AN EVALUATION OF FIRE DETECTORS FOR RESIDENTIAL PLACEMENT

Los Angeles City Fire Department

Fire Prevention Bureau

Research Unit

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DEDICATION

This report is dedicated to the Chief Engineer and General Manager of the Los Angeles City Fire Department, John C. Gerard, whose leadership and interest in research and fire safety made this report possible.

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EXECUTIVE SUMMARY

All findings and conclusions presented in this study are drawn from the original California Fire Chiefs' Fire Detector Report. Results evaluate detector response, comparing them to life safety in single-family dwellings only. They are not intended for application to multi-family public corridors, but could be applied to an individual dwelling unit of an apartment building.

As discussed in the Introduction of this report, the three basic questions relating to detectors will be answered - type, quantity, and placement.

The first group of pie charts is an assessment of all detector alarms, not just "best case" detectors. The first of the Group 1 charts quantify "high occupancy" area detector alarms for the entire test program. Tests were generally terminated at 500°F. to give all detectors the opportunity to alarm. The top graph of Group 1 provides an overall assessment of the number of detectors installed to the number of detectors actually alarming. They are also an indication that a single detector in a single location is not sufficient for adequate escape.

The middle graph of Group 1 narrows the focus of detector alarms by only considering detectors that alarmed prior to reaching any of the potentially hazardous levels. The percentage of heat detector alarms fall off dramatically from the previous graph indicating heat detectors should not be depended upon to provide the only alarm.

The bottom graph of Group 3 adds two minutes to the previous graph and considers only detectors that provided two minutes of warning prior to reaching potentially hazardous levels. These graphs further emphasize the need for more than one detector in more than one location. Heat detectors by themselves obviously do not provide sufficient warning.

In summary, Group 1 charts indicate smoke detectors, either the ionization or photoelectric type, must be relied upon to provide an alarm for adequate escape.

"Type" of detector is a difficult question to answer. The bar graphs in Group 2 record the earliest responding detector for each test and compare its alarm time to the assumed hazardous levels. Only the earliest detector to alarm is considered. All other detectors of a specific generic type are disregarded. Taking the best response of a specific generic type of detector is a conservative approach providing maximum escape time. The response characteristics of heat detectors are further graphically illustrated for each test.

The Group 3 matrix charts answer the "best type" detector question by extracting from Group 2 and breaking the data down into the following: initial ignition source, i.e., smoldering or flaming; room of fire origin; and detector location by rooms. As might be expected, ionization detectors provided the best response to flaming ignition source and photoelectric detectors responded best to smoldering fire sources. This matrix further illustrates how well a detector fared to a remote source of ignition, i.e., detectors located in other than room of fire origin.

Overall, for both one-story and two-story houses, the results point to an ionization detector in the living room and a photoelectric detector in the hall and bedrooms. Photoelectric and ionization detectors fared equally well in the kitchen. Subjectively, however, ionization detectors had to be fanned to keep them quiet before the grease fire tests in a kitchen could begin. That same problem did not occur with photoelectric detectors in the kitchen. This report must further emphasize that only the first detector of each generic type to alarm is considered for the makeup of the matrix.

The questions of how many (quantity) and where (location), need to be answered. The common area, leading to all portions of a house, is the hall. This area would be the natural location if one were to provide only one detector. Fire protection agencies recommend the public sleep with bedroom doors shut. Closed doors will provide optimum escape time for a night time scenario where an individual is asleep. The doors will diminish the amount of heat and smoke transmitted to a sleeping individual for all fires originating outside the bedroom.

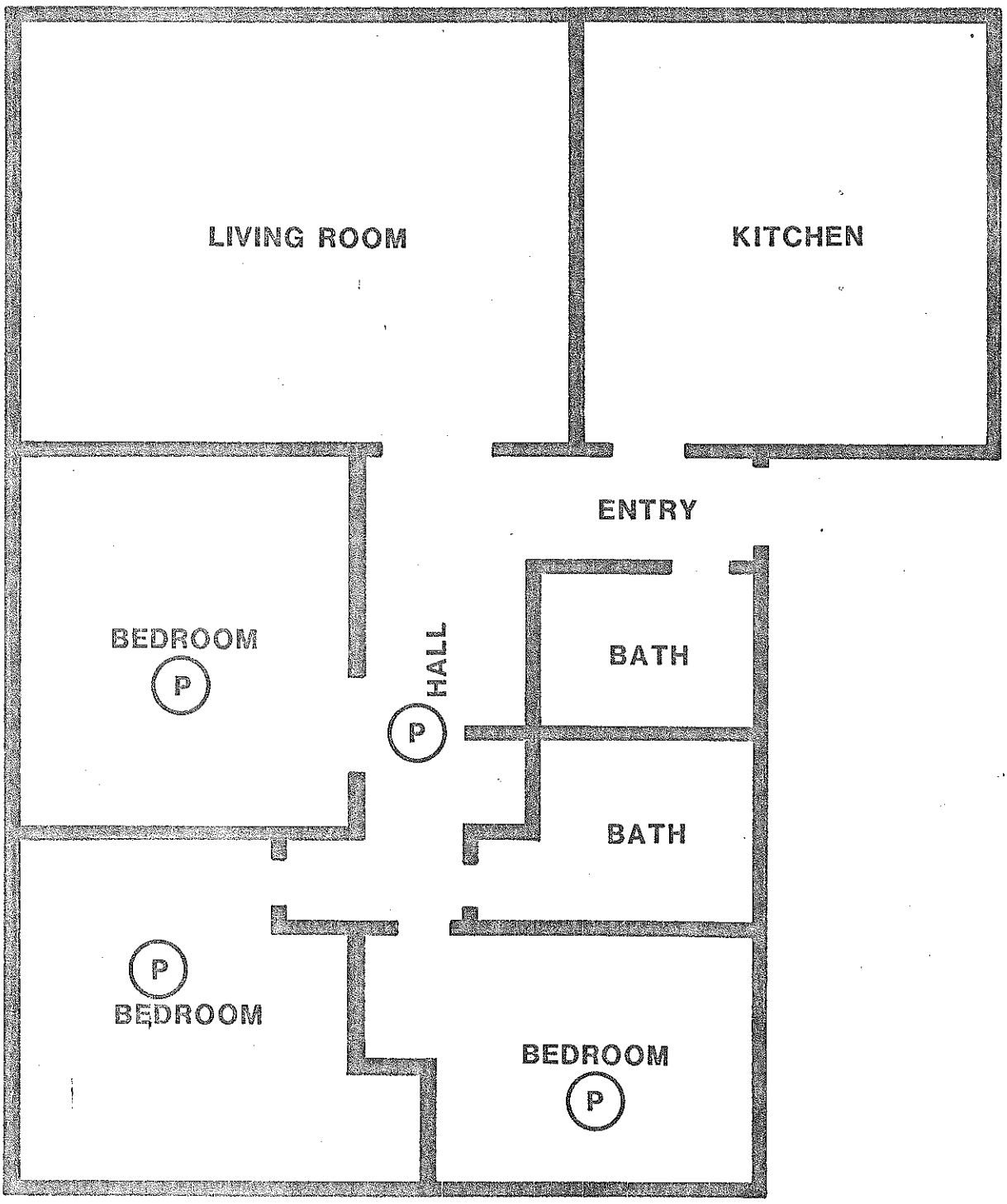
For a fire originating in the bedroom, a detection device should be provided in the bedroom; Group 2 charts illustrate the need for a detection in a bedroom for a fire originating in the bedroom whether the doors are open or closed.

Group 4 bar graphs evaluate the need for a living room detector. Probable total escape or warning time provided by detectors located in the living room and hallway for a fire originating in the living room is depicted in these bar graphs.

The one-story house had 10 scenarios with the fire originating in the living room. In all but two cases, the hall detector provided adequate escape time. The two-story house with 14 scenario fire starts in the living room showed 50 percent of the time a detector in the living room provided escape time for the occupants of the house, in those cases a hall detector did not.

SUMMARY AND FLOOR PLANS

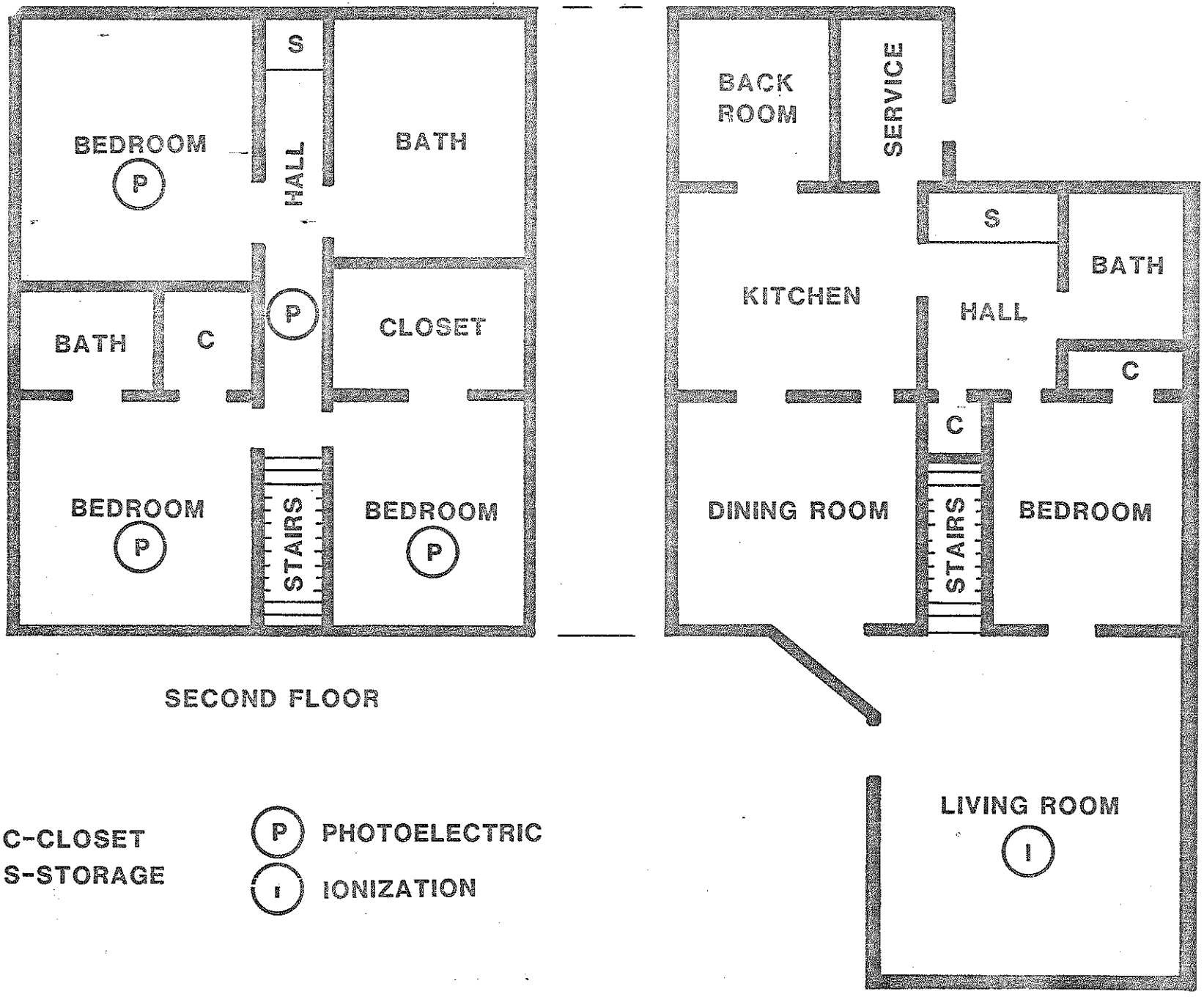
Floor plans on the following pages have been provided illustrating typical one- and two-story conventional homes of relatively modern construction. Photoelectric detectors are suggested in each of the bedrooms and the hall for both the one-story and two-story configurations. An ionization detector is added to the living room of the two-story home only. For the one-story home, the "best case" detector in the hall provided sufficient escape in 80 percent of the cases. The above generic types of detectors have been added to the floor plans. This is a minimum recommendation of life safety which affords a two minute adequate escape time from single-family residences.



TYPICAL 1-STORY RESIDENCE

(P) PHOTOELECTRIC

(I) IONIZATION



TYPICAL 2-STORY RESIDENCE

INTRODUCTION

The fire record of the United States has been by far the worst of any industrialized nation in the world. Fire deaths occur at an alarming rate every year and most of these deaths are attributed to residential fires. The public has largely ignored this deplorable situation, although it has been reported by many groups including the National Commission on Fire Prevention and Control in America Burning.

An accepted solution to part of the residential fire problem is the installation of early warning fire detectors. Fire departments and fire protection groups have encouraged early warning fire detection in habitational occupancies. Quicker detection means quicker response by the fire department, less fatalities, less injuries to civilians and fire personnel, and overall decrease in fire losses. Some jurisdictions mandate the installation of fire detectors through local codes and ordinances. The Department of Housing and Urban Development (HUD) require detectors in single and multiple dwellings and nursing homes insured or assisted by HUD.

Many of these local ordinances require a minimum of one detector near the sleeping areas of a residence, generally the hallway. America Burning recommends "all model codes specify at least a single-station, early-warning detector oriented to protect sleeping areas in every dwelling unit." As a result of model code changes and recommendations by the fire community, the public may feel a single detector will

provide adequate warning. An obvious question to this presumption is, "Is a single detector enough?"

Very little data was available on fire detectors when the California Fire Chiefs' Association initiated a plan to test fire detectors. At the same time, Chief John C. Gerard, then the Fire Marshal of the City of Los Angeles, became interested in evaluating detector response data, and he presented a test plan to the International Association of Fire Chiefs. These two test ideas merged into one called the California Fire Chiefs' Association Joint Residential Fire Detection Test Program.

Using both one- and two-story dwellings, the tests were conducted under actual fire conditions as opposed to "laboratory" testing. The houses were fully furnished and the fires were started naturally, i.e., smoking fire - a cigarette was left to smolder in a sofa and allowed to progress using no accelerant to aid the fire development. Panels of eight detectors each were located on the ceilings of various rooms in each house. Each panel had three generic types of detectors - photoelectric, ionization, and fixed-temperature heat detectors. Environmental conditions were monitored at various locations inside the house: temperature, smoke obscuration, carbon monoxide level, carbon dioxide level, and oxygen level.

Environmental levels of gas, smoke, and temperature were assessed during each fire development. These potentially hazardous levels established a time frame beyond which a detector in alarm would potentially not help the occupants of the residence. An arbitrary time period of two minutes was

chosen as minimum escape time an average family needed to exit the home. For a detector or group of detectors to provide adequate protection, the family should be warned at least two minutes before the hazardous gas, smoke, or temperature level is reached.

This report evaluates actual fire data from the California Fire Chiefs' test program for one- and two-story houses to provide answers to the following questions:

- How many detectors should be installed in a home to provide a family adequate escape time?
- What generic type of detector should be installed for optimum warning?
- Where should detectors be installed for optimum warning?

SCENARIOS AND TEST SITE

Test scenarios were based upon an analysis of a statistical study entitled "The California Fire Incident and Reporting System," prepared by the California State Fire Marshal. This study was based on a careful analysis of residential fires occurring between 9 p.m. and 6 a.m. during the period from 1974 through 1976 to determine the most commonly occurring lethal fires. The scenarios that were reenacted were representative of the most typical residential fires.

One of the test houses was a typical one-story, three-bedroom house with a central hall floor plan. The second test house was a conventional two-story dwelling with a basement such as is commonly found in midwestern and eastern communities. The test homes were completely furnished for the test with

contemporary furnishings, complete with carpets, drapes, curtains, books, bed sheets, bedspreads, blankets, etc. After each test, the structure was repaired, repainted, and furnished preparatory to the next test. Each of the basic scenarios was repeated a number of times in each of the two houses with slightly varying conditions. One test of each scenario was intended to represent a summer pattern, i.e., the bedroom doors and windows were open and the forced air heater was off. The other tests of each scenario always had the forced air heater on and the windows and doors were open in the bedrooms in different predetermined combinations.

A series of tests were also conducted in each house which simulated a child playing with matches in a clothes closet. The bedroom was completely furnished and the closet contained 50 pounds of cotton and polyester clothing hung on metal hangers as well as 20 pounds of shoes, and four boxes of children's games on the storage shelf. A lit candle placed under the hanging clothing was used to simulate the child playing with matches. In each case, the results of these tests were startling. The environment in the area of the fire would become life threatening within three minutes as judged by temperature, carbon monoxide, and smoke levels. This scenario was the most dangerous and damaging scenario tested.

While the test program was highly successful, there were numerous problems to be overcome. For example, in some cases if a burning cigarette placed in a couch self-extinguished, or if a door blew open, the entire test would be repeated.

In many cases, this would require extensive repair work, the retesting of all instrumentation, and otherwise making the house ready again.

In each test, three ionization, three photoelectric, and two heat detectors were used in various rooms of the house. These detectors were mounted, one of each kind, on a single panel. In the one-story house, seven of these panels, each with eight detectors, were mounted in various rooms of the house. In the two-story house, eight panels, each containing eight detectors, were mounted at various locations.

ESCAPE CRITERIA

The adequacy of warning provided by various detectors was evaluated along the normal escape path through high occupancy areas - namely, the bedrooms, hall, and living room. The detector warning times were compared in this study to measurements of light/smoke obscuration, carbon monoxide concentration, and temperature at the five-foot level above the floor. Selected as potentially hazardous levels for occupants of a residence were smoke obscuration of 11 percent per foot, carbon monoxide concentration of 1000 ppm, and temperature of 150°F. at the five-foot level. A brief summary for these selected values are as follows:

Smoke Obscuration Level

Light or smoke obscuration level relates to an individual's ability to locate a door, negotiate stairs, or recognize contrasting surfaces in order to exit a home. No attempt has been made to

evaluate the irritant properties or the physiological and psychological effects of smoke.

A search of technical literature produced a wide range of estimates for potentially hazardous levels of optical density or smoke obscuration. Smoke obscuration values ranging from four percent per foot to 17 percent per foot were considered by various researchers as a maximum level along the escape route from a house.

The National Bureau of Standards considers 15 percent to be the maximum point for safe evacuation. Underwriters Laboratories has considered between four percent and 17 percent per foot in the smoldering crib sealed room test for its Standard 217 and finally settled on seven percent per foot. Professor D. J. Rabash at the University of Edinburgh, Scotland, has shown that humans will turn back from an exit path where visibility is obscured over a 15-foot path by an amount of 10 percent per foot. A study performed by the Home Office of Scotland indicated individuals familiar with their surroundings can experience up to 11 percent per foot of smoke and only seven percent per foot if the person is in a foreign environment. Taking a conservative approach with the consideration that occupants of a home are familiar with their escape path, 11 percent per foot of smoke obscuration was established as potentially hazardous for this study.

Carbon Monoxide Concentration

A multitude of studies have been completed on the toxicological effects of carbon monoxide. However, the vast majority of these tests have been laboratory situations on animals with little work

on humans. Fulton (1955) indicates that hemoglobin of the body's blood has affinity for combining with carbon monoxide 200 to 300 times greater than with oxygen. Studies conducted by Henderson and Haggard (1943), and A. L. Prince (1921) suggest that concentrations of 1000 to 1200 ppm for one hour will result in unpleasant to dangerous symptoms from carbon monoxide poisoning.

W. D. Claudy indicates that exposure to 800 ppm carbon monoxide for one to two hours may cause headache, dizziness, and nausea. Hemoglobin can be saturated at a very low pressure of carbon monoxide and within a short period of time result in muscular incoordination, fixity of ideas and eventual weakness, collapse, and unconsciousness. A level of 1000 ppm (0.1 percent) appears to be sufficient to produce the above effects over fairly short periods of exposure and was choosen as the potentially hazardous level.

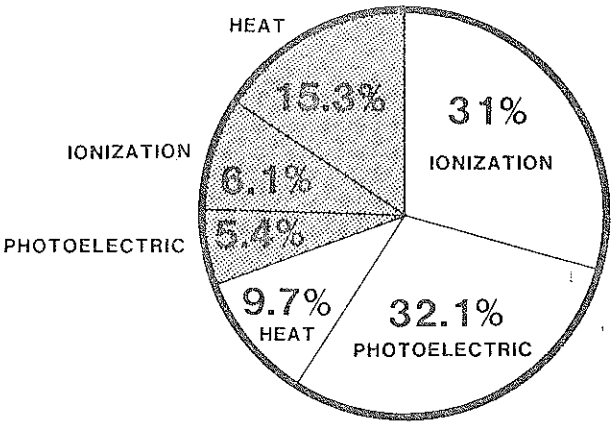
Temperature

A human being's maximum temperature exposure limit has been debated, discussed and has generated controversy for years. Operation School Burning is an accepted reference for the past two decades. The value of 150°F. was adopted for this study as the potentially hazardous level. Obviously, this temperature is dependent upon other environmental factors such as particulates of smoke and gases which tend to increase the exposure and type of clothing being worn.

GROUP 1

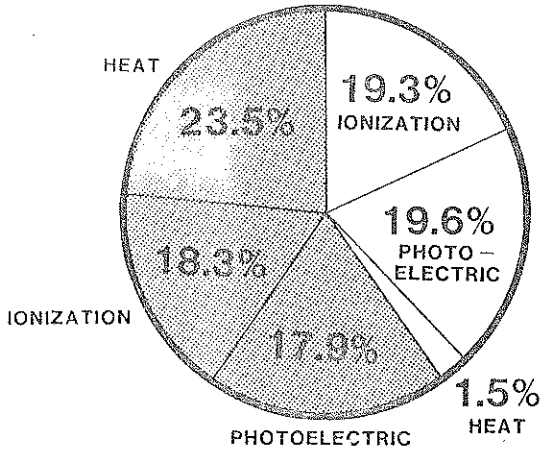
DETECTOR ALARM ASSESSMENT

ONE STORY



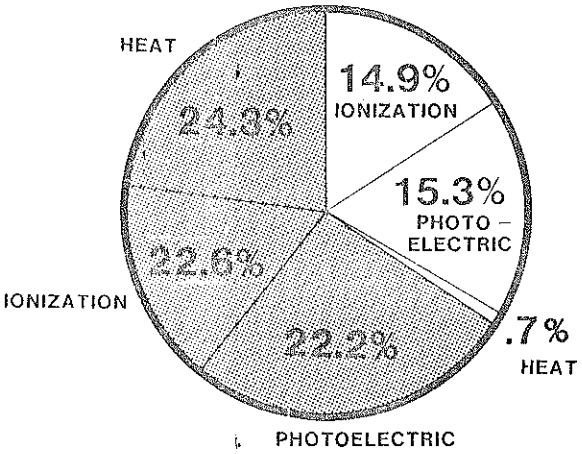
TOTAL ALARMS

CHART ILLUSTRATES THE NUMBER OF DETECTORS THAT PROVIDED AN ALARM PRIOR TO TERMINATION OF A TEST. ONLY DETECTORS LOCATED IN HIGH OCCUPANCY AREAS ARE INCLUDED. TEST TERMINATION CRITERIA WAS ONE OF THE FOLLOWING: TEMPERATURE OF 500 F, CARBON MONOXIDE LEVEL OF 10,000 PPM, CARBON DIOXIDE LEVEL OF 10%, OXYGEN DEFICIENCY OF 10%, OR FIRE WAS JUDGED TO HAVE SELF EXTINGUISED.



ALARMS PRIOR TO CRITICAL

CHART ILLUSTRATES THE NUMBER OF DETECTORS THAT PROVIDED AN ALARM PRIOR TO REACHING POTENTIALLY HAZARDOUS ENVIRONMENTAL LEVEL IN THE HIGH OCCUPANCY AREAS OF THE HOUSE.

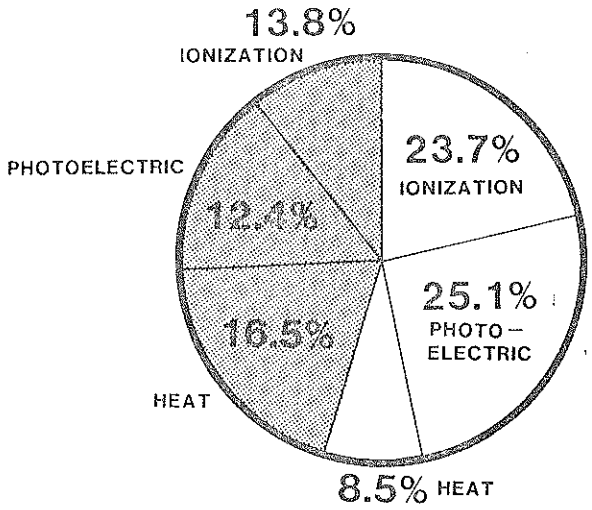


ALARMS 2 MINUTES PRIOR TO CRITICAL

CHART ILLUSTRATES THE NUMBER OF DETECTORS THAT PROVIDED AN ALARM 2 MINUTES PRIOR TO REACHING A POTENTIALLY HAZARDOUS ENVIRONMENTAL LEVEL IN THE HIGH OCCUPANCY AREAS OF THE HOUSE. TWO MINUTES IS ASSUMED TO BE THE TIME REQUIRED TO ASSURE AN EFFECTIVE ESCAPE FROM THE HOUSE. DETECTORS LOCATED IN HIGH OCCUPANCY AREAS ONLY INCLUDED.

LEGEND: NO ALARM ▒ ALARM □

TWO STORY



TOTAL ALARMS

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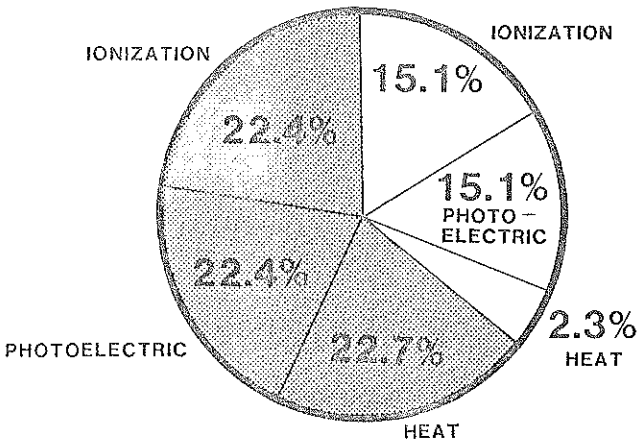
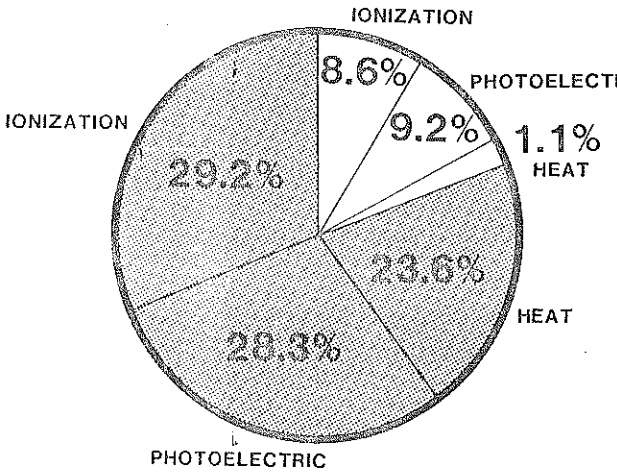


ALARMS PRIOR TO CRITICAL

CHART ILLUSTRATES THE NUMBER OF DETECTORS THAT PROVIDED AN ALARM PRIOR TO REACHING POTENTIALLY HAZARDOUS ENVIRONMENTAL LEVEL IN THE HIGH OCCUPANCY AREAS OF THE HOUSE.



ALARMS 2 MINUTES PRIOR TO CRITICAL

CHART ILLUSTRATES THE NUMBER OF DETECTORS THAT PROVIDED AN ALARM 2 MINUTES PRIOR TO REACHING A POTENTIALLY HAZARDOUS ENVIRONMENTAL LEVEL IN THE HIGH OCCUPANCY AREAS OF THE HOUSE. TWO MINUTES IS ASSUMED TO BE THE TIME REQUIRED TO ASSURE AN EFFECTIVE ESCAPE FROM THE HOUSE. DETECTORS LOCATED IN HIGH OCCUPANCY AREAS ONLY INCLUDED.

LEGEND: NO ALARM ▒ ALARM □

GROUP 2

COMPARING DETECTOR TYPE TO HAZARD LEVEL

DETECTOR TYPE VS. HAZARD LEVELS

Data presented on these graphs relate potentially hazardous environmental levels occurring during a fire to the first alarm time of the three generic fire detectors represented in the test program.

The bar graphs depict the amount of advance warning a detector provides prior to the time smoke, gas, or temperature builds to potentially hazardous levels. Potentially hazardous levels which impact upon an individual's ability to leave their residence where chosen to be the following:

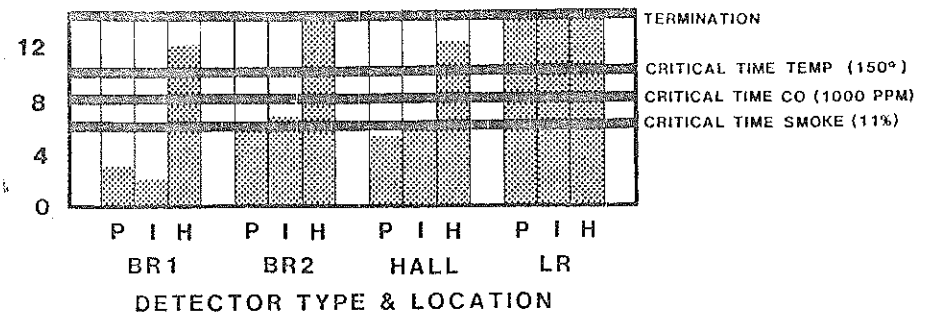
1000 ppm of carbon monoxide

150°F. temperature

11 percent per foot smoke obscuration

All values were measured at a height of five feet above the floor.

Bar graphs are presented for each scenario. Twelve bars represent the three generic types of detectors - photoelectric, ionization, and heat. Bedrooms, hall, and living room - "high occupancy" areas of the house are only illustrated. The escape route from a house would normally be through these "high occupancy" areas. An example of a graph:



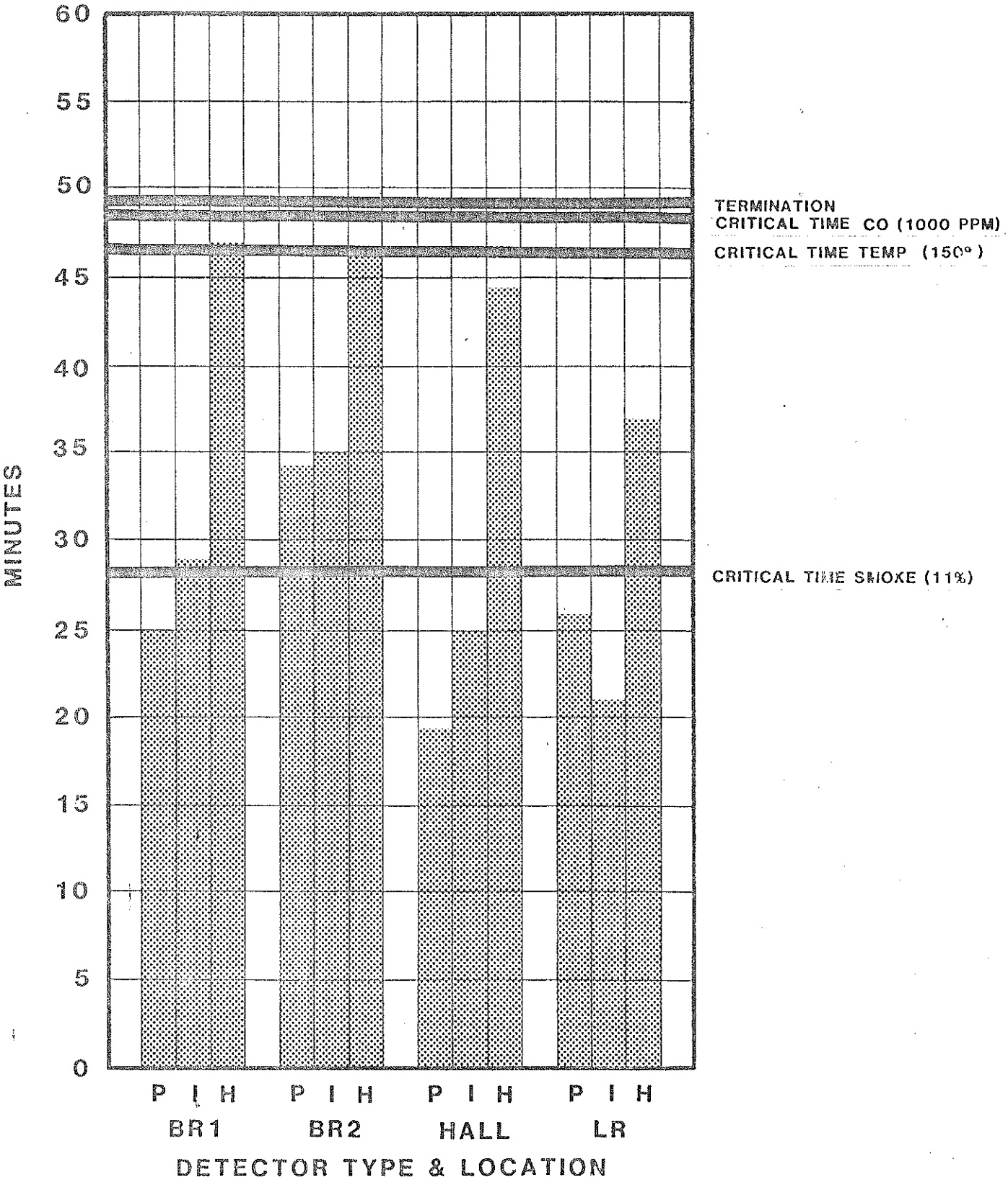
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

From this example, the potentially hazardous levels reached are as follows: smoke obscuration reached at six minutes into the test, carbon monoxide at eight minutes and temperature at ten minutes.

In Bedroom No. 1, the first photoelectric detector to respond went into alarm at three minutes, providing approximately three minutes of warning prior to the smoke reaching its potentially hazardous level. The ionization detector alarmed at 1½ minutes, thus providing 4½ minutes of advance warning. The heat detector went into alarm at 12 minutes, approximately two minutes prior to test termination at 500°F. and six minutes beyond the 11 percent per foot smoke level time.

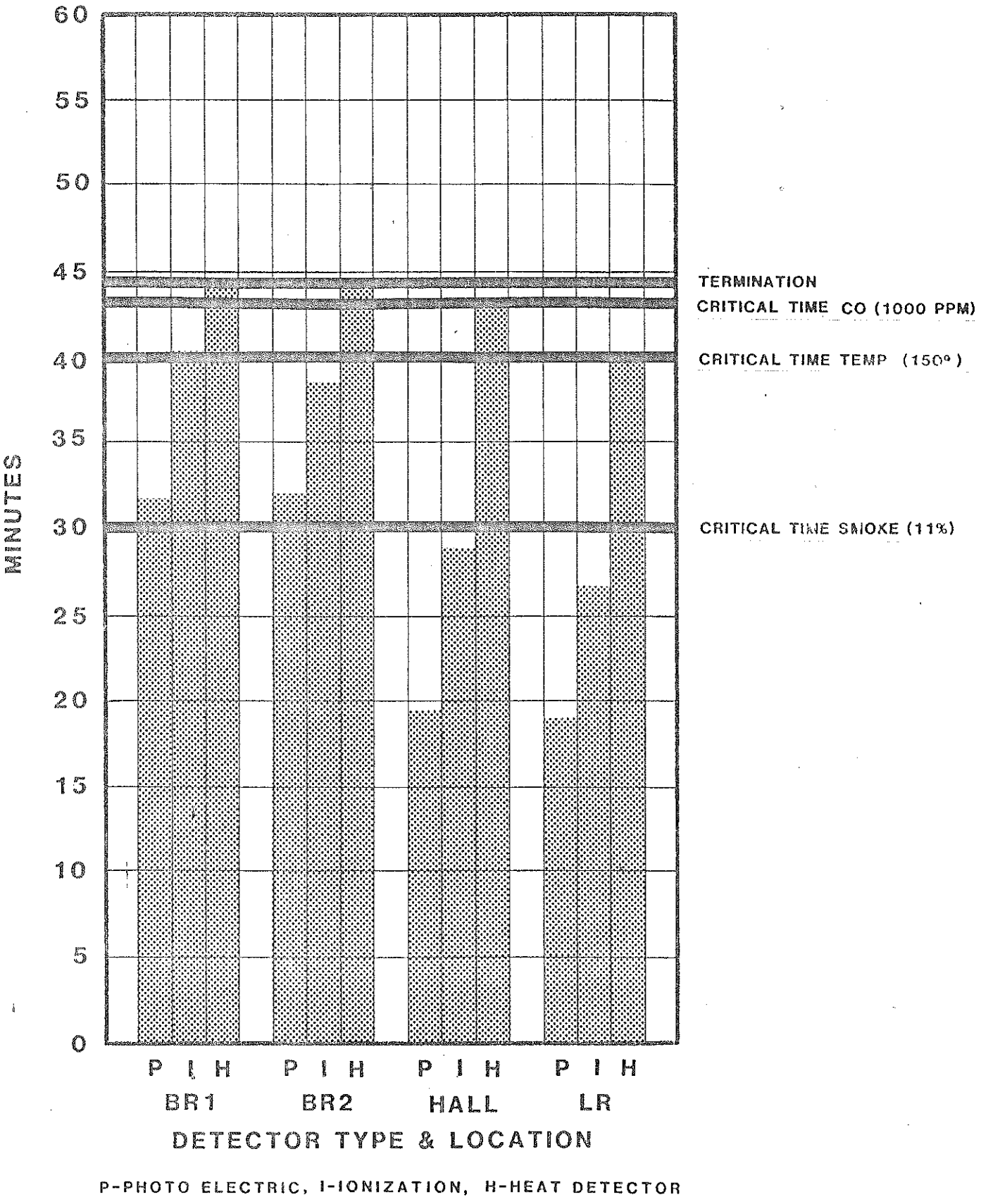
Each bar graph represents only the "best case" generic detector. Probable escape time, as it relates to a potentially hazardous level in the environment, is visually illustrated for the "best case" heat, photoelectric, or ionization smoke detector.

NAPOLEON 1
FIRE IN LIVING ROOM-SMOLDERING



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

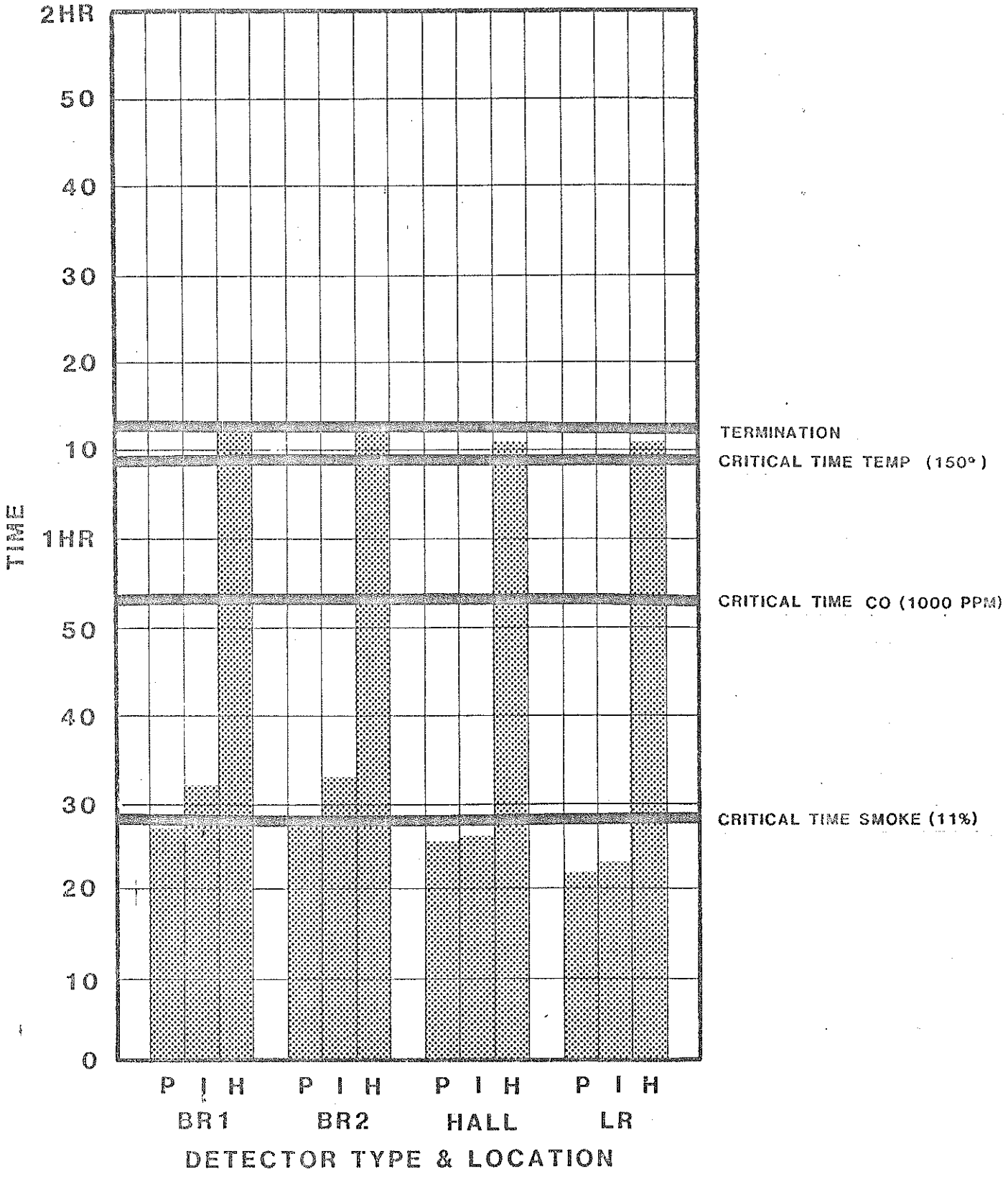
NAPOLEON 2
FIRE IN LIVING ROOM-SMOLDERING



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

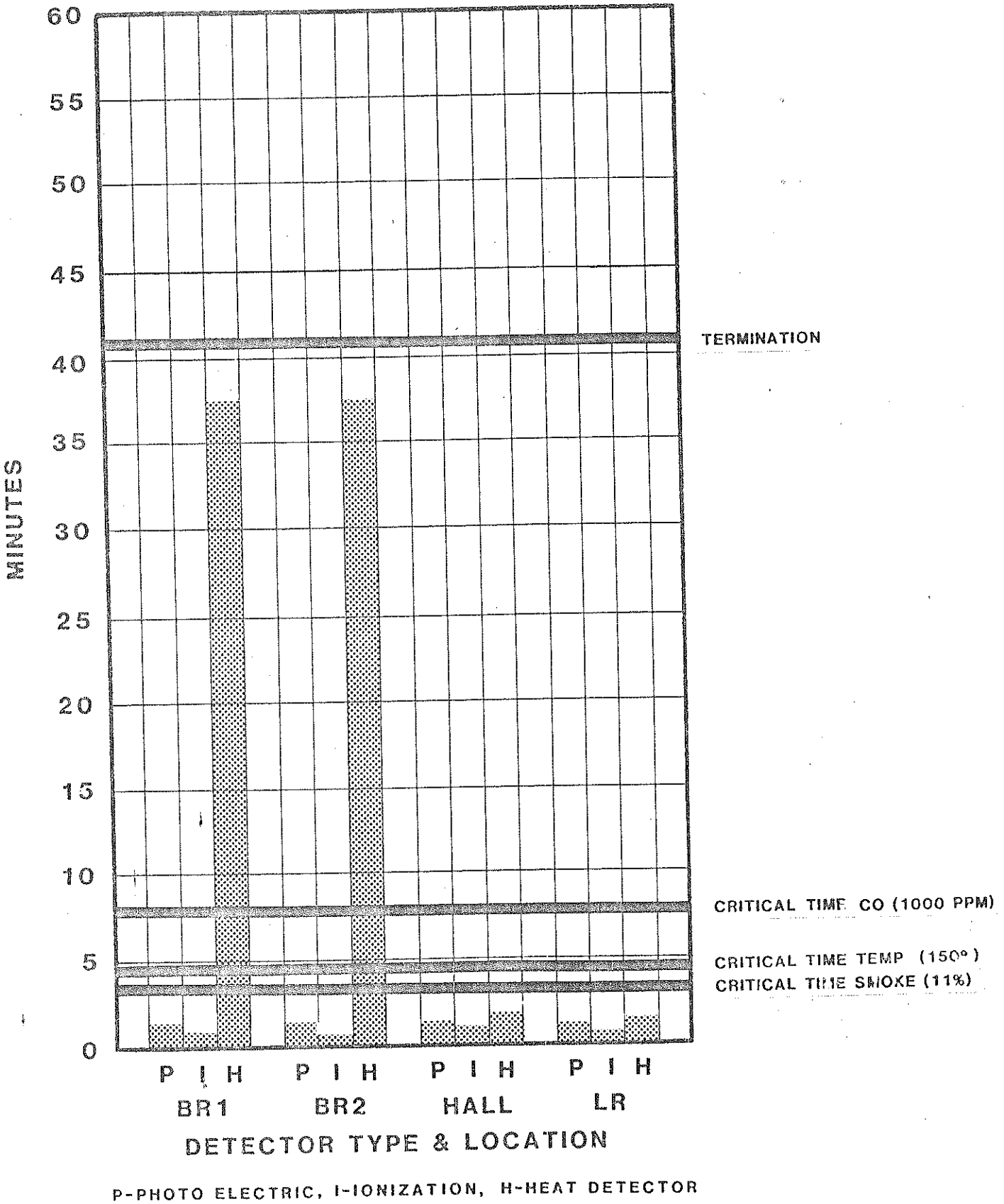
NAPOLOEON 3

FIRE IN LIVING ROOM-SMOLDERING



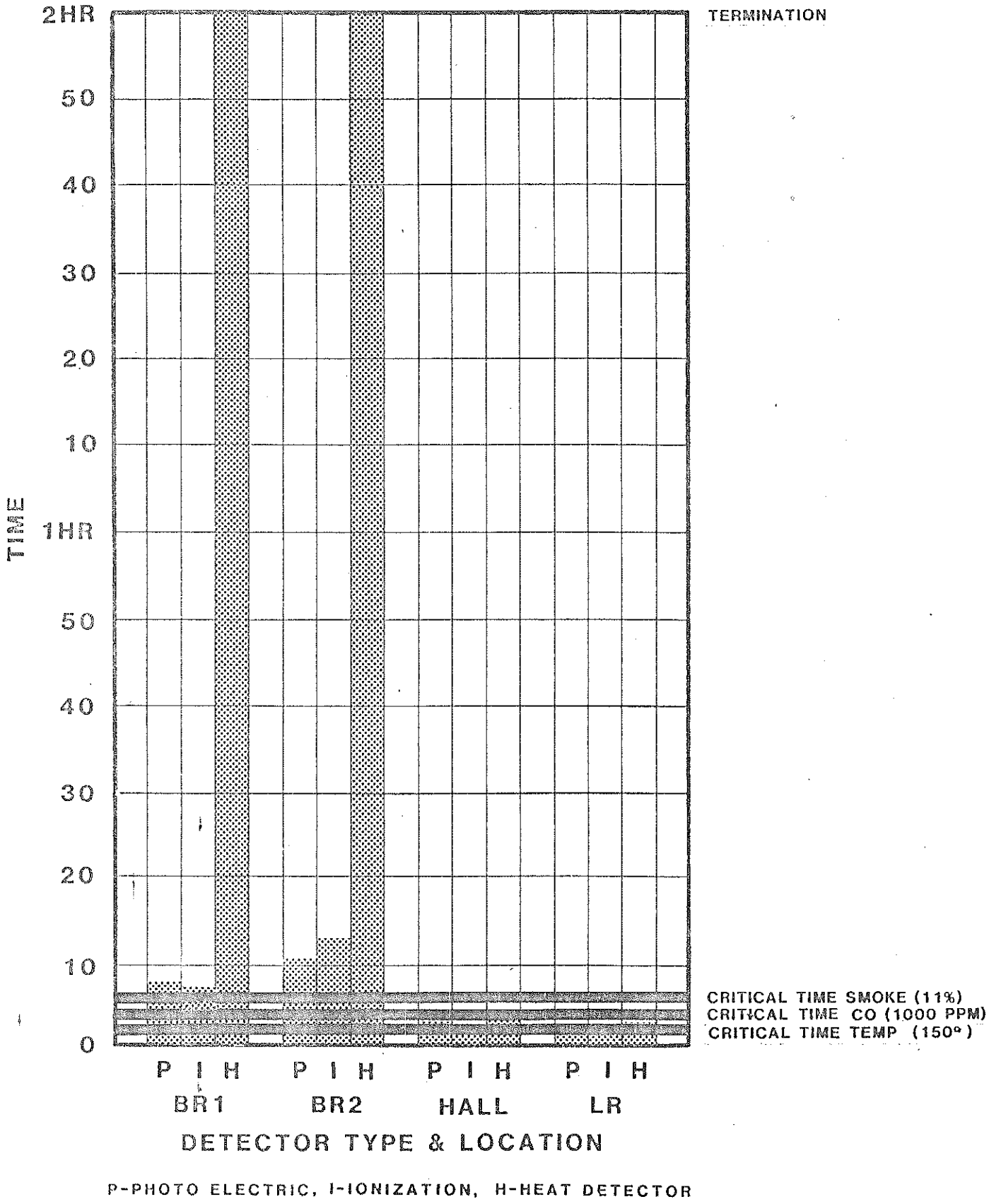
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

NAPOLEON 4
FIRE IN LIVING ROOM-OPEN FLAME



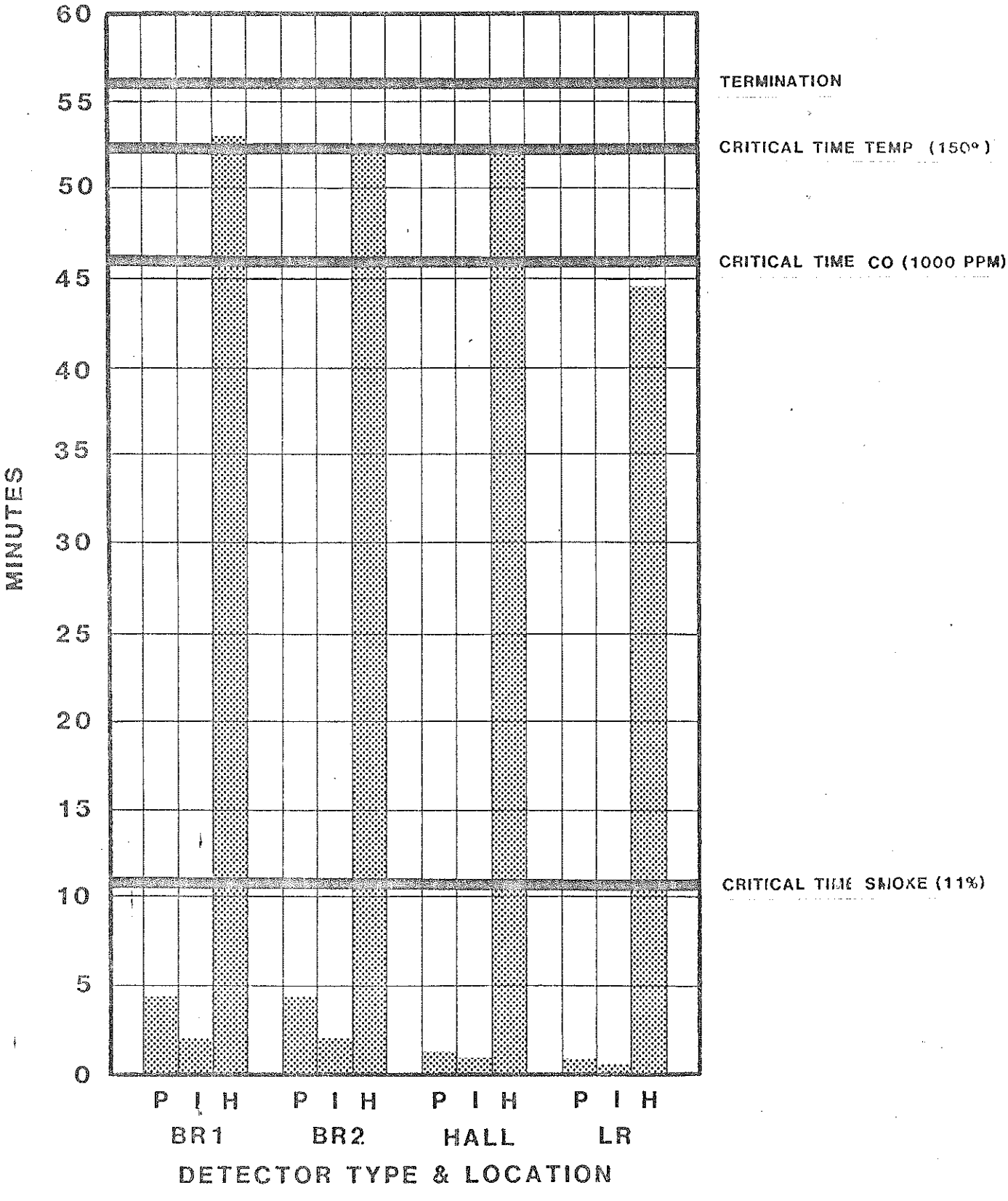
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

NAPOLEON 5
FIRE IN LIVING ROOM-OPEN FLAME



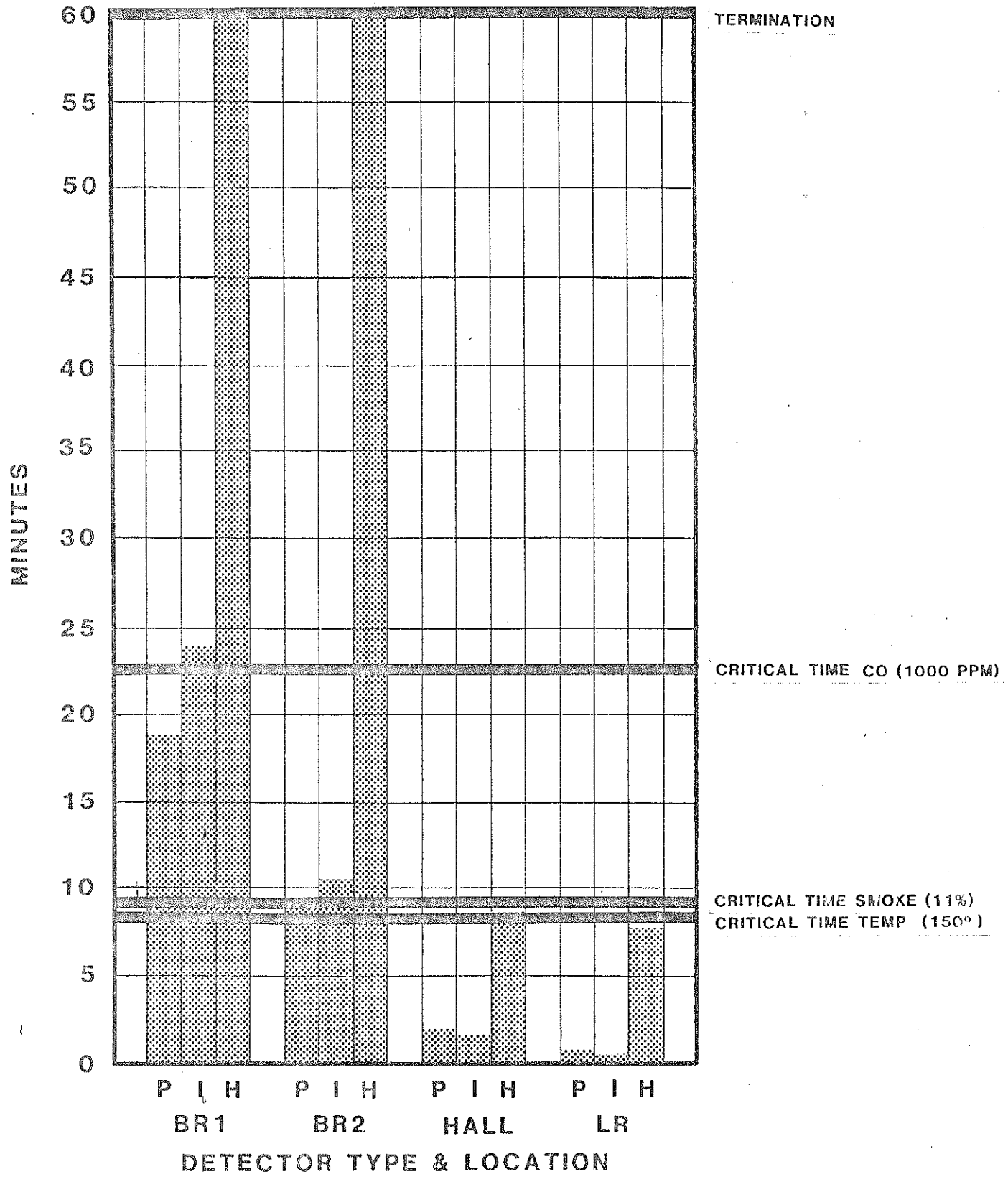
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

NAPOLEON 6
FIRE IN LIVING ROOM-OPEN FLAME

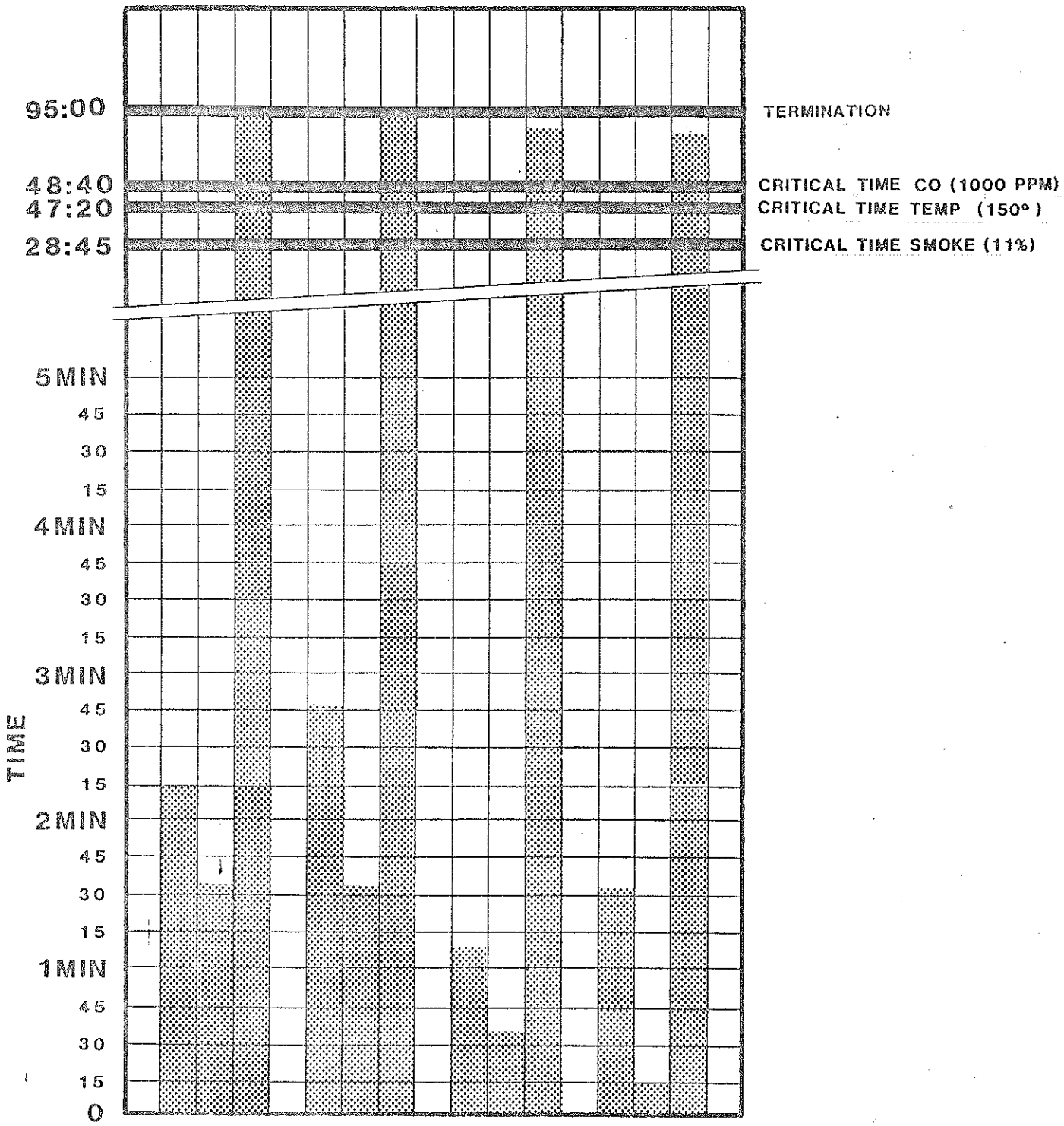


P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

NAPOLEON 7
FIRE IN LIVING ROOM-OPEN FLAME

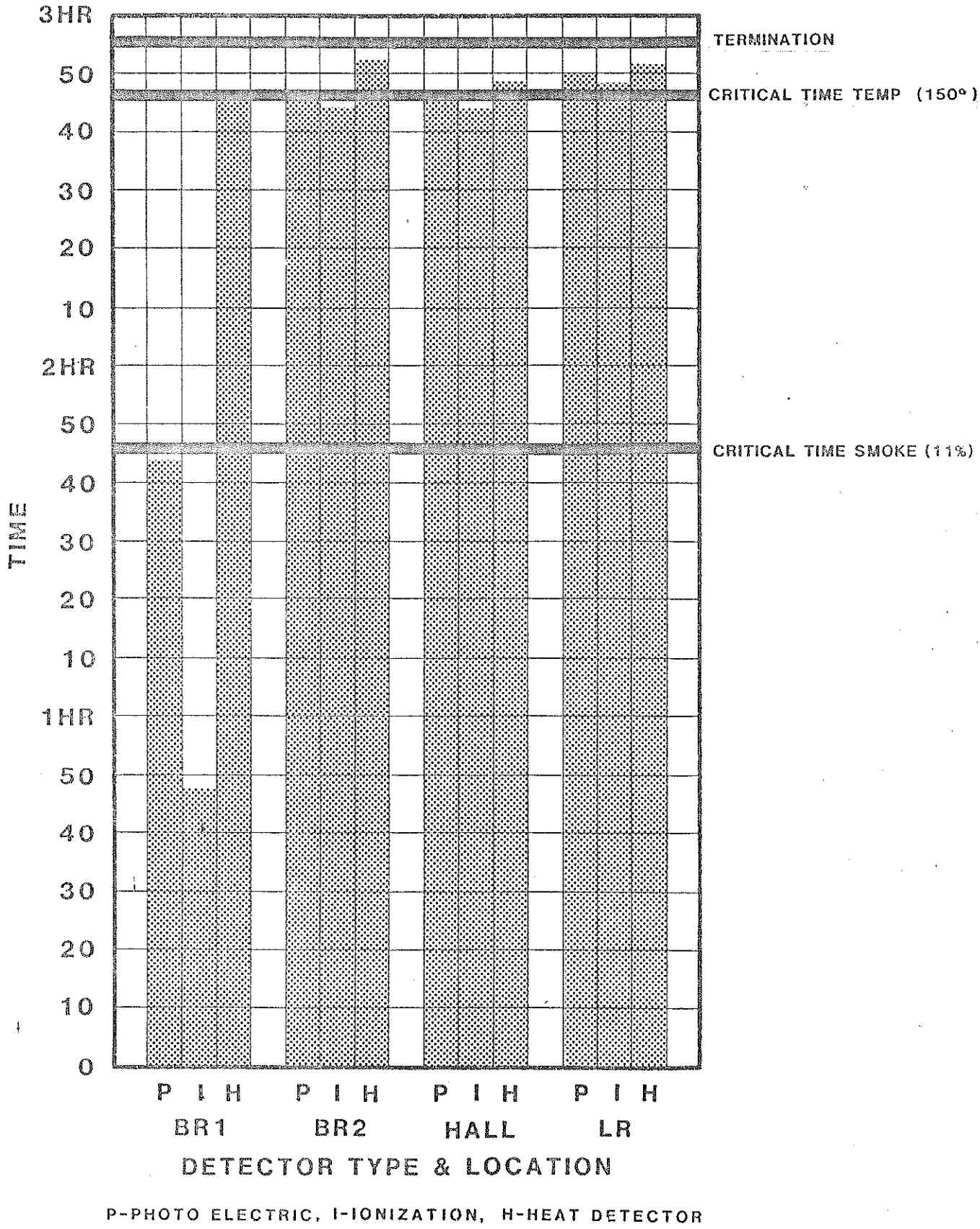


NAPOLEON 8
FIRE IN -LIVING ROOM-OPEN FLAME



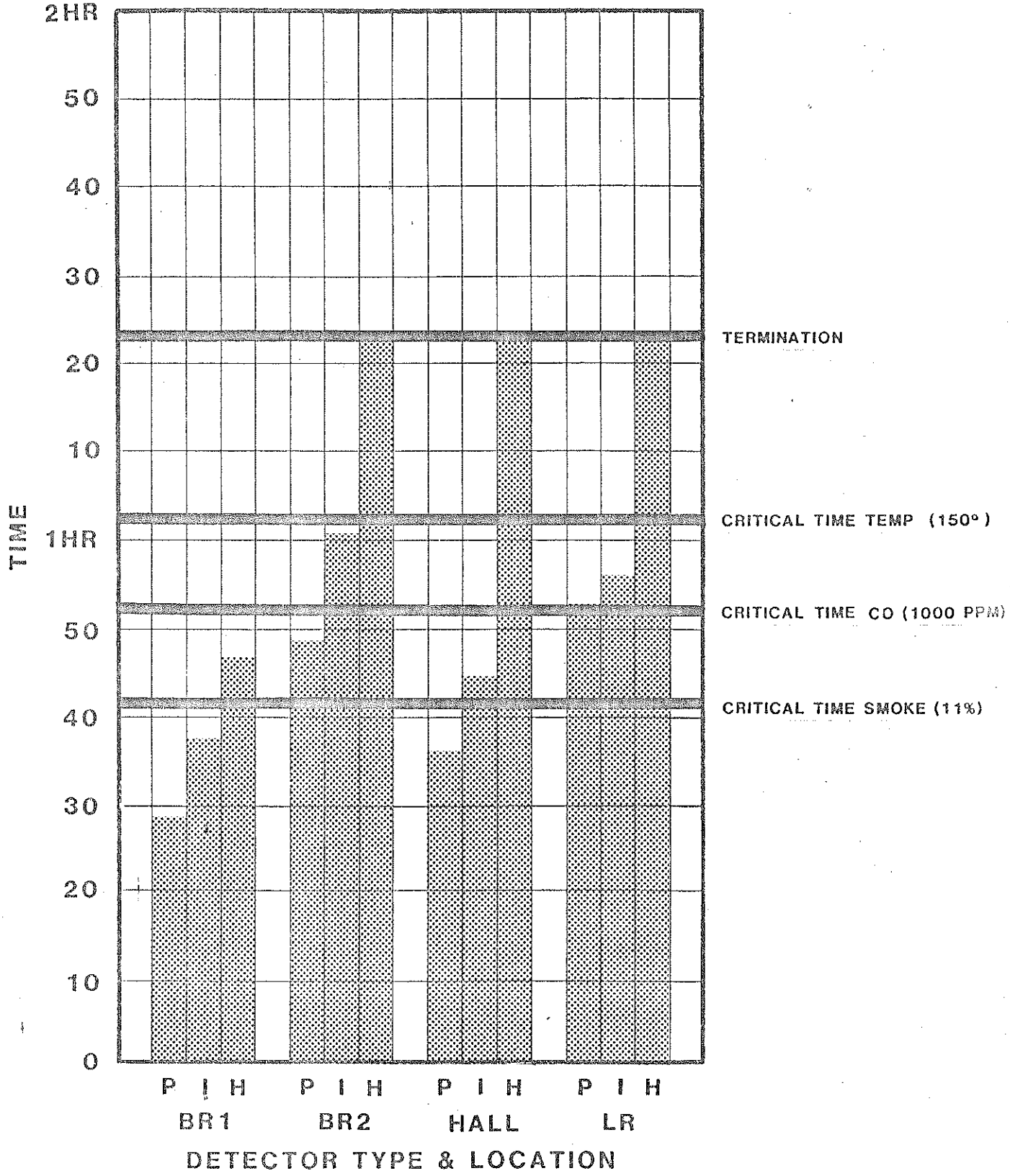
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

NAPOLEON 9
FIRE IN - BEDROOM 1-SMOLDERING



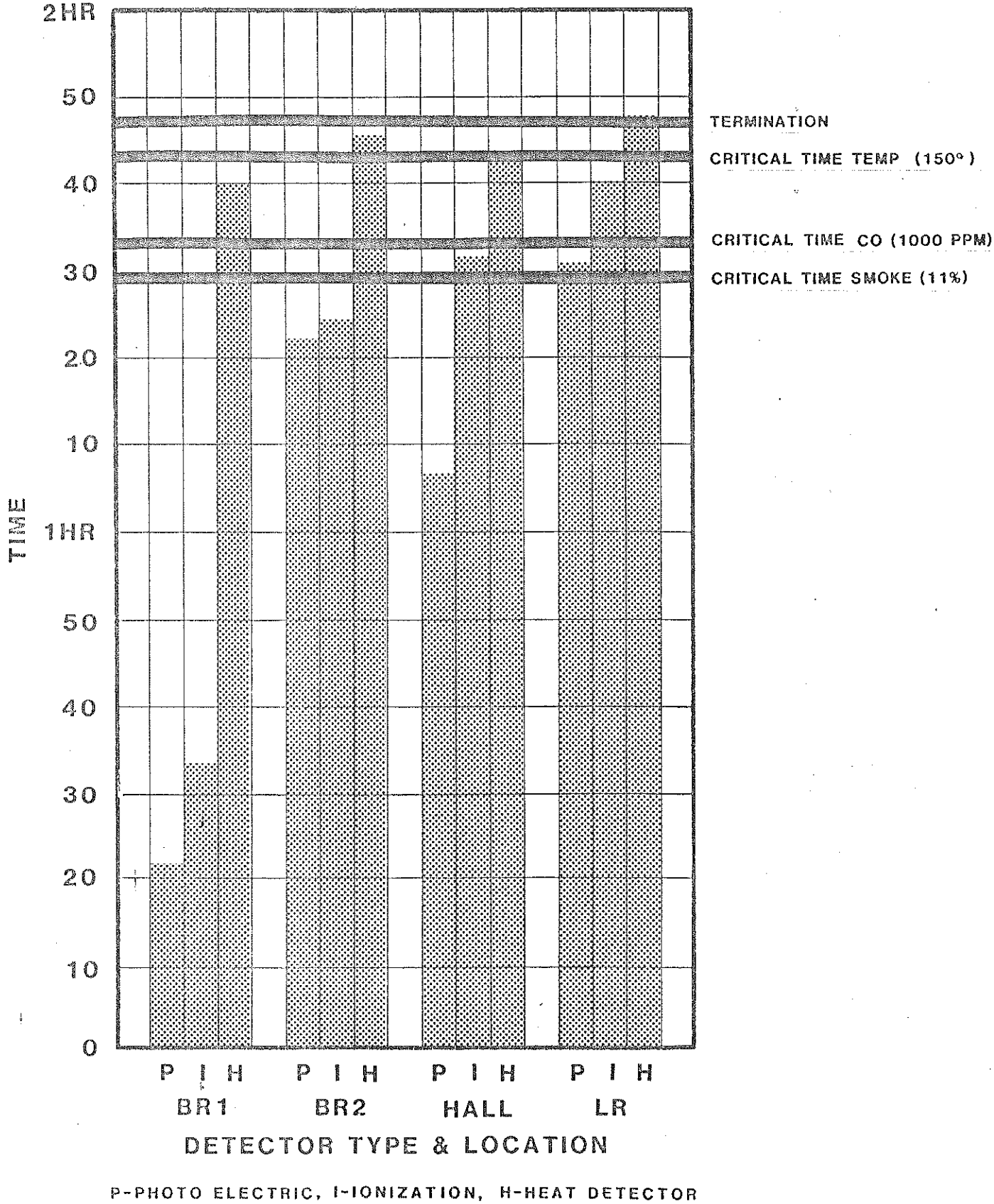
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

NAPOLEON 10
FIRE IN BEDROOM 1-SMOLDERING



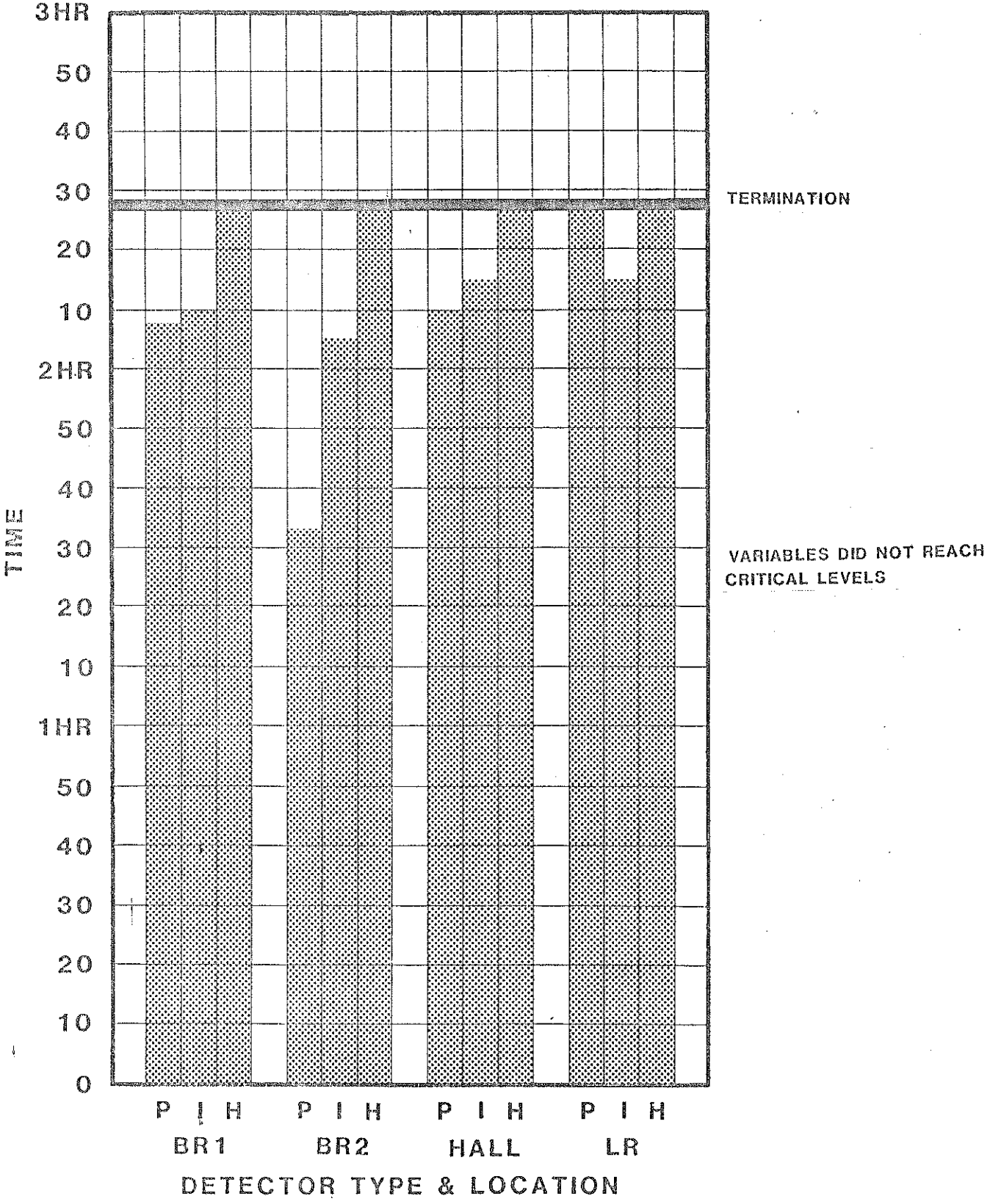
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

NAPOLEON 11
FIRE IN BEDROOM 1-SMOLDERING



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

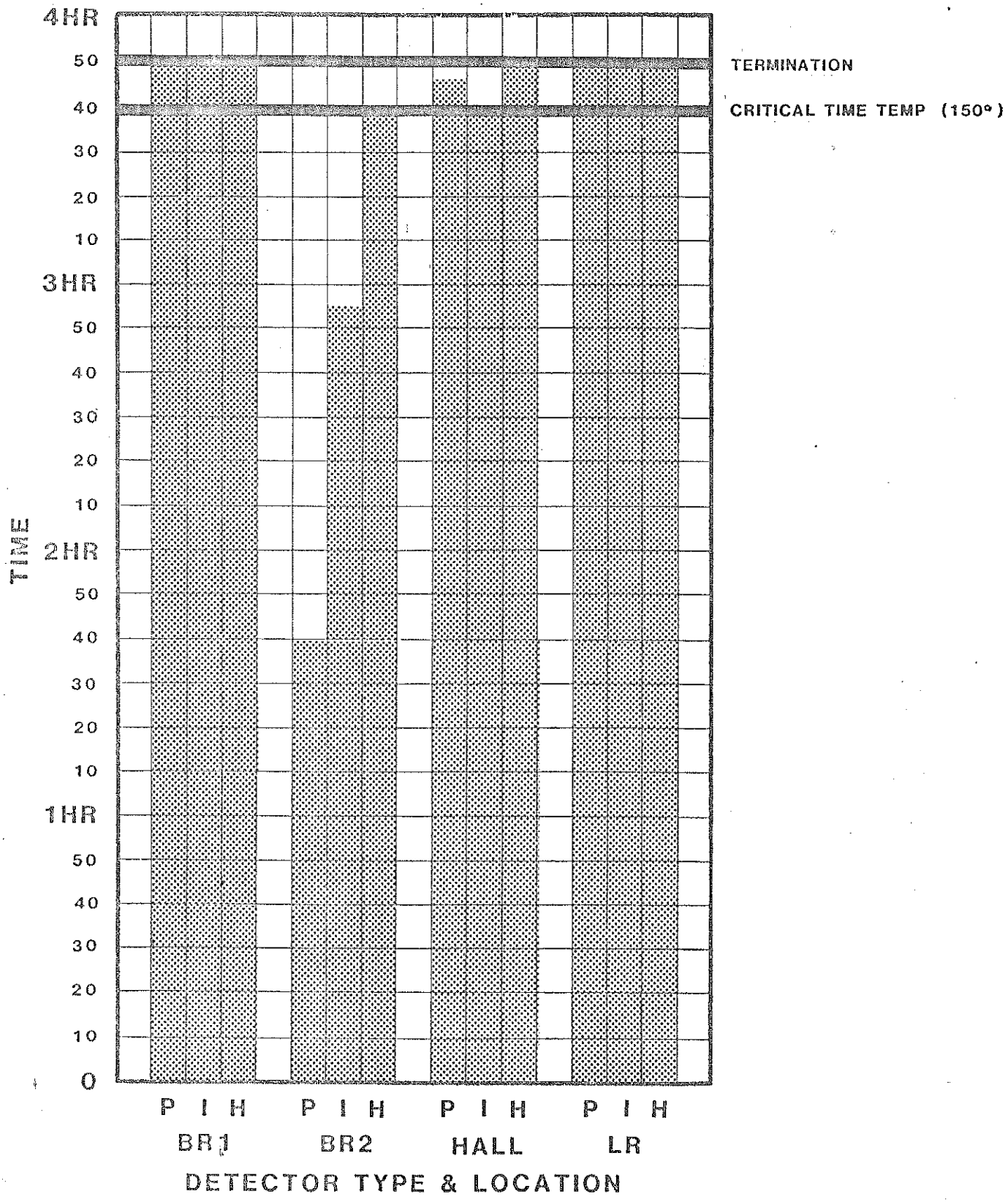
NAPOLEON 12
FIRE IN - BEDROOM 2-SMOLDERING



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

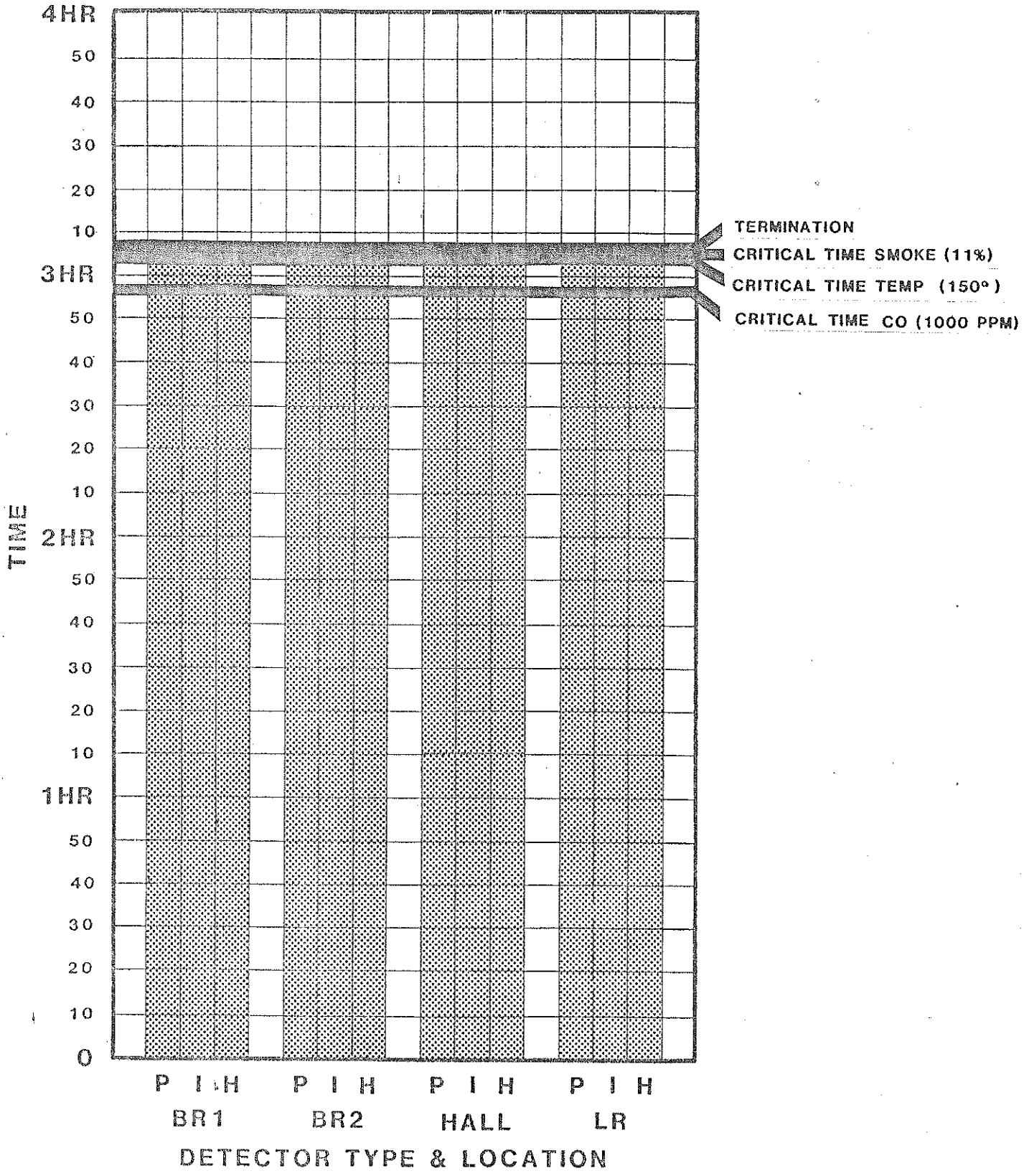
NAPOLEON 13

FIRE IN - BEDROOM 2- SMOLDERING



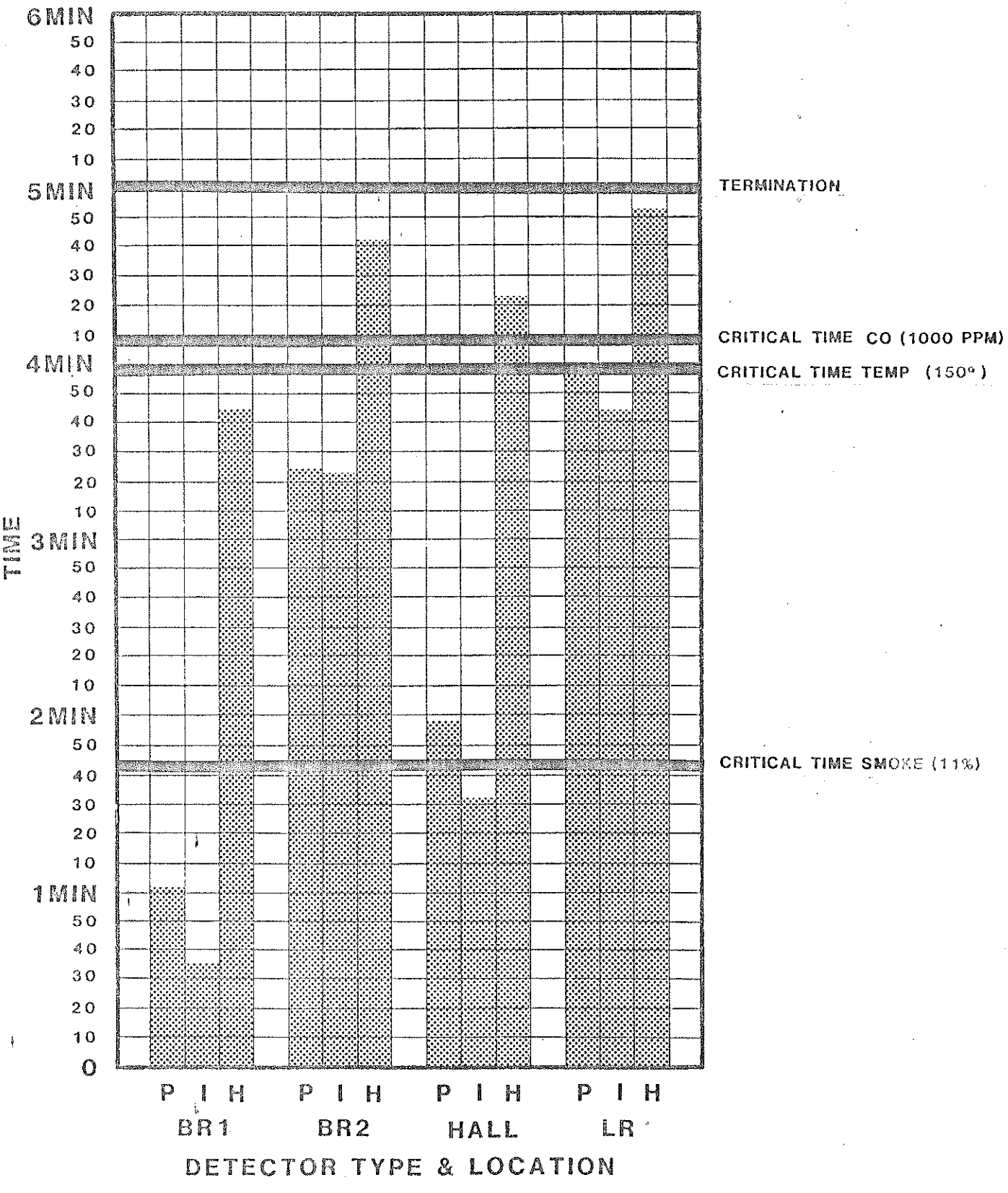
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

NAPOLEON 14
FIRE IN -BEDROOM 2-SMOLDERING



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

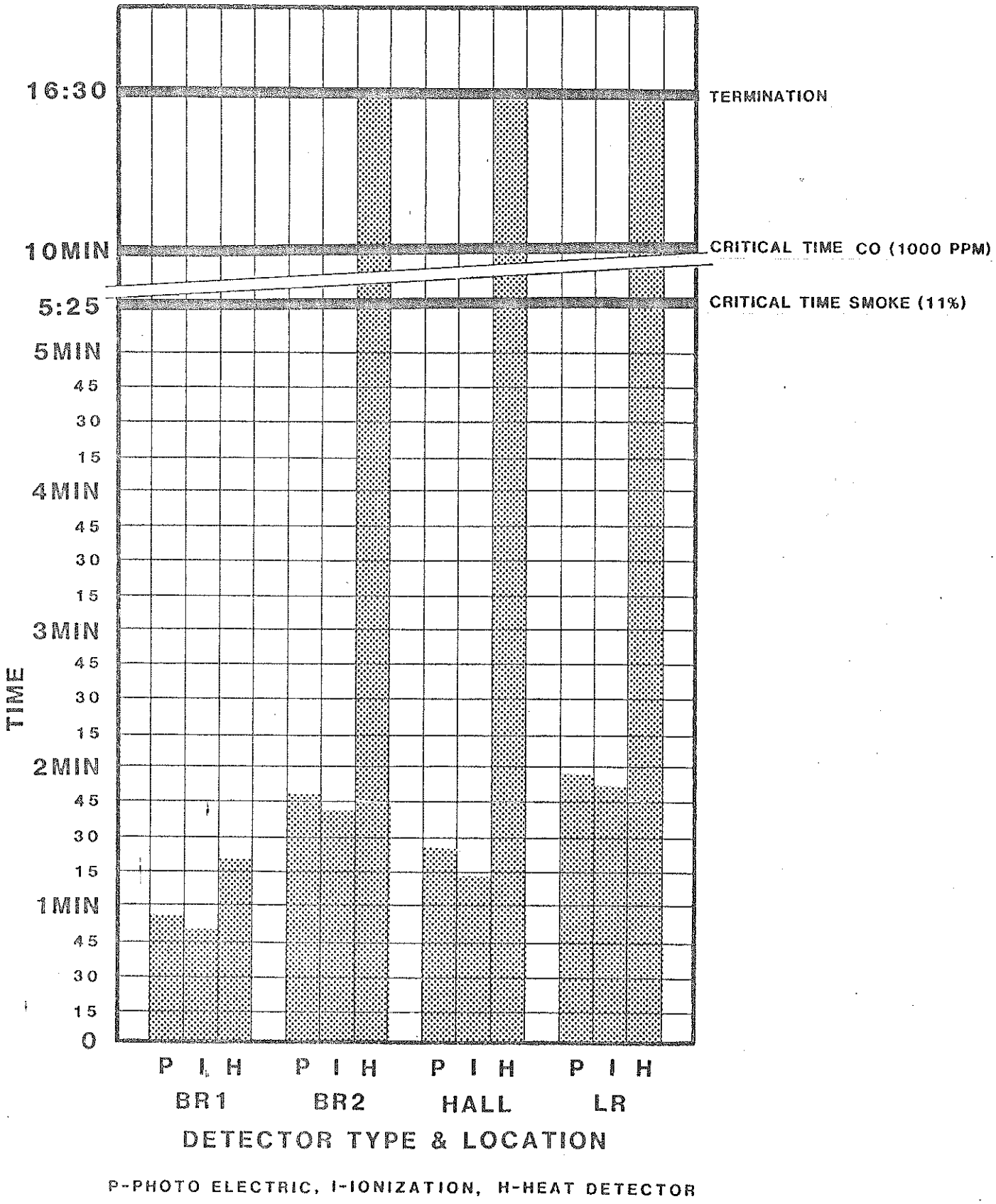
NAPOLEON 15
FIRE IN BEDROOM 1 - OPEN FLAME



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

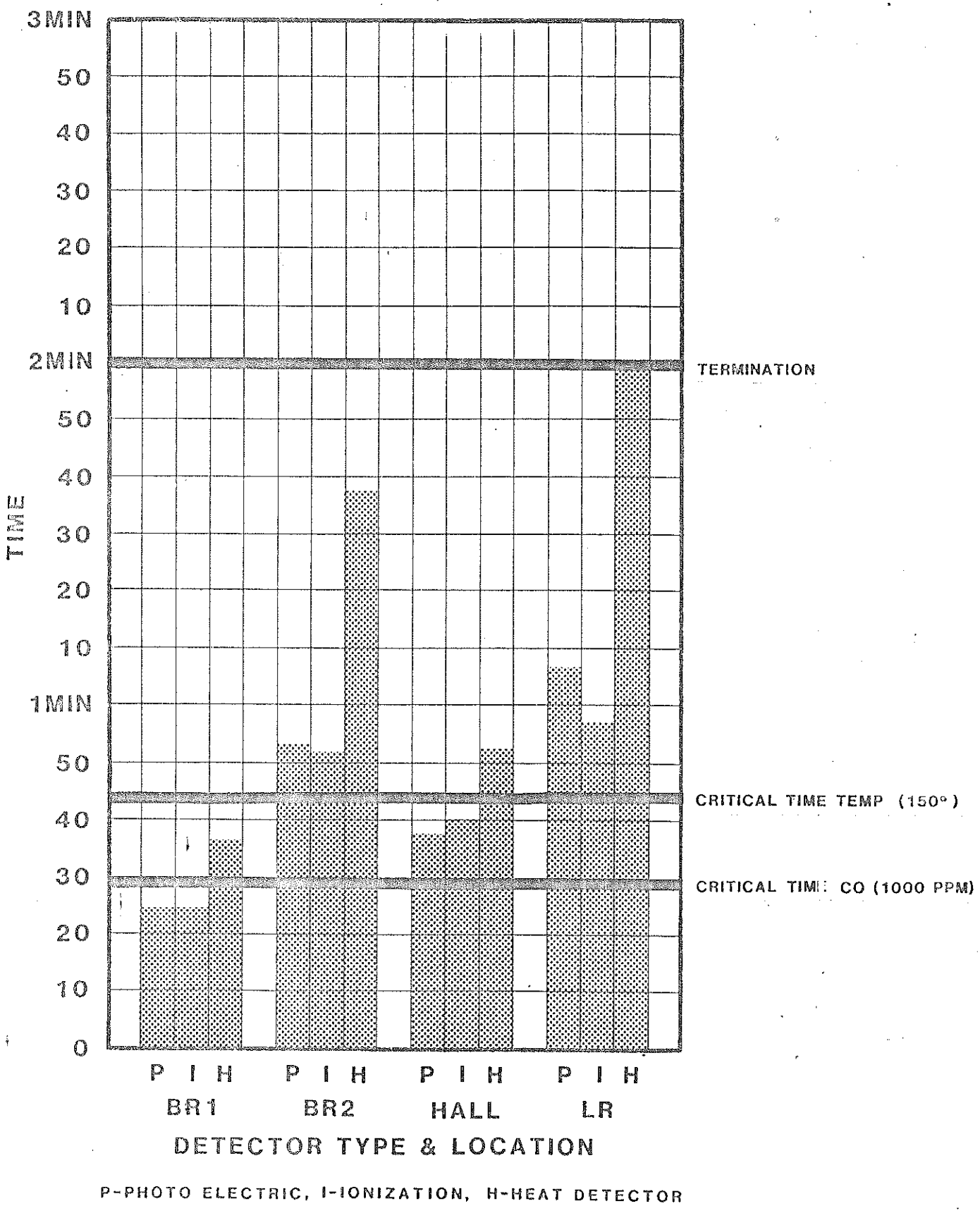
NAPOLEON 16

FIRE IN -BEDROOM 1-OPEN FLAME



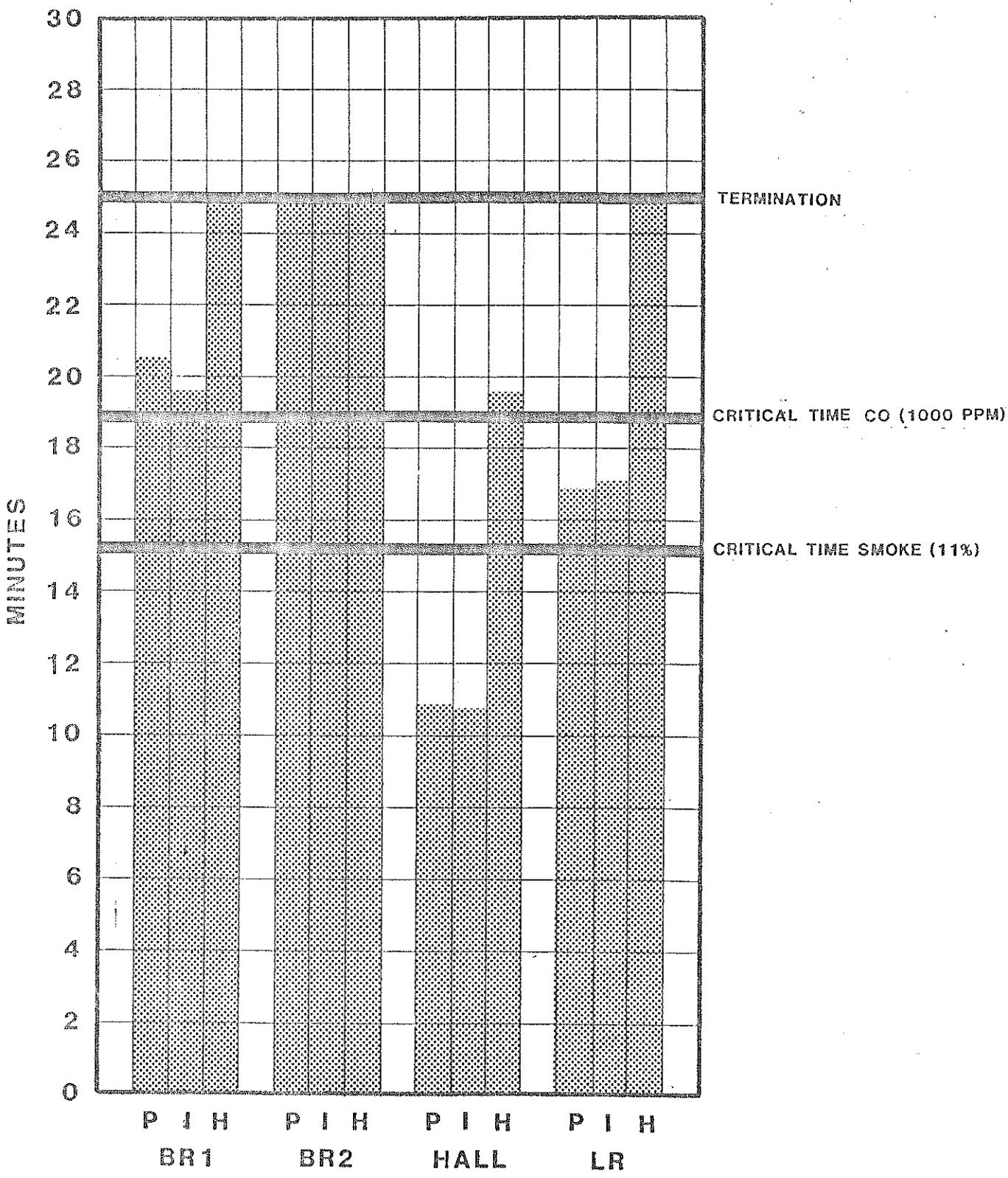
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

NAPOLEON 17
FIRE IN - BEDROOM 1-OPEN FLAME



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

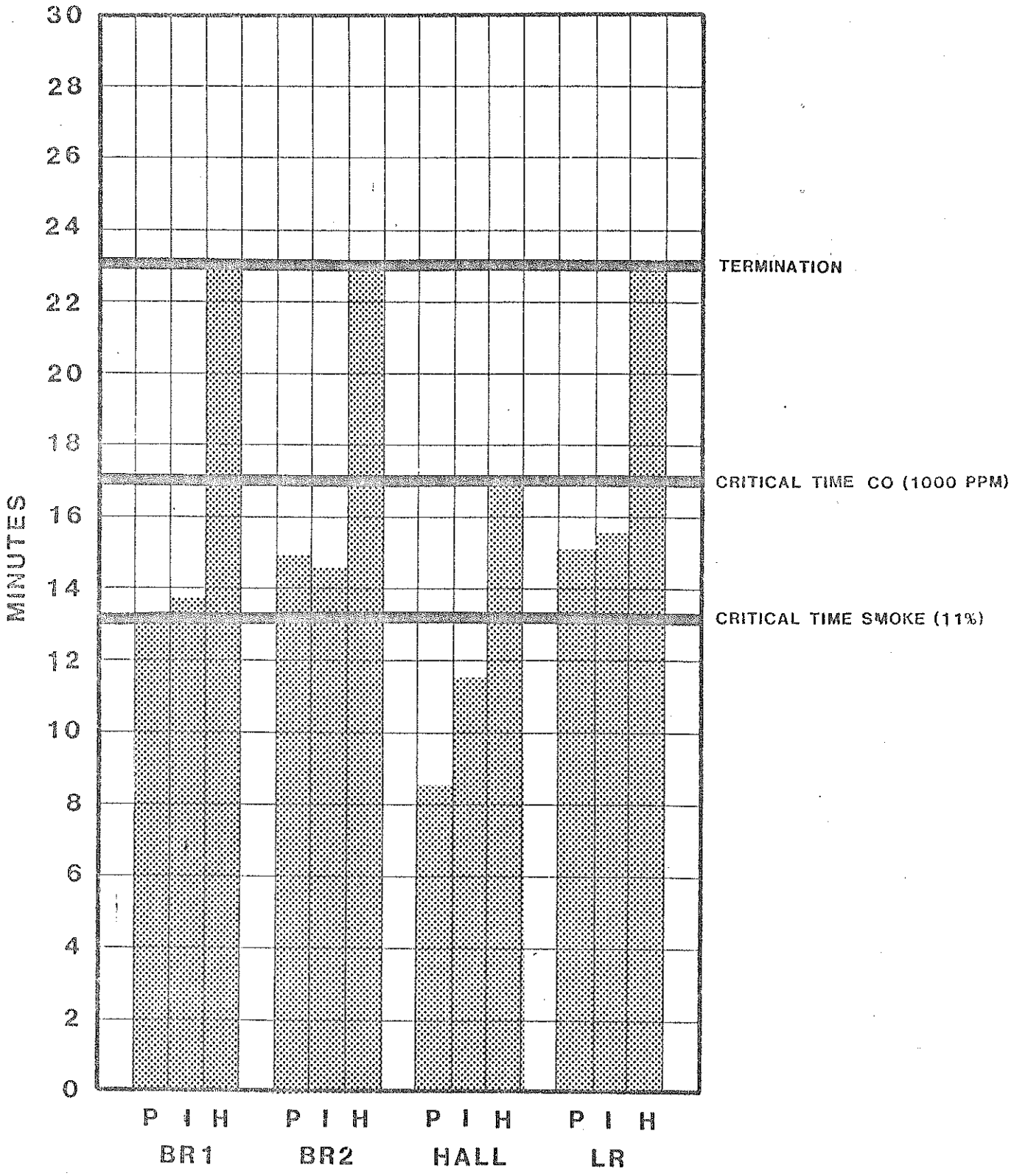
NAPOLEON 19
FIRE IN - KITCHEN-OPEN FLAME



P- PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

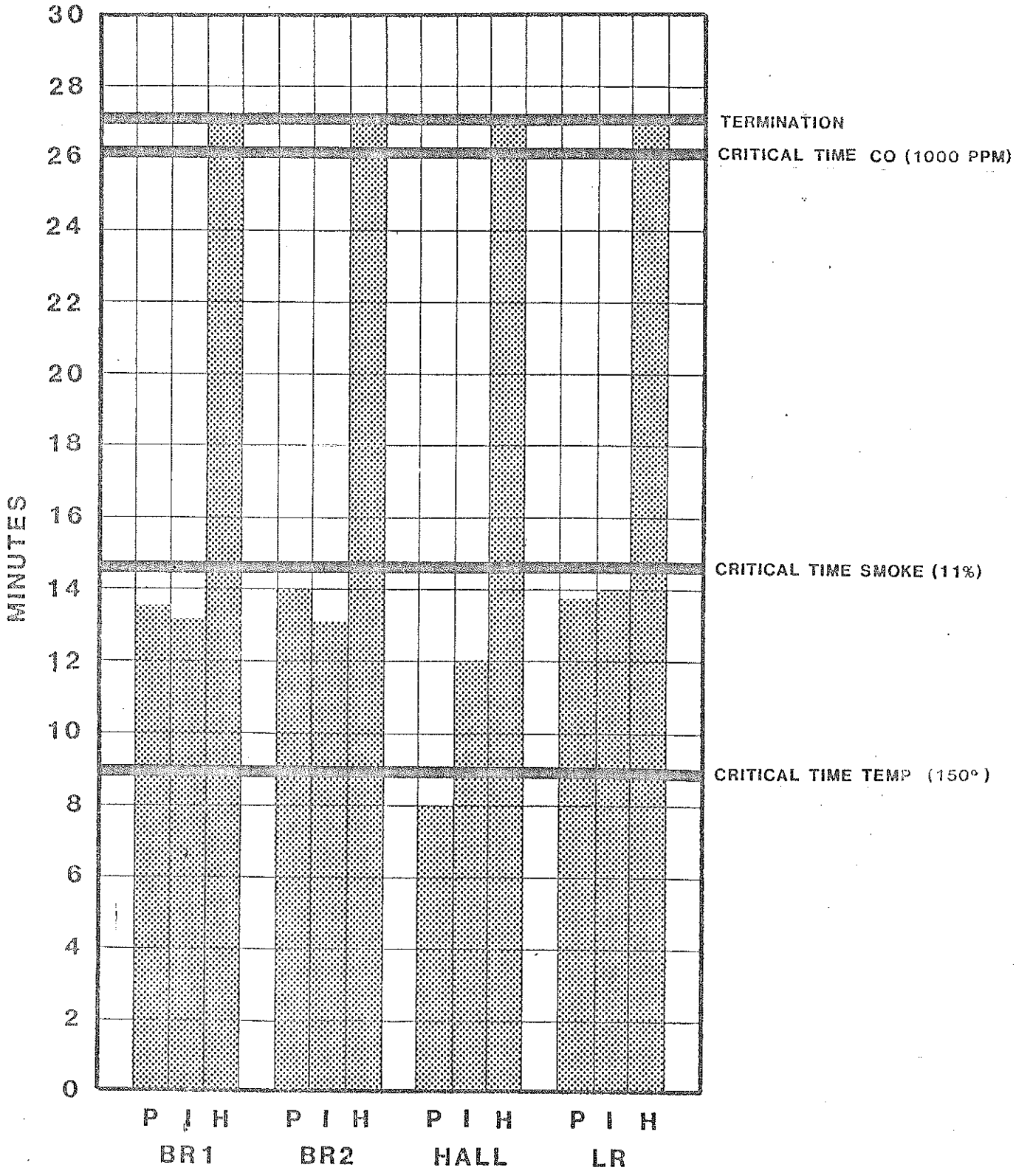
NAPOLEON 18

FIRE IN - KITCHEN-OPEN FLAME



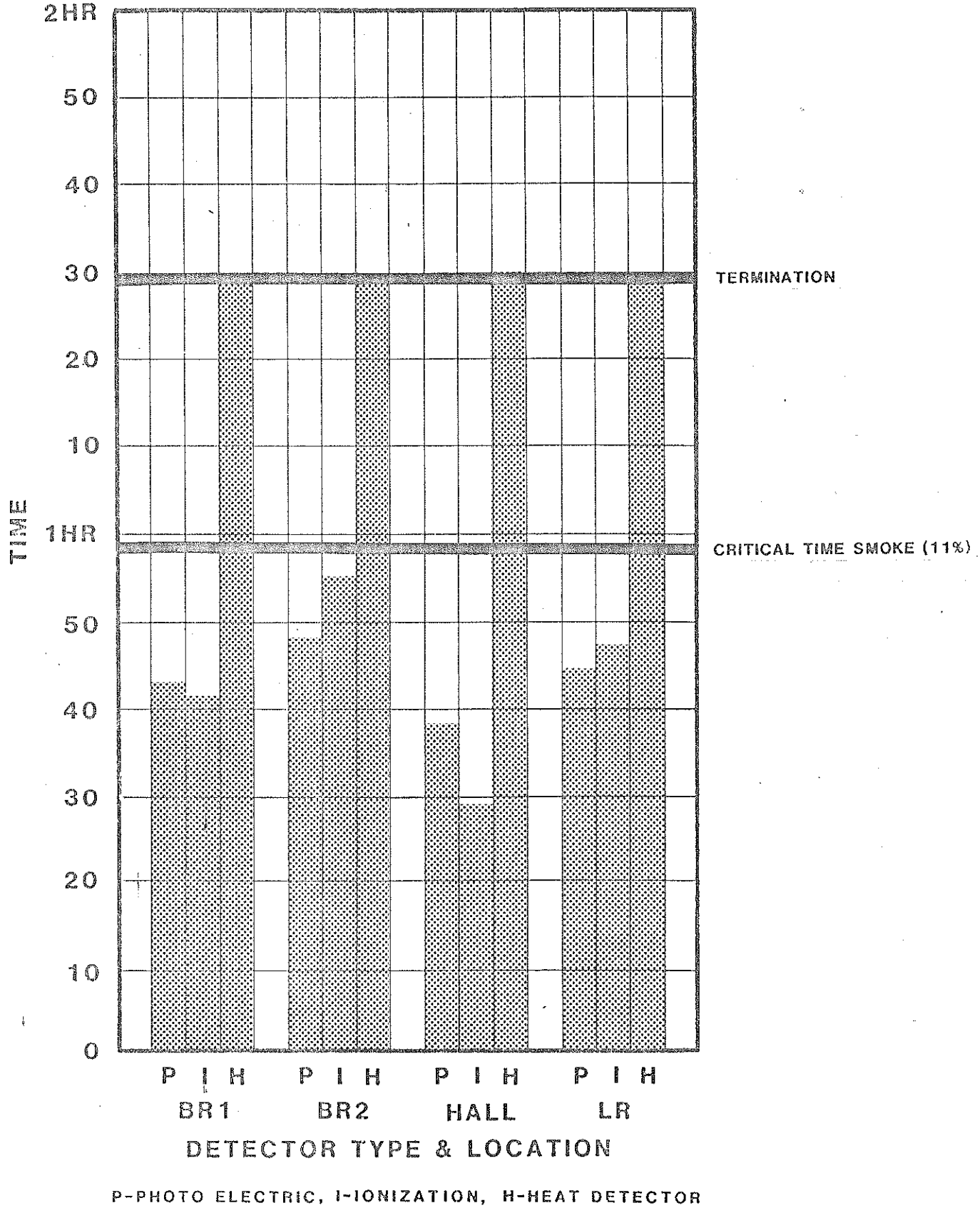
NAPOLEON 20

FIRE IN - KITCHEN-OPEN FLAME



NAPOLEON 21

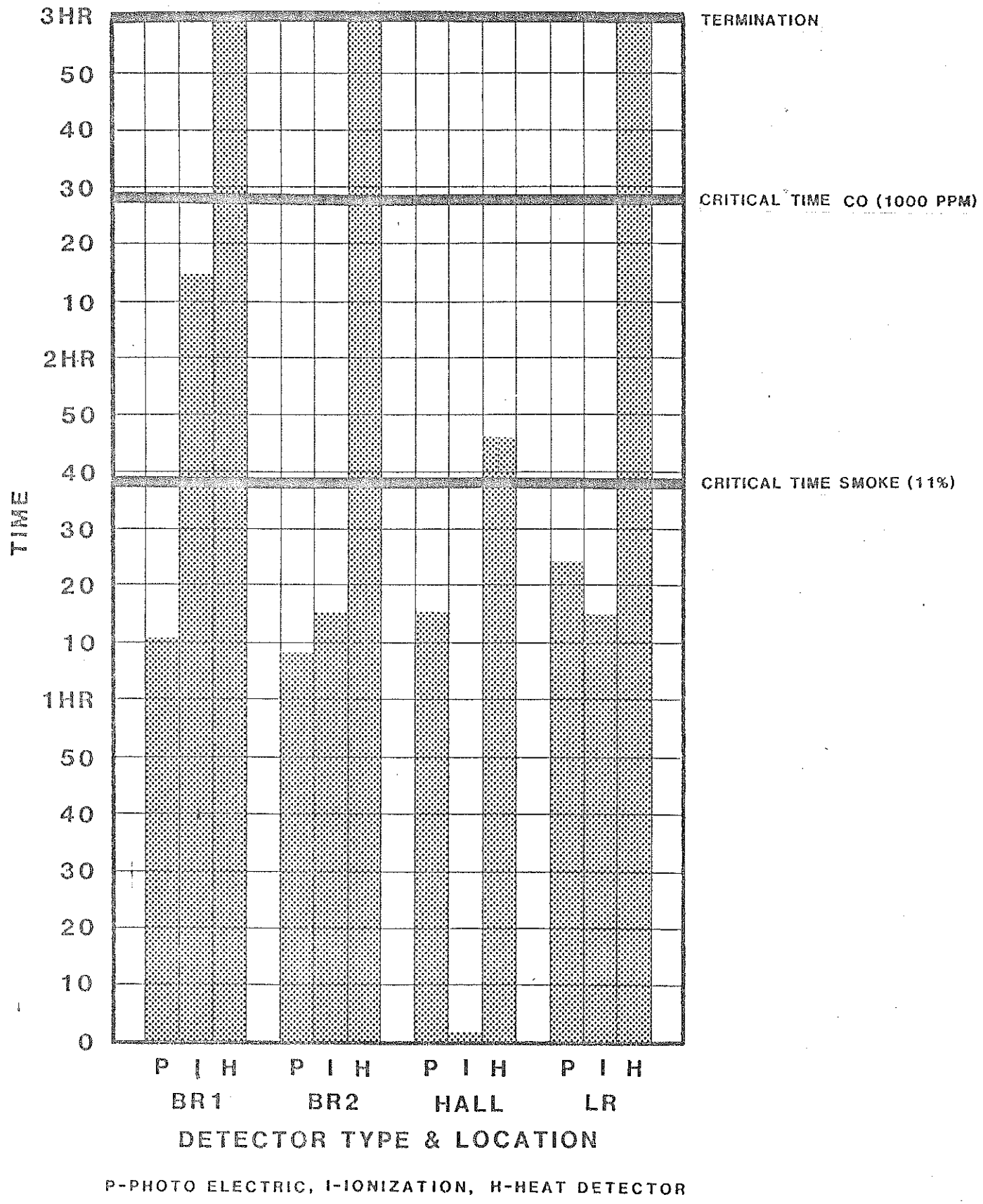
FIRE IN KITCHEN-SMOLDERING



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

NAPOLEON 22

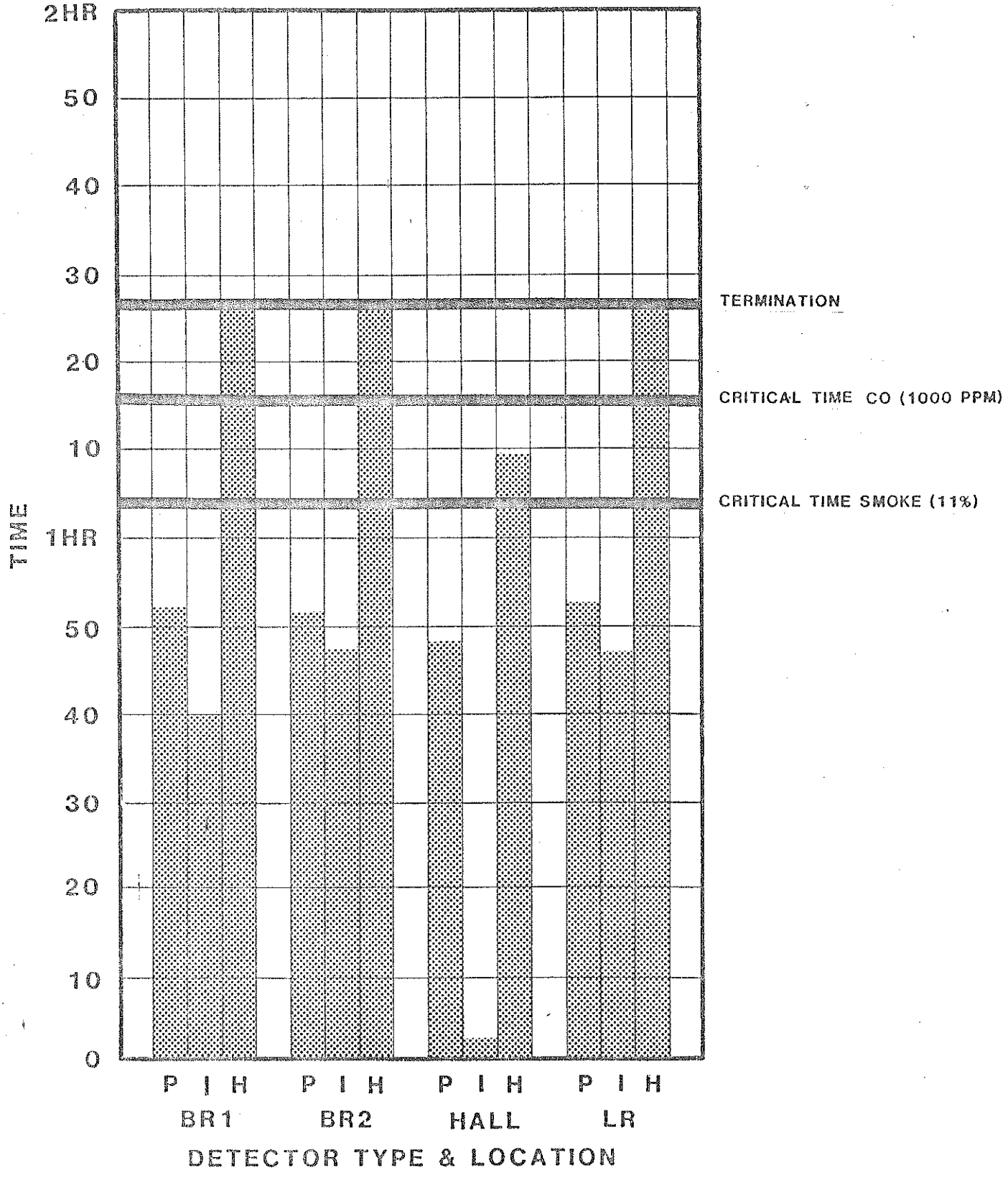
FIRE IN - KITCHEN-SMOLDERING



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

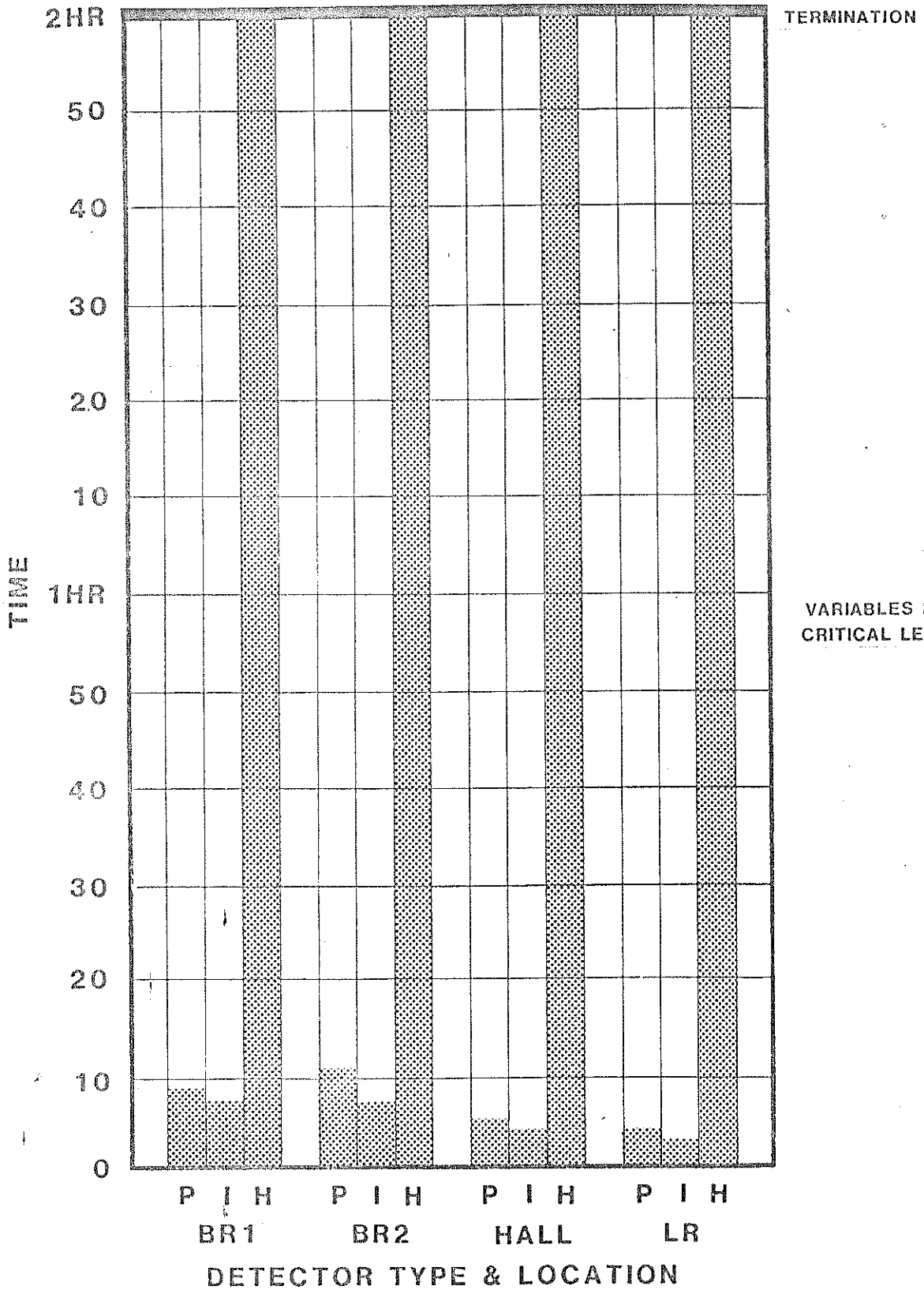
NAPOLEON 23

FIRE IN KITCHEN-SMOLDERING



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

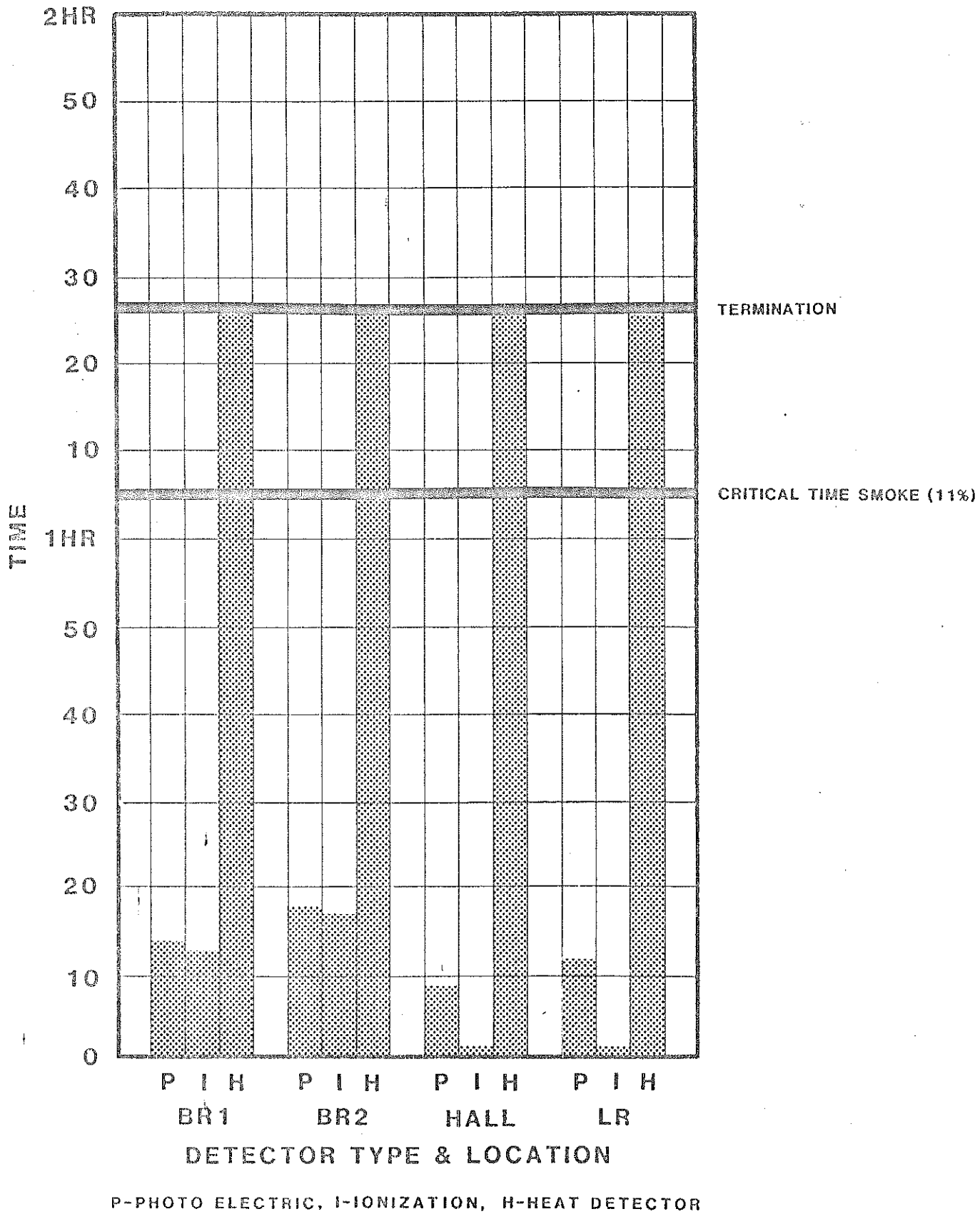
NAPOLEON 24
FIRE IN LIVING ROOM-SMOLDERING



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

NAPOLEON 25

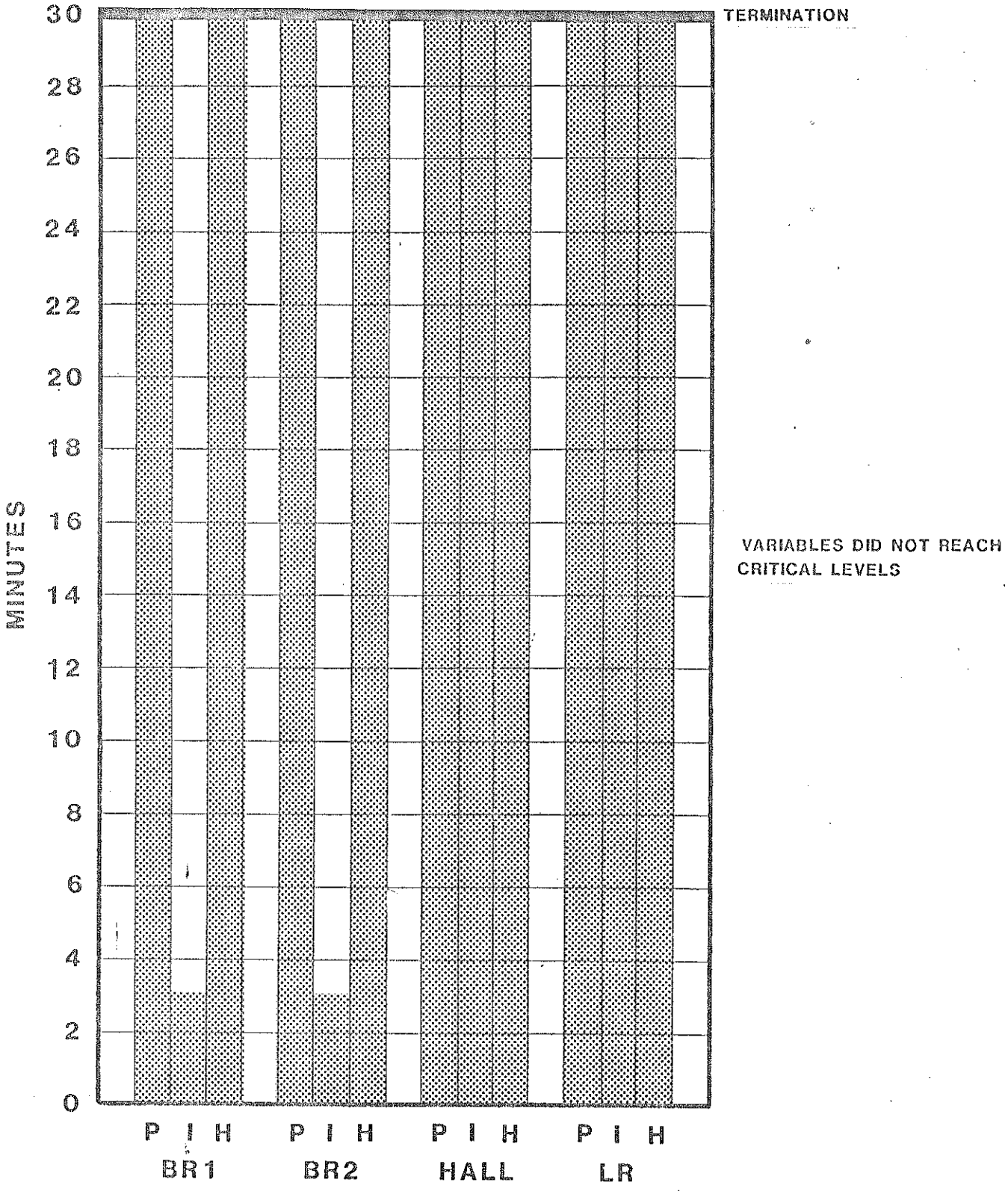
FIRE IN LIVING ROOM-SMOLDERING



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

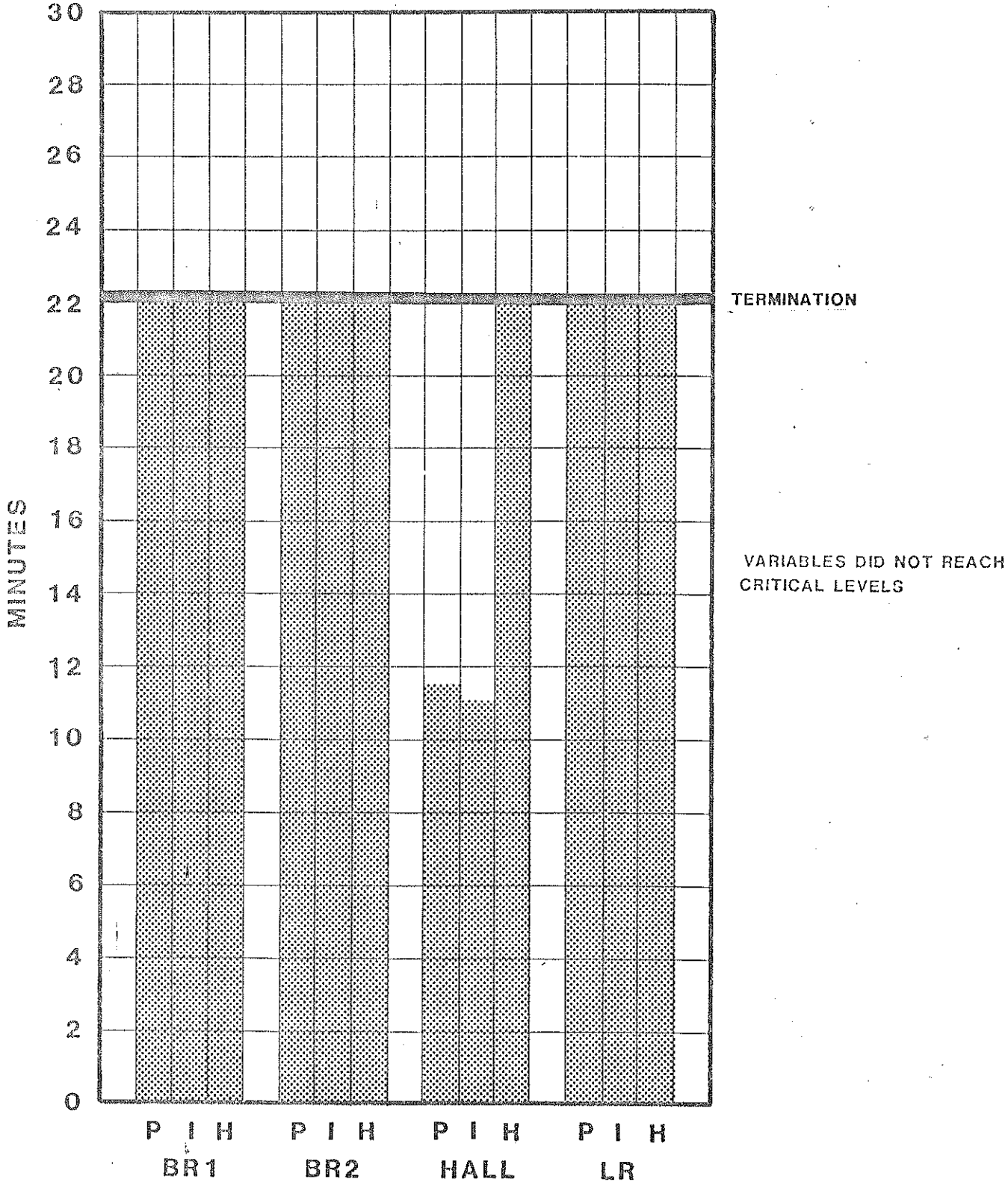
NAPOLEON 27

FIRE IN - HEATER ROOM-SMOLDERING



NAPOLEON 31

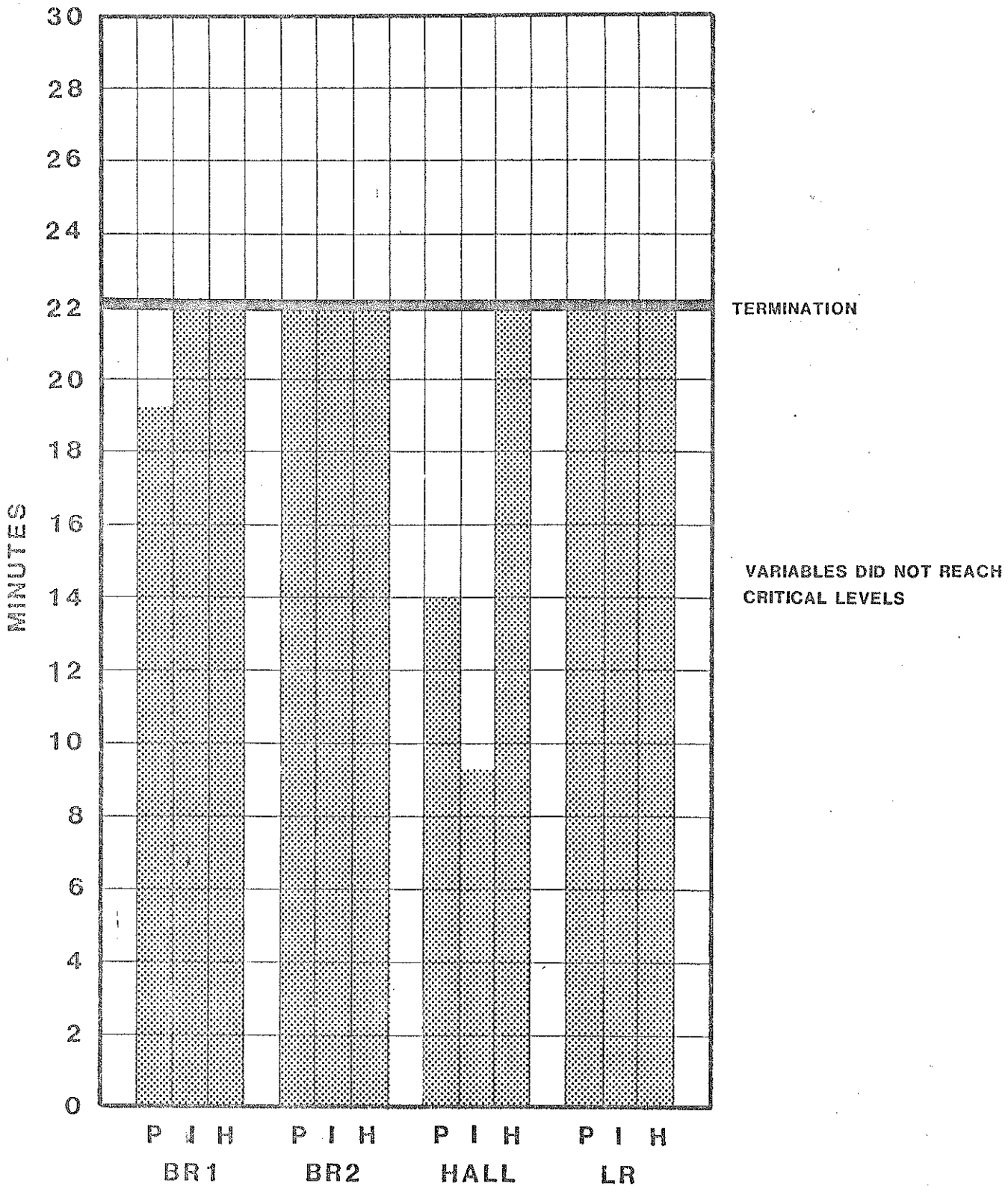
FIRE IN - KITCHEN-OPEN FLAME



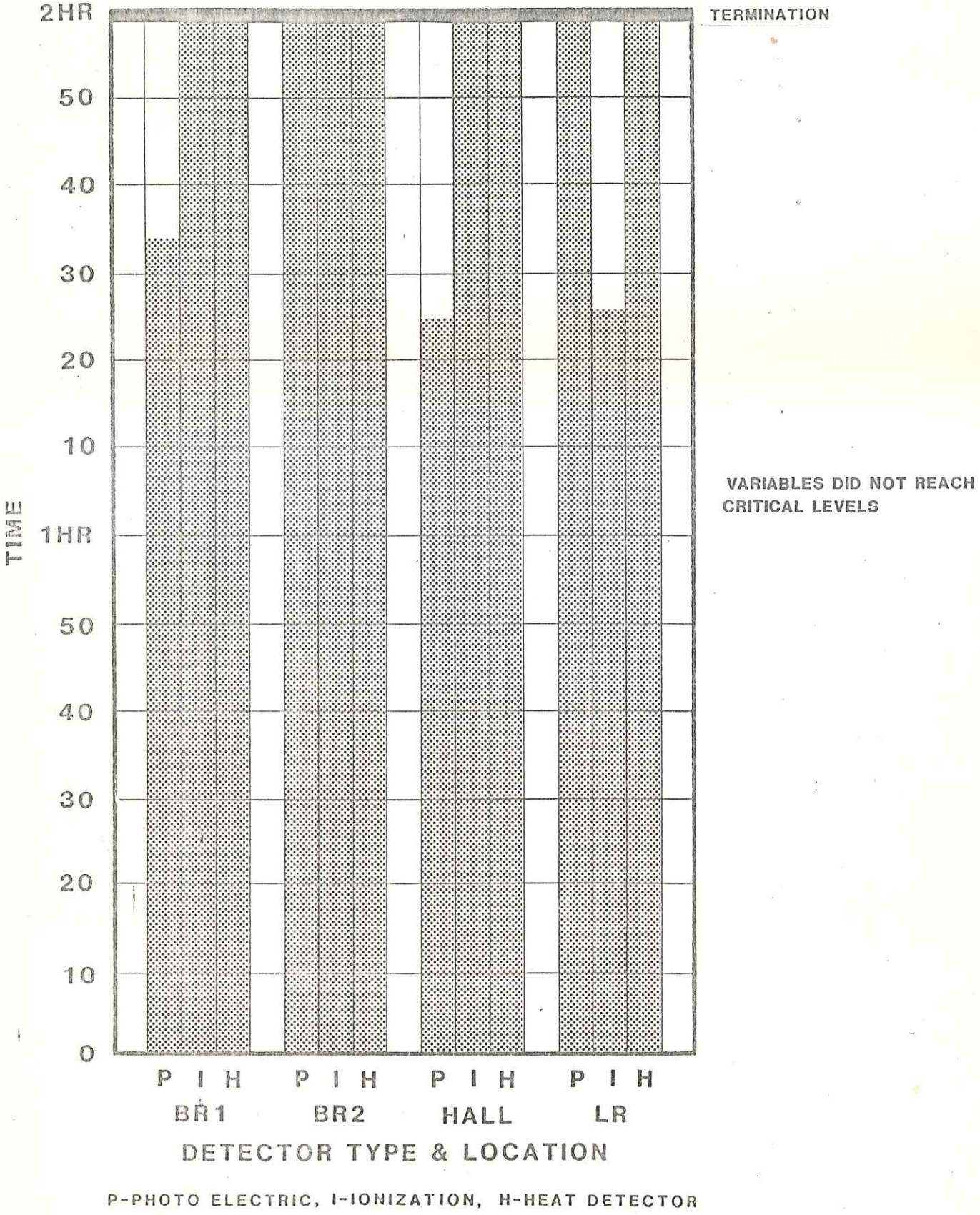
P- PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

NAPOLEON 33

FIRE IN - KITCHEN-OPEN FLAME



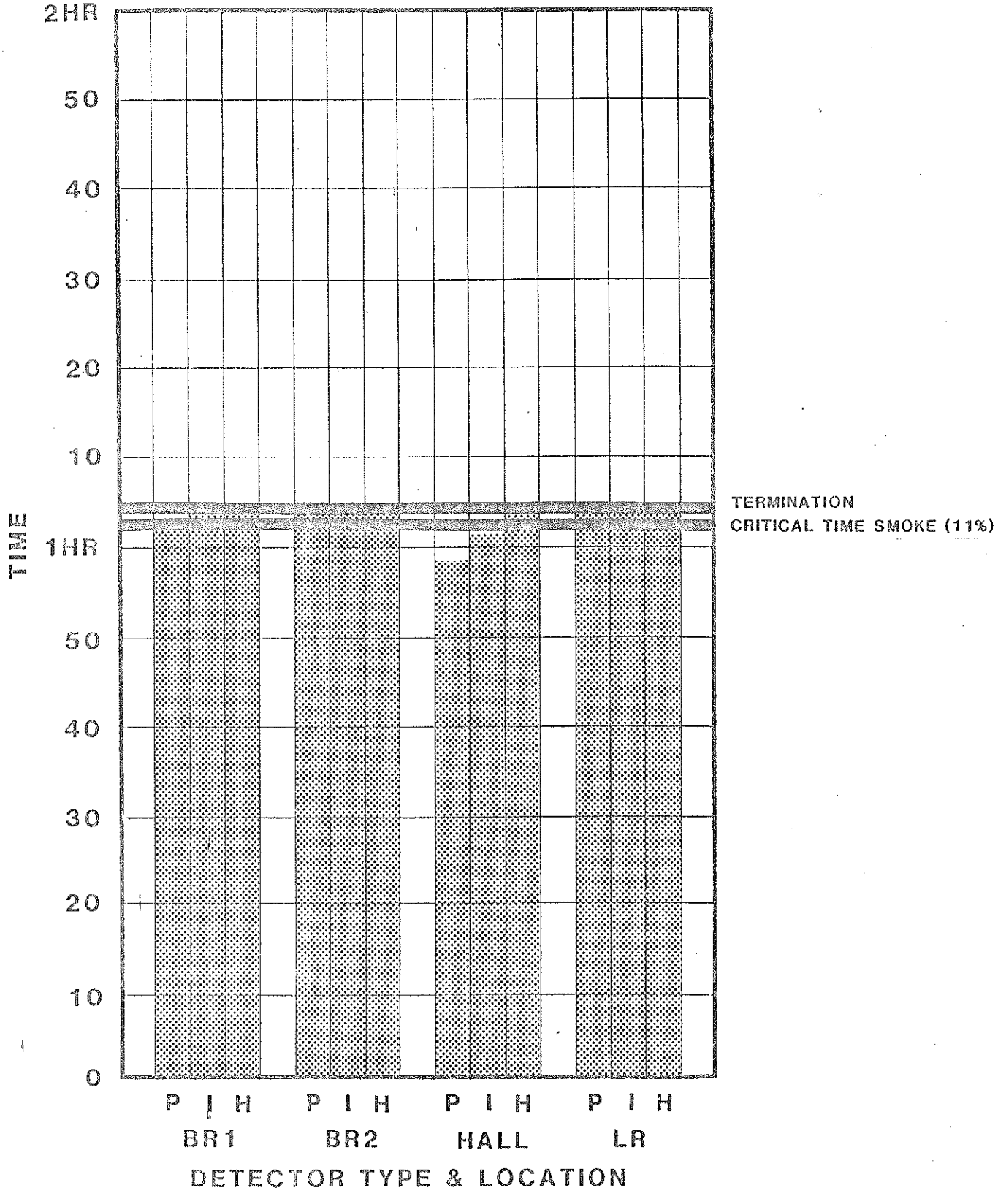
NAPOLEON 34
FIRE IN KITCHEN-SMOLDERING



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

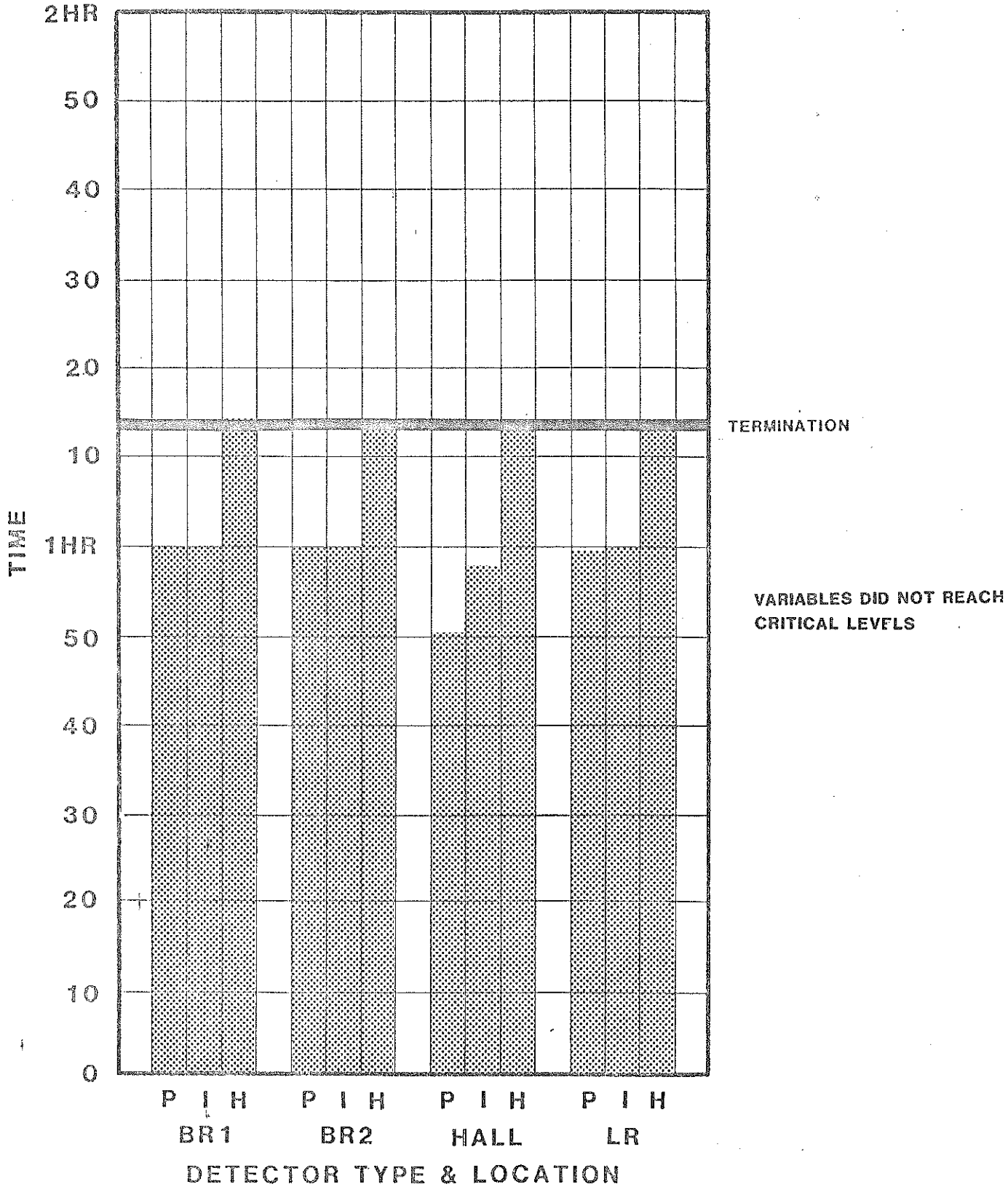
NAPOLEON 35

FIRE IN KITCHEN-SMOLDERING



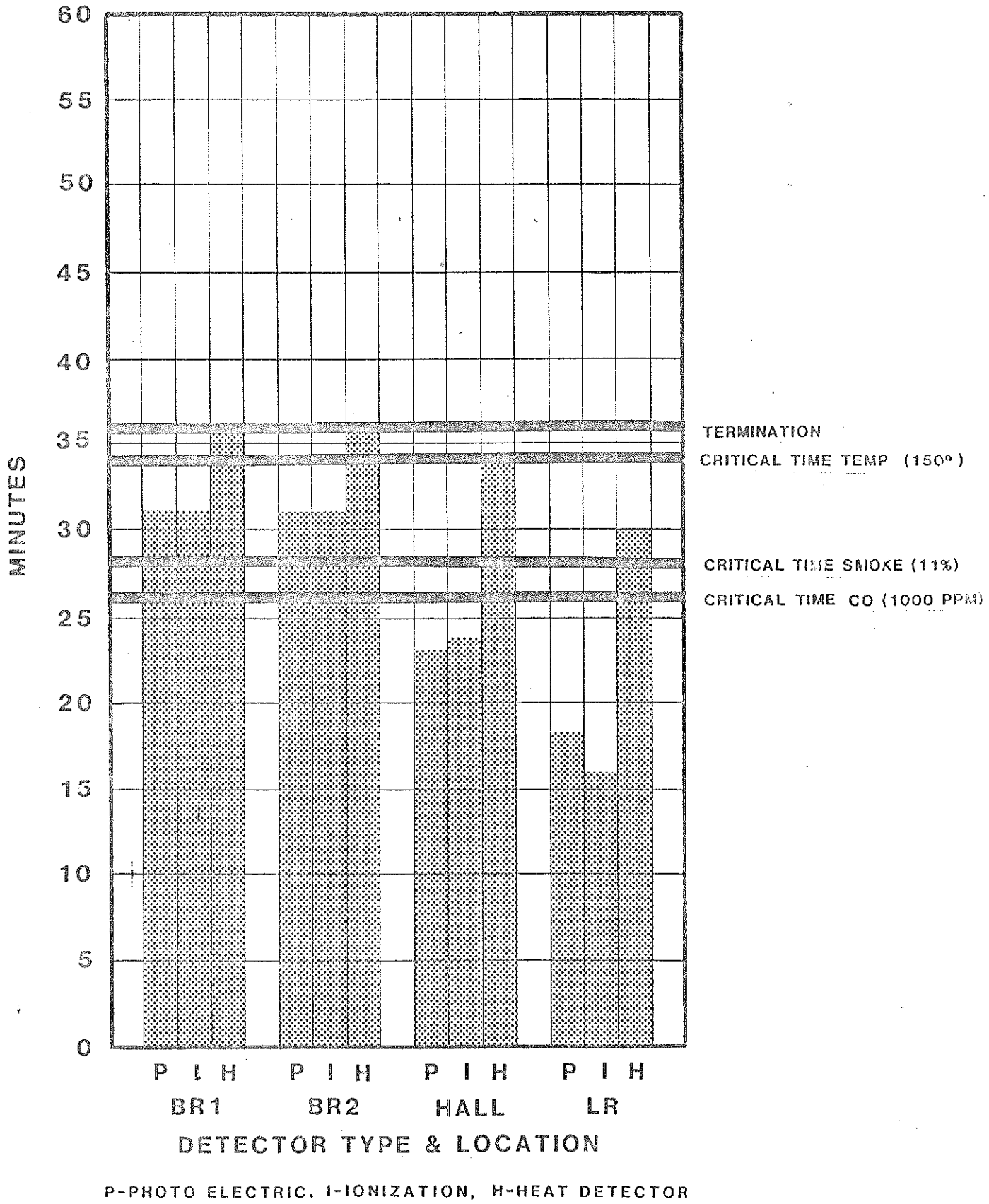
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

NAPOLEON 36
FIRE IN KITCHEN-SMOLDERING



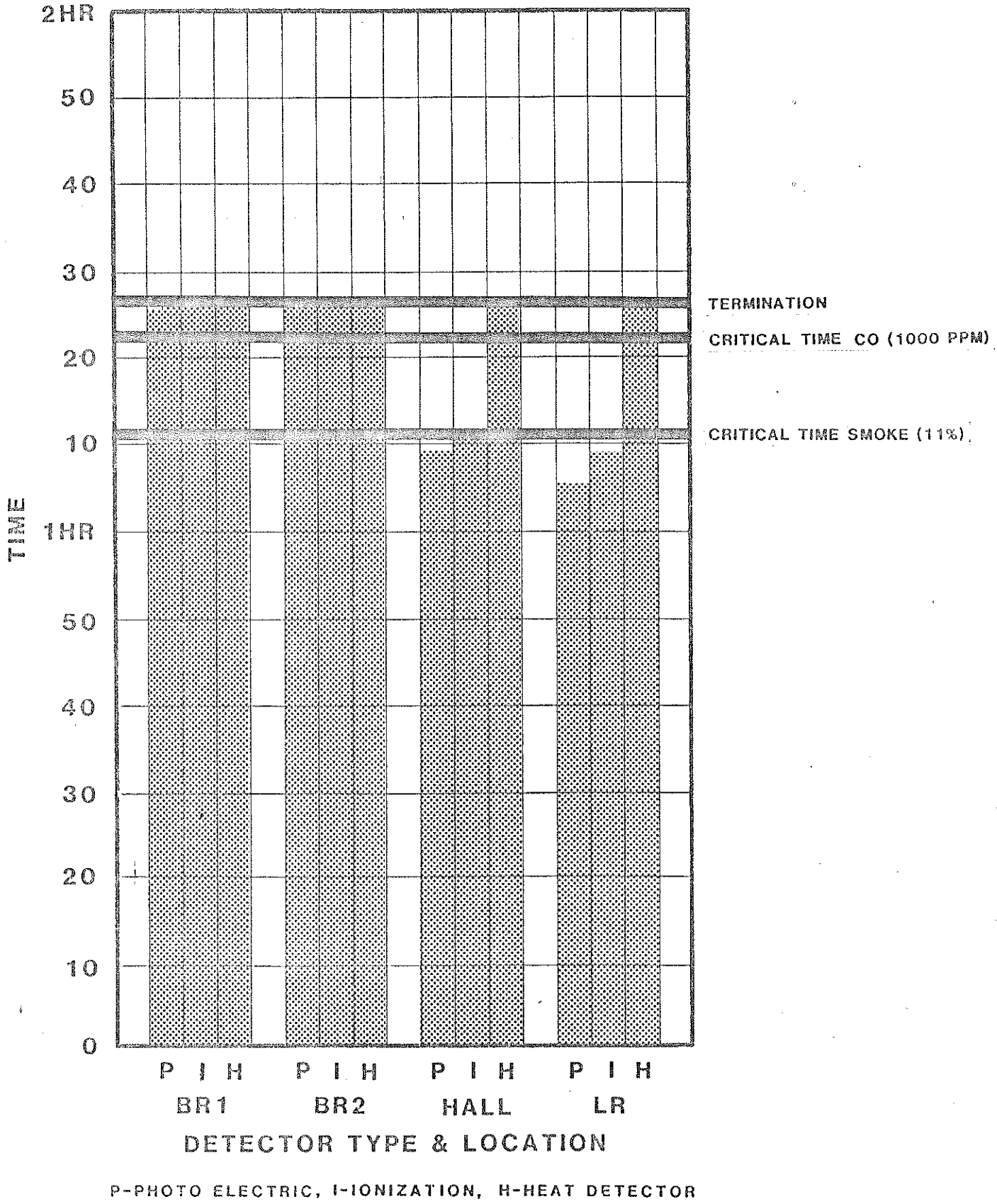
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

PALACE 1
FIRE IN LIVING ROOM-SMOLDERING



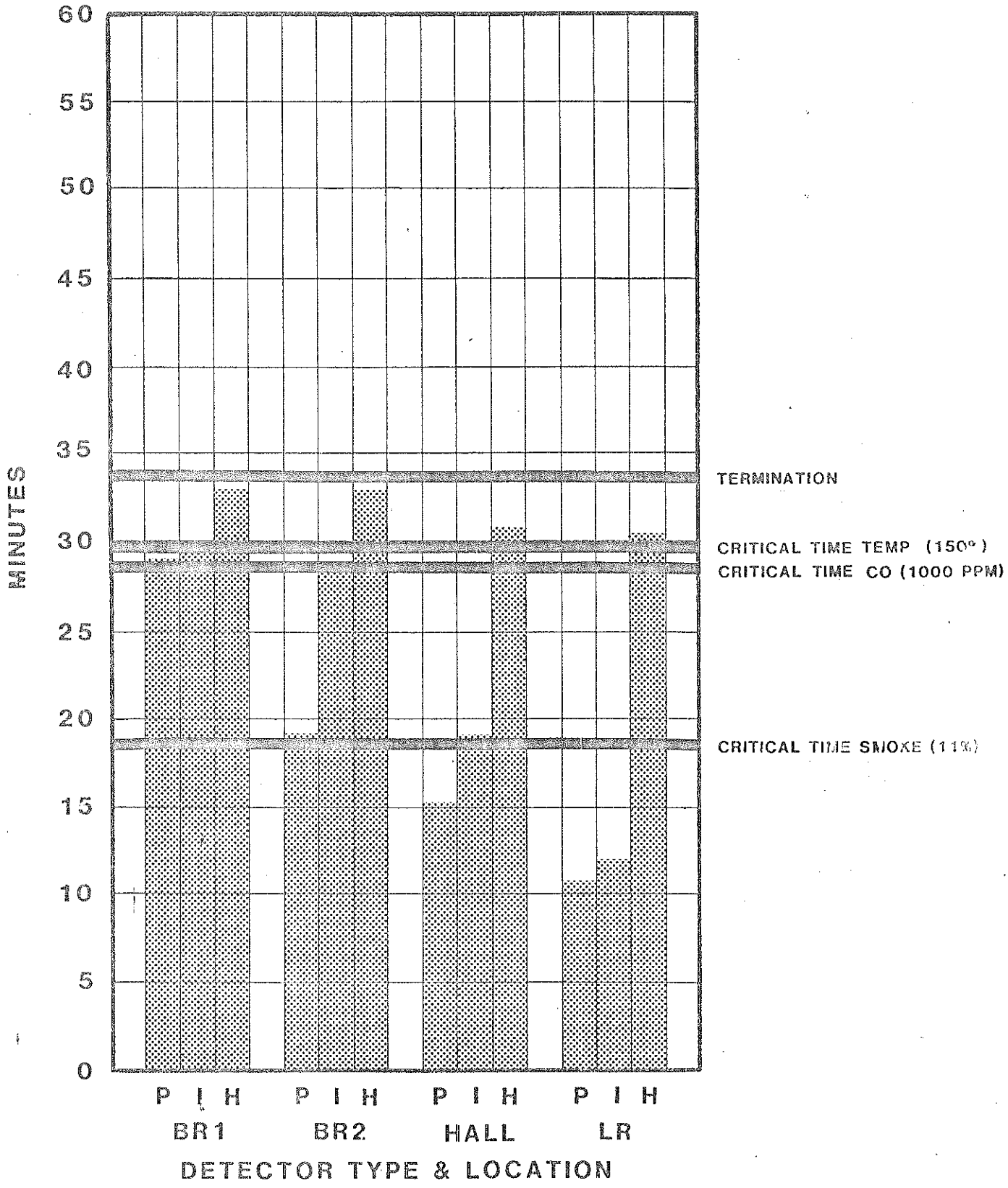
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

PALACE 2
FIRE IN LIVING ROOM-SMOLDERING



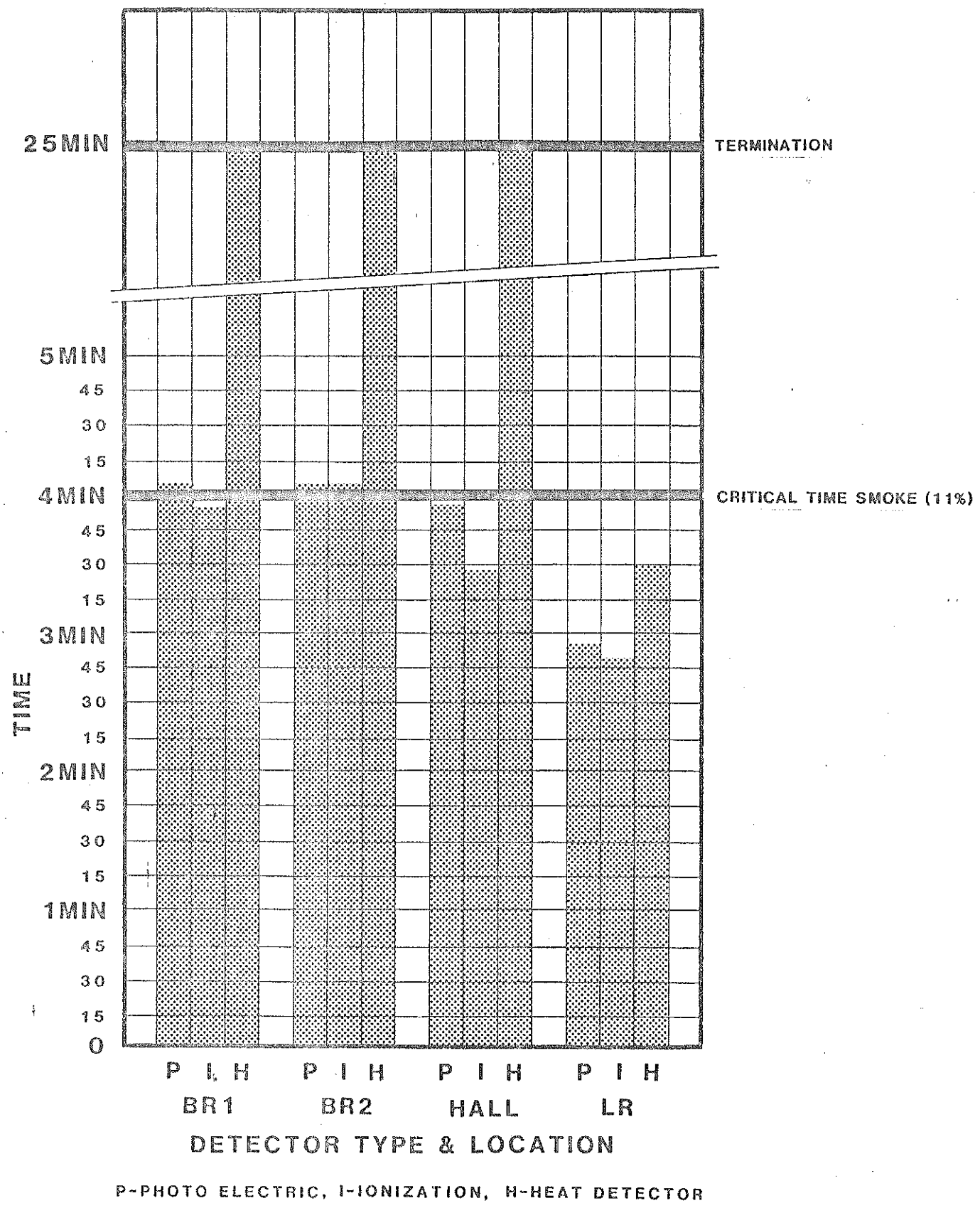
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

PALACE 3
FIRE IN LIVING ROOM, SMOLDERING FIRE



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

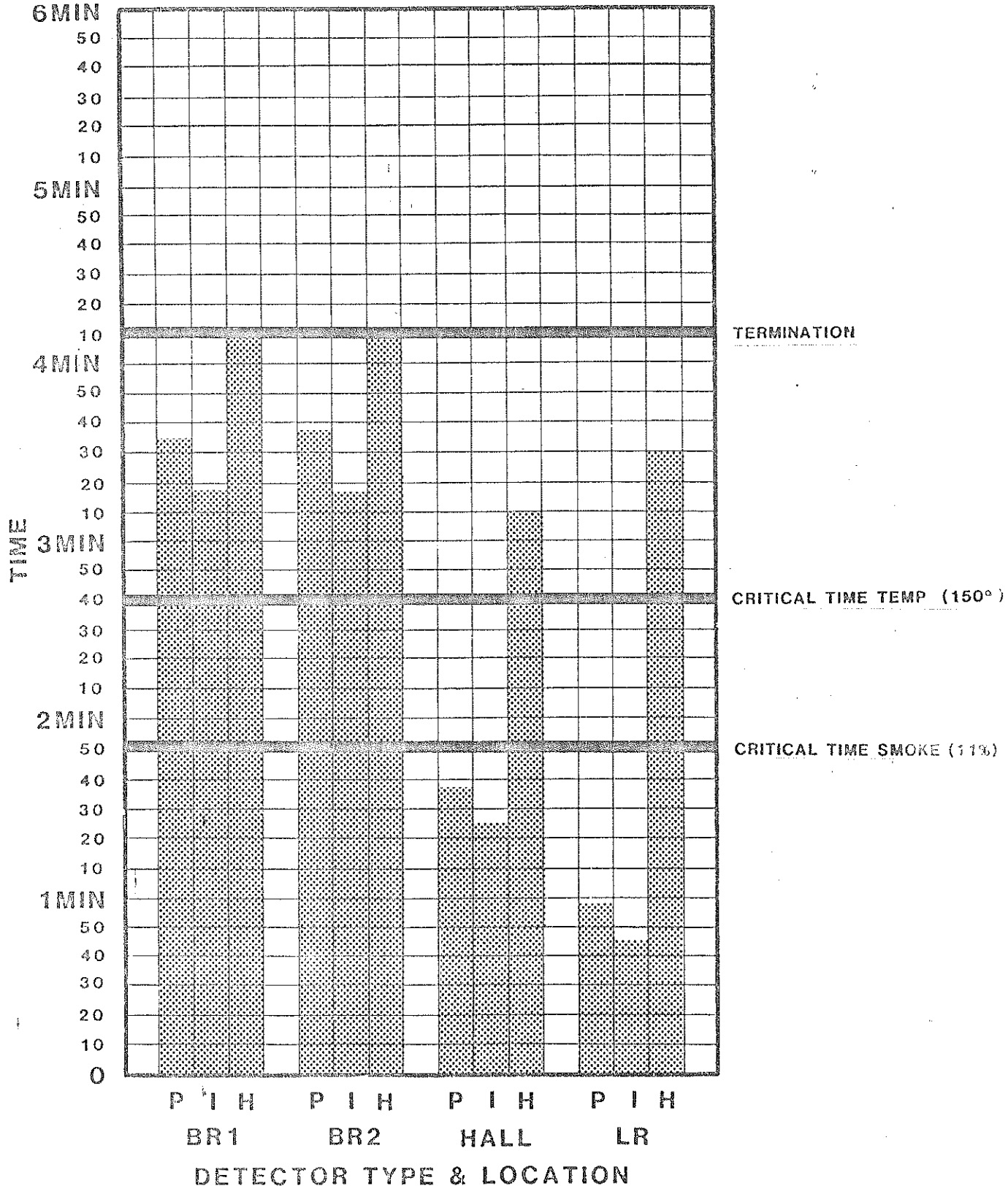
PALACE 4
FIRE IN-LIVING ROOM-OPEN FLAME



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

PALACE 5

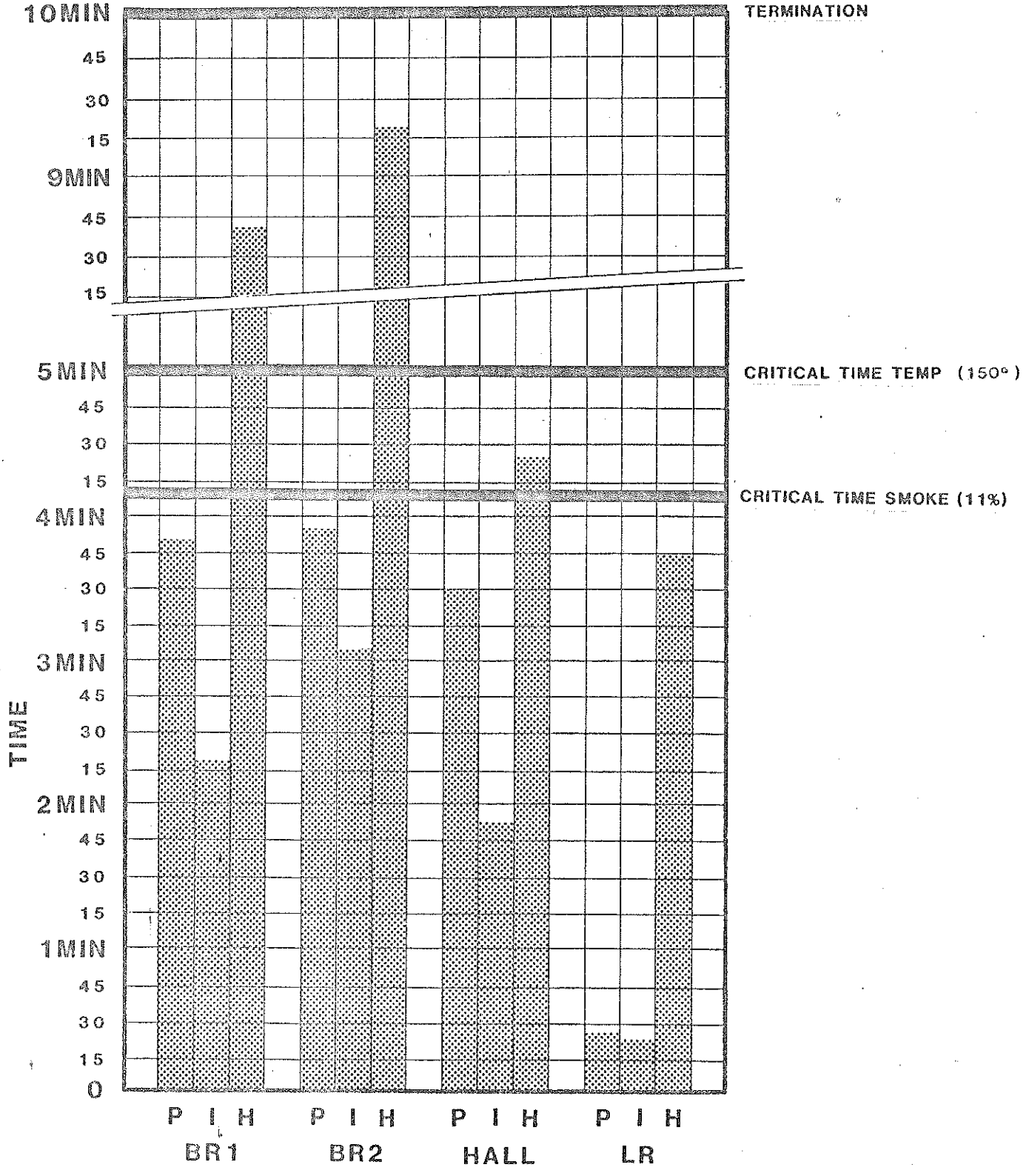
FIRE IN- LIVING ROOM-OPEN FLAME



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

PALACE 6

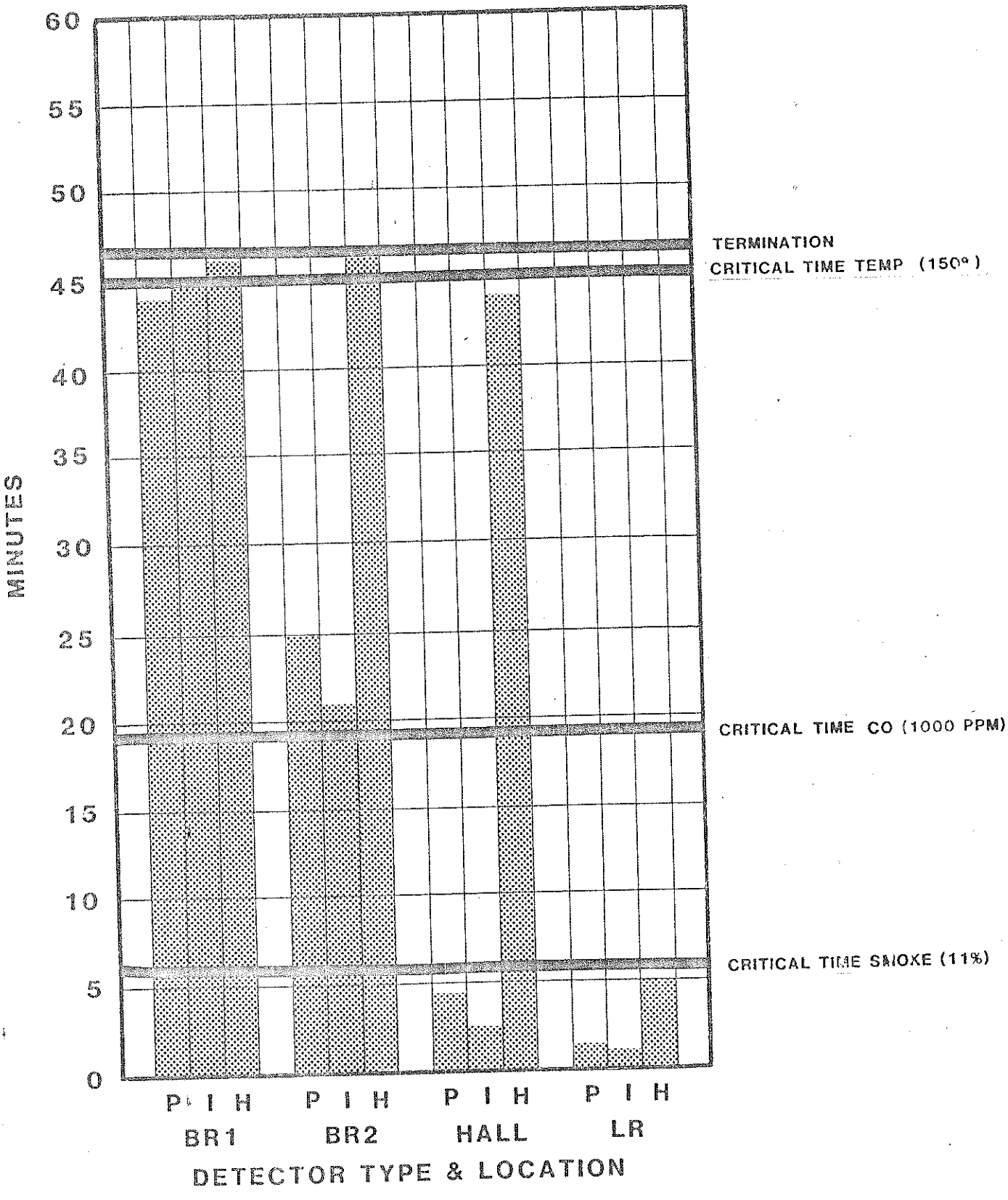
FIRE IN - LIVING ROOM -OPEN FLAME



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

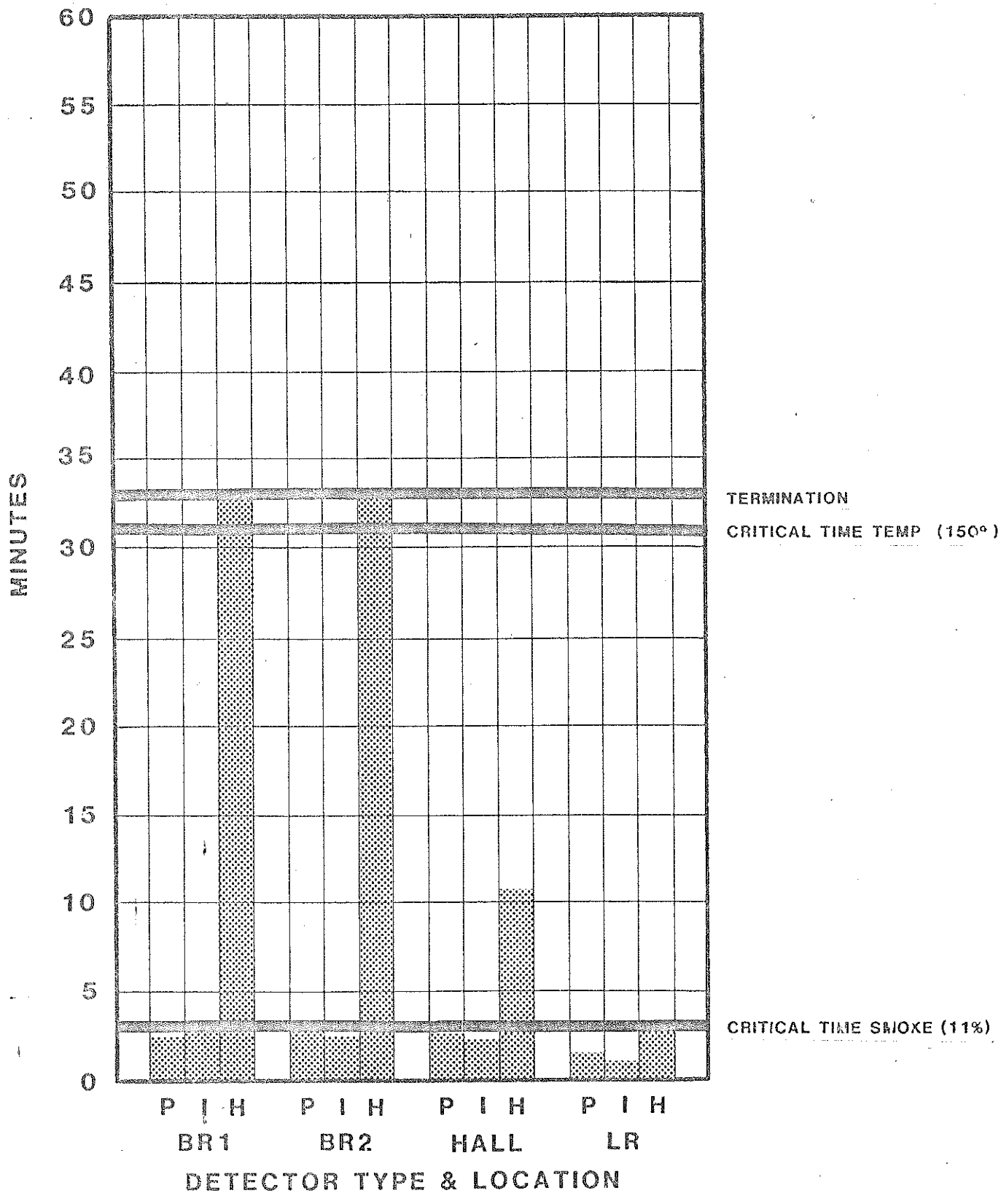
PALACE 7

FIRE IN LIVING ROOM-OPEN FLAME



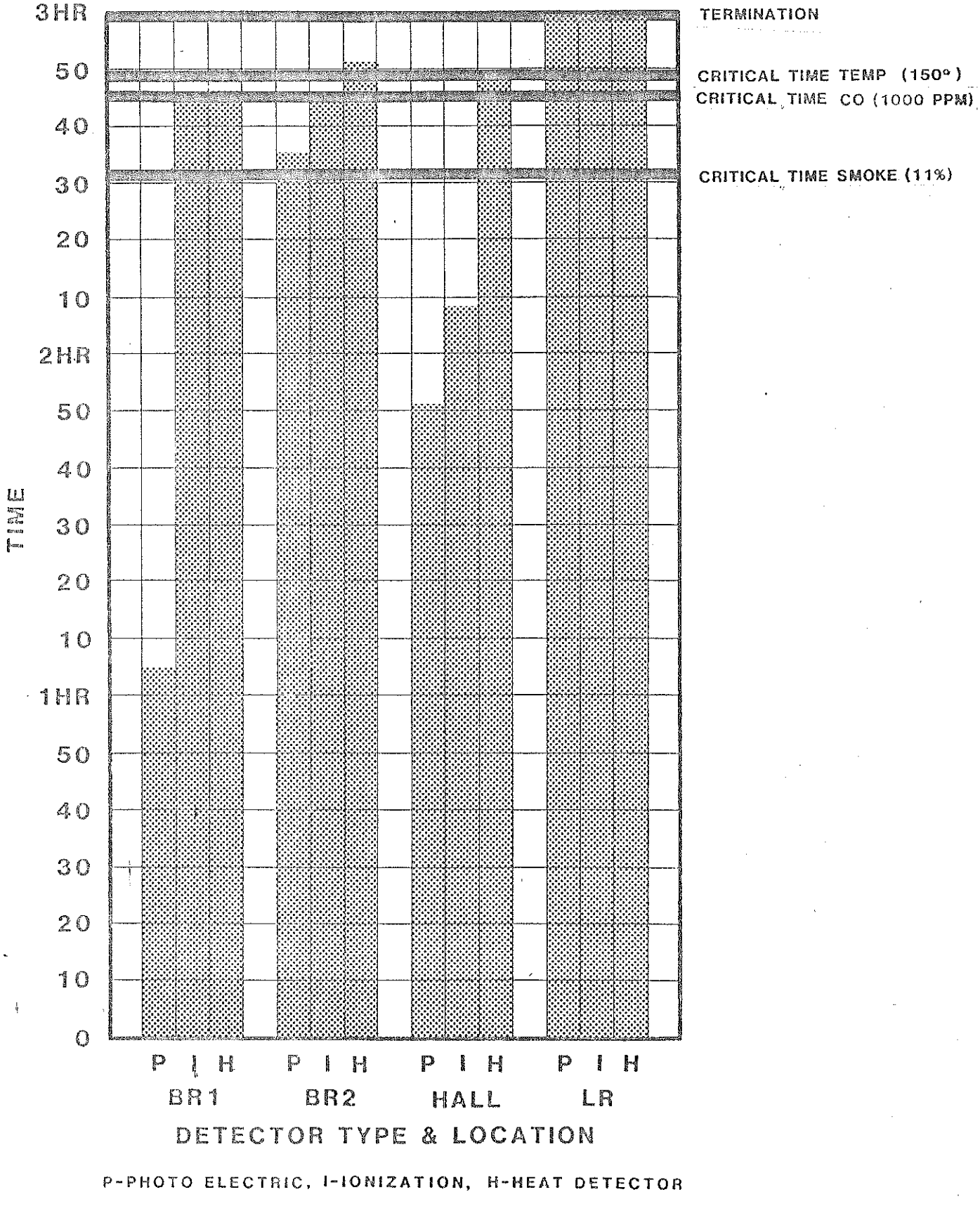
PALACE 8

FIRE IN LIVING ROOM-OPEN FLAME



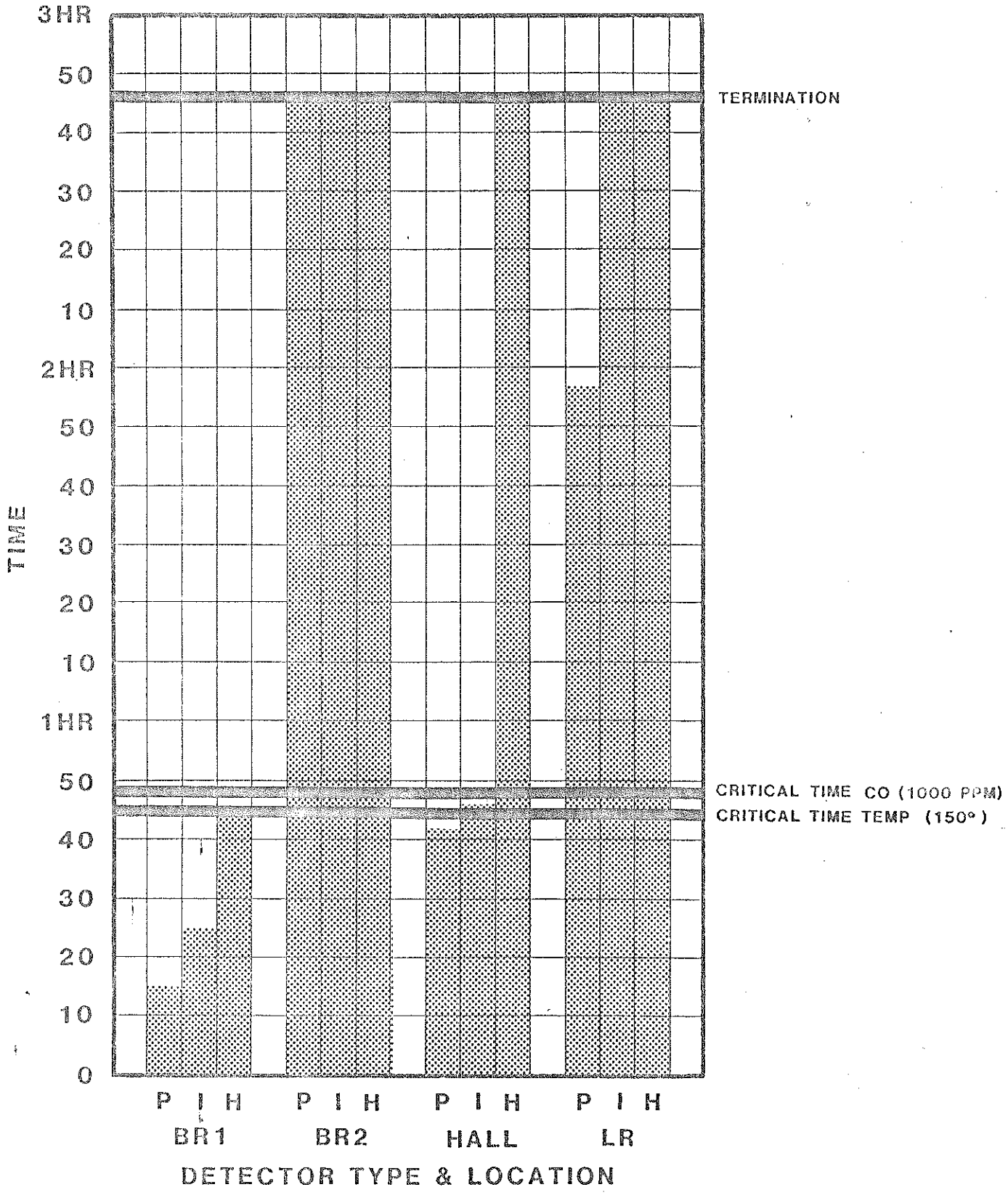
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

PALACE 9
FIRE IN - BEDROOM 1-SMOLDERING



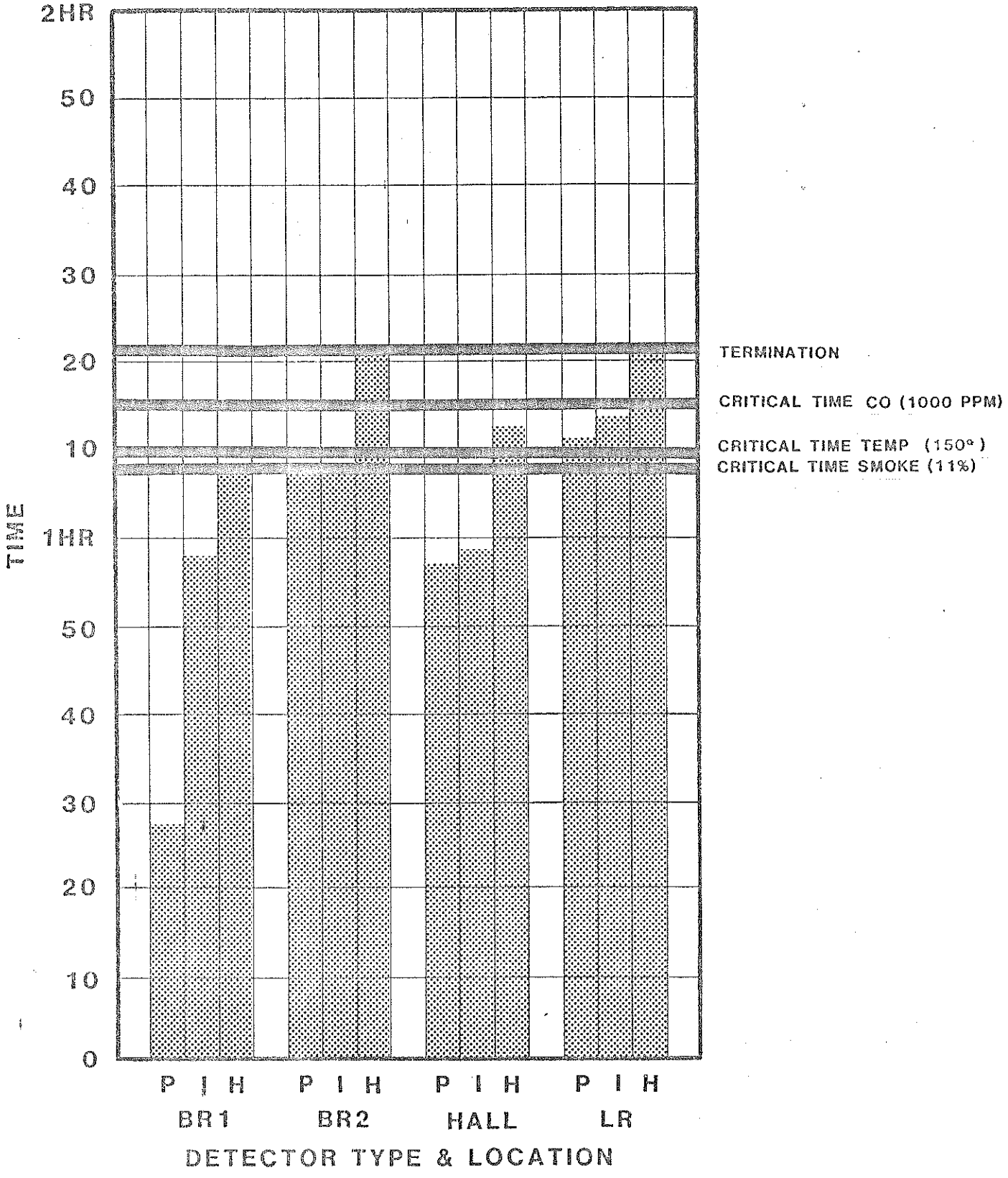
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

PALACE 10
FIRE IN - BEDROOM 1-SMOLDERING



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

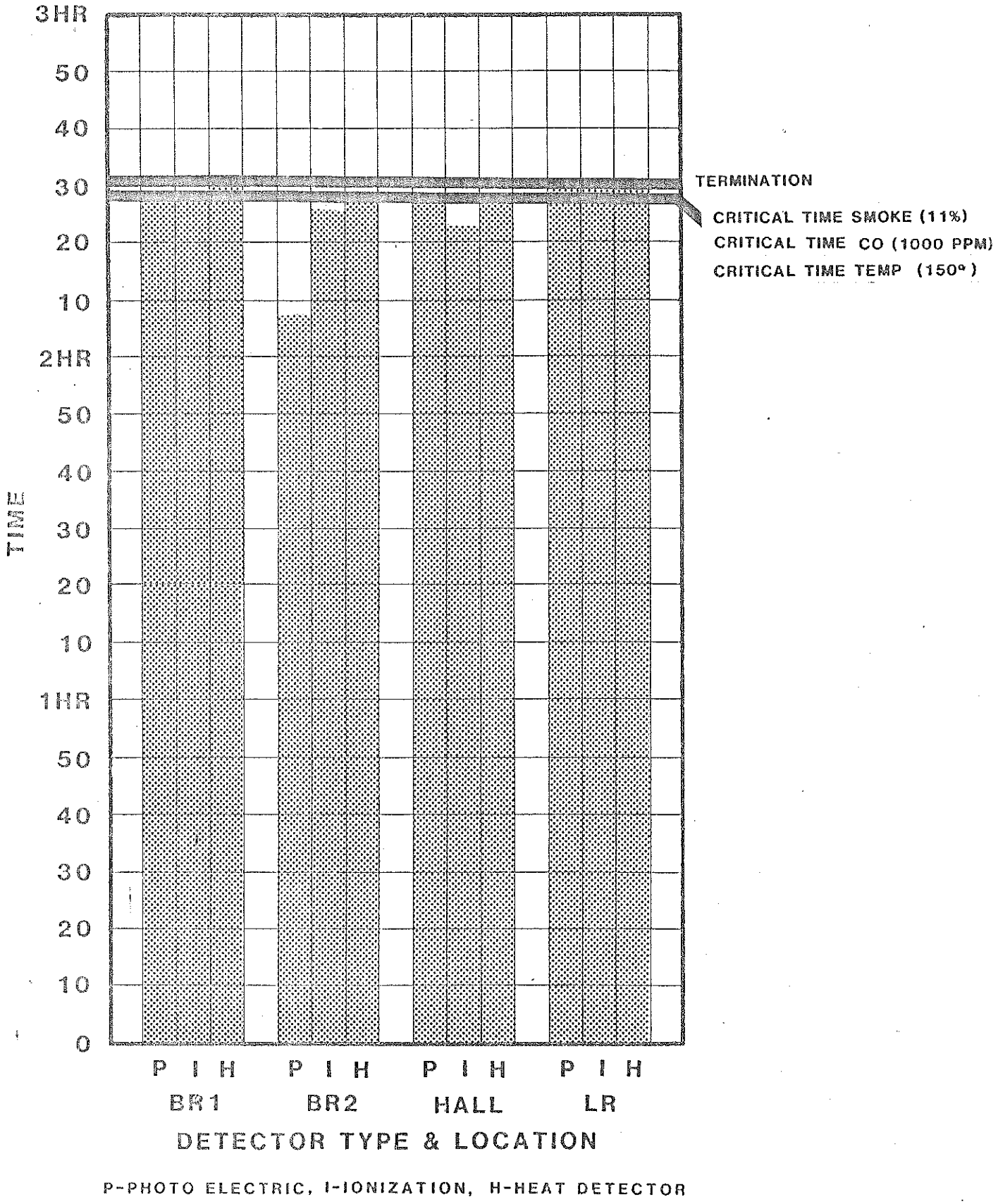
PALACE 11
FIRE IN BEDROOM 1 SMOLDERING



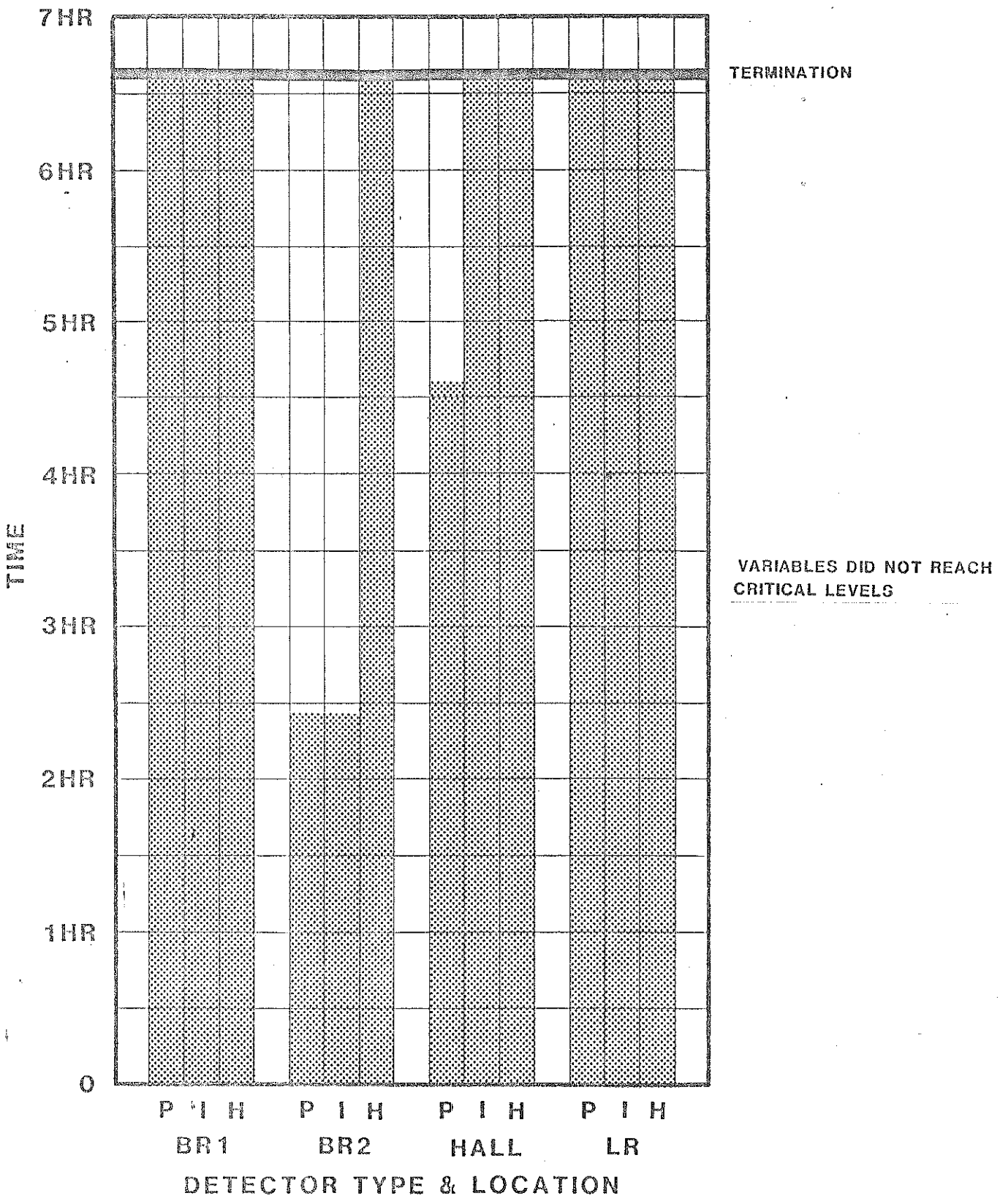
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

PALACE 12

FIRE IN -BEDROOM 2-SMOLDERING

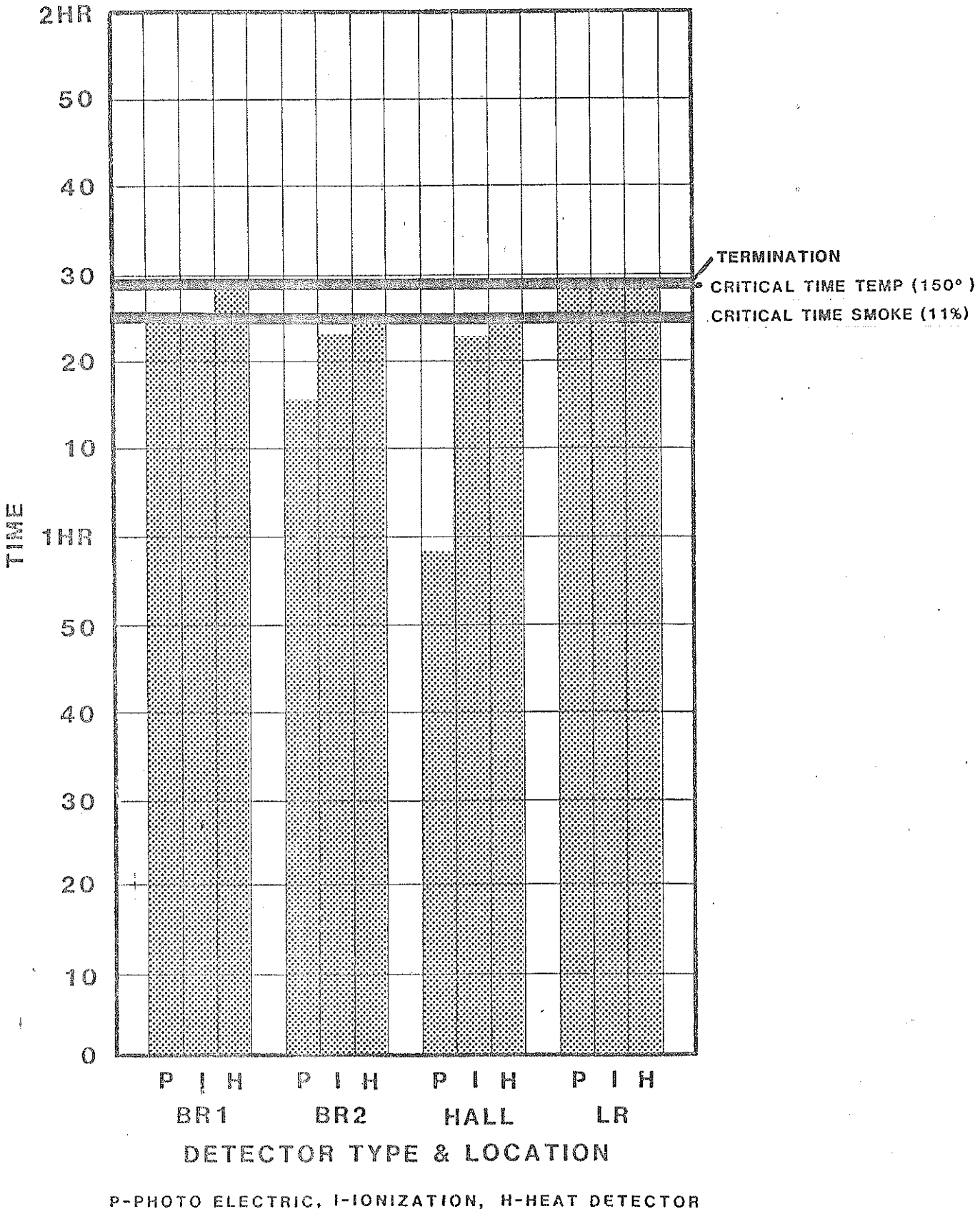


PALACE 13
FIRE IN - BEDROOM 2 -SMOLDERING FIRE



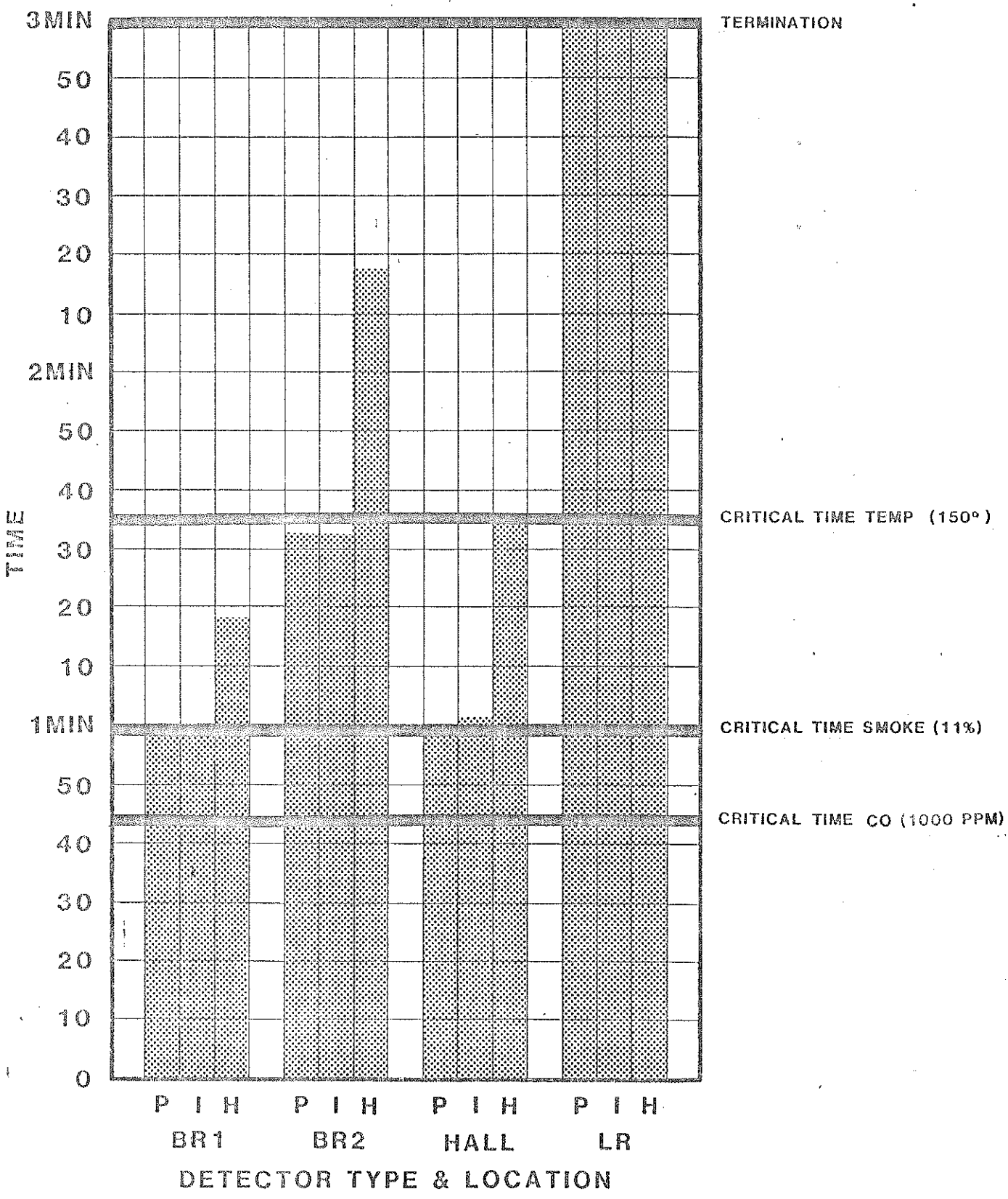
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

PALACE 14
FIRE IN BEDROOM 2-SMOLDERING



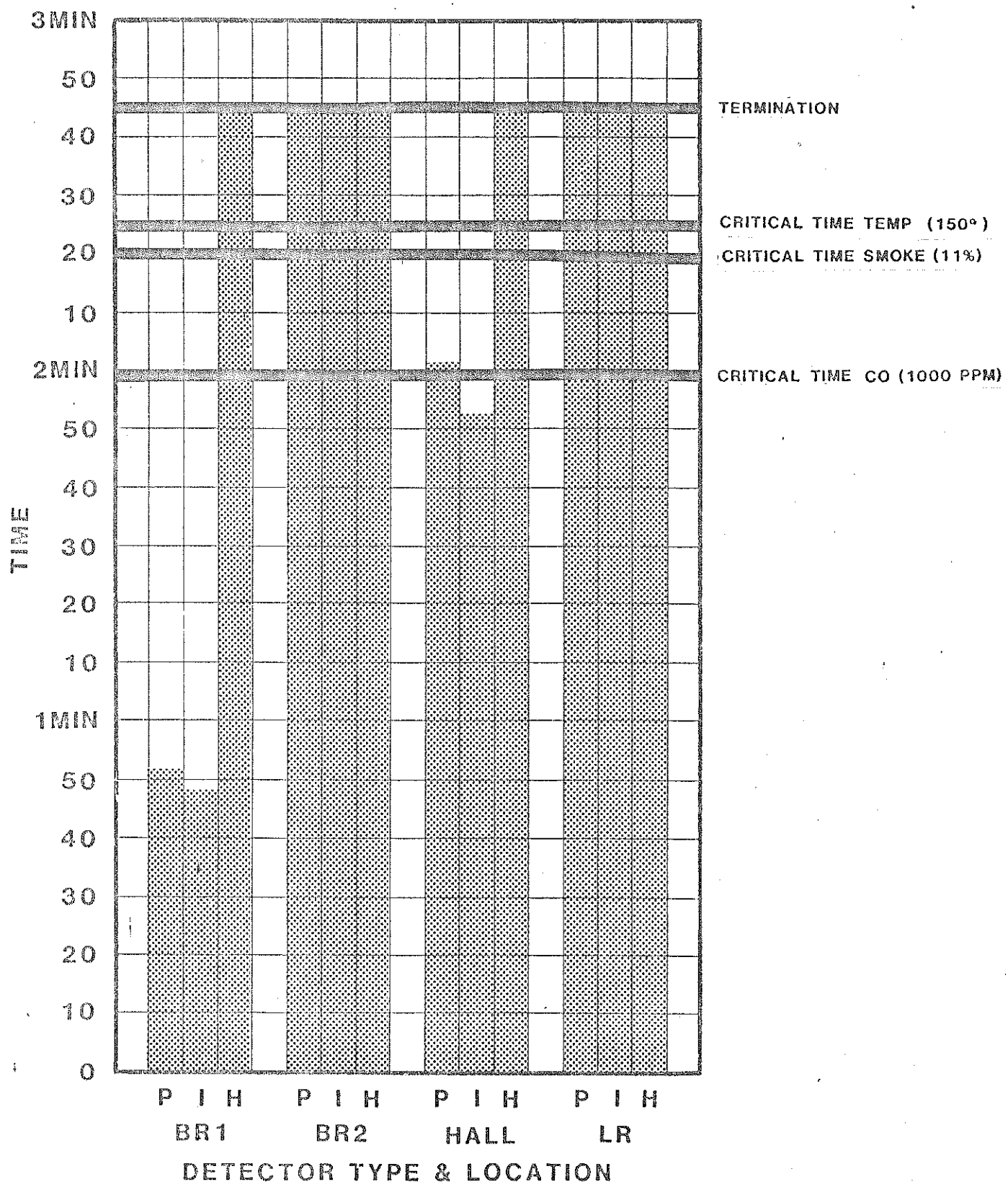
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

PALACE 15
FIRE IN - BEDROOM 1-OPEN FLAME



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

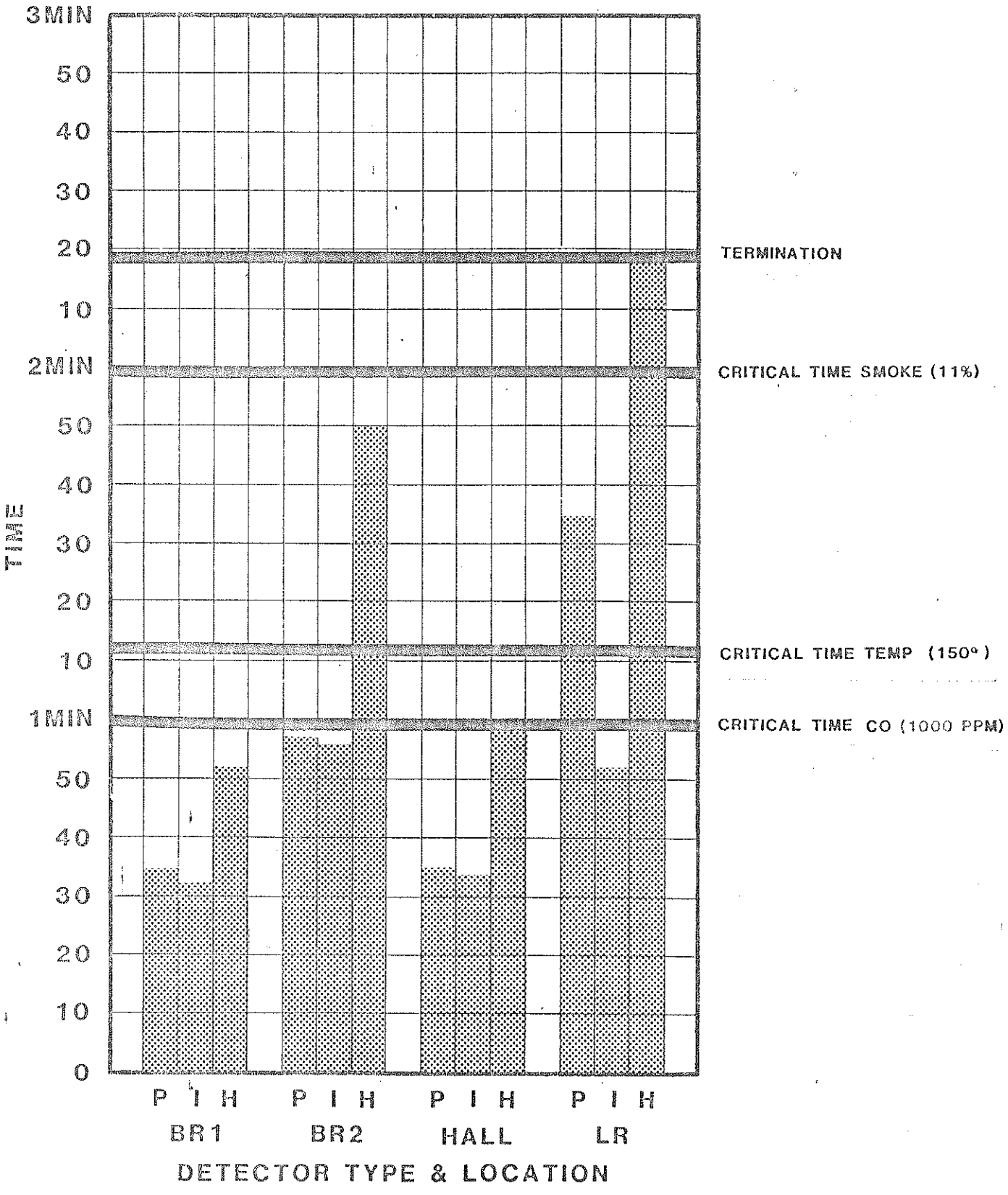
PALACE 16
FIRE IN - BEDROOM 1-OPEN FLAME



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

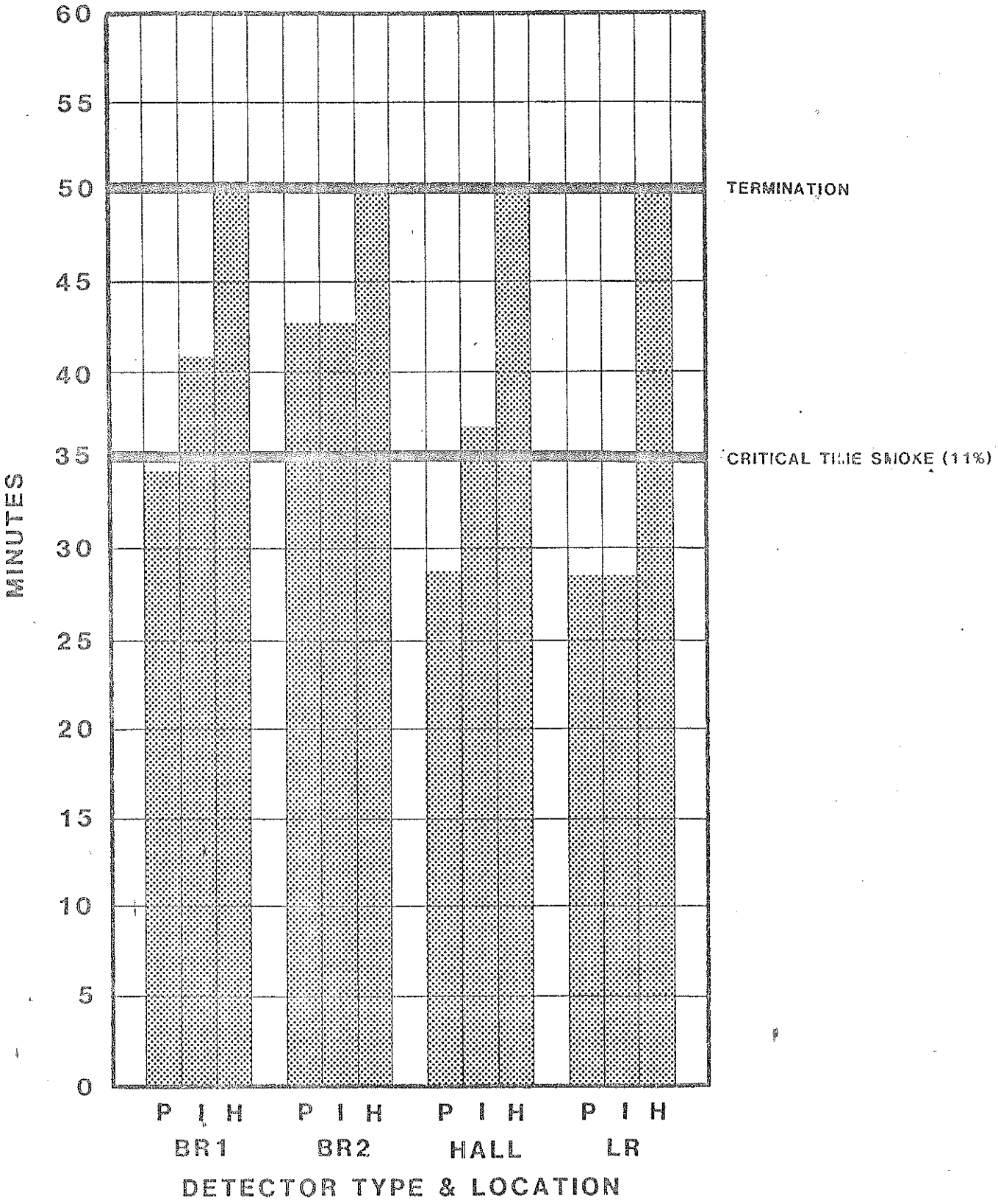
PALACE 17

FIRE IN-BEDROOM 1-OPEN FLAME



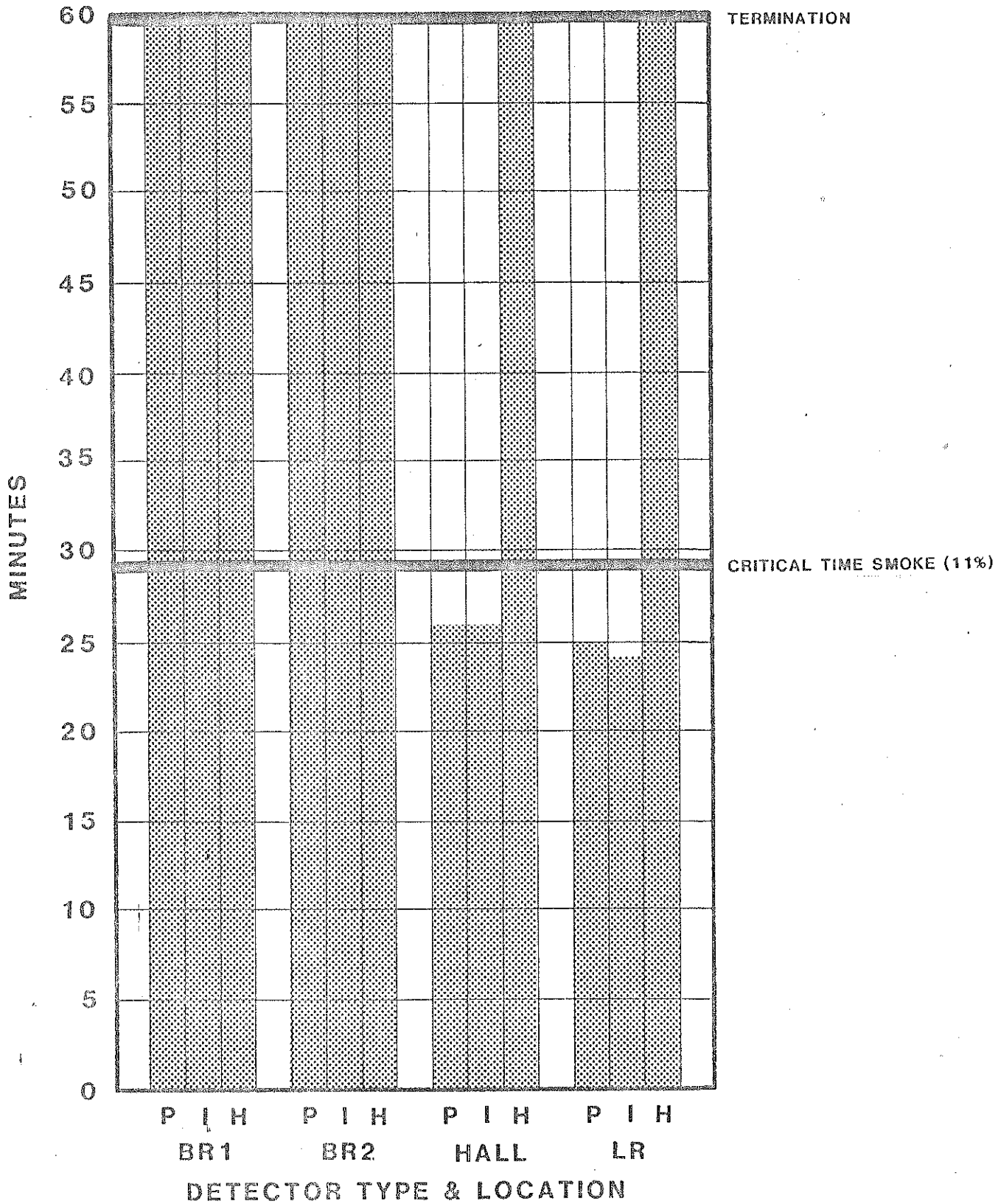
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

PALACE 18
FIRE IN KITCHEN-OPEN FLAME



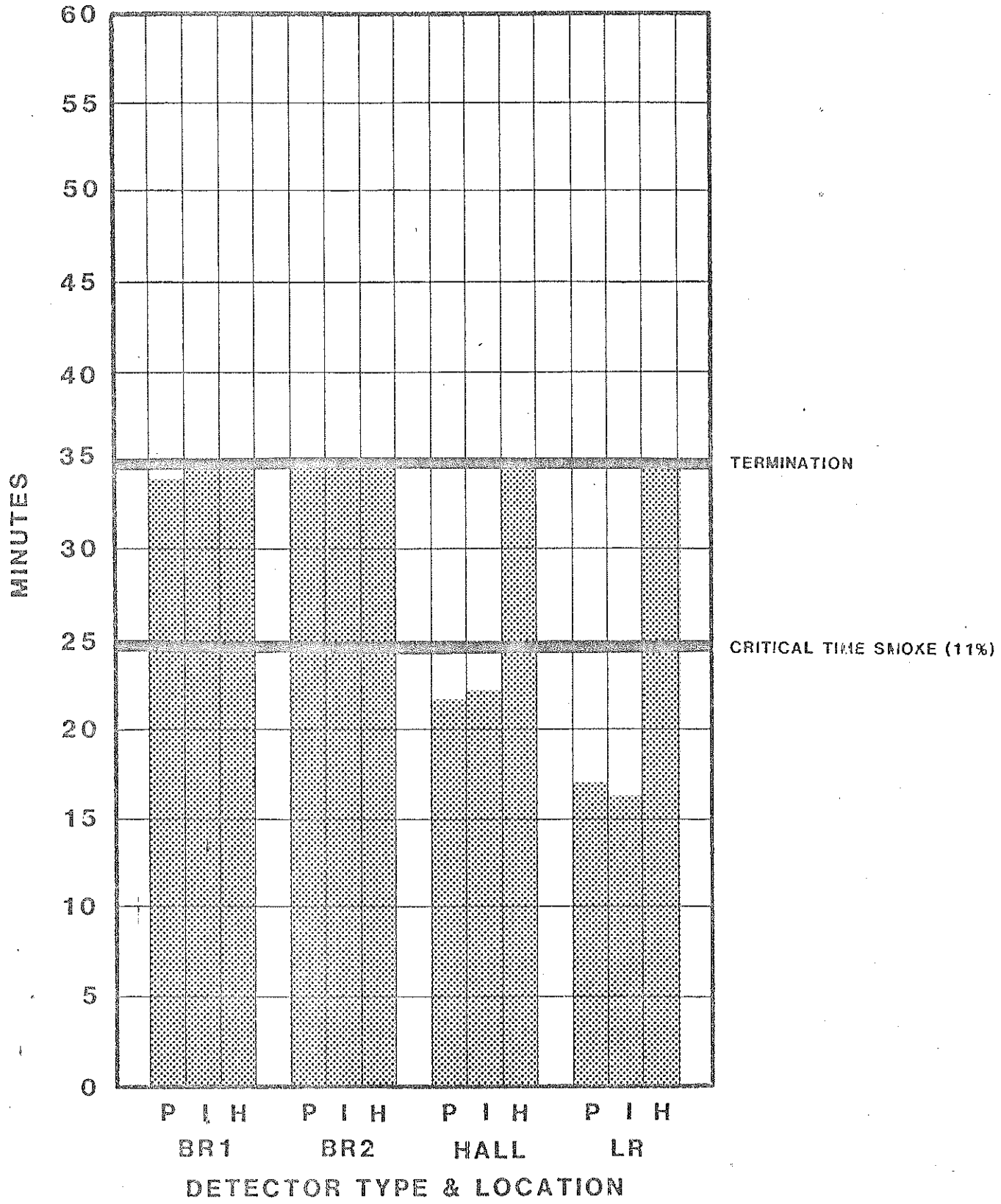
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

PALACE 19
FIRE IN KITCHEN,OPEN FLAME



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

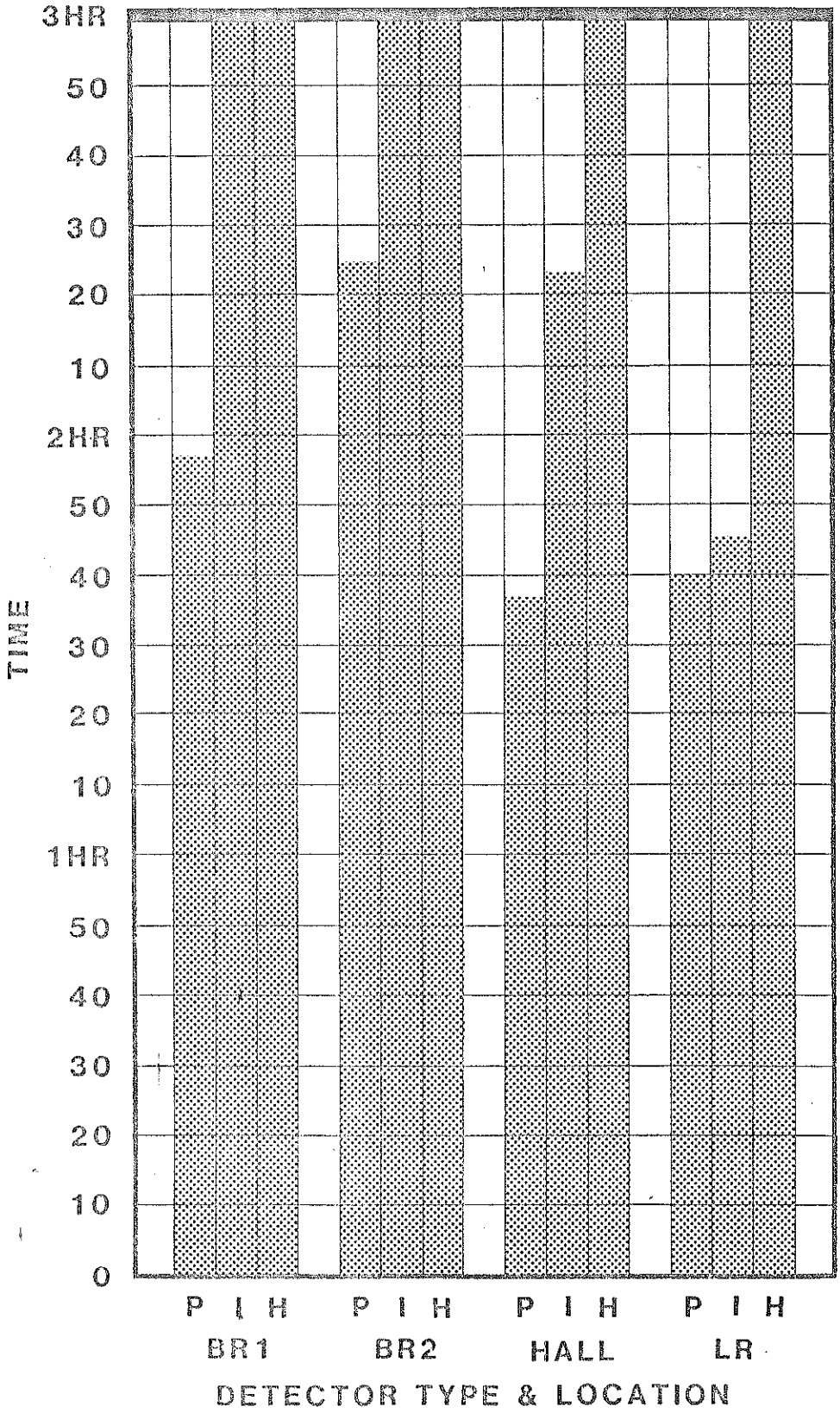
PALACE 20
FIRE IN KITCHEN,OPEN FLAME



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

PALACE 21

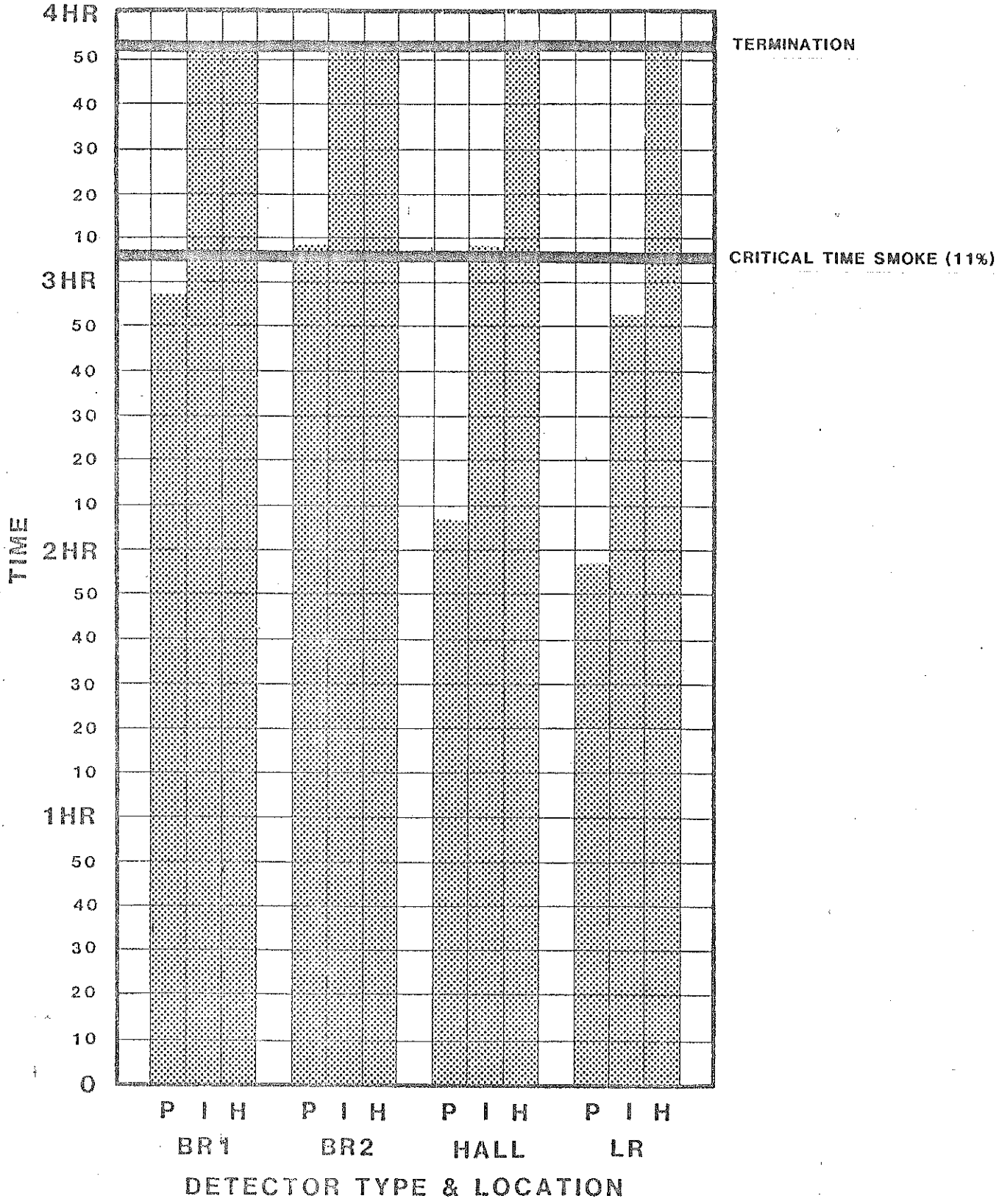
FIRE IN - KITCHEN-SMOLDERING



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

PALACE 22

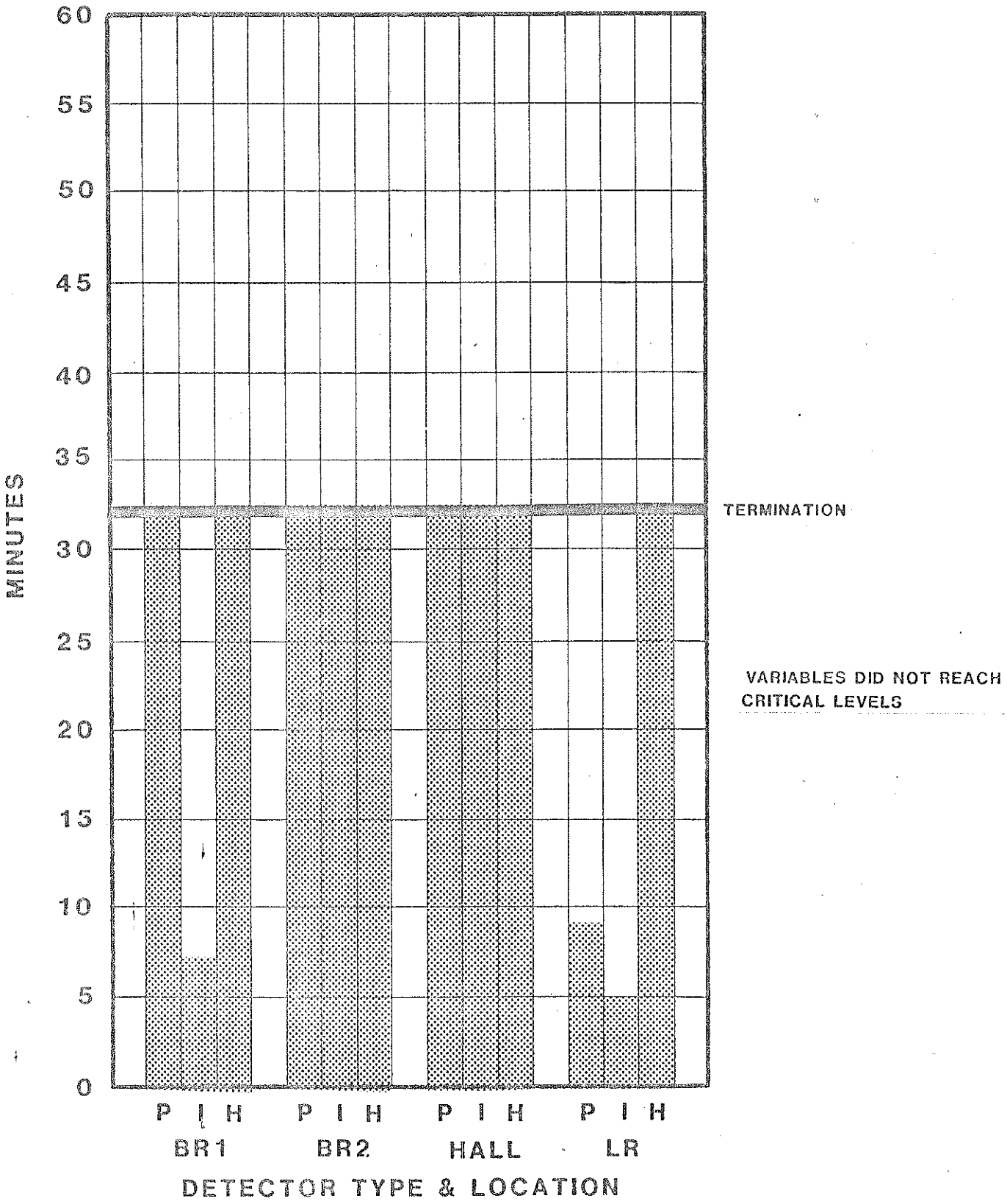
FIRE IN - KITCHEN-SMOLDERING



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

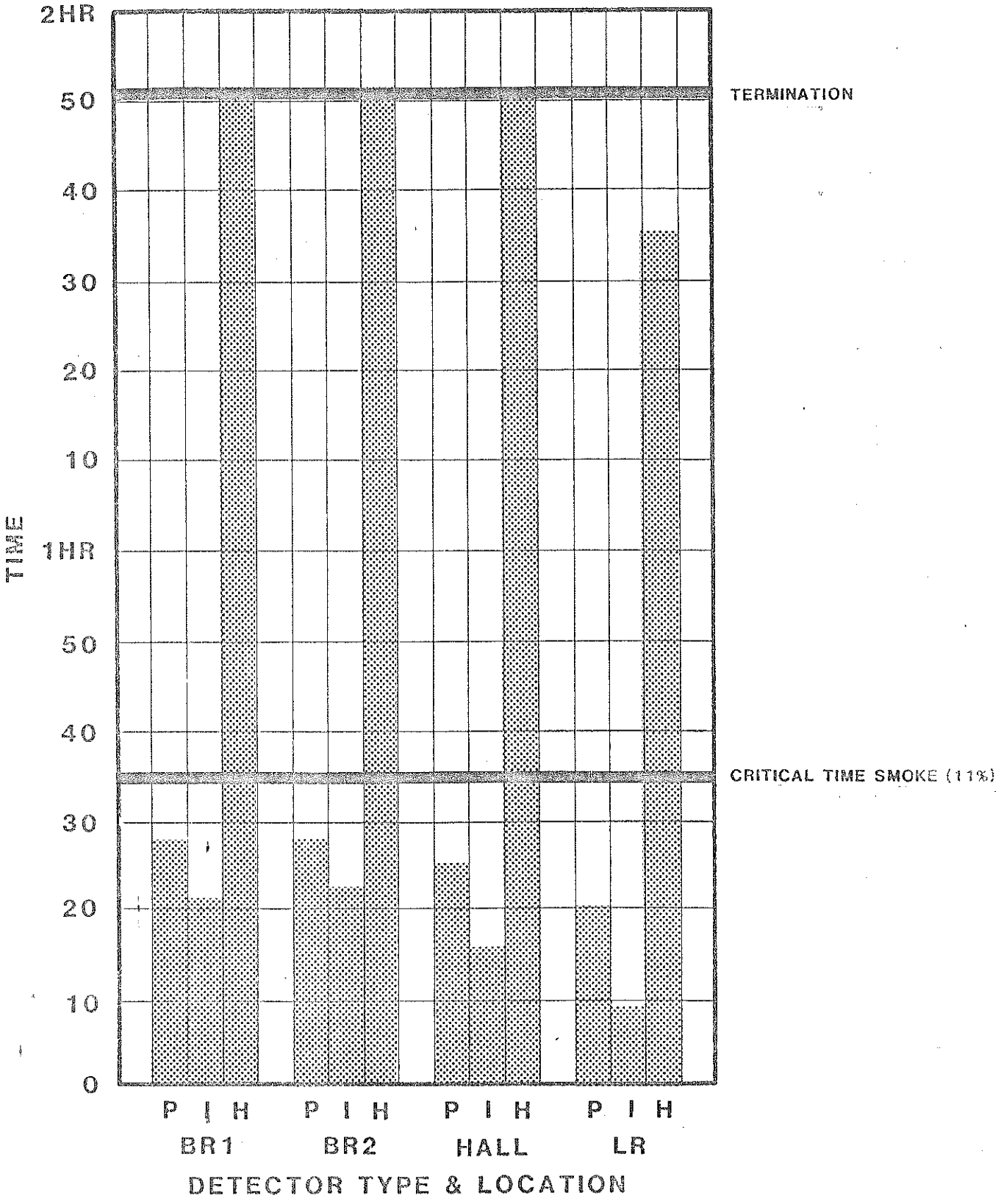
PALACE 23

FIRE IN KITCHEN,SMOLDERING FIRE



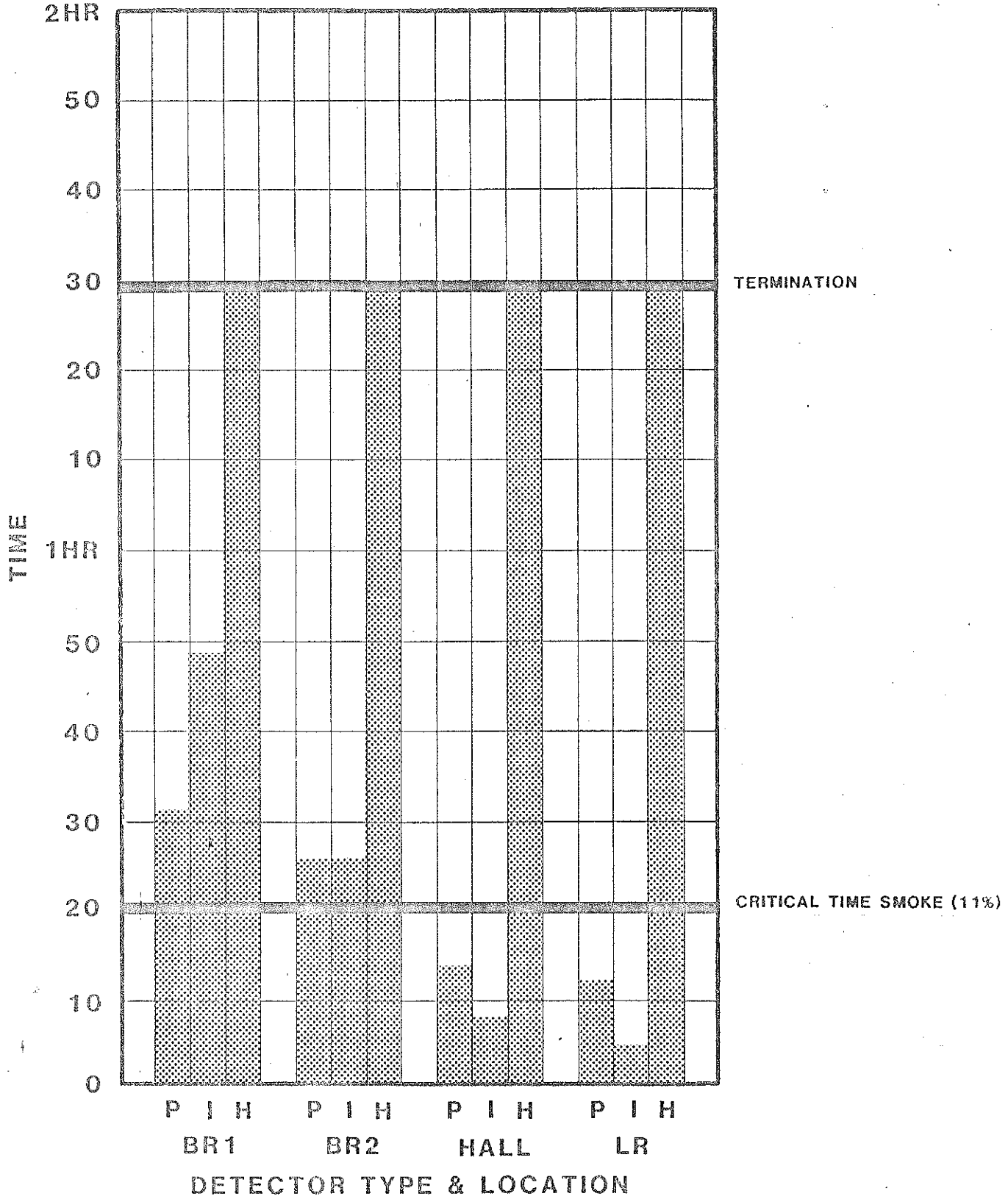
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

PALACE 24
FIRE IN LIVING ROOM SMOLDERING



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

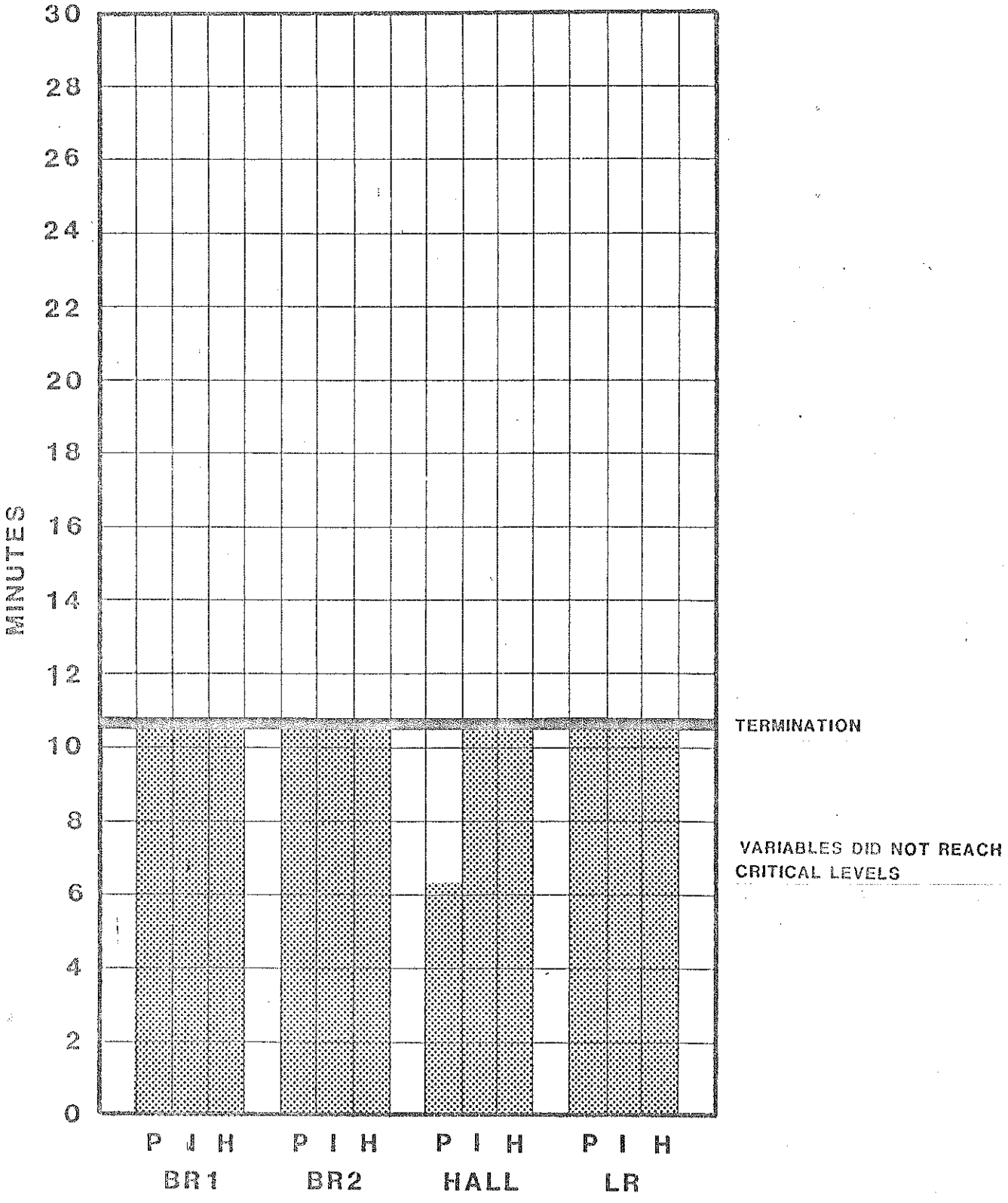
PALACE 25
FIRE IN LIVING ROOM-SMOLDERING



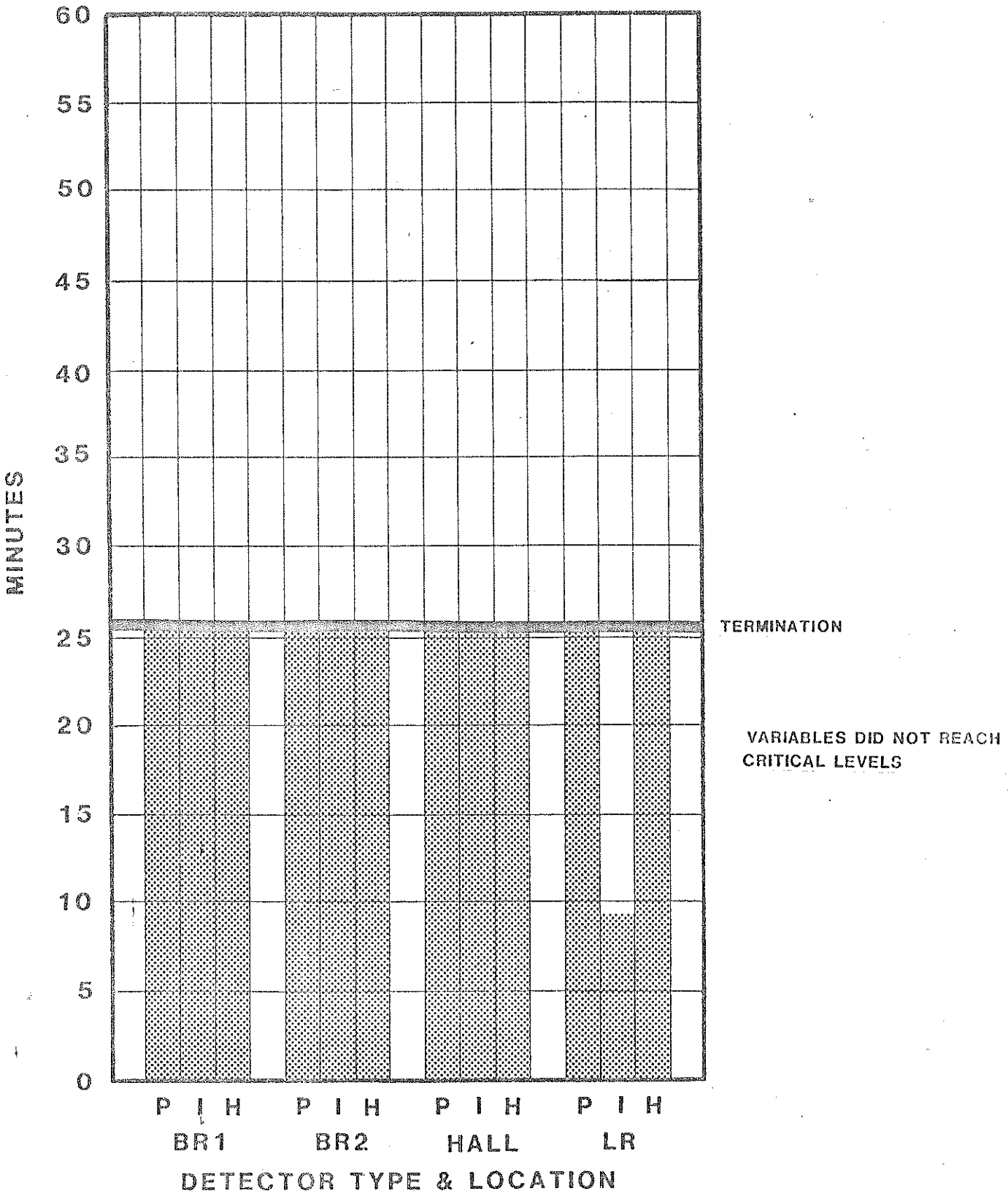
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

PALACE 31

FIRE IN - KITCHEN-OPEN FLAME

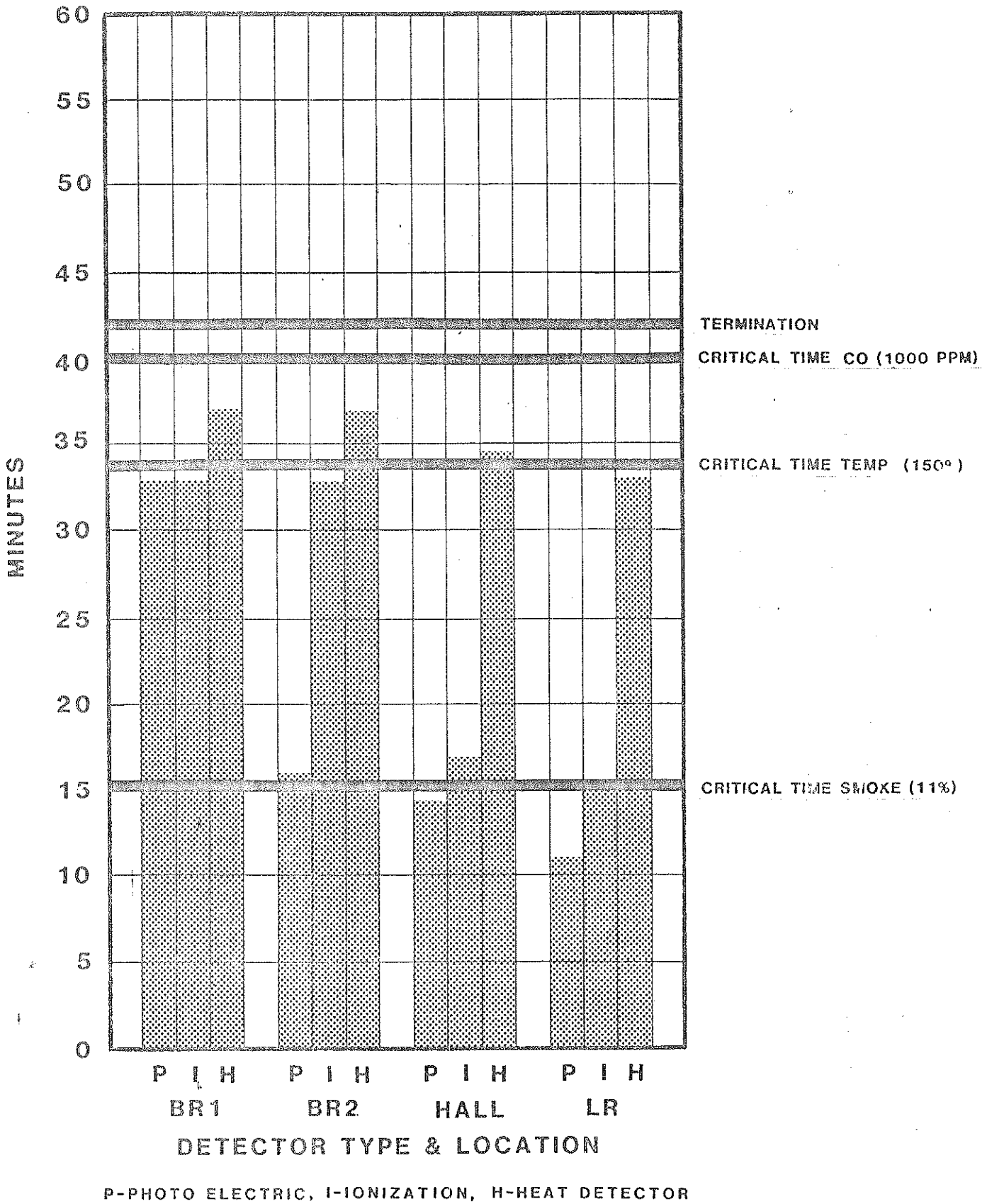


PALACE 32
FIRE IN KITCHEN,SMOLDERING FIRE



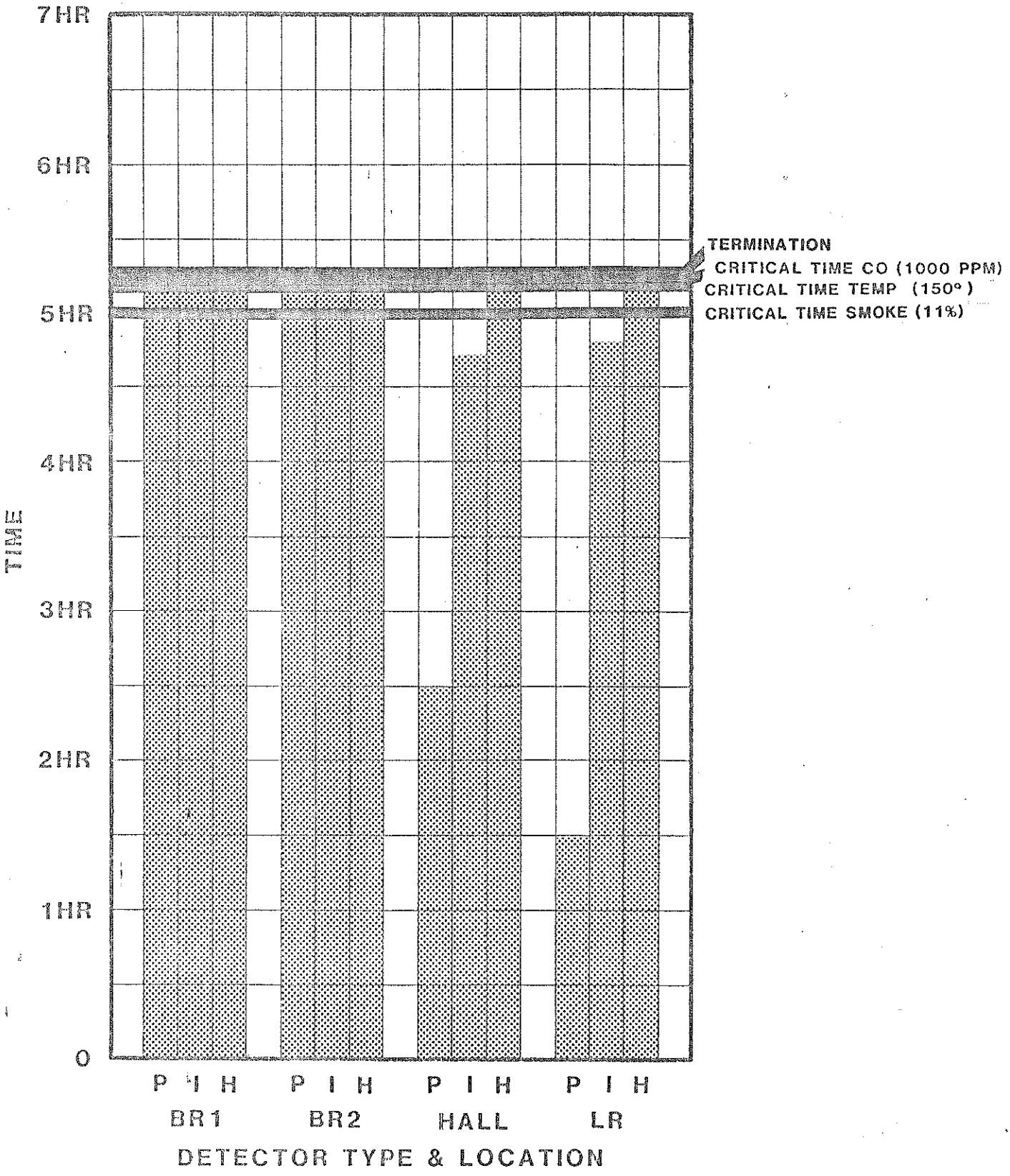
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

PALACE 1DC
FIRE IN LIVING ROOM-SMOLDERING



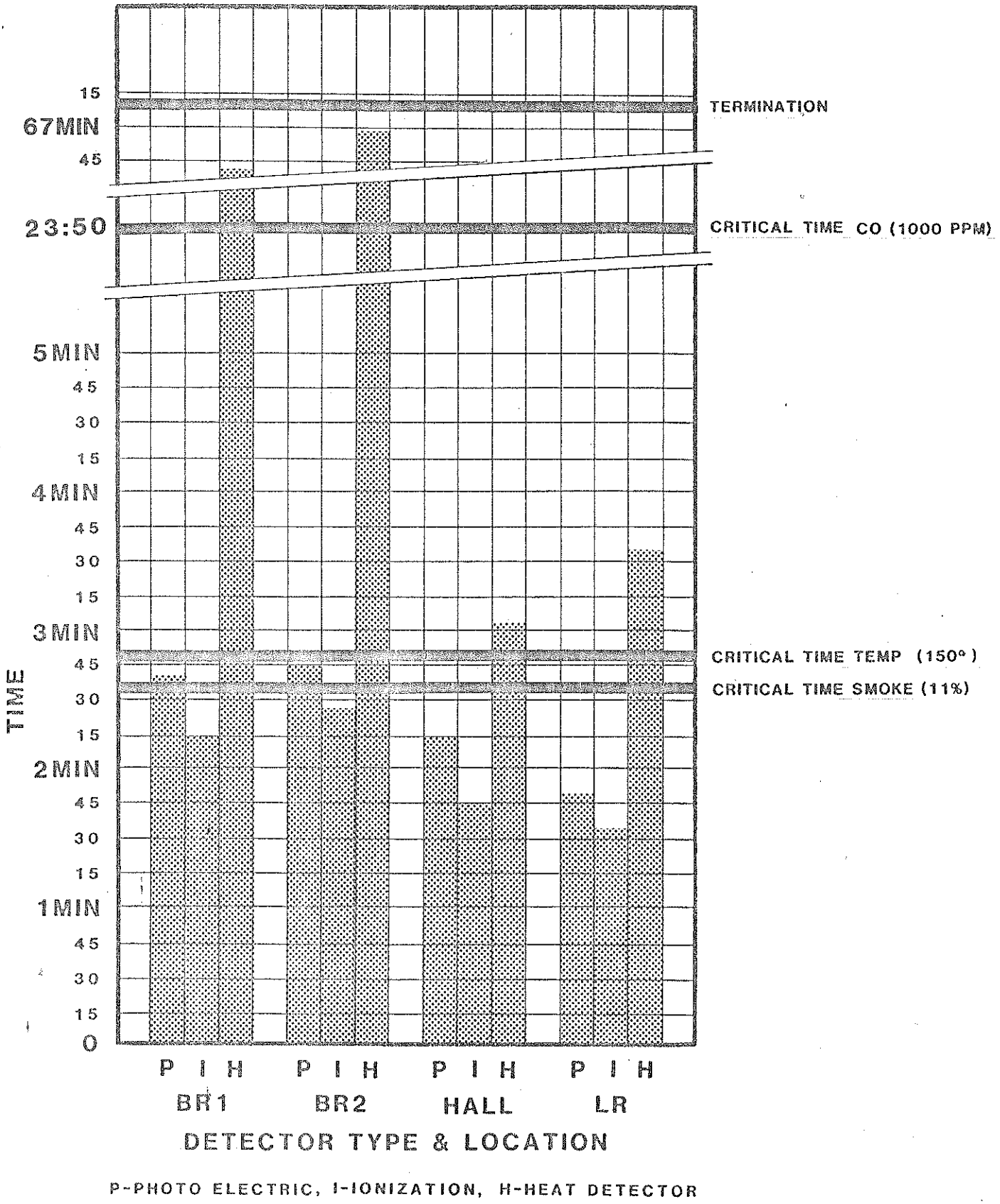
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

PALACE 2-DC
FIRE IN - LIVING ROOM-SMOLDERING



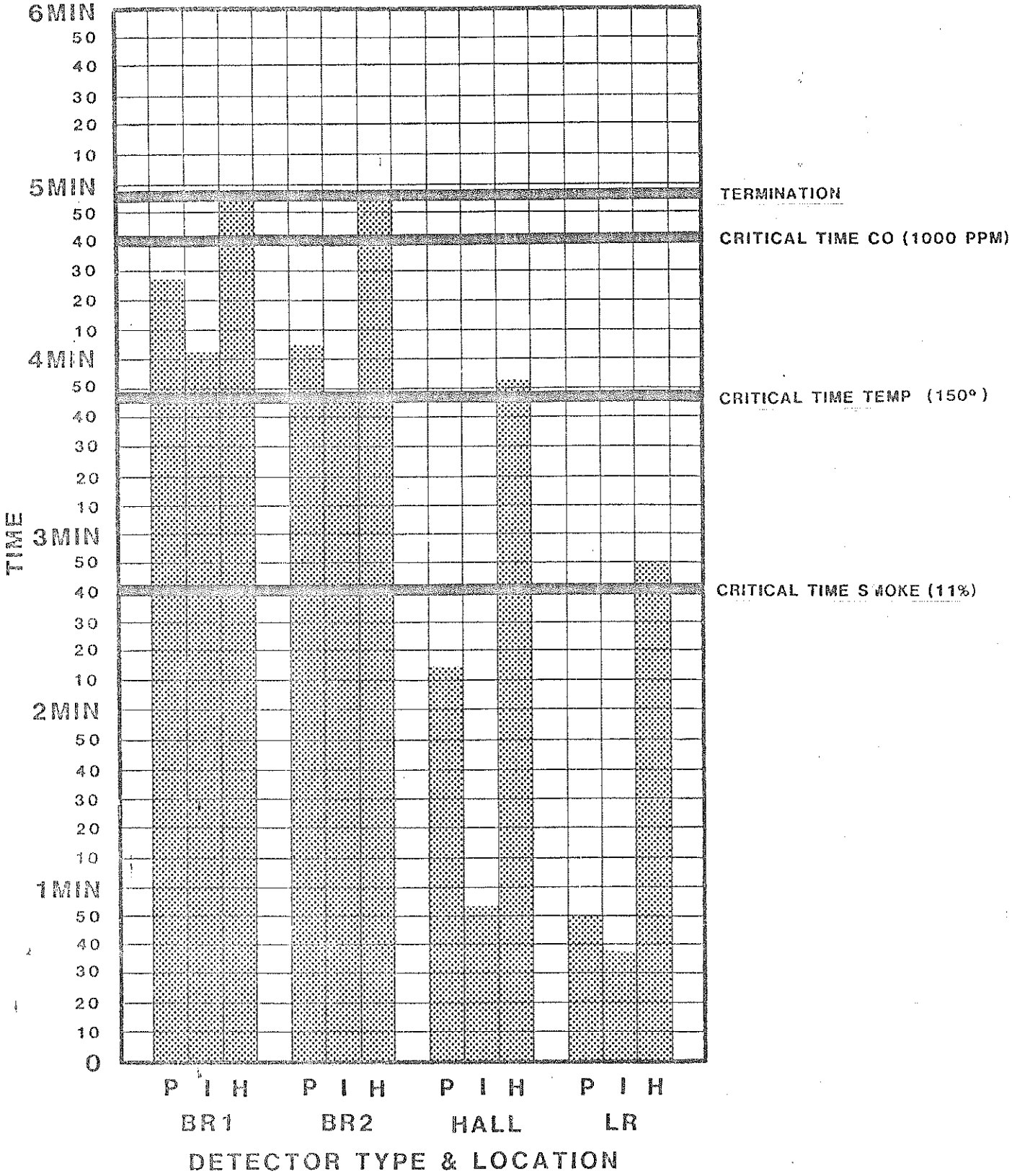
P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

PALACE 4-DC
FIRE IN -LIVING ROOM-OPEN FLAME



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

PALACE 7-DC
FIRE IN -LIVING ROOM-OPEN FLAME



P-PHOTO ELECTRIC, I-IONIZATION, H-HEAT DETECTOR

GROUP 3

BEST CASE DETECTOR

One-Story

Two-Story

Summary

ONE-STORY HOUSE

Chart indicates the "best case" generic type of detector that provided two or more minutes of alarm prior to reaching a potentially hazardous environmental level.

Smoldering

Room of Fire Origin	Bedroom	Hall	Living Room	Kitchen
Bedroom	I	P	I	P
Living Room	P	P	P/I	I
Kitchen	P/I	P	P/I	I
	P/I	P	I	I

Open Flame

Room of Fire Origin	Bedroom	Hall	Living Room	Kitchen
Bedroom	P/I	P/I	P/I	P/I
Living Room	P/I	P/I	I	P/I
Kitchen	P	P	---	P
	P	P	I	P

Summary

Room of Fire Origin	Bedroom	Hall	Living Room	Kitchen	
Bedroom	I	P	I	P	
Living Room	P	P	I	I	
Kitchen	P	P	P/I	P/I	
	P	P	I	P/I	Best Case Detector

P - Photoelectric Detector
I - Ionization Detector
H - Heat Detector
P/I - Equal Performance by Ionization and Photoelectric Detectors
--- - Indicates no detectors provided sufficient alarm

TWO-STORY HOUSE

Chart indicates the "best case" generic type of detector that provided two or more minutes of alarm prior to reaching a potentially hazardous environmental level.

Smoldering

Room of Fire Origin	Bedroom	Hall	Living Room	Kitchen
Bedroom	P	P	---	---
Living Room	P/I	P	P/I	P/I
Kitchen	P	P/I	I	P/I
	P	P	I	P/I

Open Flame

Room of Fire Origin	Bedroom	Hall	Living Room	Kitchen
Bedroom	---	---	---	---
Living Room	---	I	I	I
Kitchen	---	P	P/I	P/I
	---	P/I	I	I

Summary

Room of Fire Origin	Bedroom	Hall	Living Room	Kitchen	
Bedroom	P	P	---	---	
Living Room	P/I	P/I	I	I	
Kitchen	P	P	I	P/I	
	P	P	I	I	Best Case Detector

P - Photoelectric Detector
I - Ionization Detector
H - Heat Detector
P/I - Equal Performance by Ionization and Photoelectric Detectors
--- - Indicates no detectors provided sufficient alarm

SUMMARY FOR ONE- AND TWO-STORY HOUSES

Chart indicates the "best case" generic type of detector that provided two or more minutes of alarm prior to reaching a potentially hazardous environmental level.

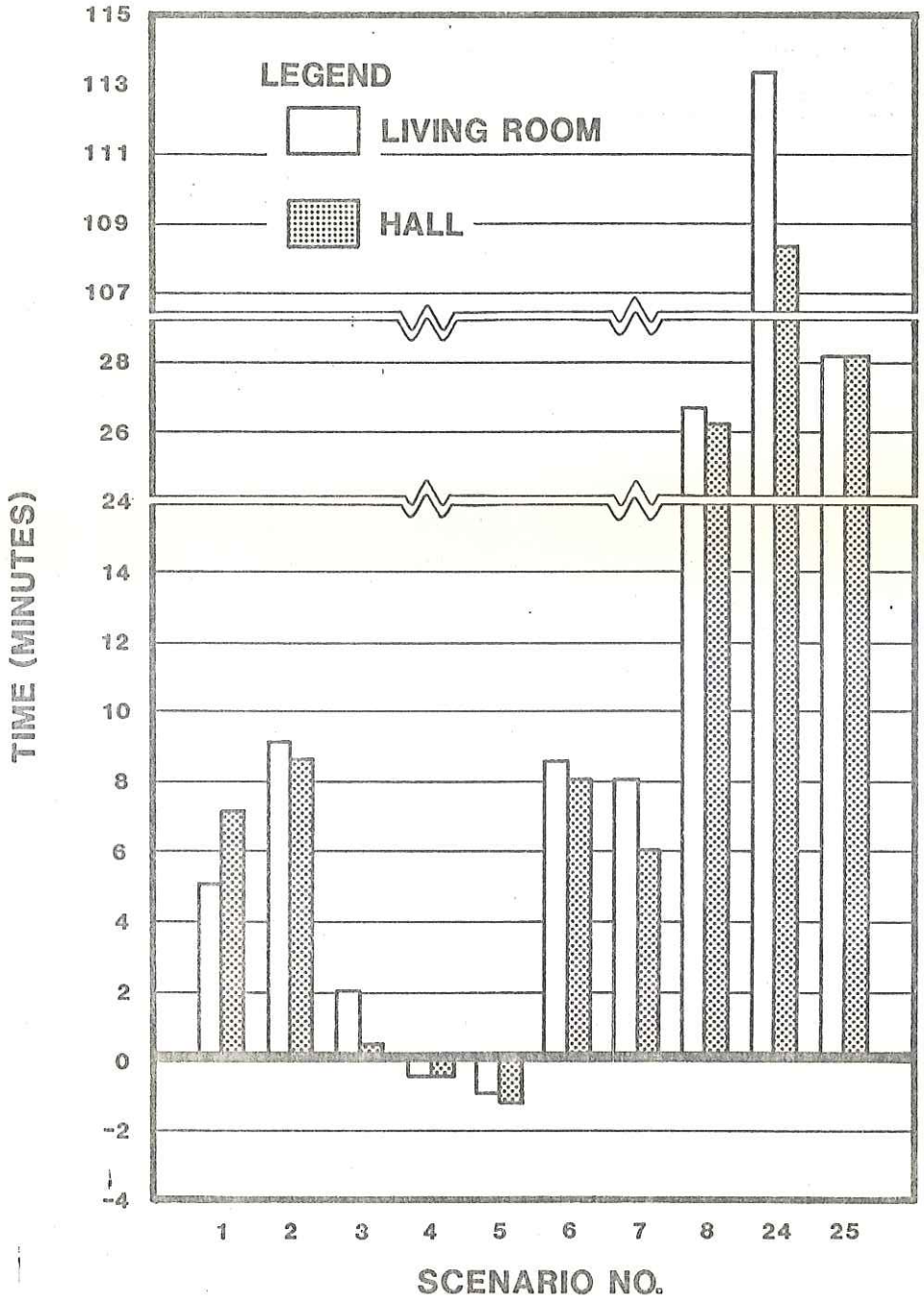
Room of Fire Origin	Bedroom	Hall	Living Room	Kitchen	
Bedroom	P/I	P	I	P	
Living Room	P	P	I	I	
Kitchen	P	P	I	P/I	
	P	P	I	P/I	Best Case Detector

P - Photoelectric Detector
I - Ionization Detector
H - Heat Detector
P/I - Equal Performance by Ionization and Photoelectric Detectors.
Data does not reflect unwarranted alarms.

GROUP 4

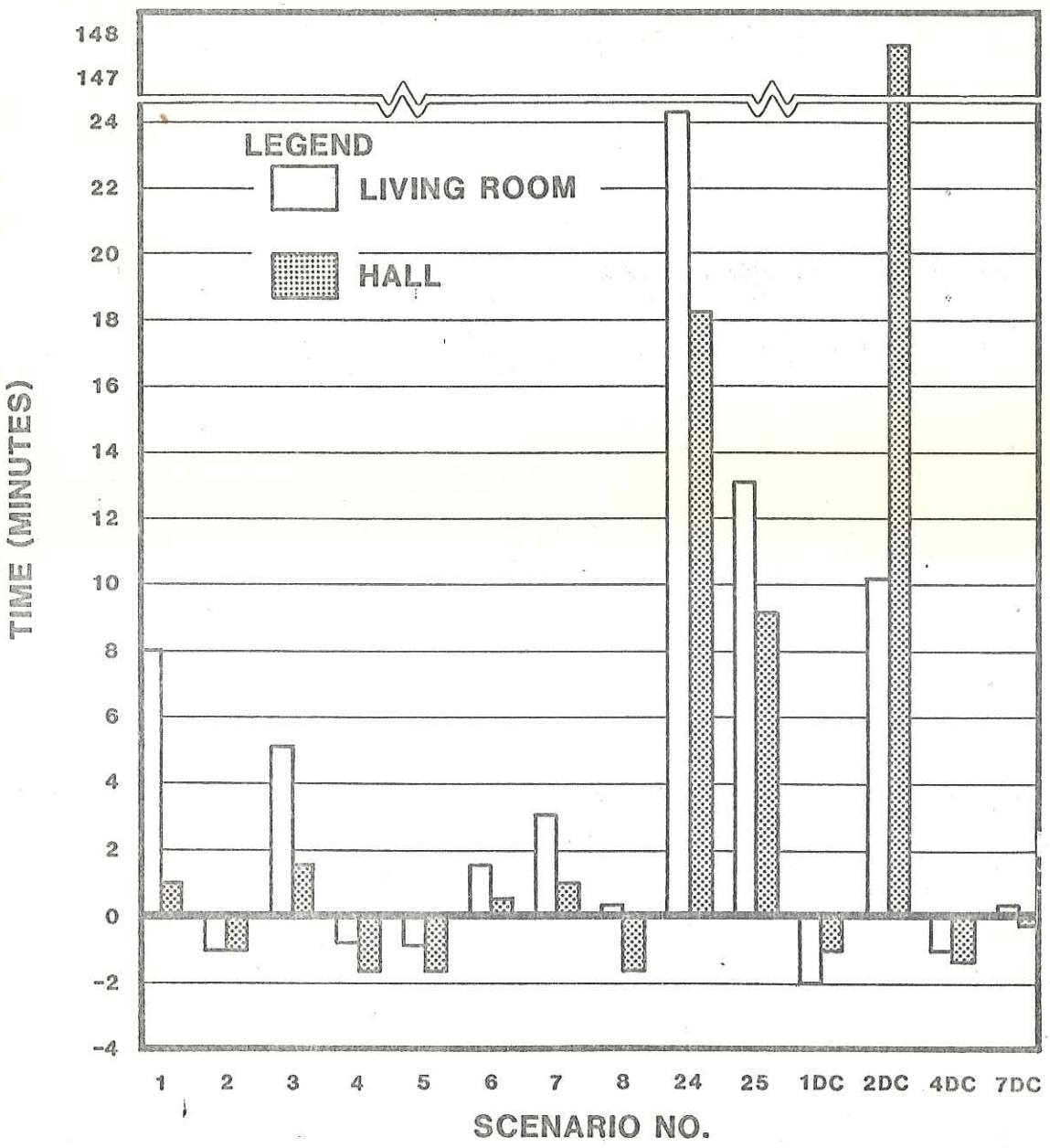
LIVING ROOM AND HALL DETECTORS

COMPARISON OF LIVING ROOM & HALL DETECTOR ALARMS
ONE STORY HOUSE



Time 0 represents the time any one of the potentially hazardous levels of temperature, smoke, or carbon monoxide was first reached plus an additional two (2) minutes for adequate escape.

COMPARISON OF LIVING & HALL DETECTOR ALARMS
TWO STORY HOUSE



Time 0 represents the time any one of the potentially hazardous levels of temperature, smoke, or carbon monoxide was first reached plus an additional two (2) minutes for adequate escape.

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