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INSULATED FIREFIGHTERS' CRASH-CREW RESCUE BOOTS AND COMPONENTS:--ETC(U)
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Insulated Firefighters' Crash-Crew Rescue Boots and Components: Field and Laboratory Evaluation

LEVEL II

MILTON BAILEY

NAVY CLOTHING AND TEXTILE RESEARCH FACILITY
21 STRATHMORE ROAD
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DECEMBER 1978

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CIVIL AND ENVIRONMENTAL ENGINEERING DEVELOPMENT OFFICE
(AIR FORCE ENGINEERING AND SERVICES CENTER)
TYNDALL AIR FORCE BASE
FLORIDA 32403

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number):

The Navy Clothing and Textile Research Facility (NCTRF) conducted an evaluation of commercial insulated firefighters' boots worn by crash firefighters representing three Navy Air Stations and three Air Force Bases. The evaluation revealed that the insulated footwear was significantly superior to the standard firefighters' boots currently in the supply system. Reflective spats, accessories sometimes used to cover boots for additional protection against high heat, were considered unnecessary by the subjects who thought

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the insulation of the test boots provided sufficient protection. Laboratory findings, however, showed that spats would indeed be needed if personnel became immobilized and were subjected to 1.89 $gcal/cm^2/sec$ heat for 30 seconds or longer. The laboratory tests also showed that the heat rapidly penetrates and destroys soiled aluminized fabrics. Based on these findings, NCTRF recommends: (1) insulated firefighters' boots replace standard firefighters' boots; (2) commercial aluminized spats be stocked as supporting gear; and (3) reflectivity of aluminized fabrics generally, and of spats particularly, be policed and maintained daily to assure peak personnel protection at all times.

PREFACE

This report was prepared by the Navy Clothing and Textile Research Facility (NCTRF) under contract AFCEC P.O. 77-02, Job Order Number 414N-30-06, for Civil and Environmental Engineering Development Office (CEEDO), Detachment 1, ADTC, Tyndall Air Force Base, Florida.

This report summarizes work done between October 1976 and September 1977. Mr C. Zemme as the lead project manager at NCTRF and Mr M. Bailey of NCTRF was the project leader. Air Force project managers (during successive periods) were Major B. Pease, Mr N. Knowles and Mr L. Redman.

The following contributed to the success of this investigation: Mr. S. Bernstein and Mr. K. Spindola of NCTRF; Mr. J. Jones, Endicott Johnson Co., Endicott, N. Y.; Mr. D. J. Kaufman, Uniroyal, Naugatuck, CN: Mr. F. Calafano and Mr R. Dean, Servus Rubber Co., Rock Island, IL.

The Air Force and Navy crash crew personnel who recorded their experiences with standard and test firefighters' boots, and their chiefs who monitored the evaluations deserve a substantial share of the credit for the information in this report. They include: Fire Chief K. L. Johnson, Naval Air Station, Oceana, Virginia Beach, VA; Fire Chief D. K. Young, Naval Air Station, Cecil Field, Jacksonville, FL; Fire Chief Price, Naval Air Station, Miramar, San Diego, CA; Major Gott, Director, Chanute Air Force Base, Firefighters' School Rantoul, IL; Fire Chief W. Million, Eilson Air Force Base, Fairbanks, AK; and Fire Chief Goodwin, Tyndall Air Force Base, Panama City FL.

This report has been reviewed by the Information Officer (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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SECTION I

INTRODUCTION

Navy Clothing and Textile Research Facility (NCTRF) tested knee-length, insulated firemen's crash-crew rescue boots and aluminized spats at six Military Air Fields in continental United States and Alaska at the request of the Commander, Civil and Environmental Engineering Development Office, HQ ADTC, Tyndall Air Force Base, Florida. The work was done to determine: (1) the relative effectiveness of insulated firefighters' boots versus standard firefighters' boots designated Type II, Knee-Length Boots, Firemen's of MIL-B-2885; and (2) the usefulness of aluminized reflective spats for protection against radiant heat energy (1.9 gcal/cm2/sec) emanating from J-P4 and J-P5 airplane fuel fires. The insulated boots are similar to standard firemen's boots except that they incorporate a layer of any one of the following insulations around the foot and ankle: urethane foam, wool fleece, or vinyl foam. In addition, they contain a 3/8-inch thickness of felt between the outsole and steel midsole. Both standard and insulated boots have outer sheets of isoprene rubber and contain steel safety toes that can protect against 75 foot-pounds impact. The steel midsole is intended for protection against jutting nails and spikes sometimes encountered in hazard areas.

The test subjects, Navy and Air Force crash firefighters, wore the commercial insulated firefighters boots and reflective aluminized spats for 4 months during severe training exercises and routine details. At the termination of the test, they completed a detailed questionnaire (see the appendix) and compared the performances of test boots with their own standard boots. Related laboratory information was obtained by measuring the heat transfer rates of the test-boot, standard-boot, and aluminized fabric spat components. The findings of the study showed that insulated firefighters' boots were preferred to the standard firefighters' boots and that they were more protective against radiant heat. Reflective spats were effective but subjects judged them unnecessary in most fire environments when insulated boots are used. Laboratory findings, however, indicate reflective spats would be essential if personnel were trapped in a fire and absorbed high heat pulses of 1.89 gcal/cm^2/sec for 30 seconds or longer. The reflective surface must be clean and shiny, however; otherwise the heat is absorbed and burns through the aluminized surface and fabric. Based on these findings NCTRF recommends: the adoption of insulated firefighters' boots to replace standard boots; the inclusion of commercial spats as supporting gear by firefighting facilities for use against high heat fires; the cleaning of reflective surfaces of spats particularly and firefighters' garments generally, immediately after wear; and the continual inspection of reflective surfaces to assure maximum reflectivity and protection to personnel at all times.

The purpose of this report is to discuss the approach and disclose new findings developed by this study which implemented prior recommendations (Reference 1).

SECTION II

PROCEDURE

The field evaluation required the procurement of insulated boots including insulated and noninsulated rubber boot component sections from the three sources: Servus Rubber Company, Rock Island, IL, which insulates with polyurethane foam; Endicott Johnson Company, Endicott, NY, which insulates with wool fleece; and Uniroyal, Naugatuck, CN, which insulates with vinyl foam.

The companies supplied sufficient component materials for duplicate and triplicate matched-set testing of insulated versus noninsulated boot sections for reliably replicate determinations of comparative heat transfer characteristics. The tests were performed as described in References 1 and 2. Comparative tests were also conducted on 20-ounce reflective, aluminized rayon and 6-ounce reflective, aluminized Nomex fabrics separately and as the outer layers of the rubber boot components to determine the heat-attenuating effects of the reflective surfaces when applied to boot components. The reflective Nomex and rayon fabrics were obtained from Fyrepel Company, Newark, OH, and Mine Safety Appliance Company, Pittsburgh, PA, respectively. They also provided Nomex aluminized spats and aluminized rayon spats for field testing.

Test sites, selected to represent a variety of climatic conditions ranging from subtropical heat to artic cold, were:

1. Naval Air Station, Oceana, Virginia Beach, VA
2. Naval Air Station, Cecil Field, Jacksonville, FL (six subjects)
3. Naval Auxiliary Landing Field, Fentriss, VA (eight subjects)
4. Naval Air Station Miramar, San Diego, CA (eight subjects)
5. Chanute Air Force Base, Rantoul, IL (12 subjects)
6. Eielson Air Force Base, Fairbanks, AK (five subjects)
7. Tyndall Air Force Base, Panama City, FL (six subjects)

The Appendix, the comparison questionnaire for determining differences between the insulated versus standard noninsulated firemen's boots, solicited comparative responses to: Overall acceptance of boots and spats, protection, fit, comfort, traction, mobility, durability, and injuries and burns attributable to fighting fires. The questionnaire was completed at the end of the 4-month test period. The responses were correlated with appearance of the test and standard footwear and spats inspected during visits to the test sites and after their return to NCTRF at the completion of the evaluations.

Subjects were also observed extinguishing training fires of JP-4 and JP-5 fuels, simulating crash-crew operations on burning planes. Subjects, their supervisors, and chiefs were interviewed after the trials about the performance of their footwear. The test and standard footwear responses for each site were averaged, analyzed, and compared.

SECTION III

DISCUSSION

Comparing insulated boots versus standard firefighters' boots shows that Navy and Air Force firefighters at all six test sites unanimously prefer the insulated boots (see Figures 1 through 6 and Tables 1 through 6). On the rating scales (Figures 1 through 6) the subjects' means for the insulated boots show that heat protection responses range from good to excellent while the comparative responses for the standard noninsulated boots fall to fair and inadequate. The insulated-boot means relating to responses (Figures 1 through 6) for general preference, pulling on boots, fit, traction, mobility, and comfort also are consistently superior to the means of the standard boots. Tables 1 through 6 show every subject but one expressed a real need for insulated boots. This subject from NAS, Oceana, VA, saw no difference between the two types of boots. It should be noted that these boots are available in women's sizes. In fact, a female test subject at the Naval Auxiliary Landing Field, Fentriss, VA, adjoining NAS Oceana, VA, also found the insulated boot superior.

The wear test showed minor damage to one insulated boot when a wheel ran over the toe at NAS, Miramar, San Diego, CA. But tears and cracks in the upper boot and the heels were reported in standard boots. These damages are considered inconsequential because the median wear of the standard item at Miramar is 36 months. At the Chanute AFB firefighters' school, where boots are exposed to high heat training-type fires at least three times weekly, the rubber skins of both insulated and standard boots were seared and softened. Here the median wear-life for the standard item is 6 months. At other sites where training fire exposures are not as severe, Tables 1 through 6 show that the wear-life of the standard boot ranges from 12 to 48 months. Inspection of worn insulated boots at the sites suggest the test boots would last as long as the standard.

Because of the extreme cold at Eielson AFB, AK, firefighters indicated the need for a felt sock similar to that worn in mukluk-type arctic footwear. To be prepared for night calls, Eielson personnel complained they are forced to sleep with three pairs of socks so that they can jump into the standard boot when summoned suddenly to a fire. The insulated boots, while superior to the standard in overall thermal protection, also require several layers of socks or one pair of suitable felt socks to withstand the sub-zero cold of Alaska.

USE OF ALUMINIZED SPATS

Reference 1 emphasized the value of heat reflective aluminized surfaces as an effective means of attenuating infrared heat. To test the concept and its acceptance by crash-crew personnel, 6-ounce aluminized Nomex spats and 20-ounce aluminized rayon spats were worn by subjects over the exposed upper foot sections of firemens' boots not covered by the pants legs. The 20-ounce rayon spats were fastened to the boots with leather straps; the 6-ounce Nomex spats used nylon-velcro fasteners.

Users found both fastening systems unsuitable. The leather straps were too short and mud compromised the holding strength of the Velcro. As shown in Tables 1 through 6, the use of spats was minimal. Subjects felt they were totally unnecessary because they expected to be completely protected by the boot insulation. The spats seemed to be a bother because they were easily soiled during work and drills and required care to maintain the reflective surfaces. Two subjects, however, cited a need for spats with the insulated boots. Inconsequential day-to-day experience and periodic drills reinforced the disinclination of most firefighting personnel to wear spats. Yet some recognized, in the event of unexpected entrapment that spats, insulated boots, and well-maintained reflectsive ensembles would be absolutely necessary for protection against high doses of infrared energy radiating from fire.

HEAT TRANSFER MEASUREMENTS

Heat transfer measurements followed the procedure reported in Reference 1 entailing the application of a 1.89 gcal/cm^2 sec heat pulse to the exterior of a component boot section and measuring the transferred heat to its interior surface. These uninsulated and matched insulated boot components were tested with and without 6-ounce aluminized Nomex or 20-ounce aluminized rayon bonded to outer rubber surface by solvent neoprene cement. Table 7 shows measurements of noninsulated components and of urethane-foam insulated components from Servus Rubber Company. Table 8 shows measurements of noninsulated components and of wool-fleece insulated components from Endicott-Johnson. Table 9 shows measurements of noninsulated components and of vinyl-foam insulated components from Uniroyal. Table 10 illustrates the heat transfer rates of aluminized fabrics used as spats and as exterior layers for the boot component sections discussed above. Tables 7 through 9 illustrate the residual heat flux of black rubber components and demonstrate why foot pain is initially experienced by standard boot users shortly after they cease being exposed to training fires. In one instance (Table 7) the transmission rate of standard boot specimen 3 reached 0.152 gcal/cm^2/ sec in 11 seconds, 5 seconds after exposure to heat radiation ceased. Had the pulse lasted 30 seconds the flux would have been sufficient to cause blisters (Reference 3). Tables 7 through 9 also show that residual heat values of the insulated boot components remain below the pain threshold value of 0.06 gcal/cm^2/sec for 30 seconds. Yet it is possible for standard boot components to transfer a relatively high residual no-pain threshold heat of 0.044 gcal/ cm^2/sec after a 20-second exposure to 1.89 gcal/cm^2/sec. The data suggest that residual heat pain would be considerably less of a problem for users of insulated boots. All black outer rubber components of standard and insulated boots tended to melt, smoke, and burn after a few seconds exposure. The matched clean component samples containing outer aluminized fabric layers did not melt. Moreover, these clean samples inhibited heat transfer. The heat transfer rates never exceeded 0.070 gcal/cm^2/sec for standard boot component sections, nor 0.026 gcal/cm^2/sec for insulated boot component sections, after 300 seconds exposure. Table 7 discloses the accelerating effect of dirt on the heat transfer rate of the aluminized-Nomex insulated boot specimen N-3 which measured 0.064 gcal/cm^2/sec after a 120-second pulse. This highlights the hazard of an accidental smudge on a reflective surface. The smudge cancelled the fabric reflectivity and behaved like a heat sink, contributing to a 0.071 gcal/cm^2/sec residual heat flux in 140 seconds - 20 seconds after the heat pulse was terminated.

Similarly, reflective aluminized rayon speciment R-2 (Table 10, Note 1), intentionally spotted with cigarette ash and ink, smoked and burned when subjected to the 1.89 gcal/cm^2/sec pulse for 195 seconds. The transferred heat rose to an injurious 0.107 gcal/cm^2/sec during the interval.

Although insulated boots are superior to noninsulated boots, the results indicate:

1. Insulated footwear exclusive of reflective barriers provides insufficient protection to personnel exposed to high infrared heat (1.89 gcal/cm^2/sec) over a period exceeding 30 seconds, as could occur were firefighters trapped in a flaming area without support needed for their rescue.

2. Soiled reflective surfaces seriously reduce the heat attenuating effects of aluminized fabrics and must be cleaned continually to assure effectiveness.

3. A reflective surface laminated to insulated components provides the greatest minimization of heat transfer and assures maximum protection by boots during prolonged exposures to fire.

SECTION IV

CONCLUSIONS

The findings of this study lead to the conclusions:

1. Insulated boots are more protective and are more preferred by firefighters than the standard insulated boots available from the Supply System.

2. Reflective spats are effective, but firefighters judge them unnecessary for day-to-day use when insulated boots are worn.

3. The use of reflective spats, however, would be absolutely necessary if firefighters were immobilized and exposed to high heat pulses of 1.89 $gcal/cm^2/sec$ over a period of 30 seconds or longer.

4. Spats could also prolong wear and prevent damage to the outer surface of rubber boots during training fires.

SECTION V

RECOMMENDATIONS

Based on results of laboratory testing and findings in field evaluations at six diverse sites the following are recommended.

1. Insulated firefighter boots should replace current standard boots for use with aluminized proximity firefighters clothing.

2. Although aluminized spats are considered unnecessary by personnel when insulated boots are used, the stocking of commercial spats by firefighting facilities is recommended as supporting gear for protection against high-heat or unquenchable fires.

3. Heat reflective surfaces cease to function effectively when marred or soiled. Consequently, they must be policed continually and cleaned daily to assure maximum reflectivity and protection for personnel who may be exposed to high energy heat at any time.

Table 1. MISCELLANEOUS RESPONSES OF CRASH CREW FIREFIGHTER SUBJECTS, IFFB (1) VERSUS SFFB (2) FROM NAVAL AIR STATION, OCEANA, VIRGINIA BEACH, VA

	IFFB	SFFB	GENERAL
Feet were burned	0%	0%	-
Feel real need for IFFB	75%	-	-
Feel real need for SFFB	-	0%	-
Feel no difference between IFFB, SFFB	-	-	25%
Median wear life in months, SFFB	-	36	-
Subjects' recommendations for improvement of boots	lighter weight, more insulation	lighter weight, add insulation, better fit, more traction	-
Boots damaged during wear	0	0	-
Subjects using aluminized spats	63%	13%	-
Subjects expressing need for spats	2-wear always 3-totally unnecessary	1-wear always	-

(1) IFFB = Insulated Firefighters' Boots
(2) SFFB = Standard Firefighters' Boots

Table 2. MISCELLANEOUS RESPONSES OF CRASH CREW FIREFIGHTER SUBJECTS, IFFB (1) VERSUS SFFB (2) FROM NAVAL AIR STATION, CECIL FIELD, JACKSONVILLE, FL

	IFFB	SFFB	GENERAL
Feet were burned	0%	0%	-
Feel real need for IFFB	100%	-	-
Feel real need for SFFB	-	0%	-
Feel no difference between IFFB, SFFB	-	-	-
Median wear life in months, SFFB	-	48	-
Subjects' recommendations for improvement of boots	more durable, lighter weight	lighter weight, better fit, more traction, add insulation	-
Boots damaged during wear	0%	0%	-
Subjects using aluminized spats	0%	0%	-
Subjects expressing need for spats	0%	0%	-

(1) IFFB = Insulated Firefighters' Boots
(2) SFFB = Standard Firefighters' Boots

Table 3. MISCELLANEOUS RESPONSES OF CRASH CREW FIREFIGHTER SUBJECTS, IFFB (1) VERSUS SFFB (2) FROM NAVAL AIR STATION, MIRAMAR, SAN DIEGO, CA

	IFFB	SFFB	GENERAL
Feet were burned	0%	13%	-
Feel real need for IFFB	100%	-	-
Feel real need for SFFB	-	0%	-
Feel no difference between IFFB, SFFB	-	-	-
Median wear life in months, SFFB	-	48	-
Subjects' recommendations for improvement of boots	better fit more rigid top edge, omit pull-on straps	more durable lighter boots, better fit, more traction	-
Boots damaged during wear	13%	63%	-
Subjects using aluminized spats	1 -	0%	-
Subjects expressing need for spats	1 - totally unnecessary	0%	-

(1) IFFB = Insulated Firefighters' Boots
(2) SFFB = Standard Firefighters' Boots

Table 4. MISCELLANEOUS RESPONSES OF CRASH CREW FIREFIGHTER SUBJECTS, IFFB (1) VERSUS SFFB (2) FROM CHANUTE AIR FORCE BASE, RANTOUL, IL

	IFFB	SFFB	GENERAL
Feet were burned	0%	67%	-
Feel real need for IFFB	-	-	-
Feel real need for SFFB	92%	-	-
Feel no difference between IFFB, SFFB	8%	-	-
Median wear life in months, SFFB	-	6	-
Subjects' recommendations for improvement of boots	more durable, lighter weight, better fit, traction on ice	more durable lighter weight, better fit, add insulation	-
Boots damaged during wear	46%	54%	-
Subjects using aluminized spats	13%	0%	-
Subjects expressing need for spats	1 - totally unnecessary	0%	-

(1) IFFB = Insulated Firefighters' Boots
(2) SFFB = Standard Firefighters' Boots

Table 5. MISCELLANEOUS RESPONSES OF CRASH CREW FIREFIGHTER SUBJECTS, IFFB (1) VERSUS SFFB (2) FROM EIELSON AIR FORCE BASE, FAIRBANKS, AK

	IFFB	SFFB	GENERAL
Feet were burned	0%	0%	-
Feel real need for IFFB	100%	-	-
Feel real need for SFFB	-	0%	-
Feel no difference between IFFB, SFFB	-	-	-
Median wear life in months, SFFB	-	24	-
Subjects' recommendations for improvement of boots	lighter weight, more traction, add insulation	lighter weight, more traction, add insulation	-
Boots damaged during wear	0%	0%	-
Subjects using aluminized spats	20%	20%	-
Subjects expressing need for spats	1 - generally unnecessary	0%	-

(1) IFFB = Insulated Firefighters' Boots
(2) SFFB = Standard Firefighters' Boots

Table 6. MISCELLANEOUS RESPONSES OF CRASH CREW FIREFIGHTER SUBJECTS, IFFB (1) VERSUS SFFB (2) FROM TYNDALL AIR FORCE BASE, PANAMA CITY, FL

	IFFB	SFFB	GENERAL
Feet were burned	0%	33%	-
Feel real need for IFFB	100%	-	-
Feel real need for SFFB	-	0%	-
Feel no difference between IFFB, SFFB	-	-	-
Median wear life in months, SFFB	-	12	-
Subjects' recommendations for improvement of boots	more durable, lighter weight, better fit	more durable, lighter weight, better fit	-
Boots damaged during wear	17%	83%	-
Subjects using aluminized spats	13%	20%	-
Subjects expressing need for spats	0%	0%	-

(1) IFFB = Insulated Firefighters' Boots
(2) SFFB = Standard Firefighters' Boots

TABLE 7. COMPARATIVE HEAT TRANSFER VALUES OF UNINSULATED (1) SFFB COMPONENTS VERSUS URETHANE-FOAM INSULATED IFFB COMPONENTS (1.89 $gcal/cm^2/sec$ RADIANT HEAT FLUX) WITH AND WITHOUT ALUMINIZED FABRIC EXTERIOR

(1) Standard Firefighters' Boot (SFFB) Components No Insulation				(2) Insulated Firefighters' Boot (IFFB) Components, Urethane-Foam Insulation			
Components Not Insulated	Maximum Transmission $gcal/cm^2/sec$	Transmission Time (sec)	Remarks	Components Urethane Insulated	Maximum Transmission $gcal/cm^2/sec$	Transmission Time (sec)	Remarks
(a) 1	0.026 0.051	4 x 7 x x	Smoke, melt - - - - -	1 (a)	0 0.020	11 x 48 x x	Smoke, melt - - - - -
2	0.032 0.051	3 x 7 x x	Smoke, melt - - - - -	2	0 0.017	12 x 57 x x	Smoke, melt - - - - -
3	0.094 0.152	6 x 11 x x	Smoke, melt - - - - -	3	0 0.016	4 x 34 x x	Smoke, melt - - - - -
N-1 (b)	0.070 -	300 x 0 x x	Smoke, aluminum smudges - - - - -	N-1 (b)	0.026 0	300 x 0 x x	No Change - - - - -
N-2	0.051 0	300 x 0 x x	No Change - - - - -	N-2	0.019 0.020	300 x 335 x x	No Change - - - - -
N-3	0.049 0	300 x 0 x x	No Change - - - - -	N-3	0.064 0.071	120 x 140 x x	Smoke, Smudges, rubber melts - - - - -
R-1 (c)	0.036 0	300 x - x x	No Change - - - - -	R-1 (c)	0.029 -	300 x - x x	No Change - - - - -
R-2	0.041 0	300 x - x x	No Change - - - - -	R-2	0.022 0.023	300 x 325 x x	No Change - - - - -
R-3	0.044 0	300 x - x x	No Change - - - - -	R-3	0.019 0.020	300 x 310 x x	No Change - - - - -

(a) 1, 2, 3 - Isoprene black rubber component, (b) N-1, N-2, N-3 - Six-ounce aluminized Nomex on isoprene black rubber component; (c) 20-ounce, aluminized rayon on isoprene black rubber component.

x time when radiant heat source was stopped.

x x time of maximum heat transmission after heat source was stopped, represents transmission of residual heat.

TABLE 8. COMPARATIVE HEAT TRANSFER VALUES OF UNINSULATED (1) SFFB COMPONENTS VERSUS WOOL FLEECE INSULATED (2) IFFB COMPONENTS (1.89 $gcal/cm^2/sec$ RADIANT HEAT FLUX) WITH AND WITHOUT ALUMINIZED FABRIC EXTERIOR

(1) Standard Firefighters' Boot (SFFB) Components No Insulation				(2) Insulated Firefighters' Boot (IFFB) Components, Wool-Fleece Insulation			
Components Not Insulated	Maximum Transmission $gcal/cm^2/sec$	Transmission Time (sec)	Remarks	Components Wool-Fleece Insulated	Maximum Transmission $gcal/cm^2/sec$	Transmission Time (sec)	Remarks
1 (a)	0.004 0.033	5 x 17 x x	Smoke - - - - -	1 (a)	0.001 0.003	5 x 66 x x	Smoke - - - - -
2	0.033 0.051	6 x 21 x x	Smoke, melt - - - - -	2	0.001 0.017	5 x 77 x x	Smoke - - - - -
3	0.094 0.051	7 x 29 x x	Smoke, melt - - - - -	3	0.003 0.013	8 x 66 x x	Smoke - - - - -
N-1 (b)	0.032 -	300 x 0 x x	No Change - - - - -	N-1 (b)	0.020 0.022	300 x 340 x x	No Change - - - - -
N-2	0.036 0	300 x 0 x x	No Change except odor of burnt rubber	N-2	0.017 0.019	300 x 340 x x	No Change - - - - -
N-3	0.032 0	300 x 0 x x	No Change - - - - -	N-3	0.019 0.020	300 x 380 x x	No Change - - - - -
R-1 (c)	0.045 0	300 x - x x	No Change - - - - -	R-1 (c)	0.017 0.020	300 x 340 x x	No Change - - - - -
R-2	0.032 0	300 x - x x	No Change - - - - -	R-2	0.016 0.017	300 x 340 x x	No Change - - - - -
R-3	0.026 0	300 x - x x	No Change - - - - -	R-3	0.015 0.017	300 x 340 x x	No Change - - - - -

(a) 1, 2, 3 - Isoprene black rubber component, (b) N-1, N-2, N-3 - Six-ounce aluminized Nomex on isoprene black rubber component; (c) R-1, R-2, R-3 - 20-ounce, aluminized rayon on isoprene black boot component.

x time when radiant heat source was stopped.

x x **time of maximum heat transmission after heat source was stopped, represents transmission of residual heat.**

TABLE 9. COMPARATIVE HEAT TRANSFER VALUES OF UNINSULATED (1) SFFB COMPONENTS VERSUS VINYL-FOAM INSULATED (2) IFFB COMPONENTS (1.89 $gcal/cm^2/sec$ RADIANT HEAT FLUX) WITH AND WITHOUT ALUMINIZED FABRIC EXTERIOR

(1) Standard Firefighters' Boot (SFFB) Components No Insulation				(2) Insulated Firefighters' Boot (IFFB) Components, Vinyl-Foam Insulation			
Components Not Insulated	Maximum Transmission $gcal/cm^2/sec$	Transmission Time (sec)	Remarks	Components Not Insulated	Maximum Transmission $gcal/cm^2/sec$	Transmission Time (sec)	Remarks
1 (a)	0 0.026	15 x 55 x x	Smoke, melt - - - - -	1 (b)	0.0073 0.023	39 x 85 x x	Smoke, Melt - - - - -
2	0.003 0.046	13 x 32 x x	Melt - - - - -	2	0.0073 0.044	20 x 85 x x	Smoke, melt - - - - -
N-1 (b)	0.028 -	300 x 0 x x	No Change - - - - -	N-1 (b)	0.017 0.019	300 x 311 x x	No Change - - - - -
N-2	0.029 0	300 x 0 x x	No Change - - - - -	N-2	0.012 0	300 x 0 x x	No Change - - - - -
R-1 (c)	0.023 0.028	300 x 358 x x x	No Change - - - - -	R-1 (c)	0.007 0	300 x 0 x x	No Change - - - - -
R-2	0.022 0	300 0	No Change - - - - -	R-2	0.017 0.019	300 x 319 x x	Soil on aluminized burns and finish cracks

(a) 1, 2, - Isoprene black rubber component, (b) N-1, N-2, - Six-ounce aluminized Nomex on isoprene black rubber component; (c) 20-ounce aluminized rayon on isoprene black boot component.

x time when radiant heat source was stopped.

x x time of maximum heat transmission after heat source was stopped, represents transmission of residual heat.

TABLE 10. COMPARATIVE HEAT TRANSFER VALUES OF SIX-OUNCE ALUMINIZED NOMEX FABRIC VERSUS 20- OUNCE ALUMINIZED RAYON FABRIC (1.89 gcal/cm²/sec RADIANT HEAT FLUX)

Six-ounce Aluminized Nomex (N)				20-ounce Aluminized Rayon (R)			
Specimen	Maximum Transmission gcal/cm²/sec	Transmission Time (sec)	Remarks	Specimen	Maximum Transmission gcal/cm²/sec	Transmission Time (sec)	Remarks
N-1	0.048 0.009	300 x 355 x x x	No Change - - - - -	R-1	0.059 0.017	300 x 365 x x x	No Change - - - - -
N-2	0.048 0.009	300 x 393 x x x	No Change - - - - -	R-2 (1)	0.052 0.010	300 x 460 x x x	No Change - - - - -
N-3	0.048 0.013	300 x 348 x x x	No Change - - - - -	R-3	0.057 0.009	300 x 457 x x x	No Change - - - - -

x time when radiant heat source was stopped.
x x x time required for heat to decline and level after radiant heat source was stopped.

(1) Specimen R-2 - Cigarette ash and black pen mark placed on R-2 reflective surface after initial exposure, then re-exposed. Black pen mark burns off; ash mark burns through aluminized rayon. Heat transfer rate 0.107 gcal/cm²/sec after 195 seconds. Skin would blister after 30 seconds exposure at 0.107 gcal/cm²/sec heat flux.

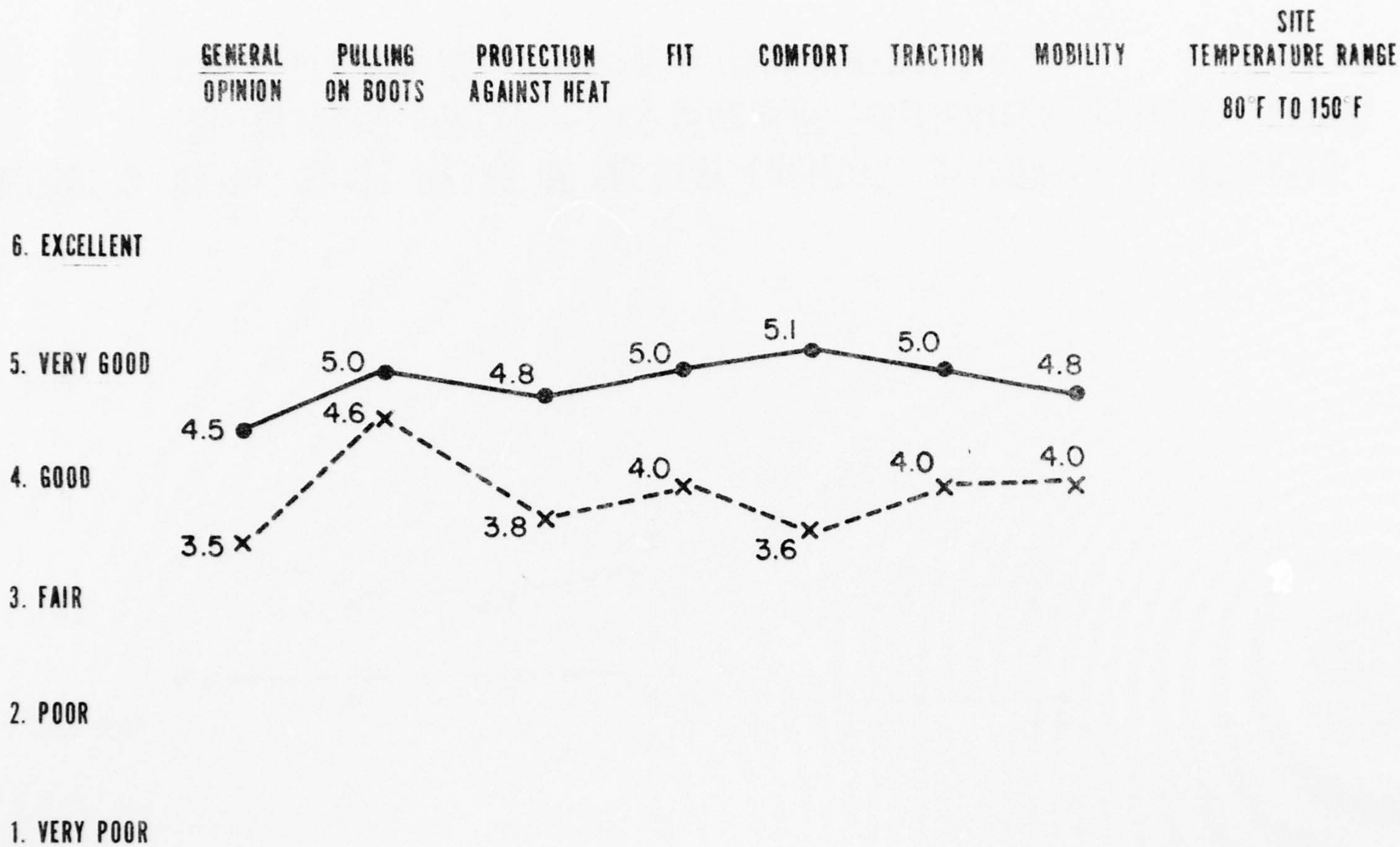

FIGURE 1. RATING SCALE MEANS OF EIGHT TEST SUBJECTS' RESPONSES TO INSULATED FIREFIGHTERS' BOOTS (•—) VS STANDARD FIREFIGHTERS' BOOTS (X----) FROM NAVAL AIR STATION, OCEANA, VIRGINIA BEACH, VA.

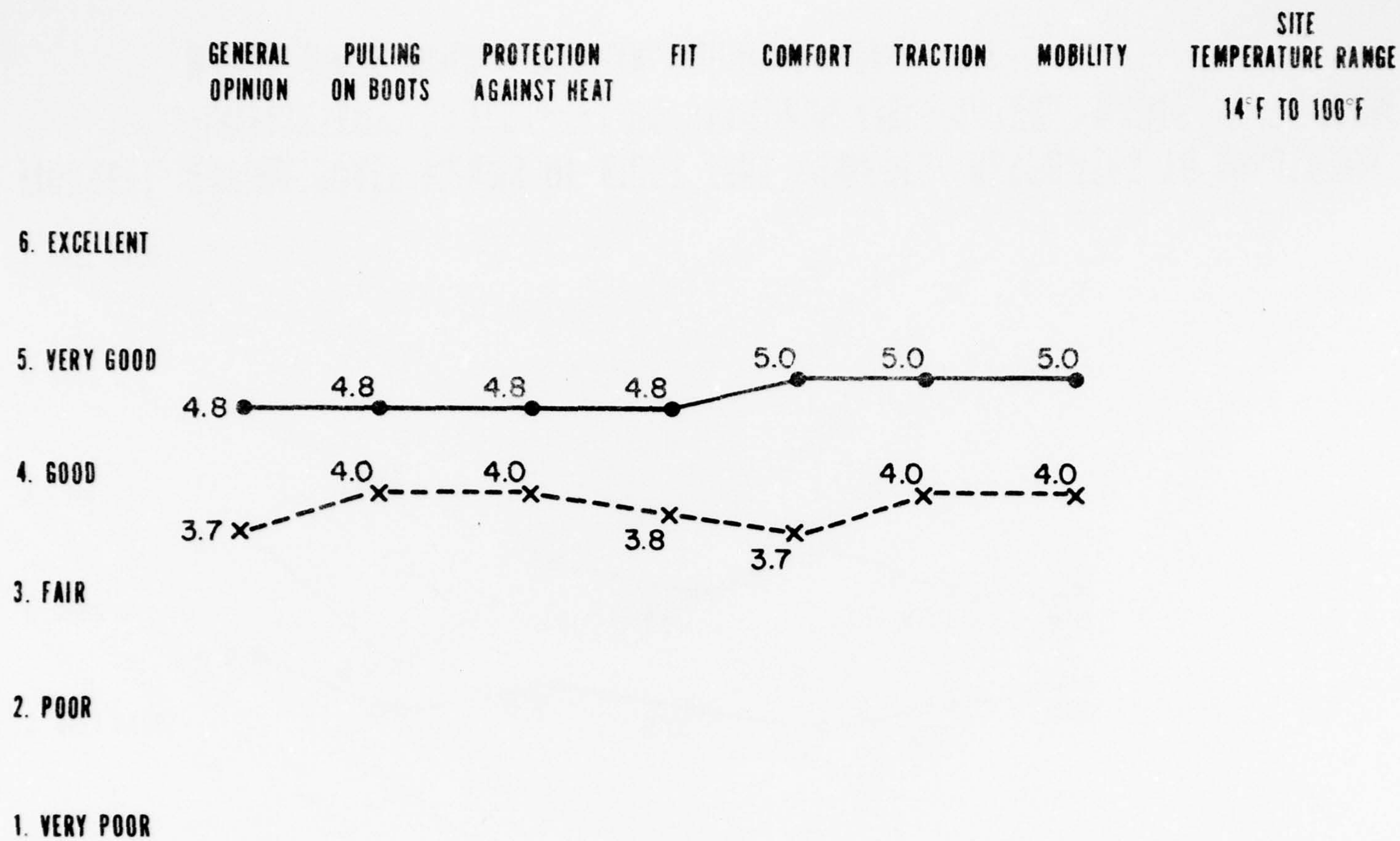

FIGURE 2. RATING SCALE MEANS OF SIX TEST SUBJECTS' RESPONSES TO INSULATED FIREFIGHTERS' BOOTS (●—) VS STANDARD FIREFIGHTERS' BOOTS (X----) FROM NAVAL AIR STATION, CECIL FIELD, JACKSONVILLE, FL.

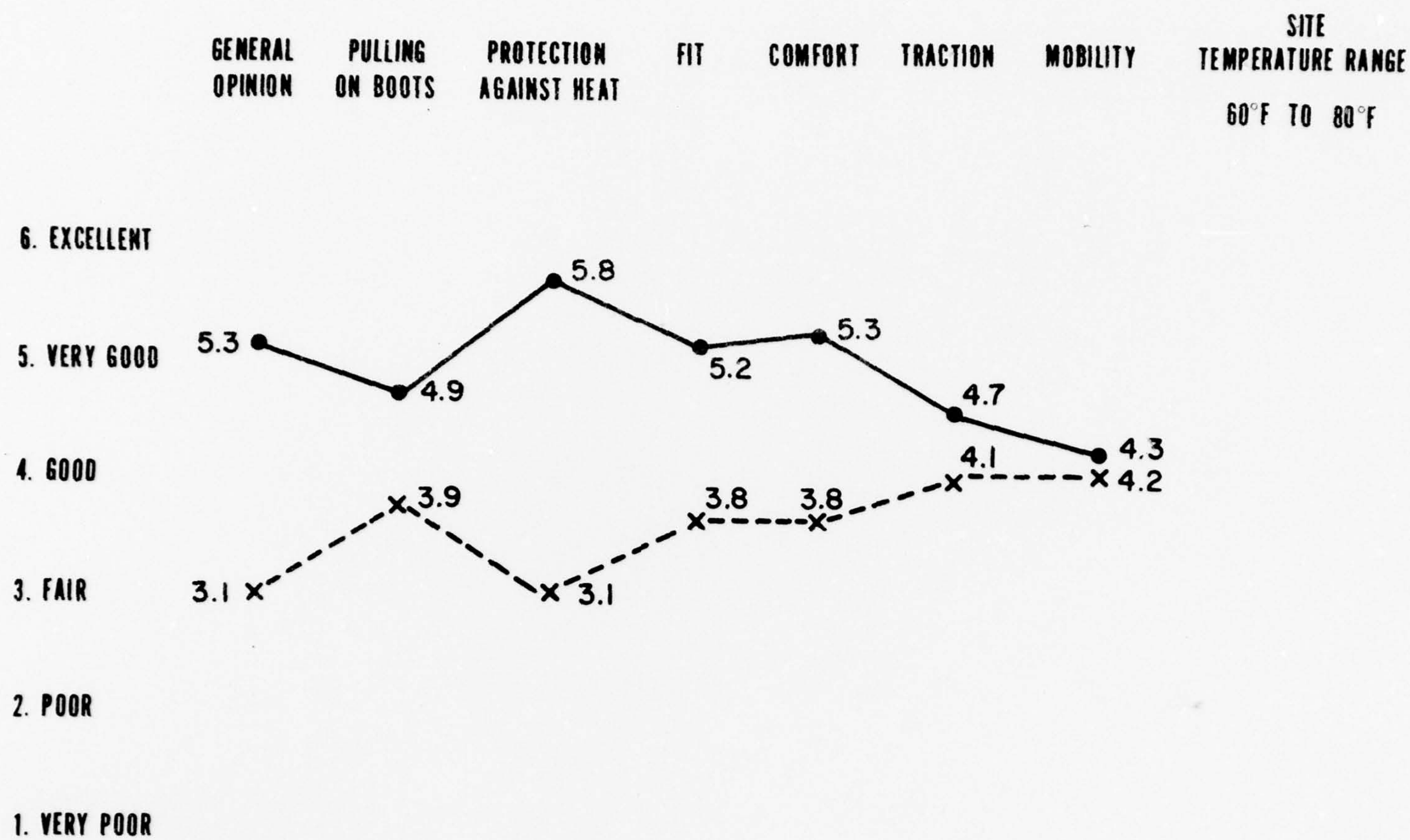

FIGURE 4. RATING SCALE MEANS OF TWELVE CRASH CREW FIREFIGHTER SUBJECTS' RESPONSES TO INSULATED FIREFIGHTERS' BOOTS (•—) VS STANDARD FIREFIGHTERS' BOOTS (X----) FROM CHANUTE AIR FORCE BASE, RANTOUL, IL.

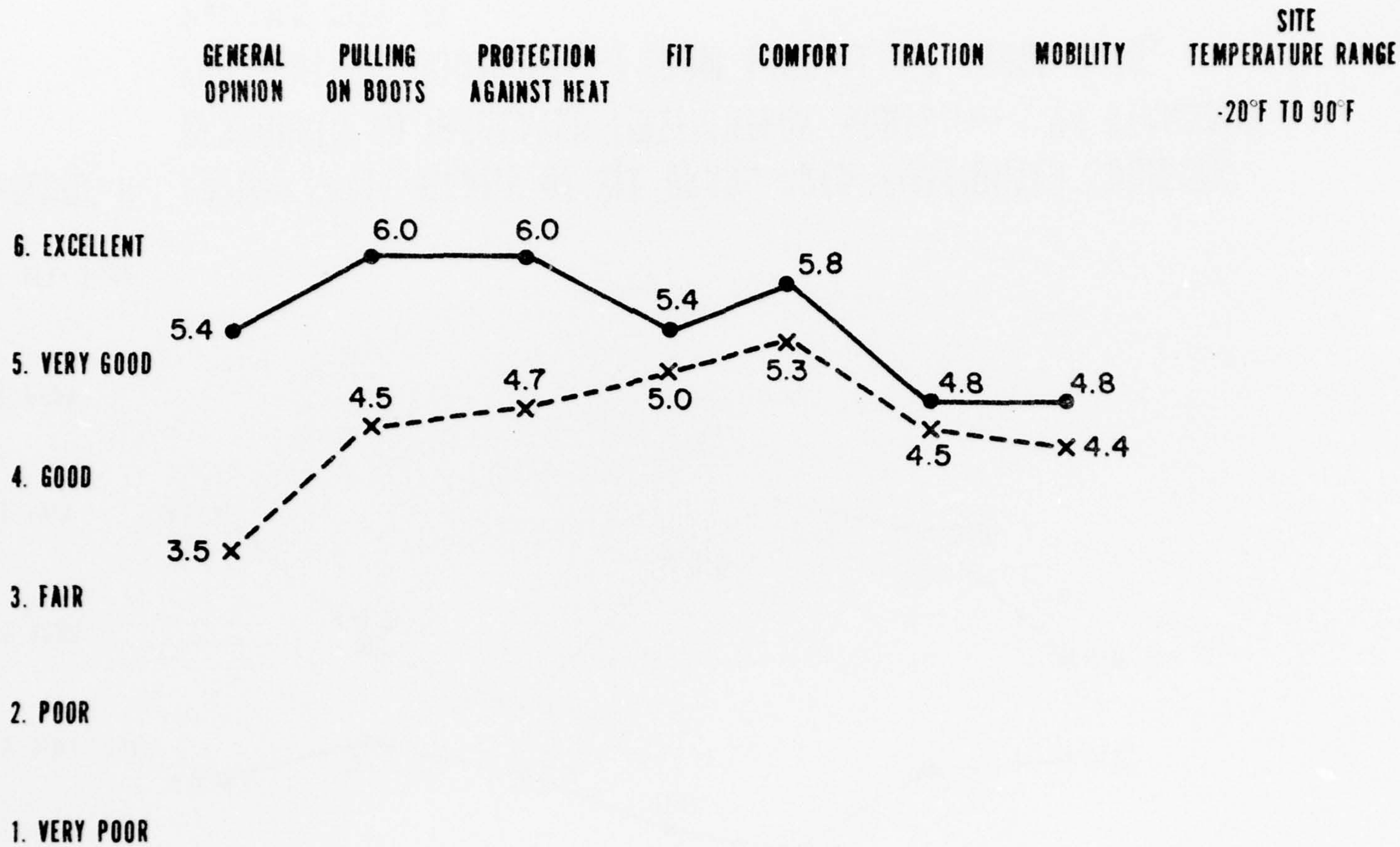

FIGURE 5. RATING SCALE MEANS OF FIVE CRASH CREW FIREFIGHTER SUBJECTS' RESPONSES TO INSULATED FIREFIGHTERS' BOOTS (•—) VS STANDARD FIREFIGHTERS' BOOTS (X----) FROM EIELSON AIR FORCE BASE, FAIRBANKS, AK.

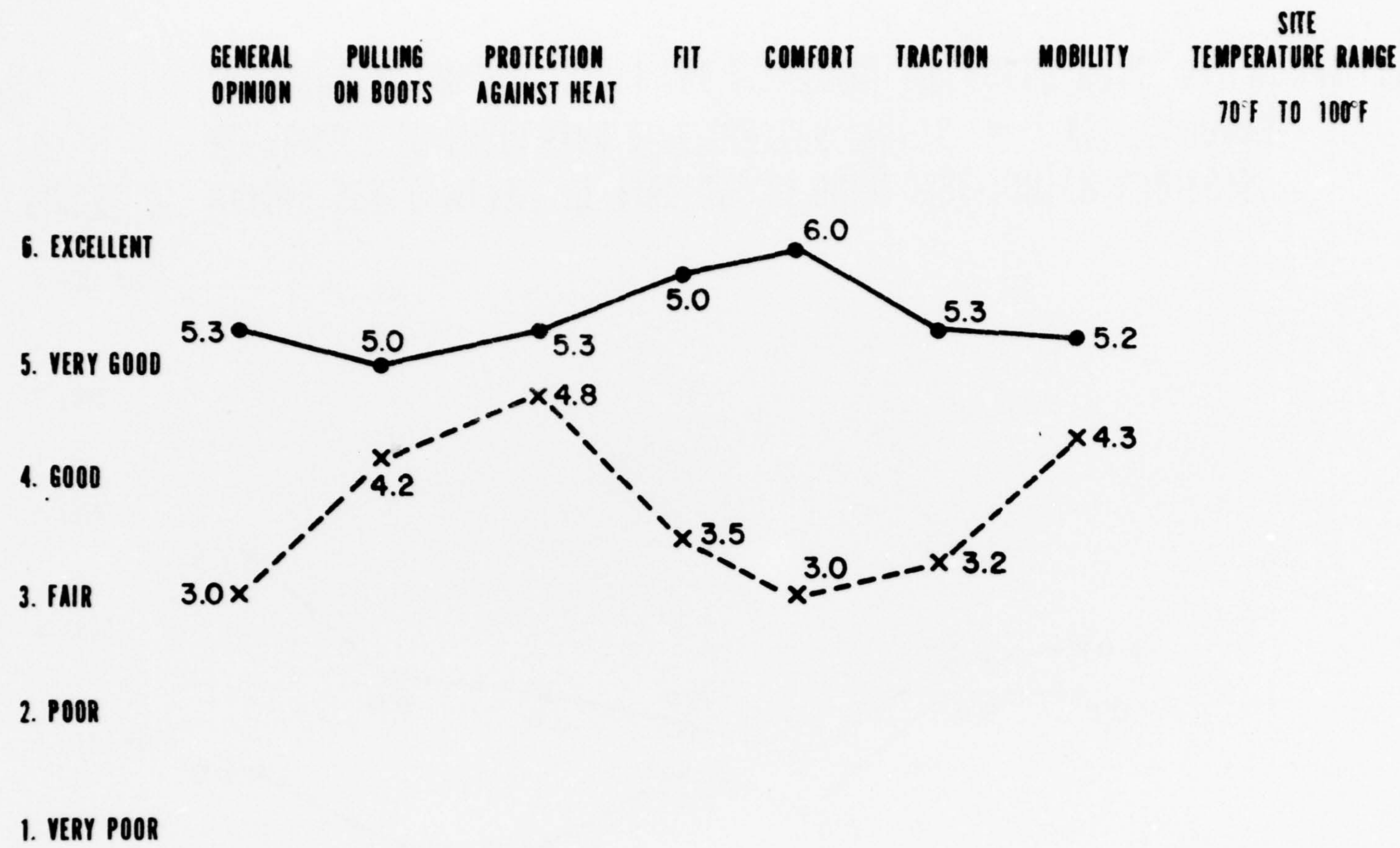

FIGURE 6. RATING SCALE MEANS OF SIX CRASH CREW FIREFIGHTER SUBJECTS' RESPONSES TO INSULATED FIREFIGHTERS' BOOTS (•—) VS STANDARD FIREFIGHTERS' BOOTS (X----) FROM TYNDALL AIR FORCE BASE, PANAMA CITY, FL.

REFERENCES

1. Bailey, M., Improved Firefighters' Crash-Rescue Boots (Feasibility Study), NCTRF Technical Report No. 120, June 1976.

2. Audet, N. F., Visor System Materials for Aluminized Firemen's Hoods (Report 2: Evaluation of Gold-Coated Plastic Substrates), NCTRF Report No. 113, June 1975.

3. Stoll, A. M., and Chianta, M. A., A Method and Rating System for Evaluation of Thermal Protection, Aerospace Medicine, 11:1232-1238, 1969.

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APPENDIX A

INFORMATION FOR TEST SUBJECTS
EVALUATING PROXIMITY FIREFIGHTERS' BOOTS

You are being asked to test insulated proximity firefighters' boots and to compare them with standard firefighters' boots generally worn by Department of Defense firefighters. Insulated firefighters' boots contain foam or fleece insulation within the boot around the upper, ankle, and instep. Standard boots do not. The insulated boot is being tested to determine if the insulation gives you better protection against heat from fires than the standard firefighters' boots.

We hope to determine from your answers to the attached questionnaire, to be completed at the termination of the test, whether insulated boots should replace the standard boots.

The same questions apply to both the test boots and standard boots. You will be required to answer by checking appropriate spaces. The checks or answers you furnish on the left side will relate to the insulated test boots which you have tested. The checks or answers you furnish on the right side of the questionnaire will relate to the standard boots which you wore before you started testing the insulated boots.

Here is an example of how someone may answer the first question if the subject likes insulated boots very much but is disatisfied with the standard boots.

SAMPLE ANSWER

1. What are your opinions of insulated firefighters' boots and standard firefighters' boots?

Insulated Test Boots		Standard Boots
______	Excellent	______
X	Very Good	______
______	Good	______
______	Fair	______
______	Poor	X
______	Very poor	______

If very poor, poor, or fair, please explain in appropriate, lined spaces below:

____________________	Standard boots hold
____________________	heat and feet burn
____________________	when standing close to
____________________	fires.

The same approach will be followed for all questions numbered from 1 to 13.

Before you start the test, you will be required to complete and sign a Property Form which outlines your obligations as a test subject. Please return this form to your Chief or test monitor.

If issued, we would also like you to evaluate two types of aluminized spats which are to be worn over both the test boots and the standard boots, so that you will be able to tell us whether the spats are useful when fighting fires, or are not needed. One set will be marked with an "N;" the other, with an "R" on the fabric side. Aluminized spats when worn over firemen's boots are intended to give your feet additional protection against high heat radiating from burning JP-4, JP-5, and other high energy fuels.

Please feel free to make any comment or suggestion you wish about the test boots and standard boots, and the spats.

NAVY CLOTHING AND TEXTILE RESEARCH FACILITY
NATICK, MASSACHUSETTS 01760

QUESTIONNAIRE FOR PROXIMITY FIREFIGHTERS' BOOTS

Comparison Questions - Insulated Firefighters' Test Boots versus Standard Non-Insulated Firefighters' Boots. Please answer all questions and supply the information requested below. Spaces on left column relate to test boots; spaces in right column relate to standard boots.

Name____________ Rank______ Date Test Began________

Age____ Length of Service______ Height______ Weight________

Organization________ Boot Size_____ Date Test Ended________

Test Site Location____________ Range of Site Temp____°F ____°F

What do you do on your job?________________________

____

Check one: Crash crew firefighter mostly____ Do both____

Structural firefighter mostly____

Be sure to check and answer the left column spaces for insulated boots; and the right column spaces for standard boots for all questions listed below.

Insulated Boot Manufacturer or Brand	Standard Boot Manufacturer or Brand
____________	____________

1. What are your opinions of insulated firefighters' boots and the standard firefighters' boots?

Insulated Test Boots		Standard Boots
________	Excellent	________
________	Very Good	________
________	Good	________
________	Fair	________
________	Poor	________
________	Very Poor	________

If very poor, poor, or fair, please explain in appropriate, lined spaces below:

____________________ ____________________

____________________ ____________________

____________________ ____________________

____________________ ____________________

2. Which of the following is the closest to your opinion about pulling on these boots?

Insulated Test Boots		Standard Boots
__________	Excellent	__________
__________	Very Good	__________
__________	Good	__________
__________	Fair	__________
__________	Difficult	__________
__________	Very Difficult	__________

If very difficult, difficult, or fair, please explain in appropriate, lined spaces below:

____________________ ____________________

____________________ ____________________

____________________ ____________________

____________________ ____________________

3. What do you think of the protection from high heat generated by flaming JP-4, JP-5, or other fires, afforded by these boots?

Insulated Test Boots		Standard Boots
__________	Excellent	__________
__________	Very Good	__________
__________	Good	__________

_______________ Fair _______________

_______________ Poor _______________

_______________ Very Poor _______________

If very poor, poor, or fair, please explain in appropriate, lined spaces below:

_______________ _______________

_______________ _______________

_______________ _______________

4. What do you think of the fit of the boots?

Insulated Test Boots		Standard Boots
_______________	Excellent	_______________
_______________	Very Good	_______________
_______________	Good	_______________
_______________	Fair	_______________
_______________	Poor	_______________
_______________	Very Poor	_______________

If fit is very poor, poor, or fair, please explain in appropriate, lined spaces below:

_______________ _______________

_______________ _______________

_______________ _______________

5. What do you think of the general comfort of these boots?

Insulated Test Boots		Standard Boots
_______________	Excellent	_______________
_______________	Very Good	_______________
_______________	Good	_______________

________	Fair	________
________	Poor	________
________	Very Poor	________

If boots are very poor, poor, or fair, please explain in appropriate, lined spaces below:

________	________
________	________
________	________

6. Which of the following is closest to your opinion about the traction of these boots?

Insulated Test Boots		Standard Boots
________	Excellent	________
________	Very Good	________
________	Good	________
________	Fair	________
________	Poor	________
________	Very Poor	________

If very poor, poor, or fair, please explain in appropriate, lined spaces below:

________	________
________	________
________	________

7. Which of the following is closest to your opinion of mobility when wearing these boots?

Insulated Test Boots		Standard Boots
____________	Excellent	____________
____________	Very Good	____________
____________	Good	____________
____________	Fair	____________
____________	Poor	____________
____________	Very Poor	____________

If very poor, poor, or fair, please explain in appropriate lined spaces below:

____________	____________
____________	____________
____________	____________

8. Did you get any foot burns or injuries while wearing these boots?

Insulated Test Boots		Standard Boots
____________	YES	____________
____________	NO	____________

If yes, please explain in the appropriate, lined spaces below:

____________	____________
____________	____________
____________	____________

9. Did the boots become damaged in any way?

Insulated Test Boots		Standard Boots
____________	YES	____________
____________	NO	____________

If yes, please explain in appropriate, lined spaces below:

__________________ __________________

__________________ __________________

__________________ __________________

10. a. Number of days you wore the test boots. _______________

b. Number of months you usually wear your standard boots before replacing them._______________

11. a. Do you think you really need insulated boots for your work?

Yes ____

No ____

No difference ____

b. Please explain your answer below:

____

____

____

12. If you could make changes in these boots, what changes would you make? (Check more than one if necessary.)

Insulated Test Boots		Standard Boots
____________	Improve durability	____________
____________	Make lighter	____________
____________	Improve fit	____________
____________	Improve traction	____________
____________	Improve insulation	____________
____________	Improve height	____________
____________	Other	____________
____________	None	____________

Please explain your recommendations in the appropriate, lined spaces below:

____________________ ____________________

____________________ ____________________

____________________ ____________________

13. a. Did you use aluminized test spats over your boots?

Insulated Test Boots		Standard Boots
__________	Yes	__________
__________	No	__________

b. If yes, what do you think of their usefulness? If no, do not answer subsequent questions 13.a., b., c.

__________	Should be worn all the time	__________
__________	Should be worn when necessary	__________
__________	Don't know	__________
__________	Generally unnecessary	__________
__________	Totally unnecessary	__________

Please explain your answers.

____________________ ____________________

____________________ ____________________

____________________ ____________________

____________________ ____________________

c. What do you think of the added protection against high heat afforded by these reflective spats when they covered your boots?

__________	Excellent	__________
__________	Very Good	__________
__________	Good	__________

Fair

Poor

Very Poor

If very poor, poor, or fair, please explain in appropriate column:

d. Which type of spats "R" or "N" did you prefer when worn over your boots?

Spats marked "R"

Spats marked "N"

No preference

Please explain your answers.

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Det 1 AFESC/TST	1
AUL/LSE 71-249	1
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USAF/TRADOC/ATEN-FE-FP	1
HQ NAVMAT/04F	1
HQ NAVFAC/10F	1
HQ NAVFAC/103B	1
NRL/6180	1
HQ NAVAIR/53433A	1
FAA-NAFEC/ANA-420	1
NGB/DEM	1
AFRES/DEMF	1
HQ PACAF/DEMF	1
HQ TAC/DEMF	1
HQ USAFE/DEMF	1
HQ USCG/G-MT-4/82	1
HQ USCG/ENE 5-B	1
USCG R&C CTR/Avery Point	1
HQ MAC/DEMF	1
HQ AAC/DEMF	1
HQ AFSC/DEMF	1
HQ SAC/DEMF	1
HQ ATC/DEMF	1
HQ ADCOM/DEMF	1
HQ AFLC/DEMF	1
W-R ALC/MMIRAB	1
AFETO/DOZ	1
Det 1 AFESC/CNS	5
3340 TTG/TTMF	1
NFPCA	1
HQ AFSC/SDAE	1
FAA/AAP-720	1
HQ NAVSEA/04H6	1
NAVSEC/6154F	1
NCTRF	50

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