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PROJECT 713109/00

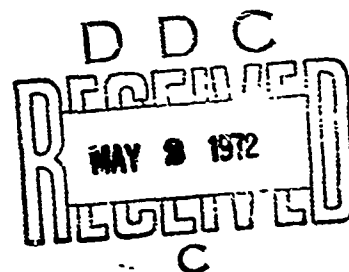
FIRE TESTING OF INDEPENDENT FIBERGLASS
FUEL TANKS WITH AND WITHOUT PROTECTIVE
COATING OF FIRE RETARDANT PAINT

AD 740783

By

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FINAL REPORT

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UNITED STATES COAST GUARD
OFFICE OF RESEARCH AND DEVELOPMENT
APPLIED TECHNOLOGY DIVISION

REPORT

FIRE TESTING OF INDEPENDENT FIBERGLASS
FUEL TANKS WITH AND WITHOUT PROTECTIVE
COATING OF FIRE RETARDANT PAINT

BY

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Unclassified

Security Classification

DOCUMENT CONTROL DATA - R & D		
(Security classification of title, body of abstract and indexing annotation must be entered when the general report is classified)		
1. ORIGINATING ACTIVITY (Corporate author) Commandant (DAT-3) U. S. Coast Guard Headquarters Washington, D. C. 20591		20. REPORT SECURITY CLASSIFICATION Unclassified
		21. GROUP None
3. REPORT TITLE Fire Testing of Independent Fiberglass Fuel Tanks With And Without Protective Coating of Fire Retardant Paint		
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Preliminary Report		
5. AUTHOR(S) (first name, middle initial, last name) LTJG John D. Richart, USCG		
6. REPORT DATE June 1971	70. TOTAL NO. OF PAGES 37	71. NO. OF REFS
80. CONTRACT OR GRANT NO. None	81. ORIGINATOR'S REPORT NUMBER(S) Project No. 713109/001	
b. PROJECT NO. 713109/001		
c.	90. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
d.		
10. DISTRIBUTION STATEMENT Unlimited		
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY Commandant, U. S. Coast Guard Office of Research and Development
13. ABSTRACT A study of the effects of using fire retardant paint on fiberglass fuel tanks was conducted. Eight cylindrical 24 gallon tanks, four painted and four unpainted, were subjected to open pan diesel fuel fires for exposure times of 6 to 11 minutes. Test objectives were to evaluate the performance of painted and unpainted tanks in the empty, 1/4 full, and full of fuel condition when exposed to fire. Thermocouple measurements, external appearance, and internal appearance showed the painted tanks to perform significantly better in these short duration fire tests than did the unpainted tanks. All tests were performed at the U. S. Coast Guard Shipboard Fire and Safety Test Facility, Mobile, Alabama.		

DD FORM 14

Unclassified

Security Classification

Unclassified

Security Classification

14.	KEY WORDS	LINK A		LINK B		LINK C	
		ROLE	WT	ROLE	WT	ROLE	WT
	Fire Test Fiberglass Fuel Tanks Fire Retardant Paint Intumescent Coatings Fire Test Facility Shipboard Fire and Safety Testing Facility Fuel Tanks Fire Testing Fuel Tanks						

Unclassified

Security Classification

PART A

ABSTRACT

A study of the effects of using fire retardant paint on fiberglass fuel tanks was conducted. Eight cylindrical 24 gallon tanks, four painted and four unpainted, were subjected to open pan diesel fuel fires for exposure times of 6 to 11 minutes. Test objectives were to evaluate the performance of painted and unpainted tanks in the empty, $\frac{1}{4}$ full, and full of fuel condition when exposed to fire. Thermocouple measurements, external appearance, and internal appearance showed the painted tanks to perform significantly better in these short duration fire tests than did the unpainted tanks. All tests were performed at the U.S. Coast Guard Shipboard Fire and Safety Test Facility, Mobile, Alabama.

PART B

PREFACE

From a fire protection point of view, most materials are compared to steel when determining their fire resistance. However, in many shipboard applications the advantages with regard to corrosion, weight, cost, and chemical compatibility which aluminum or nonmetals may offer when compared with steel should not be discarded in deference to inherent fire resistance. The subject of fire retardant coatings is one of interest to the Coast Guard because short time fire protection may be adequate to favor the otherwise better but less fire resistant material.

One of the materials worthy of testing was fiberglass constructed of non fire-retardant resins. Small panel testing had been conducted (reference (4)), but large scale testing would be necessary to establish whether or not a fire retardant coating could give precious minutes of extra protection in a fire. Independent fiberglass fuel tanks were chosen as equipment for testing.

One of the problems encountered early in the planning stages was "How does one define the term 'fire' and how can performance in one fire compare with results from another fire?" This question dominated our early thinking, especially when large scale testing at the Coast Guard's Shipboard Fire and Safety Test Facility was discussed. After considering and rejecting placement of the tanks in a full-scale bilge fire aboard the T-1 tanker m/v Rhode Island, it was decided to test the tanks individually, obtain time-temperature data and pictures, and attempt to compare the results from eight similar but different fire tests. The first two tests would parallel the Marine Department, Underwriters' Laboratories (formerly Yacht Safety Bureau) fire test for fuel tanks, whereas the goal for the remaining six tests was a 10 minute diesel fuel fire.

PART C

INTRODUCTION

Fiberglass fuel tanks have been involved in some spectacular fire tests in past years (see reference (2)). In order to evaluate the potential safety benefits of fire retardant paint, it was felt necessary to design a tank which would not fail catastrophically in a fire, and which had no areas of inherent weakness.

The resultant tank, described in detail in enclosure (1), was therefore over-designed from a commercial point of view. The cylindrical tanks looked and behaved as pressure vessels, and the increased wall thickness (3/8"-1/2") plus baffle arrangement made them quite rugged. Indeed, the 50 pound tanks were carried by the fill pipe spud with no adverse effects on the tank mounting plate connection. The superior tank construction meant that the material rather than the design would be the primary cause of tank failure.

The eight tanks were tested one at a time over an open drum of diesel fuel, ignited by paint thinner or naphtha. Diesel fuel was chosen in lieu of gasoline because of safety considerations. The tank rested on two pieces of untreated 2x4 lumber. Angle iron pieces were laid across the fuel bath to catch the tank in the event the wood burned through. The tanks were positioned about 11 inches above the initial fuel level. Thermocouples were placed 1" below both heads of the tank, and a thermocouple composed of #24 wire with a nickel bead was inserted into the tank twelve inches from the top of the vent spud. The instrumentation is discussed in greater detail in enclosure (2).

The tank set-up was located on the uppermost level of the engine room spaces, about 10 feet below the skylight hatches, which were cranked open for ventilation. Wind currents made fire conditions vary from moment to moment and no two tests were identical. A two-part door behind the set-up influenced results considerably on some of the tests (see PHOTOGRAPHS # 1 and # 2).

16 mm color movies were taken of portions of all eight fire tests. Color slides were taken at one minute intervals in each of the last six tests. Photographs were taken to show smoke, sunlight, and fire conditions at specified intervals during the tests. All photographs of tank fires were taken without flash at identical camera settings.

After testing all the tanks were cut open with a power saw and examined. Photographs of cut-open tanks were taken in similar sunlight conditions.

PART D

RESULTS AND DISCUSSION

Results of tests conducted on the eight independent fiberglass fuel tanks are summarized in Table I. Tests #1 and #2 were both for 2m30s and the time-temperature data were close to the YSB criteria for the 2m30s gasoline fire test (see FIG. 1, reference (1)). Photographs (3) and (4) show the internal appearance to be very good for both tanks. The unpainted tank has charred somewhat, causing some degradation of wall soundness, but both tanks could withstand several minutes more fire exposure before failure.

Test #3 was a severe fire on an unpainted empty tank. Photographs (5) and (6) taken during the blaze give an indication of the smoke generated as the fiberglass burned away, having no fuel inside the tank to absorb some of the heat energy. The test was stopped when an iron brace which steadied the tank gave way, causing the tank to roll off the drum onto the surrounding platform! Photographs (7) and (8) show the tank immediately after opening. The wall thickness is badly charred, with only about $\frac{1}{4}$ inch of good fiberglass left. The nails shown in the lefthand section of both photos were driven into the tank to hold the baffle in place during fabrication, unbeknownst to the test coordinator. The styrofoam baffle had become sharp and jagged and was easily dislodged when the tank was cut in half.

Test #4 was conducted within an hour after the preceding test, but the fire did not attain suitable proportions. After 7 minutes, as shown in photograph (9), the fire still had not engulfed the tank and there were no indications of weakness. The test was stopped after 10 minutes, and the results are shown in photograph (10) prior to moving and sawing. The interior of the tank was in excellent condition (photograph (11)). The tank would have been able to withstand a great deal more flame and heat than it encountered. The time-temperature data in FIG. 4 show the disparity between the two empty tank tests. Therefore, it is difficult to compare results, because of the different intensities.

Test #5 was conducted on a painted tank, $\frac{1}{4}$ full of diesel fuel. The two-part door was closed in excess of a minute into the test before it was realized that the readings of the previous test had been significantly affected. After five minutes of a severe fire smoke production was slight and the sunlight band on the bulkhead was still visible (see photographs (12) and (13)). At 8m06s the test was terminated when a leak was observed at the bottom of the tank. Subsequent examination did not reveal any defect in the tank, which may have been sealed during cooling of the tank. The intumescent coating adhered to the tank despite the draft conditions around the

PART D

tank. No . photograph (14). The interior appearance of the tank, p otograph (15), was good and there was no significant delamination of the tank wall. The leak which caused termination of the test may have occurred at a nail site around the baffle region. However, indications were that the test would have been stopped before the desired 10 minute point for other reasons. The internal temperature, shown on FIG. 7, was rising rapidly at the seven minute mark. The fuel drum was red hot along its entire length at the time of extinguishment.

Test #6 unpainted and $\frac{1}{4}$ full of fuel, produced considerably more than the previous test and was spectacular. At the one minute mark there was a good deal of sunlight in the space (p . ograph (16)), but after four minutes the engine space was dark and very smoky as shown in photograph (17). After approximately six minutes of an engulfing fire the tank appeared to be in good condition externally, with no sagging or warping indicated. However, the internal appearance shows that the tank was badly damaged by the fire (photographs (18) and (19)), and extensive charring and delamination had taken place. The tank was full of very hot vapors when cut open, indicating a more severe internal exposure than seen in Test #5. (The internal temperature reading reached 1250°F at the termination of Test #6, whereas the maximum value was 490°F in Test #5)

FIG. 1 shows that Test #6 on the unpainted tank had temperatures which fell easily between the YSB's min.-max. curves for the 2m30s independent fuel tank fire test. Test #5 did not cross over the minimum curve, due to variables beyond control. As can be seen in FIG. 5, the unpainted tank was subjected to a fire about 150°F hotter than the painted tank. However, the painted tank lasted two minutes longer and still presented a better internal appearance. The internal temperatures depicted on FIG. 7 show the temperature in Test #6 to rise sharply after two minutes. The dip in the curve can be explained as follows: the thermocouple was positioned in the vapor space and when the fuel began to boil, a droplet of fuel hit the nickel bead, causing a sharp drop in temperature reading. As the liquid vaporized, the temperature again climbed rapidly.

Test #7, unpainted and full of fuel, was a very severe fire, as shown in photographs (20), (21), and (22). Considerable smoke was generated and the tank was engulfed in 8 foot high flames throughout the 7m45s of exposure. Photograph (23) shows the tank after the fire, with the circled area the region of the tank where a leak was thought to have occurred. The internal appearance of the tank was poor, as shown in photograph (24). Three-fourths of the wall thickness was charred and the baffle was burned to a sharp, jagged consistency.

PART D

Test #8, painted and full of fuel, showed the tank to withstand severe fire exposure. As in the previous test the tank was engulfed in flames the entire time (see photographs (25) and (26)). At the eight minute mark flames were four feet high and vapors were burning at the top of the vent spud at a controlled rate. The final two photographs show the tank to be in better condition after an 11 minute fire than the unpainted counterpart was after less than 8 minutes of exposure to similar intensities (see FIG. 6).

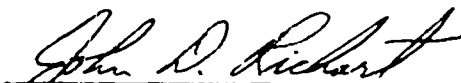
A brief overall view of the time-temperature data yields some interesting observations. The scatter in the data was much wider at thermocouple #1 (nearer the two-part door) than at thermocouple #2, indicating that wind conditions were locally affected by the door behind the test set-up (see FIGS. 2 and 3). The test temperature range was about 440°F (980°F - 1420°F) at thermocouple #1, whereas the difference between fires varied only 225°F (1150°F - 1375°F) at thermocouple #2. A look at FIG. 7 shows that all the painted tanks were insulated significantly better than the unpainted ones. In tests #7 and #8 the fires were very similar, eliminating the difficulty in comparing results from differing exposures, and the painted tank took two minutes longer to reach the 200°F internal temperature mark than did the unpainted tank. The tanks which were $\frac{1}{4}$ full of fuel, providing the most severe fuel conditions for a fire, had four minutes separating their internal behavior. The empty tanks cannot be compared realistically, because of the difference in fire intensity.

PART E

CONCLUSIONS

The following conclusions can be drawn from the eight fire tests:

1. Fire retardant paint gives significant short-time fire protection to fiberglass. Both material integrity and heat insulation benefits can be realized.
2. Independent fiberglass fuel tanks, properly constructed, can withstand the accepted 2m30s fire test from a materials aspect with or without the addition of fire protective coatings. Design should eliminate sources of high stress or delamination, such as sharp radius bends and nails driven through the wall, and provide sufficient wall thickness for a "fire protection allowance".
3. Mounting connections should be tight and secure with many bolts to minimize stresses. Neoprene gaskets did not present an appreciable fire hazard and made a leak tight seal around the opening.
4. Independent fuel tanks present a greater hazard when partially full of fuel than when empty or completely full. The generation of vapors was very rapid in the partially full tanks and the internal temperature rose much more rapidly than for the empty tanks. With full tanks there is very little surface for vaporization and more liquid volume to absorb heat energy. There is no liquid-vapor interface above which rapid deterioration of the tank will take place.
5. Independent fiberglass fuel tanks are insulated thermally by an intumescent coating to a significant degree. The coating can adhere to the fiberglass for several minutes of severe fire exposure, but prolonged engulfment by flame and updrafts cause the carbonaceous material to be carried away.
6. All painted tanks had better internal appearances and lasted longer in fires than their unpainted counterparts. However, only in the case of Tests #7 and #8, where the time-temperature data are quite close, can the fires be considered equivalent and the results be compared objectively.


John D. Richart, LTJG, USCG

PART F

REFERENCES

1. Requirements for Non-Integral Marine Fuel Tanks, YSB Standard E-3 (Tentative) dated 16 March 1965.
2. Laboratory Tests on Fiberglass Reinforced Plastic Non-Integral Fuel Tanks, USCG Contract Tcg 13,839-A, issued 22 September 1967.
3. Reports, photographs, and letters concerning the January 20, 1968, Essex Boat Yard Fire.
4. Memo to FILE of 10 July 1970, File Number 9930/9, from LTJG J. D. Richart, concerning "Fire Testing of Fire Retardant Paint"

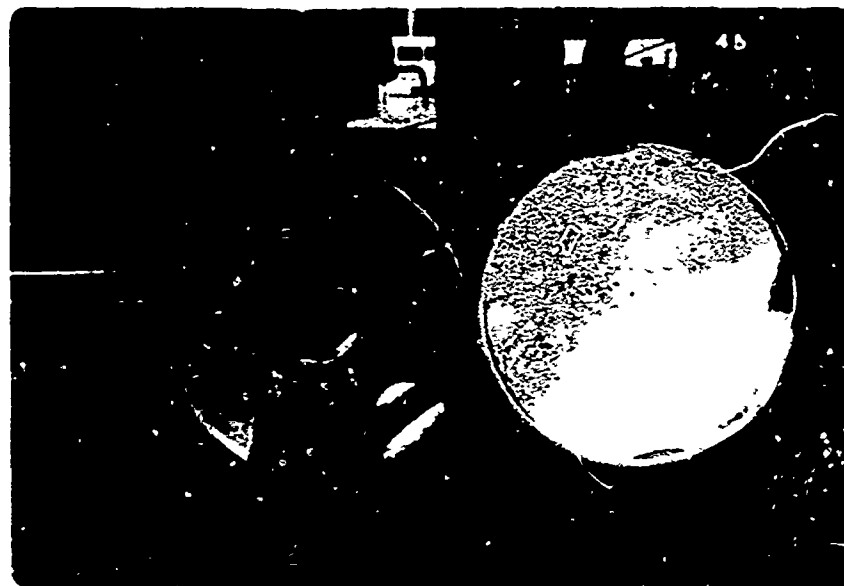
PART C



PHOTOGRAPH # 1: Ventilation skylights for engine room spaces of m/v Rhode Island. Uppermost deck about 10 feet below openings.



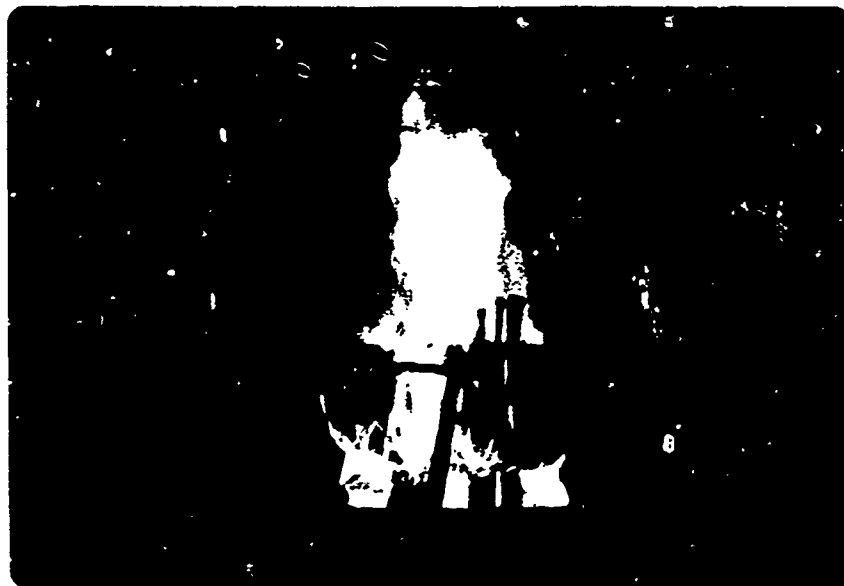
PHOTOGRAPH # 2: Test fire to determine burning characteristics of diesel fuel in drum. Note thermocouple leads on left and right sides of drum. Tank will rest on 2x4's, fall on angle iron in the event of burn-through.



PHOTOGRAPH # 3: Test #1, tank $\frac{1}{4}$ full of diesel fuel, unpainted, 2m30s of fire exposure. Note charring of top left portion of tank.



PHOTOGRAPH # 4: Test #2, tank $\frac{1}{4}$ full of diesel fuel, painted, 2m30s of fire exposure. Note soundness of tank wall.



PHOTOGRAPH # 5: Test #3, tank empty, unpainted, 2m00s into the test. Note darkness in space caused by smoke. Fire appears yellow.



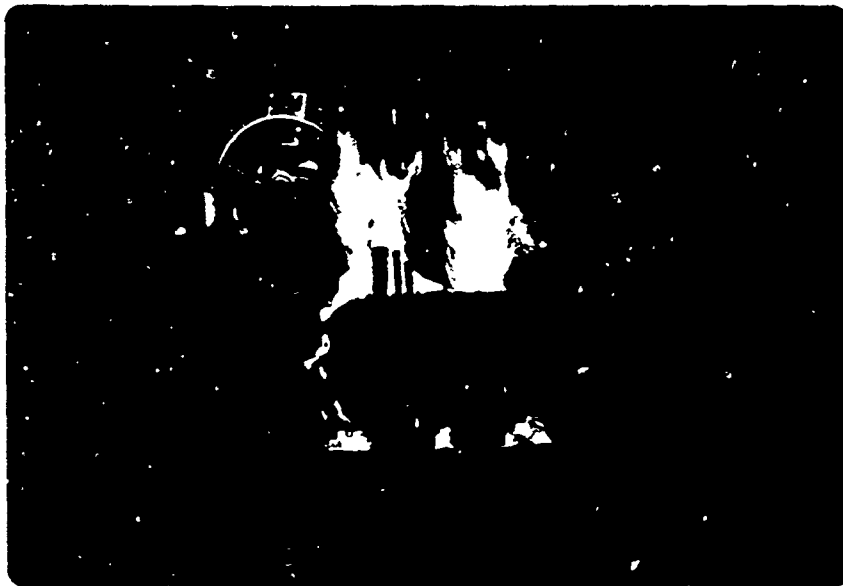
PHOTOGRAPH # 6: Test #3, 4m00s into the test. Fire appears more orangish as smoke fills space to a much greater extent.



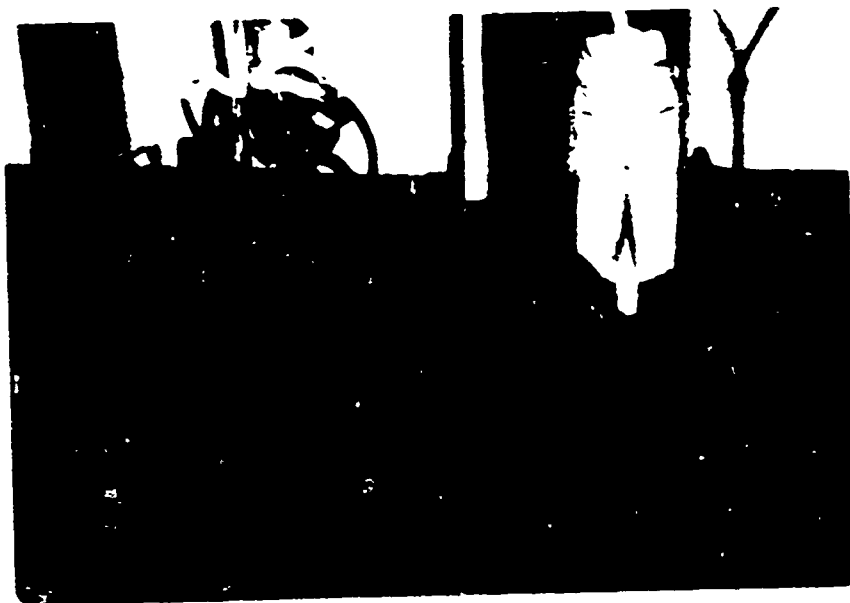
PHOTOGRAPH # 7: Test #3, tank after 7m54s of fire exposure. Note overall appearance of tank, charred wall thickness. Test was terminated when iron brace gave way, allowing the tank to roll off onto the deck.



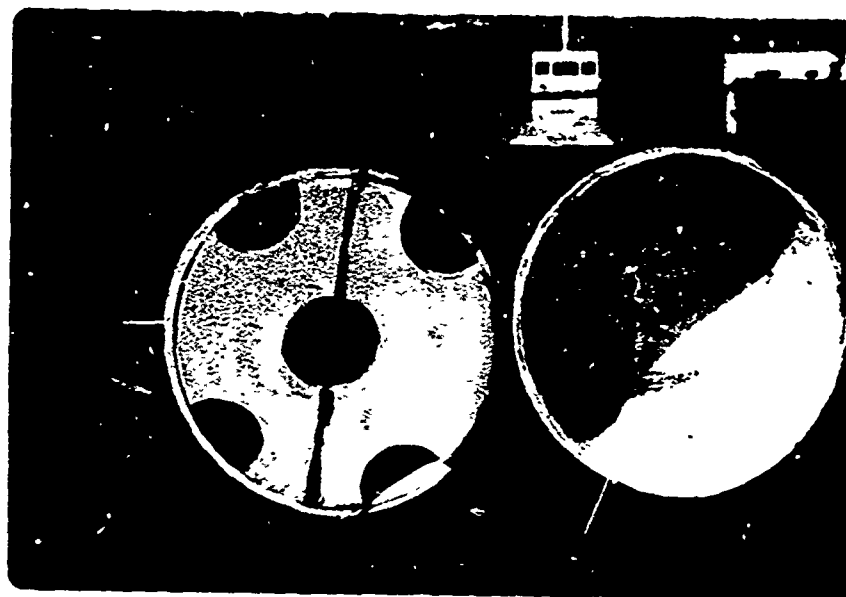
PHOTOGRAPH # 8: Test #3, close-up view of charred baffle and wall. Note nail protruding through wall in lower center of picture.



PHOTOGRAPH # 9: Test #4, tank empty, painted, 7m00s of fire exposure. Note amount of sunlight available, intumescence on tank, relative calm of fire. Partially closed two-part door in background significantly affected the intensity of this fire.



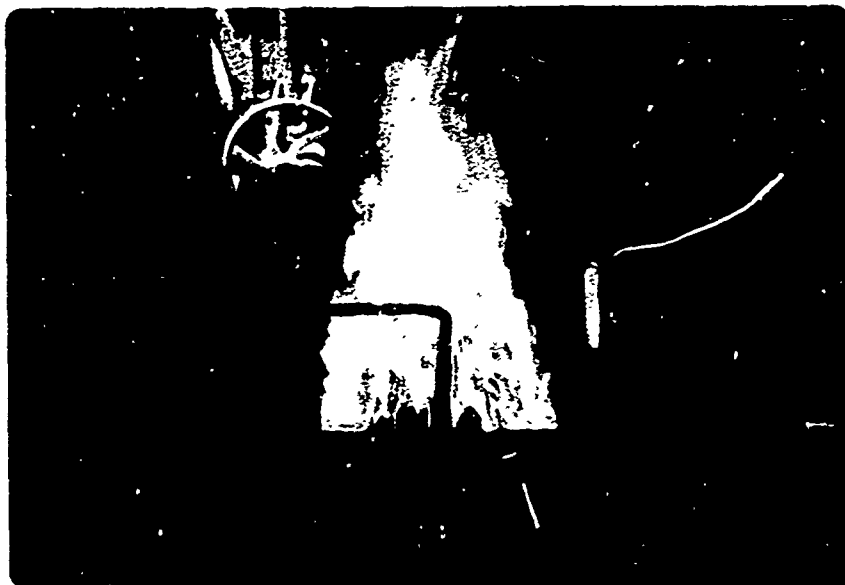
PHOTOGRAPH # 10: Test #4, tank after 10m00s of fire. Note overall intumescence from the fire retardant paint.



PHOTOGRAPH # 11: Test #4, painted tank after opening, showing excellent internal appearance of baffle and tank wall.



PHOTOGRAPH # 12: Test #5, tank $\frac{1}{2}$ full of diesel fuel, painted, at 1m00s into the test. Door behind test had been closed to protect personnel who waited to put out fires with dry chemical hand fire extinguishers. Note sunlight present.



PHOTOGRAPH # 13: Test #5, tank completely engulfed in fire at 5m00s into test. Note door position and available sunlight.



PHOTOGRAPH # 14: Test #5, painted tank after 8m06s of fire exposure. Note excellent intumescence, still adherent after severe fire. Test was terminated when it appeared that the tank split along the bottom, but no later evidence to this effect was found.



PHOTOGRAPH # 15: Test #5, painted tank's internal appearance. Baffle broke loose upon cutting tank in half, but appears in good shape.



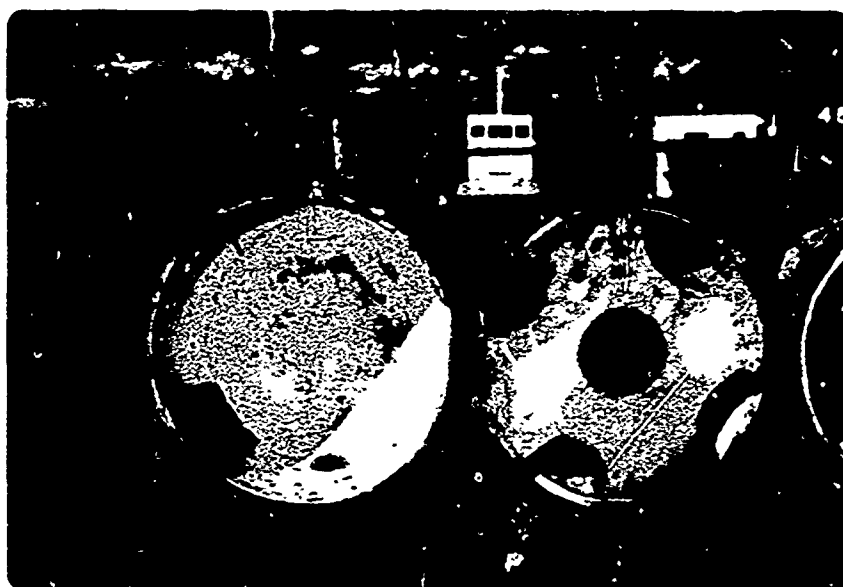
PHOTOGRAPH # 16: Test #6, tank $\frac{1}{2}$ full of diesel fuel, unpainted tank at 1m00s into the test. Note thermocouple lead into vent spud, present in all tests. Note good sunlight present, comparable to PHOTOGRAPH # 12.



PHOTOGRAPH # 17: Test # 6, 4m00s into the test. Note darkness caused by smoke generated from burning resin. Compare conditions in space with those one minute later into test with painted tank, shown in PHOTOGRAPH # 13.



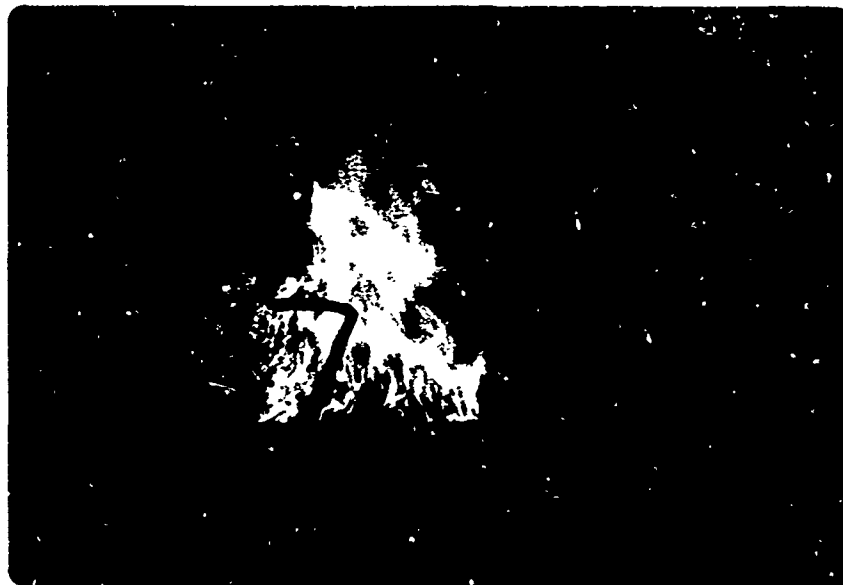
PHOTOGRAPH # 18: Test #6, unpainted tank after 5m52s of fire exposure. Fire was extinguished when a leak was detected and conditions were deemed hazardous to personnel.



PHOTOGRAPH # 19: Test #6, unpainted tank's internal appearance after fire. Note delamination in right half of tank.



PHOTOGRAPH # 20: Test #7, tank full of diesel fuel, unpainted, after 1m00s of exposure. Note height of flames, very high in this test, because diesel fuel vapors burned at the top of the open vent. Also note sunlight on the bulkhead.



PHOTOGRAPH # 21: Test #7, 4m00s into the fire. Tank is burning fiercely all over, with considerable smoke being generated. One couldn't see the end of a bulkhead 20 feet away.



PHOTOGRAPH # 22: Test #7, 7m00s into the fire. A great deal of smoke fills the air and the tank continues to burn relentlessly. However, no sagging or leaking detected at this point.



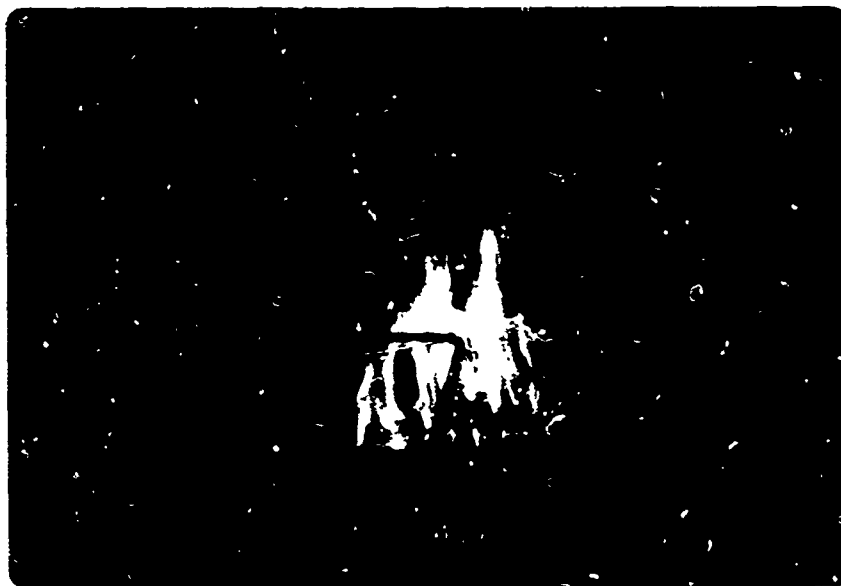
PHOTOGRAPH # 23: Test #7, unpainted tank after 7m45s fire. Area at left on tank head is believed to have leaked.



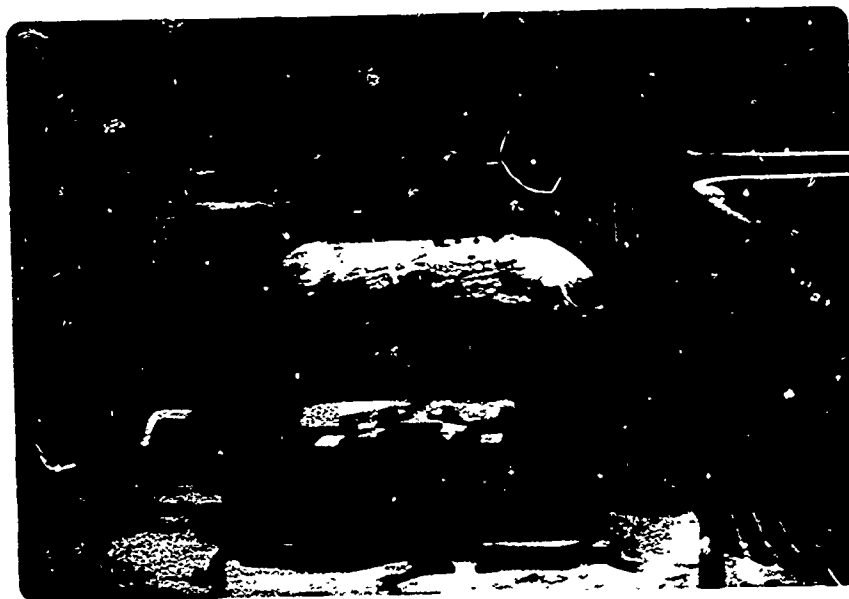
PHOTOGRAPH # 24: Test #7, internal appearance of unpainted tank after fire. Note baffle and charred wall about 3/8 inch of which is delaminated in upper right half of tank.



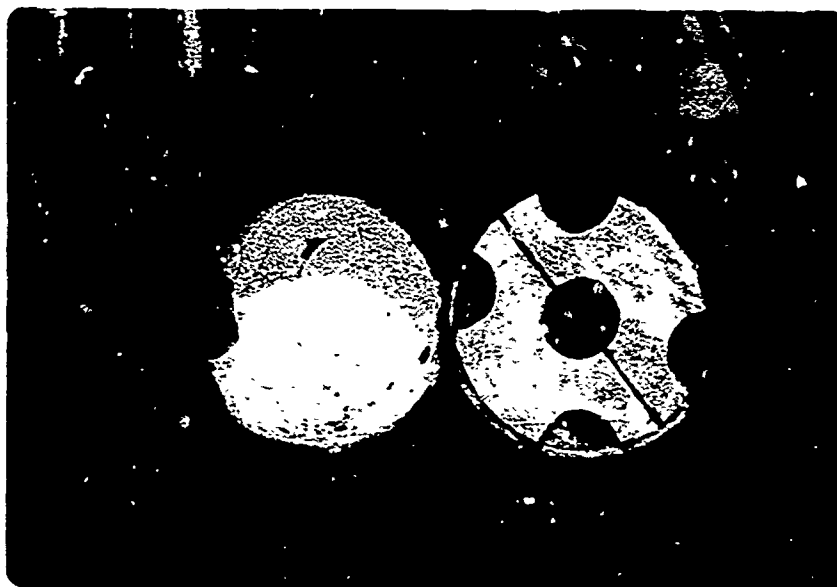
PHOTOGRAPH # 25: Test #8, tank full of diesel fuel, painted, after 4m00s of exposure. Very intense fire, but smoke generation was not nearly as bad as in the previous test.



PHOTOGRAPH # 26: Test #8, tank after 10m00s of fire. Tank started burning after 5 minutes of fire and continues to be engulfed in flame. Smoke was becoming severe at this point in the test.



PHOTOGRAPH # 27: Test #8, tank after 11m00s of exposure. Although blurred, one can see that the intumescence is not as abundant as shown on PHOTOGRAPHS # 10 and # 14, indicating that the intensity and duration of the fire may have swept the charcoal-like substance away.



PHOTOGRAPH # 28: Test #8, painted tank after 11m00s fire. Delamination took place along outside $\frac{1}{4}$ inch of wall. Otherwise, the interior was in good condition. Compare the baffle to its counterpart in Test #7.

TABLE I. SUMMARY OF TEST RESULTS

<u>Test</u>	<u>Tank Condition</u>	<u>Duration of Fire</u>
#1	Unpainted $\frac{1}{4}$ Full	2m30s
#2	Painted $\frac{1}{4}$ Full	2m30s
#3	Unpainted Empty	7m54s
#4	Painted Empty	10m00s
#5	Painted $\frac{1}{4}$ Full	8m06s
#6	Unpainted $\frac{1}{4}$ Full	5m52s
#7	Unpainted Full	7m45s
#8	Painted Full	11m00s

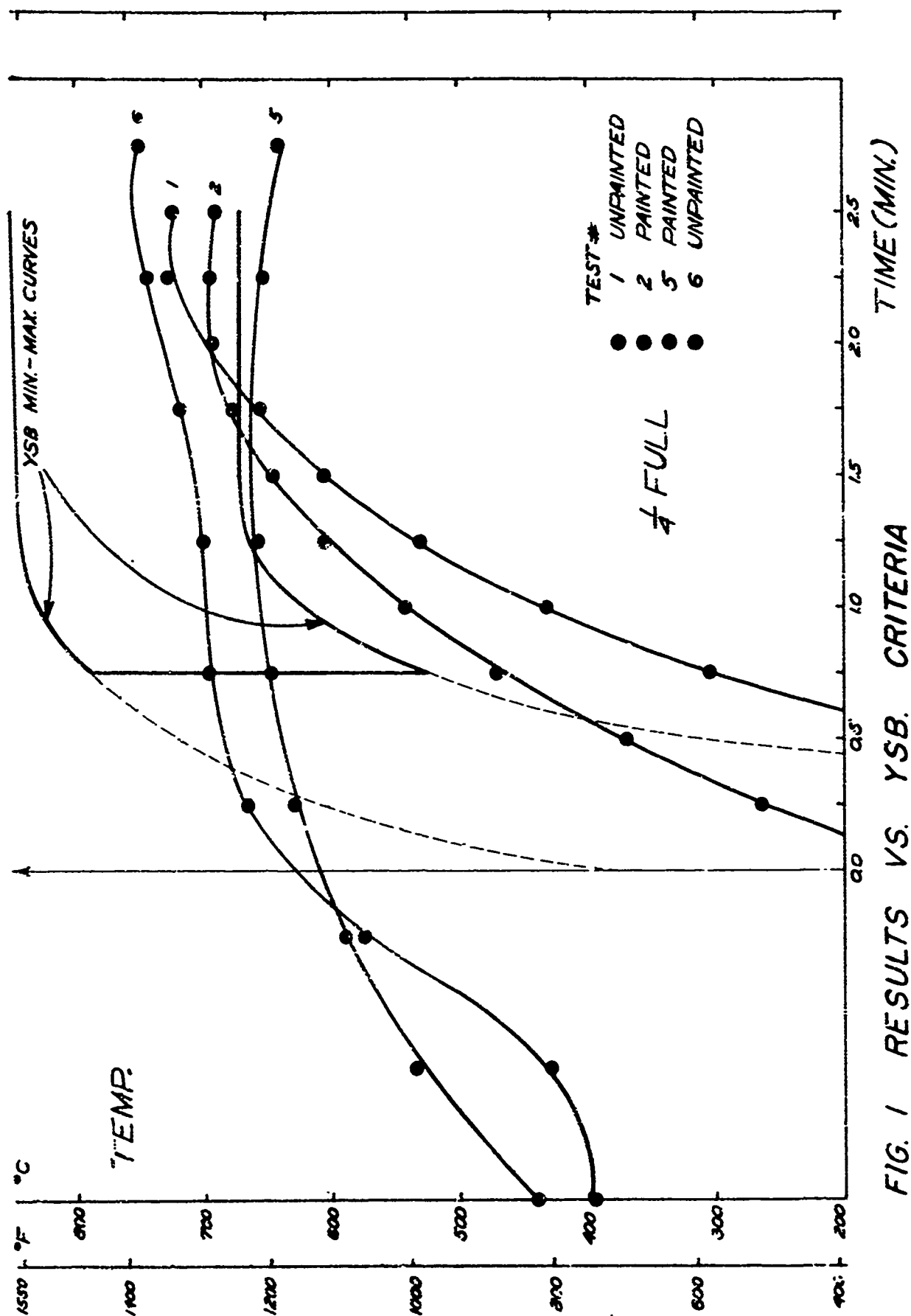


FIG. 1 RESULTS VS. YSB. CRITERIA

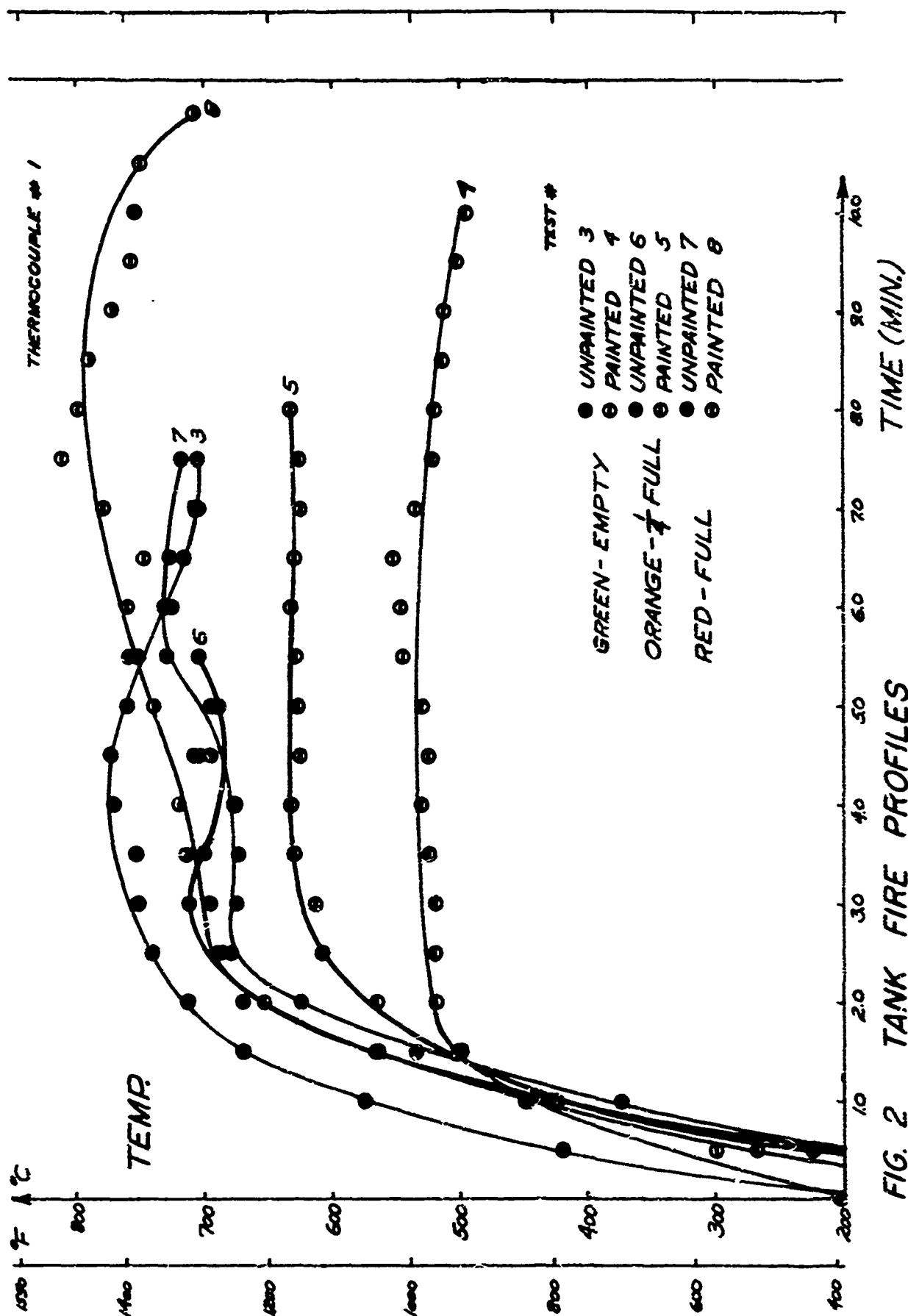
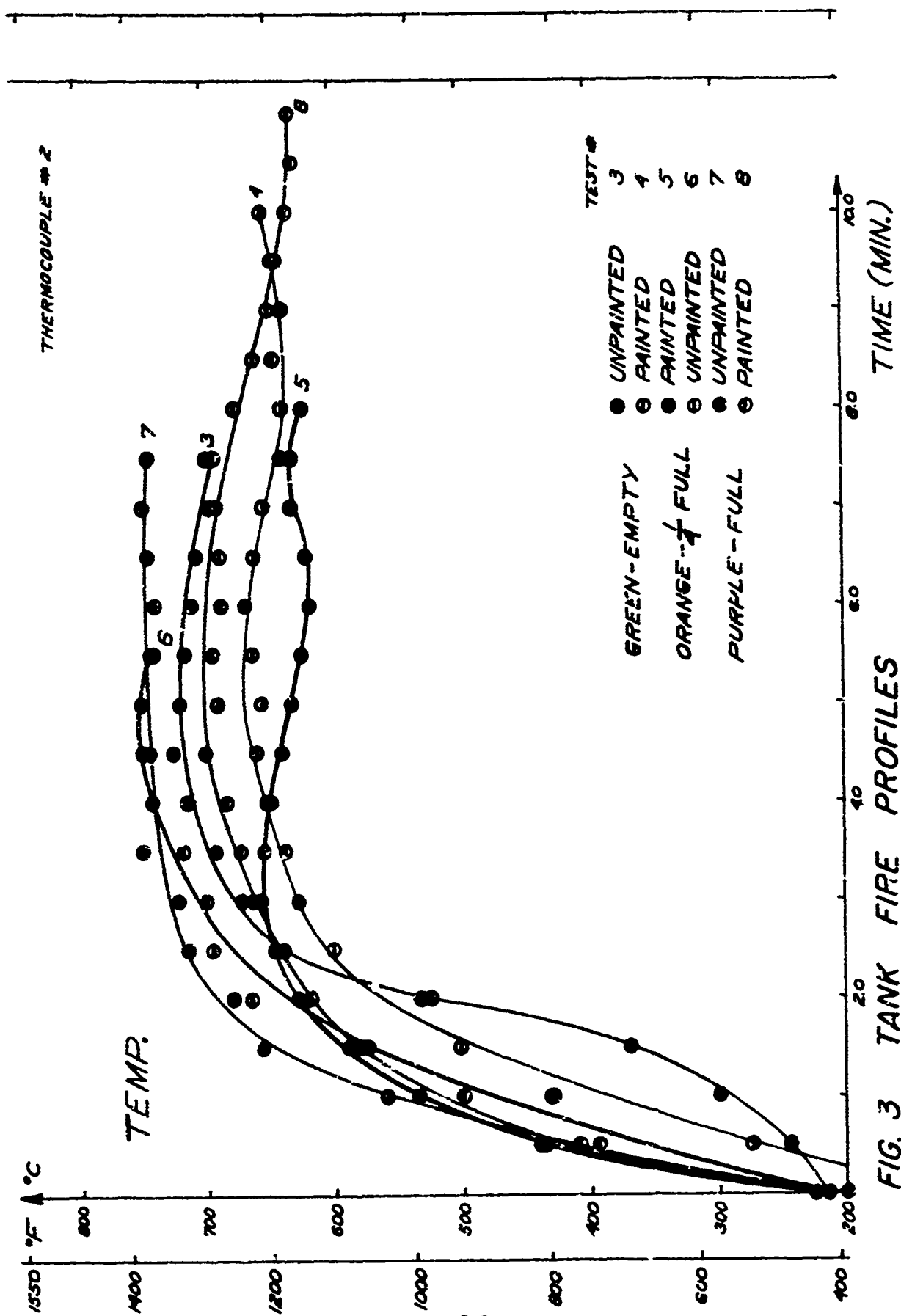


FIG. 2 TANK FIRE PROFILES



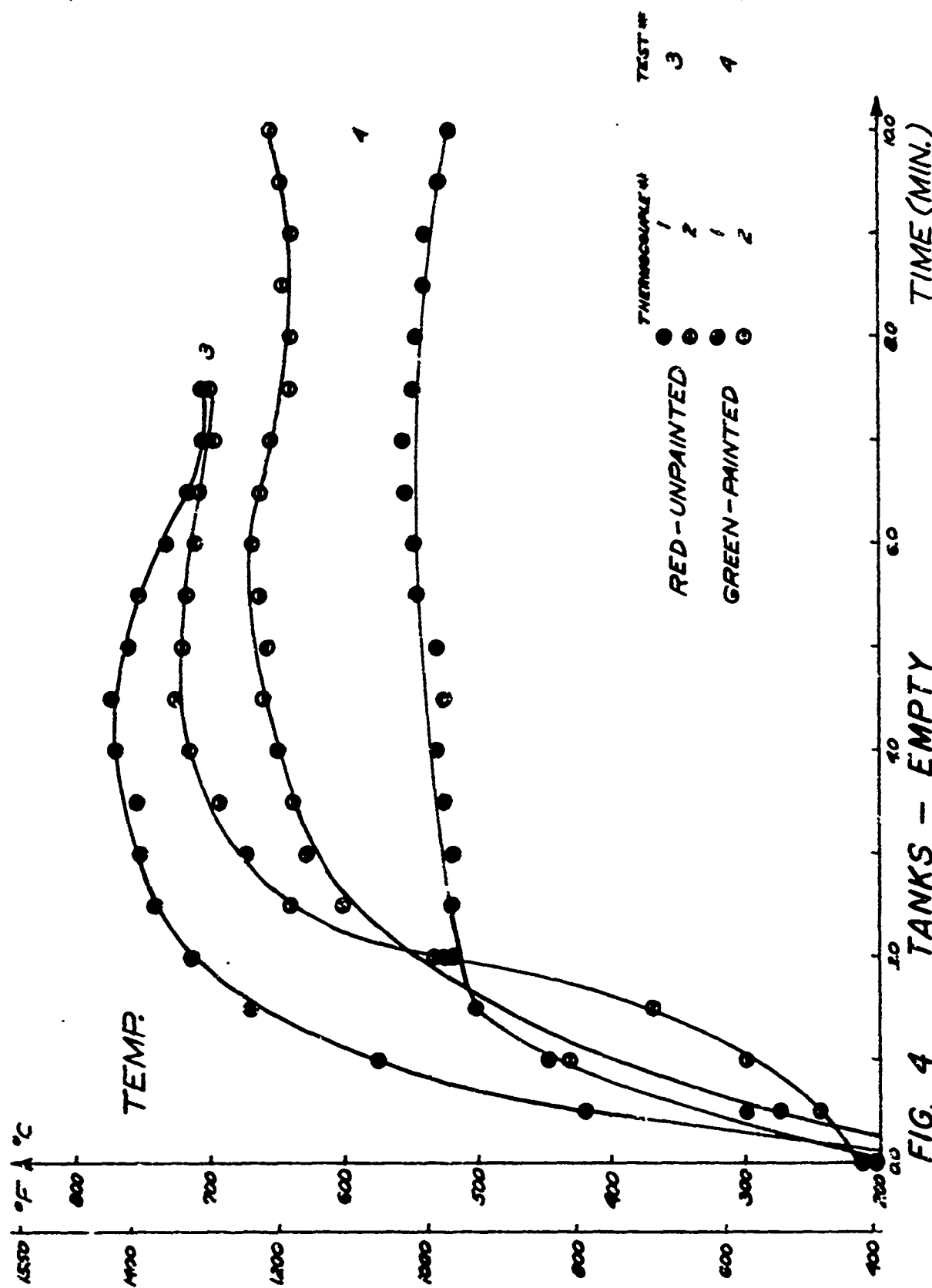
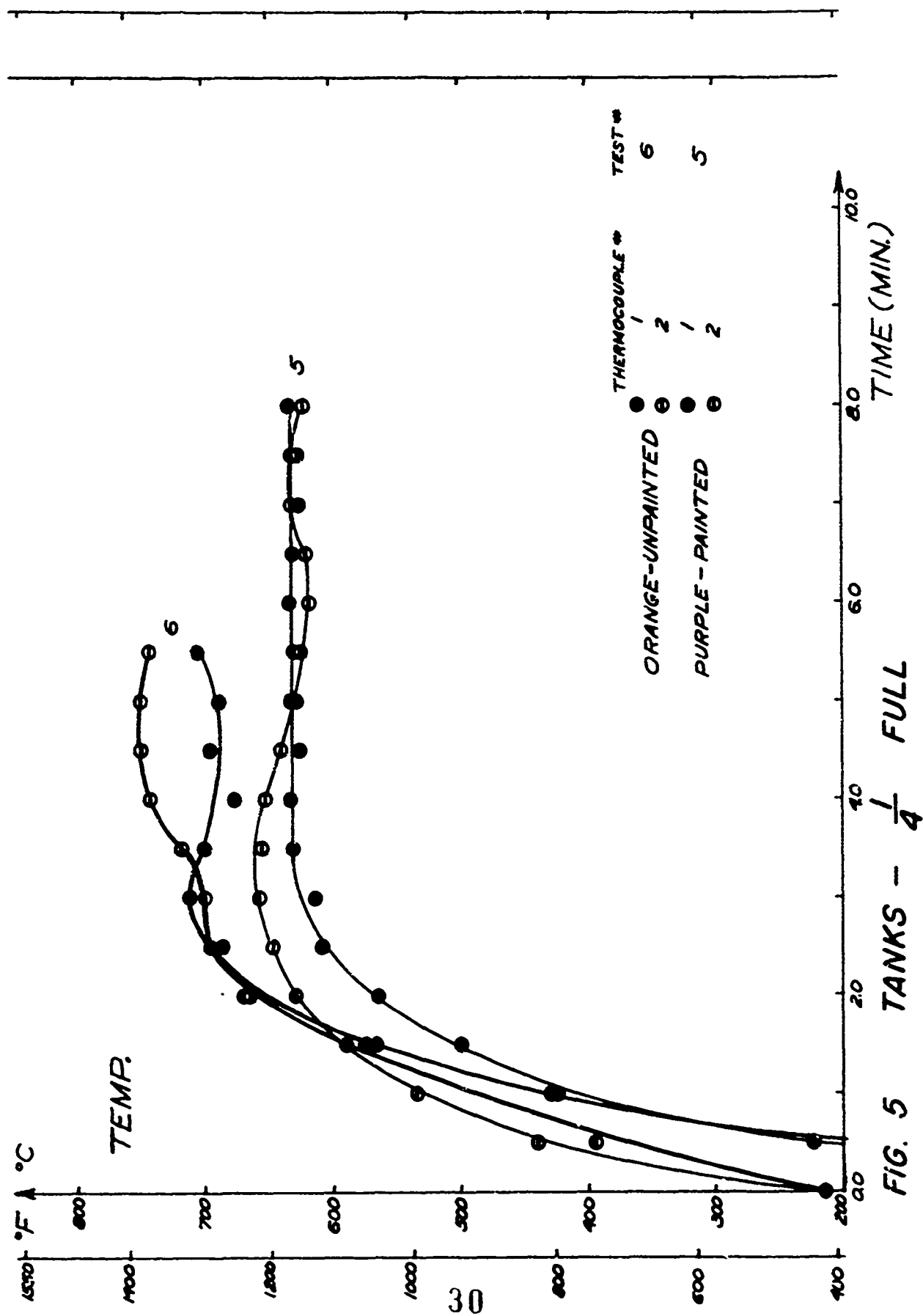


FIG. 4 TANKS - EMPTY



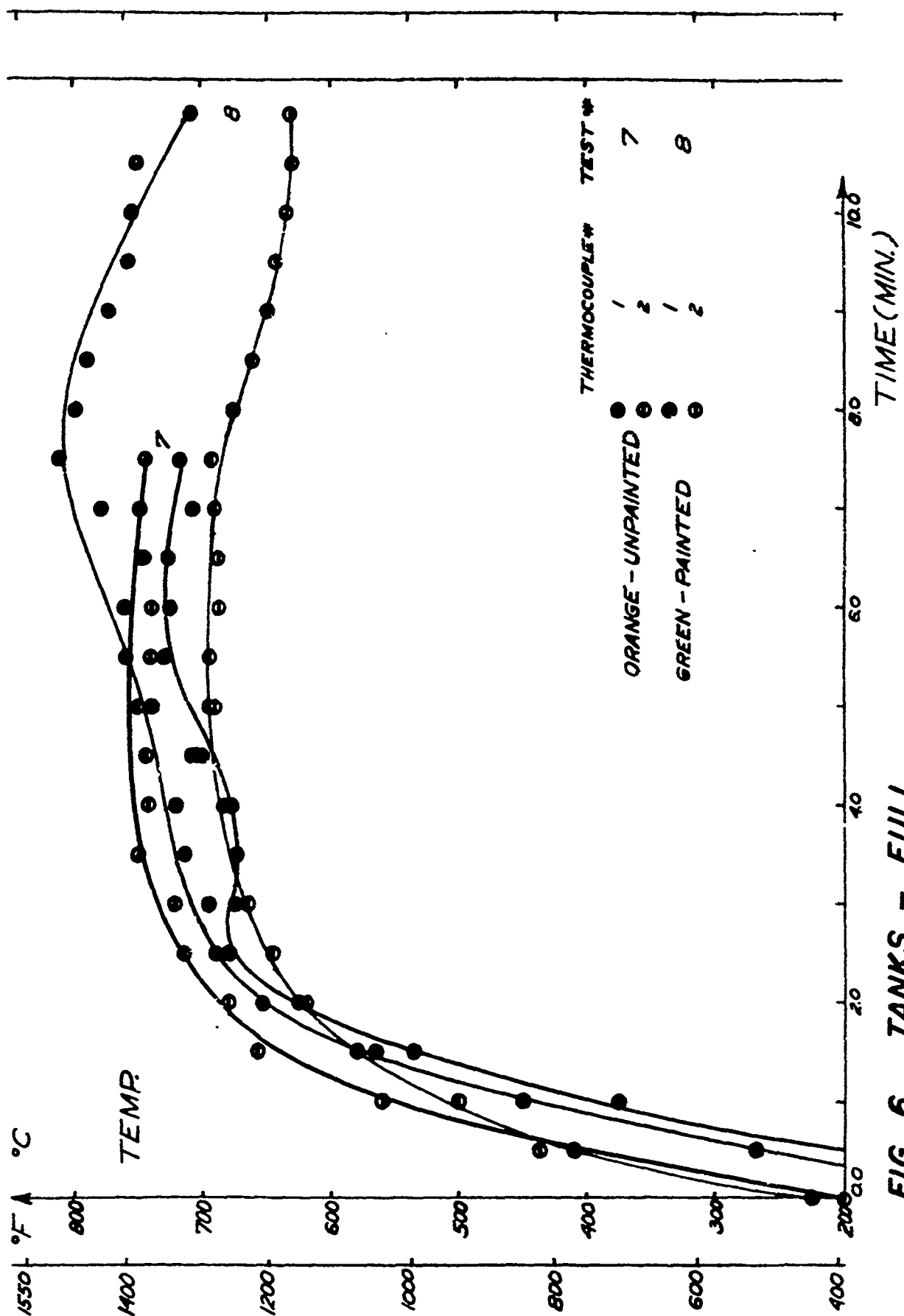


FIG. 6 TANKS - FULL

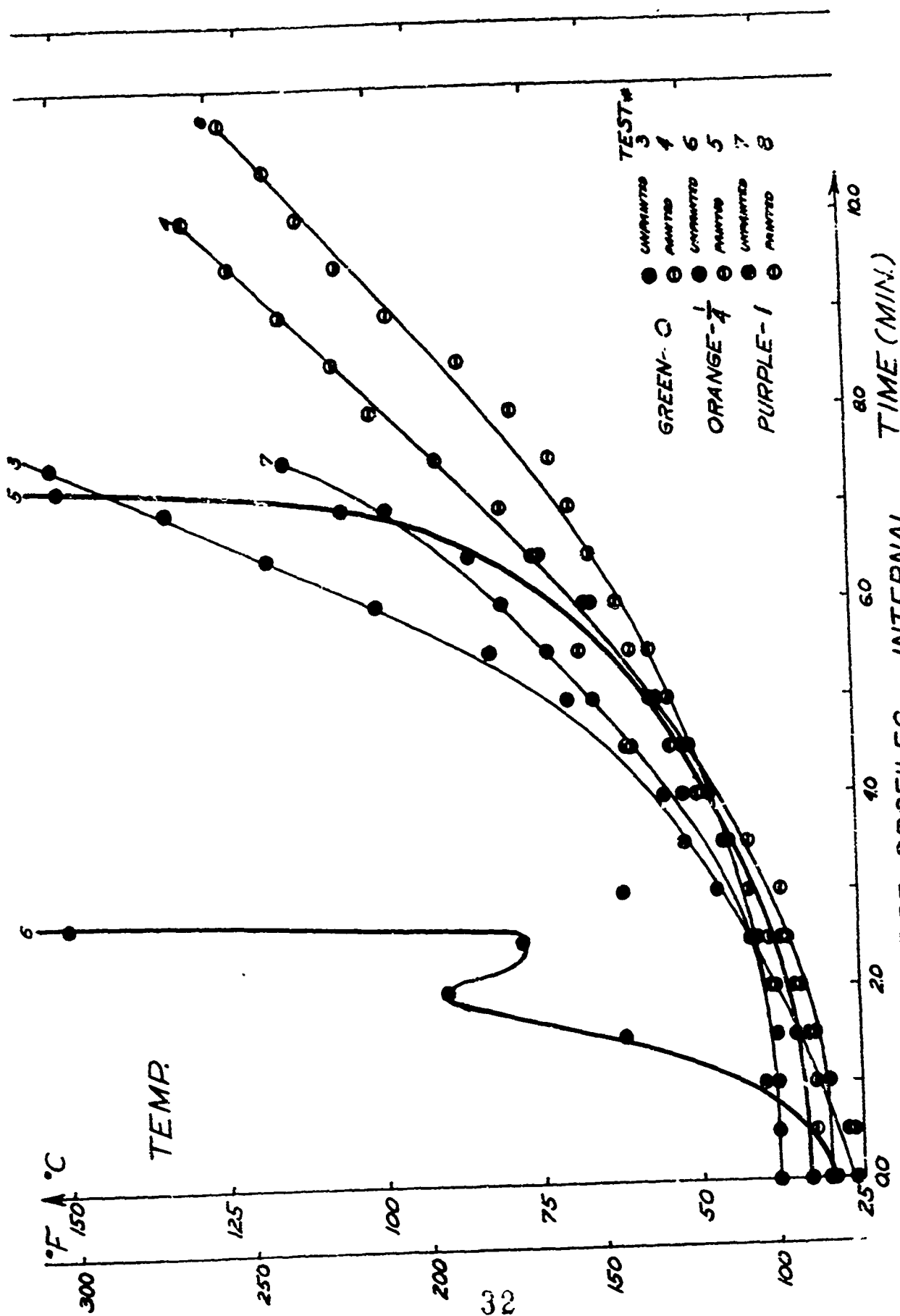


FIG. 7 TANK FIRE PROFILES - INTERNAL

PART I

Enclosure 1.

FIBERGLASS FUEL TANKS: CONSTRUCTION DETAILS

1. The tanks were layed-up by hand in halves over a styrofoam plug with a hemispherical end 16" in diameter and 18" long. Wax paper and automotive body wax were used as parting media.
2. Three pounds of gel coat (TC9-4354) were mixed with 5 ounces of hardener (TH2-3520) for each half tank. After the gel coat was applied with a rubber spreader and allowed to dry 15 minutes, the first layer of 1½ ounce mat was applied using a mixture of three pounds of epoxy resin (R 350) and 6 ounces of hardener (H-3) for wetting. After drying approximately one hour, a second layer of 1½ ounce mat was applied with a similar amount of resin.
3. The two halves were removed from the molds and placed together over a baffle constructed of 1½" thick styrofoam with a mat and resin covering. A band of mat 6" wide was placed around the center of the tank at the joint to join the two tank sections.
4. Two layers of 24-ounce woven roving were then applied over the first two layers of mat. The roving was wetted using a mixture of 7½ pounds of epoxy resin and 15 ounces of hardener per layer. A final layer of mat was applied using a 7½ pound of resin to 15 ounces of hardener to smooth out the tank surface. The total thickness of the tank was approximately 3/8".
5. A 1/8" stainless steel mounting plate with one 1½" IPS fill connection and three ½" IPS vent, supply, and return connections was fabricated by welding. A 1/8" backing plate was installed in the tank with a ¼" neoprene gasket and a 1/8" neoprene gasket was fitted under the mounting plate before the plates were made up with ¼"-20 nuts and bolts.
6. Each tank was hydrostatically tested at 10 psig and held pressure for 15 minutes.
7. Four tanks were painted with two coats of special fire retardant paint supplied by Ocean Chemical, Inc., with a 24-hour interval between coats. The total dry film thickness was 9 mils.

PART I

Enclosure 2.

Time-temperature data for all fires were provided by the National Bureau of Standards. The instrumentation van contained a Honeywell electronic 16 multipoint strip chart recorder, model number 16305866, which had 24 channels. One reading was printed on the chart every $1 \frac{2}{3}$ seconds, with a complete cycle of all 24 readings occurring in 40 seconds. Since three thermocouples were used in the tank tests, each time-temperature trace had a reading every 5 seconds on the chart recorder.

Quick-response $\frac{1}{4}$ " O.D. chromel-alumel thermocouples were used at both locations under the tanks. Number 24 wire with a nickel bead was used for the thermocouple placed inside the tanks, 12" below the top of the vent spud.

Data for all tank fire curves were taken from chart traces at 15 second intervals for the 2m30s tests and at 30 second intervals for the longer tests.