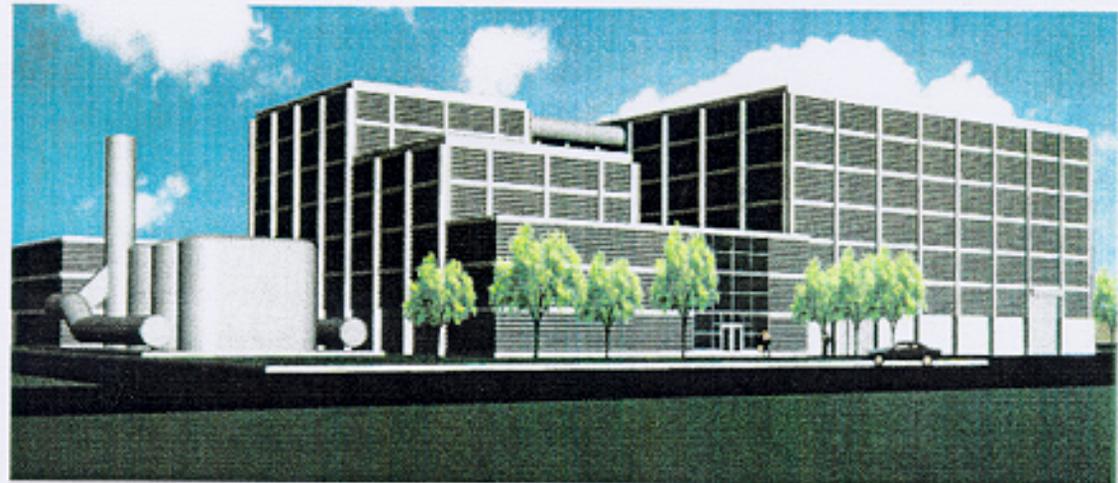


TECHNICAL REPORT
ON
STORAGE OF PALLETIZED
ISOPROPYL ALCOHOL

PREPARED BY
UNDERWRITERS LABORATORIES INC.
PROJECT 96NK33044 / NC1838
FOR
INDUSTRIAL RISK INSURERS
HARTFORD, CT

Industrial Risk Insurers
Hartford, CT



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April 18, 1997

Prepared By

Underwriters Laboratories Inc.
Project 96NK33044/NC1838

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EXECUTIVE SUMMARY

A series of eight fire tests were conducted to evaluate the level of protection required to control a fire in double row rack storage of palletized isopropyl alcohol in high density polyethylene (HDPE) plastic containers.

The containers ranged in capacity from pint to gallon and were stored in corrugated cardboard cartons on hardwood pallets. The total amount of isopropyl alcohol used in each fire test ranged from 240 gallons to 1560 gallons.

The first seven fire tests were conducted in a double row rack storage array with barriers and in-rack sprinklers. The last test was conducted in a palletized storage array under the protection of the ceiling sprinklers only. Fire Test No. 1 through Fire Test No. 6 were ignited with two gallons of alcohol in two 2 ft. x 2 ft x .75 in. steel pans located halfway within the plane of the center south face at the floor. Fire Test No. 7 utilized four cotton cellulose ignitors each measuring 3 in. long by 3 in. in diameter with 4 oz. of gasoline arranged around a point at the floor in the center of the south face. Fire Test No. 8 utilized a 6 in. long by 3 in. in diameter cotton cellulose ignitor with 8 oz. of gasoline at a point centered within the south flue space.

The in-rack sprinklers were the quick response 17/32 in. nominal large orifice upright style 165°F temperature rated sprinklers positioned on the face and flue at two levels for fire tests 1 through fire test 4 and at a single level for Fire Test No. 5 through Fire Test No. 7. A wooden barrier was positioned above the in-rack sprinklers at every level of protection. The sprinklers were arranged to operate at a flowing pressure of 50 psi.

The 286°F upright ceiling sprinklers were positioned on 8 ft. x 10 ft. spacing for Fire Test No. 1 through Fire Test No. 5. The sprinklers were positioned on 8 ft. x 8 ft. spacing for Fire Test No. 6 through Fire Test No. 8.

During Fire Test No. 1 through Fire Test No. 7 the following criteria was used to indicate that the in-rack protection was not adequate: 1.) operation of the ceiling sprinklers. 2.) fire spread above the in-rack protection. 3.) involvement of adjacent targets.

The fire tests conducted with two levels of double row rack storage, of palletized plastic containers filled with 93% to 99 % isopropyl alcohol, with in-rack sprinklers at every level demonstrated that the commodity could be adequately protected. When the lower barrier and level of in-rack sprinklers was removed there was a significant increase in the amount of product consumed during each fire test. The results of the palletized Fire Test No. 8 indicated that the ceiling only sprinklers at a discharge density of 0.40 gpm/ft.² was able to control the fire in the test commodity by preventing the outer pallets of commodity from igniting. However, it must be noted that a large floor fire opened eleven sprinklers covering a much larger area than that occupied by the 12 pallet loads of commodity. A larger test array may not have been controlled.

A table indicating the testing parameters and results obtained is presented with this executive summary. A complete description of the testing is presented in the following report.

EXECUTIVE SUMMARY TABLE

	TEST NO. 1	TEST NO. 2	TEST NO. 3	TEST NO. 4	TEST NO. 5	TEST NO. 6	TEST NO. 7	TEST NO. 8
TEST DATE	12/10/96	12/11/96	12/11/96	12/12/96	12/12/96	2/18/97	2/18/97	2/20/97
COMMODITY	RPQ	RPG	RPP	RPP	RPP, RPG,MIX	RPG,FPG	RPP,RPQ	RPG,FPG, RPN,RPQ
NUMBER OF PALLETS	8	8	8	2	4,4,8	4,4	4,4	2,2,2,6
TOTAL GALLONS OF ALCOHOL	768	864	720	180	1560	1104	1056	1452
CEILING SPRINKLER SPACING	8 FT. x 10 FT.	8 FT. x 8 FT.	8 FT. x 8 FT.	8 FT. x 8 FT.				
IN-RACK SPRINKLER SPACING AND CONFIGURATION - FLUE	4 FT. NOM. EVERY LEVEL	4 FT. NOM. SECOND LEVEL	4 FT. NOM. SECOND LEVEL	4 FT. NOM. SECOND LEVEL	N/A			
IN-RACK SPRINKLER SPACING AND CONFIGURATION - FACE	8 FT. NOM. EVERY LEVEL	8 FT. NOM. SECOND LEVEL	8 FT. NOM. SECOND LEVEL	8 FT. NOM. SECOND LEVEL	N/A			
NUMBER OF RACK SPRINKLERS OPERATED	2	2	1	2	2	3	2	N/A
FIRST RACK SPRINKLER OPERATING TIME	0:56	0:49	0:25	0:54	1:09	0:35	1:31	N/A
NUMBER OF CEILING SPRINKLERS OPERATED	0	0	0	0	0	0	1	11
FIRST CEILING SPRINKLER OPERATING TIME	N/A	N/A	N/A	N/A	N/A	N/A	6:38	2:10
FIRE SPREAD ABOVE IN-RACK SPRINKLERS	NO	NO	NO	NO	NO	NO	YES	N/A
FIRE SPREAD ACROSS AISLE	NO	NO	NO	NO	NO	YES	YES	N/A
NUMBER OF DAMAGED CARTONS	14 RPQ	3 RPG	1 RPP	20 RPP	32 RPP	17 FPG	20 RPQ 15 RPP	27 FPG 27 RPN 17 RPG 288 RPQ
QUANTITY CONSUMED	21 GL	10 GL	1 GL	25 GL	45 GL	68 GL	55 GL	710 GL

RPP ROUND PLASTIC PINT CONTAINERS FPG F-STYLE PLASTIC GALLON CONTAINERS
 RPQ ROUND PLASTIC QUART CONTAINERS RPN ROUND PLASTIC GALLONS IN DIFF. BOX
 RPG ROUND PLASTIC GALLON CONTAINERS MIX RPP AND RPG ON SAME PALLET

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Sprinkler Systems

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Quart Test Commodity

Round Gallon Test Commodity

F-Style Gallon Test Commodity

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Fire Test No. 3

Fire Test No. 4

Fire Test No. 5

Fire Test No. 6

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Fire Test No. 8

Fire Test Summary

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LIST OF ILLUSTRATIONS

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5	Storage Container Details
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LIST OF ABBREVIATIONS AND DEFINITIONS

C	Centigrade
Deg.	Degree
F	Farenheit
Fig.	Figure
Ft.	Foot
Gal	Gallon
gpm	Gallons per minute
Ill.	Illustration
In.	inch
IPA	isopropyl alcohol
IRI	Industrial Risk Insurers
LO	Large Orifice
Lb	pound
Min.	Minute
No.	Number
Pt	pint
Psi	pounds per square inch
Qt	quart
s	second
UL	Underwriters Laboratories

1.0 INTRODUCTION

General

This Report describes the Special Service Investigation conducted for Industrial Risk Insurers (IRI) to develop fire test data relative to the level of protection required for scenarios involving mixed palletized rack storage of water miscible flammable liquids in plastic containers.

A series of eight fire tests were conducted utilizing different types and configurations of palletized cartons of isopropyl alcohol (IPA) in pint, quart, and gallon containers.

Purpose

The sole purpose of this investigation was to develop test data relative to the protection of mixed rack storage of palletized water miscible flammable liquids in plastic containers using a wet pipe ceiling and in-rack sprinkler systems.

Plan

A series of fire tests were planned to be conducted using isopropyl alcohol filled, pint, quart, and gallon, plastic containers in cardboard boxes on pallets in various storage arrangements.

2.0 TEST FACILITY

Test Facility

The fire tests were conducted in a 120 ft. by 120 ft. by 54 ft. high room fitted with a 100 ft. by 100 ft. adjustable height ceiling adjusted to a height of 30 ft.

The test room is equipped with an exhaust system capable of being adjusted from near zero flow to 60,000 cubic feet per minute through a regenerative, thermal oxidizing, smoke abatement system. Make-up air is provided through four inlet ducts, each 5 ft. in diameter, positioned along the walls of the test facility.

The floor is smooth and flat measuring 100 ft. by 100 ft. and surrounded with a grated drainage trench to insure adequate floor water drainage from the test area. The water runoff from the suppression system drain is collected through a water treatment system.

3.0 EQUIPMENT AND INSTRUMENTATION

Rack Configuration

Industrial storage racks utilizing steel upright and steel beam construction were arranged to provide a double row main storage rack with three 8 ft. bays and 3 tiers in each row. The tiers were positioned to provide a nominal 63 in. tier height. The upright supports of each row of the double row main storage rack were positioned 12 in. apart. A 3/8 in. plywood barrier was positioned over the bays and longitudinal flue space at each tier through out the rack assembly for Fire Test Nos. 1,2,3 and 4. The plywood barrier was positioned only over the second tier for Fire Test Nos. 5,6 and 7. The plywood barrier was positioned approximately 9 inches above the in-rack sprinkler deflector in all fire tests. The geometric center of the rack was positioned between four ceiling sprinklers.

Sprinkler Systems

Ceiling Sprinkler System

A closed head, wet pipe, automatic sprinkler system was positioned below the movable, smooth, flat, non-combustible ceiling. Fire Test Nos. 1 through 5 were conducted with twenty four 286°F upright style sprinklers installed on 8 ft. by 10 ft. spacing. Fire Test Nos. 6 through 7 were conducted with sixteen 286°F pendent style sprinklers installed on 8 ft. by 8 ft. spacing. Fire Test No. 8 was conducted with thirty six 286°F pendent style sprinklers installed on 8 ft. by 8 ft. spacing.

The sprinklers were supplied through a looped piping system consisting of 2 in. diameter branchlines. The piping system was supplied with water with adequate pressure and flow to maintain the desired water discharge density.

Sprinkler and installation details are provided in the Fire Test section of this report.

In-Rack Sprinkler System

A wet pipe automatic sprinkler system was positioned below the plywood barriers covering each tier of the double row rack assembly. A double looped, three branch, 2 in. piping assembly was configured to position the quick response 17/32 in. nominal large orifice upright style 165°F temperature rated sprinklers on 4 foot centers in the longitudinal flue space and 8 foot centers behind the uprights on both faces of the double row rack storage assembly. The piping was positioned so that the sprinkler deflectors were 9 inches below the barrier board and 54 inches above the bottom of the respective tier to accommodate the

various sample heights. Sprinklers were not installed in the first tier for Fire Test Nos. 5, 6, and 7. The piping system was supplied with water with adequate pressure and flow to maintain the desired water discharge density.

Instrumentation

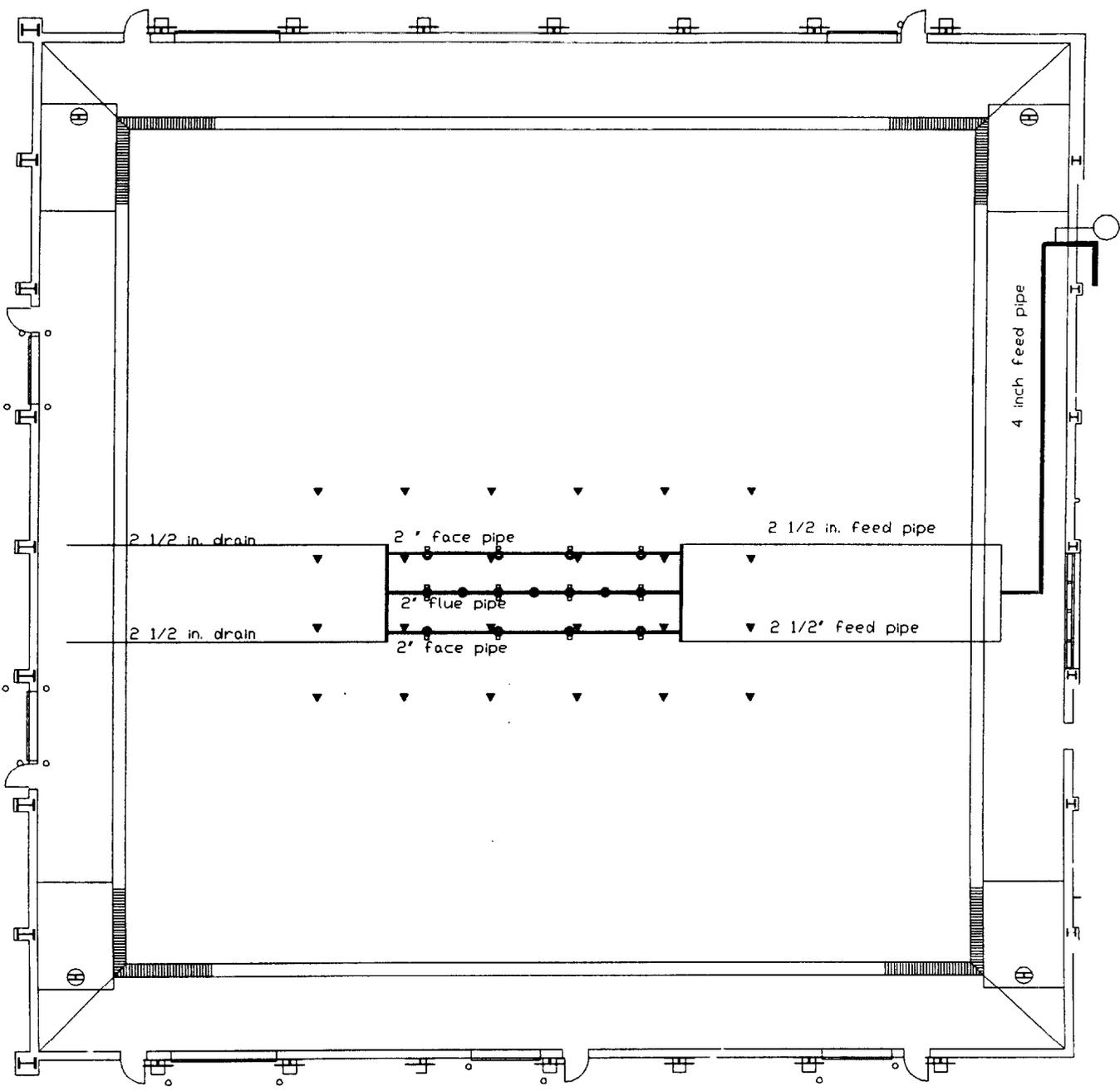
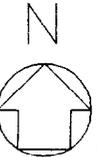
Thermocouples were located below the ceiling adjacent to each sprinkler to record ceiling temperatures.

Thermocouples were located adjacent to each in-rack sprinkler in the center bay of the first tier for Fire Test Nos. 1 - 6 and in the center bay of the second tier for Fire Test No. 7 to record in-rack temperatures,

Water pressure and flows were measured and monitored through calibrated electronic devices located within the water supply/sprinkler system.

Significant events during the fire tests were monitored and recorded with calibrated stopwatches and other timing devices located within the data acquisition system.

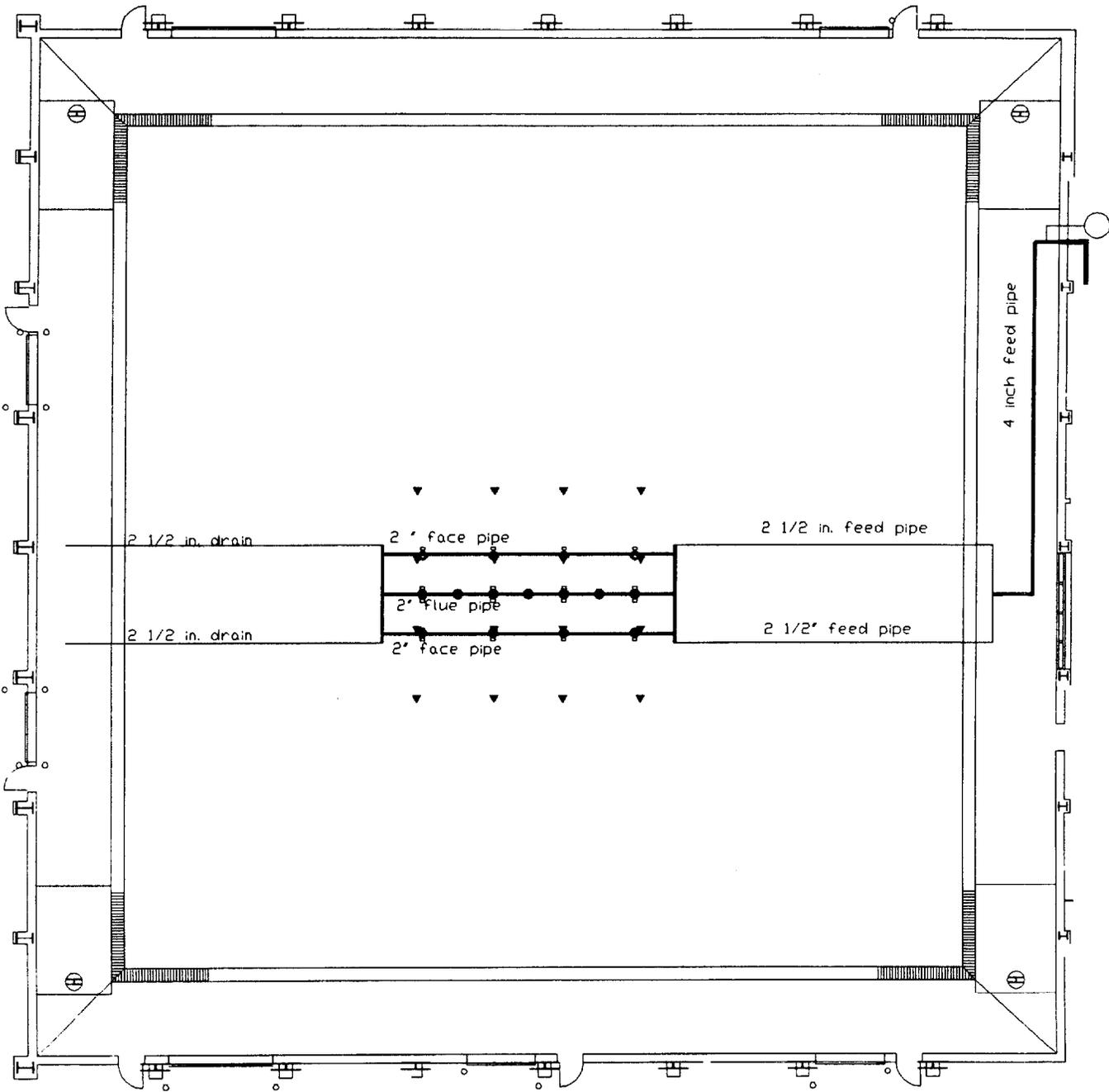
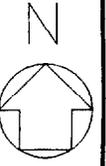
Video images of the fire tests were captured and recorded on VHS format video tape.



LEGEND

- ▼ 286 °F SPRINKLERS ON 8 FT BY 10 FT SPACING
- 165 °F IN-RACK SPRINKLERS
- ▣ RACK UPRIGHT

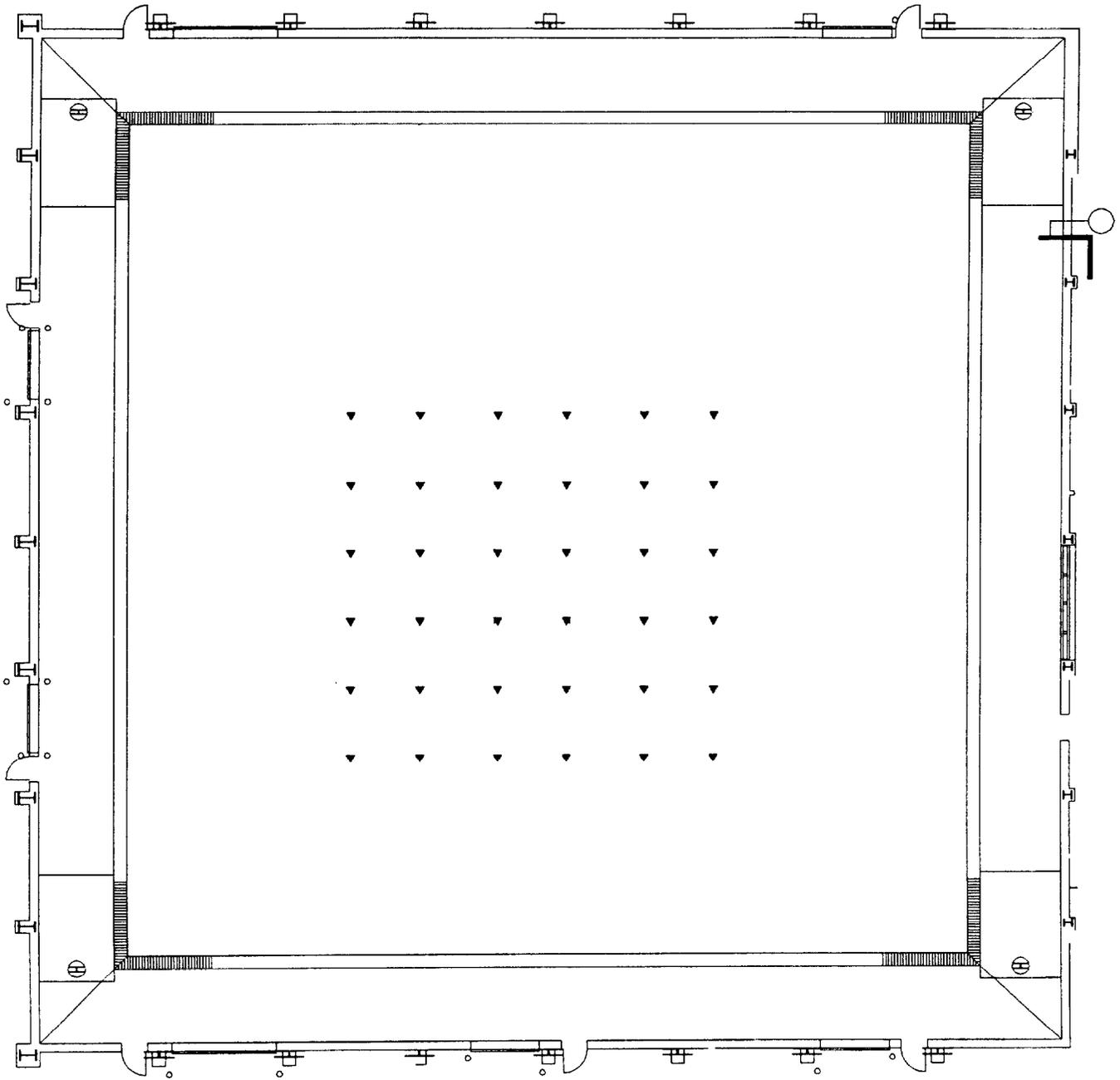
FIRE TEST No. 1 - FIRE TEST No. 5
TEST FACILITY AND SPRINKLER LOCATIONS



LEGEND

- ▼ 286 °F SPRINKLERS ON 8 FT BY 8 FT SPACING
- 165 °F IN-RACK SPRINKLERS
- RACK UPRIGHT

FIRE TEST No. 6 -- FIRE TEST No. 7
TEST FACILITY AND SPRINKLER LOCATIONS

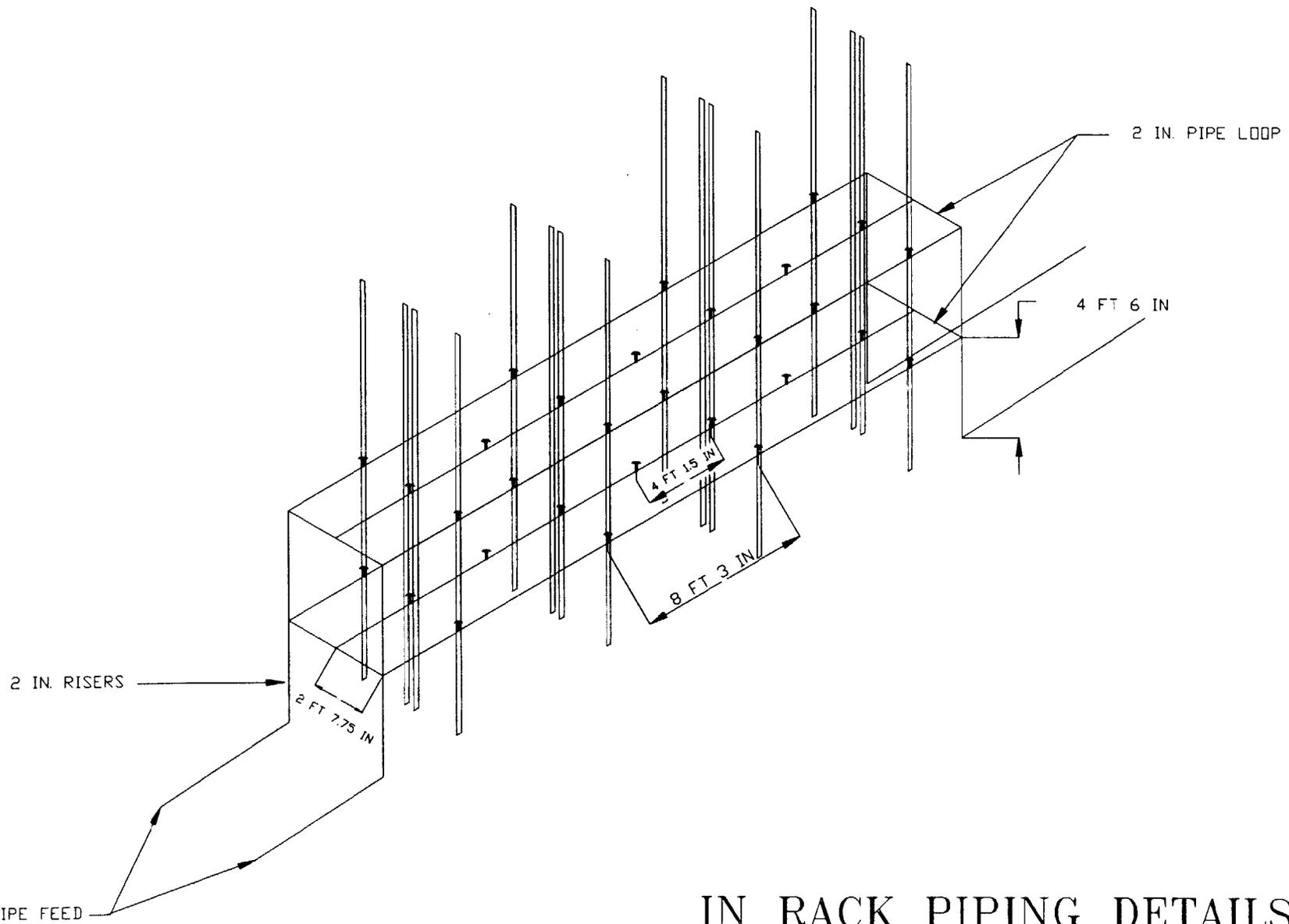


LEGEND

▼ 286 °F SPRINKLERS ON 8 FT BY 8 FT SPACING

FIRE TEST No.8
TEST FACILITY AND SPRINKLER LOCATIONS

ILL



IN RACK PIPING DETAILS

96NK33044/NC1838

4.0 TEST COMMODITY

The test commodity consisted of water miscible flammable liquid stored in plastic containers. The plastic containers were packaged in cardboard cartons which were then stacked on wooden pallets.

Water Miscible Flammable Liquid

The water miscible flammable liquids used in this investigation was a 99 % by volume isopropyl alcohol solution and a 93% by volume isopropyl alcohol solution. The water miscible flammable liquids were stored in plastic containers and packaged in cardboard cartons as described herein.

Pint Test Commodity

The 1 pint round plastic containers measured 8.25 in. high by 2.44 in. in diameter. The containers were made of high density polyethylene (HDPE) with a single fill opening approximately 0.875 in. in diameter located at the top. The sidewall of the bottle was approximately 0.027 in. thick, the bottom of the bottle was approximately 0.058 in. thick, and the bottom radial corner of the bottle was approximately 0.025 in. in thickness. The fill opening was fitted with a plastic screw type cap. The weight of a single container with cap was 0.9 lb. when full and 0.09 lb. when empty.

Twelve of these pint containers were placed within a corrugated carton, without partitions, measuring 8.5 in. by 11 in. by 8.75 in. high. The weight of an empty carton was 0.60 lbs. The weight of a full carton was 11.5 lbs. Eighty of these cartons were positioned on hardwood pallets.

The palletized commodity consisted of 4 layers of 20 cartons and measured 42 in. by 42 in. by 41 in. high. This stacking arrangement a fuel loading of 120 gallons per pallet with no vertical flue space through the pallet.

A stacking arrangement which provided the same quantity of commodity and an open vertical flue space within the pallet was used in Fire Test No. 3.

Quart Test Commodity

The 1 quart round plastic containers measured 9.25 in. high by 3.19 in. in diameter. The containers were made of high density polyethylene (HDPE) with a single fill opening approximately 0.875 in. in diameter located at the top. The sidewall of the bottle was approximately 0.031 thick, the bottom of the bottle was approximately 0.076 in. thick, and the bottom radial corner of the bottle was approximately 0.028 in. in thickness. The fill opening was fitted with a plastic screw type cap. The weight of a single container with cap was 1.8 lb. when full and 0.1 lb. when empty.

Six of these quart containers were placed within a corrugated carton, without partitions, measuring 10.25 in. by 7 in. by 10.38 in. high. The weight of an empty carton was 0.50 lbs. The weight of a full carton was 11.3 lbs. Ninety six cartons were positioned on hardwood pallets.

The palletized commodity consisted of 4 layers of 24 cartons measuring 42 in. by 42 in. by 47.5 in. high and provided a fuel loading of 144 gallons per pallet.

A stacking arrangement consisting of 3 layers of 24 cartons and measuring 42 in. by 42 in. by 36 in. high was utilized in Fire Test No. 8. This arrangement provided a fuel loading of 108 gallons per pallet.

Round Gallon Test Commodity

The 1 gallon round plastic containers measured 12.25 in. high by 6 in. in diameter. The containers were made of high density polyethylene (HDPE) with an integrated handle and a single fill opening approximately 1.25 in. in diameter located at the top. The sidewall of the bottle was approximately 0.044 in. thick, the bottom of the bottle was approximately 0.045 in. thick, and the bottom radial corner of the bottle was approximately 0.024 in. in thickness. The fill opening was fitted with a plastic screw type cap. The weight of a single container with cap was 7.1 lb. when full and 0.3 lb. when empty.

Four of the gallon containers were placed within a partitioned, corrugated carton measuring 12.5 in. by 12.5 in. by 12.5 in. high. The weight of an empty carton was 1.75 lbs. The weight of a full cartons was 30 lbs. Twenty seven of these cartons were positioned on hardwood pallets.

The palletized commodity consisted of 3 layers of 9 cartons and measured 42 in. by 42 in. by 43 in. high and provided a fuel loading of 108 gallons per pallet.

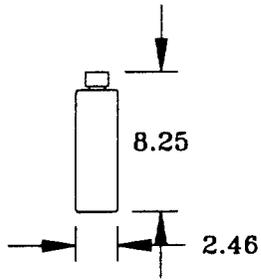
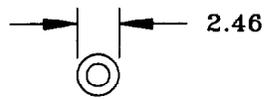
Another stacking arrangement placed four round gallon containers in a corrugated carton measuring 14.5 in. by 14.25 in. by 12.25 in. high. The weight of an empty carton was 1.3 lbs. The weight of a full carton was 29.5 lbs. Twenty seven of these cartons were positioned on hardwood pallets. The palletized commodity consisted of 3 layers of 9 cartons measuring 42 in. by 42 in. by 41 in. high and provided a fuel loading of 96 gallons per pallet.

F-Style Gallon Test Commodity

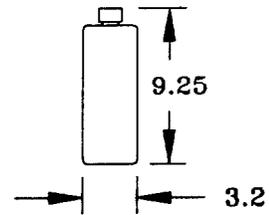
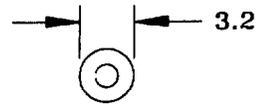
The 1 gallon F-style (oblong) plastic containers measured 4.5 in. by 7 in. by 11.75 in. high. Each container was made of high density polyethylene (HDPE) with an integrated handle and single fill opening approximately 1.125 in. in diameter located at the top at one side. The sidewall of the bottle was approximately 0.060 in. thick, the bottom of the bottle was approximately 0.058 in. thick, and the bottom radial corner of the bottle was approximately 0.032 in. in thickness. The fill opening was fitted with a plastic screw type cap. The weight of a single container with cap was 7.0 lb. when full and 0.4 lb. when empty.

Six gallon containers were placed within a corrugated carton, without partitions, measuring 14.5 in. by 14.25 in. by 12.25 in. high. The weight of an empty carton was 1.3 lbs. The weight of a full carton was 43.7 lbs. Twenty seven of these cartons were positioned on hardwood pallets.

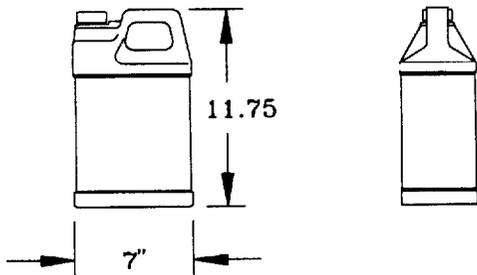
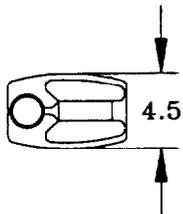
The palletized commodity consisted of 3 layers of 9 cartons measuring 42 in. by 42 in. by 41 in. high and provided a fuel loading of 162 gallons per pallet.



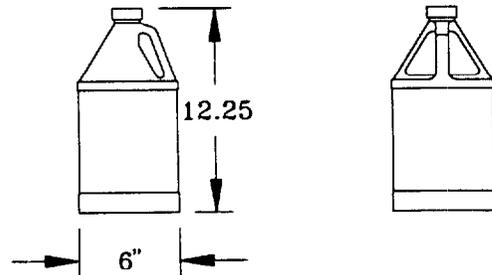
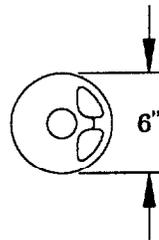
PINT



QUART

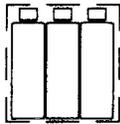
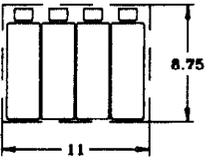
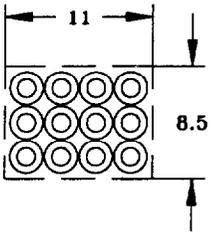


F-STYLE GALLON

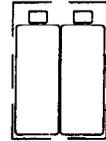
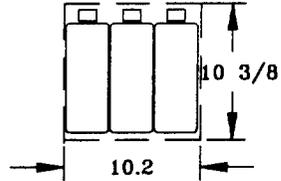
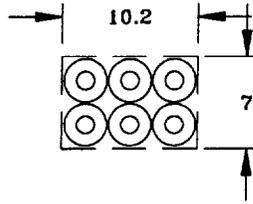


ROUND GALLON

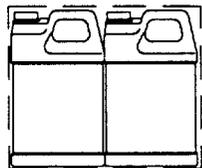
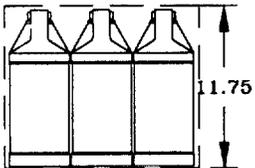
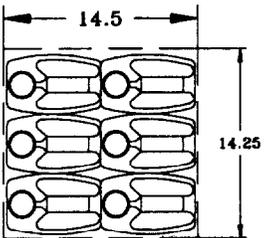
STORAGE CONTAINER DETAILS
96NK33044/NC1838



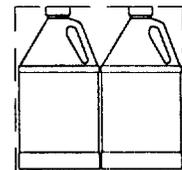
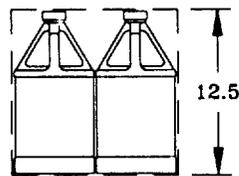
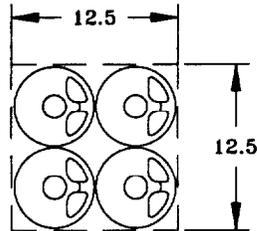
PINT



QUART

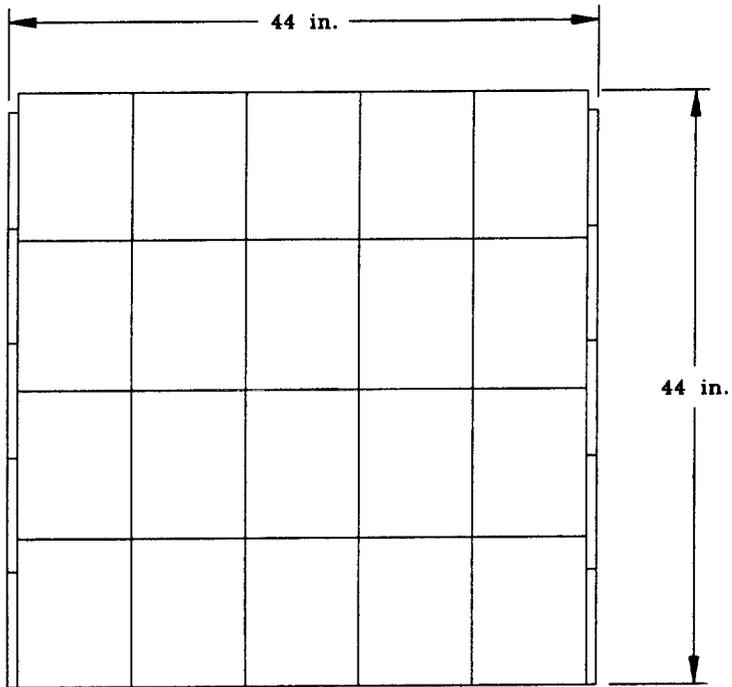


F-STYLE GALLON

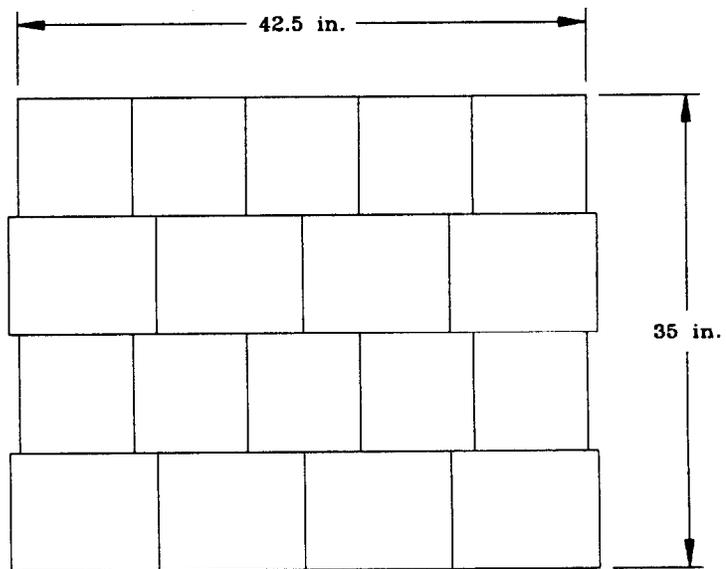


ROUND GALLON

CARTONED CONTAINER DETAILS
96NK33044/NC1838



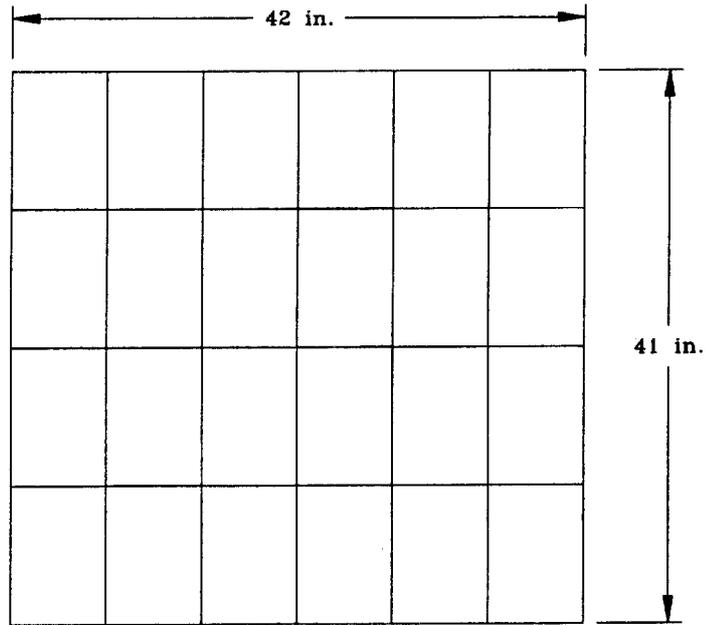
TOP VIEW



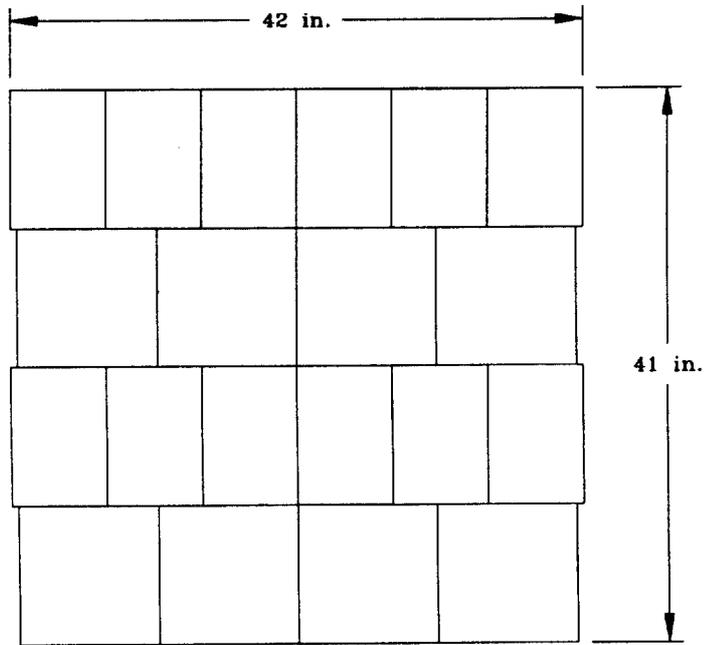
FRONT VIEW

PINTS

PALLETIZED CONTAINER DETAILS
96NK33044/NC1836

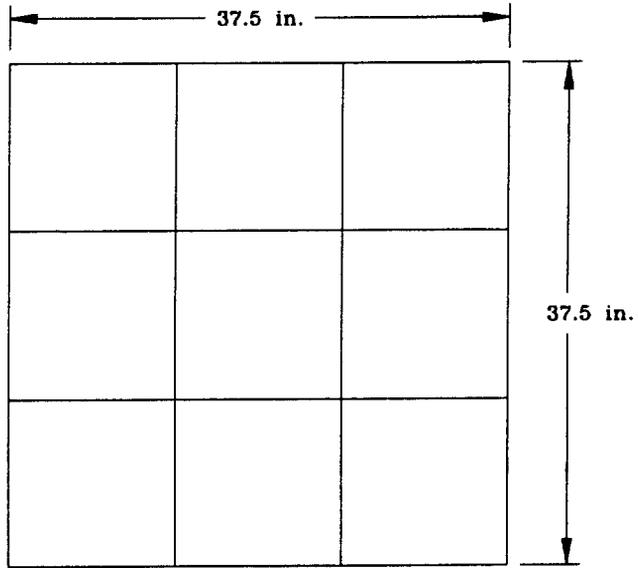


TOP VIEW

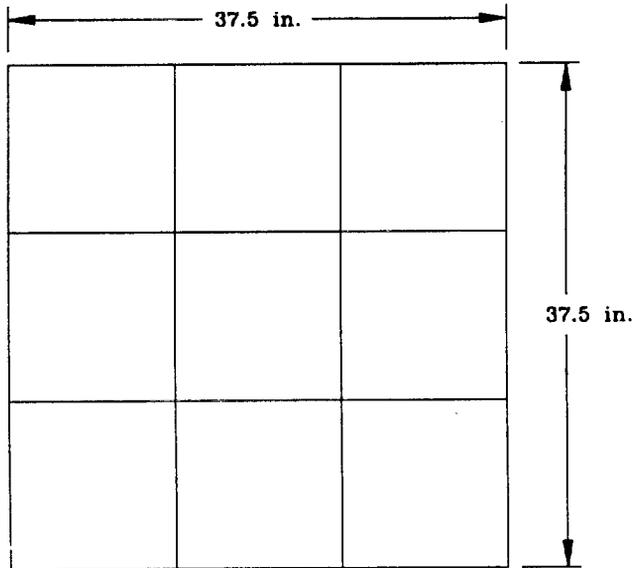


FRONT VIEW

QUARTS

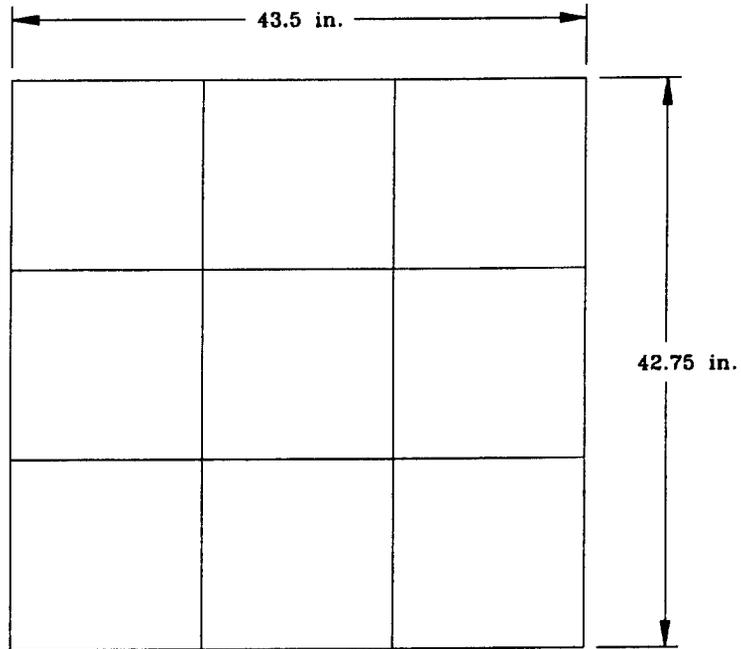


TOP VIEW

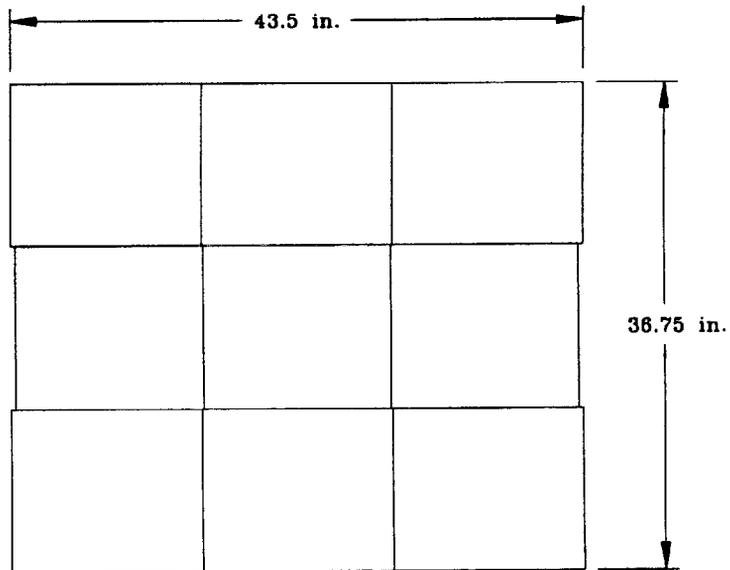


FRONT VIEW

ROUND GALLONS



TOP VIEW



FRONT VIEW

F-STYLE GALLONS

PALLETIZED CONTAINER DETAILS
98NK33044/NC1838

5.0 FIRE TESTS

Test Plan

In order to investigate the level of protection provided, parameters for Fire Test Nos. 1 to 7 were planned to compare the fire control performance using different storage arrangements with in-rack sprinkler protection. Fire Test No. 8 was conducted to determine the amount of fire spread and damage to palletized storage under ceiling sprinkler protection. The test parameters are presented in Table 1.

The series of eight fire tests were conducted. The fuel loading and protection arrangement for each of the fire tests is detailed in the respective fire test description. The tests were conducted for 30 minutes unless the ceiling sprinklers activated or fire spread to the targets surrounding the test commodity.

During Fire Test No. 1 through Fire Test No. 7 the following criteria was used to indicate that the in-rack protection was not adequate: 1.) operation of the ceiling sprinklers. 2.) fire spread above the in-rack protection. 3.) involvement of adjacent targets.

A summary of the testing is presented in Table 1. Temperature and flow data for the fire tests are presented in Appendix A.

Fire Test No. 1

Commodity

The fire test commodity consisted of of cartoned plastic quart containers of 99% isopropyl alcohol (IPA) stored on hardwood pallets. Eight of these pallets were arranged in the first tier of a double row rack storage array with nominal 6 inch longitudinal and transverse flue spaces at each tier. The center of the array was centered between four ceiling sprinklers and the clearance from the top of the commodity to the ceiling sprinkler deflectors was 15 ft. 3 in. The total quantity of isopropyl alcohol in the storage arrangement was 1152 gallons.

In-rack Protection

The in-rack protection provided for this storage array consisted of in-rack face sprinklers on nominal 8 ft. spacing, and flue sprinklers on a nominal 4 ft. spacing, in conjunction with barrier boards. The quick response, large orifice, upright style, in-rack sprinklers with a 165°F temperature rating were positioned as shown in Ill. 11. The clearance from the top of the stored commodity to the in-rack sprinkler deflectors was 6 inches. The in-rack sprinkler system was set to deliver water to the in-rack sprinklers at 50 psi upon operation of any of the in-rack sprinklers.

Ceiling Protection

Twenty four 286° F temperature rated standard response, upright style, sprinklers were installed on a nominal 10 ft. by 10 ft. spacing and mounted a nominal 9 inches under a smooth, flat, non-combustible, ceiling assembly. The ceiling sprinkler system was arranged to deliver water through the sprinklers at a discharge density of 0.35 gpm/ft² upon operation of any of the ceiling sprinklers.

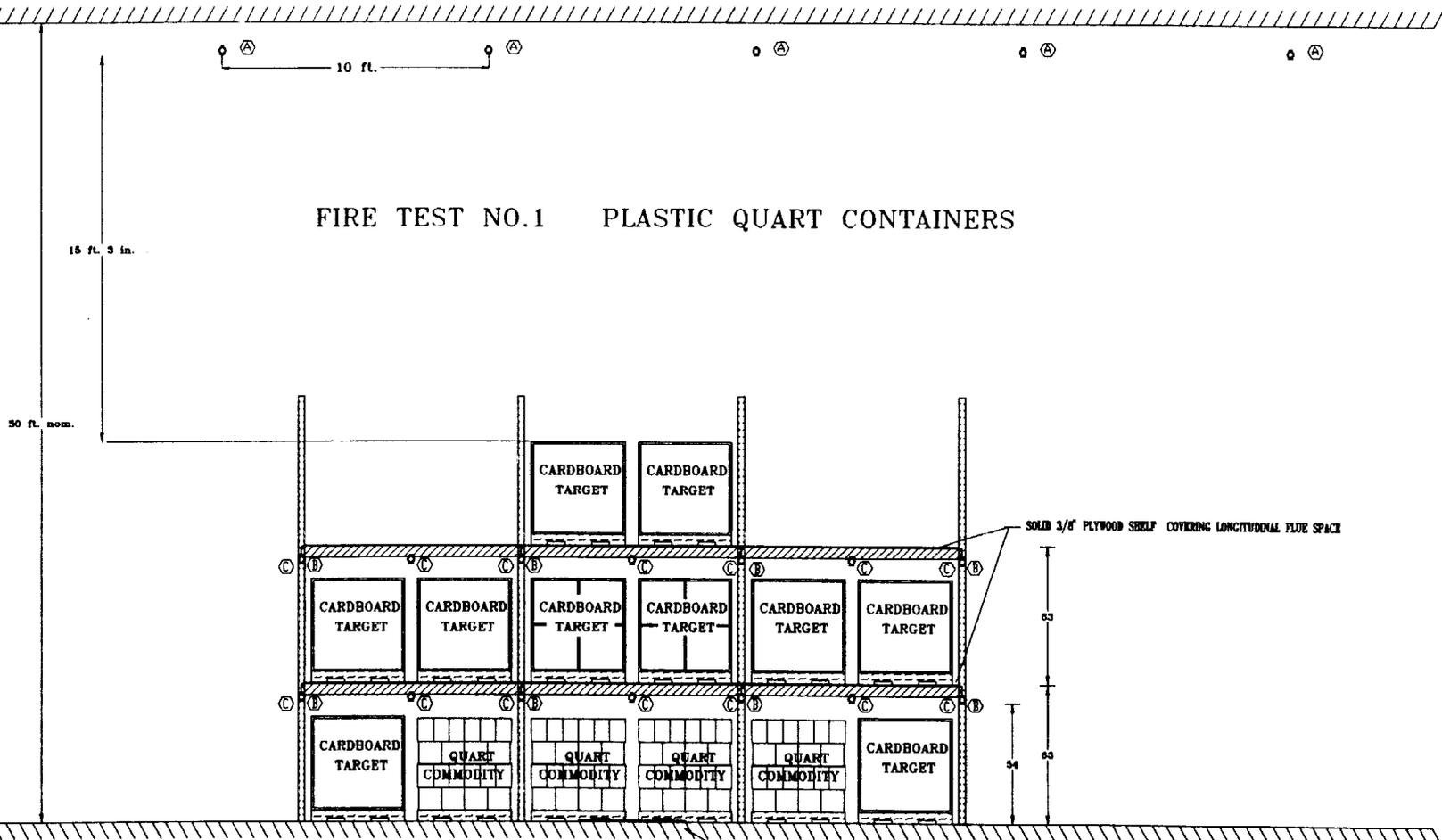
Test Procedure

Ignition was accomplished using 2 gallons of alcohol in two steel pans measuring 2 ft by 2 ft by .75 in. high. These pans were located at the south face of the storage array, at the floor level, protruding 12 in. into the aisle as shown in Ill. 11. During the test, time, temperature, and flow information were gathered using high speed data acquisition equipment. Video images were captured and recorded on VHS format video tape.

Results

During this fire test two of the in-rack sprinklers operated. The first sprinkler, located in the flue at the east side of the rack, activated at 56s. The second sprinkler, located in the flue at the west side of the rack activated at 111s. Fourteen cartons were damaged by the fire. Twenty one gallons of alcohol were consumed. There was no spread of fire to the second tier of storage or to the adjacent targets. The areas of damage are shown in Ill. 13. A summary of the testing is presented in Table I.

FIRE TEST NO.1 PLASTIC QUART CONTAINERS



ELEVATION-FRONT VIEW

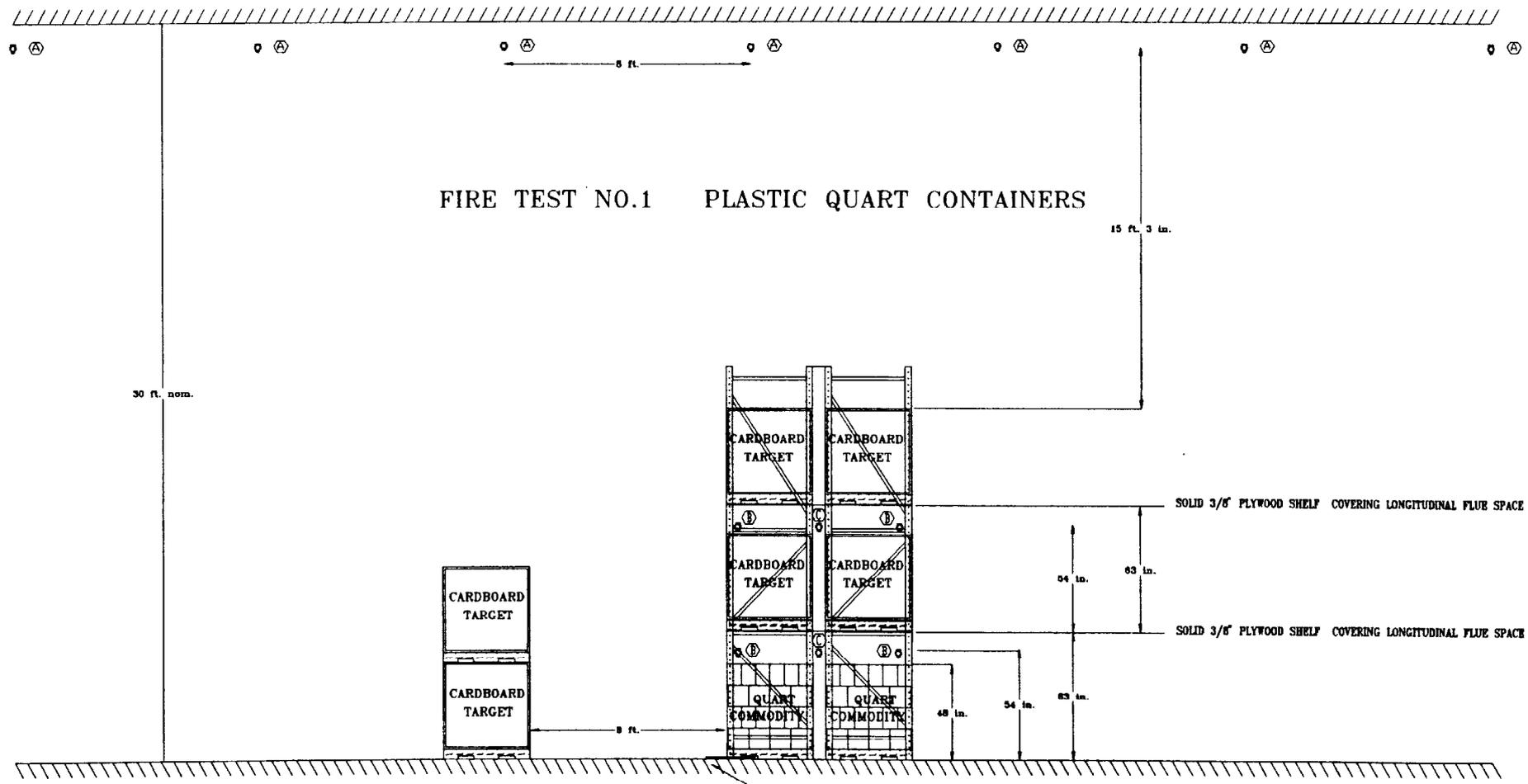
- SPRINKLER LOCATIONS
- (A) 26F UPRIGHT STYLE SPRINKLERS ON 8 FT. BY 10 FT.
- (B) 17/32 IN. 185F QUICK RESPONSE FACE RACK SPRINKLERS ON 8 FT. NOMINAL CENTERS. 50 PSI
- (C) 17/32 IN. 185F QUICK RESPONSE IN-RACK SPRINKLERS ON 4 FT. NOMINAL CENTERS. 50 PSI

RACK CONFIGURATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

ILL 11

FIRE TEST NO.1 PLASTIC QUART CONTAINERS



ELEVATION-SIDE VIEW

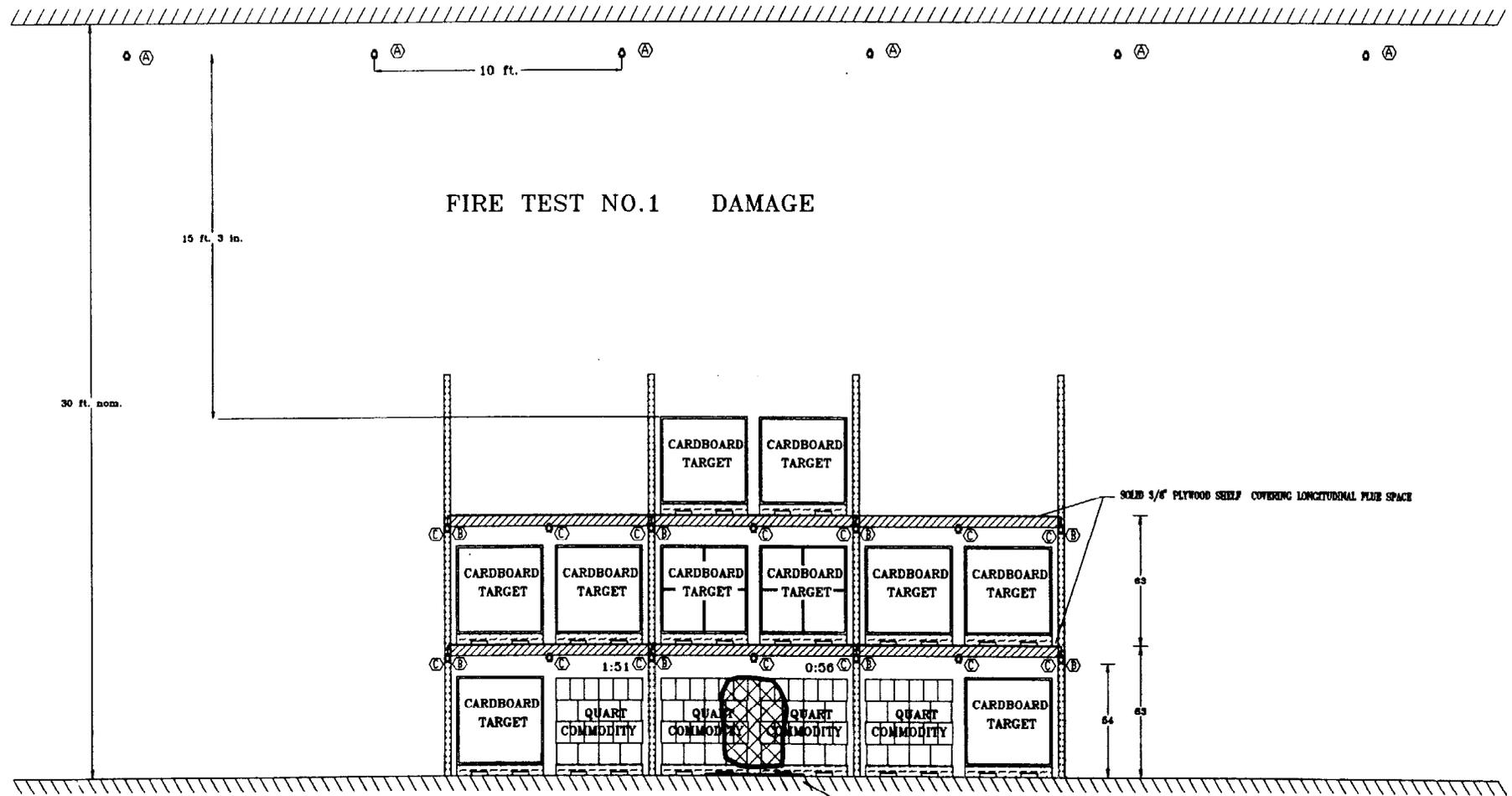
- SPRINKLER LOCATIONS
- Ⓐ 17/32 IN. 286 UPRIGHT STYLE SPRINKLERS ON 8 FT. BY 10 FT.
- Ⓑ 17/32 IN. 165°F QUICK RESPONSE UPRIGHT FACE RACK SPRINKLERS ON 8 FT. NOMINAL CENTERS. 50 PSI
- Ⓒ 17/32 IN. 165°F QUICK RESPONSE UPRIGHT INRACK SPRINKLERS ON 4 FT. NOMINAL CENTERS. 50 PSI

RACK CONFIGURATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

ILL 12

FIRE TEST NO.1 DAMAGE



ELEVATION-FRONT VIEW

- SPRINKLER LOCATIONS
- Ⓐ 286 UPRIGHT STYLE SPRINKLERS ON 8 FT. BY 10 FT.
- Ⓑ 17/32 IN. 165°F QUICK RESPONSE FACE RACK SPRINKLERS ON 8 FT. NOMINAL CENTERS. 50 PSI
- Ⓒ 17/32 IN. 165°F QUICK RESPONSE IN-RACK SPRINKLERS ON 4 FT. NOMINAL CENTERS. 50 PSI

RACK CONFIGURATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

Fire Test No. 2

Commodity

The fire test commodity consisted of of cartoned round plastic gallon containers of 93% isopropyl alcohol (IPA) stored on hardwood pallets. Eight of these pallets were arranged in the first tier of a double row rack storage array with nominal 6 inch longitudinal and transverse flue spaces at each tier. The center of the array was centered between four ceiling sprinklers and the clearance from the top of the commodity to the ceiling sprinkler deflectors was 15 ft. 3 in. The total quantity of isopropyl alcohol in the storage arrangement was 864 gallons.

In-rack Protection

The in-rack protection provided for this storage array consisted of in-rack face and flue sprinklers in conjunction with barrier boards. The quick response, large orifice, upright style, in-rack sprinklers with a 165°F temperature rating were positioned as shown in Ill. 14. The clearance from the top of the stored commodity to the in-rack sprinkler deflectors was 10 inches. The in-rack sprinkler system was set to deliver water through the in-rack sprinklers at 50 psi upon operation of any of the in-rack sprinklers.

Ceiling Protection

Twenty four 286° F temperature rated standard response, upright style, sprinklers were installed on a nominal 10 ft. by 10 ft. spacing and mounted a nominal 9 inches under a smooth, flat, non-combustible, ceiling assembly. The ceiling sprinkler system was arranged to deliver water through the sprinklers at a discharge density of 0.35 gpm/ft² upon operation of any of the ceiling sprinklers.

Test Procedure

Ignition was accomplished using 2 gallons of alcohol in two steel pans measuring 2 ft by 2 ft by .75 in. high. These pans were located at the south face of the storage array, at the floor level, protruding 12 in. into the aisle as shown in Ill. 14. During the test, time, temperature, and flow information were gathered using high speed data acquisition equipment. Video images were captured and recorded on VHS format video tape.

Results

During this fire test two of the in-rack sprinklers operated. The first sprinkler, located in the flue at the east side of the rack, activated at 49s. The second sprinkler, located on the south face at the west side of the rack activated at 60s. Nine cartons were damaged by the fire. Ten gallons of alcohol were consumed. There was no spread of fire to the second tier of storage or to the adjacent targets. The areas of damage are shown in Ill.16. A summary of the testing is presented in Table I.

FIRE TEST NO.2 PLASTIC ROUND GALLON CONTAINERS

○ (A)

○ (A)

○ (A)

○ (A)

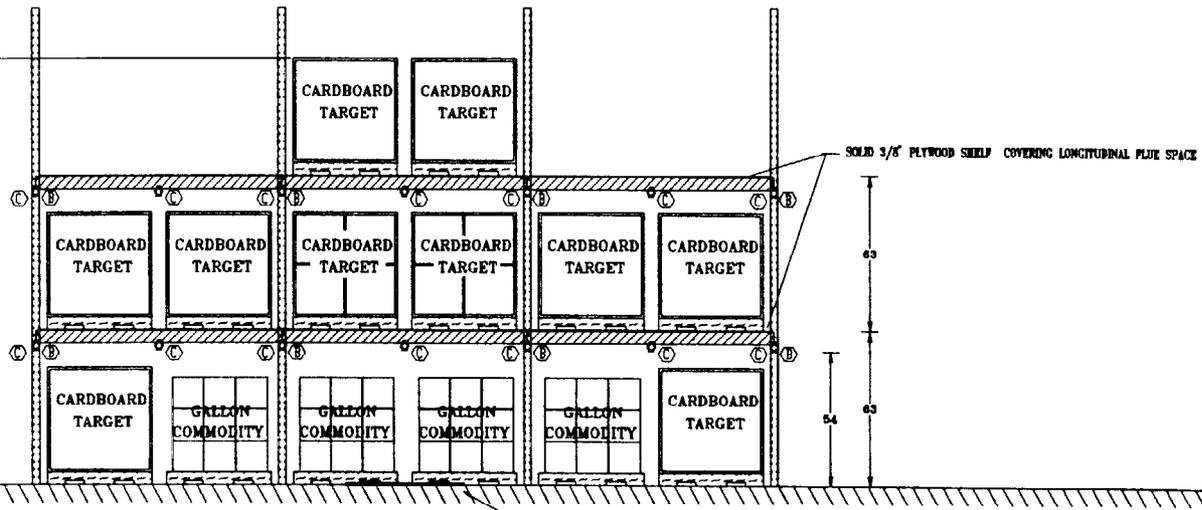
○ (A)

○ (A)

10 ft.

15 ft. 3 in.

30 ft. nom.



ELEVATION-FRONT VIEW

○ SPRINKLER LOCATIONS

(A) 285° UPRIGHT STYLE SPRINKLERS ON 8 FT. BY 10 FT.

(B) 17/32 IN. 165°F QUICK RESPONSE FACE RACK SPRINKLERS ON 8 FT. NOMINAL CENTERS. 50 PSI

(C) 17/32 IN. 165°F QUICK RESPONSE IN-RACK SPRINKLERS ON 4 FT. NOMINAL CENTERS. 50 PSI

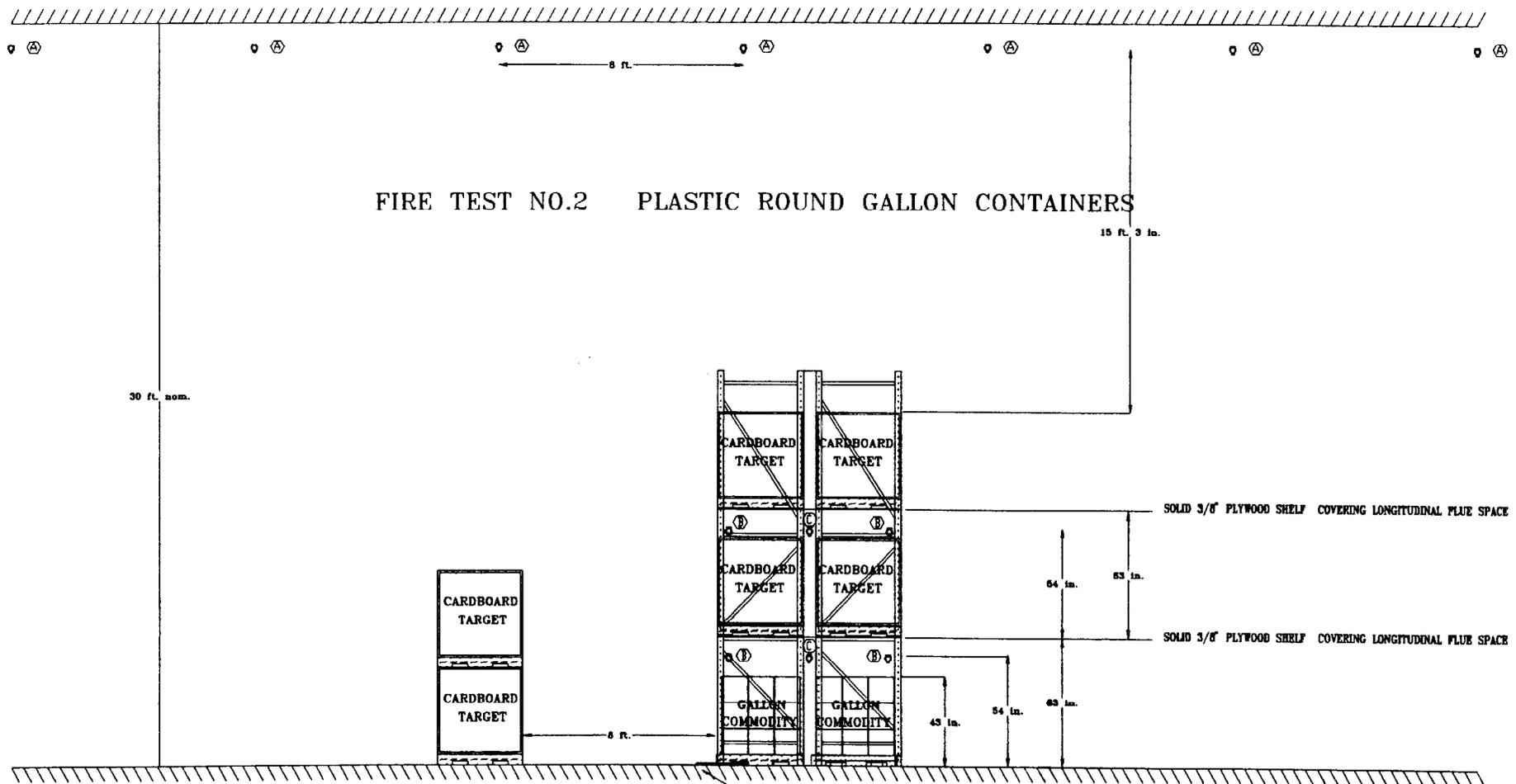
2 GALLON ALCOHOL IGNITION IN 4'x2'x1" DEEP PAN IPA PALLETS NOTCHED TO STRADDLE THE PAN

RACK CONFIGURATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

ILL 14

FIRE TEST NO.2 PLASTIC ROUND GALLON CONTAINERS



ELEVATION-SIDE VIEW

○ SPRINKLER LOCATIONS

- (A) 17/32 IN. 286° UPRIGHT STYLE SPRINKLERS ON 8 FT. BY 10 FT.
- (B) 17/32 IN. 165° F QUICK RESPONSE UPRIGHT FACE RACK SPRINKLERS ON 8 FT. NOMINAL CENTERS. 50 PSI
- (C) 17/32 IN. 165° F QUICK RESPONSE UPRIGHT INRACK SPRINKLERS ON 4 FT. NOMINAL CENTERS. 50 PSI

2 GALLON ALCOHOL IGNITION IN 4"x2"x1" DEEP PAN PALLETS NOTCHED TO STRADDLE THE PAN

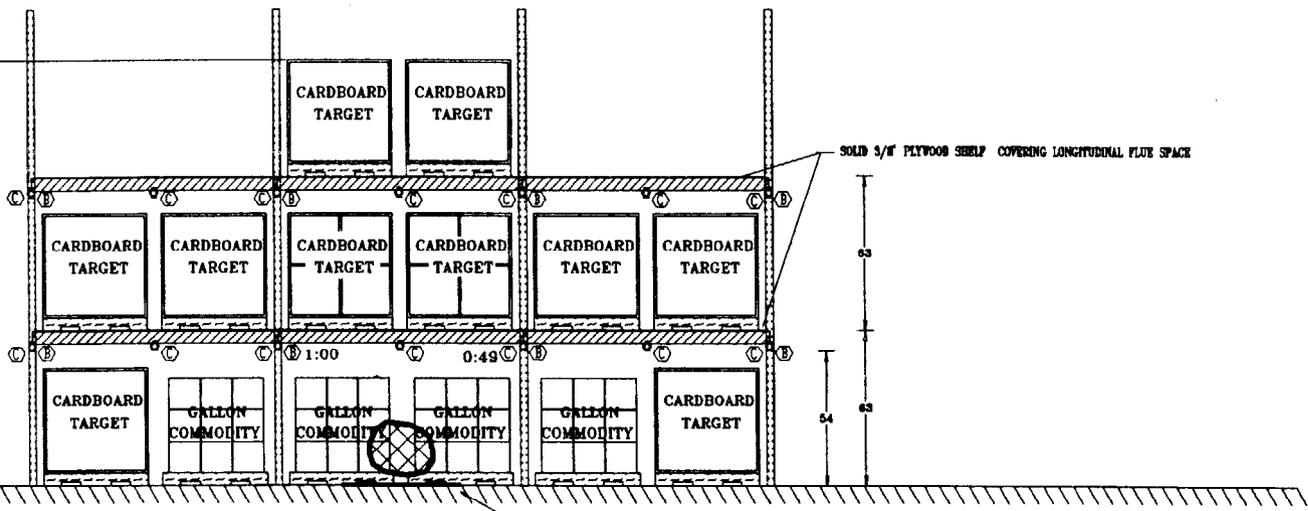
RACK CONFIGURATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

FIRE TEST NO.2 DAMAGE

15 ft. 3 in.
30 ft. nom.

10 ft.



ELEVATION-FRONT VIEW

- SPRINKLER LOCATIONS
- Ⓐ 286 UPRIGHT STYLE SPRINKLERS ON 8 FT. BY 10 FT.
- Ⓑ 17/32 IN. 165F QUICK RESPONSE FACE RACK SPRINKLERS ON 8 FT. NOMINAL CENTERS. 50 PSI
- Ⓒ 17/32 IN. 165F QUICK RESPONSE IN-RACK SPRINKLERS ON 4 FT. NOMINAL CENTERS. 50 PSI

2 GALLON ALCOHOL IGNITION ON 4'x2'x1" DEEP PAN IFA PALLETS NOTCHED TO STRADDLE THE PAN

RACK CONFIGURATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

ILL 16

Fire Test No. 3

Commodity

The fire test commodity consisted of of cartoned plastic pint containers of 99% isopropyl alcohol (IPA) stored on hardwood pallets. The cartons were stacked on the pallet to provide a vertical flue space through the load. Eight pallets were arranged in the first tier of a double row rack storage array with nominal 6 inch longitudinal and transverse flue spaces. The center of the array was centered between four ceiling sprinklers and the clearance from the top of the commodity to the ceiling sprinkler deflectors was 183 inches. The total quantity of isopropyl alcohol in the storage arrangement was 960 gallons.

In-rack Protection

The in-rack protection provided for this storage array consisted of in-rack face and flue sprinklers in conjunction with barrier boards. The quick response, large orifice, upright style, in-rack sprinklers with a 165°F temperature rating were positioned as shown in Ill.17. The clearance from the top of the stored commodity to the in-rack sprinkler deflectors was 12 inches. The in-rack sprinkler system was set to deliver water through the in-rack sprinklers at 50 psi upon operation of any of the in-rack sprinklers.

Ceiling Protection

Twenty four 286° F temperature rated standard response, upright style, sprinklers were installed on a nominal 10 ft. by 10 ft. spacing and mounted a nominal 9 inches under a smooth, flat, non-combustible, ceiling assembly. The ceiling sprinkler system was arranged to deliver water through the sprinklers at a discharge density of 0.35 gpm/ft² upon operation of any of the ceiling sprinklers.

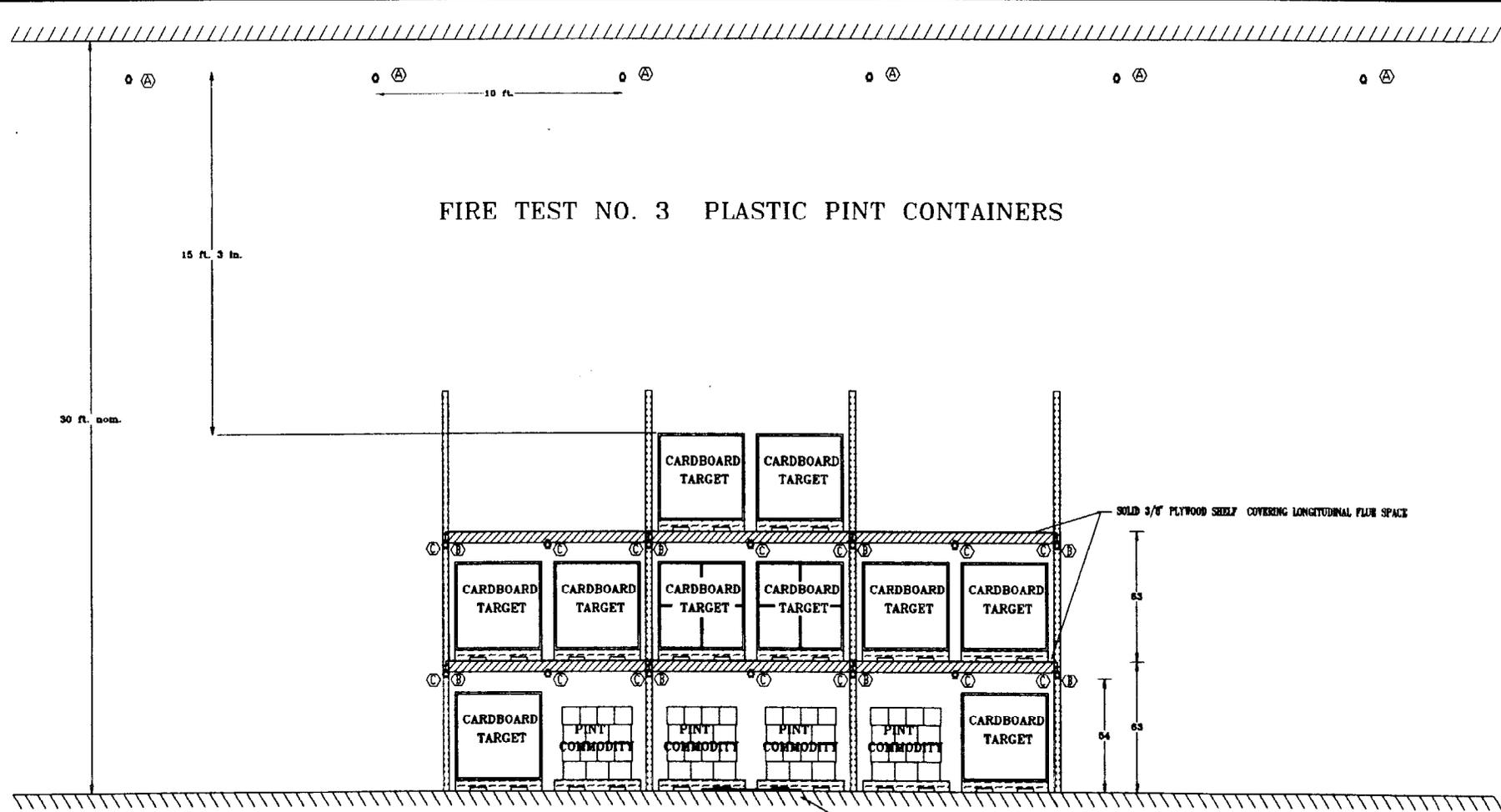
Test Procedure

Ignition was accomplished using 2 gallons of alcohol in two steel pans measuring 2 ft by 2 ft by .75 in. high. These pans were located at the south face of the storage array, at the floor level, protruding 12 in. into the aisle as shown in Ill.17. During the test, time, temperature, and flow information were gathered using high speed data acquisition equipment. Video images were captured and recorded on VHS format video tape.

Results

During this fire test one of the in-rack sprinklers operated. The first sprinkler, located in the flue at the center of the rack, activated at 25s. One carton was damaged by the fire. One gallon of alcohol was consumed. There was no spread of fire to the second tier of storage or to the adjacent targets. The areas of damage are shown in Ill.19. A summary of the testing is presented in Table I.

FIRE TEST NO. 3 PLASTIC PINT CONTAINERS



ELEVATION-FRONT VIEW

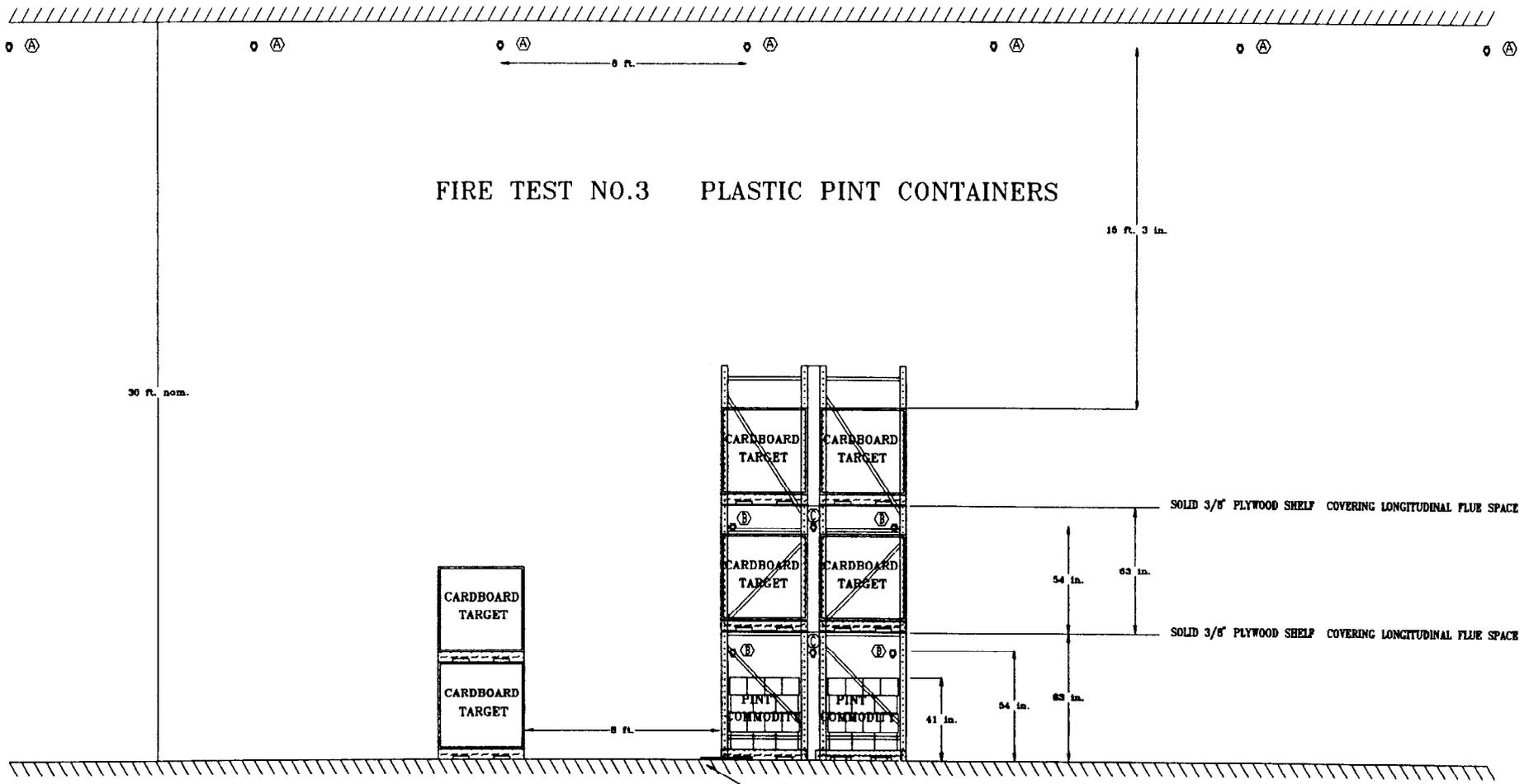
- SPRINKLER LOCATIONS
- Ⓐ 285° UPRIGHT STYLE SPRINKLERS ON 8 FT. BY 10 FT.
- Ⓑ 17/32 IN. 165°F QUICK RESPONSE FACE RACK SPRINKLERS ON 8 FT. NOMINAL CENTERS. 50 PSI
- Ⓒ 17/32 IN. 165°F QUICK RESPONSE IN-RACK SPRINKLERS ON 4 FT. NOMINAL CENTERS. 50 PSI

RACK CONFIGURATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

ILL 17

FIRE TEST NO.3 PLASTIC PINT CONTAINERS



ELEVATION-SIDE VIEW

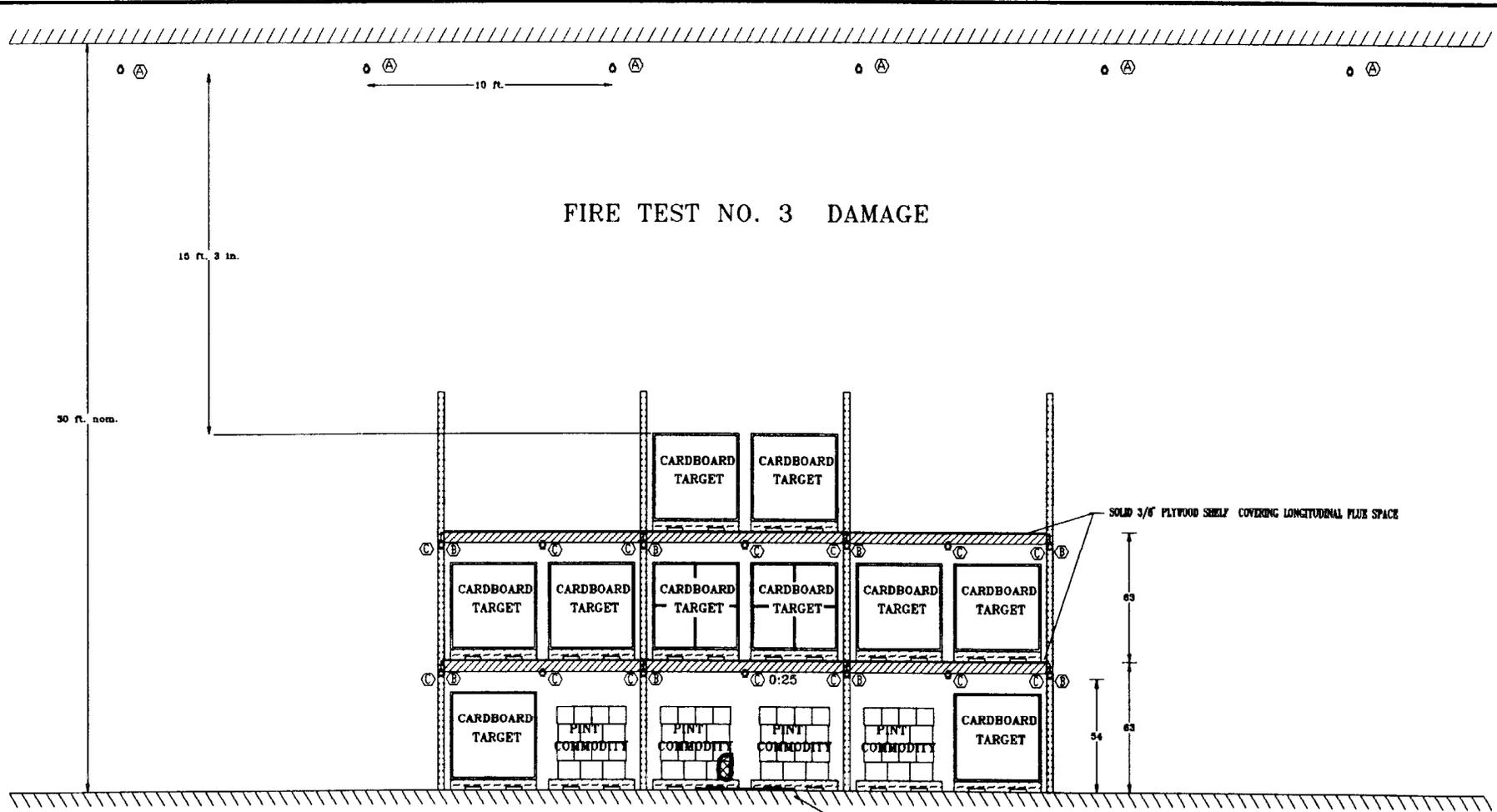
- SPRINKLER LOCATIONS
- Ⓐ 17/32 IN. 286° UPRIGHT STYLE SPRINKLERS ON 8 FT. BY 10 FT.
- Ⓑ 17/32 IN. 165° F QUICK RESPONSE UPRIGHT FACE RACK SPRINKLERS ON 8 FT. NOMINAL CENTERS. 50 PSI
- Ⓒ 17/32 IN. 165° F QUICK RESPONSE UPRIGHT INRACK SPRINKLERS ON 4 FT. NOMINAL CENTERS. 50 PSI

RACK CONFIGURATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

ILL 18

FIRE TEST NO. 3 DAMAGE



ELEVATION-FRONT VIEW

- SPRINKLER LOCATIONS
- Ⓐ 285° UPRIGHT STYLE SPRINKLERS ON 8 FT. BY 10 FT.
- Ⓑ 17/32 IN. 165°F QUICK RESPONSE FACE RACK SPRINKLERS ON 8 FT. NOMINAL CENTERS. 50 PSI
- Ⓒ 17/32 IN. 165°F QUICK RESPONSE IN-RACK SPRINKLERS ON 4 FT. NOMINAL CENTERS. 50 PSI

RACK CONFIGURATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

ILL 19

Fire Test No. 4

Commodity

The fire test commodity consisted of of cartoned plastic pint containers of 99% isopropyl alcohol (IPA) stored on hardwood pallets. Two pallets were arranged in the first tier of the south center bay of a double row rack storage array with nominal 6 inch longitudinal and transverse flue spaces. The center of the array was centered between four ceiling sprinklers and the clearance from the top of the commodity to the ceiling sprinkler deflectors was 15 ft. 3 in. The total quantity of isopropyl alcohol in the storage arrangement was 240 gallons.

In-rack Protection

The in-rack protection provided for this storage array consisted of in-rack face and flue sprinklers in conjunction with barrier boards. The quick response, large orifice, upright style, in-rack sprinklers with a 165°F temperature rating were positioned as shown in Ill. 20. The clearance from the top of the stored commodity to the in-rack sprinkler deflectors was 12 inches. The in-rack sprinkler system was set to deliver water through the in-rack sprinklers at 50 psi upon operation of any of the in-rack sprinklers.

Ceiling Protection

Twenty four 286° F temperature rated standard response, upright style, sprinklers were installed on a nominal 10 ft. by 10 ft. spacing and mounted a nominal 9 inches under a smooth, flat, non-combustible, ceiling assembly. The ceiling sprinkler system was arranged to deliver water through the sprinklers at a discharge density of 0.35 gpm/ft² upon operation of any of the ceiling sprinklers.

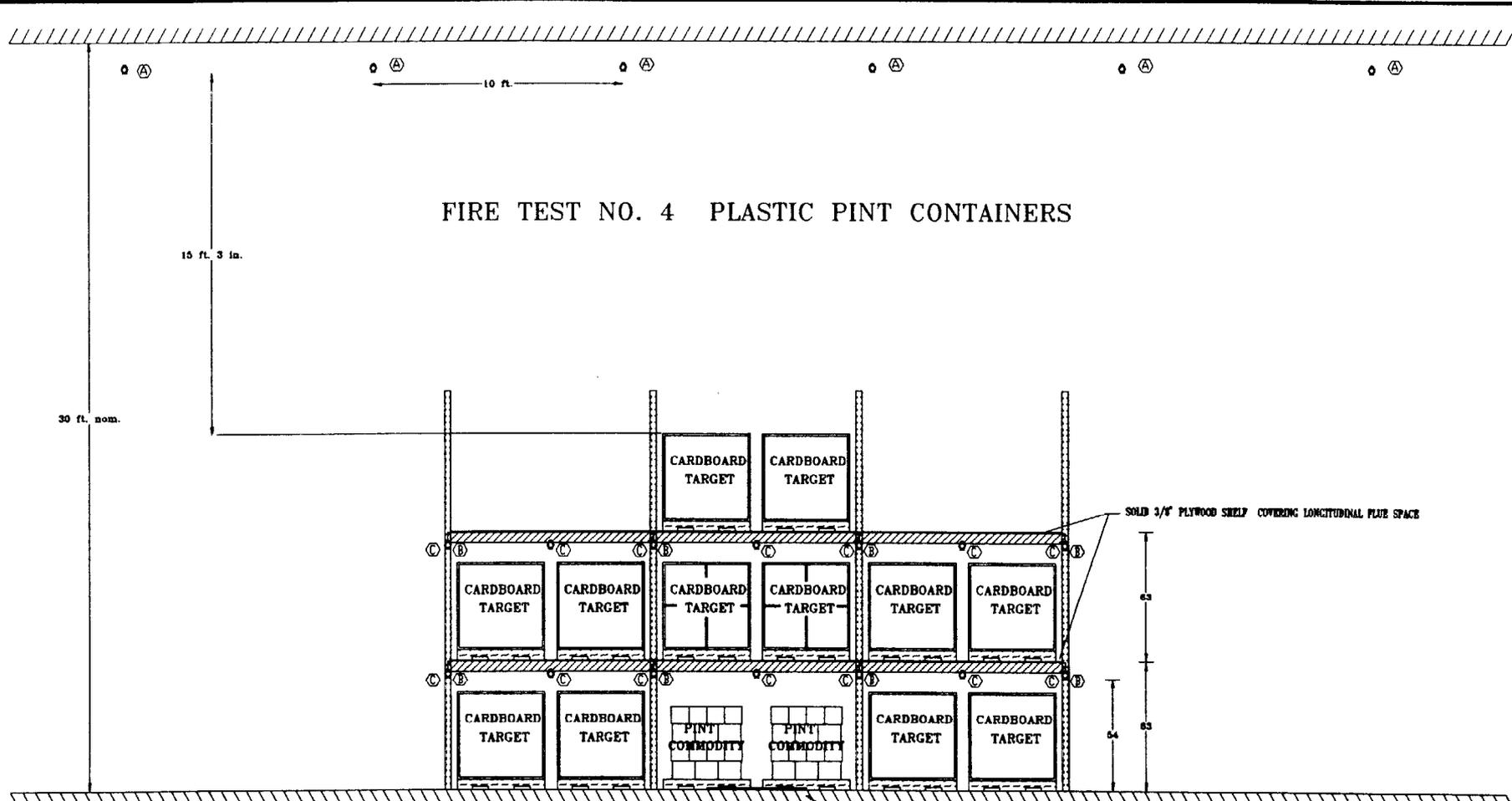
Test Procedure

Ignition was accomplished using 2 gallons of alcohol in two steel pans measuring 2 ft by 2 ft by .75 in. high. These pans were located at the south face of the storage array, at the floor level, protruding 12 in. into the aisle as shown in Ill. 20. During the test, time, temperature, and flow information were gathered using high speed data acquisition equipment. Video images were captured and recorded on VHS format video tape.

Results

During this fire test two of the in-rack sprinklers operated. The first sprinkler, located in the flue at the east side of the rack, activated at 54s. The second sprinkler, located on the south face at the west side of the rack activated at 56s. Twenty cartons were damaged by the fire. Twenty five gallons of alcohol were consumed. There was no spread of fire to the second tier of storage or to the adjacent targets. The areas of damage are shown in Ill. 22. A summary of the testing is presented in Table I.

FIRE TEST NO. 4 PLASTIC PINT CONTAINERS



ELEVATION-FRONT VIEW

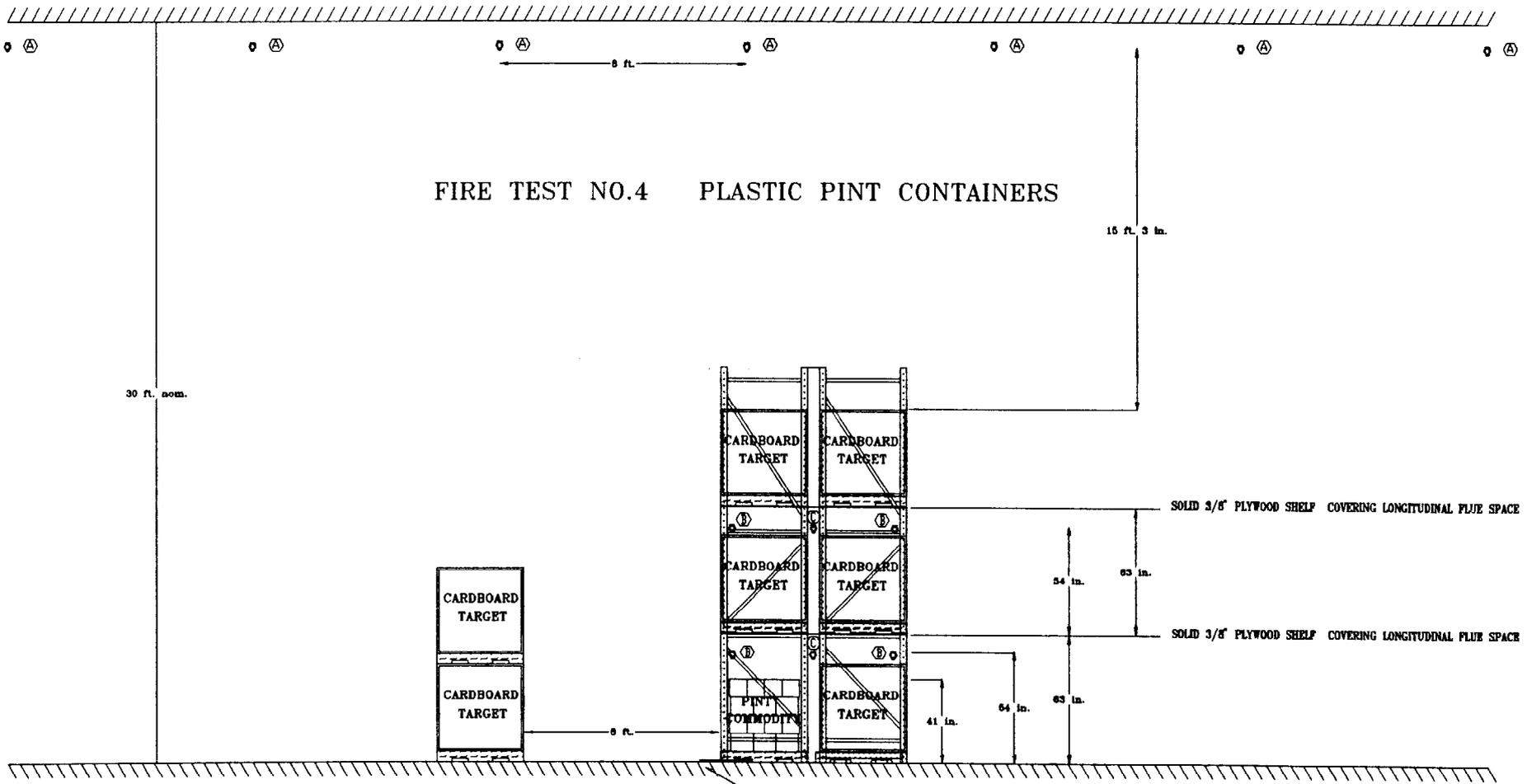
- SPRINKLER LOCATIONS
- Ⓐ 285° UPRIGHT STYLE SPRINKLERS ON 8 FT. BY 10 FT.
- Ⓑ 17/32 IN. 165°F QUICK RESPONSE FACE RACK SPRINKLERS ON 8 FT. NOMINAL CENTERS. 50 PSI
- Ⓒ 17/32 IN. 165°F QUICK RESPONSE IN-RACK SPRINKLERS ON 4 FT. NOMINAL CENTERS. 50 PSI

RACK CONFIGURATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

ILL 20

FIRE TEST NO.4 PLASTIC PINT CONTAINERS



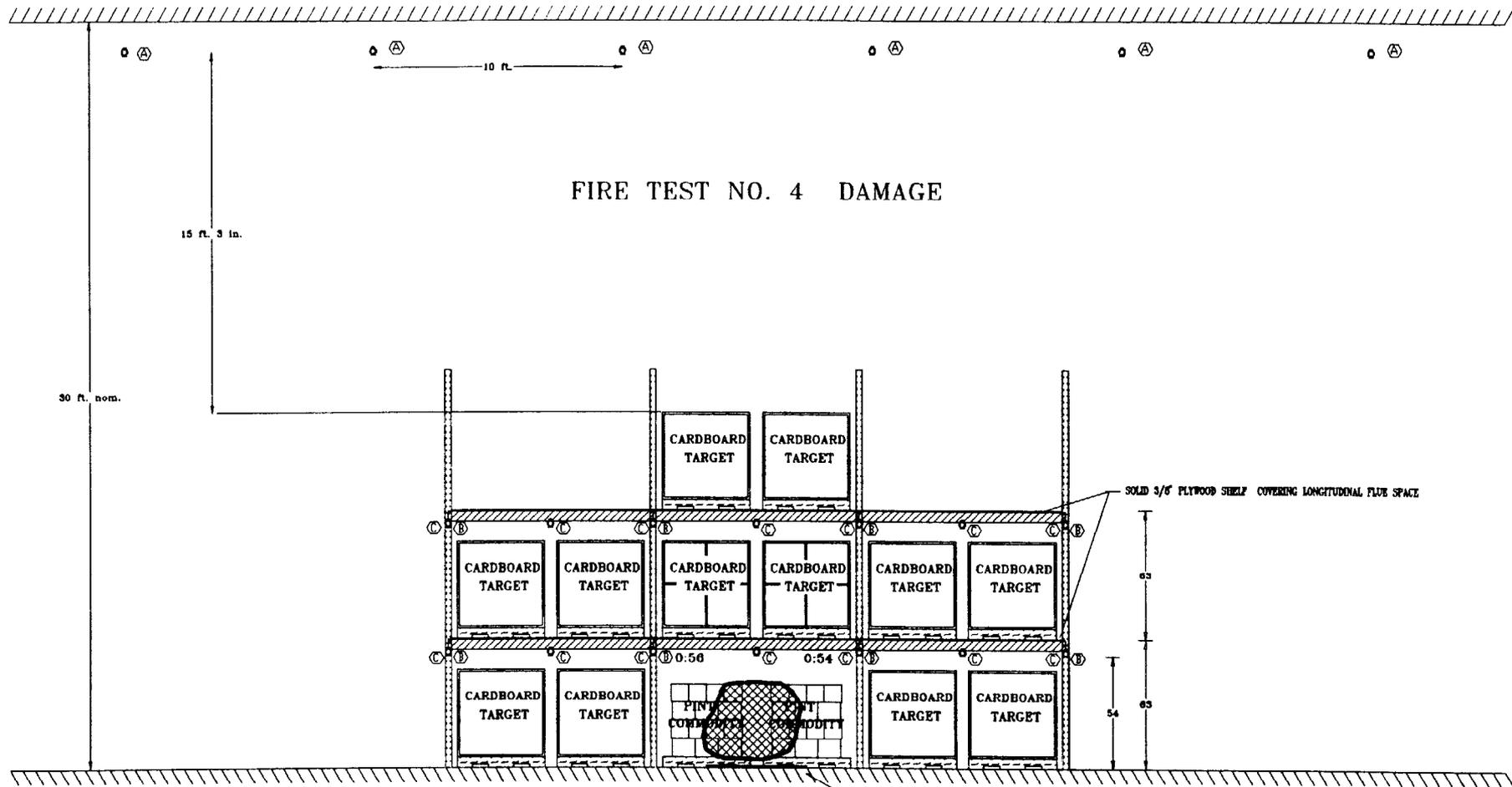
ELEVATION-SIDE VIEW

- SPRINKLER LOCATIONS
- Ⓐ 17/32 IN. 280° UPRIGHT STYLE SPRINKLERS ON 8 FT. BY 10 FT.
- Ⓑ 17/32 IN. 165° F QUICK RESPONSE UPRIGHT FACE RACK SPRINKLERS ON 8 FT. NOMINAL CENTERS. 50 PSI
- Ⓒ 17/32 IN. 165° F QUICK RESPONSE UPRIGHT INRACK SPRINKLERS ON 4 FT. NOMINAL CENTERS. 50 PSI

RACK CONFIGURATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

FIRE TEST NO. 4 DAMAGE



ELEVATION-FRONT VIEW

- SPRINKLER LOCATIONS
- Ⓐ 200° UPRIGHT STYLE SPRINKLERS ON 8 FT. BY 10 FT.
- Ⓑ 17/32 IN. 165° F QUICK RESPONSE FACE RACK SPRINKLERS ON 8 FT. NOMINAL CENTERS. 50 PSI
- Ⓒ 17/32 IN. 165° F QUICK RESPONSE IN-RACK SPRINKLERS ON 4 FT. NOMINAL CENTERS. 50 PSI

RACK CONFIGURATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

ILL 22

Fire Test No. 5

Commodity

The fire test commodity consisted of of cartoned plastic pint containers of 99% isopropyl alcohol (IPA) stored on hardwood pallets and cartoned plastic gallon containers of 93% isopropyl alcohol (IPA) stored on hardwood pallets. Four pallets of pint containers were arranged in the first and second tier of the south center bay of a double row rack storage array with nominal 6 inch longitudinal and transverse flue spaces at each tier. Four pallets of gallon containers were arranged in the first and second tier of the north center bay of a double row rack storage array with nominal 6 inch longitudinal and transverse flue spaces at each tier. Eight pallets of mixed commodity were arranged around the flanks of the center bay as targets. Cardboard boxes provided the targets above and across the aisle from the test commodity. The center of the array was centered between four ceiling sprinklers. The clearance from the top of the commodity to the ceiling sprinkler deflectors was 15 ft. 3 in. The total quantity of isopropyl alcohol in the storage arrangement was 1560 gallons.

In-rack Protection

The in-rack protection provided for this storage array consisted of in-rack face and flue sprinklers in conjunction with barrier boards above the second tier of storage. The quick response, large orifice, upright style, in-rack sprinklers with a 165°F temperature rating were positioned as shown in Ill. 23. The clearance from the top of the stored pint commodity to the in-rack sprinkler deflectors was 12 inches. The clearance from the top of the stored gallon commodity to the in-rack sprinkler deflectors was 10 inches. The in-rack sprinkler system was set to deliver water through the in-rack sprinklers at 50 psi upon operation of any of the in-rack sprinklers.

Ceiling Protection

Twenty four 286° F temperature rated standard response, upright style, sprinklers were installed on a nominal 10 ft. by 10 ft. spacing and mounted a nominal 9 inches under a smooth, flat, non-combustible, ceiling assembly. The ceiling sprinkler system was arranged to deliver water through the sprinklers at a discharge density of 0.35 gpm/ft² upon operation of any of the ceiling sprinklers.

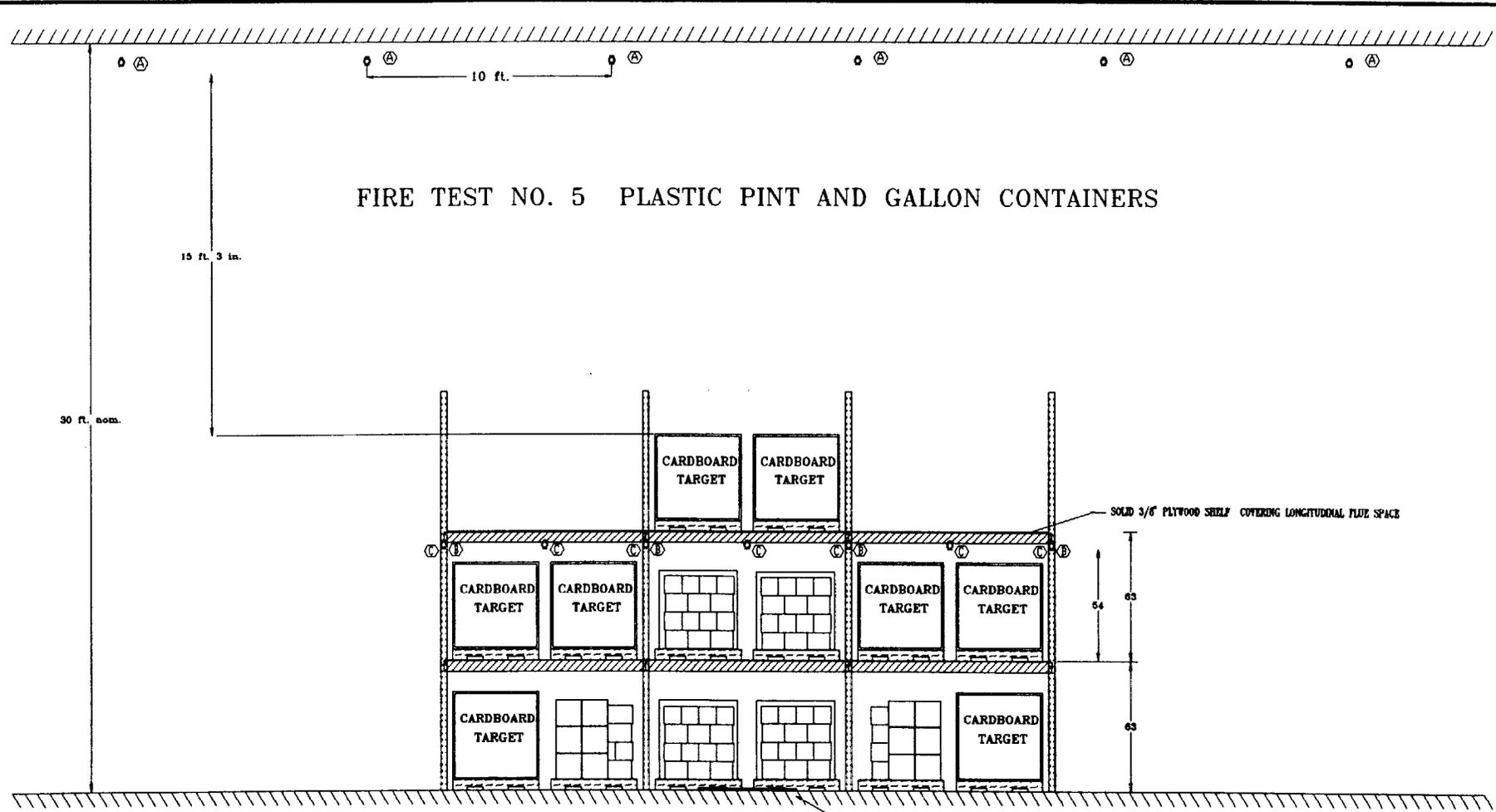
Test Procedure

Ignition was accomplished using 2 gallons of alcohol in two steel pans measuring 2 ft by 2 ft by .75 in. high. These pans were located at the south face of the storage array, at the floor level, protruding 12 in. into the aisle as shown in Ill. 23. During the test, time, temperature, and flow information were gathered using high speed data acquisition equipment. Video images were captured and recorded on VHS format video tape.

Results

During the test two of the in-rack sprinklers operated. The first sprinkler, located on the south face at the east side of the rack, activated at 69s. The second sprinkler, located in the flue at the west side of the rack activated at 85s. Thirty two cartons were damaged by the fire. Forty five gallons of alcohol were consumed. There was no spread of fire to the second tier of storage or to the adjacent targets. The areas of damage are shown in Ill. 25. A summary of the testing is presented in Table I.

FIRE TEST NO. 5 PLASTIC PINT AND GALLON CONTAINERS



ELEVATION-FRONT VIEW

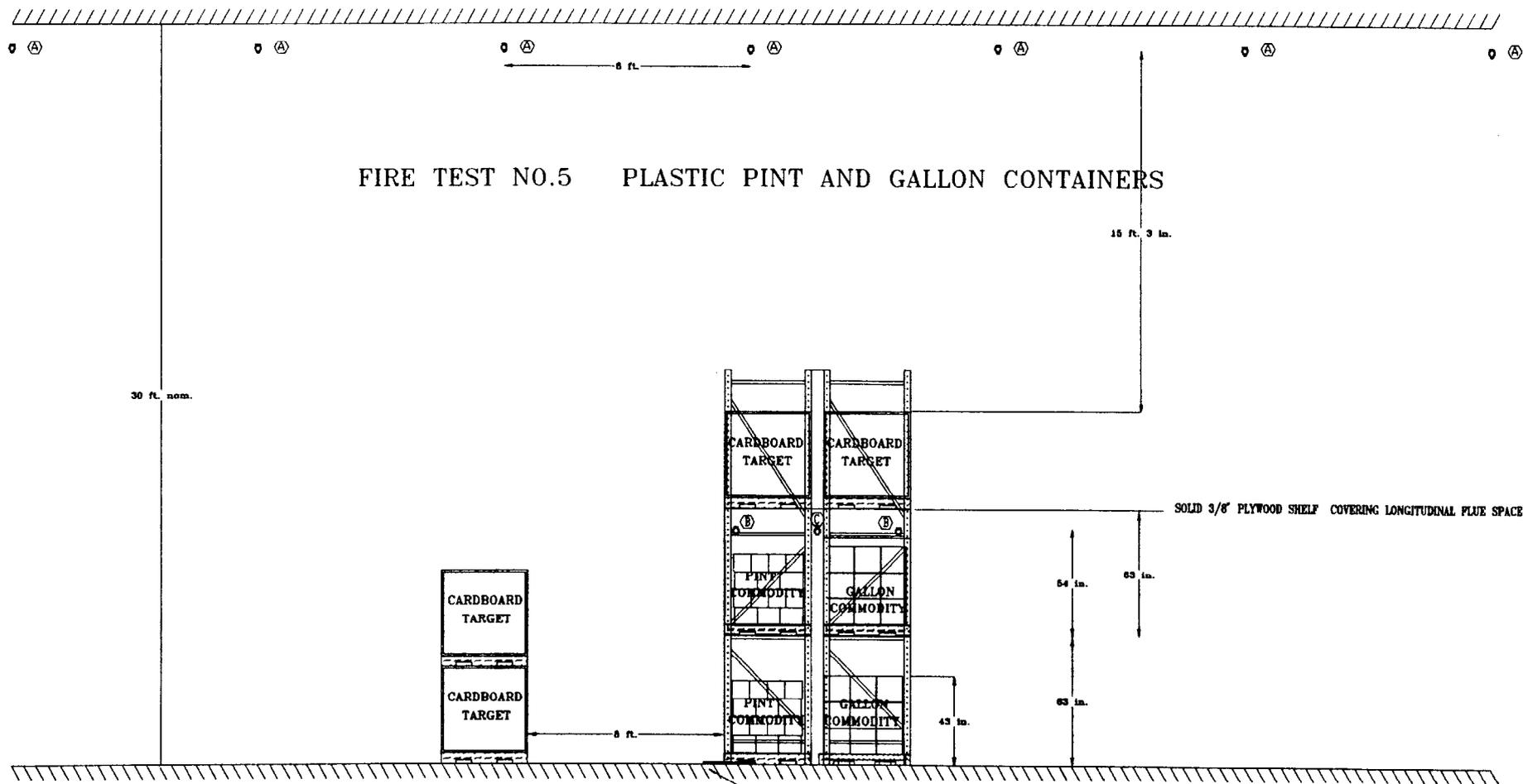
- SPRINKLER LOCATIONS
- Ⓐ 286 UPRIGHT STYLE SPRINKLERS ON 8 FT. BY 10 FT.
- Ⓑ 17/32 IN. 165°F QUICK RESPONSE FACE RACK SPRINKLERS ON 8 FT. NOMINAL CENTERS. 50 PSI
- Ⓒ 17/32 IN. 165°F QUICK RESPONSE IN-RACK SPRINKLERS ON 4 FT. NOMINAL CENTERS. 50 PSI

RACK CONFIGURATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

ILL 23

FIRE TEST NO.5 PLASTIC PINT AND GALLON CONTAINERS



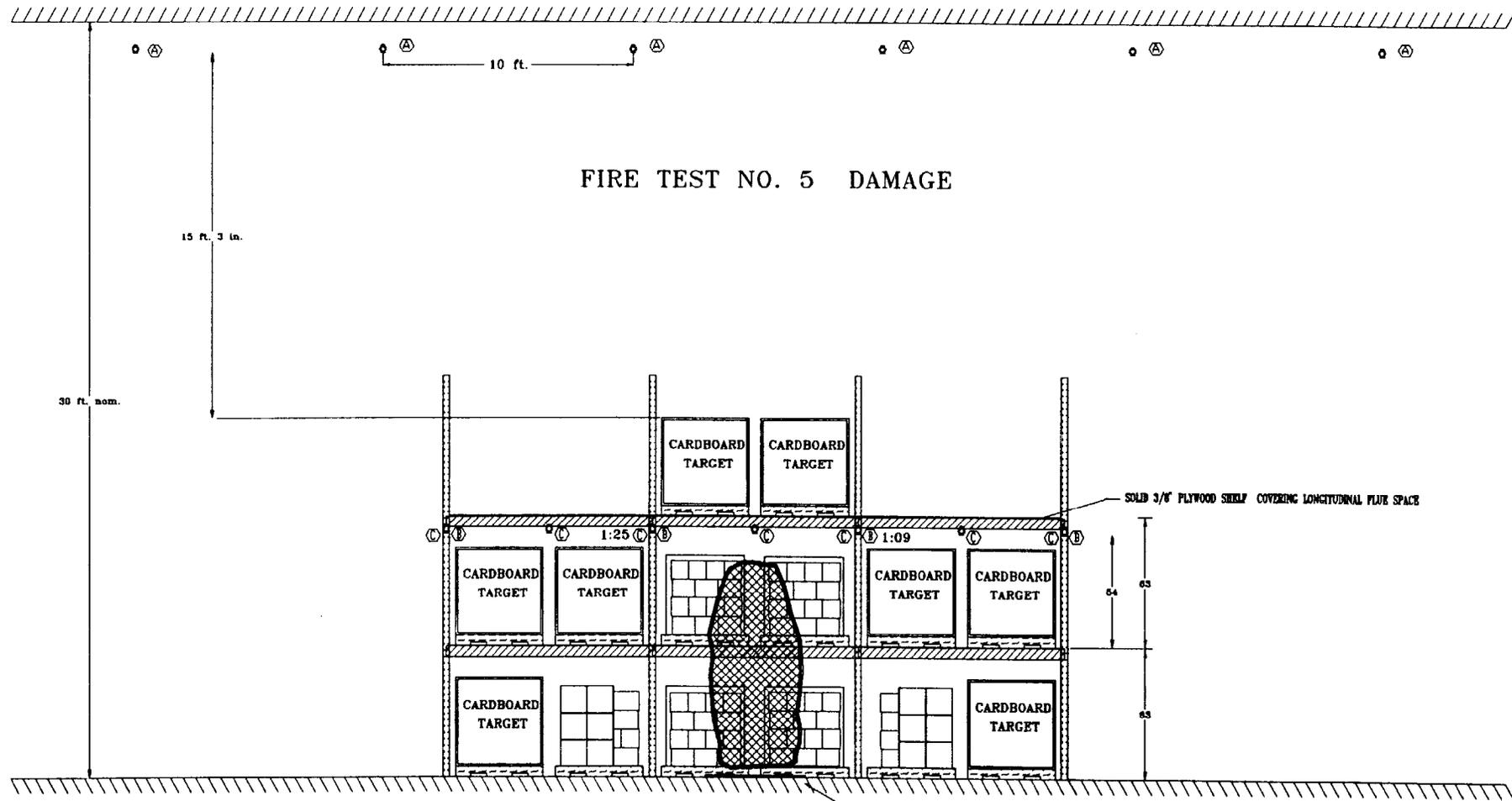
ELEVATION-SIDE VIEW

- SPRINKLER LOCATIONS
- Ⓐ 17/32 IN. 286° UPRIGHT STYLE SPRINKLERS ON 8 FT. BY 10 FT.
- Ⓑ 17/32 IN. 165° F QUICK RESPONSE UPRIGHT FACE RACK SPRINKLERS ON 8 FT. NOMINAL CENTERS. 50 PSI
- Ⓒ 17/32 IN. 165° F QUICK RESPONSE UPRIGHT INRACK SPRINKLERS ON 4 FT. NOMINAL CENTERS. 50 PSI

RACK CONFIGURATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

FIRE TEST NO. 5 DAMAGE



ELEVATION-FRONT VIEW

- SPRINKLER LOCATIONS
- Ⓐ 20¢ UPRIGHT STYLE SPRINKLERS ON 8 FT. BY 10 FT.
- Ⓑ 17/32 IN. 185F QUICK RESPONSE FACE RACK SPRINKLERS ON 8 FT. NOMINAL CENTERS. 50 PSI
- Ⓒ 17/32 IN. 185F QUICK RESPONSE IN-RACK SPRINKLERS ON 4 FT. NOMINAL CENTERS. 50 PSI

2 GALLON ALCOHOL IGNITION IN 4x2x1" DEEP PAN IBA PALLETS NOTCHED TO STRADDLE THE PAN

RACK CONFIGURATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

Fire Test No. 6

Commodity

The fire test commodity consisted of of cartoned plastic f-style gallon containers of 93% isopropyl alcohol (IPA) stored on hardwood pallets. Eight of these pallets were arranged in the first and second tiers of a double row rack storage array with nominal 6 inch longitudinal and transverse flue spaces at each tier. The center of the array was centered between four ceiling sprinklers. The clearance from the top of the commodity to the ceiling sprinkler deflectors was 15 ft. 3 in. The total quantity of isopropyl alcohol in the storage arrangement was 1104 gallons.

In-rack Protection

The in-rack protection provided for this storage array consisted of in-rack face and flue sprinklers in conjunction with barrier boards above the second tier of storage. The quick response, large orifice, upright style, in-rack sprinklers with a 165°F temperature rating were positioned as shown in Ill. 26. The clearance from the top of the stored commodity to the in-rack sprinkler deflectors was 12 inches. The in-rack sprinkler system was set to deliver water through the in-rack sprinklers at 50 psi upon operation of any of the in-rack sprinklers.

Ceiling Protection

Sixteen 286° F temperature rated standard response, pendent style, sprinklers were installed on a nominal 8 ft. by 8 ft. spacing and mounted a nominal 9 inches under a smooth, flat, non-combustible, ceiling assembly. The ceiling sprinkler system was arranged to deliver water through the sprinklers at a discharge density of 0.35 gpm/ft² upon operation of any of the ceiling sprinklers.

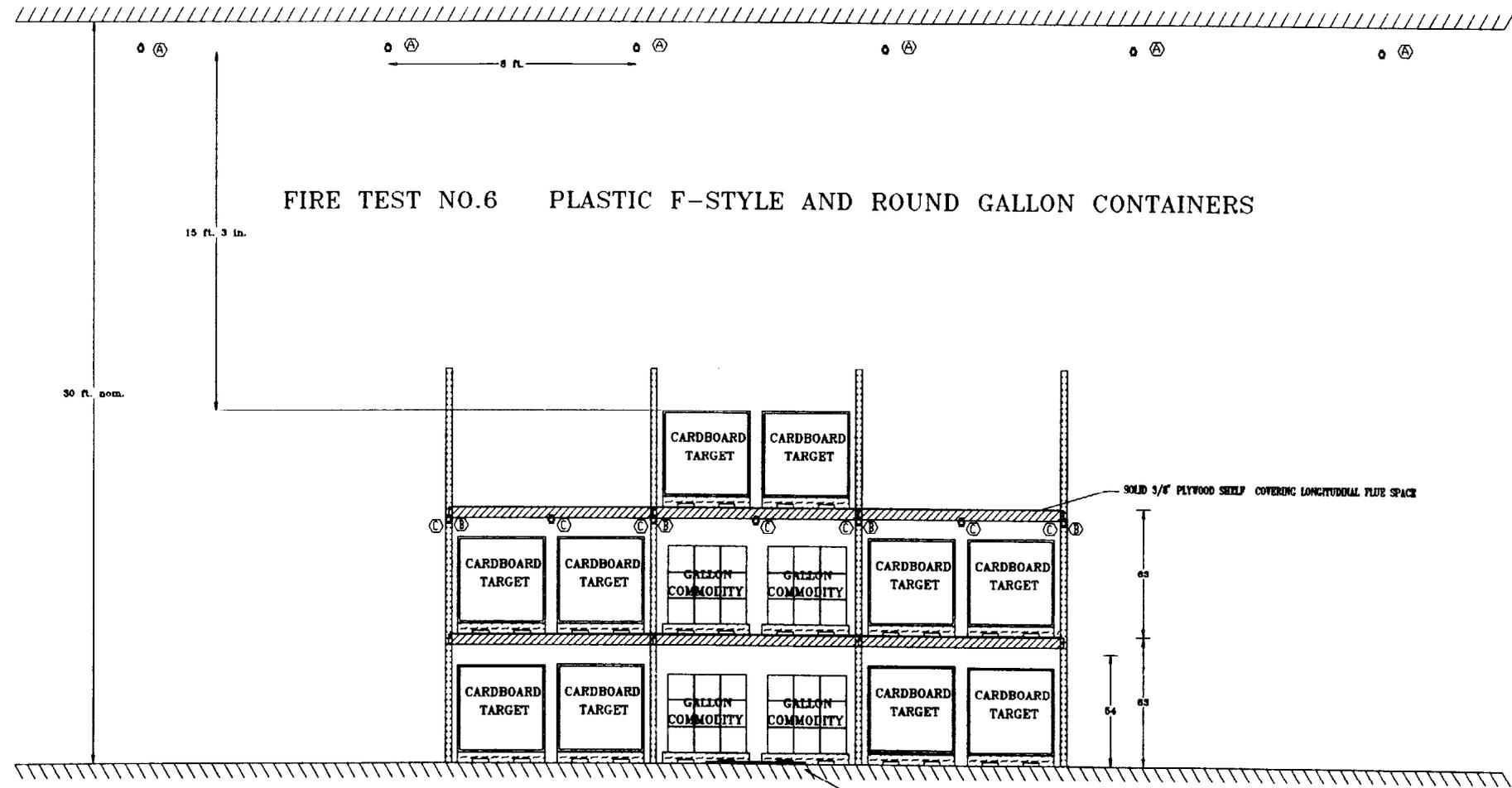
Test Procedure

Ignition was accomplished using 2 gallons of alcohol in two steel pans measuring 2 ft by 2 ft by .75 in. high. These pans were located at the south face of the storage array, at the floor level, protruding 12 in. into the aisle as shown in Ill. 26. During the test, time, temperature, and flow information were gathered using high speed data acquisition equipment. Video images were captured and recorded on VHS format video tape.

Results

During this fire test three of the in-rack sprinklers operated. The first sprinkler, located in the flue at the east side of the rack, activated at 35s. The second sprinkler, located in the flue at the center of the rack activated at 185s. The third sprinkler, located in the flue at the west side of the rack activated at 197s. Seventeen cartons were damaged by the fire. Sixty eight gallons of alcohol were consumed. There was no spread of fire above the in-rack sprinkler protection. The adjacent target commodity became involved at 229s. The areas of damage are shown in Ills. 28 and 29. A summary of the testing is presented in Table I.

FIRE TEST NO.6 PLASTIC F-STYLE AND ROUND GALLON CONTAINERS



ELEVATION-FRONT VIEW

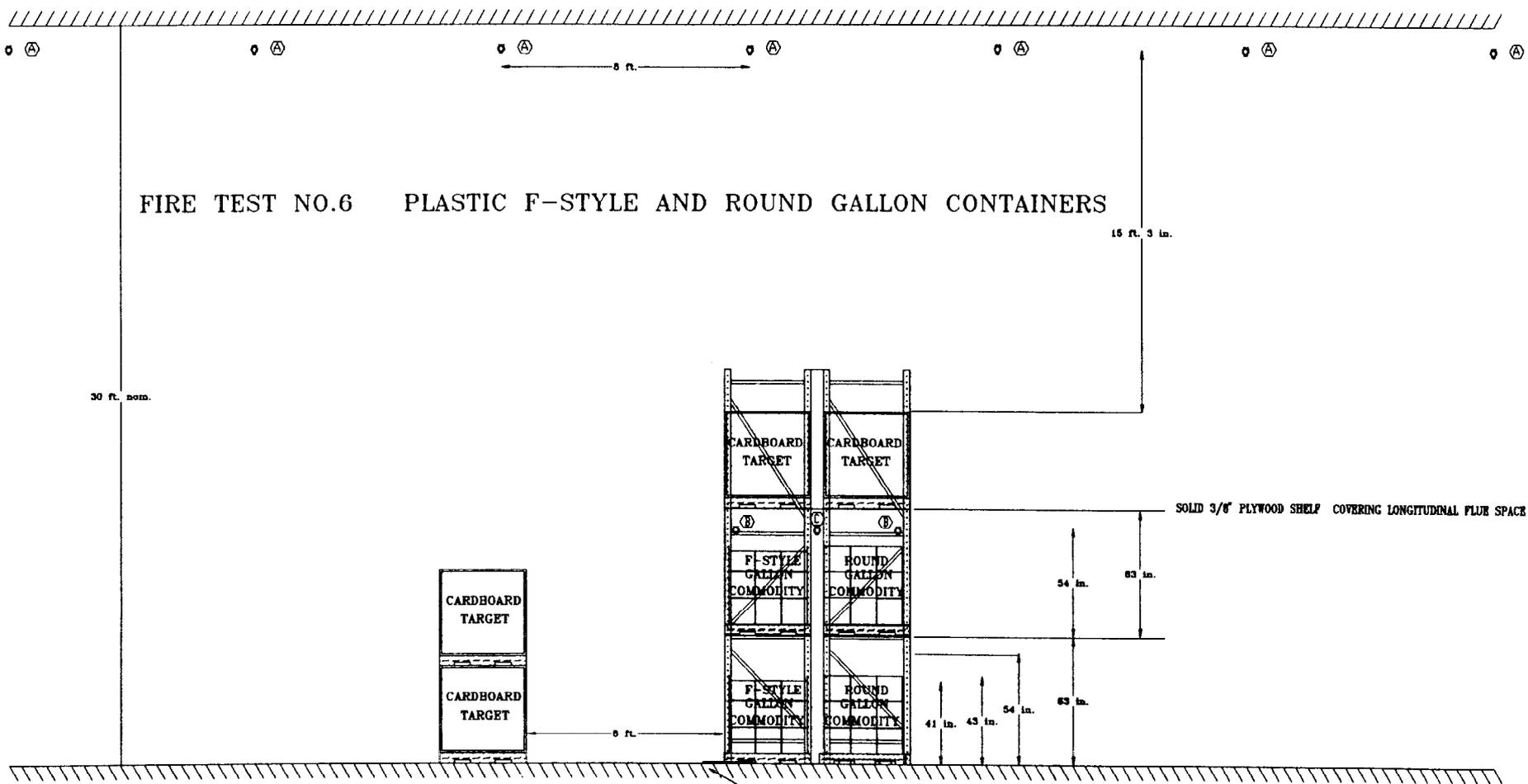
- SPRINKLER LOCATIONS
- △ 28° UPRIGHT STYLE SPRINKLERS ON 8 FT. BY 8 FT.
- ⊕ 17/32 IN. 165° QUICK RESPONSE FACE RACK SPRINKLERS ON 8 FT. NOMINAL CENTERS. 50 PSI
- ⊙ 17/32 IN. 165° QUICK RESPONSE IN-RACK SPRINKLERS ON 4 FT. NOMINAL CENTERS. 50 PSI

2 GALLON ALCOHOL IGNITION IN 4"x2"x1" DEEP PAN IPA PALLETS NOTCHED TO STRADDLE THE PAN

RACK CONFIGURATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

FIRE TEST NO.6 PLASTIC F-STYLE AND ROUND GALLON CONTAINERS



ELEVATION-SIDE VIEW

- SPRINKLER LOCATIONS
- Ⓐ 17/32 IN. 286° UPRIGHT STYLE SPRINKLERS ON 8 FT. BY 8 FT.
- Ⓑ 17/32 IN. 185°F QUICK RESPONSE UPRIGHT FACE RACK SPRINKLERS ON 8 FT. NOMINAL CENTERS. 50 PSI
- Ⓒ 17/32 IN. 185°F QUICK RESPONSE UPRIGHT INRACK SPRINKLERS ON 4 FT. NOMINAL CENTERS. 50 PSI

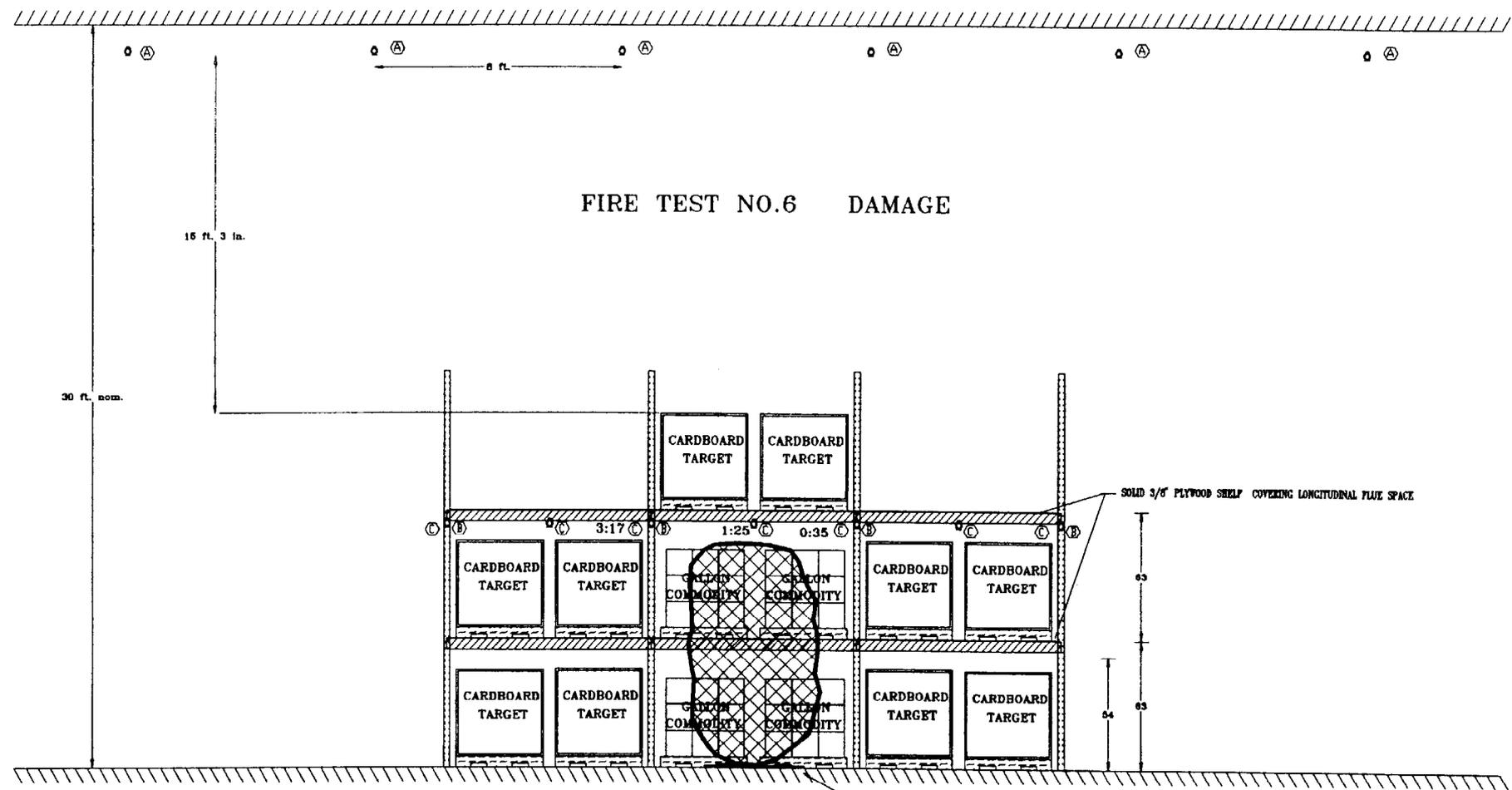
2 GALLON ALCOHOL IGNITION IN 4'x2'x1" DEEP PAN PALLETTS NOTCHED TO STRADDLE THE PAN

RACK CONFIGURATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

ILL 27

FIRE TEST NO.6 DAMAGE



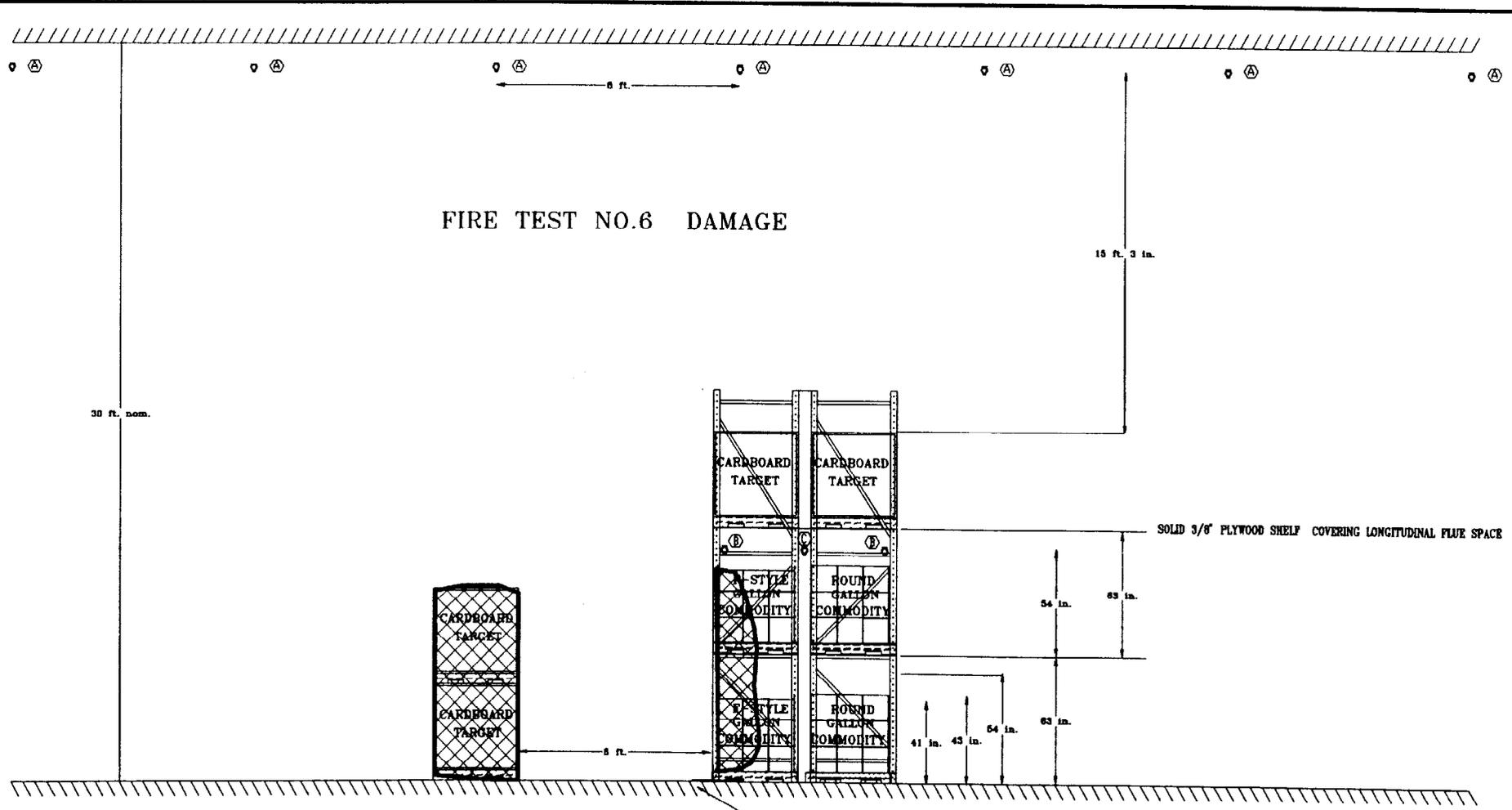
ELEVATION-FRONT VIEW

- SPRINKLER LOCATIONS
- (A) 286 1" RICHT STYLE SPRINKLERS ON 8 FT. BY 8 FT.
- (B) 17/32 IN. 165°F QUICK RESPONSE FACE RACK SPRINKLERS ON 8 FT. NOMINAL CENTERS. 50 PSI
- (C) 17/32 IN. 165°F QUICK RESPONSE IN-RACK SPRINKLERS ON 4 FT. NOMINAL CENTERS. 50 PSI

RACK CONFIGURATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

FIRE TEST NO.6 DAMAGE



ELEVATION-SIDE VIEW

- SPRINKLER LOCATIONS
- Ⓐ 17/32 IN. 286° UPRIGHT STYLE SPRINKLERS ON 8 FT. BY 8 FT.
- Ⓑ 17/32 IN. 165° F QUICK RESPONSE UPRIGHT FACE RACK SPRINKLERS ON 8 FT. NOMINAL CENTERS. 50 PSI
- Ⓒ 17/32 IN. 165° F QUICK RESPONSE UPRIGHT INRACK SPRINKLERS ON 4 FT. NOMINAL CENTERS. 50 PSI

RACK CONFIGURATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

ILL 29

Fire Test No. 7

Commodity

The fire test commodity consisted of of cartoned plastic pint and quart containers of 99% isopropyl alcohol (IPA) stored on hardwood pallets. Four pallets of plastic pints were arranged in the first tier of a double row rack storage array with nominal 6 inch longitudinal and transverse flue spaces. Four pallets of plastic quarts were arranged in the second tier of a double row rack storage array with nominal 6 inch longitudinal and transverse flue spaces. The center of the array was centered between four ceiling sprinklers. The clearance from the top of the commodity to the ceiling sprinkler deflectors was 6 inches. The total quantity of isopropyl alcohol in the storage arrangement was 1056 gallons.

In-rack Protection

The in-rack protection provided for this storage array consisted of in-rack face and flue sprinklers in conjunction with barrier boards above the second tier of storage. The quick response, large orifice, upright style, in-rack sprinklers with a 165°F temperature rating were positioned as shown in Ill. 30. The clearance from the top of the stored quart commodity to the in-rack sprinkler deflectors was 6 inches. The in-rack sprinkler system was set to deliver water through the in-rack sprinklers at 50 psi upon operation of any of the in-rack sprinklers.

Ceiling Protection

Sixteen 286° F temperature rated standard response, pendent style, sprinklers were installed on a nominal 8 ft. by 8 ft. spacing and mounted a nominal 9 inches under a smooth, flat, non-combustible, ceiling assembly. The ceiling sprinkler system was arranged to deliver water through the sprinklers at a discharge density of 0.35 gpm/ft² upon operation of any of the ceiling sprinklers.

Test Procedure

Ignition was accomplished with four standard half cellu-cotton ignitors located at the center of the south face at the floor as shown in Ill. 30 . During the test, time, temperature, and flow information were gathered using high speed data acquisition equipment. Video images were captured and recorded on VHS format video tape.

Results

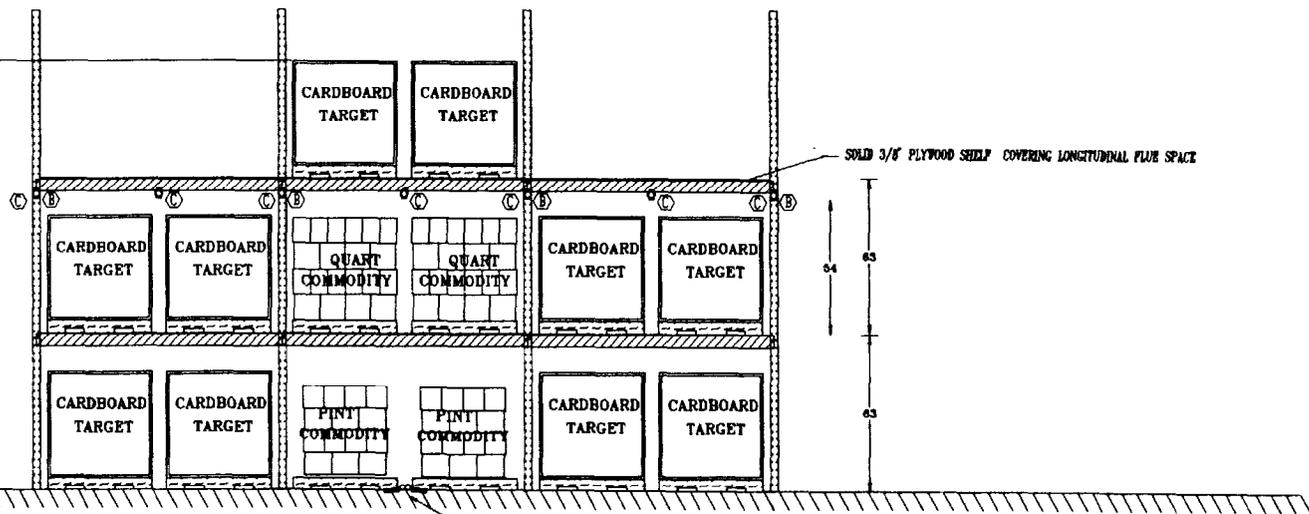
During the test two of the in-rack sprinklers operated. The test was concluded with the operation of a ceiling sprinkler. The first sprinkler, located on the south face at the east side of the rack, activated at 91s. The second sprinkler , located on the south face at the west side of the rack activated at 91s. The ceiling sprinkler operated at 6m 38s. Twenty cartons of quart containers and 15 cartons of pint containers were damaged by the fire. Fifty five gallons of alcohol were consumed. The fire spread to the second tier of storage at 90s. The adjacent target became involved at 210s. The areas of damage are shown in Ills. 32 and 33. A summary of the testing is presented in Table I.

FIRE TEST NO.7 PLASTIC PINT AND QUART CONTAINERS

15 ft. 3 in.

30 ft. nom.

8 ft



SOLID 3/8" PLYWOOD SHELF COVERING LONGITUDINAL FLUE SPACE

ELEVATION-FRONT VIEW

4 HALF STANDARD COTTON CELLULOSE IGNITORS

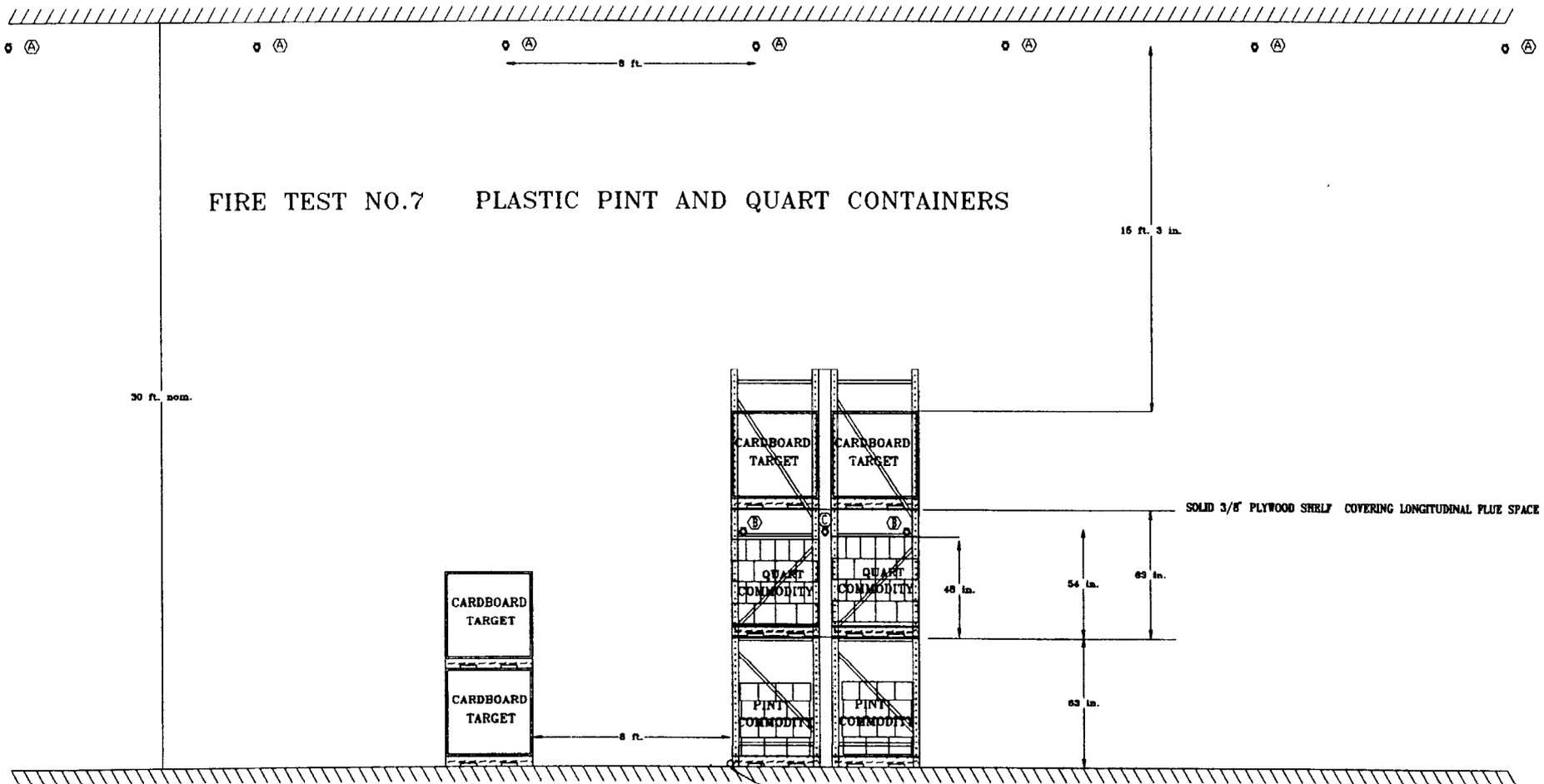
- SPRINKLER LOCATIONS
- Ⓐ 286 PENDING STYLE SPRINKLERS ON 8 FT. BY 10 FT.
- Ⓑ 17/32 IN. 165°F QUICK RESPONSE FACE RACK SPRINKLERS ON 8 FT. NOMINAL CENTERS. 50 PSI
- Ⓒ 17/32 IN. 165°F QUICK RESPONSE IN-RACK SPRINKLERS ON 4 FT. NOMINAL CENTERS. 50 PSI

RACK CONFIGURATION

ILL 30

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

FIRE TEST NO.7 PLASTIC PINT AND QUART CONTAINERS



ELEVATION-SIDE VIEW

○ SPRINKLER LOCATIONS

Ⓐ 17/32 IN. 286° UPRIGHT STYLE SPRINKLERS ON 8 FT. BY 8 FT.

Ⓑ 17/32 IN. 165°F QUICK RESPONSE UPRIGHT FACE RACK SPRINKLERS ON 8 FT. NOMINAL CENTERS. 50 PSI

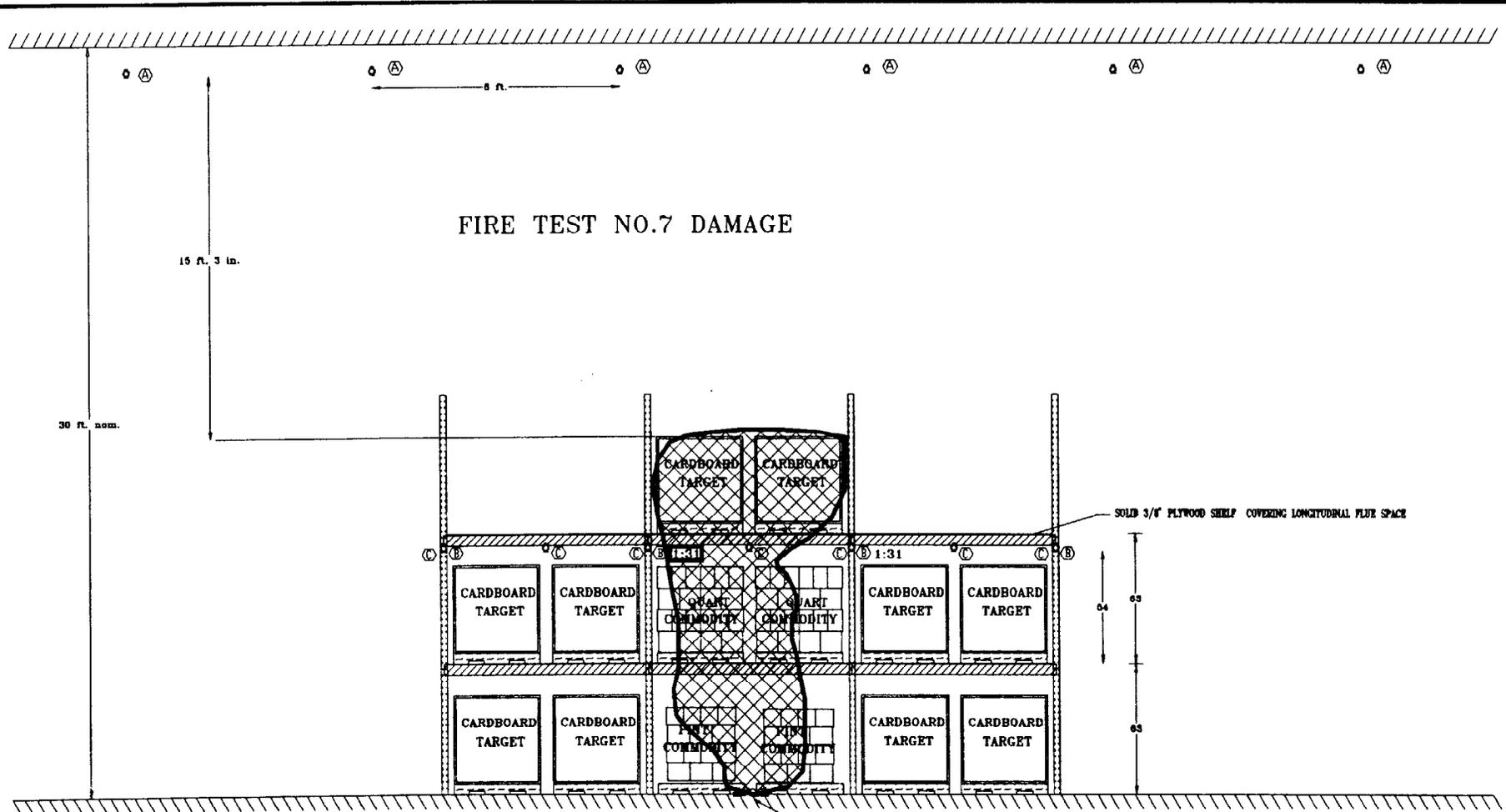
Ⓒ 17/32 IN. 165°F QUICK RESPONSE UPRIGHT INRACK SPRINKLERS ON 4 FT. NOMINAL CENTERS. 50 PSI

4 HALF STANDARD COTTON CELLULOSE IGNITORS

RACK CONFIGURATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

FIRE TEST NO.7 DAMAGE



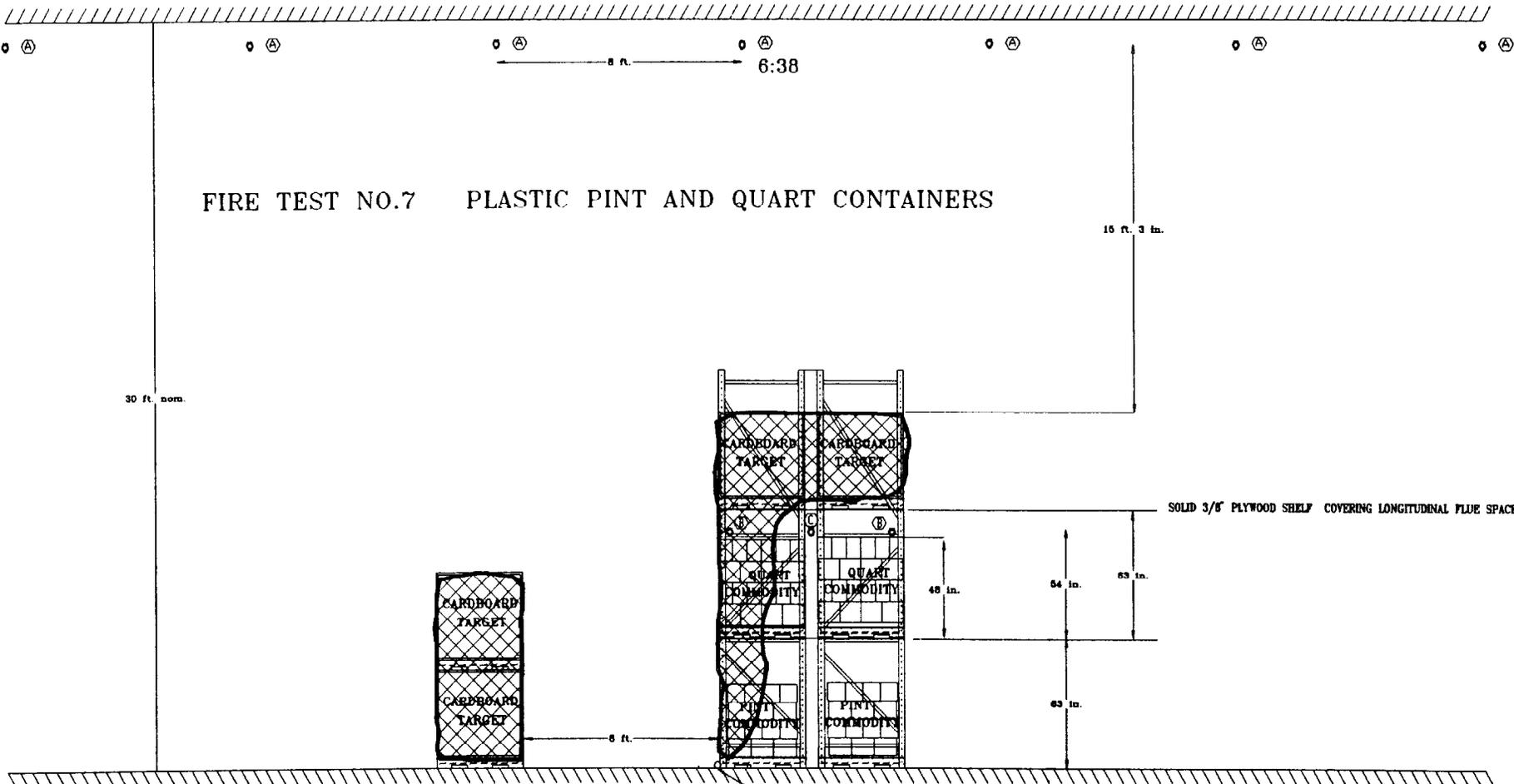
ELEVATION-FRONT VIEW

- SPRINKLER LOCATIONS
- Ⓐ 206 PENDENT STYLE SPRINKLERS ON 8 FT. BY 10 FT.
- Ⓑ 17/32 IN. 165°F QUICK RESPONSE FACE RACK SPRINKLERS ON 8 FT. NOMINAL CENTERS. 50 PSI
- Ⓒ 17/32 IN. 165°F QUICK RESPONSE IN-RACK SPRINKLERS ON 4 FT. NOMINAL CENTERS. 50 PSI

RACK CONFIGURATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

FIRE TEST NO.7 PLASTIC PINT AND QUART CONTAINERS



ELEVATION-SIDE VIEW

- SPRINKLER LOCATIONS
- Ⓐ 17/32 IN. 286° UPRIGHT STYLE SPRINKLERS ON 8 FT. BY 8 FT.
- Ⓑ 17/32 IN. 185°F QUICK RESPONSE UPRIGHT FACE RACK SPRINKLERS ON 8 FT. NOMINAL CENTERS. 50 PSI
- Ⓒ 17/32 IN. 185°F QUICK RESPONSE UPRIGHT INRACK SPRINKLERS ON 4 FT. NOMINAL CENTERS. 50 PSI

4 HALF STANDARD COTTON CELLULOSE IGNITORS

RACK CONFIGURATION

ILL 33

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

Fire Test No. 8

Commodity

The fire test commodity consisted of cartoned plastic round and f-style gallon containers of 93% isopropyl alcohol solution (IPA) stored on hardwood pallets and cartoned plastic quart containers of 99% isopropyl alcohol (IPA) stored on hardwood pallets. These pallets were arranged in a 2 x 3 x 2 palletized storage array with nominal 6 inch longitudinal and no transverse flue spaces. The bottom tier of this arrangement utilized the pallets of plastic gallons and the top tier utilized the pallets of plastic quarts. The height of the storage array was 79 inches. The center of the array was centered between four ceiling sprinklers. The clearance from the top of the commodity to the ceiling sprinkler deflectors was 17 ft. 8 in. The total quantity of isopropyl alcohol in the palletized storage array was 1452 gallons.

Ceiling Protection

Thirty six 286° F temperature rated standard response, pendent style, sprinklers were installed on a nominal 8 ft. by 8 ft. spacing and mounted a nominal 9 inches under a smooth, flat, non-combustible, ceiling assembly. The ceiling sprinkler system was arranged to deliver water through the sprinklers at a discharge density of 0.40 gpm/ft² upon operation of any of the ceiling sprinklers.

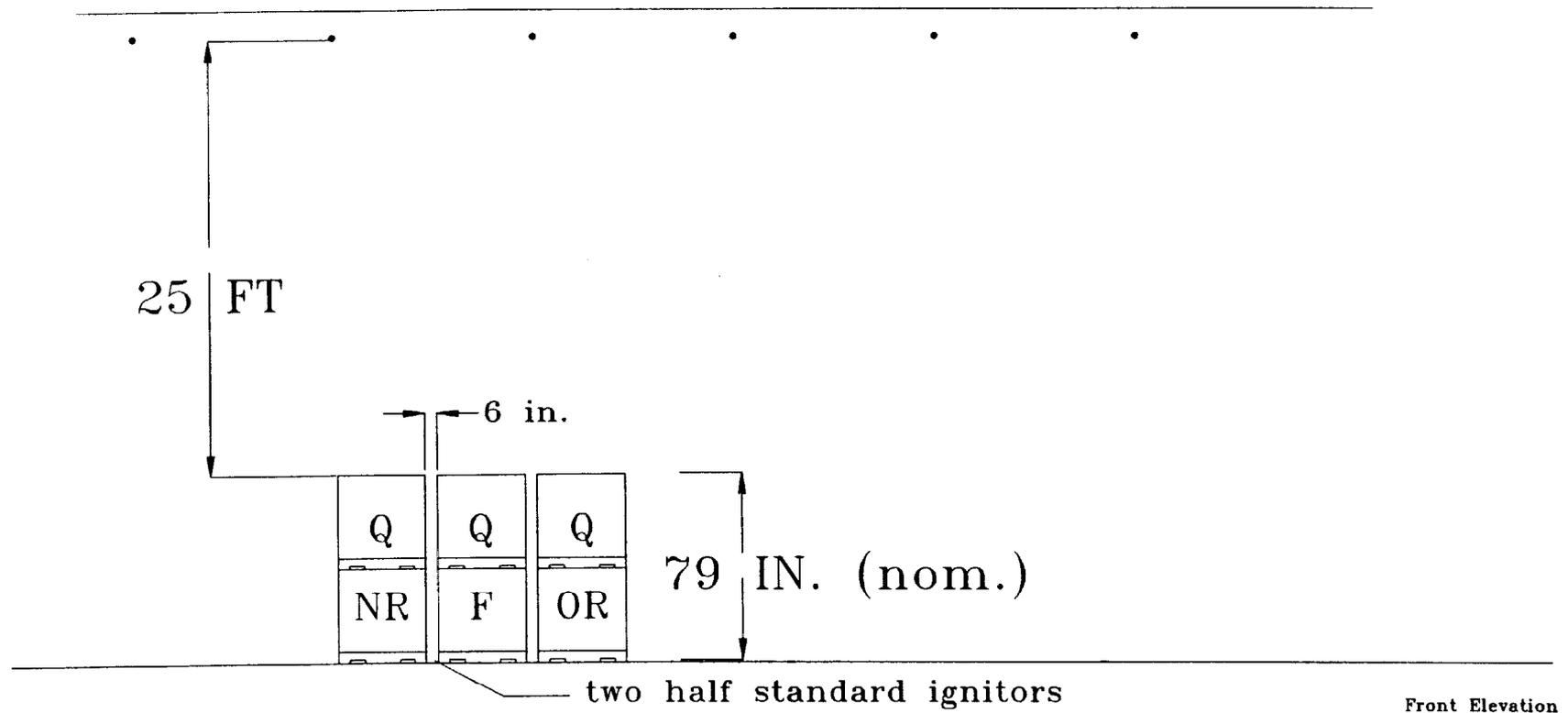
Test Procedure

Ignition was accomplished using two standard half cellu-cotton ignitors located in the center of the transverse flue on the south side of the storage array as shown in Ill. 34. During the test, time, temperature, and flow information were gathered using high speed data acquisition equipment. Video images were captured and recorded on VHS format video tape.

Results

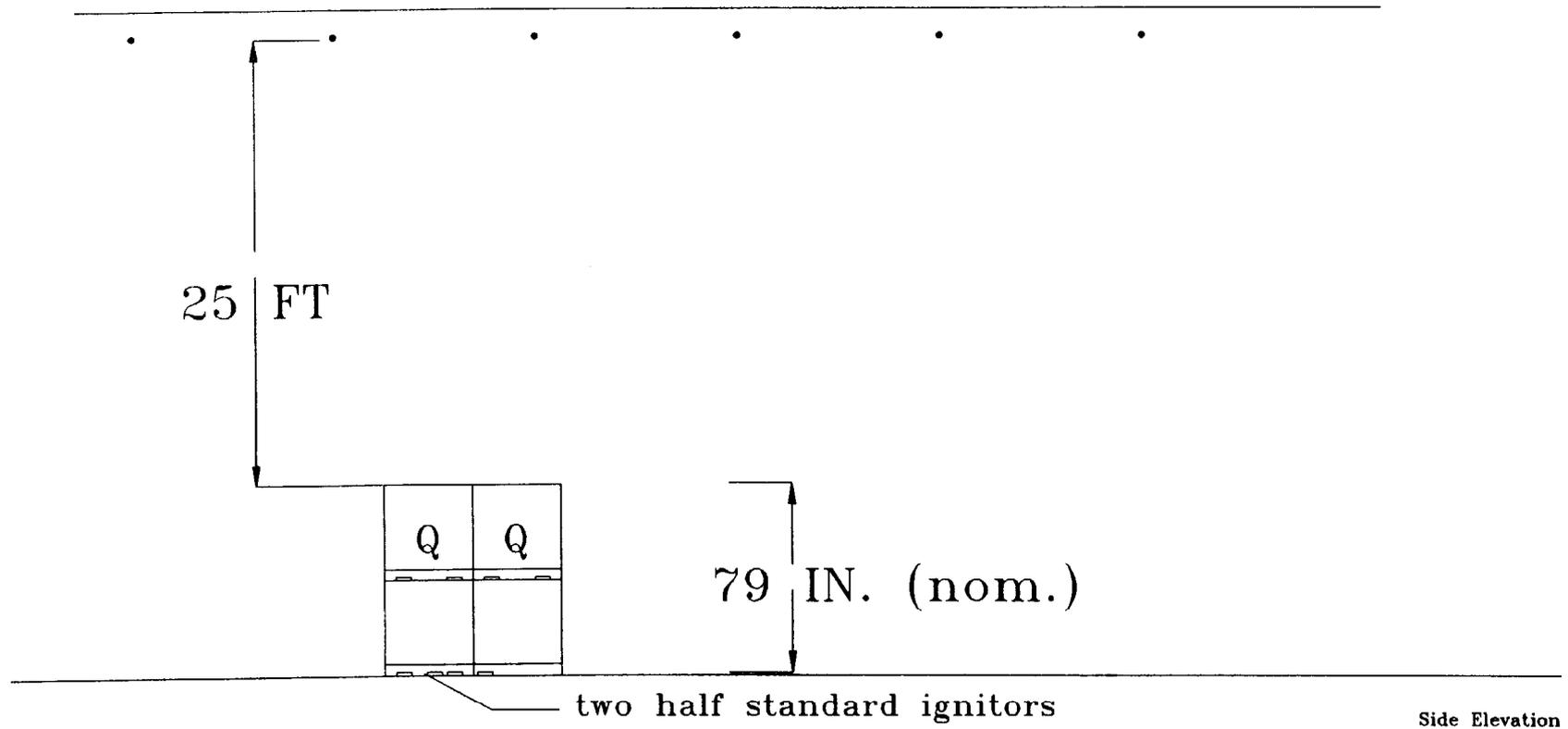
During the test 11 sprinklers operated between 130s and 301s. Six pallet loads of commodity were damaged by the fire. Seven hundred and ten gallons of alcohol were consumed. A floor fire extending out approximately 35 feet from the test array was noted during this test. The areas of damage are shown in Ills. 36 and 37. A summary of the testing is presented in Table I.

Fire Test No. 8 Mixed Palletized Plastic Containers



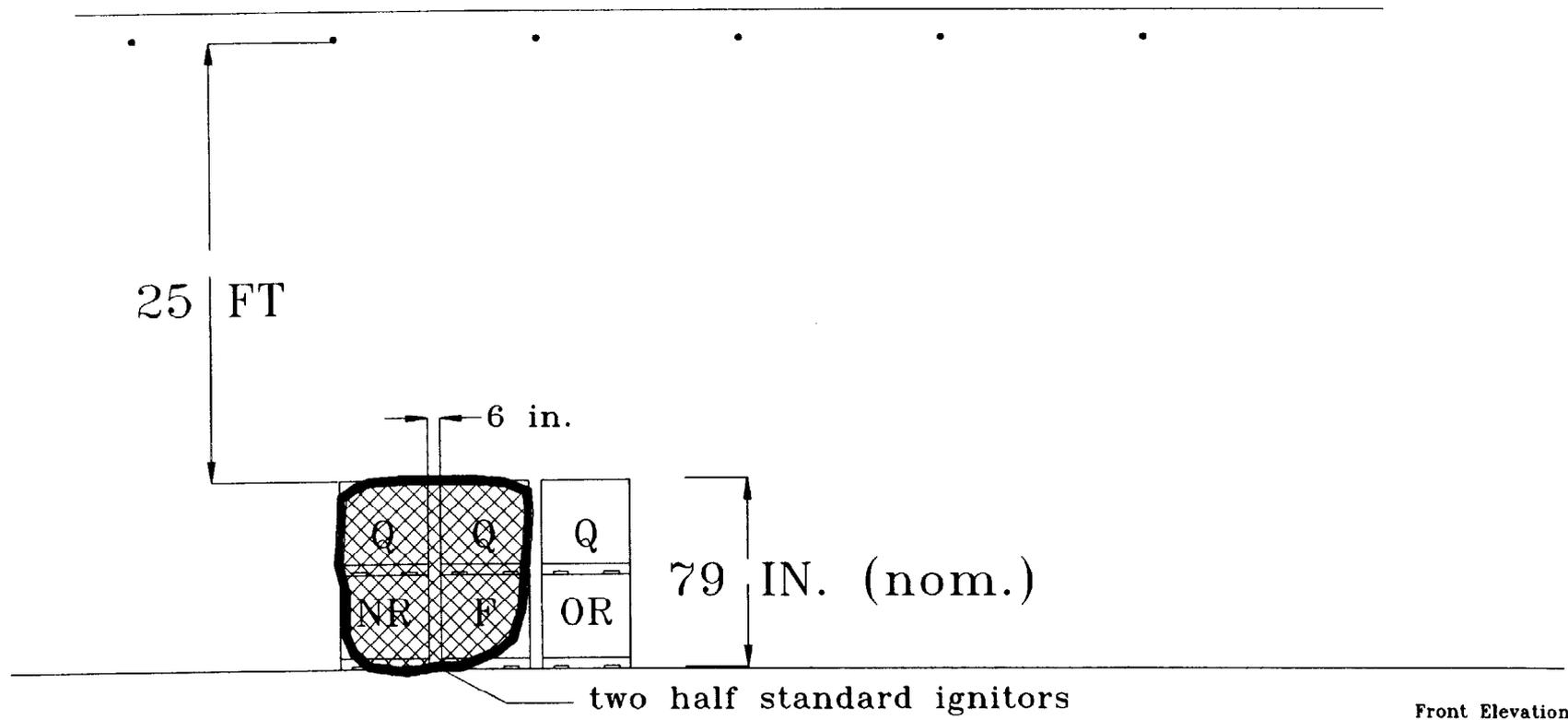
- - 286°F Sprinklers on 8 ft. x 8 ft. spacing arranged to provide 0.40 gpm/sqft
- Q - Palletized plastic quart containers
- F - Palletized plastic F-style gallon containers
- OR - Palletized plastic round gallon containers in compartmented cartons
- NR - Palletized plastic round gallon containers

Fire Test No. 8 Mixed Palletized Plastic Containers



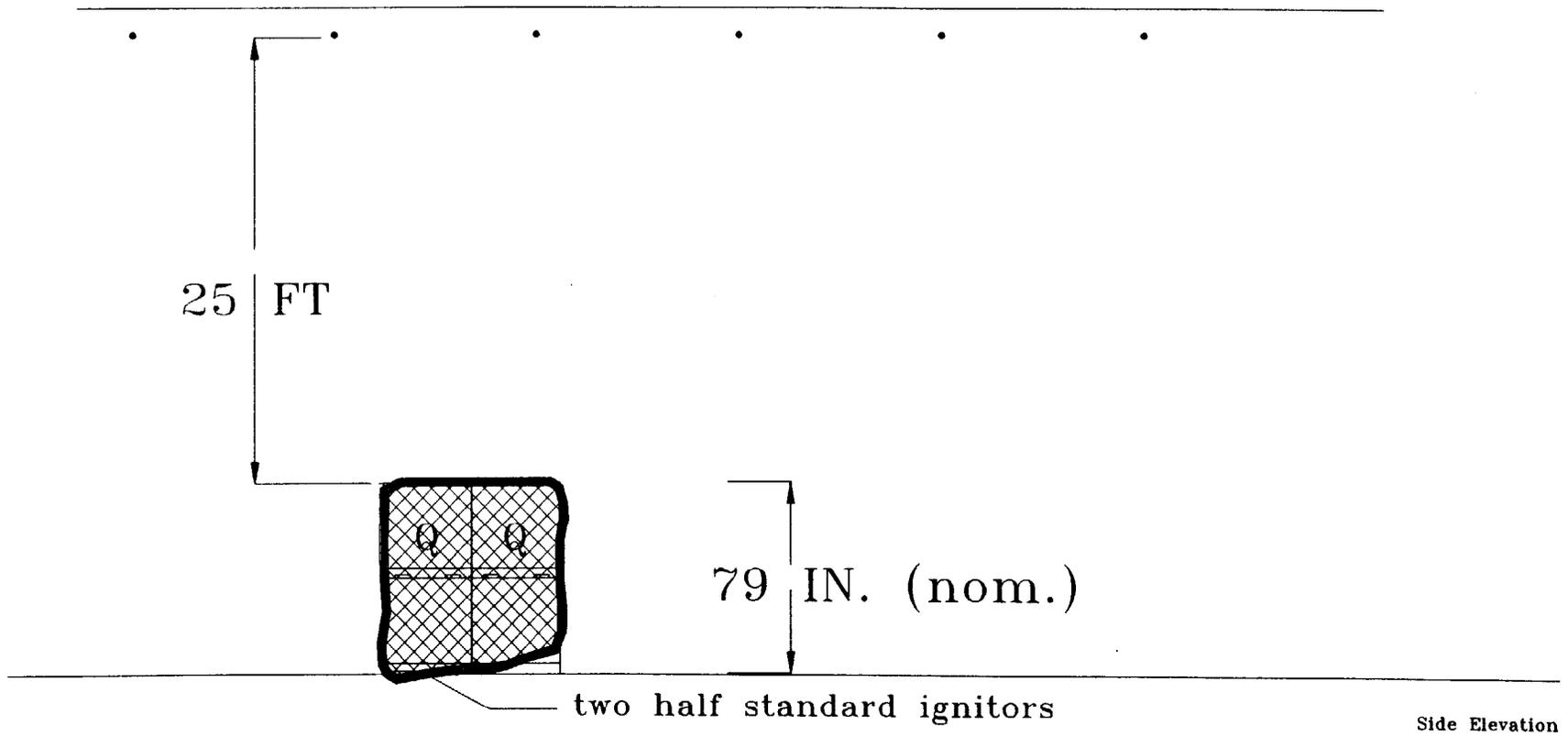
- - 286°F Sprinklers on 8 ft. x 8 ft. spacing arranged to provide 0.40 gpm/sqft
- Q - Palletized plastic quart containers
- F - Palletized plastic F-style gallon containers
- OR - Palletized plastic round gallon containers in compartmented cartons
- NR - Palletized plastic round gallon containers

Fire Test No. 8 Damage

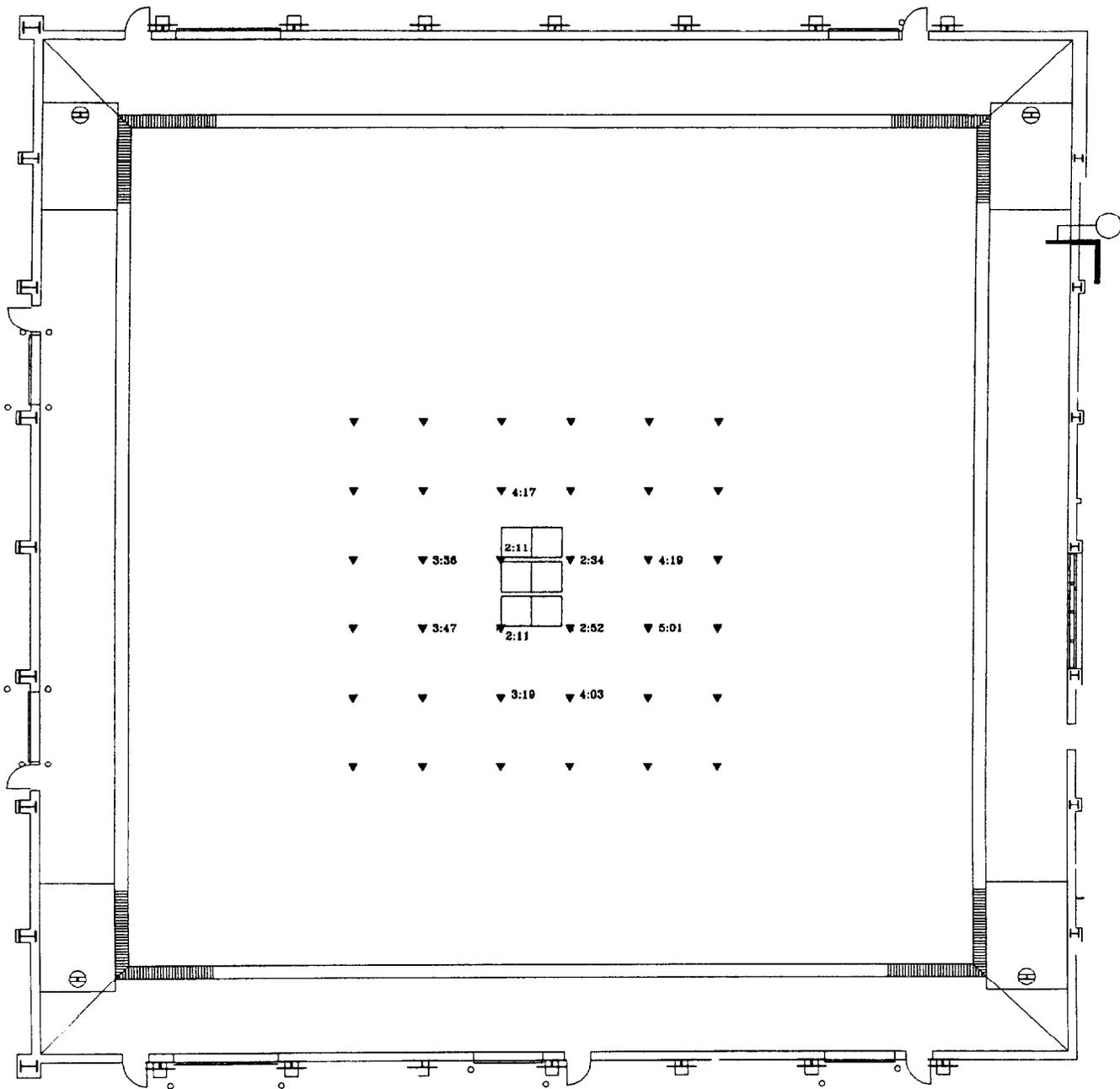
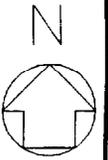


- - 286°F Sprinklers on 8 ft. x 8 ft. spacing arranged to provide 0.40 gpm/sqft
- Q - Palletized plastic quart containers
- F - Palletized plastic F-style gallon containers
- OR - Palletized plastic round gallon containers in compartmented cartons
- NR - Palletized plastic round gallon containers

Fire Test No. 8 Damage



- - 286°F Sprinklers on 8 ft. x 8 ft. spacing arranged to provide 0.40 gpm/sqft
- Q - Palletized plastic quart containers
- F - Palletized plastic F-style gallon containers
- OR - Palletized plastic round gallon containers in compartmented cartons
- NR - Palletized plastic round gallon containers



LEGEND

▼ 286 °F SPRINKLERS ON 8 FT BY 8 FT SPACING

FIRE TEST No.8
SPRINKLER OPERATIONS

TABLE 1

	TEST NO. 1	TEST NO. 2	TEST NO. 3	TEST NO. 4	TEST NO. 5	TEST NO. 6	TEST NO. 7	TEST NO. 8
TEST DATE	12/10/96	12/11/96	12/11/96	12/12/96	12/12/96	2/18/97	2/18/97	2/20/97
COMMODITY	RPQ	RPG	RPP	RPP	RPP, RPG,MIX	RPG,FPG	RPP,RPQ	RPG,FPG, RPN,RPQ
NUMBER OF PALLET	8	8	8	2	4,4,8	4,4	4,4	2,2,2,6
TOTAL GALLONS OF ALCOHOL	768	864	720	180	1560	1104	1056	1452
IGNITION TYPE	pan	pan	pan	pan	pan	pan	point	point
CEILING SPRINKLER SPACING	8 FT. x 10 FT.	8 FT. x 8 FT.	8 FT. x 8 FT.	8 FT. x 8 FT.				
CEILING SPRINKLER DENSITY	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.4
IN-RACK SPRINKLER SPACING AND CONFIGURATION - FLUE	4 FT. NOM. EVERY LEVEL	4 FT. NOM. EVERY LEVEL	4 FT. NOM. EVERY LEVEL	4 FT. NOM. EVERY LEVEL	4 FT. NOM. SECOND LEVEL	4 FT. NOM. SECOND LEVEL	4 FT. NOM. SECOND LEVEL	N/A
IN-RACK SPRINKLER SPACING AND CONFIGURATION - FACE	8 FT. NOM. EVERY LEVEL	8 FT. NOM. EVERY LEVEL	8 FT. NOM. EVERY LEVEL	8 FT. NOM. EVERY LEVEL	8 FT. NOM. SECOND LEVEL	8 FT. NOM. SECOND LEVEL	8 FT. NOM. SECOND LEVEL	N/A
IN-RACK SYSTEM PRESSURE	50 Psi	50 Psi	50 Psi	N/A				
NUMBER OF RACK SPRINKLERS OPERATED	2	2	1	2	2	3	2	N/A
FIRST RACK SPRINKLER OPERATING TIME	0:56	0:49	0:25	0:54	1:09	0:35	1:31	N/A
NUMBER OF CEILING SPRINKLERS OPERATED	0	0	0	0	0	0	1	11
FIRST CEILING SPRINKLER OPERATING TIME	N/A	N/A	N/A	N/A	N/A	N/A	6:38	2:10
FIRE SPREAD ABOVE IN-RACK SPRINKLERS	NO	NO	NO	NO	NO	NO	YES	N/A
FIRE SPREAD ACROSS AISLE	NO	NO	NO	NO	NO	YES	YES	N/A
NUMBER OF DAMAGED CARTONS	14 RPQ	3 RPG	1 RPP	20 RPP	32 RPP	17 FPG	20 RPQ 15 RPP	27 FPG 27 RPN 17 RPG 288 RPQ

RPP ROUND PLASTIC PINT CONTAINERS FPG F-STYLE PLASTIC GALLON CONTAINERS
 RPQ ROUND PLASTIC QUART CONTAINERS RPN ROUND PLASTIC GALLONS IN DIFF. BOX
 RPG ROUND PLASTIC GALLON CONTAINERS MIX RPP AND RPG ON SAME PALLET

Fire Test Summary

A series of fire tests has been conducted to evaluate the level of protection required to control a fire in double row rack storage of palletized isopropyl alcohol in plastic containers.

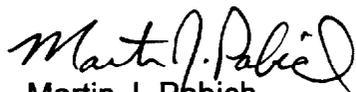
The high density polyethylene (HDPE) containers ranged capacity from pint to gallon and were stored in corrugated cardboard cartons on hardwood pallets. The total stored amount of isopropyl alcohol used in each fire test ranged from 240 gallons to 1560 gallons.

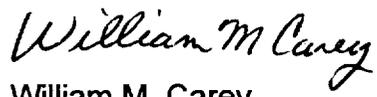
The first seven tests were conducted in a double row rack storage array which was fitted with barriers and in-rack sprinklers. The last test was conducted in a palletized storage array under the protection of the ceiling sprinklers only. Fire test 1 through fire test 6 were ignited with an 8ft² alcohol pan fire located halfway within the plane of the center south face at the floor. Fire Test No. 7 utilized a point ignition at the floor in the center of the south face. Fire Test No. 8 utilized a point ignition centered within the south flue space.

The fire tests conducted with two levels of double row rack storage, of palletized plastic containers filled with 93% to 99 % isopropyl alcohol, with in-rack sprinklers at every level demonstrated that the commodity could be adequately protected even though the flames were never extinguished in any of the tests. When the lower barrier and level of in-rack sprinklers was removed there was a significant increase in the amount of product consumed and the extent of fire spread during each fire test. The results of the palletized Fire Test No. 8 indicated that the ceiling only sprinklers at a discharge density of 0.40 gpm/ft.² was able to control the fire in the test commodity by preventing the outer pallets of commodity from igniting. However, it must be noted that a large floor fire opened eleven sprinklers covering a much larger area than that occupied by the 12 pallet loads of commodity. A larger test array may not have been controlled.

A table indicating the testing parameters and results obtained is presented as Table 1.

Report by:


Martin J. Pabich
Senior Project Engineer
Large Scale Fire Research


William M. Carey
Senior Staff Engineer
Large Scale Fire Research

APPENDIX

<u>ILL. NO.</u>	<u>DESCRIPTION</u>
A1	In-Rack Temperatures Test 1
A2	In-Rack Temperatures Test 1
A3	In-Rack Temperatures Test 1
A4	Pressure Curve Test 1
A5	In-Rack Temperatures Test 2
A6	In-Rack Temperatures Test 2
A7	In-Rack Temperatures Test 2
A8	Pressure Curve Test 2
A9	In-Rack Temperatures Test 3
A10	In-Rack Temperatures Test 3
A11	In-Rack Temperatures Test 3
A12	Pressure Curve Test 3
A13	In-Rack Temperatures Test 4
A14	In-Rack Temperatures Test 4
A15	In-Rack Temperatures Test 4
A16	Pressure Curve Test 4
A17	In-Rack Temperatures Test 5
A18	In-Rack Temperatures Test 5
A19	In-Rack Temperatures Test 5
A20	Pressure Curve Test 5
A21	In-Rack Temperatures Test 6
A22	In-Rack Temperatures Test 6
A23	In-Rack Temperatures Test 6
A24	Pressure Curve Test 6
A25	In-Rack Temperatures Test 7
A26	In-Rack Temperatures Test 7
A27	In-Rack Temperatures Test 7
A28	Pressure Curve Test 7
A29	Ceiling Temperatures Test 8
A30	Ceiling Temperatures Test 8
A31	Pressure Curve Test 8

ILLUSTRATION A1

IRI TEST #1, 12/10/96
IPA COMMODITY IN PLASTIC QUART CONTAINERS,
8 PALLETS
WEST SPRINKLERS

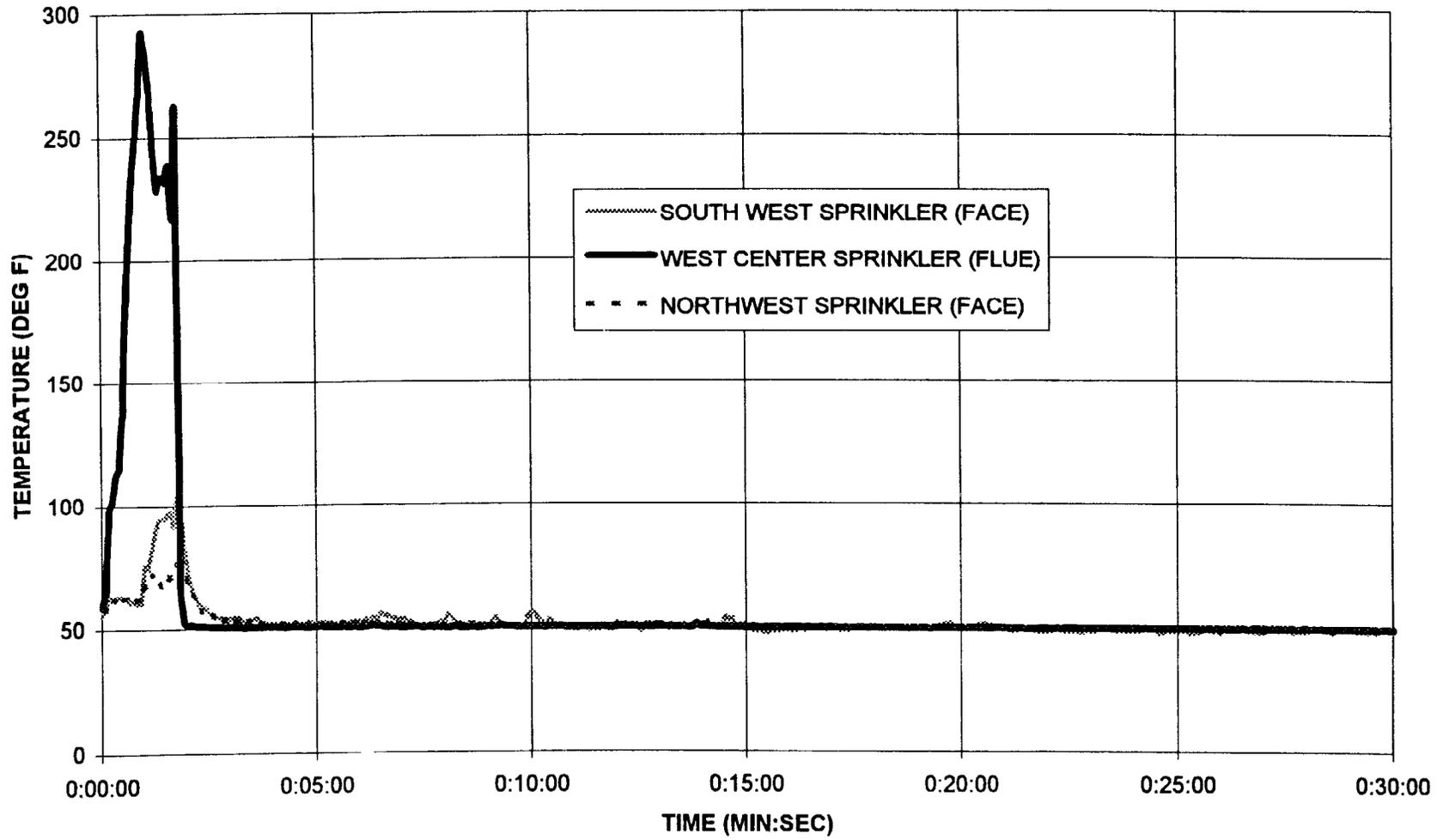


ILLUSTRATION A2

IRI TEST #1, 12/10/96
IPA COMMODITY IN PLASTIC QUART CONTAINERS,
8 PALLETS
CENTER SPRINKLER

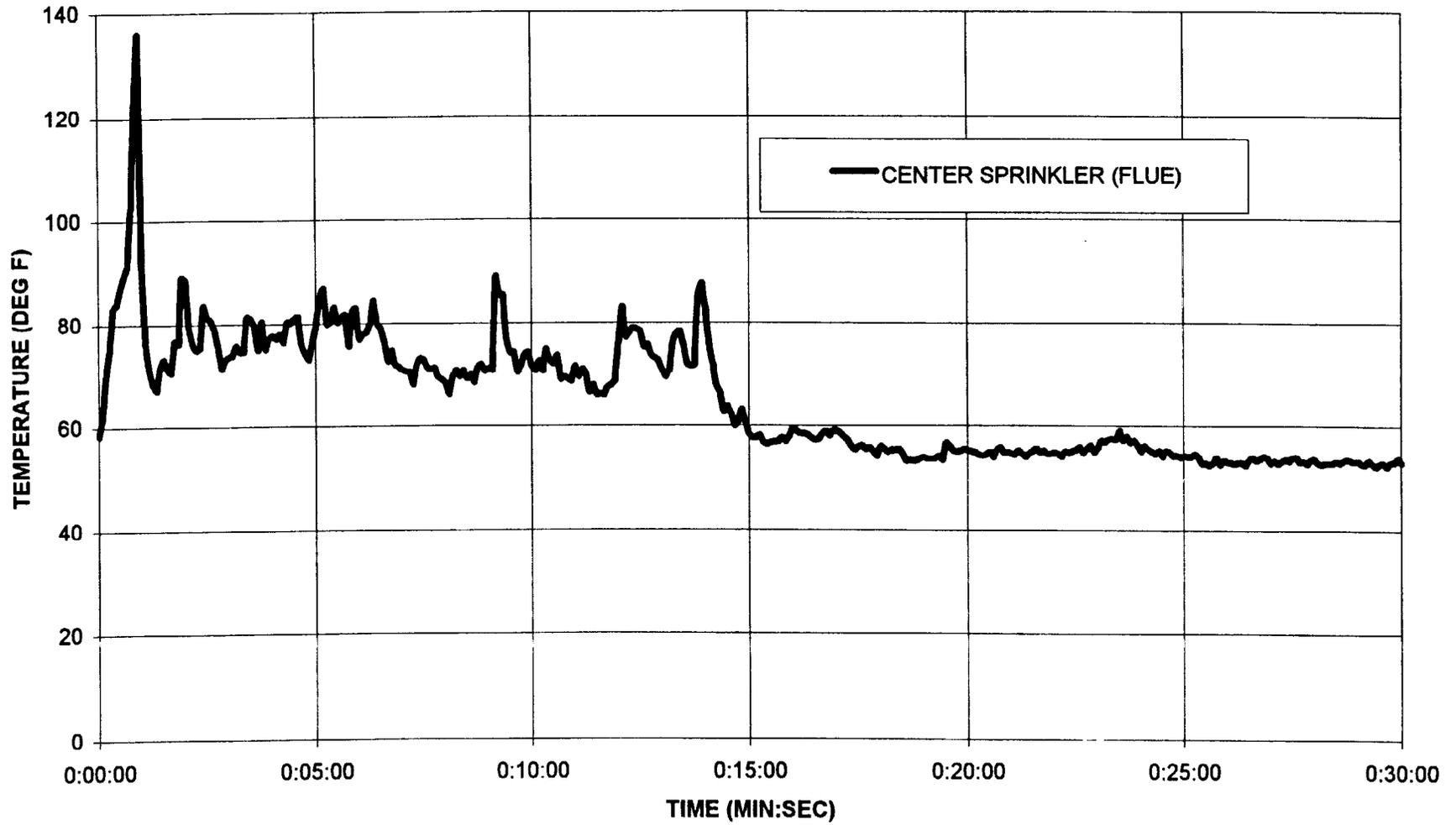
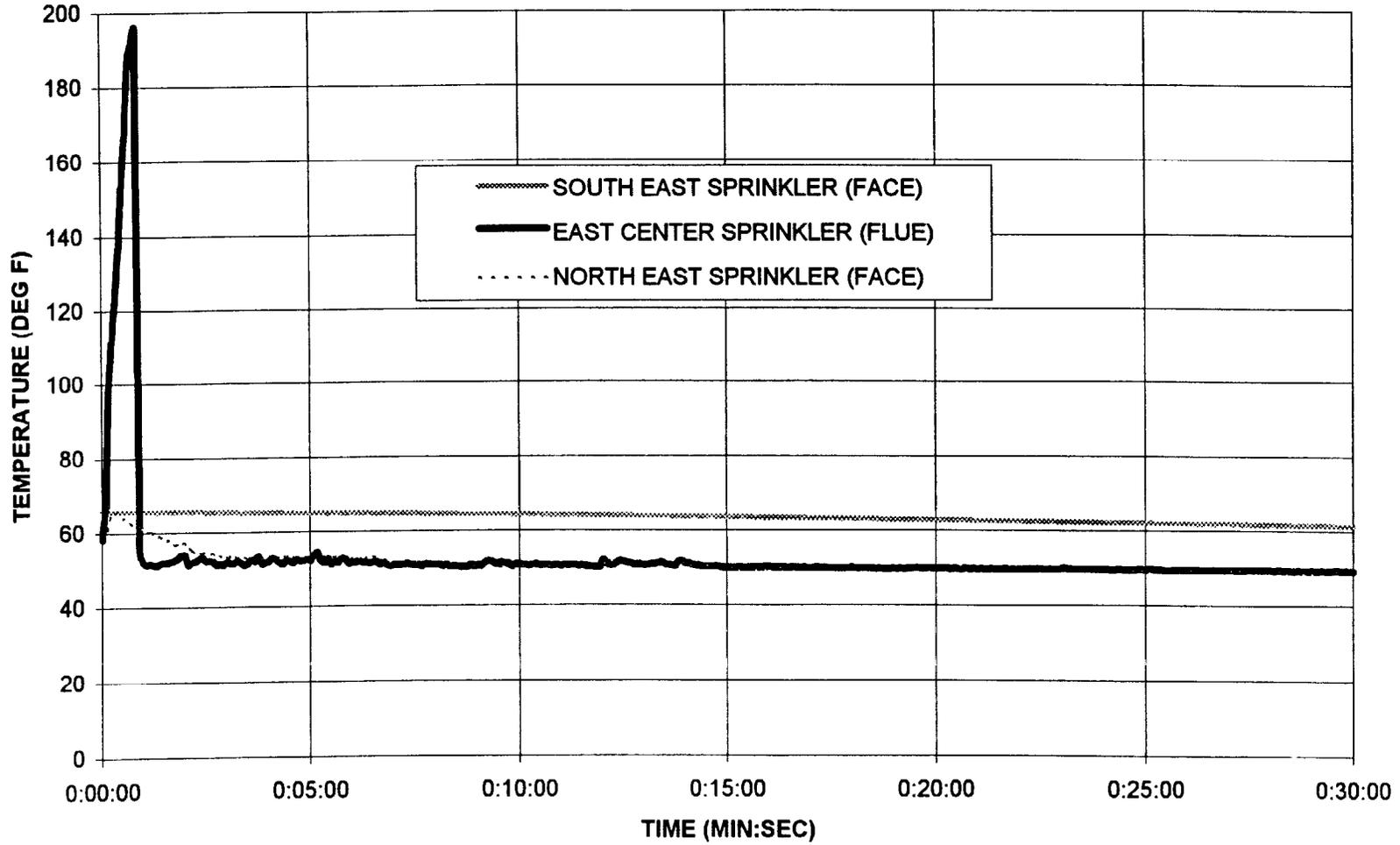
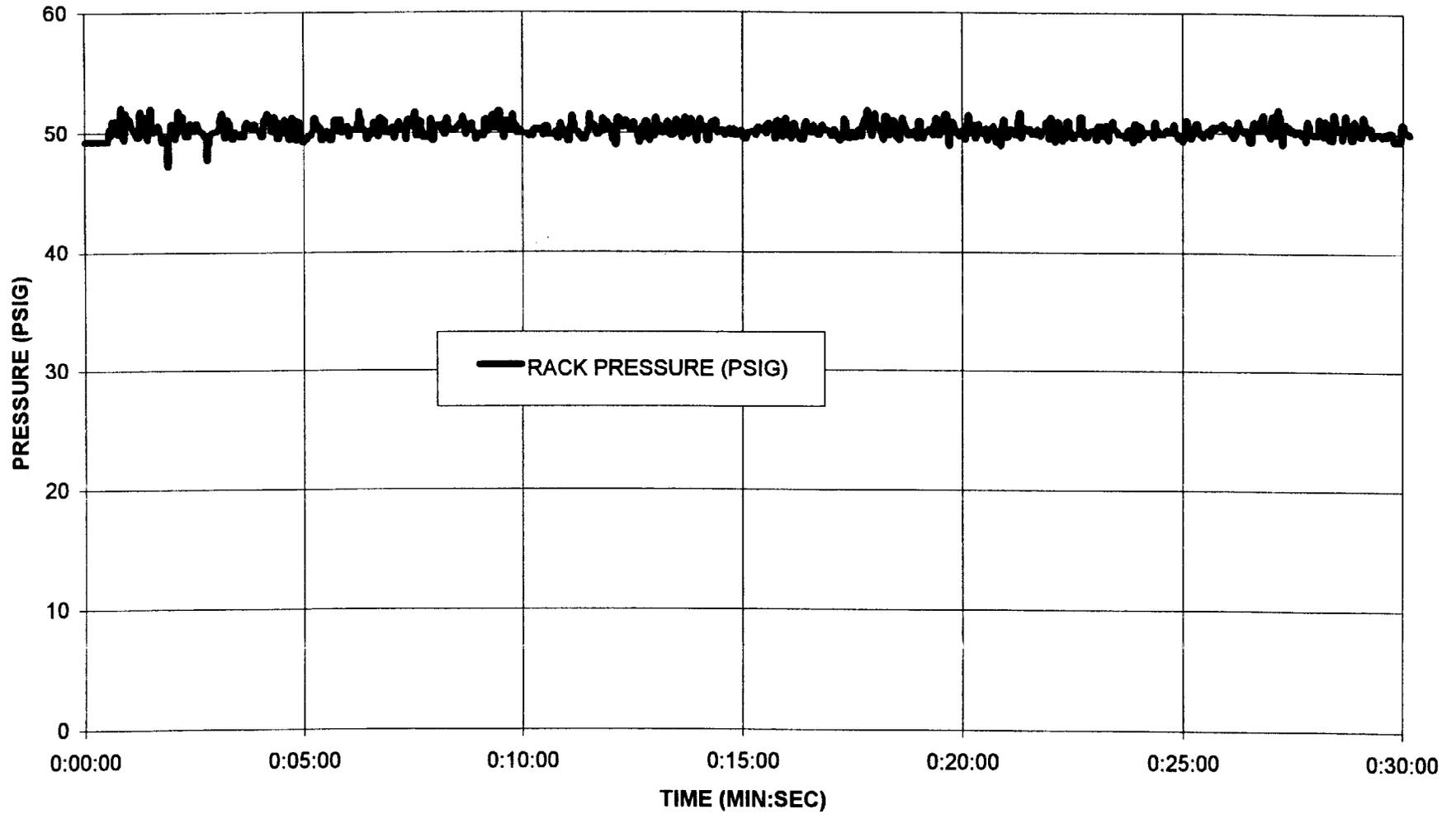


ILLUSTRATION A3

IRI TEST #1, 12/10/96
IPA COMMODITY IN PLASTIC QUART CONTAINERS,
8 PALLETS
EAST SPRINKLERS



IRI TEST #1, 12/10/96
RACK STORAGE OF IPA IN PLASTIC CONTAINERS - PLASTIC QUARTS
PROTECTION BY IN-RACK SPRINKLERS
RACK PRESSURE CHART



IRI TEST #2
12/11/96, IPA COMMODITY IN PLASTIC GALLON CONTAINERS
8 PALLETS
WEST SPRINKLERS

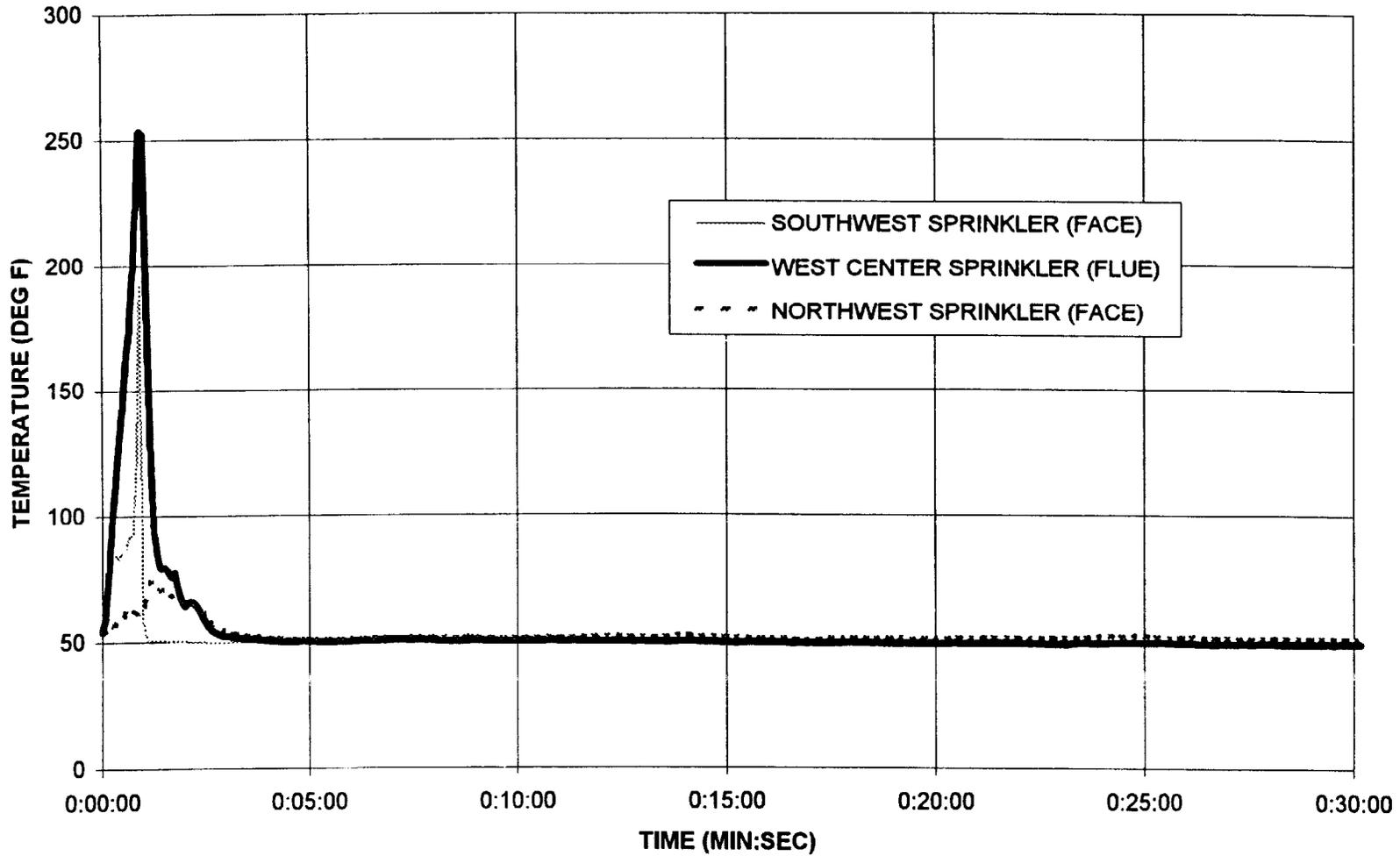


ILLUSTRATION A6

IRI TEST #2, 12/11/96
IPA COMMODITY IN PLASTIC GALLON CONTAINERS,
8 PALLETS
CENTER SPRINKLER

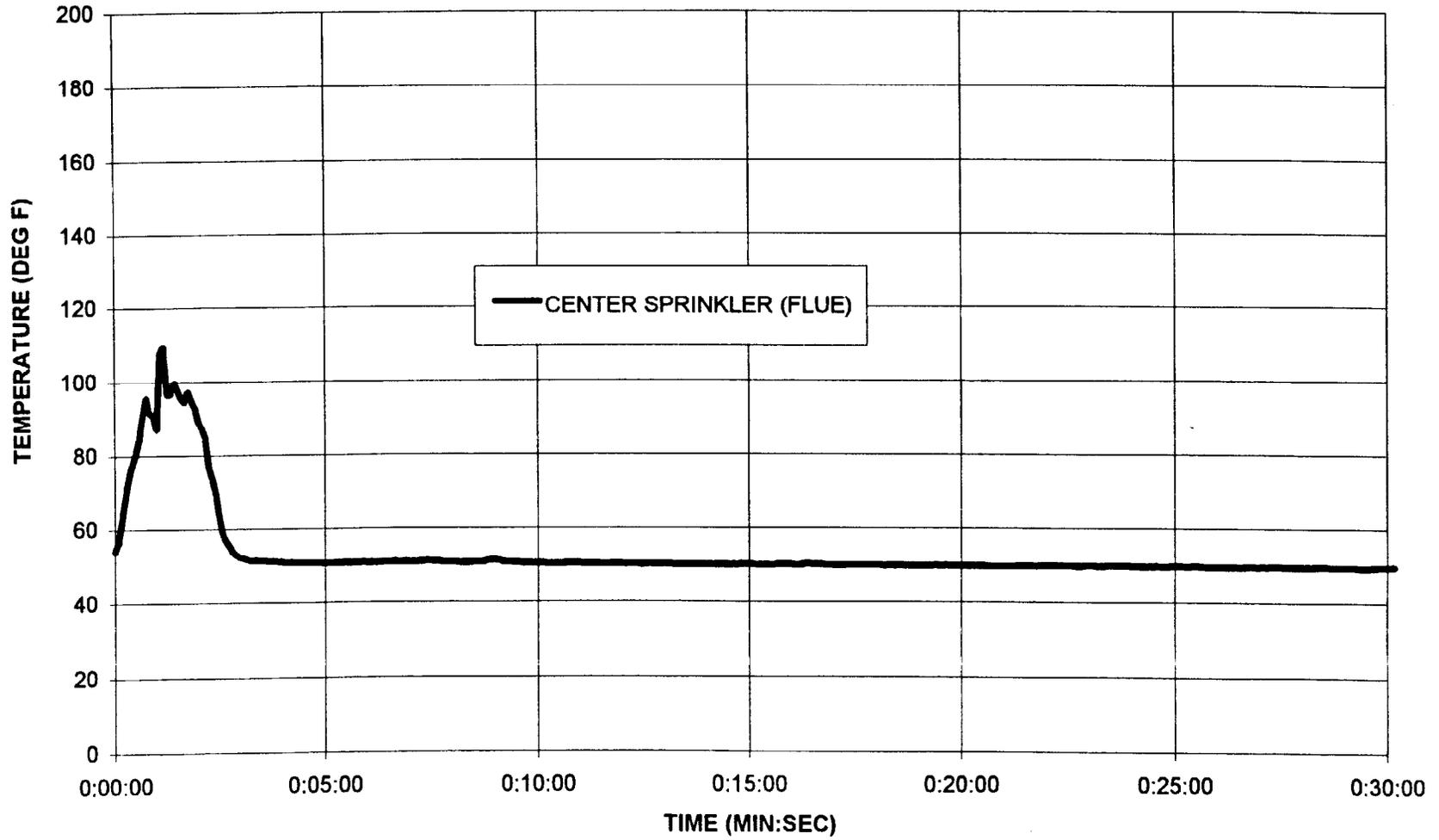
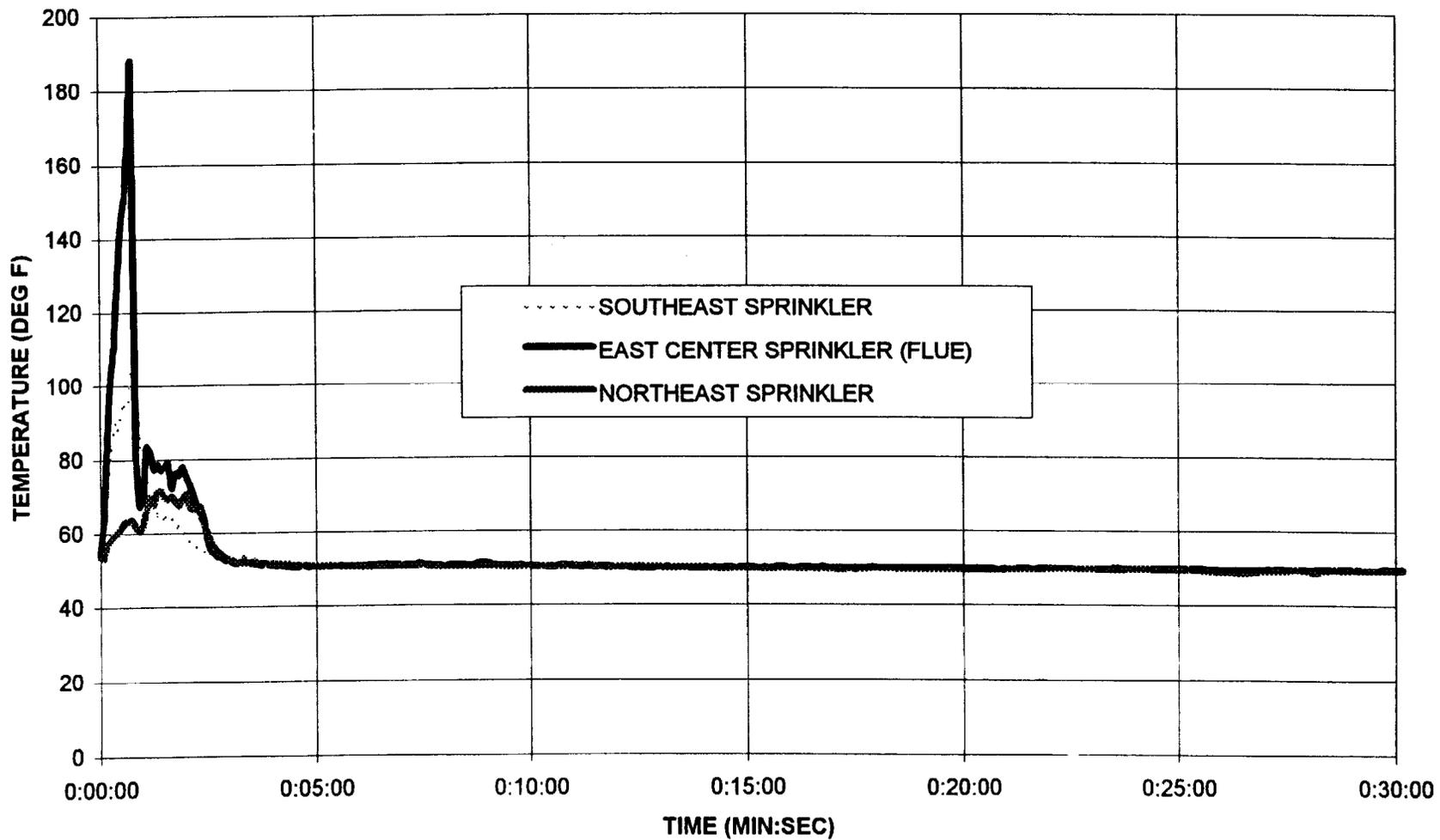
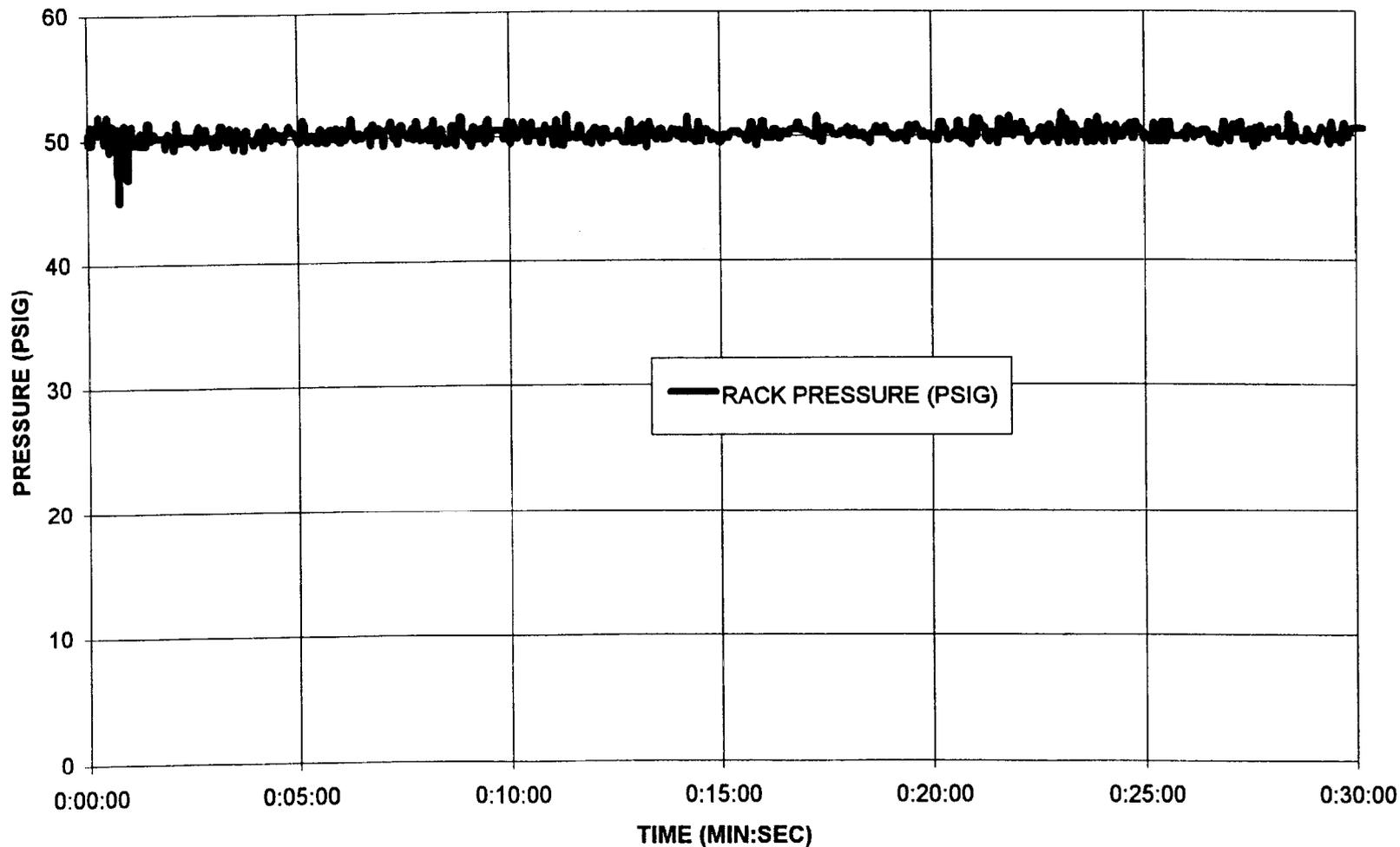


ILLUSTRATION A7

IRI TEST #2
12/11/96, IPA COMMODITY IN PLASTIC GALLON CONTAINERS,
8 PALLETS
EAST SPRINKLERS



IRI TEST #2, 12/11/96
RACK STORAGE OF IPA IN PLASTIC CONTAINERS - PLASTIC GALLONS
PROTECTION BY IN-RACK SPRINKLERS
RACK PRESSURE CHART



IRI TEST #3, 12/11/96
IPA COMMODITY IN PLASTIC PINT CONTAINERS, 8 PALLETS
WEST SPRINKLERS

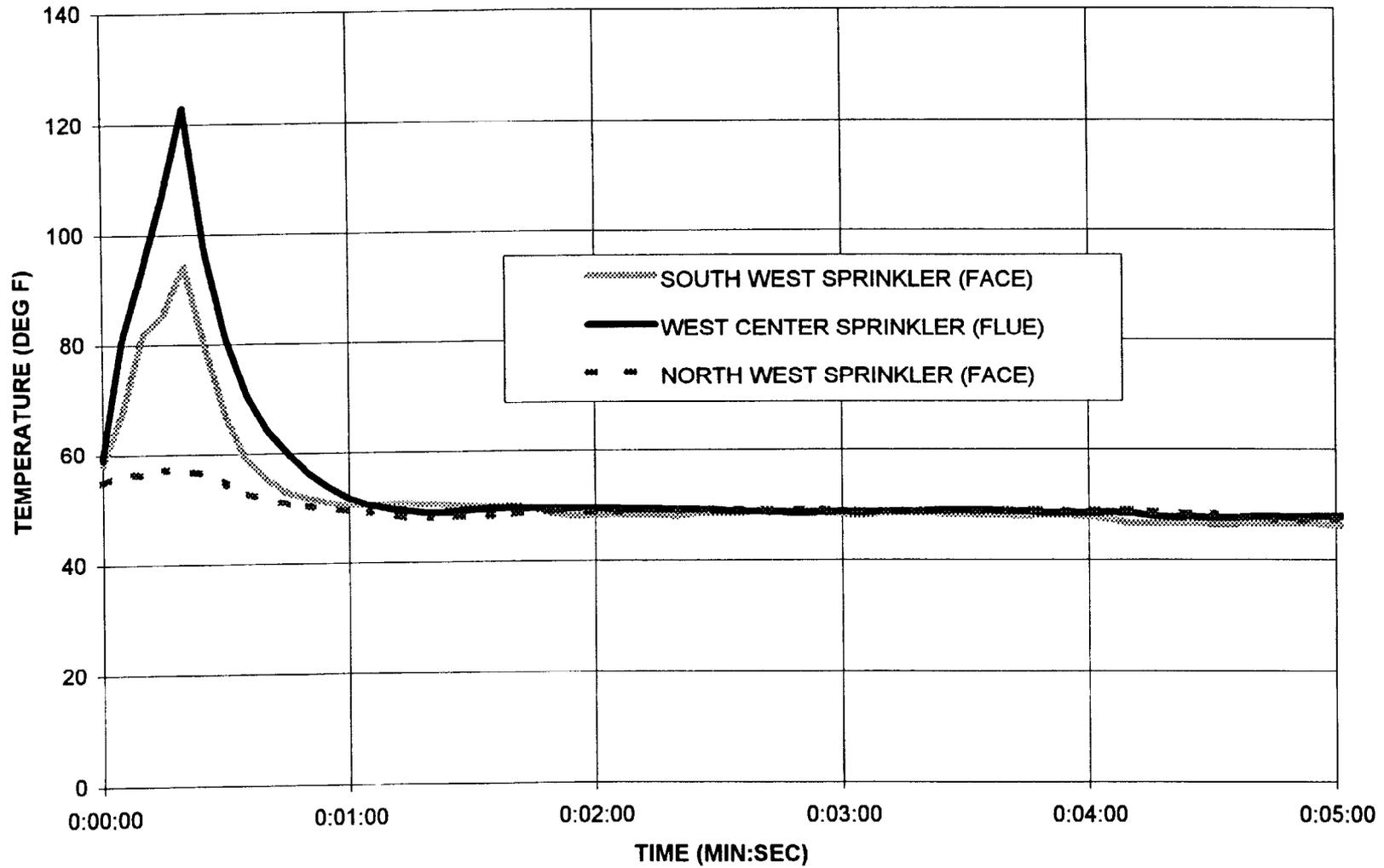
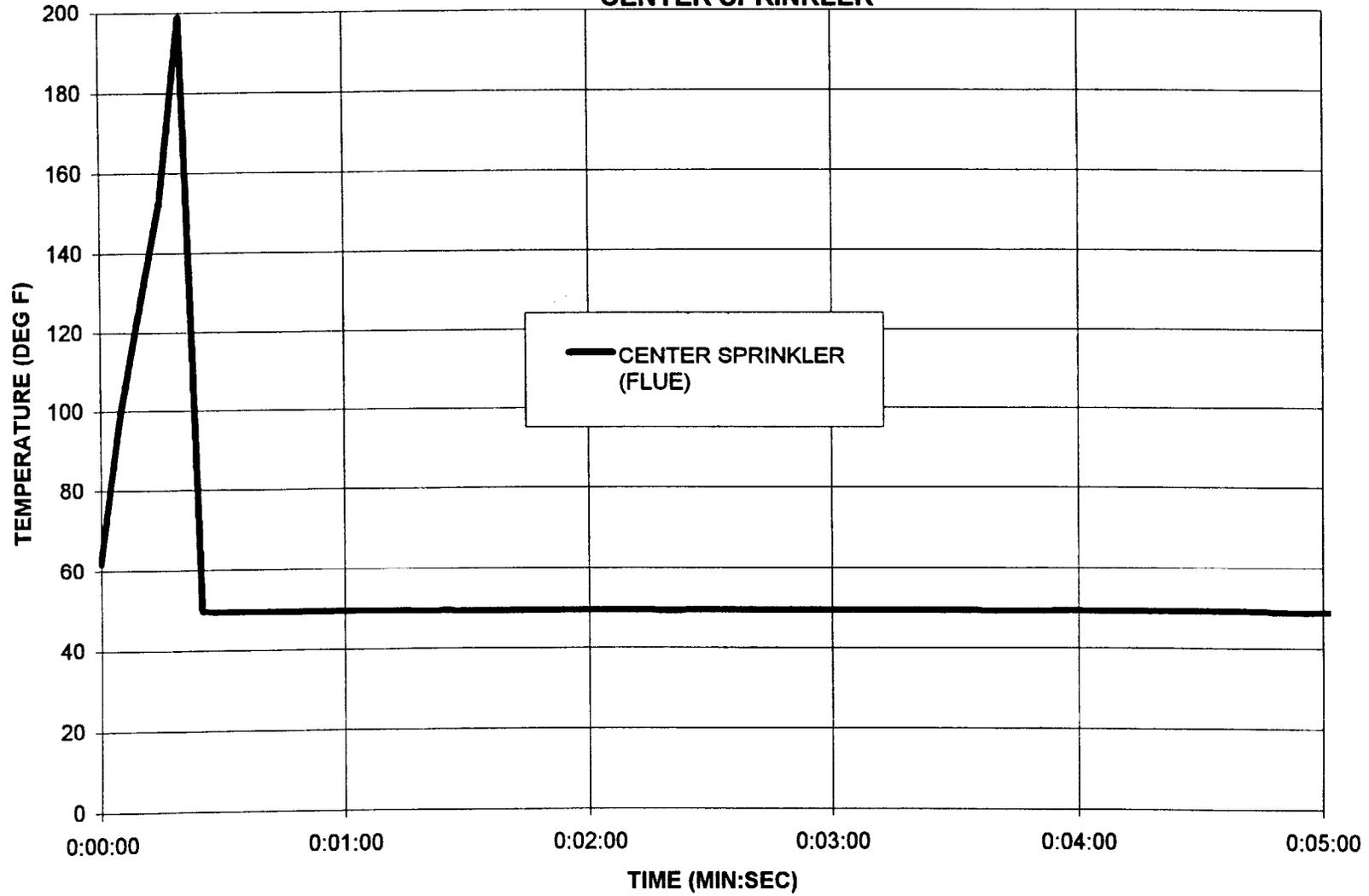
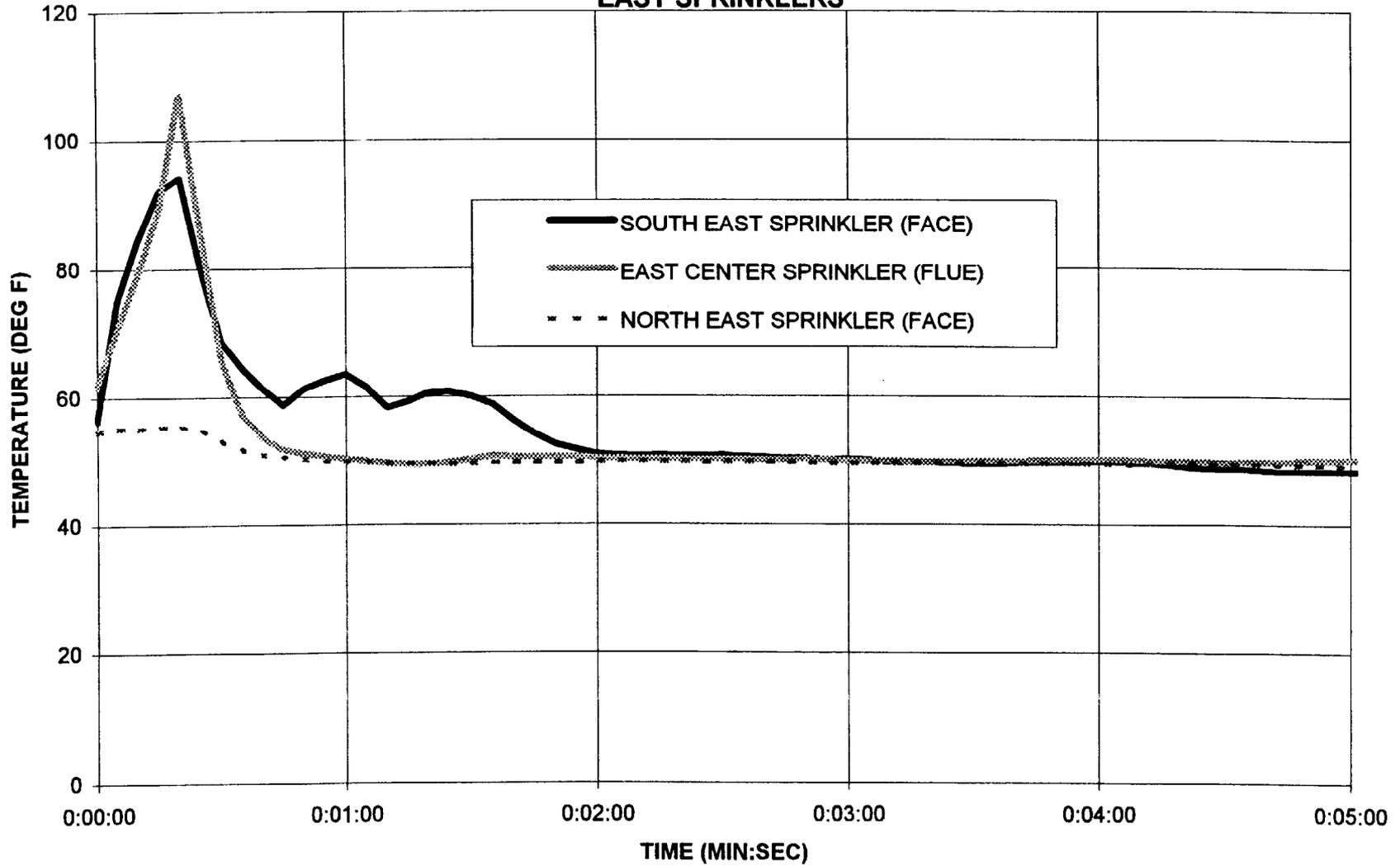


ILLUSTRATION A10

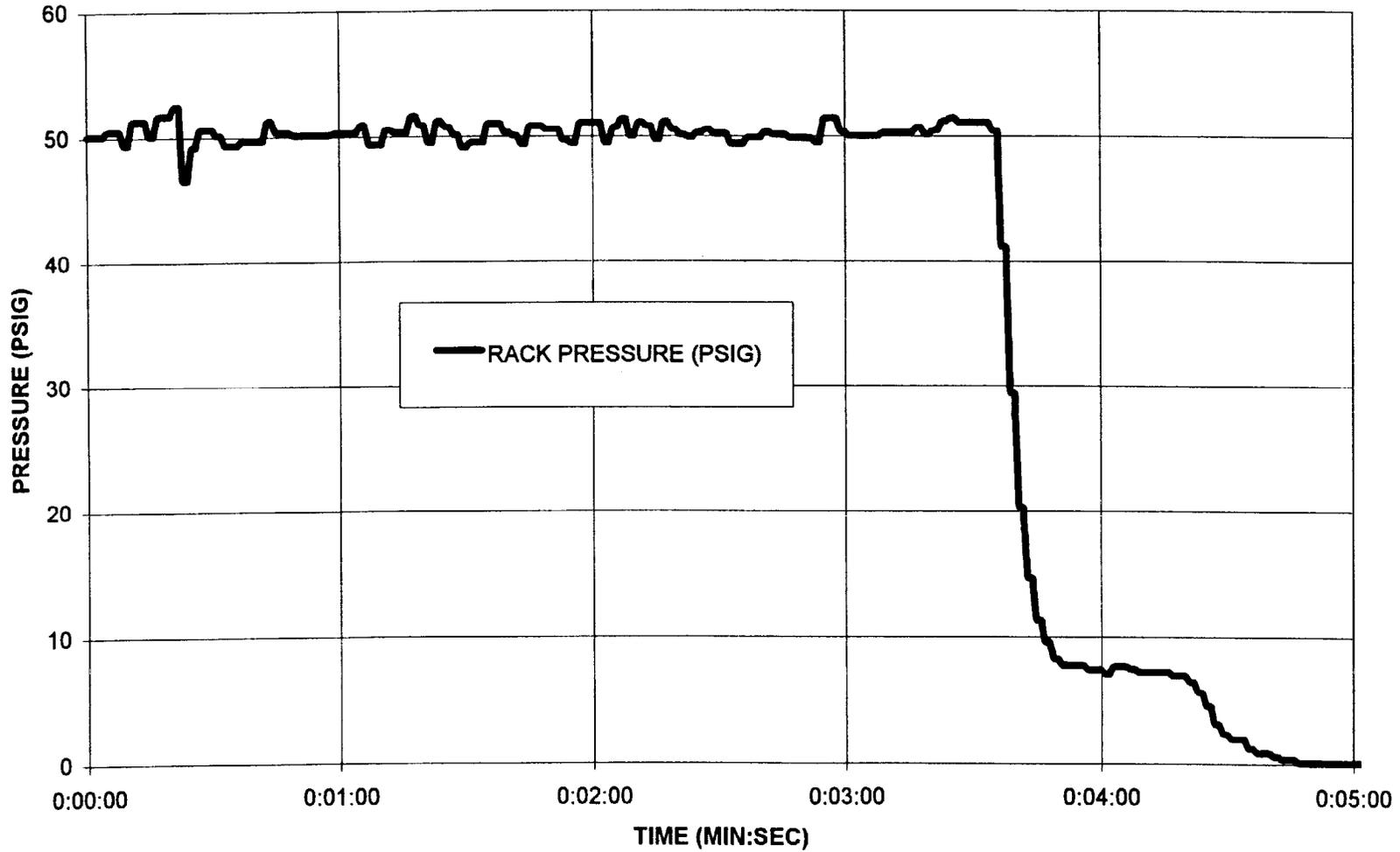
IRI TEST #3, 12/11/96
IPA COMMODITY IN PLASTIC PINT CONTAINERS, 8 PALLETS
CENTER SPRINKLER



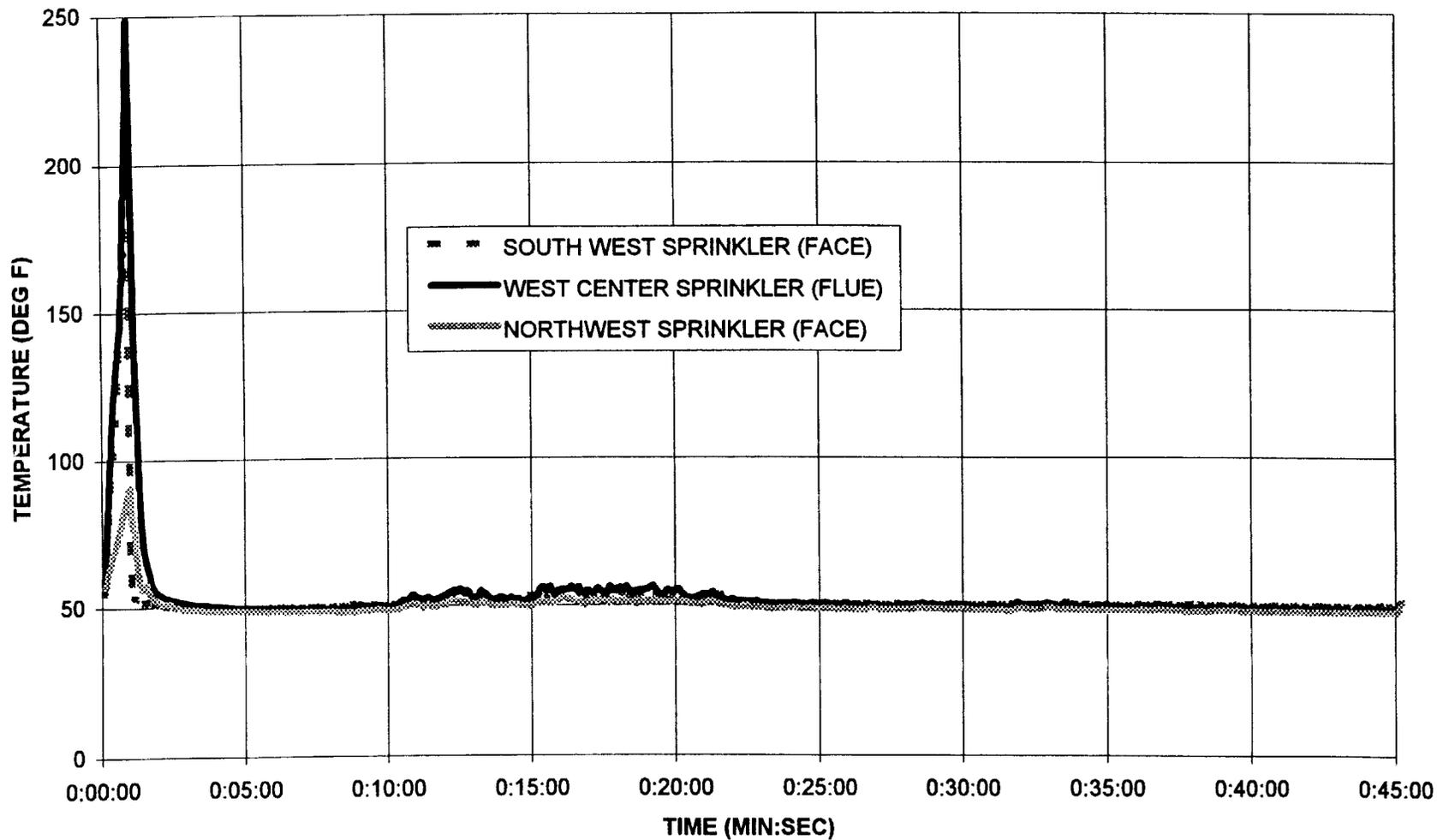
IRI TEST #3, 12/11/96
IPA COMMODITY IN PLASTIC PINT CONTAINERS, 8 PALLETS
EAST SPRINKLERS



IRI TEST #3, 12/11/96
RACK STORAGE OF IPA IN PLASTIC CONTAINERS - PLASTIC PINTS
PROTECTION BY IN-RACK SPRINKLERS
RACK PRESSURE CHART



IRI TEST #4, 12/12/96
IPA COMMODITY IN PLASTIC PINT CONTAINERS,
2 PALLETS
WEST SPRINKLERS



**IRI TEST #4, 12/12/96
IPA COMMODITY IN PLASTIC PINT CONTAINERS,
2 PALLETS
CENTER SPRINKLER**

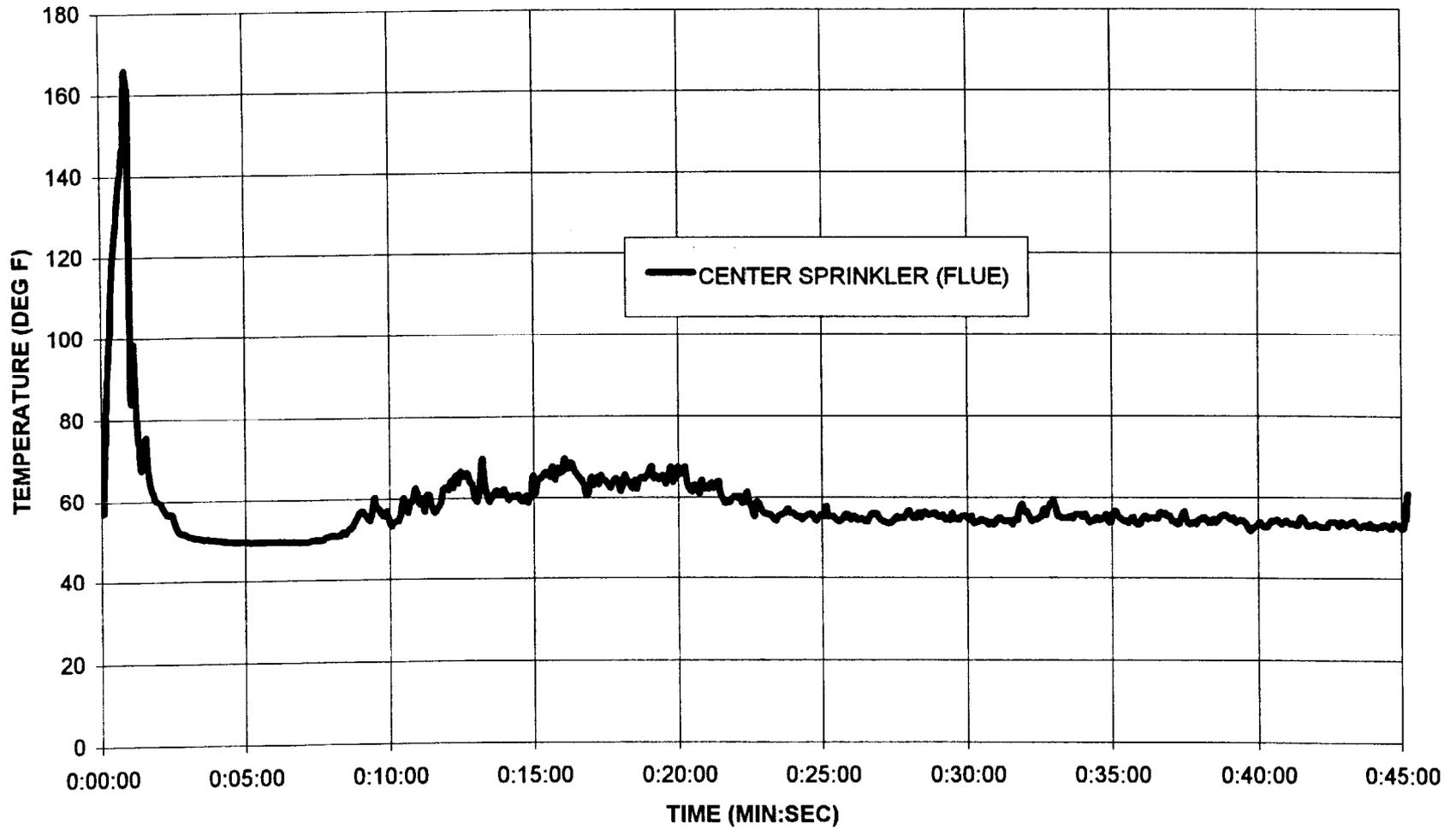
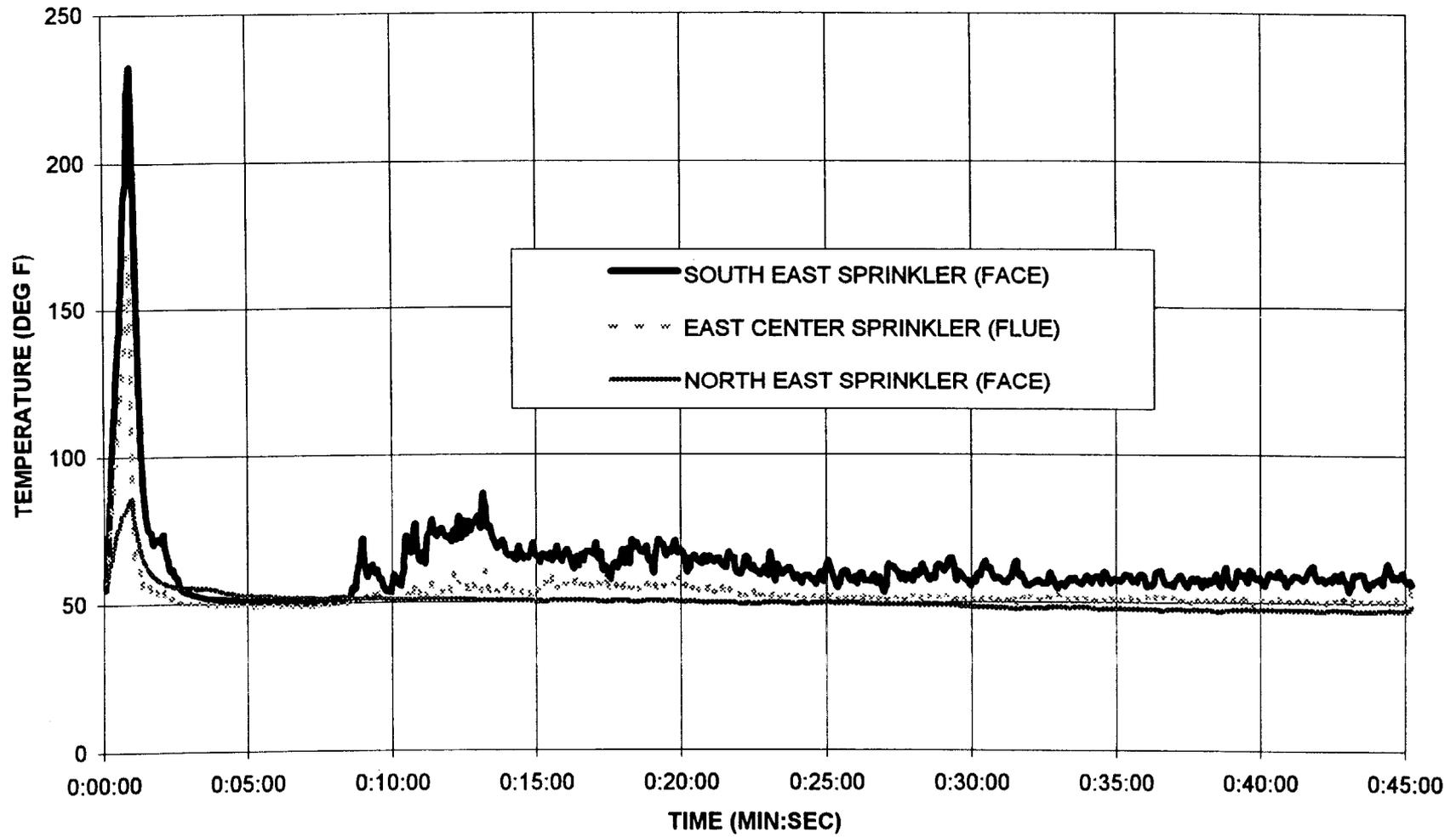
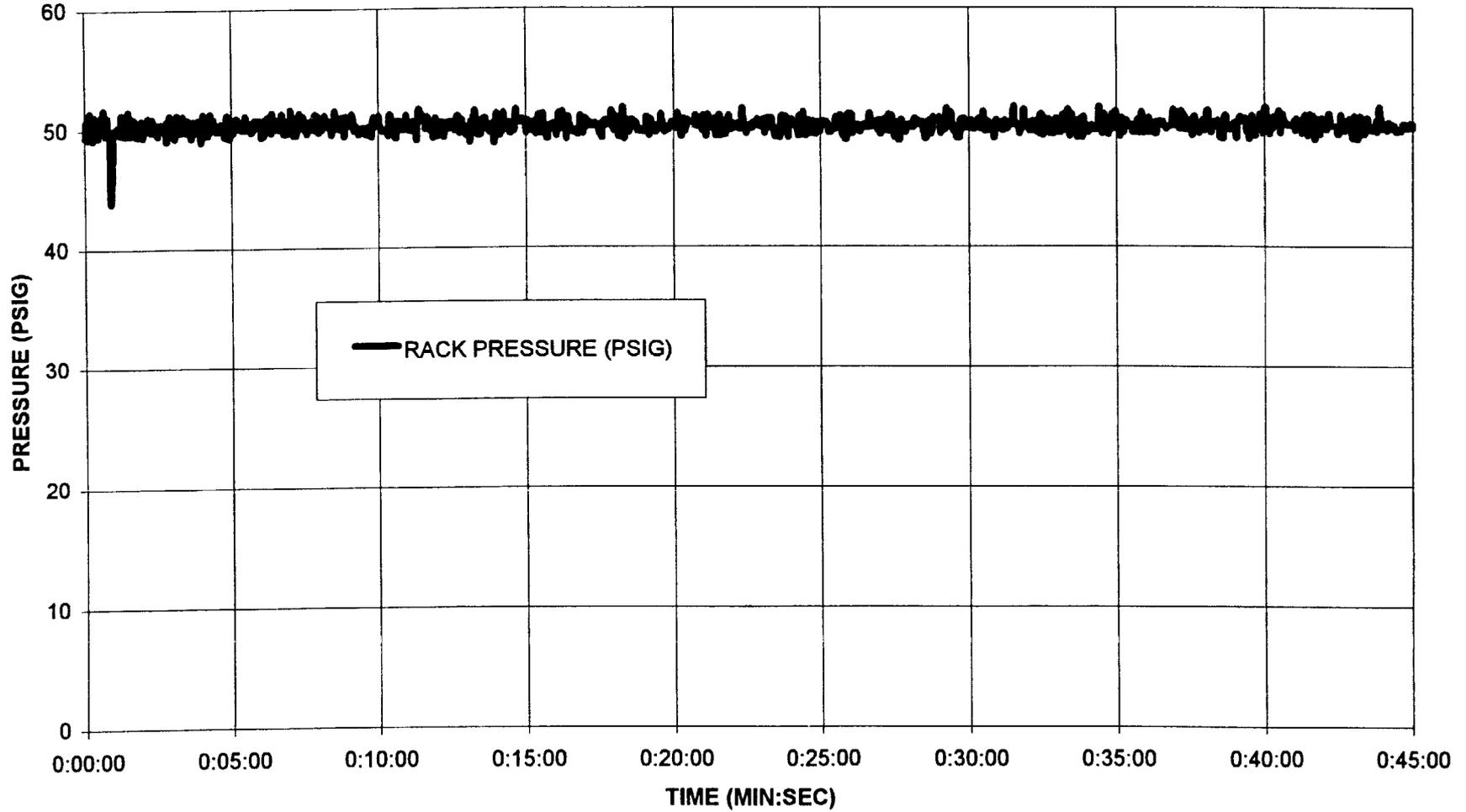


ILLUSTRATION A15

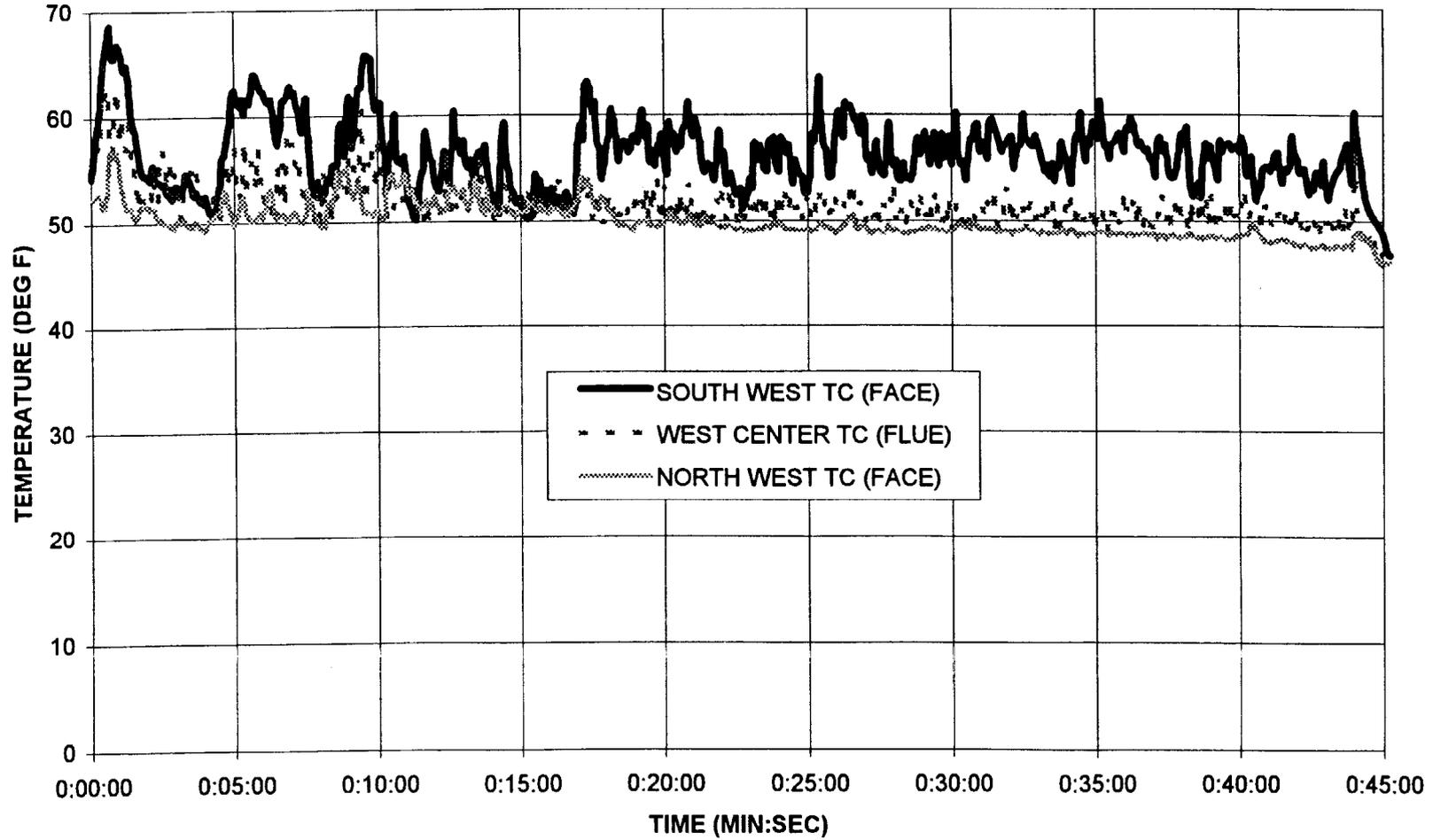
IRI TEST #4, 12/12/96
IPA COMMODITY IN PLASTIC PINT CONTAINERS,
2 PALLETS
EAST SPRINKLERS



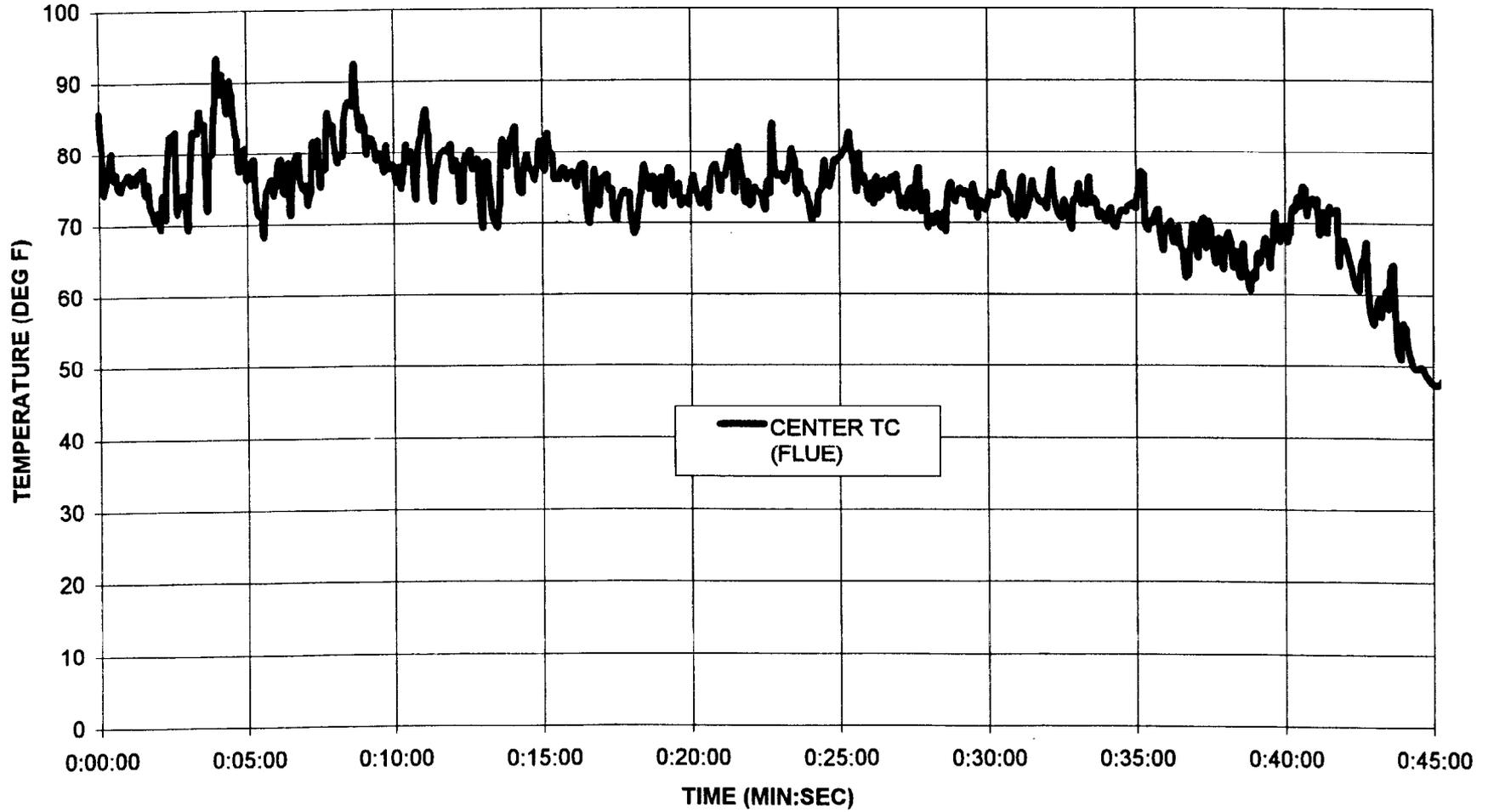
IRI TEST #4, 12/12/96
RACK STORAGE OF IPA IN PLASTIC CONTAINERS - PLASTIC PINTS
PROTECTION BY IN-RACK SPRINKLERS
RACK PRESSURE CHART



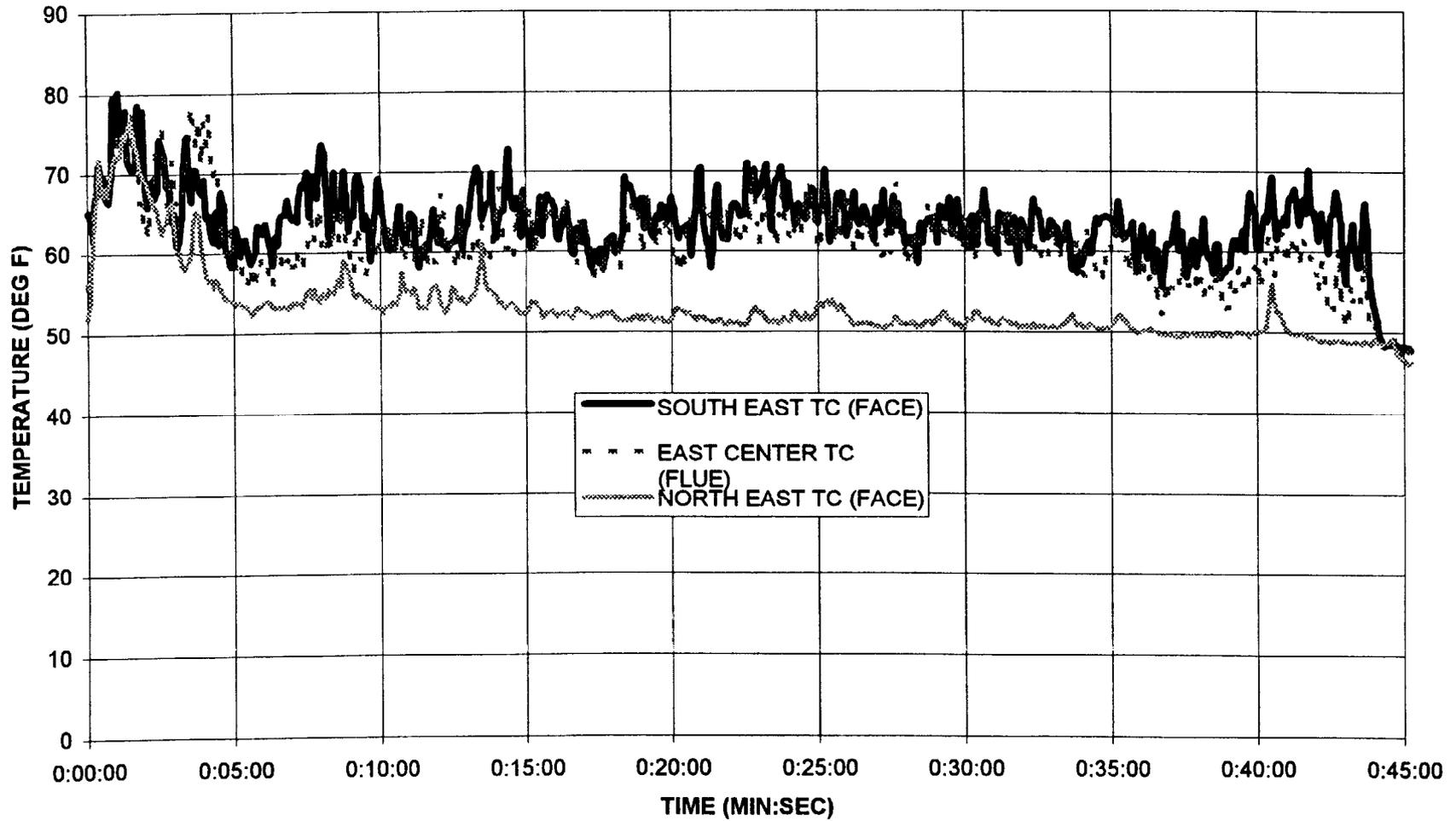
IRI TEST #5, 12/12/96
IPA COMMODITY IN PLASTIC PINT, GALLON AND MIXED CONTAINERS,
4, 4 AND 8 PALLETS RESPECTIVELY
FIRST TIER - WEST THERMOCOUPLES



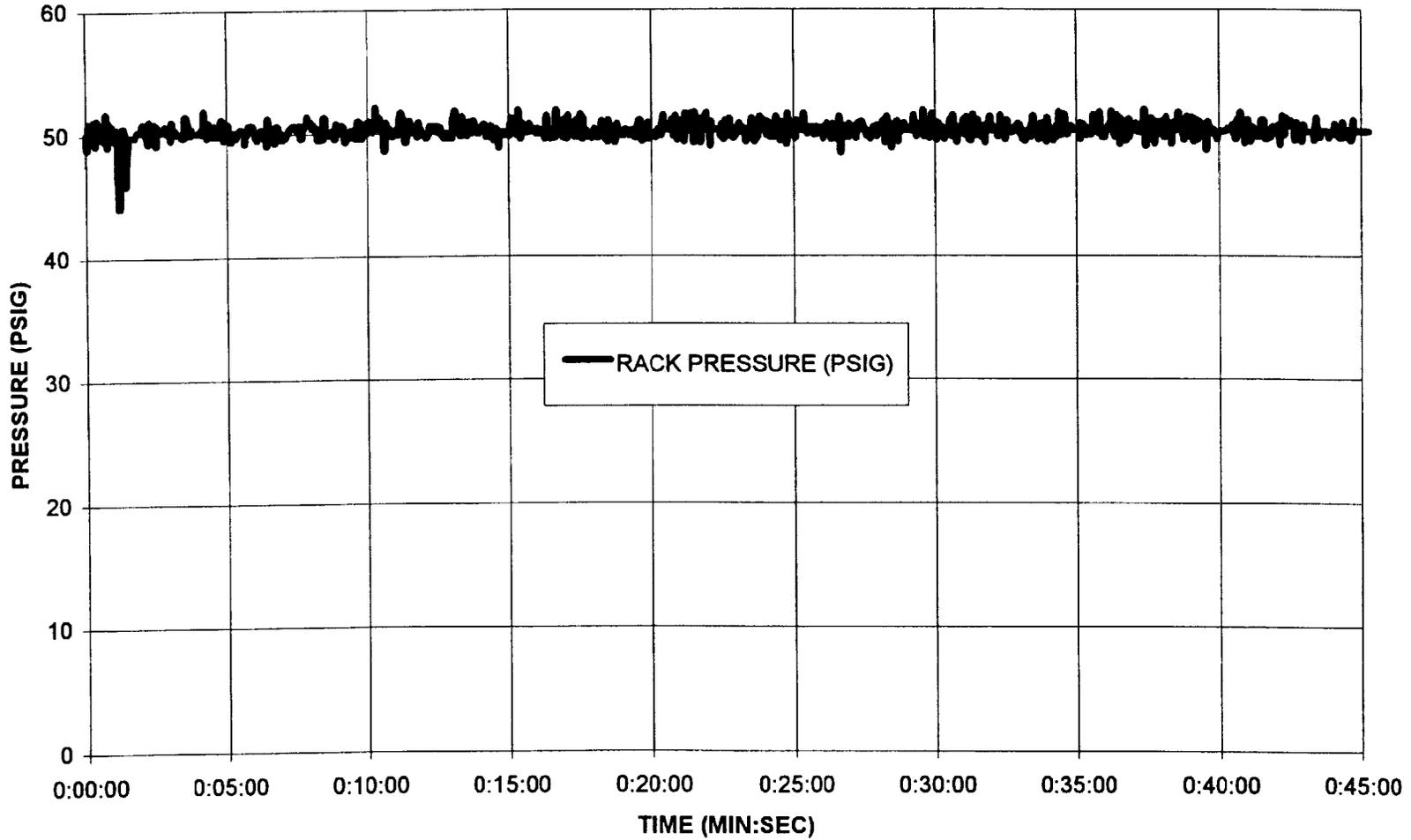
IRI TEST #5, 12/12/96
IPA COMMODITY IN PLASTIC PINT, GALLON AND MIXED CONTAINERS,
4, 4 AND 8 PALLETS RESPECTIVELY
FIRST TIER - CENTER THERMOCOUPLE



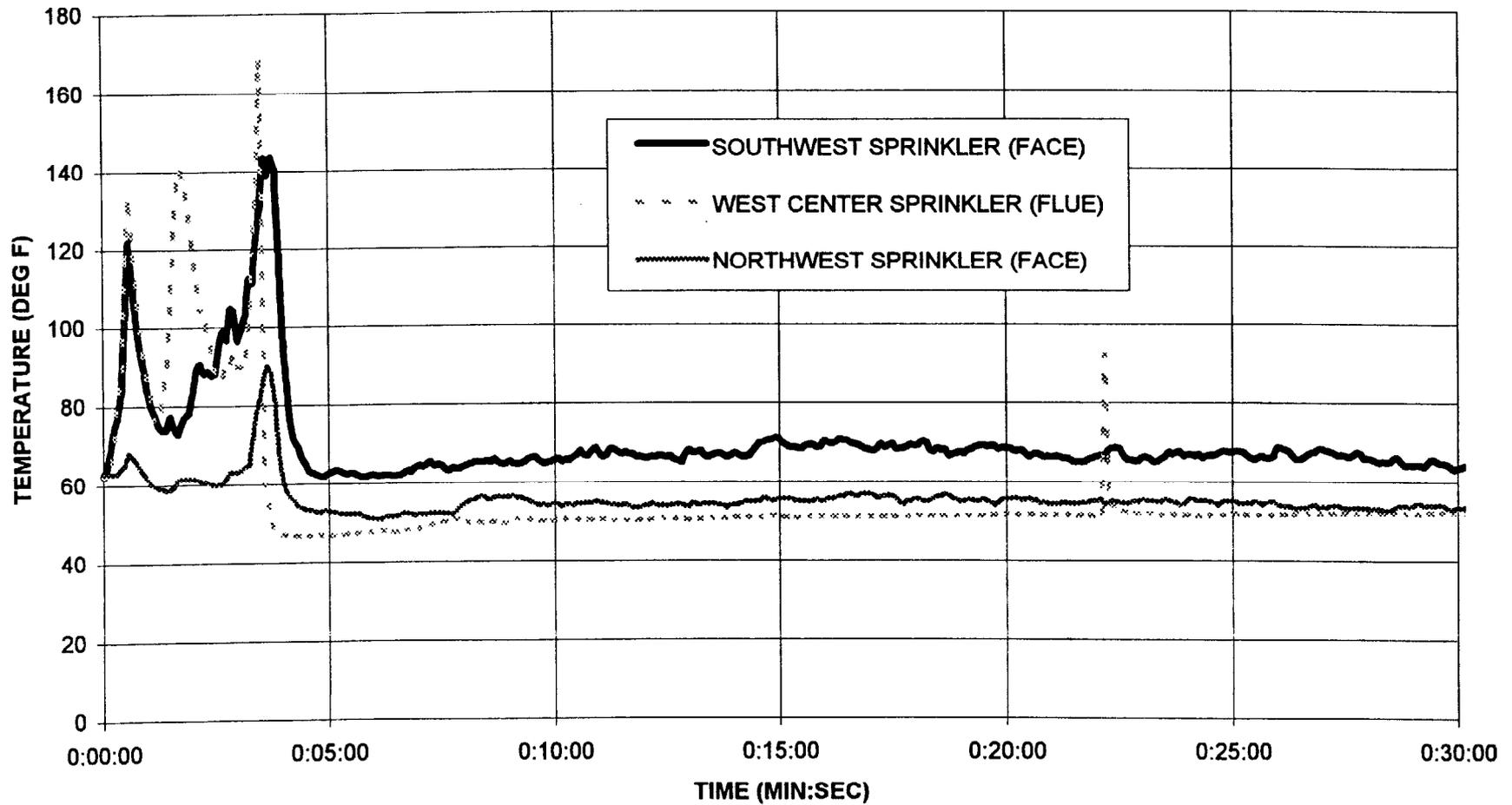
IRI TEST #5, 12/12/96
IPA COMMODITY IN PLASTIC PINT, GALLON AND MIXED CONTAINERS,
4, 4 AND 8 PALLETS RESPECTIVELY
FIRST TIER - EAST THERMOCOUPLES



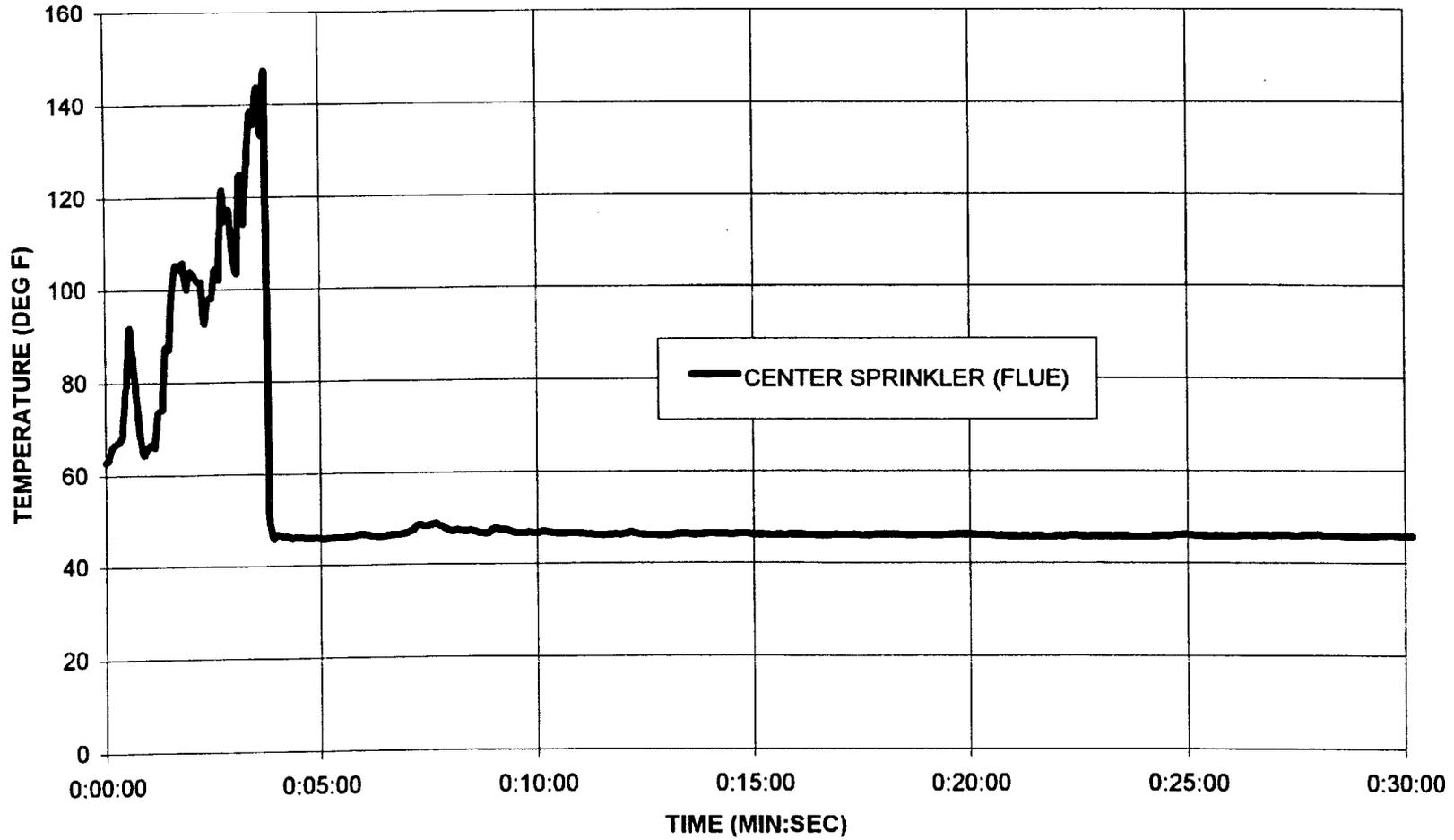
IRI TEST #5, 12/12/96
RACK STORAGE OF IPA IN PLASTIC CONTAINERS - PLASTIC PINTS AND GALLONS
PROTECTION BY IN-RACK SPRINKLERS
RACK PRESSURE CHART



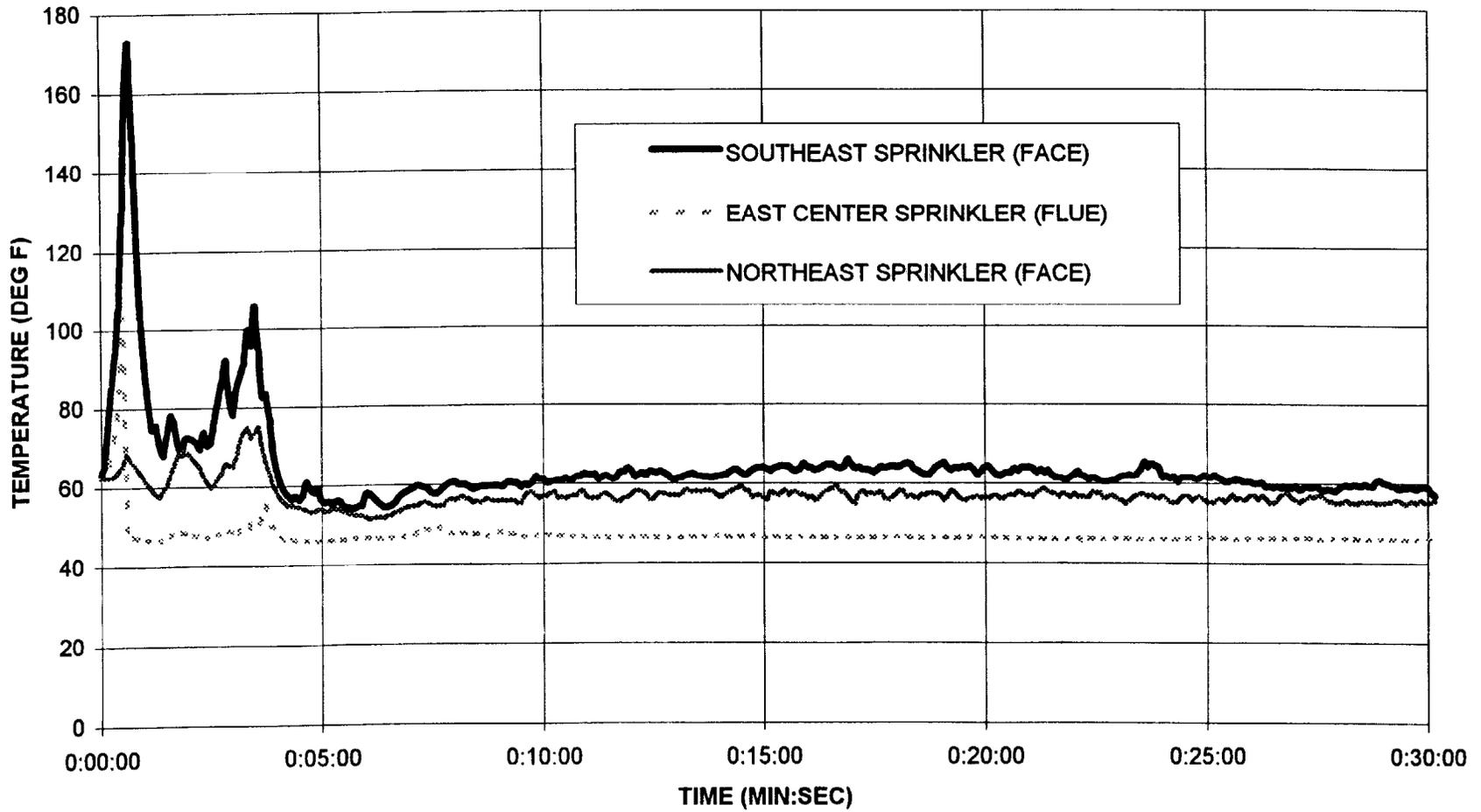
IRI TEST #6, 2/18/97
IPA COMMODITY IN PLASTIC GALLON AND PLASTIC F STYLE GALLON CONTAINERS,
4 AND 4 PALLETS RESPECTIVELY
WEST SPRINKLERS



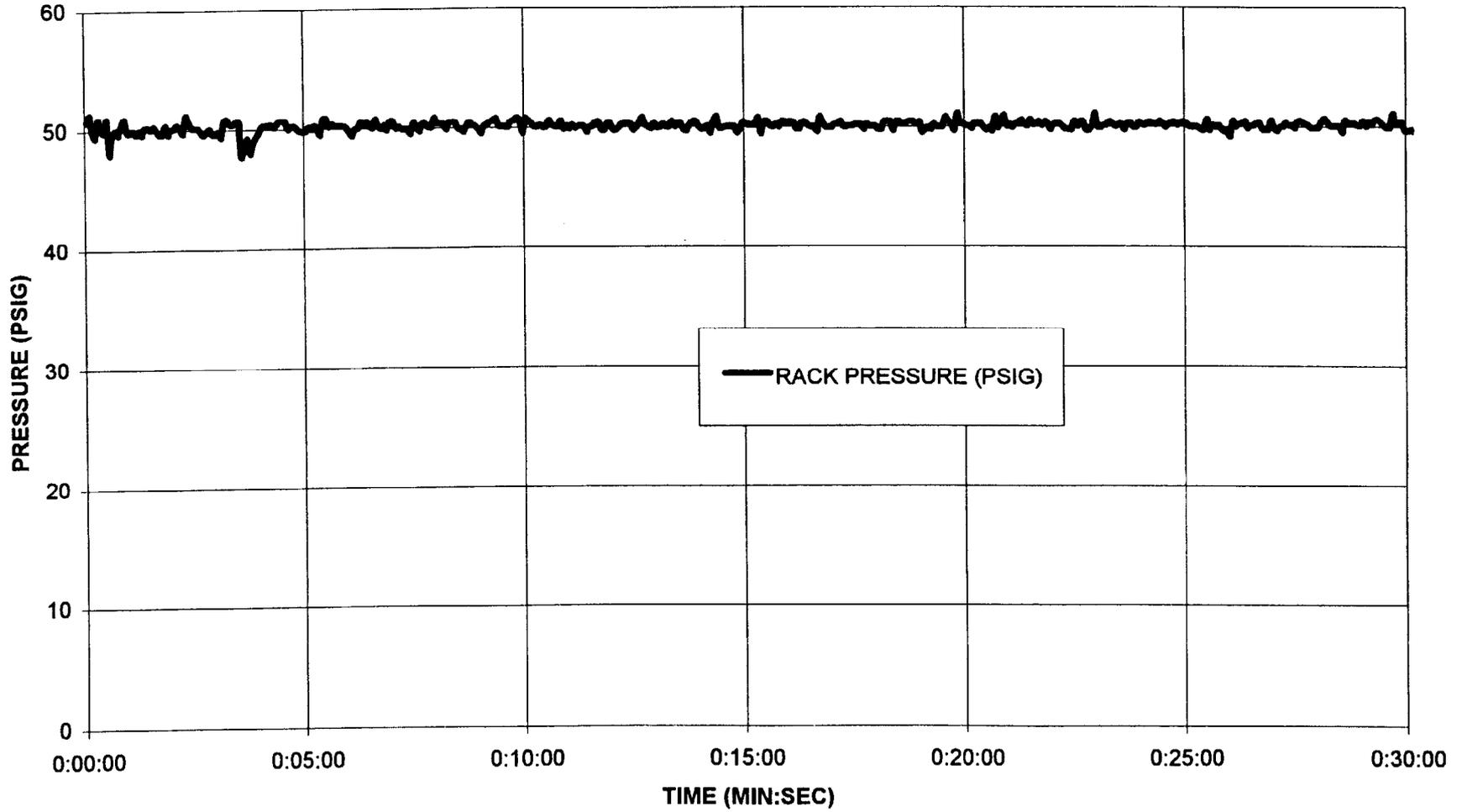
IRI TEST #6, 2/18/97
IPA COMMODITY IN PLASTIC GALLON AND PLASTIC F STYLE GALLON CONTAINERS,
4 AND 4 PALLETS RESPECTIVELY
CENTER SPRINKLER



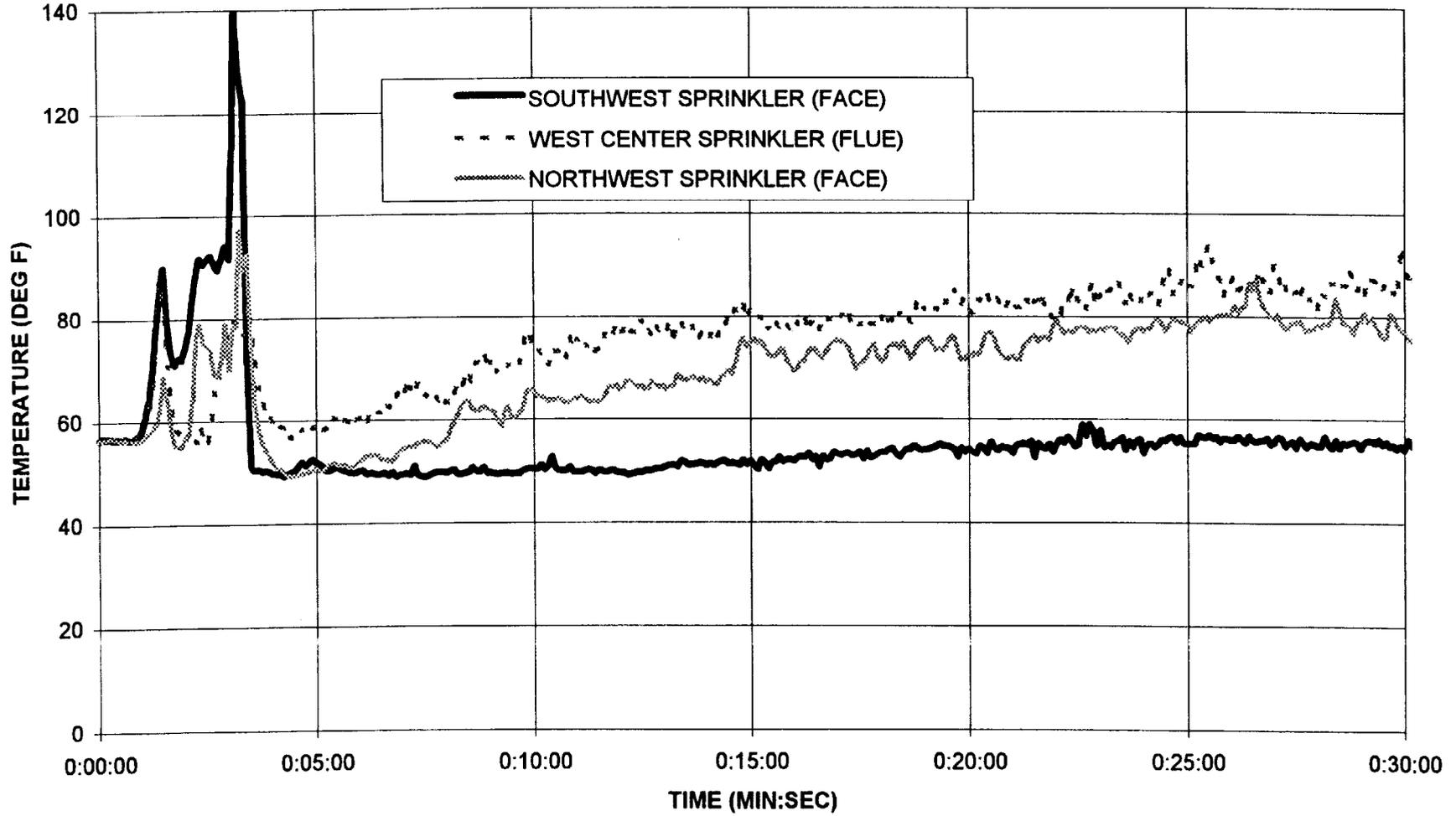
IRI TEST #6, 2/18/97
IPA COMMODITY IN PLASTIC GALLON AND PLASTIC F STYLE GALLON CONTAINERS,
4 AND 4 PALLETS RESPECTIVELY
EAST SPRINKLERS



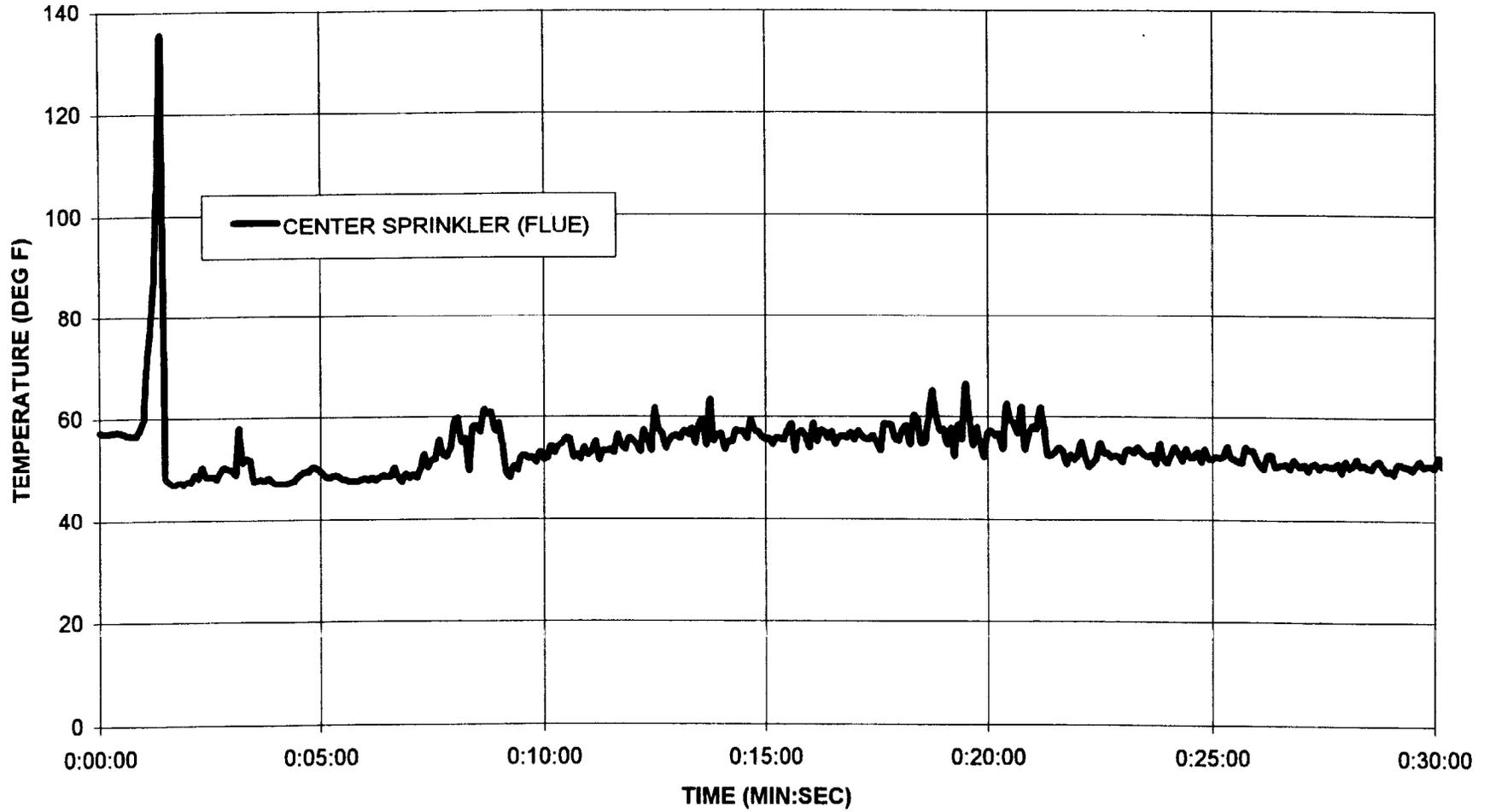
IRI TEST #6, 2/18/97
RACK STORAGE OF IPA IN PLASTIC CONTAINERS - F STYLE PLASTIC GALLONS,
PROTECTION BY IN-RACK SPRINKLERS,
RACK PRESSURE CHART



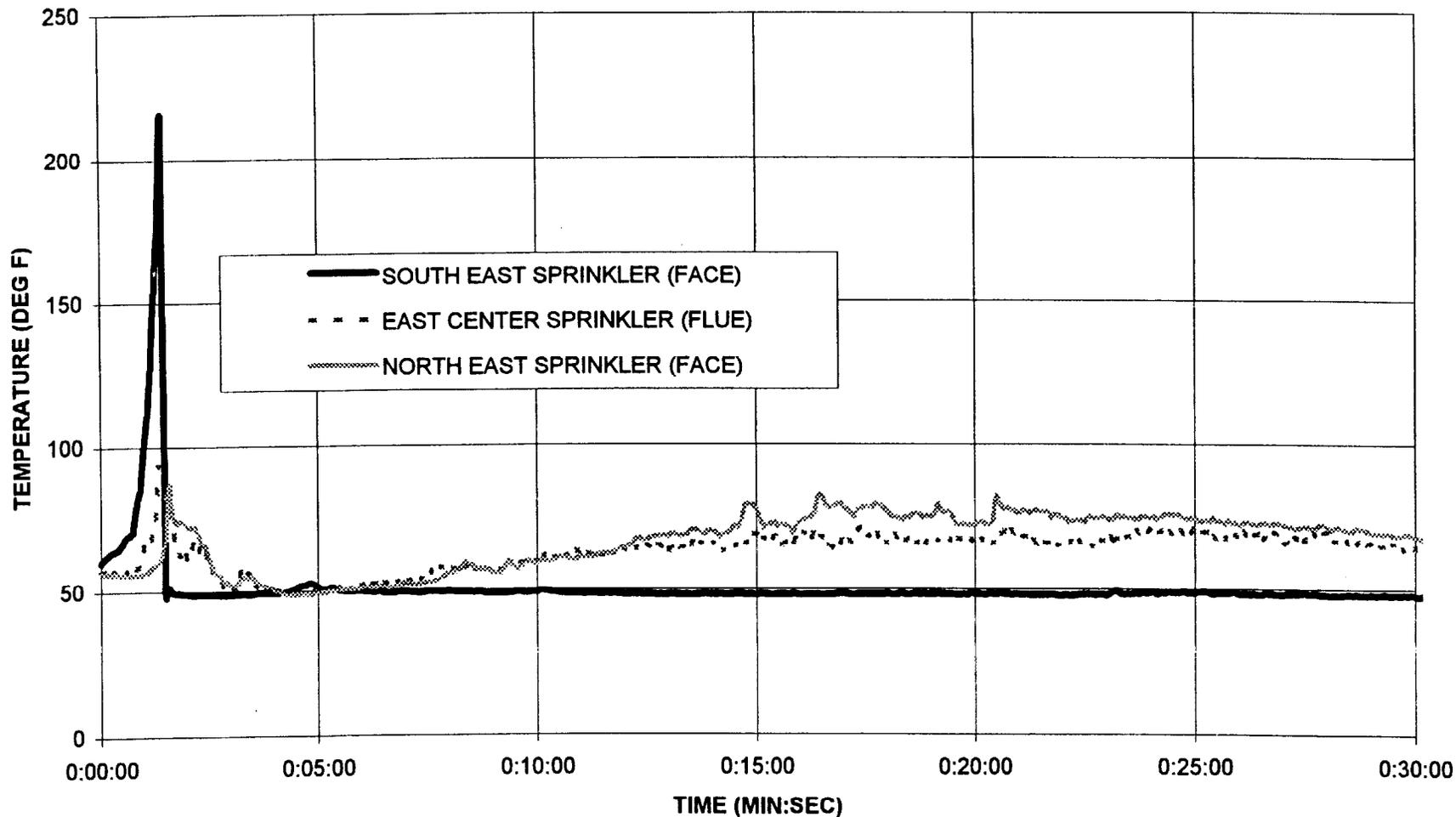
IRI TEST #7, 2/19/97
IPA COMMODITY IN PLASTIC PINT AND QUART CONTAINERS,
4 AND 4 PALLETS RESPECTIVELY
WEST SPRINKLERS



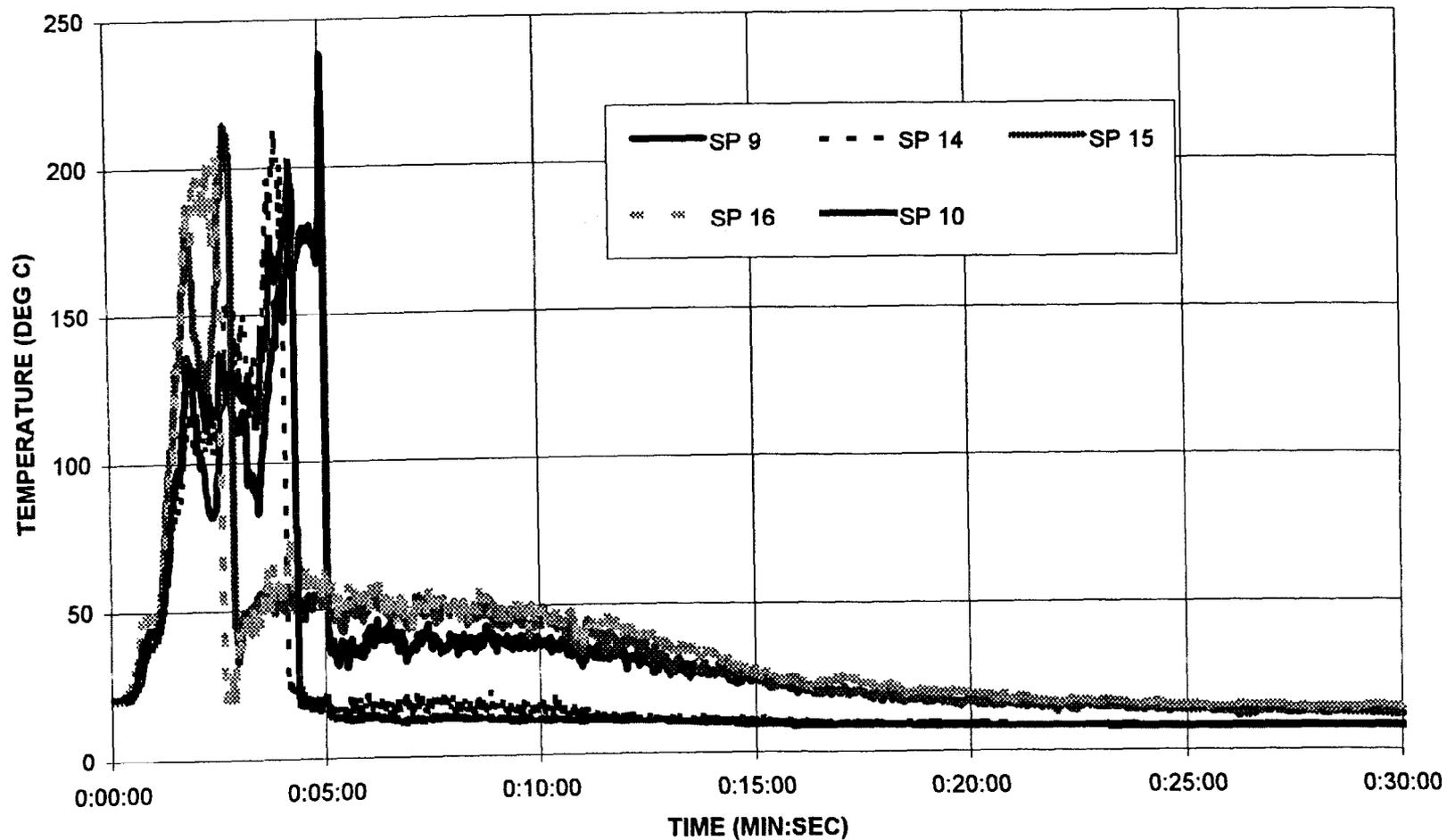
IRI TEST #7, 2/19/97
IPA COMMODITY IN PLASTIC PINT AND QUART CONTAINERS
4 AND 4 PALLETS RESPECTIVELY
CENTER SPRINKLER



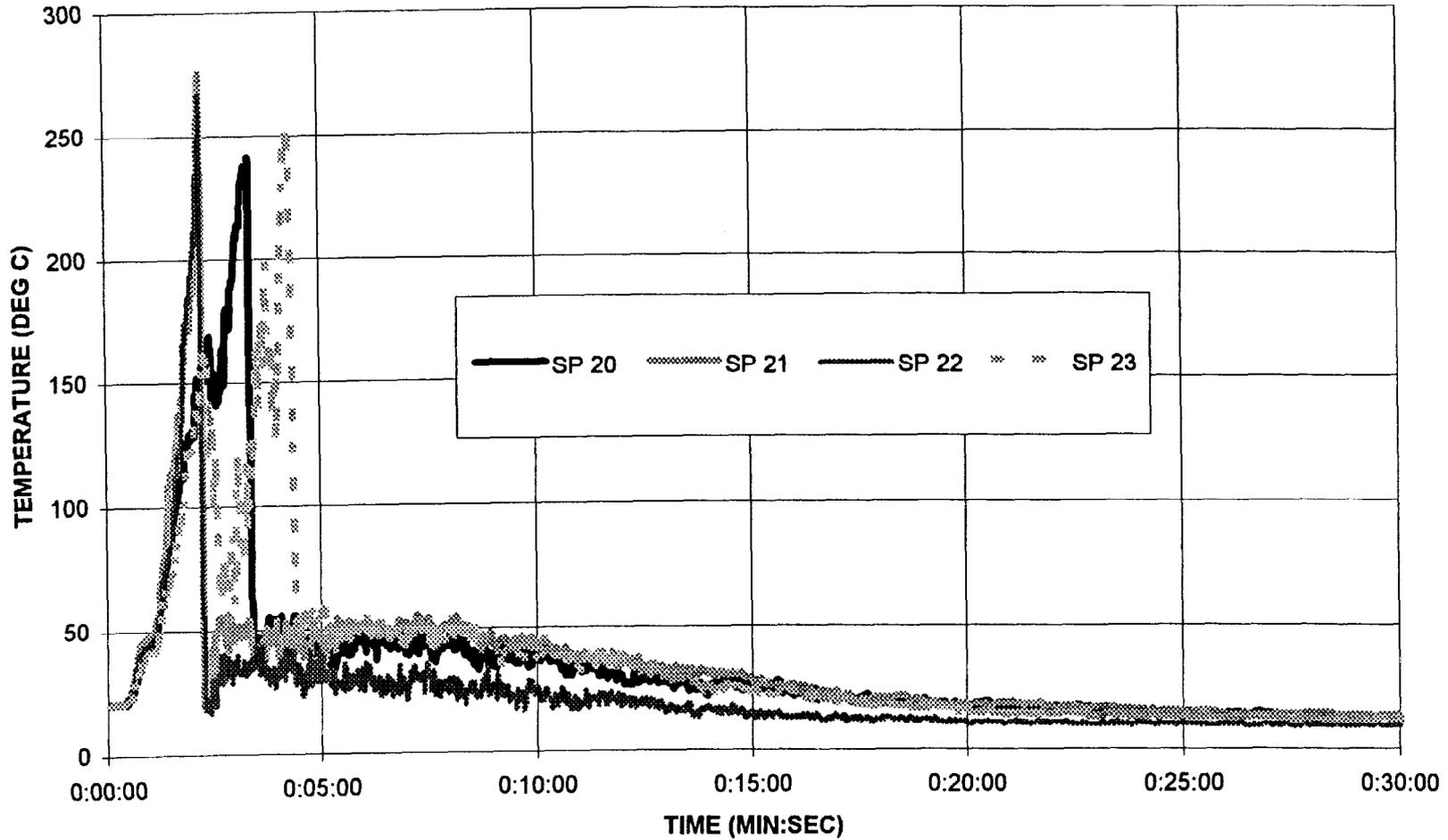
IRI TEST #7, 2/19/97
IPA COMMODITY IN PLASTIC PINT AND QUART CONTAINERS,
4 AND 4 PALLETS RESPECTIVELY
EAST SPRINKLERS



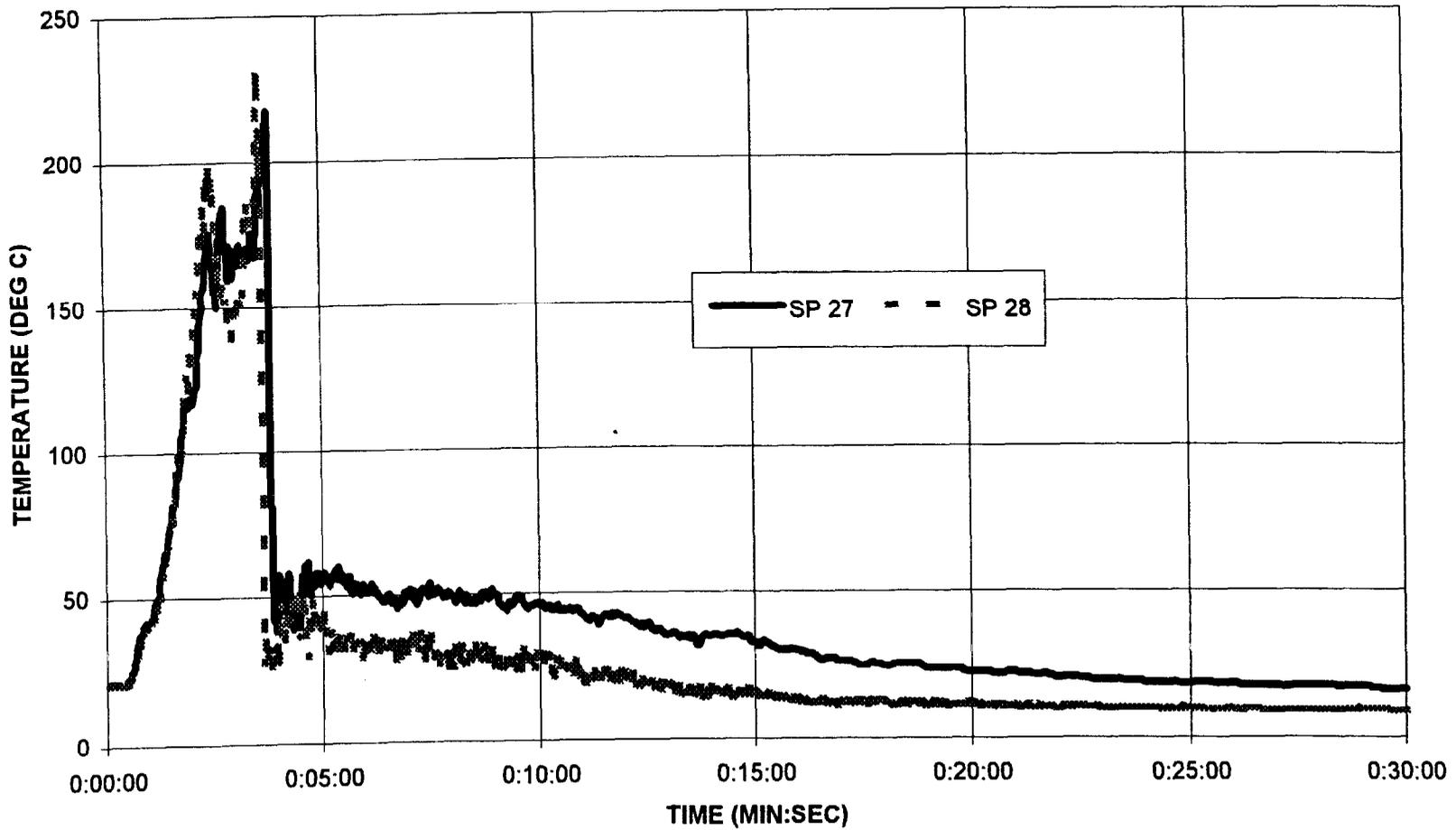
IRI TEST #8, 2/20/97
IPA COMMODITY IN PLASTIC CONTAINERS (VARIED SIZES)
PALLETIZED STORAGE WITH CEILING SPRINKLER PROTECTION
12 PALLETS
SPRINKLER NOS. 9, 10, 14, 15 AND 16



IRI TEST #8, 2/20/97
IPA COMMODITY IN PLASTIC CONTAINERS (VARIED SIZES)
PALLETIZED STORAGE WITH CEILING SPRINKLER PROTECTION
12 PALLETS
SPRINKLER NOS. 20, 21, 22 AND 23



IRI TEST #8, 2/20/97
IPA COMMODITY IN PLASTIC CONTAINERS (VARIED SIZES)
PALLETIZED STORAGE WITH CEILING SPRINKLER PROTECTION
12 PALLETS
SPRINKLER NOS. 27 AND 28



IRI TEST #8, 2/20/97
PALLETIZED STORAGE OF IPA IN PLASTIC CONTAINERS, PROTECTION BY CEILING
SPRINKLERS
PRESSURE CHART

