NASA CONTRACTOR
REPORT

(NASA-CR-161532) PROJECT FIRES. VOLUME 4: PROTOTYPE PROTECTIVE ENSEMBLE QUALIFICATION TEST REPORT, PHASE 1B Final Report (Grumman Aerospace Corp.) 127 p HC A07/MF A01 CSCL 06Q G3/54

N80-32099

Unclas
28588

PROJECT FIRES, VOLUME 4: PROTOTYPE PROTECTIVE ENSEMBLE QUALIFICATION TEST REPORT, PHASE 1B

By Fred J. Abeles
Grumman Aerospace Corporation
Advanced Development Department
Bethpage, New York 11714

May 1980

Final Report

Prepared by

NASA - George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

PREFACE

The Firefighters' Integrated Response Equipment System (FIRES) program was conducted by the Advanced Development Department of the Grumman Aerospace Corporation, under a contract jointly sponsored by the National Aeronautics and Space Administration (NASA), George C. Marshall Space Flight Center, and the United States Fire Administration (USFA). The program consists of three phases. Phase 1A led to the preliminary design of a prototype system. Phase 1B, the subject of this report, consists of prototype development, fabrication, and laboratory testing. Phase 2 will proceed through field testing and evaluation of the prototypes, resulting in an economical, fully-acceptable ensemble and finalized specification.

Project FIRES is a systematic approach toward the development of improved protection for structural firefighters. The system protects against such hazards as heat, flame, smoke, toxic fumes, moisture, impact, penetration and electricity. It also affords improved firefighter performance through increased maneuverability, lighter burdens, and improved human engineering designs.

This report is presented in four volumes as follows:

- Volume 1 - Program Overview and Summary
- Volume 2 - Protective Ensemble Performance Standards (PEPS) "Goals for Firefighter Protection"
- Volume 3 - Protective Ensemble Design & Procurement Specification
- Volume 4 - Prototype Protective Ensemble Qualification Test Report

4

PROJECT FIRES

PROTOTYPE PROTECTIVE ENSEMBLE
QUALIFICATION TEST REPORT

CONTENTS

REFERENCED DOCUMENTS

Model Performance Criteria for Structural Firefighters Helmets, National Fire Protection Control Administration, Aug 1977

American National Standard - ANSI 289.3 - 1960 Safety Requirements for Industrial Head Protection

American National Standard - ANSI Z24.22 - "Measurement of the Rear Ear Attenuation of Ear Protectors; Method for."

Human Factors Study for Project FIRES (Phase I) - to be published, R. J. Del Vecchio, Grumman Aerospace Corp., 1978

REFERENCED DOCUMENTS (CONTD)

American National Standard - ANSI Z90.1 - 1971 "Specifications for Protective Headgear for Vehicular Users."

American National Standard - ANSI 287.1 - 1965, "Practice for Occupational and Educational Eye and Face Protection."

Federal Test Methods Standard 406.

Manual of Directions Hand-Tool Dexterity Test - 1965 Revision, George K. Bennett, The Psychological Corp., N.Y.

Coletta, G. C., Arons, I. J. Et al., "The Development of Criteria for Firefighters Gloves," A. D. Little, Inc. Feb. 1976

American National Standard - ANSI Z41-1967, "Standard for Men's Safety-Toe Footwear."

4

ILLUSTRATIONS

4

TABLES

ABSTRACT

Title: Project FIRES Phase 1B Final Report

Author: Fred J. Abeles

Text:
(Keywords) Firefighters' Protective Clothing, Turnout Gear, Helmets, Faceshields, Turnout Coats and Pants, Gloves, Boots, Garment Testing, Advanced-Design Garments, Prototype Protective Garment

(Body) In Phase 1A overall performance requirements and evaluation methods for firefighters protective equipment were established and published as the Protective Ensemble Performance Standards (PEPS).

Current firefighters protective equipment was tested and evaluated against the PEPS requirements, and the preliminary design of a prototype protective ensemble was performed.

In Phase 1B the design of the prototype protective ensemble was finalized. Prototype ensembles were fabricated and then subjected to a series of qualification tests which were based upon the PEPS requirements.

Engineering drawings and purchase specifications were prepared for the new protective ensemble.

PROJECT FIRES

INTRODUCTION

This document describes the qualification test program performed during Phase 1B of Project FIRES. All Prototype protective equipment developed during this portion of the program was evaluated against requirements derived from those specified in the Protective Ensemble Performance Standards (PEPS) Revision E also prepared during Phase 1B of Project FIRES. Test methods used in the evaluation were derived from those test methods specified in the same E Revision of the PEPS.

The test program was conducted in two phases:

- Individual Subsystem Testing - These tests included measurements of individual subsystem characteristics in areas relating to both physical testing, such as heat, flame, impact penetration and human factors testing, such as dexterity, grip and mobility.
- Complete Protective Ensemble Testing - These tests were performed on the complete integrated protective ensemble and included measurements related to both physical and human factors testing which can only be ascertained on the complete ensemble, such as water protection, metabolic expenditures and compatibility.

Requirements used for the qualification of prototype protective equipment in Phase 1B were based upon and in most cases are the same as those requirements specififed in the E Revision of the PEPS. However, where tests performed during Phase 1A and the first half of Phase 1B indicated that materials and equipment available for incorporation into the Prototype Protective Ensemble could not meet the requirements specified in the PEPS, or that meeting of a particular performance requirement would have an adverse effect upon another requirement of higher priority, the requirement was reduced to a value which could be attained. These revised requirements were also incorporated into the Specification Control Drawings (SCDs) and purchase specifications. In the test program summary (Table 1), all performance requirements which differ from the PEPS have been identified.

Not all of the requirements specified in this report were evaluated by testing during Phase 1B. The requirements that fall into this category include:

- those requirements requiring life cycle testing, such as acceptance, durability, reliability and maintainability which will be confirmed during Phase 2 field tests
- those requirements where reliable data was available from previous Phase 1A testing
- those requirements readily ascertained by inspection and/or vendor certification

The test methods used for qualification testing were those methods specified in the E Revision of the PEPS. Apparatus required to perform each qualification test in many cases is the same or similar to apparatus currently used for testing to an existing standard. A major portion of the physical testing of the individual subsystems was performed at manufacturer's facilities because in most cases they possess the equipment needed to perform tests to meet current standards. In those cases where they did not have the apparatus, a testing laboratory or Grumman was used to perform the testing. However regardless of where the testing was performed, a Grumman representative was always present.

Qualification testing of the complete protective ensemble was conducted at the following facilities:

- Water penetration and compatability testing of the ensemble took place at the Fire Academy operated by the New York City Fire Department
- Mobility testing of the ensemble took place at Grumman
- Heat testing of the ensemble took place at Stanford Research Institute, Camp Parks, CA

A summary of the test program is presented in Table 1. Included are brief descriptions of the requirement, for the PEPS as well as the qualification test, the test method, the test apparatus and the test results. A discussion of the testing follows, after which there are more detailed descriptions of the qualification test methods on an item-by-item basis.

TABLE 1 PROJECT FIRES QUALIFICATION TEST PROGRAM SUMMARY (Page 1 of 17)

HEAD/EAR PROTECTION					
TEST	REQUIREMENTS		TEST METHOD	TEST APPARATUS	RESULTS
	PEPS	QUALIFICATION			
IMPACT, APEX	BRICK FALLING 4 STORIES WITH IMPACT FORCE OF 152 ft lb/150 gs TRANSMITTED	(PEPS)	SAME METHOD AS ANSI Z90.1 EXCEPT HEAD FORM/HELMET IS DROPPED FROM APPROPRIATE HEIGHT THAT GIVES 152 ft-lb	ANSI Z90.1 SLED	PASS
IMPACT, SIDE	SAME AS ABOVE EXCEPT 152 ft lb/400 gs				
	• ABOVE TESTS TO BE RUN AT ROOM TEMP	101 ft lb/400 g	SAME AS ABOVE EXCEPT 101 ft-lb	ANSI Z90.1 SLED	PASS
	• ABOVE TESTS TO BE RUN AFTER REACHING EQUILIBRIUM AT -23°C	SAME AS ABOVE	SAME AS ABOVE WITH THERMAL PRECONDITIONING	SAME AS ABOVE PLUS A CONDITIONING CHAMBER	PASS
	• ABOVE TESTS AFTER CLASS 2 & 3 HEAT	SAME AS ABOVE	SAME AS ABOVE WITH THERMAL PRECONDITIONING	SAME AS ABOVE PLUS A CONDITIONING CHAMBER	PASS
PENETRATION	CORNER OF A BRICK FALLING 4 STORIES WITH IMPACT FORCE OF 152 ft-lb	101 ft-lb	SAME METHOD AS ANSI Z90.1 EXCEPT STRIKER IS DROPPED FROM APPROPRIATE HEIGHT THAT GIVES 101 ft-lb	ANSI Z90 PUNCTURE TEST APPARATUS	PASS
	NO THROUGH PENETRATION				
	THE ABOVE TESTS ARE TO BE REPEATED FOR THE SAME 3 CONDITIONS AS FOR IMPACT TEST	SAME AS ABOVE	SAME AS ABOVE WITH THERMAL PRE-CONDITIONING AS REQUIRED	SAME AS ABOVE PLUS CONDITIONING CHAMBER	PASS

TABLE 1 PROJECT FIRES QUALIFICATION TEST PROGRAM SUMMARY (Page 2 of 17)

HEAD/EAR PROTECTION (CONTD)					
TEST	REQUIREMENTS		TEST METHOD	TEST APPARATUS	RESULTS
	PEPS	QUALIFICATION			
CUT	GLASS FALLING 4 STORIES WITH AN IMPACT FORCE OF 39 ft lb, PROTECTOR NOT CUT THROUGH	(PEPS)	SAME METHOD AS ANSI Z41.1	ANSI Z41.1 IMPACT TESTER ADAPTED WITH SPECIAL CUTTING EDGE	CUT TESTS WERE NOT PERFORMED BECAUSE PENETRATION REQUIREMENTS ARE MORE SEVERE
	THE ABOVE TESTS ARE TO BE REPEATED FOR THE SAME 3 CONDITIONS AS FOR IMPACT TEST	(PEPS)	SAME AS ABOVE WITH THERMAL PRECONDITIONING AS REQUIRED	SAME AS ABOVE PLUS CONDITIONING CHAMBERS	
FLAME	NOT BURN, CHAR, IGNITE, AFTER 5 SEC EXPOSURE TO A 1200°F FLAME	(PEPS)	BUNSEN BURNER FLAME DIRECTED AT HELMET	BUNSEN BURNER	PASS
HEAT	UNDERGO COMBINATION OF RADIANT & CONVECTIVE HEAT CONDITIONS (CLASS 1, 2 & 3 IN PEPS)	(PEPS)	HELMET INSTRUMENTED & PLACED IN CONDITIONING CHAMBER	SPECIALLY INSTRUMENTED OVEN	PASS
ELECTRICITY	LIMIT CURRENT FLOW TO <3 ma WITH A 2200 VAC POTENTIAL	(PEPS)	ANSI Z89.1	ANSI Z89.1	PASS
	THE ABOVE TESTS ARE TO BE REPEATED FOR THE SAME CONDITIONS AS FOR THE IMPACT TEST	(PEPS)			
HEARING	NOT TO ATTENUATE BY MORE THAN 10%	(PEPS)	ANSI Z24.22	ANSI Z24.22	PASS

TABLE 1 PROJECT FIRES QUALIFICATION TEST PROGRAM SUMMARY (Page 3 of 17)

HEAD/EAR PROTECTION (CONTD)					
TEST	REQUIREMENTS		TEST METHOD	TEST APPARATUS	RESULTS
	PEPS	QUALIFICATION			
HEAT INSULATION	NOT TO INCREASE ENERGY EXPENDITURES BY MORE THAN 1%	(PEPS)	GRUMMAN STEP TEST	STEP TEST EQUIPMENT PLUS ENVIRONMENTAL CHAMBER	PASS
WATER PENETRATION	DEFLECT WATER FROM AN OVERHEAD SPRINKLER	(PEPS)	HELMET WORN BY SUBJECT	MULTIPLE SPRINKLER HEADS	PASS
WEIGHT	SYSTEM SHALL WEIGH LESS THAN 30 oz	33 OZ MAX	WEIGHING	BALANCE	PASS
FIT	FULL RANGE OF SIZES	(PEPS)	VISUAL EXAMINATION ANSI Z89.3	TAPE MEASURE ANSI Z89.3	PASS
RETENTION	NO INJURY WHEN BRIM IS IMPACTED WITH 152 ft-lb	(PEPS)	SAME METHOD AS ANSI Z90.1 BUT IMPACT IS ON THE BRIM	ANSI Z90.1 SLED	NOT TESTED TEST APPARATUS NOT AVAILABLE
MAINTAINABILITY	CAPABLE OF BEING PERFORMED IN FIRE HOUSE	(PEPS)	FIELD EVALUATION	FIELD	TO BE EVALUATED IN FIELD TEST
RELIABILITY	(PEPS)	(PEPS)	FIELD EVALUATION		TO BE EVALUATED IN FIELD TEST
DONNING/ DOFFING	BE ABLE TO DON IN 5 sec	(PEPS)	TIMING OF SUBJECTS		PASS
RECOGNIZABILITY	VISUAL RECOGNITION BY SUBJECT AT 200 ft	(PEPS)	VISUAL RECOGNITION IN SIMULATED CONDITIONS		PASS
DRYABILITY	DRY IN AN OVEN AT 200° AFTER 1 hr	(PEPS)	WET & PLACE IN OVEN FOR 1 HR	OVEN & BALANCE	PASS
ACCEPTANCE	ACCEPTABLE TO FIRE SERVICE	(PEPS)	FIELD EVALUATION		TO BE EVALUATED IN FIELD TEST
COMPATABILITY	(PEPS)	(PEPS)	OBSERVATION	SYSTEM TEST	PASS

TABLE 1 PROJECT FIRES QUALIFICATION TEST PROGRAM SUMMARY (Page 4 of 17)

FACE/EYE PROTECTION					
TEST	REQUIREMENTS		TEST METHOD	TEST APPARATUS	RESULTS
	PEPS	QUALIFICATION			
IMPACT	BRICK FALLING 4 STORIES WITH IMPACT ENERGY OF 152 ft-lb • NO SHATTERING OR SPALLING THE ABOVE TEST IS TO BE RUN AT	REDUCED ENERGY OF 101 ft-lb	SAME METHOD AS ANSI Z90.1 EYE SHIELD IS MOUNTED ON HELMET	ANSI Z90.1 SLED	DOES NOT PASS. DEVELOPMENT WORK CURRENTLY UNDERWAY TO IMPROVE PRODUCT
	• ROOM TEMP	SAME AS ABOVE	SAME AS ABOVE		
	• AFTER REACHING EQUILIBRIUM AT -23 F	SAME AS ABOVE	SAME AS ABOVE WITH THERMAL PRECONDITIONING	SAME AS ABOVE PLUS A CONDITIONING CHAMBER	
	• AFTER CLASS 2 & 3 HEAT	CONDITIONING FOR CLASS 3 HEAT IS REDUCED TO 1 MIN AT 485 F	SAME AS ABOVE WITH THERMAL PRECONDITIONING	SAME AS ABOVE PLUS CONDITIONING CHAMBER	
PENETRATION	4 PENNY NAIL IMPACTING WITH AN ENERGY OF 10 ft-lb	(PEPS)	ANSI Z90.1 EXCEPT STRIKER ADAPTED FOR 4 PENNY NAIL & HEIGHT ADJUSTED AS NECESSARY	ANSI Z90.1 PUNCTURE TEST, MODIFIED	SAME AS IMPACT
CUT	SURFACE NOT CUT OR SCRATCHED BY A METAL BLIND	(PEPS)	DRAW METAL BLIND ACROSS THE PROTECTOR	METAL BLIND	PASS
SCRATCH	NOT SCRATCHED AFTER RUBBED WITH SAND	(PEPS)	RUB OIL SAND & OIL MIXTURE OVER PROTECTOR	50/50 OIL & SAND MIXTURE	PASS
FLAME	NOT BURN, CHAR, IGNITE, AFTER 5 SEC EXPOSURE TO A 1200 F FLAME	(PEPS)	BUNSEN BURNER FLAME DIRECTED AT PROTECTOR	BUNSEN BURNER	PASS

TABLE 1 PROJECT FIRES QUALIFICATION TEST PROGRAM SUMMARY (Page 5 of 17)

FACE/EYE PROTECTION (CONTD)					
TEST	REQUIREMENTS		TEST METHOD	TEST APPARATUS	RESULTS
	PEPS	QUALIFICATION			
HEAT	UNDERGO A COMBINATION OF RADIANT & CONVECTIVE HEAT CONDITIONS, (CLASS 1, 2, & 3 IN PEPS); NO DISTORTION) NO FACIAL CONTACT POINT TEMPERATURE >113°F	SAME AS PEPS	SUBSYSTEM PLACED IN CONDITIONING CHAMBER	INSTRUMENTED OVEN	NOT TESTED IMPROVED; PRODUCT CURRENTLY UNDER DEVELOPMENT
ELECTRICITY	LIMIT CURRENT FLOW TO < 3 ma WITH A 2200 VAC POTENTIAL	(PEPS)	ANSI Z89.1	ANSI Z89.1	VERIFIED
COVERAGE	SHALL COVER EYES, NOSE, CHEEKS & UPPER LIP	(PEPS)	INSPECTION	VOLUNTEER SUBJECTS	PASS
VISIBILITY	MEET OPTICAL PERFORMANCE OF ANSI Z87.1	(PEPS)	ANSI Z87.1	ANSI Z87.1	NOT TESTED; IMPROVED PRODUCT CURRENTLY UNDER DEVELOPMENT
FOG PREVENTION	PREVENT THE FORMATION OF FOG OR CONDENSATION	(PEPS)	TEST SUBJECT EXERCISING AT ATMOSPHERIC CHAMBER	ENVIRONMENTAL CHAMBER	
WATER PENETRATION	DEFLECT WATER FROM AN OVERHEAD SPRINKLER	(PEPS)	FACE/EYE SHIELD PLUS HELMET WORN BY SUBJECT & SUBJECTED TO SHOWER	MULTIPLE SPRINKLER HEADS	PASS
WEIGHT	SHALL WEIGHT LESS THAN 6 oz INCLUDING ATTACHMENT HARDWARE	(PEPS)	WEIGHING	BALANCE	NOT TESTED IMPROVED; PRODUCT CURRENTLY UNDER DEVELOPMENT

TABLE 1 PROJECT FIRES QUALIFICATION TEST PROGRAM SUMMARY (Page 6 of 17)

FACE/EYE PROTECTION (CONTD)					
TEST	REQUIREMENTS		TEST METHOD	TEST APPARATUS	RESULTS
	PEPS	QUALIFICATION			
FIT	SHALL BE ADJUSTABLE OR PROVIDED IN MULTIPLE SIZES SO AS TO PROVIDE ADEQUATE PROTECTION FOR ALL	(PEPS)	VISUAL EXAMINATION	TAPE MEASURE	PASS
MAINTAINABILITY	CAPABLE OF BEING PERFORMED IN THE FIRE HOUSE	(PEPS)	VISUAL EXAMINATION		TO BE EVALUATED IN FIELD TEST
RELIABILITY DURABILITY	REPLACEABLE LENS TO LAST 6 MONTHS	PEPS	FIELD EVALUATION		TO BE EVALUATED IN FIELD TEST
DONNING DOFFING	DEPLOYED IN ≤ 2 sec & STOWED IN ≤ 3 sec	PEPS	TIMING OF SUBJECTS	STOPWATCH	PASS
ACCEPTANCE	ACCEPTABLE TO FIRE SERVICE	PEPS	FIELD EVALUATION		TO BE EVALUATED IN FIELD TEST
COMPATIBILITY	MUST BE COMPATIBLE WITH VARIOUS SYSTEMS & SUBSYSTEMS	(PEPS)	VISUAL INSPECTION	SYSTEM TEST	PASS

TABLE 1 PROJECT FIRES QUALIFICATION TEST PROGRAM SUMMARY (Page 7 of 17)

TORSO/LIMB PROTECTION					
TEST	REQUIREMENTS		TEST METHOD	TEST APPARATUS	RESULTS
	PEPS	QUALIFICATION			
IMPACT	SHOULDERS & BACK TO BE PROTECTED FROM AN IMPACT ENERGY OF 43 ft-lb. THE KNEES & ELBOWS SHALL ALSO BE PROTECTED	PROVIDE PROTECTION	NOT REQUIRED		MEETING THE PEPS WOULD RESULT IN UNACCEPTABLE DECREASE IN MOBILITY
PENETRATION	NOT TO BE PUNCTURED BY A 4 PENNY NAIL WITH A FORCE OF 22 lb	(PEPS)	4 PENNY NAIL MOUNTED IN FIXTURE FORCES AGAINST SAMPLE UNTIL PUNCTURE	GRUMMAN TEST FIXTURE	PASS
CUT	NOT TO BE CUT THROUGH BY A FORCE OF 22 lb	(PEPS)	NIOSH TEST METHOD	NIOSH TEST APPARATUS	PASS
FLAME	NOT BURN, CHAR, IGNITE, ETC, AFTER A 5 sec EXPOSURE TO A 1200°F FLAME	(PEPS)	BUNSEN BURNER FLAME DIRECTED AT SAMPLE	BUNSEN BURNER	PASS
HEAT (RADIANT & CONVECTIVE)	UNDERGO A COMBINATION OF RADIANT & CONVECTIVE HEAT CONDITIONS (CLASS 1, 2, & 3 IN PEPS)	(PEPS)	SUBSYSTEM MOUNTED ON AN INSTRUMENT MANIKIN & TESTED IN AN ENVIRONMENTAL CHAMBER	INSTRUMENTED MANIKIN & ENVIRONMENTAL	PASS

TABLE 1 PROJECT FIRES QUALIFICATION TEST PROGRAM SUMMARY (Page 8 of 17)

TORSO/LIMB PROTECTION (CONTD)					
TEST	REQUIREMENTS		TEST METHOD	TEST APPARATUS	RESULTS
	PEPS	QUALIFICATION			
HEAT (CONDUCTIVE)	SHALL BE ABLE TO KNEEL ON 250°F FOR 5 min INSIDE TEMP <113°F	(PEPS)	INSTRUMENTED MANIKIN IN SUBSYSTEM IS PRESSED AGAINST HOT PLATE SURFACE	INSTRUMENTED MANIKIN & HOT PLATE	PASS
	TEST REPEATED AFTER WETTING WITH 180°F WATER		SAME AS ABOVE	SAME AS ABOVE	PASS
MOBILITY	SHALL BE ABLE TO CLIMB, REACH, RUN	(PEPS)	STEP TEST	GRUMMAN STEP TEST	PASS
COLD INSULATION	SHALL KEEP THE FIRE FIGHTER > 64° WHEN EXPOSED TO COLD	(PEPS)	VOLUNTEER WEARING SYSTEM WITH WINDCHILL OF -58°F	VOLUNTEER	PASS
HEAT INSULATION	NOT TO INCREASE ENERGY EXPENDITURE BY MORE THAN 10%	(PEPS)	PROJECT FIRES STEP TEST	STEP TEST EQUIPMENT	PASS
WATER PENETRATION	NOT WET ON THE INSIDE WHEN SHOWERED FROM AN OVERHEAD SPRINKLER	(PEPS)	ENTIRE SYSTEM MOUNTED ON A VOLUNTEER SUBJECTED TO SHOWER. WEIGHT BEFORE & AFTER	SHOWER & A SCALE	PASS
	SUBSYSTEM SHALL NOT ABSORB MORE THAN 5% WATER				PASS
WEIGHT	SUBSYSTEM SHALL WEIGH LESS THAN 5[illegible] FOR 95TH PERCENTILE	SUBSYSTEM SHALL WEIGH LESS THAN 6.5 lb FOR 95TH PENCENTILE	WEIGHT SUBSYSTEM	SCALE	PASS
FIT	SUBSYSTEM TO BE PROVIDED IN NUMERICAL SIZES	(PEPS)	VISUAL EXAMINATION		PASS

TABLE 1 PROJECT FIRES QUALIFICATION TEST PROGRAM SUMMARY (Page 9 of 17)

TORSO/LIMB PROTECTION (CONTD)					
TEST	REQUIREMENTS		TEST METHOD	TEST APPARATUS	RESULTS
	PEPS	QUALIFICATION			
MAINTAIN-ABILITY	CAPABLE OF BEING PER-FORMED IN THE FIRE HOUSE	(PEPS)	VISUAL EXAMINATION		PHASE 2
RELIA-BILITY/ DURABILITY	SUBSYSTEM TO LAST 3 YEARS	(PEPS)	FIELD EVALUATION		TO BE EVALU-ATED IN FIELD TEST
DONNING/ DOFFING	CAPABLE OF BEING DONNED OR DOFFED IN 10 SEC	20 SECONDS	TIMING OF SUBJECTS	STOPWATCH	PASS
RECOG-NIZABILITY	VISUAL RECOGNITION AT 200 FT	(PSPS)	VISUAL RECOGNITION IN SIMULATED CONDITIONS		PASS
DRY-ABILITY	DRY FOR ONE HOUR AT 200°F AFTER WATER PENETRATION TEST	(PEPS)	AFTER WATER PENETRATION TEST, PLACE IN OVEN	OVEN & SCALES	PASS
ACCEPT-ANCE	ACCEPTABLE TO FIRE SERVICE	(PEPS)	FIELD EVALUATION		TO BE EVALU-ATED IN FIELD TEST
COMPAT-IBILITY	MUST BE COM-PATIBLE WITH VARIOUS SYS-TEMS AND SUB-SYSTEMS	(PEPS)	VISUAL EVALUATION	SYSTEM TEST	PASS

TABLE 1 PROJECT FIRES QUALIFICATION TEST PROGRAM SUMMARY (Page 10 of 17)

HAND/WRIST PROTECTION					
TEST	REQUIREMENTS		TEST METHOD	TEST APPARATUS	RESULTS
	PEPS	QUALIFICATION			
PENETRATION	NOT TO BE PUNCTURED BY A 4 PENNY NAIL WITH A FORCE OF 99 lb	FORCE REDUCED TO 45 LB	PROJECT FIRES PUNCTURE TEST	PUNCTURE TEST APPARATUS	PASS
CUT	NOT TO BE CUT THROUGH BY A SHARP EDGE WITH A FORCE OF 99 lb	FORCE REDUCED TO 22 lb	NIOSH TEST METHOD	NIOSH TEST APPARATUS	PASS
FLAME	NOT BURN, CHAR, IGNITE, AFTER A 5 SEC EXPOSURE TO A 1200°F FLAME	(PEPS)	BUNSEN BURNER FLAME DIRECTED AT SAMPLE	BUNSEN BURNER	PASS
HEAT (RADIANT & CONVECTIVE)	UNDERGO A COMBINATION OF RADIANT & CONVECTIVE HEAT CONDITIONS (CLASS 1, 2, & 3 IN PEPS) INSIDE TEMP <113°F	(PEPS)	SUBSYSTEM MOUNTED ON INSTRUMENTED MANIKIN & TESTED IN AN ENVIRONMENTAL CHAMBER	INSTRUMENTED MANIKIN AND ENVIRONMENTAL CHAMBER	PASS
	• TEST REPEATED AFTER WET WITH WATER	(PEPS)	SAME AS ABOVE	SAME AS ABOVE	PASS
HEAT (CONDUCTIVE)	SHALL BE ABLE TO HOLD 950°F OBJECT FOR 5 SEC, INSIDE TEMP <113°F	(PEPS)	SUBSYSTEM MOUNTED ON INSTRUMENTED HANDFORM THEN PRESSED AGAINST HOT SURFACE	INSTRUMENTED HANDFORM & HOT PLATE	PASS
	• TEST REPEATED AFTER WET WITH WATER	(PEPS)	SAME AS ABOVE	SAME AS ABOVE	PASS

TABLE 1 PROJECT FIRES QUALIFICATION TEST PROGRAM SUMMARY (Page 11 of 17)

HAND/WRIST PROTECTION (CONTD)					
	REQUIREMENTS				
TEST	PEPS	QUALIFICATION	TEST METHOD	TEST APPARATUS	RESULTS
GRIP	CAPABLE OF GRIPPING WITH 85% OF BARE-HANDED GRIP	(PEPS)	GRUMMAN GRIP TEST	GRUMMAN TEST APPARATUS	PASS
COLD INSUL-ATION	SHALL KEEP THE HANDS >59°F WHEN EXPOSED TO COLD	(PEPS)	VOLUNTEER WEARING GLOVES WITH WINDCHILL OF -58°F	VOLUNTEER	PASS
WATER	NOT ALLOW WATER TO ENTER FREELY AT THE WRIST	(PEPS)	MOUNT SUBSYSTEM ON HAND IMMERSE FOR 30 SECONDS	VOLUNTEER	PASS (COATED GLOVE)
	NOT ABSORB MORE THAN 5% WATER AFTER IMMERSION	(PEPS)	WEIGHT BEFORE & AFTER THE PREVIOUS TEST		PASS (COATED GLOVE)
WEIGHT	SUBSYSTEM SHALL WEIGH LESS THAN 8 OZ/ PAIR FOR 95TH PERCENTILE	(PEPS)	WEIGH SUBSYSTEM	BALANCE	PASS
FIT	AT LEAST 3 SIZES TO FIT 5TH-95TH PERCENTILE	(PEPS)	VISUAL EXAMINATION	HANDFORM LASTS	PASS
MAINTAIN-ABILITY	CAPABLE OF BEING PER-FORMED IN FIRE HOUSE	(PEPS)	VISUAL EXAMINATION		TO BE EVALU-ATED IN FIELD TEST
RELIABILITY/ DURABILITY	SUBSYSTEM TO LAST 6 MONTHS	(PEPS)	FIELD EVALUATION		TO BE EVALU-ATED IN FIELD TEST

TABLE 1 PROJECT FIRES QUALIFICATION TEST PROGRAM SUMMARY (Page 12 of 17)

HAND/WRIST PROTECTION (CONTD)					
TEST	REQUIREMENTS		TEST METHOD	TEST APPARATUS	RESULTS
	PEPS	QUALIFICATION			
DEXTERITY	PERFORM A STANDARDIZED TEST WITHIN ALLOTTED TIME	(PEPS)	BENNET DEXTERITY TEST	BENNET TESTER	PASS
DONNING	CAPABLE OF BEING DONNED IN 5 sec	10 sec	TIMING OF SUBJECTS	STOPWATCH	PASS
DRYABILITY	DRY IN AN OVEN AT 20°F AFTER 60 MIN	(PEPS)	AFTER WATER IMMERSION ON HANDFORM, PLACE IN OVEN	OVEN & SCALES HANDFORM	PASS
ACCEPTANCE	ACCEPTABLE TO FIRE SERVICE	(PEPS)	FIELD EVALUATION		TO BE EVALUATED IN FIELD TEST
COMPATIBILITY	MUST BE COMPATIBLE WITH TORSO LIMBS PROTECTION SUBSYSTEMS	(PEPS)	VISUAL EXAMINATION	SYSTEM TEST	PASS

TABLE 1 PROJECT FIRES QUALIFICATION TEST PROGRAM SUMMARY (Page 13 of 17)

FOOT/ANKLE PROTECTION					
TEST	REQUIREMENTS		TEST METHOD	TEST APPARATUS	RESULTS
	PEPS	QUALIFICATION			
IMPACT	TOE NOT BRUISED BY AN IMPACT OF 110 ft-lb	(PEPS)	ANZI Z41.1-1967 (R1972) MODIFIED TO IMPACT FORCE OF 110 ft lb	ANSI Z41.1-1967 (R1972)	PASS
	INSTEP NOT BRUISED BY AN IMPACT OF 40 ft-lb	(PEPS)	ANSI Z41.2-1976 MODIFIED TO IMPACT FORCE OF 40 ft lb	ANSI Z41.2-1976	PASS
COMPRES-SION	ABLE TO TAKE A COMPRESSIVE FORCE OF 3000 lb WITH NO IN-JURY	ABLE TO TAKE A COMPRESSIVE FORCE OF 2200 lb WITH NO INJURY	ANSI Z41.1	ANSI Z41.1	PASS
PENETRA-TION	SHALL BE ABLE TO STEP ON 4 PENNY NAIL • BOTTOM OF FOOT • ARCH & SIDE WITH NO PENETRATION	(PEPS)	ANSI Z41.5-1977	ANSI Z41.5-1977	PASS
		PEPS	ARCH & SIDE TESTING USE GRUMMAN PUNCTURE TEST	GRUMMAN PUNCTURE TEST APPARATUS	PASS
CUT	TOE NOT CUT THRU BY A POWER SAW IN 5 SEC	(PEPS)	APPLY POWER SAW TO TOE	POWER SAW	PASS
	REMAINDER NOT CUT THRU BY A SHARP EDGE WITH A FORCE OF 22 lb	(PEPS)	NIOSH TEST METHOD	NIOSH CUT TEST APPA-RATUS	PASS
FLAME	NO BURN, CHAR IGNITE, AFTER A 5 SEC EXPOSURE TO A 1200°F FLAME	(PEPS)	BUNSEN BURNER FLAME DIRECTED AT SAMPLE	BUNSEN BURNER	PASS

TABLE 1 PROJECT FIRES QUALIFICATION TEST PROGRAM SUMMARY (Page 14 of 17)

FOOT/ANKLE PROTECTION (CONTD)					
TEST	REQUIREMENTS		TEST METHOD	TEST APPARATUS	RESULTS
	PEPS	QUALIFICATION			
HEAT (RADIANT & CONVECTIVE)	UNDERGO A COMBINATION OF RADIANT & CONVECTIVE HEAT CONDITIONS (PEPS CLASS 1, 2, & 3) INSIDE TEMP ≤ 113°F	(PEPS)	SUBSYSTEM MOUNTED ON INSTRUMENTED & TESTED IN AN ENVIRONMENTAL CHAMBER	INSTRUMENTED & ENVIRONMENTAL CHAMBER	PASS
	• TEST REPEATED AFTER WET WITH WATER	(PEPS)	SAME AS ABOVE	SAME AS ABOVE	PASS
HEAT (CONDUCTIVE)	SHALL BE ABLE TO STAND ON A 250° F SURFACE FOR 10 MIN INSIDE TEMP <113 F	(PEPS)	SUBSYSTEM MOUNTED ON INSTRUMENTED FOOTFORM, THEN PRESSED AGAINST HOT PLATE	INSTRUMENTED FORM & HOT PLATE	PASS
	TEST REPEATED AFTER WET WITH WATER	(PEPS)	SAME AS ABOVE	SAME AS ABOVE	PASS
	SHALL BE ABLE TO STAND IN 180° F WATER FOR 10 MIN	(PEPS)	SUBSYSTEM MOUNTED ON AN INSTRUMENTED FOOTFORM IMMERSED IN 180° F WATER	SAME AS ABOVE	PASS
ELECTRICITY	LIMIT CURRENT FLOW TO 0-3 MA WITH A 2200 VOLT AC POTENTIAL BOTH WET & DRY	(PEPS)	ANSI Z41.4 1976	ANSI Z41.4 1976	PASS
MOBILITY	ABLE TO CLIMB STAIRS AT EXPENDITURE 110% OF STREET SHOES	(PEPS)	GRUMMAN STEP TEST	GRUMMAN STEP TEST	PASS

TABLE 1 PROJECT FIRES QUALIFICATION TEST PROGRAM SUMMARY (Page 15 of 17)

FOOT/ANKLE PROTECTION (CONTD)					
TEST	REQUIREMENTS		TEST METHOD	TEST APPARATUS	RESULTS
	PEPS	QUALIFICATION			
TRAC-TION	PROVIDE TRACTION ON DRY SUR-FACE, WET SURFACE, & ICY SURFACE	(PEPS)	PROJECT FIRES METHOD	HORIZONTAL SPRING FORCE GAGE	PASS
COLD INSUL-ATION	SHALL BE ABLE TO REMAIN IN SNOW FOR 30 MIN. TEMP IN-SIDE TO REMAIN 59°F	(PEPS)	SUBSYSTEM WORN BY VOLUNTEER IN AN ICEWATER BATH	VOLUNTEER	PASS
WATER PENETRA-TION	SHALL BE ABLE TO STAND IN 8 IN. WATER FOR 30 MIN WITHOUT WATER ENTRY	(PEPS)	SUBSYSTEM ON FOOTFORM IMMERSED IN TANK	WATER TANK & FOOTFORM	PASS
WEIGHT	SUBSYSTEM SHALL WEIGH LESS THAN 4 lb/PAIR FOR THE 95th PER-CENTILE	(PEPS)	WEIGH SUBSYSTEM	BALANCE	PASS
FIT	SHALL BE AVAIL-ABLE IN SAME COMMON RANGES AS STREET SHOES	(PEPS)	MEASUREMENTS USING SUBJECTS & FOOT LASTS	FOOT LASTS	PRES-ENTLY AVAIL-ABLE IN WHOLE SIZES; FITS ALL
SUPPORT	SYSTEM SHALL INCORPORATE A LADDER SHANK & AN OPTIONAL ARCH SUPPORT	(PEPS)	INSPECTION		PASS

TABLE 1 PROJECT FIRES QUALIFICATION TEST PROGRAM SUMMARY (Page 16 of 17)

FOOT/ANKLE PROTECTION (CONTD)					
TEST	REQUIREMENTS		TEST METHOD	TEST APPARATUS	RESULTS
	PEPS	QUALIFICATION			
MAIN-TAIN-ABILITY	SHALL BE CAPA-BLE OF BEING PERFORMED IN THE FIRE HOUSE	(PEPS)	VISUAL EXAMINATION		TO BE EVALU-ATED IN FIELD TEST
RELI-ABILITY/ DUR-ABILITY	SUBSYSTEM TO LAST 2 YEARS	(PEPS)	FIELD EVALUATION		TO BE EVALU-ATED IN FIELD TEST
DONNING/ DOFFING	CAPABLE OF BEING DONNED IN 8 SEC DOFFED	DON. - 15 sec DOFF. - 20 sec	TIMING OF SUBJECTS	STOPWATCH	PASS
RECOG-NIZABIL-ITY	VISUAL REC-OGNITION BY SUBJECT AT 200 ft	(PEPS)	VISUAL RECOGNITION IN SIMU-LATED CONDITION		PASS
DRY-ABILITY	DRY IN AN OVEN AT 200° F AFTER 1 hr	(PEPS)	AFTER WATER IMMERSION ON FOOTFORM, PLACE IN OVEN	OVEN, FOOTFORM & SCALES	PASS
ACCEP-TANCE	ACCEPTABLE TO FIRE SERVICE	(PEPS)	FIELD EVALUATION		TO BE EVALU-ATED IN FIELD TEST
COMPAT-IBILITY	MUST BE COM-PATIBLE WITH TORSO/LIMBS PROTECTION SUBSYSTEM	(PEPS)	VISUAL EXAMINATION		PASS

TABLE 1 PROJECT FIRES QUALIFICATION TEST PROGRAM SUMMARY (Page 17 of 17)

PROTOTYPE PROTECTIVE ENSEMBLE					
TEST	REQUIREMENTS		TEST METHOD	TEST APPARATUS	RESULTS
	PEPS	QUALIFICATION			
WATER PENETRATION	DEFLECT WATER FROM OVERHEAD SPRINKLER	(PEPS)	VOLUNTEERS SUBJECTED TO SPRINKLER SHOWER	SPRINKLERED TEST BUILDING	PASS
MOBILITY	ENERGY INCREASE OF 21% MAXIMUM	(PEPS)	GRUMMAN TEST METHODS	GRUMMAN STEP TEST	PASS
COMPATIBILITY	MUST BE COMPATIBLE WITH VARIOUS SYSTEMS AND SUBSYSTEMS	(PEPS)	SEARCH AND RESCUE TRAINING EXERCISE	SMOKE HOUSE	PASS
FLASHOVER	CLASS 4 HEAT: 1500°F, 4.2 watts/cm^2 10 sec	(PEPS)	EXPOSURE TO FLASHOVER	FLASHOVER CHAMBER	PASS
COLD INSULATION	PERFORM NORMAL DUTIES WITH WINDCHILL OF -58°F	(PEPS)	VOLUNTEER WEARING ENSEMBLE	VOLUNTEER	PASS

4

DISCUSSION OF TEST RESULTS

Head/Ear Protection Subsystem

Apex and Side Impact Test - Apex impact and side impact tests were performed using the test methods and apparatus developed for the American National Standards Institute (ANSI) specification Z90.1 1971, entitled "Protective Headgear for Vehicle Users, Specifications for."

This apparatus consists of an eleven pound headform mounted on a vertical rail. The test helmet is fitted on the headform, raised to a specified height, and allowed to fall in order to impact against an anvil mounted at the base of the apparatus. The headform can be rotated on the mounting neck so that apex or side impacts can be performed. An accelerometer inside the headform measures the response of the headform to the impact. The accelerometer electrical output is processed and displayed on the instrumentation that is part of the test apparatus. The impact performance of each helmet is thus evaluated by the accelerometer response to the drop test. The better the protection offered by the helmet, the less severe will be the response of the accelerometer.

The Z90 apparatus that was used for the impact tests has a maximum drop height of 10 feet. This is adequate for the Z90 test which calls for a drop height of approximately 6 feet. However, the apex impact test requires a drop height of approximately 11.5 ft to provide an impact force of 152 ft lb. Additional impact energy could have been imparted by adding more weight to the headform, but it was felt that the headform mounting bracket might have been overstressed. Therefore, it was decided to run the apex test at a drop height of 10 feet and extrapolate. The side impact tests required no interpolation.

Thermal conditioning was performed using apparatus developed for the NFPA Specification No. 1972, "Structural Fire Fighters' Helmets 1979."

All test requirements were successfully met.

Penetration Test - The puncture tests were performed using the same method and apparatus developed for ANSI specification Z90. As with the Z90 test, the helmet was mounted on a headform positioned at the base of the apparatus. A 6 lb 10 oz penetrator is attached to the sliding mounting bracket so that it is free to fall and hit the headform at the apex contact plate. A failure of the puncture test is determined if the falling penetrator breaks through the helmet and contacts the striker plate.

In this case an indicator light will come on and stay on until reset, even if the penetrator bounces back off the contact plate.

Thermal conditioning was performed using the apparatus developed for the NFPA Specification No. 1972, "Structural Fire Fighters' Helmets 1979."

All test requirements were successfully met.

Flame Test - The flame tests were performed on the entire helmet, rather than a test coupon as is done in most other flame tests. A Bunsen burner flame was employed as the ignitio' source in order to provide a hot flame. The flame was applied to the surface of the helmet at a 45° angle, providing a more realistic duplication of fire ground conditions than other laboratory tests which call for bottom-edge ignition of a bare test coupon.

The flame tests took place in a 3 ft x 1 ft laboratory fume hood, at room temperature, with the fume hood blower off. This provided a relatively draft-free area, which is a conservative approach, and also enables the test to be safety conducted in case a flammable specimen was encountered. The test specimen performed satisfactorily, showing no degradation or sign of change.

Heat Test - Heat tests were performed on the entire ensemble, and is described in the Prototype Ensemble Test Section under Ensemble Heat Tests.

Electricity Test - Electrical testing has been performed satisfactorily at the helmet manufacture. The test conformed with the requirements of ANSI Z89.1.

Heat Insulation-Physiological Stress Test - In order to evaluate the physiological penalties of wearing the test article, a spirometer stress test was employed. The spirometer was used to measure the amount of oxygen that a subject consumes while performing a particular exercise. Oxygen intake directly relates to the energy expended by the subject in performing the task. The subject was asked to climb up and down an 18 in. step at a rate of 30 times per minute for one minute while breathing oxygen from the spirometer. The test was performed while wearing street clothes and then repeated with the addition of the test helmet. Repeat tests were done after an appropriate rest period, so that there was no fatigue effect to cloud the test results.

It was concluded that there is no discernible physiological penalty associated with the addition of the prototype helmet.

Water Penetration Test - The head/ear water penetration test was performed at the New York Fire Department training grounds as part of a complete ensemble evaluation. Two volunteers wore the complete ensemble while being subjected to overhead sprinkler sprays and sprays from a 1½ in. line for periods well beyond the test requirements. There was no water penetration after the tests.

Hearing Test - The hearing test was deemed unnecessary to be run since the helmet as constructed did not cover the ears. With the loose fitting hood of the torso/limbs protection subsystem in place, it was also determined that no hearing degradation would take place.

Donning and Doffing Test - A series of donning and doffing tests were run at Grumman that demonstrated the helmet could be donned in 2 - 3 seconds, and doffed in 1 second.

Recognizability Test - The prototype helmets developed during Phase 1B were not tested for recognizability. However, if Reflexite was applied to the helmet it would pass the visibility requirement since Reflexite meets these requirements.

Dryability - The dryability test on the prototype helmet was performed at Cairns and Brothers by immersing the helmet for 5 seconds in a drum filled with water. The helmet was then removed and all the water shaken out. The helmet was placed in a circulating oven at 200°F. After one hour the helmet was removed and it was dry.

Compatibility Tests - Compatibility tests were performed at the New York City Fire Department's training grounds as part of the entire ensemble evaluation. The helmet was tried on and removed several times and determined to be compatible with the rest of the system.

Weight Test - A polycarbonate version of the prototype helmet was weighed on a balance at Grumman. It weighed 33 ounces. The helmet contained all accessories except the faceshield. The ERM production helmets should be approximately the same weight.

Fit Test - The prototype helmets utilized a standard adjustable head band which fit all of the individuals who tried the helmet.

Face/Eye Protection Subsystem

Impact, Penetration and Heat Tests - At the time of this writing the face/eye protector is still under development. Preliminary tests have shown that many of the performance requirements are met by the new chem tempered glass faceshield, however impact, penetration and heat tests could not be carried out at the present time.

Cut, Scratch and Abrasion Tests - Cut and abrasion tests were performed as a measure of durability. The cut test involved drawing the edge of a 12-in. section of a metal Venetian blind across the surface of the face shield. In the abrasion test a 50-50 mixture of oil and sand is rubbed across the surface of the shield with a gloved finger under moderate pressure five times. Results of both the cut and abrasion tests performed on various faceshield materials such as glass and coated plastic clearly show that the surface of the shield passes cut and abrasion requirements.

Flame Test - Flame testing was performed on various faceshield materials during Phase 1A by holding a Bunsen burner flame on the shield for five seconds. Flame impingement was applied at a 45° angle to the surface of the faceshield. The shields suffered no damage during this test.

Electricity Test - It was unnecessary to perform electrical tests on the face/eye protection subsystem, since it is constructed of polycarbonate and glass which is inherently electrically insulative.

Water Penetration Test - Water penetration tests were performed at the New York Fire Department training grounds. Two volunteers wore the complete ensemble including a polycarbonate version of the faceshield while being subjected to sprinkler sprays and sprays from a 1½ in. line. There was no water penetration after the tests.

Donning/Doffing Coverage, Fit, Compatability Tests - Donning and doffing, compatibility, fit and coverage were all evaluated as part of the complete ensemble evaluation test performed at the New York City Fire Department training grounds. The faceshields were deployed and checked for coverage, fit, and compatability. They were found to be satisfactory. The faceshield was deployed in less than 2 seconds and stowed in 1 second.

Torso/Limb Protection Subsystem

Penetration Test - The torso/limbs protection subsystem penetration test was performed by applying a force to a 4-penny penetrometer. The test article was lightly held over a U shaped frame and the applied force is gradually increased until penetration takes place. The force required to penetrate the specimen was 22 lb, meeting the test requirement.

Cut Test - Cut tests were performed on the torso/limbs protection subsystem using the apparatus developed by A. D. Little. ("The Development of Criteria for Firefighters' Gloves," Arthur D. Little; U. S. Department of Health, Education, and Welfare; National Institute for Occupational Safety and Health; Division of Physical Sciences and Engineering; Cincinnati, Ohio 45202; Contract number CDC-99-74-59; DHEW (NIOSH); Publication number 77-134-B, Volume II.)

A sample of the fabric is mounted on a movable fixture, and a knife edge is lowered so that it rests on the fabric. The appropriate weight is then applied to the knife edge. The fabric holding fixture is then moved at the predetermined rate across the stationary knife edge. Complete cutting through of the subsystem fabric is considered a failure. The test item passed the requirement not to be cut with a 22 lb force.

Flame Test - The flame test used on the torso/limbs protection subsystem was similar to the flame tests performed on the other subsystems described and illustrated in this report. Flame tests were performed on the test article by holding a Bunsen burner flame at a 45° angle to the outer surface for five seconds. This test provides a more realistic duplication of fire ground conditions than other laboratory tests which call for bottom edge ignition of a swatch of material. The Bunsen burner flame was employed to provide a hot enough flame to reveal any tendancy toward ignition.

The results of this test clearly show that the test item was not affected by the flame and therefore meets the test requirements.

Heat Tests (Radiant andConvective). - Radiant and convective heat tests were performed on the entire ensemble as is described in the Prototype Ensemble Section under Ensemble Heat Tests.

Heat Test (Conductive) - The knee area of the test garment was pressed against a 250° hot plate for 5 minutes without the inside of the garment rising about 113°F.

Mobility - Energy Penalty - Spirometer testing was used to evaluate the energy penalties associated with each turnout coat. The apparatus is discussed in the Head/Ear Heat Insulation - Physiological Stress Test section. The test item passed the requirements and more detailed description of the results are presented with the prototype ensemble tests.

Mobility - Range of Motion - The garments were tested at Grumman against the requirement that the range of motion with the garment on shall not be less than 95% of the range without the garment. All of the test items succeeded in passing this requirement. There was no apparent degradation in motion with the garment on.

Cold Insulation - Cold insulation testing was carried out at the New York City Fire Department's training grounds during the evaluation of the complete ensemble. The windchill factor was approximately -25°F that day. The volunteers wore the entire ensemble for about 1½ hours and were comfortably warm.

Water Penetration Test - Water penetration tests were performed at the New York City Fire Department training grounds during the evaluation of the complete ensemble. Two volunteers wore the complete ensemble while being subjected to overhead sprinkler sprays and sprays from a 1½ in. line. There was no water penetration after the tests.

Weight Test - Two sets of the garments were weighed at Grumman. The short jacket bib pants ensemble weighed 6.5 pounds and the long coat, bunket pants ensemble weighed 6.3 pounds.

Fit Test - The prototype garments were cut to fit size 40 short and 42 long. Both fit well after the manufacturer made some modifications. It is obvious that the garment could be made to fit all sizes properly.

Donning/Doffing Test - Donning and doffing tests were conducted at Grumman by individuals for whom the garment was sized. Both ensembles were donnable in just about 20 seconds. Factors that have a strong bearing on donning time are fit of the garment and the physical condition of the firefighter.

Recognizability Test - Recognizability tests were not run on the prototype garments because both materials being considered for use as the reflective tape; Scotchlite, and Reflexite meet the requirements.

Dryability Test - During the thermal evaluation tests that were performed on sample layups of the various materials at Grumman it was necessary to thoroughly soak the samples. The samples were then heated with a heat lamp. It was apparent from these

5 minute tests that any of the samples would be completely dry in about 30 minutes at 200°F.

Compatibility Test - Compatibility tests were performed at the New York City Fire Department's training grounds as part of the entire ensemble evaluation. All mating portions of the subsystem such as the hood, the wristlet, the gloves and the boots were evaluated. The system was also evaluated with a breathing apparatus in place. The torso/limbs protection subsystem was determined to be compatible with the rest of the system.

Hand/Wrist Protection Subsystem

Penetration Test - The penetration test performed on the hand/wrist protection subsystem is the same test as that performed on the torso/limbs protection system. Using the penetrometer, a 4-penny nail was pushed into the palm area of the gloves and the force to puncture was determined. The gloves were supported by a thin-walled plastic handform which offered insignificant puncture resistance. The results show that the leather-palm glove meets the test requirements of 45 pounds. Actual readings were 46 pounds.

Cut Tests - Tests were performed using the apparatus developed by A. D. Little, discussed in the section on Torso/Limb Cut testing.

In the A. D. Little tests, a glove sample is mounted on a movable fixture and a knife edge lowered so that it rests on the material. A weight is then applied to the knife edge. The fixture on which the sample is mounted is then moved at a predetermined rate across the stationary knife edge. If there is no cut observed, the weight is increased and the test is repeated. Complete cutting through of the subsystem fabric is considered a failure. It was found that a force greater than 22 pounds was necessary to cut the leather palm specimen, thus this item pass the requirements.

Flame Test - The flame test used on the hand/wrist protection subsystem was similar to the flame test performed on the other subsystems. Flame tests were performed by holding a Bunsen burner flame at a 45° angle to the outer surfaces for five seconds. This test provides a more realistic duplication of fire ground conditions than other laboratory tests which call for bottom edge ignition of a swatch of material. The Bunsen burner flame was employed as the ignition source because it provides a hot flame which would insure ignition if the item has such a tendency. No degradation or char was observed after the test was performed.

Heat Tests (Radiant and Convective) - Radiant and convective heat tests were performed on the entire ensemble as described in the section on Ensemble Heat Tests.

Heat Tests (Conductive) - Conductive heat tests were performed at Grumman by pressing the gloves against a 750°F hot plate for 10 seconds (4 psi pressure), instead of 950°F for 5 seconds. The reason being that the hot plate could only attain 750°F. The increase in time of contact more than made up for the reduced temperature. Inner surface temperatures of the both gloves remained well below 113°F, passing the test.

Grip Tests - Grip tests were performed using a ½ inch nylon lanyard and a spring-force tester. Both gloves pass the requirement of being able to exert 85% of the bare-handed grip both wet and dry. The dry grip was close to 95% for the dry leather palm glove and 90% for the dipped glove. However, both gloves' grip was close to 100% when wet.

Cold Insulation Test - Cold insulation testing was carried out at the New York City Fire Academy on a day when the windchill factor was approximately -25°F. The volunteers wore the ensembles for about 1½ hours and were comfortably warm.

Water Penetration Tests - The coated glove was donned and immersed in a bucket of water up to the wrist, and the hand was clenched and unclenched for 30 seconds. No internal leakage occurred.

Dexterity Tests - Dexterity was evaluated using the Bennet Dexterity Test. Bare-handed base-lines were first established for each volunteer. The volunteer was required to remove all the bolts and nuts from one side of the frame and reattach them to the other side. Wrenches and a screwdriver were needed to remove and retighten the nuts. After taking off each nut and bolt, they were remounted on the other side of the frame, so that the bolt heads faced in the opposite direction to where they were before starting. The test is repeated wearing the gloves, and the time to perform the tasks are recorded. To pass the test no more than 150% of the barehanded time should be required when wearing gloves.

The test requirements were met by both prototype gloves. The leather palmed glove tested during phase 1A required 144% of the barehanded time, and the dipped glove required 146% of the barehanded time.

Weight Test - A pair of leather palmed gloves weigh 7.3 ounces.

Fit Test - The gloves provided in 3 sizes (small, medium, and large) were judged to be of adequate fit by the various people who evaluated them.

Donning Test - A series of tests were run at Grumman to determine donning times. Though previous tests had shown average times to don the gloves of up to 10 seconds, recent tests show that 7 seconds would be a more realistic value.

Dryability Test - After being immersed in water for 15 seconds, the gloves were placed in a 200°F circulating oven for 1 hour. After being withdrawn, the gloves were inspected and were dry.

Acceptance Test - As part of the complete ensemble evaluation test at the New York City Fire department training grounds, the gloves were donned and doffed several times. The gloves were determined compatible with the rest of the ensemble, particularly the wristlet.

Foot/Ankle Protection Subsystem

Toe Impact Tests - Toe impact testing was performed using the Z-41.1 drop test apparatus; 110 ft-lb of impact energy were applied, per the requirements. In this test, the toe section of the subsystem is cut off and held in a fixture. A weight which is guided between two rails is dropped onto a metal striker which in turn impacts the toe section. Prior to the test some modeling clay is fitted into the toe section. Upon impact, the clay is compressed and retains its deformed shape even if the toe cap springs back to its original shape. After impact, the clay is removed and its minimum cross-section thickness is measured. This section was greater than one-half inch, thus the specimen is considered to have pass the test.

Toe Compression Tests - Using the same apparatus as that used for the toe impact test, with the addition of a hydraulic compression cylinder, the toes of the test samples were squeezed until ½ inch of clearance remained. The force required to achieve this clearance is measured by a load cell. The initial test item failed the test with a force of 2200 lb required to achieve ½ in. clearance. A force of 2500 lb was required. An improved toe cap was to be placed in the boot and the boot reevaluated, however due to problems with the manufacturer, the boots were not made.

Penetration Tests - Penetration tests were not performed on the soles because it has been demonstrated in manufacturer's data that the steel plates in the soles will afford much more than the 400 lb protection required; similarly the addition of the metal arch protector affords greater protection than the 300 lb required.

Cut Tests - Toe cap cut tests were performed using a Partner power saw fitted with a tungsten carbide blade. The blade slipped off the cap and would not penetrate. Cut testing of the other portions of the foot/ankle protection was evaluated using the A. D. Little tester described above in the Torso/Limb and Hand/Wrist sections. All cut tests were successfully passed by the test item. The surface of the toe did show some cut marks but was not cut through.

Flame Tests - The flame test performed on the foot/ankle protection subsystems was similar to the flame test performed on the other subsystem described in this report. The test item pass the flame requirements with no signs of char or degradation.

Heat Tests (Radiant and Convective) - These tests were performed on the entire ensemble, as described under Ensemble Heat Tests.

Heat Tests (Conductive) - The heat conductivity tests were performed during Phase 1A testing by placing the instrumented test specimen on a hot plate. In the 250°F test, the boots were weighted with lead shot and placed on a metal plate that rested on the hot plate. In the 180°F water test, a pan holding 1½ inches of water was placed on the hot plate and heated to 180°F. The weighted test items were then placed in the dish. Results of these tests show that the prototypes meet the requirements.

Electric Insulation Tests - Electrical insulation tests were performed during Phase 1A testing in accordance with the ANSI Z-41.1 Electrical Hazard Test, except that the test voltage was 2,000 volts rather than the 14,000 volts called for in Z-41.4. This change was made so that the voltage protection requirement for the protective ensemble was consistent among the individual subsystems at 2,000 volts. The tests were performed with the footwear dry and also after the insoles had been soaked with a 1 percent sodium chloride solution for five minutes. All requirements were met.

Mobility Test - Spirometer testing as described in the other sections, showed that the energy penalty attributed to the boots was too low to quantify. When the entire protective ensemble was tested the penalty was less than 10%. Therefore, the requirements for the boots were met.

Traction Test - Using a spring-force tester it was determined that the dry traction of the test item exceeded that of the Vibram soled hiking boots used as the comparison standard by approximately 20%. The wet traction was approximately equal to that of the dry, thus all requirements were met.

Cold Insulation/Water Penetration Tests - Tests were performed by the U.S. Army on boots very similar to those developed for Project FIRES. The results of these tests show that they would readily pass Project FIRES requirements.

Weight Test - The weight of a pair of the polyurethane boots in size 9 is 3.4 lb.

Fit Test - The fit of the polyurethane boot was determined to be much better than that of the current rubber boots. Since the polyurethane boot stretches half sizes are not necessary and good fit can be provided by full sizes. It must be noted that proper fit can only be assured by trying the boots on and not by ordering boots based on shoe size.

Support Test - Inspection of the polyurethane boots reveal the same ladder shank as provided on current rubber boots.

Donning and Doffing Test - A series of donning and doffing tests were run on boots of various sizes. The results of these tests show that with proper fit there is little difficulty getting the boots on within 15 seconds. There is, however, more difficulty in doffing the boots. Though the boots can be doffed within the 15 seconds allocated, more work must be done to improve the ease of doffing.

Recognizability Test - The prototype boots developed during Phase 1B were not tested for recognizability. However, if Reflexite was applied to the boots they would pass the visibility requirement since Reflexite meets these requirements.

Dryability Tests - Dryability testing was performed during heat tests performed in Phase 1A. The boots were immersed in a pail of water for 5 seconds and then placed in a convection oven at 200°F for 1 hour, after which they were withdrawn. The boots were dry when removed.

Compatibility Test - Boot compatibility was evaluated as part of the complete ensemble evaluation test performed at New York City Fire Department training grounds. The boots were evaluated in two modes. One with the boots attached to the trousers and the other with the boots completely separated as is the current mode of operation. In both cases the boots were determined compatible.

Prototype Protective Ensemble

Heat Tests

Purpose

Evaluate the thermal protection that is provided to the firefighter by the Project FIRES Prototype Protective Ensemble (PPE). The tests also provided data comparing thermal protection of current turnout gear with the PPE.

Test Requirements

The protective ensemble shall withstand the thermal environments of Class 2 and 3 of Table 2 without any degradation and without allowing the skin temperature of a wearer to reach 113°F, the pain threshold. In addition, when subjected to the environment of Class 4 of Table 2, the subject's skin shall not blister, by not exceeding the values given by Figure 1.

Test Ensembles

Two variations of the PPE and one representative current ensemble were tested as listed in Table 3 and illustrated in Figure 2. The test ensembles included all the protective equipment worn by the firefighter. Head/ear, face/eye, torso/limb, hand/wrist and foot/ankle protective subsystems are provided. The ensembles were chosen to test PPE options, such as outer shell material, and type of glove. Ensemble 3 had a 50/50 Kevlar-Nomex outer shell, Ensemble 2 had a PBI outer shell, and Ensemble 1 used presently-available Nomex. Variations in vapor barrier material were also tested, since the Gore-Tex used in the PPE is a relatively new material. Comparisons between it and conventional Neoprene were of interest. Items 2 and 3 used Gore-Tex, while Item 1 used Neoprene vapor barriers. Both ensembles 2 and 3 had short jackets and bib pants while Ensemble 1 was the conventional long coat with standard bunker pants.

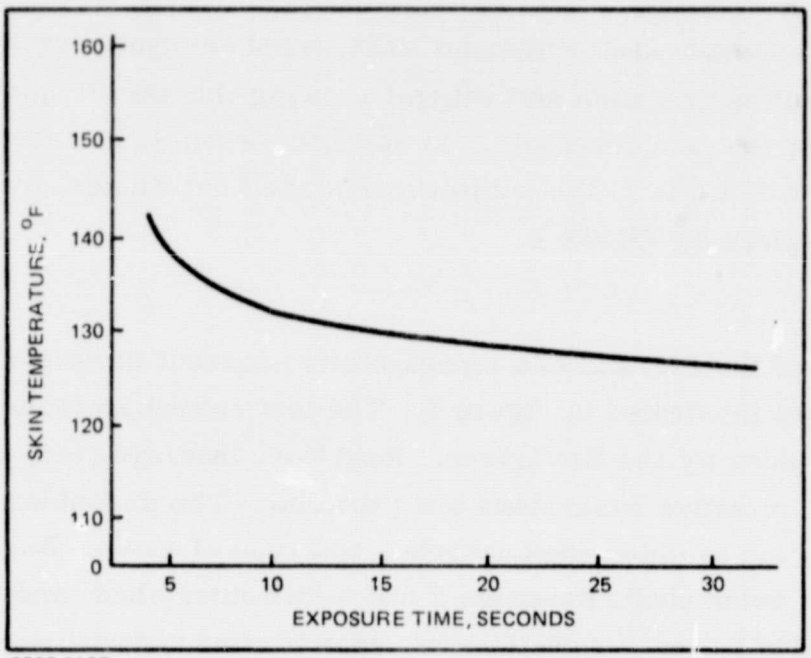
In addition to the variations in the torso/limbs protection subsystem, there were also variations in the other subsystems. In the head/ear subsystem, Ensemble 1, the current system, was tested with a Cairns 660 polycarbonate helmet, Ensemble 2 the PBI prototype had the newly developed epoxy/Kevlar helmet, and Ensemble 3 the 50/50 Kevlar-Nomex prototype had a currently used glass reinforced helmet made by Bullard. The traditional rubber boot was worn with Ensemble 1. However, they were folded down under the turnout pants. The newly developed short length lightweight polyurethane boots were worn with Ensembles 2 and 3. No faceshields were used in any of the tests since the only material available for evaluation at the time was polyurethane.

4

TABLE 2 THERMAL ENVIRONMENTS

CLASS	AIR TEMP, °C	RADIANT FLUX, WATTS/CM^2	EXPOSURE TIME
1	40 (104°F)	0.050	30 min
2	95 (203°F)	0.100	15 min
3	250 (482°F)	0.175	5 min
4	815 (1500°F)	4.200	10 sec

0505-011D



0505-013D

Fig. 1 Exposure Conditions for Threshold Blister

(a) ENSEMBLE 1 (b) ENSEMBLE 2 (c) ENSEMBLE 3

0505-014D

Fig. 2 Test Ensembles

Since polyurethane was certain to melt and possibly ruin the facial area of the manikin, no faceshields were used, and the face of the manikin was wrapped with an asbestos substitute to prevent damage. With regard to hand/wrist protection, a variety of gloves were evaluated. During each run different gloves were worn on each hand. A list of the gloves evaluated is presented in Table 3 and the specific glove worn during each test is identified in each test run. The gloves evaluated included two variations developed by A. D. Little for NASA, the Janesville Cal-OSHA glove, the Tempo leather glove with and without a knit wool liner, and a latex dipped glove made by Advance Glove Co.

The test ensembles were mounted on an instrumented department store manikin, which was made of fiberglass. The manikin was clothed with standard cotton underwear (tee shirt and boxer shorts), and with 5.5 oz/yd^2 long-sleeved cotton shirt and with 7 oz/yd^2 cotton pants. The manikin had an array of 20 thermocouples to measure simulated skin temperature (Figure 3). The thermocouples were selected and mounted in a fashion that would simulate skin response.

Test Facility

The tests were conducted at the SRI International Fire Research Test Room. The inner dimensions of the concrete block test cell are 10' x 10' x 8'. Figure 4 shows the test setup. The propane fires are regulated by adjusting the fuel-air ratio, and when test conditions are established, the doors and hinges are manipulated to subject the test articles to the thermal insult for the required period of time. The manikin was fitted with the array of thermocouples shown in Figure 3 to record the manikin's skin temperature during the test run. These impulses were transmitted by hard wire to a nearby trailer where the data was recorded on strip charts.

Test Procedure

Class 4 Tests

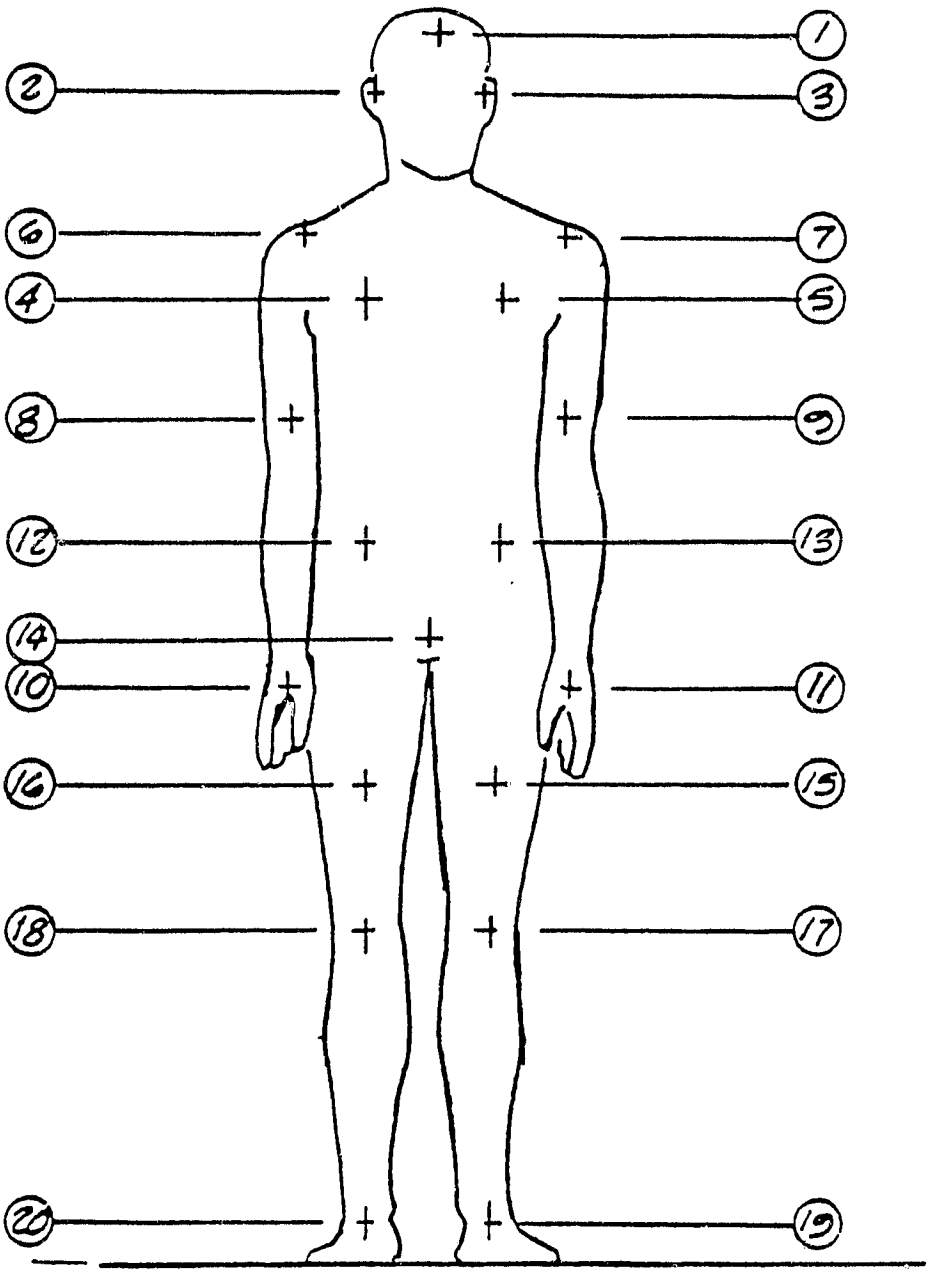
1. Prior to starting this test, the first manikin with thermocouples located in the positions shown in Figure 3 was dressed in Ensemble 1. The manikin was mounted on the internal door (4) as shown in Figure 4 and then the external door (2) closed.
2. The three propane valves illustrated in Figure 4 were ignited.
3. Readings on pyrometer and thermocouples were taken until equilibrium was reached.

4

TABLE 3 TEST ENSEMBLE DESCRIPTIONS

ENSEMBLE NO. / SUBSYSTEM	REPRESENTATIVE CURRENT ENSEMBLE	PROTOTYPE ENSEMBLES	
	1	2	3
HEAD/EAR	CURRENT POLYCARBONATE (CAIRNS 660)	PROTOTYPE	CURRENT GLASS REINFORCED BULLARD)
TORSO/LIMBS	LONG COAT	SHORT JACKET	
TYPE	NFPA 1971	PROTOTYPE	
SHELL MATERIAL	7 1/2 OZ NOMEX	7 1/2 OZ PBI	7 1/2 OZ 50/50
VAPOR BARRIER	NEOPRENE/ NOMEX 6.5 OZ	GORE-TEX/NOMEX 3.5 OZ	
THERMAL LINER	NFPA 1971	NOMEX BATTING 4.4 OZ QUILTED TO 3.1 OZ NOMEX PAJAMA CHECK, TOTAL = 7.5 OZ	
BUNKER PANTS	STANDARD	BIB PANTS	
HAND/WRIST	CURRENT DIPPED	DIPPED PROTOTYPE	LEATHER-PALM PROTOTYPE
FOOT/ANKLE	TRADITIONAL RUBBER	PROTOTYPE POLYURETHANE	
TRIM	3M-SCOTCHLITE	REFLEXITE	

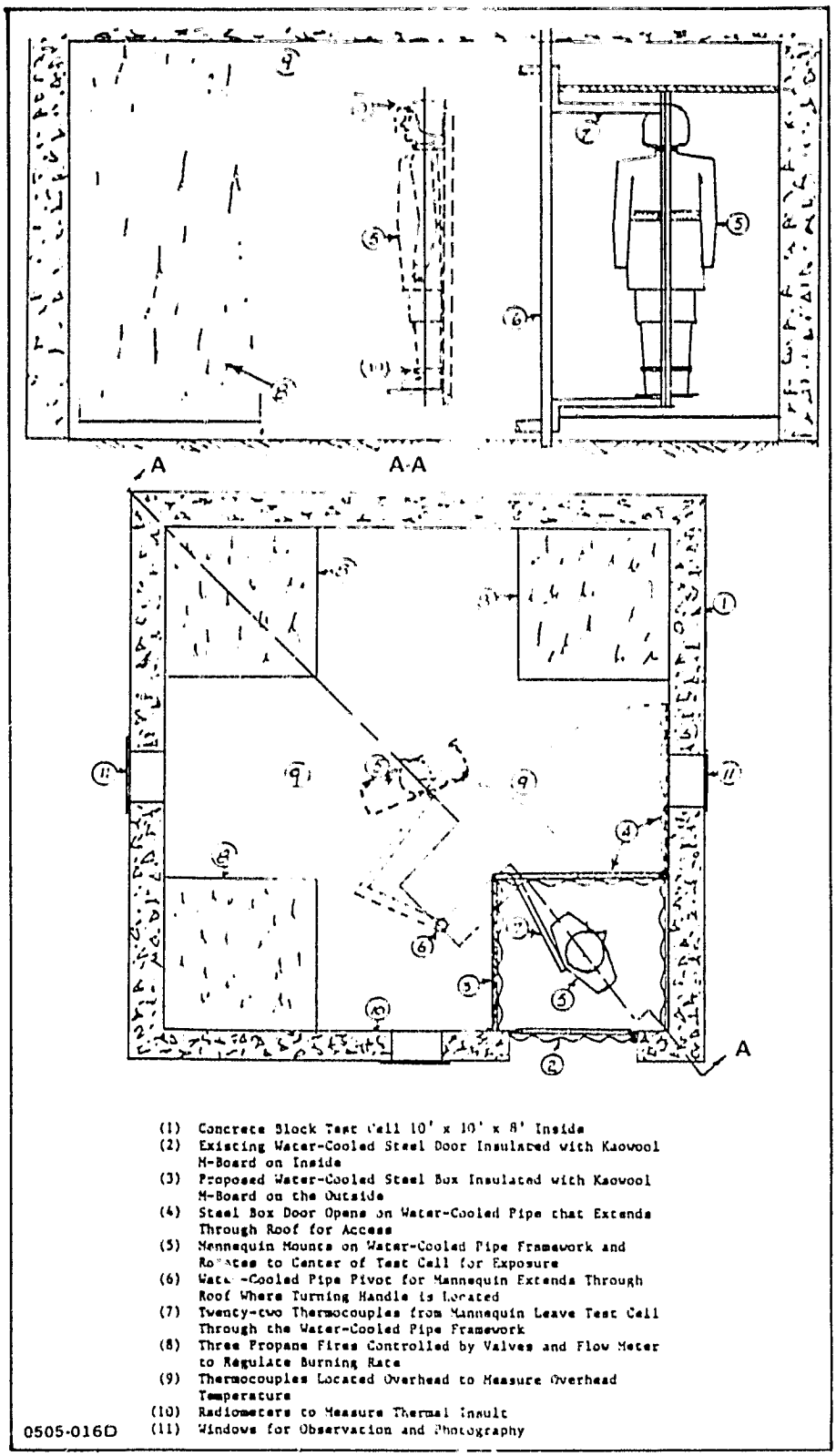
0505-010D
4



0505-015D

Fig. 3 Thermocouple Locations

4



(1) Concrete Block Test Cell 10' x 10' x 8' Inside
(2) Existing Water-Cooled Steel Door Insulated with Kaowool M-Board on Inside
(3) Proposed Water-Cooled Steel Box Insulated with Kaowool M-Board on the Outside
(4) Steel Box Door Opens on Water-Cooled Pipe that Extends Through Roof for Access
(5) Mannequin Mounts on Water-Cooled Pipe Framework and Rotates to Center of Test Cell for Exposure
(6) Water-Cooled Pipe Pivot for Mannequin Extends Through Roof Where Turning Handle is Located
(7) Twenty-two Thermocouples from Mannequin Leave Test Cell Through the Water-Cooled Pipe Framework
(8) Three Propane Fires Controlled by Valves and Flow Meter to Regulate Burning Rate
(9) Thermocouples Located Overhead to Measure Overhead Temperature
(10) Radiometers to Measure Thermal Insult
(11) Windows for Observation and Photography

0505-016D

Fig. 4 Test Setup

4. If conditions simulating Class 4 were not attained, adjustments in fuel and air valves to regulate burning rate were made.
5. Steps 3 and 4 were repeated until Class 4 conditions were attained.
6. With the chamber stabilized at Class 4 conditions, the inner door (4) was opened thereby exposing manikin to Class 4 conditions; the time was noted.
7. After manikin was exposed for 10 seconds, the inner door (4) was closed, withdrawing the manikin, and outer door (2) opened.
8. Time and temperature readings on manikin were continued for a few minutes after manikin was withdrawn.
9. Steps 1 through 8 were repeated for remaining ensembles 2 and 3.

Class 2 and 3 Tests

To perform these tests, steps 1 through 9 listed for performing the Class 4 test were repeated. However, in each case, the thermal conditions and exposure times were adjusted to coincide with those requirements listed in Table 2.

TEST RESULTS

Class 4 Tests - Class 4 PEPS test conditions of 1500°F and 4.2 watts/cm^2 were fairly well reproduced when the test chamber reached approximately 1500°F and 4.2 watts/cm^2. The actual conditions recorded averaged 1550°F near the ceiling and 3.6 watts/cm^2 at face level and 2.4 watts/cm^2 at foot level. The slight decrease in heat flux level was due to partial blocking of the radiometer located over the right shoulder by the manikin's head. There was no attempt to control heat flux at the lower level since in actual fire scene conditions there would be thermal stratification with a higher flux at the higher elevations. It was also apparent that due to the method of inserting and withdrawing the manikin, the left side of the manikin would be first in and last out and would therefore have a slightly longer exposure. In addition the manikin was more directly facing the wall opposite the entry door. This also resulted in slightly higher heat flux on the left shoulder and arm.

The thermocouple readings for the three ensembles tested for Class 4 are presented in Table 4. Because the rise in temperature was in most cases small, only the temperature differences between start of the test and 12 seconds exposure were plotted. Except for the hands, the left shoulder, the left arm and the left knee there appears to be little difference between all three ensembles, and all pass Class 4 requirements. However on closer inspection we can see that Ensemble 2 performed best, even taking into account the lack of bib pants on Ensemble 1 which would influence thermocouples 4 and 5.

Though the recorded data showed little differences, the visual results were quite dramatic and different for each ensemble.

Ensemble 1, the currently used equipment comprised of a long coat and bunker pants with an outer shell constructed of Nomex immediately burst into flames when the manikin faced the thermal insult. Within one second, the polycarbonate helmet had melted. After ten seconds exposure, the outer garment was virtually completely destroyed, it was charred and shriveled. The work shirt and work pants were also charred to a much lesser degree and there were places on the upper left chest where the underwear had burned through. The lower portion of the garment faired somewhat better though the outer shell of the pants was charred to a much lesser degree than the coat and the boots were slightly singed. Apex leather gloves were worn on both hands. The one on the right hand had no liner while the one on the left hand had a knit liner. The glove without the liner shrunk considerably; unfortunately the

TABLE 4 CLASS 4 HEAT TEST RESULTS

THERMOCOUPLE		Δ TEMP RISE AFTER 12 SEC. EXPOSURE - °F		
NO.	LOCATION	ENSEMBLE NO. 1 NFPA 1971	ENSEMBLE NO. 2 PROTOTYPE PBI	ENSEMBLE NO. 3 PROTOTYPE 50/50
1	HEAD	2.7	2.2	0.5
2	RT CHEST	3.8	1.3	1.3
5	LEFT CHEST	6.4	0.9	1.4
6	RT SHOULDER	8.4	4.3	6.4
7	LEFT SHOULDER	11.1	4.0	20.7
8	RT ARM	0	1.5	7.1
9	LEFT ARM	11.4	2.7	5.9
10	RT HAND	(A) 0	(C) 75.5	(E) 14.4
11	LEFT HAND	(B) 5.9	(D) 4.6	(F) 7.1
12	RT HIP	0	2.6	2.9
13	LEFT HIP	1.8	0.7	1.8
14	GROIN	3.4	0.7	1.6
15	LEFT THIGH	2.6	1.9	0
16	RIGHT THIGH	1.7	6.1	7.5
17	LEFT KNEE	12.4	0	7.8
18	RT KNEE	4.9	0	3.0
19	LEFT FOOT	0	0	0
20	RT FOOT	0.6	0	0.6
	CEILING, °F	1535	1550	1565
	Q_{HEAD} - watts/cm^2	3.6	3.6	3.6
	Q_{FEET} - watts/cm^2	2.4	2.4	2.4

NOTE: THERMOCOUPLES 16 - 20 RECORDED ON A DIFFERENT RECORDER -- DATA NOT AVAILABLE AT TIME OF REPORT

GLOVE IDENTIFICATION:

- (A) TEMPO GLOVE WITHOUT LINER
- (B) TEMPO GLOVE WITH LINER
- (C) NASA DEVELOPED GLOVE - KEVLAR (NOT DIPPED)
- (D) TEMPO GLOVE WITH LINER
- (E) NASA DEVELOPED GLOVE - KEVLAR (DIPPED)
- (F) NASA DEVELOPED GLOVE - KEVLAR (NOT DIPPED)

0505-017D

thermocouple misfunctioned. The glove with the knit liner on the left performed fairly well and would have passed the test. Visual results of the Class 4 heat test for Ensemble 1 are presented in Figure 5.

Ensemble 2, the garment employing PBI as the outer shell material, showed a dramatic improvement. There were no immediate flames, except at the Reflexite reflective trim. After a few seconds, the upper torso area did start to burn. The helmet remained intact throughout the test. After the exposure, the outer shell of the garment was singed in the upper torso area. However, the PBI shell was still intact and remained a fabric. The lower torso and the high bib pants under the jacket were practically unscathed, with only minor discoloration. The work uniform and the underwear were also not affected. The polyurethane boots shows some discoloration and slight signs of blistering. The helmet had lost a lot of gel coat and some of the resin was driven off in the front bac area; otherwise it appeared structurally sound.

The A. D. Little developed glove worn on the right hand was not dipped and had no vapor barrier. It performed poorly. The glove on the left hand, a Tempo glove with a liner, performed very well. Visual results of the Class 4 heat tests for Ensemble 2 are presented in Figure 6.

Ensemble 3, the garment with an outer-shell constructed of 50/50 Nomex and Kevlar blend had results that at first appeared almost identical to Ensemble 1, the Nomex garment. Ensemble 3 burst into flames after about two seconds exposure, and emerged from the test charred and brittle. However, the bib pants portion under the jacket was in good shape and only slightly charred, as were the work shirt and work pants. There was no indication that the underwear had burnt. There was, however, a discoloration from the dye material in the 50/50 blend, on the work shirt and work pants and the underwear. The lower torso of the bib pants were slightly charred, and the polyurethane boots were slightly discolored and showed signs of slight blistering. The glass reinforced helmet worn during this test was still intact, however, all the resin had been driven off and the helmet offered very little protection. During this test both A. D. Little gloves were worn. The dipped glove on the right hand charred slightly but pass the test and the nondipped glove worn on the left hand did well. Visual results of the Class 4 heat test for Ensemble 3 are presented in Figure 7.

Fig. 5 Visual Results of Class 4 Heat Tests - Ensemble 1

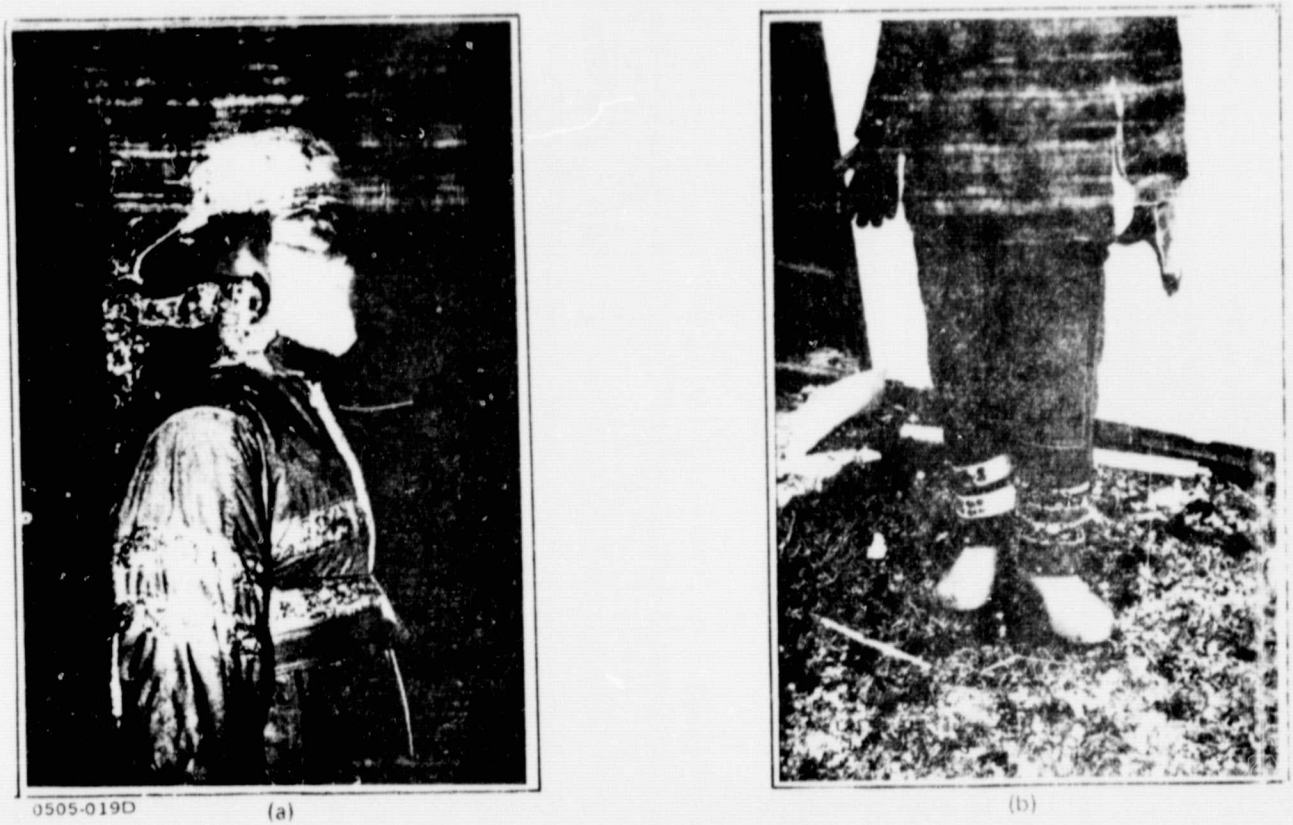


Fig. 6 Visual Results of Class 4 Heat Tests - Ensemble 2

4

Fig. 7 Visual Results of Class 4 Heat Tests
Ensemble 3

Class 3 Tests - Class 3 PEPS test conditions of 482°F and 0.175 watts/cm^2 were not reproduced too closely. This was due to an error in reading the chamber temperature as 500°F when it was actually reading closer to 600°F. The corresponding heat flux that resulted when the chamber stabilized was about 0.80 watts/cm^2 or 4.25 times greater than Class 3 conditions.

It is felt that an exposure time of between 1 and 2 minutes at these conditions would be equivalent to 5 minutes at the Class 3 conditions. Both Ensembles 1 and 2 were subjected to these conditions for a period of 5 minutes. Except for the melting of the polycarbonate helmet on Ensemble 1 and the melting of the Reflexite tape on Ensemble 2 both ensembles looked untouched. The results of the test are presented in Table 5 and are plotted in Figures 8 and 9. The results show that both ensembles pass 2 minutes exposure, except for the left hand and the left arm Ensemble 2, passed 3 minutes exposure. Except for the head, both hands and the left shoulder Ensemble 1 passed 3 minutes exposure. The prototype helmet clearly outperformed the current polycarbonate helmet. Temperature under the crown of the current helmet reached 166°F after 5 minutes while the temperature under the crown of the prototype reached 92°F after 5 minutes, only a 13 degree rise. The polycarbonate helmet melted as it did during Class 4 tests, while the prototype helmet was unmarked. Neither the current rubber boots or the prototype polyurethane boots were marked. The Advanced latex dipped glove performed the worst of the four gloves evaluated, failing the Class 3 requirement after 1.75 minutes. The latex also became tacky and remained that way. Next to fail was the Tempo glove without the knit wool liner. This glove failed class 3 after 2 minutes. Following were the A. D. Little Kevlar glove (not dipped) which failed after 2.6 minutes and the Janesville Cal-OSHA glove which failed after 4.3 minutes.

Class 2 Tests - Class 2 PEPS test conditions of 200°F and 0.1 watts/cm^2 were initially reproduced fairly well (Table 6). Chamber conditions started at 236°F and 0.1 watts. Evidently the chamber had not reached equilibrium before the test started since after 5 minutes the temperature dropped to 189°F. A slight adjustment was made and the 10 and 15 minute readings were 327°F and 300°F. Because the flames required to generate these conditions were quite low, the resultant heat flux at the lower level was higher than the flux at the upper level. In addition, since there was this rather large difference in the temperature difference between the desired chamber temperature and the actual chamber temperature for the final 10 minutes of the run, it is felt that an exposure time of approximately 10 minutes at these conditions would be equivalent

4

TABLE 5 CLASS 3 HEAT TEST RESULTS

THERMOCOUPLE NO.	LOCATION	TEMPERATURE F AFTER EXPOSURE							
		ENSEMBLE NO 1 NFPA 1971				ENSEMBLE NO. 2 PROTOTYPE PBI			
		START	1 MIN	3 MIN	5 MIN	START	1 MIN	3 MIN	5 MIN
1	HEAD	89 5	97 0	1.28 0	166 0	79 0	81 0	85 0	92 0
4	RT CHEST	73 7	75 0	97 0	109 0	74 0	79 0	102 0	123 0
5	LEFT CHEST	70 9	73 0	97 0	119 0	64 0	66 0	66 0	79.0
6	RT SHOULDER	77 0	84 0	120 0	157 0	76 0	86 0	112 0	128 0
7	LEFT SHOULDER	66 0	74 0	110 0	146 0	72 0	84 0	111 0	127 0
8	RT ARM	64 0	68 0	92 0	116 0	66 0	71 0	105 0	122 0
9	LEFT ARM	74 0	77 0	101 0	131 0	76.0	88 0	115 0	139 0
10	RT HAND	(A) 69 0	73 0	120 0	166 0	(C) 69 0	71 0	95 0	126 0
11	LEFT HAND	(B) 60 0	76 0	135 0	152 0	(D) 63 0	85 0	151 0	191 0
12	RT HIP	56 0	55 0	59 0	73 0	64 0	67 0	87 0	105 0
13	LEFT HIP	57 0	58 0	69 0	87 0	68 0	68 0	87 0	104 0
14	GROIN	67 0	66 0	67 0	75 0	72 0	72 0	88 0	105 0
15	LEFT THIGH	63 0	66 0	93 0	116 0	70 0	75 0	86 0	102 0
16	RT THIGH	46 0			98 0	48 0			96 0
17	LEFT KNEE	48 0			94 0	63 0			113 0
18	RT KNEE	51 0			99 0	55 0			84 0
19	LEFT FOOT	44 0			58 0	51 0			60 0
20	RT FOOT	57 0			67 0	65 0			71 0
	CEILING °F	611.0	605 0	598.0	601 0	581.0	574.0	567.0	578.0
	Q_{HEAD} watts/cm^2	0.75	0.75	0 75	0 75	0.84	0.84	0.84	0.84
	Q_{FEET} watts/cm^2	0.68	0 68	0 68	0 68	0 78	0.78	0 78	0.84

NOTES:

1. ENSEMBLE NO. 1 WAS RUN AT APPROXIMATELY 600°F AND 0.75 watts/cm^2 WHICH IS APPROXIMATELY 100°F HIGHER THAN CLASS 3 AND 4X THE HEAT FLUX.
2. ENSEMBLE NO. 2 WAS RUN AT APPROXIMATELY 580°F AND 0.85 watts/cm^2 WHICH IS APPROXIMATELY 100°F HIGHER THAN CLASS 3 AND 4.5X THE HEAT FLUX.

GLOVE IDENTIFICATION:

ENSEMBLE NO. 1

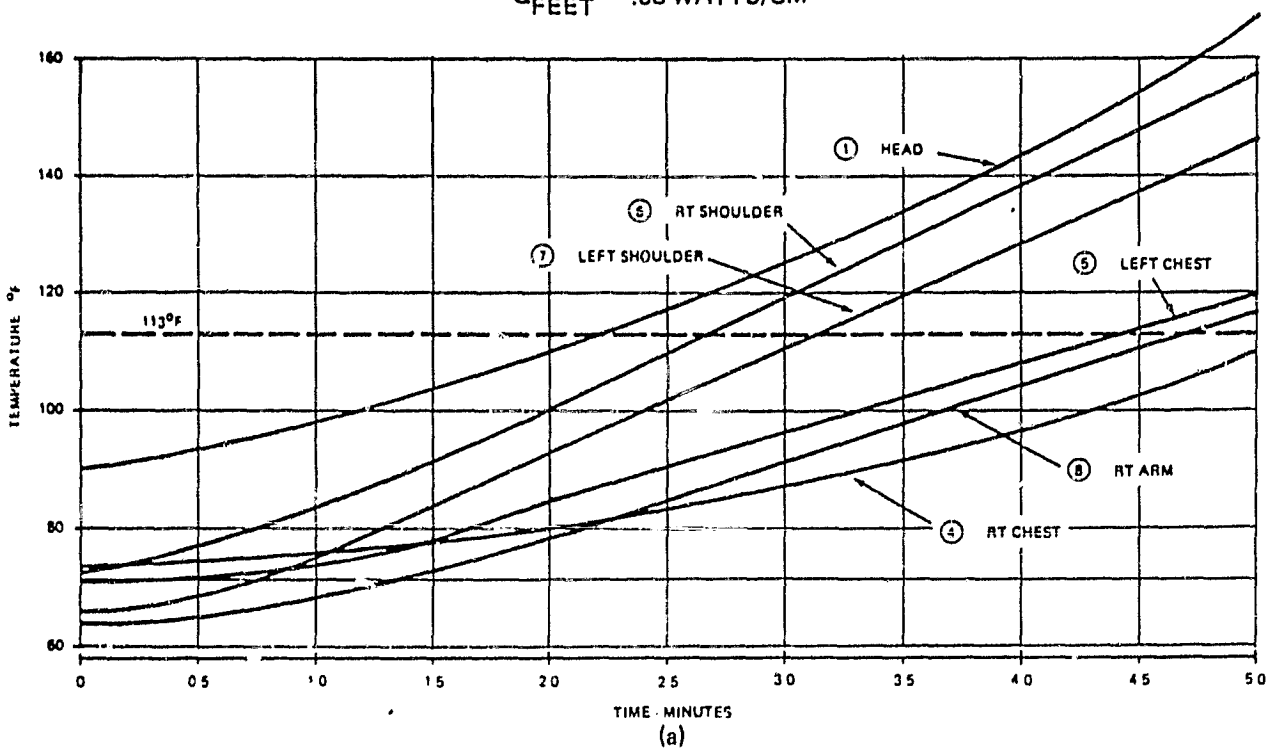
- (A) RIGHT HAND NASA DEVELOPED GLOVE KEVLAR (NOT DIPPED)
- (B) LEFT HAND TEMPO GLOVE WITH KNIT LINER

ENSEMBLE NO. 2

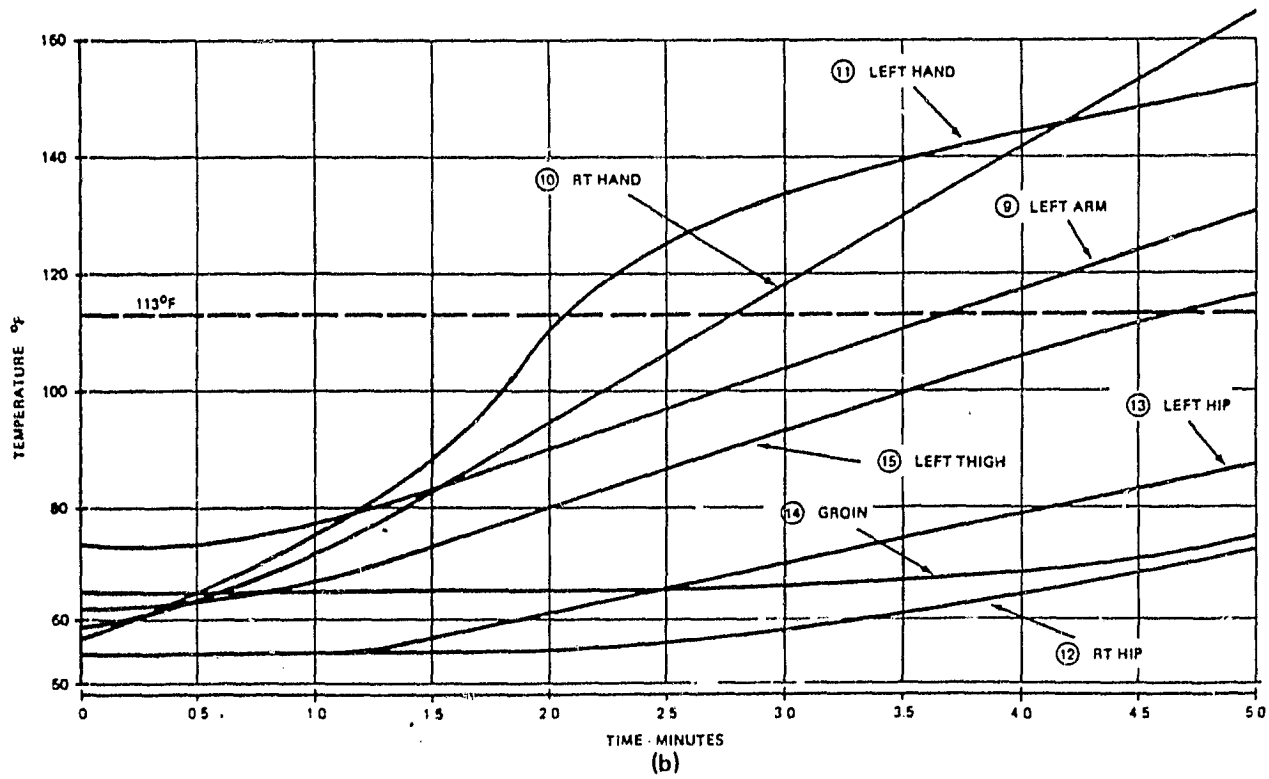
- (C) RIGHT HAND JANESVILLE, CALIFORNIA - OSHA
- (D) LEFT HAND ADVANCED GLOVE (DIPPED LATEX)

STANDARD NFPA WITH PANTS

T_{AMB} = 600°F
Q_{HEAD} = .75 WATTS/CM^2
Q_{FEET} = .68 WATTS/CM^2



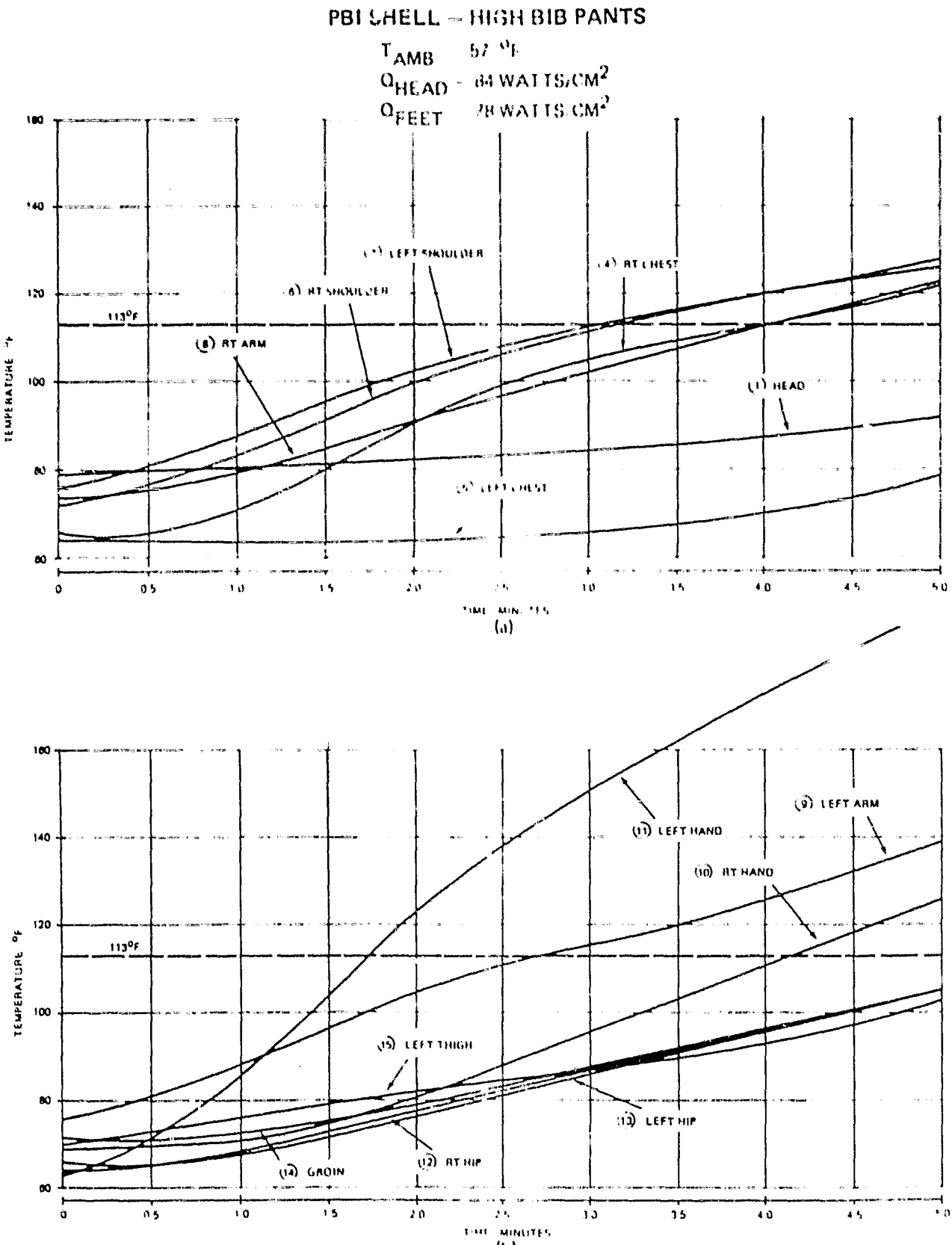
(a)



(b)

0505-022D

Fig. 8 Class 3 Heat Tests - Ensemble No. 1



0505-023D

Fig. 9 Class 3 Heat Tests Ensemble No. 2

4

TABLE 6 CLASS 2 HEAT TESTS RESULTS

THERMOCOUPLE		SKIN TEMPERATURE, °F AFTER EXPOSURE			
NO.	LOCATION	ENSEMBLE NO. 1 NFPA 1971			
		ST.	3 MIN	10 MIN	15 MIN
1	HEAD	134	142	154	176
4	RT CHEST	108	111	118	130
5	LEFT CHEST	103	105	114	126
6	RT SHOULDER	109	117	132	146
7	LEFT SHOULDER	103	109	127	143
8	RT ARM	102	108	116	125
9	LEFT ARM	113	117	128	139
10	RT HAND	79	(A) 90	110	126
11	LEFT HAND	79	(B) 92	117	139
12	RT HIP	86	85	88	94
13	LEFT HIP	92	93	99	108
14	GROIN	90	101	102	107
15	LEFT THIGH	92	96	106	118
16	RT THIGH	69	73	80	88
17	LEFT KNEE	72	76	86	98
18	RT KNEE	75	78	86	94
19	LEFT FOOT	69	70	71	81
20	RT FOOT	78	78	80	86
	CEILING, °F	236	189	327	300
	Q_{HEAD}, watts/cm^2	0.1	0.1	0.1	0.1
	Q_{FEET}, watts/cm^2	0.3	0.3	0.3	0.3

NOTE:
CLASS 2 DATA ON ENSEMBLE NO. 1 ONLY, DATA ON ENSEMBLE NO. 2 NOT AVAILABLE BECAUSE OF MALFUNCTION IN TEMPERATURE RECORDER.

GLOVE IDENTIFICATION

(A) NASA DEVELOPED GLOVE - KEVLAR (NOT DIPPED)

(B) TEMPO GLOVE WITH KNIT LINER

0505-024D

to the 15 minute exposure at the Class 2 condition. It should also be noted that the Class 2 test was started after a short cool down period after completing the Class 3 run. Apparently the manikin did not cool down as low a level as the previous runs. This explains the high starting temperatures.

Both ensemble 1 and 2 were subjected to these conditions for a period of 15 minutes. Neither showed any signs of degradation after completion of the tests. Data has only been provided for the run on Ensemble 1 because of malfunction in the temperature recorder during the run on Ensemble 2.

The results of the test show that after 10 minutes at these conditions the ensemble passed the Class 2 protection requirement except for the head, the right shoulder, and the right and left arms. If the extremely high start temperatures for these areas are taken into account then all of these areas would pass the test. The results after 15 minutes taking the high start temperatures into account show that the head, the hands, the shoulders, and the left arm did not pass. If the excessive temperature at the upper level is taken into account along with the higher heat flux on the left side, then the entire ensemble except for the helmet and possibly one of the gloves, passed the test.

It is concluded that Ensemble 2, including the prototype helmet, would have passed the Class 2 test. This is based on the results of the Class 3 tests and the Class 2 run on Ensemble 1.

Wet Garment Heat Tests — Class 3 and Class 2 heat tests were repeated for Ensembles 1 and 2; however, prior to running the tests both ensembles were thoroughly drenched with water from a hose. The wet ensembles were then subjected to the same conditions of Class 3 and 2. The purpose of this test was to evaluate if the vapor generated from the wetted garment would penetrate the Goretex water barrier and cause a rise in temperature. During the Class 3 tests, temperatures were very similar to that of the dry garment; during Class 2, there was actually a cooling effect attributed to the wetted outer shell.

Conclusions

On the basis of the heat test results, the following conclusions were made:

(a) The prototype helmet clearly met all heat test requirements, whereas the current helmets evaluated, failed.

(b) The polyurethane boots performed as well as current firefighter rubber boots and both passed all heat test requirements.

(c) Glove testings results though limited, appeared to confirm that use of a vapor barrier protects against heat as well as water. Best results were obtained with the Cal-OSHA glove and the dipped version of the NASA glove.

(d) The current NFPA turnout coat and bunker pants combination as well as both the long coat bunker pants prototype and the short jacket, bib pants prototype pass PEPS Class 2, 3 and 4 heat requirements. However, the bib pants version of the prototype affords greater protection than either the NFPA ensemble or the long coat bunker pants prototype ensemble under Class 4 conditions.

(e) PBI clearly offers greater protection against flame than Nomex or 50/50 Kevlar/Nomex.

(f) Use of Goretex as a vapor barrier does not cause a steam hazard to the firefighter when his garment get wet and he operates in high heat environments.

Water Penetration Test - Water penetration tests were performed on both versions of the prototype protective ensemble at the New York City Fire Department training grounds. Two firefighters donned both versions of the ensemble (the short jacket and the long coat) and then were subjected to a deluge of water from a series of overhead sprinklers. While the sprinklers were on, the men simulated a series of motions and activities related to firefighting. After an exposure of over 10 minutes the sprinklers were shut off and the men opened their coats. As observed, both men were dry inside, and both stated so. There was less than a one pound increase in weight due to wetting of the complete ensemble. The test was repeated using a fog nozzle directed perpendicular to the body. The men leaned on the spray, kneeled and went through a series of motions. Both men remained dry during this test.

Compatibility Test - Prior to running the water tests described in the above paragraph the two volunteers donned the complete ensemble including a new 4500 psi breathing apparatus. The men then went through a series of simulated firefighting activities in the smoke house. After approximately 10 minutes, the test was concluded. The men

stated they were very comfortable and were able to perform all operations freely. Thus it was concluded that the system met compatibility requirements.

Cold Insulation Tests - The ambient temperature during which the water penetration and compatibility tests took place was approximately 18°F with a wind chill factor of less than -25°F. The water penetration tests and the compatability tests lasted more than an hour. Upon conclusion of the tests, the men were interviewed as to their comfort. Both said they were warm and comfortable throughout the test.

Mobility Tests - Using the spirometer set up described in previous sections, a series of tests were run at Grumman to determine the metabolic penalty a firefighter would pay if he climbs a flight of stairs wearing the complete prototype ensemble. The tests show that the penalty was much less than the 21% allowed and was closer to 10%. Thus the system meets the mobility requirement.

PROJECT FIRES QUALIFICATION TEST METHODS

HEAD/EAR PROTECTION SUBSYSTEM

IMPACT

Requirements:

The head/ear protection subsystem shall limit the acceleration of the head to within the safe range of the Wayne State University Tolerance Standards presented in Figure 10, when impacted with 152 ft-lb on the top (apex), and when impacted with 101 ft-lb on the front, back and sides of the head. This requirement shall be met at room temperature, within 20 seconds after being subjected to the Class 3 heat environment described in Table 2; and within 20 seconds after achieving equilibrium at -10°F.

Apparatus:

The ANSI Z90 impact test apparatus shall be used.

Procedure:

1. Follow the ANSI Z90 procedure, except for drop height.
2. Mount the helmet on the headform and adjust the drop height to provide the required impact energy when the helmet strikes the anvil.

Criteria:

Resulting headform accelerations shall not exceed 400 g. Accelerations above 200 g's shall not exceed 3 milliseconds in duration. Accelerations above 150 g shall not exceed 5 milliseconds.

PROJECT FIRES QUALIFICATION TEST METHODS

HEAD/EAR PROTECTION SUBSYSTEM (Cont)

PENETRATION

Requirements:

The head/ear protection subsystem shall prevent any injury resulting from a penetrator impacting with a force of 101 ft lb. The prescribed protection shall be provided at; room temperature, within 20 seconds after being subjected to the Class 3 environment described in Table 2, and within 20 seconds after achieving equilibrium at -10°F.

Apparatus:

The ANSI Z90 penetration test apparatus shall be used.

Procedures:

1. Follow the ANSI Z90 procedure, except for drop height.
2. Fasten the helmet on the headform so that the penetrator will strike the helmet.
3. Adjust the drop height so that 101 ft-lb of impact energy will be applied to the helmet when the penetrator strikes.
4. Test penetration at the apex and at the front, back, and sides.

Criteria:

There shall be no contact between the penetrator tip and the headform.

PROJECT FIRES QUALIFICATION TEST METHODS

HEAD/EAR PROTECTION SUBSYSTEM (Cont)

FLAME

Requirements:

The materials that comprise the head/ear protection subsystem shall not ignite, burn, char, melt, shrivel, or otherwise visually degrade when exposed to the tip of the inner cone of a Bunsen burner flame for 5 seconds.

Apparatus:

Bunsen burner with a barrel of 1/2 ±1/8 inches, without a flame spreader, fueled by gas of 1100 ±200 Btu/ft^3.

Procedure:

1. Adjust inner cone of Bunsen flame to be 1 to 1-1/2 inches long.
2. Place tip of inner cone at a 45° angle to the test surfaces for 5 seconds and remove, and let surface cool.
3. Repeat the test on all the different materials present in the protector.

Criteria:

There shall be no ignition, burning, charring, melting, shrivelling, or any other visual degradation.

PROJECT FIRES QUALIFICATION TEST METHODS

HEAD/EAR PROTECTION SUBSYSTEM (Cont)

HEAT

Requirement:

The head/ear protection subsystem shall withstand the thermal environments of Class 3 defined in Table 2, without any visible distortion or degradation and without any of the inner surfaces that contact the head or ears reaching 113°F, the pain threshold, and subsequently meet all other requirements of this specification.

When subjected to the Class 4 environment defined in Table 2, the inner surfaces of the protection subsystem that contact the head or ears shall not exceed the time-temperature limits presented in Figure 1.

Apparatus:

Environmental test chamber similar to that detailed in method 505 of MIL-STD-810, with appropriate modifications to accommodate the desired air temperature, radiant flux and exposure times; thermocouples and temperature reading devices.

Procedure:

1. Mount the protector on a headform, and place thermocouples at the head band.
2. Establish test conditions in the chamber and then place the helmet mounted on the headform into the chamber for the required exposure period. During this period, chamber temperatures shall not drop more than 25°F below the desired temperature.

Criteria:

Contact surfaces shall be $\leq$113°F during Class 3 testing; contact surfaces shall be within time-temperature curve of Figure 1 during Class 4 testing.

HEAD/EAR PROTECTION SUBSYSTEM (Cont)

ELECTRICITY

Requirement:

The head/ear protection subsystem shall limit the current flow to less than 3 milliamperes when there is a 2200 volt A/C electrical potential between the outer surface of the system and the head.

Apparatus:

Insulation test apparatus with transformer having sinusoidal output voltage with a crest factor of 1.41 ±0.07, and capability of applying 2200 volts A/C and monitoring leakage currents of 0 to 10 milliamperes.

Procedure:

Use the procedure outlined by ANSI Z89.1, Section 8.

Criteria:

There shall be less than 3 milliamperes current.

PROJECT FIRES QUALIFICATION TEST METHODS

HEAD/EAR PROTECTION SUBSYSTEM (Cont)

HEARING

Requirement:

The head/ear protection must not attenuate sound more than 10%.

Apparatus:

The ANSI Z24.22 shall be used.

Procedure:

Follow ANSI Z24.22.

Criteria:

Sound must not be attenuated more than 10%.

PROJECT FIRES QUALIFICATION TEST METHODS

HEAD/EAR PROTECTION SUBSYSTEM (Cont)

WATER PENETRATION

Requirement:

The head/ear protection subsystem shall deflect falling water from dripping down the face and neck areas of the firefighter.

Apparatus:

Volunteer test subject and an overhead sprinkler system.

Procedure:

1. Mount the face/eye protector on the helmet.
2. The volunteer test subject, wearing the helmet and face shield, shall stand for 1 minute under a sprinkler head, which is discharging at a rate of at least 13 gallons per minute.
3. The volunteer walks through the discharge spray a total of 15 times. With the head erect, the volunteer makes each walk-through at a slow walking pace.

Criteria:

No water shall enter the face and head area of the subject.

PROJECT FIRES QUALIFICATION TEST METHODS

HEAD/EAR PROTECTION SUBSYSTEM (Cont)

RETENTION

Requirement:

The head/ear protection subsystem shall remain on the head when impacted with 10 ft-lb.

Apparatus:

The ANSI Z90 penetration test apparatus shall be used.

Procedure:

1. Place the helmet, retained by the chinstrap, on a floor-mounted headform.
2. Position the helmet so the impactor will strike the outer edge of the brim.
3. Adjust the drop height so that 10 ft lb will be applied to the brim when the penetration drops.

Criteria:

The helmet shall not be knocked off the headform by the 10 ft lb impact applied by the penetrator to the outer edge of the brim.

PROJECT FIRES QUALIFICATION TEST METHODS

HEAD/EAR PROTECTION SUBSYSTEM (Cont)

DONNING/DOFFING

Requirement:

The head/ear protection subsystem shall be capable of being donned or doffed in under 5 seconds.

Apparatus:

Five volunteer test subjects.

Procedure:

Volunteers don the head/ear protector and face shield combination.

Criteria:

The 5-second donning requirement may be met without fastening the retention system.

PROJECT FIRES QUALIFICATION TEST METHODS

HEAD/EAR PROTECTION SUBSYSTEM (Cont)

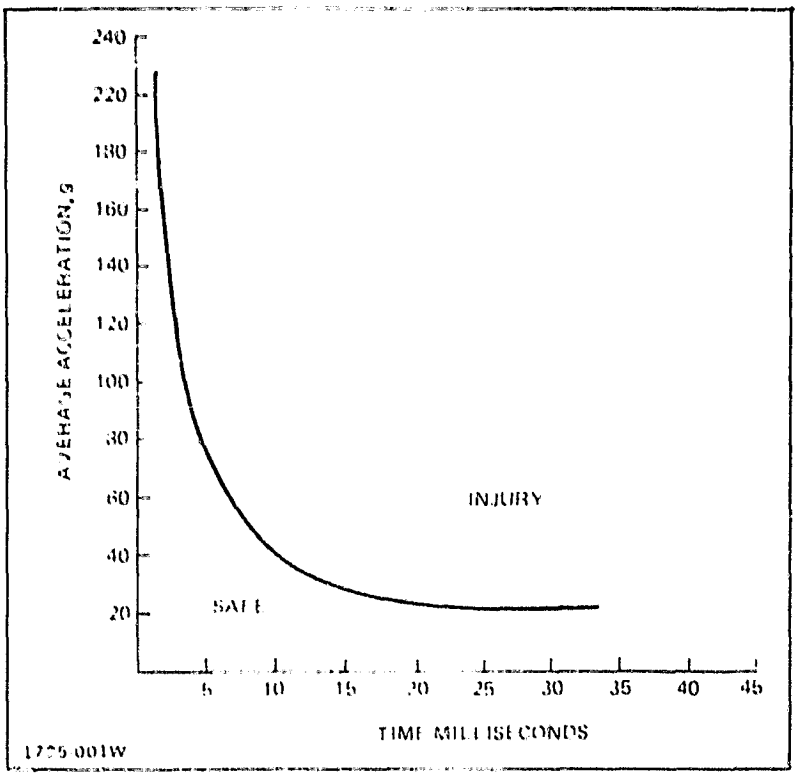


Fig. 10 Wayne State University Cerebral Concussion Tolerance Curve

TABLE 2 THERMAL ENVIRONMENTS

CLASS	AIR TEMP °C	RADIANT FLUX WATTS/CM²	EXPOSURE TIME
1	40 (104°F)	0.050	30 MIN
2	95 (203°F)	0.100	15 MIN
3	250 (482°F)	0.175	5 MIN
4	815 (1500°F)	4.200	10 SEC

1725-010D

PROJECT FIRES QUALIFICATION TEST METHODS

HEAD/EAR PROTECTION SUBSYSTEM (Cont)

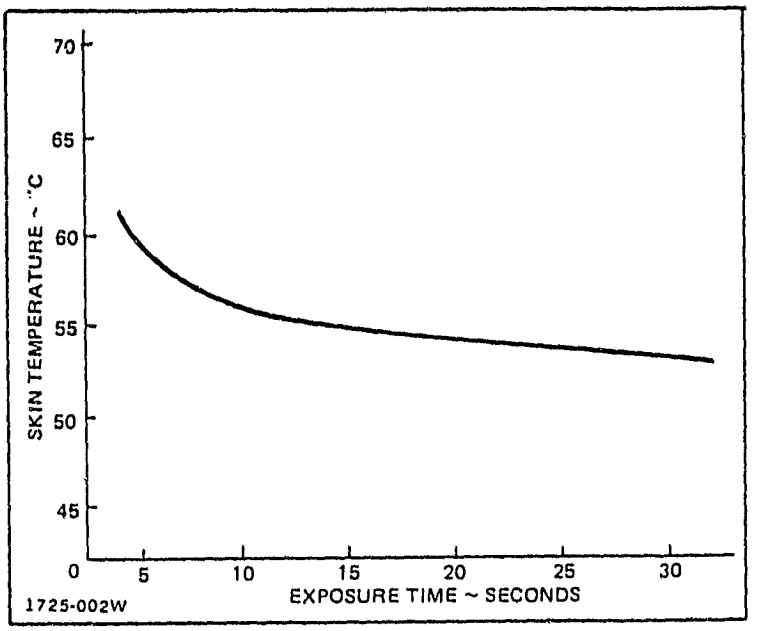


Fig. 1 Exposure Conditions for Threshold Blister

PROJECT FIRES QUALIFICATION TEST METHODS

HEAD/EAR PROTECTION SUBSYSTEM (Cont)

DRYABILITY

Requirement:

A head/ear protection subsystem that has been immersed in water for 5 seconds shall be capable of being dried after 1 hour in a 200°F oven.

Apparatus:

A container of water which is large enough to immerse the helmet, plus an oven.

Procedure:

1. Immerse the helmet in the water for 5 seconds.
2. Remove, shake off surface water, and place in 200°F oven for 1 hour.

Criteria:

All parts of the helmet shall be dry to the touch after the test.

PROJECT FIRES QUALIFICATION TEST METHODS

FACE/EYE PROTECTION SUBSYSTEM

IMPACT

Requirements:

The face/eye protection subsystem shall protect the firefighter's face and eyes from injury when impacted with 101 ft-lb. There shall be no spalling or shattering of the protector in the rearward direction (toward the face). The mounts that hold the protector to the head/ear protector shall not fail. This requirement shall be met at room temperature, immediately after the system has been subjected to the Class 3 heat environment described in Table 1, and immediately after achieving an equilibrium temperature of -7.5°F.

Apparatus:

The ANSI Z90 impact test apparatus shall be used.

Procedure:

1. Mount the face/eye protector to the helmet.
2. Fasten the helmet on the headform so that the deployed protector will strike a section of a rail on the floor.
3. Adjust the drop height so that 101 ft-lb of impact energy will be applied to the deployed protector when it strikes the rail.
4. The falling helmet and protector strikes the rail at the intersection of the basic and mid-sagittal planes as defined in the ANSI Z90.
5. Perform the tests at room temperature and within 20 seconds after being removed from the Class 3 heat environment described in Table 1, and immediately after achieving an equilibrium temperature of -7.5°F.

Criteria:

1. There shall be no visible particles, splinters, or debris ejected in a rearward direction (toward the face).

4

2. There shall be no breakage of the mounting hardware after testing. The protector shall be capable of being deployed and retracted freely after the impact testing. Surface scratches after the testing are permissible.

PROJECT FIRES QUALIFICATION TEST METHODS

FACE/EYE PROTECTION SUBSYSTEM (Cont)

PENETRATION

Requirements:

The face/eye protection subsystem shall not be penetrated by the tip of a 4 penny nail impacting the system with 10 ft-lb.

Apparatus:

The ANSI Z90 impact test apparatus shall be used.

Procedures:

1. Mount the face/eye protector to the helmet.
2. Fasten the helmet on the headform so that the deployed protector will strike the tip of a 4 penny nail which protrudes from a floor-mounted fixture.
3. Adjust the drop height so that 10 ft-lb of impact energy will be applied to the deployed protector when it strikes the tip of the nail.
4. The falling helmet and protector strikes the rail at the intersection of the basic and mid-sagittal planes as defined in the ANSI Z90.

Criteria:

1. There shall be no visible particles, splinters, or debris ejected in a rearwards direction (towards the face).
2. There shall be no evidence of penetration of the nail tip through the rear surface of the shield.

PROJECT FIRES QUALIFICATION TEST METHODS

FACE/EYE PROTECTION SUBSYSTEM (Cont)

CUT

Requirement:

The face/eye protection subsystem shall not be cut nor suffer any surface impairment by the sharp edge of a metal Venetian blind being drawn against the protector.

Apparatus:

Household type metal Venetian blind slat.

Procedure:

Draw the edge of the Venetian blind slat, under its own weight, across the surface of the faceshield for a distance of 12 inches.

Criteria:

There shall be no visible cut or surface degradation.

PROJECT FIRES QUALIFICATION TEST METHODS

FACE/EYE PROTECTION SUBSYSTEM (Cont)

SCRATCH

Requirement:

The face/eye protection subsystem shall not scratch after being rubbed with a dirty, sandy firefighter's glove at a moderate fingertip pressure over the width of the protection equipment for 5 cycles.

Apparatus:

Leather firefighter's glove and a 50-50 mixture (by weight) of motor oil and fine sand (approximately 140 mesh silica flour).

Procedure:

1. Saturate fingertips of the glove with the test mixture.
2. Rub the fingertips across the face of the protector at a contact pressure of approximately 1 psi for a total of five complete cycles.
3. Wash the debris off the protector with soap and water, and inspect the surface.

Criteria:

There shall be no visible scratches or surface degradation.

PROJECT FIRES QUALIFICATION TEST METHODS

FACE/EYE PROTECTION SUBSYSTEM (Cont)

FLAME

Requirement:

The face/eye protection subsystem shall not ignite, burn, char, melt, shrivel, or otherwise visually degrade when exposed to the tip of the inner cone of a Bunsen burner flame for 5 seconds.

Apparatus:

Bunsen burner with a barrel of 1/2 ±1/8 inchs without a flame spreader, fueled by gas of 1100 ± 200 Btu/ft^3.

Procedure:

1. Adjust inner cone of Bunsen flame to be 1 to 1-1/2 inches long.
2. Place tip of inner cone at a 45° angle to the test surfaces for 5 seconds and remove, and let surface cool.
3. Repeat the test on all the different materials present in the protector.

Criteria:

There shall be no ignition, burning, charring, melting, shrivelling, or any other visual degradation.

PROJECT FIRES QUALIFICATION TEST METHODS

FACE/EYE PROTECTION SUBSYSTEM (Cont)

HEAT

Requirement:

The face/eye protection subsystem shall withstand the thermal environments of Class 3 defined in Table 2 without any visible distortion and subsequently meet all other requirements of this specification.

When subjected to the Class 4 environment, the face/eye protection system shall remain intact.

Apparatus:

Environmental test chamber similar to that detailed in method 505 of MIL-STD-810, with appropriate modifications to accommodate the desired air temperature, radiant flux, and exposure times; thermocouples and temperature reading devices.

Procedure:

1. Mount the face/eye protector on the helmet.
2. Fit the helmet on a headform; deploy the face/eye protector.
3. Establish test conditions in the chamber and then place the helmet mounted on the headform into the chamber for the required exposure period. During this period, chamber temperatures shall not drop more than 25°F below the desired temperature.

Criteria:

There shall be no visible distortion after Class 3 exposures. The shield must only remain intact after Class 4 exposure.

PROJECT FIRES QUALIFICATION TEST METHODS

FACE/EYE PROTECTION SUBSYSTEM (Cont)

ELECTRICITY

Requirement:

The face/eye protection subsystem shall limit the current flow to less than 3 milliamperes when there is a 2200 volt A/C electrical potential between the outer surface of the system and the head.

Apparatus:

Insulation test apparatus with transformer having sinusoidal output voltage with a crest factor of 1.41 ± 0.07, and capability of applying 2200 volts A/C and monitoring leakage currents of 0 to 10 milliamperes.

Procedure:

1. Attach one terminal of the transformer to one face surface of the protector.
2. Attach the second terminal to the other face of the protector.
3. Apply a 60 Hz alternating current voltage and increase it to 2200 volts root mean square.
4. Maintain the voltage at 2200 ± 2% for 3 minutes.
5. Monitor the leakage current across the electrodes across the face of the shield.

Criteria:

There shall be less than 3 milliampere.. current.

PROJECT FIRES QUALIFICATION TEST METHODS

FACE/EYE PROTECTION SUBSYSTEM (Cont)

COVERAGE AND VISIBILITY

Requirement:

The face/eye protection subsystem shall:

a) cover the eyes, nose, cheekbones, and extend downwards from the head/ear protector to approximately the upper lip. It shall extend backwards to approximately the temple area, and in no way shall it reduce the firefighter's peripheral field of vision.

b) meet the latest revision of the optical performance requirements of the American National Standards Institute specification, ANSI Z87.1.

Apparatus:

1. Volunteer subjects covering the 5th to 95th anthropomorphic percentile.
2. Standard optical test apparatus per ANSI Z87.1.

Procedure:

1. Mount the face/eye protector on the test subjects and make visual observations of the coverage.
2. Follow the standard optical test procedures of ANSI 287.1.

Criteria:

As listed under requirements above.

PROJECT FIRES QUALIFICATION TEST METHODS

FACE/EYE PROTECTION SUBSYSTEM (Cont)

FOG

Requirement:

Fog shall not be allowed to form on the inside surface of the protector, nor shall moisture condense thereon.

Apparatus:

Source of boiling water, such as a kettle.

Procedure:

Hold the face/eye protector over the source of steam for 30 seconds.

Criteria:

No vapor shall condense on the vision surfaces of the protector.

PROJECT FIRES QUALIFICATION TEST METHODS

FACE/EYE PROTECTION SUBSYSTEM (Cont)

WATER PENETRATION

Requirement:

The face/eye protection subsystem shall not permit dripping overhead water or driving water from a rainstorm to enter the covered face area of the firefighter.

Apparatus:

Volunteer test subject and an overhead sprinkler system.

Procedure:

1. Mount the face/eye protector on the helmet.
2. The volunteer test subject, wearing the helmet and face shield, stands for 1 minute under a sprinkler head which is discharging at a rate of at least 13 gallons per minute.
3. The volunteer walks through the discharge spray a total of 15 times. With the head erect, the volunteer makes each walk-through at a slow walking pace.

Criteria:

No water shall enter the face and head area of the subject.

PROJECT FIRES QUALIFICATION TEST METHODS

FACE/EYE PROTECTION SUBSYSTEM (Cont)

DONNING/DOFFING

Requirement:

The face/eye protection subsystem shall not increase the time-to-don or the time to-doff of any other piece of firefighter's gear. It shall be capable of being deployed in 2 seconds, and shall be capable of being stowed in an out-of-the-way position within 3 seconds.

Apparatus:

Five volunteer test subjects.

Procedure:

The volunteers doff, don, deploy, and stow the face/eye protector and helmet combination.

Criteria:

As in the requirements above.

FACE/EYE PROTECTION SUBSYSTEM (Cont)

TABLE 2 THERMAL ENVIRONMENTS

CLASS	AIR TEMP °C	RADIANT FLUX WATTS/CM^2	EXPOSURE TIME
1	40 (104°F)	0.050	30 MIN
2	95 (203°F)	0.100	15 MIN
3	250 (482°F)	0.175	5 MIN
4	815 (1500°F)	4.200	10 SEC

1725-007D

PROJECT FIRES QUALIFICATION TEST METHODS

TORSO/LIMBS PROTECTION SUBSYSTEM

PENETRATION

Requirement:

The torso/limbs protection subsystem shall not be punctured by a 4 penny nail applied with a force of 22 lb.

Apparatus:

Spring-force penetration tester, mounting jig to hold garment.

Procedure:

1. Place a section of the garment on the mounting jig so that the test section is freely supported and not backed up by any structure.
2. Support the edges of the test section so the outer surface is taut.
3. Using the spring-force penetrator, determine the force required to drive a new 4 penny nail through the taut test surface.
4. Repeat until all representative surfaces are tested.

Criteria:

The force to penetrate must be greater than 22 lb.

PROJECT FIRES QUALIFICATION TEST METHODS

TORSO/LIMBS PROTECTION SUBSYSTEM (Cont)

CUT

Requirement:

The torso/limbs protection subsystem shall not be cut through when a 22 lb force is applied by a 21 gage sheet metal blade sharpened to a 60° angle.

Apparatus:

Weighted edge cut-test apparatus, such as described in "The Development of Criteria for Firefighters' Gloves", contract No. CDC-99-74-59, U.S. Department of Health, Education and Welfare, NIOSH, Cincinnati, Ohio 45202, Feb. 1976.

Procedure:

1. Place a section of the torso/limbs protection on the movable mandril of the test apparatus.
2. With increasing weights on the test edge, draw the sample across the blade.
3. Determine the minimum weight to cut through the protector.

Criteria:

The protector shall not be cut through when a force of 22 lb is applied to the test blade.

PROJECT FIRES QUALIFICATION TEST METHODS

TORSO/LIMBS PROTECTION SUBSYSTEM (Cont)

FLAME

Requirement:

1. Cell materials used in the torso/limbs protection subsystem shall meet the following performance when tested under Method 5903 of Federal Test Method Standard 191, Textile Test Methods:

Char length	4.0 inches maximum
After flame	2.0 seconds maximum

2. In addition, the protective subsystem shall not ignite, burn, char, melt, shrivel, or otherwise visually degrade when exposed to the tip of the inner cone of a Bunsen burner flame for 5 seconds.

Apparatus:

1. Flame test apparatus for Method 5903 of Federal Standard 191.
2. A Bunsen burner with a barrel of 1/2 ± 1/8 inch, without a flame spreader, fueled by gas of 1100 ± 200 Btu/ft^3.

Procedure:

1. For Method 5903, refer to Federal Standard 191.
2. Bunsen method:
   - Adjust inner cone of Bunsen flame to be to 1 to 1-1/2 inch
   - Place tip of inner cone at a 45° angle to the test surfaces for 5 seconds and remove, and let surface cool.
   - Repeat the test on all the different materials present in the protector.

Criteria:

1. For Method 5903: char length, 4.0 in. maximum; after flame, 2.0 seconds maximum.
2. For the 45° Bunsen burner test, there shall be no ignition, burning, charring, melting, shrivelling, or any other visual degradation.

PROJECT FIRES QUALIFICATION TEST METHODS

TORSO/LIMBS PROTECTION SUBSYSTEM (Cont)

HEAT

Requirement:

1. The torso/limbs protection subsystem shall withstand the thermal environment of Class 3 defined in Table 1 without any of the inner surfaces that contact the torso or limbs reaching 113°F, the pain threshold.
2. When subjected to the Class 4 environment defined in Table 2, the inner surfaces of the torso/limbs protection subsystem shall not exceed the temperature time limitations presented in Figure 1.
3. After having been showered with 180°F water at a rate of 16 gallons per minute for 1 minute, the subsystem shall withstand the thermal environments of Class 3 without vapor temperatures on the inside of the protector that exceed 113°F.
4. The subsystem shall allow the firefighter to kneel on a hot surface of 250°F for 5 minutes without the inner surface of the garment reaching 113°F, the pain threshold.
5. After wetting the subsystem under the conditions of paragraph 3, the firefighter shall be able to kneel on a 250°F hot surface for 5 minutes without the inside of the garment reaching more than 113°F, the pain threshold.

Apparatus:

Environmental test chamber similar to that detailed in Method 505 of MIL-STD-810 with appropriate modifications to accommodate the desired air temperature, radiant flux and exposure times; hot plate for contact temperature testing; sprinkler heads capable of flowing 16 gallons per minute; thermocouples and temperature recording devices.

Procedure:

1. Attach thermocouples to the inner surfaces of the garment and fit the garment on a manikin.
2. Establish test conditions in the chamber and perform any specimen conditioning, such as wetting, on the mounted specimen.

TORSO/LIMBS PROTECTION SUBSYSTEM (Cont)

HEAT (Cont)

Procedure (Cont):

3. Place the mounted specimen in the test chamber for the required exposure period. During this period, chamber temperatures shall not drop more than 25°F below the desired test temperature.

4. For the kneeling test, place the assembly on a 250°F hot plate pressed down with a force of 2 psi.

Criteria:

Inner surface temperatures shall not exceed the limits given in the requirements above.

PROJECT FIRES QUALIFICATION TEST METHODS

TORSO/LIMBS PROTECTION SUSBYSTEM (Cont)

MOBILITY

Requirement:

1. When wearing the torso/limbs protection subsystem, the firefighter shall be able to climb a flight of stairs at an energy expenditure no more than 10% greater than he would wearing his normal street clothes.
2. The subsystem shall allow a range of motion which is 95% of a firefighter without the subsystem.

Apparatus:

Five volunteer test subjects, Spirometer, 12-inch step

Procedure:

1. Energy expenditure:
   - A spirometer shall be used to measure the subject's oxygen consumption when performing a step test that simulates climbing a flight of stairs.
   - Run the step test with the subject stepping up and down at the rate of 30 steps a minute for 1 minute.
   - Perform the step test first wearing street clothes and then wearing the torso/limb protection subsystem.
   - Perform the tests when the subject is rested so there is no fatigue build up.
   - Perform three sets of tests on each subject and average the results for street clothes and for the protection subsystem.
2. Measure the range of motions the subjects can perform with and without the protection subsystem.

Criteria:

1. Energy expenditure wearing the protection subsystem shall be no more than 10% greater than the step test performed in street clothes.
2. Range of motions shall be 95% of that possible in street clothes.

PROJECT FIRES QUALIFICATION TEST METHODS

TORSO/LIMBS PROTECTION SUBSYSTEM (Cont)

WATER PENETRATION

Requirements:

The torso/limbs protection subsystem shall not:

1. Be wet on the inside by water falling on it at a rate of 13 gallons per minute from a height of 5 feet for 3 minutes,
2. increase in weight more than 5% after being subjected to the conditions of paragraph 1.
3. allow the firefighter to climb stairs at 116 steps per minute (approximately 580 Kcal/hr (2300 Btu/hr) heat production) for 3 minutes, without a sweat retention by the garment more than 50% greater than if he were wearing street clothes alone.

Apparatus:

Volunteer test subjects and an overhead sprinkler system.

Procedure:

1. Water spray:
   - The volunteer test subject, wearing the entire protective ensemble, stands for 1 minute under a sprinkler head which is discharging at a rate of at least 13 gallons per minute.
   - The volunteer walks through the discharge spray a total of 15 times. With the head erect, the volunteer makes each walk-through at a slow walking pace.
2. Weigh the torso/limbs protection subsystem after the test in paragraph 1.
3. Stair climbing:
   - Weigh the volunteer's entire clothing before performing the stair climbing task.
   - Immediately after the task, weight the clothing again. The increase in weight is considered due to sweat retention.

Procedure: (Cont)

- Repeat the step test wearing the torso/limbs protection subsystem, weighing the garments before and after the test.
- Determine the weight of sweat retained when wearing the protection system.

Criteria:

As listed in Requirements, above.

PROJECT FIRES QUALIFICATION TEST METHODS

TORSO/LIMBS PROTECTION SUBSYSTEM (Cont)

DONNING/DOFFING

Requirement:

The torso/limbs protection subsystem shall be capable of being donned or doffed in under 20 seconds.

Apparatus:

Five volunteer test subjects.

Procedure:

The volunteers doff and don the torso/limbs protector.

Criteria:

Donning or doffing within 20 seconds.

PROJECT FIRES QUALIFICATION TEST METHODS

TORSO/LIMBS PROTECTION SUBSYSTEM (Cont)

TABLE 2 THERMAL ENVIRONMENTS

CLASS	AIR TEMP °C	RADIANT FLUX WATTS/CM^2	EXPOSURE TIME
1	40 (104°F)	0.050	30 MIN
2	95 (203°F)	0.100	15 MIN
3	250 (482°F)	0.175	5 MIN
4	815 (1500°F)	4.200	10 SEC

1725-008D

PROJECT FIRES QUALIFICATION TEST METHODS

TORSO/LIMBS PROTECTION SUBSYSTEM (Cont)

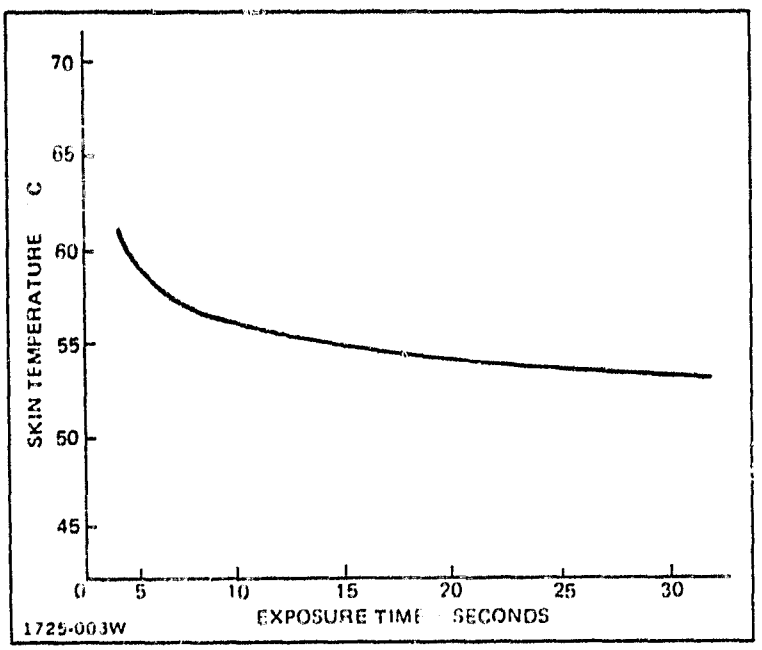


Fig. 1 Exposure Conditions for Threshold Blister

PROJECT FIRES QUALIFICATION TEST METHODS

HAND/WRIST PROTECTION SUSYSTEM

PENETRATION

Requirement:

The palm of the hand/wrist protection subsystem shall not be punctured by 4 penny nail applied with a force of 38.5 lb.

Apparatus:

Spring-force penetration tester, mounting jig to hold sample.

Procedure:

1. Place the protector on the mounting jig so that the test section is freely supported and not backed up by any structure.
2. Support the edges of the test section so the outer surface is taut.
3. Using the spring-force penetrator, determine the force required to drive a new 4 penny nail through the taut test surface.
4. Repeat until all representative surfaces are tested.

Criteria:

The force to penetrate the palm must be greater than 38.5 lb.

PROJECT FIRES QUALIFICATION TEST METHODS

HAND/WRIST PROTECTION SUBSYSTEM (Cont)

CUT

Requirement:

The hand/wrist protection subsystem shall not be cut through when a 22 lb force is applied by a 21 gage sheet metal blade sharpened to a 60° angle.

Apparatus:

Weighted edge cut-test apparatus, such as described in "The Development of Criteria for Firefighters' Gloves", contract No. CDC-99-74-59, U.S. Department of Health, Education and Welfare, NIOSH, Cincinnati, Ohio 45202, Feb. 1976.

Procedure:

1. Place a section of the hand/wrist protection on the movable mandril of the test apparatus.
2. With increasing weights on the test edge, draw the sample across the blade.
3. Determine the minimum weight to cut through the protector.

Criteria:

The protector shall not be cut through when a force of 22 lb is applied to the test blade.

PROJECT FIRES QUALIFICATION TEST METHODS

HAND/WRIST PROTECTION SUBSYSTEM (Cont)

FLAME

Requirement:

1. All materials used in the hand/wrist protection subsystem shall meet the following performance when tested under Method 5903 of Federal Test Method Standard 191, Testile Test Methods:

Char length	4.0 inches maximum
After flame	2.0 seconds maximum

2. In addition, the protective subsystem shall not ignite, burn, char, melt, shrivel, or otherwise visually degrade when exposed to the tip of the inner cone of a Bunsen burner flame for 5 seconds.

Apparatus:

1. Flame test apparatus for Method 5903 of Federal Standard 191.
2. A Bunsen burner with a barrel of 1/2 ± 1/8 inch, without a flame spreader, fueled by gas of 1100 ± 200 Btu/ft^3.

Procedure:

1. For Method 5903, refer to Federal Standard 191.
2. Bunsen method:
   - Adjust inner cone of Bunsen flame to be 1 to 1-1/2 inch
   - Place tip of inner cone at a 45° angle to the test surfaces for 5 seconds and remove, and let surface cool.
   - Repeat the test on all the different materials present in the protector.

Criteria:

1. For Method 5903, char length, 4.0 in. maximum; after flame, 2.0 seconds maximum.
2. For the 45° Bunsen burner test, there shall be no ignition, burning, charring, melting, shrivelling, or any other visual degradation.

PROJECT FIRES QUALIFICATION TEST METHODS

HAND/WRIST PROTECTION SUBSYSTEM (Cont)

HEAT

Requirements:

1. The hand/wrist protection system shall withstand the thermal environment of Class 3 defined in Table 2 without any of the inner surfaces that contact the hand or wrist reaching 113°F, the pain threshold..
2. When subjected to the Class 4 environment defined in Table 2, the inner surfaces of the hand/wrist protection subsystem shall not exceed the temperature time limitations presented in Figure 1.
3. The subsystem shall allow the firefighter to grip a 950°F hot surface with 4 psi pressure for five seconds without the inner surface of the garment reaching 113°F, the pain threshold.

Apparatus:

Environmental test chamber similar to that detailed in Method 505 of MIL-STD-810 with appropriate modifications to accomodate the desired air temperature, radiant flux and exposure times; hot plate for contact temperature testing; thermocouples and temperature recording devices.

Procedure:

1. Attach the thermocouples to the inner surfaces of the protector and fit the protector on a handform.
2. Place the mounted specimen in the test chamber for the required exposure period. During this period, chamber temperatures shall not drop more than 25°F below the desired test temperature.
3. For the grip test, place the assembly on a 950°F hot plate pressed down with a force of 4 psi.

Criteria:

Inner surface temperatures shall not exceed the limits given in the requirements above.

PROJECT FIRES QUALIFICATION TEST METHODS

HAND/WRIST PROTECTION SUBSYSTEM (Cont)

GRIP

Requirement:

A firefighter wearing the hand/wrist protection subsystem, both wet and dry, shall be capable of pulling a 1/2-inch nylon halyard with a force of at least 85% of his bare-handed capability.

Apparatus:

1/2-inch nylon halyard attached to spring force tester, pail of water, five volunteer test subjects

Procedure:

1. Each volunteer grips the halyard bare-handed without twisting his hand, and pulls vertically. Record the maximum pull exerted.
2. Repeat the test wearing the dry hand/wrist protection subsystem after a 5-minute rest period.
3. Repeat the tests after the protection subsystem has been held submerged in water up to the wrist for 15 seconds. While in the water, the fingers should be flexed into a fist and relaxed, once every 2 seconds.
4. After each volunteer performs the test three times, determine the average bare handed and average gloved dry and gloved wet results.

Criteria:

The average pulling force for each subject wearing the protection subsystem shall be at least 85% of each subject's force exerted bare-handed.

PROJECT FIRES QUALIFICATION TEST METHODS

HAND/WRIST PROTECTION SUBSYSTEM (Cont)

WATER PENETRATION

Requirements:

The hand/wrist protection subsystem shall:

1. prevent liquids from entering freely at or above the wrist,
2. absorb hand perspiration so that it does not feel uncomfortable,
3. not increase more than 50% of original weight after a gloved hand is immersed in water up to the wrist for 15 seconds,
4. not allow water to penetrate through the subsystem when it is immersed in water up to the wrist for thirty seconds (waterproof option only).

Apparatus:

Five volunteer test subjects, pail of water.

Procedure:

1. Items 1 and 2 above are to be evaluated subjectively.
2. Weigh the subsystem dry, and after immersion up to the wrist for 15 seconds, during which the fingers are clenched into a fist and unclenched once every 2 seconds.
3. For the waterproof option glove, the test subjects shall don the protector and immerse their hands up to the wrist for 30 seconds, clenching and unclenching their fingers once every 2 seconds.

Criteria:

As listed in Requirements, above.

PROJECT FIRES QUALIFICATION TEST METHODS

HAND/WRIST PROTECTION SUBSYSTEM (Cont)

DEXTERITY

Requirement:

A firefighter wearing the hand/wrist protection subsystem shall be capable of performing the Bennett Dexterity Test, in a time span less than 50% greater than the time required to perform the test with bare hands alone.

Apparatus:

Five volunteer test subjects; the Bennett Dexterity Test apparatus.

Procedure:

1. Using bare hands, and the tools provided, determine the time it takes for a volunteer to transfer the set of bolts and nuts from one side of the Bennett frame to the other.
2. Determine the time it takes the volunteer to do the task wearing the hand/wrist protection subsystem.
3. Each volunteer performs the task three times on different days. Average the times to complete the task bare-handed and wearing the protectors.

Criteria:

The averaged time for each subject to complete the Bennett test while wearing the hand/wrist protection subsystem shall be no more than 150% of his averaged time to complete the test bare-handed.

PROJECT FIRES QUALIFICATION TEST METHODS

HAND/WRIST PROTECTION SUBSYSTEM (Cont)

DONNING/DOFFING

Requirement:

The hand/wrist protection subsystem shall be capable of being donned or doffed in under 7 seconds.

Apparatus:

Five volunteer test subjects.

Procedure:

The volunteers doff and don the hand/wrist protector.

Criteria:

Donning or doffing within 7 seconds.

PROJECT FIRES QUALIFICATION TEST METHODS

HAND/WRIST PROTECTION SUBSYSTEM (Cont)

TABLE 2 THERMAL ENVIRONMENTS

CLASS	AIR TEMP °C	RADIANT FLUX WATTS/CM^2	EXPOSURE TIME
1	40 (104°F)	0.050	30 MIN
2	95 (203°F)	0.100	15 MIN
3	260 (482°F)	0.175	5 MIN
4	815 (1500°F)	4.200	10 SEC

1725-009W

PROJECT FIRES QUALIFICATION TEST METHODS

HAND/WRIST PROTECTION SUBSYSTEM (Cont)

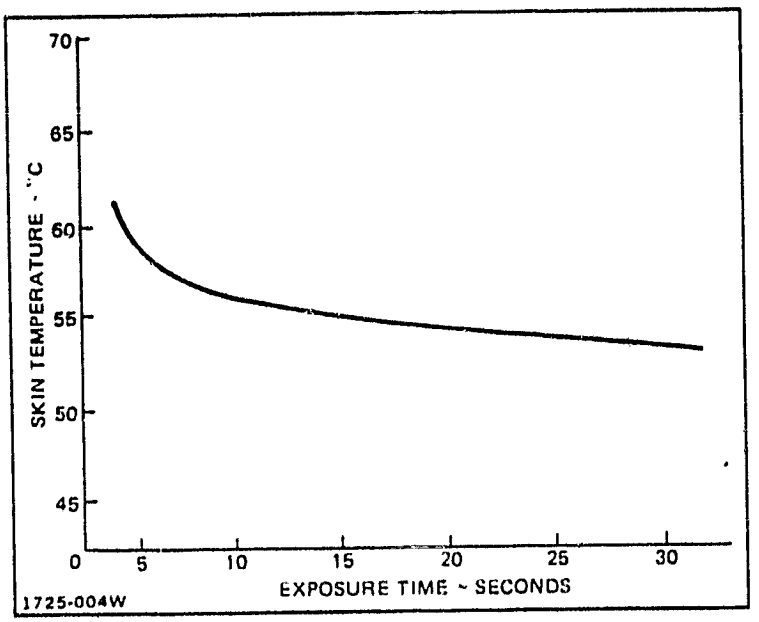


Fig. 1 Exposure Conditions for Threshold Blister

PROJECT FIRES QUALIFICATION TEST METHODS

FOOT/ANKLE PROTECTION SUBSYSTEM

IMPACT

Requirements:

The foot/ankle protection subsystem shall protect the toe from being bruised when impacted with 110 ft-lb, and shall protect the instep from being bruised by an impact force of 40 ft-lb.

Apparatus:

The ANSI Z41 Standard drop test apparatus shall be used.

Procedure:

Follow the ANSI Z41 procedure with appropriate modifications to impact mass and/or drop height to provide the required input energy.

Criteria:

The clearance criteria specified in ANSI Z41 shall be maintained.

PROJECT FIRES QUALIFICATION TEST METHODS

FOOT/ANKLE PROTECTION SUBSYSTEM (Cont)

COMPRESSION

Requirements:

The toe of the foot/ankle protection subsystem shall not be bruised by a 2200-lb compressive load.

Apparatus:

The ANSI Z41.1 compression test apparatus shall be used.

Procedure:

As in the ANSI Z41.1

Criteria:

The clearance criteria specified in ANSI Z41.1 (1/2-inch) shall be maintained.

FOOT/ANKLE PROTECTION SUBSYSTEM (Cont)

PENETRATION

Requirement:

1. The mid-sole of the foot/ankle protection subsystem shall not be penetrated by a 4 penny nail when a 400 lb force is applied.
2. The arch shall not be penetrated by a 4 penny nail when a 300 lb force is applied at right angles to the surface of the protector.

Apparatus:

Standard penetration test apparatus such as a spring force, or a load cell tester per ANSI Z41.5, shall be used.

Procedure:

Using the tester, determine the force to push new 4 penny nails through the mid-sole and through the arch area of the protector.

Criteria:

As in Requirements, above

PROJECT FIRES QUALIFCATION TEST PLANS

FOOT/ANKLE PROTECTION (Cont)

CUT - POWER SAW

Requirement:

The toe shall not be cut through by 5 seconds contact with a rotating tungsten - carbide blade of the firefighter's power saw.

Apparatus:

Power saw fitted with a tungsten-carbide blade.

Procedure:

1. Obtain the test specimens by cutting through the short dimension of the footwear not less than 1 inch back of the toe box. The upper and vamp shall be cut through so that the inner surfaces of the toe may be inspected.
2. Place a lump of modelling clay formed as a vertical cylinder into the test specimen.
3. Mount the test specimen on a cutting board either by nails or clamps so that it is firmly held.
4. Apply the rotating saw blade using the weight of the saw to bear down on the specimen.
5. Keep the blade in contact with the toe for 5 seconds.
6. Remove the cylinder of modelling clay and inspect for any evidence of cut.

Criteria:

There shall be no evidence of cutting through the toe cap.

PROJECT FIRES QUALIFICATION TEST METHODS

FOOT/ANKLE PROTECTION SUBSYSTEM (Cont)

CUT

Requirement:

The foot/ankle protection subsystem shall not be cut through when a 22 lb force is applied by a 21 gage sheet metal blade sharpened to a 60° angle.

Apparatus:

Weighted edge cut-test apparatus, such as described in "The Development of Criteria for Firefighters' Gloves", contract No. CDC-99-74-59, U.S. Department of Health, Education and Welfare, NIOSH, Cincinnati, Ohio 45202, Feb. 1976.

Procedure:

1. Place a section of the foot/ankle protection on the movable mandril of the test apparatus.
2. With increasing weights on the test edge, draw the sample across the blade.
3. Determine the minimum weight to cut through the protector.

Criteria:

The protector shall not be cut through when a force of 22 lb is applied to the test blade.

PROJECT FIRES QUALIFICATION TEST METHODS

FOOT/ANKLE PROTECTION SUBSYSTEM (Cont)

FLAME

Requirement:

The materials that comprise the foot/ankle protection subsystem shall not ignite, burn, char, melt, shrivel, or otherwise visually degrade when exposed to the tip of the inner cone of a Bunsen burner flame for 5 seconds.

Apparatus:

Bunsen burner with a barrel of 1/2 + 1/8 inch, without a flame spreader, fueled by gas of 1100 ± 200 Btu/ft^3.

Procedure:

1. Adjust inner cone of Bunsen flame to be 1 to 1-1/2 inch long.
2. Place tip of inner cone at a 45° angle to all materials for 5 seconds and remove, and let surface cool.
3. Repeat the test on all the different materials present in the protector.

Criteria:

There shall be no ignition, burning, charring, melting, shrivelling, or any other visual degradation.

PROJECT FIRES QUALIFICATION TEST METHODS

FOOT/ANKLE PROTECTION SUBSYSTEM (Cont)

HEAT

Requirements:

1. The foot/ankle protection subsystem shall withstand the thermal environments of Class 3 defined in Table 2 without any of the inner surfaces that contact the feet or ankles reaching 113°F, the pain threshold.
2. When subjected to the Class 4 environment defined in Table 2, the inner surfaces of the foot/ankle protection subsystem shall not exceed the time temperature limits presented in Figure 1.
3. After soaking the exterior of the protector in water for 5 minutes, the system shall withstand the thermal environments of Class 3 without resulting in temperatures on the inside of the protector that exceed 113°F.
4. The firefighter shall be able to stand on a metal surface 250°F for 10 minutes without any surface of the foot/ankle protection subsystem reading 113°F, the pain threshold.
5. The firefighter shall be able to stand in 180°F water 1-1/2 inch deep for 10 minutes without any inner surface of the foot/ankle protection subsystem reaching 113°F, the pain threshold.

Apparatus:

Environmental test chamber similar to that detailed in Method 505 of MIL-STD 810, with appropriate modifications to accommodate the desired air temperature, radiant flux and exposure times; thermocouples and temperature reading devices; hot plate; hot water bath.

Procedure:

1. Thermocouples shall be attached to the following areas inside the boot:
   - Insole ball area
   - Insole heel area
   - Upper vamp (over the ball area)
   - Side ankle area
   - Rear upper area

FOOT/ANKLE PROTECTION SUBSYSTEM (Cont)

HEAT (Cont)

Procedure (Cont):

2. A mandrel simulating a foot, ankle and calf shall be inserted into the boot to prevent ambient airflow.
3. For tests in paragraphs 1 through 3 under "Requirements," establish the test conditions in the chamber first, and then place the boot together with the mandrel and the temperature transducers in the chamber for the required exposure period.
4. Conduct heat test for items 4 and 5 under "Requirements," using a hot plate and a temperature controlled bath. In both cases, weigh the assembly down to provide 4 psi contact pressure.

Criteria:

As listed in the Requirements, above.

PROJECT FIRES QUALIFICATION TEST METHODS

FOOT/ANKLE PROTECTION SUBSYSTEM (Cont)

ELECTRICITY

Requirement:

The foot/ankle protection subsystem shall limit the current flow to less than 3 milliamperes when there is a 2200 volt A/C electrical potential between the outer surface of the system and the head.

Apparatus:

Insulation test apparatus with transformer having sinusoidal output voltage with a crest factor of 1.41 ± 0.07, and capability of applying 2200 volts A/C and monitoring leakage currents of 0 to 10 milliamperes.

Procedure:

Use the procedure outlined by ANSI Z41.4 1976 Standard for Electrical Hazard Safety Toe Footwear.

Criteria:

There shall be less than 3 milliamperes current.

PROJECT FIRES QUALIFICATION TEST METHODS

FOOT/ANKLE PROTECTION SUBSYSTEM (Cont)

MOBILITY

Requirement:

When wearing the foot/ankle protection subsystem, the firefighter shall be able to climb a flight of stairs at an energy expenditure no more than 10% greater than he would wearing his normal street clothes.

Apparatus:

Five volunteer test subjects.

Procedure:

1. Use a spirometer to measure the subject's oxygen consumption when performing the 12 in. step test that simulates climbing a flight of stairs.
2. Run the 12 in. step test with the subject stepping up and down at the rate of 30 steps a minute for 1 minute.
3. Perform the 12 in. step test wearing street clothes and when wearing the foot/ankle protection subsystem.
4. Perform the tests when the subject is rested so there is no fatigue build-up.
5. Perform three sets of tests on each subject and average the results for street clothes and for the protection subsystem.

Criteria:

Energy expenditure wearing the protection subsystem shall be no more than 10% greater than the step test performed in street clothes.

PROJECT FIRES QUALIFICATION TEST PLANS

FOOT/ANKLE PROTECTION SUBSYSTEM (Cont)

TRACTION

Requirement:

The foot/ankle protection subsystem shall provide the same traction on dry surfaces as that provided by Vibram-soled hiking boots. On wet surfaces 90% of the dry-surface traction shall be provided.

Apparatus:

1/2-inch nylon halyard attached to spring-force tester.

Procedure:

1. Attach the frame of the spring-force tester to a fixed support such as a wall, at approximately waist level of a volunteer wearing Vibram-soled hiking boots.
2. Fasten a 1/2-inch nylon halyard to the spring end of the tester.
3. The volunteer grasps the halyard with both hands, places his feet together, and leans back away from the tester keeping his knees together.
4. The volunteer leans back until his feet start to slip. Note the reading on the spring-force tester when slippage first occurs.
5. Repeat Steps 3 and 4 with the volunteer wearing the test item.
6. Repeat Step 5 with the test surface wet.

Criteria:

With a dry surface, the force reading at which the test item slips shall be equal or greater than the reading when the Vibram-soled hiking boots slip. With a wet surface the test item reading shall be 90% or greater than that obtained with the dry surface.

FOOT/ANKLE PROTECTION SUBSYSTEM (Cont)

WATER PENETRATION

Requirement:

The firefighter shall be able to stand in 8-inch deep water for 30 minutes without water penetrating through the foot/ankle protection subsystem. The interface between the foot and leg protectors shall prevent water entry.

Apparatus:

Water bath and footform.

Procedure:

1. Fit the subsystem with a flexible footform around which blotting paper has been applied.
2. Lower the weighted boot and footform into room temperature water and allow to stand for the 30-minute exposure period in a normal upright position.
3. During this time, flex the footform to simulate boot flexing during a normal 3 mph walking gait.
4. At the conclusion of the period, examine the blotting paper for any evidence of seepage.

Criteria:

There shall be no evidence of water seepage on the blotting paper.

PROJECT FIRES QUALIFICATION TEST METHODS

FOOT/ANKLE PROTECTION SUBSYSTEM (Cont)

DONNING/DOFFING

Requirement:

The foot/ankle protection subsystem shall be capable of being donned or doffed in under 15 seconds.

Apparatus:

Five volunteer test subjects.

Procedure:

The volunteers don and doff the foot/ankle protection subsystem.

Criteria:

Donning and doffing must each be accomplished within 15 seconds by all of the volunteer subjects.

PROJECT FIRES QUALIFICATION TEST PLANS

FOOT/ANKLE PROTECTION SUBSYSTEM (Cont)

TABLE 2 THERMAL ENVIRONMENTS

CLASS	AIR TEMP °C	RADIANT FLUX WATTS/CM^2	EXPOSURE TIME
1	40 (104°F)	0.050	30 MIN
2	95 (203°F)	0.100	15 MIN
3	250 (482°F)	0.175	5 MIN
4	815 (1500°F)	4.200	10 SEC

1725-010D

PROJECT FIRES QUALIFICATION TEST PLANS

FOOT/ANKLE PROTECTION SUBSYSTEM (Cont)

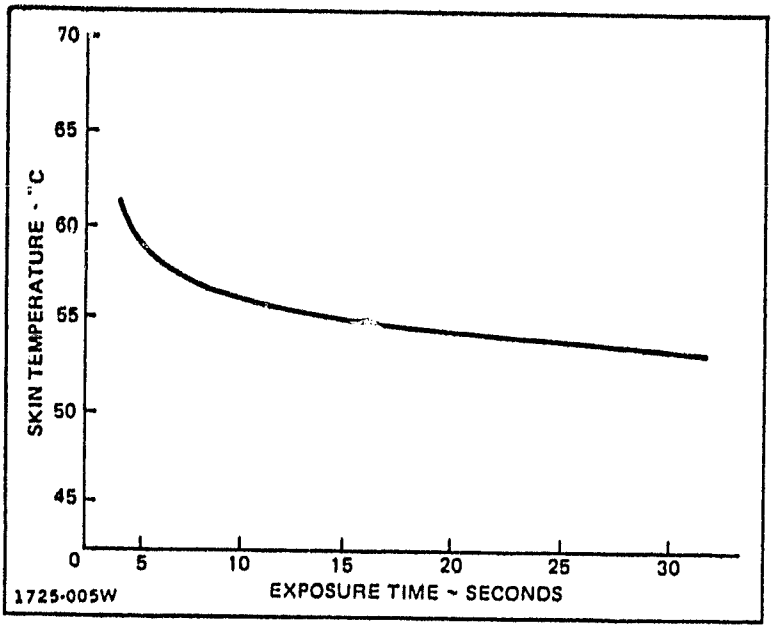


Fig. 1 Exposure Conditions for Threshold Blister

PROJECT FIRES QUALIFICATION TEST METHODS

PROTOTYPE PROTECTIVE ENSEMBLE

WATER PENETRATION

Requirement:

The protective ensemble shall not allow any penetration by falling water at a rate of 13 gallons per minute from a height of 5 feet.

Apparatus:

Volunteer test subjects and an overhead sprinkler system.

Procedure:

1. The volunteer test subject, wearing the entire protective ensemble, stands for 1 minute under a sprinkler head which is discharging at a rate of at least 13 gallons per minute.
2. The volunteer test subject then walks through the discharge spray a total of 15 times. With the head erect, the volunteer makes each walk-through at a slow walking pace.

Criteria:

There shall be no water penetration felt by the volunteer.

PROJECT FIRES QUALIFICATION TEST METHODS

PROTOTYPE PROTECTIVE ENSEMBLE (Cont)

MOBILITY

Requirement:

When wearing the complete protective ensemble, the firefighter shall be able to climb a flight of stairs at an energy expenditure no more than 21% greater than he would wearing his normal street clothes.

Apparatus:

Five volunteer test subjects, Spirometer, 12-inch step

Procedure:

1. Use a spirometer to measure the subject's oxygen consumption when performing a step test that simulates climbing a flight of stairs.
2. Run the step test with the subject stepping up and down at the rate of 30 steps a minute for 1 minute.
3. Perform the step test first wearing street clothes and then wearing the protective ensemble.
4. Perform the tests when the subject is rested so there is no fatigue build-up.
5. Perform three sets of tests on each subject and average the results for street clothes and for the protective ensemble.

Criteria:

Energy expenditure wearing the ensemble shall be no more than 21% greater than the step test performed in street clothes.

PROJECT FIRES QUALIFICATION TEST METHODS

PROTOTYPE PROTECTIVE ENSEMBLE (Cont)

COMPATIBILITY

Requirement:

There shall be no interferences between the various components of the system, and between any parts of the system and the 4500 psi-breathing system and/or a sling-type communication system.

Apparatus:

Volunteer test subjects, self-contained, breathing system, sling-type communication system, fire academy smoke house.

Procedure:

1. Using the fire academy smoke house facility, the volunteers perform a search-and-rescue training exercise.
2. Establish smoke conditions before the volunteer enters the building.
3. The subject uses the radio to communicate his progress.
4. Locate and carry the rescue dummy out of the building.
5. Query the volunteers to ascertain if there were any interferences felt during the experiment.

Criteria:

There shall be no interferences experienced by the volunteers.

PROJECT FIRES QUALIFICATION TEST METHODS

PROTOTYPE PROTECTIVE ENSEMBLE (Cont)

HEAT CLASS 4 (FLASHOVER)

Requirements:

The protective ensemble shall prevent blistering of the skin when exposed to a combined heat load of 1500°F ambient temperature plus 4.2 watts/cm radiation, for 10 seconds.

Apparatus:

Instrumented manikin, flashover chamber

Procedure:

1. Install thermocouples in the instrumented manikin to monitor the simulated skin temperature.
2. Clothe the manikin with the complete protective ensemble.
3. Establish the required test conditions in the chamber and expose the manikin for 10 seconds.

Criteria:

The recorded skin time-temperature curve shall be lower than or equal to the curve shown by Figure 1.

PROJECT FIRES QUALIFICATION TEST PLANS

PROTOTYPE PROTECTIVE ENSEMBLE (Cont)

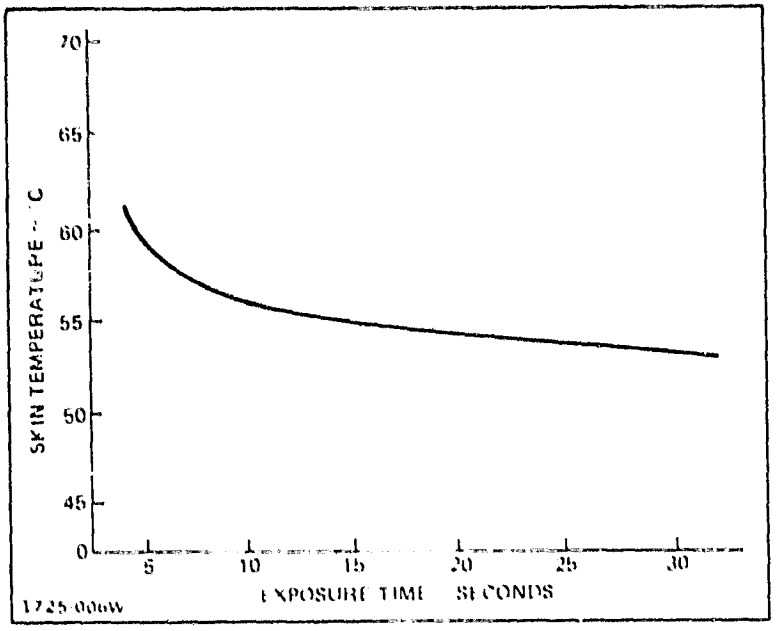


Fig. 1 Exposure Conditions for Threshold Blister

PROJECT FIRES QUALIFICATION TEST PLANS

PROTOTYPE PROTECTIVE ENSEMBLE (Cont)

COLD INSULATION

Requirement:

When wearing the protective ensemble the firefighter shall be able to perform his normal duties without compromise for 15 minutes in a 10°F atmosphere with a wind-chill factor of -58°F.

Apparatus:

Volunteer subject and an environmental chamber.

Procedure:

The subject shall don the entire protective ensemble and enter the cold chamber for the required time, until he requests to leave.

Criteria:

The ensemble shall allow the volunteer to remain in the chamber for 15 minutes.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1980-640 247/99 REGION NO. 4