PENNSYLVANIA POWER & LIGHT CO.

NUREG-0612

CONTROL OF HEAVY LOADS

6 MONTH REPORT

8106240265

RESPONSE TO REQUIREMENTS IN NUREG 0612

"CONTROL OF HEAVY LOADS AT NUCLEAR POWER PLANTS"

TABLE OF CONTENTS

TABLES

FIGURES

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1.0 INTRODUCTION

This document contains PP&L's response to each requirement contained in NUREG-0612, "Control of Heavy Loads at Nuclear Power Plants". This document is divided into sections which correspond directly to Sections 2.1, 2.2, and 2.3 of Enclosure 3, "Request for Additional Information on Control of Heavy Loads," to the Staff's letter of December 22, 1980[1]. Our responses to NUREG-0612 will be submitted in two parts as requested in the December 22, 1980 letter and as modified by the Staff's letter of February 3, 1981. The first part, contained herein, is the response to Section 2.1; the second part which is to be submitted by September 22, 1981, will contain the responses to Sections 2.2 and 2.3.

PP&L's basic objective in responding to NUREG-0612 is to insure that the handling of the overhead loads at SSES is performed in a safe and efficient manner by providing operators with the proper training, operating procedures, and the equipment safeguards necessary, and by insuring that as many overhead operations as possible are performed along defined safe load paths. Where loads must be handled in the vicinity of new or spent fuel, or nuclear safety related equipment, the ultimate objectives are to insure:

1. radioactive release as a result of a potential load drop is within the requirements of 10 CFR Part 100,

2. damage to fuel will not result in a K_{eff} greater that 0.95.

3. damage to the RPV or spent fuel pool will not uncover fuel, and

4. damage to equipment will not result in the loss of safe shut down capability nor the capability to remove decay heat.

For the purposes of this response, a heavy load was considered to be any load in excess of one thousand pounds. This was the most realistic weight limit to evaluate because many cranes, monorails and hoists were rated in units of ¼, ½, or 1 ton units. In addition, the weight of some loads was estimated and a convenient unit (½ ton) was conservatively used for relatively small loads..

2.0 INFORMATION REQUESTED FROM LICENSEE

2.1 General Requirements

NUREG-0612, Section 5.1.1 identified several general guidelines related to the design and operation of overhead load-handling systems in the areas where spent and new fuel is stored, in the vicinity of the reactor core, and in other areas of the plant where a load drop could result in damage to equipment required for safe shutdown or decay heat removal. The information supplied in Sections 2.1.1 through 2.1.3 of this response is intended to provide the Staff with the results of our reviews and identify any potentially hazardous load-handling operations which would require special procedures or equipment modifications to insure the intent of NUREG-0612 is met.

1 On December 22, 1980, the NRC requested all applicants for operating licenses to implement NUREG-0612, reference letter from Darrell G. Eisenhut, Director, Division of Licensing.

2.1.1 Plant Arrangement Review

Statement Requirement:
Report the results of your review of plant arrangements to identify all overhead handling systems from which a load drop may result in damage to any system required for plant shutdown or decay heat removal (taking no credit for any interlocks, technical specifications, operating procedures, or detailed structural analysis).

Interpretation:
None required.

Statement of Response:
A detailed review of all overhead load handling systems was performed by PP&L for the purpose of identifying those handling systems from which a load drop may result in damage to equipment required for plant shutdown or decay heat removal. The SSES Equipment Index was utilized as a check to insure all cranes, monorails, and hoists were reviewed. Also included in the review were potential locations for rigging for the removal of miscellaneous equipment. Table 1, Part A and Part B, list all handling systems at SSES capable of lifting heavy loads. Table 1, Part B identifies those handling systems from which a load drop could potentially impact safety related equipment, fuel, or fuel pool cooling equipment. Figures 1 thru 26 are color coded to indicate the following: orange, location of handling systems; yellow, safe load paths; green, safe-shutdown equipment, and; pink, location of fuel and vessel. Attachment A supplements Figures 1 thru 23.

2.1.2 Exclusion of Overhead Handling Systems

Statement of Requirement:
Justify the exclusion of any overhead handling system from the above category by verifying that there is sufficient physical separation from any load-impact point and any safety-related component to permit a determination by inspection that no heavy load drop can result in damage to any system or component required for plant shutdown or decay heat removal.

Interpretation:
Table 2 "Systems Required for Safe Shutdown" lists those systems which were reviewed to verify exclusion from impact analysis. For overhead handling systems excluded under this section, physical separation was considered to be 1) no safety related equipment in the area or, 2) physical separation sufficient to insure that a load drop along any safe load path would not impact safety related equipment.

Statement of Response:
PP&L has complied with this requirement by performing a physical walkdown of all cranes, monorails and hoists located in the plant. Visual inspections were performed by plant engineers and maintenance engineers to insure that loads with the largest physical dimensions could be moved along defined safe load paths without impacting safety related equipment in the event of a load drop. Where cranes or monorails travel over hatches or access ways, the lower areas were also visually inspected for the potential impact of a load drop. During the walkdown consideration

was also given to the lateral movement of loads due to deflections caused by the possibility of loads striking structural members. Table 1, Part A "Cranes Excluded from Heavy Loads Analysis" is a tabulation of those overhead handling systems which were eliminated as having no potential for impact on safety related equipment. Overhead handling systems traveling over or in close proximity to safety related equipment (i.e. not excluded during this phase of the walkdown inspection) will be reviewed in detail and the results, including modifications or changes required to meet NUREG-0612, will be included in our final report.

2.1.3 Compliance with Guidelines of NUREG-0612, Section 5.1.1

With respect to the design and operation of heavy load handling systems in the reactor building and the load handling systems identified in Table 1, the following information is included to verify our compliance with NUREG-0612, Section 5.1.1.

2.1.3.a Safe Load Paths

Statement of Requirement:
Provide drawings or sketches sufficient to clearly identify the location of safe load paths, spent fuel, and safety-related equipment.

Interpretation:
None required.

Statement of Response:
Plant Staff engineers have reviewed the load handling systems for the purpose of identifying safe load paths relative to safety equipment and spent fuel. Figures 1 thru 26 were marked to indicate the safety related equipment, spent fuel and the paths chosen. Also included in the figures are structural steel prints used to determine the most feasible safe load paths. These paths were defined for handling systems that both fell under the area of concern with respect to NUREG-0612, and were of the bridge crane type. Monorails were excluded from this analysis, since load movement is dedicated by the monorail itself. Safe load paths will be clearly marked on the floor of the plant by the constructor. PP&L's Mechanical Maintenance is committed to incorporate the safe load paths into the appropriate operating procedures.

2.1.3.b Load Handling Procedures

Statement of Requirement:
Provide a discussion of measures taken to ensure that load-handling operations remain within safe load paths, including procedures, if any, for deviation from these paths.

Interpretation:
None required.

Statement of Response:
PP&L is currently preparing general operating procedures for overhead handling systems. These procedures will include precautions and guidelines to be observed while operating the systems. A general operating procedure for the Unit 1 Reactor Building Crane is currently being prepared by PP&L and will be available for use prior to fuel load

date (approximate implementation date is July, 1981). A draft copy is attached for information purposes (see Attachment B, "Reactor Building Crane Operating Procedure"). The draft copy indicates how compliance with NUREG-0612 will be accomplished; it describes in detail the operational procedure and precautions to be taken to insure safe handling of loads. In addition to crane operating procedures, PP&L is developing special handling procedures for major heavy loads. Such procedures will supplement the general crane operating procedure by providing additional precautions and a safe load path for that unique load. A draft copy of the procedure "Reactor Pressure Vessel Head Installation and Removal" is attached for information purposes (see Attachment C). Now that the handling systems that could impact safe shutdown equipment have been identified, PP&L will develop procedures governing movements within these areas. All specific fuel handling processes and load movements on the Refueling Floor will be covered by addending a special load handling procedure for that particular evolution, to the general operating procedure for the crane to be used.

2.1.3.c Tabulation of Heavy Loads

Statement of Requirement:
Provide a tabulation of heavy loads to be handled by each crane which includes the load identification, load weight, its designated lifting device, and verification that the handling of such load is governed by a written procedure containing, as a minimum, the information identified in NUREG-0612, Section 5.1.1(2).

Interpretation:
The tabulation of heavy loads includes only those loads which, if dropped, could impact safety-related equipment, new or spent fuel or fuel pool cooling equipment.

Statement of Response:
Table 1, Part B, "Cranes Requiring a Detailed Review" lists the heavy loads associated with each handling system from which a load drop could potentially impact safety-related equipment or fuel. The table includes: crane identification, crane location (building and elevation), load identification and weight, safety-related equipment that could be impacted, and hazard elimination category. A written procedure will be developed for each heavy load that, if dropped, could impact safety related equipment.

2.1.3.d Verification of Design of Lifting Devices

Statement of Requirement:
Verification that lifting devices for loads identified in 2.1.3.c, above, comply with the requirements of ANSI N14.6 - 1978, or ANSI B30.9-1971 as appropriate. For lifting devices where these standards, as supplemented by NUREG 0612, Section 5.1.1(4) or 5.1.1(5), are not met, describes any proposed alternatives and demonstrate their equivalency in terms of load-handling reliability.

Interpretation:
None Required.

Statement of Response:
Slings and special lifting devices have not been procured for use at SSES except the strongback used for the RPV head and the lifting device for the dryer and separator. These items have been designed and supplied by the NSSS vendor. Sufficient information is not yet available for determining full compliance with ANSI B30.91971; however, the strongback

for the RPV has been proof-load tested to 125 tons, inspected by magnetic particle examination and used to move the RPV head for Unit 1, and the dryer/separator lifting device meets the proof-load requirements of ANSI B30.9-1971 and has been inspected by magnetic particle examination. All other slings and/or lifting devices which will handle heavy loads that could impact safety-related equipment or fuel will be installed and used in accordance with the guidelines of ANSI B30.9-1971. In selecting the proper sling, the load used will be the sum of the static and the maximum dynamic load (SSE will not be included in the dynamic load imposed in the sling or lifting device). The rating identification on the sling will be in terms of the "static load" which produces the maximum static and dynamic load. Where this restricts slings to use on only certain cranes, the slings will be marked as to the cranes with which they may be used. Special lifting devices to be used with spent fuel shipping containers will be designed, installed and used in accordance with the guidelines of ANSI N14.6-1978.

2.1.3.e. <u>Verification of inspection, testing and maintenance</u>

Statement of Requirement:
Provide a verification that ANSI B30.2-1976, Chapter 2-2, has been invoked with respect to crane inspection, testing, and maintenance. Where any exception is taken to this standard, sufficient information should be provided to demonstrate the equivalency of proposed alternatives.

Interpretation:
None Required.

Statement of Response:
PP&L is presently developing a preventative maintenance program to include all cranes and hoists. This program will include requirements for inspection, testing, and maintenance in accordance with the guidelines of Chapter 2-2 of ANSI B30.2-1976 with the exception that tests and inspections will be performed prior to use where it is not practical to meet the frequencies of ANSI B30.2 for periodic inspection and test, or where frequency of crane use is less than the specified inspection and test frequency. The diesel building cranes (0H501 A,B,C and D) and the reactor building crane (auxiliary hoist, 1H213) have been used during plant construction. The construction group has performed the necessary inspecting, testing, and maintenance requirements of Chapter 2-2, ANSI B30.2-1967.

2.1.3.f <u>Verification of Crane Design</u>

Statement of Requirement:
Provide verification that crane design complies with the guidelines of CMAA Specification 70 and Chapter 2-1 of ANSI B30.2-1976, including the demonstration of equivalency of actual design requirements for instances where specific compliance with these standards is not provided.

Interpretations:
None Required.

Statement of Response:
Design requirements, for those cranes from which a load drop could impact safety related equipment or fuel, are in accordance with the Crane Manufacturers Association of America (CMAA) Specification 70 and ANSI B30.2. The reactor building crane (1H213) and the diesel building cranes (0H501A,B,C and D) are designed in accordance with CMAA-70 Class C and ANSI B30.2-1967. The design requirements for the refueling platform hoists (1H201, 1H203, and 1H214) which are supplied by the NSSS under will be included in PP&L's final report. The

monorail hoists are designed in accordance with ANSI B30.16. The design of the jib crane is in accordance with ANSI B30.2-1976 and CMAA-70.

2.1.3.g Exceptions to ANSI B30.2-1976 (Operator Training)

Statement of Requirement:
Identify exceptions, if any, taken to ANSI B30.2-1976 with respect to operator training, qualification, and conduct.

Interpretation:
None Required.

Statement of Response:
We make no exceptions to ANSI B30.2-1976. The crane operator's training program was developed to meet the requirements of chapter 2.3 of ANSI B30.2-1976 "Overhead and Gantry Cranes". A procedure is currently being written by plant staff mechanical maintenance section to formalize the program and furnish the necessary forms to document the training. All crane operators will be qualified to this procedure.

2.2 Specific Requirements for Reactor Building (1)

2.3 Specific Requirements for Other Areas (1)

(1) Per the guidelines of Mr. D. L. Eisenhut's letter of December 22, 1981, these sections are to be submitted in PP&L's final report.

A. CRANES EXCLUDED FROM HEAVY LOADS ANALYSIS

CRANE EQUIPMENT NO.	LOCATION		SAFETY RELATED EQUIPMENT (1)	HAZARD ELIMINATION CATEGORY (2)
	BUILDING	ELEVATION		
OH301	RADWASTE BUILDING	715'	NONE	C
OH302	RADWASTE BUILDING	676'	NONE	C
OH303	RADWASTE BUILDING	676'	NONE	C
OH304	RADWASTE BUILDING	646'	NONE	C
OH305	RADWASTE BUILDING	691'	NONE	C
OH508	RADWASTE BUILDING	691'	NONE	C
OH503	CIRCULATING WATER PUMPHOUSE	676'	NONE	C
OH506	ENGINEERED SAFEGUARD PUMPHOUSE	685'	NONE	C
OH507	CHLORINE AND ACID STORAGE BUILDING	697'	NONE	C
OH700 OH701	SERVICE AND ADMINISTRATION BUILDING	676'	NONE	C
OH102A	TURBINE BUILDING	762'	NONE	C
OH102B	TURBINE BUILDING	762'	NONE	C
1H101	TURBINE BUILDING	676'	NONE	C
1H102	TURBINE BUILDING	729'	NONE	C
1H103	TURBINE BUILDING	762'	NONE	C
1H104	TURBINE BUILDING	699'	NONE	C

A. CRANES EXCLUDED FROM HEAVY LOADS ANALYSIS

CRANE EQUIPMENT NO.	LOCATION		SAFETY RELATED EQUIPMENT (1)	HAZARD ELIMINATION CATEGORY (2)
	BUILDING	ELEVATION		
1H105	TURBINE BUILDING	699'	NONE	C
1H107	TURBINE BUILDING	656'	NONE	C
1H108	TURBINE BUILDING	699'	NONE	C
1H109A	TURBINE BUILDING	729'	NONE	C
1H109B	TURBINE BUILDING	729'	NONE	C
1H109C	TURBINE BUILDING	729'	NONE	C
1H204	REACTOR BUILDING	719'	NONE	C
1H206	REACTOR BUILDING	719'	NONE	C
1H207A	REACTOR BUILDING	719'	NONE	C
1H207B	REACTOR BUILDING	719'	NONE	C
1H208A	REACTOR BUILDING	683'	REACTOR HEAT REMOVAL EXCHANGER	C - PICKS UP EXCHANGER BUT DOES NOT TRAVEL OVER OTHER SAFETY RELATED EQUIPMENT.
1H208B	REACTOR BUILDING	683'	REACTOR HEAT REMOVAL EXCHANGER	C - PICKS UP EXCHANGER BUT DOES NOT TRAVEL OVER OTHER SAFETY RELATED EQUIPMENT.
1H212	REACTOR BUILDING	818'	FUEL POOL	C - CAPACITY 200#
1H215	REACTOR BUILDING	799'	NONE	C
1H216	REACTOR BUILDING	670'	NONE	C
1H217	REACTOR BUILDING	690'	NONE	C

A. CRANES EXCLUDED FROM HEAVY LOADS ANALYSIS

CRANE EQUIPMENT NO.	LOCATION		SAFETY RELATED EQUIPMENT (1)	HAZARD ELIMINATION CATEGORY (2)
	BUILDING	ELEVATION		
1H218	REACTOR BUILDING	719'	NONE	C
1H239	REACTOR BUILDING	739'	NONE	C
1H240	REACTOR BUILDING	739'	NONE	C
1H241	REACTOR BUILDING	739'	NONE	C
1H242	REACTOR BUILDING	739'	NONE	C
1H243	REACTOR BUILDING	719'	NONE	C
1H402A	REACTOR BUILDING	752'	NONE	C
1H402B	REACTOR BUILDING	752'	NONE	C

B. CRANES REQUIRING DETAILED REVIEW

CRANE: OH501 A,B,C,D

LOCATION	DIESEL GENERATOR BUILDING ELEV. 710'		
IMPACT AREA / LOADS	ELEVATION	SAFETY RELATED EQUIPMENT (1)	HAZARD ELIMINATION CATEGORY (2)
STATOR (24,200 LBS.)	670'	DIESEL GENERATOR	C - DOES NOT TRAVEL OVER THE DIESEL; LOADS HANDLED ONLY DURING DIESEL MAINTENANCE.
ROTOR (27,114 LBS.)	670'	DIESEL GENERATOR	C - DOES NOT TRAVEL OVER THE DIESEL; LOADS HANDLED ONLY DURING DIESEL MAINTENANCE.

B. CRANES REQUIRING DETAILED REVIEW

CRANE: 1H210

LOCATION	REACTOR BUILDING ELEV. 683'		
IMPACT AREA / LOADS	ELEVATION	SAFETY RELATED EQUIPMENT (1)	HAZARD ELIMINATION CATEGORY (2)
REACTOR BUILDING CLOSED COOLING WATER HEAT EXCHANGERS (24,715 LBS.)	683'	FIK907 F1K939	NOTE (3)
CORE SPRAY PUMP (7,115 LBS.)	645'	F1K907 F1K939	NOTE(3)
CORE SPRAY PUMP MOTOR (6,330 LBS.)	645'	F1K907 F1K939	NOTE(3)
CORE SPRAY PUMP ROTOR (1,379 LBS.)	645'	F1K907 F1K939	NOTE(3)
CORE SPRAY PUMP STATOR (2,700 LBS.)	645'	F1K907 F1K939	NOTE(3)

B. CRANES REQUIRING DETAILED REVIEW

CRANE: 1H201, 1H203, 1H214 (REFUEL PLATFORM)

LOCATION	REACTOR BUILDING ELEV. 818'		
IMPACT AREA / LOADS	ELEVATION	SAFETY RELATED EQUIPMENT (1)	HAZARD ELIMINATION CATEGORY (2)
NUCLEAR FUEL		FUEL	NOTE (3)

B. CRANES REQUIRING DETAILED REVIEW

CRANE: 1H211

LOCATION	REACTOR BUILDING ELEV. 818'		
IMPACT AREA / LOADS	ELEVATION	SAFETY RELATED EQUIPMENT (1)	HAZARD ELIMINATION CATEGORY (2)
FUEL BUNDLE (APPROXIMATELY 800 LBS.)		FUEL	NOTE (3)

B. CRANES REQUIRING DETAILED REVIEW

CRANE: 1H213 (AUXILIARY HOIST)

LOCATION	REACTOR BUILDING ELEV. 818'		
IMPACT AREA / LOADS	ELEVATION	SAFETY RELATED EQUIPMENT (1)	HAZARD ELIMINATION CATEGORY (2)
NUCLEAR FUEL	645' TO 818'	FUEL	NOTE (3)
FUEL POOL COVERS	818'	FUEL	NOTE (3)

B. CRANES REQUIRING DETAILED REVIEW

CRANE: 1H213 (MAIN HOIST)

LOCATION	REACTOR BUILDING 818'		
IMPACT AREA / LOADS	ELEVATION	SAFETY RELATED EQUIPMENT (1)	HAZARD ELIMINATION CATEGORY (2)
MISSILE/SHIELD BLOCKS (143,000 - 197,000 LBS.)	818'	FUEL	NOTE (3)
DRYWELL HEAD (85,000 LBS.) - ESTIMATED	818'	FUEL	NOTE (3)
FUEL POOL GATES (6,000 LBS.) - ESTIMATED	818'	FUEL.	NOTE (3)
TENSIONER MONORAIL (2,000 LBS.) - ESTIMATED	818'	FUEL	NOTE (3)
SPENT FUEL SHIPPING CASK (110,000 LBS.)	818'	FUEL	NOTE (3)
REFUELING JIB CRANE (5,200 LBS.)	818'	FUEL	NOTE (3)
STEAM DRYERS (40,000 LBS.)	818'	FUEL	NOTE (3)
STEAM SEPARATOR (75,000 LBS.)	818'	FUEL	NOTE (3)

B. CRANES REQUIRING DETAILED REVIEW

CRANE: 1H213 (MAIN HOIST)

LOCATION	REACTOR BUILDING ELEV. 818'		
LOADS \ IMPACT AREA	ELEVATION	SAFETY RELATED EQUIPMENT (1)	HAZARD ELIMINATION CATEGORY (2)
THERMAL SHIELD (WITHOUT PANELS) (20,850 LBS.)	818'	FUEL	NOTE (3)
VESSEL HEAD (96,000 LBS.) - ESTIMATED	818'	FUEL	NOTE (3)
LOAD BLOCK (10,000 LBS.) - ESTIMATED	818'	FUEL	NOTE (3)

B.. CRANES REQUIRING DETAILED REVIEW

CRANE: XHXXX*

LOCATION	REACTOR BUILDING ELEV. 818'		
IMPACT AREA / LOADS	ELEVATION	SAFETY RELATED EQUIPMENT (1)	HAZARD ELIMINATION CATEGORY (2)
RESIN BED SHIELD COVERS (30,500 LBS.)	818'	FUEL	NOTE (3)
*THIS CRANE HAS NOT BEEN PURCHASED; THEREFORE, NO EQUIPMENT NUMBER IS AVAILABLE.			

B. CRANES REQUIRING DETAILED REVIEW

CRANE: 1H219

LOCATION	REACTOR BUILDING ELEV. 719'		
IMPACT AREA / LOADS	ELEVATION	SAFETY RELATED EQUIPMENT (1)	HAZARD ELIMINATION CATEGORY (2)
EQUIPMENT ACCESS DOOR (21,000 LBS.)	719'	EIPH81	NOTE (3)

B. CRANES REQUIRING DETAILED REVIEW

CRANE: 1H403, 1H404, 1H406, 1H407, 1H408, XHXXX

LOCATION	REACTOR BUILDING ELEV. 719'		
IMPACT AREA / LOADS	ELEVATION	SAFETY RELATED EQUIPMENT (1)	HAZARD ELIMINATION CATEGORY (2)
SAFETY VALVE (2,800 LBS.)	752'	E1K149 E1K150 E1K151 E1K036	NOTE (3)

B. CRANES REQUIRING DETAILED REVIEW

CRANE: 1H205

LOCATION	REACTOR BUILDING ELEV. 719'		
IMPACT AREA / LOADS	ELEVATION	SAFETY RELATED EQUIPMENT (1)	HAZARD ELIMINATION CATEGORY (2)
RECIRCULATION PUMP (27,200 LBS.)		HYDRAULIC CONTROL UNITS	NOTE (3)
RECIRCULATION PUMP STATOR (21,860 LBS.)		HYDRAULIC CONTROL UNITS	NOTE (3)
RECIRCULATION PUMP ROTOR (10,315 LBS.)		HYDRAULIC CONTROL UNITS	NOTE (3)

TABLE 1 (PART B, CONT'D)

B. CRANES REQUIRING DETAILED REVIEW

CRANE: 1H209

LOCATION	REACTOR BUILDING ELEV. 683'		
IMPACT AREA / LOADS	ELEVATION	SAFETY RELATED EQUIPMENT (1)	HAZARD ELIMINATION CATEGORY (2)
CORE PUMP SPRAY MOTOR (6,330 LBS.)	645'	MCC1B226 1D264	NOTE (3)
CORE SPRAY PUMP ROTOR (1,379 LBS.)	645'	MCC1B226 1D264	NOTE (3)
CORE SPRAY PUMP STATOR (2,700 LBS.)	645'	MCC1B226 1D264	NOTE (3)
CORE SPRAY PUMP (7,115 LBS.)	645'	MCC1B226 1D264	NOTE (3)
HIGH PRESSURE COOLANT INJECTION PUMP (6,200 LBS.)	645'	MCC1B226 1D264	NOTE (3)
HIGH PRESSURE COOLANT INJECTION BOOSTER PUMP (3,900 LBS.)	645'	MCC1B226 1D264	NOTE (3)
HIGH PRESSURE COOLANT INJECTION GEAR REDUCER (1,260 LBS.)	645'	MCC1B226 1D264	NOTE (3)
HIGH PRESSURE COOLANT INJECTION STOP VALVE (2,900 LBS.)	645'	MCC1B226 1D264	NOTE (3)

B. CRANES REQUIRING DETAILED REVIEW

CRANE: 1H209

LOCATION	REACTOR BUILDING ELEV. 683'		
IMPACT AREA / LOADS	ELEVATION	SAFETY RELATED EQUIPMENT (1)	HAZARD ELIMINATION CATEGORY (2)
HIGH PRESSURE COOLANT INJECTION TURBINE UPPER HEAD CASE (7,500 LBS.)	645'	MCC1B226 1D264	NOTE (3)
HIGH PRESSURE COOLANT INJECTION TURBINE ROTOR (1,400 LBS.)	645'	MCC1B226 1D264	NOTE (3)
REACTOR CORE ISOLATION COOLING PUMP (5,275 LBS.)	645'	MCC1B226 1D264	NOTE (3)
REACTOR CORE ISOLATION COOLING TURBINE (3,400 LBS.)	645'	MCC1B226 1D264	NOTE (3)
REACTOR HEAT REMOVAL PUMP (20,650 LBS.)	645'	MCC1B226 1D264	NOTE (3)
REACTOR HEAT REMOVAL PUMP MOTOR (18,020 LBS.)	645'	MCC1B226 1D264	NOTE (3)
REACTOR HEAT REMOVAL ROTOR (4,690 LBS.)	645'	MCC1B226 1D264	NOTE (3)
REACTOR HEAT REMOVAL STATOR (6,960 LBS.)	645'	MCC1B226 1D264	NOTE (3)

TABLE 1

NOTE (1) Nuclear Safety Related Equipment located in the immediate vicinity which could be impacted by a load drop.

NOTE (2) Hazard Elimination Categories

a. Crane travel for this area/load combination prohibited by electrical interlocks or mechanical stops.

b. System redundancy and separation precludes loss of capability of system to perform its safety-related function following this load drop in this area.

c. Site-specific considerations eliminate the need to consider load/equipment combination.

d. Likelihood of handling system failure for this load is extremely small (i.e. section 5.1.6 NUREG 0612 satisfied).

e. Analysis demonstrates that crane failure and load drop will not damage safety-related equipment.

NOTE (3) Handling of this load requires further review to determine whether modifications or procedural requirements are to be implemented to meet the intent of NUREG-0612. Results of the review will be in PP&L's final report.

TABLE 2

SYSTEMS REQUIRED FOR SAFE SHUTDOWN

Group I - Systems Required for Both Hot and Cold Shutdown

Control Rod Drive - Manual Scram Circuits only
Main Steam Isolation Valves (manual closure functions only)
Suppression Pool Temperature Monitoring
Reactor Pressure Vessel Instrumentation

Group II - Systems Required for Hot Shutdown

Division I

RCIC
ADS
ESW
ESSW Pumphouse HVAC
Diesel Generators and Auxiliaries
Diesel Generator HVAC
Containment Instrument Gas

Division II

HPCI
plus all Division II of those systems under Group II, Division I except RCIC

Group III - Systems Required for Cold Shutdown

Division I

RHR
RHRSW
ESW
ESSW Pumphouse HVAC
Diesel Generators and Auxiliaries
Diesel Generator HVAC

Division II

All Division II of above systems under Group III, Division I.

([illegible])

Attachment A

Supplemental Information to Figures 1 thru 26

The following information is intended to supplement Figures 1 thru 26 and Table 1, Part B, in identifying for review, those areas where load drops could impact areas of concern. Also included here are PP&L's preliminary solutions for problem areas.

Crane No.	Concern
OH501 A,B,C,D	These cranes (one per Diesel Bay) travel over portions of the Diesel Generators and several associated components. (Preliminary review indicated that the crane does not travel over the Diesel Generators except during diesel maintenance.)
1H210	Hoist travels over the Reactor Building Closed Cooling Water Heat Exchanger, which is located between some safeguard components such as raceways F1K907 and F1K939 which feed to the Emergency Service Water Transfer "B" electrical system. Heavy loads will only be handled during major shutdown periods. Smaller loads or unexpected maintenance may, however, require the use of this hoist. In such a case, an operating procedure, safe load path or barrier (as determined by further review) will be inplemented to insure safe load movement.
1H201	Crane has the capability of traveling over the spent fuel pool new fuel vault and the reactor pressure vessel. A detailed review of this crane including mechanical interlocks, electrical interlocks, and handling procedures will be included in our final report.
1H203	(See 1H201 above)
1H211	(See 1H201 above)
1H213(auxiliary hoist)	(See 1H201 above)
1H214	(See 1H201 above)
xHxxx	(See 1H201 above) Refer to Table 1, Part B, Page 11
1H219	The end stop for this hoist places loads in close proximity to a 1E raceway (E1PH81) that contains cables for the Residual Heat Removal Reactor Head Spray Isolation Valve, High Pressure Coolant Injection Inboard Supply Isolation Valve and Core Spray Pumps (1P206A). Following approval of Plant Engineers, the end stop for this monorail will be moved to eliminate this potential impact. If end stop cannot be relocated, a physical barrier will be installed.

Crane No.	Concern
1H403 1H404 1H406 1H407 1H408 xHxxx[1]	Hoist may be used to move loads over 1E raceways (E1K149, E1K150 and E1K151) which feed the solenoid valves for the Automatic Depressurization System. Hoist may also traverse raceway E1K036 which is associated with the Reactor Core Isolation Cooling Division I Control and High Pressure Coolant Injection Division I Control.

(1) An additional 14 hoists are being purchased for monorails already installed

1H205	Hoist, as it moves along the southern part of its monorail, travels in close proximity to the Hydraulic Control Units. Our tentative solution is to install a barrier to provide protection during load handling operations. Our final report will document this.
1H209	Hoist traverses near MCC 1B226, the power supply for some Residual Heat Removal and Core Spray moroe operated valves, and 1D264, a power supply for portions of the High Pressure Coolant Injection System. For an impact to occur when using this crane, the load must swing literally 3 to 4 feet to strike cables running along the wall. The implementation of a load handling procedure will insure safe load handling. If this does not provide adequate protection as evidenced by further review, a barrier will be installed.

PENNSYLVANIA POWER & LIGHT COMPANY
SUSQUEHANNA SES UNITS 1 & 2

Attachment B

PROCEDURE APPROVAL FORM

	Effective Date
TITLE: MT-99-001 REACTOR BUILDING CRANE OPERATING ~~INSTRUCTIONS~~ PROCEDURE	REVISION 0 PAGE 1 OF 11
PORC REVIEW REQUIRED: YES ( ) NO ( )	Meeting Number
ORIGINATOR: L. Kittelson	
APPROVALS: SECTION HEAD	DATE
SUPERINTENDENT OF PLANT	DATE

UNCONTROLLED COPY

1.0 PURPOSE

This procedure provides guidelines for operation of the Reactor Building Crane. Procedures for carrying specific major loads such as listed in Attachment A are included within the procedure which includes the lift.

2.0 REFERENCES

2.1 ANSI B30.20 - 1976, "Overhead and Gantry Cranes".

2.2 NUREG-0612 "Control of Heavy Loads at Nuclear Power Plants" Section 5.1.1.2 (Procedures).

2.3 NUREG-0554, "Single Failure Proof Cranes for Nuclear Power Plants", Section 2.4, (Material Properties).

2.4 Susquehanna Steam Electric Station, Final Safety Analysis Report (FSAR), Section 3.13.

3.0 PREREQUISITES

3.1 The crane operator shall meet the requirements of AD-00-015, "Crane Operator Qualification Program"

3.2 The crane operator shall complete the "Reactor Building Crane Preoperational and Operational Checklist" (Attachment B) which will be kept on the crane. The checklist will be completed with a grease pencil and no permanent record is necessary. The crane shall not be operated until all descrepancies are cleared.

3.3 Check ~~panels~~ Push Button Stations and Alarm Indication to ensure that normal conditions exist, prior to operation. (Attachment D)

3.4 If a lift requires use of the main hoist within Travel Restriction Area "A", (Attachment C), the "Zone Bypass Key" must be obtained from the shift supervisor.

3.5 Insure that special operating procedures are followed whenever loads in Attachment A are lifted.

4.0 PRECAUTIONS

4.1 The operator shall not engage in any practice which will divert attention while actually engaged in operating the crane.

4.2 The operator shall respond to signals from the person who is directing the lift, or an appointed signalperson. When a signalperson or a crane follower is not required as part of the crane operation, the operator is then responible for the lifts. However, the operator shall obey a stop signal at all times, no matter who gives it.

4.3 Each operator shall be responsible for those operations under the operator's direct control. Whenever there is any doubt as to safety, the operator shall consult with the task supervisor before handling the load~~s~~.

4.4 Before leaving the crane unattended, the operator shall land any attached load, place controllers in the "off" position and open the main line disconnect.

4.5 If power goes off during operation, the operator shall immediately place all controllers in the "off" position. Prior to reuse of the crane, operating motions shall be checked for proper direction.

4.6 The crane shall not be used for side pulls.

4.7 The operator shall not lift, lower or travel while anyone is on the load or hook.

4.8 The operator should avoid carrying loads over people.

4.9 The operator shall check the hoist brakes at least once each shift if a load approaching the rated load is to be handled. This shall be done by raising the load a short distance and applying the brakes.

4.10 The load shall not be lowered below the point where less than ~~two~~ one wrap~~s~~ of rope shall remain on each anchorage of the hoisting drum. ~~unless a lower limit device is provided, in which case no less than one wrap shall remain.~~

4.11 The operator shall not leave the position at the controls while the load is suspended.

4.12 The hoist limit device which controls the upper limit of travel of the load block shall not be used as an operating control.

4.13 Signals to the operator should be in accordance with the standards prescribed in PP&L's Safety Rule Book. If communication equipment (radio, or equivalent) is utilized. Signals should be discernible or audible at all times. Some special operations may required additions to, or modifications of the basic signals standardized herein. For all such cases, these special signals should be agreed upon and thoroughly understood by both the signalperson and the operator and should not be in conflict with the standard signals.

4.14 The proximity switches protecting the three Travel Restriction Areas shall not be used except when testing their operability. Maintain awareness of the main hoists proximity to the Travel Restriction Areas (Attachment C).

4.15 Power to the crane parallels the east bridge rail. Personnel shall stay clear of the power supply rails.

5.0 PROCEDURE

5.1 CAB CONTROL - Select "CAB" on the OPERATION control switch and "CAB" on the TRANSFER SWITCH.

5.2 FLOOR CONTROL - Select "FLOOR" on the OPERATION CONTROL SWITCH and "CAB" on the TRANSFER SWITCH.

5.3 RADIO CONTROL - Select "RADIO" on the OPERATION CONTROL SWITCH and "RADIO" on the TRANSFER SWITCH.

5.4 Frequently check alarm panels to ensure an alarm condition is detected quickly - see Attachment D.

5.5 All alarm indications shall be considered valid. When an alarm indication exists place the load in a safe condition, and inform the person in charge.

5.6 Follow the approved "Heavy Load Path" for all loads greater than 1000 lbs.

5.7 Lifts over the "Travel Restriction Areas" with the auxiliary hoist will be limited to necessary lifts only. There shall be no lift short cuts over "Travel Restriction Areas".

5.8 The appointed person directing the lift shall insure that the load is well secured, properly balanced and positioned in the sling or lifting device before it is lifted more than a few inches.

5.9 The warning horn shall be activated each time before traveling and intermittently when approaching workpersons.

5.10 There shall be no sudden acceleration or deceleration of the moving load.

6.0 ACCEPTANCE CRITERIA

None

ATTACHMENT A

Lifts for which special instructions must be written:

1. Missile or shield plugs
2. Drywell Head
3. Reactor Vessel Head
4. Steam Dryers
5. Moisture Separators
6. Spent Fuel Pool Gates
7. Refueling Slot Plugs
8. Spent Fuel Shipping Cask
9. Vessel Service Platform
10. Waste and Debris Shipping Casks
11. Thermal Shielding

APPROVAL: ______________________/________
Section Head Date

ATTACHMENT B

REACTOR ~~BULDING~~ BUILDING CRANE
PREOPERATIONAL AND OPERATIONAL CHECKLIST

ALL CONTROLLERS OFF ________
CRANE CONTROL RADIO ________ BRIDGE ________
TEMPERATURE GREATER THAN 60°F ________

	BRIDGE EAST	DRIVE WEST	TROLLEY DRIVE	MAIN HOIST NORTH	DRIVE SOUTH	AUX HOIST DRIVE
OIL						
HOSES						
SPRINGS						

ROPE VISUAL, (INCLUDING TIGHTNESS OF END CLAMPS AND ROPE CLIPS)
MAIN ________
AUXILIARY ________ RAILS CLEAR ________
TROLLEY LIMIT SWITCHES ________
STRUCTURAL INTEGRITY ________
CLEANLINESS SATISFACTORY ________

WITH ALL CONTROLLERS "OFF", AND PERSONNEL CLEAR, CLOSE THE MAIN LINE DISCONNECT AND LINE CONT. CIRUIT BKR.

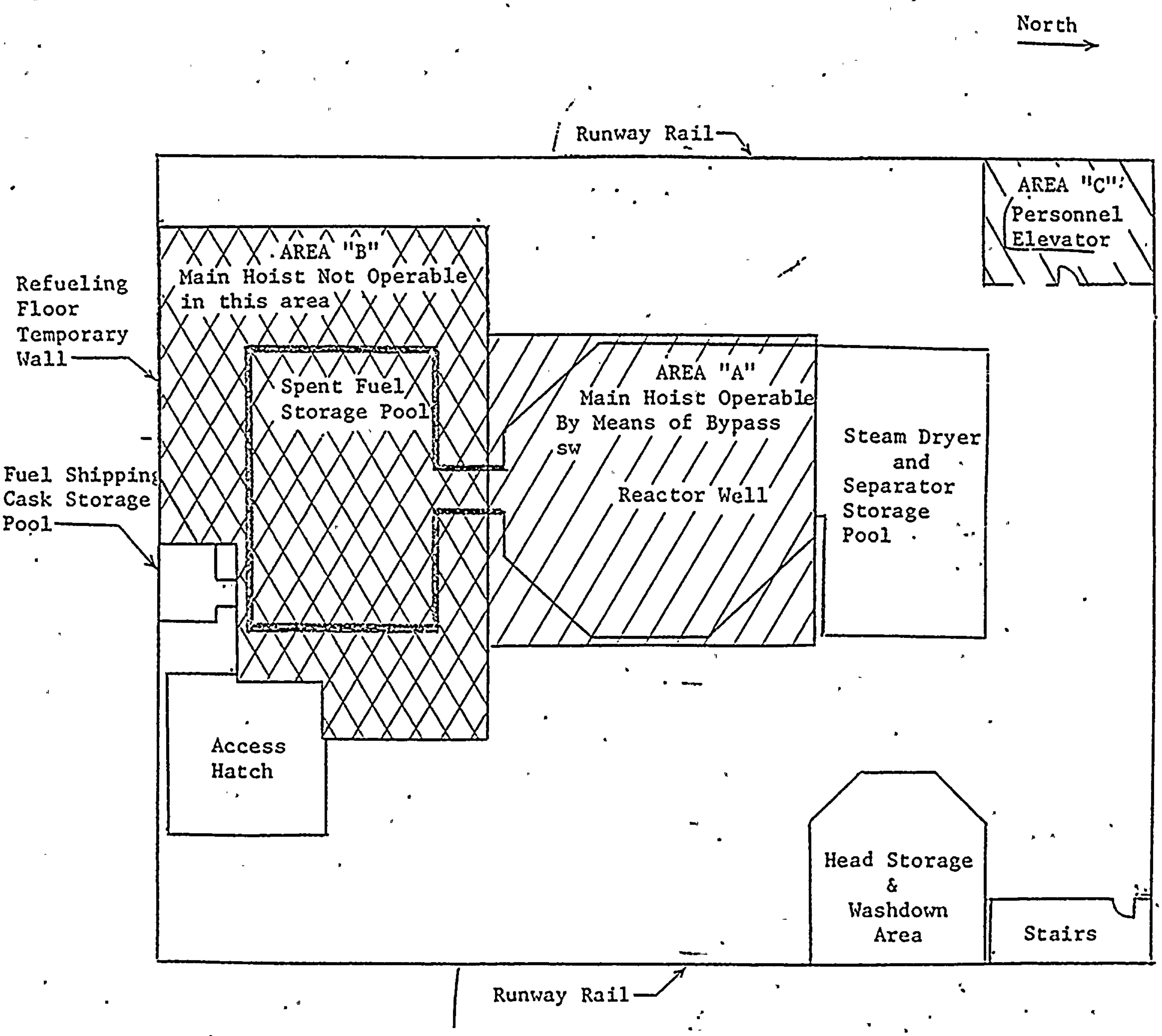
OPERABILITY CHECKS
AUX HOIST UPPER LIMIT ________
MAIN HOIST UPPER LIMIT ________
OPERATE TROLLEY EAST/WEST ________
OPERATE BRIDGE NORTH/SOUTH ________
FOOT BRAKES ________

VISUAL INSPECTION MAIN HOOK ________
AUX. HOOL ________
HOOK LATCHES ________
SLINGS ________

NOTE: ANY DEFICIENCY FOUND DURING THE ABOVE CHECKS SHALL BE CORRECTED PRIOR TO LIFTING ANY LOADS.

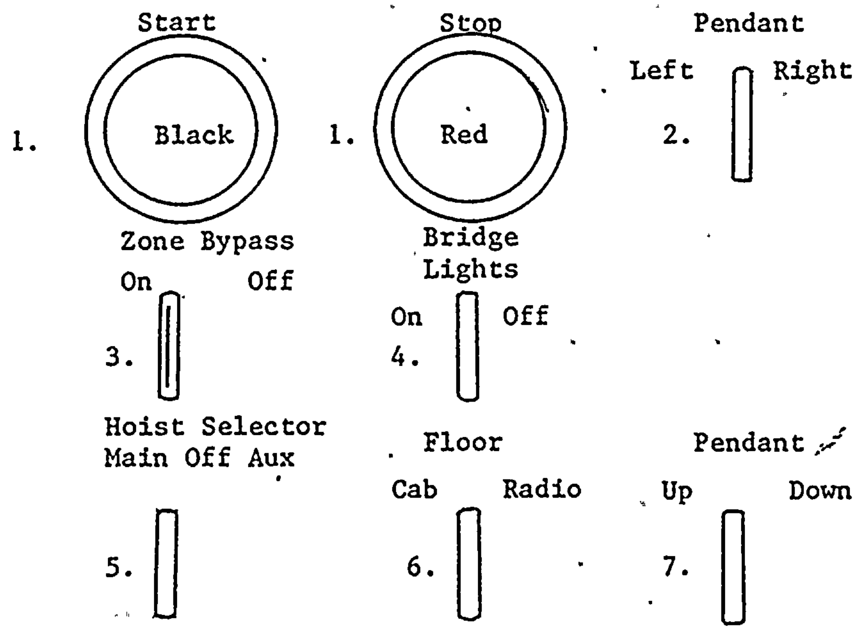
ATTACHMENT C

UNIT REACTOR BUILDING 818' 1"



ATTACHMENT D

Push Button Station #1



PUSHBUTTON STATION #1 LEGEND

1. START/STOP PUSH-BUTTONS - Used to energize and deenergize the cab controls.

2. PENDANT SWITCH - Controls which pendant hoist may be used. Ensures that only one pendant is operated at a time.

3. ZONE BYPASS KEY SWITCH - When the ZONE BYPASS in "on" the main hoist may be operated over Travel Restriction Area "A". The ZONE BYPASS KEY is controlled by the shift supervisor.

4. BRIDGE LIGHT SWITCH - Controls the bridge lights.

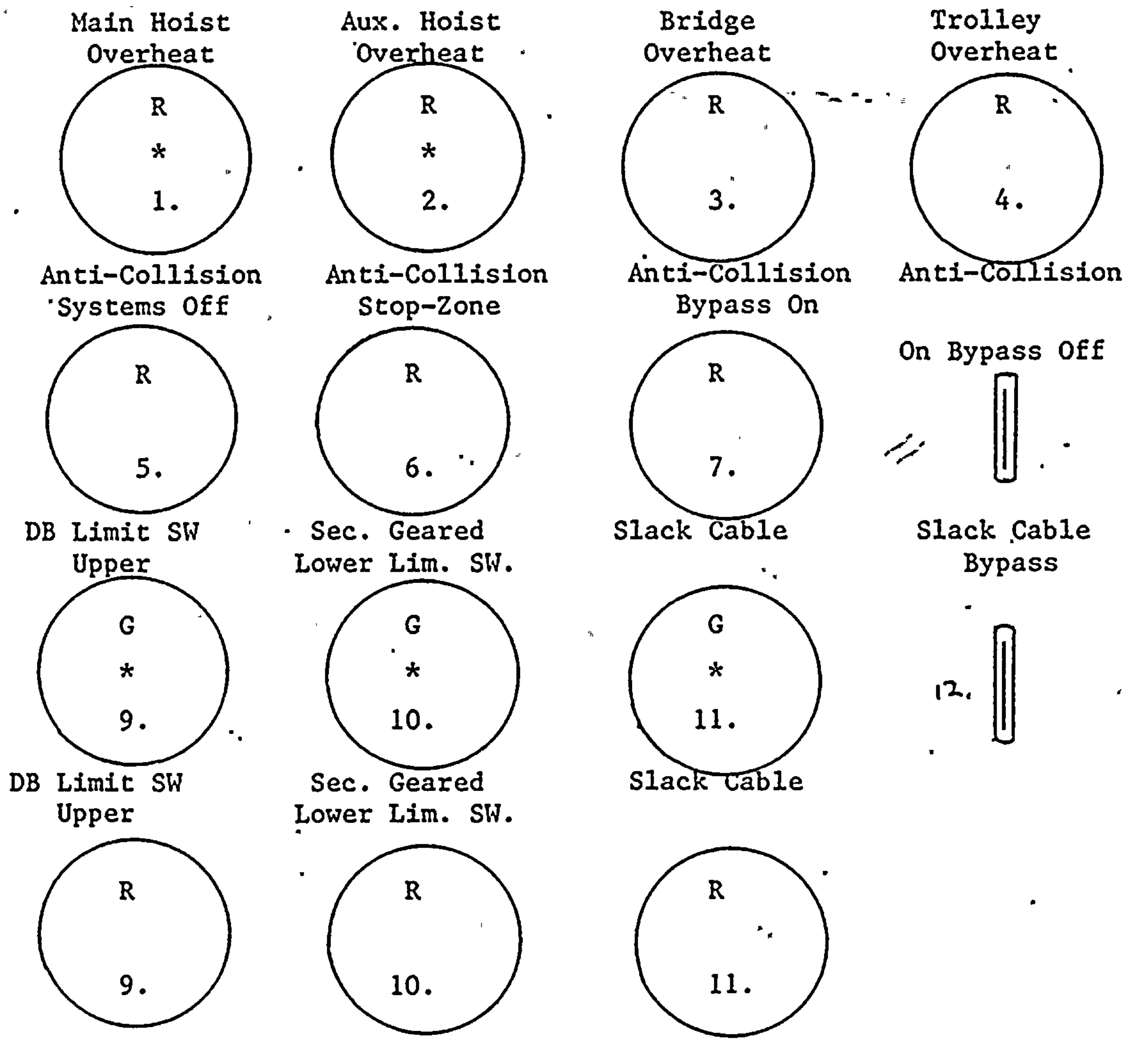
5. HOIST SELECTOR SWITCH - Controls power to the hoists. Ensures that only one hoist is operated at a time.

6. OPERATION CONTROL SWITCH - Determines the source of crane control, cab, floor or radio.

7. PENDANT CONTROL SWITCH - Controls the motion of whichever pendant is selected on the PENDANT SWITCH.

ATTACHMENT D

Push Button Station #2



R - Red
G - Green
* - Normally Lit

ATTACHMENT D

PUSH-BUTTON STATION #2 LEGEND

1. MAIN HOIST OVERHEAT - Normally lit. The red light goes out when the main hoist motor overheats.

2. AUX HOIST OVERHEAT - Normally lit. The red light goes out when the auxiliary hoist motor overheats.

3. BRIDGE OVERHEAT - Normally unlit. Lights red when the bridge motor overheats.

4. TROLLEY OVERHEAT - Normally unlit. Lights red when the trolley motor overheats.

5. ANTI-COLLISION SYSTEMS OFF - Normally unlit. Lights red when the ANTI-COLLISION control KEY SWITCH selected to "OFF".

6. ANTI-COLLISION STOP ZONE - Normally unlit. Lights red when the Anti-Collision step zone is entered.

7. ANTI-COLLISION BYPASS ON - Normally unlit. Lights red when the ANTI-COLLISION CONTROL KEY SWITCH is selected to "BYPASS".

8. ANTI-COLLISION CONTROL KEY SWITCH - Controls the Anti-Collision system mode of operation.

9. DB LIMIT SWITCH UPPER - Normally lit green, lights red when the main hoist bottom block contacts the trip bar.

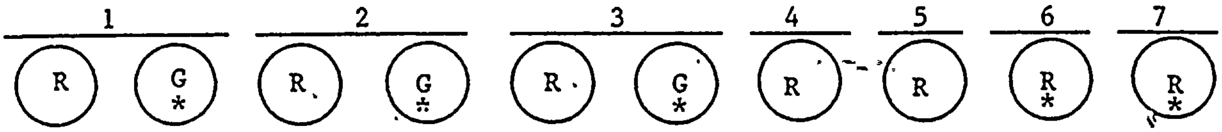
10. SEC. GEARED LOWER LIM. SW. - Normally lit green, lights red when the main hoist bottom block reaches its lower limit.

11. SLACK CABLE - Normally lit green, lights red when a slack cable condition exists on one of the main cables.

12. SLACK CABLE KEY SWITCH - Allows for bypassing the slack cable interlock circuit when the main hoist must be moved during a slack cable situation.

ATTACHMENT D

Crane Alarm Indication for Radio and Floor Controlled Operation
(View of Lights from Refueling Floor)



1. SLACK CABLE - Normally lit green, lights red when a slack cable condition exists on one of the main cables.

2. DB LIMIT SWITCH UPPER - Normally lit green, lights red when the main hoist bottom block contacts the trip bar.

3. SEC. GEARED LOWER LIM. SW. - Normally lit green, lights red when the main hoist bottom block reaches its lower/limit.

4. BRIDGE OVERHEAT - Normally unlit. Lights red when the bridge motor overheats.

5. TROLLEY OVERHEAT - Normally unlit. Lights red when the trolley motor overheats.

6. AUX. HOIST OVERHEAT - Normally lit. The red light goes out when the auxiliary hoist motor overheats.

7. MAIN HOIST OVERHEAT - Normally lit. The red light goes out when the main hoist motor overheats.

R-RED
G-GREEN
*-NORMALLY LIT

Attachment G

UNCONTROLLED COPY

PROCEDURE APPROVAL FORM

	Upon Approval Effective Date
TITLE: MT-TY-001 REACTOR PRESSURE VESSEL HEAD INSTALLATION AND REMOVAL W/O "O" RINGS OR TENSIONING	REVISION 0 PAGE 1 OF 9
PORC REVIEW REQUIRED: YES (X) NO ( )	81-15 Meeting Number
ORIGINATOR: L. Kittelson	
APPROVALS: [signature] SECTION HEAD	5-27-81 DATE
[signature] SUPERINTENDENT OF PLANT	5-27-81 DATE

UNCONTROLLED COPY

1.0 PURPOSE

This procedure provides an outline of the steps necessary for placing the vessel head on, and removing the vessel head from the Unit 1 reactor pressure vessel.

2.0 REFERENCES

2.1 Instruction Manual, Susquehanna I and II, Nuclear Reactor Vessels, PP&L, CBI Contract 68-3331/2, Rev. 2, IOM #253

2.2 NUREG-0612, Control of Heavy Loads at Nuclear Power Plants

2.3 ANSI B30.2.0-1976, Overhead and Gantry Cranes

2.4 MT-62-001, Rev. 0, Reactor Vessel Head Removal

2.5 MT-62-004, Rev. 0, Reactor Vessel Head Replacement

2.6 MT-GM-012, Rev. 0, Primary System Boundary Entry

3.0 PREREQUISITES

Witness *3.1 Establish cleanliness Zone C whenever head is seated on the vessel. Cleanliness Zone D shall be established in accordance with MT-GM-012, "Primary System Boundary Entry", whenever the head is removed from the vessel.

3.2 Perform preoperational checks on the Reactor Building Crane (1H213). Use ATTACHMENT B as a checklist.

3.3 Clean the reactor vessel head including the bolt holes with approved cleaning agents.

Witness *3.4 Insure the reactor building crane is cleaned to safeguard the cleanliness of the vessel and the vessel cavity.

3.5 Check that all stud caps are in place.

3.6 Check that all the alignment pins are in place.

4.0 PRECAUTIONS

4.1 Use only approved cleaning agents and lubricants. (Isopropanol alcohol, methanol alcohol or acetone)

4.2 Special care must be taken to prevent foreign material from falling in to the reactor well. An exclusion area bounded by railings shall be maintained around the reactor well.

4.3 Notify the shift supervisor if any foreign material falls into the reactor vessel.

4.4 The crane operator will be qualified per ANSI B 30.20-1976.

4.5 Use proper crane hand signals.

4.6 Place the load in a safe condition if crane problems develop.

5.0 PROCEDURE

5.1 Placement of the vessel head on the reactor vessel. For removing the vessel head go to Step 5.2.

5.1.1 Inform the shift supervisor that the reactor vessel head will be placed on the vessel.

5.1.2 Attach the reactor building crane main hook to the strongback.

NOTE: The safety latch must be removed for hook insertion into the strongback.

5.1.3 Center the strongback over the reactor vessel head. (Attach the strong back to the vessel head for the best lift).

5.1.4 Attach the turnbuckles to the head.

5.1.5 Lift the reactor vessel head off the pedestals, and check that it hangs level.

5.1.6 Adjust the turnbuckles as necessary to level the load.

Witness *5.1.7 Clean the head flange with approved cleaning agents.

5.1.8 Remove the reactor flange seal protector.

Witness *5.1.9 Clean the vessel flange with approved cleaning agents.

5.1.10 Position the vessel head over the vessel via the designated route shown on Attachment A.

5.1.11 Ensure the vessel head is centered over the vessel and orientated with the flange hole and stud numbers matching.

5.1.12 Lower the vessel head at the slowest crane speed to about 24 inches above the head studs.

5.1.13 Manually guide the head to align the stud holes over the corresponding numbered studs.

5.1.14 Lower the head to within 12 inches of the vessel flange, checking that the holes are properly centered over the guide caps.

Witness *5.1.15 Reinspect the flanges to ensure they are clean, and that no material has sheared off the guide caps. Reclean if necessary.

5.1.16 Lower the head onto the vessel until it seats.

5.1.17 Disconnect the vessel head strongback from the vessel head.

5.1.18 Place the strongback in its storage location.

5.1.19 Inform the shift supervisor that the vessel head is in place.

5.2 Removal of the vessel head from the reactor vessel.

5.2.1 Inform the shift supervisor that the reactor vessel head will be removed.

5.2.2 Attach the reactor building crane main hook to the strongback.

NOTE: The safety latch must be removed for hook insertion into the strongback.

5.2.3 Center the strongback over the reactor vessel head.

5.2.4 Attach the turnbuckles to the head.

5.2.5 Take a strain on the head.

5.2.6 Adjust the turnbuckles as necessary to equalize the load.

5.2.7 Carefully lift the head about 1 inch.

5.2.8 Check the clearances 90° apart.

5.2.9 Adjust the turnbuckles as necessary to equalize the clearances.

5.2.10 Raise the head until it is clear of the studs and guide sleeves.

5.2.11 Transfer the vessel head to the support pedestal via the designated route shown on ATTACHMENT A.

Witness *5.2.12 Inspect head flange and pedestal surfaces. Clean the seating surfaces as necessary.

5.2.13 Lower the head on to the pedestal.

5.2.14 Install vessel flange surface protectors.

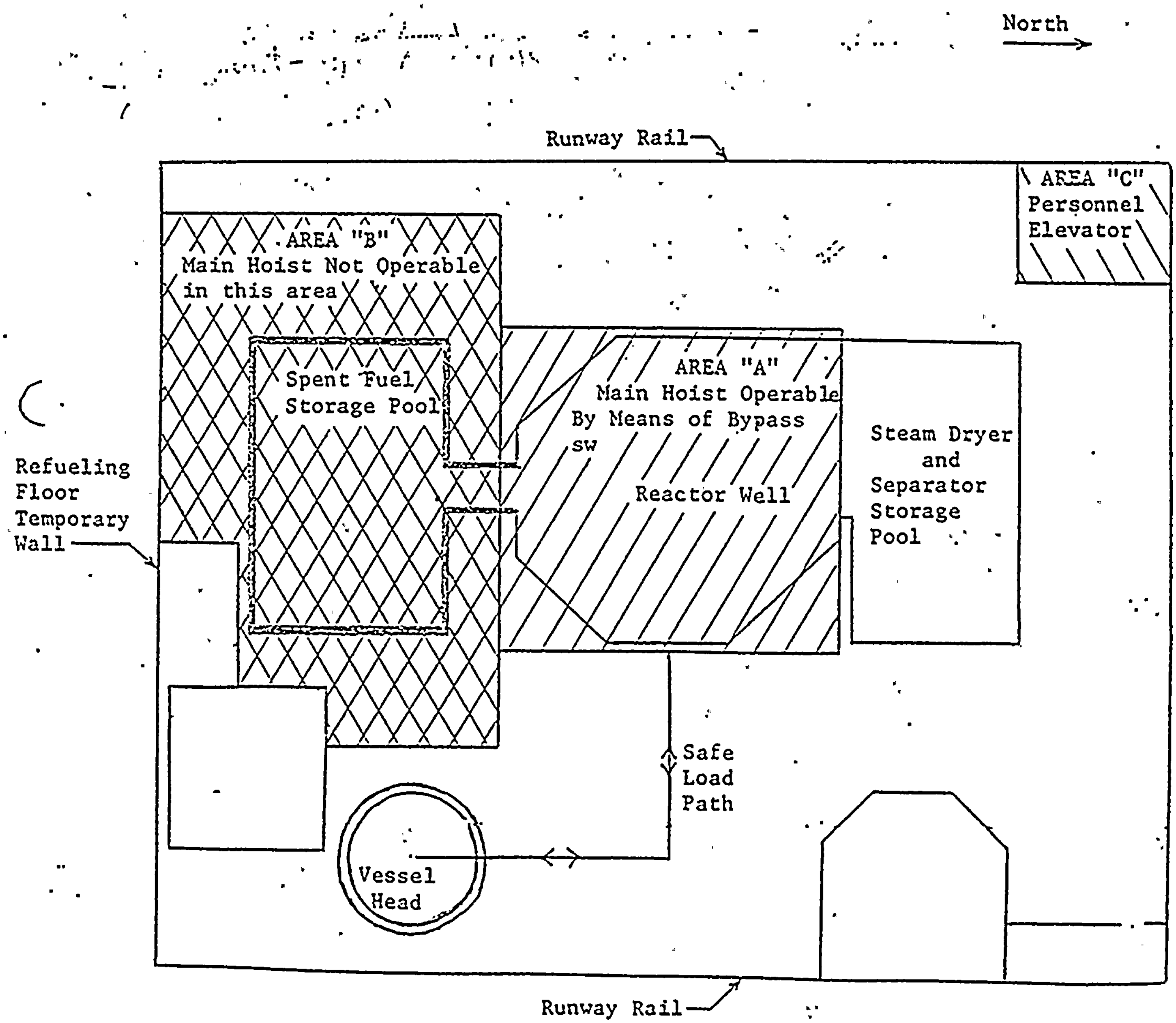
5.2.15 Inform the shift supervisor that the vessel head has been removed.

6.0 ACCEPTANCE CRITERIA

Cleanliness verified and documented per witness points.

ATTACHMENT A

SAFE LOAD PATH



APPROVAL: ______________________
Section Head 6-2-81 / Date

ATTACHMENT B

REACTOR BUILDING CRANE
PREOPERATIONAL AND OPERATIONAL CHECKLIST

ALL CONTROLLERS OFF ________
CRANE CONTROL RADIO ________ BRIDGE ________

	BRIDGE DRIVE EAST	BRIDGE DRIVE WEST	TROLLEY DRIVE	MAIN HOIST DRIVE NORTH	MAIN HOIST DRIVE SOUTH	AUX HOIST DRIVE
OIL						
HOSES						
SPRINGS						

ROPE VISUAL, INCLUDING TIGHTNESS OF END CLAMPS AND ROPE CLIPS

MAIN ________

AUXILIARY ________

RAILS CLEAR ________

TROLLEY LIMIT SWITCHES ________

STRUCTURAL INTEGRITY ________

IF ALL CONTROLLER "OFF", AND PERSONNEL CLEAR, CLOSE THE MAIN LINE DISCONNECT AND LINE CONT. CIRCUIT BKR.

OPERABILITY CHECKS
AUX HOIST UPPER LIMIT ________
MAIN HOIST UPPER LIMIT ________
OPERATE TROLLEY EAST/WEST ________
OPERATE BRIDGE NORTH/SOUTH ________
FOOT BRAKES ________

VISUAL INSPECTION MAIN HOOK ________
AUX. HOOK ________
HOOK LATCHES ________
SLINGS ________

NOTE: ANY DEFICIENCY FOUND DURING THE ABOVE CHECKS SHALL BE CORRECTED PRIOR TO LIFTING ANY LOADS.

ATTACHMENT B (continued)
(Reverse Side of Attachment B)

REACTOR BUILDING CRANE
PREOPERATIONAL AND OPERATIONAL CHECKLIST

ALL CONTROLLERS OFF ________ (Check that all controllers are off)
CRANE CONTROL RADIO ________ BRIDGE ________ (Check which mode the crane control switch is in.)

	BRIDGE DRIVE East	WEST	TROLLEY DRIVE	MAIN HOIST DRIVE NORTH	SOUTH	AUX HOIST DRIVE
OIL (Check all oil reservoir levels)						
HOSES (Check the integrity of all the hoses)						
SPRINGS (Check that the springs are installed properly)						

ROPE VISUAL, INCLUDING TIGHTNESS OF END CLAMPS AND ROPE CLIPS
MAIN ________ (Inspect the ropes per ANSI B30.20 - 1976)
AUXILIARY ________
RAILS CLEAR ________ (Ensure that the trolley and bridge rails are clear)

TROLLEY LIMIT SWITCHES ________ (Check that the trolley extreme travel limit switches are in the proper orientation).

STRUCTURAL INTEGRITY ________ (Check structural integrity per ANSI B30.20 - 1976)

IF ALL CONTROLLERS "OFF", AND PERSONNEL CLEAR, CLOSE THE MAIN LINE DISCONNECT AND LINE CONT. CIRCUIT BKR.

OPERABIITY CHECKS (Check for proper crane operation)
AUX HOIST UPPER LIMIT ________
MAIN HOIST UPPER LIMIT ________
OPERATE TROLLEY EAST/WEST ________
OPERATE BRIDGE NORTH/SOUTH ________
FOOT BRAKES ________

VISUAL INSPECTION MAIN HOOK ________ (Inspect the following items per ANSI B30.20-1976)
AUX. HOOK ________
HOOK LATCHES ________
SLINGS ________

NOTE: ANY DEFICIENCY FOUND DURING THE ABOVE CHECKS SHALL BE CORRECTED PRIOR TO LIFTING ANY LOADS.

APPROVAL: [signature] 6.2.81
Section Head Date

ATTACHMENT C

Reactor Vessel Head Placement

Quality Data Sheet

Unit #1

Step No.	Verified By	Date	Description
3.4	________	________	The reactor building crane is clean for operation over the reactor vessel.
5.1.7	________	________	The head flange is clean.
5.1.9	________	________	The vessel flange is clean.
5.1.15	________	________	The head and vessel flanges are clean.

APPROVAL: Robert L. Byers / 6-2-81
Section Head Date

ATTACHMENT D

Reactor Vessel Head Removal

Quality Data Sheet

Unit #1

Step No.	Verified By	Date	Description
5.2.12	__________	______	Inspect the head flange and pedestal surfaces for cleanliness.

Work Completed by: ____________________ / __________
Name Date

BALLISTIC RESEARCH LABORATORIES

INTERIM MEMORANDUM REPORT NO. 459

DECEMBER 1975

COMPARISON OF VARIOUS THERMAL SYSTEMS FOR THE PROTECTION OF RAIL TANK CARS TESTED AT THE FRA/BRL TORCHING FACILITY

C. Anderson
W. Townsend
R. Markland
J. Zook

Detonation and Deflagration Dynamics Laboratory

Funded Under Federal Railroad Administration
DCN AR 30026/Req 731231

ABERDEEN PROVING GROUND, MARYLAND

B A L L I S T I C   R E S E A R C H   L A B O R A T O R I E S

INTERIM MEMORANDUM REPORT NO. 459

CAnderson/srr
Aberdeen Proving Ground, Md.
December 1975

COMPARISON OF VARIOUS THERMAL SYSTEMS FOR THE PROTECTION OF RAIL TANK CARS TESTED AT THE FRA/BRL TORCHING FACILITY

ABSTRACT

One proposed method for thermally protecting high pressure rail tank cars from a fire environment is through the use of an insulating coating. This report investigates the thermal response of steel plates when insulated with one of ten different coating systems; eight of these thermal systems are used in conjunction with a steel shield. All plates were exposed to an LPG torch using the BRL/DOT torch simulator at the DOT Transportation Test Center.

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LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

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I. BACKGROUND

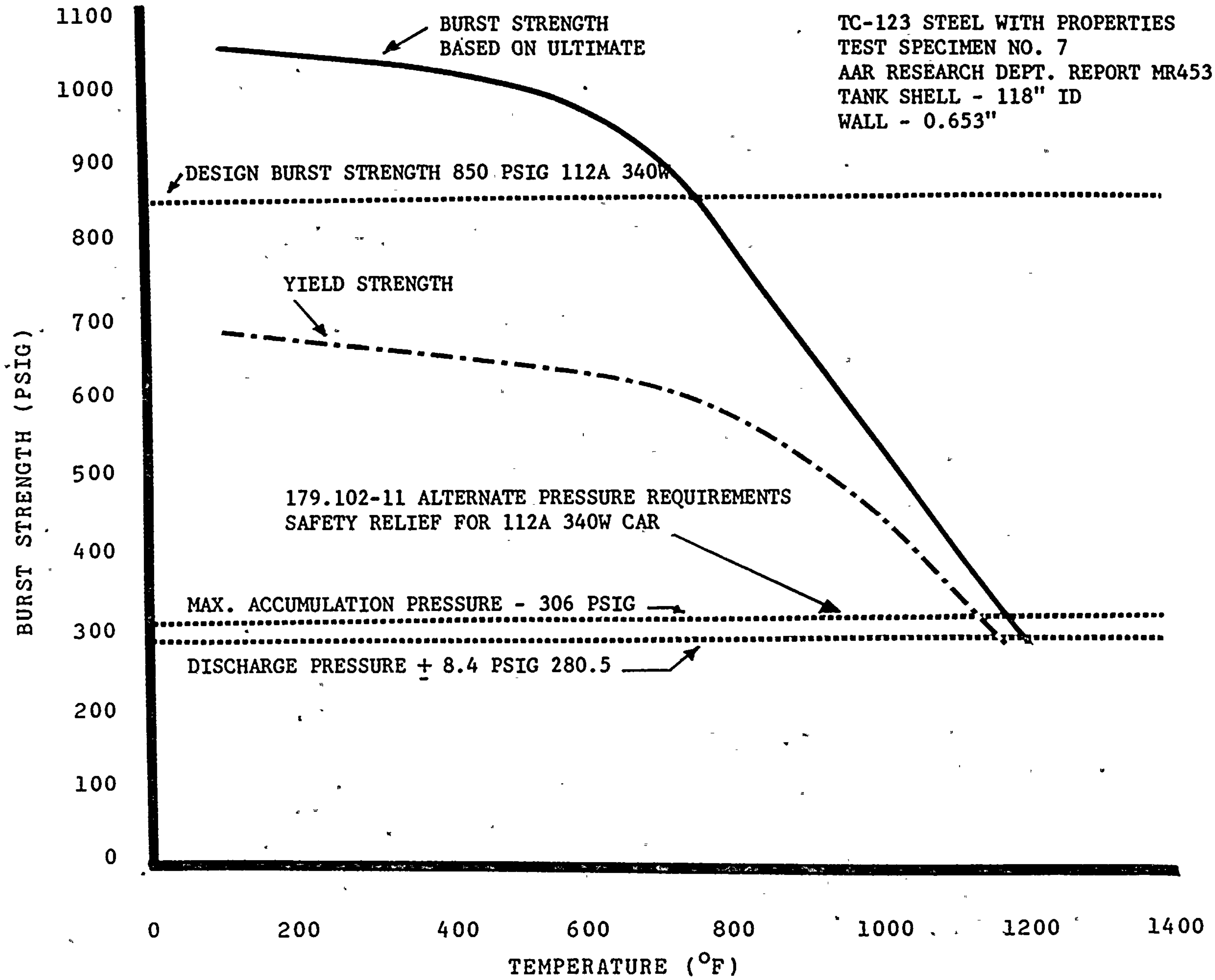
Approximately 20,000 railroad tank cars of the 33,000 gallon, non-insulated pressure tank car series are presently in service in transporting liquified petroleum gas (LPG), anhydrous ammonia and vinyl chloride. A number of these tank cars have explosively ruptured during exposure to fire. In many instances, these fires have resulted from a rail accident where lading is discharged because of a puncture in the tank head or shell with subsequent ignition of the hazardous material under high pressure. These tank car explosions have caused substantial dollar loss, property damage, personal injuries and casualties.

Typically, when a tank car containing LPG, for example, is exposed to fire conditions, the heat of the fire is conducted through the steel shell to the contents of the car. In addition to raising the lading temperature, the internal pressure increases until the "start-to-discharge" pressure of the relief valve is reached. The valve opens and vents. If the fire is severe enough, the capacity of the existing valves is insufficient to preclude a further increase of tank pressure.

Because of the low heat transfer rates from the tank shell to the ullage (vapor portion of the contents of the tank), the portion of the shell in contact with the ullage increases in temperature at a faster rate by comparison to a portion of the shell in contact with the liquid lading. If at any time during the heating the combination of thermal and pressure stress of the shell exceeds the strength capability of the shell material the tank car fails - catastrophically. The higher the skin temperature, the lower the material strength for a specified pressure. This change in mechanical strength versus temperature is shown in Figure 1.

Tank failures have often taken the form of large, rapidly propagating cracks with nearly instantaneous release of lading. As the pressure is released and large amounts of lading are converted to a gaseous state and burned, portions of the tank car weighing several thousand kilograms (several tons) can be rocketed hundreds of meters with resulting physical damage and the spreading of fire. Even without rocketing, the area of damage increases greatly when a tank ruptures.

The possibility exists of thermally insulating rail tank cars to retard the effects of the anticipated range of fire environments. Thermal insulation reduces the effects of fire by reducing the heat input. A reduction of heat input in turn reduces the relief valve flow requirements for maintaining a prerequisite "safe" pressure. Further, the insulation reduces the heating of the portion of the tank shell in contact with the ullage, extending the time required for the shell to fail. This extension of time allows more lading to escape via the relief valve thus reducing the destructive damage resulting from a failure, and perhaps preventing severe catastrophic chain reactions (the failure of one tank car followed by the failure of another) from



TANK CAR SHELL BURST STRENGTH VARIATION WITH TEMPERATURE

Figure 1

occurring. Finally, thermal insulation reduces thermal gradients in the tank shell and therefore reduces the thermal stress of the shell material.

II. OBJECTIVES

The Federal Railroad Administration (FRA) desires to develop procedures to insure that when railroad tank cars are exposed to a range of fire environments, they will not rupture catastrophically and cause subsequent chain reactions, thereby confining the fire to a localized area. A secondary goal is to delay the time to rupture. Delaying rupture allows time for additional lading to escape, allows time to take appropriate measures for minimizing damage to surrounding property, and allows time for evacuating the area.

One proposed method for protecting tank cars is to use thermal insulation to reduce the heat input to tank cars, hopefully to the extent of preventing ruptures. The FRA in this phase of work is developing procedures for coating tank cars and developing coating specifications which will technically describe the thermal and physical characteristics of any coating or insulation system which is to be applied to a rail tank car. Some of the necessary characteristics of any thermal coating system, to be feasible in large scale application to rail tank cars, are:

a) good insulating properties

b) good weathering characteristics

c) good adhesion

d) moisture resistance

e) resistance to spillage

f) shock and vibration resistance.

Additionally, the thermal coating system should have minimal maintenance costs with little loss of thermal properties for the lifetime of the coating.

The Ballistic Research Laboratories (BRL) has been contracted by the FRA to conduct field tests on several different thermal protection systems. These field investigations included the design and fabrication of a torch simulator; instrumentation of test plates; reduction, analysis and reporting of the test data.

III. TEST SETUP AND TEST PROCEDURES

An LPG large scale torch simulator was constructed at the Transportation Test Center, Pueblo, Colorado. A separate BRL report describes the test setup in detail.[1] A brief description, however, is also provided herein. Figures 2, 3 and 4 depict the general layout of the torch test site, the specimen plate cart and torch characterization cart.

A supply tank of approximately 1.90 kiloliters (500 gallons) capacity was placed in a water bath. A generator is then used to heat the water, thus heating the LPG in the supply tank. The liquid level, pressure and temperature in the supply tank are monitored and recorded for each test. Control valves then monitor the amount of liquid and vapor flow. A 0.95 cm (3/8 in) diameter square edge orifice comprises the exit for the LPG jet. A pressure gauge and thermocouple continuously monitor the pressure and temperature of the LPG just before entering the orifice. An electronic spark actuator ignites the LPG and then is cut off as the combustion becomes self-sustaining.

For each test, a cart on which a 1.22 m by 1.22 m by 1.59 cm (4 ft by 4 ft by 5/8 in) steel plate can be mounted, is positioned 3.66 m (12 ft) from the orifice. The steel plates were coated with different thermal systems of varying thicknesses. To record the temperature responses of the plates, each plate is instrumented with chromel-alumel-inconel shield thermocouples.

Each pressure gauge and thermocouple is sampled sequentially during the test and their output recorded digitally on magnetic tape by a Vidar recording system. Upon the completion of testing, the magnetic tape is transferred to the Ballistic Research Laboratories for data reduction and analysis. The torch tests typically run 30 to 70 minutes for the insulated plates.

IV. BARE PLATE TESTS

Fire tests have been performed on uninsulated and thermally protected plates under conditions of liquid and vapor flow, selected to simulate the burning lading exiting under pressure from a punctured tank. Selected key physical characteristics describing the torch plate tests are listed in Table I. Figure 5 depicts the thermal response of a bare plate during exposure to the "torching environment".

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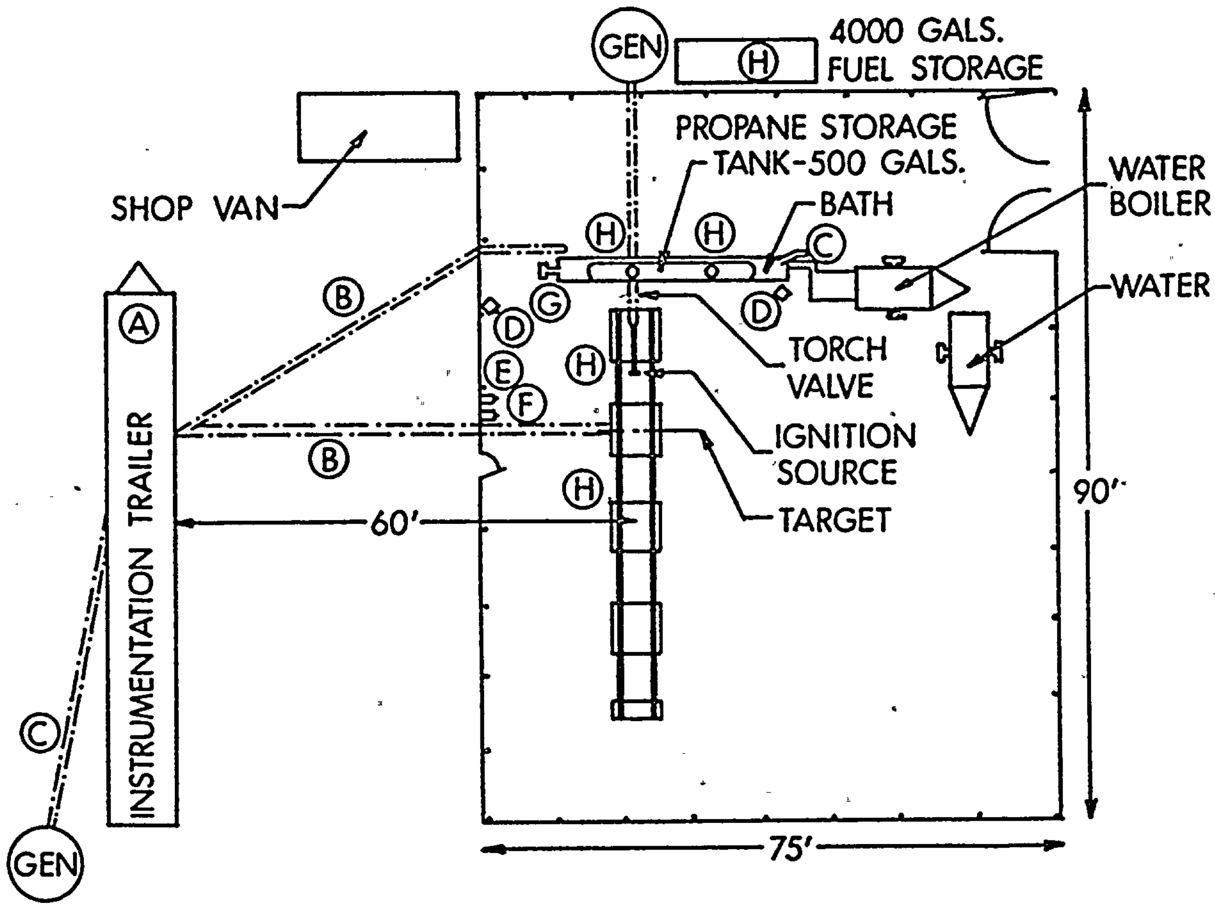
1. *W. Townsend and R. Markland, Preparation of the BRL Tank Car Torch Facility at the DOT, Transportation Test Center, Pueblo, Colorado, BRL IMR No. 431, September 1975.*

GENERAL LAYOUT OF TORCH TEST SITE AT TTC, PUEBLO, COLORADO



A - KEY OPERATED CONTROL FOR TORCH & IGNITION SOURCE
B - INSTRUMENTATION LINES
C - POWER LINES
D - CAMERAS
E - PYROMETER
F - RADIOMETER
G - CIRCULATING
H - PROPANE AREA MONITORS
GEN - GENERATOR

Figure 2

GENERAL CONFIGURATION OF TORCH, SUPPLY TANK AND SPECIMEN PLATE CART

16

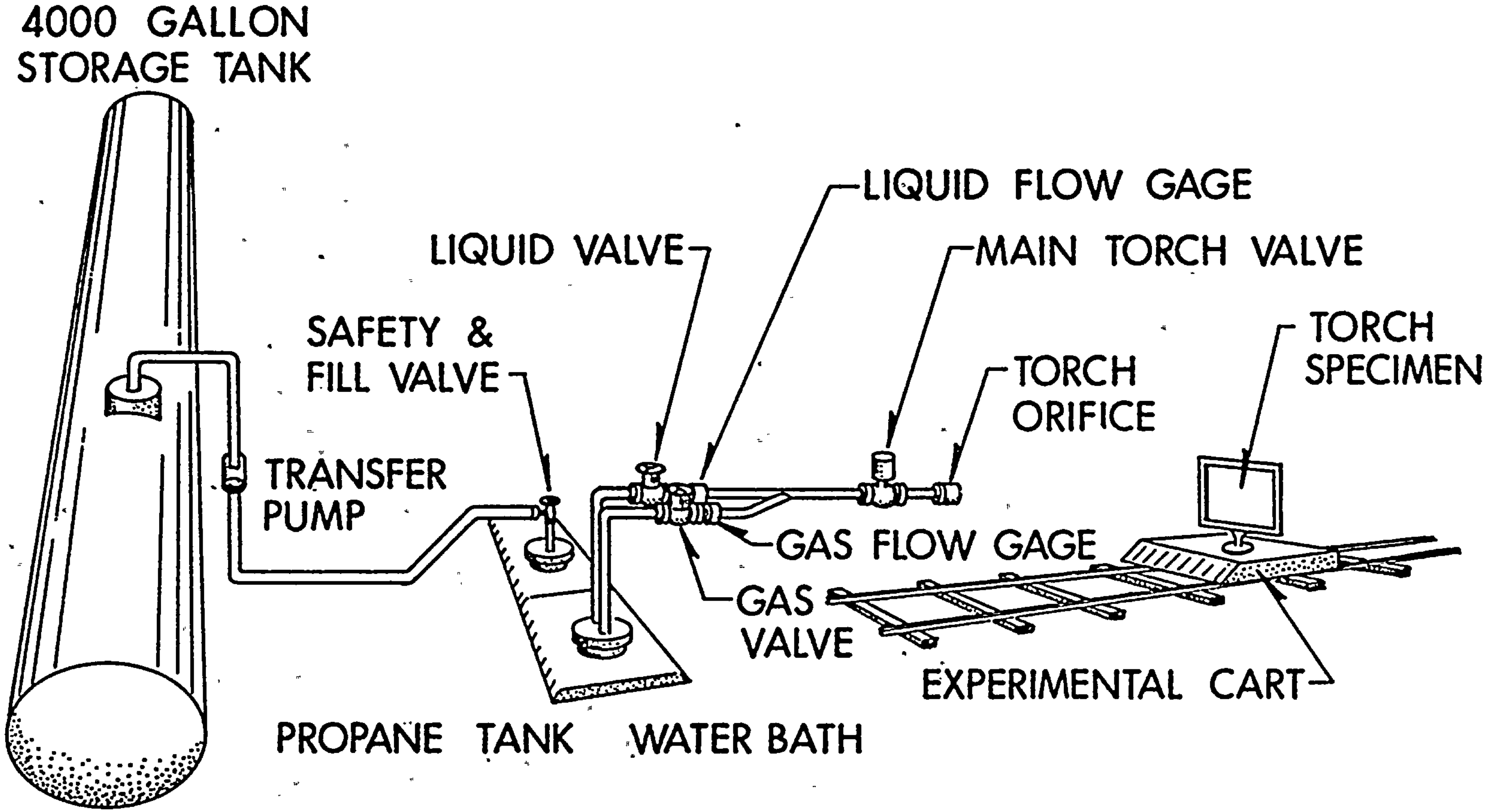


Figure 3

TORCH CHARACTERIZATION CART
SHOWING PLATINUM-RHODIUM THERMOCOUPLE GRID

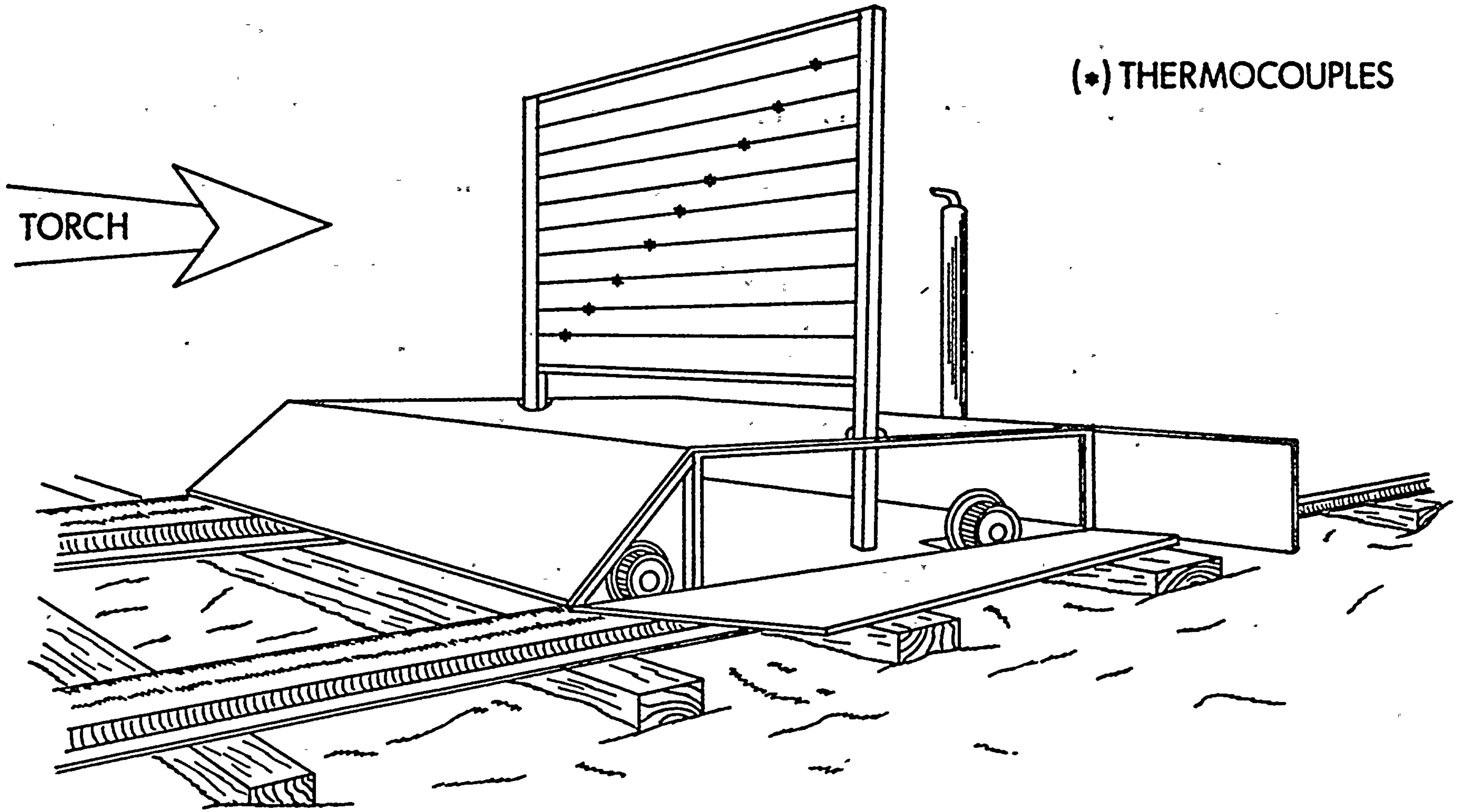


Figure 4

TABLE I. SELECTED OPERATING PARAMETERS OF FRA TORCH FACILITY

	TEST 12-B	TEST 21-B
Supply Tank Pressure	1.55×10^6 Pa (225 PSIA)	1.58×10^6 Pa (229 PSIA)
Supply Tank Temperature	37.8°C (100.0°F)	42.5°C (108.5°F)
Duration of Torching Test	35.05 Minutes	20.09 Minutes
Orifice Pressure	1.33×10^6 Pa (193 PSIA)	1.43×10^6 Pa (207 PSIA)

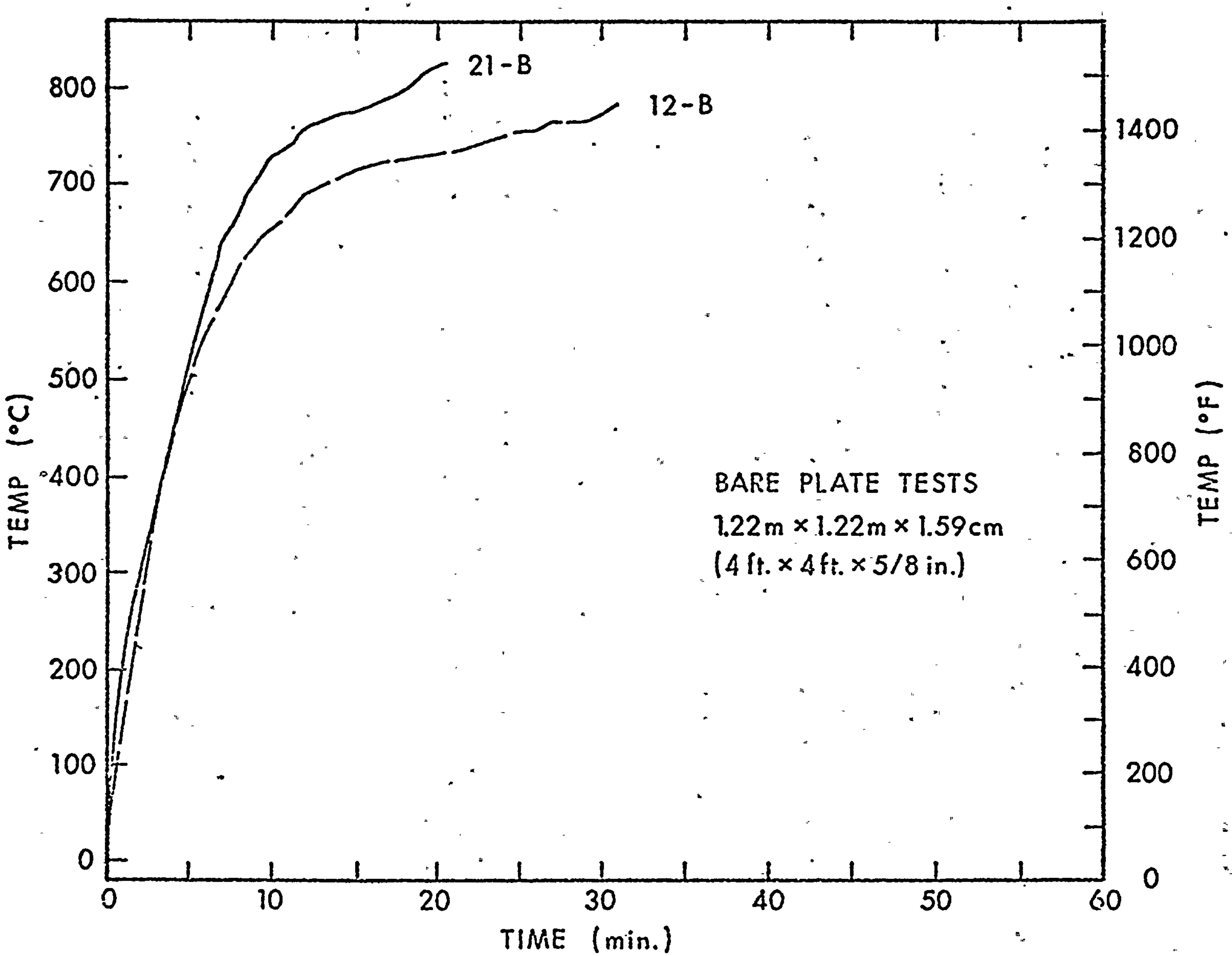


Figure 5. Maximum Thermocouple Response vs. Time; Bare Plates

The heat flux to the bare plates can be computed. First the heat gained by a portion of the plate in raising the plate temperature from T_1 to T_2 in a time interval Δt is computed by:

$$\dot{q}_t = \rho C_p \tau \frac{(\Delta T)_t}{\Delta t} \qquad (1)$$

where:

$\dot{q}_t$ = Heat gained per unit area in the time interval Δt: cal/sec-cm^2 (BTU/hr-ft^2);

ρ = Density of plate: gm/cm^3 (lb/ft^2);

C_p = Specific Heat of plate: cal/gm-^{o}C (BTU/lb-^{o}F);

τ = Thickness of plate: cm (ft);

$(\Delta T)_t$ = Temperature difference in time interval Δt: ^{o}C (^{o}F);

and

Δt = Time interval: sec (hr).

In addition to raising the temperature at a particular region of the plate, some of the heat is conducted away to cooler regions. This contribution to the net heat absorbed by that region of the plate is computed from:

$$q_x = k \frac{(\Delta T)_x}{\Delta x} \qquad (2)$$

where:

q_x = Heat loss per unit area by conduction: cal/sec-ft^2 (BTU/hr-ft^2);

k = Thermal conductivity of the plate: cal/sec-cm-^{o}C (BTU/hr-ft-^{o}F);

$(\Delta T)_x$ = Thermal gradient in the plate: ^{o}C (^{o}F);

and

Δx = Distance over which thermal gradient is computed: cm(ft).

Therefore, the net heat absorbed per unit area per unit time by a region of the plate is the sum of equations 1 and 2,

$$\dot{q}\text{ (absorbed)} = \dot{q}_t + \dot{q}_x . \qquad (3)$$

Equation 3 is applied to determine the initial heat flux to the center region of the plate. The values determined for the left hand side of equation 3 were plotted versus the temperature recorded by the center plate thermcouple. A linear regression analysis was then performed on these data points to obtain an equation of the form:

$$\dot{q} = a_o + a_1 T_p \qquad (4)$$

where:

T_p = Temperature at center of plate: ^oC (^oF);

a_o = Coefficient;

and

a_1 = Coefficient.

The coefficients for equation 4 for the two bare plate tests are given below:

TEST NO.	COEFFICIENT a_o	COEFFICIENT a_1
12-B	4.85	-0.00678
21-B	5.19	-0:00659

Using this data, the average heat fluxes to the center of the plates were determined to be as follows:

12-B	4.71 cal/sec-cm^2	(62,500 BTU/hr-ft^2)
21-B	5.06 cal/sec-cm^2	(67,200 BTU/hr-ft^2)

Further, using the data obtained herein and the method of characteristics, the heat flux and temperature distribution of the torching wake were determined and are shown in Figures 6 and 7.

For comparison with the plates which were protected by various thermal systems, the times for the plates to reach certain specified temperatures are tabulated in Table II.

V. SANDWICH INSULATING SYSTEMS

Different types of sandwich insulating systems are currently in use on some of the smaller tank cars. The insulation thickness generally varies from 2.54 cm to 10.2 cm (1. in to 4. in) depending on the design. The insulators are usually protected with a 0.318 cm (1/8 in) steel shield.

Several types of sandwich insulating systems were included in the test program - polyurethane foam, cork, fiberglass, mineral wool, et cetera. Some of these insulating systems are actually in use, others were tested for possible use and comparison. Two shield configurations were tested for the foam insulation.

For cases where the insulation alone supports the shield, as the insulation melts or otherwise fails, the weight of the shield pulls the shield down toward the tank car shell. To simulate this condition, with the vertically suspended plates being tested, cables were connected to the sides of the metal shield. These cables were then connected to "come-alongs". As the test proceeded, the cables were continually tightened to maintain the shield flush with the insulation. For cases where the steel shield is in a fixed position, the metal shield was mounted at a specified distance from the tank car shell by using fixed "standoffs".

Polyurethane foam is manufactured in different densities. Hence, two different foam densities were tested. Also, since the foam insulation is the only system where standoffs are not always used, tests were conducted on the foam insulated plates using both the "come-alongs" (floating shield) and "standoffs" (fixed shield). Tests involving cork, fiberglass, S-1, S-2, S-3 and S-4 insulation all used fixed shields.

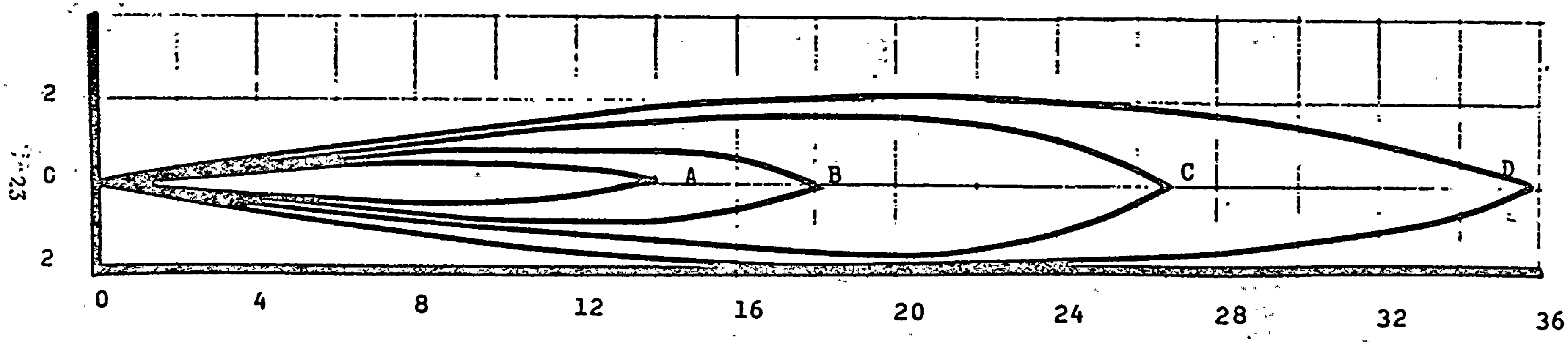
Tables III and IV list the different tests by the type of insulation used. Figures 8 through 20 show the thermal response of the sandwich plates when exposed to the standard torch conditions.

Comparisons of the ability of a thermal insulation system to retard the high heat flux rates resulting from a fire environment have been made using the bare plate torch environment as a standard basis. One of the comparison criteria was the time interval at which the plate temperature

ESTIMATED TEMPERATURE DISTRIBUTION

DOT TORCHING FACILITY

PUEBLO, COLORADO



DISTANCE IN FEET

(LINES REPRESENT SURFACES AT CONSTANT TEMPERATURE)

ISOTHERMAL ZONE:

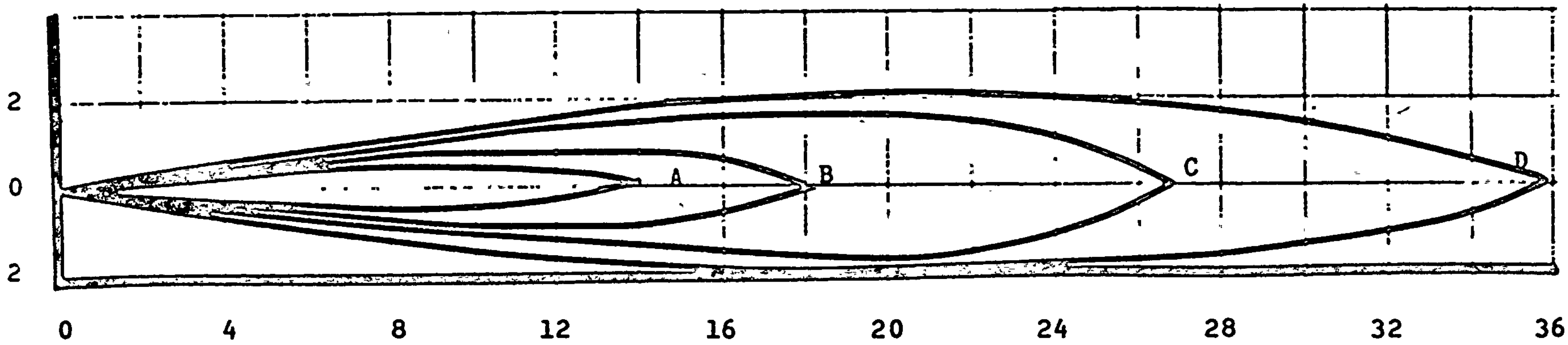
A	2200°F	C	1320°F
B	1600°F	D	1060°F

Figure 6

ESTIMATED HEAT FLUX DISTRIBUTION

DOT TORCHING FACILITY

PUEBLO, COLORADO



DISTANCE IN FEET

(LINES REPRESENT SURFACES OF CONSTANT HEAT FLUX)

ADIABATIC ZONES:

A	78000	$\frac{BTU}{FT^2HR}$
B	67000	"
C	40200	"
D	30000	"

Figure 7

TABLE II. TIME FOR BARE PLATES TO REACH SPECIFIED TEMPERATURES

TEST NUMBER	93°C (200°F)	204°C (400°F)	316°C (600°F)	427°C (800°F)
12-B	0.64	1.66	2.66	3.94
21-B	0.29	0.96	2.28	3.73

TABLE III. SANDWICH INSULATING SYSTEMS

(All Systems have a 0.318 (1/8 in) Steel Shield)

TYPES OF INSULATION	THICKNESS OF INSULATION	DENSITY	TYPE OF SHIELD	TEST NUMBER
Polyurethane Foam	5.1 cm (2. in)	0.160 gm/cm^3 (10. lb/ft^3)	Fixed	22
	5.1 cm (2. in)	0.032 gm/cm^3 (2. lb/ft^3)	Fixed	32, 33
	5.1 cm (2. in)	0.032 gm/cm^3 (2. lb/ft^3)	Floating	31, 34, 36
	10.2 cm (4. in)	0.032 gm/cm^3 (2. lb/ft^3)	Fixed	28, 29, 30
	10.2 cm (4. in)	0.032 gm/cm^3 (2. lb/ft^3)	Floating	24, 25
Fiberglass	10.2 cm (4. in)		Fixed	38, 39, 40
Cork	2.5 cm (1. in)		Fixed	43, 45
	10.2 cm (4. in)		Fixed	41

TABLE IV. SANDWICH INSULATING SYSTEMS

(All Systems have a 0.318 cm (1/8 in) Steel Fixed Shield)

TYPES OF INSULATION	THICKNESS OF INSULATION	TYPES OF SHIELD	TEST NUMBER
S-1	5.1 cm (2. in)	Fixed	48
	1.3 cm (0.5 in)	Fixed	49
S-2	3.2 cm (1.25 in)	Fixed	50
S-3	2.5 cm (1. in)	Fixed	51
S-4	2.5 cm (1. in)	Fixed	52

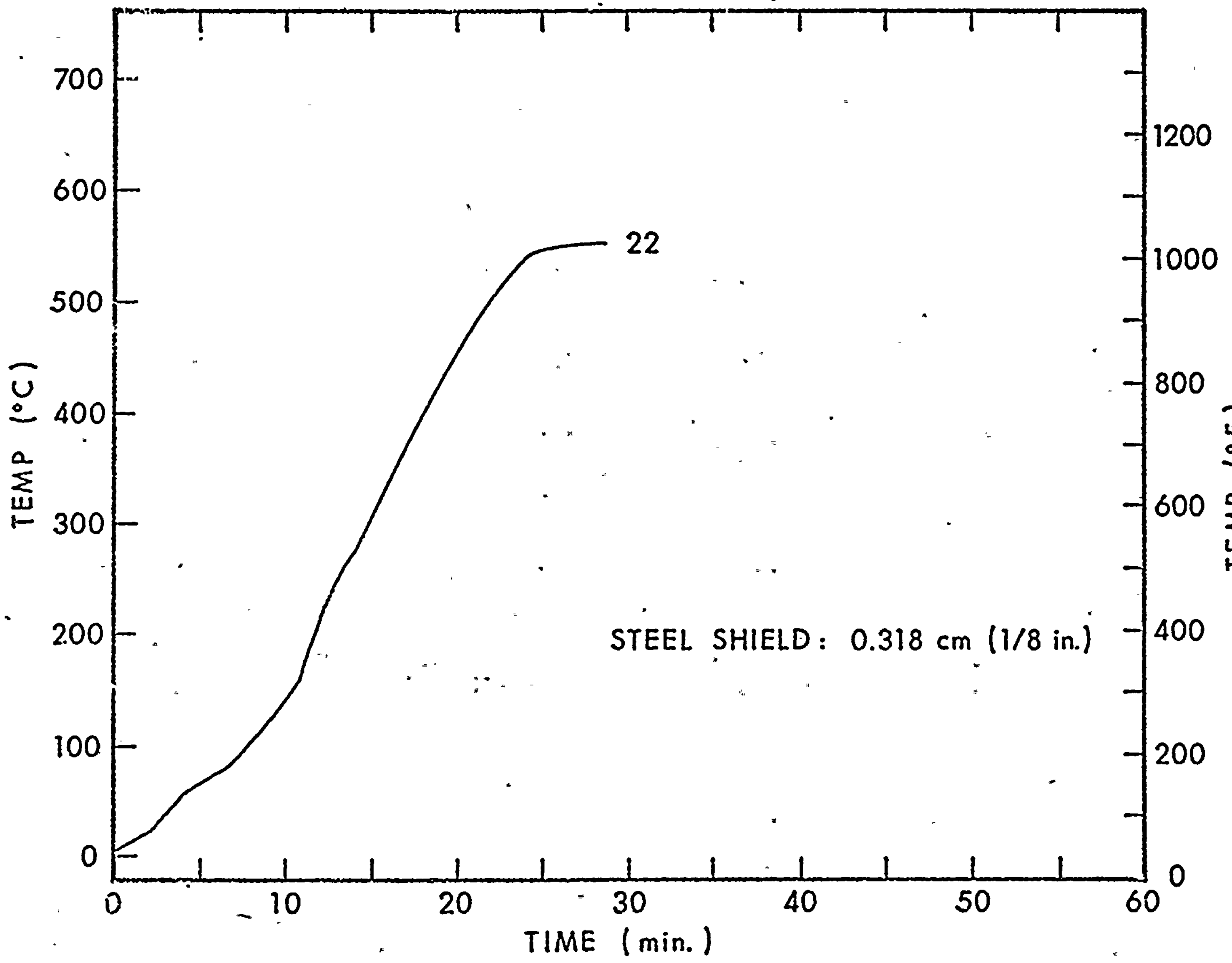


Figure 8. 5.1 cm (2 in.) FOAM, Fixed Shield, 0.160 gm/cm^2 (10 lb/ft^3)

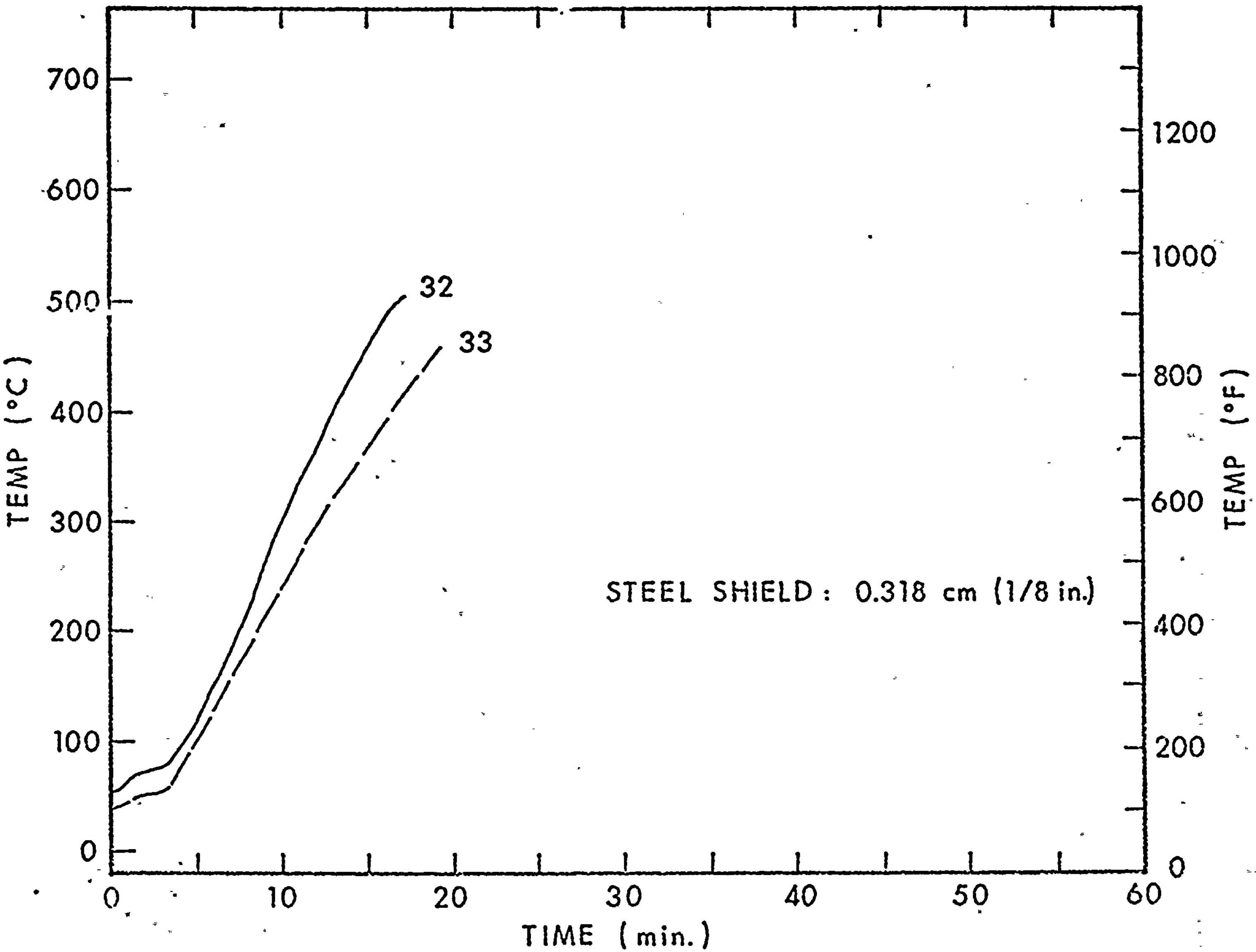


Figure 9. 5.1 cm (2in.) FOAM, Fixed Shield, 0.032 gm/cm^2 (2 lb/ft^3)

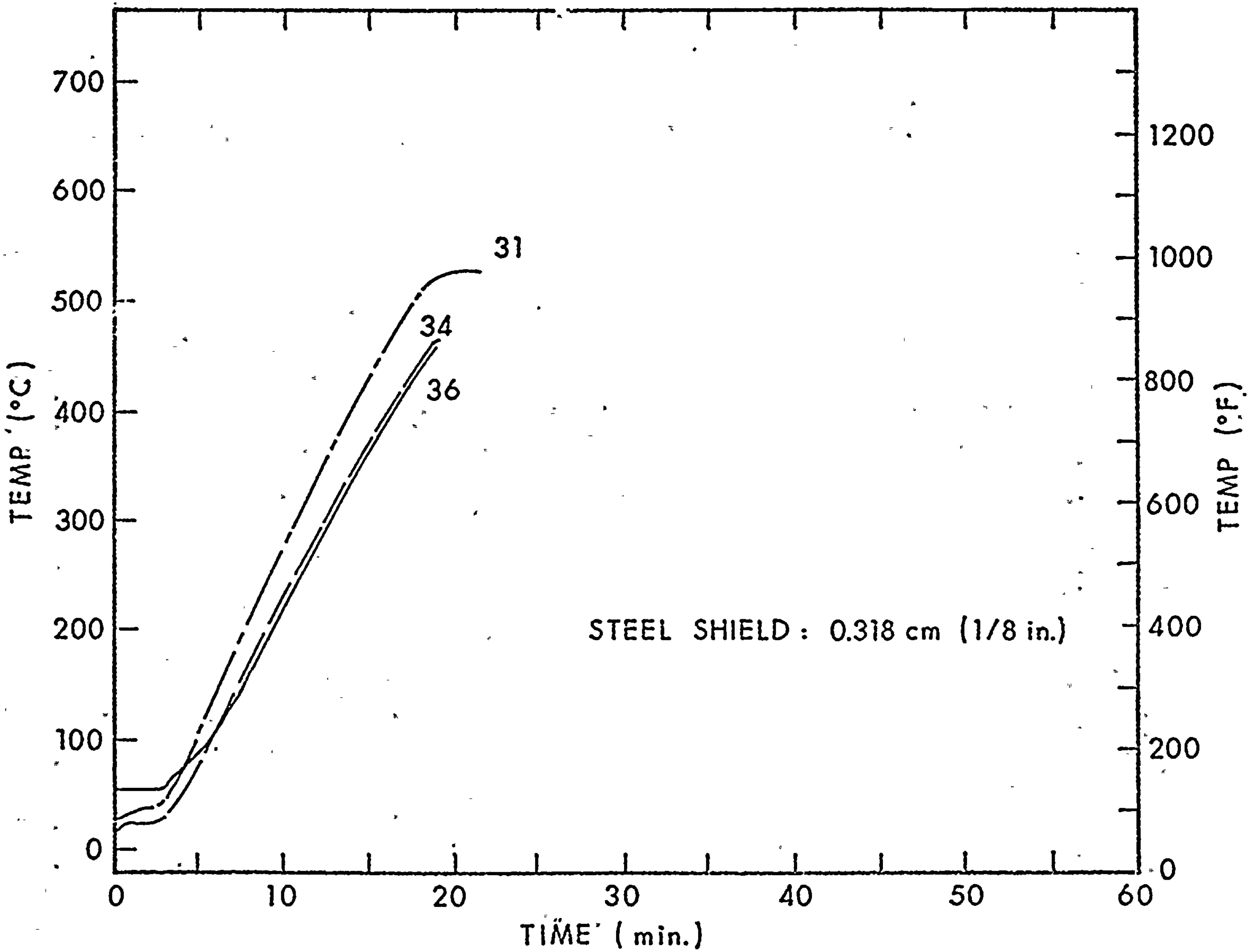


Figure 10. 5.1cm (2in.) FOAM, Floating Shield, 0.032 gm/cm^2 (2lb/2ft^3)

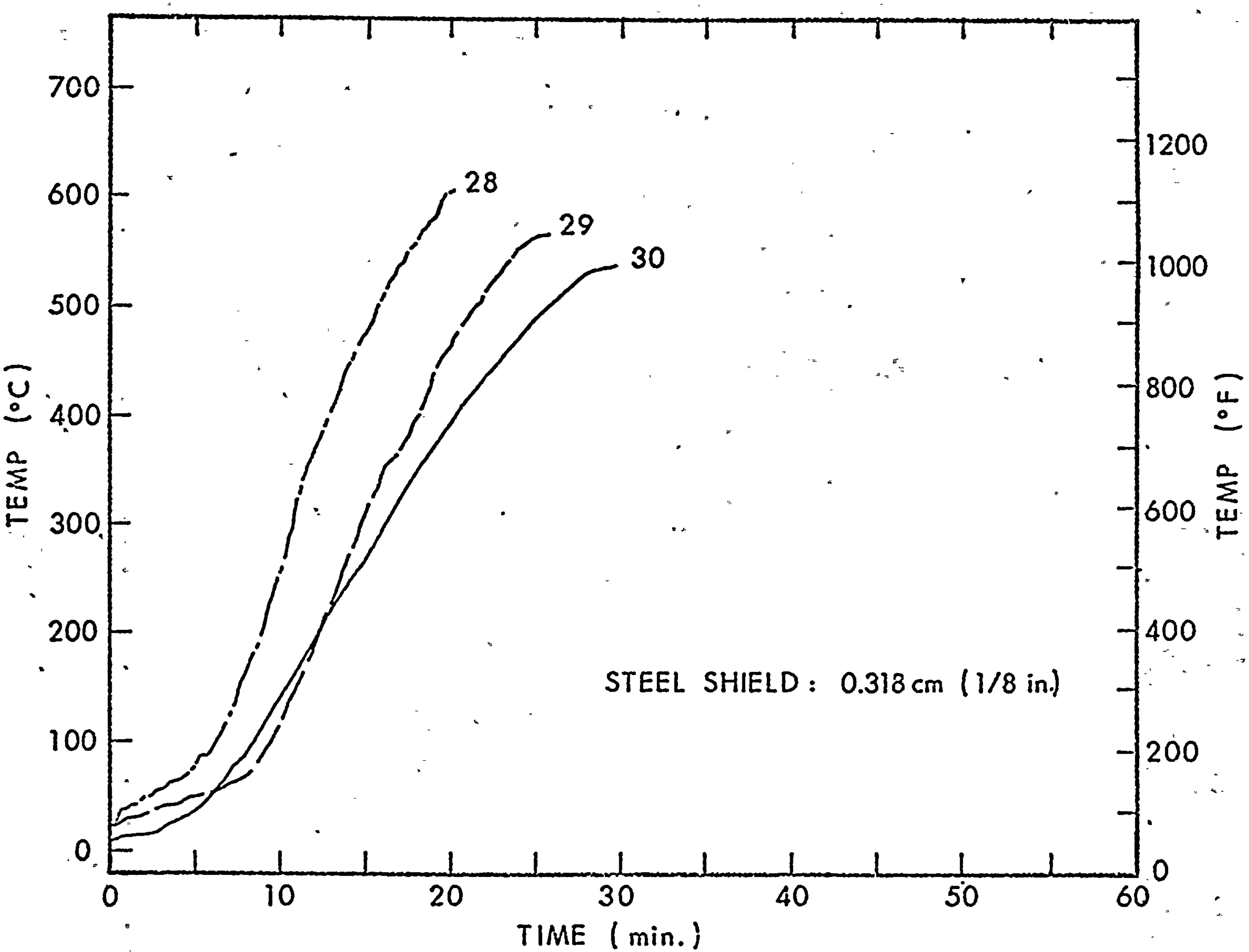


Figure 11. 10.2 cm (4 in.) FOAM, Fixed Shield, 0.032 gm/cm^2 (2 lb / 2 ft^3)

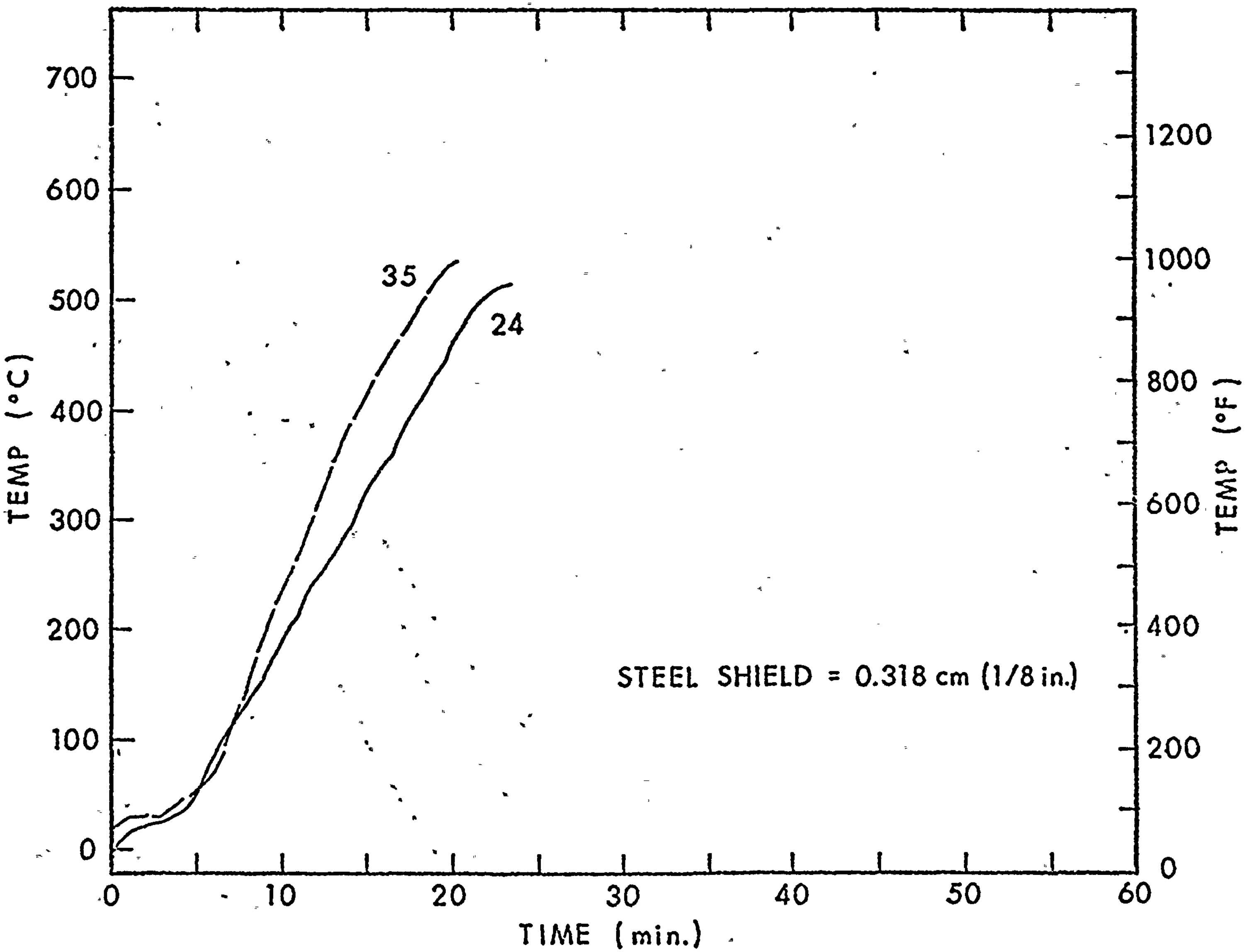


Figure 12. 10.2 cm (4 in.) FOAM, Floating Shield, 0.032 gm/cm^2 (2 lb/ft^3)

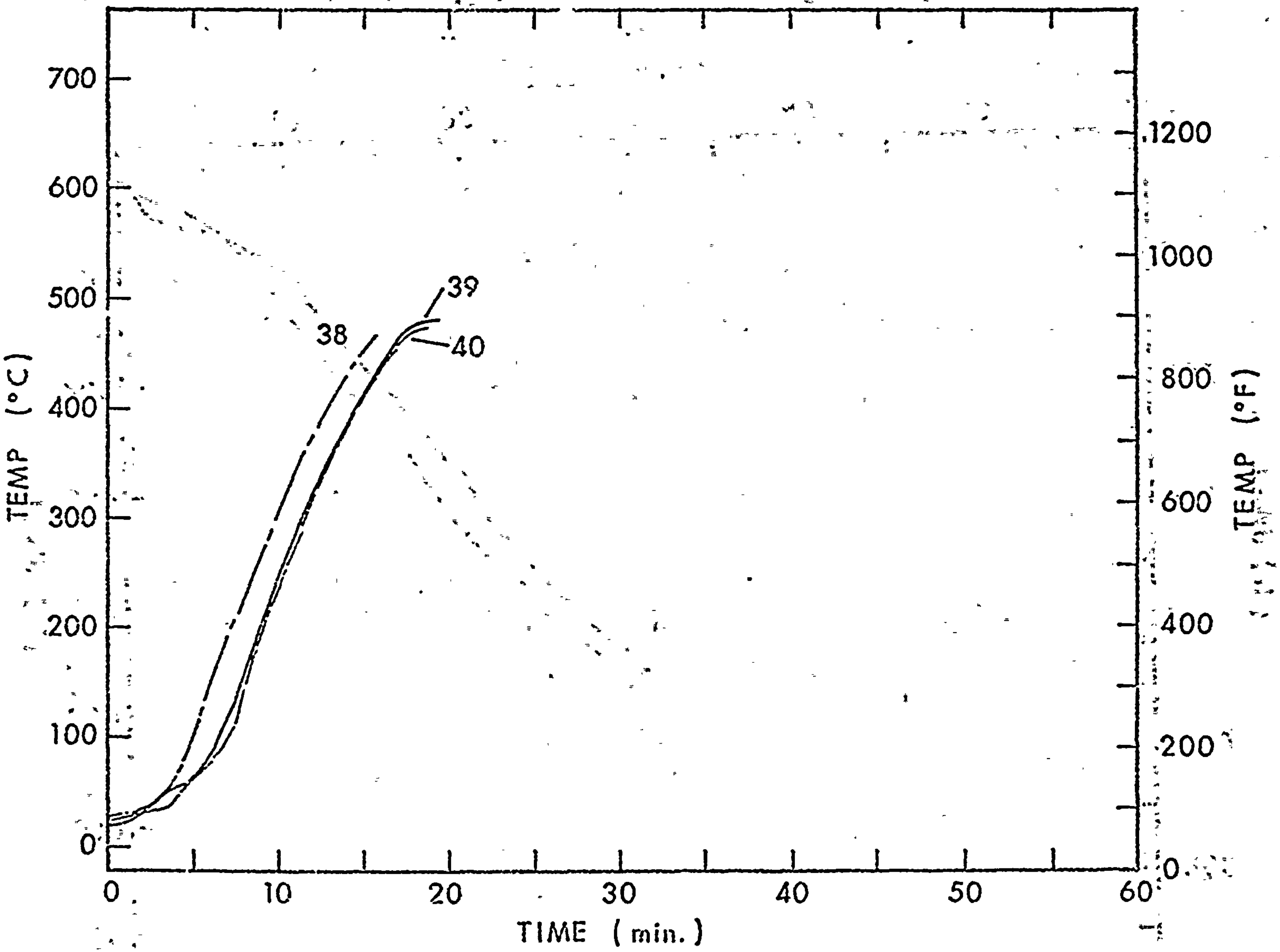


Figure 13. 10.2 cm (4 in.) FIBERGLASS with 0.32 cm (1/8 in.) Steel Shield

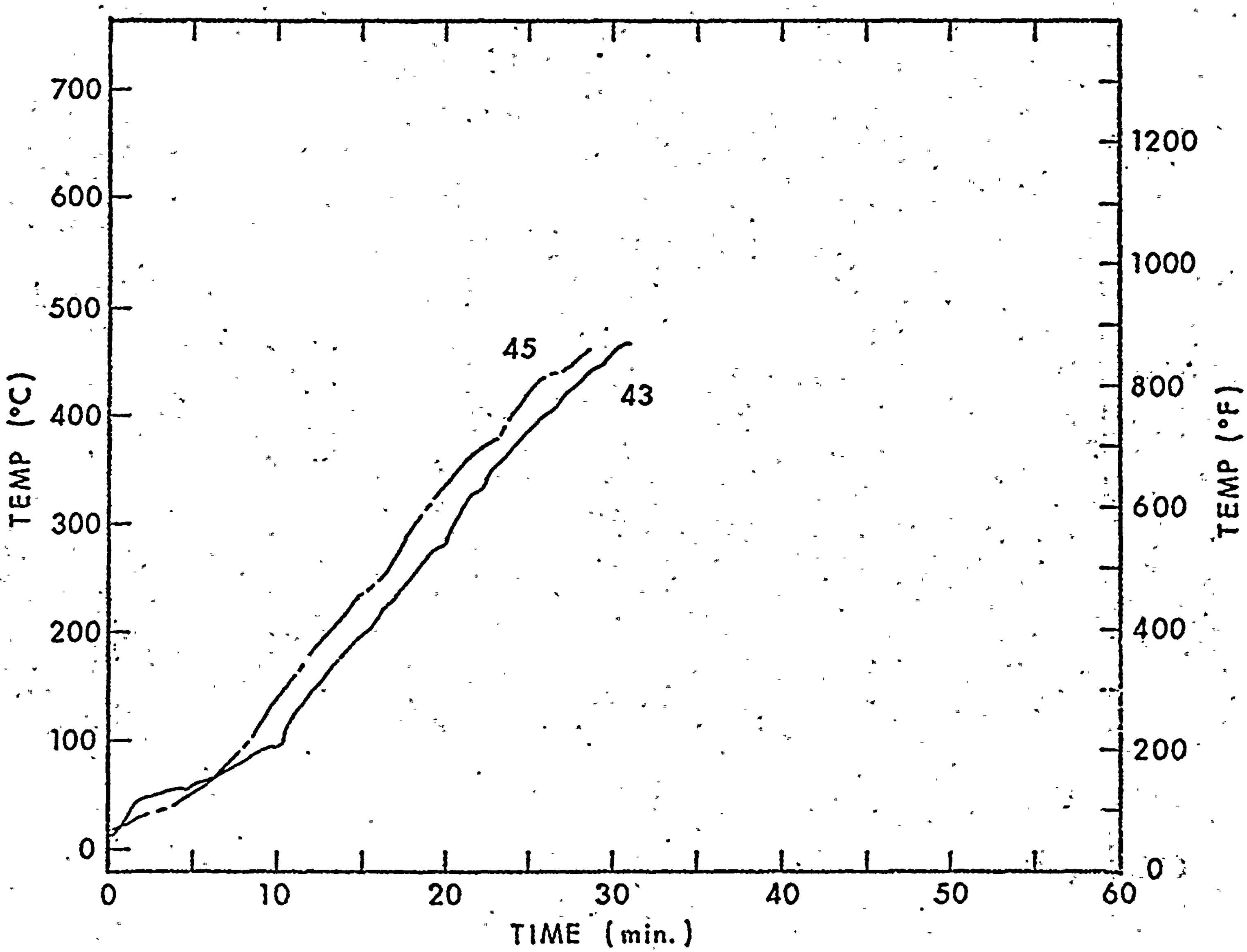


Figure 14. 2.5 cm (1 in.) CORK with 0.32 cm (1/8 in.) Steel Shield

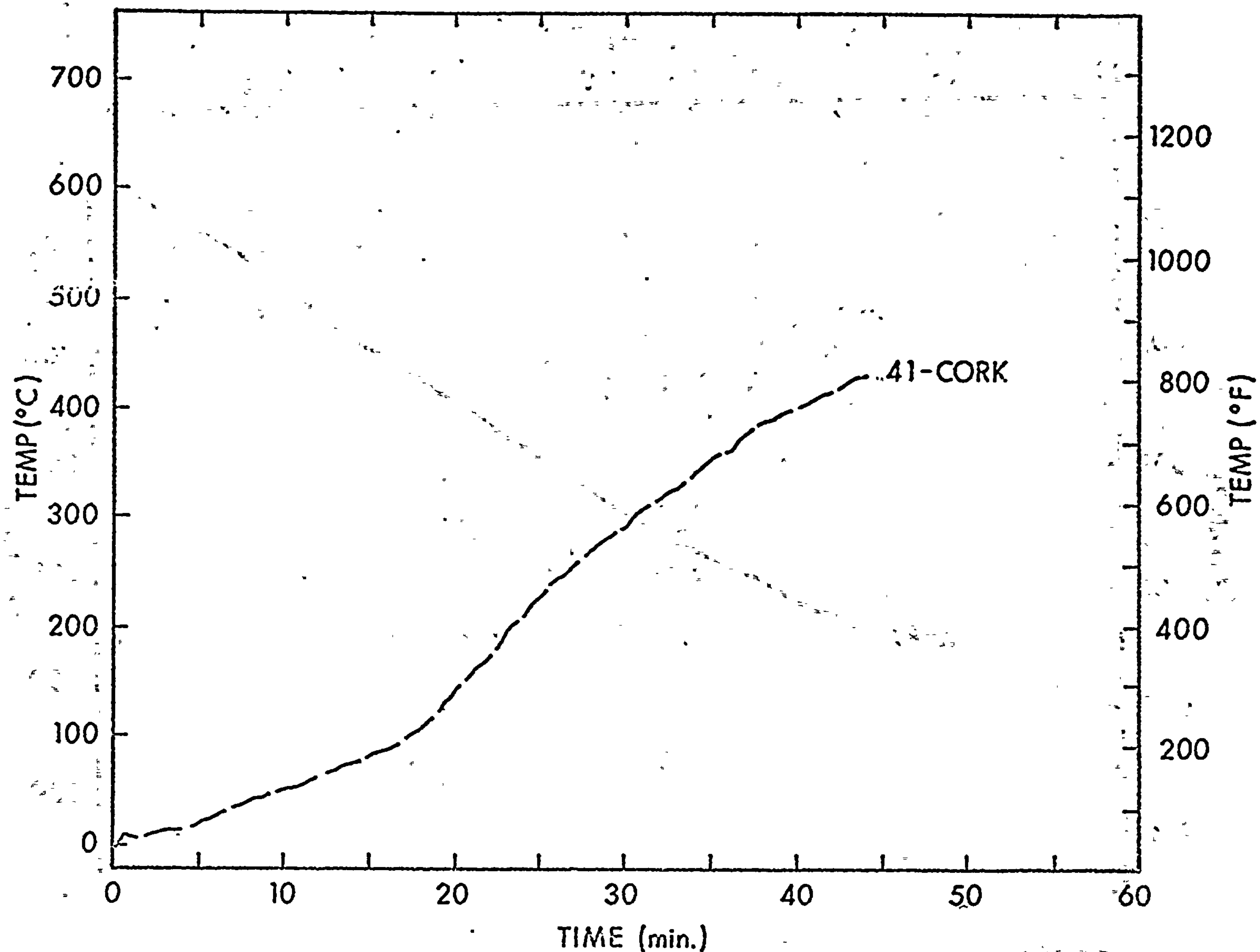


Figure 15. 10.2 cm (4 in.) CORK with 0.32 cm (1/8 in.) Steel Shield

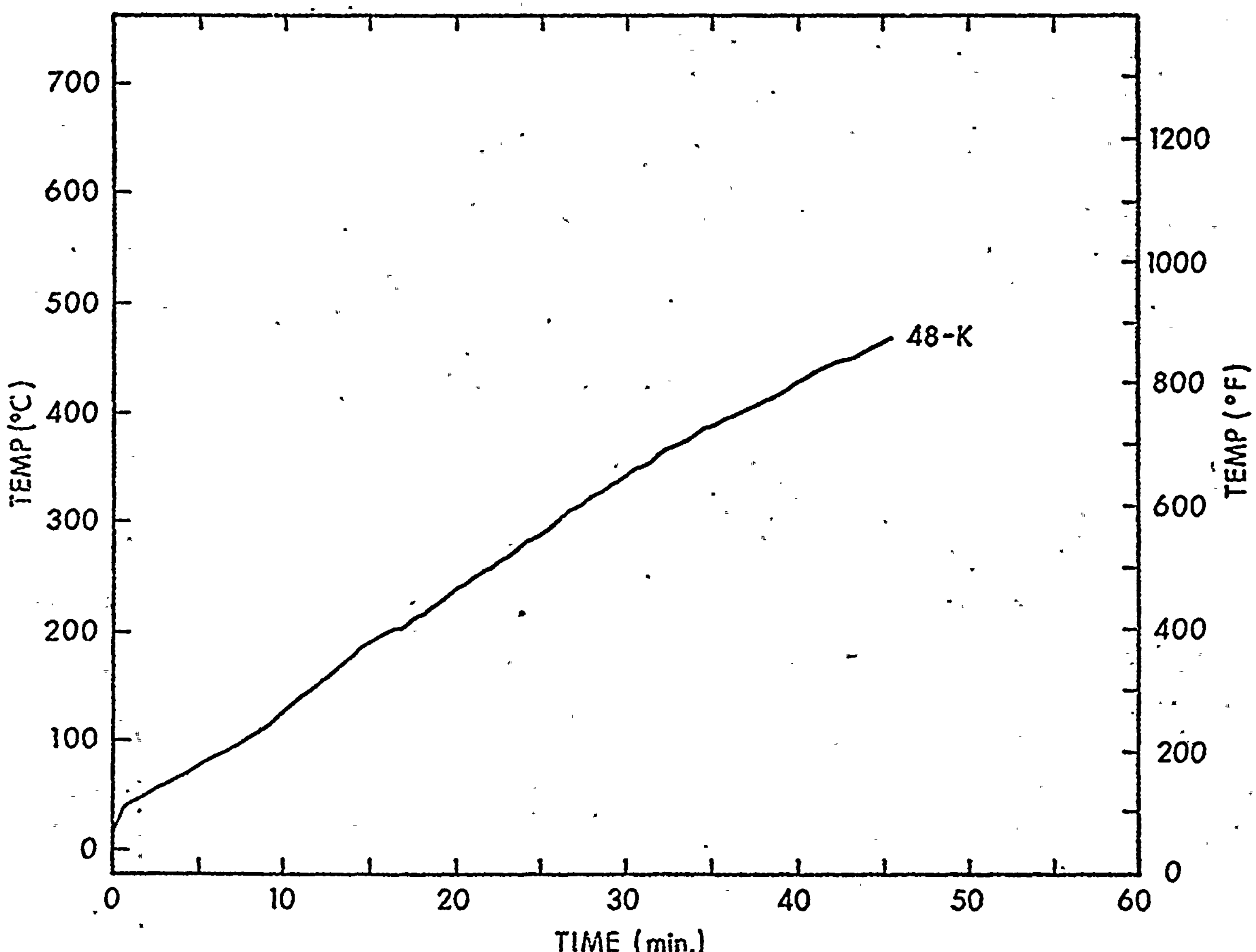


Figure 16. 5.1cm (2 in.) I s-1 with 0.32cm (1/8in.) Steel Shield

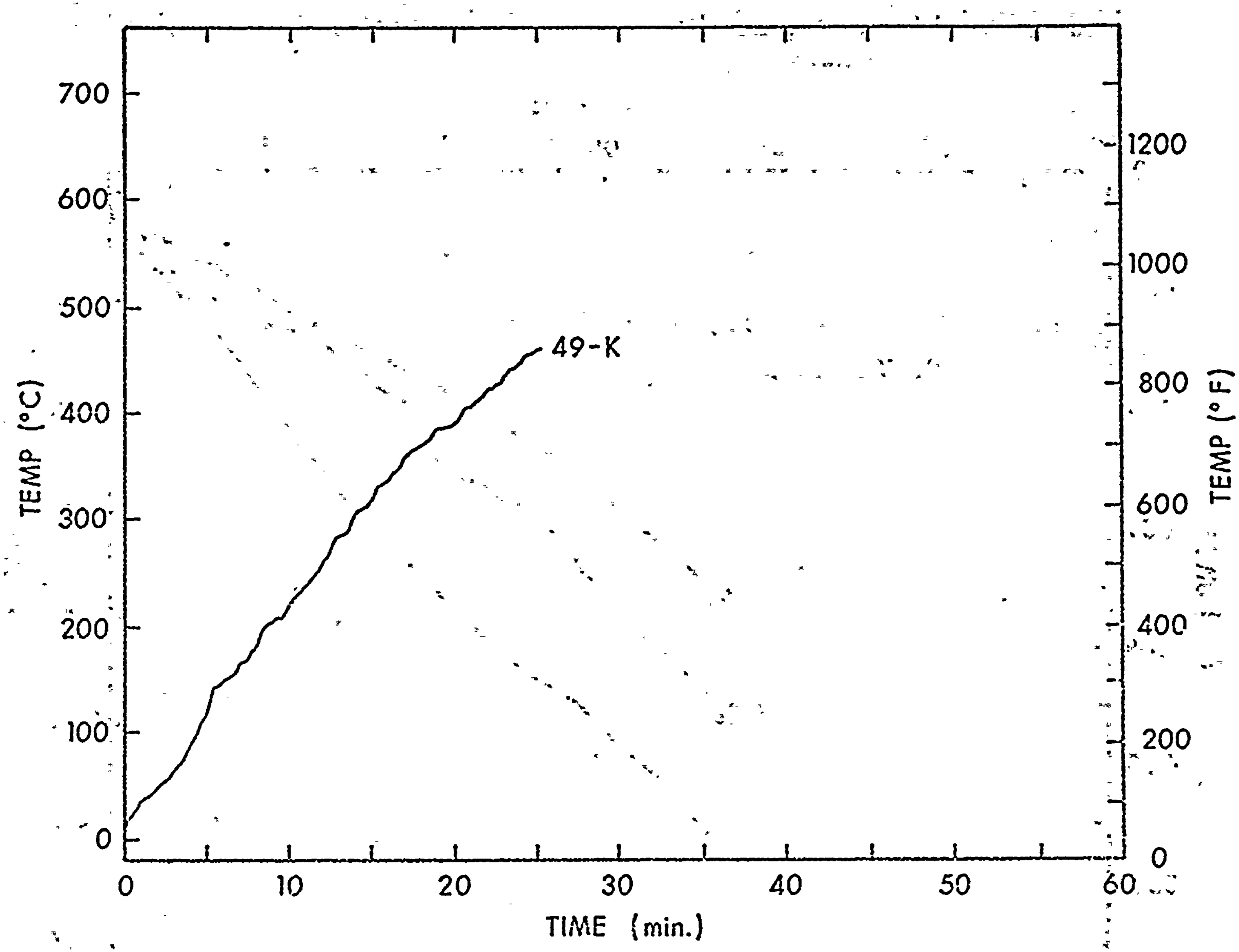


Figure 17. 1.3 cm (0.5 in.) S-1 with 0.32 cm (1/8 in.) Steel Shield

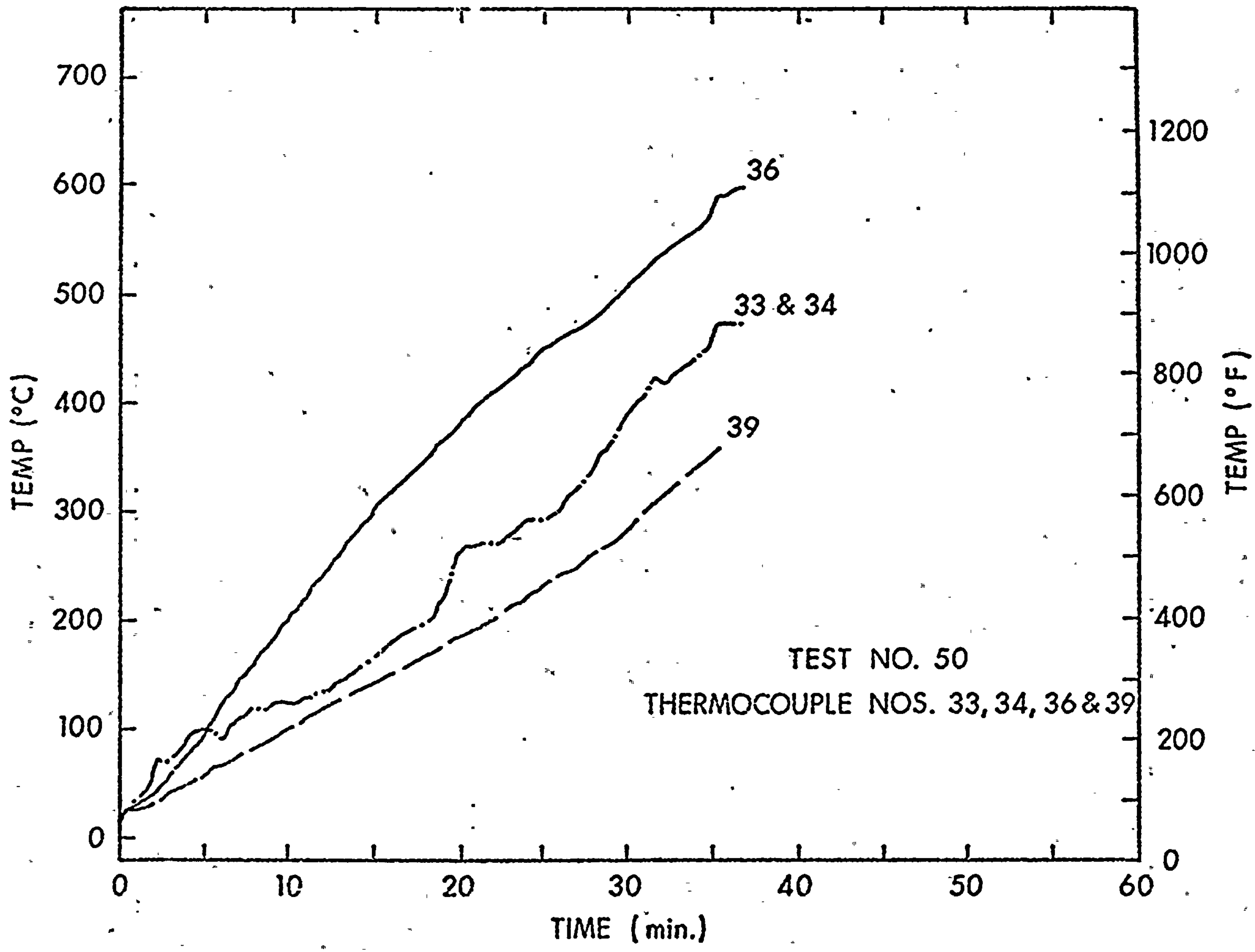


Figure 18. 3.18 (1.25 in.) s-2 with 0.32 cm (1/8 in.) Steel Shield

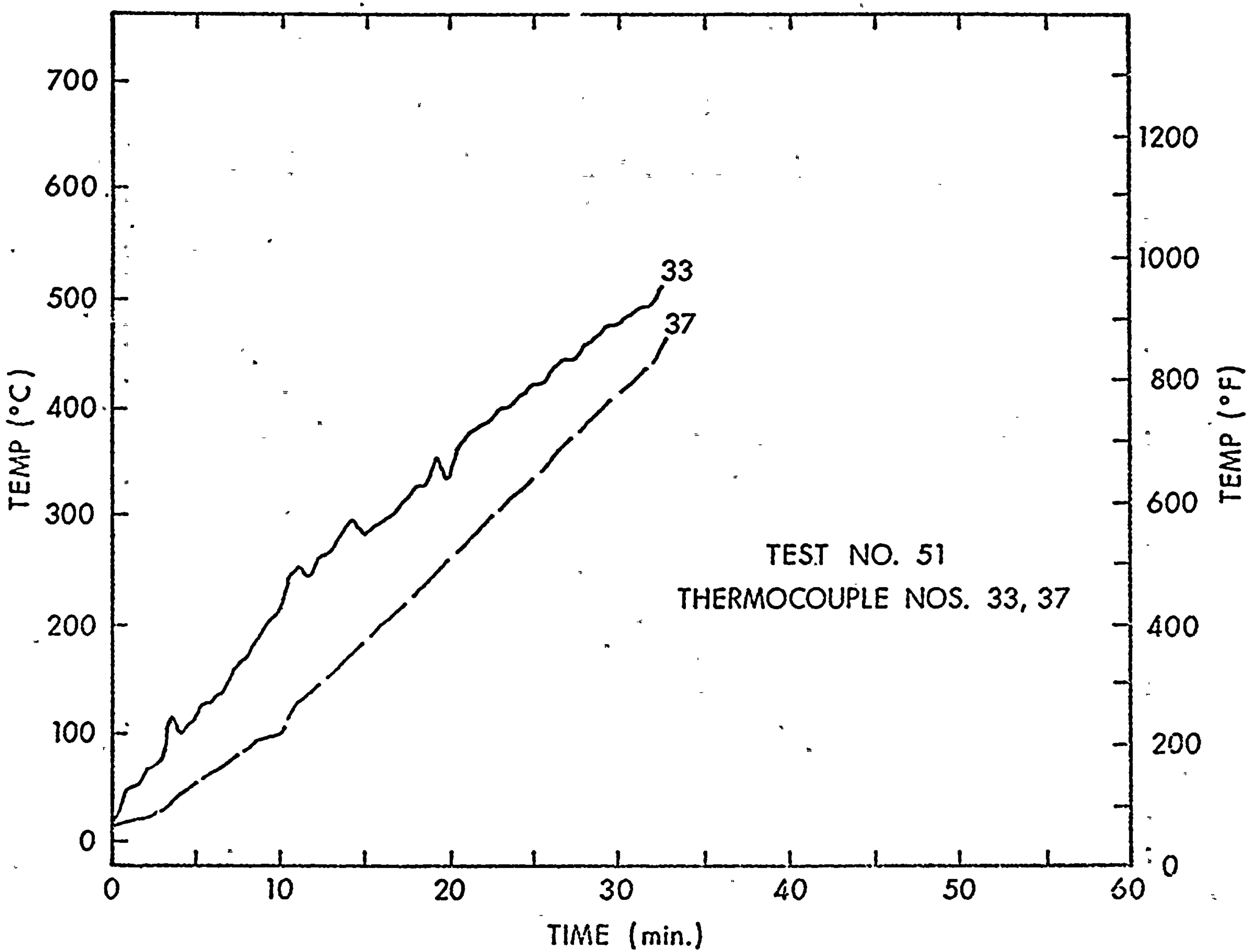


Figure 19. 2.5 cm (1 in.) S-3 with 0.32 cm (1/8 in.) Steel Shield

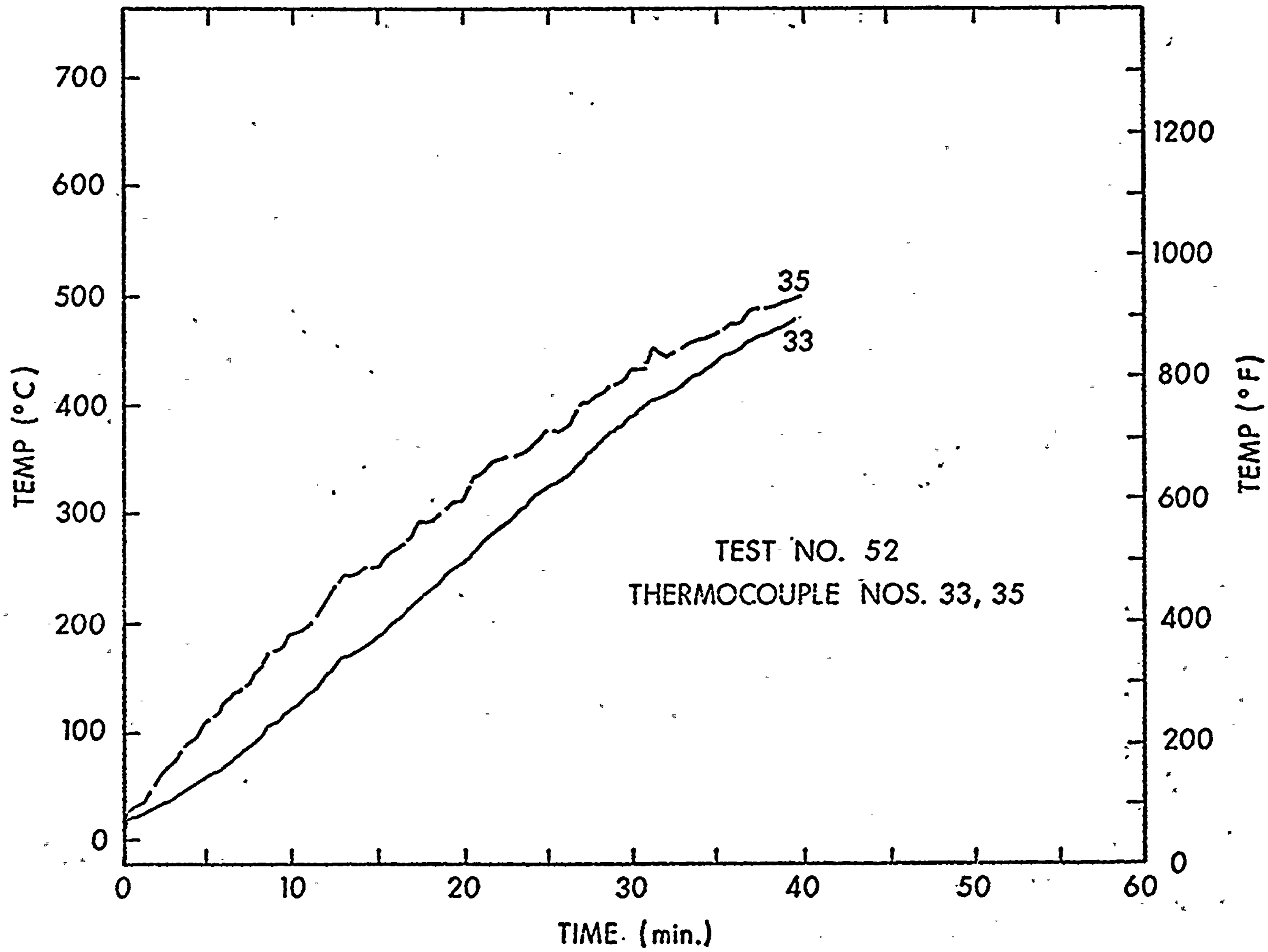


Figure 20. 2.5 cm (1 in.) s-4 with 0.32 cm (1/8 in.) Steel Shield

reached 93°C, 204°C, 316°C, and 427°C (200°F, 400°F, 600°F, and 800°F). The times to reach these temperatures are recorded in Tables V and VI.

All sandwich insulation systems provided some degree of protection - see Figures 8 through 20. Of the sandwich insulation systems tested, the 10.2 cm (4. in) thick cork provided the best insulating properties. By way of comparison, 2.54 cm (1.0 in) of cork provided better insulation than 10.2 cm (4. in) of fiberglass.

There is a considerable spread in the thermal response of the steel test plates insulated with 10.2 cm (4. in) of polyurethane foam when tested in the "fixed shield" configuration. This is probably due to the highly exothermic nature of the degradation process of urethane and the uncontrolled availability of oxygen within the confines of the model. Results of tests 28 and 29 (Figure 11) demonstrate this behavior.

There does not appear to be any significant differences between the overall thermal response of the plates when comparing a "fixed shield" to a "floating shield" design. For both the 5.1 cm and 10.2 cm (2. in and 4. in) thicknesses of insulation, the trend appears to be that the "floating" design provided slightly better insulating properties at lower temperatures - 93°C to 204°C (200°F to 400°F). This effect, however, was not measurably significant at higher temperatures. A careful examination of the respective time-temperature plots show that the sharp change in slope for the "fixed" shield cases occurs at approximately 26°C (79°F), lower than the "floating" shield cases.

The 10.2 cm (4. in) of polyurethane foam provided only a slight improvement in thermal insulation over the sample half as thick. Similarly, the 0.160 gm/cm³ (10.0 lb/ft³) density urethane foam provided some improvement over the 0.032 gm/cm³ (2.0 lb/ft³) density foam for identical thicknesses. However, the slight improvement in heat retarding qualities of the two different density materials is certainly not sufficient to warrant five times the additional weight.

The fiberglass insulating system (fiberglass plus shield) exhibited comparable insulating properties to the 0.032 gm/cm³ (2.0 lb/ft³) density urethane foam. A 1.3 cm (0.5 in) thickness of the S-1 insulating system retarded the attainment of the steel plate temperature of 427°C (800°F) for 22.5 minutes, while a 5.1 cm (2. in) thickness required 41 minutes to reach the same temperature. A 3.2 cm (1.25 in) thickness of S-2 with steel shield required 31 minutes for the steel plate to reach 427°C (800°F). The S-3 insulating system in a thickness of 2.5 cm (1. in) required 27.5 minutes for the plate to reach the same temperature. Finally, the S-4 insulating system of 2.5 cm (1. in) of insulation plus the steel shield kept the plate temperature below 427°C (800°F) for a period of 34 minutes in one test and 29 minutes in a second test.

TABLE V. TIME FOR PLATES TO REACH SPECIFIED TEMPERATURES: SANDWICH INSULATING SYSTEMS

TYPE OF INSULATION	THICKNESS OF INSULATION	TEST NUMBER	TIME (MINUTES) 93°C (200°F)	204°C (400°F)	316°C (600°F)	427°C (800°F)
Polyurethane Foam	5.1 cm (2. in)	22	7.00	11.75	15.00	19.00
	5.1 cm (2. in)	32	3.75	7.50	10.25	14.00
	5.1 cm (2. in)	33	4.75	8.50	12.50	17.50
	5.1 cm (2. in)	31	4.50	7.85	11.00	14.75
	5.1 cm (2. in)	34	5.25	9.00	12.75	17.00
	5.1 cm (2. in)	36	5.50	9.25	13.00	17.25
	10.2 cm (4. in)	28	5.50	8.75	10.75	13.50
	10.2 cm (4. in)	29	9.00	12.35	15.00	18.75
	10.2 cm (4. in)	30	7.85	12.35	16.50	21.50
	10.2 cm (4. in)	24	6.00	10.25	14.25	18.65
	10.2 cm (4. in)	25	6.25	9.00	11.80	15.00
Fiberglass	10.2 cm (4. in)	38	4.75	7.25	10.00	14.00
	10.2 cm (4. in)	39	6.12	7.85	11.65	15.50
	10.2 cm (4. in)	40	6.75	9.05	11.75	15.50
Cork	2.5 cm (1. in)	43	9.00	15.00	21.00	27.50
	2.5 cm (1. in)	45	7.75	13.00	18.00	25.00
	10.2 cm (4. in)	41	16.00	22.25	31.25	43.00

TABLE VI. TIME FOR PLATES TO REACH SPECIFIED TEMPERATURES: SANDWICH INSULATING SYSTEMS

TYPE OF INSULATION	THICKNESS OF INSULATION	CHANNEL NUMBER	TIME (MINUTES) 93°C (200°F)	204°C (400°F)	316°C (600°F)	427°C (800°F)
S-1	5.1 cm (2 in)	33	6.0	16.0	27.0	41.0
	1.3 cm (0.5 in)	33	4.0	8.0	15.0	22.5
S-2	3.2 cm (1.25 in)	33 & 34	5.0	18.0	26.5	31.0
	3.2 cm (1.25 in)	36	5.0	10.0	15.5	23.0
	3.2 cm (1.25 in)	39	9.0	23.0	31.0	
S-3	2.5 cm (1 in)	35	8.0	14.5	20.5	27.5
S-4	2.5 cm (1 in)	33	7.5	16.0	24.0	34.0
	2.5 cm (1 in)	35	4.5	10.0	19.5	29.0

VI. C-1 COATING

C-1 is a three part system designed for spray application to steel - non-insulated tank cars to provide protection against external fires.

The C-1 system consists of a corrosion inhibiting primer, which gives adhesion to the substrate and serves as a base coat; C-1 Coating, which provides the heat shielding properties to the system; and a white decorative topcoat, which protects the C-1 against environmental conditions.

The primer is a two component epoxy, spray applied to approximately 0.02 mm (0.7 mil) film thickness over sandblasted metal. It cures at ambient temperatures. It is formulated to provide good adhesion and corrosion protection to the metal and serve as a tie coat for the Korotherm Coating.

The C-1 Heat Shield Coating is a two component urethane containing heat protecting fibers. They form a fiberous char which retains its integrity after the binder is burned away during fire exposure. It is spray applied in multiple coats to film thickness of 0.32 cm to 0.64 cm (125 to 250 mils), depending upon the defined heat condition. It cures at ambient temperatures.

The topcoat is an aliphatic urethane, spray applied over the C-1 Coating to an approximate 0.05 mm (2 mil) film thickness. This coating protects the C-1 Coating against film degradation from the environment to give the overall C-1 System long life expectancy. It also cures at ambient temperatures.

Six tests were performed on the C-1 Coating System. Four plates were coated with a thickness of 0.32 cm (1/8 in) and two with 0.64 cm (1/4 in) of C-1 Coating. Table VII lists selected performance parameters from testing these insulated plates. Figures 21 and 22 depict the plates' thermal responses to the LPG standard torching environment for the two thicknesses of the C-1 Coating System.

The method used to compute the initial heat flux, etc., for the bare plates was applied to the data resulting from testing the plates coated with C-1 A linear regression analysis was applied to the data. The coefficients to the curve fit described by equation 4 are:

TEST NO.	COEFFICIENT a_o	a_1
8-D	0.864	-0.000492
14-D	0.844	-0.001680
7-D	0.438	-0.000699
10-D	0.985	-0.000538

TABLE VII. TORCH TESTS ON PLATES INSULATED WITH C-1 COATING

	TEST 7-D	TEST 8-D	TEST 10-D	TEST 14-D
Supply Tank Pressure	1.47×10^6 Pa (213 PSIA)	1.92×10^6 Pa (278 PSIA)	1.52×10^6 Pa (220 PSIA)	1.63×10^6 Pa (236 PSIA)
Supply Tank Temperature	36.4°C (97.5°F)	51.4°C (124.5°F)	37.5°C (99.5°F)	42.0°C (107.5°F)
Duration of Torching Test	37.00 Minutes	20.75 Minutes	37.00 Minutes	24.00 Minutes
Orifice Pressure	1.26×10^6 Pa (183 PSIA)	1.54×10^6 Pa (223 PSIA)	1.22×10^6 Pa (177 PSIA)	1.32×10^6 Pa (191 PSIA)

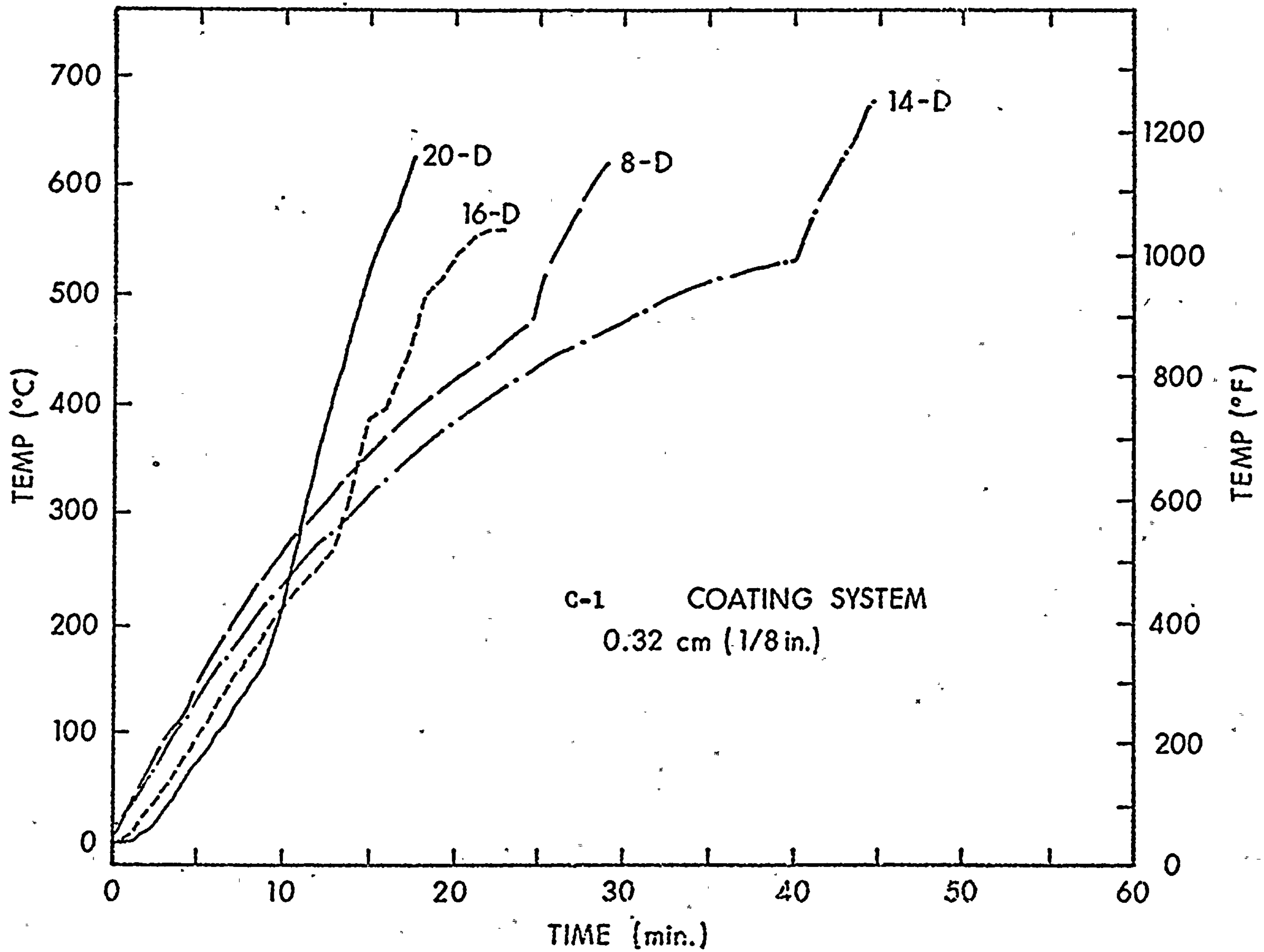


Figure 21. Plate Response for 0.32cm (1/8 in.) C-1 Insulation

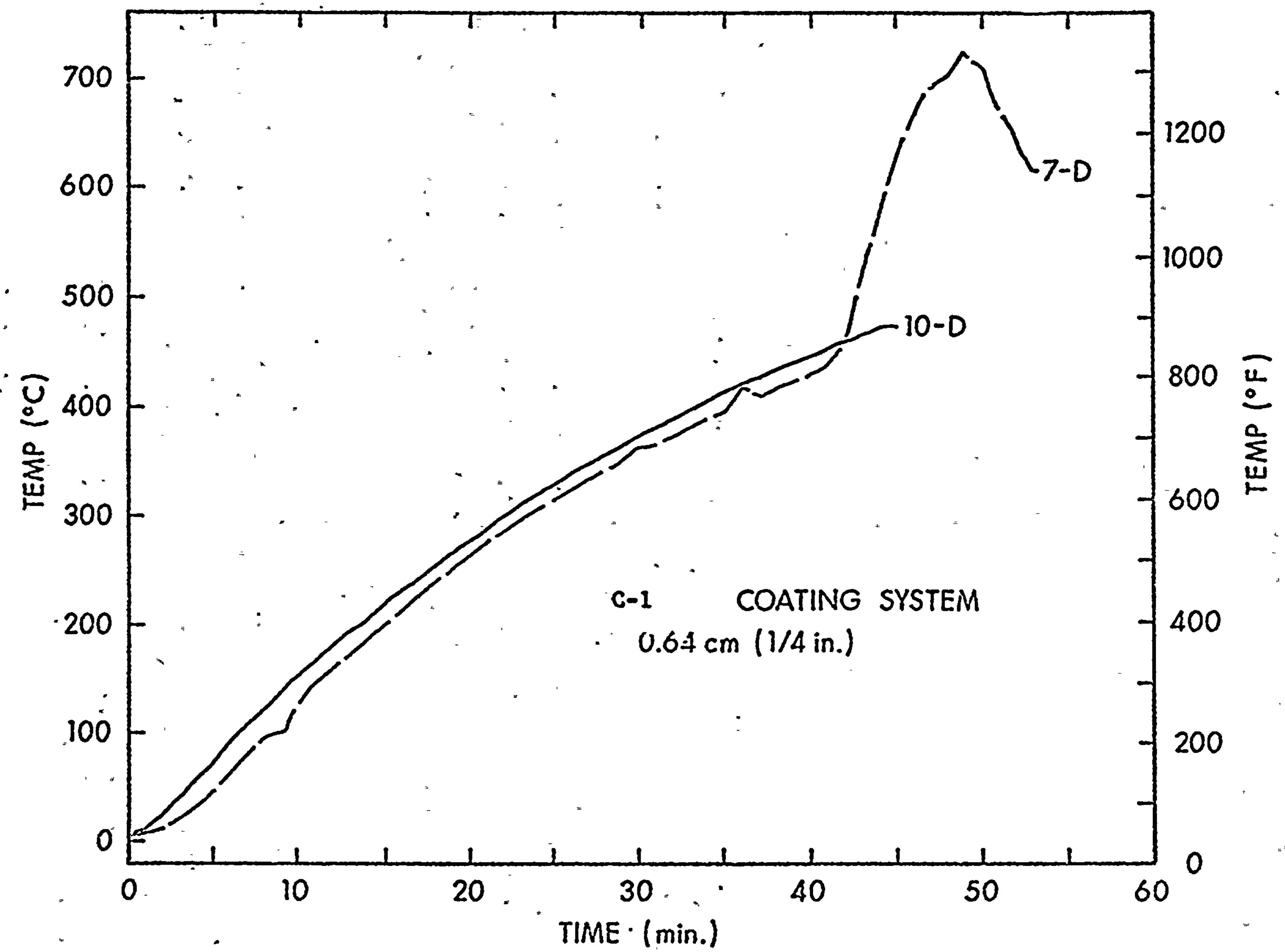


Figure 22. Plate Response for 0.64cm (1/4 in.) C-1 Insulation

The initial heat fluxes through the material as determined from the curve fits are as follows:

$\dot{q}$	0.845 cal/sec-cm^2 (11,200 BTU/hr-ft^2)	Test 8-D
$\dot{q}$	0.810 cal/sec-cm^2 (10,800 BTU/hr-ft^2)	Test 14-D
$\dot{q}$	0.425 cal/sec-cm^2 (5,640 BTU/hr-ft^2)	Test 7-D
$\dot{q}$	0.474 cal/sec-cm^2 (6,290 BTU/hr-ft^2)	Test 10-D

Note that 0.32 cm (1/8 in) of C-1 retards the initial heat input to the plate by a factor of 5.9 compared to a bare plate. Doubling the thickness of C-1 from 0.32 cm (1/8 in) to 0.64 cm (1/4 in) improved the ability to insulate the steel plate by a factor of two.

The time for the plate to reach 93°C, 204°C, 316°C and 427°C (200°F, 400°F, 600°F and 800°F) are tabulated in Table VIII. Except for tests 16-D and 20-D, the test results, supported by visual observations made during and after the testing, indicate that C-1 loses adhesion at approximately 427°C (800°F) and sometimes before reaching this temperature. In tests 16-D and 20-D, the coating lost adhesion at lower temperatures test 16-D at 260°C (500°F) and test 20-D at 177°C (350°F). Research is being conducted to determine changes in the formulation of the coating system to prevent separation from occurring.

VII. C-2 COATING

C-2 is a subliming, insulating coating for application to materials for thermal protection. The coating is applied to reduce, limit or restrict heat transfer to a substrate. The thermal mechanism of sublimation is employed to absorb and block incident heat energy and provide a temperature limiting, thermostatic effect.

The subliming coating is used in conjunction with a corrosion inhibiting primer and a topcoat. Since C-2 is a one component, water based system, it is applied using commercial, airless, "mastic-type" spray equipment. The degree of thermal protection from the fire is a direct function of coating thickness.

TABLE VIII. TIME FOR C-1 COATED PLATES TO REACH SPECIFIED TEMPERATURES

		TIME (MINUTES)			
THICKNESS OF INSULATION	TEST NUMBER	93°C (200°F)	204°C (400°F)	316°C (600°F)	427°C (800°F)
0.32 cm (1/8 in)	8	2.00	7.00	12.65	20.75
0.32 cm (1/8 in)	14	3.65	8.00	14.75	24.00
0.32 cm (1/8 in)	16	4.75	9.50	14.00	16.80
0.32 cm (1/8 in)	20	5.30	9.50	11.00	13.00
0.64 cm (1/4 in)	7	7.50	15.15	25.00	37.00
0.64 cm (1/4 in)	10	5,80	13.75	22.50	37.00

Seven tests were performed on C-2 Subliming Coating System. All plates were coated with the primer, applied at a thickness of 0.05 mm (2 mils). Two plates each were coated with a thickness of 0.32 cm (1/8 in) and 0.48 cm (3/16 in) of C-2 Subliming Coating, and three plates tested with a thickness of 0.64 cm (1/4 in) of C-2 Subliming Coating. All test plates were topcoated with a topcoat at a thickness of 0.18 mm (7 mils). Table IX lists selected facility operational data.

Figures 23, 24 and 25 depict the thermal response of the C-2 coated plates subjected to the standardized LPG torching thermal environment. Figure 23 exemplifies the duplication of the thermal response for the plates coated with a thickness of 0.32 cm (1/8 in) of C-2 Subliming Coating. 371°C (700°F) was reached by both plates at approximately 23 minutes. Plate 18-T reached the limiting temperature of 427°C (800°F) at 25 minutes, and plate 13-T at 26 minutes.

Similar correlation and close duplication of data is observed for the results of testing the two 0.48 cm (3/16 in) thick coated plates (plates 6-T and 11-T). At 43 minutes, both plates reached a temperature of 371°C (700°F). At 54 minutes, the temperature of plate 6-T was 427°C (800°F). Plate 11-T, for the same thickness, reached 427°C (800°F) at 59.5 minutes.

Figure 25 shows the duplication of performance for equal coating thicknesses of 0.64 cm (1/4 in). Due to limitation of fuel capacity of the test facility, only two plates could be tested sufficiently long to reach a temperature of 427°C (800°F). Plate 46 attained that point at 61 minutes, while plate 47 reached that temperature at 65 minutes.

Three tests (6-T, 11-T, and 13-T) were selected for an in detail analysis. The heat fluxes to the plates were evaluated as a function of plate backside temperature. Subsequently, this data was subjected to a linear regression analysis to fit an equation in the form of equation 4.

The 0.32 cm (1/8 in) of C-2 retards the initial heat flux to the steel plate by a factor of 7 compared to the uninsulated plate. Increasing the thickness of the C-2 Coating System initially applied to the plate significantly retards the quantity of heat to the steel plate. For instance, doubling the coating thickness from 0.32 cm to 0.64 cm (1/8 in to 1/4 in) retarded the achievement of a plate temperature of 427°C (800°F) from 26 minutes to 65 minutes and 61 minutes for plates 47-T and 46-T respectively.

The time for the plates to reach the specified temperatures of 93°C, 204°C, 316°C and 427°C (200°F, 400°F, 600°F and 800°F) are tabulated in Table X.

TABLE IX. TORCH TESTS ON PLATES INSULATED WITH C-2 COATING

	TEST 6-T	TEST 11-T	TEST 13-T
Supply Tank Pressure	1.50×10^6 Pa (218 PSIA)	1.59×10^6 Pa (231 PSIA)	1.58×10^6 Pa (229 PSIA)
Supply Tank Temperature	36.6°C (97.8°F)	39.2°C (102.5°F)	43.1°C (101.6°F)
Duration of Torching Test	54.0 Minutes	59.5 Minutes	26.0 Minutes
Orifice Pressure	1.17×10^6 Pa (170 PSIA)	1.19×10^6 Pa (172 PSIA)	1.44×10^6 Pa (209 PSIA)

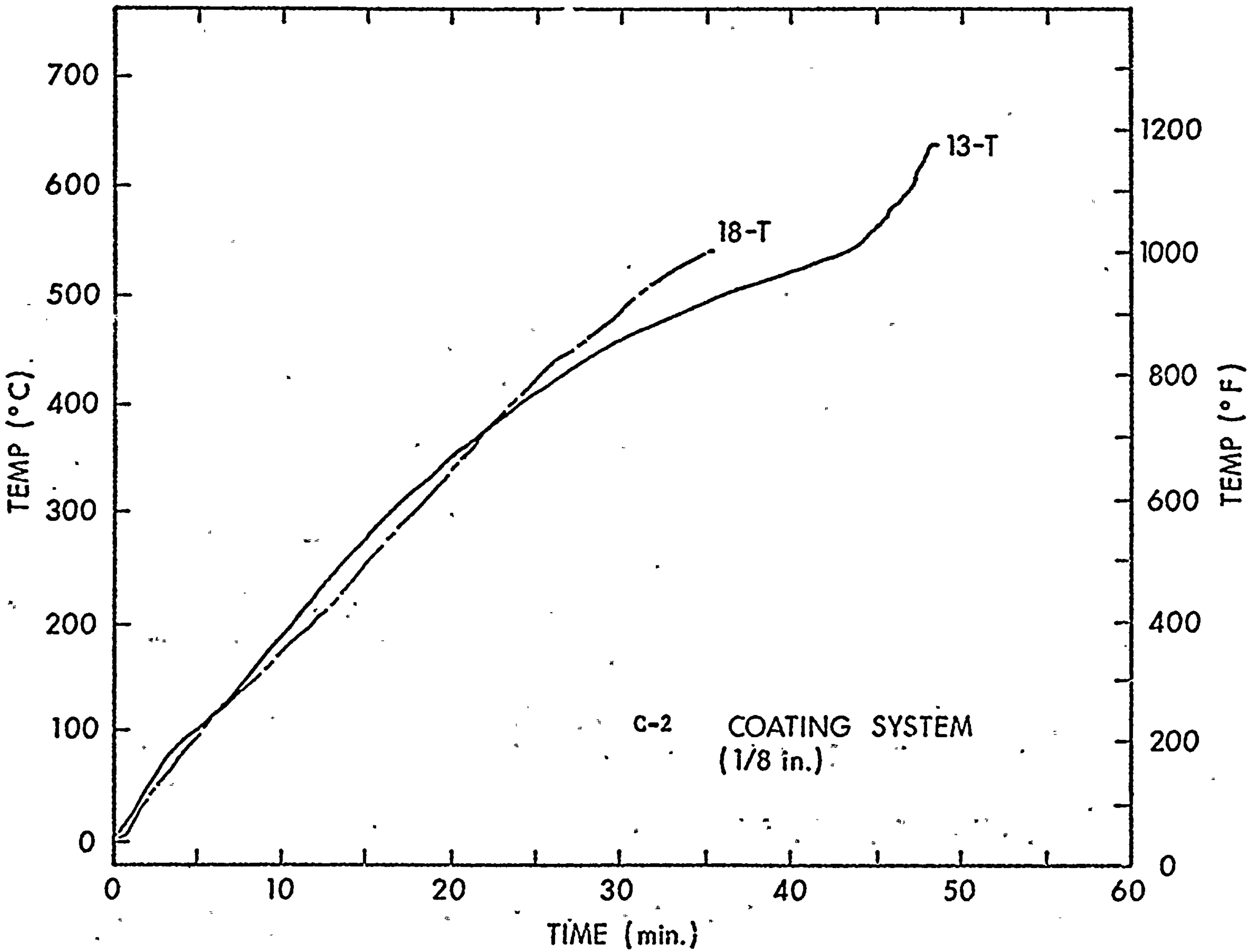


Figure 23. Plate Response for 0.32 cm C-2 Insulation

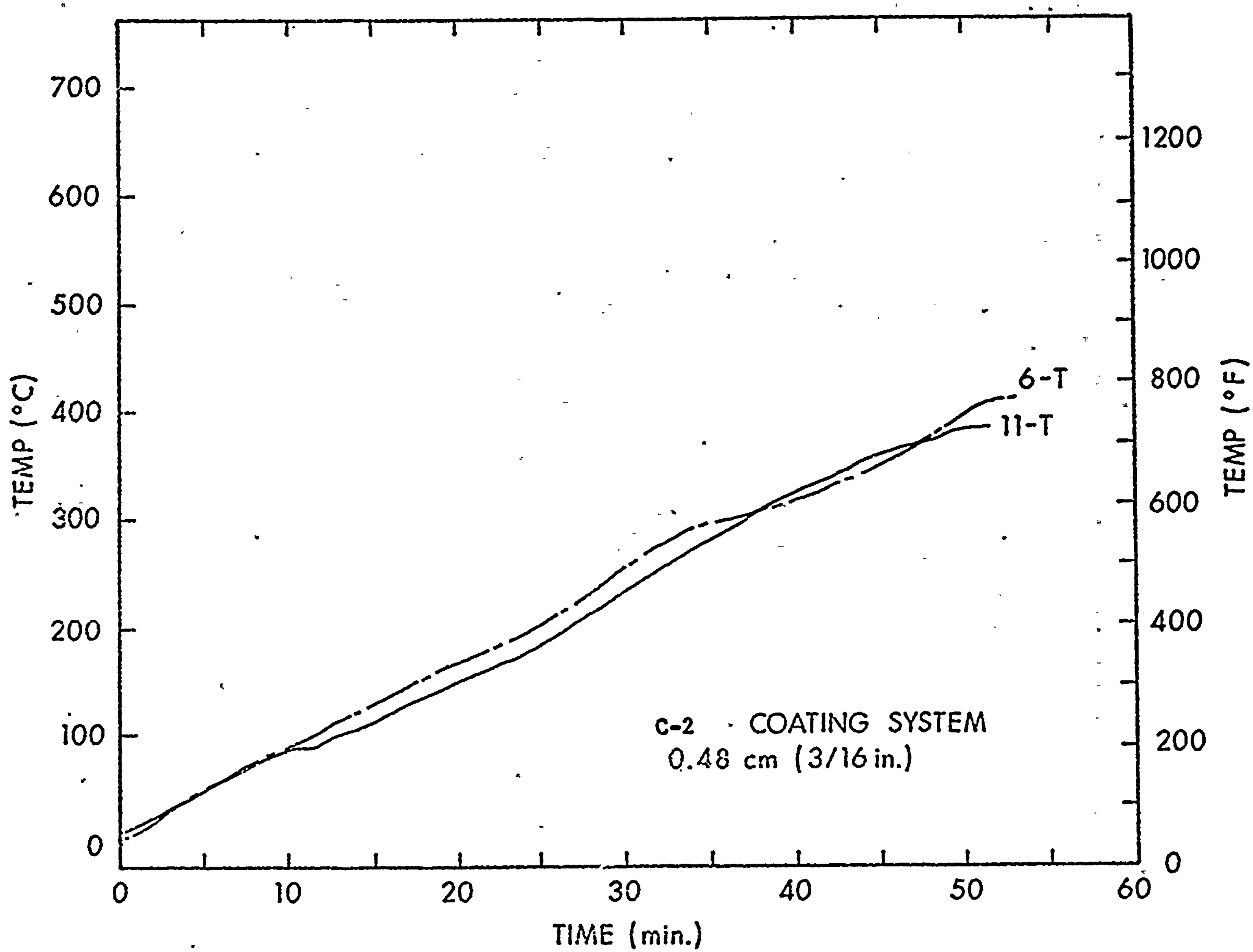


Figure 24. Plate Response for 0.48 cm C-2 Insulation

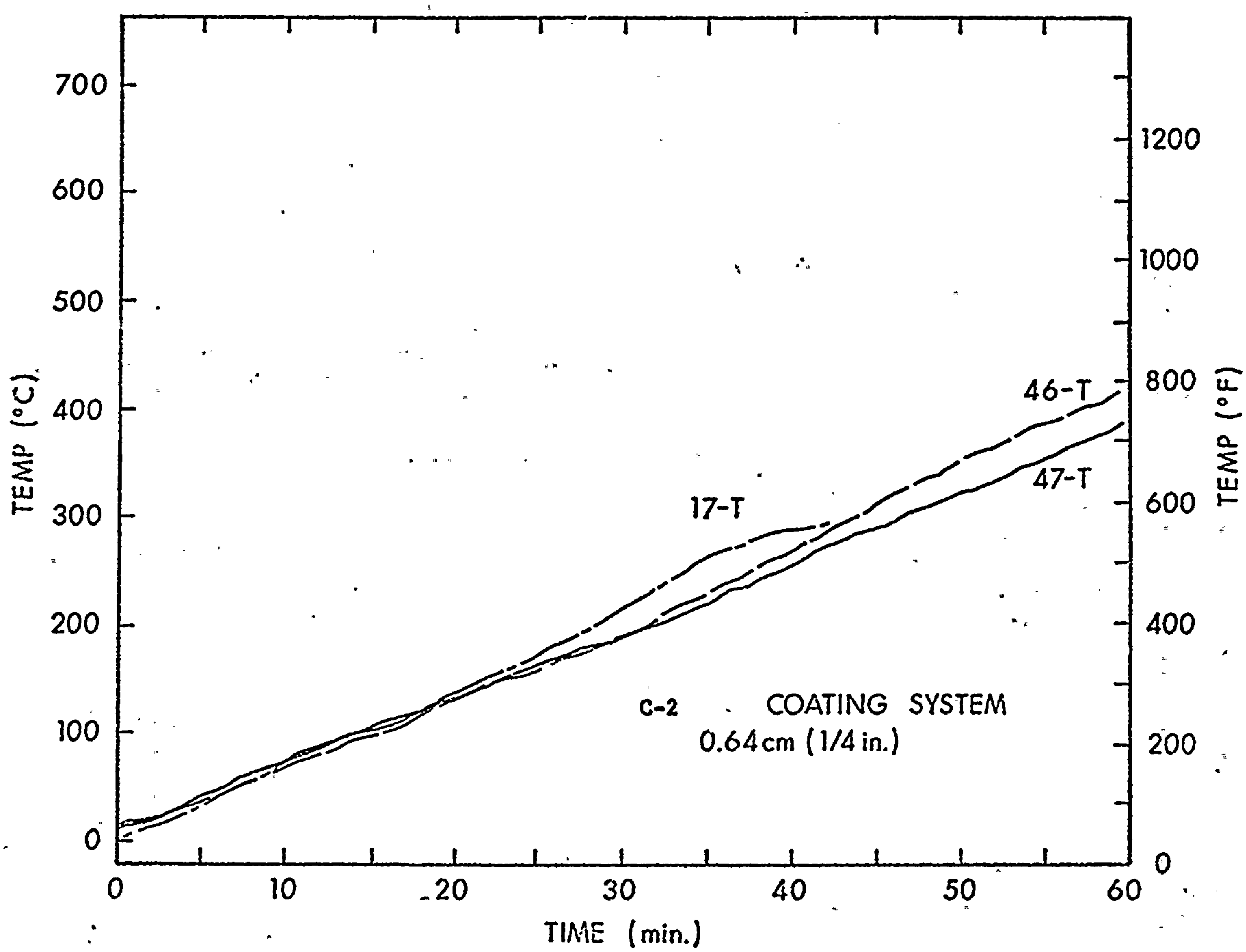


Figure 25. Plate Response for 0.64 cm (1/4 in.) C-2 Insulation

TABLE X. TIME FOR C-2 COATED PLATES TO REACH SPECIFIED TEMPERATURES

THICKNESS OF INSULATION	TEST NUMBER	TIME (MINUTES) 93°C (200°F)	204°C (400°F)	316°C (600°F)	427°C (800°F)
0.32 cm (1/8 in)	13	3.89	10.75	17.25	26.00
0.32 cm (1/8 in)	18	4.50	12.00	18.35	25.00
0.48 cm (3/16 in)	6	10.00	24.75	39.50	54.00
0.48 cm (3/16 in)	11	12.00	27.15	39.25	59.50
0.64 cm (1/4 in)	17	13.65	29.65	-	-
0.64 cm (1/4 in)	46	12.00	30.00	45.00	61.00
0.64 cm (1/4 in)	47	15.00	31.50	48.50	65.00

VIII. SUMMARY

A rigorous test program was performed by the Ballistic Research Laboratories, Aberdeen Proving Ground, under contract to FRA, to enhance the fire safety of hazardous materials in railroad tank cars, and to eliminate the probability of explosive ruptures with subsequent chain reactions when exposed to the anticipated range of fire environments.

Coatings, and commonly used insulators in "sandwich" construction, clad with 0.32 cm (1/8 inch) thick steel plates, were evaluated. Full scale fire engulfment tests on 125 kiloliters (33,000 gallon) capacity LPG loaded tank cars, and fire torching on 1.22 m by 1.22m by 1.59 cm (4 foot by 4 foot by 5/8 inch) thick steel plates protected with several thermal protective systems under evaluation, were tested. Installation and quality control procedures for the more promising systems were accumulated, documented and will be reported at a later date.

Of the various systems tested, **C-2** Subliming Coating System provided the most effective protection per unit thickness of insulation, followed by **C-1** Coating, and the insulators in "sandwich" construction such as cork, **S-2, S-1, S-4,** fiberglass and polyurethane foam (see Figures 27 and 28).

The performance data obtained from the torching tests were analytically correlated with results obtained from the full scale engulfment tests on fully loaded 125 kiloliters (33,000 gallons) propane tank cars. The results of these tests indicate that the steel shell backed by the vapor space of an unprotected tank car reaches 427°C (800°F) in approximately 15 minutes, followed by an explosive failure at 24.5 minutes. The unprotected steel plates, when exposed to the significantly more intense torching fire, will reach 427°C (800°C) in approximately 3.73 minutes.

Referring to Figure 29, under full engulfment fire exposure, the **C-2** Coating is expected to offer one hour protection to the steel shell to the 427°C (800°F) limit in a thickness of 0.32 cm (1/8 inch), and 2 hours and 30 minutes in a thickness of 0.64 cm (1/4 inch). Using the same criteria, **C-1** is expected to offer 50 minutes of protection in a thickness of 0.32 cm (1/8 inch), and 1 hour and 30 minutes in a thickness of 0.64 cm (1/4 inch). Under torching environments, **C-2** will maintain the tank car steel shell below a temperature of 427°C (800°F) for a period of 1 hour and 5 minutes, while the **C-1** will accomplish the same for a period of 37 minutes.

All passive insulators are expected to be used in "sandwich" construction employing an exterior steel shield approximately 0.32 cm (1/8 inch) thick. Urethane foam in a 5.1 cm (2 inch) and 10.2 cm (4 inch) thickness will provide protection under torching environment for a period of approximately 17 minutes.

Fiberglass in a 10.2 cm (4 inch) thickness will provide protection of up to 15.5 minutes. Cork in a thickness of 2.54 cm (1 inch) will provide protection for a period of 27.5 minutes, and in a 10.2 cm (4 inch) thickness of 43 minutes. S-1 in a thickness of 1.3 cm (1/2 inch) will provide protection for a period of 22 minutes and in a thickness of 5.1 cm (2 inches) for a period of 41 minutes.

S-2 in a thickness of 1.25 inches will provide thermal protection for a period of 31 minutes. S-3 in a thickness of 2.54 cm (1 inch) will provide protection for a period of 27.5 minutes. Cerefelt in a thickness of 2.45 cm (1 inch) will provide protection for a period of up to 34 minutes.

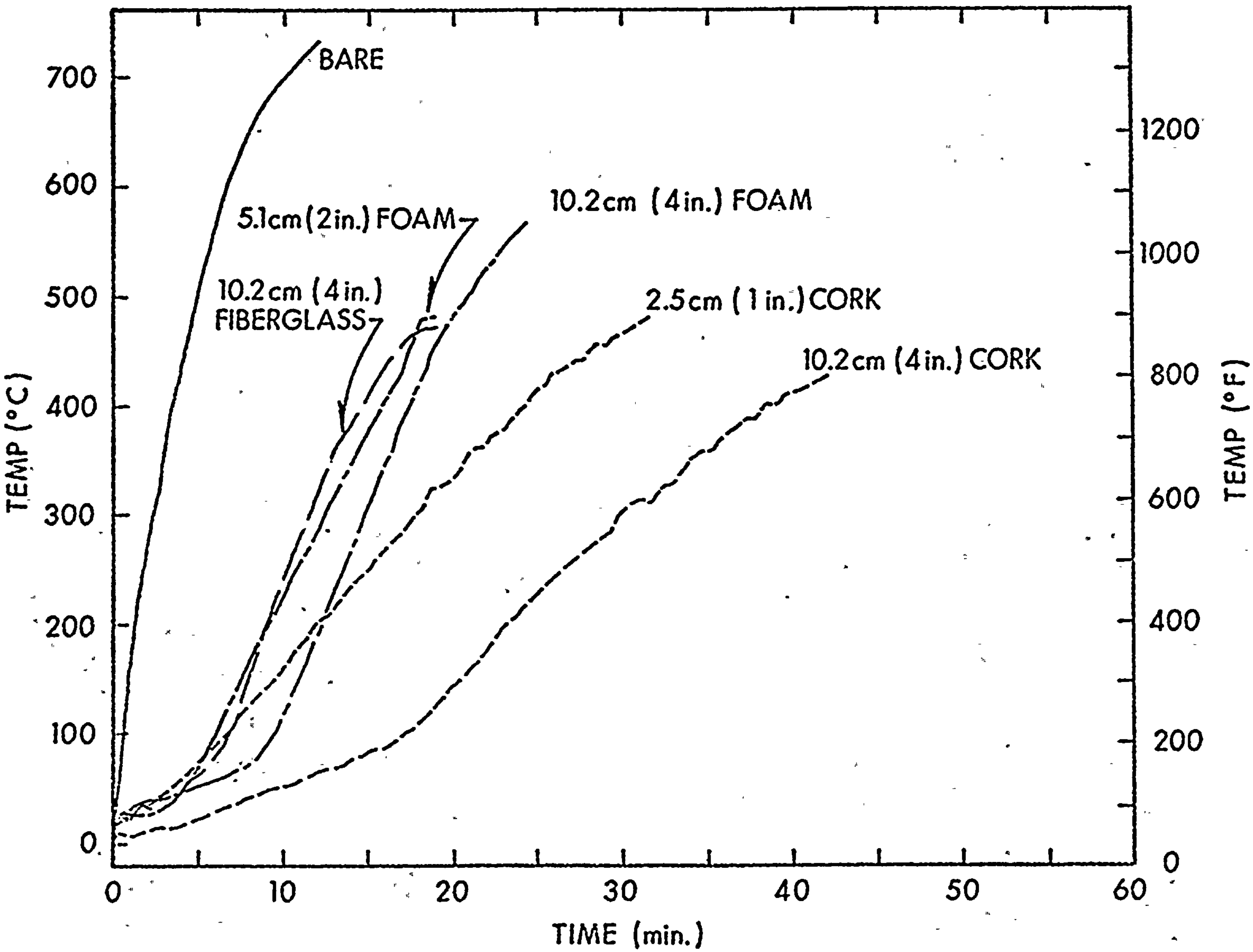


Figure 26. Comparison of Insulators, Sandwich Insulating System

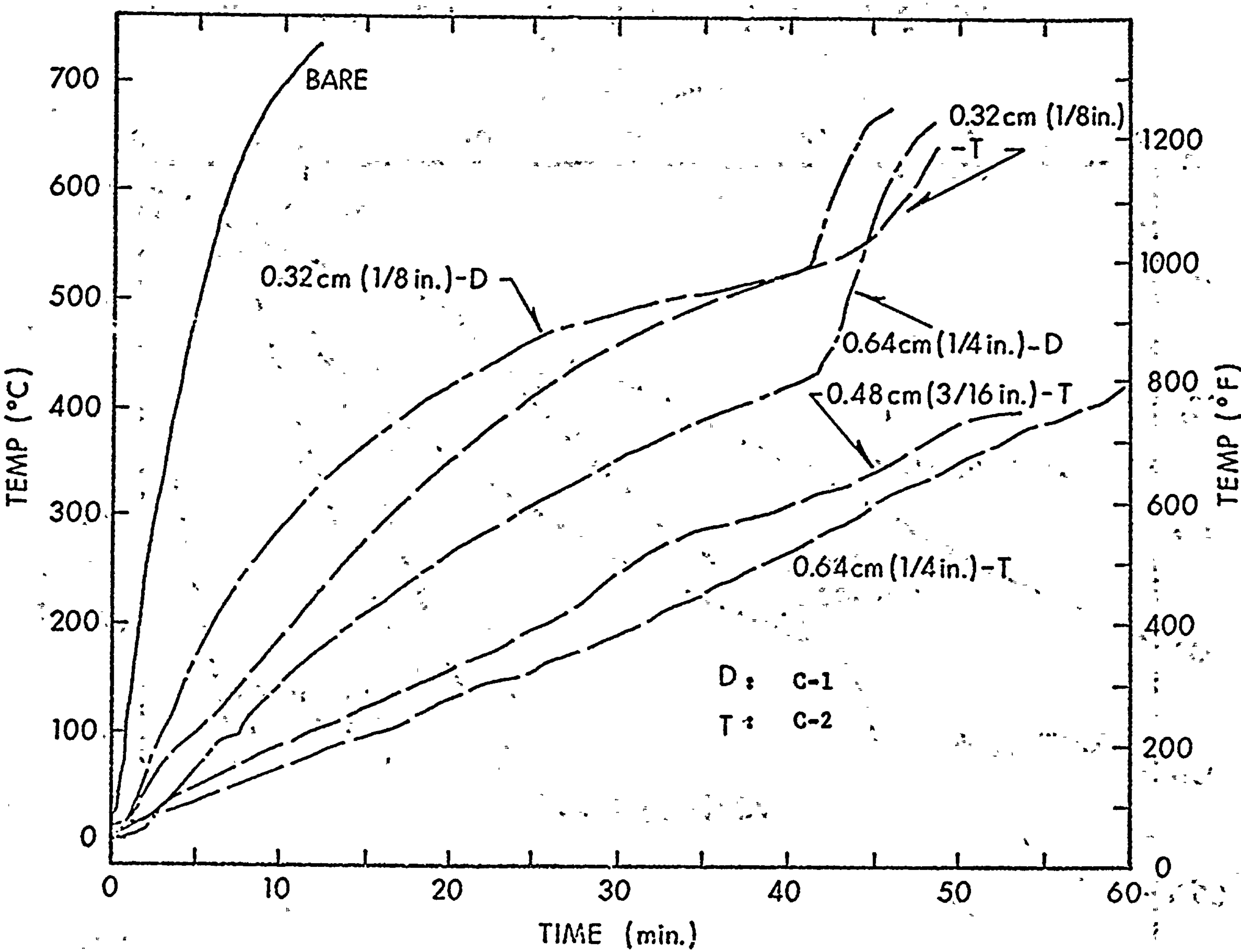


Figure 27. Comparison of Insulators, C-1 and C-2

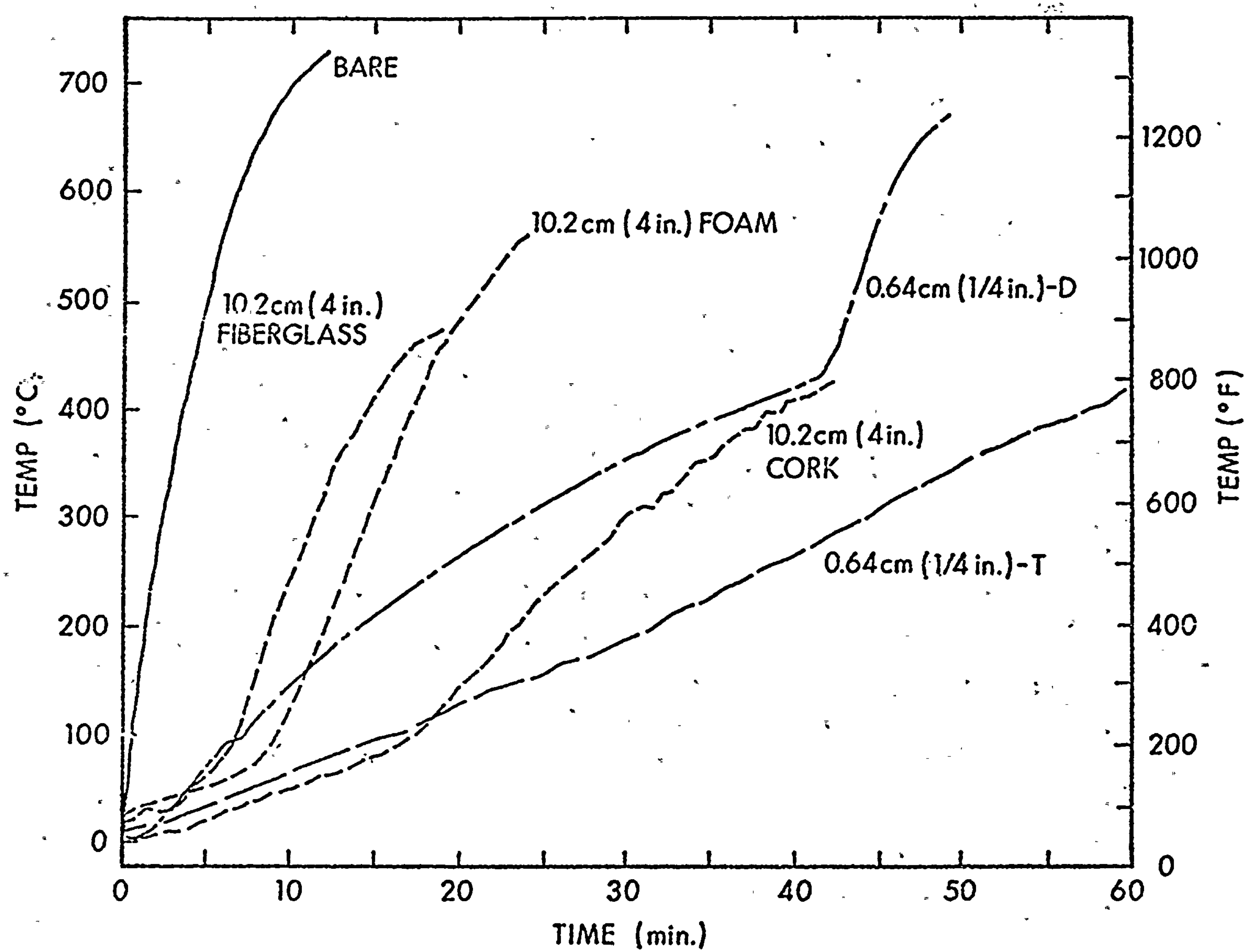


Figure 28. Comparison of Insulators, Selected Systems

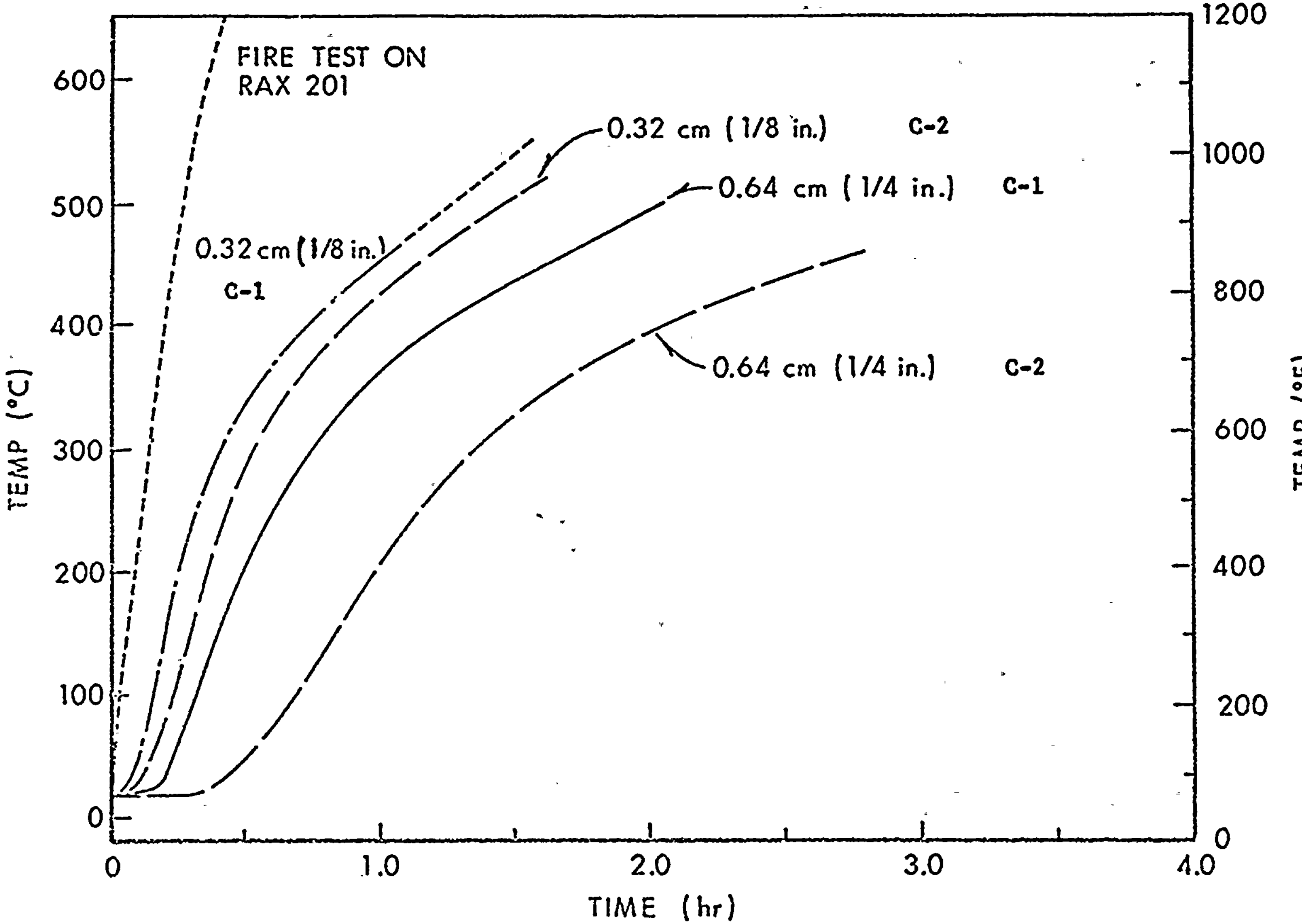


Figure 29. Predicted Shell Temperature vs Time for a Tank Car in a Pool Fire

BALLISTIC RESEARCH LABORATORIES

INTERIM MEMORANDUM REPORT NO. 459

DECEMBER 1975

ADDENDUM NO. 1

COMPARISON OF VARIOUS THERMAL SYSTEMS FOR THE PROTECTION OF RAIL TANK CARS TESTED AT THE FRA/BRL TORCHING FACILITY

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Funded Under Federal Railroad Administration
DCN AR 30026/Rez 731231

ABERDEEN PROVING GROUND, MARYLAND

B A L L I S T I C   R E S E A R C H   L A B O R A T O R I E S

INTERIM MEMORANDUM REPORT NO. 459

CAnderson/srr
Aberdeen Proving Ground, Md.
December 1975

COMPARISON OF VARIOUS THERMAL SYSTEMS FOR THE PROTECTION OF RAIL TANK CARS TESTED AT THE FRA/BRL TORCHING FACILITY

ABSTRACT - REVISED

One proposed method for thermally protecting high pressure rail tank cars from a fire environment is through the use of an insulating coating. This report investigates the thermal response of steel plates when insulated with one of eleven different coating systems; nine of these thermal systems are used in conjunction with a steel shield. All plates were exposed to an LPG torch using the BRL/DOT torch simulator at the DOT Transportation Test Center.

LIST OF ILLUSTRATIONS - REVISED

(Continued)

TABLE OF CONTENTS - REVISED

IX. C-3 COATING

C-3 is a two part, catalyzed, epoxy, intumescing coating wire mesh reinforced, designed for spray application to non-insulated steel tank cars to provide protection against external fires.

The C-3 System consists of a corrosion inhibiting primer which gives adhesion to the substrate and serves as a base coat; C-3 Coating which provides the heat shielding properties; and a white decorative topcoat which protects the C-3 Coating against environmental conditions. The thermal mechanism of intumescence and ablation is employed to provide the heat shielding properties to the system.

Since the C-3 Coating is a two component, epoxy based system, it is applied by the use of a multi-component mastic type spray equipment. The degree of thermal protection from fire is a function of coating thickness.

Three tests were performed on the C-3 System. The insulated wire mesh was mechanically attached to the plates. All plates were subsequently coated with the primer, and with a thickness of 0.32 cm (1/8"), 0.48 cm (3/16") and 0.64 cm (1/4") of the C-3 intumescent coating, respectively. All test plates were coated.

Table XI lists selected facility operational data. Figures 30, 31 and 32 depict the thermal response of the C-3 coated plates subjected to the standarized LPG torching environment.

The 0.32 cm (1/8") of C-3 coating retards the initial heat flux to the steel plate by a factor of 5, compared to the uninsulated plate. The 0.48 cm (3/16") of C-3 coating retards the initial heat flux to the steel plate by a factor of 10, compared to the uninsulated plate. The 0.64 cm (1/4") of C-3 coating retards the initial heat flux to the steel plate by a factor of 12.4, compared to the uninsulated plate.

Increasing the thickness of the C-3 coating system initially applied to the plate significantly retards the quantity of heat to the steel plate. For instance, doubling the coating thickness from 0.32 cm (1/8") to 0.64 cm (1/4") retarded the attainment of the plate temperature of 427°C (800°F) from 20 minutes to 49 minutes.

TABLE XI. TORCH TESTS ON PLATES INSULATED WITH C-3 COATING

Supply Tank Pressure	1.45×10^6 Pa (210 PSIA)	1.59×10^6 Pa (230 PSIA)	1.52×10^6 Pa (220 PSIA)
Supply Tank Temperature	36.4°C (97.5°F)	42.0°C (107.5°F)	37.5°C (99.5°F)
Duration of Torching Test	20.00 Minutes	40.00 Minutes	49.00 Minutes
Orifice Pressure	1.15×10^6 Pa (167 PSIA)	1.19×10^6 Pa (172 PSIA)	1.22×10^6 Pa (177 PSIA)

TABLE XII. TIME FOR C-3 COATED PLATES TO REACH SPECIFIED TEMPERATURES

THICKNESS OF INSULATION	TIME (MINUTES)			
	93°C (200°F)	204°C (400°F)	316°C (600°F)	427°C (800°F)
0.32 cm (1/8 in)	4.70	9.50	15.00	20.00
0.48 cm (3/16 in)	9.50	19.50	29.50	40.00
0.64 cm (1/4 in)	11.00	23.00	36.00	49.00

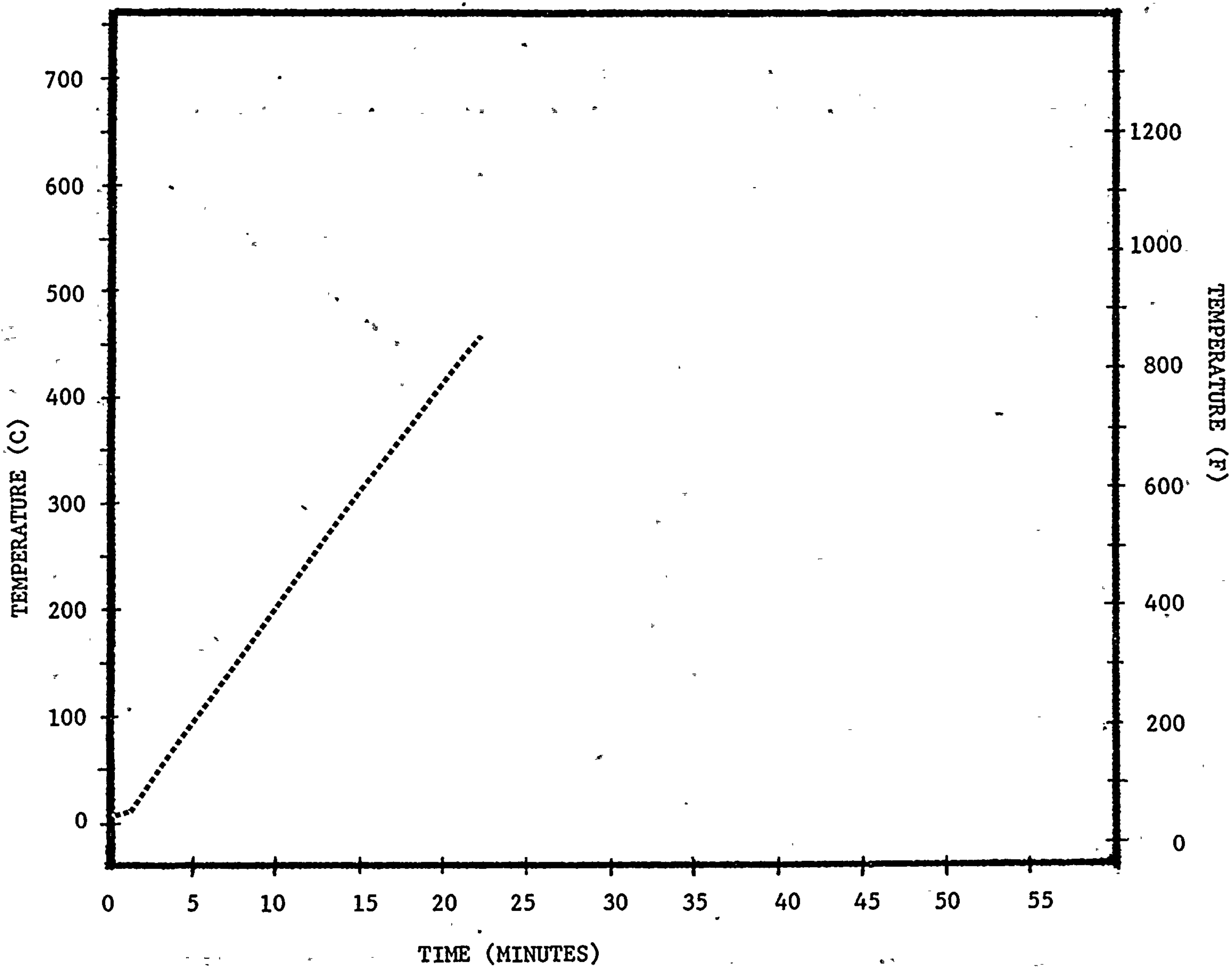

FIGURE 30. PLATE RESPONSE FOR 0.32 cm (1/8 in) C-3 INSULATION

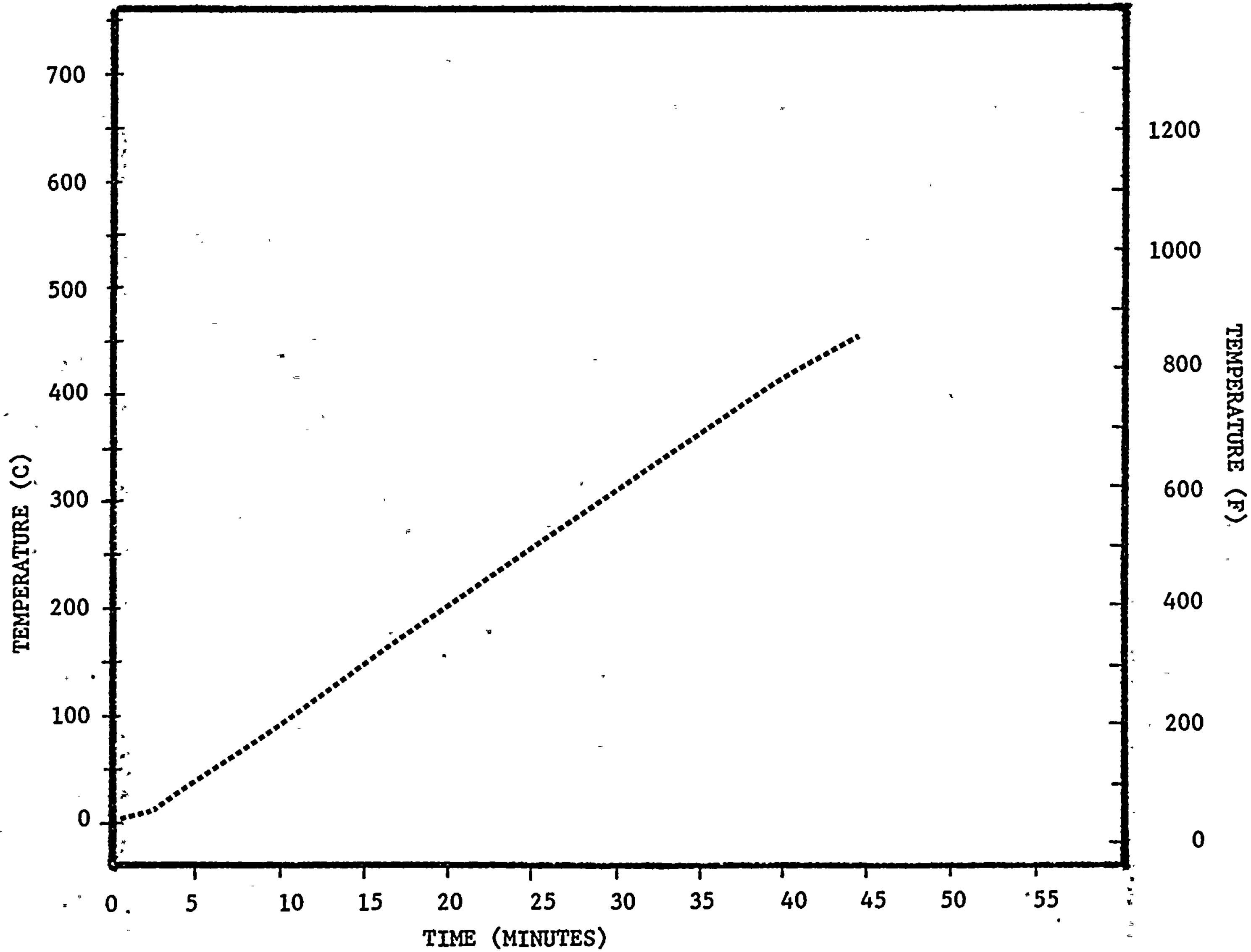

FIGURE 31. PLATE RESPONSE FOR 0.48 cm (3/16 in) C-3 INSULATION

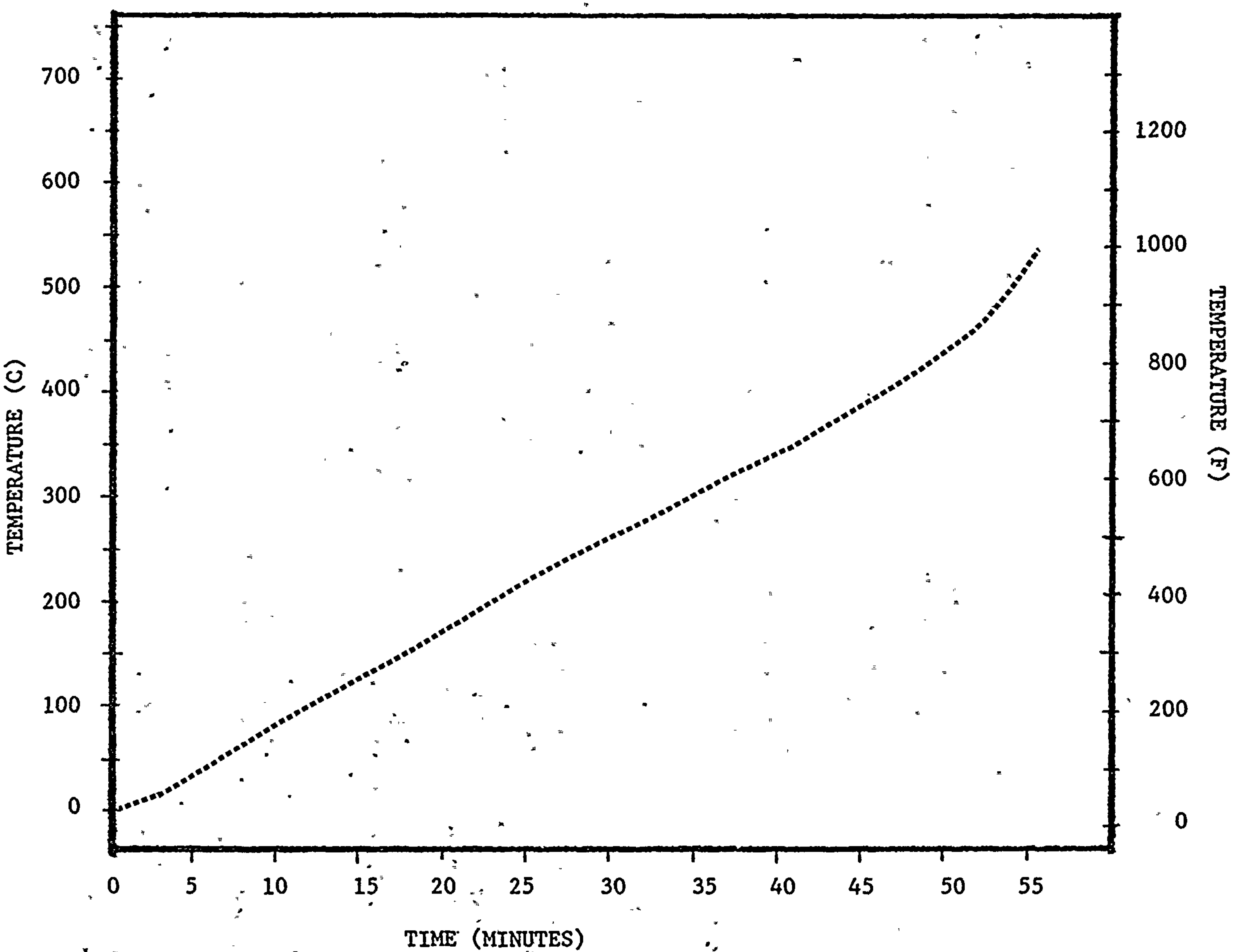

FIGURE 32. PLATE RESPONSE FOR 0.64 cm (1/4 in) C-3 INSULATION

X. SUMMARY - REVISED

A rigorous test program was performed by the Ballistic Research Laboratories, Aberdeen Proving Ground, under contract to FRA, to enhance the fire safety of hazardous materials in railroad tank cars, and to eliminate the probability of explosive ruptures with subsequent chain reactions when exposed to the anticipated range of fire environments.

Coatings, and commonly used insulators in "sandwich" construction, clad with 0.32 cm (1/8 inch) thick steel plates were evaluated. Full scale fire engulfment tests on 125 kiloliters (33,000 gallon) capacity LPG loaded tank cars, and fire torching on 1.22 m by 1.22 m by 1.59 cm (4 foot by 4 foot by 5/8 inc) thick steel plates protected with several thermal protective systems under evaluation, were tested. Installation and quality control procedures for the more promising systems were accumulated, documented and will be reported at a later date.

Of the various systems tested, C-2 Subliming Coating System provided the most effective protection per unit thickness of insulation, followed by C-3 Coating, C-1 Coating, and the insulators in "sandwich" construction such as cork, S-2, S-1, S-4, fiberglass and polyurethane foam (see figures 27, 28, 33 and 34).

The performance data obtained from the torching tests were analytically correlated with results obtained from the full scale engulfment tests on fully loaded 125 kiloliters (33,000 gallon) propane tank cars. The results of these tests indicate that the steel shell backed by the vapor space of an unprotected tank car reaches 427°C (800°F) in approximately 15 minutes, followed by an explosive failure at 24.5 minutes. The unprotected steel plate, when exposed to the significantly more intense torching fire, will reach 427°C (800°F) in approximately 3.73 minutes.

Referring to Figure 35, under full engulfment fire exposure, the C-2 Coating is expected to offer one hour protection to the steel shell to the 427°C (800°F) limit in a thickness of 0.32 cm (1/8 inch), and 2 hours and 30 minutes in a thickness of 0.64 cm (1/4 inch). Using the same criteria, C-1 and C-3 coatings are expected to offer 50 minutes of protection in a thickness of 0.32 cm (1/8 inch), however, C-3 coating is expected to offer 1.8 hours of protection in a thickness of 0.64 cm (1/4 inch) while C-1 coating offers 1.5 hours protection in a thickness of 0.64 cm (1/4 inch).

Under torching environment, C-2 will maintain the tank car steel shell below a temperature of 427°C (800°F) for a period of 1 hour and 5 minutes, while the C-3 will accomplish the same for a period of 49 minutes, and C-1 coating for a period of 37 minutes. In a thickness of 0.48 cm (3/16 inch), the C-2 coating system offered protection to the same limiting temperature of 427°C (800°F) for an average period of 57 minutes, while C-3 coating accomplished the same for a period of 40 minutes. In a thickness of 0.32 cm (1/8 inch), C-2 coating offered protection for a period of 25 minutes, C-3 coating for a period of 20 minutes, and C-1 coating for a period of 19 minutes.

All passive insulators are expected to be used in "sandwich" construction employing an exterior steel shield approximately 0.32 cm (1/8 inch) thick. Urethane foam in a 5.1 cm (2 inch) and 10.2 cm (4 inch) thickness will provide protection under torching environment for a period of approximately 17 minutes.

Fiberglass in a 10.2 cm (4 inch) thickness will provide protection of up to 15.5 minutes. Cork in a thickness of 2.54 cm (1 inch) will provide protection for a period of 27.5 minutes, and in a 10.2 cm (4 inch) thickness of 43 minutes. S-1 in a thickness of 1.3 cm (1/2 inch) will provide protection for a period of 22 minutes and in a thickness of 5.1 cm (2 inches) for a period of 41 minutes.

S-2 in a thickness of 1.25 inches will provide thermal protection for a period of 31 minutes. S-2 in a thickness of 2.54 cm (1 inch) will provide protection for a period of 27.5 minutes. Cerefelt in a thickness of 2.45 cm (1 inch) will provide protection for a period of up to 34 minutes.

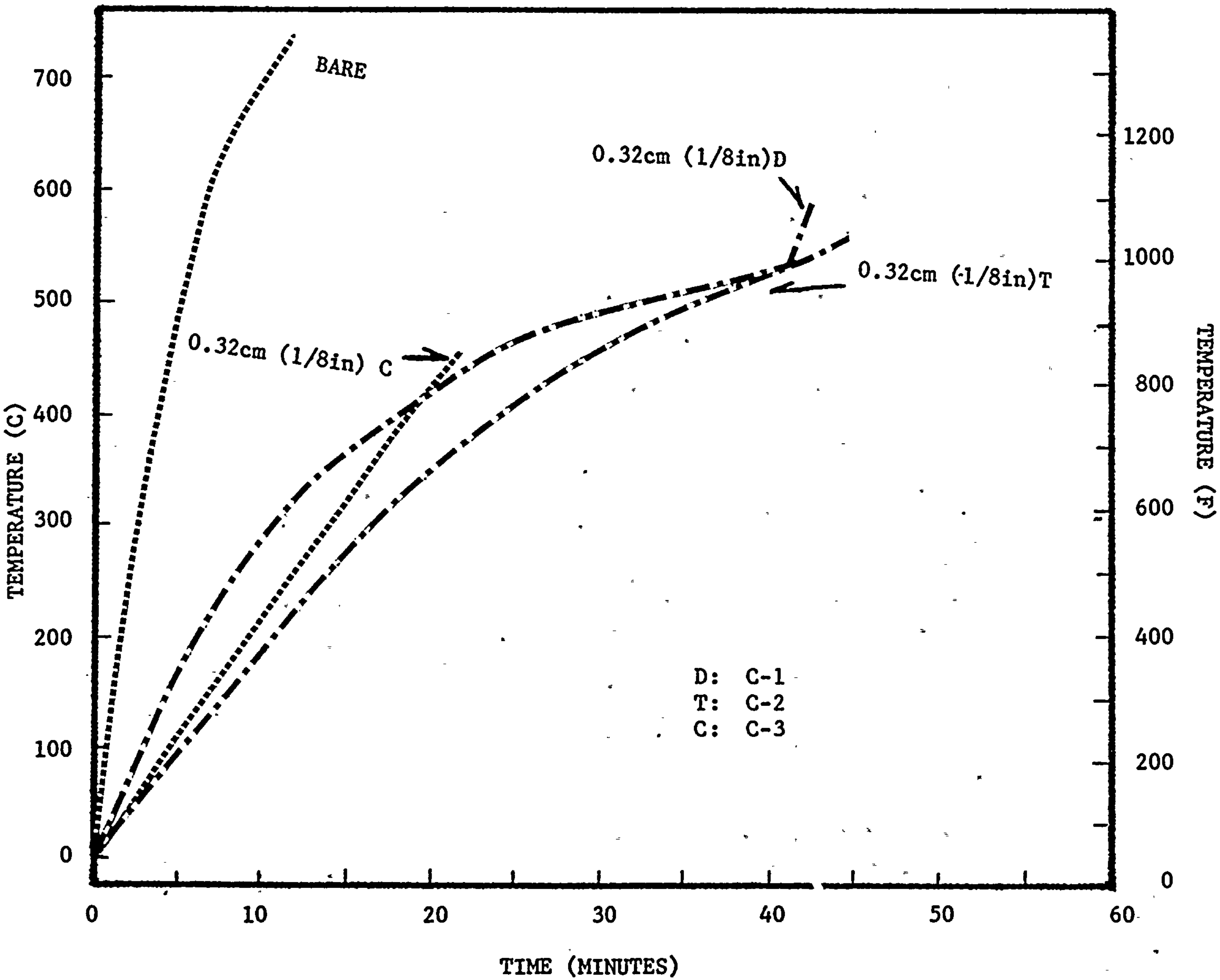

FIGURE 33. COMPARISON OF INSULATORS, C-1, C-2, AND C-3 (0.32cm THICKNESS)

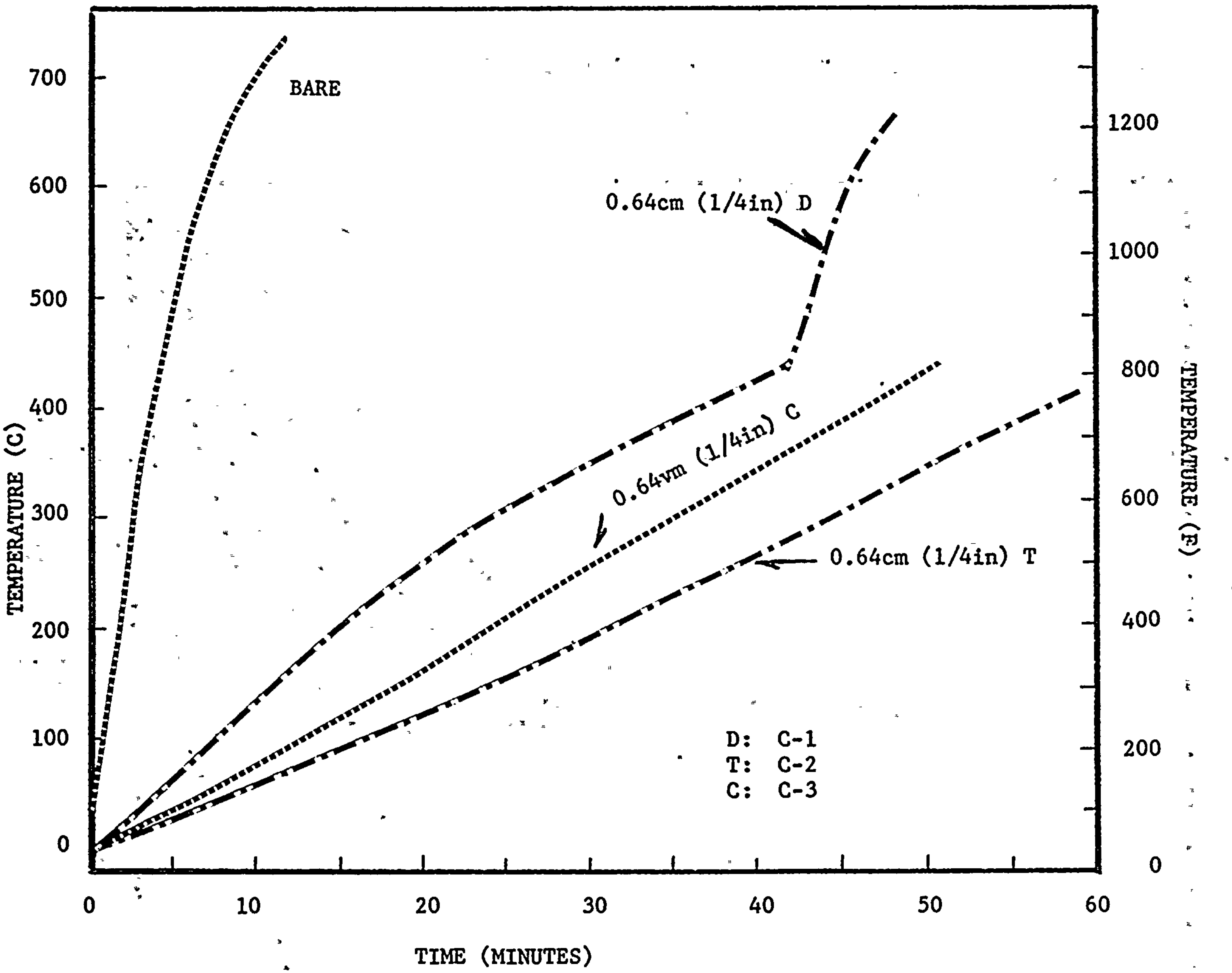

FIGURE 34. COMPARISON OF INSULATORS, C-1, C-2, AND C-3 (0.64 cm THICKNESS)

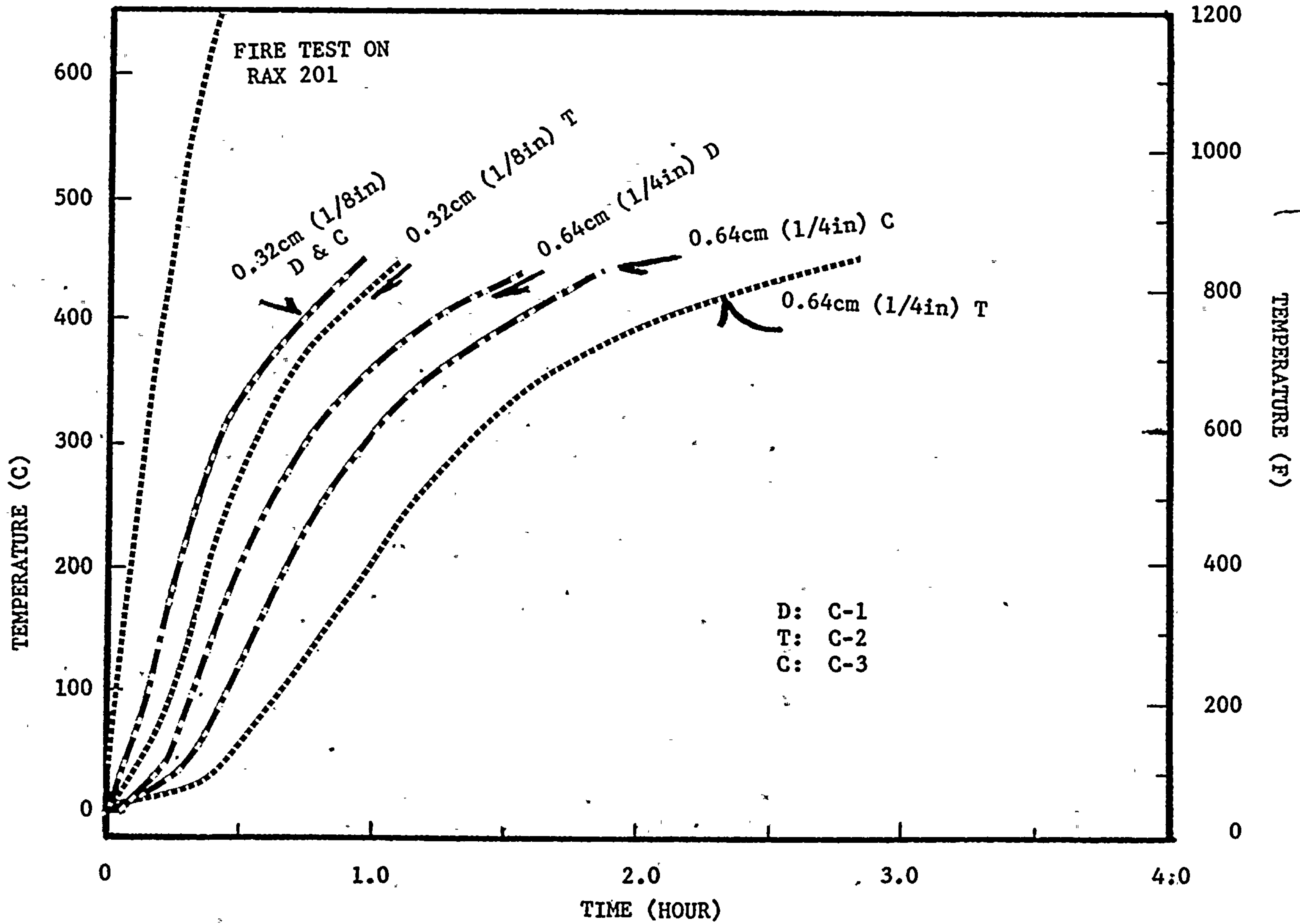

FIGURE 35. PREDICTED SHELL TEMPERATURE VS. TIME FOR A TANK CAR IN A POOL FIRE