UNDERWRITERS LABORATORIES INC.
REPORT OF
IN-RACK SPRINKLER COMPARISON FIRE TESTS

CONDUCTED FOR HSB INDUSTRIAL RISK INSURERS

NC1838 97NK31099 **MAY 22, 1998**

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EXECUTIVE SUMMARY

Eight fire tests were conducted to evaluate and compare the level of protection provided by 1/2 in. nominal orifice in-rack sprinklers operating at a flowing pressure of 30 psi and 17/32 in. nominal orifice in-rack sprinklers flowing at 30 gpm.

The fire tests were conducted in a double row rack storage array with in-rack sprinklers. Ignition was accomplished with two half cotton cellulose ignitors positioned 18 in. from the aisle.

The in-rack sprinklers for Fire Test Nos. 4 and 6 were standard response 1/2 in. nominal orifice 165°F temperature rated sprinklers positioned in the longitudinal flue at the center of the bay on one level. The sprinkler was arranged to operate at a flowing pressure of 30 psi.

The in-rack sprinkler for Fire Test Nos. 1 and 7 were standard response 1/2 in. nominal orifice 165°F temperature rated sprinklers positioned in the longitudinal flue at the rack uprights on one level. The sprinkler was arranged to operate at a flowing pressure of 30 psi.

The in-rack sprinklers for Fire Test Nos. 3 and 5 were the standard response 17/32 in. nominal orifice 165°F temperature rated sprinklers positioned in the longitudinal flue at the center of the bay on one level. The sprinkler was arranged to operate at a flow of 30 gpm.

The in-rack sprinkler for Fire Test Nos. 2 and 8 were the standard response 17/32 in. nominal orifice 165°F temperature rated sprinklers positioned in the longitudinal flue at the rack uprights on one level. The sprinklers were arranged to operate at a flow of 30 gpm per sprinkler.

The tests were conducted under an oxygen consumption calorimeter to measure the heat release rates.

A Table E-1 provides the testing parameters and results obtained. A complete description of the testing is presented in the following Report.

TABLE E-1

SUMMARY OF TEST PARAMETERS AND RESULTS

Test No.	Pressure/Flow (psig)/(gpm)	Sprinkler Type	Sprinkler Location	Sprinkler Activation Time (s)	Peak HRR (kW)
1	30/30	1/2 in. pendent	At Uprights	107, 118	15,702
2	15/30	17/32 in. pendent	At Uprights	107, 116	19,028
3	15/30	17/32 in. pendent	At Midspan	57	3,400
4	30/30	1/2 in. pendent	At Midspan	52	3,563
5	15/30	17/32 in. upright	At Midspan	66	4,643
6	30/30	1/2 in. upright	At Midspan	65	4,251
7	30/30	1/2 in. upright	At Uprights	103, 115	17,819
8	15/30	17/32 in. upright	At Uprights	149, 150	17,332

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1.0 INTRODUCTION

GENERAL

This Report describes the Special Service Investigation conducted for HSB Industrial Risk Insurers to develop fire test data relative to the level of protection required for scenarios involving mixed palletized rack storage of Group A plastic and Class II commodity.

Eight fire tests were conducted utilizing different sizes and locations of pendent in-rack sprinklers.

PURPOSE

The sole purpose of this investigation was to develop information and test data relative to the protection of mixed rack storage of Group A plastic and Class II commodity with in-rack sprinkler systems fitted with nominal 1/2 in. and 17/32 in. orifice sprinklers flowing at 30 gpm. The information obtained by this investigation is to be used by HSB Industrial Risk Insurers for their use only.

PLAN

Eight fire tests were conducted under a 10 MW oxygen consumption heat release calorimeter. The tests were conducted using a single bay, three tier, double row rack storage arrangement with a single level of in-rack sprinkler protection positioned in the longitudinal flue pace above the second tier. The first two tiers were loaded with Group A plastic commodity. The third tier was loaded with Class II commodity. The sprinkler systems were fitted with upright or pendent, 1/2 in. or 17/32 in. nominal orifice sprinklers positioned at the rack uprights or the beam midspan.

2.0 TEST FACILITY

HEAT RELEASE RATE RATE TEST FACILITY

The fire tests were conducted in a 45 by 45 by 55 ft high room fitted with a 25 ft diameter collection hood. Positioned 25 ft above the floor.

The test room is equipped with an exhaust system capable of being adjusted from near zero flow to 60,00 ft^3/min through a regenerative, thermal oxidizing, smoke abatement system.

Make-up air is provided through four inlet ducts, positioned along the walls of the test facility.

The floor is smooth, flat 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 one 8 ft bay and three tiers in each row. The tiers were positioned to provide a nominal 60 in. tier height. The upright supports of each row of the double row main storage rack were positioned 12 in. apart. The geometric center of the double row rack was positioned below a 25 ft diameter calorimeter collection hood.

SPRINKLER SYSTEMS

IN-RACK SPRINKLER SYSTEM

A 2 in. in-rack wet pipe automatic sprinkler system was positioned 114 in. above the floor.

The in-rack sprinkler for Fire Test Nos. 4 and 6 were the standard response 1/2 in. nominal orifice pendent style 165°F temperature rated sprinklers positioned in the longitudinal flue at the center of the bay on one level. The sprinkler was arranged to operate at a flowing pressure of 30 psi.

The in-rack sprinklers for Fire Test Nos. 1 and 7 were the standard response 1/2 in. nominal orifice pendent style 165°F temperature rated sprinklers positioned in the longitudinal flue on 8 ft centers, at the rack uprights, on one level. The sprinkler was arranged to operate at a flowing pressure of 30 psi.

The in-rack sprinkler for Fire test Nos. 3 and 5 were the standard response 17/32 in. nominal orifice pendent style 165°F temperature rated sprinklers positioned in the longitudinal flue at the center of the bay on one level. The sprinkler was arranged to operate at a flow of 30 gpm.

The in-rack sprinklers for Fire Test Nos. 2 and 8 were the standard response 17/32 in. nominal orifice pendent style 165°F temperature rated sprinklers positioned in the longitudinal flue on 8 ft centers, at the rack uprights, on one level. The sprinklers were arranged to operate at a flow of 30 gpm per sprinkler.

INSTRUMENTATION

Thermocouples were located adjacent to each in-rack sprinkler in the center bay of the first and second tier to record in-rack temperatures.

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

Heat release rate equipment consisting of oxygen concentration paramgnetic analyzer gas sampling system, and a bidirectional velocity transducer were located in the exhaust duct.

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.

4.0 TEST COMMODITY

Test samples consisted of storage commodities defined in NFPA 231C as Class II and Group A, as described as follows:

CLASS II - Double tri-wall corrugated cardboard cartons with five sided steel stiffeners inserted for stability. The carton measures a nominal 42 by 42 by 42 in. and are placed on 42 by 42 by 5 in. high hardwood pallets.

GROUP A - Single wall corrugated cardboard cartons measuring a nominal 20 by 20 by 20 in. containing 125 crystalline polystyrene cups in separate compartments within the carton. The compartmentation was accomplished with single wall corrugated cardboard sheets to separate the five layers and interlocking single wall corrugated cardboard vertical dividers to separate the five rows and five columns comprising each layer. Eight of the cartons were arranged in a 2 by 2 by 2 array, with the open end of the cups facing down, placed on a 42 by 42 by 5 in. high hardwood pallet.

5.0 FIRE TESTS

TEST PLAN

In order to investigate the level of protection provided, parameters for fire test were planned to compare the fire control performance using different sprinkler locations and orifice sizes within a 2 by 2 by 3 rack storage arrangement with in-rack sprinkler protection below a 10 MW heat release calorimeter.

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.

Temperature and flow data for the fire tests are presented in App. A.

FIRE TEST NO. 1

Storage Arrangement

Racking was arranged to provide a single bay, three tier, double row rack with beams located at 5 and 10 ft. The Group A commodity was placed on the lower two tiers and the Class II commodity was placed on the uppermost tier. The commodity positioning provided a 6 in. longitudinal and transverse flue.

In-Rack Protection

The in-rack sprinkler system consisted of 165°F temperature rated, 1/2 in. nominal orifice, pendent sprinklers positioned at the rack uprights 114 in. above the floor. The sprinklers were arranged to operate at 30 psig with a flow of 30 gpm per sprinkler.

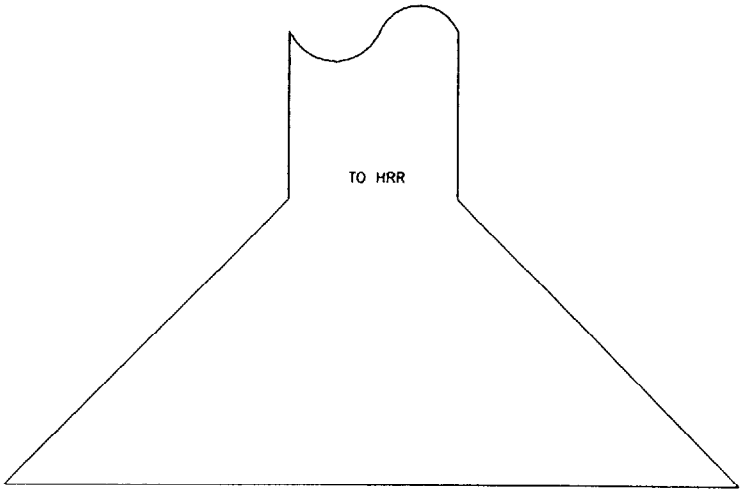
Test Procedure

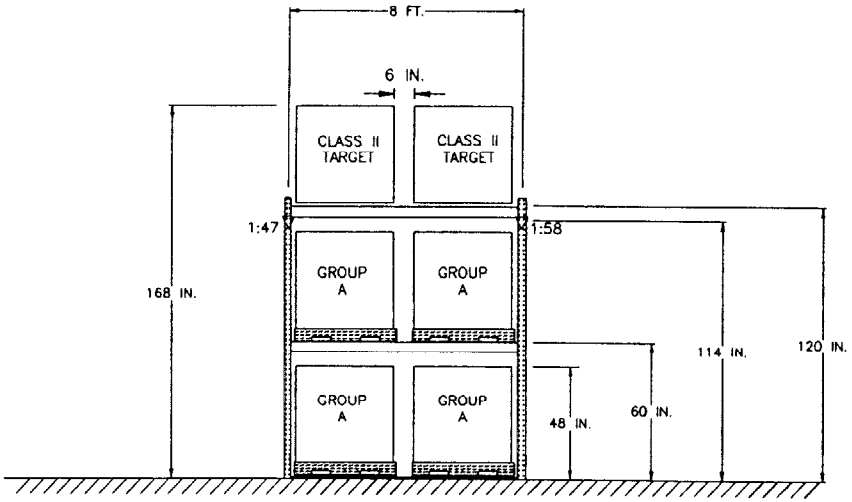
Ignition was accomplished with two half cotton cellulose igniters positioned 18 in. in from the aisle. Products of combustion were collected and analyzed.

Test Results

During this test two in-rack sprinkler operated at 107 and 118 s. The peak Heat Release Rate was measured to be 15,702 kW. The Total Heat Released was measured to be 4927 kJ.

FIRE TEST NO. 1, SPRINKLER OPERATION TIMES





ELEVATION–FRONT VIEW

△ IN-RACK SPRINKLER LOCATIONS, SPRINKLERS TO BE 165° TEMP RATING STANDARD RESPONSE, INTERMEDIATE LEVEL

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

1/2 IN. NOMINAL ORIFICE PENDENT @ 30 PSI POSITIONED AT UPRIGHTS
HEAT RELEASE RATE COMPARISON TESTS

ILL 1

FIRE TEST NO. 2

Storage Arrangement

Racking was arranged to provide a single bay, three tier, double row rack with beams located at 5 and 10 ft. The Group A commodity was placed on the lower two tiers and the Class II commodity was placed on the uppermost tier. The commodity positioning provided a 6 in. longitudinal and transverse flue.

In-Rack Protection

The in-rack sprinkler system consisted of 165°F temperature rated, 17/32 in. nominal orifice, pendent sprinklers positioned at the rack uprights 114 in. above the floor. The sprinklers were arranged to operate at 15 psig with a flow of 30 gpm per sprinkler.

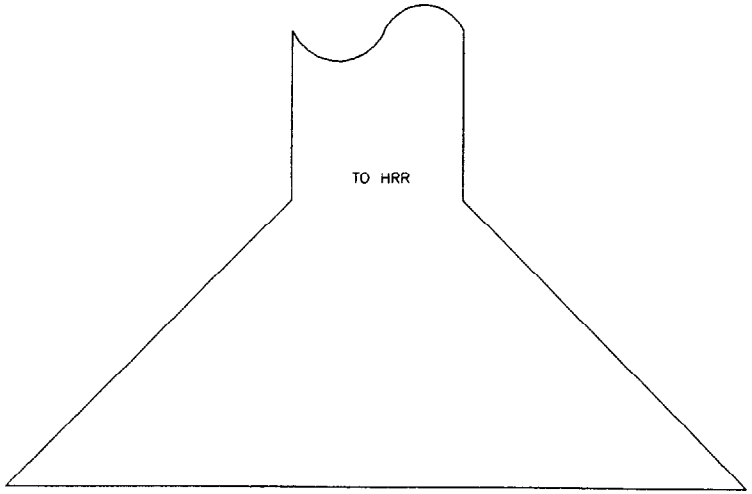
Test Procedure

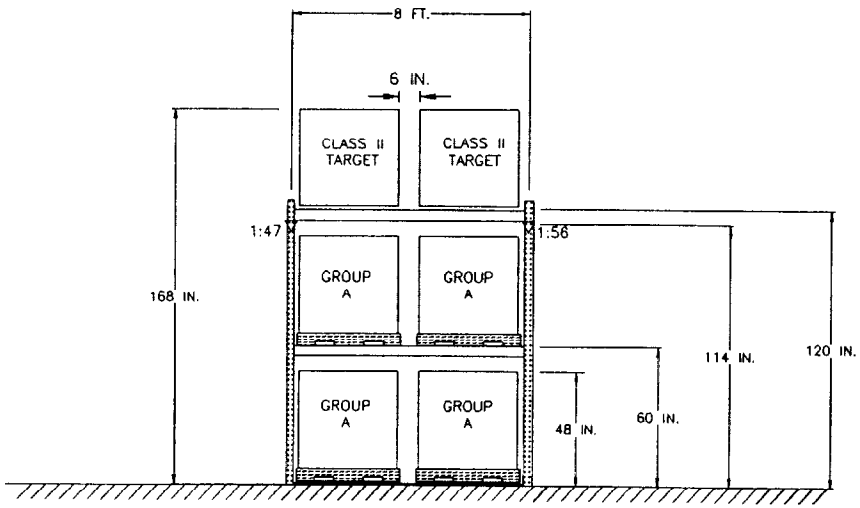
Ignition was accomplished with two half cotton cellulose igniters positioned 18 in. in from the aisle. Products of combustion were collected and analyzed.

Test Results

During this test two in-rack sprinkler operated at 107 and 116 s. The peak Heat Release Rate was measured to be 19,028 kW. The Total Heat Released was measured to be 4029 kJ.

FIRE TEST NO. 2, SPRINKLER OPERATION TIMES





ELEVATION-FRONT VIEW

△ IN-RACK SPRINKLER LOCATIONS, SPRINKLERS TO BE 165' TEMP RATING STANDARD RESPONSE, INTERMEDIATE LEVEL

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

17/32 IN. NOMINAL ORIFICE PENDENT @ 15 PSI POSITIONED AT UPRIGHTS
HEAT RELEASE RATE COMPARISON TESTS

ILL 2

FIRE TEST NO. 3

Storage Arrangement

Racking was arranged to provide a single bay, three tier, double row rack with beams located at 5 and 10 ft. The Group A commodity was placed on the lower two tiers and the Class II commodity was placed on the uppermost tier. The commodity positioning provided a 6 in. longitudinal and transverse flue.

In-Rack Protection

The in-rack sprinkler system consisted of 165°F temperature rated, 17/32 in. nominal orifice, pendent sprinklers positioned at the rack midspan 114 in. above the floor. The sprinklers were arranged to operate at 15 psig with a flow of 30 gpm per sprinkler.

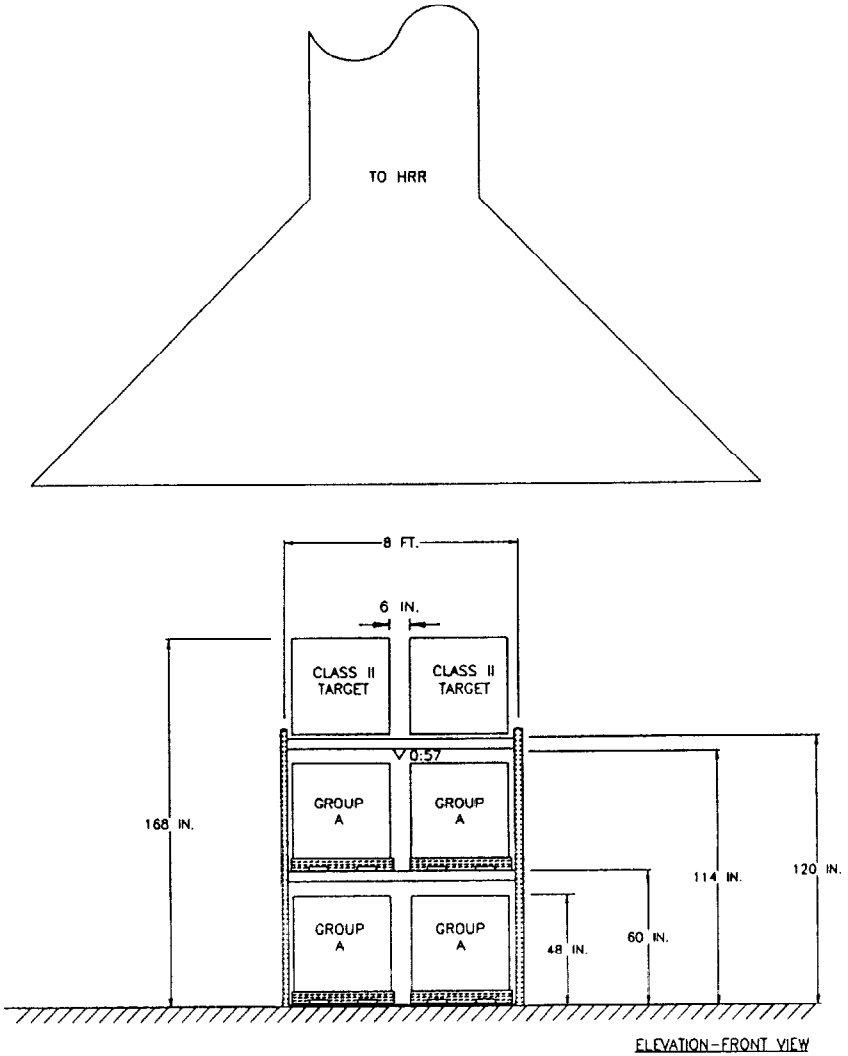
Test Procedure

Ignition was accomplished with two half cotton cellulose igniters positioned 18 in. in from the aisle. Products of combustion were collected and analyzed.

Test Results

During this test one in-rack sprinkler operated at 57 s. The peak Heat Release Rate was measured to be 3400 kW. The Total Heat Released was measured to be 798 kJ.

FIRE TEST NO. 3, SPRINKLER OPERATION TIMES



Δ IN-RACK SPRINKLER LOCATIONS, SPRINKLERS TO BE 165° TEMP RATING STANDARD RESPONSE, INTERMEDIATE LEVEL

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

17/32 IN. NOMINAL ORIFICE PENDENT @ 15 PSI POSITIONED AT MIDSPAN
HEAT RELEASE RATE COMPARISON TESTS

ILL 3

FIRE TEST NO. 4

Storage Arrangement

Racking was arranged to provide a single bay, three tier, double row rack with beams located at 5 and 10 ft. The Group A commodity was placed on the lower two tiers and the Class II commodity was placed on the uppermost tier. The commodity positioning provided a 6 in. longitudinal and transverse flue.

In-Rack Protection

The in-rack sprinkler system consisted of 165°F temperature rated, 1/2 in. nominal orifice, pendent sprinklers positioned at the rack midspan 114 in. above the floor. The sprinklers were arranged to operate at 30 psig with a flow of 30 gpm per sprinkler.

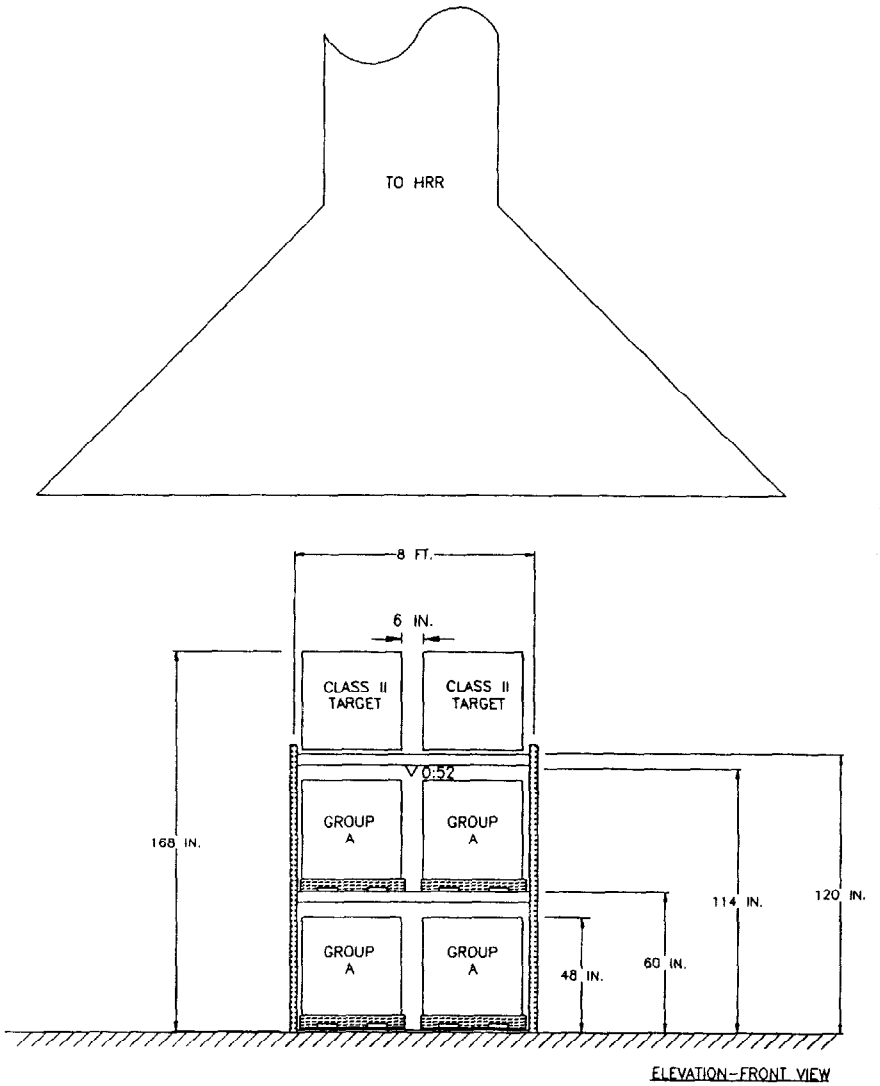
Test Procedure

Ignition was accomplished with two half cotton cellulose igniters positioned 18 in. in from the aisle. Products of combustion were collected and analyzed.

Test Results

During this test one in-rack sprinkler operated at 52 s. The peak Heat Release Rate was measured to be 3563 kW. The Total Heat Released was measured to be 905 kJ.

FIRE TEST NO. 4, SPRINKLER OPERATION TIMES



△ IN-RACK SPRINKLER LOCATIONS, SPRINKLERS TO BE 165° TEMP RATING STANDARD RESPONSE, INTERMEDIATE LEVEL

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

1/2 IN. NOMINAL ORIFICE PENDENT @ 30 PSI POSITIONED AT MIDSPAN
HEAT RELEASE RATE COMPARISON TESTS

ILL 4

FIRE TEST NO. 5

Storage Arrangement

Racking was arranged to provide a single bay, three tier, double row rack with beams located at 5 and 10 ft. The Group A commodity was placed on the lower two tiers and the Class II commodity was placed on the uppermost tier. The commodity positioning provided a 6 in. longitudinal and transverse flue.

In-Rack Protection

The in-rack sprinkler system consisted of 165°F temperature rated, 17/32 in. nominal orifice, upright sprinklers positioned at the rack midspan 114 in. above the floor. The sprinklers were arranged to operate at 15 psig with a flow of 30 gpm per sprinkler.

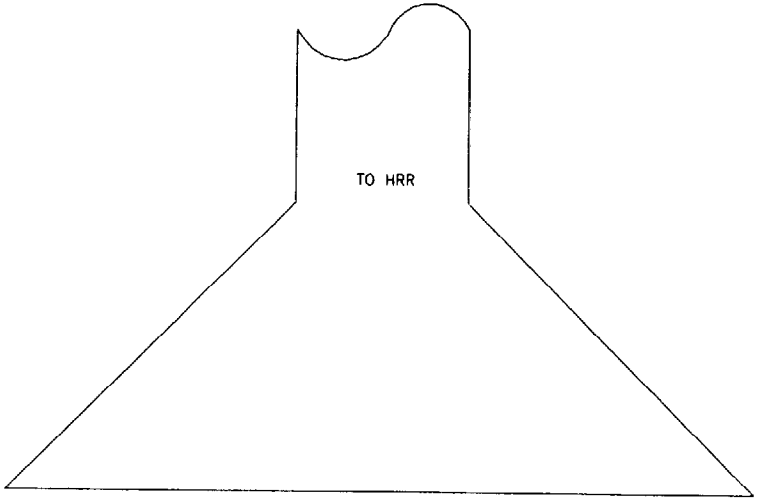
Test Procedure

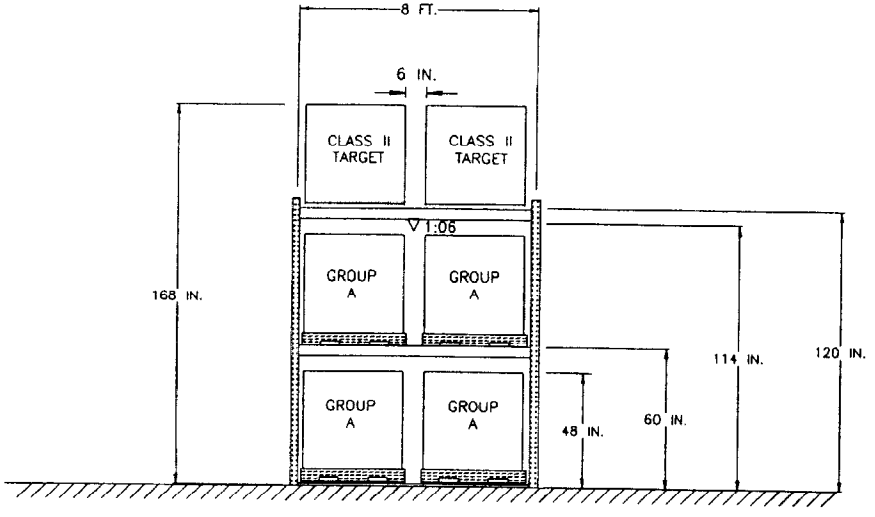
Ignition was accomplished with two half cotton cellulose igniters positioned 18 in. in from the aisle. Products of combustion were collected and analyzed.

Test Results

During this test one in-rack sprinkler operated at 66 s. The peak Heat Release Rate was measured to be 4643 kW. The Total Heat Released was measured to be 2671 kJ.

FIRE TEST NO. 5, SPRINKLER OPERATION TIMES





ELEVATION–FRONT VIEW

△ IN–RACK SPRINKLER LOCATIONS, SPRINKLERS TO BE 165° TEMP RATING STANDARD RESPONSE, INTERMEDIATE LEVEL

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

17/32 IN. NOMINAL ORIFICE UPRIGHT @ 15 PSI POSITIONED AT MIDSPAN
HEAT RELEASE RATE COMPARISON TESTS

ILL 5

FIRE TEST NO. 6

Storage Arrangement

Racking was arranged to provide a single bay, three tier, double row rack with beams located at 5 and 10 ft. The Group A commodity was placed on the lower two tiers and the Class II commodity was placed on the uppermost tier. The commodity positioning provided a 6 in. longitudinal and transverse flue.

In-Rack Protection

The in-rack sprinkler system consisted of 165°F temperature rated, 1/2 in. nominal orifice, upright sprinklers positioned at the rack midspan 114 in. above the floor. The sprinklers were arranged to operate at 30 psig with a flow of 30 gpm per sprinkler.

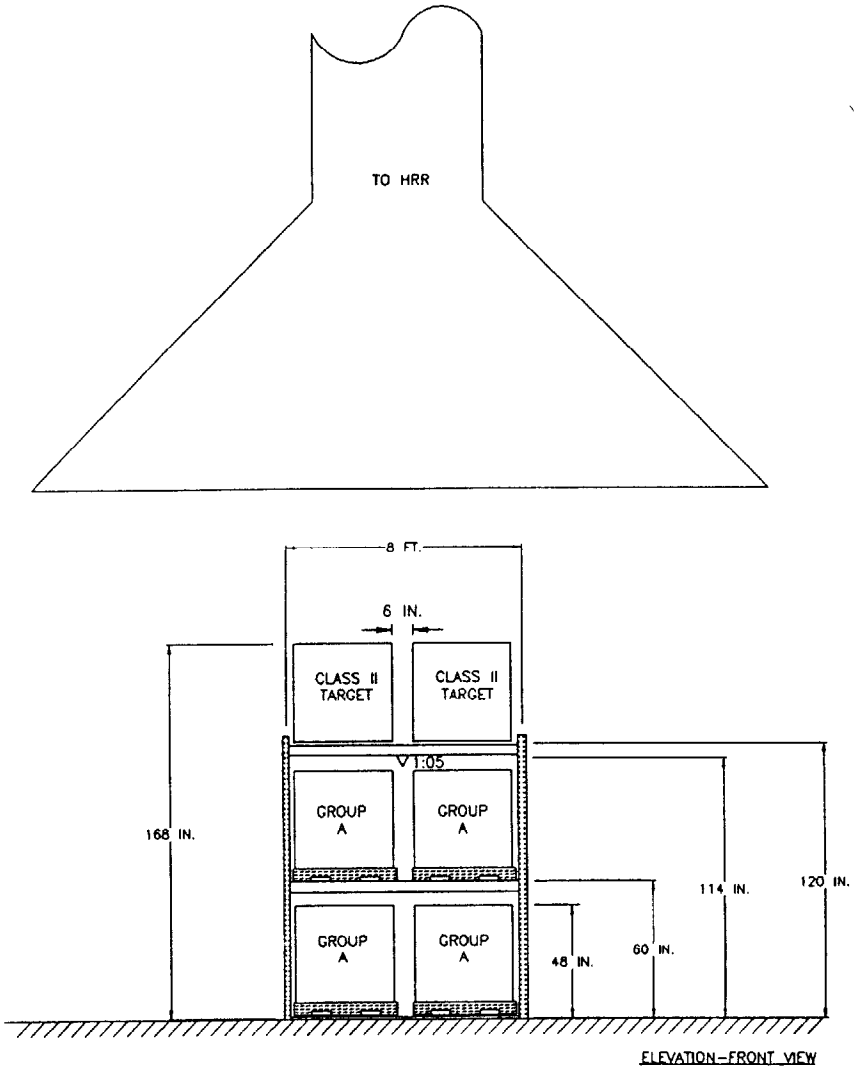
Test Procedure

Ignition was accomplished with two half cotton cellulose igniters positioned 18 in. in from the aisle. Products of combustion were collected and analyzed.

Test Results

During this test one in-rack sprinkler operated at 65 s. The peak Heat Release Rate was measured to be 4251 kW. The Total Heat Released was measured to be 4028 kJ.

FIRE TEST NO. 6, SPRINKLER OPERATION TIMES



△ IN-RACK SPRINKLER LOCATIONS, SPRINKLERS TO BE 165° TEMP RATING STANDARD RESPONSE, INTERMEDIATE LEVEL

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

1/2 IN. NOMINAL ORIFICE UPRIGHT @ 30 PSI POSITIONED AT MIDSPAN
HEAT RELEASE RATE COMPARISON TESTS

ILL 6

FIRE TEST NO. 7

Storage Arrangement

Racking was arranged to provide a single bay, three tier, double row rack with beams located at 5 and 10 ft. The Group A commodity was placed on the lower two tiers and the Class II commodity was placed on the uppermost tier. The commodity positioning provided a 6 in. longitudinal and transverse flue.

In-Rack Protection

The in-rack sprinkler system consisted of 165°F temperature rated, 1/2 in. nominal orifice, upright sprinklers positioned at the rack uprights 114 in. above the floor. The sprinklers were arranged to operate at 30 psig with a flow of 30 gpm per sprinkler.

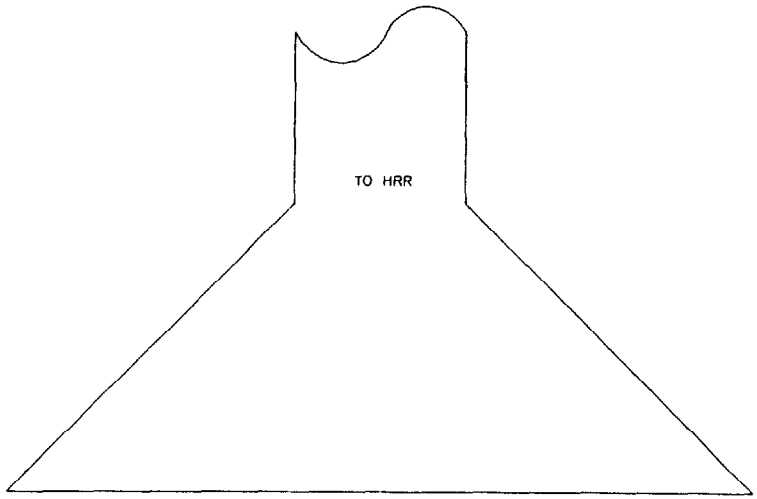
Test Procedure

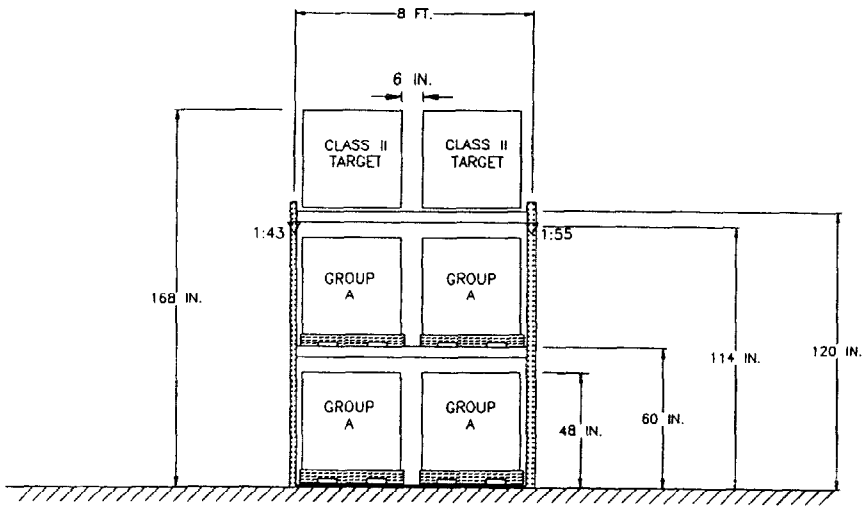
Ignition was accomplished with two half cotton cellulose igniters positioned 18 in. in from the aisle. Products of combustion were collected and analyzed.

Test Results

During this test two in-rack sprinkler operated at 103 and 115 s. The peak Heat Release Rate was measured to be 17,819 kW. The Total Heat Released was measured to be 3776 kJ.

FIRE TEST NO. 7, SPRINKLER OPERATION TIMES





ELEVATION-FRONT VIEW

△ IN-RACK SPRINKLER LOCATIONS, SPRINKLERS TO BE 165° TEMP RATING STANDARD RESPONSE, INTERMEDIATE LEVEL

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

1/2 IN. NOMINAL ORIFICE UPRIGHT @ 30 PSI POSITIONED AT UPRIGHTS
HEAT RELEASE RATE COMPARISON TESTS

ILL 7

FIRE TEST NO. 8

Storage Arrangement

Racking was arranged to provide a single bay, three tier, double row rack with beams located at 5 and 10 ft. The Group A commodity was placed on the lower two tiers and the Class II commodity was placed on the uppermost tier. The commodity positioning provided a 6 in. longitudinal and transverse flue.

In-Rack Protection

The in-rack sprinkler system consisted of 165°F temperature rated, 17/32 in. nominal orifice, upright sprinklers positioned at the rack uprights 114 in. above the floor. The sprinklers were arranged to operate at 15 psig with a flow of 30 gpm per sprinkler.

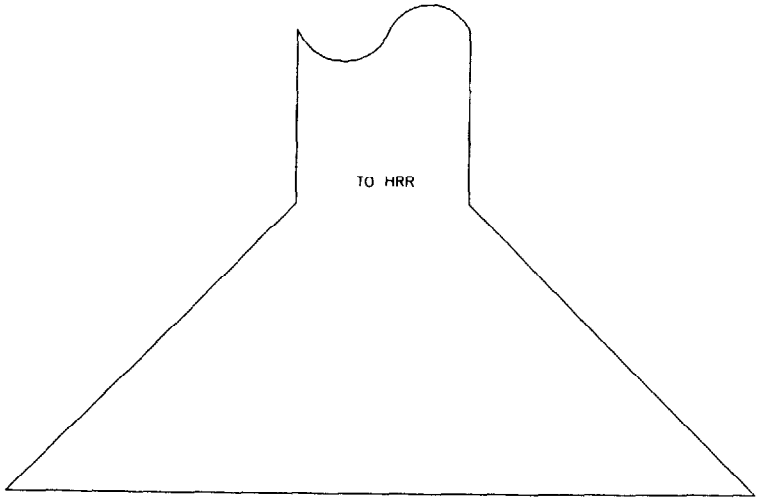
Test Procedure

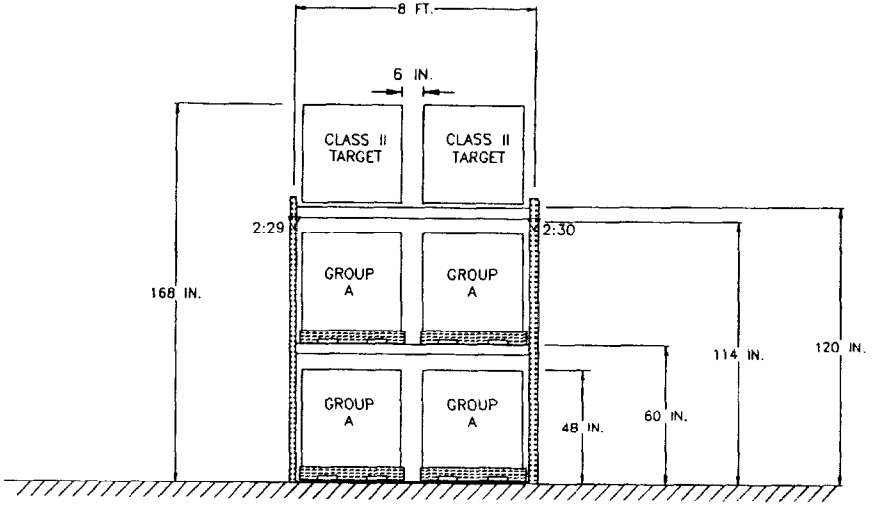
Ignition was accomplished with two half cotton cellulose igniters positioned 18 in. in from the aisle. Products of combustion were collected and analyzed.

Test Results

During this test two in-rack sprinkler operated at 149 and 150 s. The peak Heat Release Rate was measured to be 17,332 kW. The Total Heat Released was measured to be 2588 kJ.

FIRE TEST NO. 8, SPRINKLER OPERATION TIMES





ELEVATION–FRONT VIEW

△ IN-RACK SPRINKLER LOCATIONS, SPRINKLERS TO BE 165° TEMP RATING STANDARD RESPONSE, INTERMEDIATE LEVEL

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

17/32 IN. NOMINAL ORIFICE UPRIGHT @ 15 PSI POSITIONED AT UPRIGHTS
HEAT RELEASE RATE COMPARISON TESTS

ILL 8

CONCLUSION

All anticipated work under Project 96NK27008 has been completed with this Report. Should you have any questions of concerns, please do not hesitate to contact the writer.

Report by:

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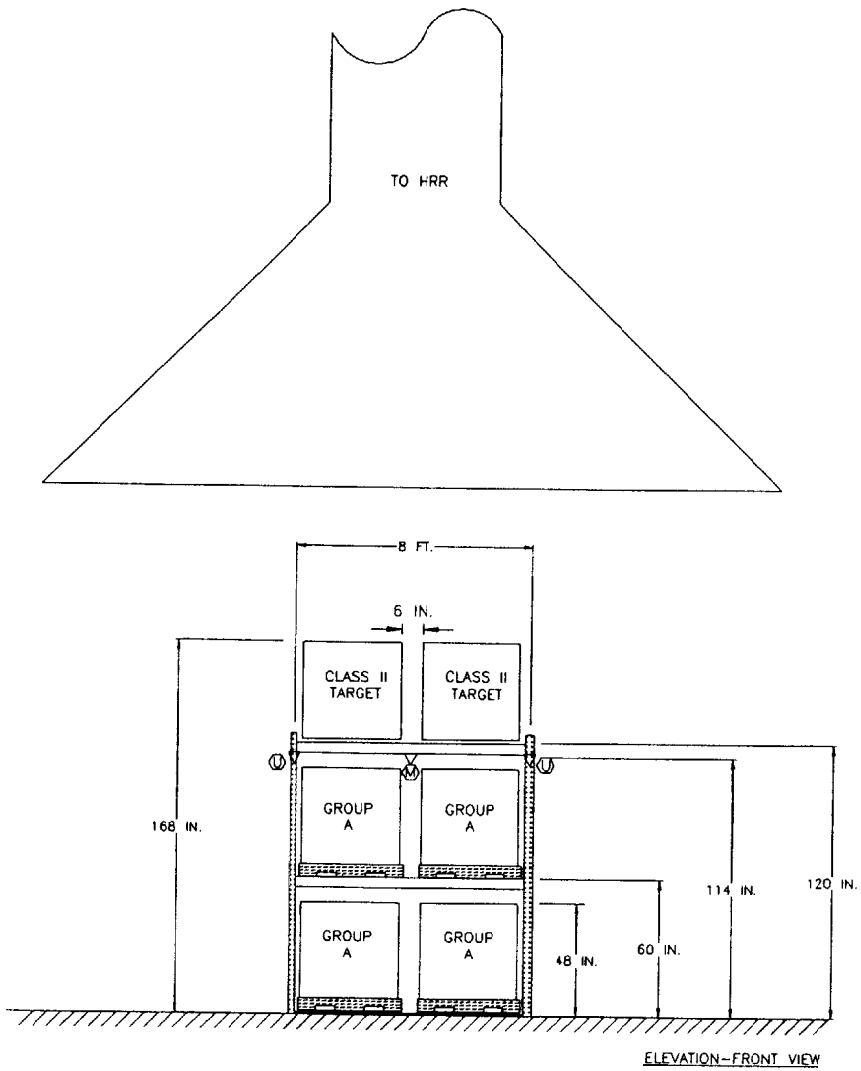
MJP:mrs/bam
s:/fpsave/MPABICH.MAY
1492/1653

APPENDIX A

Test Layout Drawings
Heat Release Rate Curves

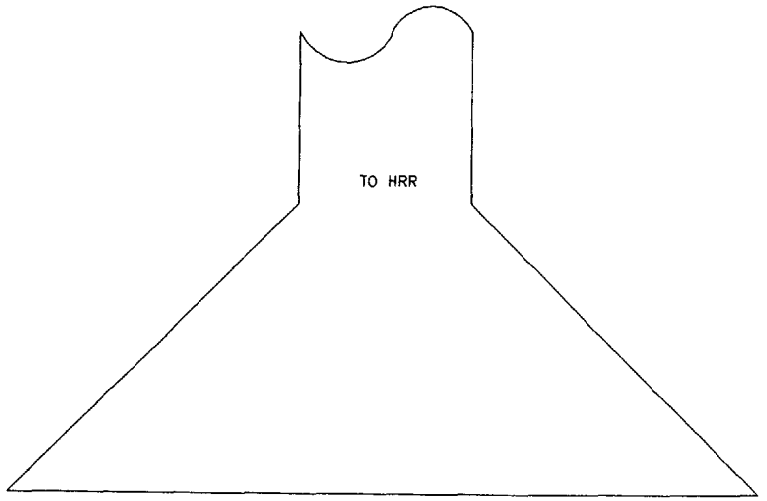


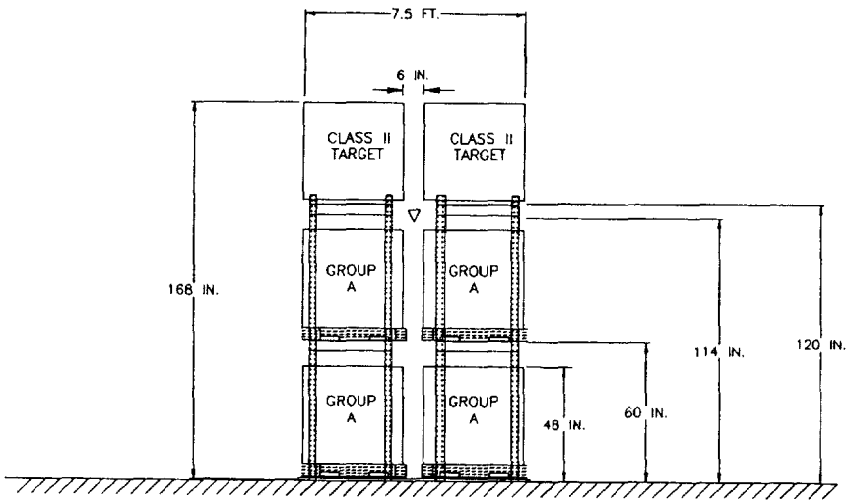
△ IN–RACK SPRINKLER LOCATIONS, SPRINKLERS TO BE 165' TEMP RATING STANDARD RESPONSE, INTERMEDIATE LEVEL
⬡ TEST POSITIONING IDENTIFICATION; U = TESTS 1,2,7,8 M = TESTS 3,4,5,6

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

1/2 IN. NOMINAL ORIFICE @ 30 PSI vs 17/32 IN. NOMINAL ORIFICE @ 15 PSI
HEAT RELEASE RATE COMPARISON TESTS

ILL A1





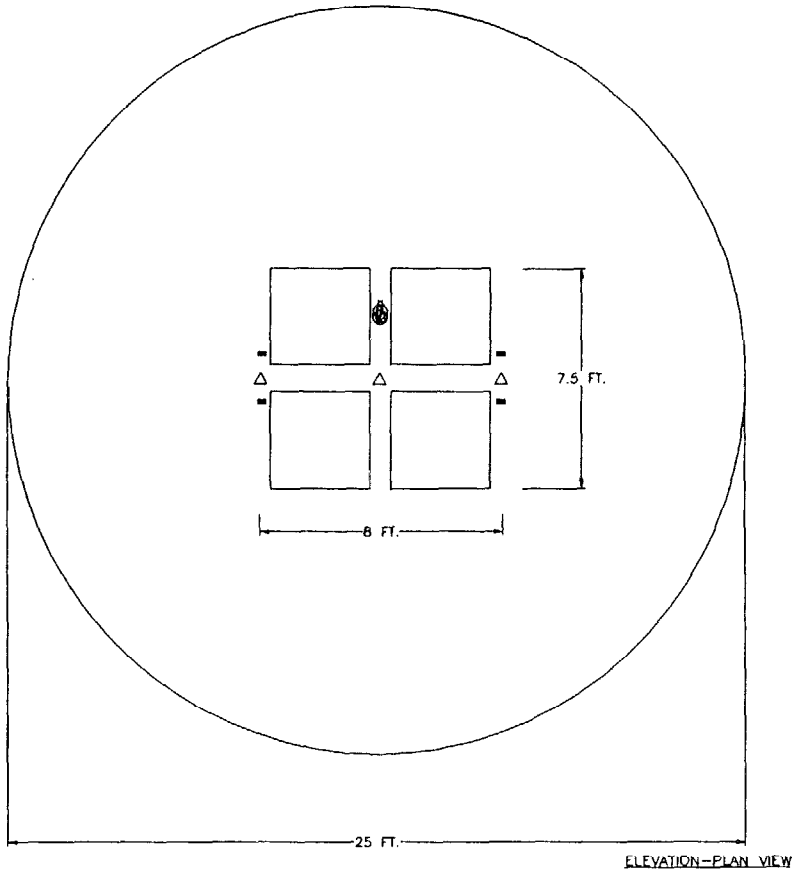
ELEVATION-SIDE VIEW

△ IN-RACK SPRINKLER LOCATIONS, SPRINKLERS TO BE 165° TEMP RATING STANDARD RESPONSE.
⬡ TEST POSITIONING IDENTIFICATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

1/2 IN. NOMINAL ORIFICE @ 30 PSI vs 17/32 IN. NOMINAL ORIFICE @ 15 PSI
HEAT RELEASE RATE COMPARISON TESTS

ILL A2



ELEVATION–PLAN VIEW

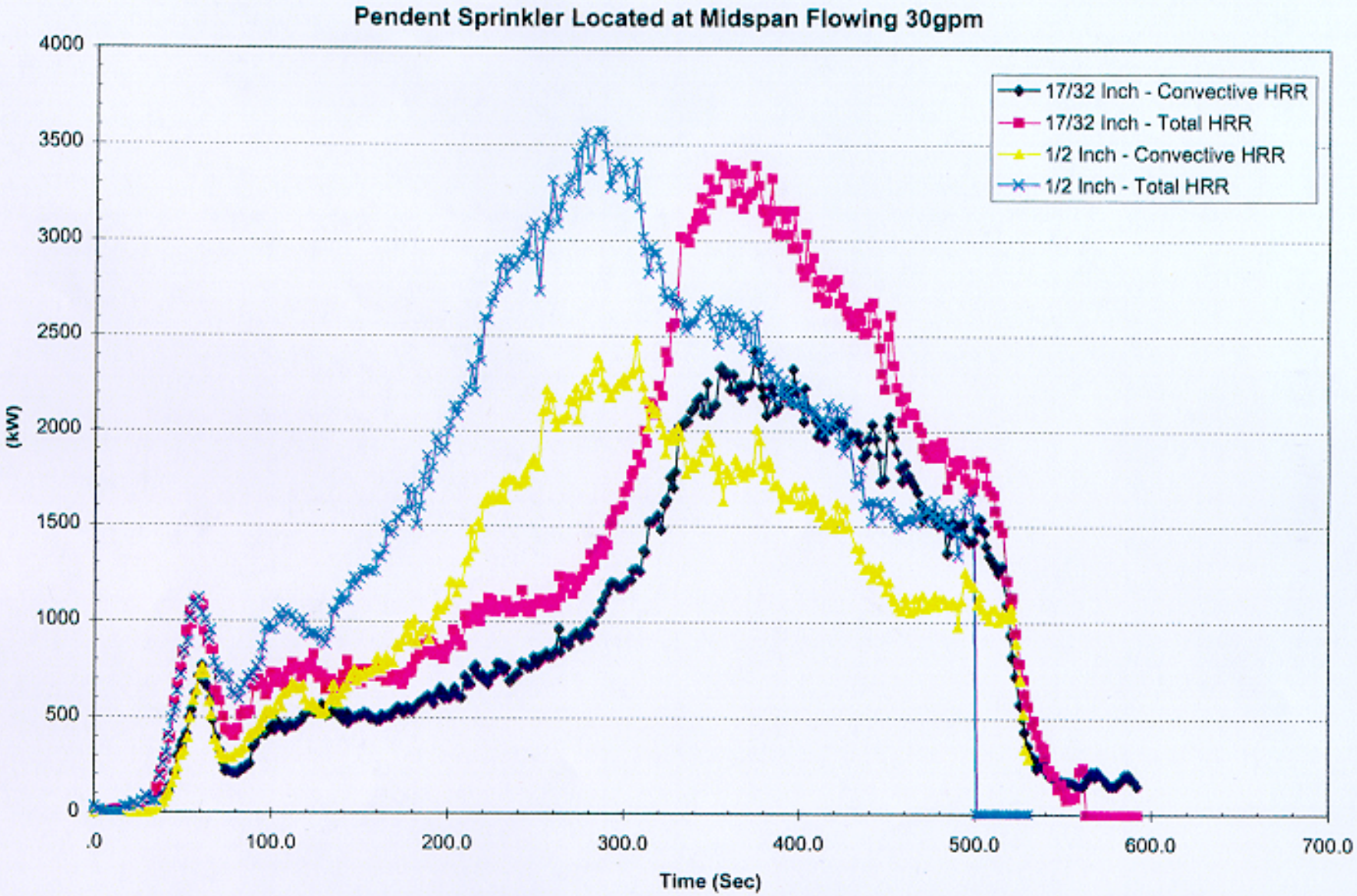
△ IN–RACK SPRINKLER LOCATIONS, SPRINKLERS TO BE 165° TEMP RATING STANDARD RESPONSE, INTERMEDIATE LEVEL

IGNITION LOCATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

1/2 IN. NOMINAL ORIFICE @ 30 PSI vs 17/32 IN. NOMINAL ORIFICE @ 15 PSI
HEAT RELEASE RATE COMPARISON TESTS

ILL A3



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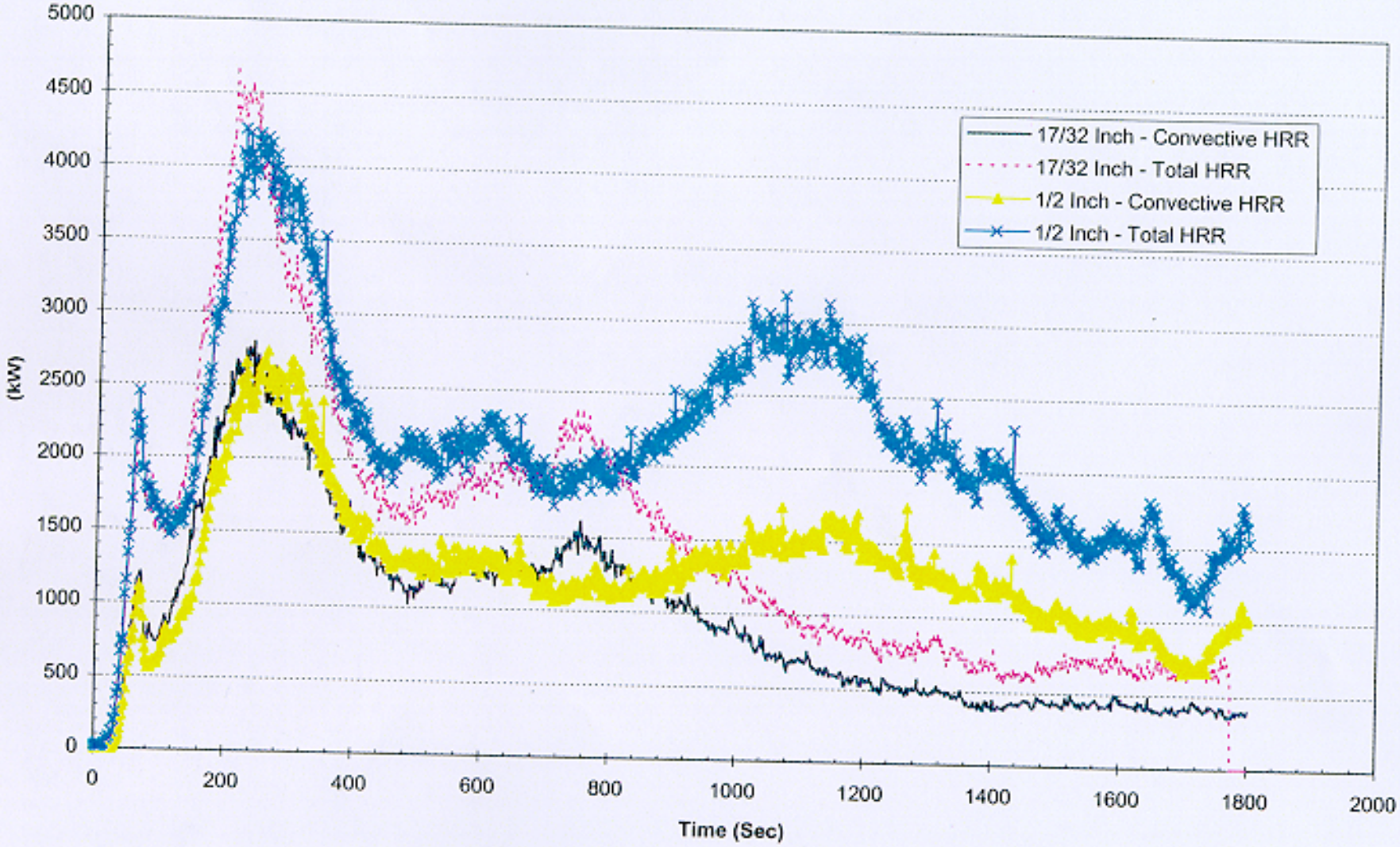
Test Date :

10179703.xls

Upright Sprinklers located at Midspan Flowing 30gpm



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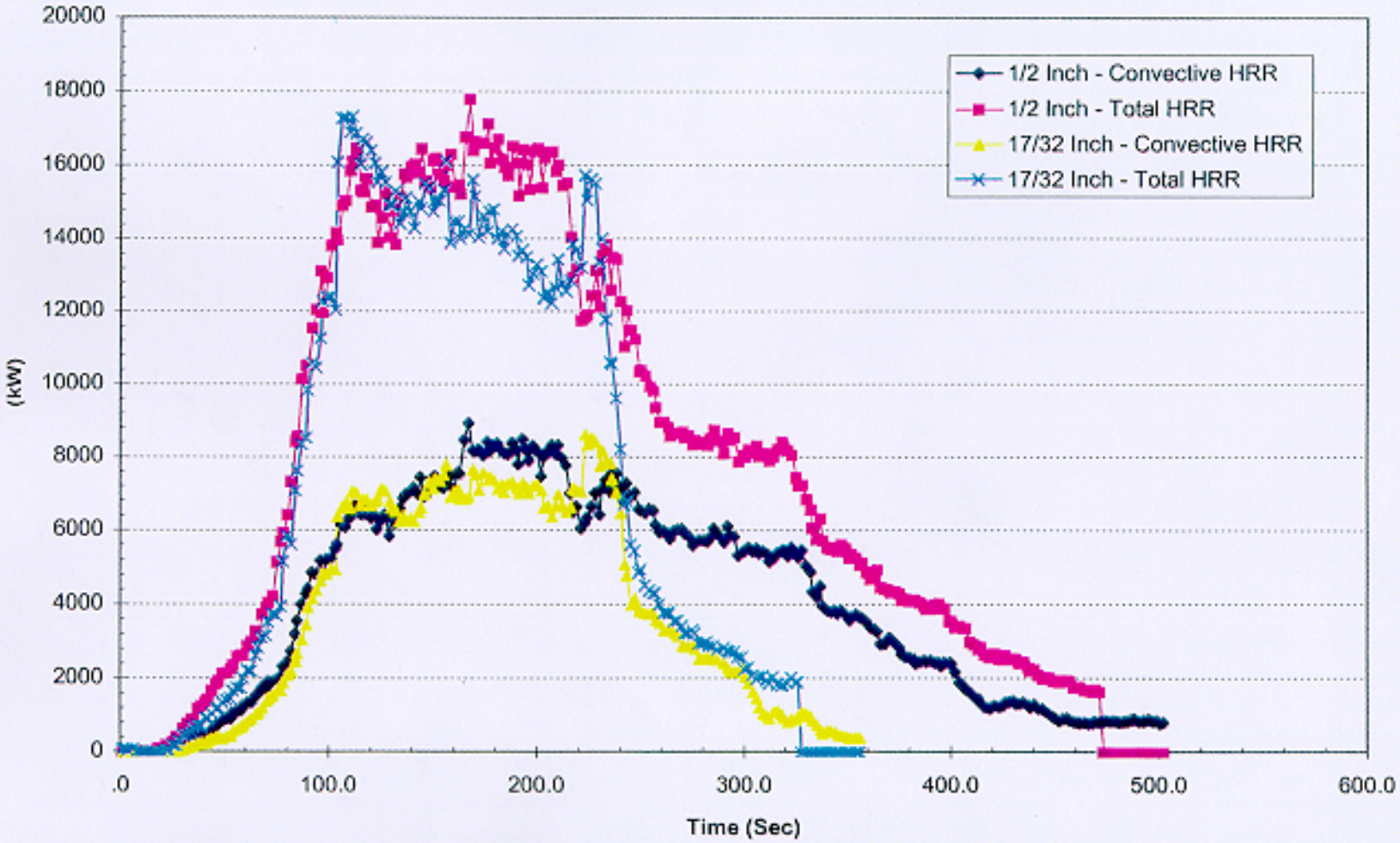
Test Date :

10209702.xls

Upright Sprinklers Located at Uprights Flowing 30gpm



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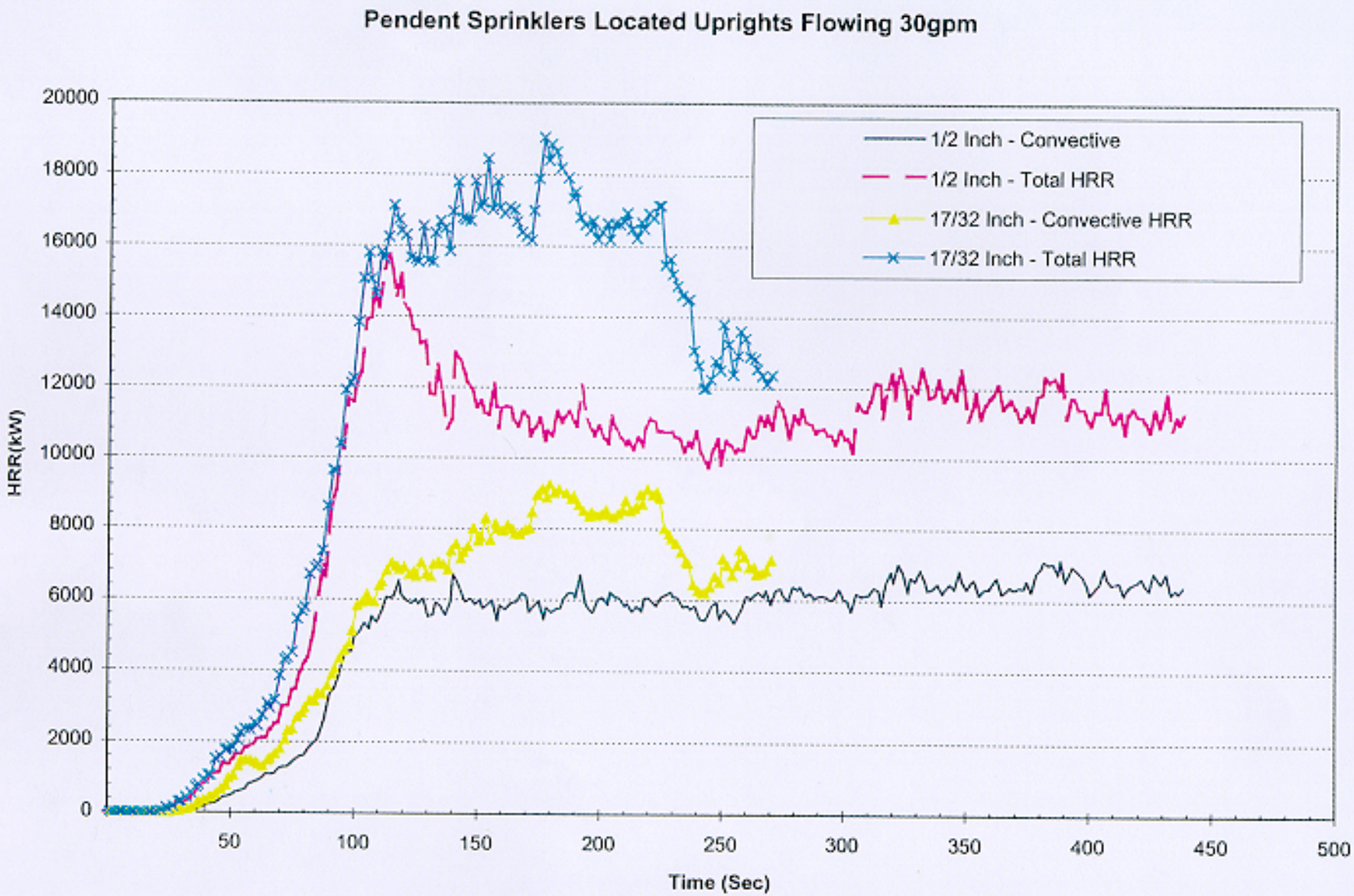
Test Date :

10219701.xls



IRI
Test Code: 10169701.xls
Test No. 1
Project NC1838/97NK31099