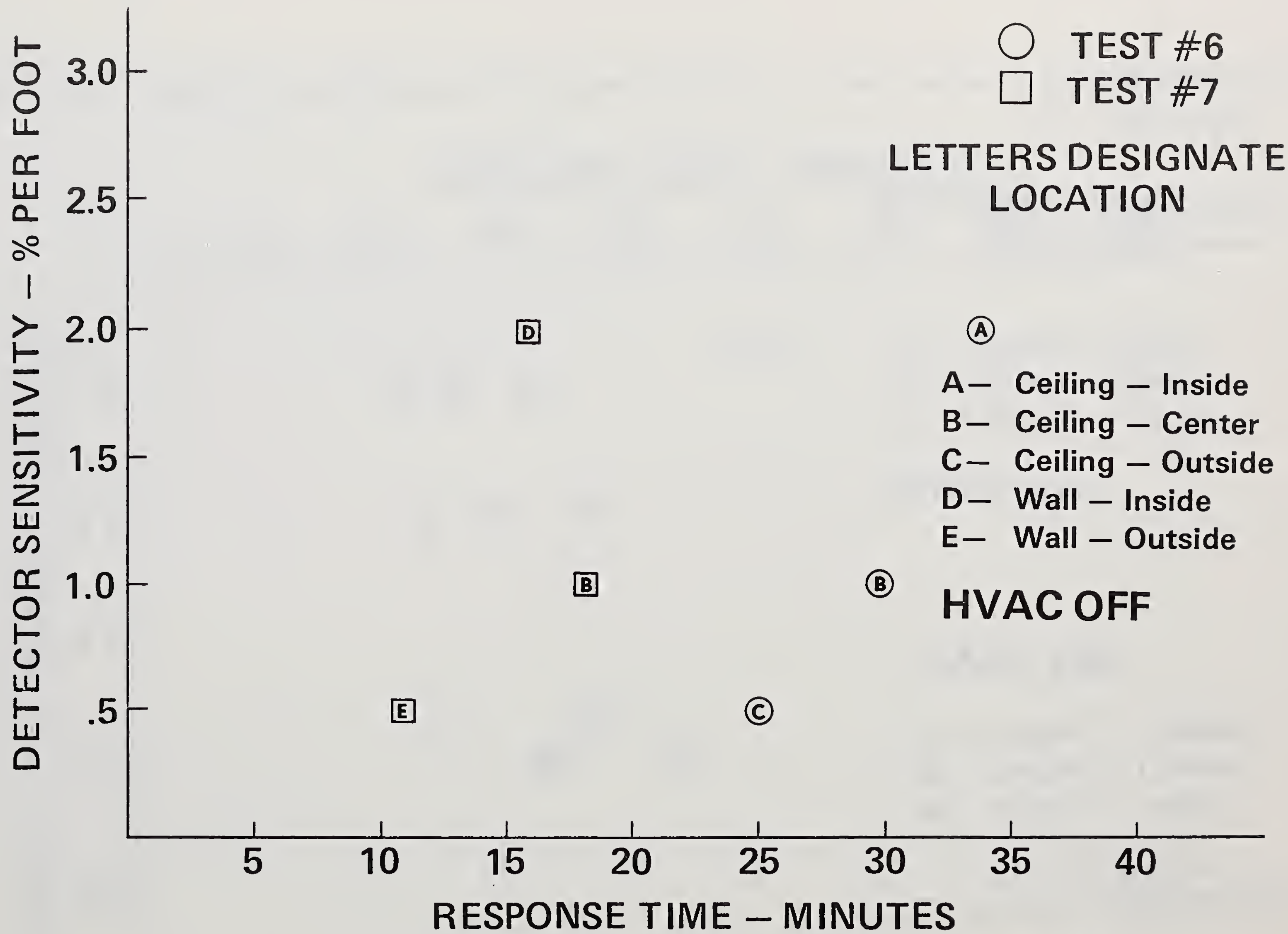

Figure 12. Detector Response Time vs Sensitivity — Test Series A, Tests 6 and 7

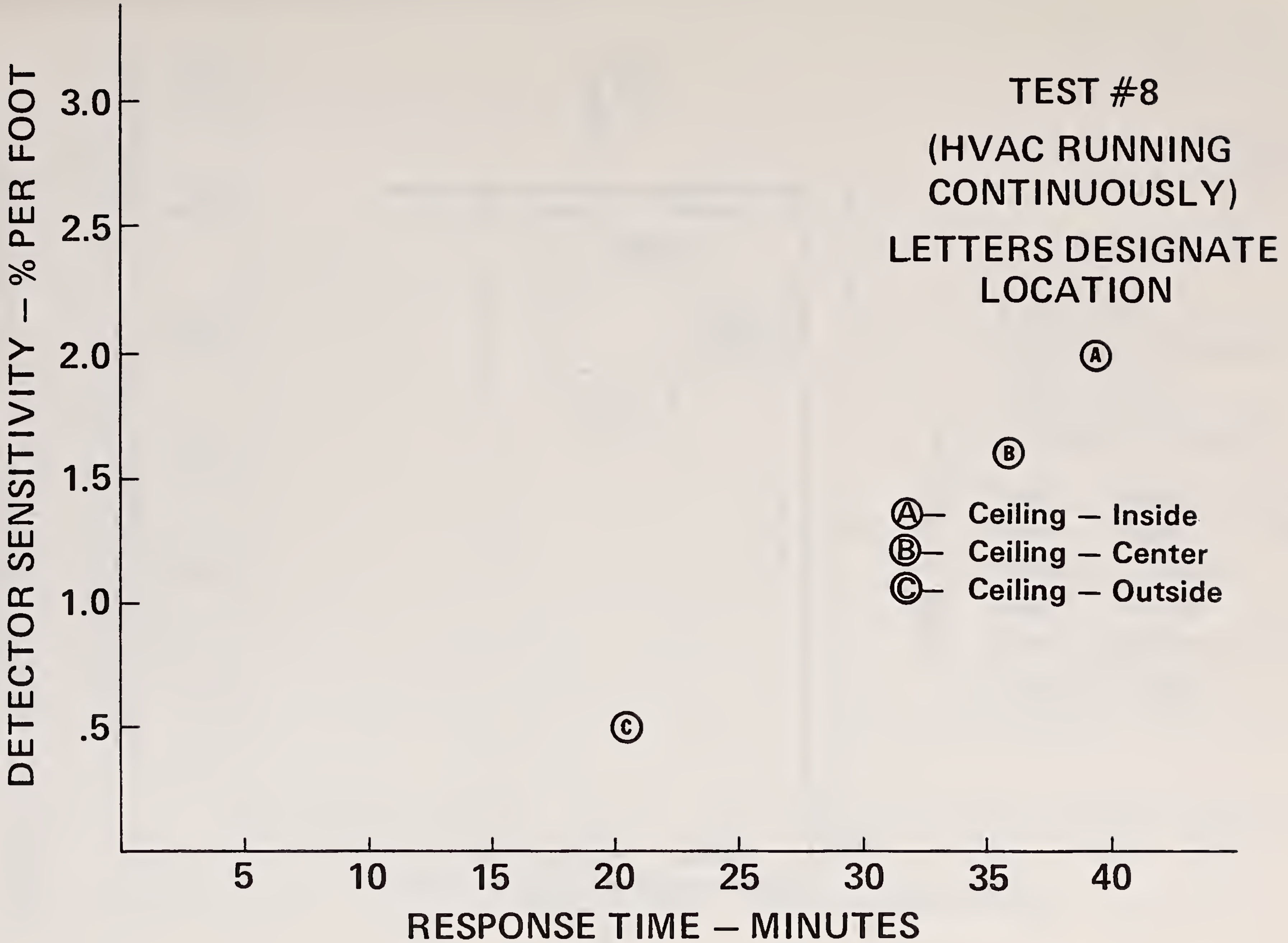

Figure 13. Detector Response Time vs Sensitivity — Test Series A, Test 8

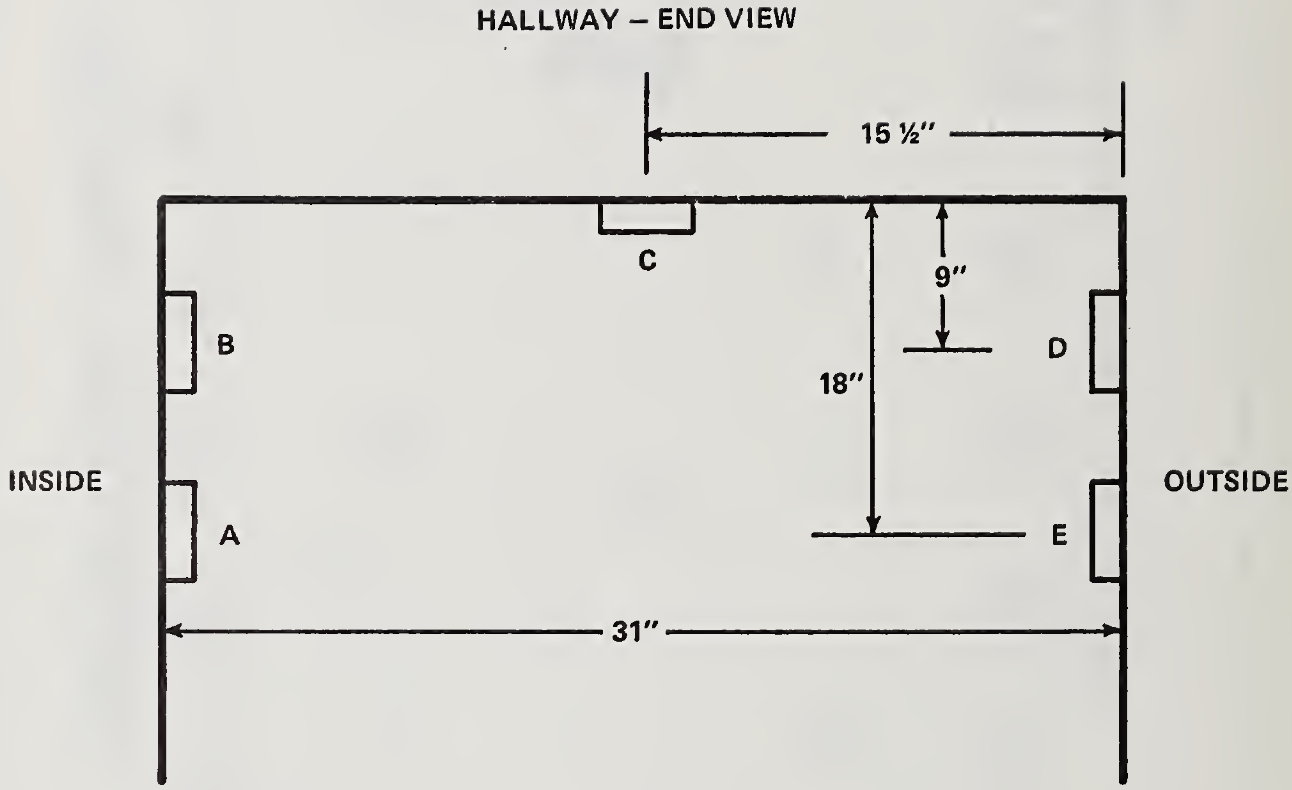

Figure 14. Detector Locations — Test Series B

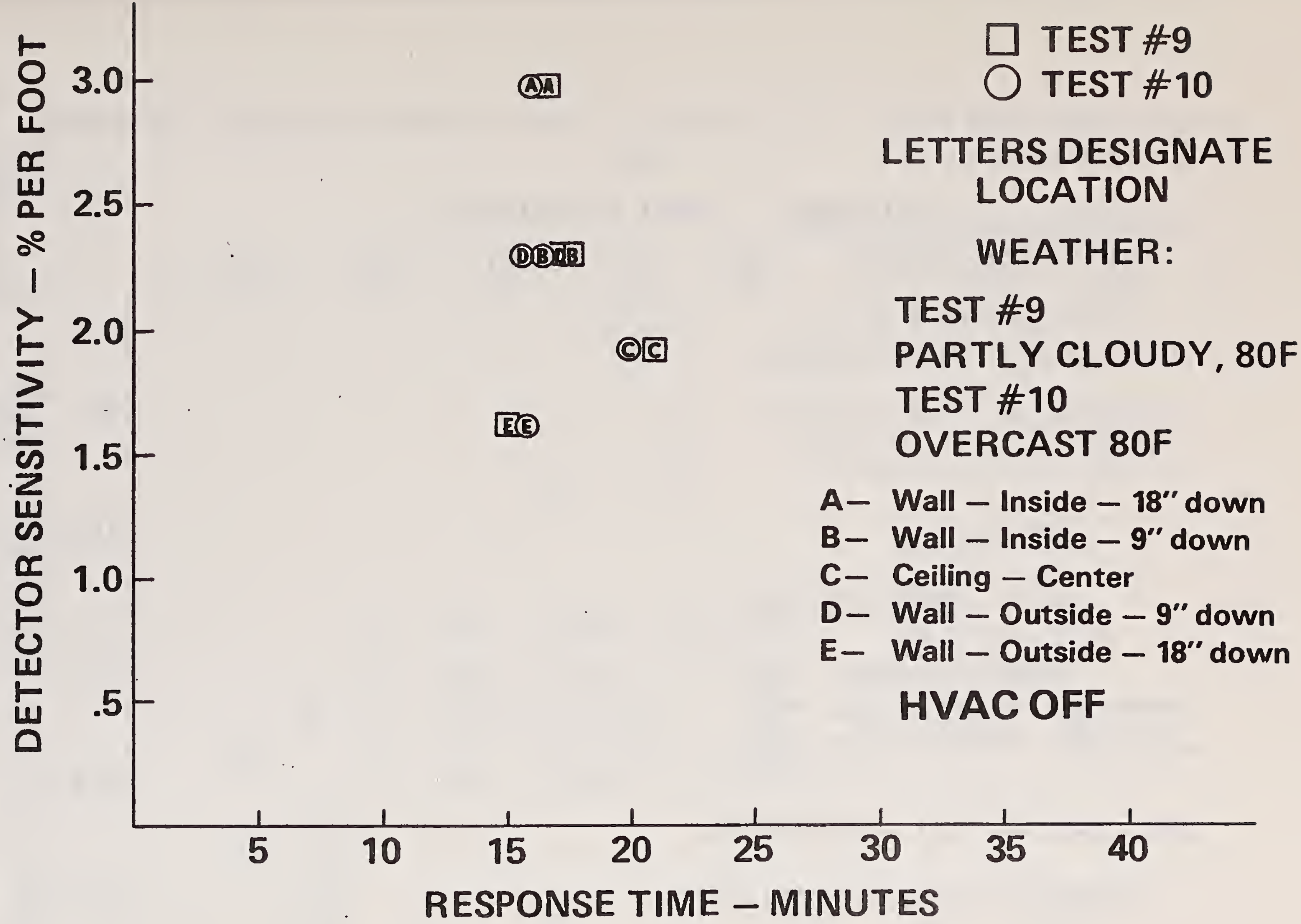

Figure 15. Detector Response Time vs Sensitivity — Test Series B, Tests 9 and 10

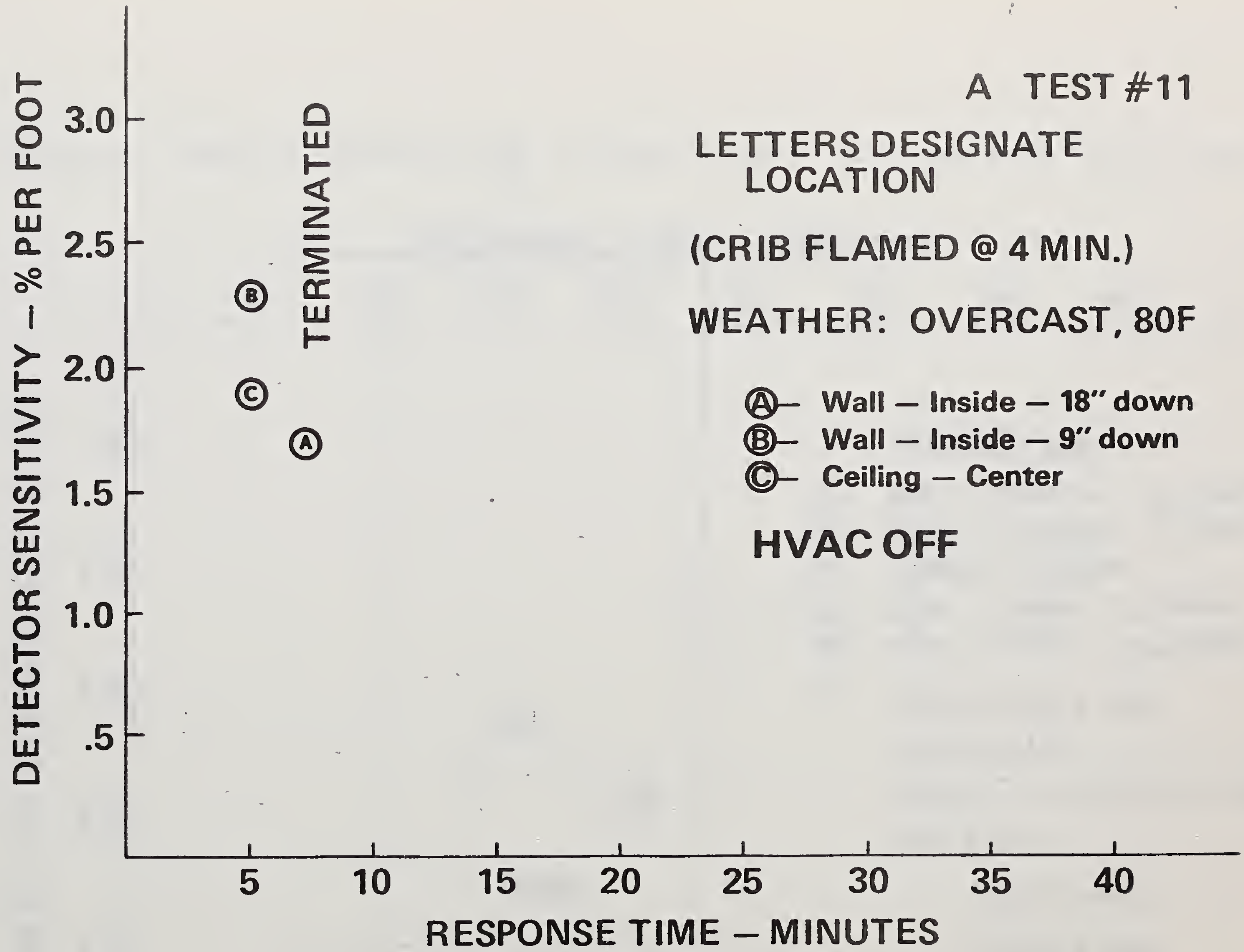

Figure 16. Detector Response Time vs Sensitivity — Test Series B, Test 11

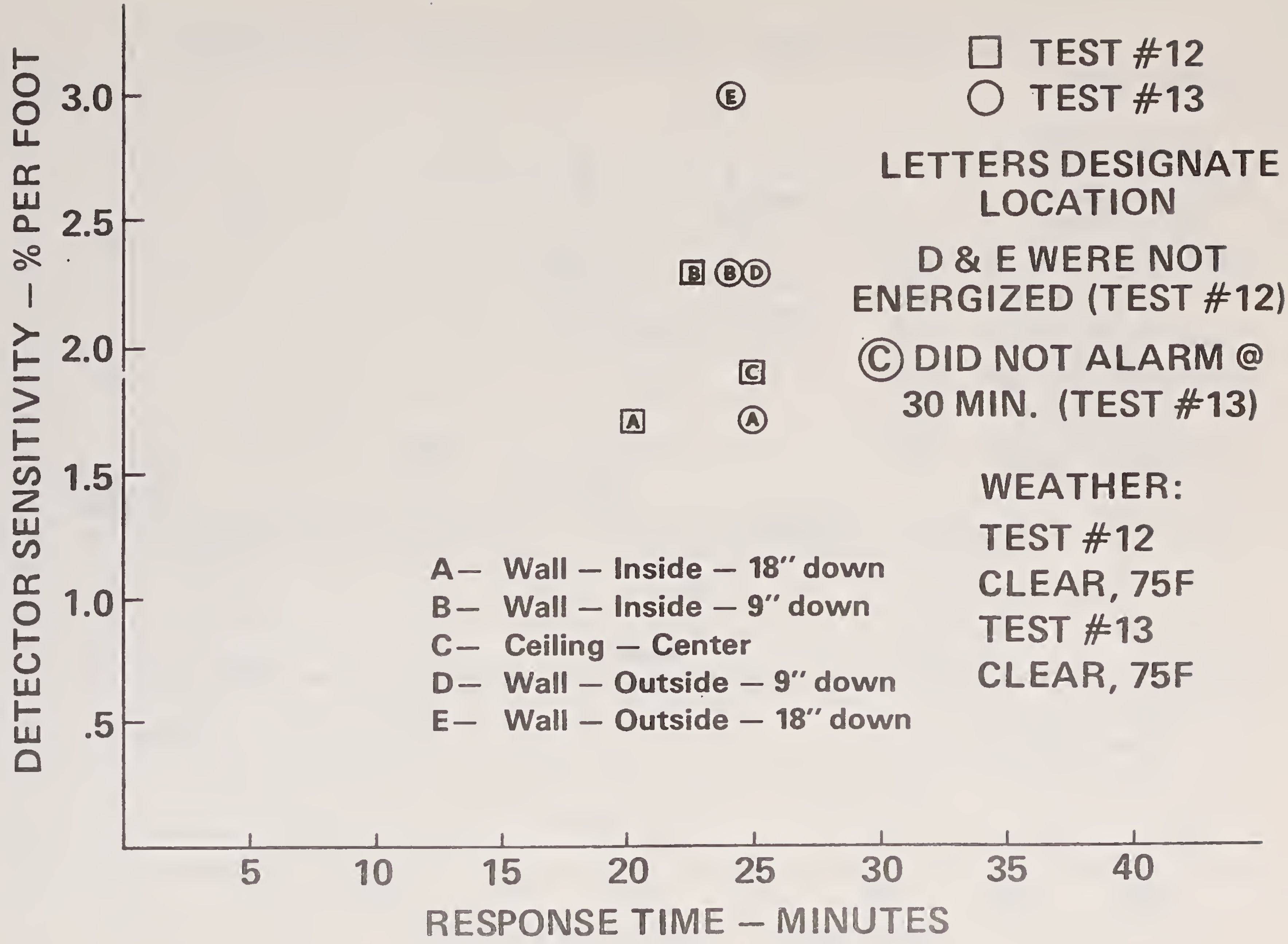

Figure 17. Detector Response Time vs Sensitivity — Test Series B, Tests 12 and 13

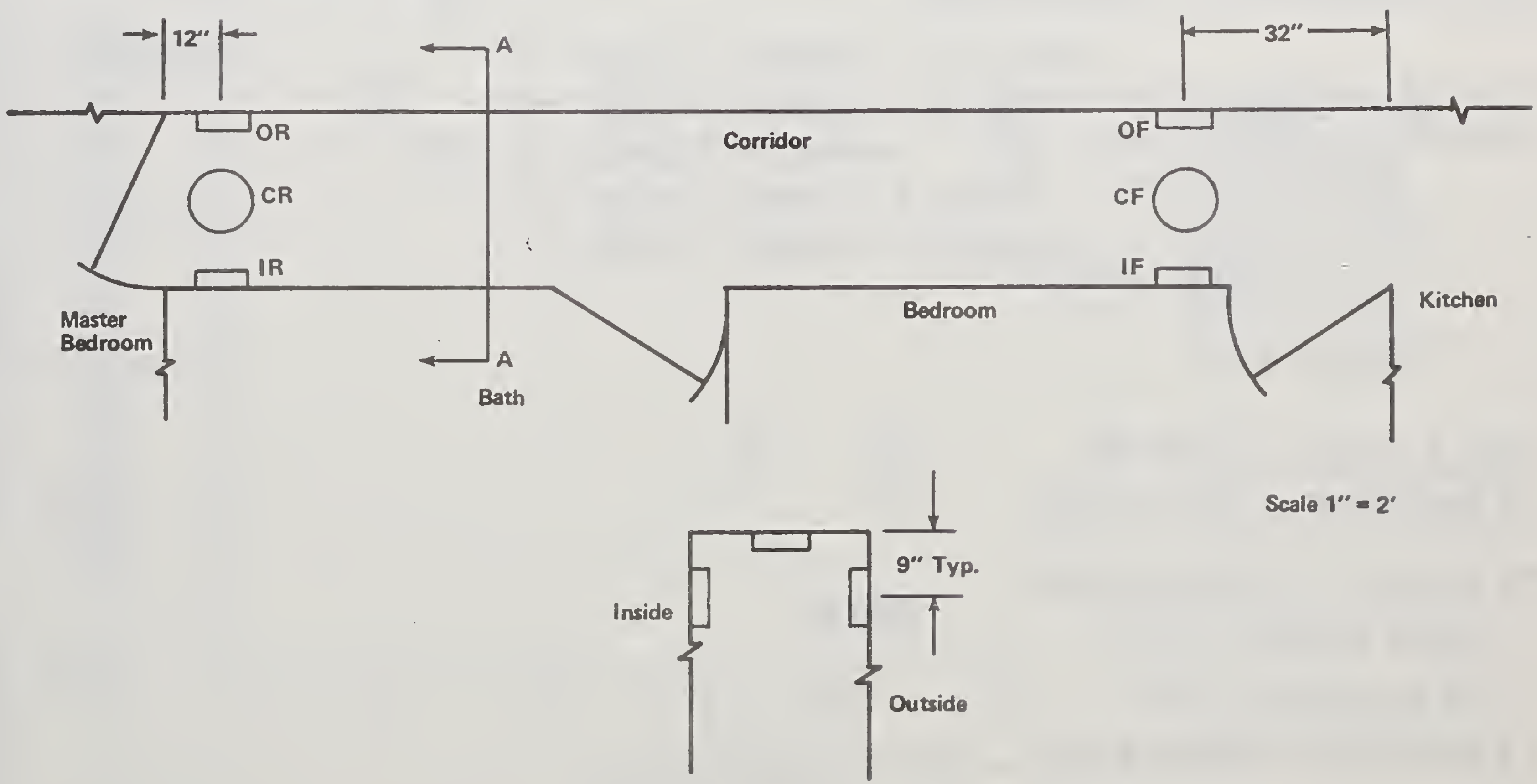

Figure 18. Detector Locations — Test Series C and D

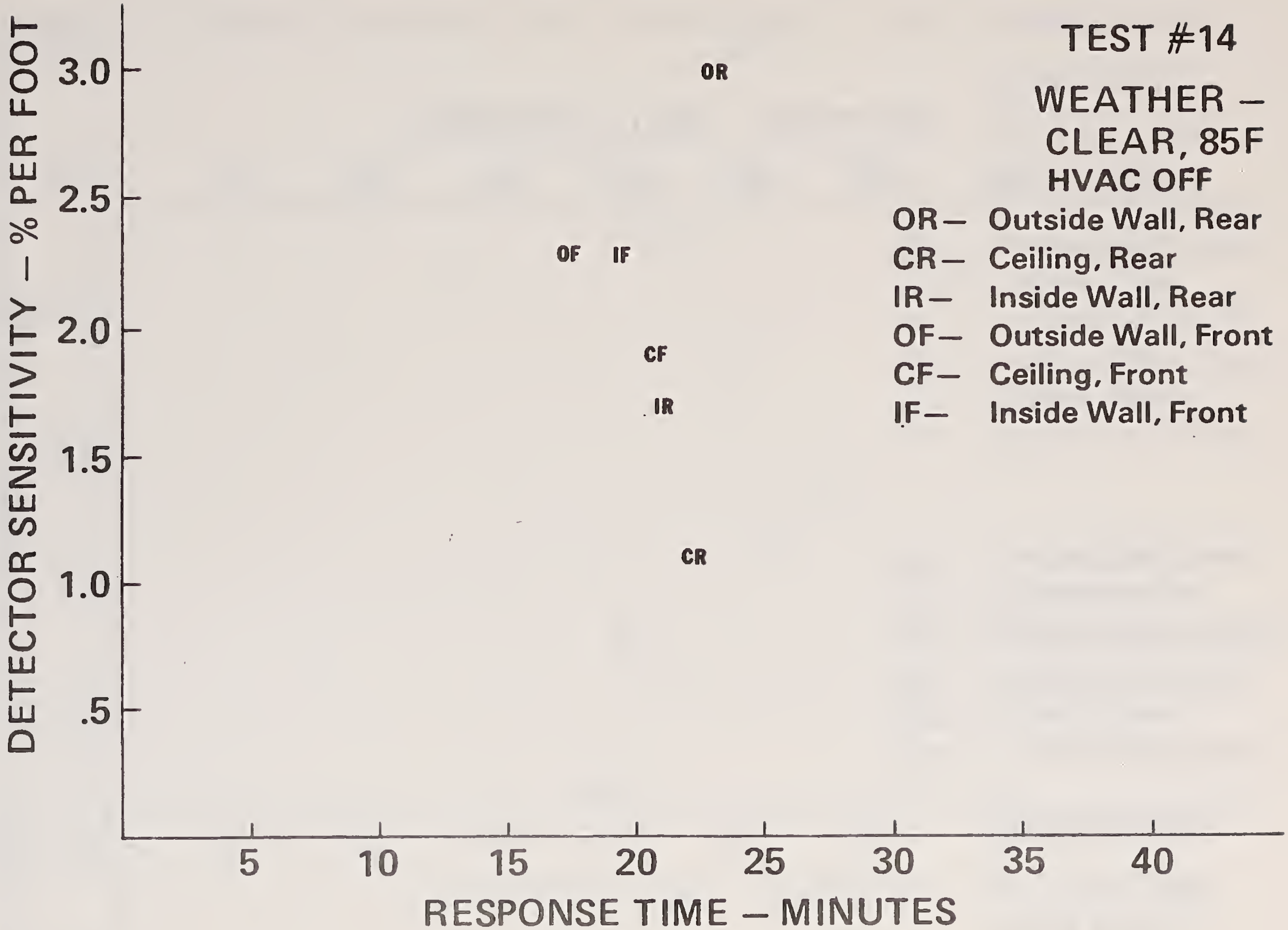

Figure 19. Detector Response Time vs Sensitivity — Test Series C, Test 14

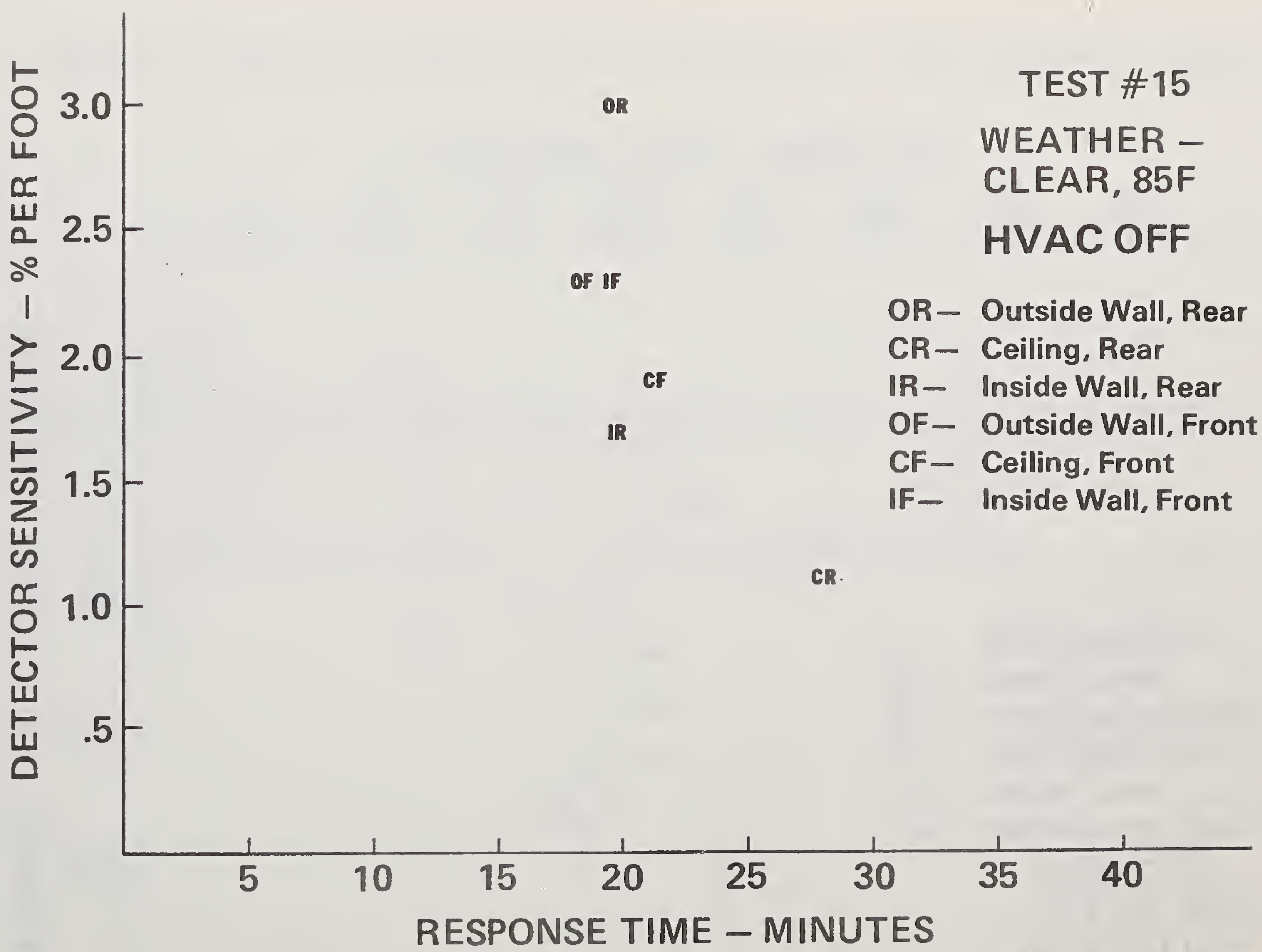

Figure 20. Detector Response Time vs Sensitivity — Test Series C, Test 15

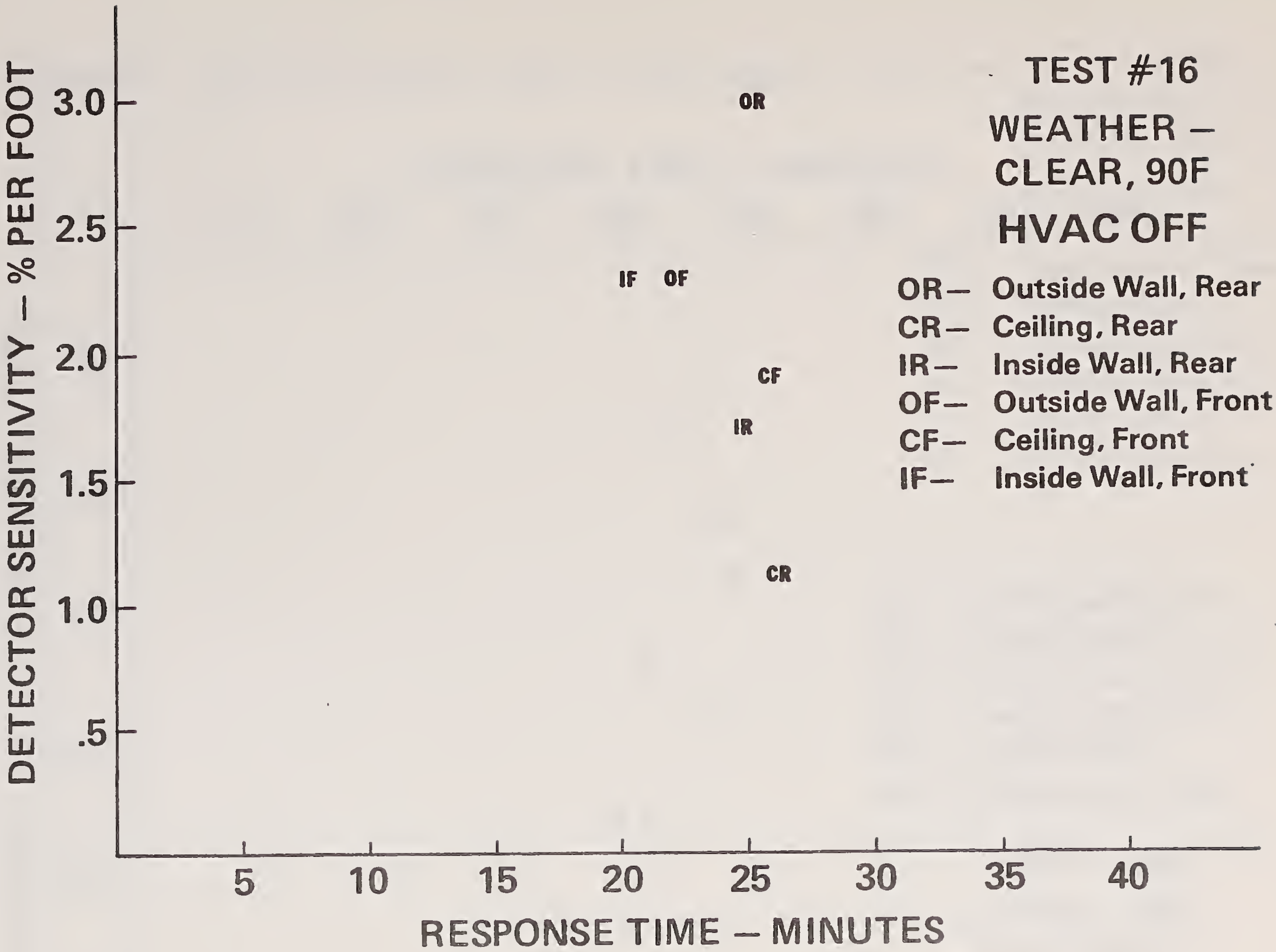

Figure 21. Detector Response Time vs Sensitivity — Test Series C, Test 16

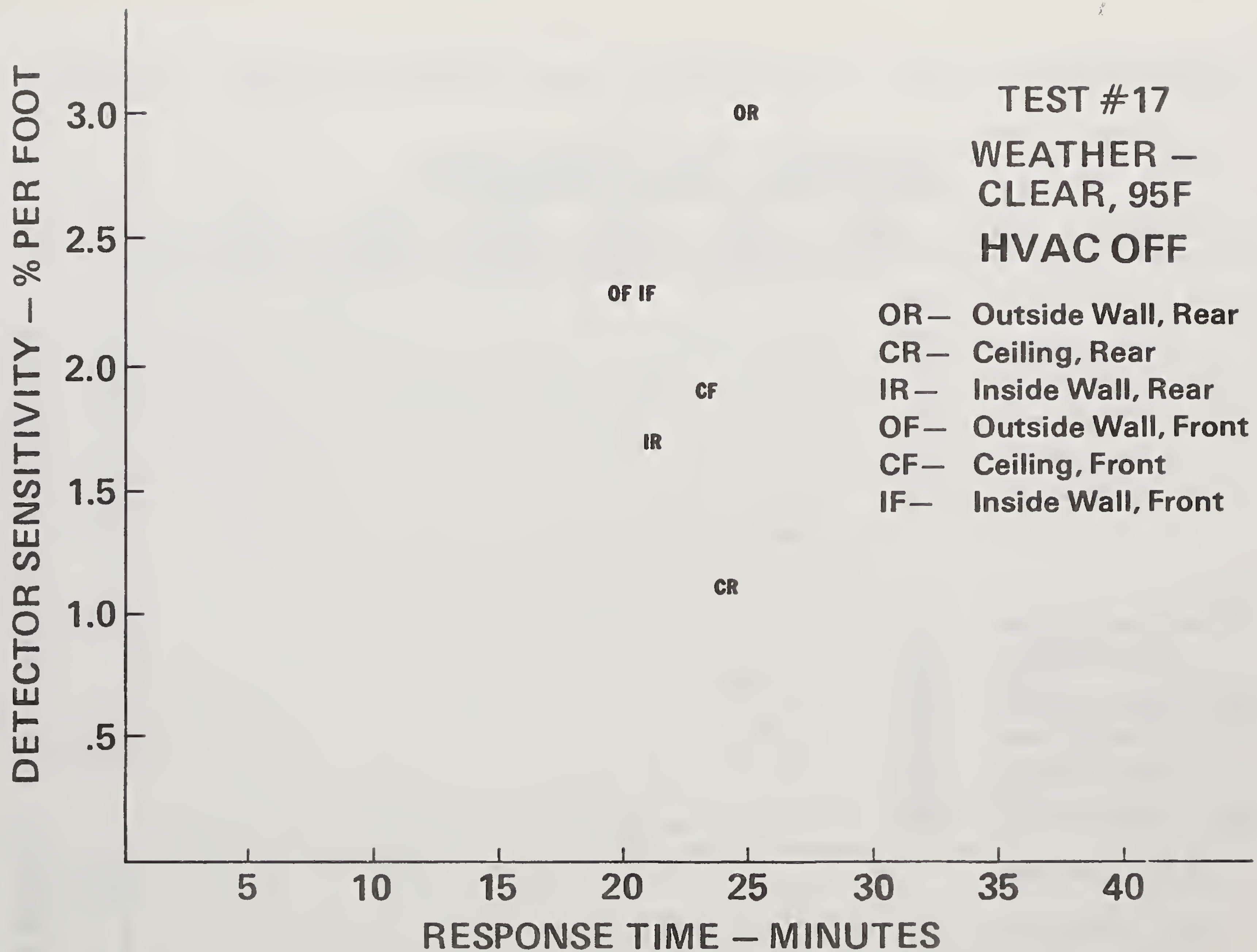

Figure 22. Detector Response Time vs Sensitivity — Test Series C, Test 17

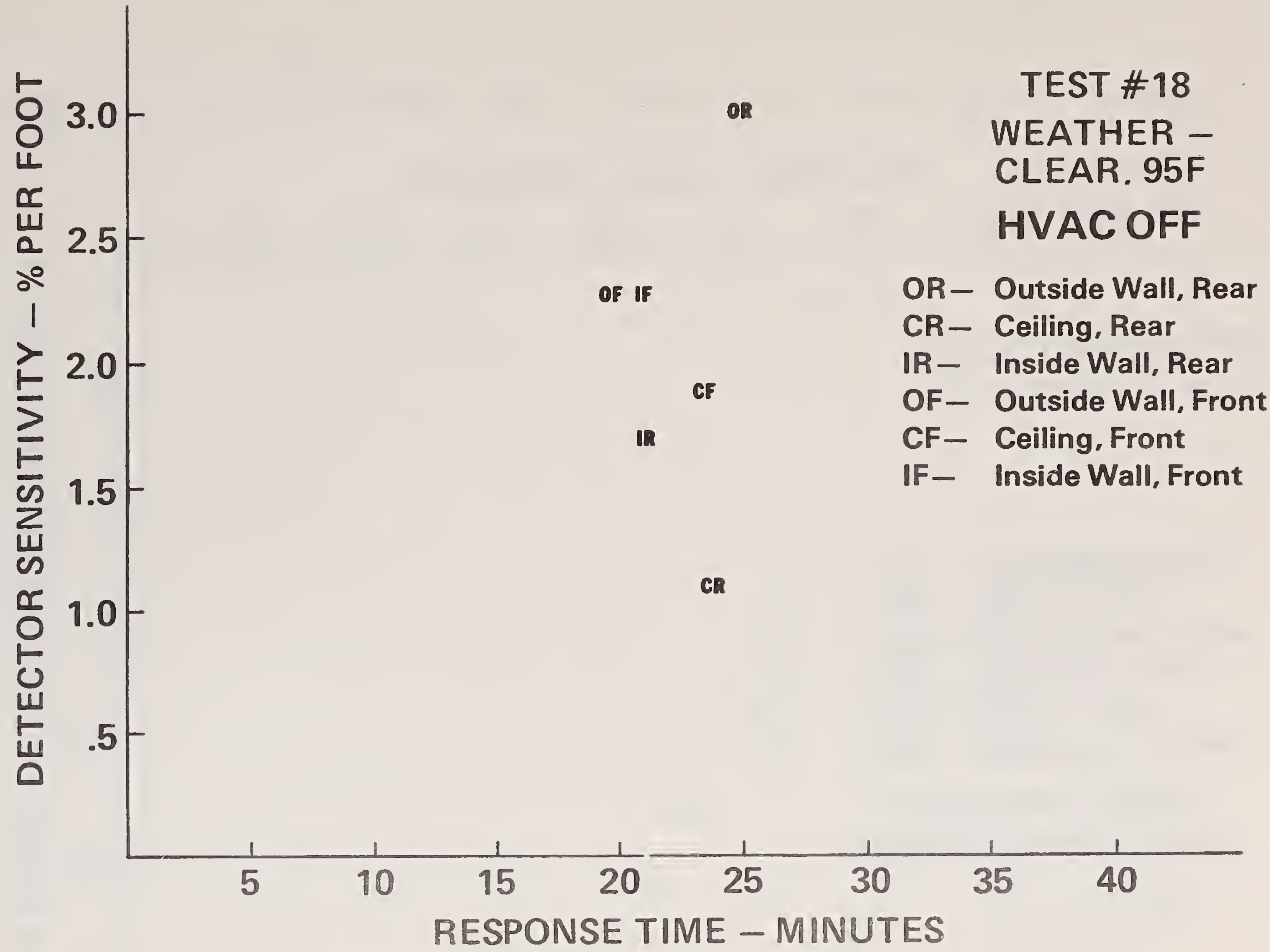

Figure 23. Detector Response Time vs Sensitivity — Test Series C, Test 18

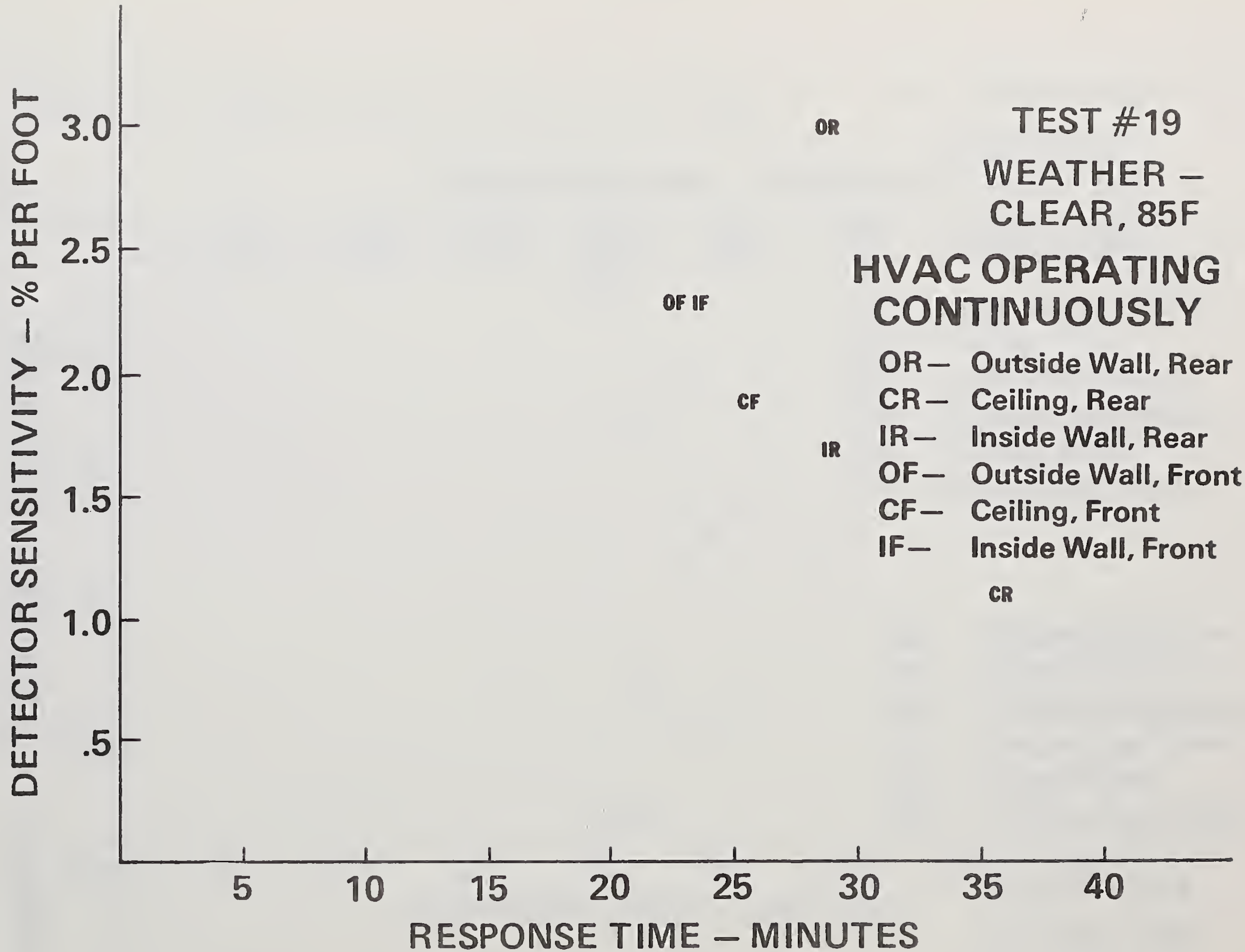

Figure 24. Detector Response Time vs Sensitivity — Test Series C, Test 19

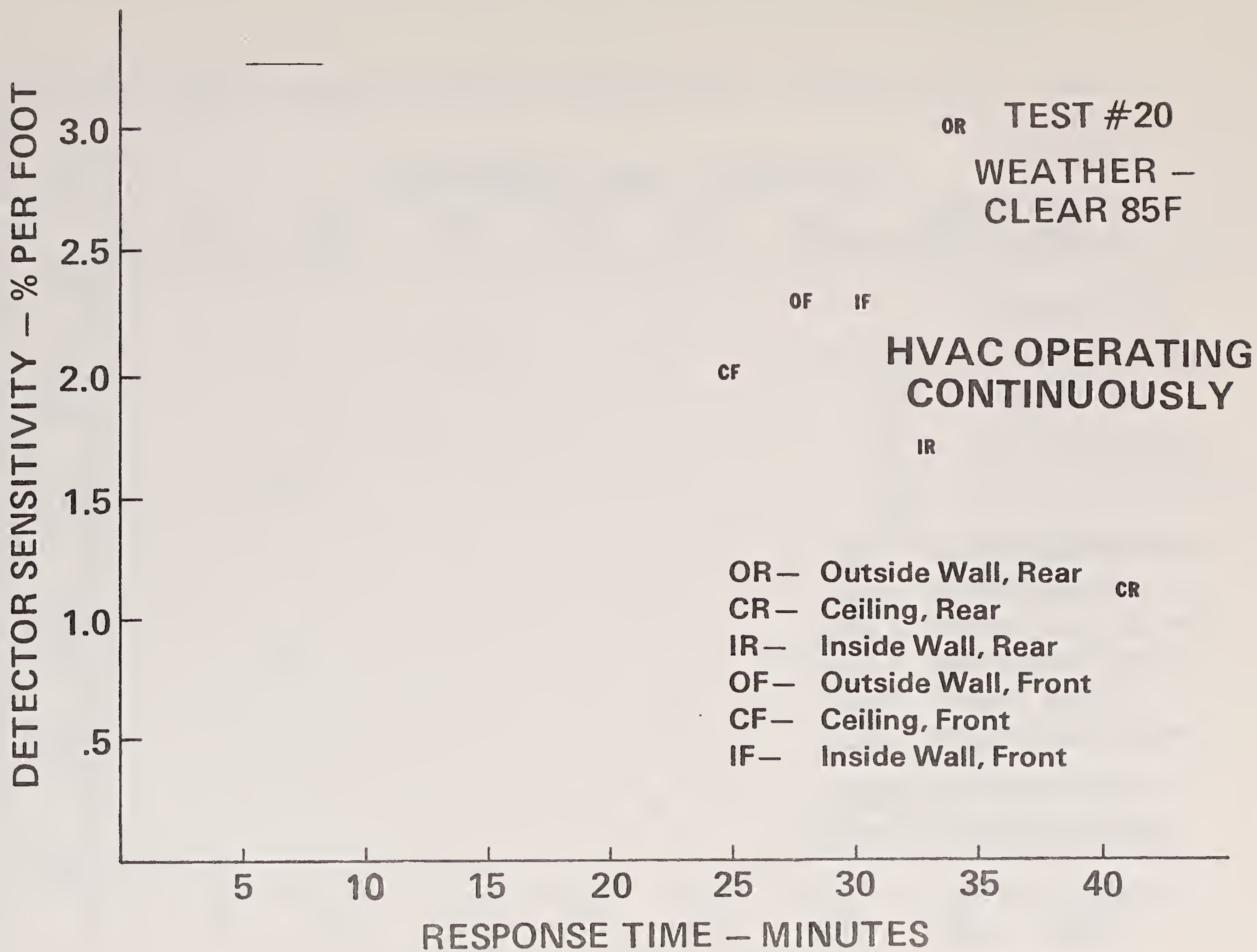

Figure 25. Detector Response Time vs Sensitivity — Test Series C, Test 20

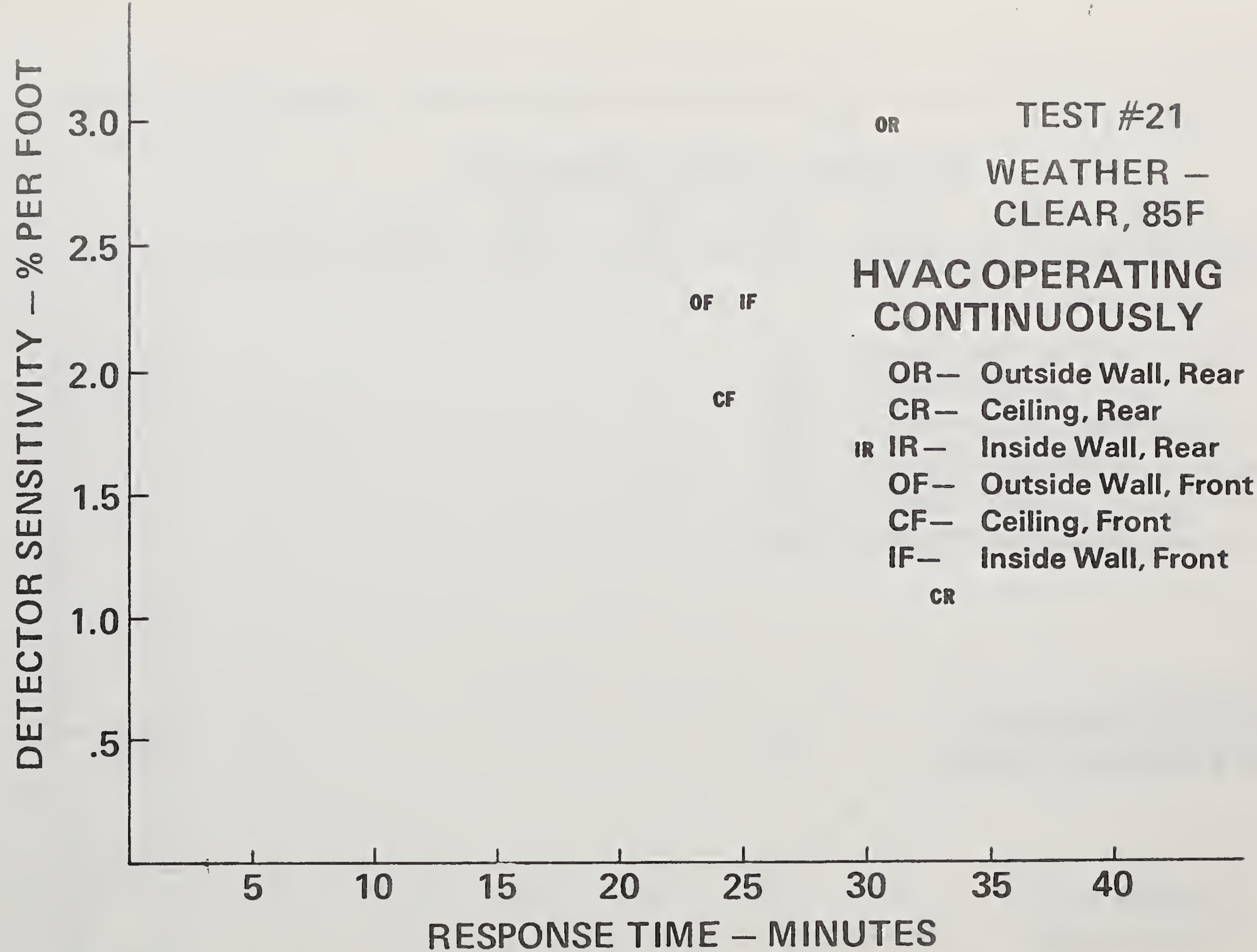

Figure 26. Detector Response Time vs Sensitivity — Test Series C, Test 21

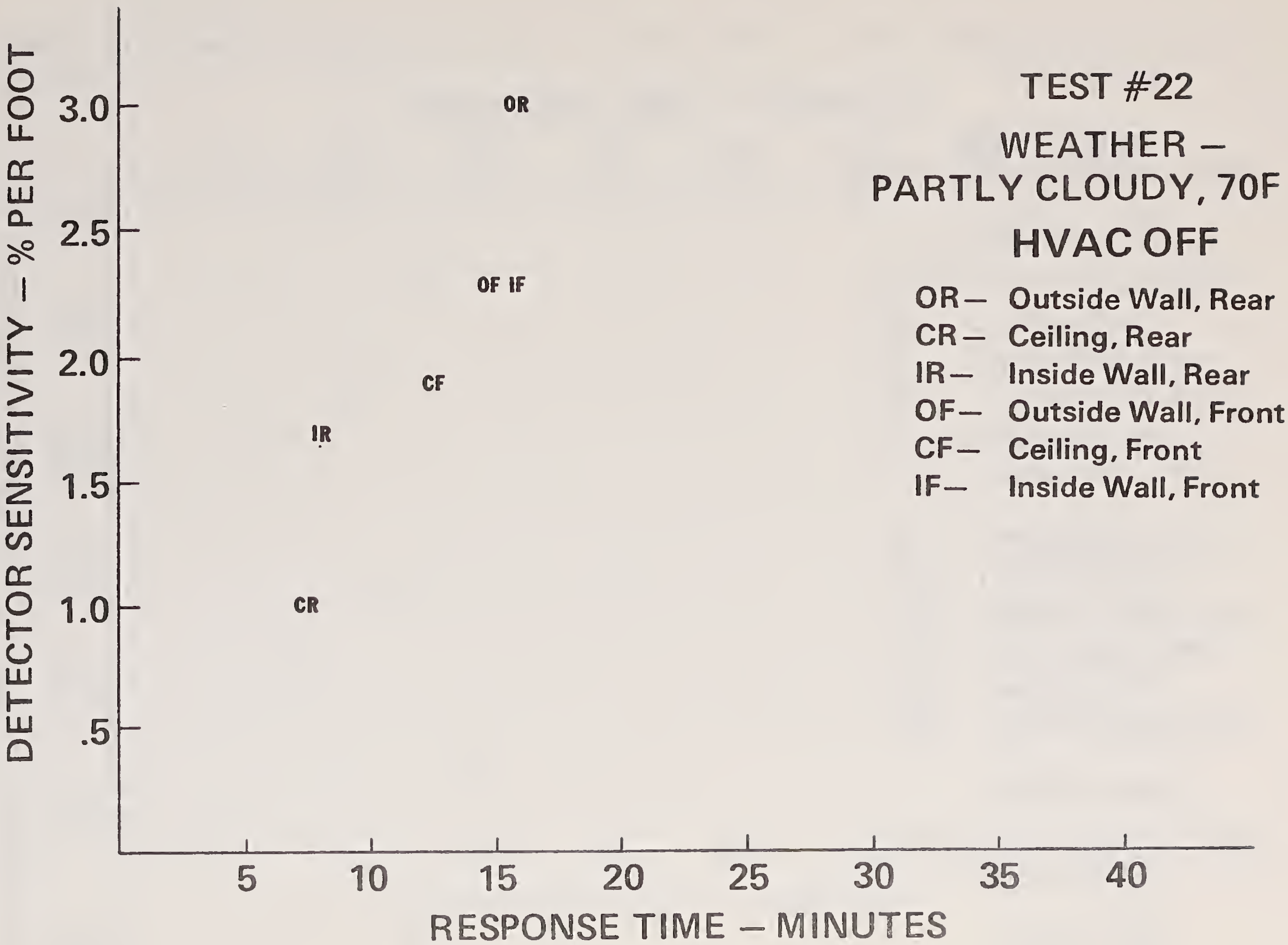

Figure 27. Detector Response Time vs Sensitivity — Test Series D, Test 22

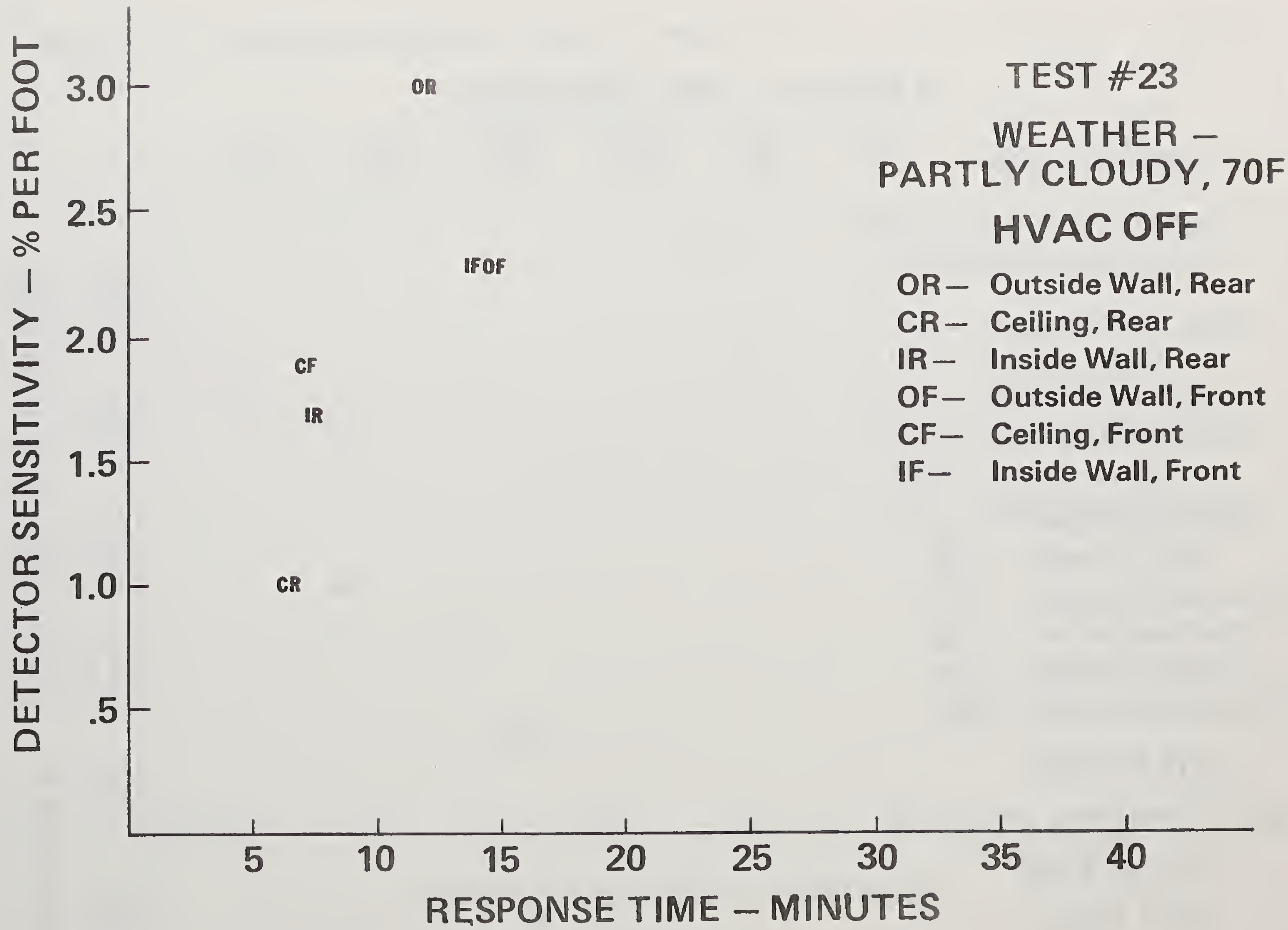

Figure 28. Detector Response Time vs Sensitivity — Test Series D, Test 23

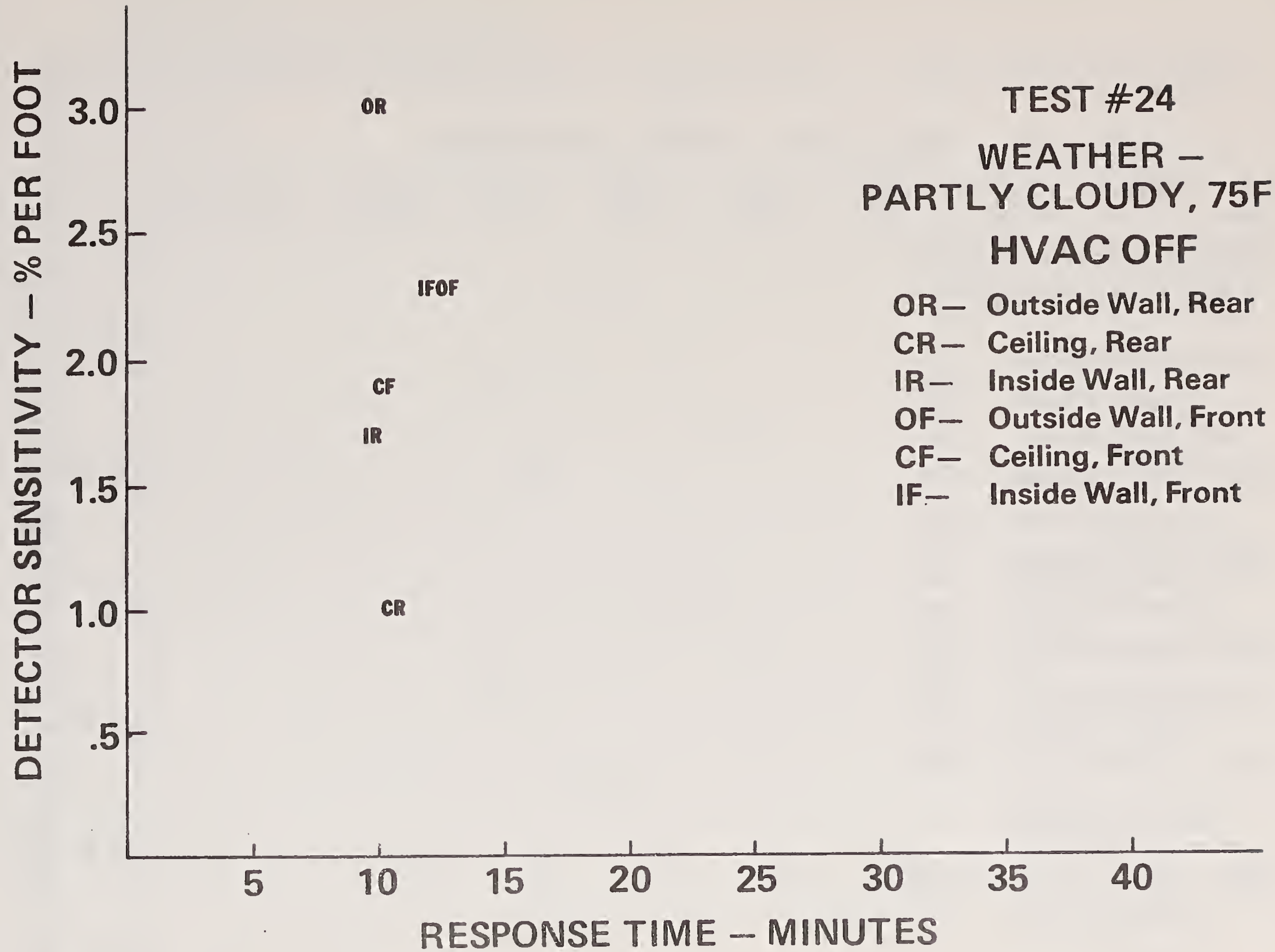

Figure 29. Detector Response Time vs Sensitivity — Test Series D, Test 24

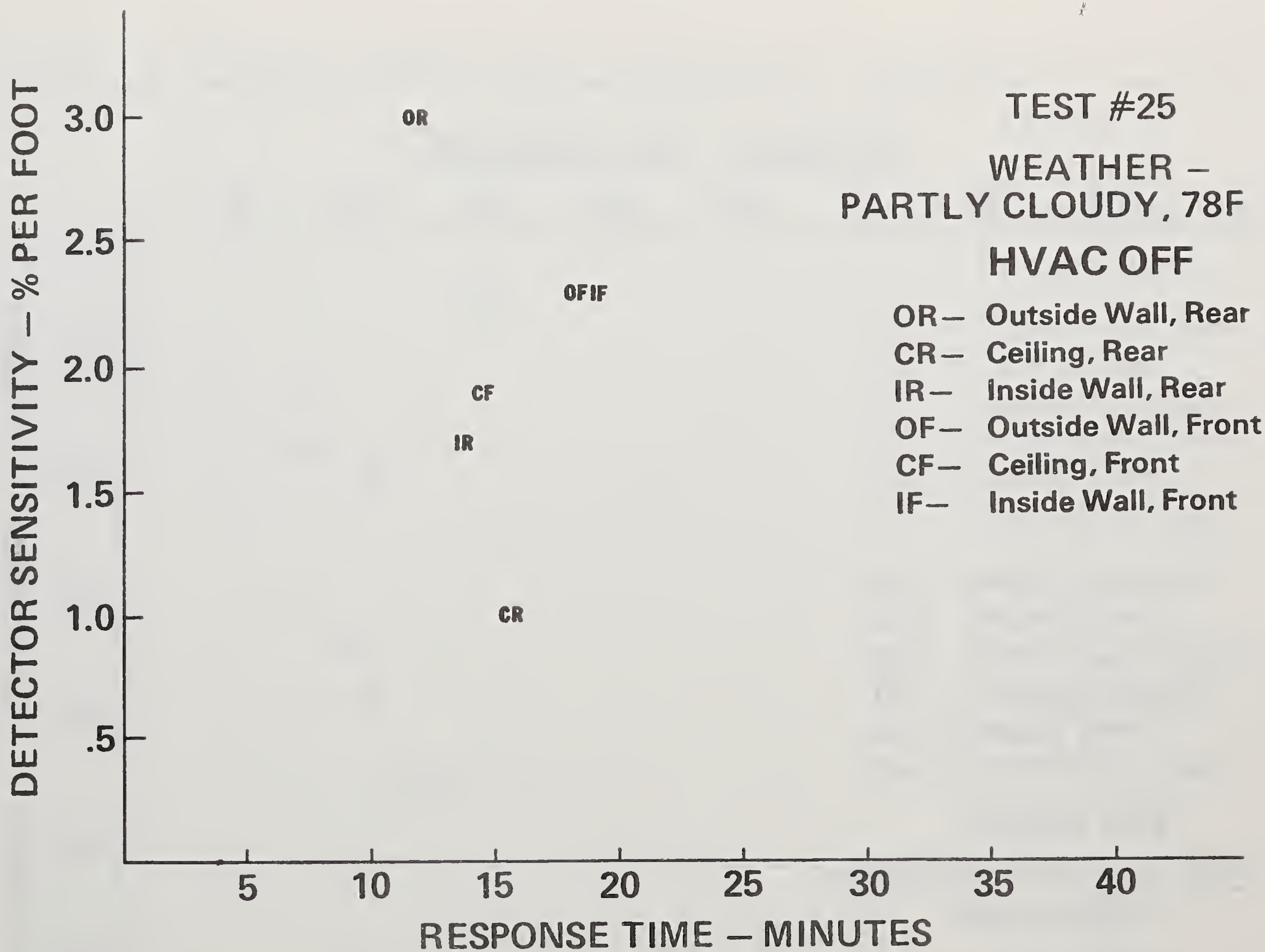

Figure 30. Detector Response Time vs Sensitivity — Test Series, D, Test 25

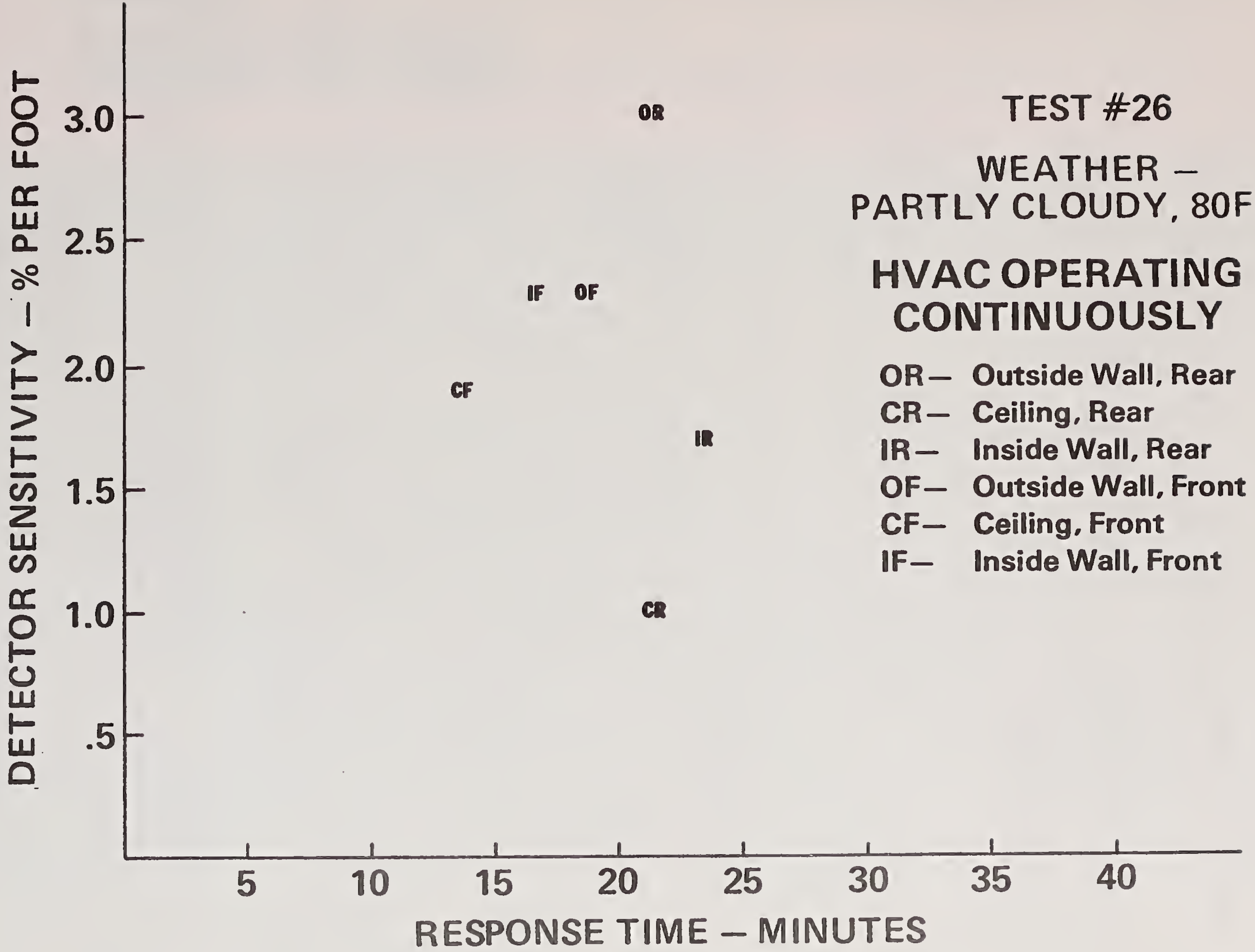

Figure 31. Detector Response Time vs Sensitivity — Test Series D, Test 26

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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.)*

An investigation was conducted to evaluate the significance of smoke detector locations to response time for a specific set of fire conditions in a mobile home. Parameters having the potential of affecting response time include: the physical location within a mobile home such as inside wall vs outside wall or wall vs ceiling installations; the impact of air circulation resulting from the operation of the heating, ventilating, and air-conditioning system; and the basic detector parameter of smoke detector alarm threshold. For the study only photoelectric-type smoke detectors were used. These detectors utilize the Tyndall Effect in their sensing mechanism. This limitation was imposed to limit the number of variables. Detector response was evaluated for fires in both smoldering and flaming modes. The results of the study provide a case for wall installations as opposed to ceiling installations. Further, inside wall installations may be marginally superior to outside wall installations. The most significant finding of the study suggests that, when in operation, the forced-air circulating system has a major delaying effect on detector response time to a given fire size.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)* Detector sensitivity; fire detectors; mobile homes; photoelectric smoke detectors; smoke detector installation; smoke detector placement; smoke detectors.

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