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JUL 0 2 1998

L-98-153
10 CFR §50.12
10 CFR §50.48
10 CFR Part 50 Appendix R

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D. C. 20555

Subject: Turkey Point Units 3 and 4
Docket Nos. 50-250 and 50-251
Response to Request for Additional Information on
Request for Exemption - Fire Rating of Raceway Fire
Barriers in the Open Turbine Building

By letter L-97-181, dated July 31, 1997, Florida Power & Light (FPL) submitted a request for exemption from the requirements of Appendix R subsection III.G.2.a for electrical raceways in the open turbine building. By letter dated March 23, 1998, the Nuclear Regulatory Commission (NRC) requested additional information (RAI) in order to complete the review. In accordance with the NRC request, Attachment 1 provides the additional information requested. FPL's response incorporates information requested by the NRC during the May 26, 1998 public meeting between NRC and FPL.

Should there be any questions, please contact us.

Very truly yours,

R. J. Hovey
Vice President
Turkey Point Plant

OIH

Attachment
Enclosures

cc: L. A. Reyes, Regional Administrator, Region II, USNRC
T. P. Johnson, Senior Resident Inspector, USNRC, Turkey Point

CATEGORY 1

REGULATORY INFORMATION DISTRIBUTION SYSTEM (RIDS)

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INTERNAL:	FILE CENTER 01	2	2	NRR/DSSA/SPLB	1	1
	NUDOCS-ABSTRACT	1	1	OGC/HDS3	1	0
EXTERNAL:	NOAC	1	1	NRC PDR	1	1

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JUL 02 1998

L-98-153
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10 CFR §50.48
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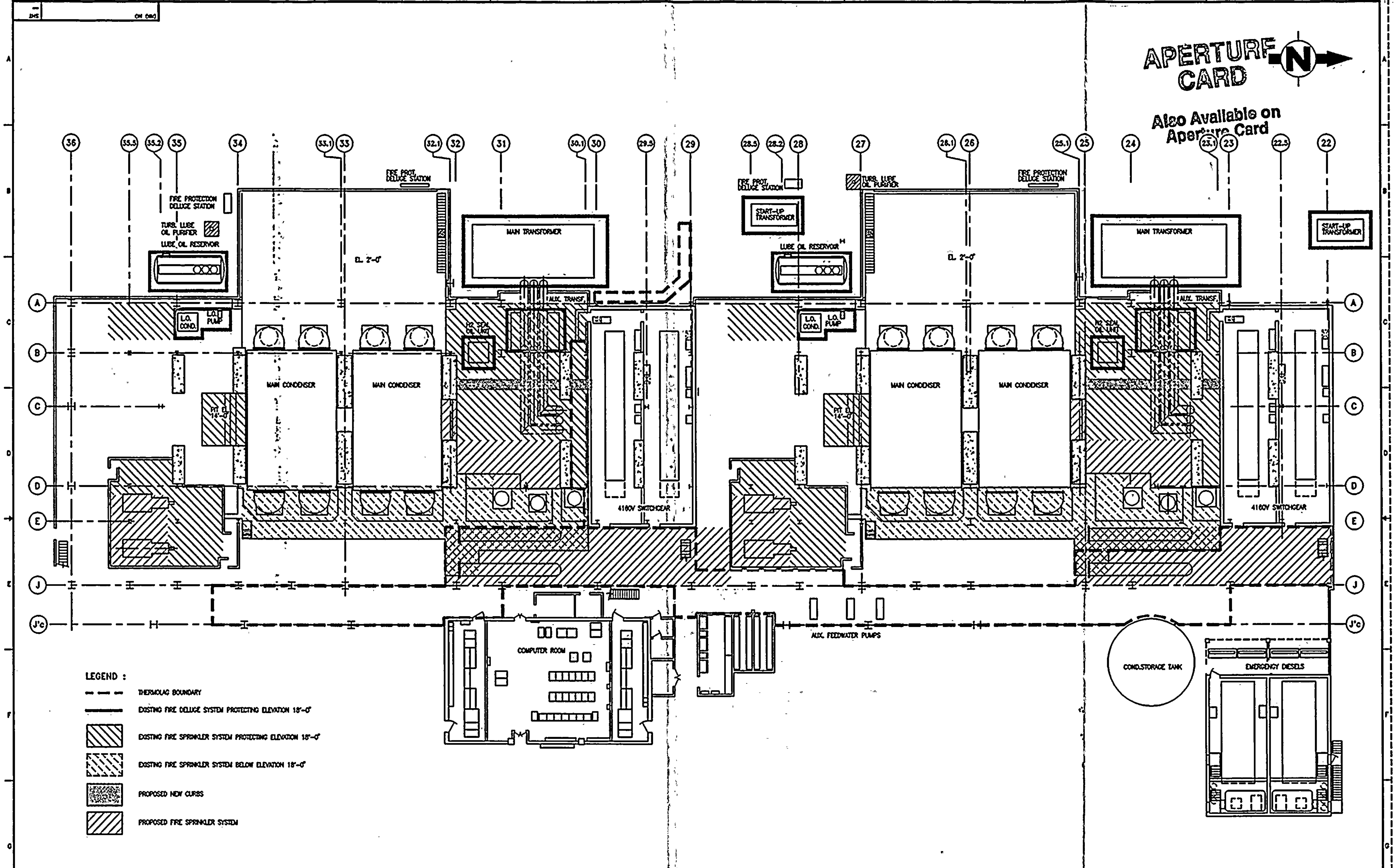
OIH

Attachment
Enclosures

cc: L. A. Reyes, Regional Administrator, Region II, USNRC
T. P. Johnson, Senior Resident Inspector, USNRC, Turkey Point

A006.



9807080062 -01

REV	DATE	REVISION	BY	CH	APP	APP

TURKEY POINT NUCLEAR UNITS 3 & 4

GENERAL ARRANGEMENT

FIRE PROTECTION GROUND FLOOR PLAN EL. 18'-0" & BELOW

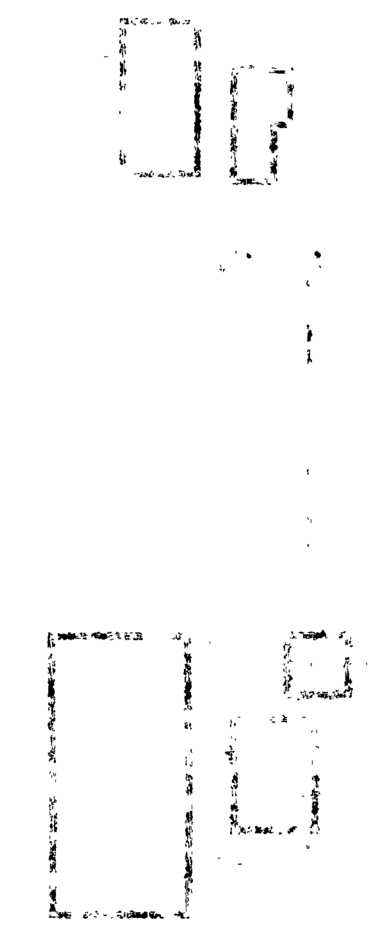
FLORIDA POWER & LIGHT

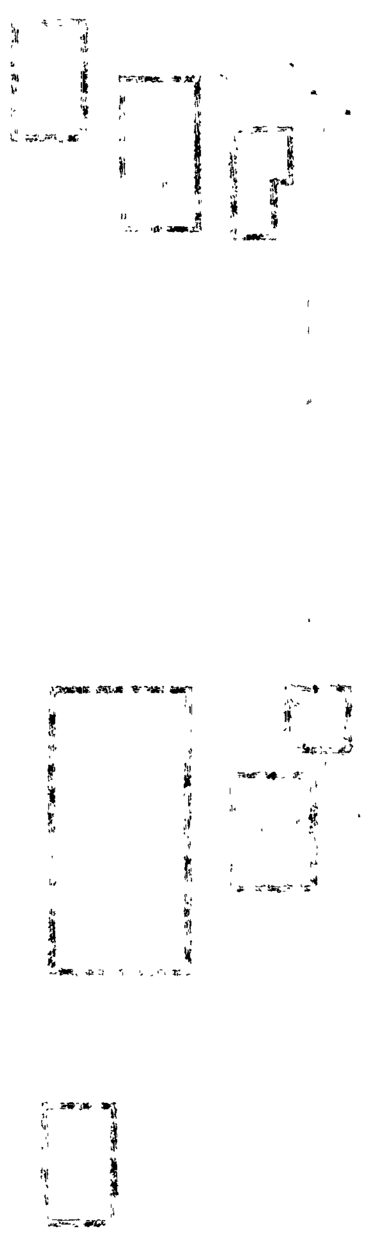
DRAWING NUMBER: FIGURE 1 (L-98-153)

SYS —

REV

SHEET





APERTURE CARD

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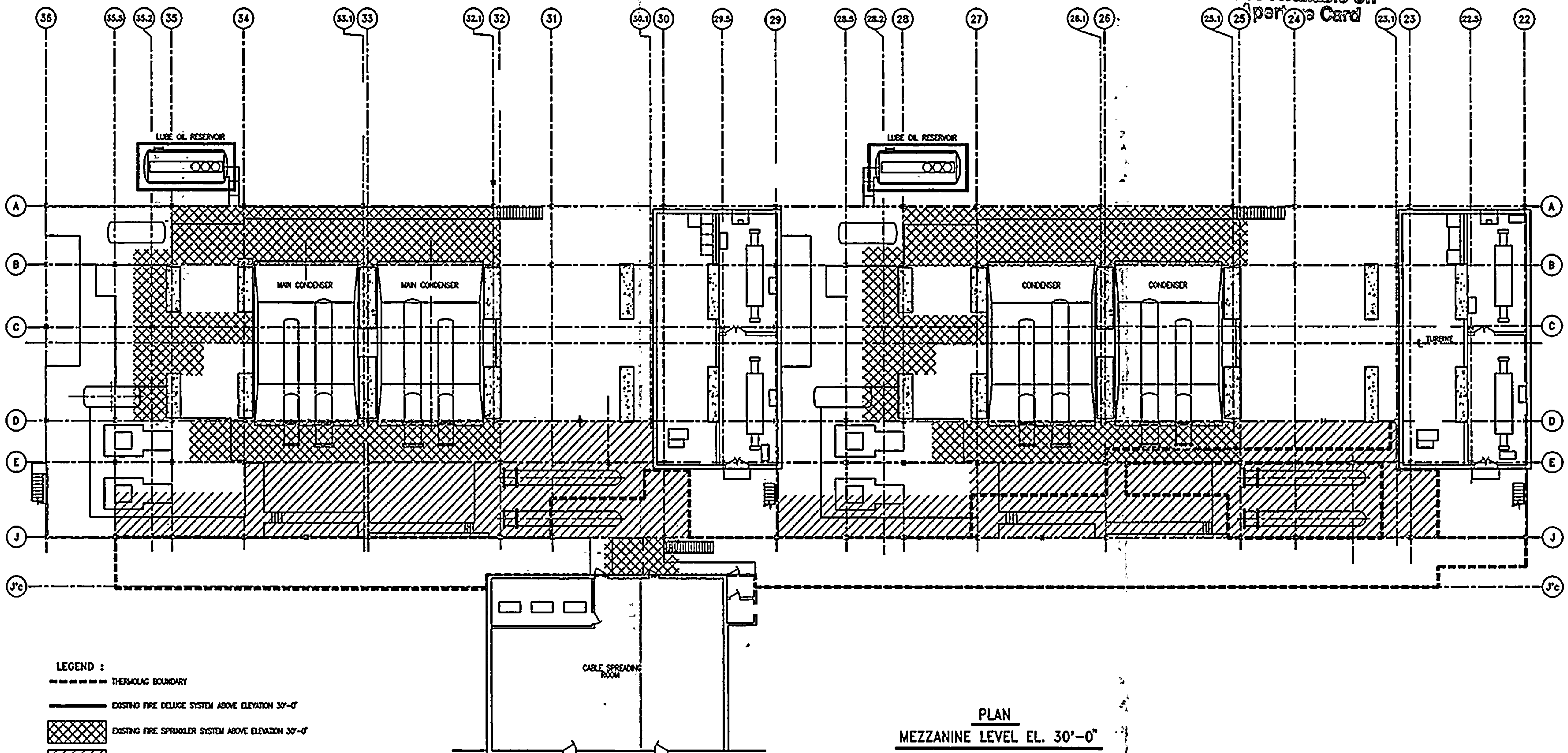


LEGEND :

- THERMOLAG BOUNDARY
- EXISTING FIRE DELUGE SYSTEM ABOVE ELEVATION 30'-0"
- EXISTING FIRE SPRINKLER SYSTEM ABOVE ELEVATION 30'-0"
- PROPOSED FIRE SPRINKLER SYSTEM ABOVE ELEVATION 30'-0"

PLAN
MEZZANINE LEVEL EL. 30'-0"

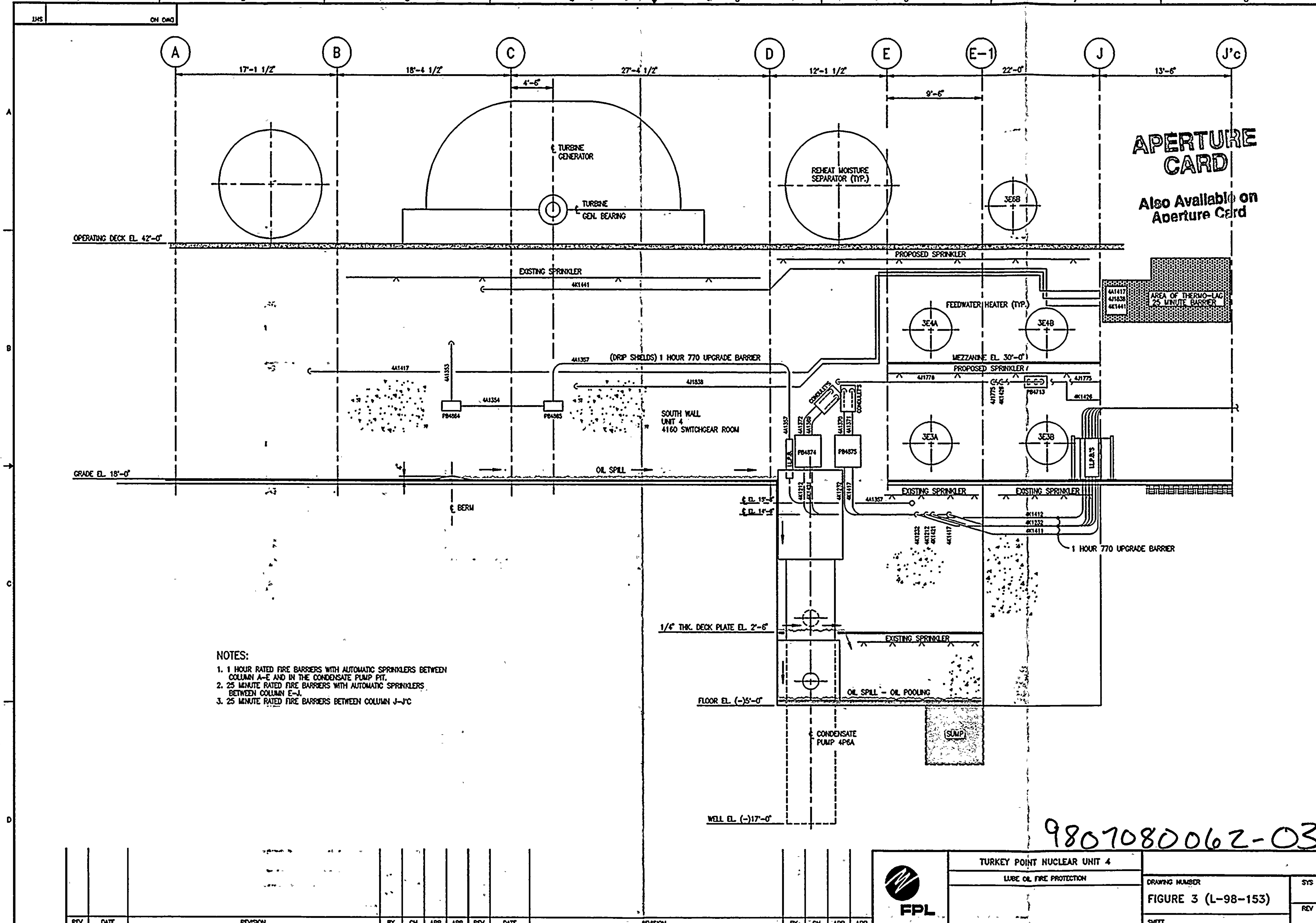
9807080062-02

REV	DATE	REVISION	BY	CH	APP	APP	REV	DATE	REVISION	BY	CH	APP	APP

FPL

TURKEY POINT NUCLEAR UNITS 3 & 4
GENERAL ARRANGEMENT
FIRE PROTECTION
MEZZANINE LEVEL
ELEVATION 30'-0"

FLORIDA POWER & LIGHT
DRAWING NUMBER
FIGURE 2 (L-98-153)
SYS
—
REV
SHEET



A
B
C
D
E
E-1
J
J'c
17'-1 1/2"
18'-4 1/2"
4'-6"
27'-4 1/2"
12'-1 1/2"
9'-6"
22'-0"
13'-6"
APERTURE CARD
Also Available on Aperture Card
TURBINE GENERATOR
TURBINE GEN. BEARING
REHEAT MOISTURE SEPARATOR (TYP.)
3E5B
OPERATING DECK EL. 42'-0"
PROPOSED SPRINKLER
EXISTING SPRINKLER
4K1441
AREA OF THERMO-LAG 25 MINUTE BARRIER
FEEDWATER HEATER (TYP.)
3E4A
3E4B
MEZZANINE EL. 30'-0"
PROPOSED SPRINKLER
(DRIP SHIELDS) 1 HOUR 770 UPGRADE BARRIER
4A1357
4A1417
4A1353
4A1354
PB4364
PB4365
4J1838
4J1778
4J1775
PB4713
4K1426
SOUTH WALL UNIT 4 4160 SWITCHGEAR ROOM
CONDULETS
PB4374
PB4375
3E3A
3E3B
ILPA'S
GRADE EL. 18'-0"
OIL SPILL
BERM
EXISTING SPRINKLER
EXISTING SPRINKLER
EL. 15'-6"
EL. 14'-6"
4K1412
4K1232
4K1411
1 HOUR 770 UPGRADE BARRIER
1/4" THK. DECK PLATE EL. 2'-6"
EXISTING SPRINKLER
OIL SPILL - OIL POOLING
FLOOR EL. (-)5'-0"
SUMP
CONDENSATE PUMP 4P6A
WELL EL. (-)17'-0"
NOTES:
1. 1 HOUR RATED FIRE BARRIERS WITH AUTOMATIC SPRINKLERS BETWEEN COLUMN A-E AND IN THE CONDENSATE PUMP PIT.
2. 25 MINUTE RATED FIRE BARRIERS WITH AUTOMATIC SPRINKLERS BETWEEN COLUMN E-J.
3. 25 MINUTE RATED FIRE BARRIERS BETWEEN COLUMN J-J'C
9807080062-03
REV
DATE
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REV
DATE
REVISION
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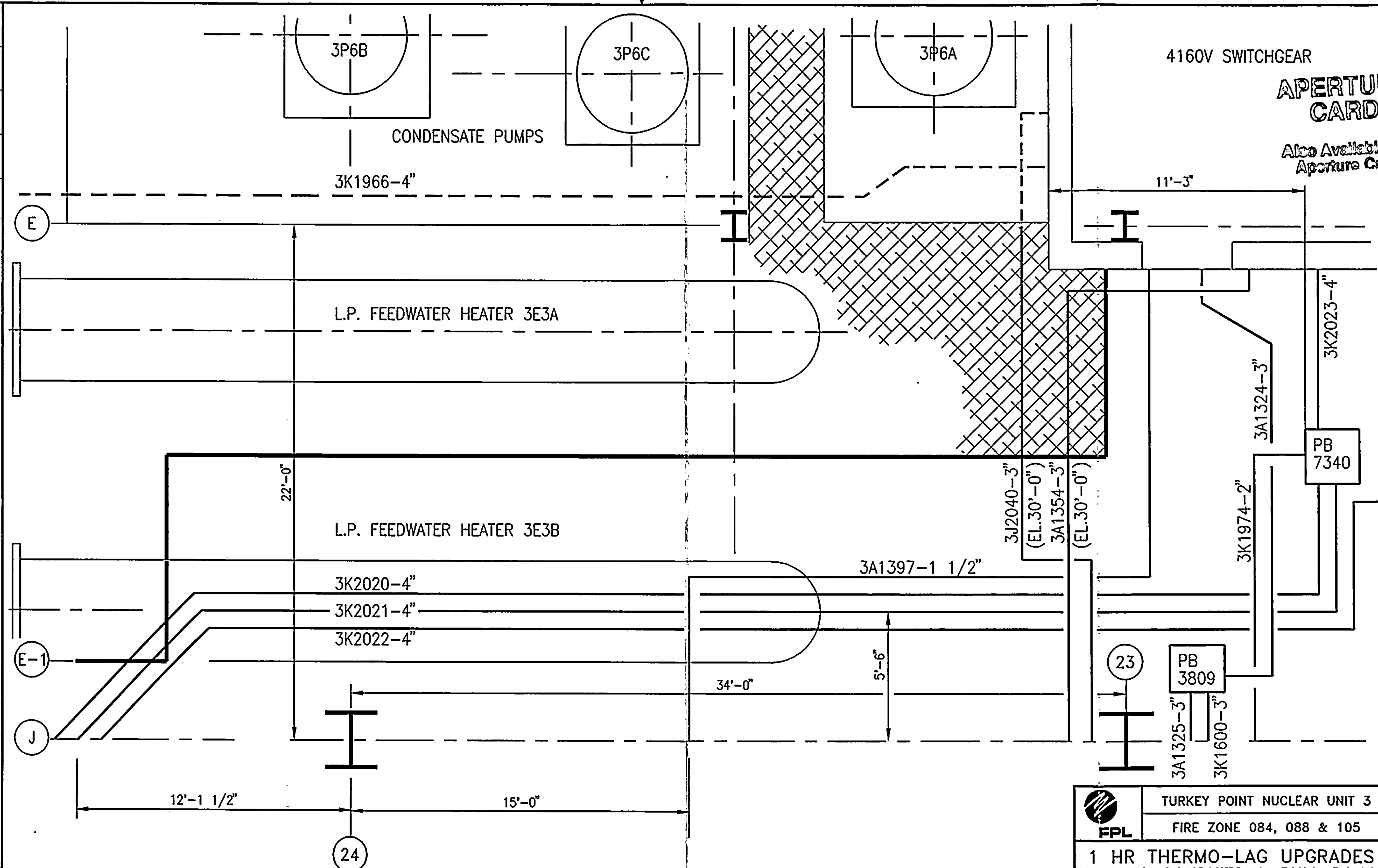
APP
APP
FPL
TURKEY POINT NUCLEAR UNIT 4
LUBE OIL FIRE PROTECTION
DRAWING NUMBER
FIGURE 3 (L-98-153)
SYS
REV
SHEET



APP	APP	CH	BY	REVISION	DATE	REV

FPL

TURKEY POINT NUCLEAR UNIT 3

FIRE ZONE 084, 088 & 105

1 HR THERMO-LAG UPGRADES
VARIOUS CONDUITS & PULL BOXES
PLAN @ EL.18'-0" & EL.30'-0"

DWG NO FIGURE 4 (L-98-153)

SYS

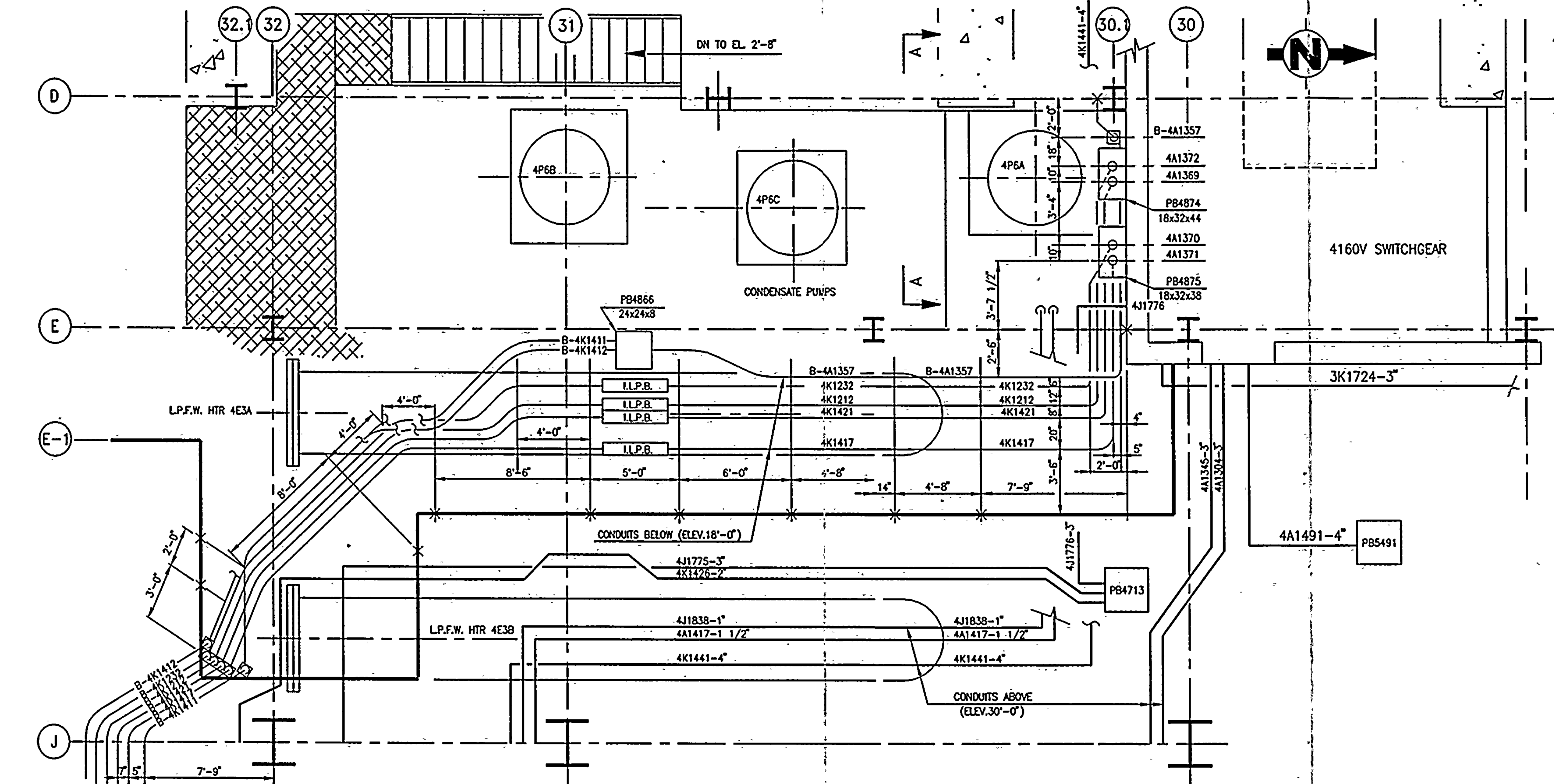
REV 0

SHEET 5

11 X 17 B SIZE 04/06/94

ptm004sh5.DWG

9807080062-04



APERTURE CARD

Also Available on Aperture Card

9807080062-05

TURKEY POINT NUCLEAR UNIT 4

FIRE ZONE 079 & 105

1 HR THERMO-LAG UPGRADES VARIOUS CONDUITS & PULL BOXES EL.30'-0", 18'-0" & BELOW

DWG NO	SYS
FIGURE 5 (L-98-153)	REV 0
SHEET 1A	

11 X 17 B SIZE 04/06/94

ptm004sh1A.DWG

REV | DATE | REVISION | BY | CH | APP | APP

FACTORY MUTUAL RESEARCH CORPORATION 10-7-57

FM

1151 BOSTON-PROVIDENCE TURNPIKE,
NORWOOD, MASS.

September 9, 1957

FIRE TESTS OF AUTOMATIC SPRINKLER PROTECTION FOR OIL SPILL FIRES

I INTRODUCTION AND ABSTRACT

At the request of the United States Atomic Energy Commission, the Factory Mutual Research Corporation has conducted a series of fire tests at their facilities at Norwood, Massachusetts. The purpose of the tests was to learn if automatic sprinklers will protect buildings, such as the Commission's gaseous diffusion plants, against fire in lubricating oil accidentally spilled on the floor.

Fire tests were made involving oil, at elevated temperatures, covering 2100 sq ft of floor, also at elevated temperatures, and employing various methods of ignition.

In all of the tests the floor fires were quickly controlled and minimized and the test building was satisfactorily protected by sprinkler discharge at relatively low pressure. In the fifth test an oil spray discharging from a nozzle above floor level provided an auxiliary fire against which the building was protected by low discharge from the sprinklers. The spray fire was not extinguished in this case and a steel structural member adjacent to it was not protected against severe local exposure.

It is concluded that the Atomic Energy Commission's gaseous diffusion plants can be satisfactorily protected by automatic sprinklers. In the case of floor spill fires alone, protection would be complete against general and individual structural failure and against involvement of insulated metal deck roof construction. In the event of additional fire in oil spraying from ruptured equipment, general structural protection would be maintained and involvement of insulated metal deck roof construction would be prevented. Failure of individual structural members could occur in this situation if such members were so located as to be exposed severely by the fire in the oil spray.

II. OBJECT

The principal objectives of the test program were based on fires in lubricating oil spilled on a level concrete floor, with both oil and floor

at temperatures which would be expected in a typical gaseous diffusion plant.

1. To determine rate of flame spread radially from a local ignition source with no fire protection.

2. To determine the minimum practical water discharge density from a sprinkler system required to control and to extinguish an oil spill fire.

3. To obtain with our test facilities information which would lead to a conclusion as to the effect of ceiling height around the order of 50 feet in bringing about any significant delay in operation of automatic sprinklers.

4. To determine, with and without sprinkler protection, the effect of an oil spill fire directly exposing structural steel in bringing about excessive steel temperatures and in causing elevated ceiling temperatures.

5. To obtain from test results information which, combined with previous test experience and judgment, might lead to an intelligent estimate of the number of sprinkler heads which might operate due to an oil fire, so as to assist in the design of an effective automatic sprinkler system.

6. Another objective which was developed during the test program was to determine whether a fire in hot lubricating oil discharged at a substantial rate in the form of an elevated spray could be extinguished or controlled by sprinklers within the range of ordinary discharge densities, and what the effect would be of a fire of this type on ceiling and exposed steel temperatures.

III TESTS

A. Method

All of the tests were conducted in the high ceiling area of the fire test building illustrated by photograph and sketches on pages 2A, 2B and 2C. This area measures 40 ft by 60 ft by 33 ft high and is equipped with a smooth level concrete floor. It has protected steel frame construction, 12 in. brick walls, and a vermiculite plaster on metal lathe ceiling suspended from steel beams which also support a poured concrete roof. The locations and sizes of doors, windows and roof hatches are given in the sketch on page 2B.

The sprinkler system employed in the tests is a standard arrangement of 24 standard spray sprinkler heads (8 in. below the ceiling) on 10 ft by 10 ft spacing. There are 4 heads on each of 6 branch lines all supplied by a single cross main. The cross main is fed by a riser, just inside the west wall of the test area, which in turn is supplied by underground piping from the pump room. In all of the tests the water supply to the sprinklers was controlled to provide a known discharge pressure at the head indicated in the sketch on page 2C.

Air temperatures 8 in. below the ceiling at the 6 locations shown in the diagram on Appendix Sheet 1 were measured by thermocouples (20 gauge, chromel-alumel). The temperature of the concrete floor was also measured by the same type of thermocouples imbedded 1 in. below its surface at locations shown on Appendix Sheet 1.

In order to evaluate the effect of fire exposure and protection on exposed steel structural members a steel test structure was erected in the building. Its construction and location are illustrated in the sketches on Appendix Sheet 2 and page 2C. The temperatures at 24 locations on this structure were measured during the tests by 20 gauge CA thermocouples imbedded 1/10 in. deep in the steel. Diagrams on Appendix Sheet 3 show the locations of the thermocouples.

A means of measuring rate of flame spread was provided by placing labeled firebricks standing on end on the floor at 5 ft intervals radially from the ignition point in the point source ignition tests. The time at which the flame front reached these markers was recorded by observers during the tests.

Since the tests were to simulate normal temperature conditions at the gaseous diffusion plants, a means was provided to heat the floor of the test area to at least 130° before each test and to heat the oil to at least 165° when spilled on the floor.

B. Procedure

The essential features of all fire tests were the same. They were:

1. The floor was heated to a specified temperature.

2. Lubricating oil (see Appendix Sheet 4 for properties) was heated to a specified temperature and spilled on the floor of the test area through a distribution system consisting of:

a. Perforated pipe (1-1/4 in.) located along the east and west ends of the floor and containing 3/16 in. diameter holes 1 ft on centers. The oil was pumped from the heated oil storage tank to this piping.

b. Drain connections (2 in. pipe) carrying oil by gravity head from the heated oil storage tank to two points on the floor at its south side approximately 15 ft from the east and west ends.

Three hundred and fifty gallons of oil was spilled on the floor in each test except the last. This gave a depth of 1/4 in. over the 2100 sq ft of level floor in the test area. ("Hi-Sect." frame area, 2400 sq ft, less wall thickness areas, drainage trench area and ramp areas equals 2100 sq ft). Typical total time to spill 350 gallons of oil was 4-1/4 minutes.

3. The oil was ignited. (Method and location for each test are described under "Tests".)

4. Following ignition the rate of flame spread, the burning characteristics of the oil and the visible effect of sprinkler discharge were recorded by observers. The temperatures of the floor, of the air at the ceiling and of the steel test structure were recorded by instruments.

5. Sprinkler discharge was either automatic (natural) or manual (by opening a valve supplying open heads) depending on the individual test requirements. In all cases the discharge pressure was controlled.

C. Test Conditions and Results (Tabulations of the test conditions and observations are included in the Appendix of this report (Sheets 22 and 23). The following descriptions include only the essential information.)

Test 1.

The primary purpose of the first test was to determine the rate at which fire spreads in the oil. Therefore, open sprinkler heads were used and the water supply was withheld from them until visual observation of fire spread had become impossible so that all possible data on uninhibited spread of fire in the oil could be obtained.

The temperature of the oil when spilled on the floor was 165 to 170° and the temperature of the floor was 130° when the oil was ignited.

A fire was started in the oil at the base of the steel structure's central column by four gasoline-wet cellucotton ignitors* located one at each corner of the column. Because these were slow to start the oil burning, a handful of excelsior was added at two of the corners at 15-1/2 min after the original ignitors were lighted.

Flame spread in the oil was established at about 16 min and continued at an accelerating rate. This rate is illustrated by the graph on Appendix Sheet 5 which is a plot of the data recorded by four observers.

When the radius of the burning area had increased to 15 ft the air temperature at the ceiling was at 1200° and increasing rapidly. Therefore, water was supplied to the sprinklers at 20 min, 45 sec (approx. 5 min after the start of fire spread) at a controlled pressure of 5 psi at the heads (.13 gpm/sq ft).

* These ignitors consist of rolls (2-3/4 in. diameter, 6 in. long) of 20 ply cellucotton wadding each weighing 2-1/4 ounces, dry. As used in these tests they contained 6-3/4 ounces of gasoline each, absorbed in the roll.

Smoke prevented a precise observation of the time when the fire was controlled but it was possibly as early as 1/2 min. after the beginning of sprinkler discharge and definitely by 1-3/4 minutes. At that time only lingering flame remained along the foot members of the steel structure. This fire could have been completely extinguished by continued sprinkler discharge but in order to prevent heat loss from the floor to the sprinkler water, which would delay preparation for the following test, the sprinkler water supply was turned off and the lingering fire extinguished by a 1-1/2 in. hose spray nozzle 3-3/4 min after the start of sprinkler discharge.

Temperature records on Appendix Sheets 6, 7, and 8 illustrate the intensity and duration of fire exposure to the building and steel structure during the test.

Test 2.

The object of the second test was to determine the effectiveness of automatic opening of sprinklers as compared to the delayed manual control used in the first test. Standard, upright, 212° heads were used.

The oil temperature when discharged onto the floor was 170 to 175° and the temperature of the floor itself was 138° at ignition. The air temperature under the ceiling was 105° F. Both roof hatches (total 56 sq ft) were opened at the time of ignition.

The ignition source was located at the base of the steel structure as in Test 1. but consisted of a quantity of commercial oil-absorbent ("Speedi-Dri") at each corner of the column; the saturated oil-absorbent being ignited by 1/4 size gasoline-wet cellucotton ignitors. This also resulted in a slow start and fire was not established in the oil until about 18-1/4 minutes. However, the usual accelerating flame spread rate followed.

The first automatic sprinkler operated 17 sec after the burning area had grown to a radius of 5 ft (19 min, 57 sec after the start of the test) and several additional heads operated quickly thereafter. (Sprinkler control pressure was 5 psi = .13 gpm/sq ft discharge density.)

The maximum observed fire spread radius was 6 ft at 18 sec after the first head opened but the fire was knocked down and reduced to a lingering flame at the base of the steel structure one minute after the first head opened. Again, in order to preserve floor temperature, the sprinkler water supply was turned off and the lingering flame extinguished by hose stream at 25 minutes.

A total of 17 heads opened during the fire period. The pattern of these openings is shown on Appendix Sheet 21.

Temperature records on Appendix Sheets 9, 10, and 11, compared to those of Test 1. illustrate the rapid control of the fire produced by the automatic (natural) operation of the sprinklers.

Test 3.

Since the ceiling height in the test area is less than in some areas of the gaseous diffusion plants, it was desired to simulate the effect of added ceiling height by providing additional upper ventilation in Test 3.; the purpose being to determine if an appreciable delay in operation of automatic sprinklers would result. Therefore, 5 upper window units on the south and west faces of the "Hi-Sect."were opened before the test in excess of the two hatch openings used in Test 2. The total ventilation area was 161 sq ft.

In addition the ignition method was changed in order to eliminate the long delay in establishing burning in the oil as experienced in the first two tests. The new method consisted of pouring one pint of a 50-50 mix of gasoline-kerosene into the oil at each corner of the steel structure H-column at its base. This priming fluid was ignited immediately after pouring so the size of the ignition area was no greater than in the previous tests.

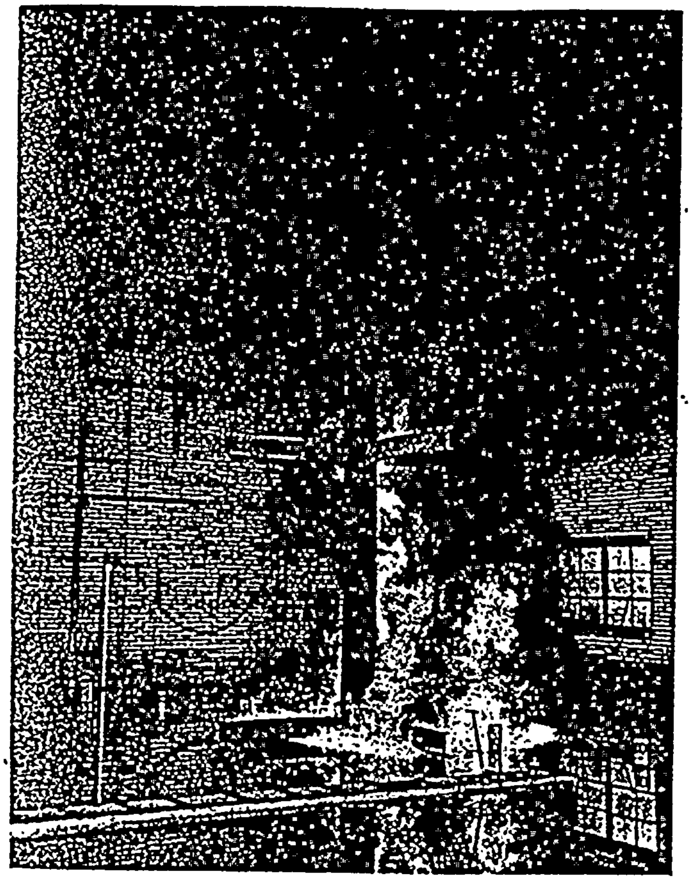
Protection was the same as in Test 2. That is, 24 automatic, standard, upright, 212° sprinkler heads with the discharge pressure controlled at 5 psi = .13 gpm/sq ft.

The temperature of the oil when spilled on the floor was 180 to 185° and the temperature of the floor was 133° when the oil was ignited. The ceiling air temperature was 95° F.

A spreading fire in the oil was established without delay and the radius of the burning area reached 5 ft at 1 min, 25 sec and 6 ft at 1 min 45 seconds The first automatic sprinkler operated at 2 min, 1 sec at which time the fire area radius probably did not exceed 7 feet. Additional heads operated at 2 min, 7 sec and the fire was almost completely extinguished at 2 min, 20 sec at which time lingering small flames persisted only at the north side of the steel structure foot members.

The sprinkler water was turned off and a 1-1/2 in. hose spray nozzle used to mop-up at 3 min 55 sec in order to preserve floor temperature.

Photographs on page 6A show the behavior of this fire before and just after the first sprinkler discharge. It should be borne in mind that the photographs contained in this report indicate the conditions existing only at the very early stages of the fire. The very nature of a lubricating oil fire produces extremely large volumes of heavy, dense, black smoke (see photograph on page 2A) precluding the taking of pictures, still or motion,



Test 3 - Before sprinkler discharge.
Time - about 1 min., 15 sec.

(306-3)

Test 3 - Just after initial sprinkler discharge.

(306-4)

shortly after the initial spread of fire. In fact, the smoke density became so great in from 2 to 5 min after the initial spread of fire that visual observation at floor level was usually impossible.

Eleven heads opened in this test in the pattern illustrated by the diagram on Appendix Sheet 21. It is noteworthy that the time required for sprinklers to operate after fire spread was established in the oil was 2 min in this test compared with 1-3/4 min in Test 2.

Temperature records on Appendix Sheets 12, 13, and 14 again illustrate the quick control of the fire produced by automatic operation of the sprinklers.

Test 4.

The purpose of this test was to determine the action of sprinklers against a fire that might occur in a large spill of oil at or near its flash point or with simultaneous ignition in several locations. Under such conditions a flashover would be expected and a large area of oil would be burning before heat could reach the ceiling to actuate sprinklers. This test also indicates the effect of a delayed water supply to the sprinklers.

In order to simulate this situation the oil spill was ignited in six locations and allowed to burn freely while withholding water from open sprinklers until a large area of oil was burning. Also to simulate added ceiling height all 8 upper window units and the "Hi-Sect." roof hatches were open. Total upper ventilation area was 224 sq ft.

The sprinkler heads were, in effect, all open for this test. Actually the 11 heads open after Test 3. were open and the remaining 13 heads undoubtedly fused before water was supplied to them. They were all 212°, standard upright heads and the discharge pressure was again controlled at 5 psi = .13 gpm/sq ft.

At the time the oil was spilled on the floor it was at 184°. The floor was not heated since its temperature would not affect the test and at test time it was 109°.

The oil was ignited by tipping containers of burning priming fluid into it at 6 locations simultaneously. There was 1 pt of 50-50 gasoline-kerosene mix in each container and they were located in a symmetrical pattern 20 ft on centers.

Six circular burning areas of increasing diameter resulted. Typical diameter growth was 5 ft at 55 sec; 7 ft at 1 min, 15 sec; 10 ft at 1 min, 35 seconds. Two fires merged north and south at 1 min, 40 sec and two more at 1 min, 45 sec at which time the signal for supplying water to the sprinklers was given. Water actually began discharging from the heads at 1 min, 50 seconds.

At that time the total burning area was estimated to be 1400 sq ft or ap mately 2/3 of the whole oil surface. Because observers were forced out t building, no precise observation was made of the time when the fire was extinguished but it was between 2-1/3 and 4 minutes. During the period befo extinguishment flames issued 5 to 10 ft out from the upper windows and from the roof hatches to an unestimated height.

All heads in the sprinkler system were open at the end of the test.

It will be noted in the temperature records of this test on Appendix Sheets 15, 16, and 17 that the recording instruments were off for a period of approximately 1 minute. This was caused by the shorting of an actuating circuit by radiant heat from the fire. On the basis of other supporting observations it is believed that the maximum temperatures were recorded before the power failure.

When water was supplied to the sprinklers the ceiling temperature was 1200°. This shows that water was withheld beyond the time normally required for automatic sprinklers to operate. Nevertheless, the fire was brought under control quickly without damaging effects to the building.

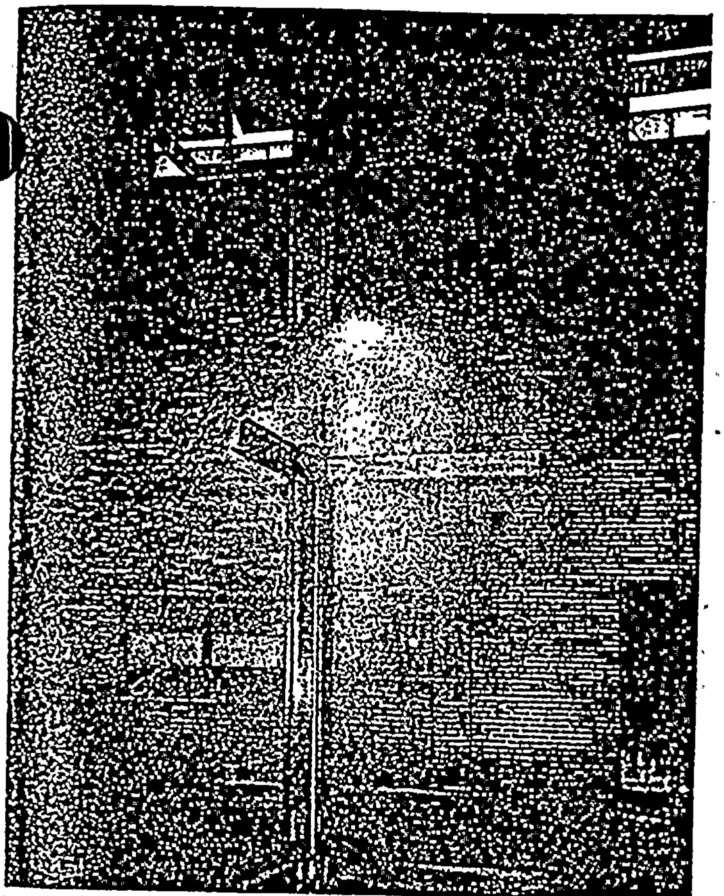
Test 5.

The object of this test was to determine the effect of an additional fire such as might occur in oil spraying from ruptured equipment. Other conditions as regards the oil spill fire were the same as in Test 3. exca that approximately 700 sq ft of floor area at the east end of the test area was cut off from the spill area by curbs to conserve oil supply for the spray fire. Actually 290 gal of oil was spilled on a 1400 sq ft floor area. The temperature of the oil when spilled was 165 to 170° and the floor was 117° at ignition.

The oil leakage fire was simulated by pumping oil to a nozzle (open "Automatic" 38-600B, SSU head with .316 in. tapered orifice) located 12 ft above the floor and 2 ft southeast of the steel structure H-column. Pumping to this overhead nozzle, at a rate of 10.8 gpm, was begun at 1 min, 23 sec after the floor fire was started.

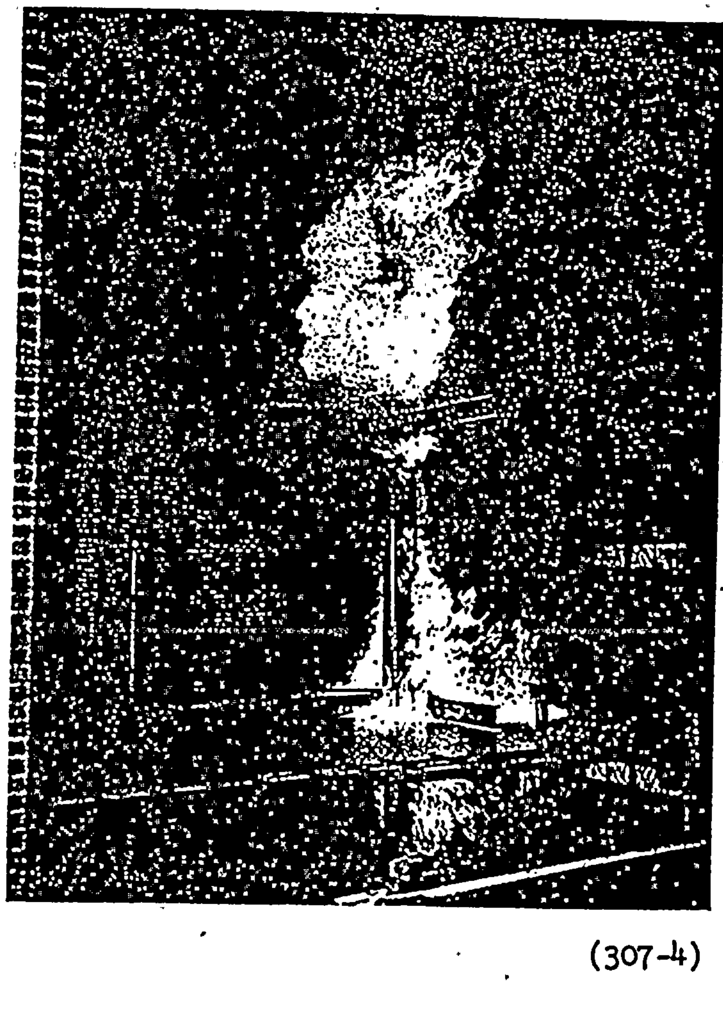
As far as the floor fire was concerned it developed in the usual fashio The radius of the burning area was 5 ft at 1 min, 35 sec and it did not excee 6 ft except momentarily. It was controlled by the sprinklers, the first of which operated at 1 min, 39 sec, and it was minimized in less than 3 minutes.

The spray fire, on the other hand could not be extinguished. Photographs on pages 8A and 8B show the form of the oil spray and the behavior o the fire that developed from it. This fire caused all of the sprinkler heads to open (probably by 2-1/2 min) and, although the floor fire was controlled and the building itself protected against the exposure from both fires by the 5 psi discharge, the steel structure continued to register temperature



(307-2)

Test 5 - Shape of oil spray from elevated nozzle. (Not burning)



(307-4)

Test 5 - Oil spray fire before sprinkler discharge. (Spattering in oil on floor is from unburned oil falling from spray fire.)

(307-5)

Test 5 - Oil spray fire
after sprinkler discharge began

in the range from 1400° to 1800°. Therefore, the sprinkler discharge pressure was increased as follows:

At 3 min, 20 sec pressure to 10 psi = .19 gpm/sq ft density
At 5 min, 0 sec pressure to 15 psi = .23 gpm/sq ft density
At 5 min, 30 sec pressure to 18 psi = .25 gpm/sq ft density
At 6 min, 45 sec pressure to 28 psi = .31 gpm/sq ft density
At 8 min, 0 sec pressure to 38 psi = .36 gpm/sq ft density

This increased water discharge prevented further increase of the steel structure temperature but it did not reduce the temperature. Therefore, at 10 min the oil supply to the overhead nozzle was shut off. All temperatures (See Appendix Sheets 18, 19, and 20) decreased quickly and the sprinkler water was shut off at 13-1/2 min with the usual mop-up by hose stream.

IV CONCLUSIONS

1. Once a fire has been established and begins to spread beyond the ignition source, the rate of flame spread is relatively rapid and increases as the fire progresses. It requires about 1-1/2 to 3 minutes (depending upon strength of ignition source) to spread to a radius between 4 and 5 feet, about 1-1/2 minutes from 5 feet to 10 feet radius, and only about 30 seconds for 10 feet to 15 feet radius. (Observations beyond about 15 to 16 feet could not be made in our tests on account of loss of visibility due to smoke.)

Once an oil spill has been ignited and spreading of flame begun, the rapid growth of fire and volume of smoke produced indoors is such that effective manual fire fighting can only be done within a period of about 5 or possibly 6 minutes from initiation of spread.

2. Automatic sprinklers will stop the spread and extinguish the fire in an oil spill on the floor at a discharge density of 0.13 gpm/sq ft, - with some margin of safety.

3. There would be no serious delay in operation of automatic sprinklers at an elevation of about 50 or 60 feet from a floor spill fire in a large area as compared to results in the test building with a 33 foot ceiling height with no upper ventilation. The delay in operation would be about 15 seconds representing an increase in fire radius of from about 6 feet to 6-2/3 feet.

4. With a floor spill fire around a building column but with automatic sprinkler protection, the results indicate no temperatures which would result in failure of structural steel. However, serious distortion and actual column failure would be expected within a period less than 10 minutes without automatic sprinklers in service.

Where oil may be discharged in the form of a spray at an elevation above floor level, whether or not there is initially any substantial oil

spill on the floor, a fire under these conditions may bring about failure of exposed steel in the immediate vicinity of the fire. The discharge from automatic sprinklers at any practical density may not extinguish the spray fire. There is no other economically practicable automatic fire protection means available which will extinguish such a spray fire at any one of a large number of possible locations distributed over a wide area, even if it were considered necessary to extinguish.

However, automatic sprinklers, even at flowing pressures as low as 5 psi, will afford reliable fire control by limiting dangerous temperatures for both structural steel and roof areas to a location of relatively small radius laterally from the oil spray fire. Consequently, for as long as sprinkler discharge can be maintained, serious damage should be well localized.

5. Our tests indicate that, with an oil spill fire on the floor and a single small ignition source not over 2 to 3 ft in diameter, the number of automatic sprinklers which might be expected to operate when supplied at 5 psi pressure would probably not exceed 15 heads. Even under somewhat unfavorable conditions of interference with sprinkler distribution by piping or structural elements no more than 20 heads would be expected to open.

If a fire should start and spread in an oil spill fire involving several hundred gallons of oil with the water supply to sprinklers shutoff, large numbers of heads would be expected to open so that the water discharge density following delayed restoration of water supply might be reduced to a totally ineffective value.

It is difficult to estimate the number of sprinkler heads which might be operated in the event of a continuous well distributed fine oil spray fire, but our best estimate based on the test results and our background of previous experience is that we might expect the number of heads to be opened eventually would be in the order of from 40 to 60 heads for an oil spray around 10 gpm, and for larger oil spray discharge rates a correspondingly greater number of heads. If a break should occur releasing oil in a solid stream or with poor distribution and a minimum of atomization, a smaller number of heads might be opened even at larger oil discharge rates.

Considering the construction and occupancy of these plants, it is expected that properly designed automatic sprinkler protection would

be effective despite the opening of large numbers of heads, in view of the strong water supplies now being contemplated for the sprinklers.

FACTORY MUTUAL RESEARCH CORPORATION

Norman J. Thompson

Norman J. Thompson,
Vice-President

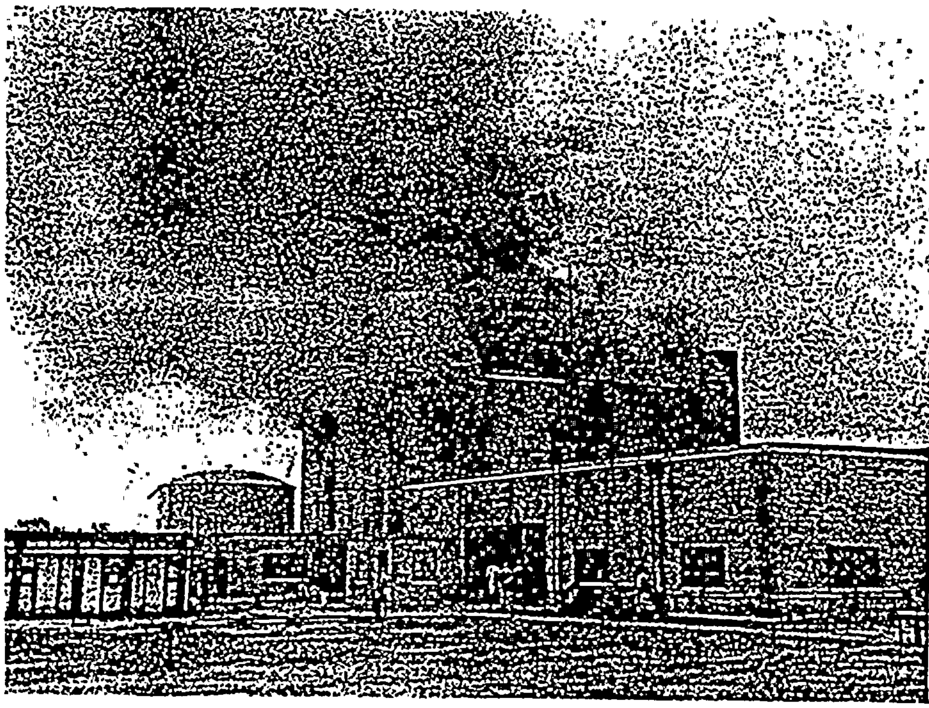
NJT:RJ-150

REPORT BY: N. J. Thompson
J. B. Smith
E. W. Cousins
P. E. Cotton

TESTS BY: Test Station Staff

ORIGINAL DATA: Notebook No. 155

ATTACHED: Appendix - 23 Sheets

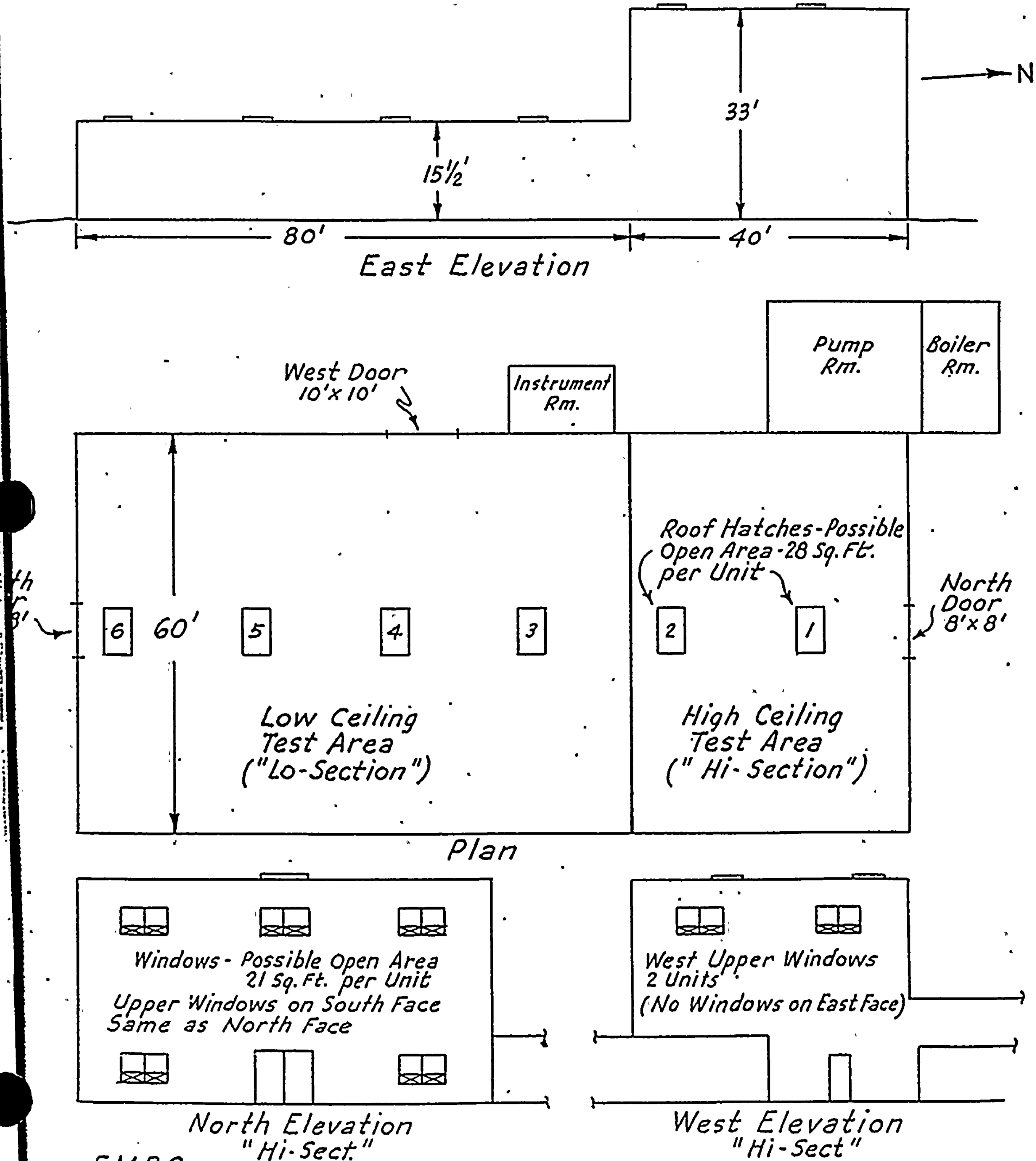


(307-10)

View of fire test building from southwest.
(Photo taken during Test No. 5).

Diagram of Test Areas and Openings
Building No. 18

Vertical Dimensions Are Clear
Horizontal Dimensions Are Frame Dimensions
Scale 1" = 20'



FMRC
Norwood, Mass.

Rpt. No. 13434
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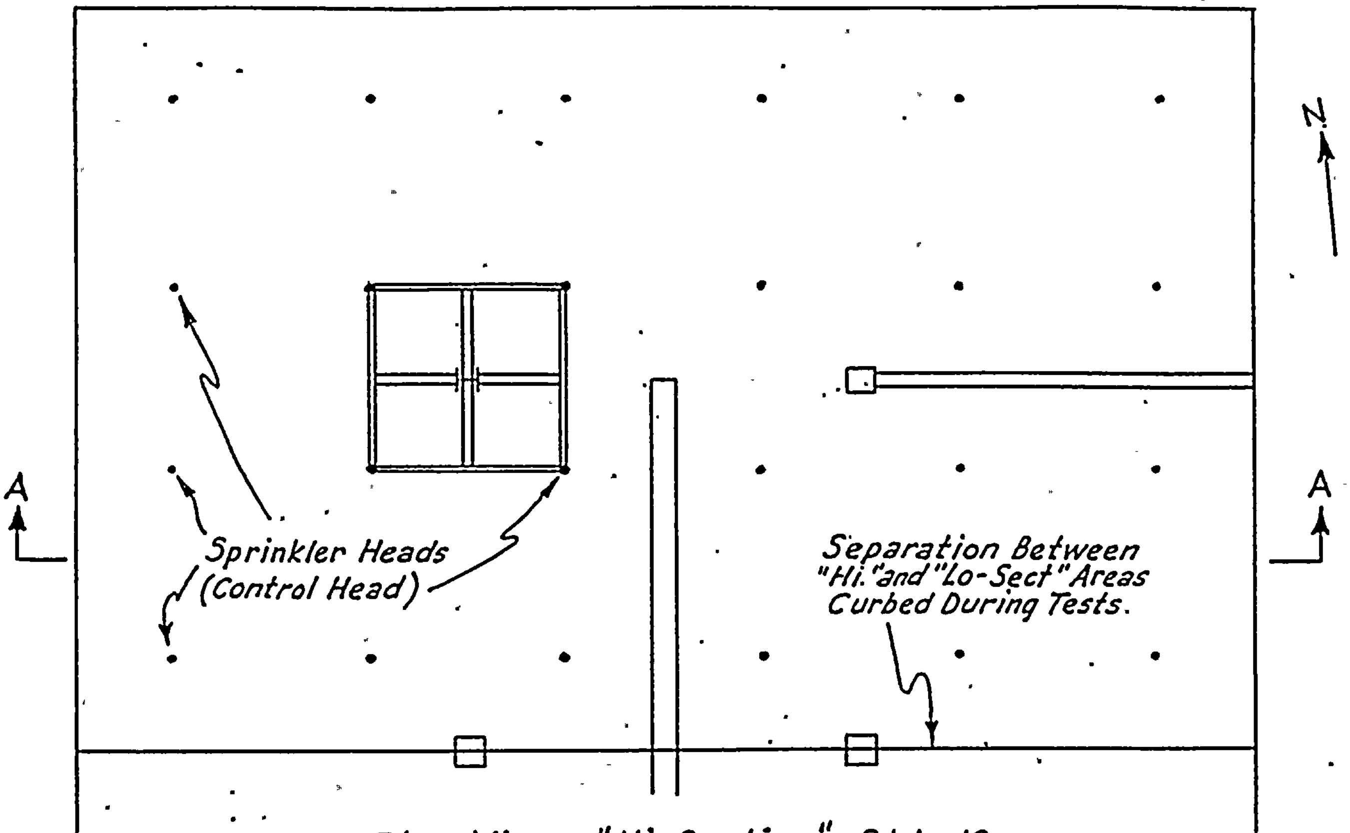
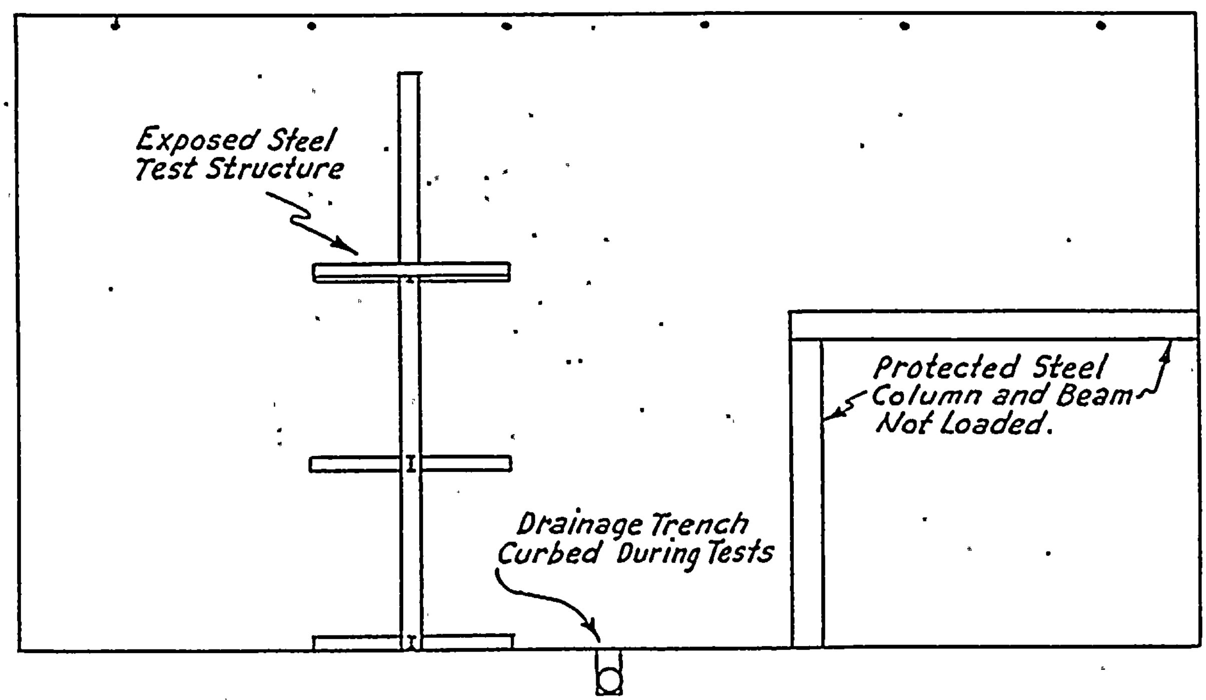
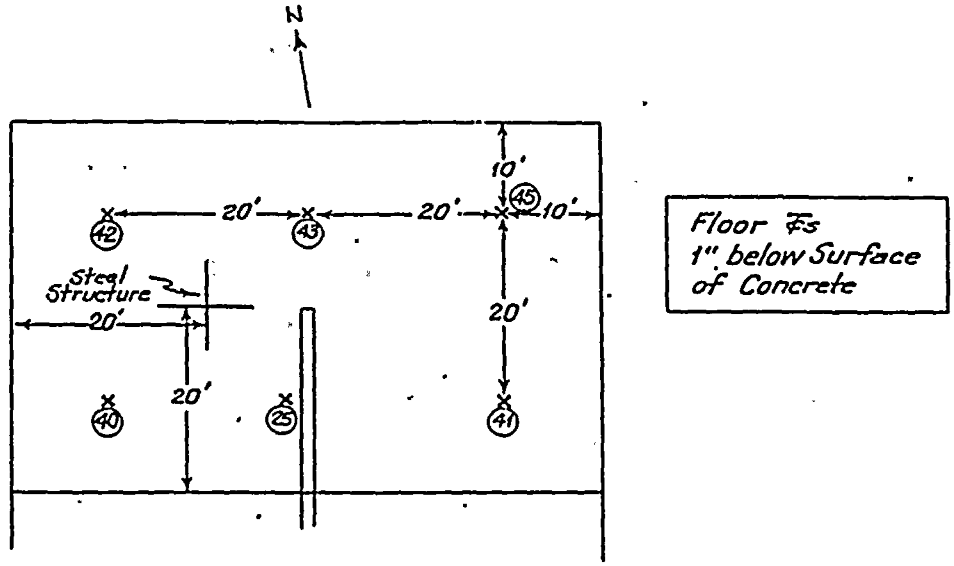


Plan View – "Hi-Section" – Bldg. 18

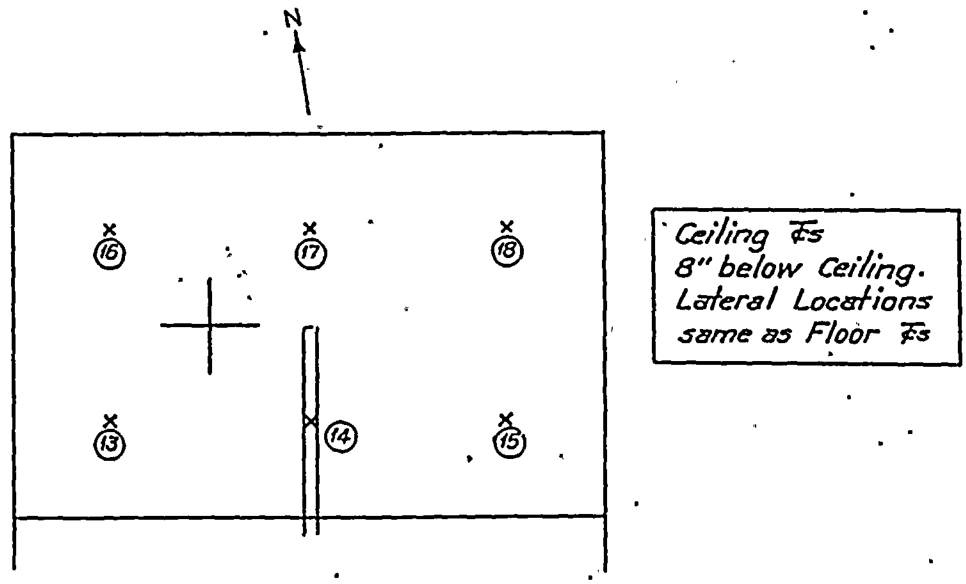


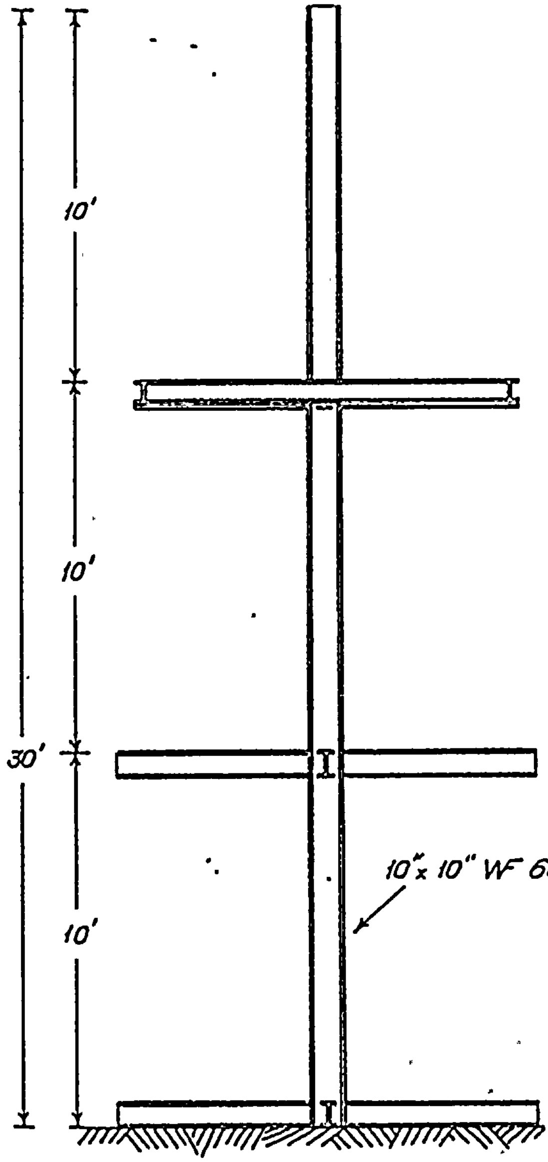
Section A-A

LOCATIONS AND IDENTIFICATIONS OF FLOOR AND CEILING THERMOCOUPLES 13434

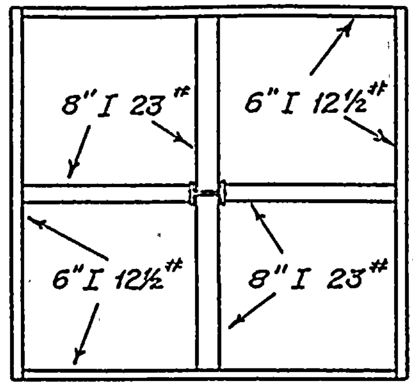


Plan Views High Sect. Bldg. 18

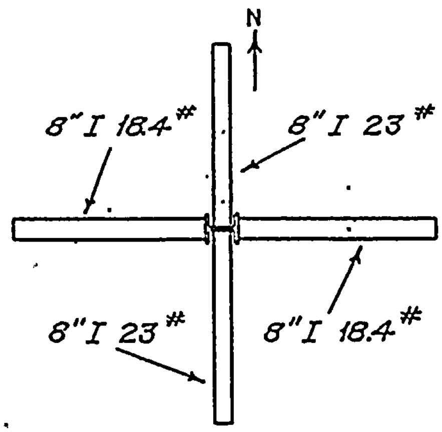




North or South
Elevation



Plan at 20 ft. Level

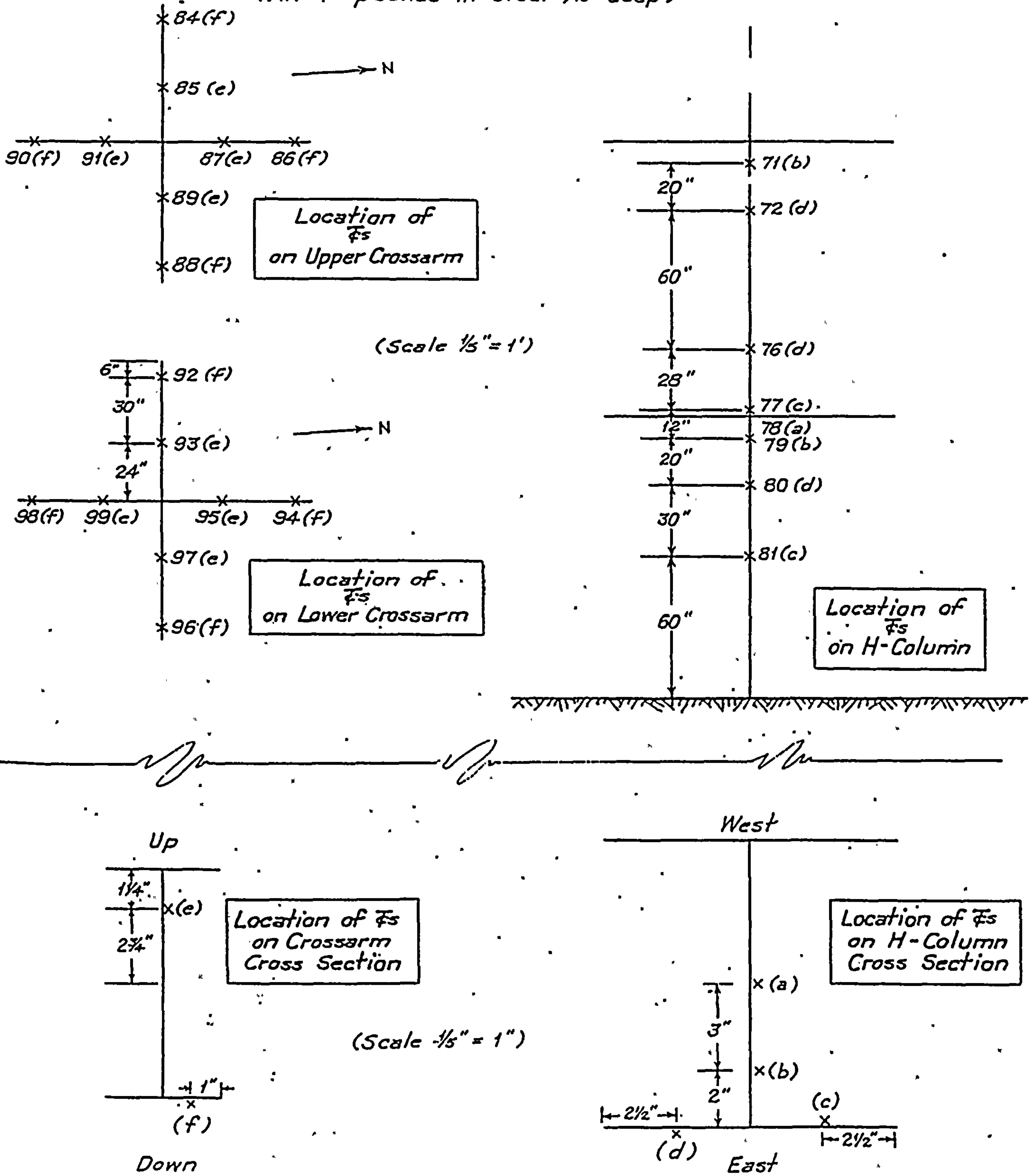


Plan at both the 10 ft.
& Floor Levels

STEEL TEST STRUCTURE

All 8" I Beams at both the 10 ft. & Floor Levels are 5' long. The Members forming the 20 ft. Horizontal Level were cut to make a 10' x 10' Square. The Assembly was formed by Elec. Arc Welding.

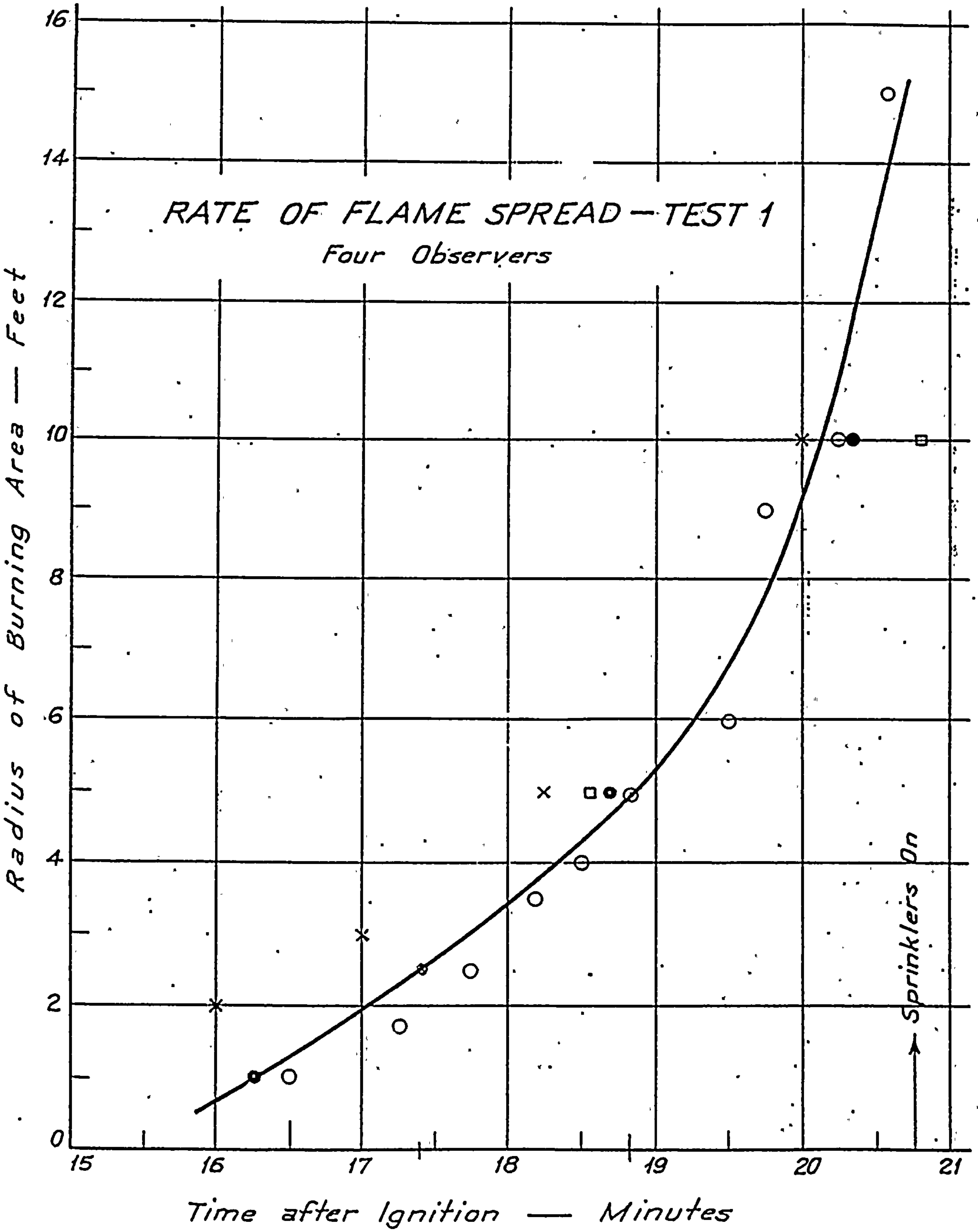
LOCATION OF THERMOCOUPLES ON STEEL STRUCTURE
13434
(All Tcs peened in Steel 1/10" deep)

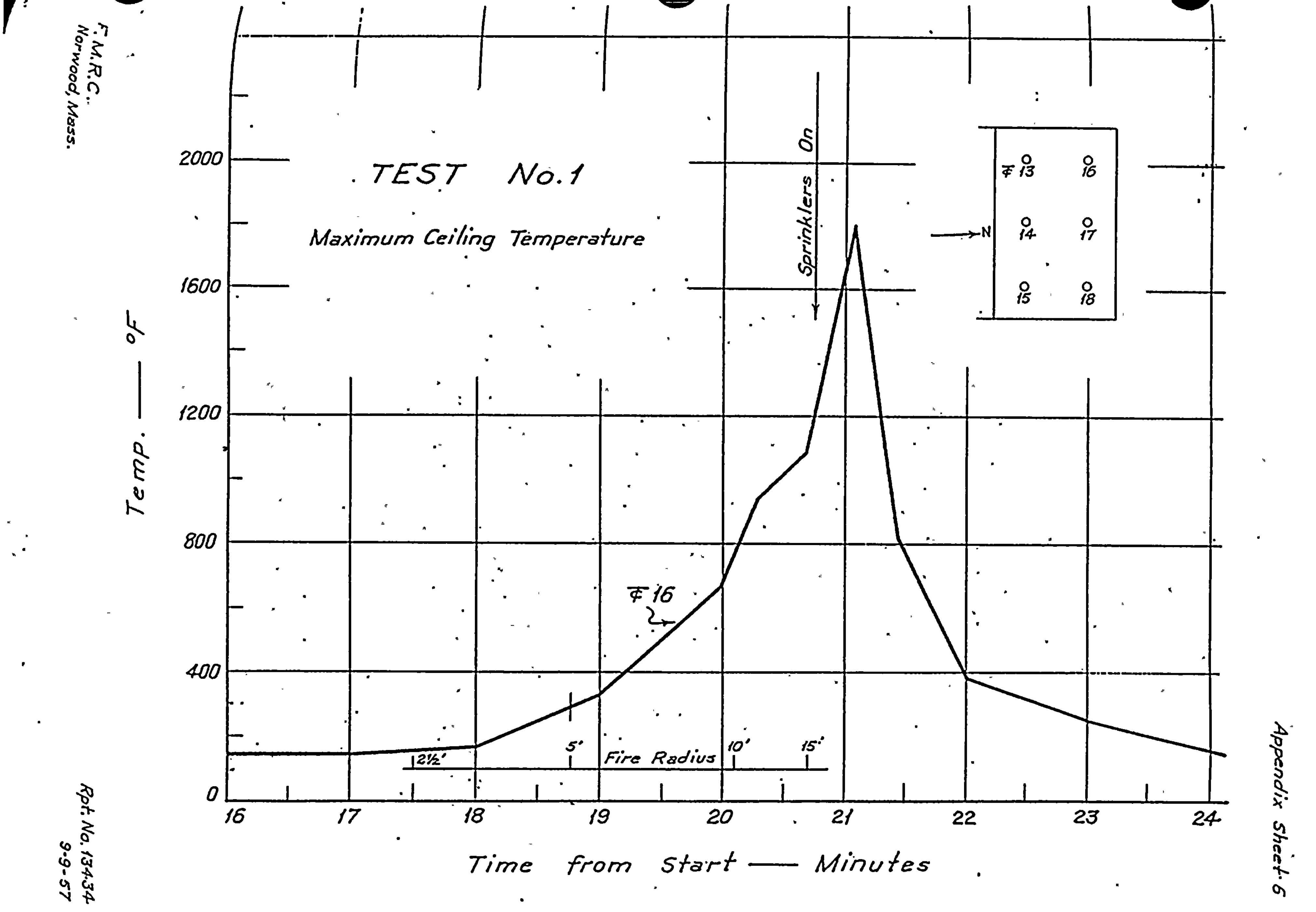


PROPERTIES OF LUBRICATING OIL USED

Test No.	Type of Oil Used	Viscosity 77° F	Viscosity 165° F	O.C. Flash Point - °F	O.C. Fire Point - °F
1, 2, and 3	Gulf - "Paragon 41"	5 min, 36 sec	59 sec	345	365
4 and 5*	86% Gulf-"Par. 38") 14% Gulf-"Par. 41")	3 min, 28 sec	48 sec	345	355

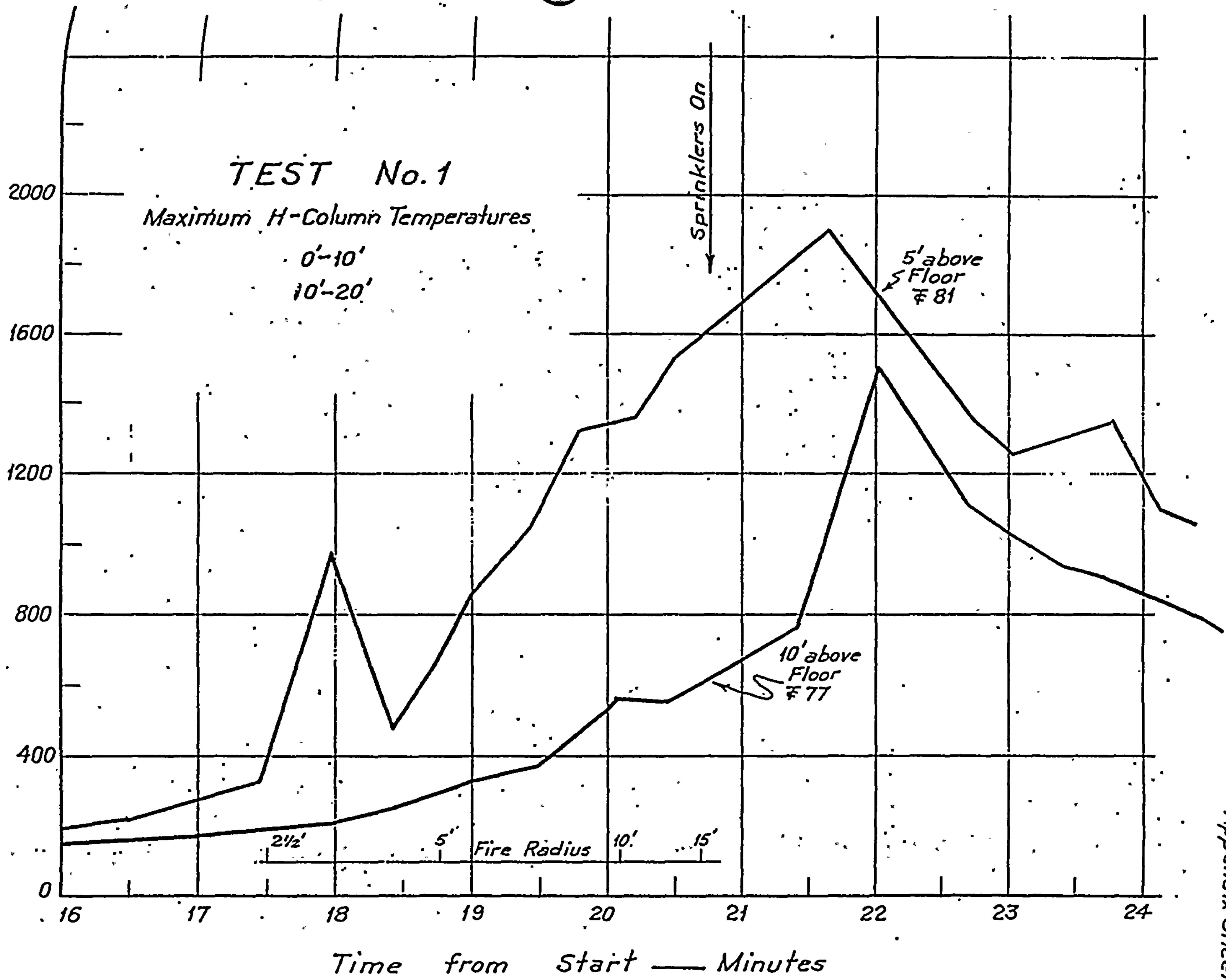
*Proportions are by volume. The original intent was to use Gulf "Paragon 41" throughout. Gulf "Paragon 38" was used in the proportions shown due to an inadequate supply of Gulf "Paragon 41".


RATE OF FLAME SPREAD — TEST 1
Four Observers
Radius of Burning Area — Feet
Time after Ignition — Minutes
Sprinklers On
0
2
4
6
8
10
12
14
16
15
16
17
18
19
20
21



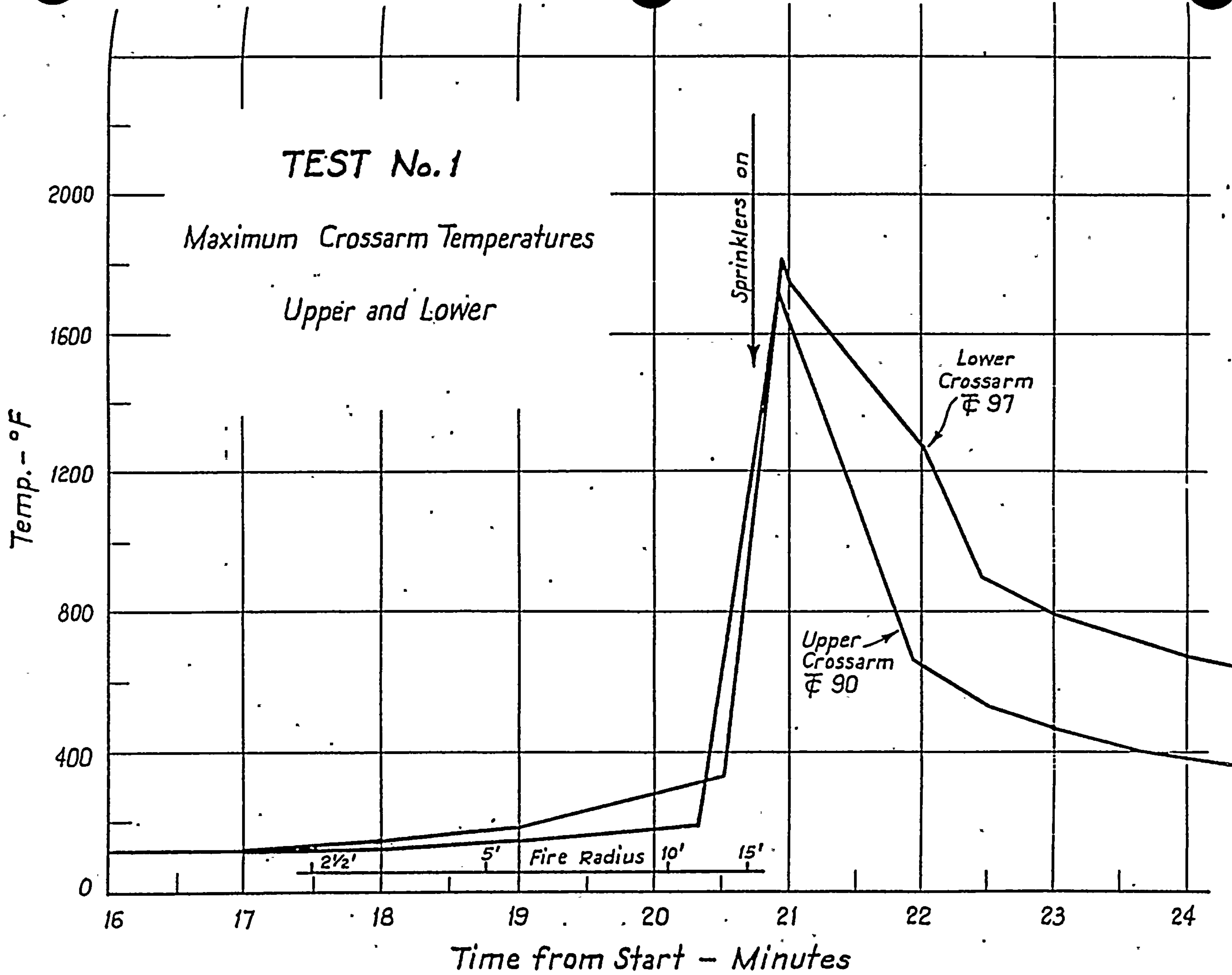
F.M.R.C.
Norwood, Mass.
TEST No.1
Maximum Ceiling Temperature
Sprinklers On
Temp. — °F
2000
1600
1200
800
400
0
13
16
N
14
17
15
18
16
2½'
5'
Fire Radius
10'
15'
16
17
18
19
20
21
22
23
24
Time from Start — Minutes
Rpt. No. 13434
9-9-57
Appendix Sheet 6

F.M.R.C.
Norwood, Mass.



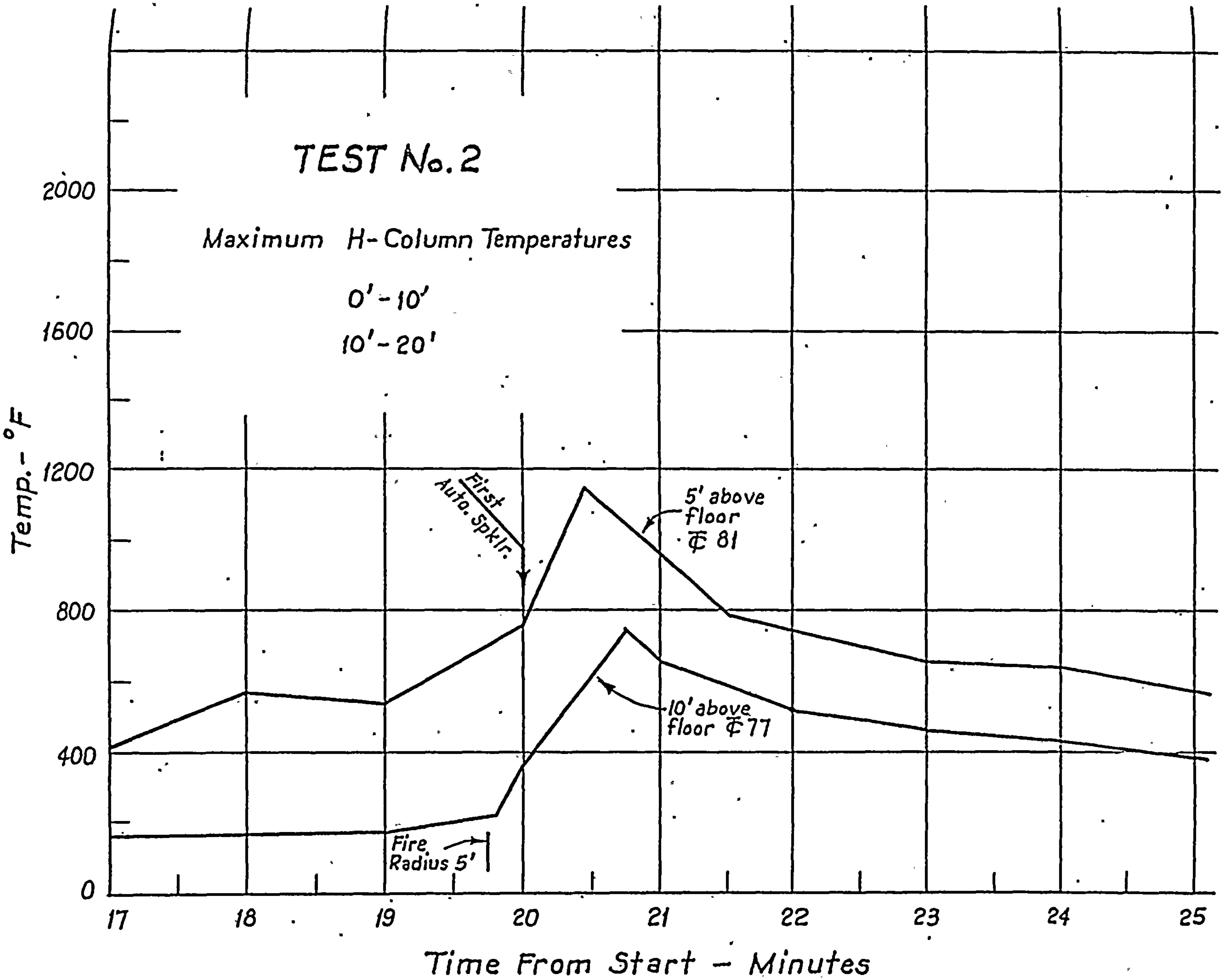
Rpt. No. 13434
9-9-57

FMRC
Norwood, Mass.

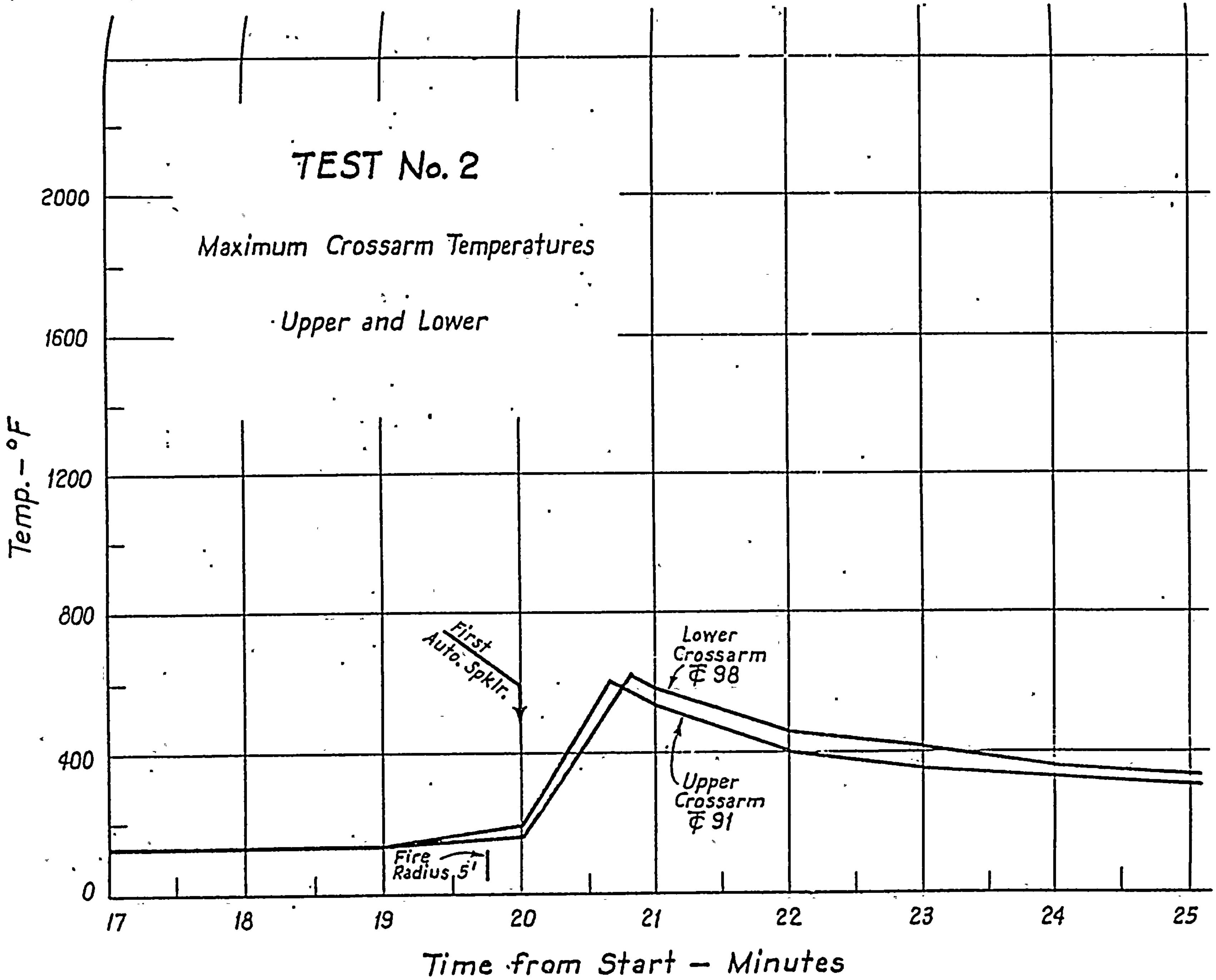


Rept. No. 13434
9-9-57

Appendix Sheet 8


TEST No. 2
Maximum H-Column Temperatures
0'-10'
10'-20'
Temp. - °F
2000
1600
1200
800
400
0
First Auto. Spklr.
5' above floor ℄ 81
10' above floor ℄ 77
Fire Radius 5'
17
18
19
20
21
22
23
24
25
Time From Start - Minutes

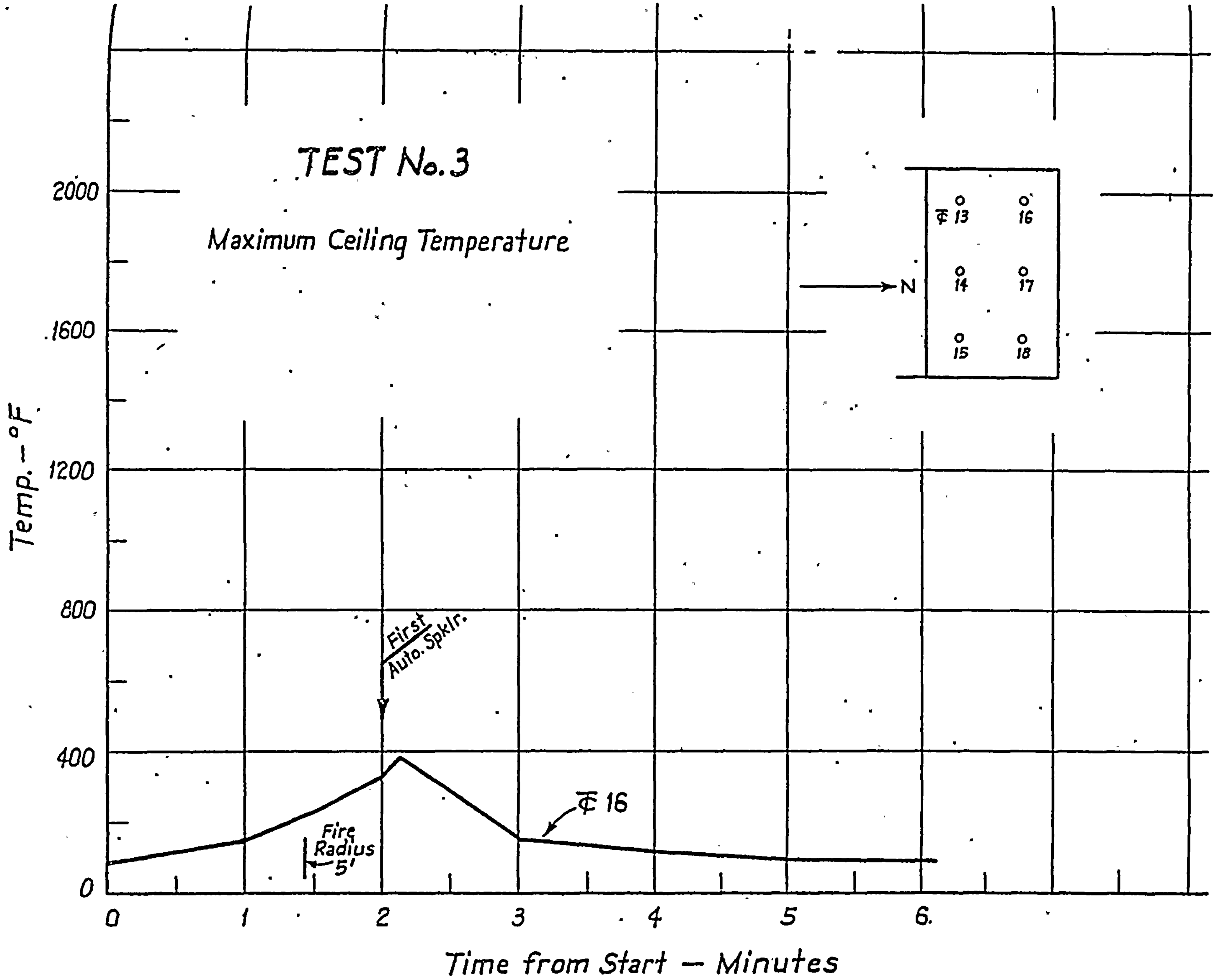
FMRC
Norwood, Mass.



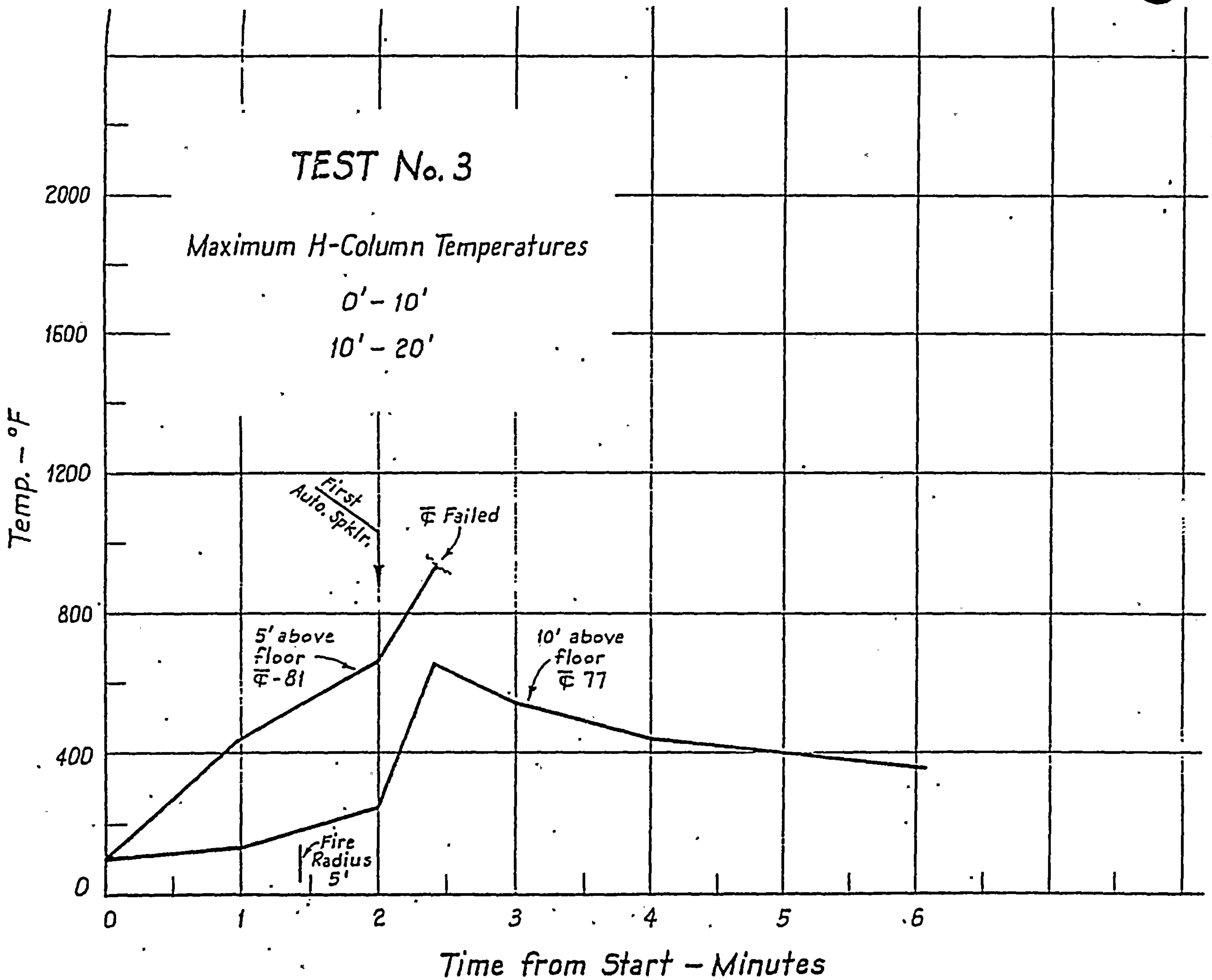
Rept. No. 13434
9-9-'57

Appendix Sheet 11

FMRC
Norwood, Mass.

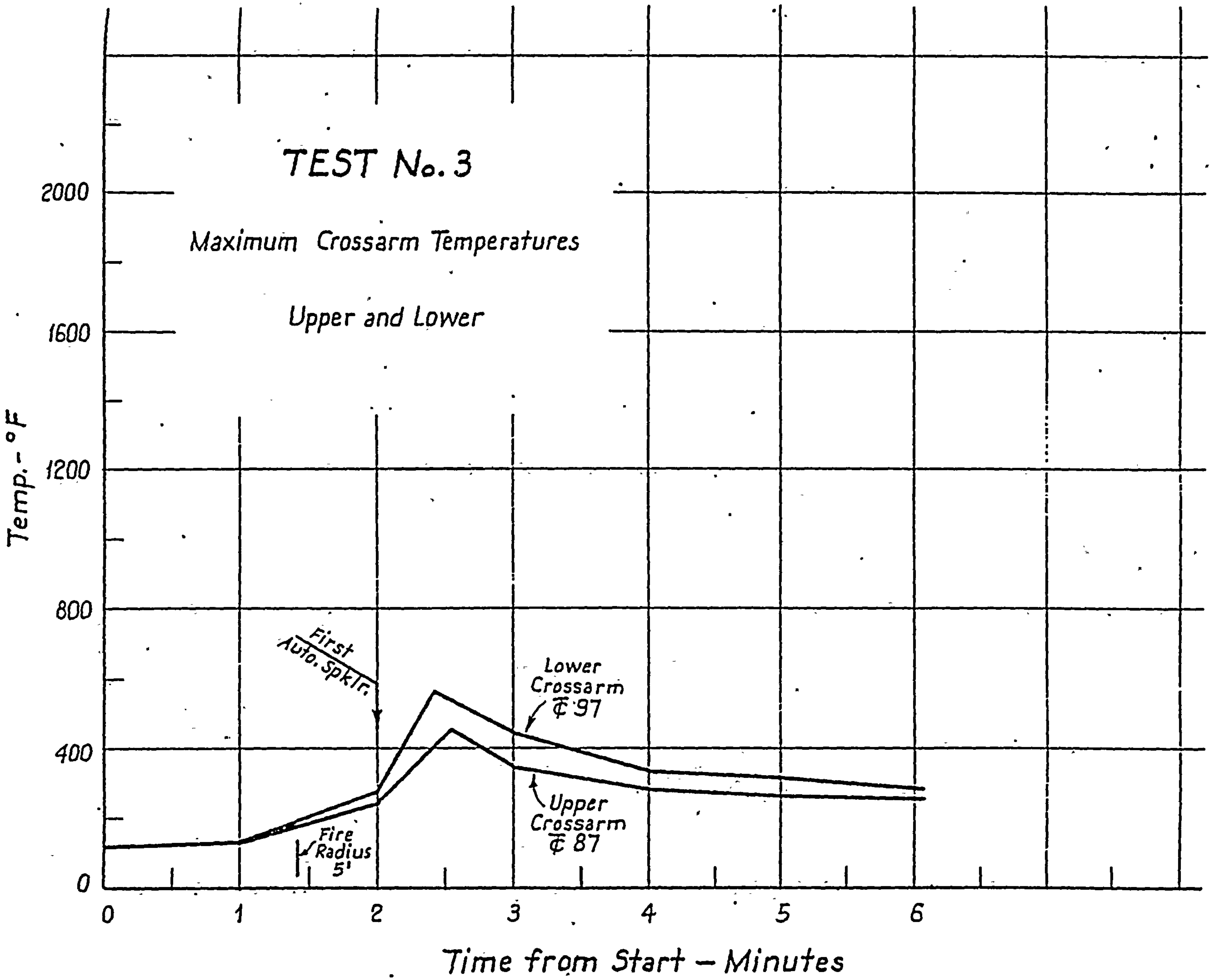


FMRC
Norwood, Mass.

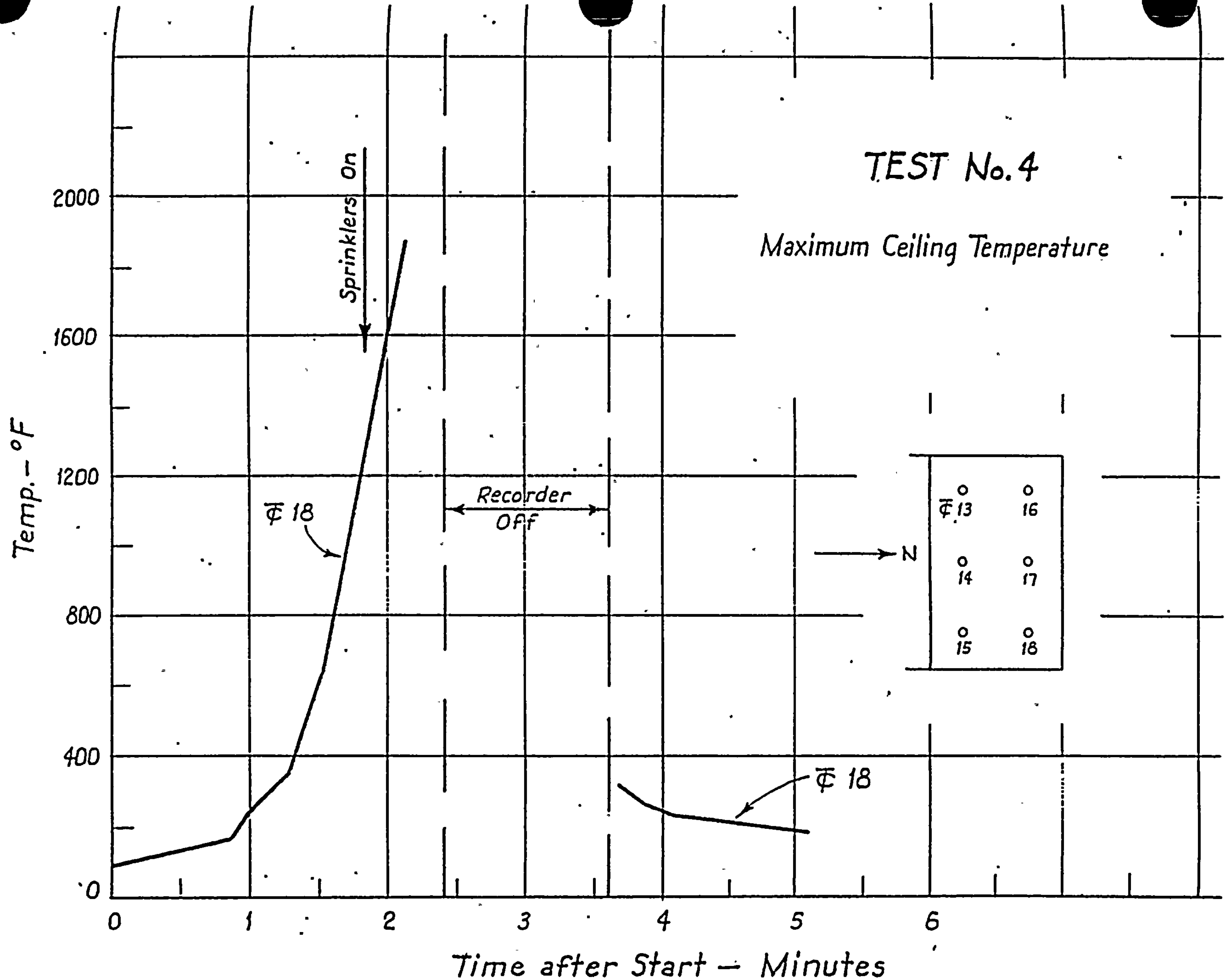


Rept. No. 13434
9-9-57

Appendix Sheet 13


TEST No. 3
Maximum Crossarm Temperatures
Upper and Lower
Temp. - °F
0
400
800
1200
1600
2000
0
1
2
3
4
5
6
Time from Start - Minutes
First Auto. Spklr.
Fire Radius 5'
Lower Crossarm ℄ 97
Upper Crossarm ℄ 87

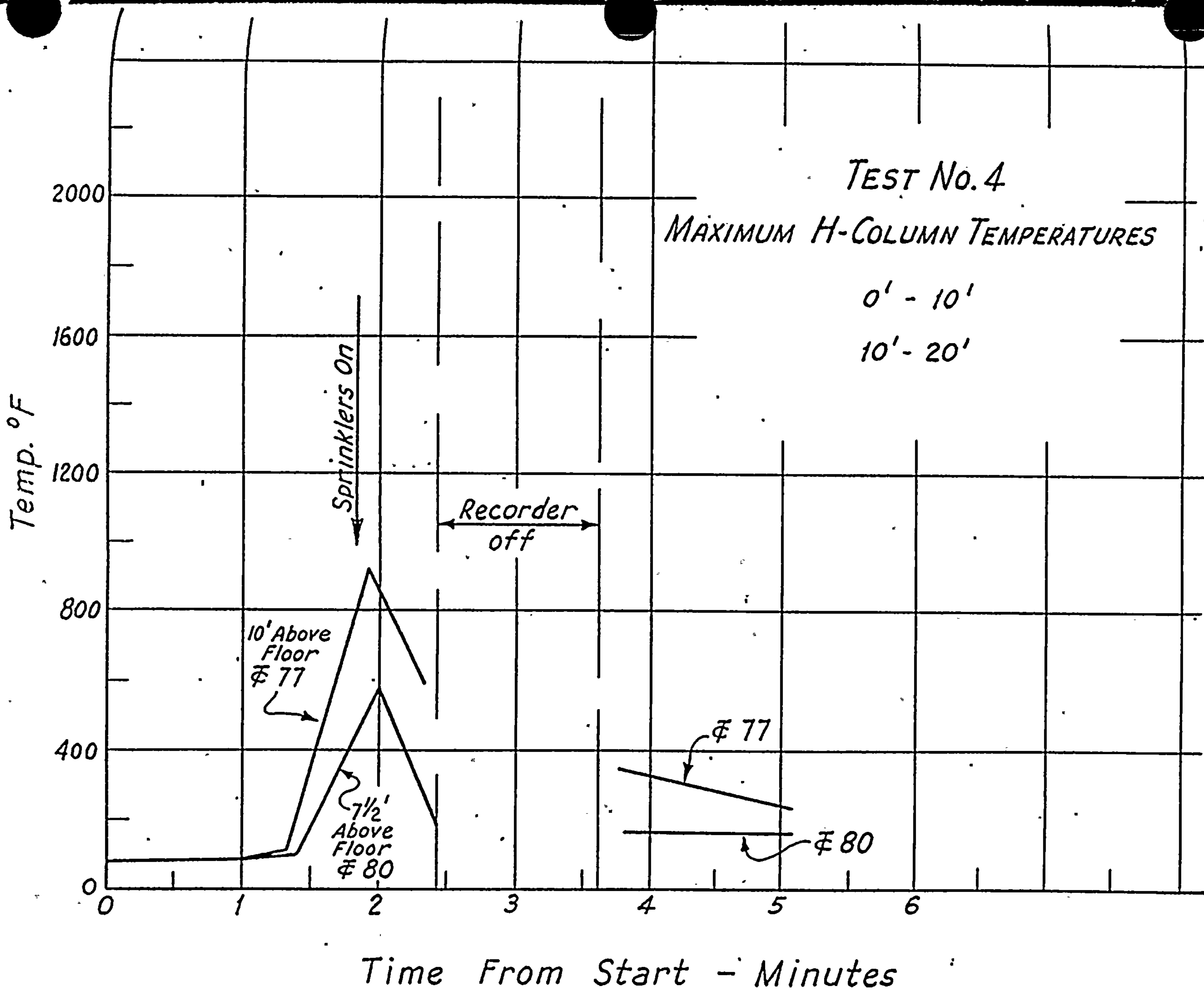
FMRC
Norwood, Mass.



Rept. No. 13434
9-9-'57

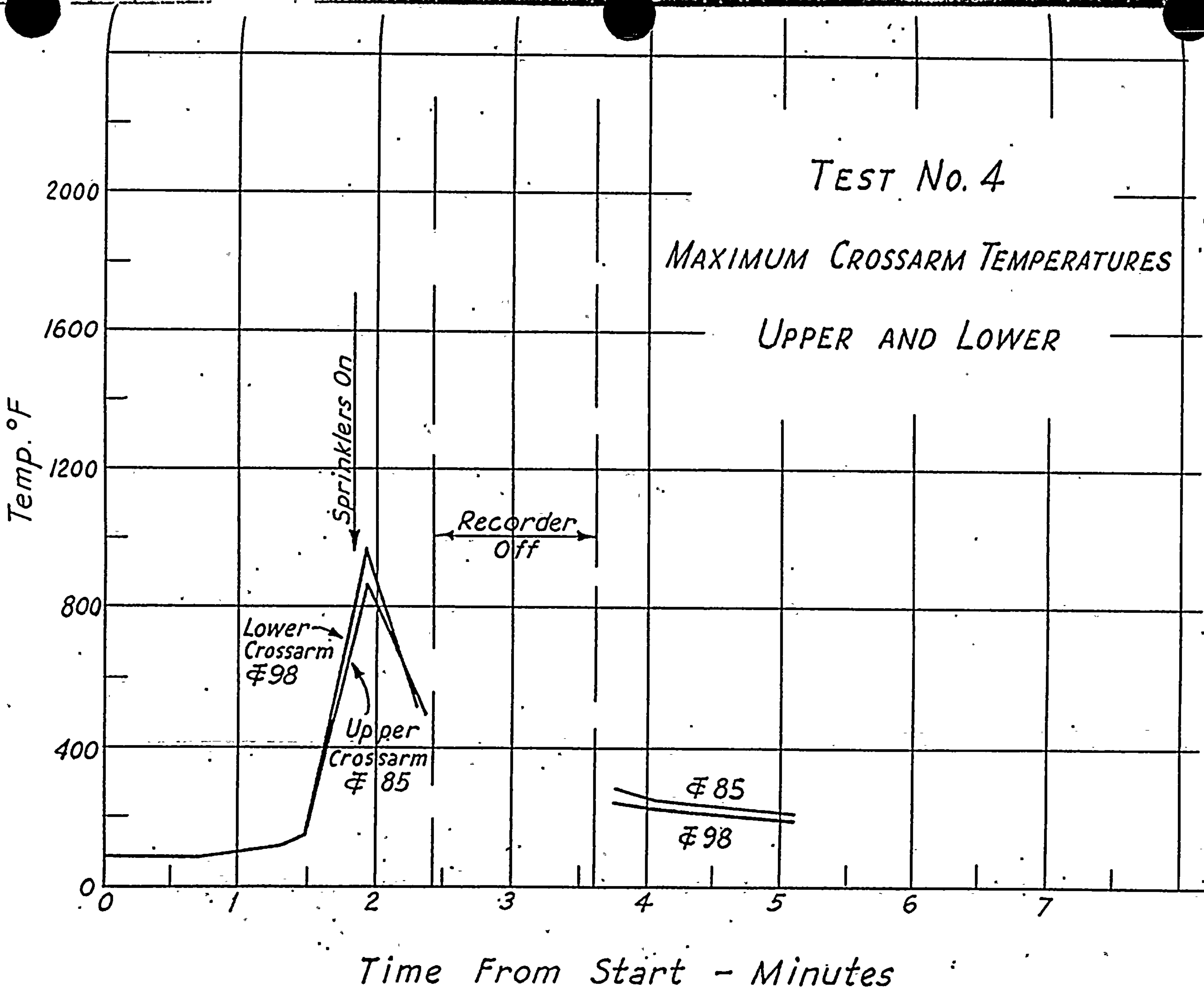
Appendix Sheet 15

FMRC
Norwood, Mass.



Rpt. No. 13434
9 . 9 . 57

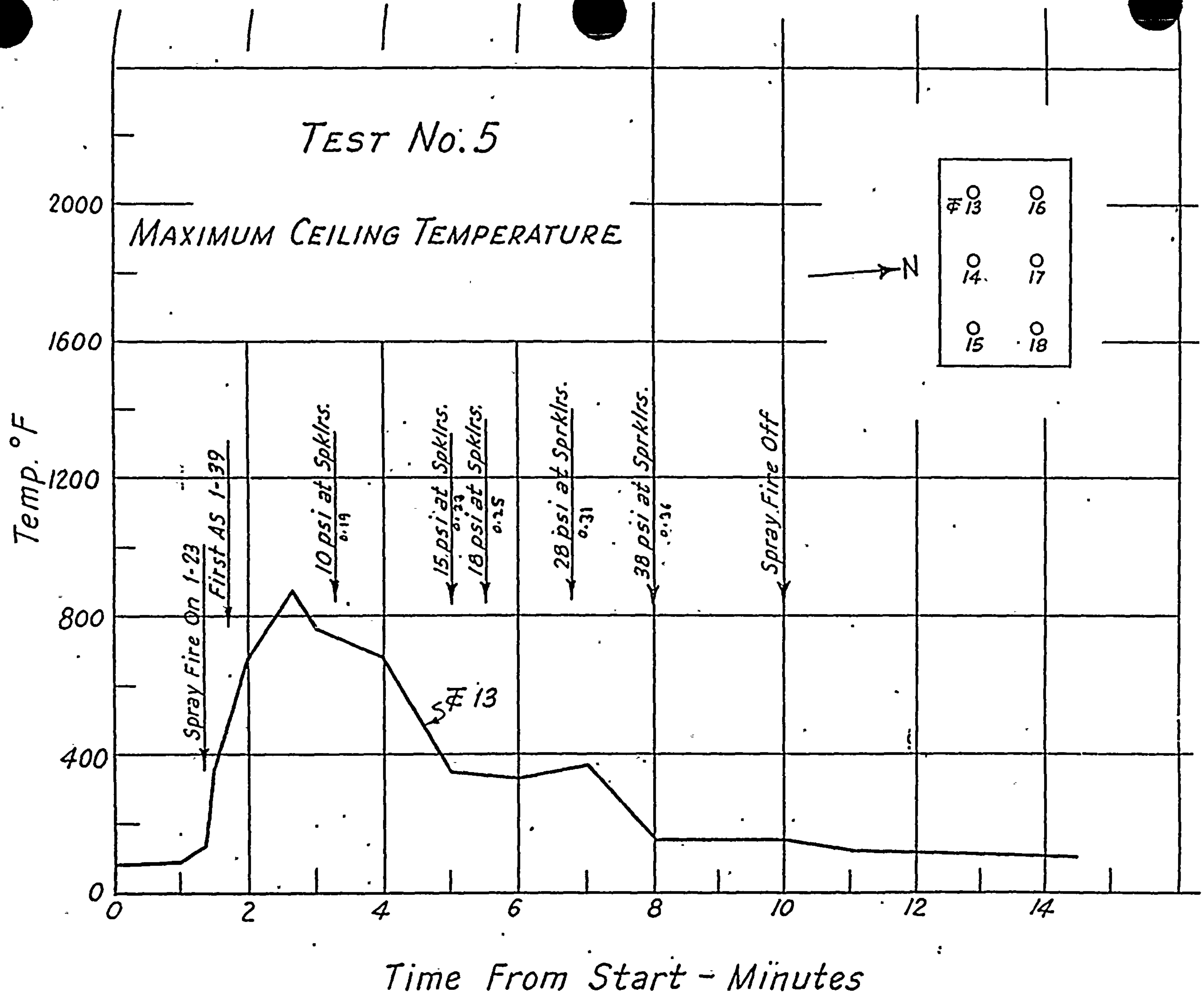
FMRC
Norwood, Mass.



Rpt. No. 13434
9 · 9 · 57

Appendix Sheet 17

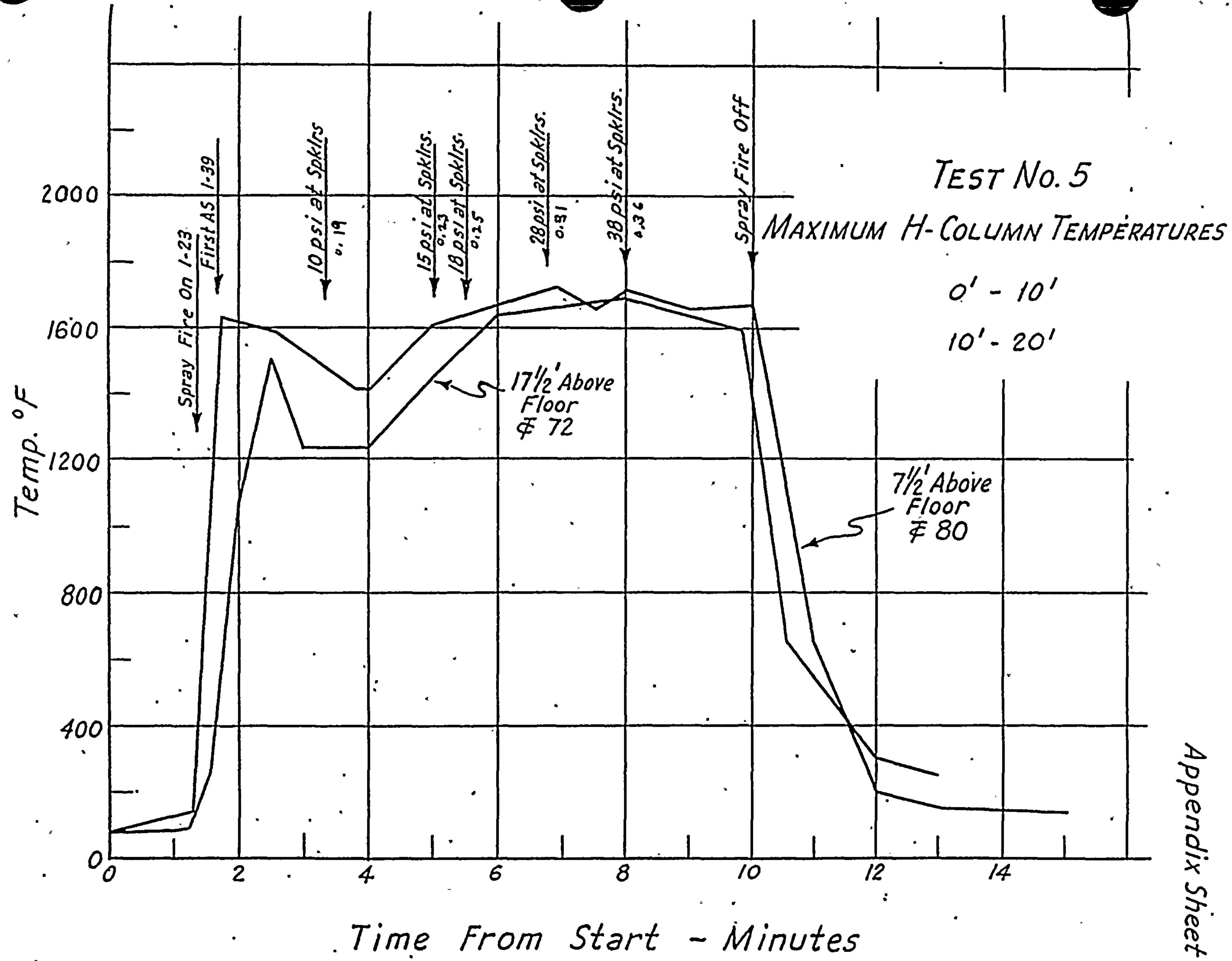
FMRC
Norwood, Mass.



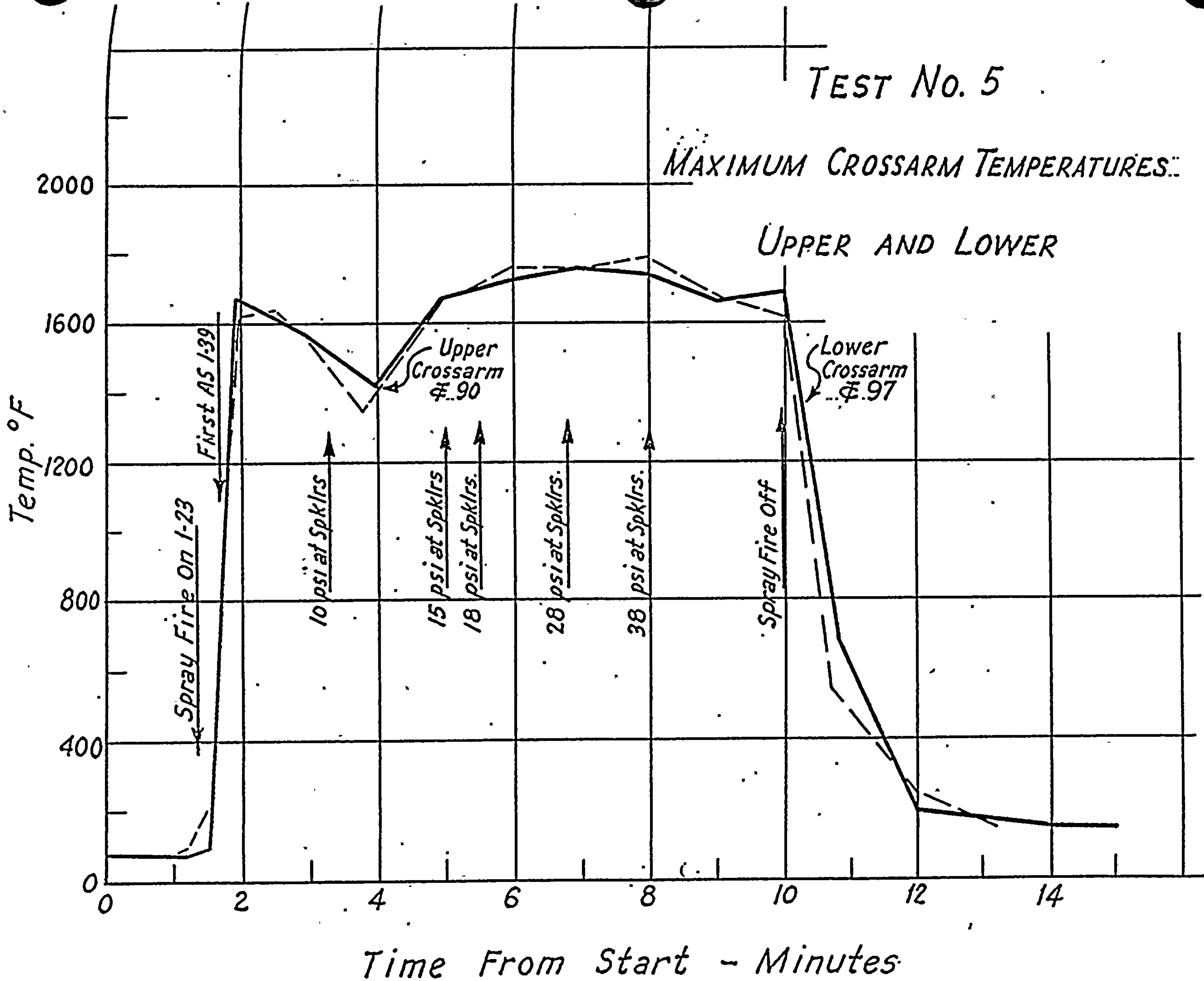
Rpt. No. 13434
9 · 9 · 57

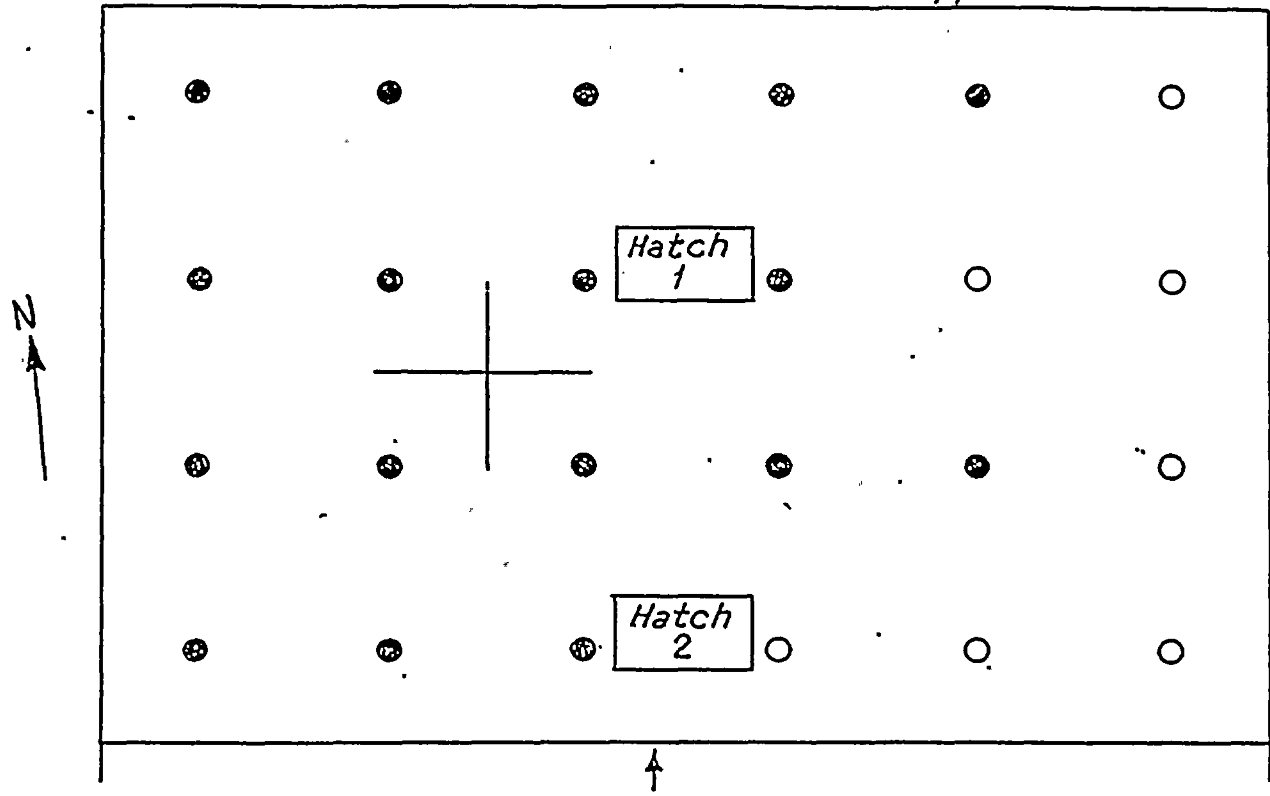
Appendix Sheet 18

FMRC
Norwood, Mass.

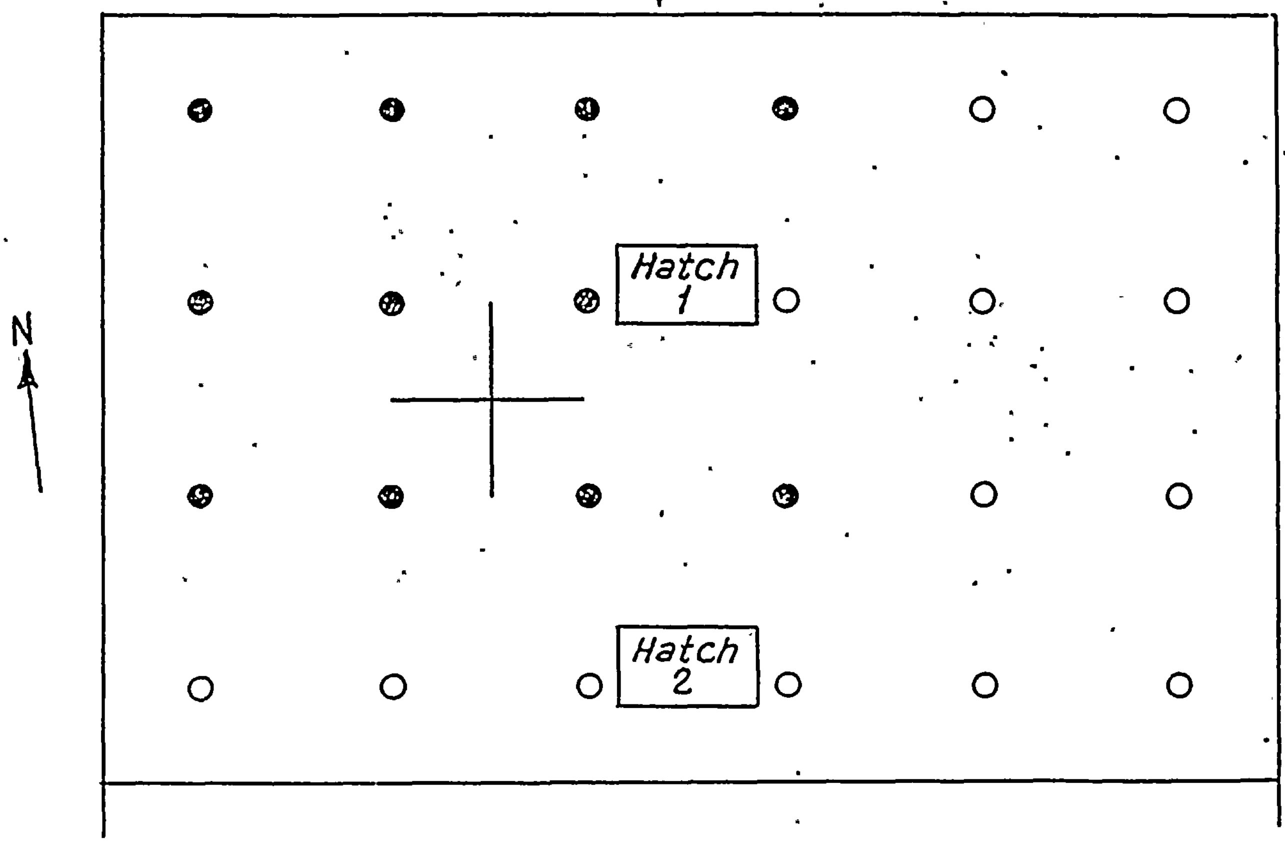


Rpt. No. 13434
9.9.57


TEST No. 5
MAXIMUM CROSSARM TEMPERATURES:
UPPER AND LOWER
Temp. °F
0
400
800
1200
1600
2000
0
2
4
6
8
10
12
14
Time From Start - Minutes
Spray Fire On 1-23
First AS 1-39
10 psi at Spklrs
15 psi at Spklrs
18 psi at Spklrs.
28 psi at Spklrs.
38 psi at Spklrs.
Spray Fire Off
Upper Crossarm ℄ 90
Lower Crossarm ℄ 97



Test 2
Plan View -"Hi-Sect." Showing Pattern of Sprinkler Heads Opened (⊛)
Test 3



TABULATION OF TEST CONDITIONS AND RESULTS

Test No.	Floor Temp-°F	Oil Temp-°F	Ventilation In Area Sq Ft	Ventilation In Opened at Min-Sec	Ventilation Out Area-Sq Ft	Ventilation Out Opened at Min-Sec	Wind Direction Degrees From North	Wind Velocity MPH	Outside Temp-°F
1	130	165-170	32 +33	0-00 10-00	28 +28	10 to 15m 18-1/2 to 20m	270	25	86
2	138	170-175	164	0-00	56	0-00	-- No Observation --		
3	133	180-185	164	0-00	161	0-00	-- No Observation --		
4	109	184	164	0-00	224	0-00	140	10-15	69
5	117	165-170	164	0-00	224	0-00	180	10	60

Test No.	Time of First Observed Fire Spread Min-Sec	Time to 5 ft Radius after Start of Spread Min-Sec	Fire Radius When 1st A.S. Operates Ft	Maximum Fire Radius Observed Ft
1	16-00	2-45	---	15
2	18-19	1-21	6	6
3	0-00	1-25	6	6
4(1)	0-00	0-55	---	10(2)
5	0-00	1-35	5	5(3)

(1) Six simultaneous fires. Figures are typical of one fire area.
(2) Maximum radius possible for individual fire area before merging with adjacent fire area. (Max. area involved - 1400 sq ft)
(3) Maximum persistent size is given. Occasional momentary outshoots not included.

Test No.	Time 1st Sprinkler Operates Min-Sec From Ignition	Time 1st Sprinkler Operates Min-Sec From 1st Fire Spread	Discharge Pressure At Sprinklers PSI	Sprinkler Discharge Density GPM/Sq Ft	Number of Sprinklers Opened
1	20-45	4-45	5	0.13	24(2)
2	19-57	1-38	5	0.13	17
3	2-01	2-01	5	0.13	11
4	1-50	1-50	5	0.13	24(2)
5	1-39	1-39	5(1)	0.13(1)	24

(1) Initial values only. See text for increases.
(2) Manual control. All 24 heads open when water supplied to them.

SUMMARY OF MAXIMUM TEMPERATURE DATA

Test No.	Averages of Maximum Recorded Temperatures - °F					
	At Ceiling 14 ft Laterally from Ignition Point	At Ceiling 32 ft Laterally from Ignition Point	Steel Structure H-Column 0' to 10' Above Floor	Steel Structure H-Column 10' to 20' Above Floor	Steel Structure Lower Cross-arms (10' Level)	Steel Structure Upper Cross-arms (20' Level
1	1325	865	1430	1480	1600	1035
2	455	350	660	505	550	430
3	345	275	580	430	505	355
4(1)	1375(2)		600	900	950	870
5	860	605	1145	1380	1510	1510

(1) Average maxima are probably above values shown for Test No. 4 because rapid temperature changes occurred in less time than that required for one complete printing cycle of temperature recorders.

(2) Single average maximum ceiling value given because this fire was from multiple rather than single point ignition.

FACTORY MUTUAL RESEARCH CORPORATION
Norwood, Mass.

Report No. 13434
September 9, 1957