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FIRE ENDURANCE OF ALUMINUM AND STEEL HATCH COVERS. (U)

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# FIRE ENDURANCE OF ALUMINUM AND STEEL HATCH COVERS

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June 1977

Final Report

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<p>16. Abstract</p> <p>The fire resistance of aluminum and steel hatch covers was compared in full-scale fire tests. The tests were conducted on the deck of T/V A.E. WATTS at the U.S. Coast Guard Fire and Safety Test Detachment, Mobile, Alabama. Five hatch covers were placed in a 1000 square foot (90 m<sup>2</sup>) → 50 m fire which burned for 30 minutes. Two of these were steel and the other three were aluminum. Flame temperatures reached 1922°F (1050°C) during the test. The aluminum hatch covers had melted within 17 minutes of igniting the fire while the steel covers remained intact throughout.</p> <p style="text-align: right;"><b>DDC RECEIVED MAR 20 1978</b></p> <p style="text-align: center;">408 730</p>			
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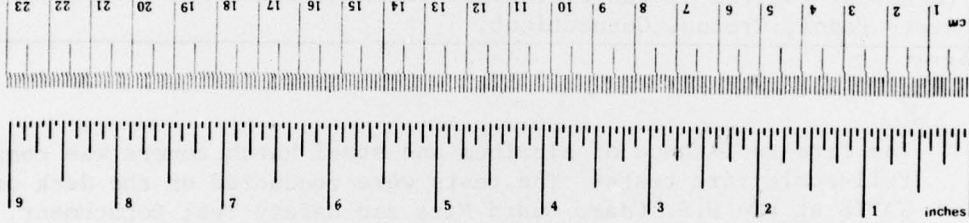
## METRIC CONVERSION FACTORS

### Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
<b>LENGTH</b>				
in	inches	2.5	centimeters	cm
ft	feet	30	meters	m
yd	yards	0.9	kilometers	km
mi	miles	1.6		
<b>AREA</b>				
in <sup>2</sup>	square inches	6.5	square centimeters	cm <sup>2</sup>
ft <sup>2</sup>	square feet	0.09	square meters	m <sup>2</sup>
yd <sup>2</sup>	square yards	0.8	square meters	m <sup>2</sup>
mi <sup>2</sup>	square miles	2.6	square kilometers	km <sup>2</sup>
	acres	0.4	hectares	ha
<b>MASS (weight)</b>				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
<b>VOLUME</b>				
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft <sup>3</sup>	cubic feet	0.03	cubic meters	m <sup>3</sup>
yd <sup>3</sup>	cubic yards	0.76	cubic meters	m <sup>3</sup>
<b>TEMPERATURE (exact)</b>				
°F	Fahrenheit temperature	.5 (after subtracting 32)	Celsius temperature	°C

### Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
<b>LENGTH</b>				
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
<b>AREA</b>				
cm <sup>2</sup>	square centimeters	0.16	square inches	in <sup>2</sup>
m <sup>2</sup>	square meters	1.2	square yards	yd <sup>2</sup>
km <sup>2</sup>	square kilometers	0.4	square miles	mi <sup>2</sup>
ha	hectares (10,000 m <sup>2</sup> )	2.5	acres	
<b>MASS (weight)</b>				
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
<b>VOLUME</b>				
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m <sup>3</sup>	cubic meters	35	cubic feet	ft <sup>3</sup>
m <sup>3</sup>	cubic meters	1.3	cubic yards	yd <sup>3</sup>
<b>TEMPERATURE (exact)</b>				
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



\*1 in = 2.54 exactly. For other exact conversions and more detailed tables, see NBS Mon. Publ. 286, Units of Weights and Measures, Price \$2.25, SD Catalog No. C13.10-286.

ACKNOWLEDGMENTS

The U. S. Coast Guard appreciates the assistance of Washington Aluminum Company, Incorporated, in providing the aluminum hatch covers for the accomplishment of this test program.

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## TABLE OF CONTENTS

	<u>Page</u>
1.0 PURPOSE OF TESTING	1
2.0 BACKGROUND	1
3.0 HATCH COVER TEST PROCEDURES	1
3.1 Description of Hatch Covers	4
3.2 Burn Area and Fuel	4
3.3 Instrumentation	4
4.0 TEST RESULTS	4
4.1 Conditions During Fire	4
4.2 Effects on Aluminum Hatch Covers	7
4.3 Effects on Steel Hatch Covers	7
5.0 CONCLUSIONS	7
REFERENCES	9

## LIST OF ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
1	Strength versus Temperature	2
2	Aluminum and Steel Hatch Covers	3
3	Test Coaming Dimensions and Thermocouple Placement	5
4	Flame and Hatch Cover Temperatures	6
5	Aluminum Hatch Cover Failures	8

## 1.0 PURPOSE OF TESTING

This test program was undertaken to investigate the fire resistance of aluminum hatch covers as compared to steel hatch covers. Two steel and three aluminum hatch covers were involved in a 30-minute fire. The temperatures and exposure times which created hatch cover failures were recorded to characterize them.

## 2.0 BACKGROUND

Aluminum hatch covers have been permitted on U.S. vessels since the early 1960's. Presently, Coast Guard Rules and Regulations for Tank Vessels (Title 46, CFR 32.57, and CFR 164.006) require steel or an equivalent stiffened fire-resistant metal as the primary structural material in the construction of tank vessel decks.<sup>1,2</sup> As stated in the SS KEYTRADER and SS BAUNE marine casualty report,<sup>3</sup> "aluminum covers had been permitted on U.S. vessels because it was believed that the lighter covers were less of a human safety hazard, and that if a cargo was exposed to open flames by a hatch cover failure, there would be little or no contribution to a vessel failure." If, however, aluminum covers are to be considered for approved use, they should be equivalent to steel in their fire-resistive capabilities.<sup>4</sup>

Tank vessel casualties show that aluminum hatch covers melt and thereby compromise the deck's fire protection integrity.<sup>3</sup> In the deck fire involving the SS KEYTRADER, the intense heat melted the aluminum hatch covers and allowed the fluids in tanks that were not damaged in the collision to be exposed to the fire. These additional fuel sources made the fire more difficult to extinguish and increased the extent of damage. The extensive fire damage sustained by the aluminum containers on the deck of the SS. C.V. SEA WITCH also refutes the use of aluminum as a structural component. These case histories tend to dispute the premise which permitted the use of aluminum hatch covers.

Steel is the primary construction material in tank vessels. It is also incombustible and provides high strength retention at elevated temperatures (Figure 1). Although deck fire temperatures have been measured as high as 1900°F (1038°C), steel with its higher melting point of 2606°F (1430°C) would not be expected to melt.<sup>5</sup> The suitability of steel as a fire-resistive material is further upheld as case histories of tank vessel fires show that steel decks remain intact after being subjected to intense heat.<sup>3,6</sup>

## 3.0 HATCH COVER TEST PROCEDURES

The hatch cover test was conducted at the U.S. Coast Guard Fire and Safety Test Detachment in Mobile, Alabama. The testing took place on the after deck of the Tank Vessel A.E. WATTS. The 30-minute fire involved two oval steel hatch covers, two circular aluminum hatch covers, and one oval aluminum hatch cover (Figure 2). Each hatch cover was positioned on top of a 21-inch (0.53 m) high steel coaming inside the test pen.

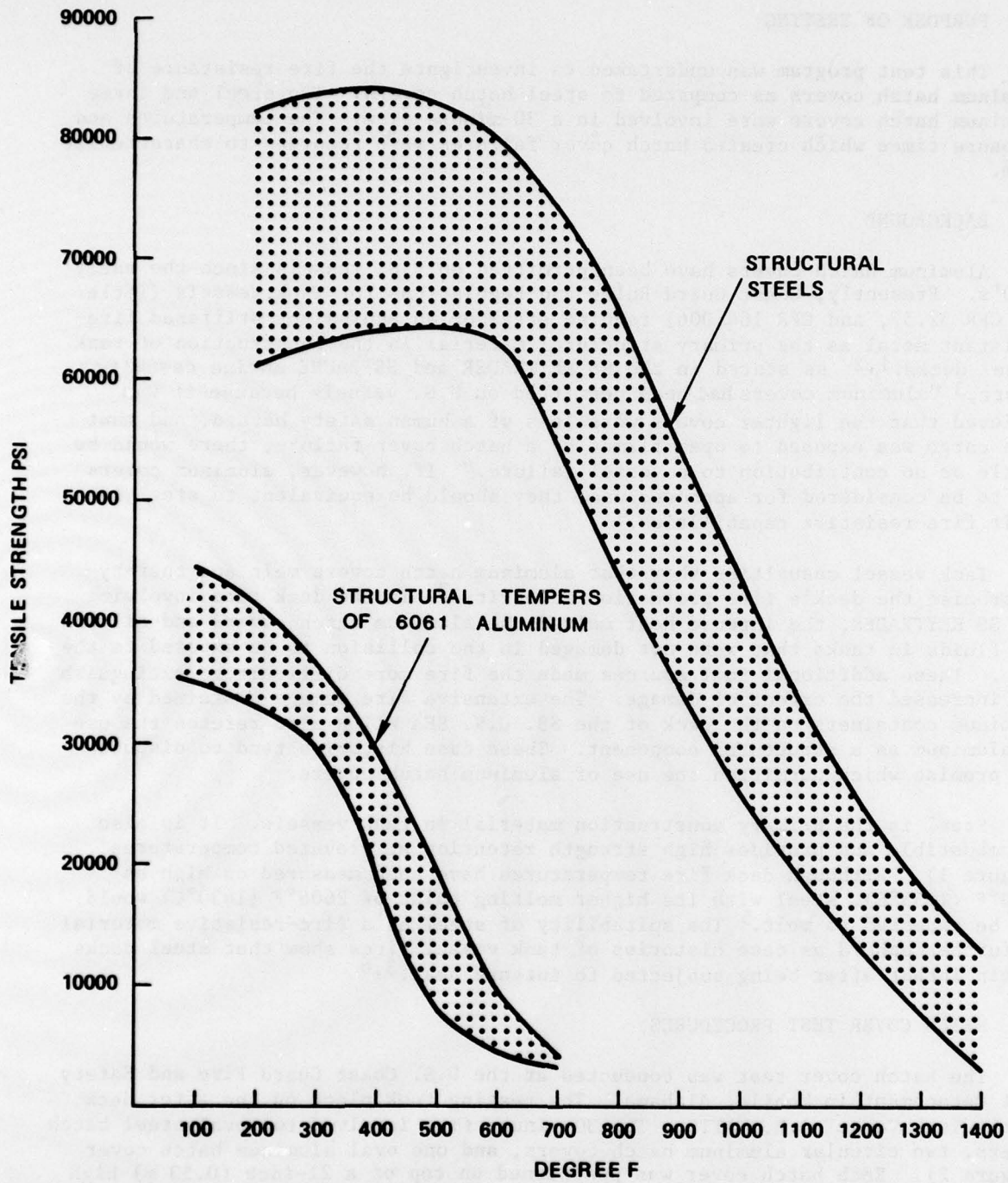
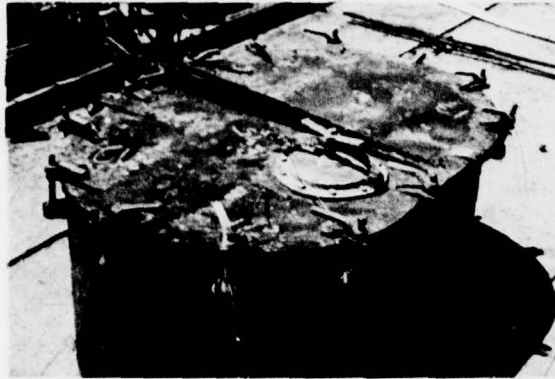
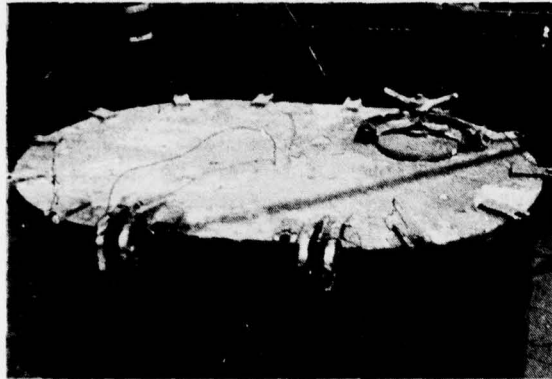


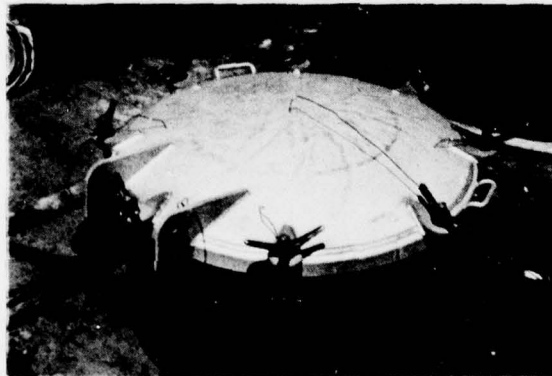
FIGURE 1  
STRENGTH VERSUS TEMPERATURE



OVAL STEEL HATCH COVER



OVAL ALUMINUM HATCH COVER



CIRCULAR ALUMINUM HATCH COVER

FIGURE 2

ALUMINUM AND STEEL HATCH COVERS

### 3.1 Description of Hatch Covers

The oval steel hatch covers were fabricated from low carbon steel. They were 6.25 feet x 4.25 feet x 0.5 inch (1.91m x 1.30m x 0.0127m) thick (Figure 2) with a 1 inch (2.5 cm) thick by 4 inch (10 cm) wide rubber gasket used to seal them to the coamings. The circular aluminum hatch covers were constructed of 6061 aluminum alloy in the T6 heat-treated condition. They were 4 feet (1.22 m) in diameter by 0.5 inch (1.25 cm) thick while the oval aluminum cover had the same dimensions as the steel hatch covers. All of the covers had a 1 inch (2.5 cm) thick by 4 inch (10 cm) wide rubber gasket to seal them to the coamings.

### 3.2 Burn Area and Fuel

A series of steel coamings, 21 inches (0.53 m) high, were constructed on the main deck of A.E. WATTS to form a shallow burn pen. The pen was 33.3 feet (10.15 m) long by 30 feet (9.14 m) wide, giving an area of 1000 square feet (90 m<sup>2</sup>) (Figure 3).

Thirty-one hundred gallons (11,780 l) of No. 2 marine diesel fuel were floated on several inches of water inside the pen. The water removed the effect of the ship's camber, and allowed the fuel to cover the entire test pen except for existing tank tops and obstacles. It also reduced the fire's effect on the main deck thus creating safer test conditions.

### 3.3 Instrumentation

Type K Inconel sheathed thermocouples were embedded 0.125 inch (0.3125 cm) into each hatch cover to measure the cover's temperature (Figure 3). Three additional thermocouples were positioned on top of the pen coamings (Figure 3) and extended 8 inches (20 cm) into the flame area. This permitted a flame temperature comparison to the internal hatch cover temperatures. Ambient temperature, wind direction, and wind speed were also recorded. Prior to fuel ignition, all instrumentation channels were recorded for four minutes to obtain background conditions.

## 4.0 TEST RESULTS

### 4.1 Conditions During Fire

The following observations and data were recorded during the test. The ambient temperature was 76°F (24°C). Wind direction was northwest to southeast at an average speed of 5 miles per hour (8 km/hr). Two minutes after ignition, the test pen was totally involved in flames. It continued to burn for a 30-minute period. Five mile per hour (8 km/hr) winds created openings in the flames and permitted observations of the hatch covers. Flame temperatures were recorded up to 1922°F (1050°C) and were high enough to melt the brass handles on the tank inspection covers inside the test pen.

The hatch cover thermocouples indicated a similar temperature rise for each cover (Figure 4). This rise varied only slightly between thermocouples on

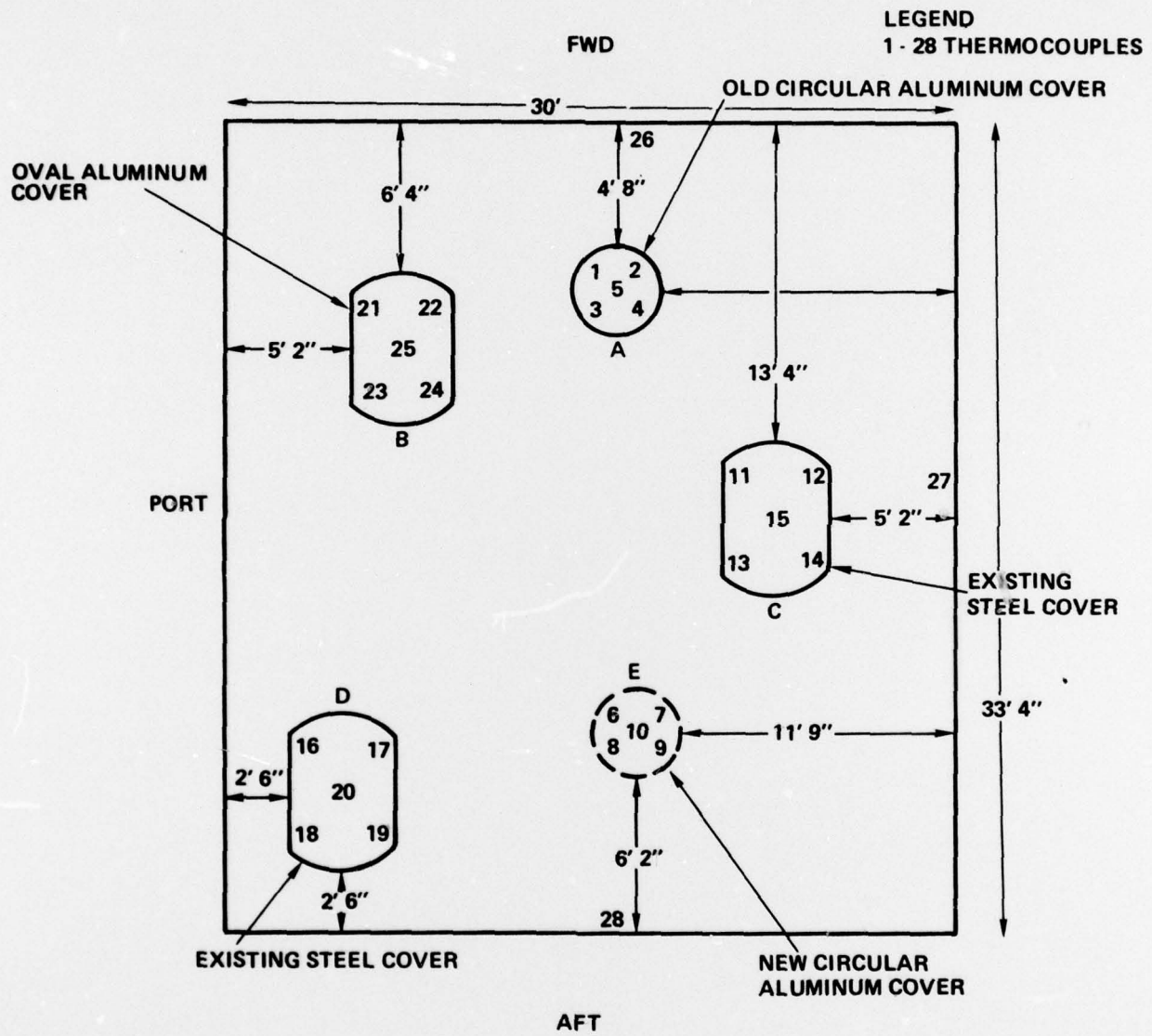
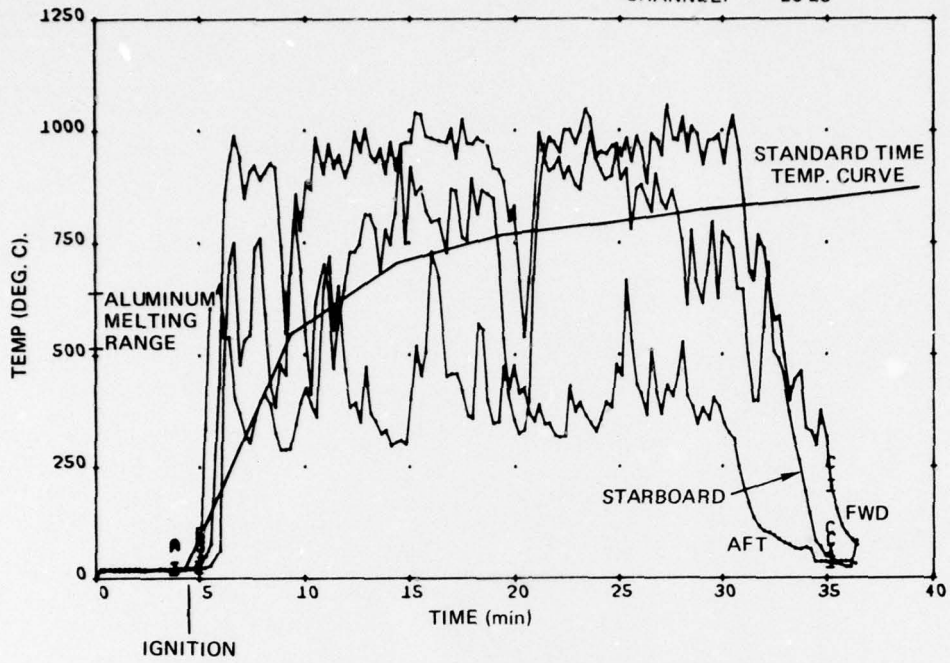


FIGURE 3

TEST COAMING DIMENSIONS AND THERMOCOUPLE PLACEMENT

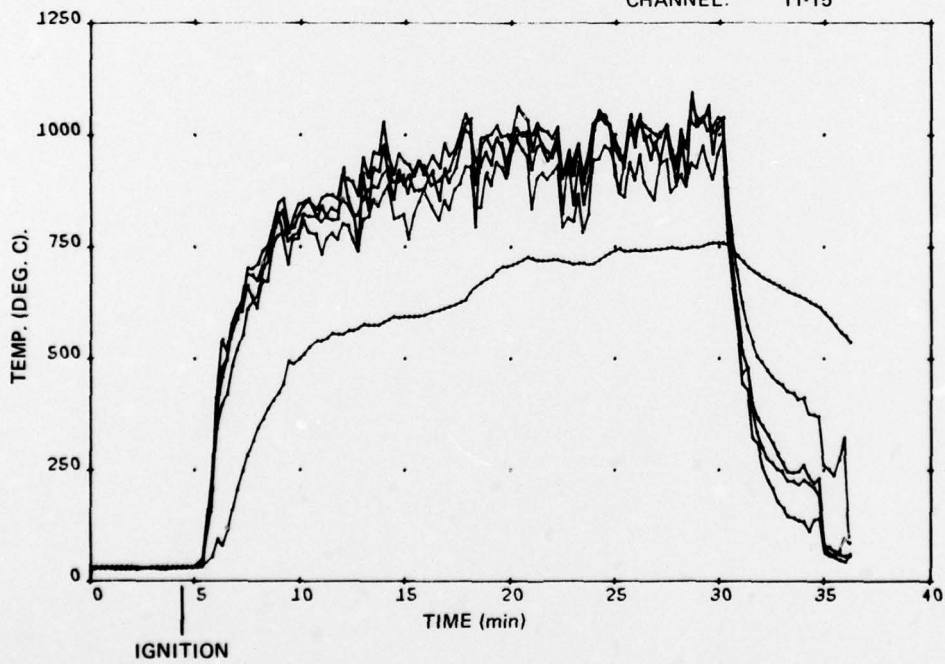
THERMOCOUPLES LOCATED ON TEST PEN COAMING

CHANNEL: 26-28



EXISTING STEEL COVER (C)

CHANNEL: 11-15



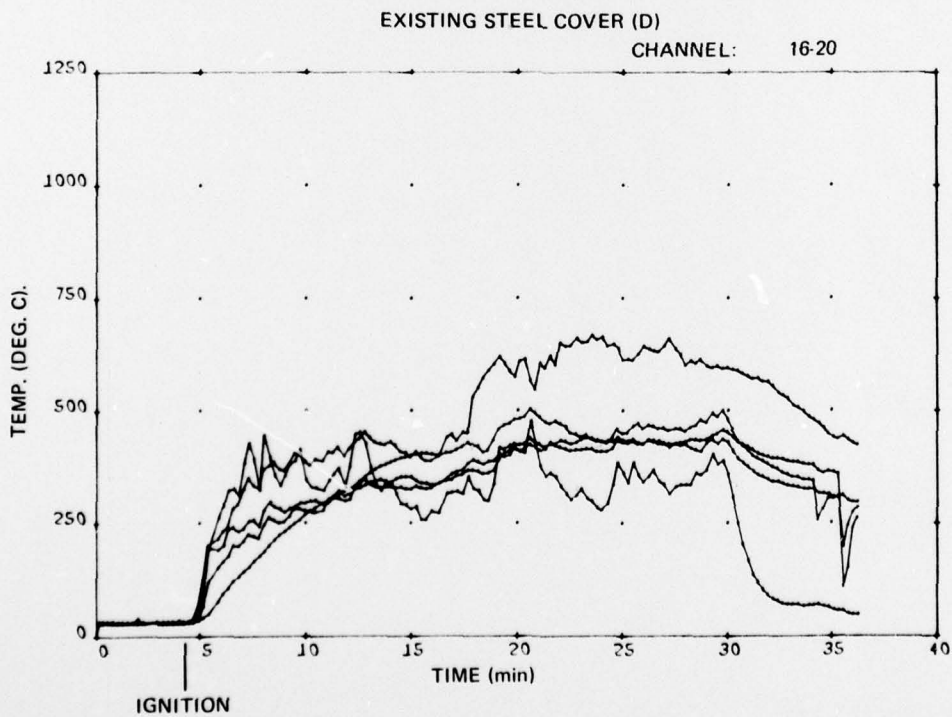
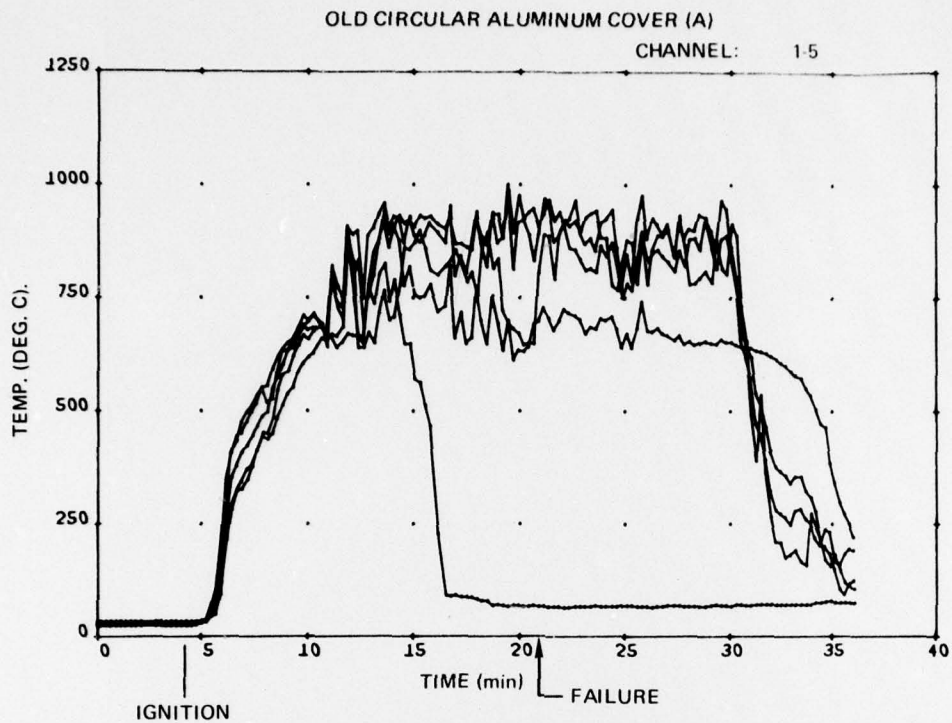


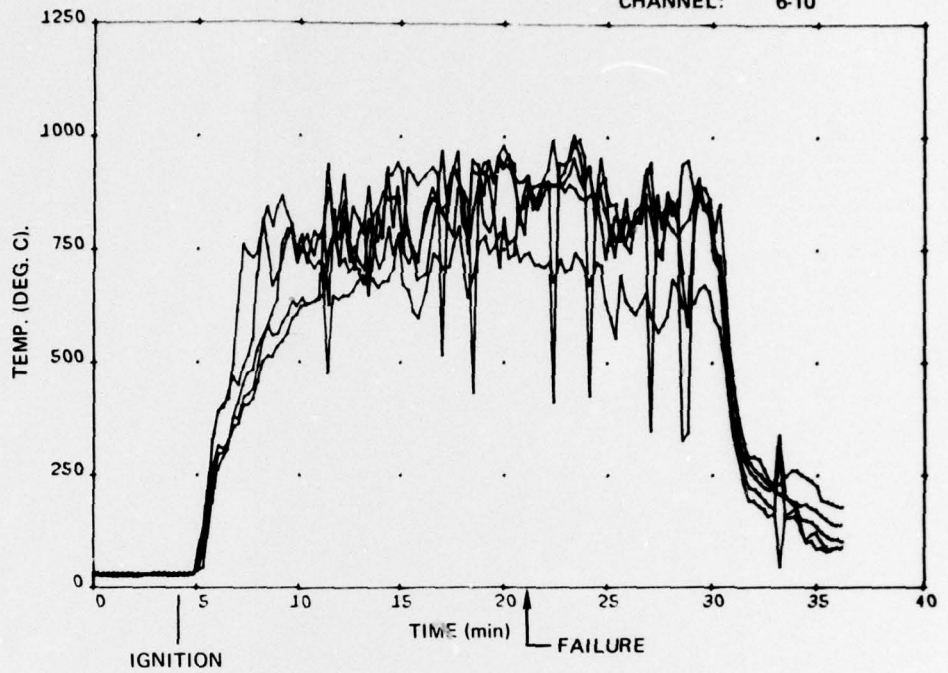
FIGURE 4

FLAME AND HATCH COVER TEMPERATURES

2

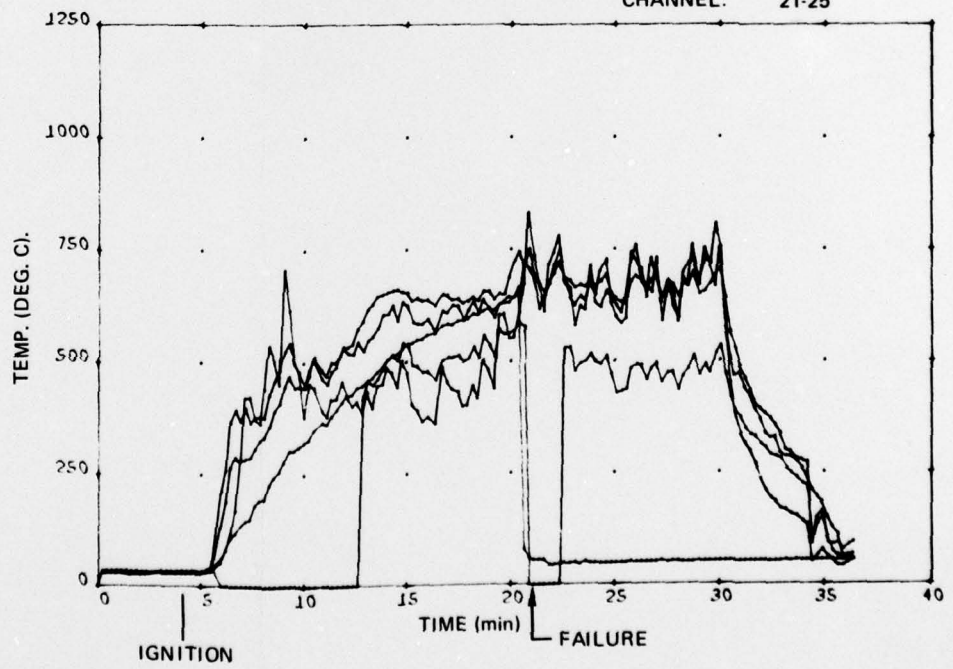
OVAL ALUMINUM COVER (B)

CHANNEL: 6-10



NEW CIRCULAR ALUMINUM COVER (E)

CHANNEL: 21-25



3

any one hatch. The variation was more pronounced between hatch covers. Hatch Cover D stands out because its overall temperature curve is lower than the others. This can be attributed to its unique positioning and its closeness to the fire pen edge. Its positioning was such that the northwest to southeast wind was blowing flames away from the cover throughout the test.

Comparing the time temperature curves of the hatch covers, we observe that a temperature plateau is achieved at approximately 8 minutes after fuel ignition, but this plateau is different for each cover (Figure 4). Wind conditions, flame exposure, and cover positioning could create the variation in the temperature plateaus.

#### 4.2 Effects on Aluminum Hatch Covers

Ten minutes after ignition, the circular aluminum hatch covers had changed shape from convex to concave. They had melted within 17 minutes of ignition, but the exact time of melting could not be determined because observations had to be made through openings in the flames. At the 17-minute point, the flame temperatures had reached 1832°F (1000°C). By then, the oval aluminum hatch cover had melted at its outer edges and collapsed below the water level inside its 21-inch (0.53 m) coaming. At the conclusion of the 30-minute test, the circular aluminum covers had been reduced to melted fragments (Figure 5).

The Standard Time Temperature Curve, adopted by the *Coast Guard* (Title 46, CFR 32.57-5), defines the required exposures that an approved hatch cover must withstand. The melting range of aluminum is well below this time temperature curve (Figure 4) thus the covers would be expected to melt and would, of course, fail to maintain the required structural fire protection of the vessel's deck.

Aluminum has less tensile strength than steel at both low and high temperatures (Figure 1).<sup>7</sup> For aluminum to match steel's strength, its thickness must be increased by a factor of 1.7.<sup>8</sup> This equivalent strength is present only at room temperature for as aluminum is subjected to increasing temperatures, its strength decreases more rapidly than steel's.

#### 4.3 Effects on Steel Hatch Covers

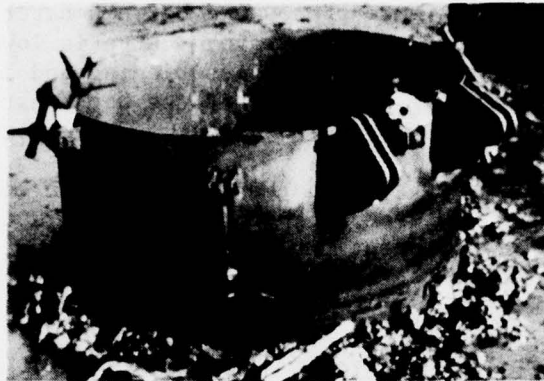
The steel hatch covers remained intact throughout the fire test. The oval rubber gaskets located beneath them were partially disintegrated.

### 5.0 CONCLUSIONS

(1) Aluminum hatch covers melt and collapse when exposed to temperatures experienced in tank vessel deck fires.

(2) Aluminum hatch covers fail to provide the required fire protection integrity for tank vessel deck construction.

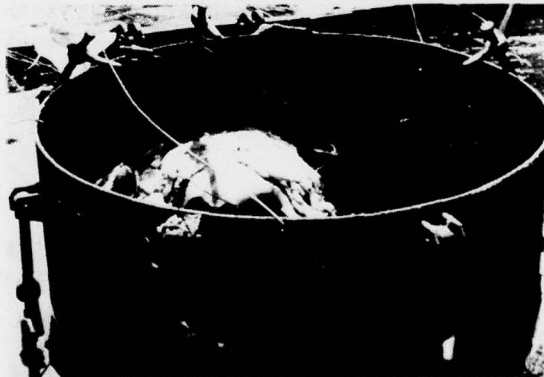
(3) When exposed to a 30-minute tank vessel deck fire, steel hatch covers provide the required structural fire protection integrity.



OLD CIRCULAR ALUMINUM HATCH COVER (A)



OVAL ALUMINUM HATCH COVER (B)



NEW CIRCULAR ALUMINUM HATCH COVER (E)

FIGURE 5

ALUMINUM HATCH COVER FAILURES

#### REFERENCES

- (1) Rules and Regulations for Tank Vessels. Subchapter D (Title 46, CFR Parts 30 to 40 inclusive), CG 123.
- (2) Rules and Regulations for Tank Vessels. Subchapter Q (Title 46, CFR Parts 150 to 199 inclusive), CG 123.
- (3) National Transportation Safety Board and U.S. Coast Guard. SS KEYTRADER AND SS BAUNE (Norwegian); Collision in the Mississippi River. Marine Casualty Report, Washington, DC.
- (4) The Society of Naval Architects. Aluminum Fire Protection Guidelines. Technical Research Bulletin 2-21, July 1974.
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- (8) Richards, Robert and Vorthman, Robert. Full-Scale Ship's Hull Exposure Fire Tests. Department of Transportation, U.S. Coast Guard, June 1976.