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THE DEVELOPMENT OF CRITERIA FOR FIREFIGHTERS' GLOVES

VOLUME I: GLOVE REQUIREMENTS

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE / Public Health Service
Center For Disease Control / National Institute For Occupational Safety And Health

THE DEVELOPMENT OF CRITERIA FOR FIREFIGHTERS' GLOVES

VOLUME I: GLOVE REQUIREMENTS

by

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FOREWORD

The National Institute for Occupational Safety and Health (NIOSH) is responsible for helping to ensure that every person in the Nation has safe and healthful working conditions. To accomplish this end, the Institute engages in research on occupational safety and health problems including evaluation of hazards and the development of testing and performance requirements for personal protective equipment.

One of the many work hazards considered for investigation by the Institute is fire-fighting. At the present time, there are no comprehensive standards or other requirements available for use in the manufacturing, selecting and testing of firefighters' gloves. Thus, we are pleased to publish this initial research effort for recommended standards.

It should be noted that this research work is based on a specific contract scope of work. Further evaluation and validation of the criteria recommended in this document are necessary. The Division of Physical Sciences and Engineering has performed an initial evaluation of the performance criteria and test methods developed by the contractor. A copy of this evaluation report will be published by NIOSH in the near future.

John F. Finklea, MD

John F. Finklea, M.D.
Director, NIOSH

PREFACE

This report, which describes the development of criteria for firefighters' gloves, has been prepared in 2 volumes.

Volume I, contained herein, identifies glove requirements in detail and presents recommendations for both glove standards and a prototype glove system which will meet those standards. This has been accomplished through study of injury statistics, firefighting tasks, existing glove standards and gloves currently used by firefighters.

Volume II is a supporting technical document in 2 parts. Part I traces the quantitative development of the glove criteria which are summarized in the recommendations for glove standards in Volume I. Part II describes the test methods which were devised for validating the protective and other properties of firefighters' gloves.

Arthur D. Little, Inc., carried out this research assignment for the National Institute for Occupational Safety and Health (NIOSH) under the direction of Project Officer Jeff I. Kamin of the Engineering Branch, Division of Physical Sciences and Engineering. NIOSH, a Research Institute of the U.S. Department of Health, Education and Welfare, was created by the Occupational Safety and Health Act of 1970. As mandated by this Act, NIOSH performs and sponsors research and develops criteria for recommended standards applicable to the problems of Occupational Safety and Health.

The data collected in this and in subsequent investigations are intended to become the bases for safety standards which are needed to ensure that the personal protection requirements of firefighters are met.

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- Arlington, Massachusetts
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- New York, New York
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B. FIRE SERVICE ORGANIZATIONS

- National Fire Protection Association
- International Association of Fire Fighters

C. STATE ORGANIZATIONS

- State of New York, Office for Local Government
- State of California, Division of Labor Statistics and Research
- State of Wisconsin, Department of Industry, Labor and Human Relations

D. FEDERAL ORGANIZATIONS

- National Bureau of Standards
- Department of Labor, Bureau of Labor Statistics
- U.S. Army Development Center, Natick, Massachusetts

E. WORK GLOVE MANUFACTURERS

- Best Manufacturing Corporation
- Boss Manufacturing/Davids Gloves, Inc.
- Edmont Wilson
- Globe Manufacturing Company
- The Glove Corporation
- The Granet Corporation
- Jomac Products, Inc.

E. WORK GLOVE MANUFACTURERS (Continued)

- M. Papa and Sons
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ABSTRACT

Title: **The Development of Criteria for Firefighters' Gloves**

Author: **Gerard C. Coletta**

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(Keywords) Gloves, Firefighters-Gloves, Protective-Clothing, Injuries, Criteria, Test-Methods, Standards

(Body) Overall requirements for firefighters' gloves are identified by an analysis of hand and wrist injury statistics and an analysis of firefighters' task-oriented needs. These qualitative requirements provide a framework for developing the quantitative criteria needed in establishing the suitability of gloves used in firefighting.

The development of such quantitative criteria is described in depth. Specific performance levels are identified for the several glove requirements by considering the characteristics of individual firefighting tasks, the nature of firefighting hazards, the resistance of human skin to these hazards, and the performance of gloves currently used by the Fire Services.

New test methods which provide a means for validating the suitability of gloves have been devised and are described.

In addition, recommendations are made for both new glove standards and a prototype glove system which will meet these standards.

I. EXECUTIVE SUMMARY

In this study, a set of quantitative criteria was developed for firefighters' gloves. These criteria form the basis from which recommendations are made for both new glove standards and a prototype glove system which will meet those standards.

An analysis of hand and wrist injury statistics and firefighters' task-oriented needs has provided an in-depth identification of glove requirements. Hand protection is the most important requirement. The primary hand injuries sustained by firefighters are cut, puncture, burn, scald, frostbite and electrical trauma. These are all preventable with proper glove design and construction.

Although intuition would suggest burn as the most frequent and severe injury, this study has identified penetrating mechanical injuries – cut and puncture – as more substantial. Conversely, non-penetrating mechanical injuries – bruise and contusion – are considerably less important. Non-penetrating injuries can be reduced in severity if gloves are designed to withstand the penetrating hazards.

The other glove requirements relate more to manipulative ability and a glove's resistance to degradation under fire conditions. In order of importance, they are: dexterity, resistance to the effects of liquids, comfort, resistance to flame, durability, ease of drying and visibility.

These qualitative glove requirements provided a framework from which the quantitative criteria needed for establishing the suitability of gloves used in firefighting were developed. Specific performance levels were identified for the above requirements by considering the nature of individual firefighting hazards, the resistance of human skin to these hazards, the performance of gloves currently used in the Fire Services, and the task-oriented functional needs of firefighters. In addition, two design considerations – glove fit and wrist construction – which have direct bearing on several of these requirements, were discussed in-depth.

Moreover, test methods were developed to provide a means for validating the suitability of gloves to be judged by these criteria. These methods evaluate glove dexterity, durability and resistance to cut, puncture, heat penetration, electricity, water penetration and flame. They have been written in a format corresponding to present Federal test method standards.

None of the gloves currently used by firefighters in the United States adequately meet all of these criteria. The reasons for such deficiencies are described by a review of (1) existing standards for firefighters' gloves, (2) a description of the gloves actually used by the Fire Services, and (3) an overview of the glove manufacturing industry:

At the present time there are no comprehensive standards or other specifications available for use in manufacturing or selecting gloves. The standards which have been written offer only a superficial overview of glove characteristics. For the most part, current standards emphasize construction parameters without addressing the firefighters' actual needs. They do not provide in-depth technical information in three areas which are essential to a useful standard. These are:

- clear, quantitative definitions for glove performance requirements,
- methods for validating glove performance, and
- recommendations for glove use and care.

Since there are no adequate standards to serve as guidelines, none of the gloves currently used satisfy all of the diverse needs of the firefighter. Gloves have not been specifically designed for firefighting; but rather, they have been chosen from an extensive selection of general-purpose work gloves available to the average consumer. Most gloves commonly used are made of cotton, leather, vinyl, wool, or infrequently, neoprene and various rubbers. Each of these work gloves has characteristics which may be appropriate for its intended industrial use; however, serious gaps in protection and function develop when they are used in firefighting.

The work glove manufacturing industry in the United States has evolved from a tradition-bound, art/craft-based technology and currently is geared to mass-produced, low cost general-purpose products. Several companies have taken a modern approach to glove design and manufacture that could point the way to progress by the rest of the industry. There is room for advancement in glove design practices which relate to specific occupational groups such as firefighting.

Recommendations are made for a new set of standards for firefighters' gloves. This set of standards is in three parts – one part relating to glove performance, one to glove testing and one to glove use. The criteria and test methods developed in this study form the basis for these standards. Glove manufacturers should be able to produce a product meeting the requirements of these standards within three years after final promulgation. The most time consuming aspects will be setting up the several test methods and completing glove designs.

Lastly, recommendations are made for a prototype glove system which will meet the new standards. This system consists of three components: a general-purpose firefighters' glove which meets most of the criteria, a pull-over to provide additional protection against heat, and a pull-over to provide additional protection against cold.

II. INTRODUCTION

Firefighters are continually exposed to a variety of hazards capable of causing substantial injury.[1,2] Cuts, lacerations and punctures result from frequent contacts with the broken glass, sharp metal objects, sharp plastic objects, nails and wood splinters encountered in nearly all structural fires. Thorns, insects and animals often cause injury when brush and forest fires are being fought. Burns, whether from radiant thermal energy, hot objects or open flame, can occur in any fire. In addition, firefighters can be exposed to electricity and hazardous liquids while fighting structural fires. All of these hazards are often obscured by poor lighting or smoke and therefore become even more dangerous.

To make matters worse, debris, soot, and water or other extinguishing agents normally cover and permeate everything at and adjacent to a fire scene, including the firefighters. Consequently, discomfort can be severe – adding to both firefighter stress and reduced alertness. Such poor working conditions are further intensified by the effects of hot weather in summer and cold weather in northern winters.

However, in the United States, injury and discomfort are no longer accepted as inevitable. Firefighters believe that technological advances, demonstrated reductions in the injury rates of other hazardous occupations, and a strong Federal effort toward achieving occupational safety should translate into substantial research and development aimed toward their protection. Unfortunately, too few efforts have been undertaken, and those that have been were often misdirected and incomplete. It is the intention of the National Institute for Occupational Safety and Health (NIOSH) to reverse this trend and develop criteria for firefighters' protective clothing.

The needs of the firefighters have been described in published reports: Utech has reviewed the overall injuries and hazards encountered in firefighting and has recommended some general improvements.[3] Seymour has reviewed the inadequacies of the protective clothing used by the Fire Services and also made general recommendations.[4] However, very little use has been made of these preliminary works, even as starting points for concerted efforts to improve individual items of protective clothing.

In his report, Seymour stated that "the problem with gloves is the sorriest of all personal protective clothing items." It is appropriate, then, that the NIOSH-sponsored study described in this report provides for the in-depth development of criteria for firefighters' hand protection.

This study has been conducted in five major tasks, or phases, which incorporated all of the contract-specified NIOSH objectives. These tasks were:

Task I – Determine, and rank by importance, the performance requirements for firefighters' gloves.

Task IA – As a related evaluation, investigate the possibility of improving firefighters' wrist protection.

Task IB – Also as a related evaluation, investigate the adequacy of sizing methods for firefighters' gloves.

Task II – Devise test methods with which to evaluate each performance requirement of firefighters' gloves. Evaluate currently-used gloves to assist in establishing quantitative values for tested parameters.

Task III – In conjunction with Task II, devise appropriate and reasonable performance criteria for firefighters' gloves based on the output of Task I.

Task IIIA – Review glove industry capabilities and state-of-the-art manufacturing technology to propose a date by which firefighters' glove performance criteria could be met by an actual product.

Task IV – Prepare recommendations for standards describing the performance, testing and use of firefighters' gloves.

Task V – Prepare recommendations for a prototype glove (or gloves) which meets, to the maximum extent possible, the requirements of the new criteria.

With only minor rearrangement, the results of this study are reported according to the categories suggested by these five tasks. The next section begins the presentation with a detailed identification of glove requirements.

III. GLOVE REQUIREMENTS

Intuitively, a most important requirement of firefighters' gloves is to provide hand protection. However, firefighters' gloves should also possess a number of other important characteristics. For example, gloves are expected to be comfortable, to permit execution of the many tasks necessary for successful firefighting and to be durable. These, as well as additional requirements which are described in this report, have been identified by determining the firefighters' needs in both hand protection and other task-oriented glove functions.*

A. HAND PROTECTION REQUIREMENTS

Since successful firefighting is highly dependent on manual tasks, firefighters' hands and arms are exposed to all fire scene conditions. The frequent pushing, pulling, lifting and grabbing motions which are necessary in rescuing a fire victim, in ventilating and extinguishing a fire, and in overhauling or cleaning up a fire scene make the hands especially susceptible to contact with every hazard. Moreover, the environmental conditions usually experienced during firefighting are considered to be extraordinarily hazardous and stressful. Hand protection to prevent injury is a necessity.

In contrast, the conditions experienced by the firefighter during travel to and from a fire or while operating apparatus at a distance from a fire are less severe than those of actual firefighting. At worst, exposure to weather and extinguishing agents contribute to discomfort and an inability to easily manipulate equipment. The few hazards encountered are far overshadowed in number and severity by those in and adjacent to a fire. Therefore, injuries sustained under these circumstances are of secondary importance and are not considered in depth.

1. Hand and Wrist Injuries

Firefighters' protective needs are best identified through an analysis of hand and wrist injury statistics. Injury frequency and severity relate to modes or types of protection required in gloves, while injury distribution determines the location of this protection in gloves. This information is also useful for the rank-ordering of injuries by importance.

Published data describing the details of firefighters' hand and wrist injuries are somewhat scarce. Typically, information that is available lacks depth and is based on only limited samplings. Most injury data have been reported according to the systems promulgated by either the American National Standards Institute's (ANSI) Manual Z 16.2-1962 (R1969) or the National Fire Protection Association's (NFPA) Manual 901. These systems allow for

*Task oriented requirements are defined in an overall, general sense so that hand protection is one of the requirements. However, since hand protection is so important, it is considered separately throughout this report.

the identification of injuries to the fingers, hand, wrist, forearm and, more loosely, the upper extremity. However, the descriptions of the injuries themselves are overly general. For example, no distinction is made between the broken skin injuries of cut and puncture, even though they result from penetration by objects of substantially different geometries and are therefore physiologically different. Moreover, the agent (such as glass or nails) and motion or accident type (such as struck by or against) categories are adapted from general industry and are not always appropriate for firefighting.

Injury data which have been published nearly always lack correlation among injury type or classification, anatomical location, agent and motion. These data are presented as unrelated summaries: a total for each injury type or classification, a total for all anatomical areas, a total for all injuries by each agent, and a total for all injuries by each motion. Such summaries are inadequate in identifying specific injury/hazard/accident combinations to be protected against.

Therefore, a new survey was conducted to gather this information with as much internal correlation as possible.

Injury data were collected from six fire departments and three large state agencies which represent large and small departments, rural and urban locations, and hot and cold climates:*

(1) Denver (Colorado) Fire Department
(2) Cambridge (Massachusetts) Fire Department
(3) Los Angeles County Fire Department
(4) New York City Fire Department
(5) New York State, Office for Local Government
(6) State of California, Division of Labor Statistics and Research
(7) Wisconsin Department of Industry, Labor and Human Relations
(8) Chicago Fire Department
(9) Tucson (Arizona) Fire Department

For each source, the number of injuries occurring within the past five years (1969-1974) was identified and tabulated by classification, anatomical location and, where possible, by agent and motion causing the injury. Minor injuries that required only first aid and resulted in no lost time were excluded. These data are presented in Appendix A.

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*Several of these sources had previously published information, but in the general form described above. With these and the remaining sources, the original raw data were reviewed and then retabulated.

a. The Importance of Hand and Wrist Injuries

During 1973, the New York State office for Local Government reported 1,358 injuries to firefighters. Of these, 293, or 21.6%, were to the fingers, hand, wrist and forearm.* Moreover, during the years 1970-1973, Wisconsin reported 941 lost time or compensable injuries to firefighters. Of these, 154, or 16.3%, were to the fingers, hand, wrist and forearm. These statistics show that hand and wrist area injuries comprise about 20% of all fire scene injuries.

The International Association of Firefighters (IAFF) reported in its 1973 National Survey that the 130,532 firefighters questioned sustained 48,825 injuries while fighting fires.[5] This very large number of injuries translates to an annual rate of 37.4 fire scene inuries for every 100 firefighters. Furthermore, by combining these data with those of the previous paragraph, it has been estimated that 7.5 hand and wrist injuries are sustained annually by every 100 firefighters in the United States. This rate supports the contention that firefighting is exceptionally hazardous to firefighters' hands.

b. Relative Frequency of Hand and Wrist Injuries

As a minimum, each of the nine data sources provided statistics for several primary injury classifications identified in ANSI Z 16. These are the somewhat general classifications such as "mechanical wound with broken skin" and "thermal injury by heat." Table 1, which summarizes all of these data, indicates a surprising order of frequency. Intuition suggests that burns would be the injury encountered most often in firefighting. In reality, however, mechanical wounds with broken skin – such as cut and puncture – occur much more often than any other injury.

The impact of differences from any one source to another – attributable to geographic location or climate – is reduced in such a summary tabulation. For example, Felton implied that the Los Angeles Fire Department incurs non-typical injuries because of a high incidence of brush and forest fires.[6] When combined with all other sources, Los Angeles data contribute to the order of importance but do not determine it.

Note that only those injuries which have been directly correlated with a specific anatomical location were counted here. Injuries shown in Appendix A as being sustained by an "upper extremity" were considered too vague.

Accident records do not usually indicate whether gloves were being worn at the time of injury. Even if such information were available, its reliability would be questioned. Firefighters might have been injured while not wearing gloves, but they most likely would not admit to this fact because of possible "punishment" and insurance losses for having omitted protective clothing. It is estimated, however, that no more than 20% of hand and wrist area injuries occur when gloves are not being worn.

*The forearm has been included to avoid confusion about where the wrist ends and the forearm begins.

TABLE 1

FREQUENCY OF FIREFIGHTER HAND AND WRIST INJURIES
TOTAL NUMBER OF INJURIES, PRIMARY CLASSIFICATIONS

Injury Type	ANSI Z 16.2-1962 (R1969) Injury Classification	Injury Frequency (sources 1-9)*		U.S. Bureau of Labor Statistics, Unpublished National Survey, 1964	
		No.	%	No.	%
1. Mechanical					
a. Wound with broken skin	170	1,751	67.3	1,045	66.9
b. Wound without broken skin	160	305	11.7	202	12.9
2. Thermal					
a. Heat	120	510	19.6	314	20.2
b. Cold	220	7	0.3		
3. Chemical					
a. Burn	130	8	0.3		
b. Poisioning	180 & 270	15	0.6		
4. Electrical (burn)	200	5	0.2		
TOTAL		2,601	100.0%	1,561	100.0%

***Notes:** All nine sources were used for primary categories to provide the largest possible statistical data base.

Only injuries that specifically correlate with anatomical location (fingers, hand, wrist, forearm) were used.

Interestingly, the frequency data of Table 1 are supported by the results of another national survey prepared, but unpublished, by the U.S. Bureau of Labor Statistics in 1965. This study represents 1964 injury data collected from 50 of the largest fire departments in the country plus a sampling of smaller departments. The injury classification also followed the ANSI format. Minor injuries representing less than one day of lost time were excluded. Table 1 also shows a summary of this work; more detailed data are provided in Appendix A.

It would appear that hand protection has improved but little during the past ten years.

Five of the sources further reduced their data to describe individual injuries. For example, injuries such as cut, laceration, puncture, abrasion and amputation were broken out under the "mechanical injury with broken skin" primary classification. Such subclassifications represent more detail than is permitted by either the ANSI or NFPA format.

These data are summarized in Table 2. The frequencies clearly show a specific order of occurrence: laceration, cut, puncture, bruise, burn, crush, abrasion, etc.

c. Severity of Hand and Wrist Injuries

Physiological healing time, when it is recorded, provides an absolute measure of an injury's severity. Lost time, compensable time and actual compensation (number of dollars) do not give a firm basis for judging an injury's severity because of variations in recording injury-related data by the responsible agencies.

For example, both lost time and compensable time figures often exclude an initial period ranging from one to four days which is accounted for by sick leave. Moreover, firefighters frequently return to work before their injuries are completely healed. Such action terminates the accrual of time. Omission of such times, which vary from state to state at least, preclude direct integration and comparison of data describing the impact of an injury.

The actual compensation paid for an injury is usually a combination of a negotiated medical benefit and a "workman's compensation" benefit which has a salary-based ceiling (as does Social Security). Neither of these payment methods is an effective means of directly addressing the severities of the various injuries.

Healing time data were available for firefighters' hand and wrist injuries from the Wisconsin Department of Industry, Labor and Human Relations. These are recorded in Table 3 for both individual injuries and primary injury classifications. Clearly, mechanical wounds are by far the most severe, requiring an average of 7-11 days for healing. Even the less severe thermal burn requires an average of 6 days to heal.

For comparison, available lost time data from the New York City Fire Department are also recorded in Table 3. The severity trend suggested by these data is similar to Wisconsin's.

TABLE 2

FREQUENCY OF FIREFIGHTER HAND AND WRIST INJURIES
TOTAL NUMBER OF INDIVIDUAL INJURIES

Injury Type	Injury Frequency (Sources 1-3, 7, 9)* No.	%
1. Mechanical		
a. Wound with broken skin		
• Cut or scratch	106	20.5
• Laceration	140	27.1
• Puncture	103	19.9
• Abrasion	11	2.1
• Amputation	7	1.4
b. Wound without broken skin		
• Crush or pinch	21	4.1
• Bruise or contusion	64	12.4
2. Thermal		
a. Heat		
• Burn	53	10.3
• Scald	0	0
b. Cold		
• Frostbite	2	0.4
• Freezing	0	0
3. Chemical		
a. Burn	4	0.8
b. Poisoning	6	1.2
4. Electrical (burn)	0	0
TOTAL	517	100.0%

*Notes: Only sources with complete injury subcategories were used in this compilation.

Only injuries that specifically correlate with anatomical location (fingers, hand, wrist, forearm) were used.

TABLE 3

SEVERITY OF HAND AND WRIST INJURIES

Injury Type	Average Healing Time (Days) Wisconsin: Individual Injuries	Average Healing Time (Days) Wisconsin: Primary Classifications	Average Lost Time (Days) New York City: Individual Injuries	Average Lost Time (Days) New York City: Primary Classifications
1. Mechanical				
a. Wound with broken skin		10.7		10.0
• Cut or scratch	11.4			
• Laceration	12.5			
• Puncture	4.6			
• Abrasion	4.3			
• Amputation	9.6			
b. Wound without broken skin		7.1		6.5
• Crush or pinch	12.3			
• Bruise or contusion	5.4			
2. Thermal				
a. Heat		6.3		8.5
• Burn	6.3			
• Scald	6.3*			
b. Cold		1.0		
• Frostbite	1.0			
• Freezing	1.0*			
3. Chemical				
a. Burn		2.0*		2.0
b. Poisoning		4.0		
4. Electrical (burn)		2.0*		

*Estimates for injuries of low frequency.

d. Distribution of Hand and Wrist Injuries

Table 4 shows the frequency of injuries in each primary classification among the four anatomical locations of fingers, hand, wrist and forearm. This tabulation does not allow a cross (horizontal) comparison of the frequencies of individual classifications in the four locations because every data source did not report on all four (see Table 5). However, the data in Table 4 do permit one to describe an overall injury distribution for each of the four anatomical locations:

- **Fingers** – The most common injuries to the fingers are mechanical injuries, in particular, mechanical wounds with broken skin. Mechanical injuries account for 94% of the injuries to the fingers and about four out of every five involve broken skin. Thermal injury by heat is the only other significant injury to the fingers.

- **Hand** – About 75% of the injuries to the hand (both palm and back) are mechanical wounds and again the preponderance of these involve broken skin. However, thermal injury by heat accounts for slightly more than 25% of hand injuries and ranks ahead of mechanical injury without broken skin.

- **Wrist** – Thermal injury by heat is as important in the wrist area as mechanical injury with broken skin. Wounds without broken skin are third.

- **Forearm** – The data indicate the order of frequency is wound with broken skin, thermal injury by burn and wound without broken skin.

One important conclusion to be drawn from the data is that wrist injuries constitute a substantial portion of all hand and wrist area injuries. This is surprising since the wrist is not actively involved in pushing, pulling, lifting or grabbing. Thus the wrist injuries, together with the number of forearm injuries, demonstrates the inadequacies of the protection provided in these areas by currently-used gloves.

2. Causes of Hand and Wrist Injuries

Historically, very little detailed information describing the causes of firefighters' hand and wrist injuries has been recorded. What data are on record have been tabulated in general industrial categories describing the agent of injury and the accident type or motion. Most often, these categories are not descriptive enough to clearly identify the hazards encountered in firefighting. However, some insight into accident trends or patterns can be gained by a review of even limited information.

TABLE 4

FREQUENCY OF FIREFIGHTER HAND AND WRIST INJURIES*
TOTAL NUMBER OF INJURIES, PRIMARY CLASSIFICATIONS AND ANATOMICAL LOCATIONS

	Sources 1-9							
	Fingers (ANSI Code 340)		Hand (ANSI Code 330)		Wrist (ANSI Code 320)		Forearm (ANSI Code 315)	
	No.	%	No.	%	No.	%	No.	%
1. Mechanical								
a. Wound with broken skin	860	79.0	715	62.7	151	45.1	25	67.6
• Cut or scratch								
• Laceration								
• Puncture								
• Abrasion								
• Amputation								
b. Wound without broken skin	166	15.3	113	9.9	24	7.2	2	5.4
• Crush or pinch								
• Bruise or contusion								
2. Thermal								
a. Heat	49	4.5	296	25.9	156	46.6	9	24.3
• Burn								
• Scald								
b. Cold	2	0.2	5	0.4	0	0	0	0
• Frostbite								
• Freezing								
3. Chemical								
• Burn	3	0.3	3	0.3	2	0.6	0	0
• Poisoning	4	0.4	8	0.7	2	0.6	1	2.7
4. Electrical (burn)	4	0.4	1	0.1				
TOTAL	1,088	100.0%	1,141	100.0%	335	100.0%	37	100.0%

***Note:** The number of injuries in one anatomical location *cannot* be compared directly with those in another anatomical location because every source did not contain data on each of the four.

TABLE 5

FREQUENCY OF FIREFIGHTER HAND AND WRIST INJURIES
PERCENTAGE DISTRIBUTION OF DATA AMONG ANATOMICAL LOCATIONS

	Anatomical Region				
	Fingers (ANSI Code 340) %	Hand (ANSI Code 330) %	Wrist (ANSI Code 320) %	Forearm (ANSI Code 315) %	Total Injuries
1. Sources listing four locations					
Denver	58.3	29.2	4.2	8.3	24
New York State	34.2	55.2	8.5	2.1	658
Wisconsin	35.8	48.8	6.5	8.9	123
Chicago	31.3	48.3	17.4	3.0	265
Tuscon	44.0	32.0	16.0	8.0	25
2. Sources listing three locations					
Cambridge	42.5	32.5	25.0	–	40
New York City	35.8	39.2	25.0	–	539
California	46.6	41.3	12.1	–	622
3. Sources listing two locations					
Los Angeles	69.2	30.8	–	–	305
					2,601

Six of the fire departments and state agencies surveyed were able to provide some data describing the agent and type of injuries. Table 6 correlates these accident characteristics with the primary injury classifications. This provides an overview which is useful in the development of quantitative glove criteria as described in Volume II, Part I of this report.

a. Causative Agents

As can be seen from the column headings in Table 6, categories describing the agents causing injury are rather broad in scope. In addition, several categories have been grouped in pairs, providing even less detail. For example, metal objects and glass have been grouped together in a single category. This represents the most specific common denominator for all six data sources. However, where it was possible, separate figures have been reported for these agents in the individual tabulations of Appendix A.

Several general conclusions can be drawn from these data:

- Wounds with broken skin, such as cut and puncture, usually result from contact with glass, metal objects and equipment or tools. The other agents are less important and less well identified.

- Wounds without broken skin, such as crush and bruise, usually result from encounters with equipment or tools.

- Most burns result from contact with flame and hot objects, or from exposure to high heat. This is an expected conclusion.

b. Accident Types

Categories describing the types of accidents inflicting hand and wrist injuries are also rather broad in scope. Moreover, several categories have again been grouped in pairs to provide a common denominator for all six data sources.

Several general conclusions can again be drawn from the data in Table 6:

- Nearly all wounds with broken skin result from grabbing or impact-type accidents (struck by or against).

- Wounds without broken skin result from both grabbing or impact-type accidents and pinch-type accidents (caught in or between).

- Burns result directly from contact or exposure to high temperature thermal energy sources.

TABLE 6
CHARACTERISTICS OF FIREFIGHTERS' HAND AND WRIST INJURIES
NUMBER OF INJURIES – TOTAL OF ALL SOURCES

CAUSATIVE AGENT

GLOVE ORIENTED HAZARDS	DEBRIS	METAL OBJECTS / GLASS	BLDG. FIXTURES OR STRUCTURE	FLORA OR FAUNA	EQUIPMENT OR TOOLS / MACHINERY	VEHICLE	FLOOR, GROUND, OR WORKING SURFACE	ICE	ANOTHER PERSON	BODILY MOTION	HEAT, FLAME, OR HOT OBJECT	COLD	CHEMICALS	CLOTHING	MISC.	
1. MECHANICAL																
a. Wound with broken skin • cut or scratch • laceration • puncture* • abrasion • amputation	42	344	69	43	259	75	27		8	18				1	121	
b. Wound without broken skin • crush or pinch • bruise or contusion	7	12	34		86	34	10	3	6	8					20	
2. THERMAL																
a. Heat • burn • scald	22	12	12		17	6			1		180				5	
b. Cold • frostbite • freezing												3	1			
3. CHEMICAL																
a. Burn													6		1	
b. Poisoning (including skin disease)	1			7					1	1					4	
4. ELECTRICAL		1	3		1											
TOTAL GLOVE ORIENTED INJURIES	72	369	118	50	363	115	37	3	16	27	180	3	7	1	151	

TOTAL "AGENT" INJURIES = 1512

ACCIDENT TYPE

GLOVE ORIENTED HAZARDS	STRUCK BY / STRUCK AGAINST	LIFTING, MOVING, HANDLING	CAUGHT IN OR BETWEEN	FELL FROM / FELL ONTO	EXPOSED TO / CONTACT WITH	MISC.	
1. MECHANICAL							
a. Wound with broken skin	802	14	83	37	15	30	
b. Wound without broken skin	147	5	80	25	1	6	
2. THERMAL							
a. Heat	12	2	1	3	343	2	
b. Cold					2		
3. CHEMICAL							
a. Burn	1				6		
b. Poisoning (including skin disease)	3				9	2	
4. ELECTRICAL					2		
TOTAL GLOVE ORIENTED INJURIES	965	21	164	65	378	40	

TOTAL "TYPE" INJURIES = 1633

* Puncture includes splinters, insect stings, and animal bites.

B. OVERALL GLOVE REQUIREMENTS

Members of seven fire departments were surveyed for information which would identify the non-protective, task-oriented glove requirements. These departments are:

(1) Arlington (Massachusetts) Fire Department
(2) Cambridge (Massachusetts) Fire Department
(3) Concord (Massachusetts) Fire Department
(4) New York City Fire Department
(5) Chicago Fire Department
(6) Denver (Colorado) Fire Department
(7) Tucson (Arizona) Fire Department

Moreover, this survey also generated additional, but subjective, information relating to hand and wrist injuries.

This survey information was combined with the quantitative injury data previously described and glove requirements were rank-ordered in two parts: 1) in-depth hand protection requirements, and 2) overall glove requirements. These rank-ordered requirements provide a framework from which to develop the quantitative criteria needed for establishing the suitability of gloves used in firefighting. This development is carried out in Volume II, Part I of this report.

1. Hand Protection Requirements

Rank-ordered hand protection requirements directly correlate with rank-ordered hand and wrist injuries. These are shown in Table 7. The relative importance of each injury was determined by considering both the previously reported injury data and the survey's subjective Fire Service opinions (tabulated to record the number of times each injury was cited as being important). The calculations determining this rank-ordering are described in Appendix B.

Several items identified by the injury statistics were omitted or modified in preparing this final injury ranking. These omissions or modifications are especially noticeable if one compares Appendix B with the arrangement shown in Table 7. These changes, which were based on experience and technical judgment, are listed below:

- Amputation has been reported in the mechanical injury classification. However, it is felt that a glove is not likely to protect against the energies capable of cutting off a finger or even the whole hand. A glove designed to protect against amputation would have to be rigid and stiff. These characteristics would directly conflict with the important requirement that the glove permit dexterity of movement. Moreover, a glove which will defend against cut and puncture will shift many potential amputation injuries to less severe injuries such as cuts or bruises. Therefore, amputation has been removed from further consideration.

- The freezing of a finger or other member is considered an extensive case of frostbite. Therefore, both frostbite and freezing have been combined into one overall category.

- Mechanical injuries without broken skin are reported throughout the injury statistics. A glove with padding will afford only marginal protection against the hazards causing such injuries. They are therefore considered to be of secondary importance and have been reranked to follow thermal injuries due to cold.

- Chemical injuries can be reduced by designing a glove resistant to liquid penetration – both through the materials of construction and the wrist closure. Therefore, this characteristic is considered a ramification of a glove's resistance to liquid penetration and has been deleted from the injury tabulation.

TABLE 7

HAND PROTECTION REQUIREMENTS FOR FIREFIGHTERS' GLOVES
(listed in order of importance)

Resistance To:

- **Mechanical injury – wound with broken skin**
  1. cut, scratch or laceration
  2. puncture (including splinters, animal bites, and insect stings)
  3. abrasion

- **Thermal injury – heat**
  1. burn
  2. scald (for example, by live steam)

- **Thermal injury – cold**
  1. frostbite and freezing

- **Mechanical injury – wound without broken skin**
  1. bruise or contusion
  2. crush or pinch

- **Chemical injury – poisoning**
  (including skin disease or allergic reaction)

- **Chemical injury – burn**

- **Electrical injury – burn**
  (or electrocution)

2. Overall Requirements

Hand protection and all other requirements for firefighters' gloves, arranged in order of importance to the firefighter, are listed in Table 8. The relative ordering of these characteristics resulted from an analysis of the firefighters' opinions identified in the survey (tabulated to record the number of times each characteristic was cited as being necessary). The characteristics having the most citations were regarded as most important. The "ideal" glove system profiled by this tabulation would afford a firefighter both complete protection from his working environment and the dexterity to easily use his tools and equipment.

Note that several characteristics initially identified by the firefighters were omitted from this tabulation:

- Although firefighters thought "thermal sensitivity" (the ability to sense a hot area by placing the back of the hand against a door, wall, ceiling, etc.) was an important requirement for a properly designed glove, it has been deleted since it directly conflicts with the more important need for protection against thermal burn.

- Harmful chemicals (i.e., strongly toxic or reactive) were initially included under "Resistance to the Effects of Liquids." However, these substances have been deleted in favor of treating such exposure as a special firefighting situation. Although fires do occur in areas containing these substances, firefighters, because of their training procedures, seldom handle or come in contact with them. When industrial or other firefighting situations which involve harmful substances are encountered, special gloves are used when possible.

- Glove construction characteristics (such as style, glove or mitten configuration, multiple structures for varying seasons and cost) were also mentioned. However, they are not included here, because they relate more to design than function.

TABLE 8

OVERALL REQUIREMENTS FOR FIREFIGHTERS' GLOVES
(listed in order of importance)

- **Hazard Protection**
  (see Table 7 for details of individual injuries to be protected against)
  1. hand and finger protection
  2. wrist and forearm protection

- **Dexterity or "Workability"**
  1. flexibility/grip (friction control, wet and dry)
  2. fit (little or no sloppiness or tightness due to poor sizing)
  3. freedom of motion for fingers
  4. tactile sensitivity ("feel" of surroundings)

- **Resistance to the Effects of Liquids**
  (resistance to penetration, retention, and material degradation)
  1. water
  2. common, non-harmful (physiologically) chemicals
     a. petroleum products, cleaning fluids
     b. extinguishing agents

- **Comfort**
  1. "feel" to the hand
     a. fit (little or no sloppiness or tightness due to poor sizing)/softnes
     b. tightness of the wrist
  2. insulation from hot and cold environments
  3. perspiration removal from the hand (absorption)
  4. low weight and bulkiness

- **Resistance to Flame**

- **Easily Donned and Doffed**

- **Durability**

- **Rapid Drying**

- **Visibility**
  (brightness of color for recognition in a dark smoky environment)

IV. DEFICIENCIES OF CURRENTLY USED GLOVES

None of the gloves currently used by firefighters in the United States provide both adequate protection and function as previously identified in Tables 7 and 8. The many deficiencies of these gloves are described by a review of existing standards for firefighters' gloves, a description of the gloves actually used by the Fire Services, and a brief overview of the work glove manufacturing industry:

A. EXISTING STANDARDS FOR FIREFIGHTERS' GLOVES

At the present time, there are no comprehensive standards or other specifications available for use by the Fire Services in selecting gloves. The standards which have been written offer only a superficial overview of glove characteristics. For the most part, current glove standards emphasize design and construction parameters but not protection and other requirements. They do not provide in-depth technical information in three areas which are essential to a useful standard. These are:

- clear, quantitative definitions for glove performance requirements,
- methods for validating actual glove performance, and
- recommendations for glove use and care.

The following review of several domestic and foreign standards and specifications has assisted in substantiating these deficiencies.

1. Domestic Standards

In the United States, both fire service organizations and government agencies have written standards or specifications for firefighters' gloves.

a. Fire Service Organizations

In their documents, the National Fire Protection Association (NFPA) and the International Association of Fire Fighters (IAFF) have listed performance requirements, but they are without substantial technical content or support. Moreover, standards prepared by individual fire departments are actually purchase specifications and do not describe specific performance requirements.

(1) *NFPA Tentative Standard No. 19A-T (1973): Protective Clothing for Fire Fighters.** This standard addresses itself to firefighters' gloves, but only as a subcategory in considering the requirements for full turnout gear. Highlights of Standard 19A-T's performance requirements and several testing procedures are presented below:

---

*In May of 1975, the NFPA published a final draft of Standard 19A for review, comment and subsequent adoption at the NFPA fall meeting in Pittsburgh (November 17-20, 1975). In this draft, all mention of firefighters' gloves was withdrawn. The reasons for this action are unclear.

- **Hazard Protection** – "Consideration should be given to cut, puncture and abrasion resistance . . . . all gloves should provide protection against extreme temperature . . . . mittens are usually essential in cold climates . . . . gloves shall be flame resistant . . . . special nonconductive gloves are needed when contact is made with electrically energized equipment . . . . consideration should be given to liquid repellency . . . . gauntlets should cover the wrist area . . . . glove length should be sufficient to extend at least one inch beyond the cuffs of protective coats."

- **Dexterity** – "Finger types improve dexterity over mittens . . . . . Gloves should be able to grasp small objects such as nozzle tips and couplings."

- **Comfort** – "Gloves should allow fingers to move comfortably."

- **Materials** – "Wool is slow burning and comfortable for manual tasks . . . utility gloves should be of canvas, leather, or plastic, neoprene or rubber coated . . . . special purpose gloves should be of asbestos, aluminized asbestos, combination leather and asbestos or other highly heat resistant materials."

- **Special Clothing (including gloves)** – Recommendations are made for special materials which should be used in entry suits (exposure to direct flame of 1500-2000°F), proximity suits (exposure to radiant heat of 1200-2000°F), and acid and chemical resistant protective clothing.

- **Test Methods** – Federal test methods are referenced for evaluating tear resistance (Method 5132), abrasion resistance (Method 5306), flame resistance (Method 5903), liquid penetration (Method 5524) and cleaning durability (Methods 5612 and 5621). In addition, very simple qualitative-type tests are described for tear resistance (using a knife and a nail to initiate tearing), abrasion resistance (using sandpaper), flame resistance (using a match) and thermal energy penetration resistance (using low melting point polyethylene behind glove materials exposed to a heat source).

The most prominent characteristic of this standard is the omission of a recommended performance level for each requirement. Glove acceptance is apparently based on intuitive performance or on the best of the currently available gloves, not on the firefighter's protective and functional needs. In addition, the test methods which are recommended do not provide for evaluating a glove under simulated firefighting conditions. Test conditions do not correlate with the exposures typical of the fire environment.

(2) *IAFF Proposed Standards on Protective Clothing and Equipment for Fire Fighters.* The IAFF is currently preparing a set of proposed standards on firefighters' protective clothing and equipment under contract to the National Bureau of Standards (Grant

No. 4-9018). Gloves are included and form the basis for one of the standards. However, the intent of this work is not to develop new ideas or recommendations, but only to categorize protective clothing and equipment as it currently exists.* The IAFF glove standard (as reviewed in draft form) does not adequately address both fire scene hazards and the functional requirements of firefighting.

Inadequacies found in currently used gloves are perpetuated by this document. For example, the following sentences describe the expected performance of glove outer materials: "The exterior material shall provide resistance to abrasion and puncture; it shall not readily absorb water or other liquids; it shall provide thermal protection and shall not melt under ordinary operational conditions." "The entire glove shall be designed and constructed to insure maximum feel in the palm and fingers while protecting against injury from handling and carrying hot objects." Little technical definition is offered for abrasion, puncture, water absorption, thermal protection, melting, ordinary operational conditions, maximum feel and protection. Therefore, evaluating a glove's performance and determining its acceptability will prove to be difficult.

(3) *Fire Department Specifications.* Several fire departments have prepared purchase specifications for gloves. Both the Boston, Massachusetts and Newark, New Jersey Fire Departments are examples. These documents emphasize material and construction preferences rather than performance requirements. They have been prepared using successful firefighting experiences to identify the best materials.

b. U.S. Government Agencies

In addition to the Military, the Forest Service and the National Aeronautics and Space Administration (NASA) have described limited-use firefighters' gloves.

(1) *Forest Service Specification 6170-5a (January, 1974): Specification for Forest Workers' Leather Gloves.* This purchase specification describes gloves intended for general purpose use by forestry personnel engaged in outdoor manual labor, including forest firefighting. The gloves recommended here were identified in a joint program with the work glove industry in response to a Forest Service study of injuries among forest workers. This specification does not describe a new glove, but rather provides for quality control in the manufacture and purchase of a modified version of the most suitable currently available work glove. Emphasis is placed on glove materials, design and construction. No performance requirements are provided.

(2) *NASA Firesuit Development Plan (1972).* In an effort to more effectively utilize technology generated in the Space Program, the NASA undertook to develop protective clothing for firefighters. This effort was intended to culminate in detailed specifications for structural firefighters' suits and proximity firefighters' suits. Firesuits, including gloves, were fabricated and field tested. However, too much emphasis was placed on protection from thermal hazards and not enough on function and protection from mechanical hazards. Accordingly, the Fire Services generally found the clothing unacceptable. The program was discontinued and specifications were not finalized.

*These conclusions are based on a communication with Michael J. Smith of the IAFF.

(3) *Military Specifications.* Special purpose firefighters' gloves have been described by the Military. However, as is true for the Forest Service leather gloves, such specifications tend to be written for use in ensuring quality control in manufacture and purchase. Focus is placed on specifying glove materials, designs and constructions (including such minor items as the number of stitches per seam inch). Even though substantial testing may have been conducted in validating the performance of selected materials and designs, performance and functional requirements are not addressed in any depth in these documents.

For example, MIL-G-82262B (June, 1974) describes firefighters' aluminized proximity gloves. It lists the material and construction specifications for heat reflective protective gloves fabricated of aluminized asbestos cloth. Such gloves are not applicable in general firefighting conditions. They are intended for use in fighting aircraft and fuel fires at close range. No performance requirements or exposure conditions are provided.

2. Foreign Standards

None of the foreign standards reviewed address firefighters' needs in the necessary depth.

a. Standards Writing Organizations

The International Organization for Standardization (ISO) and the British Standards Institution have identified industrial glove requirements, several of which relate to firefighting.

(1) *ISO Standard No. 2801 (1973): Clothing for Protection Against Heat and Fire – General Recommendations for Users and for Those in Charge of Such Users.* ISO is a worldwide federation of national standards institutes. Its Standard No. 2801 is overly general and does not address itself to individual items of protective clothing. It has little technical content and therefore is of little value in describing glove requirements.

(2) *British Standard 1651 (1966): Specification for Industrial Gloves.* "This British Standard specifies a range of preferred types of glove for protection against common industrial hazards; the standard classifies these common hazards and recommends gloves for protection against each." Although this standard does not specifically describe firefighting hazards, it does relate glove materials to several qualitative firefighting hazards. However, data describing the magnitude or extent of these hazards is not provided.

As is characteristic of U.S. military specifications, this British standard provides information addressing glove materials and designs for quality control in manufacture and purchase. Test methods for flame resistance (B.S. 3120), electrical resistance (B.S. 697), liquid penetration, tear and tensile (B.S. 903) strengths, and durability (B.S.903) are recommended.

b. Government Agencies

The British and Australian governments have identified agencies which have given consideration to firefighters' hand protection.

(1) *British Fire Research Board, Special Report No. 3: Protective Clothing Against Flame and Heat.* This report provides one of the most comprehensive technical reviews of thermal conditions in the firefighting environment. "The conditions in which protective clothing may be used are analyzed; the likely effects on the human body and the role of clothing in mitigating or preventing these effects is outlined. Specific points discussed are the differing functions of reflectivity, thermal insulation and thermal capacity in long and short term exposures and the special problems of providing protection for the head, feet, and hands." Although specific performance requirements for non-thermal aspects of firefighters' gloves are not given, this British report is technically relevant and is referenced in Volume II of this NIOSH report.

(2) *Australian Defence Standard DEF (AUST) 97: Fireman's Protective Clothing.* This standard is not issued to non-government organizations outside Australia; however, it is believed that it briefly discusses firefighters' gloves. The primary glove requrement presented is that gloves should be manufactured from flame/heat resistant material and may be of the gauntlet or wristlet type.

B. CURRENTLY USED GLOVES

Since there are no adequate standards to serve as guidelines, none of the gloves used in the United States satisfy all of the diverse needs of the firefighter. Primarily, this is because gloves have not been specifically designed for firefighting; but rather, they have been chosen from an extensive selection of general purpose work gloves available to the average consumer.

There is little question that firefighters have unique and severe glove requirements. However, glove manufacturers have not conducted research and development programs aimed at designing gloves to meet these requirements. A lack of incentives for such programs (such as an unattractive return on investment) has prevailed – mainly due to the firefighters themselves. Many glove manufacturers consider firefighters to be diverse in preference and perceived needs, bound by tradition and resistant to change or newness. In the past, this has been an accurate appraisal. Therefore firefighters have constituted a fragmented and somewhat limited market.

1. Glove Materials

The gloves most commonly used by firefighters are made of cotton, leather, vinyl, wool, or infrequently, neoprene and various rubbers. Each of these work gloves has characteristics which may be appropriate for its intended industrial use; however, serious gaps in protection and function develop when used in firefighting. The Fire Services have assisted in identifying these gaps as well as in identifying the primary advantages of each material. This information is summarized in Table 9.

A much more comprehensive overview of these and other glove materials is presented in Table 10: for each glove, the most prominent characteristics have been identified.* Safety features, special features (such as dexterity, grip and comfort), common wrist styles and available sizes are included.

2. Glove Styles

Figure 1 shows the "clute" and "gunn" styles used for most work gloves manufactured in the United States. Nearly all cotton and leather gloves, and many thin cotton support shells for dipped vinyl, neoprene and rubber gloves are assembled in one of these configurations.

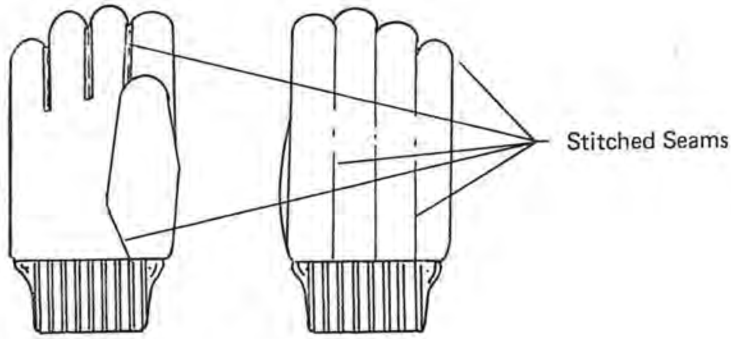
Each style has its individual drawbacks when applied to firefighting. However, an important deficiency common to both styles is a stitched seam across each finger tip. This causes the formation of "duck-feet" fingers and greatly hinders dexterity. Also, these stitched seams can allow water seepage during firefighting. Another problem common to both is bunching of the palm material when the hand is partially closed (e.g., a hand grasp such as in picking up a ball). Such bunching reduces the effectiveness of the firefighter's grip. A variation of thumb design from a straight configuration to a more natural wing configuration is sometimes used in an attempt to alleviate this problem. However, relatively little improvement has been shown.

Figure 2 illustrates common wrist styles that are compatible with both "clute" and "gunn" cut gloves. The short wrist coverings – knit, band top and short gauntlet – don't adequately cover and protect the wrist. The longer gauntlet styles protect against mechanical injury, but they funnel water, debris and hot embers into a glove whenever a firefighter's arm is below horizontal. None of these styles integrate well with the turnout coat sleeve to form an impermeable covering for the wrist.

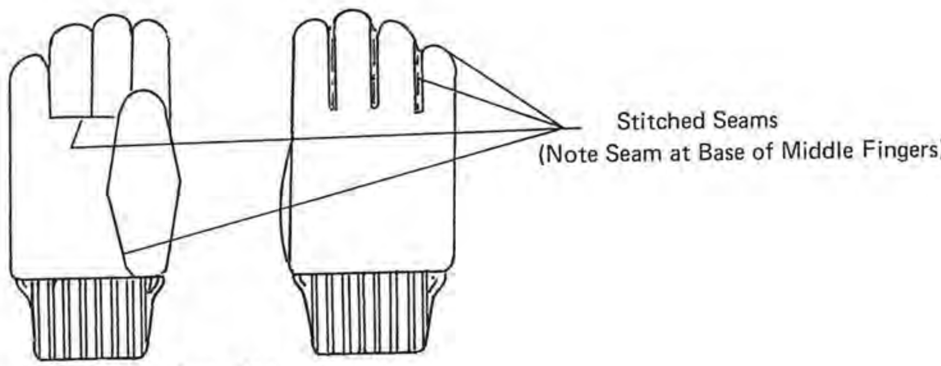
C. THE WORK GLOVE MANUFACTURING INDUSTRY

The work glove manufacturing industry in the United States has evolved from a tradition-bound, art/craft-based technology that is still somewhat resistant to change. The industry has geared itself to mass-produced, low cost general-purpose products. Although several companies have modernized their approach to glove design and manufacture, there

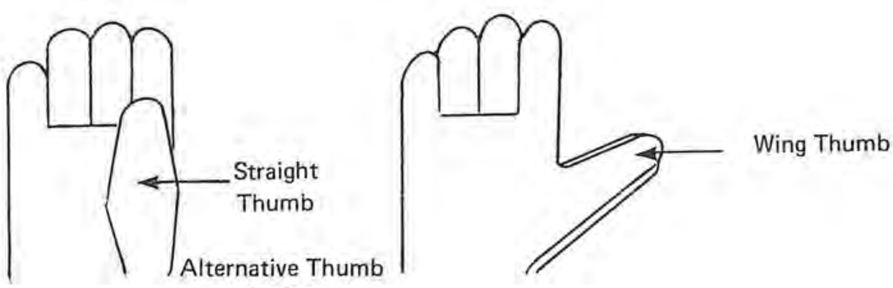
*It is not intended that this tabulation precisely describe all glove designs and configurations. This is a general overview of work gloves available to the firefighter. Specific glove designs within a material category could conflict with the overall characteristics cited.



Clute Cut



Gunn Cut



Alternative Thumb
Designs

FIGURE 1 COMMON WORK GLOVE STYLES

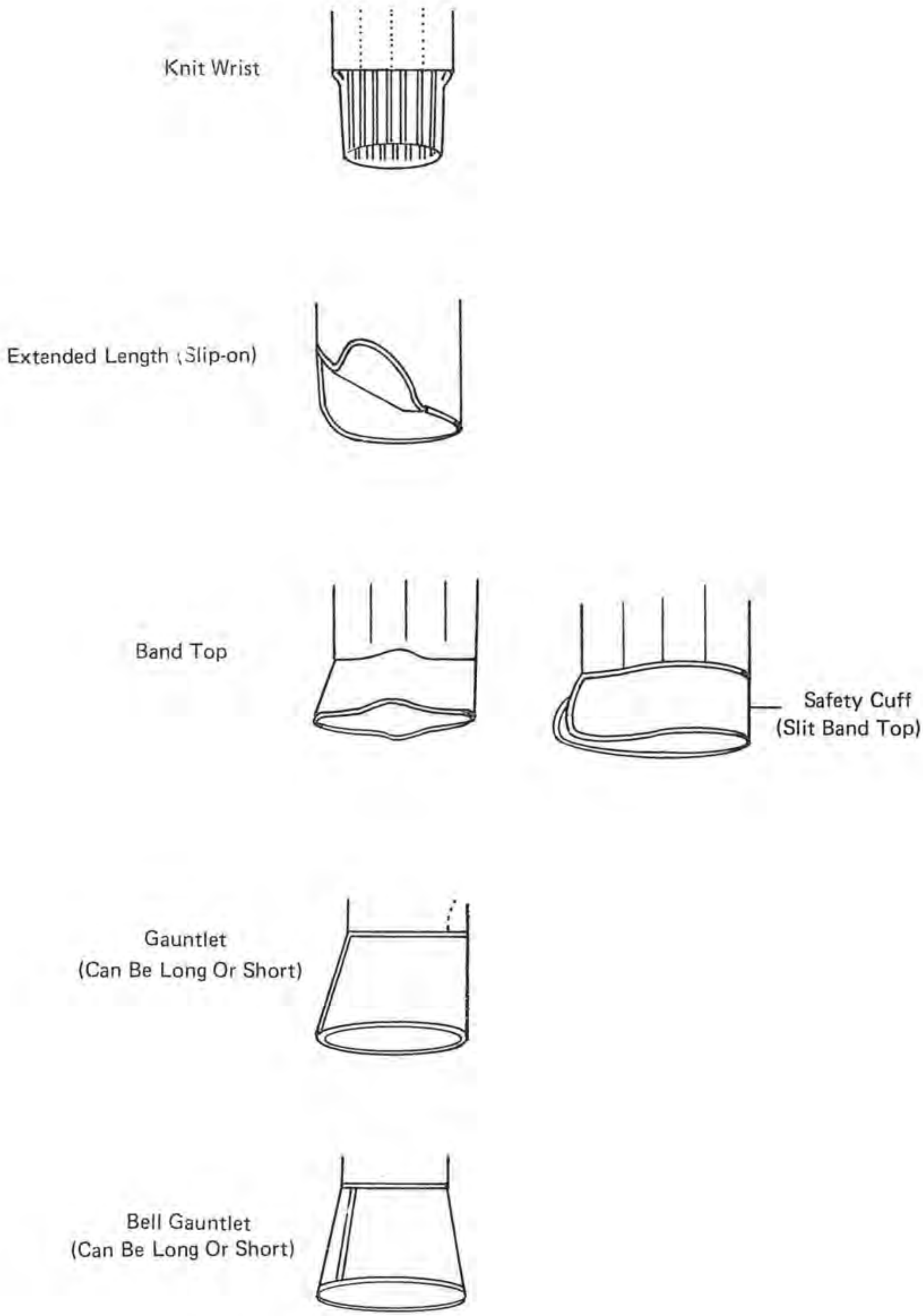


FIGURE 2 WORK GLOVE WRIST STYLES

TABLE 9

CURRENTLY-USED FIREFIGHTERS' GLOVES

Material	Primary Disadvantages	Primary Advantages
Cotton		
Knit-Jersey	Susceptible to mechanical hazards Burns when exposed to direct flame Cold in winter Wettable Non-durable	Provides dexterity Cool in summer Comfortable Inexpensive
Canvas	Susceptible to most mechanical hazards Cold in winter Wettable Non-durable	Resistant to cut Cool in summer Inexpensive
Leather		
Cotton back-leather palm	Cold in winter Wettable Abrasive to the hand when wet Cumbersome Non-durable	Resistant to most mechanical hazards Resistant to flame Initially comfortable
Vinyl		
Supported-Coated or impregnated fabric without insulation	Cold in winter Softens and melts with heat Burns when exposed to direct flame Difficult to dry Cumbersome, poor fit	Resistant to puncture Resistant to water penetration Durable Provides dry and wet grip
Vinyl Supported-Coated or impregnated fabric with insulation	Softens and melts with heat Burns when exposed to direct flame Retains accumulated heat Difficult to dry Very cumbersome, poor fit	Warm in winter Resistant to puncture Resistant to water penetration Durable Provides dry and wet grip
Wool		
Knit-Fisherman's	Wettable Soggy when wet Very cumbersome No dexterity	Warm in winter
Neoprene and Natural Rubber		
Supported-Coated fabric without insulation	Cold in winter Difficult to dry Very cumbersome, poor fit	Resistant to mechanical hazards Resistant to liquid penetration Durable Provides dry and wet grip

TABLE 10
CHARACTERISTICS OF INDUSTRIAL WORK GLOVES

Materials (Single Layer and Composites)	Thermal Insulation (Hot and Cold Environments)	Dexterity (including flexibility)	Tactile Sensitivity	Dry Grip	Wet Grip	In-Service Durability	Cleanability	Comfort	Cut or Scratch	Laceration	Puncture	Abrasion	Crush or Pinch	Bruise or Contusion	Flame Resistant	Non-Degrading Under High Heat	Insulates Against High Radiant Energy	Insulates Against High Conductive Energy	Water	Aromatic Solvents	Ketonic Solvents	Chlorinated Solvents	Petroleum Products	Corrosive Liquids	Liquid Proof (impermeable)	Liquid Repellant (resists penetration)	Electrical	Bacteriological	Radiological (gloves must be leaded)	Knit or Elastic	Extended Length	Band or Slit Band Top	Short Gauntlet	Long Gauntlet	No Wrist Covering	Men's	Women's	S, M, L, XL	Dress Glove Sizes
	Special Features								Safety Features: Protection Against Mechanical Injury						Safety Features: Resistance to Thermal Hazards				Safety Features: Protection Against Exposure to Chemicals – Material Stable When Exposed to:								Safety Features: Protection Against Other Hazards			Available Wrist (cuff) Styles						Available Hand Sizes			
Wool																																							
Knit –																																							
Single Layer Glove or Mitten		●		●			●	●				●			●				●	●	●	●	●							●	●					●			
Fisherman's (double layer mitten)	●						●					●			●			●	●	●	●	●	●							●	●					●			
Cotton																																							
Knit –																																							
Jersey (cotton or polyester/cotton blend)		●	●				●	●				●							●	●	●	●	●							●	●		●			●	●		
Lisle (two-ply cotton)		●	●				●	●				●							●	●	●	●	●							●	●		●			●	●		
Woven –																																							
Terry Cloth (single layer cotton or Lisle)	●	●		●		●	●	●	●	●		●						●	●	●	●	●	●							●		●	●			●	●		
Flannel (Canton)	●	●		●		●	●	●	●	●		●						●	●	●	●	●	●							●		●	●			●	●		
Canvas (cotton or nylon/cotton blend)							●		●			●							●	●	●	●	●							●		●	●			●	●	●	
Nylon																																							
Knit –																																							
Tricot (Warp Knit Fabric)		●	●			●	●	●											●		●	●	●							●		●				●	●		●
Woven –																																							
Terry Cloth	●	●		●		●	●	●	●	●		●						●	●		●	●	●							●		●	●			●	●		
Leather																																							
Cotton Back –																																							
Leather Palm (with or without leather finger(s) and knuckles)				●					●	●	●	●			●															●		●	●	●		●	●		
Full Leather				●		●			●	●	●	●			●														●	●		●	●	●				●	
Heat Resistant Leather (welder's glove)				●		●			●	●	●	●			●	●		●													●			●		●			●
Natural Rubber (milled or latex)																																							
Supported –																																							
Coated Fabric (i.e., cotton)				●	●	●		●	●	●	●	●							●		●			●		●				●	●	●	●	●		●	●		
Coated Fabric with Insulation	●			●	●	●		●	●	●	●	●							●		●			●		●				●									
Unsupported –																																							
Full Rubber		●	●	●	●	●		●	●	●	●	●							●		●			●	●		●	●	●		●								●
Neoprene (milled or latex)																																							
Supported –																																							
Coated Fabric (i.e., cotton)				●	●	●		●	●	●	●	●			●	●			●		●		●	●		●				●	●			●		●		●	●
Coated Fabric with Insulation	●			●	●	●		●	●	●	●	●			●	●			●		●		●	●		●								●		●		●	●
Unsupported –																																							
Full Neoprene		●	●	●	●	●			●	●	●	●			●	●			●		●		●	●	●			●	●		●							●	●
Nitrile Rubber (NBR: milled or latex)																																							
Supported –																																							
Coated Fabric (i.e., cotton)				●	●	●		●	●	●	●	●							●	●		●	●	●		●				●			●			●	●		
Coated Fabric with Insulation	●			●	●	●		●	●	●	●	●							●	●		●	●	●		●				●						●	●		
Unsupported –																																							
Full Nitrile Rubber		●	●	●	●	●			●	●	●	●							●	●		●	●	●	●			●	●		●							●	●
Vinyl (primarily PVC)*																																							
Supported –																																							
Coated Fabric (i.e., cotton)				●	●	●					●	●							●	PVA		PVA	PVA	●		●				●	●	●	●	●	●	●	●	●	
Coated Fabric with Insulation	●			●	●	●		●			●	●							●	PVA		PVA	PVA	●		●				●	●		●	●		●		●	
Impregnated Fabric (i.e., cotton)				●	●	●						●							●					●		●				●			●	●	●	●	●	●	
Impregnated Fabric with Insulation	●			●	●	●		●				●							●					●		●		●	●	●			●			●		●	
Polyethylene																																							
Unsupported –																																							
Full Polyethylene		●	●									●							●	●	●	●	●	●	●					●					●			●	
Asbestos																																							
Plain Asbestos						●						●			●	●		●	●	●	●	●	●									●	●	●		●			
Aluminized Asbestos												●			●	●	●	●	●	●	●	●	●									●	●	●		●			
Leather Reinforced Asbestos						●			●	●	●	●			●	●		●														●	●	●		●			
Metal (i.e., stainless steel)																																							
Flexible Mesh (chain-mail)						●			●	●									●	●	●	●	●							●		●				●	●	●	

References

1. Product Catalogues of Work Glove Manufacturers:
   - Edmont Wilson (Becton, Dickinson and Co.)
   - Newton Gloves (Norton Company)
   - Pioneer Rubber Company
   - Good Luck Glove Company
   - Allied Glove Corporation
   - American Optical Corporation
   - Charleston Rubber Company
   - Jomac Products Corporation
   - Granet Corporation
   - Arbill Industries, Inc.
   - Whiting and Davis Company

2. Prowse, W.A., and D.A. Williams, "Hand and Arm Protection", Occupational Health Bulletin, Canadian Department of National Health and Welfare, 26, No. 5-6, June 1971

3. "Hand Protection", National Safety News, 108, No. 3, Sept. 1973

4. Arthur D. Little, Inc., occupational safety specialists

Note:

*PVA (polyvinyl alcohol) is used in limited, specific applications such as to withstand exposure to solvents.

is considerable progress yet to be made. This is particularly true of glove design practices and automation of manufacturing procedures. The discussion of glove sizing techniques in Volume II, Part I of this report exemplifies this situation.

1. Industry History

The glove industry in the United States can be traced back to the founding of Gloversville, New York, in colonial days. The city is still considered the center of the American dress glove industry. However, the work glove manufacturing portion of the industry has spread throughout the country.

As with other colonial settlements, the population was primarily made up of immigrants from Europe. The need for craftsmen with glovemaking skills was met by these immigrants and many came with old country trade secrets. Many techniques for designing gloves, preparing leathers and other materials, sizing, etc., which were brought to the U.S. by these early craftsmen, have been retained and are still closely guarded secrets.

2. Manufacturing Methods

Work gloves are presently manufactured by methods which are based on economical techniques for handling the various materials used in glove constructions. With few exceptions, the techniques used are straightforward knitting, sewing and dip-forming.

a. Knit Gloves

Wool, cotton, nylon and other textile materials are used for knit gloves and mittens. Such gloves are manufactured as either assembled components or unitized structures. Knitting is nearly always automated and done by machine. The assembly of component-type knit gloves by sewing comprises the only substantive labor-intensive component of this operation.

b. Sewn Gloves

Many types of work gloves are manufactured by sewing together precut components. Cotton, nylon, leather, asbestos and multiple material gloves are in this category. Many companies still use the hand-operated machines in large numbers, although some use larger, semi-automated equipment.

c. Dip-formed Gloves

Dip-formed gloves are of two types: supported and unsupported. The supported type is manufactured by dipping a thin, sewn glove in a vinyl, neoprene or rubber solution or mixture for coating. In manufacturing the unsupported type, a hand form is dipped in a vinyl, neoprene or rubber solution or mixture. The elastomer is coated in sufficient thickness that it retains enough shape and integrity to become a glove when removed from the hand form.

V. NEW STANDARDS FOR GLOVES

It is evident that a set of standards are needed to insure that firefighters are provided with adequate hand protection and glove function. Such a set of standards should be in three parts – one part relating to glove performance, one to glove testing and one to glove use. These standards should be applicable to gloves for all but specialty firefighting situations. Moreover, these standards should establish technical guidelines so that glove requirements can be met through innovative glove design and manufacture.

Recommendations for the content of each of the three standards follow. It is estimated that glove manufacturers should be able to produce a product meeting the requirements of these standards within three years after final promulgation. The most time consuming aspects will be setting up the several test methods and completing glove designs.

A. PERFORMANCE STANDARD

This standard should list the requirements and performance levels for all classifications of firefighters' gloves. It is expected that the information included in this standard will be complete enough to support a comprehensive glove certification and testing program.

1. Format for Performance Standard

This performance standard should be structured as follows:

(1) Scope and Purpose
(2) Definitions for terminology used
(3) Glove classifications
(4) General glove requirements
  (a) Materials' considerations
    - Compatibility of glove components, including such construction components as thread and adhesives
    - Physiological inertness of glove components
  (b) Glove construction
    - Glove configuration or styling
    - Wrist construction
    - Identification markings
    - Warning labels
  (c) Glove sizing
  (d) Glove visibility
  (e) Ancillary data, such as instructions for proper glove selection, use and maintenance.

(5) Glove performance requirements

(a) Hand protection

- Resistance to cut
- Resistance to puncture
- Resistance to heat penetration
- Resistance to "wet" heat penetration
- Resistance to cold
- Resistance to electricity

(b) Other Requirements

- Dexterity
- Resistance to Liquids
- Resistance to Flame
- Durability
- Drying

A substantial portion of the data needed to expand this outline are contained in the glove criteria developed under this contract.

2. Glove Criteria

The qualitative requirements for firefighters' gloves have been summarized earlier in Tables 7 and 8. These requirements are subjective in describing an "ideal" glove or glove system. Nonetheless, they provide a framework from which to develop the quantitative criteria needed for establishing the suitability of gloves used in firefighting.

Part I of Volume II of this report describes the step-by-step development of such performance criteria for the requirements which are amenable to measurement. These requirements are divided into two categories: 1) hand protection and 2) other requirements. In addition, two design considerations which have direct bearing on several of these requirements are discussed in-depth.

A synopsis of these criteria is presented here.

a. Hand Protection Requirements

Six hand protection requirements from Table 7 were determined to be appropriate for glove specifications.

(1) *Resistance to Cut.* Materials used for the outer surfaces of all firefighters' gloves should resist surface cut by a blade (1) with an edge having a 60° included angle and a 0.025-mm (0.001-in.) radius, (2) under an applied force of 7.2 kg (16 lbs), and (3) at a slicing velocity of $\leqslant$ 2.5 cm/sec (60 in./min). These criteria are applicable to all gloves exposed to fire-scene hazards and apply whether the outer glove materials are dry or wet.

(2) *Resistance to Puncture.* Materials used for the palm and palm side of the fingers of firefighters' gloves should resist puncture by a penetrometer (1) simulating a 4d lath nail, (2) under an applied force of 6 kg (13.2 lb), and (3) at a velocity $\leqslant$ 0.85 cm/sec (20 in./min). These criteria are applicable to all gloves exposed to fire-scene hazards and apply whether the outer glove materials are dry or wet.

(3) *Resistance to Heat Penetration.* Firefighters' gloves should protect the hands from exposures to both radiant and conductive thermal energies. To accomplish this, skin temperatures must be kept below the reversible injury profile shown in Figure 3.

Three levels of protection are necessary in defining the resistance to radiant energy. Gloves used by engine company firefighters should protect against relatively mild "routine" radiant exposures. No testable flux need be defined for these exposures. Gloves used by ladder company firefighters should protect against a "hazardous" flux of 0.2 cal/cm^2-sec (2660 Btu/ft^2-hr) for a 10-minute exposure. Gloves used by rescue company firefighters should protect against an "emergency" flux of 2.5 cal/cm^2-sec (33,192 Btu/ft^2-hr) for a 10-second exposure.

All firefighters' gloves should protect against 500°C (932°F), 5-sec, 4-psi conductive energy contacts with hot objects.

Radiant energy protection should be placed primarily in the backs of the hand and fingers; conductive energy protection should be placed primarily in the palm and palm side of the fingers. The materials of construction should show no visible evidence of burning, melting or shrinking under these exposures.

(4) *Resistance to "Wet" Heat Penetration.* Firefighters' gloves should protect against scald-type injury by meeting the criteria for both resistance to heat penetration (above) and resistance to liquid penetration (following in b).

(5) *Resistance to Cold.* Firefighters' gloves used in winter conditions should be constructed with enough insulation to keep the skin above 18°C (64°F) during non-sedentary exposures to an ambient temperature of –30°C (-22°F) for up to 2 hours. Gloves should meet the criteria for resistance to liquid penetration (following in b) as an integral part of these criteria.

(6) *Resistance to Electricity.* All firefighters' gloves should offer sufficient electrical resistance to prevent injury from contacts with a direct current source at 240 volts. Such resistance is established by limiting current leakage through glove materials to less than 5 milliamps. This applies to both dry and wet gloves.

b. Other Requirements

After a thorough review of the overall requirements listed in Table 8, seven were determined to be appropriate for glove specifications.

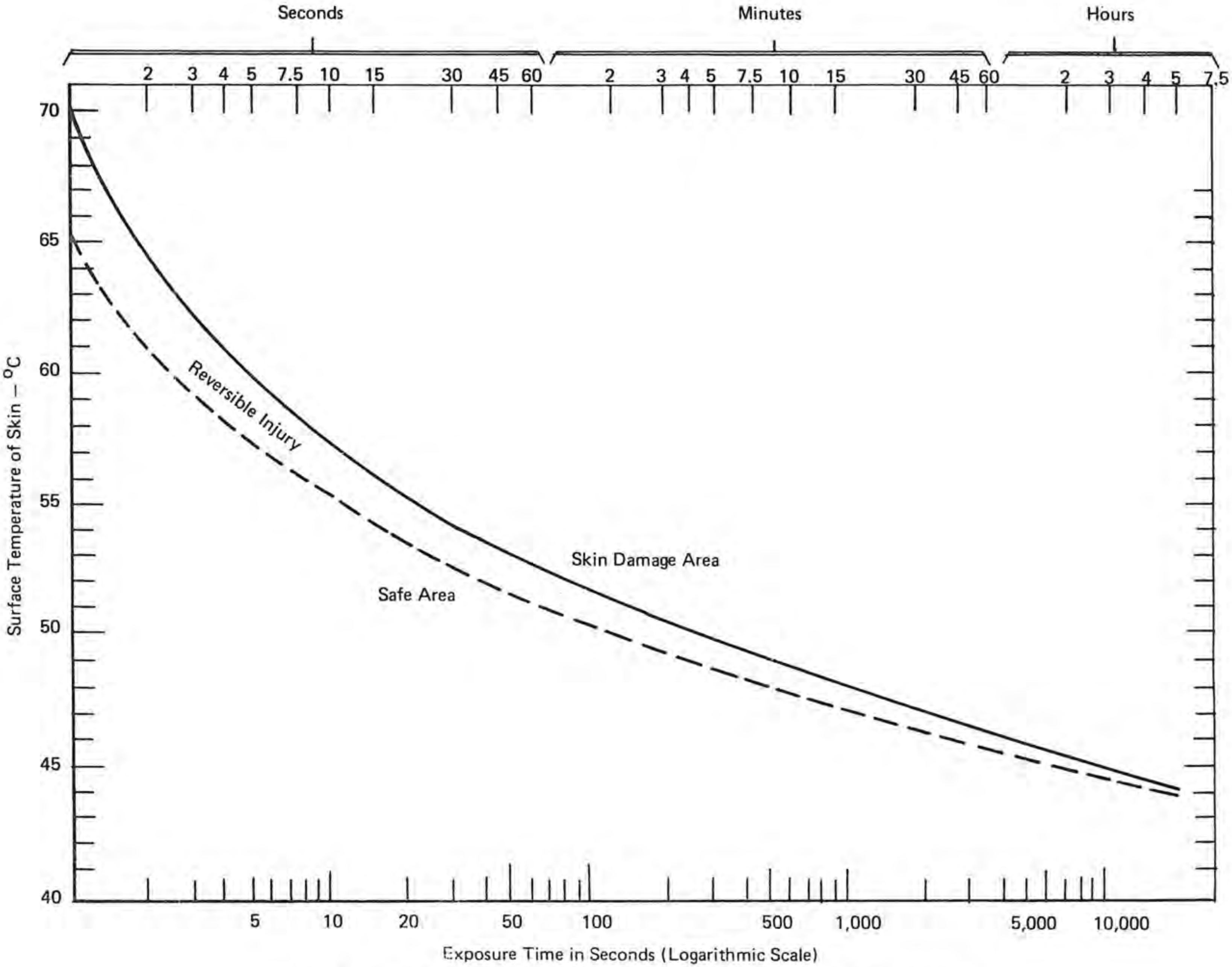


FIGURE 3 TIME-TEMPERATURE THRESHOLDS AT WHICH SKIN BURN OCCURS

(1) *Dexterity.* Firefighters' gloves should be constructed to allow enough dexterity that a pencil, dry or wet, can be picked up from a flat surface by each of the four possible combinations of thumb and finger. A pencil is simulated by a smooth-surfaced stainless-steel rod of 5.0-mm (0.20-in.) diameter and 40.0-mm (1.6-in.) length.

(2) *Resistance to Liquids.* Firefighters' gloves should be constructed to resist each of three hazards relating to liquids:

- **Liquid Penetration** – At least one material layer and all seams should be impermeable to commonly encountered liquids. A glove structure is considered impermeable if it withstands a differential water pressure of 4 psi for 1 minute without detectable leakage or seepage. Also, wrist closures should be designed to prevent liquids from freely entering (following in c).

- **Liquid Retention** – Gloves should retain less than 15% water (by weight) after the outside has been soaked in a water bath and mildly shaken free of excess liquid. This pertains to the outer materials only – water is prevented from entering to the inside.

- **Material Degradation** – Glove outer materials should not show visible signs of chemical attack, swelling or stiffening when exposed for 15 minutes to petroleum fuel products and common (OSHA-approved) solvents and cleaning fluids.

(3) *Comfort.* Firefighters' gloves should meet all aspects of the following criteria in order to provide minimum acceptable levels of comfort:

- **Thermal Energy Penetration** – Gloves should maintain hand-skin temperatures within the range of 64-111°F (18-44°C). These temperature limitations will be met if the criteria for resistance to both cold and heat penetration (above in a) are achieved.

- **Material Absorbency** – Glove linings or inner materials should absorb at least 30% water (by weight) at a rate of 0.01 milliliter per second.

- **Glove Weight** – Each glove should weigh no more than 0.5 lb (228 gm).

- **Material Stiffness** – Glove linings or inner materials should have a soft and flexible "hand." Overall glove stiffness or flexibility requirements will be met if the criteria for dexterity (above) are achieved.

- **Glove Fit** – Gloves should be sized to provide a good fit (following in c).

(4) *Resistance to Flame.* Materials used for the outer surfaces of firefighters' gloves should resist degradation on exposure to a 1200°F (980°C) flame for 12 seconds. Resistance to degradation is established by the following:

- **Measurable Changes**

  After-flame time should not exceed 2 seconds.
  After-glow time should not exceed 2 seconds.
  Visible charring should not exceed 1 inch.
  Consumed material should not exceed 5% by weight.

- **Observable Changes**

  There should be no visible evidence of melting or dripping.
  There should be no visible evidence of embrittlement or shrinkage.

(5) *Durability.* To demonstrate adequate durability, firefighters' gloves – including the wrist construction – should withstand cycles of exposure to water, dry heat and abrasion. Each exposure cycle is defined in the following manner:

Exposure Condition	Exposure Time
Water at 65-75°F (18-24°C)	20 minutes
Dry heat at 300°F (149°C) then at 150°F (66°C)	10 minutes 20 minutes
Abrasion by 2 traversals in each of two directions at right angles to each other, using 30 or 36-grit emery cloth at 4 psi pressure.	–

Gloves should withstand 24 of these cycles. It is estimated that this corresponds to a six-month service life.

(6) *Drying.* Firefighters' gloves should dry easily, both inside and outside, in three hours or less at ambient conditions.

(7) *Visibility.* It is recommended that firefighters' gloves be as visible as possible through use of lime-yellow or reflectorized light-colored components.

c. Design Considerations

Two glove design considerations – glove sizing and wrist construction – are included because of their direct impact on glove performance. Sizing influences glove comfort and dexterity; wrist construction influences injury susceptibility and liquid penetration.

(1) *Glove Sizing.* Firefighters' gloves should be manufactured in a minimum of three sizes correlating with firefighters' hand dimensions. Glove sizes should be based on the four groups of critical hand dimensions illustrated in Figure 4. The sizes should correspond to the 15th, 50th and 95th percentile data presented in Table 11. If manufacturing

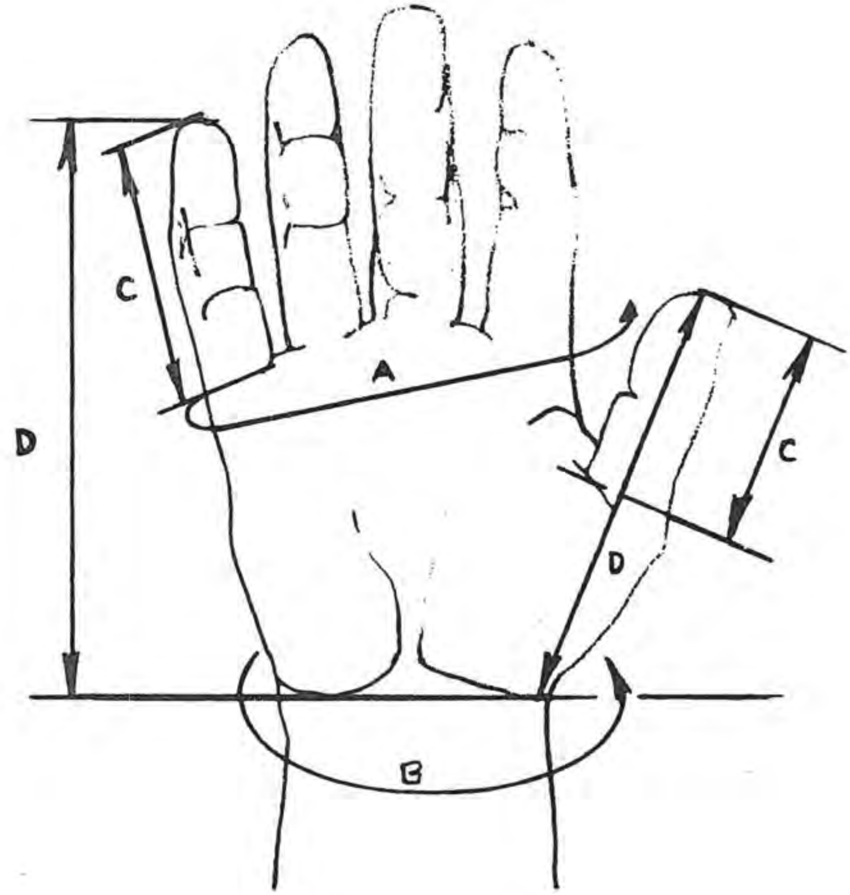


FIGURE 4 CRITICAL HAND DIMENSIONS

TABLE 11

ANTHROPOMETRIC DATA FOR CRITICAL HAND DIMENSIONS (MALE)

DIMENSION	Population Distribution - Percentiles*									
	15%		40%		50%		70%		95%	
	in.	cm	in.	cm	in.	cm	in.	cm	in.	cm
(A) Hand Circumference - Metacarpal	8.15	20.70	8.38	21.30	8.47	21.51	8.67	22.02	9.09	23.08
(B) Wrist Circumference	6.51	16.53	6.79	17.23	6.88	17.46	7.07	17.95	7.52	19.09
(C) Finger Length - Tip to Crotch:										
Thumb	2.12	5.39	2.27	5.76	2.31	5.88	2.41	6.12	2.59	6.57
First	2.77	7.03	2.91	7.39	2.96	7.52	3.06	7.77	3.23	8.19
Second	3.16	8.02	3.31	8.40	3.36	8.53	3.48	8.83	3.73	9.47
Third	2.98	7.57	3.10	7.87	3.15	7.99	3.26	8.28	3.52	8.93
Fourth	2.75	5.71	2.35	5.98	2.40	6.08	2.50	6.35	2.75	6.99
(D) Finger Length - Tip to Wrist Crease:										
Thumb	4.54	11.54	4.87	12.37	4.98	17.66	5.22	13.26	5.78	14.68
First	6.93	17.60	7.19	18.26	7.28	18.48	7.46	18.96	7.90	20.06
Second	7.33	18.62	7.56	19.20	7.65	19.43	7.87	19.98	8.28	21.04
Third	7.03	17.85	7.23	18.36	7.32	18.59	7.55	19.18	7.98	20.28
Fourth	6.21	15.77	6.43	16.34	6.51	16.54	6.71	17.04	7.13	18.10

*The percentile values for a particular set of data are treated as though plotted on normal probability graph paper.

economics are favorable, gloves should be manufactured in a minimum of four sizes. These sizes should correspond to the 15th, 40th, 70th and 95th percentile data presented in Table 11.

(2) *Wrist Construction.* To provide isolation and protection of the wrist from firefighting hazards, firefighters' gloves should be designed to:

- Provide an impermeable wrist closure to keep water and debris from entering;
- Provide a wrist covering which will resist liquid penetration and firefighting hazards; and,
- Provide an impermeable interface with the turnout coat sleeve.

d. Glove Classifications

The quantitative criteria which have been developed here are applicable, for the most part, to all firefighters' gloves. The exceptions to this statement are the criteria developed for resistance to heat penetration. The three task-oriented resistance levels for radiant thermal energy clearly provide for three distinct glove classifications. Accordingly, separate gloves can be described for engine company firefighters, ladder company firefighters and rescue company firefighters.

Ideally, one glove should be sufficient for all firefighters, regardless of their duties. However, considering the current states of materials technology and glove manufacturing, the concept of one glove can not be realized for some time. Therefore, such a three-part classification system allows for technological and economic trade-offs without compromising protection. Table 12 summarizes this concept.

B. TESTING STANDARD

This standard should describe test methods and equipment for evaluating gloves which are proposed for use in firefighting. Evaluations should be made according to the criteria listed in the Performance Standard.

1. Format for Testing Standard

This testing standard should contain, as a minimum, information in the following categories:

(1) Purpose and scope

(2) Testing protocol, such as the sequence of conducting the several test methods expected in this standard

(3) Individual test methods

FIREFIGHTERS' GLOVE CLASSIFICATIONS

APPLICABLE CRITERIA \ GLOVE CLASSIFICATION	ENGINE (GENERAL PURPOSE)	LADDER (PROXIMITY)	RESCUE (ENTRY)
<u>Hand Protection</u>			
Resistance to cut	X	X	X
Resistance to puncture	X	X	X
Resistance to heat	X	X	X
• Routine	•		
• Hazardous		•	
• Emergency			•
Resistance to "wet" heat	X	X	X
Resistance to cold*	•	•	•
Resistance to electricity	X	X	X
<u>Function</u>			
Dexterity	X	X	X
Resistance to liquids	X	X	X
Comfort	X	X	X
Resistance to flame	X	X	X
Durability	X	X	X
Drying	X	X	X
Visibility	X	X	X
<u>Design</u>			
Sizing	X	X	X
Wrist construction	X	X	X

*This is applicable to gloves used in winter conditions.

In addition, information for each test method should be provided:

(1) Scope
(2) Test Specimens
(3) Number of Tests
(4) Test Apparatus
(5) Test Procedure
(6) Report of Test Results

A substantial portion of the data needed to expand this outline are contained in the test methods developed under this contract.

2. Test Methods

Few glove manufacturers test their products to insure that they meet the protective and functional needs of the glove user. Of 10 leading work glove manufacturers questioned, only three responded that they have any formal testing program. However, even these programs are limited and consist mostly of evaluating glove resistance to cut and abrasion. There is no testing to evaluate resistance to puncture, heat penetration, or flame – three of the requirements which are very important in firefighting.

A thorough review of published test methods from other industries as well as those of the glove industry failed to identify any that are completely applicable to validating candidate firefighters' gloves. Therefore, it was necessary to design a number of test methods for this purpose. They are methods for determining:

- Resistance to (static) cut;
- Resistance to (static) puncture;
- Resistance to heat penetration;
- Resistance to electricity;
- Dexterity;
- Resistance to liquid penetration;
- Resistance to flame; and,
- Durability.

These methods are described in Part II, Volume II of this report. Two additional methods, one for determining resistance to (dynamic) cut and one for determining resistance to (dynamic) puncture, are also described in that section.

In developing test methods, a number of factors were considered.[7] First, a test must be able to be carried out by comparatively unskilled operators with a minimum of apparatus and material. The test should produce consistently reproducible results, both in different laboratories and even in the same laboratory at different times. The test results should be meaningful in differentiating between the performance of materials or constructions when there are known to be significant differences, and vice versa, not differentiating between the performance of materials or constructions when there are no significant differences. Lastly, the test should give representative results. In selecting test conditions, it is most important to simulate the environment or hazard so that the test method clearly tests against end-use conditions.

In developing test methods for firefighters' gloves, these factors were adhered to. Test conditions were based on the "glove's environment" during a fire: heat, flame, water, steam, glass, nails, and other debris.

C. USER STANDARD

This standard should provide detailed information on proper glove selection, use and maintenance, and on determining the time for glove replacement. It should contain, as a minimum, information in the following categories:

(1) Scope and Purpose
(2) Glove selection
  (a) Glove classifications
  (b) Correlation of glove classification with firefighting duties
  (c) Glove sizes
(3) Glove use
  (a) Cautions on use, such as stating the necessity for adhering to the segregation of firefighting duties as expressed by the glove classifications.
  (b) Recommendations to prevent glove abuse
(4) Glove maintenance
  (a) Timetable for inspection
  (b) Cleaning
(5) Glove repair and replacement
  (a) Conditions necessitating glove repair
  (b) Procedures for glove repair
  (c) Conditions necessitating glove replacement

Most information needed to expand this outline will be subjective in nature and has yet to be generated.

D. SPECIALTY FIREFIGHTING SITUATIONS

There are several firefighting situations which result in exceptionally severe or unusual conditions. They are characterized by potential exposures to hazardous substances or organisms, to highly concentrated thermal energy sources or to radiological sources. This study did not address itself to developing glove criteria for these situations. In some cases they already exist – such as the various military standards for protective clothing used in aircraft and fuel fires. Several specialty situations are:

- Fires in which physiologically harmful chemicals (acids, bases, and other corrosive substances) are directly involved.

- Fires in which poisonous substances, bacteria, or other harmful organisms are directly involved.

- Fires in which radiation from a nuclear source is a direct hazard.

- Fuel fires (with the resulting very high energy emissions).

- Forest fires (although use of general-purpose firefighters' gloves may be appropriate here).

- Electrical fires (especially with high voltage sources supporting a fire).

Many of these situations demand protective clothing which allows close proximity to or actual entry into a fire. This fact alters the emphasis on glove requirements from both protective and functional to nearly all protective.

VI. A PROTOTYPE GLOVE SYSTEM

During the criteria development and glove testing phases of this study (Volume II, Part I), it was demonstrated that currently-used gloves do not adequately provide for firefighters' hand protection and function. Furthermore, it became clear that upgrading currently-used gloves by using better materials would not eliminate all of the deficiencies. The necessary improvements can be achieved, however, by combining new glove designs with the use of better materials.

Investigations into design concepts and material characteristics have led to recommendations, as described below, for developing a prototype glove system to meet, and thereby demonstrate the viability of, the new glove criteria.* In addition, a number of candidate materials have been tested for suitability in a prototype glove system. These data are also reported in the following paragraphs.

A. GLOVE DESIGN

The current state of both materials' technology and glove fabrication techniques appear to preclude the development of a single glove (or rather, a single-component glove) which will provide both complete hand protection and function. Rather, these requirements can best be met by a three-component glove system.

1. Component 1

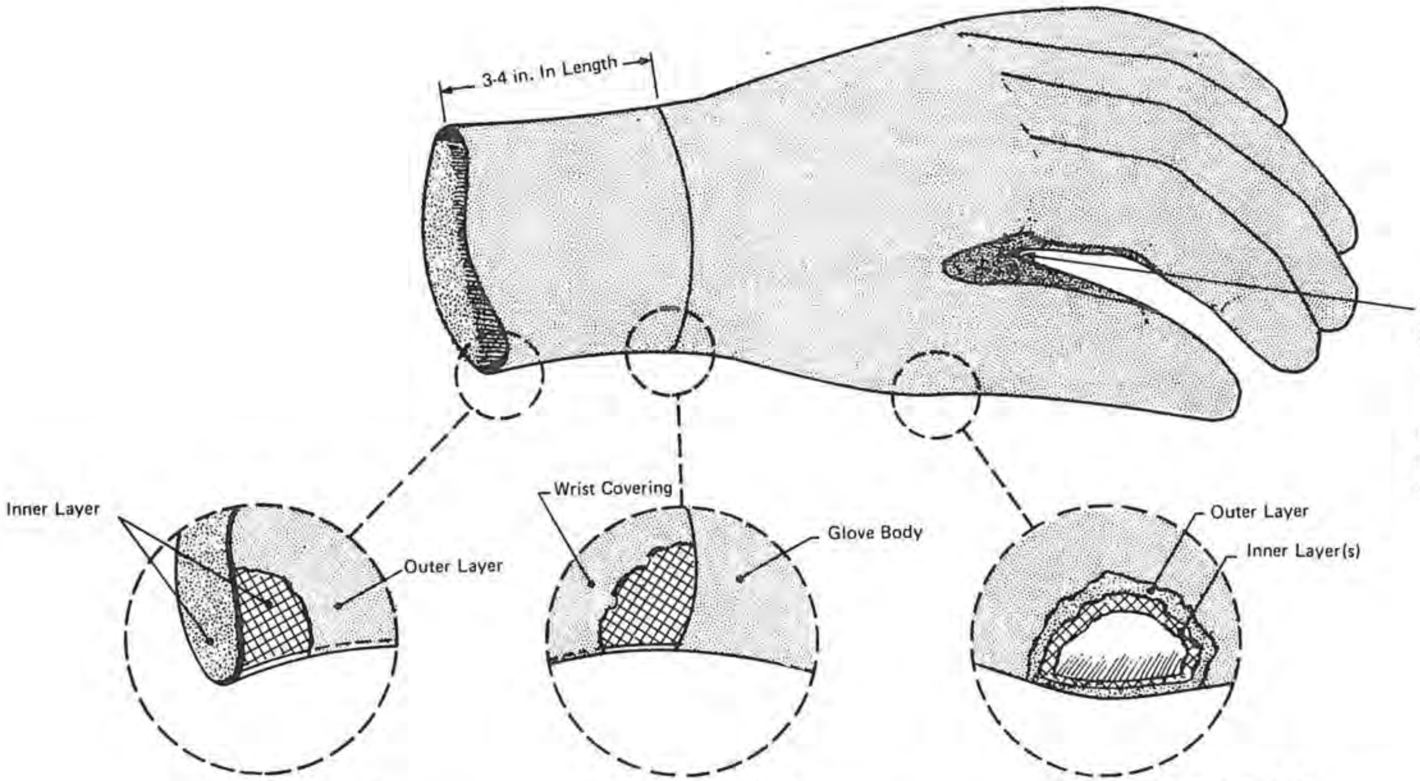
The primary component of this system is a general-purpose glove which meets all of the criteria specified for the engine-company glove classification. This includes all criteria except those for exposures to "hazardous" and "emergency" radiant energies and cold weather conditions. Several features of the design in Figure 5 are essential for achieving the necessary performance levels. They are:

a. Two-layer Wrist Covering

The wrist covering of this glove should be constructed of two layers which are separate from each other except at the outer end and at the juncture of the wrist covering and glove body. The wrist covering should be 3-4 in. (7.6-10.2 cm) long to allow easy integration with a turnout coat sleeve.

The outer layer should be an elastomer-coated material that provides resistance to cut, electricity, liquids and flame. The outer layer turns under to become the uncoated inner

*Since most emphasis was placed on developing glove criteria, these recommendations are not as detailed as other parts of this report. The glove system will need refinement.



Glove Palm

The Palm and Palm Side of The Fingers Should Provide:

- Resistance To Puncture; and,
- Resistance To Conductive Thermal Energy.

This May Require an Additional Material Which Could be Attached By Adhesive.

Two-Layer Wrist Covering

The Inner Layer Should be an Elastic Material That Clings Tightly but Comfortably to the Wrist.

The Outer Layer Should be a Coated Material That Provides:

- Resistance to Cut;
- Resistance to Electricity;
- Resistance to Liquids; and,
- Resistance To Flame

Juncture of Wrist Covering and Glove Body

The Inner Layer of The Wrist Covering Ends at This Primary Juncture. The Outer Layer Should Be Continuous With The Coated Surface of The Glove Body.

Multi-Layer Glove Body

The Inner Layer or Layers Should be Constructed of One or More Materials Which Provide:

- Resistance To "Routine" Radiant Thermal Energy;
- Comfort; and,
- Ease of Drying

The Outer Layer Should be a Coating or a Coated Material Which Provides:

- Resistance To Cut;
- Resistance To Electricity;
- Resistance To Liquids; and
- Resistance To Flame

FIGURE 5 ENGINE-COMPANY GLOVE

layer. The inner layer of the wrist covering should be an elastic material that clings tightly, but comfortably, to the wrist and forearm.

b. Multi-layer Glove Body

The entire glove body should be a multi-layer assembly. The inner layer should be constructed of one or more materials which provide resistance to "routine" radiant thermal energy penetration as well as comfort and ease of drying. The outer layer should be either an elastomeric coating or an elastomer-coated material which provides resistance to cut, electricity, liquids and flame. The coating should be continuous with the coating on the wrist covering.

c. Glove Palm

The glove palm and palm side of the glove fingers should provide resistance to puncture and conductive thermal energy. If the glove body does not already provide these protections, an additional material will be necessary. This layer should not be attached by through-stitching; it should be attached by an alternative method such as the use of a flexible adhesive.

2. Component 2

Protection against "hazardous" and "emergency" radiant thermal energy exposures can be achieved by use of a disposable outer pull-over. Materials can be selected so that one pull-over is capable of resisting "hazardous" exposures and another is capable of resisting "emergency" exposures. Such pull-overs would upgrade an engine-company glove to a ladder-company glove or a rescue-company glove, respectively.

The design in Figure 6 utilizes an aluminized material with an elastomeric closed-cell foam underlay. This underlay insures that the pull-over fits snugly and prevents liquids from easily seeping underneath. Since the firefighters' fingers are normally turned under in grasping an object or tool, the pull-over need not cover the outer half of the fingers. This will assist in retaining dexterity.

The palm side of the pull-over should not be aluminized and should be constructed to be compatible with, and not obstruct, the palm of the engine-company glove.

3. Component 3

Thermal insulation for protection against cold weather can be provided by a separate pull-over. This would upgrade an engine-company glove so that it meets the cold criteria. This would also eliminate the problems associated with requiring a single glove to resist cold as well as meet all of the other criteria. A cold weather pull-over should not be used when radiant energy pull-overs are needed.

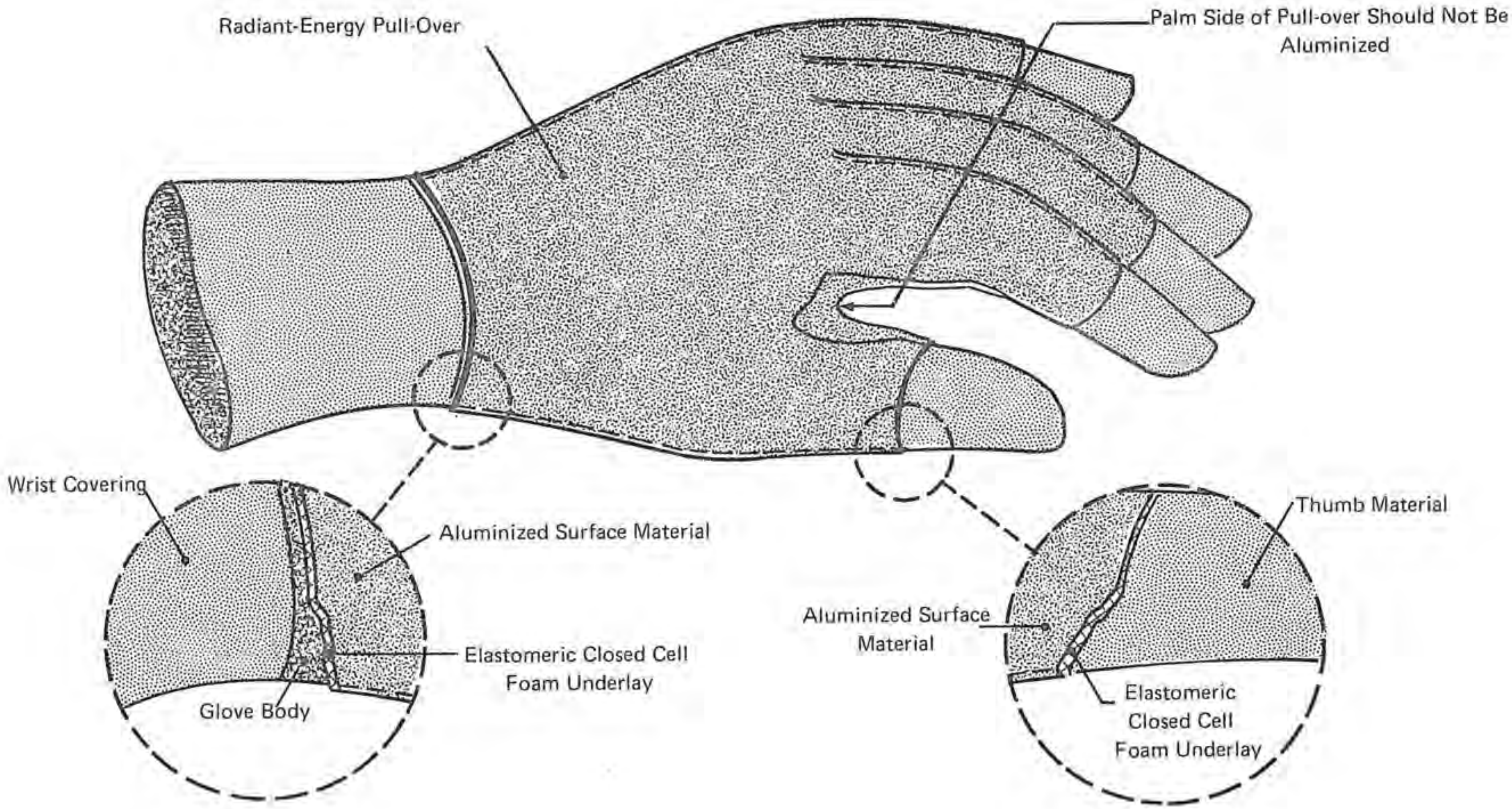


FIGURE 6 ENGINE-COMPANY GLOVE WITH RADIANT-ENERGY PULL-OVER (SUITABLE FOR LADDER-OR-RESCUE COMPANY GLOVE CLASSIFICATIONS)

B. CANDIDATE GLOVE MATERIALS

A number of candidate materials have been evaluated. Data have been generated for resistance to cut, puncture, heat penetration, flame and liquid penetration. These data provide direction for additional testing. A more thorough testing program is needed to identify an optimum combination of materials for the prototype glove system.

Of the materials evaluated, some were tested individually while others were tested in composite or sandwhich assemblies with two or more layers. A detailed listing of the synthetic and treated materials is presented in Appendix C. The test results are discussed in terms of individual criteria:

(1) Resistance to Cut

A limited number of materials were tested for resistance to static cut. As shown in Figure 7, several met the resistance levels specified in the criteria. These are Nomex duck, Viton coated Kevlar, aluminized Nomex and Foylon (aluminized Kevlar).

The testing carried out on currently-used gloves showed that canvas, leather, natural rubber-coated cotton and heavy neoprene-coated cotton are also resistant to static cut.*

(2) Resistance to Puncture

A series of materials were subjected to both static and dynamic puncture testing. As shown in Figure 8, none of the materials met the resistance levels specified in the criteria. Since most materials are woven or knit fabrics, it is understandable that they were easily penetrated. Coated fabrics or random fiber layups (such as leather) tend to be more resistant to puncture.

The testing carried out on currently-used gloves showed that leather and neoprene can effectively resist puncture.* Therefore, a number of leather and neoprene samples were tested further. Figure 9 shows the effect of thickness and backing materials on improving the puncture resistance of these materials.

(3) Resistance to Heat Penetration

A limited number of materials were tested for resistance to radiant and conductive energy penetration. As noted earlier in this report, heat penetration is monitored by the temperature of a skin simulant mounted behind the material(s)

*Test results for currently-used gloves are described in Volume II, Part I of this report.

FIGURE 7 CUT RESISTANCE TEST RESULTS
STATIC CUT
CANDIDATE MATERIALS

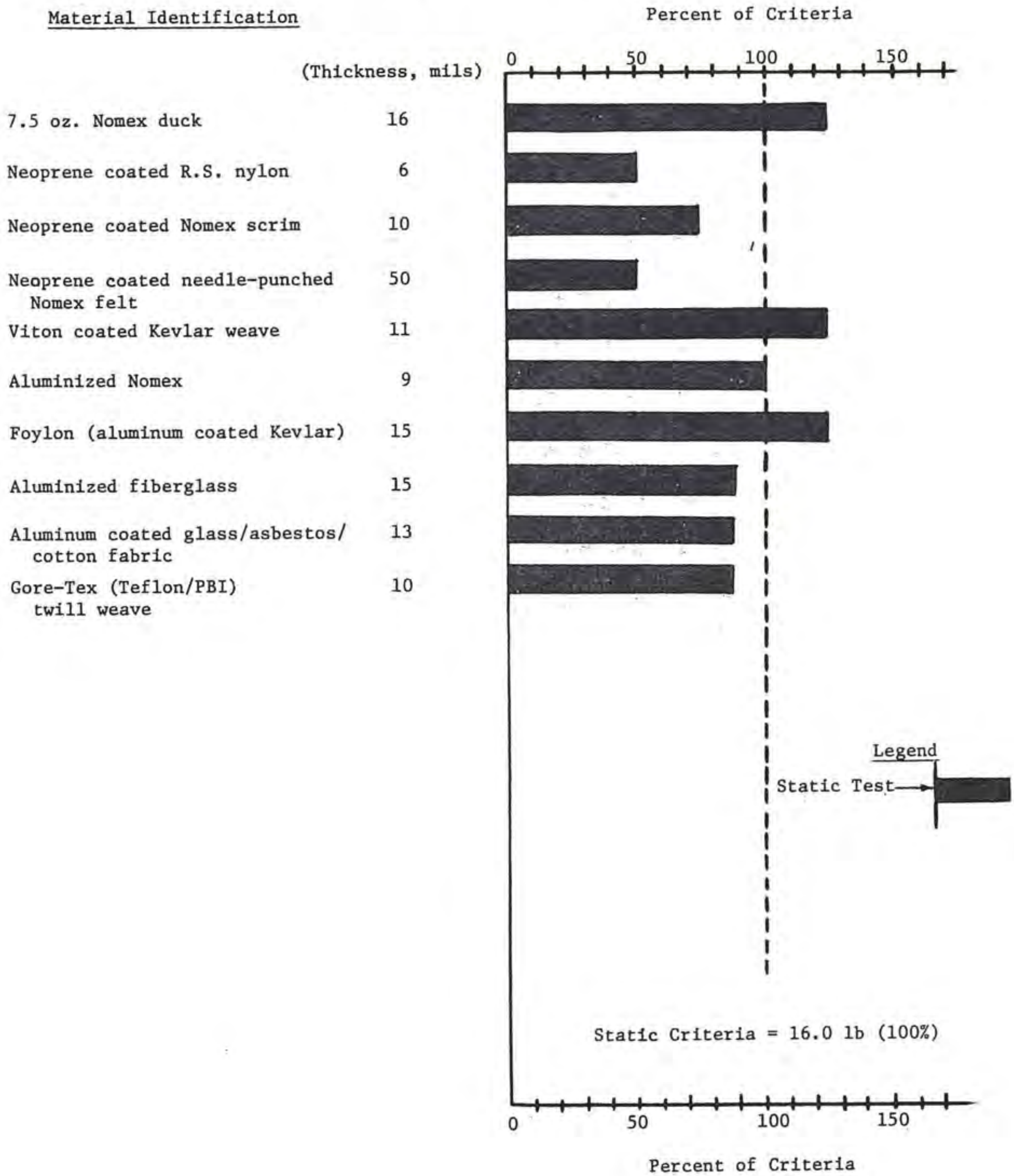


FIGURE 8 PUNCTURE RESISTANCE TEST RESULTS
STATIC AND DYNAMIC PUNCTURE
CANDIDATE MATERIALS

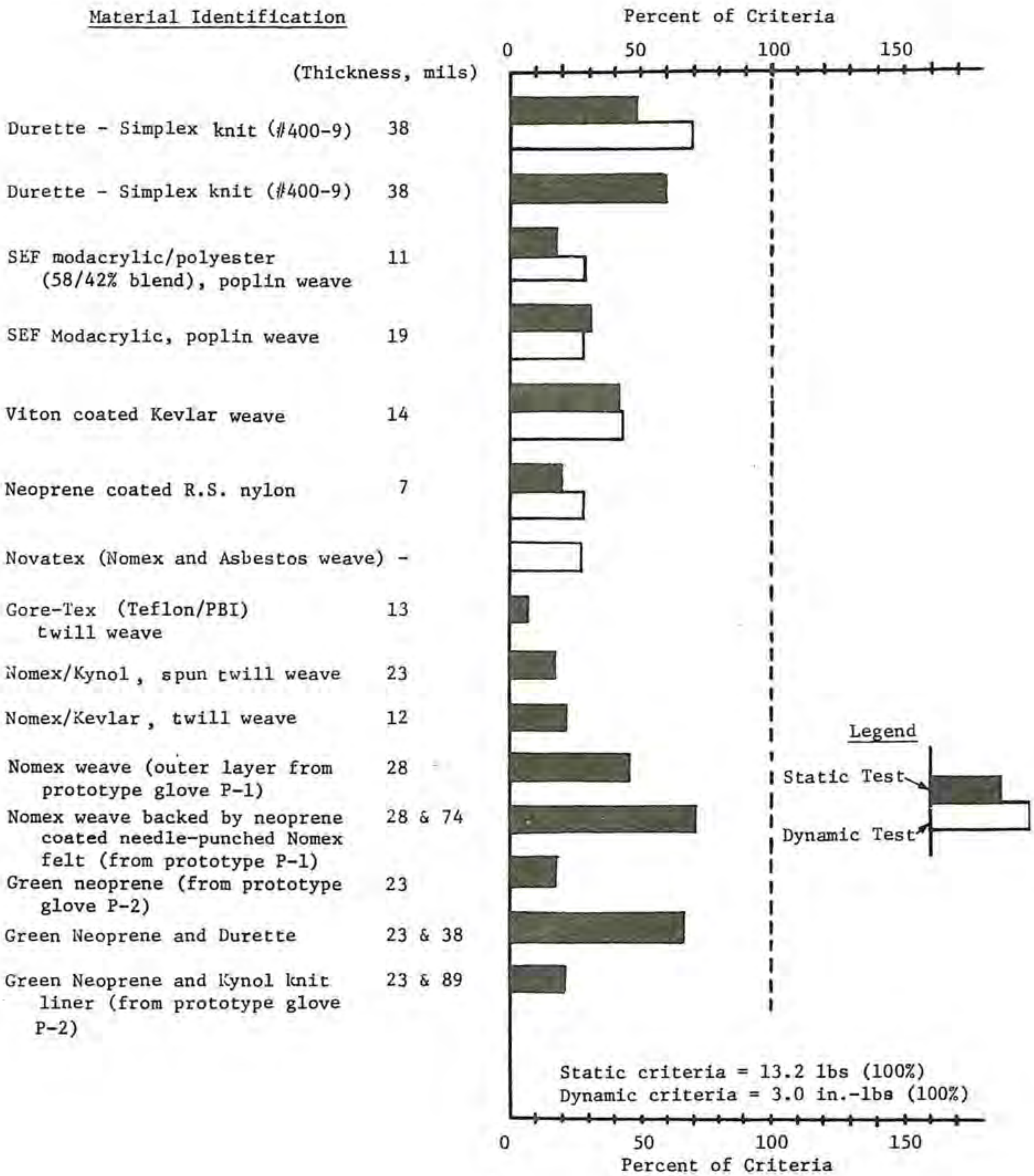
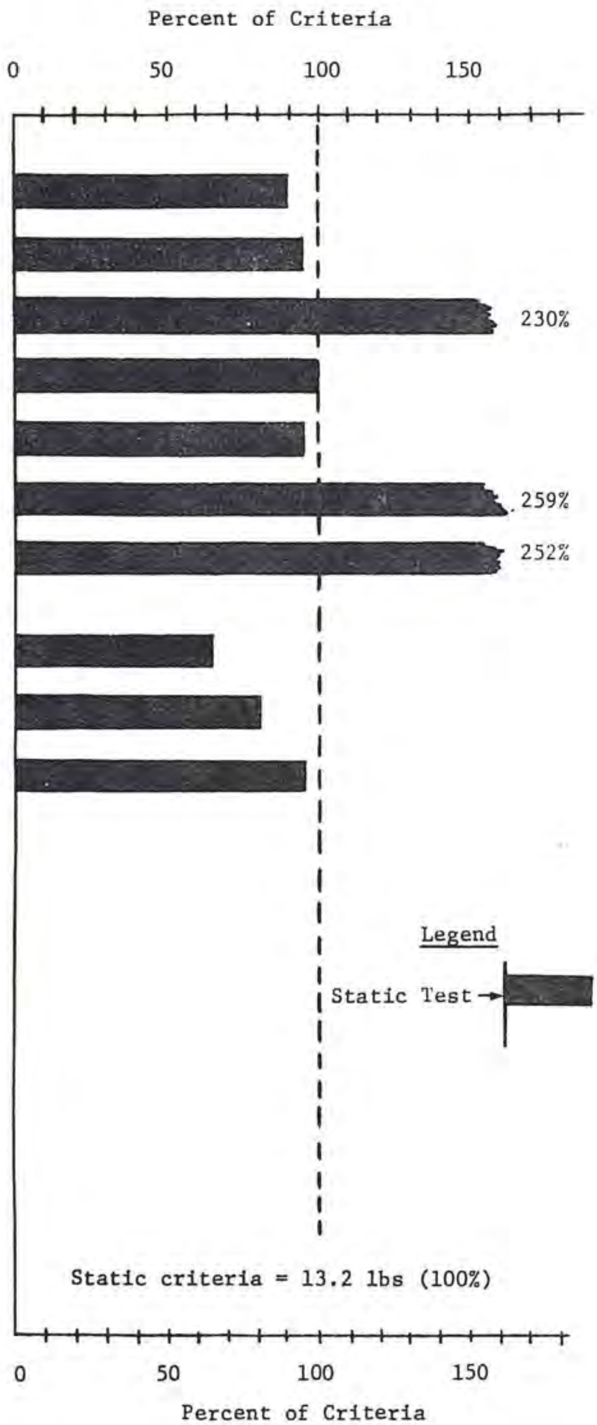


FIGURE 9 PUNCTURE RESISTANCE TEST RESULTS STATIC PUNCTURE CURRENTLY USED GLOVE MATERIALS

Material Identification
(As taken from currently used gloves)

(Code)	Brief Description	Thickness (mils)
Leather		
(L-2)	Leather	45
(L-2)	Leather	57
(L-2)	Leather - Double Thickness	115
(L-2)	Leather and Cotton Liner	56 & 46
(L-2)	Leather and Durette	45 & 38
(L-2)	Leather/Durette/Leather	57/38/58
(L-2)	Leather/Lining/Leather	60/62/58
Neoprene		
(NE-1)	Neoprene Coated Flannel Liner	67
(NE-1)	Neoprene and 9 oz. Jersey	71 & 49
(NE-1)	Neoprene and Durette	71 & 38



being tested. If the temperature reaches the temperature threshold for skin injury, the insulative properties of the material(s) are inadequate.* Test results are presented according to these guidelines.

Figure 10 shows the temperature changes of a skin simulant when three composites were exposed to "hazardous" radiant thermal energies. None of the specimens offered enough protection to keep the simulated skin temperatures below the injury threshold.

Figure 11 shows the temperature changes of a skin simulant when the same three composites were exposed to "emergency" radiant thermal energies. None of the specimens offered enough protection to keep the simulated skin temperatures below the injury threshold. However, the second and third composites were very close to meeting the criteria.

Figure 12 shows the temperature changes of a skin simulant when materials were exposed to conductive thermal energies. Two composites – a Nomex/Kynol spun-twill weave backed by Foylon and terry cloth, and a Nomex/Kynol spun-twill weave backed by Foylon and needle-punched nomex felt – appear to offer suitable protection. However, the Nomex outer surfaces of both composites were badly charred and effectively destroyed.

(4) Resistance to Flame

Table 13 presents detailed data describing the flame resistance of candidate materials. Several met all aspects of the performance criteria with little or no degradation. Materials such as Durette, Kevlar, Nomex (in very specific constructions), Foylon and Ortho fabric are most promising. It would appear from these data, however, that many of the specialty materials (such as SEF modacrylic and Nomex in several of its other constructions) will not resist direct flame well enough to be acceptable as an outer layer of a prototype glove. It should also be noted that leather, natural rubber and neoprene, which are used in currently-used gloves, also meet the performance criteria.**

(5) Resistance to Liquid Penetration

Table 14 tabulates the results of very brief liquid penetration testing. A neoprene-coated, needle-punched Nomex felt performed well in meeting the liquid penetration criteria.

This result is consistent with the resistance provided by certain materials found in gloves currently used by firefighters.**

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*These criteria are described in detail in Volume II, Part I of this report.

**Test results for currently-used gloves are described in Volume II, Part I of this report.

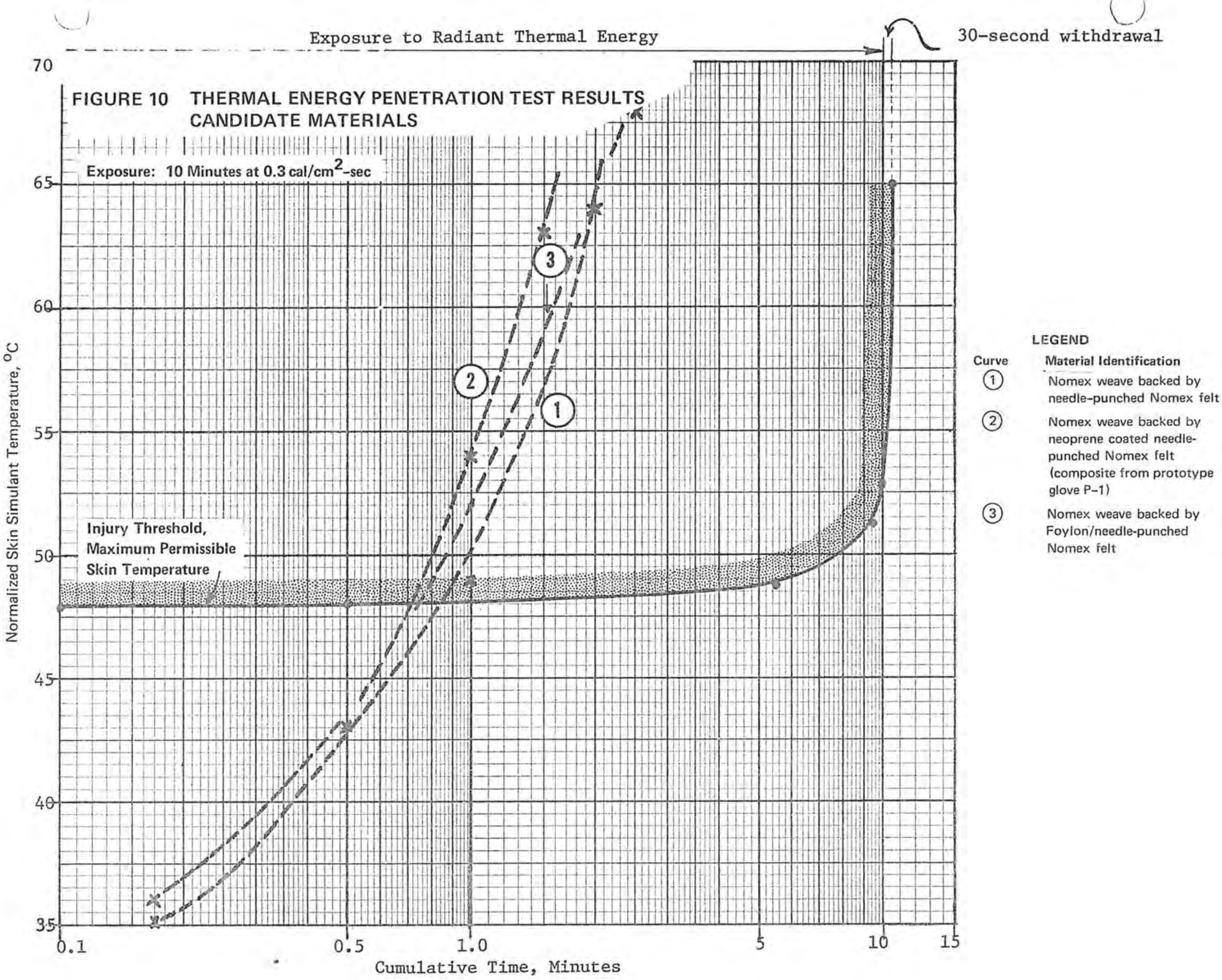

FIGURE 10 THERMAL ENERGY PENETRATION TEST RESULTS CANDIDATE MATERIALS

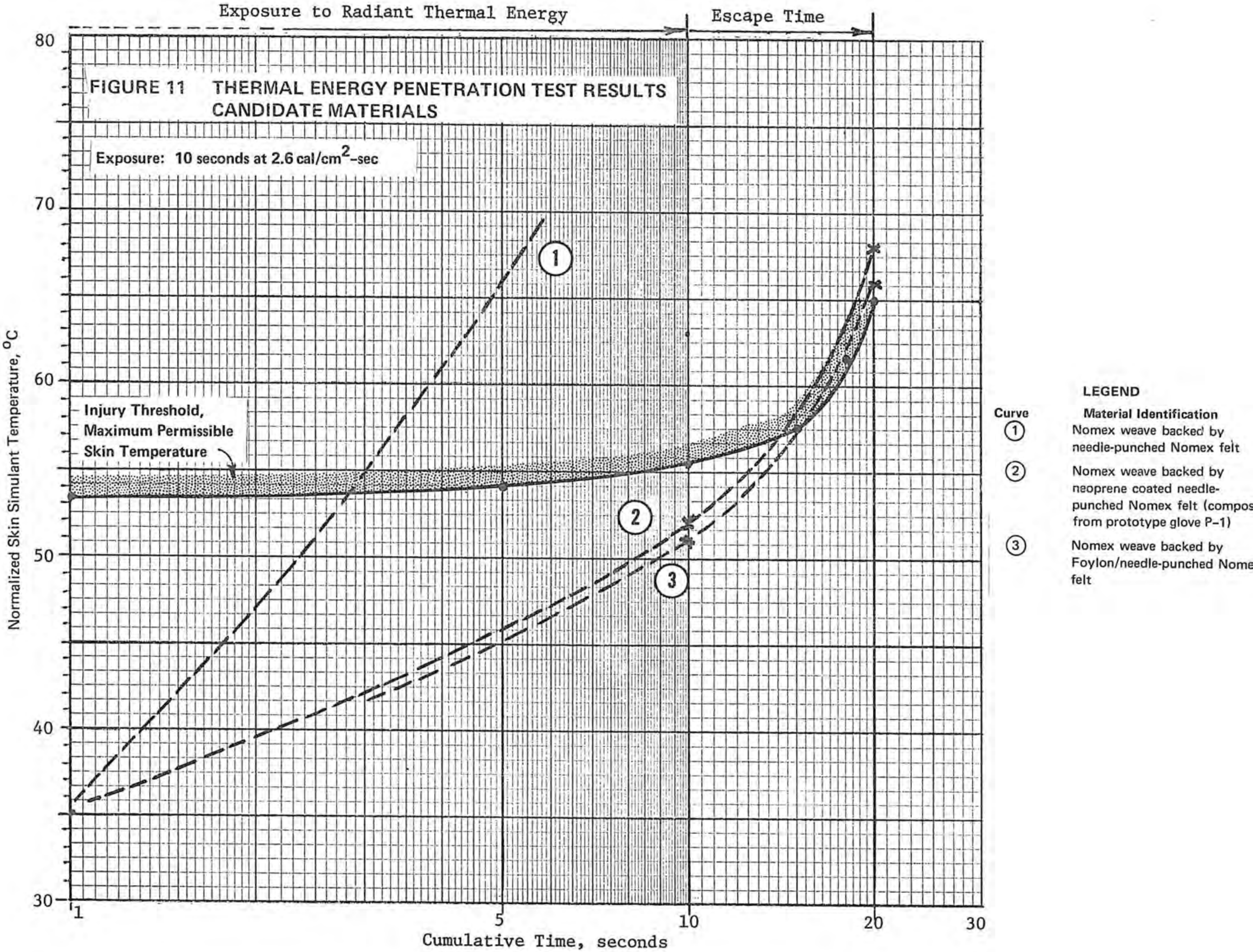

FIGURE 11 THERMAL ENERGY PENETRATION TEST RESULTS CANDIDATE MATERIALS

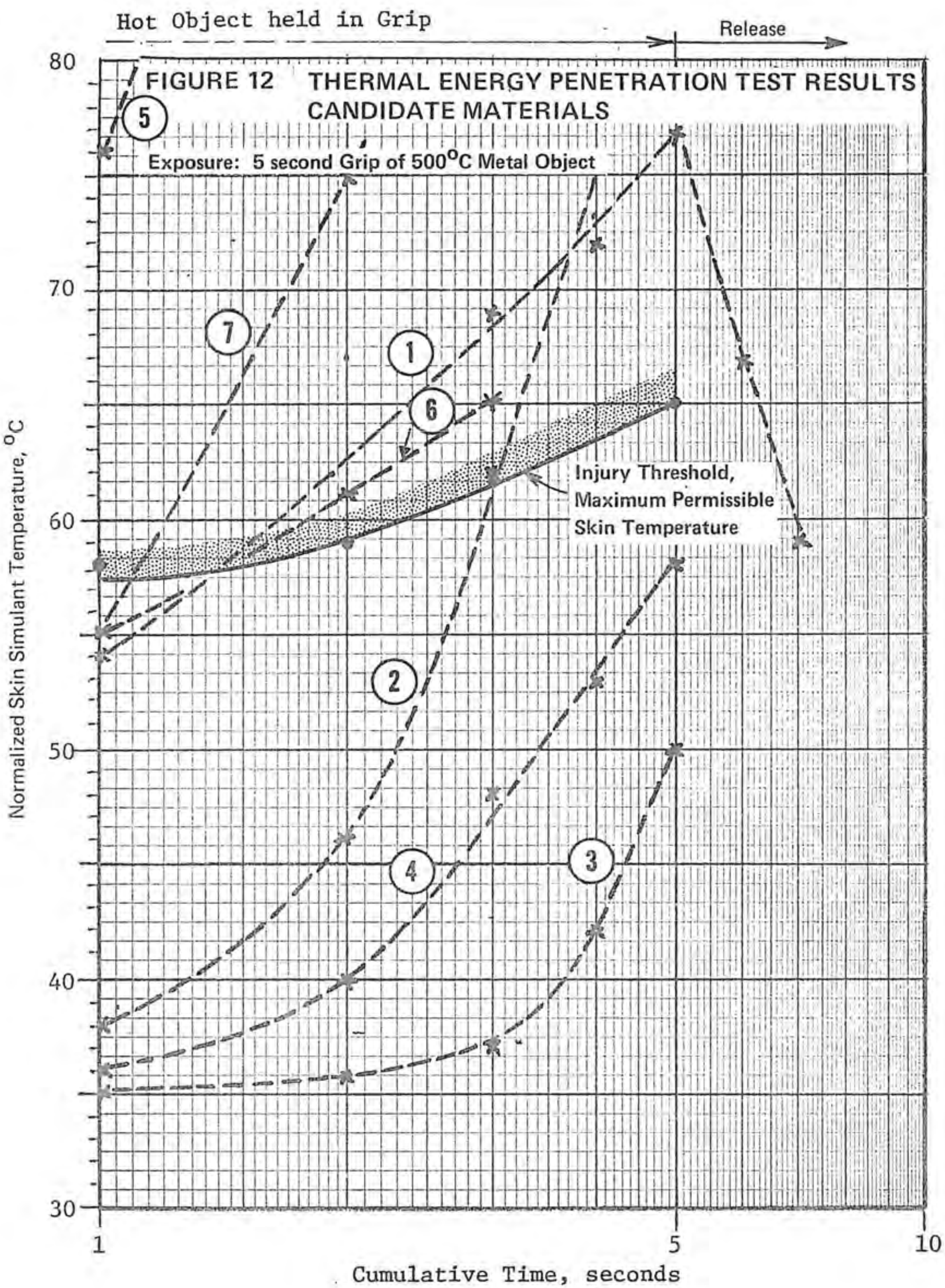

FIGURE 12 THERMAL ENERGY PENETRATION TEST RESULTS CANDIDATE MATERIALS

LEGEND

Curve	Material Identification
(1)	Nomex weave backed by needle-punched Nomex felt
(2)	Nomex weave backed by Foylon/needle-punched Nomex felt
(3)	Nomex/Kynol, spun twill weave backed by Foylon/ terry cloth (Nomex/Kynol)
(4)	Nomex/Kynol, spun twill weave backed by Foylon/needle-punched Nomex felt
(5)	Ortho fabric
(6)	Ortho fabric backed by needle-punched Nomex felt
(7)	Viton coated Kevlar backed by needle-punched Nomex felt

TABLE 13
FLAME RESISTANCE TEST RESULTS
CANDIDATE MATERIALS

MATERIAL IDENTIFICATION	DATA FOR FLAME EXPOSURE					CRITERIA RATING	
	After Flame Time (sec)	After Glow Time (sec)	Char Length (inches)	Percent Consumed	Observations of Melting, Dripping, Shrinking, etc.	Pass	Primary Failure
PERFORMANCE CRITERIA:	≤ 2.0	≤ 2.0	≤ 1.00	≤ 5.0	None		
Durette-Simplex knit (#400-9)	0	0	Slight	1.0	Slight stiffening	Yes	--
SEF modacrylic/polyester (58/42% blend), poplin weave	30+	--	--	100	--	No	Consumed
Kevlar weave	0	0	Slight	1.5	--	Yes	--
Viton coated Kevlar weave	0	0	1.00	1.3	--	Yes	--
Neoprene coated R.S. nylon	0	0	2.50	4.9	Embrittled	No	Char
Novatex (Nomex and asbestos weave)	0	0	1.50	1.4	Slight stiffening	No	Char
Gore-Tex (Teflon/PBI) twill weave	0	0	2.00	0.5	Teflon melted, moderate shrinking	No	Char
Nomex/Kynol, spun twill weave	0	0	2.25	1.5	Embrittled	No	Char
Nomex/Kevlar, twill weave	0	0	1.00	1.0	--	Yes	--
Nomex weave (outer layer from prototype glove P-1)	0	0	0.25	0.6	Minor burn-through, embrittled	No	Burn-through

TABLE 13 (Cont.)
FLAME RESISTANCE TEST RESULTS
CANDIDATE MATERIALS

MATERIAL IDENTIFICATION	DATA FOR FLAME EXPOSURE					CRITERIA RATING	
	After Flame Time (sec)	After Glow Time (sec)	Char Length (inches)	Percent Consumed	Observations of Melting, Dripping, Shrinking, etc.	Pass	Primary Failure
PERFORMANCE CRITERIA:	≤ 2.0	≤ 2.0	≤ 1.00	≤ 5.0	None		
Nomex weave backed by neoprene coated needle-punched Nomex felt (composite from prototype glove P-1)	0	0	0.25	0.3	Minor scorch	Yes	—
Neoprene coated needle-punched Nomex felt (from prototype glove P-1)	0	0	1.25	1.1	—	No	Char
Needle-punched Nomex felt	0	0	1.50	1.3	Burn-through	No	Char
Neoprene coated Nomex scrim	0	0	2.50	2.1	Heavy char, Burn-through	No	Char
Foylon (aluminum coated Kevlar)	0	0	1.00	1.0	Slight burn-through	Marginal	—
Foylon backed by neoprene coated needle-punched Nomex felt	0	0	1.00	0.4	Burn-through	No	Burn-through
Nomex/Kynol backed by needle-punched Nomex felt	0	0	2.50	—	Moderate char	No	Char
Ortho fabric (Gore-Tex/Nomex/Kevlar)	0	0	0.50	0.5	Some shrinking, high heat retention	Yes	—
Aluminum coated glass/asbestos/cotton fabric	0	0	2.25	0.2	Decomposition of aluminum coating	No	Char

NOTE: Underline (xxxxx) = surface exposed to flame.

TABLE 14
LIQUID PENETRATION TEST RESULTS
CANDIDATE MATERIALS

Material Identification	Water Penetration Pressure (psig)	Observations	Criteria Rating
PERFORMANCE CRITERIA:	> 4.0		
Cotton twill	0	No resistance	Failed
Asbestos fabric	3	--	Failed
Nomex weave (outer layer from prototype glove P-1)	0	No resistance	Failed
Neoprene coated needle-punched Nomex felt (from prototype glove P-1)	5	Performance good	Passed

NOTE: Underline (xxxxx) = surface exposed to water.

VII. CONCLUSIONS AND RECOMMENDATIONS

A comprehensive, realistic set of criteria for firefighters' gloves was developed to meet a very pressing need in firefighting safety. Based on these criteria, recommendations for standards and for a prototype glove system meeting those standards were made. Such a glove system appears to be achievable at reasonable cost with current materials technology.

To achieve the long-term NIOSH objective of preparing a formal set of standards, additional work should be carried out in several areas. They are:

- The glove-durability criteria and its test method should be fully evaluated in the laboratory and modifications made where necessary.
- The design for the prototype glove system should be refined, materials should be fully tested, and prototypes should be assembled.
- A demonstration program using prototype gloves should be conducted to establish firefighter acceptance of the prototype glove system vis-à-vis glove criteria.
- Standards for firefighters' gloves should be drafted and then submitted to interested organizations for review and comment.

Furthermore, this work should be expanded to include other items of firefighters' protective clothing and equipment. A protocol has been developed for successfully identifying firefighters' needs and translating these needs into quantitative criteria for protective clothing. It would be appropriate to use this technique in developing criteria for boots, turnout gear and helmets.

VIII. APPENDICES

APPENDIX

APPENDIX A
DETAILED HAND AND WRIST INJURY STATISTICS

Firefighters' hand and wrist injuries have been tabulated in two separate formats:

- In the first, the number of injuries occurring in each injury classification during a specified time period are segregated according to the anatomical location of injury (fingers, hand, wrist and forearm). In addition, those ambiguous injuries not correlated with a specific anatomical location are included as upper extremity injuries. Glove-oriented injuries are separated from non glove-oriented injuries, such as fractures and sprains, which would most probably occur whether a glove is worn or not.

- In the second, the number of injuries occurring in each injury classification during a specified time period are segregated, where possible, according to both causative agent and accident type (or motion). Glove-oriented injuries are again separated fron non glove-oriented injuries.

All sources provided data for frequency versus anatomical location; however, not all provided data describing causative agent and accident type.

The listing below identifies the injury data contained in the following Tables:

		Injury Classification Versus		
Table Number	Source	Anatomical Location	Causative Agent	Accident Type
A-1a	Denver Fire Department	X		
A-1b	Denver Fire Department		X	X
A-2	Cambridge Fire Department	X		
A-3a	Los Angeles County Fire Department	X		
A-3b	Los Angeles County Fire Department		X	X
A-4a	New York City Fire Department	X		
A-4b	New York City Fire Department		X	X
A-5	New York State	X		
A-6a	State of California	X		
A-6b	State of California		X	X
A-7a	State of Wisconsin	X		
A-7b	State of Wisconsin		X	X
A-8a	Chicago Fire Department	X		
A-8b	Chicago Fire Department		X	–
A-9	Tucson Fire Department	X		
A-10	U.S. Bureau of Labor Statistics	X		

TABLE A–1a

FREQUENCY OF FIREFIGHTER HAND AND ARM INJURIES

	INJURIES IDENTIFIABLE BY ANATOMICAL LOCATION																					OTHER REGIONAL INJURIES					TOTAL HAND AND ARM INJURIES (SUM OF IDENTIFIABLE AND REGIONAL INJURIES)
	FINGERS					HAND					WRIST					FOREARM					TOTAL IDENTIFIABLE INJURIES	UPPER EXTREMITIES				TOTAL(Σ*) REGIONAL INJURIES	
GLOVE ORIENTED HAZARDS	70	71	72	73	Σ*	70	71	72	73	Σ*	70	71	72	73	Σ*	70	71	72	73	Σ*		70	71	72	73		
1. MECHANICAL																											
a. Wound with broken skin			9		9			3		3			1		1			2		2	15						15
• cut or scratch			6		6			1		1			1		1			2		2	10						
• laceration			2		2			0		0			0		0			0		0	2						
• puncture**			1		1			2		2			0		0			0		0	3						
• abrasion			0		0			0		0			0		0			0		0	0						
• amputation			0		0			0		0			0		0			0		0	0						
b. Wound without broken skin			5		5			2		2											7			1		1	8
• crush or pinch			3		3			0		0											3			0		0	
• bruise or contusion			2		2			2		2											4			1		1	
2. THERMAL																											
a. Heat								2		2											2						2
• burn								2		2											2						
• scald								0		0											0						
b. Cold																											
• frostbite																											
• freezing																											
3. CHEMICAL																											
a. Burn																											
b. Poisoning (including skin disease)																											
4. ELECTRICAL																											
5. BACTERIOLOGICAL																											
6. RADIOLOGICAL																											
TOTAL GLOVE ORIENTED INJURIES			14		14			7		7			1		1			2		2	24			1		1	25
OTHER HAND HAZARDS																											
1. MECHANICAL																											
a. Bones																		1		1	1						1
• fracture																		1		1	1						
• dislocation																		0		0	0						
b. Joints, tendons, muscles													2		2						2						2
• inflammation													0		0						0						
• sprain and strain													2		2						2						
2. MISCELLANEOUS																											
a. Multiple injuries																								1		1	1
b. Ill-defined or unknown																											
TOTAL OTHER HAND INJURIES			0		0			0		0			2		2			1		1	3			1		1	4
TOTAL INJURIES			14		14			7		7			3		3			3		3	27			2		2	29

* Σ = Sum of data for the years 1970 – 1973.
** Puncture includes splinters, insect stings, and animal bites.

Source: Denver, Colorado, Fire Department
Number of Injuries During the Year 1972

TABLE A–1b
CHARACTERISTICS OF FIREFIGHTER HAND AND ARM INJURIES

CAUSATIVE AGENT

	DEBRIS	METAL OBJECTS	GLASS	BLDG. FIXTURES OR STRUCTURE	FLORA OR FAUNA	EQUIPMENT OR TOOLS	MACHINERY	VEHICLE	FLOOR, GROUND, OR WORKING SURFACE	ICE	ANOTHER PERSON	BODILY MOTION	HEAT, FLAME, OR HOT OBJECT	COLD	CHEMICALS	CLOTHING	MISC.
GLOVE ORIENTED HAZARDS																	
1. MECHANICAL																	
a. Wound with broken skin		1	5	1	1	5		2									
• cut or scratch		0	5	0	0	4		1									
• laceration		1	0	0	0	0		1									
• puncture *		0	0	1	1	1		0									
• abrasion		0	0	0	0	0		0									
• amputation		0	0	0	0	0		0									
b. Wound without broken skin				2		5		1									
• crush or pinch				1		2		0									
• bruise or contusion				1		3		1									
2. THERMAL																	
a. Heat				1									1				
• burn				1									1				
• scald				0									0				
b. Cold																	
• frostbite																	
• freezing																	
3. CHEMICAL																	
a. Burn																	
b. Poisoning (including skin disease)																	
4. ELECTRICAL																	
5. BACTERIOLOGICAL																	
6. RADIOLOGICAL																	
TOTAL GLOVE ORIENTED INJURIES		1	5	4	1	10		3	0				1				0
OTHER HAND HAZARDS																	
1. MECHANICAL																	
a. Bones									1								
• fracture									1								
• dislocation									0								
b. Joints, tendons, muscles									1								1
• inflammation									0								0
• sprain and strain									1								1
2. MISCELLANEOUS																	
a. Multiple injuries									1								
b. Ill-defined or unknown																	
TOTAL OTHER HAND INJURIES		0	0	0	0	0		0	3				0				1
TOTAL INJURIES		1	5	4	1	10		3	3				1				1

ACCIDENT TYPE / **SEVERITY INDEX**

	STRUCK BY	STRUCK AGAINST	LIFTING, MOVING, HANDLING	CAUGHT IN OR BETWEEN	FELL FROM	FELL ONTO	EXPOSED TO	CONTACT WITH	MISC.	AVERAGE HEALING TIME, DAYS
GLOVE ORIENTED HAZARDS										
1. MECHANICAL										
a. Wound with broken skin	5	5	1	3					1	
• cut or scratch	4	4	0	2					0	
• laceration	0	1	0	1					0	
• puncture *	1	0	1	0					1	
• abrasion	0	0	0	0					0	
• amputation	0	0	0	0					0	
b. Wound without broken skin	4	2		2						
• crush or pinch	1	0		2						
• bruise or contusion	3	2		0						
2. THERMAL										
a. Heat	1							1		
• burn	1							1		
• scald	0							0		
b. Cold										
• frostbite										
• freezing										
3. CHEMICAL										
a. Burn										
b. Poisoning (including skin disease)										
4. ELECTRICAL										
5. BACTERIOLOGICAL										
6. RADIOLOGICAL										
TOTAL GLOVE ORIENTED INJURIES	10	7	1	5		0		1	1	
OTHER HAND HAZARDS										
1. MECHANICAL										
a. Bones						1				
• fracture						1				
• dislocation						0				
b. Joints, tendons, muscles			1			1				
• inflammation			0			0				
• sprain and strain			1			1				
2. MISCELLANEOUS										
a. Multiple injuries						1				
b. Ill-defined or unknown										
TOTAL OTHER HAND INJURIES	0	0	1	0		3		0	0	
TOTAL INJURIES	10	7	2	5		3		1	1	

* Puncture includes splinters, insect stings, and animal bites.

Source: Denver, Colorado Fire Department
Number of Injuries During the Year 1972

TABLE A–2

FREQUENCY OF FIREFIGHTER HAND AND ARM INJURIES

	INJURIES IDENTIFIABLE BY ANATOMICAL LOCATION																					OTHER REGIONAL INJURIES					TOTAL HAND AND ARM INJURIES
	FINGERS					HAND					WRIST					FOREARM					TOTAL IDENTIFIABLE INJURIES	UPPER EXTREMITIES				TOTAL(Σ*) REGIONAL INJURIES	(SUM OF IDENTIFIABLE AND REGIONAL INJURIES)
GLOVE ORIENTED HAZARDS	70	71	72	73	Σ*	70	71	72	73	Σ*	70	71	72	73	Σ*	70	71	72	73	Σ*		70	71	72	73		
1. MECHANICAL																											
a. Wound with broken skin		4	8	2	14		3	1	5	9		2	2	3	7						30						30
• cut or scratch		2	1	1	4		1	0	2	3		0	2	2	4						11						
• laceration		2	4	0	6		0	0	2	2		0	0	1	1						9						
• puncture		0	2	1	3		2	1	1	4		2	0	0	2						9						
• abrasion		0	0	0	0		0	0	0	0		0	0	0	0						0						
• amputation		0	1	0	1		0	0	0	0		0	0	0	0						1						
b. Wound without broken skin		1	1	1	3				2	2											5						5
• crush or pinch		0	0	0	0				1	1											1						
• bruise or contusion		1	1	1	3				1	1											4						
2. THERMAL																											
a. Heat									2	2		2	0	1	3						5						5
• burn									2	2		2	0	1	3						5						
• scald									0	0		0	0	0	0						0						
b. Cold																											
• frostbite																											
• freezing																											
3. CHEMICAL																											
a. Burn																											
b. Poisoning (including skin disease)																											
4. ELECTRICAL																											
5. BACTERIOLOGICAL																											
6. RADIOLOGICAL																											
TOTAL GLOVE ORIENTED INJURIES		5	9	3	17		3	1	9	13		4	2	4	10						40						40
OTHER HAND HAZARDS																											
1. MECHANICAL																											
a. Bones		1			1																1						1
• fracture		1			1																1						
• dislocation		0			0																0						
b. Joints, tendons, muscles		2	1		3								1	2	3						6						6
• inflammation		0	0		0								0	0	0						0						
• sprain and strain		2	1		3								1	2	3						6						
2. MISCELLANEOUS																											
a. Multiple injuries																											
b. Ill-defined or unknown		1	2	1	4		1	2	1	4		1		1	2						10						10
TOTAL OTHER HAND INJURIES		4	3	1	8		1	2	1	4		1	1	3	5						17						17
TOTAL INJURIES		9	12	4	25		4	3	10	17		5	3	7	15						57						57

* Σ = Sum of data for the years 1970 - 1973.
**Several Injuries were reported for the first portion of 1974, but were included with 1973 figures.

Source: Cambridge, Massachusetts, Fire Department
Number of Injuries During the Period 1971 – 1973**

TABLE A–3a

FREQUENCY OF FIREFIGHTER HAND AND ARM INJURIES

	INJURIES IDENTIFIABLE BY ANATOMICAL LOCATION																						OTHER REGIONAL INJURIES					TOTAL HAND AND ARM INJURIES (SUM OF IDENTIFIABLE AND REGIONAL INJURIES)
	FINGERS					HAND					WRIST					FOREARM					TOTAL IDENTIFIABLE INJURIES		UPPER EXTREMITIES				TOTAL(Σ*) REGIONAL INJURIES	
GLOVE ORIENTED HAZARDS	A	B	C	D	Σ*	A	B	C	D	Σ*	A	B	C	D	Σ*	A	B	C	D	Σ*			A	B	C	D		
1. MECHANICAL																												
a. Wound with broken skin	33	85	21	31	170	11	33	5	7	56											226							226
• cut or scratch	10	12	1	4	27	0	7	1	2	10											37							
• laceration	15	34	11	14	74	9	11	4	2	26											100							
• puncture ***	7	36	9	11	63	2	12	0	3	17											80							
• abrasion	1	2	0	2	5	0	3	0	0	3											8							
• amputation	0	1	0	0	1	0	0	0	0	0											1							
b. Wound without broken skin	5	20	4	3	32	5	14	1	3	23											55							55
• crush or pinch	1	5	1	1	8	1	0	0	0	1											9							
• bruise or contusion	4	15	3	2	24	4	14	1	3	22											46							
2. THERMAL																												
a. Heat		4	2		6	3	5	2		10											16							16
• burn		4	2		6	3	5	2		10											16							
• scald		0	0		0	0	0	0		0											0							
b. Cold								1		1											1							1
• frostbite								1		1											1							
• freezing								0		0											0							
3. CHEMICAL																												
a. Burn		1	1		2		1			1											3							3
b. Poisoning (including skin disease)	1				1		2		1	3											4							4
4. ELECTRICAL																												
5. BACTERIOLOGICAL																												
6. RADIOLOGICAL																												
TOTAL GLOVE ORIENTED INJURIES	39	110	28	34	211	19	55	9	11	94											305							305
OTHER HAND HAZARDS																												
1. MECHANICAL																												
a. Bones	3	20	5	5	33	1	2			3											36							36
• fracture	2	16	5	5	28	1	2			3											31							
• dislocation	1	4	0	0	5	0	0			0											5							
b. Joints, tendons, muscles	3	34	6	1	44	2	2	1	1	6											50							50
• inflammation	0	5	0	0	5	1	0	0	0	1											6							
• sprain and strain	3	29	6	1	39	1	2	1	1	5											44							
2. MISCELLANEOUS																												
a. Multiple injuries		2	1		3																3							3
b. Ill-defined or unknown	6	10	3	4	23	2	5		1	8											31							31
TOTAL OTHER HAND INJURIES	12	66	15	10	103	5	9	1	2	17											120							120
TOTAL INJURIES	57	176	43	44	314	24	64	10	13	111											425							425

LEGEND

OCCUPATIONAL CLASSIFICATIONS

A LABORER

B FIREFIGHTER

C FIRE CAPTAIN

D MISCELLANEOUS (INCLUDING DRIVERS, AIRCRAFT PILOTS, JUMPERS, AND OTHERS)

* Σ = Sum of data for occupational categories -A- through -D-
** Data was not segregated on a yearly basis
*** Puncture includes splinters, insect stings, and animal bites

Source: Los Angeles County, California, Fire Department
Number of Injuries During the Period 1969 – 1973**

TABLE A–3b
CHARACTERISTICS OF FIREFIGHTER HAND AND ARM INJURIES

CAUSATIVE AGENT

	Debris	Metal Objects	Glass	Bldg. Fixtures or Structure	Flora or Fauna	Equipment or Tools	Machinery	Vehicle	Floor, Ground, or Working Surface	Ice	Another Person	Bodily Motion	Heat, Flame, or Hot Object	Cold	Chemicals	Clothing	Misc.
GLOVE ORIENTED HAZARDS																	
1. MECHANICAL																	
a. Wound with broken skin	20	59		12	26	66		15				18					10
• cut or scratch	3	13		0	2	11		1				7					0
• laceration	10	19		6	2	42		11				7					3
• puncture*	6	26		6	22	11		1				3					5
• abrasion	1	1		0	0	1		2				1					2
• amputation	0	0		0	0	1		0				0					0
b. Wound without broken skin		5		5		16		11	2		2	8					6
• crush or pinch		0		2		2		1	0		0	1					3
• bruise or contusion		5		3		14		10	2		2	7					3
2. THERMAL																	
a. Heat		2				1		1					12				
• burn		2				1		1					12				
• scald		0				0		0					0				
b. Cold															1		
• frostbite															1		
• freezing															0		
3. CHEMICAL																	
a. Burn															3		
b. Poisoning (including skin disease)	1				1						1	1					
4. ELECTRICAL																	
5. BACTERIOLOGICAL																	
6. RADIOLOGICAL																	
TOTAL GLOVE ORIENTED INJURIES	21	66		17	27	83		27	2		3	27	12		4	0	16
OTHER HAND HAZARDS																	
1. MECHANICAL																	
a. Bones		2		2	6	6		5	2		3	7					3
• fracture		2		1	5	5		4	2		3	6					3
• dislocation		0		1	1	1		1	0		0	1					0
b. Joints, tendons, muscles		4		6	4	6		2	3		2	14				1	8
• inflammation		1		0	2	0		1	0		0	2				0	0
• sprain and strain		3		6	2	6		1	3		2	12				1	8
2. MISCELLANEOUS																	
a. Multiple injuries						2			1								
b. Ill-defined or unknown		2		4	2	5		4	6								8
TOTAL OTHER HAND INJURIES	0	8		12	12	19		11	12		5	21	0		0	1	19
TOTAL INJURIES	21	74		29	39	102		38	14		8	48	12		4	1	35

ACCIDENT TYPE / **SEVERITY INDEX**

	Struck By	Struck Against	Lifting, Moving, Handling	Caught In or Between	Fell From	Fell Onto	Exposed To	Contact With	Misc.	Average Healing Time, Days
GLOVE ORIENTED HAZARDS										
1. MECHANICAL										
a. Wound with broken skin	53	142	3	13	1	3		3	8	
• cut or scratch	14	19	2	1	0	0		0	1	
• laceration	16	67	1	10	0	1		1	4	
• puncture*	20	54	0	0	0	1		2	3	
• abrasion	3	2	0	1	1	1		0	0	
• amputation	0	0	0	1	0	0		0	0	
b. Wound without broken skin	14	14		20		4			3	
• crush or pinch	4	0		5		0			0	
• bruise or contusion	10	14		15		4			3	
2. THERMAL										
a. Heat								16		
• burn								16		
• scald								0		
b. Cold								1		
• frostbite								1		
• freezing								0		
3. CHEMICAL										
a. Burn	1							2		
b. Poisoning (including skin disease)	1	2						1		
4. ELECTRICAL										
5. BACTERIOLOGICAL										
6. RADIOLOGICAL										
TOTAL GLOVE ORIENTED INJURIES	69	158	3	33	1	7		23	11	
OTHER HAND HAZARDS										
1. MECHANICAL										
a. Bones	11	9		10		2			4	
• fracture	11	8		7		2			3	
• dislocation	0	1		3		0			1	
b. Joints, tendons, muscles	6	15	11	6		6			6	
• inflammation	1	3	0	1		0			1	
• sprain and strain	5	12	11	5		6			5	
2. MISCELLANEOUS										
a. Multiple injuries		1		2						
b. Ill-defined or unknown	3	10	4	4	2	2			6	
TOTAL OTHER HAND INJURIES	20	35	15	22	2	10		0	16	
TOTAL INJURIES	89	193	18	55	3	17		23	27	

* Puncture includes splinters, insect stings, and animal bites.

Source: Los Angeles County Fire Department
Number of Injuries During the Period 1969 – 1973

TABLE A–4a
FREQUENCY OF FIREFIGHTER HAND AND ARM INJURIES

	INJURIES IDENTIFIABLE BY ANATOMICAL LOCATION																					OTHER REGIONAL INJURIES					TOTAL HAND AND ARM INJURIES (SUM OF IDENTIFIABLE AND REGIONAL INJURIES)
	FINGERS					HAND					WRIST					FOREARM					TOTAL IDENTIFIABLE INJURIES	UPPER EXTREMITIES				TOTAL(Σ*) REGIONAL INJURIES	
GLOVE ORIENTED HAZARDS	E	L	R	O	Σ*	E	L	R	O	Σ*	E	L	R	O	Σ*	E	L	R	O	Σ*		E	L	R	O		
1. MECHANICAL																											
a. Wound with broken skin	42	80	5	6	133	32	46	2	6	86	11	32			43						262						262
Combined { • cut or scratch • laceration • puncture • abrasion • amputation	42	80	5	6	133	32	46	2	6	86	11	32			43						262						
b. Wound without broken skin	12	36			48	15	14	1	1	31	2	3	1		6						85						85
• crush or pinch	0	0			0	0	0	0	0	0	0	0	0		0						0						
• bruise or contusion	12	36			48	15	14	1	1	31	2	3	1		6						85						
2. THERMAL																											
a. Heat	4	7		1	12	53	31	1	9	94	45	31	1	8	85						191						191
Combined { • burn • scald	4	7		1	12	53	31	1	9	94	45	31	1	8	85						191						
b. Cold • frostbite • freezing																											
3. CHEMICAL																											
a. Burn												1			1						1						1
b. Poisoning (including skin disease)																											
4. ELECTRICAL																											
5. BACTERIOLOGICAL																											
6. RADIOLOGICAL																											
TOTAL GLOVE ORIENTED INJURIES	58	123	5	7	193	100	91	4	16	211	58	67	2	8	135						539						539
OTHER HAND HAZARDS																											
1. MECHANICAL																											
a. Bones	14	16	2	2	34	5	3	1		9	6	3			9						52						52
• fracture	13	15	2	2	32	5	3	1		9	6	3			9						50						
• dislocation	1	1	0	0	2	0	0	0		0	0	0			0						2						
b. Joints, tendons, muscles	16	14		3	33	8	5		2	15	18	22	2		42						90						90
• inflammation	0	0		0	0	0	0		0	0	0	0	0		0						0						
• sprain and strain	16	14		3	33	8	5		2	15	18	22	2		42						90						
2. MISCELLANEOUS																											
a. Multiple injuries	1	1			2	1				1											3						3
b. Ill-defined or unknown		4			4	3	1			4	1	1			2						10						10
TOTAL OTHER HAND INJURIES	31	35	2	5	73	17	19	1	2	29	25	26	2	0	53						155						155
TOTAL INJURIES	89	158	7	12	266	117	100	5	18	240	83	93	4	8	188						694						694

LEGEND

FIRE COMPANY CLASSIFICATIONS

E Engine
L Ladder
R Rescue
O Others including Officers and Training

* Σ = Sum of data for Department Companies -E- through -O-

Source: New York City Fire Department
Number of Injuries During the Period June, 1973 – March

TABLE A–4b

CHARACTERISTICS OF FIREFIGHTER HAND AND ARM INJURIES

	CAUSATIVE AGENT *																	ACCIDENT TYPE									SEVERITY INDEX
	DEBRIS	METAL OBJECTS	GLASS	BLDG. FIXTURES OR STRUCTURE	FLORA OR FAUNA	EQUIPMENT OR TOOLS	MACHINERY	VEHICLE	FLOOR, GROUND, OR WORKING SURFACE	ICE	ANOTHER PERSON	BODILY MOTION	HEAT, FLAME, OR HOT OBJECT	COLD	CHEMICALS	CLOTHING	MISC.	STRUCK BY	STRUCK AGAINST	LIFTING, MOVING, HANDLING	CAUGHT IN OR BETWEEN	FELL FROM	FELL ONTO	EXPOSED TO	CONTACT WITH	MISC.	AVERAGE Lost TIME, DAYS
GLOVE ORIENTED HAZARDS																											
1. MECHANICAL																											
a. Wound with broken skin	1	22	33	7		6	1	2										77	155	2	13		5		1	9	
Combined { • cut or scratch • laceration • puncture • abrasion • amputation	1	22	33	7		6	1	2										77	155	2	13		5		1	9	10.0
b. Wound without broken skin	1	1		9		15	1	1	2								1	23	34	1	18	5	4				
• crush or pinch	0	0		0		0	0	0	0								0	0	0	0	0	0	0				—
• bruise or contusion	1	1		9		15	1	1	2								1	23	34	1	18	5	4				6.5
2. THERMAL																											
a. Heat	20	5		5		3							16					4	1	1		1	1		183		
Combined { • burn • scald	20	5		5		3							16					4	1	1		1	1		183		8.5
b. Cold • frostbite • freezing																											
3. CHEMICAL																											
a. Burn															1										1		2.0
b. Poisoning (including skin disease)																											
4. ELECTRICAL																											
5. BACTERIOLOGICAL																											
6. RADIOLOGICAL																											
TOTAL GLOVE ORIENTED INJURIES	22	28	33	21		24	2	3	2				16		1		1	104	190	4	31	6	10	0	185	9	
OTHER HAND HAZARDS																											
1. MECHANICAL																											
a. Bones				6				1	2									5	17	3	12	9	5			1	
• fracture				4				1	2									5	16	3	12	8	5			1	15.9
• dislocation				2				0	0									0	1	0	0	1	0			0	10.5
b. Joints, tendons, muscles	1	3		8		9		1	7								1	11	30	18	4	9	7	1	2	8	
• inflammation	0	0		0		0		0	0								0	0	0	0	0	0	0	0	0	0	—
• sprain and strain	1	3		8		9		1	7								1	11	30	18	4	9	7	1	2	8	5.9
2. MISCELLANEOUS																											
a. Multiple injuries			1					1													2					1	19.0
b. Ill-defined or unknown				2		2			1									2	2				1		1	4	9.3
TOTAL OTHER HAND INJURIES	1	3	1	16		11	0	3	10				0		0		1	18	49	21	18	18	13	1	3	14	
TOTAL INJURIES	23	31	34	37		35	2	6	12				16		1		2	122	239	25	49	24	23	1	188	23	

* Causative Agent data not available for the period June - December, 1973; only January - March, 1974, is tabulated above.

Source: New York City Fire Department
Number of Injuries During the Period June 1973 – March 1974

TABLE A–5

FREQUENCY OF FIREFIGHTER HAND AND ARM INJURIES

	INJURIES IDENTIFIABLE BY ANATOMICAL LOCATION																					OTHER REGIONAL INJURIES					TOTAL HAND AND ARM INJURIES
	FINGERS					HAND					WRIST					FOREARM					TOTAL IDENTIFIABLE INJURIES	UPPER EXTREMITIES				TOTAL(Σ*) REGIONAL INJURIES	(SUM OF IDENTIFIABLE AND REGIONAL INJURIES)
GLOVE ORIENTED HAZARDS	70	71	72	73	Σ*	70	71	72	73	Σ*	70	71	72	73	Σ*	70	71	72	73	Σ*		70	71	72	73		
1. MECHANICAL																											
a. Wound with broken skin • cut or scratch • laceration • puncture • abrasion • amputation		66	54	82	202		85	100	90	275		7	10	13	30		2	5	1	8	515		12	12	11	35	550
b. Wound without broken skin • crush or pinch • bruise or contusion		1	2	8	11		3	7	9	19			1	2	3						33		6	6	13	25	58
2. THERMAL																											
a. Heat		4	4	2	10		16	24	27	67		10	5	8	23		2	3	1	6	106		4	3	10	17	123
• burn		4	4	2	10		16	24	27	67		10	5	8	23		2	3	1	6	106		4	3	10	17	
• scald		0	0	0	0		0	0	0	0		0	0	0	0		0	0	0	0	0		0	0	0	0	
b. Cold • frostbite • freezing			1		1			1	1	2											3				1	1	4
3. CHEMICAL																											
a. Burn																											
b. Poisoning (including skin disease)				1	1																1						1
4. ELECTRICAL																											
5. BACTERIOLOGICAL																											
6. RADIOLOGICAL																											
TOTAL GLOVE ORIENTED INJURIES		71	61	93	225	0	104	132	127	363		17	16	23	56		4	8	2	14	658	0	22	21	35	78	736
OTHER HAND HAZARDS																											
1. MECHANICAL																											
a. Bones		3	5	2	10		1	1	3	5		3	1	1	5				1	1	21		2		2	4	25
• fracture		2	4	2	8		1	1	3	5		3	1	1	5				1	1	19		2		2	4	
• dislocation		1	1	0	2		0	0	0	0		0	0	0	0				0	0	2		0		0	0	
b. Joints, tendons, muscles		4	4	4	12		4	2	2	8		9	2	14	25		2			2	47		5	1	5	11	58
• inflammation		0	0	0	0		1	0	0	1		2	0	1	3		1			1	5		2	0	1	3	
• sprain and strain		4	4	4	12		3	2	2	7		7	2	13	22		1			1	42		3	1	4	8	
2. MISCELLANEOUS																											
a. Multiple injuries																							1			1	1
b. Ill-defined or unknown		7	13	7	27	140	6	10	9	165		2	4	5	11		1	1		2	205	17	10	15	5	47	252
TOTAL OTHER HAND INJURIES		14	22	13	49	140	11	13	14	178		14	7	20	41		3	1	1	5	273	17	18	16	12	63	336
TOTAL INJURIES		85	83	106	274	140	115	145	144	541		31	23	43	97		7	9	3	19	931	17	40	37	47	141	1072

* Σ = Sum of data for the years 1970 - 1973.

Source: New York State, Office for Local Government
Number of Injuries During the Period 1970 – 1973

TABLE A–6a
FREQUENCY OF FIREFIGHTER HAND AND ARM INJURIES

	INJURIES IDENTIFIABLE BY ANATOMICAL LOCATION																					OTHER REGIONAL INJURIES					TOTAL HAND AND ARM INJURIES (SUM OF IDENTIFIABLE AND REGIONAL INJURIES)
	FINGERS					HAND					WRIST					FOREARM					TOTAL IDENTIFIABLE INJURIES	UPPER EXTREMITIES				TOTAL(Σ*) REGIONAL INJURIES	
GLOVE ORIENTED HAZARDS	70	71	72	73	Σ*	70	71	72	73	Σ*	70	71	72	73	Σ*	70	71	72	73	Σ*		70	71	72	73		
1. MECHANICAL																											
a. Wound with broken skin	55	64	68	32	219	33	34	49	17	133	8	12	11	8	39						391						391
Combined { • cut or scratch • laceration • puncture***	55	62	66	30	213	32	34	48	16	130	8	12	11	7	38						381						
• abrasion	0	1	0	1	2	1	0	1	1	3	0	0	0	1	1						6						
• amputation	0	1	2	1	4	0	0	0	0	0	0	0	0	0	0						4						
b. Wound without broken skin	13	12	17	10	52	9	12	4	2	27	1	7	3	2	13						92						92
• crush or pinch	7	8	8	0	23	0	2	1	1	4	0	1	1	0	2						29						
• bruise or contusion	6	4	9	10	29	9	10	3	1	23	1	6	2	2	11						63						
2. THERMAL																											
a. Heat	4	3	6	3	16	30	21	22	16	89	2	6	7	6	21						126						126
• burn	4	3	6	3	16	28	21	22	16	87	2	6	5	5	18						121						
• scald	0	0	0	0	0	2	0	0	0	2	0	0	2	1	3						5						
b. Cold																											
• frostbite																											
• freezing																											
3. CHEMICAL																											
a. Burn		1			1	1			1	2											3						3
b. Poisoning (including skin disease)	1				1	1	3	1		5	1	1			2						8						8
4. ELECTRICAL (Burn)			1		1	1				1											2						2
5. BACTERIOLOGICAL																											
6. RADIOLOGICAL																											
TOTAL GLOVE ORIENTED INJURIES	73	80	92	45	290	75	70	76	36	257	12	26	21	16	75						622						622
OTHER HAND HAZARDS																											
1. MECHANICAL																											
a. Bones	22	15	21	13	71	4	4	7	1	16	12	11	12	8	43						130						130
• fracture	19	15	18	13	65	4	4	7	1	16	12	11	12	8	43						124						
• dislocation	3	0	3	0	6	0	0	0	0	0	0	0	0	0	0						6						
b. Joints, tendons, muscles	15	16	19	12	62	8	5	2	4	19	23	17	22	10	72						153						153
• inflammation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						0						
• sprain and strain	15	16	19	12	62	8	5	2	4	19	23	17	22	10	72						153						
2. MISCELLANEOUS																											
a. Multiple injuries																											
b. Ill-defined or unknown	8	14	21	7	50	7	7	13	3	30	7	11	9	5	32						112						112
TOTAL OTHER HAND INJURIES	45	45	61	32	183	19	16	22	8	65	42	39	43	23	147						395						395
TOTAL INJURIES	118	125	153	77	473	94	86	98	44	322	54	65	64	39	222						1017						1017

* Σ = Sum of data for the years 1970 - 1973.
**For 1973, only January through June data were available
***Puncture includes splinters, insect stings, and animal bites

Source: State of California, Division of Labor Statistics and Research
Number of Injuries During the Period 1970 – 1973*

TABLE A–6b

CHARACTERISTICS OF FIREFIGHTER HAND AND ARM INJURIES

	CAUSATIVE AGENT																ACCIDENT TYPE								SEVERITY INDEX
GLOVE ORIENTED HAZARDS	DEBRIS	METAL OBJECTS	GLASS	BLDG. FIXTURES OR STRUCTURE	FLORA OR FAUNA	EQUIPMENT OR TOOLS / MACHINERY	VEHICLE	FLOOR, GROUND, OR WORKING SURFACE	ICE	ANOTHER PERSON	BODILY MOTION	HEAT, FLAME, OR HOT OBJECT	COLD	CHEMICALS	CLOTHING	MISC.	STRUCK BY / STRUCK AGAINST	LIFTING, MOVING, HANDLING	CAUGHT IN OR BETWEEN	FELL FROM	FELL ONTO	EXPOSED TO	CONTACT WITH	MISC.	AVERAGE HEALING TIME, DAYS
1. MECHANICAL																									
a. Wound with broken skin	14	14	90	29	13	145	42	24		2						18	298	8	48	6	14		11	6	
Combined { • cut or scratch • laceration • puncture*	13	14	90	28	13	142	37	24		2						18	293	8	45	5	14		10	6	
• abrasion	1	0	0	1	0	1	3	0		0						0	4	0	0	1	0		1	0	
• amputation	0	0	0	0	0	2	2	0		0						0	1	0	3	0	0		0	0	
b. Wound without broken skin	4	4		14		39	17	3		4						7	43	4	36	2	5			2	
• crush or pinch	1	3		6		14	2	0		0						3	5	2	21	0	0			1	
• bruise or contusion	3	1		8		25	15	3		4						4	38	2	15	2	5			1	
2. THERMAL																									
a. Heat	1	1	1	5		10	5					102				1	2						124		
• burn	1	1	1	5		10	5					97				1	2						119		
• scald	0	0	0	0		0	0					5				0	0						5		
b. Cold																									
• frostbite																									
• freezing																									
3. CHEMICAL																									
a. Burn														2		1							3		
b. Poisoning (including skin disease)					6											2							7	1	
4. ELECTRICAL (Burn)		1				1																			
5. BACTERIOLOGICAL																									
6. RADIOLOGICAL																									
TOTAL GLOVE ORIENTED INJURIES	19	20	91	48	19	195	64	27		6		102		2		29	343	12	84	8	19		147	9	
OTHER HAND HAZARDS																									
1. MECHANICAL																									
a. Bones		1	1	12		43	22	40		7						4	44	9	20	15	35		4	3	
• fracture		1	1	11		41	21	39		6						4	44	6	20	14	34		4	2	
• dislocation		0	0	1		2	1	1		1						0	0	3	0	1	1		0	1	
b. Joints, tendons, muscles		1	1	15		57	33	33		6						7	29	33	12	20	31		8	20	
• inflammation		0	0	0		0	0	0		0						0	0	0	0	0	0		0	0	
• sprain and strain		1	1	15		57	33	33		6						7	29	33	12	20	31		8	20	
2. MISCELLANEOUS																									
a. Multiple injuries																									
b. Ill-defined or unknown		1	1	19		49	14	16		2						10	44	8	18	18	13		2	9	
TOTAL OTHER HAND INJURIES	0	3	3	46	0	149	69	89		15		0		0		21	117	50	50	53	79		14	32	
TOTAL INJURIES	19	23	94	94	19	344	133	116		21		102		2		50	460	62	134	61	98		161	41	

* Puncture includes splinters, insect stings, and animal bites.

Source: State of California Division of Labor Statistics and Research
Number of Injuries During the Period 1970 – 1973

TABLE A–7a
FREQUENCY OF FIREFIGHTER HAND AND ARM INJURIES

	INJURIES IDENTIFIABLE BY ANATOMICAL LOCATION																					OTHER REGIONAL INJURIES					TOTAL HAND AND ARM INJURIES
	FINGERS					HAND					WRIST					FOREARM					TOTAL IDENTIFIABLE INJURIES	UPPER EXTREMITIES				TOTAL(Σ*) REGIONAL INJURIES	(SUM OF IDENTIFIABLE AND REGIONAL INJURIES)
GLOVE ORIENTED HAZARDS	70	71	72	73	Σ*	70	71	72	73	Σ*	70	71	72	73	Σ*	70	71	72	73	Σ*		70	71	72	73		
1. MECHANICAL																											
a. Wound with broken skin	7	7	6	11	31	11	9	6	13	39	1	1	1		3	2	2	2	2	8	81	1	2	3		6	87
• cut or scratch	4	2	3	7	16	5	4	3	9	21	1	0	1		2	2	1	1	1	5	44	0	2	2		4	
• laceration	2	3	2	0	7	6	4	0	3	13	0	0	0		0	0	1	1	1	3	23	0	0	0		0	
• puncture	0	0	0	2	2	0	1	2	1	4	0	1	0		1	0	0	0	0	0	7	0	0	1		1	
• abrasion	0	0	1	0	1	0	0	1	0	1	0	0	0		0	0	0	0	0	0	2	1	0	0		1	
• amputation	1	2	0	2	5	0	0	0	0	0	0	0	0		0	0	0	0	0	0	5	0	0	0		0	
b. Wound without broken skin	5	2	2	2	11	1			2	3									1	1	15	2	3	2	2	9	24
• crush or pinch	3	1	1	1	6	0			0	0									0	0	6	0	0	0	0	0	
• bruise or contusion	2	1	1	1	5	1			2	3									1	1	9	2	3	2	2	9	
2. THERMAL																											
a. Heat				1	1	3	7	2	5	17	2	1		2	5		1			1	24	3			1	4	28
• burn				1	1	3	7	2	5	17	2	1		2	5		1			1	24	3			1	4	
• scald				0	0	0	0	0	0	0	0	0		0	0		0			0	0	0			0	0	
b. Cold						1				1											1						1
• frostbite						1				1											1						
• freezing						0				0											0						
3. CHEMICAL																											
a. Burn																											
b. Poisoning (including skin disease)				1	1											1				1	2						2
4. ELECTRICAL																											
5. BACTERIOLOGICAL																											
6. RADIOLOGICAL																											
TOTAL GLOVE ORIENTED INJURIES	12	9	8	15	44	16	16	8	20	60	3	2	1	2	8	3	3	2	3	11	123	6	5	5	3	19	142
OTHER HAND HAZARDS																											
1. MECHANICAL																											
a. Bones		3	2	2	7	2		1	1	4	2	1		2	5	1			1	2	18	2	1	1	2	6	24
• fracture		2	1	2	5	2		1	1	4	2	1		2	5	1			1	2	16	2	0	1	2	5	
• dislocation		1	1	0	2	0		0	0	0	0	0		0	0	0			0	0	2	0	1	0	0	1	
b. Joints, tendons, muscles	1	2	1	1	5			1	2	3	3	1	1		5						13	1	4	3	5	13	26
• inflammation	0	0	0	0	0			0	0	0	0	0	0		0						0	1	0	0	1	2	
• sprain and strain	1	2	1	1	5			1	2	3	3	1	1		5						13	0	4	3	4	11	
2. MISCELLANEOUS																											
a. Multiple injuries																											
b. Ill-defined or unknown																											
TOTAL OTHER HAND INJURIES	1	5	3	3	12	2	0	2	3	7	5	2	1	2	10	1	0	0	1	2	31	3	5	4	7	19	50
TOTAL INJURIES	13	14	11	18	56	18	16	10	23	67	8	4	2	4	18	4	3	2	4	13	154	9	10	9	10	38	192

* Σ = Sum of data for the years 1970 - 1973.

Source: Wisconsin Department of Industry, Labor, and Human Relations
Number of Injuries During the Period 1970 – 1973

TABLE A–7b
CHARACTERISTICS OF FIREFIGHTER HAND AND ARM INJURIES

CAUSATIVE AGENT

	Debris	Metal Objects	Glass	Bldg. Fixtures or Structure	Flora or Fauna	Equipment or Tools	Machinery	Vehicle	Floor, Ground, or Working Surface	Ice	Another Person	Bodily Motion	Heat, Flame, or Hot Object	Cold	Chemicals	Clothing	Misc.
GLOVE ORIENTED HAZARDS																	
1. MECHANICAL																	
a. Wound with broken skin	2	10	42			15		6	1		1					1	9
• cut or scratch	0	6	27			6		2	0		1					0	6
• laceration	1	2	13			4		2	0		0					0	1
• puncture	1	2	2			1		0	1		0					0	1
• abrasion	0	0	0			2		0	0		0					1	0
• amputation	0	0	0			2		2	0		0					0	1
b. Wound without broken skin	1	2		1		6	2	4	2	3							3
• crush or pinch	1	0		0		3	0	1	0	0							1
• bruise or contusion	0	2		1		3	2	3	2	3							2
2. THERMAL																	
a. Heat		2											24				2
• burn		2											24				2
• scald		0											0				0
b. Cold														1			
• frostbite														1			
• freezing														0			
3. CHEMICAL																	
a. Burn																	
b. Poisoning (including skin disease)																	2
4. ELECTRICAL																	
5. BACTERIOLOGICAL																	
6. RADIOLOGICAL																	
TOTAL GLOVE ORIENTED INJURIES	3	14	42	1		21	2	10	3	3	1	0	24	1		1	16
OTHER HAND HAZARDS																	
1. MECHANICAL																	
a. Bones		1		1		3		5	10	1	2						1
• fracture		1		1		3		5	9	1	0						1
• dislocation		0		0		0		0	1	0	2						0
b. Joints, tendons, muscles	1	1		2		6	1	4	5	1	3	1					1
• inflammation	0	0		0		0	0	0	1	0	0	1					0
• sprain and strain	1	1		2		6	1	4	4	1	3	0					1
2. MISCELLANEOUS																	
a. Multiple injuries																	
b. Ill-defined or unknown																	
TOTAL OTHER HAND INJURIES	1	2	0	3		9	1	9	15	2	5	1	0	0		0	2
TOTAL INJURIES	4	16	42	4		30	3	19	18	5	6	1	24	1		1	18

ACCIDENT TYPE and **SEVERITY INDEX**

	Struck By	Struck Against	Lifting, Moving, Handling	Caught In or Between	Fell From	Fell Onto	Exposed To	Contact With	Misc.	Average Healing Time, Days
GLOVE ORIENTED HAZARDS										
1. MECHANICAL										
a. Wound with broken skin	37	30		6	2	6			6	
• cut or scratch	21	20		1	0	2			4	11.4
• laceration	11	7		2	1	2			0	12.5
• puncture	2	3		0	1	1			1	4.6
• abrasion	0	0		1	0	1			1	4.3
• amputation	3	0		2	0	0			0	9.6
b. Wound without broken skin	7	6		4		5		1	1	
• crush or pinch	4	0		2		0		0	0	12.3
• bruise or contusion	3	6		2		5		1	1	5.4
2. THERMAL										
a. Heat	4		1	1		1	1	18	2	
• burn	4		1	1		1	1	18	2	6.3
• scald	0		0	0		0	0	0	0	
b. Cold							1			
• frostbite							1			1.0
• freezing							0			
3. CHEMICAL										
a. Burn										
b. Poisoning (including skin disease)								1	1	4.0
4. ELECTRICAL										
5. BACTERIOLOGICAL										
6. RADIOLOGICAL										
TOTAL GLOVE ORIENTED INJURIES	48	36	1	11	2	12	2	20	10	
OTHER HAND HAZARDS										
1. MECHANICAL										
a. Bones	6	3	1	1	2	10		1		
• fracture	5	3	0	1	2	9		1		33.0
• dislocation	1	0	1	0	0	1		0		45.7
b. Joints, tendons, muscles	2	3	11	1	1	6			2	
• inflammation	0	0	0	0	0	1			1	18.0
• sprain and strain	2	3	11	1	1	5			1	13.0
2. MISCELLANEOUS										
a. Multiple injuries										
b. Ill-defined or unknown										
TOTAL OTHER HAND INJURIES	8	6	12	2	3	16	0	1	2	
TOTAL INJURIES	56	42	13	13	5	28	2	21	12	

Source: Wisconsin Department of Industry, Labor, and Human Relations
Number of Injuries During the Period 1970 – 1973

TABLE A–8a
FREQUENCY OF FIREFIGHTER HAND AND ARM INJURIES

INJURIES IDENTIFIABLE BY ANATOMICAL LOCATION — FINGERS and HAND

	FINGERS 71	FINGERS 72	FINGERS 73	FINGERS 74	FINGERS Σ*	HAND 71	HAND 72	HAND 73	HAND 74	HAND Σ*
GLOVE ORIENTED HAZARDS										
1. MECHANICAL										
a. Wound with broken skin			44	30	74			75	33	108
• cut or scratch			1	1	2			0	0	0
• laceration***			43	26	69			70	25	95
• puncture			0	3	3			5	8	13
• abrasion			0	0	0			0	0	0
• amputation			0	0	0			0	0	0
b. Wound without broken skin				2	2			2	3	5
• crush or pinch				0	0			0	0	0
• bruise or contusion				2	2			2	3	5
2. THERMAL										
a. Heat			3		3			7	7	14
• burn			3		3			7	7	14
• scald			0		0			0	0	0
b. Cold				1	1			1		1
• frostbite				1	1			1		1
• freezing				0	0			0		0
3. CHEMICAL										
a. Burn										
b. Poisoning (including skin disease)										
4. ELECTRICAL (Burn)			3		3					
5. BACTERIOLOGICAL										
6. RADIOLOGICAL										
TOTAL GLOVE ORIENTED INJURIES			50	33	83			85	43	128
OTHER HAND HAZARDS										
1. MECHANICAL										
a. Bones			2		2			9	1	10
• fracture			2		2			9	1	10
• dislocation			0		0			0	0	0
b. Joints, tendons, muscles			2	1	3			4	4	8
• inflammation			0	0	0			0	0	0
• sprain and strain			2	1	3			4	4	8
2. MISCELLANEOUS										
a. Multiple injuries										
b. Ill-defined or unknown			1	1	2			2	3	5
TOTAL OTHER HAND INJURIES			5	2	7			15	8	23
TOTAL INJURIES			55	35	90			100	51	151

INJURIES IDENTIFIABLE BY ANATOMICAL LOCATION (continued) — WRIST, FOREARM; OTHER REGIONAL INJURIES; TOTAL HAND AND ARM INJURIES

	WRIST 71	WRIST 72	WRIST 73	WRIST 74	WRIST Σ*	FOREARM 71	FOREARM 72	FOREARM 73	FOREARM 74	FOREARM Σ*	TOTAL IDENTIFIABLE INJURIES	UPPER EXTREMITIES 71	UPPER EXTREMITIES 72	UPPER EXTREMITIES 73	UPPER EXTREMITIES 74	TOTAL(Σ*) REGIONAL INJURIES	TOTAL HAND AND ARM INJURIES (SUM OF IDENTIFIABLE AND REGIONAL INJURIES)
GLOVE ORIENTED HAZARDS																	
1. MECHANICAL																	
a. Wound with broken skin			19	9	28			1	5	6	216						216
• cut or scratch			0	0	0			0	0	0	2						
• laceration***			19	8	27			1	4	5	196						
• puncture			0	1	1			0	0	0	17						
• abrasion			0	0	0			0	1	1	1						
• amputation			0	0	0			0	0	0	0						
b. Wound without broken skin				2	2				1	1	10						10
• crush or pinch				0	0				0	0	0						
• bruise or contusion				2	2				1	1	10						
2. THERMAL																	
a. Heat			8	8	16				1	1	34						34
• burn			8	8	16				1	1	34						
• scald			0	0	0				0	0	0						
b. Cold											2						2
• frostbite											2						
• freezing											0						
3. CHEMICAL																	
a. Burn																	
b. Poisoning (including skin disease)																	
4. ELECTRICAL (Burn)											3						3
5. BACTERIOLOGICAL																	
6. RADIOLOGICAL																	
TOTAL GLOVE ORIENTED INJURIES			27	19	46			1	7	8	265						265
OTHER HAND HAZARDS																	
1. MECHANICAL																	
a. Bones				5	5				1	1	18						18
• fracture				5	5				1	1	18						
• dislocation				0	0				0	0	0						
b. Joints, tendons, muscles			8	5	13				1	1	25						25
• inflammation			0	0	0				0	0	0						
• sprain and strain			8	5	13				1	1	25						
2. MISCELLANEOUS																	
a. Multiple injuries																	
b. Ill-defined or unknown				1	1						8						8
TOTAL OTHER HAND INJURIES			8	11	19			0	2	2	51						51
TOTAL INJURIES			35	30	65			1	9	10	316						316

* Σ = Sum of data for the years 1971 - 1974.
** Data covers only the months of January through August in 1974.
*** Reporting system was very general in nature--most all wounds with broken skin were called lacerations.

Source: Chicago, Illinois, Fire Department
Number of Injuries During the Period 1973 – 1974**

TABLE A–8b
CHARACTERISTICS OF FIREFIGHTER HAND AND ARM INJURIES

	CAUSATIVE AGENT																	ACCIDENT TYPE									SEVERITY INDEX
	DEBRIS	METAL OBJECTS	GLASS	BLDG. FIXTURES OR STRUCTURE	FLORA OR FAUNA	EQUIPMENT OR TOOLS	MACHINERY	VEHICLE	FLOOR, GROUND, OR WORKING SURFACE	ICE	ANOTHER PERSON	BODILY MOTION	HEAT, FLAME, OR HOT OBJECT	COLD	CHEMICALS	CLOTHING	MISC.**	STRUCK BY	STRUCK AGAINST	LIFTING, MOVING, HANDLING	CAUGHT IN OR BETWEEN	FELL FROM	FELL ONTO	EXPOSED TO	CONTACT WITH	MISC.	AVERAGE HEALING TIME, DAYS
GLOVE ORIENTED HAZARDS																											
1. MECHANICAL																											
a. Wound with broken skin	5	16	52	20	3	19	2	8	2		5						84										
• cut or scratch	0	0	0	0	0	0	0	1	0		0						1										
• laceration	4	9	49	20	3	18	2	7	2		5						77										
• puncture	0	7	3	0	0	1	0	0	0		0						6										
• abrasion	1	0	0	0	0	0	0	0	0		0						0										
• amputation	0	0	0	0	0	0	0	0	0		0						0										
b. Wound without broken skin	1			3		2			1								3										
• crush or pinch	0			0		0			0								0										
• bruise or contusion	1			3		2			1								3										
2. THERMAL																											
a. Heat	1	1		1		3					1		25				2										
• burn	1	1		1		3					1		25				2										
• scald	0	0		0		0					0		0				0										
b. Cold														2													
• frostbite														2													
• freezing														0													
3. CHEMICAL																											
a. Burn																											
b. Poisoning (including skin disease)																											
4. ELECTRICAL (Burn)				3																							
5. BACTERIOLOGICAL																											
6. RADIOLOGICAL																											
TOTAL GLOVE ORIENTED INJURIES	7	17	52	27	3	24	2	8	3	0	6		25	2			89										
OTHER HAND HAZARDS																											
1. MECHANICAL																											
a. Bones		1		4		2		1	2	1	1						6										
• fracture		1		4		2		1	2	1	1						6										
• dislocation		0		0		0		0	0	0	0						0										
b. Joints, tendons, muscles				2		4		1	6	2	1						9										
• inflammation				0		0		0	0	0	0						0										
• sprain and strain				2		4		1	6	2	1						9										
2. MISCELLANEOUS																											
a. Multiple injuries																											
b. Ill-defined or unknown					1	2			1								4										
TOTAL OTHER HAND INJURIES	0	1	0	6	1	8	0	2	9	3	2		0	0			19										
TOTAL INJURIES	7	18	52	33	4	32	2	10	12	3	8		25	2			108										

* Data covers only the months of January through August in 1974.
** Reporting system tends to be vague in specifying characteristics and results in a high incidence of "Miscellaneous" agents.

Source: Chicago, Illinois, Fire Department
Number of Injuries During the Period 1973 – 1974*

TABLE A–9
FREQUENCY OF FIREFIGHTER HAND AND ARM INJURIES

	INJURIES IDENTIFIABLE BY ANATOMICAL LOCATION					OTHER REGIONAL INJURIES		TOTAL HAND AND ARM INJURIES
	FINGERS Σ*	HAND Σ*	WRIST Σ*	FOREARM Σ*	TOTAL IDENTIFIABLE INJURIES	UPPER EXTREMITIES	TOTAL(Σ*) REGIONAL INJURIES	(SUM OF IDENTIFIABLE AND REGIONAL INJURIES)
GLOVE ORIENTED HAZARDS								
1. MECHANICAL								
a. Wound with broken skin	8	6		1	15			15
• cut or scratch	4	0		0	4			
• laceration	3	2		1	6			
• puncture**	0	4		0	4			
• abrasion	1	0		0	1			
• amputation	0	0		0	0			
b. Wound without broken skin	2	1			3			3
• crush or pinch	2	0			2			
• bruise or contusion	0	1			1			
2. THERMAL								
a. Heat	1	1	3	1	6			6
• burn	1	1	3	1	6			
• scald	0	0	0	0	0			
b. Cold								
• frostbite								
• freezing								
3. CHEMICAL								
a. Burn			1		1			1
b. Poisoning (including skin disease)								
4. ELECTRICAL								
5. BACTERIOLOGICAL								
6. RADIOLOGICAL								
TOTAL GLOVE ORIENTED INJURIES	11	8	4	2	25			25
OTHER HAND HAZARDS								
1. MECHANICAL								
a. Bones	1				1			1
• fracture	1							
• dislocation	0							
b. Joints, tendons, muscles			2		2			2
• inflammation			0					
• sprain and strain			2					
2. MISCELLANEOUS								
a. Multiple injuries								
b. Ill-defined or unknown								
TOTAL OTHER HAND INJURIES	1	0	2	0	3			3
TOTAL INJURIES	12	8	6	2	28			28

* Σ = Sum of data for the period July, 1972 - October, 1974

** Puncture includes splinters, insect stings, and animal bites

Source: Tucson, Arizona Fire Department
Number of Injuries During the Period of July, 1972 – October, 1974

TABLE A–10
FREQUENCY OF FIREFIGHTER HAND AND ARM INJURIES

	INJURIES IDENTIFIABLE BY ANATOMICAL LOCATION					** OTHER REGIONAL INJURIES		TOTAL HAND AND ARM INJURIES
	FINGERS Σ*	HAND Σ*	WRIST Σ*	FOREARM Σ*	TOTAL IDENTIFIABLE INJURIES	UPPER EXTREMITIES	TOTAL (Σ*) REGIONAL INJURIES	(SUM OF IDENTIFIABLE AND REGIONAL INJURIES)
GLOVE ORIENTED HAZARDS								
1. MECHANICAL								
a. Wound with broken skin	434	512	99		1045		160	1205
Combined { • cut or scratch • laceration • puncture	427	502	97		1026		143	
• abrasion	7	10	2		19		17	
• amputation	0	0	0		0		0	
b. Wound without broken skin • crush or pinch • bruise or contusion	96	95	11		202		190	392
2. THERMAL								
a. Heat • burn • scald	14	270	30		314		91	405
b. Cold • frostbite • freezing								
3. CHEMICAL								
a. Burn								
b. Poisoning (including skin disease)								
4. ELECTRICAL								
5. BACTERIOLOGICAL								
6. RADIOLOGICAL								
TOTAL GLOVE ORIENTED INJURIES	544	877	140		1561		441	2002
OTHER HAND HAZARDS								
1. MECHANICAL								
a. Bones	118	54	78		250		124	374
• fracture	118	54	78		250		124	
• dislocation	0	0	0		0		0	
b. Joints, tendons, muscles	71	35	95		201		104	305
• inflammation	0	0	0		0		0	
• sprain and strain	71	35	95		201		104	
2. MISCELLANEOUS								
a. Multiple injuries								
b. Ill-defined or unknown	61	40	5		106		47	153
TOTAL OTHER HAND INJURIES	250	129	178		557		275	832
TOTAL INJURIES	794	1006	318		2118		716	2834

* Σ = Sum of data for the year 1964.
** Defined here as injuries for the arm above the wrist.

Source: U.S. Bureau of Labor Statistics Unpublished National Survey, 1964 data
Number of Injuries During the Year 1964

APPENDIX B
RANK-ORDERING OF HAND AND WRIST INJURIES

The statistical frequency and severity of individual injuries* have been combined with the subjective citation data for injuries to provide a single, comprehensive ranking (R) of hand and wrist injuries. Such a ranking takes into account the more severe injuries reported in the statistical data (occupational injuries which resulted in lost time) and the less severe injuries identified in the Fire Service survey (for example, injuries requiring first aid).

Injuries identified in each of these two data categories were ranked separately (r_1 and r_2) and the two subrankings were then combined to provide an index (i) suitable for overall injury ranking (R) by importance. Both the injury subrankings and the combined rankings are described in the following paragraphs and tables.

1. INJURY SUBRANKING BY STATISTICS, r_1

The first subranking, r_1, is based on both frequency of injury and an index of injury severity. The analyses are based on all nine data sources (as detailed in Appendix A).

It was necessary to determine injury frequency in two parts because several injury reporting systems are incomplete. Each of the nine sources provided data for the primary injury classifications (such as mechanical wounds with broken skin, etc.), but only five split data into specific individual injuries (subcategories such as cut or scratch, laceration, etc.). Therefore, primary injury classifications were evaluated using the largest possible data base – all nine sources. The individual injuries were separately evaluated as subcategories using data available from the five detailed sources.

a. Frequency of Primary Injury Classifications

Table 1 of this report presents the frequency tabulation for the primary injury classifications.

b. Frequency of Individual Injuries

Table 2 of this report presents the frequency tabulation for the individual injuries within each primary classification.

c. Severity Index for Injuries

Table 3 of this report presents a severity index in terms of injury healing times.

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*NOTE: Only injury data that are specifically correlated with anatomical location (finger, hand, wrist, forearm) were utilized.

d. Calculation of Subranking, r_1

The statistical ranking, r_1, is determined by use of the product, P, of injury frequency and severity index. The injuries having the larger values of P are judged to be more important. In Table B-1 both the frequency and the severity index for each primary injury classification and each individual injury have been repeated. The product, P, of these two factors is calculated and is used to independently rank the primary injury classifications and the individual injuries within each classification. Table B-1 contains the results of this first subranking exercise.

2. INJURY SUBRANKING BY CITATIONS, r_2

Finger, hand and wrist injuries were identified and ranked using frequency of citation data. The injuries receiving most citations were considered to be most important. This data source insured inclusion of non-lost-time injuries such as frostbite, minor cuts and scratches, and minor burns. Table B-2 contains the results of this second subranking exercise.

3. OVERALL RANK-ORDERING, R

The final ranking index, i, was calculated by summing the two subrankings as $r_1 + 0.5r_2$. More emphasis was given to the injury statistics in identifying a proper ranking by reducing the contribution of the citation ranking, r_2, by half. Table B-3 shows the results of this calculation.

The overall injury ranking, R, is also shown in Table B-3. This was directly determined from the values of i. The injuries having the lowest values of i were considered most important. The results of these manipulations provide a strong indication of which injuries require most consideration in a firefighter's glove. These results were incorporated in the preparation of Table 7 of this report.

TABLE B-1

r_I, INJURY SUBRANKING BY STATISTICS

Injury Type	Frequency x Healing Time = P			Subranking, r_I	
	(Number)* x	(Days) =	(Injury-Days)	Individual Injuries	Primary Classification
1. Mechanical					
a. Wound with broken skin	1,751	10.7	18,736		1
• Cut or scratch	106	11.4	1,208	2	
• Laceration	140	12.5	1,750	1	
• Puncture	103	4.6	473	3	
• Abrasion	11	4.3	47	5	
• Amputation	7	9.6	67	4	
b. Wound without broken skin	305	7.1	2,165		3
• Crush or pinch	21	12.3	258	2	
• Bruise or contusion	64	5.4	346	1	
2. Thermal					
a. Heat	510	6.3	3,213		2
• Burn	53	6.3	334	1	
• Scald	0	6.3	0	2	
b. Cold	7	1.0	7		7
• Frostbite	2	1.0	2	1	
• Freezing	0	1.0	0	2	
3. Chemical					
a. Burn	8	2.0	16		5
b. Poisoning	15	4.0	60		4
4. Electrical (burn)	5	2.0	10		6

*The number of injuries listed here represent a combination of the data in Tables 1 and 2, each of which was prepared from different data sources. Therefore, the individual injuries below a primary classification, added together, do not equal the total given for that primary classifiction.

TABLE B-2

r_2, INJURY SUBRANKING BY CITATIONS

Injury Type	Subranking, r_2	
	Individual Injuries	Primary Classifications
1. Mechanical		
a. Wound with broken skin		3
• Cut or scratch	2	
• Laceration	4	
• Puncture	1	
• Abrasion	3	
• Amputation	5	
b. Wound without broken skin		5
• Crush or pinch	2	
• Bruise or contusion	1	
2. Thermal		
a. Heat		2
• Burn	1	
• Scald	2	
b. Cold		1
• Frostbite	1	
• Freezing	2	
3. Chemical		
a. Burn		6
b. Poisoning		7
4. Electrical (burn)		4

TABLE B-3

OVERALL INJURY RANKING

Injury Type	Subrankings r_1 Individual Injuries	Subrankings r_1 Primary Classif.	Subrankings r_2 Individual Injuries	Subrankings r_2 Primary Classif.	Ranking Index, i ($i=r_1 + 0.5r_2$) Individual Injuries	Ranking Index, i ($i=r_1 + 0.5r_2$) Primary Classif.	Final Injury Ranking, R (Based on value of "i") Individual Injuries	Final Injury Ranking, R (Based on value of "i") Primary Classif.
1. Mechanical								
a. Wound with broken skin		1		3		2.5		1
• Cut or scratch	2		2		3.0		1	
• Laceration	1		4		3.0		1	
• Puncture	3		1		3.5		2	
• Abrasion	5		3		6.5		3	
• Amputation	4		5		6.5		3	
b. Wound without broken skin		3		5		5.5		3
• Crush or pinch	2		2		3.0		2	
• Bruise or contusion	1		1		1.5		1	
2. Thermal								
a. Heat		2		2		3.0		2
• Burn	1		1		1.5		1	
• Scald	2		2		3.0	2.0		
b. Cold		7		1		7.5		4
• Frostbite	1		1		1.5		1	
• Freezing	2		2		3.0		2	
3. Chemical								
a. Burn		5		6		8.0		5
b. Poisoning		4		7		7.5		4
4. Electrical (burn)		6		4		8.0		5

APPENDIX C
A LIST OF CANDIDATE MATERIALS FOR A PROTOTYPE FIREFIGHTERS' GLOVE

Material	Description	Manufacturer or Supplier	Comments
Nomex	Needle-punched felt 7.5 oz and 20 oz duck 12 oz duck Knit fabric Filament weave	E. I. Du Pont E. I. Du Pont Racine Glove Co. E. I. Du Pont E. I. Du Pont	Nomex, manufactured by Du Pont, is an aramid fiber which can be used in many fabric constructions with many types of finishes.
Nomex/neoprene	Neoprene coated needle-punched Nomex felt Neoprene coated 3.5 oz Nomex scrim	Racine Glove Co., and Southern Mills E. I. Du Pont	
Nomex/Zepel	Zepel coated Nomex	Racine Glove Co., and Southern Mills	
Nomex/Kynol	50/50 blend of Nomex and Kynol fibers in various plain weaves, twills, knits, poplin weaves, satin weaves and terry cloths. 55/45 blend of Nomex and Kynol fibers in a honey-comb weave	Collins and Aikman; Jomac Products, Inc. Collins and Aikman	Kynol is a FR cross-linked phenolic fiber manufactured by Carborundum.
Nomex/Kynol/neoprene	Neoprene coated 50/50 blend of Nomex and Kynol fibers in plain weave and in satin weave	Collins and Aikman	
Nomex/Kynol/urethane	FR urethane coated 50/50 blend of Nomex and Kynol fibers in a broken twill	Collins and Aikman	
Nomex/Kynol/aluminum	Aluminum coated 50/50 blend of Nomex and Kynol fibers in plain weaves and twills	Collins and Aikman; Gentex Corporation	
Novatex (Nomex/asbestos)	Nomex and asbestos fibers in a plain weave	Raybestos Manhattan	

APPENDIX C (Continued)

Material	Description	Manufacturer or Supplier	Comments
Kevlar (Fiber B)	6.8 oz and 9.5 oz filament woven fabric	E. I. Du Pont	Kevlar is an aramid fiber, manufactured by Du Pont, which can be used in many fabric constructions with many types of finishes.
Kevlar/Viton	Viton (flame resistant elastomeric polymer) coated Kevlar fabric	E. I. Du Pont; A. D. Little	
Foylon	Aluminum coated polyethylene (Tyvek), polyester scrim, Kevlar or Dacron	Duracote Corporation	
Durette	Simplex knit	Monsanto	Durette is a treated polyamide fiber manufactured by Monsanto.
SEF modacrylic	Poplin weave	Monsanto; J. P. Stevens	
SEF modacrylic/polyester	58/42 blend in a poplin weave	Monsanto J. P. Stevens	
Cotton	Knitted terry cloth with a FR treatment	Jomac Products	
Gore-Tex	Teflon and PBI fibers in a twill weave	Fabric Development	PBI is polybenzimidizole, a non-shrinking, high temperature fiber by Celanese
Ortho Fabric	Combination of Nomex, Kevlar and Gore-Tex in a single construction	Fabric Development	
Aluminum/fiberglass/cotton	Aluminum coated fiberglass fabric backed with cotton	Textured Products	

APPENDIX D
REFERENCES

1. Kimball, W.Y., "Firefighting Casualties," *Fireman,* Vol. 37, No. 4, April 1970.

2. Atwood, R.L., "Death and Injury of Firefighters," *Fire Command,* Vol. 38, April 1971.

3. Utech, H.P., "Injuries Show What Protection Improved Clothing Should Offer," *Fire Engineering,* Vol. 125, No. 4, April, 1972.

4. Seymour, T.H., "A Study of Personal Protective Clothing Standards for Firefighters," University of Maryland, College of Engineering, Fire Protection Curriculum, May 30, 1972.

5. "Annual Death and Injury Survey," Published by the International Association of Firefighters, November 1974.

6. Felton, J.S., and J.A. Johnson, "Costs of Firefighter Injuries," National Safety News, Vol. 109, June 1974.

7. Simms, D.L., "The Design of Test Methods for Industrial Fabrics for Protection Against Fire," Textile Institute and Industry, February 1966.

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