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Protective Clothing and Equipment Needs of Emergency Responders for Urban Search and Rescue Missions

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PROTECTIVE CLOTHING AND EQUIPMENT NEEDS OF EMERGENCY RESPONDERS IN URBAN SEARCH AND RESCUE MISSIONS

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Note: The Emergency Responder User Requirements Committee (ERURC) which participated in the development of this reported agreed on terminology and definitions in order to have common reference points for discussion. Some search and rescue professionals and organizations may use differing definitions or terminology.

This report is intended for use by search and rescue professionals and others who may wish to work toward the development of search and rescue protective clothing and equipment standards. This report should be considered a first step in that direction and it is hoped that the professional search and rescue community will find this report helpful in that regard.

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EXECUTIVE SUMMARY

This report documents the protective clothing and equipment needs for emergency responders engaged in urban search and rescue activities. Urban search and rescue has been defined as those areas of emergency rescue activities not undertaken as part of other traditionally defined response efforts such as fire fighting, hazardous materials response, and emergency medical services. Examples of urban search and rescue incidents include building collapses, trench cave-ins, victim extrication from vehicles, flooding, and contaminated water diving. These incidents pose a variety of hazards which are primarily physical in nature, but may include incidental fire contact, chemical exposure, prolonged exposure to adverse weather, contact with biological contaminants, and drowning. Due to the specialized nature of these emergency response missions, specific clothing and equipment are necessary to satisfy a minimum level of protection while allowing the responder to properly complete his or her assigned tasks.

To direct the assessment of urban search and rescue protective clothing/equipment needs, an Emergency Responder User Requirements Committee (ERURC) was formed which included representatives of the fire service and other groups experienced in urban search and rescue missions. Input from the ERURC was used, together with information obtained in literature surveys, to clearly define urban search and rescue missions, to identify needs associated with each mission, to determine what clothing and equipment should be used to meet those needs, and to propose generic performance requirements for each clothing and equipment item.

As a result of ERURC efforts, different urban search and rescue protective ensembles were defined for three distinct areas: (1) technical rescue, (2) swift water rescue, and (3) contaminated water diving. This classification was based on grouping similar protection needs and ensemble clothing/equipment needs into categories. The technical rescue ensemble covers nearly all land-based urban search and rescue missions. The ERURC proposed that this ensemble consist of a one- or two-piece garment, helmet, gloves, and boots in combination with goggles and an air-purifying respirator. The ensemble should be designed primarily to offer physical protection but also to provide limited protection against fire, electrical, chemical, and biological hazards, as well as long term comfort and visibility. The swift water rescue ensemble was proposed to meet protection needs during flooding. The suggested ensemble would consist of a personal flotation device, dry suit, gloves, booties (with swimming fins), and vented helmet. A knife and whistle should also be included in the ensemble. Protection priorities in swift water rescue are flotation, isolation from cold water exposure, and resistance to physical hazards. Lesser needs are for chemical and biological protection. The last ensemble designated by the ERURC was the contaminated water diving ensemble. Because the responders may be immersed directly in hazardous substances, this situation represents one of the more potentially hazardous environments. Such an ensemble would include a dry suit with integrated gloves, booties, fins, and helmet or mask. Two variants of the ensemble were proposed: a supplied air and a self-contained diving ensemble. Each dictates its own specific set of supplemental equipment. In each case, protection of breathing air and of the wearer from physical, thermal, chemical, and biological hazards were given equal priority.

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INTRODUCTION

This report describes the needs of emergency responders for personal protection during urban search and rescue activities. The report was prepared as part of U.S. Fire Administration contract number EMW-91-C-3662, “Development of Criteria for Urban Search and Rescue Protective Clothing.” The objectives of this contract were:

1. To establish a Emergency Responder User Requirements Technical Assistance Committee (ERURC);

2. To create an effective liaison with the National Fire Protection Association (NFPA) Technical Committee on Fire Service Protective Clothing and Equipment as well as American Society for Testing and Materials (ASTM) Committees F23 on Protective Clothing and F32 on Search and Rescue;

3. To identify specific needs and priorities for Urban Search and Rescue (USAR) protective clothing/equipment;

4. To develop performance criteria and test requirements for selected USAR protective clothing and equipment items;

5. To document contract findings in a comprehensive report which clearly describes USAR protective clothing/ equipment needs and recommended performance criteria; and

6. To propose new test methods and performance standards for adoption by ASTM and NFPA respectively.

The contract objectives were designed to support the development of new comprehensive performance standards which could be used to address the protection needs of urban search and rescue missions. Contract work was divided into the following four tasks:

1. **Task A** provided a detailed plan to meet the objectives of the contract. This work plan was based on the critical areas of setting up an emergency responder user requirements committee (ERURC) and formulating a strategy for interaction with national consensus standards organizations.

2. **Task B** involved ERURC determination of emergency responder needs for urban search and rescue protective clothing/equipment. This task identified specific clothing and equipment items to be used by emergency responders for urban search and rescue, as well as the expected performance for these items.

3. **Task C** entailed the development of performance criteria for protective

clothing and equipment which would reflect the needs of the emergency responders for consistent protection. This was accomplished through a four step process to include (a) defining specific clothing and equipment performance areas in the various urban search and rescue missions; (b) selecting appropriate test methods or practices to evaluate these performance areas; (c) conducting tests and evaluations to validate selected test methods and to document performance of selected clothing or equipment; and (d) recommending specific performance requirements (or design requirements) which meet emergency responder needs identified in Task B.

4. **Task D** provided complete documentation of contract work through monthly reports and the preparation of a final report, as well as draft standards and test methods.

This report follows the Work Plan submitted to complete Task A and the Needs Assessment provided in to fulfill the requirements of Task B.

BACKGROUND

The Need for Protective Clothing and Equipment Standards

Historically, protective clothing has often been chosen on the basis of its appearance and its cost. For years, fire fighters and other emergency responders chose clothing and equipment which was more traditional than functional. The results were inadequate clothing and equipment designs or materials which often led to large numbers of injuries or fatalities within the fire service or related emergency responder organizations.

Greater concern for the protection of individuals coupled with new technology has improved the situation dramatically. While design was the primary driving force in past clothing and equipment configurations, performance-oriented specifications now have a more significant role. Performance-oriented specifications allow clothing and equipment manufacturers to demonstrate protective qualities through the use of agreed-upon test methods or standardized evaluation protocols. Emphasis is placed on performance criteria for selecting adequate protective clothing and equipment. This allows for easy identification of superior materials or configurations since manufacturer and end user alike can compare products on the same basis. As a consequence, standards:

- provide documentation of product performance;
- define minimum performance;
- allow end users to compare products on the same basis; and
- provide incentives for manufacturers to continually improve products.

Efforts by national consensus standards organizations such as the American Society for Testing and Materials (ASTM) and National Fire Protection Association (NFPA) have encouraged improvements in worker protection in a variety of hazardous applications. ASTM has promoted a number of test methods for protective clothing and material evaluation. NFPA has adopted comprehensive performance specifications using ASTM and other standards methods that define minimum protection to be offered by a number of clothing and equipment items. Each organization is continually expanding its scope to cover more and more types of protection, A new ASTM committee was established specifically to develop standards related to search and rescue activities.

Developing Protection Standards for Urban Search and Rescue

As described in the following sections, the emergency responder in urban search and rescue has to be prepared for potential exposure to a number of hazards. Each response is different and the available protective clothing and equipment must provide adequate protection against each hazard. The unique nature and combination of these hazards warrant specific clothing and equipment to protect emergency responders in the various missions they undertake. These requirements appear to be different from those needed for related emergency response missions which include:

- structural fire fighting;
- hazardous chemical response; and
- emergency medical services.

Separate protective clothing performance standards have been established for each of these areas. While some elements of performance from each area are similar to those needed in urban search and rescue, urban search and rescue activities generally involve lower levels of the different hazards and thus dictate specific requirements.

Current practices for protecting emergency responder vary dramatically throughout the country. Depending on the type of mission, emergency responders from two different organizations might use completely different protective clothing in responding to similar incidents. Therefore, the current urban search and rescue protection strategies vary, as do the required missions to which rescuers respond. Unfortunately, little guidance is available for their selection of appropriate protective clothing and equipment. Most emergency responders or tire departments base clothing and equipment purchases on experience. But experience cannot anticipate all possible situations or hazards. Comprehensive standards are clearly needed to support this area and provide needed levels of protection.

Strategy for Developing Standards

This U. S. Fire Administration contract was intended to provide the necessary support to encourage the development of a comprehensive performance standard on urban search and rescue protective clothing and equipment. To accomplish this overall goal, an Emergency Responder User Requirements Committee (ERURC) was established as part of the contract effort. The ERURC represented the primary group for presenting experience, identifying needs, evaluating test methods and data, and ultimately recommending performance requirements. Specific ERURC responsibilities included:

- identifying needs for protective clothing and equipment performance;
- setting priorities for clothing/equipment items on which the committee should concentrate its efforts;
- determining specific performance areas for each clothing/equipment item;
- selecting appropriate test methods or protocols for evaluating clothing/equipment performance;
- reviewing test data and results to determine adequacy of methods; and
- recommending specific performance and design requirements, and test methods for the selected areas of protective clothing and equipment.

TRI/Environmental’s role relative to the ERURC was to:

- provide meeting support;
- provide technical support; and
- document ERURC decisions and recommendations.

In this approach, the ERURC established. the specific needs for emergency responder protection during urban search and rescue missions. These clothing needs were then translated into performance requirements which become the basis of the performance-based specifications. Specifically, this process entailed the following steps:

1. defining the various missions USAR personnel engage in, as well as the hazards posed by each mission type;

2. identifying the types of protective clothing and equipment needed for USAR personnel in each mission area;

3. specifying performance areas (or design areas) for each clothing and equipment item which is identified above;

4. assembling a list of performance areas and generic criteria;

5. developing specific criteria by selecting potential tests methods or protocols and determining the type of requirement to be developed;

6. performing needed testing to validate the selection of test methods and to provide data on representative materials which could be used to recommend specific performance requirements; and

7. recommending performance requirements.

The ERURC was instrumental throughout this process not only in providing input, but also in making key decisions. The ERURC also reviewed data and determined what measured performance met the protection needs originally identified.

After the above process was completed, a list of performance requirements was developed and test methods for each area of need identified. These requirements and test methods can now be used as the foundation for an overall performance specification in the form of an NFPA standard.

URBAN SEARCH AND RESCUE

While ancient in its application, urban search and rescue is a relatively new title for a field of specialization within the fire service. It is sometimes known as heavy or technical rescue, and is principally undertaken by municipal or county fire departments, although several private organizations exist. Urban search and rescue typically applies to events where people have been trapped or are in perilous situations other than through fire or chemical exposure. As with other emergency response activities, urban search and rescue entails its own set of different threats to the emergency responder including:

- physical hazards (metal and masonry debris, working around heavy equipment, floating and submerged debris);
- thermal hazards (exposure to cold water, heat stress);
- flame and heat hazards (fire, chemical flash fire, electrical shock);
- chemical hazards (broken gas lines, open containers of solvents);
- biological hazards (direct exposure to bacteria contaminated water, involvement in emergency medical services; contact with victims having infectious diseases).

The degree of hazard varies with the mission and the type of activity to be performed.

Mission Areas

Examples of urban search and rescue missions are:

- building/structural collapse
- vehicle/person extraction
- confined space entry
- trench/cave-in rescue
- search operations (air, water, torrential)
- high angle rescue
- swift or still water rescue
- contaminated water diving

The first five missions entail what is generally known as technical rescue. Each of these missions potentially entails rugged physical environments and numerous hazards to the emergency responder. Typically, the emergency responder requires a high level of mobility and only limited protection against flame, heat, chemicals, or biological contaminants.

Structural or ***building collapse,*** often associated with earthquakes or bombings, can happen due to a variety of causes or during construction. The environment present during these situations contains assorted debris. Primary hazards to the responder are physical in nature. and include abrasions, cuts, tears, and punctures. Nevertheless, in some incidents possible rupture of gas lines or exposure to chemicals can pose additional hazards. And as with all rescues, emergency responder exposure to victim's blood may be possible. On a lesser scale, these represent the same hazards associated with extraction of victims from ***vehicle accidents.*** This includes accidents involving not only automobiles, but trains and aircraft as well.

Confined space entry imposes to its own unique environments. Many confined space rescues are associated with chemical incidents, and, as a consequence, may involve exposure to oxygen deficient or flammable atmospheres. The biggest constraint in these rescues is the limited space which restricts wearer movement and makes rescue operations difficult. These same conditions occur in ***high angle rescue.*** High angle rescue refers to rescues involving ladder trucks that require the fire fighter to enter a building through windows or on roof-tops. ***Trench cave-ins*** offer similar circumstances to both high angle and confined space entry, but generally do not involve chemical or fire hazards.

Search operations encompass a variety of environmental settings. Though not common in a urban setting, search can be associated with major disasters such as earthquakes, hurricanes, and floods. Many times, it can involve transport of injured persons from locations near a city, such as mountain peaks. Some of these operations involve emergency responders traveling by foot, on boats, or in air craft, particularly helicopters. For these missions, it is imperative that the clothing be designed for long wear times and resistance to physical hazards.

Flooding imposes a unique set of circumstances on the emergency responder. The greatest hazards are associated with ***swift water rescue,*** including:

- significant water pressure (flood forces);
- physical hazards through contact with debris;
- contamination from sewage or chemicals; and
- hypothermia.

At 3 miles per hour, current exerts a pressure of about 17 pounds per square inch against the legs of a person standing in its path. Doubling the water speed increases the water pressure to 68 psi. When this water is directed through flood control channels, where there are no obstructions or eddies to aid victims caught in flooding water, the potential for drowning is significant. Flood water carries significant amounts of debris which can puncture, tear, rip, and entangle flood victims. Sediment at the bottom of flood waters can impede rescue efforts. Flood water is likely to carry chemicals and other forms of contamination, especially sewage. Lastly, cold temperature exposure can cause hypothermia in both victim or rescuer if not adequately protected [1].

An extremely hazardous type of urban search and rescue mission is ***contaminated water diving.*** Fire departments and other emergency groups are increasingly called upon to perform a variety of functions underwater. These tasks include body recovery, evidence recovery, and recovery of submerged vehicles. In cold weather areas, due to the phenomenon known as the “diving reflex” or “cold reflex,” the potential exits for actual rescues to occur, even after the victim has been submerged for a prolonged period of time. This “diving reflex” phenomenon refers to a bodily response analogous to hibernation in which the metabolism slows to protect the heart and brain. Some victims have fully recovered after such situations [5].

Diving in contaminated or cold water can involve severe hazards. Many bodies of water are polluted with chemical or biological wastes. Chemicals may sink, mix, float or evaporate when released into the waterways. These chemicals can be corrosive or toxic but may not produce any outward/visible effects. Some poisons can take years to produce symptoms. While many chemicals are diluted, chemicals that sink or float may be encountered at concentrated levels. Stagnant drainage ditches may contain accumulated levels of pesticides from runoff in agricultural areas. More common are biological hazards, primarily in the form of harmful bacteria, protozoans and virus from the dumping of raw sewage. These contaminants can cause disorders ranging from swimmer’s ear to diarrhea, and in the worst cases can be fatal [3-5;6,p.6].

The principal hazards in contaminated water diving are exposures to chemical or biological agents. But other hazards exist as well, because diving can be performed in low and high temperature water. A number of physical hazards may be involved. If dive suits tear or puncture, the wearers risk chemical/biological exposure. Divers may become entangled and trapped. Particularly when supplied air is used, the diver’s air supply may be vulnerable to the same hazards as the protective clothing that he or she is wearing. Adequate buoyancy must be provided so that diver mobility is not affected. Zero visibility may exist [6, p. 64]. Effective communications and non-interruption of the air supply are essential [6,p. 77]. In no other urban search and rescue mission is the emergency responder so dependent on the performance of his or her protective clothing [4;6, p.3].

A summary of the various hazards in the different urban search and rescue missions is provided in Table 1.

Emergency Response Organizations

A number of groups participate in urban search and rescue responses. These groups include:

- public fire departments;
- public police stations;
- volunteer organizations;
- private or commercial response teams; and
- regional government response teams.

The responsibility of urban search and rescue in each of these organizations varies. Many fire departments integrate the functions of urban search and rescue throughout their different stations. Larger departments, such as those in major U.S. cities, have separate divisions or groups which specialize in these activities, Sometimes, urban search and rescue fire fighters are grouped into Special Operations units. Some cities even have separate

Table 1

Hazards Involved in Different Urban Search and Rescue Missions

Mission	Type of Hazard							
	Physical	Cold Exposure	Heat Stress	Flame Contact	Chemical Flashover	Electrical Exposure	Chemical Exposure	Biological Exposure
Building/Structural Collapse	X		X	L	L	L	M	M
Vehicle/Person Extraction	X			L	L			L
Confined Space Entry	X		X		X		L	
Trench/Cave-In Rescue	X	X	X				M	M
Search Operations	X	X	X					
High Angle Rescue	X		X	L	L	L		
Swift or Still Water Rescue	X	X	X				L	L
Contaminated Water Diving	X	X	L				X	X

KEY: X - Primary hazard
M - Moderate hazard
L - Limited hazard

rescue teams for different types of missions, particularly for contaminated water diving. In some regions of the country, specialized organizations have been established for responding to certain types of emergencies. This is particularly the case for emergency response associated with large, natural or other disasters. Lastly, the Federal Emergency Management Agency is setting up regional teams which will provide federal capability for emergency response for large scale urban search and rescue operations [7, p.61].

As responsibility varies, so do the resources available to the groups that perform response activities. The availability of specialized protective clothing differs from group to group. Most fire departments, unless they have dedicated teams, are unlikely to possess dedicated clothing for urban search and rescue. Instead, they rely on their conventional protective clothing (i.e. ,structural fire fighting bunker gear). When water-related responses occur, teams may or may not be equipped with wet/dry suits and other appropriate equipment for water rescue. Only teams with extensive resources or extended responsibilities are likely to have diving equipment. In a number of cases, departments depend on people who already have their own equipment and who take an interest in participating in diving [5].

Emergency Responder Injuries or Fatalities

Few statistics are kept concerning to injuries or fatalities related specifically to urban search and rescue responses. This is mainly due to the fact that urban search and rescue is an area only recently identified as a separate mission within the fire service. Statistics provided by the U. S. Fire Administration on fire fighter fatalities from 1987 to 1990 include a number of deaths which occurred during urban search and rescue missions. These statistics are presented in Table 2. Fatalities are listed by type of mission. In each mission, the number of fire fighter deaths was noted and an explanation made to determine if the protective clothing/equipment (or lack of it) contributed to the fatality. If the protective clothing or equipment was a factor, then the specific protection needs were identified.

Table 2

Fire Fighter Fatalities Related to Urban Search and Rescue Mission (1987 - 1990)

Type of Mission	Cause of Death	# of Deaths	Could P.C. Be An Issue?	Protection Needs
I. WATER MISSIONS				
• Ice Rescue	Drowning	2	Yes	PFD; dry suit
• Water Rescue	Drowning	3	Yes	PFD; dry suit; capsize-resistant boat/raft
• Flood Rescue	Heart	1	Yes	PFD; dry suit
• Flood Control	Drowning	1	No	
• Diving (body/materials recovery)	Drowning	2	Yes	Dry suit; air supply; communications system
• Water Rescue Training	Cerebral Hemorrhage	1	No	
• Water Reservoir Cleaning	Heart	1	No	

Table 2 (Continued)

Fire Fighter Fatalities Related to Urban Search and Rescue Mission (1987 - 1990)

Type of Mission	Cause of Death	# of Deaths	Could P.C. Be An Issue?	Protection Needs
II. LAND MISSIONS				
Mountain Rescue	75' fall caused by severing of safety rope	1	Yes	Improved safety rope materials; back-up rope
• Person Extrication (MVA)	Heart attack	1	No	
• Person Extrication (trapped Boat Hull)	Asphyxiation	1	Yes	SCBA
• EMS call 1	Injuries from MVA en route	1	No	
• Cat Rescue (power pole)	Electrocution	3	Yes	Electrically insulated gloves/boots
• Arcing Power Line investigation	Head injury from falling tree	1	Yes	Helmet
• Investigating Electrical Hazards in Snowstorm	Electrocution	1	Yes	Electrically insulated gloves/boots
• Gas Pipeline Leak	Thermal Burns	1	Yes	Flame-resistant apparel
• Evacuation of Occupants (near gas 1eak		1	Yes	Flame-resistant apparel
• Ammonia Leak	Thermal Burns			
• Rescue of Occupants Trapped in Burning Building	Crushed by Pumper		No	
	Heart Attack	1	No	
		2		

Table 2 (Continued)

Fire Fighter Fatalities Related to Urban Search and Rescue Mission (1987 - 1990)

Type of Mission	Cause of Death	# of Deaths	Could P.C. Be An Issue?	Protection Needs
III. FIRE MISSIONS				
• Fire	Electrocution	1	Yes	Electrically insulated gloves/boots
• Grass, Brush, and Rangeland Fires	Electrocution	1	Yes	Electrically insulated gloves/boots
	Stroke	1	No	
	Heatstroke	1	Yes	Apparel with higher thermal comfort
	Heart	15	No	
	Thermal Injury	1	Yes	Flame-resistant apparel
	Smoke Inhalation and Heat	1	Yes	SCBA
	MVA	8	No	
	Aircraft Accident	2	No	
	Pulmonary Embolism (caused by fall)	1	No	

Table 2 (Continued)

Fire Fighter Fatalities Related to Urban Search and Rescue Mission (1987 - 1990)

Type of Mission	Cause of Death	# of Deaths	Could P.C. Be An Issue?	Protection Needs
• Forest, Timber, Woods, Mountain, Wildlands Fires	Lighting	1		
	Stroke	1	No	
	Heatstroke	1	Yes	Apparel with higher thermal comfort
	Heart	2	No	
	Thermal Injuries	3	Yes	Flame-resistant apparel
	Smoke Inhalation	1	Yes	SCBA
	Thermal Injuries and Smoke Inhalation	7	Yes	Flame-resistant apparel; SCBA
	Injuries from fallingtree	7	Yes	Helmet
	MVA			
	Aircraft-Accident	5	No	
	Drowning	13	No	
		1	Yes	PFD
a Fire Assessment	Aircraft crash (drowning)	1	Yes	PFD
	Aircraft crash (trauma)	1	No	

PROTECTIVE CLOTHING NEEDS AND RECOMMENDATIONS

A review of the different urban search and rescue missions by the ERURC revealed that responses could be classified into three general areas:

1. technical rescue;
2. swift water rescue; and
3. contaminated water diving.

This classification was adopted by grouping missions into areas having similar hazards. Most urban search and rescue missions can be considered technical rescue. These missions are generally land-based and the principal hazards are physical in nature. More unique hazards are encountered in swift water rescue, where the principal hazard is drowning, and in contaminated water diving where chemical or biological threats can be very serious. In each area, a different protective system, or ensemble, is needed. The ERURC decided that these three areas of urban search and rescue missions could be best benefitted by the development of minimum performance standards.

Each area is further defined below. In developing a list of specific protection needs, the following information is discussed:

- the current protection strategies used;
- the basic protection needs and priorities;
- the type of clothing and equipment necessary to provide complete full body protection; and
- the specific performance needed for each clothing and equipment item in the protective ensemble.

Technical Rescue

Current Protection Strategies. The fire service uses a variety of protective clothing and equipment for urban search and rescue operations. In structural collapse and similar situations, many departments employ the usual turnout clothing typically used for fire fighting. For extended operations such as person extraction from collapsed structures, this kind of clothing is too heavy and bulky. Other departments have gone to lighter weight flame resistant clothing such as 4.5 oz. to 6.0 oz. Nomex (or PBI/Kevlar or FR cotton) jumpsuits or two piece garments. Some of these are similar to garments used in wildland fire fighting and provide greater mobility and less bulk while still affording limited thermal, chemical, barrier, and physical protection. Many urban search and rescue personnel are required to operate -around heavy equipment such as cranes, bulldozers, etc. (for removal of debris) and to participate in helicopter (air) operations. As a consequence, many teams use “flight suit-like” coveralls that have form fitting designs with multiple pockets for carrying necessary accessories [8].

Protection Needs and Priorities. The chief hazards facing emergency responders during technical rescues are generally those of a physical nature. The response environments can vary greatly--from a collapsed building to confined spaces to trenches or tunnels. Clothing worn in these environments should be rugged to withstand abrasion, tearing, cuts, and punctures. Particularly vulnerable are hands, feet, knees, and elbows. Because many operations involve tight work in close quarters, garments should be form-fitting. Due to the nature of several missions, garments should also have few openings, and no loose straps, or exposed edges that could be caught in machinery. Since rescue operations generally require rapid response, rescuers must have good mobility and be able to carry essential supplies to the hazard site while still maintaining adequate protection. In addition, the clothing should be comfortable. Some urban search and rescue missions can proceed for several hours, even days [7, p.63]. Clothing that is too heavy can quickly tire responders and contribute to heat stress.

Other hazards may exist during technical rescue. Collapsed buildings may create the potential for ruptured gas lines, broken chemical containers, and exposed electrical wiring. These situations and others may involve the potential for flammable atmospheres or flame contact. Confined spaces may contain toxic chemicals or be deficient in oxygen. Rescuers may be exposed to blood and other body fluids, potentially infected with viruses, in the transport of victims away from the danger area or in the performance of emergency patient care. All of these hazards dictate specific protection needs. Nevertheless, in the majority of urban search and rescue missions, these needs are secondary and protection may be provided by other means. For example, if fire is present, then the emergency responder is likely to wear structural fire fighting clothing. If there is evidence of toxic chemicals, then chemical protective clothing may be worn. Medical protective gloves may be donned when providing emergency patient care. Nevertheless, the clothing worn during technical rescue should provide some minimum protection for all these hazards, but not at the levels required for more specialized clothing.

On the basis of this discussion, the ERURC assigned the following priorities to protection needed during technical rescue:

1. Physical hazard protection (abrasion, tearing, cuts, and punctures);
2. On site visibility;
3. Garment form, fit, and mobility (design and comfort);
4. Particulate protection;
5. Limited flame and heat protection;
6. Limited chemical flash fire protection;
7. Limited electrical exposure protection;
8. Minimal chemical protection; and
9. Minimal biological fluid protection.

Table 3 shows the relationship of these protection needs to different parts of the body.

The assignment of these priorities indicates the primary need for an ensemble that can protect against physical hazards for an extended period of time. Since many operations can occur during the night without adequate lighting, good visibility is needed. Due to the

Table 3

Emergency Responder Protection Needs For Technical Rescue

Protection Needed	Portion of Body to Be Protected					
	Head/ Neck	Torso/ Limbs	Hands	Feet	Respiratory System	Eyes
Physical Hazards	X	X	X	X		X
On-Site Visibility		X				
Thermal Comfort		X	X			
Particulates					X	X
Flame and Heat	X	**X**	**X**	X		X
Electrical Contact			X	X		
Chemical Flash Fire	X	X	X	X	X	X
Chemical Exposure			X	X	X	X
Biological Fluid Exposure			X	X		X

nature of many responses, some limited flame, flash, and electrical protection are needed. The ERURC made certain assumptions for levels of protection balanced against needs for comfort and mobility. Similarly, the ERURC considered chemical and biological fluid contacts to be lesser threats. Complete protection in these areas would require tradeoffs with the comfort and mobility needed to safely perform urban search and rescue activities. For this reason the ERURC felt that additional chemical or biological protection might best be provided by using detachable, supplemental liners with the primary technical rescue clothing.

The area of particulate protection is unique to certain areas of the body, primarily eyes and respiratory system. For these bodily areas, the relative priority is high, but in most cases, the contact of particulates with the responder's skin is not considered hazardous. Exceptions to this approach include cases where chemical particulates are encountered.

The Technical Rescue Ensemble. To achieve the protection needed against the variety of hazards that can be encountered during technical rescue, a protective ensemble consisting of the following items should be worn:

- a one or two piece protective garment (with or without a hood; if without a hood, a separate hood should be provided);
- protective gloves;
- protective boots;
- a protective helmet on which a battery operated headlight can be mounted;
- goggles, or eye protection provided from a full face mask;
- a half or full face particulate air purifying respirator; and
- ear (noise) protectors.

This ensemble centers around a garment that is light weight, yet rugged for varied physical environments, together with helmet, goggles, gloves, and boots. The other items should be part of the ensemble but may not be necessary for all urban search and rescue missions. Air purifying respirators are limited to protecting the wearer against dusts and particulates, but not chemical vapors or smoke. In some cases, a self-contained breathing apparatus may be needed for respiratory protection against fumes and contaminants other than dusts encountered during incidents involving chemicals. Similarly, ear protectors may be needed in noisy environments, particularly around heavy equipment, but could interfere with other rescue operations. The general performance requirements for each item are provided in Table 4. These requirements are generic in nature and represent a minimum level of protection. The requirements are not intended to cover protection from all hazards in all situations.

While protection needs are established for the entire ensemble, the ERURC recognized that some areas of the body require, and thus, certain items should offer, greater protection. For example, garments should have reinforced knees and elbows since these areas are most likely to be abraded during crawling.

Table 4

Technical Rescue Ensemble Clothing and Equipment Design or Performance Needs

Clothing/Equipment Item	Design or Performance Needs
Protective Garment	Should cover the wearer's upper and lower torso, legs, and arms; may be one piece coveralls or two piece coat and trousers; two piece garments should have sufficient overlap for mid-torso protection
	Materials should resist tearing, snagging, and abrasion due to physical environment
	Should be reinforced at elbows and knees
	Seam and closure strength should be equal to material
	Should provide high visibilityat night time
	Material should be breathable and comfortable to wear for extended periods of time
	Materials should resist ignition when contacted by flame
	When exposed to convective and radiant heat, materials should prevent transmission of heat that could burn the wearer's skin
	In hot environments, materials should not shrink
	Should maintain measured size when repeatedly cleaned
	Materials should resist static charge accumulation
	Supplemental liners should be provided which prevent chemical penetration of common fire scene chemicals and biological liquids

* Existing performance specifications will be used for clothing or equipment item

Table 4 (Continued)

Technical Rescue Ensemble Clothing and Equipment Design or Performance Needs

Clothing/Equipment Item	Design or Performance Needs
Protective Hood	Should cover the wearer's head and neck with the exception of those areas of the face which may be covered by an SCBA or air-purifying respirator Material should be breathable and comfortable to wear for extended periods of time Material should resist ignition when contacted by flame When exposed to convective and radiant heat, material should prevent transmission of heat that could bum to the wearer's skin In hot environments, material should not shrink Should maintain measured size when repeatedly cleaned Material should resist static charge accumulation

* Existing performance specifications will be used for clothing or equipment item

Table 4 (Continued)

Technical Rescue Ensemble Clothing and Equipment Design or Performance Needs

Clothing/Equipment Item	Design or Performance Needs
Protective Gloves	Should cover the wearer's hands to one inch above the wrist
	Should include a wristlet which prevents entry of foreign objects into the glove
	Materials should resist tearing, cutting, punctures, or abrasion due to the physical environment
	Materials should be breathable and comfortable to wear for extended periods of time
	Should offer adequate dexterity and grip to handle tools and machinery
	Materials should resist ignition when contacted by flame
	When exposed to convective and radiant heat, materials should prevent transmission of heat that could bum the wearer's skin
	In hot environments, materials should not shrink
	Materials should insulate wearer from electrical currents
	Supplemental gloves should be provided which prevent chemical penetration of common tire scene chemicals and biological liquids

* Existing performance specifications will be used for clothing or equipment item

Table 4 (Continued)

Technical Rescue Ensemble Clothing and Equipment Design or Performance Needs

Clothing/Equipment Item	Design or Performance Needs
Protective Boots	Should cover wearer's foot from the bottom of the foot to a point eight inches above the foot bottom
	Should not have any exposed metal parts
	Should include a ladder shank and non-metallic toe protective cap
	Upper materials should resist abrasion, cutting, or puncture due to the physical environment
	Soles should resist abrasion and punctures due to the physical environment
	Materials should resist ignition when contacted by flame
	When exposed to convective and radiant heat, materials should prevent transmission of heat that could bum the wearer's shin
	In hot environments, materials should not shrink
	Should maintain water-tight integrity following repeated flexing
	Should insulate the wearer from electrical currents
	Materials should prevent chemical penetration of common fire scene chemicals and biological liquids

* Existing performance specifications will be used for clothing or equipment item

Table 4 (Continued)

Technical Rescue Ensemble Clothing and Equipment Design or Performance Needs

Clothing/Equipment Item	Design or Performance Needs
Protective Helmet	Should cover the top of the wearers head
	Should resist impact on top and sides from falling objects
	Straps should keep helmet in place when impacted
	Materials should resist ignition when contacted by flame
	When exposed to convective and radiant heat, materials should prevent transmission of heat that could bum the wearer's skin
	In hot environments, materials should not shrink
Goggles	Should prevent impact of foreign objects to the eyes
	Should keep particulates from reaching eyes
	Materials should resist ignition when contacted by flame
	When exposed to convective and radiant heat, materials should prevent transmission of heat that could bum the wearer's eyes
	In hot environments, materials should not shrink

* Existing performance specifications will be used for clothing or equipment item

Table 4 (Continued)

Technical Rescue Ensemble Clothing and Equipment Design or Performance Needs

Clothing/Equipment Item	Design or Performance Needs
Air Purifying Respirator*	Should be NIOSH certified Should keep fine particulates from entering wearer's respiratory system
Ear Protectors*	Should meet ANSI requirements for ear and hearing protection

* Existing performance specifications will be used for clothing or equipment item

Swift Water Rescue

Current Protection Strategies. Except where departments or other groups have set up special teams for swift water rescue, few teams are equipped for protection during these operations. Typical clothing and equipment for flood or river rescue include:

- a Coast Guard approved personal flotation device;
- a light weight pair of shoes;
- a light climbing or kayak helmet;
- a water proof headlamp; and
- a light weight rain suit.

If water entry is required, wet or dry suits are generally employed. When operations extend into contaminated water, dry suits are often chosen [6, p.31]. Some teams have gone to using disposable coveralls which have become available in the market place. Also, river-rescue dry suits have been developed which provide limited chemical resistant barriers. Most responders carry or wear knives so they may cut themselves free when entangled in flood debris. In some cases, face masks and light weight respirators in combination with gloves are used in inspecting flooded vehicles. Conventional self-contained breathing apparatus or SCUBA gear are found to be too heavy and bulky in the close quarters required in many rescue work tasks [1].

Protection Needs and Priorities. The principal danger during swift water rescues is drowning. This means than all persons involved in swift water rescue operations should wear an approved personal floatation device. Other protective clothing and equipment worn must allow for drowning exposure hazards. For example, garments should not have loose straps or openings which can create entanglement hazards with floating debris. Regular helmets cannot be worn since they can fill with water and make it difficult for the responder to move. In addition, temperatures of flood water can be quite low (near freezing). Exposure to cold water for extended periods of time results in reduced hand and foot function as the body's circulatory system limits blood flow to the extremities. Overexposure to these conditions can result in hypothermia. Lastly, flood water can carry chemical and sewage contamination capable of causing acute or chronic health effects.

In considering these different hazards, the ERURC set the following priorities for protection to be offered by the protective clothing ensemble:

1. flotation (buoyancy);
2. insulation from cold water exposure;
3. physical hazard protection (abrasion, tearing, cuts, and punctures);
4. on site visibility;
5. garment form, fit, and mobility (design and comfort);
6. limited chemical protection; and
7. limited biological fluid protection.

The first three priorities are considered of equal ranking. Priorities 4 and 5 are also weighted similarly, but are considered less important that the first three. While chemical and biological protection is warranted, the ERURC considers these requirements to be less important than the other protection needs. This is consistent with the type and causes of fatalities most often reported for swift water rescue [2; 9-12]. Moreover, the ERURC realized that certain tradeoffs in protection might be necessary for practical protective clothing. For example, total body chemical and biological protection can be achieved with full body clothing akin to that used in contaminated water diving. However, the mobility constraints imposed by this clothing would make most swift water rescues more dangerous (i.e., increased entanglement and drowning hazards) when compared with potential harm from chemical and biological exposure.

The relationship of protection needs and the areas of the body intended for protection are given in Table 5.

The Swift Water Rescue Ensemble. To meet the protection needs in swift water rescue defined above, an ensemble consisting of the following items is needed:

- a Coast Guard approved personal flotation device (types III-V are recommended);
- a full body dry suit with neck, wrist, and ankle seals;
- dive booties which are compatible with swimming tins;
- “short” swimming fins;
- protective gloves;
- a vented protective helmet;
- a sheathed single edge knife; and
- a non-metallic, no pall whistle.

ERURC recommended performance for each of these items is presented in Table 6. A key factor in the development of these generic requirements was the need to protect as much of the body from different exposures as possible. Therefore, a goal in designing this clothing configuration was not to eliminate water contact but to minimize the contact areas to reduce the effects of cold water exposure. Breathable but waterproof garment materials were considered optimum since responders may experience hot temperatures on shore before entering cold water. Certain components such as gloves and booties do not necessarily prevent water contact. In fact, some gloves depend on a thin layer of water between the glove fabric and the hand to act as insulation. Many booties are designed in a similar fashion.

Some items of equipment are well standardized through existing specifications. These include the personal flotation device, through Coast Guard requirements, and the recommended helmet, based on UIAA standards. The ERURC believes that selection of appropriate specifications for each item should adequately document the necessary performance criteria.

Table 5

Emergency Responder Protection Needs for Swiftwater Rescue

Protection Needed	Portions of Body to be Protected					
	Head/ Neck	Torso/ Limbs	Hands	Feet	Respiratory System	Eyes
Flotation	X	X				
Cold Water Exposure		X	X	X		
Physical Hazards	X	X	X	X		
On-Site Visibility		X				
Thermal Comfort		X	X	X		
Chemical Exposure		X	X	X		
Biological Fluid Exposure		X	X	X		

Table 6

Swift Water Rescue Ensemble
Clothing and Equipment Design or Performance Needs

Clothing/Equipment Item	Design or Performance Needs
Personal Flotation Device*	Should meet Coast Guard requirements for Type III or Type V Should include hardware for attaching lifeline, corrosion resistant, and with sufficient strength to withstand swift water forces
Protective Dry Suit	Should cover wearer's upper and lower torso, arms, and legs Should prevent water penetration to parts of body covered (should include wrist, foot, and neck seals) Should be easily and quickly donned Materials should provide insulation from cold water exposure for at least one hour Materials should resist tearing, snagging, and abrasion due to physical environment Should be reinforced at elbows and knees Seam and closure strength should be equal to material Should not shrink after cleaning or contact with warm water Should provide high visibility at night Materials should be breathable and comfortable to wear for extended periods of time Materials should prevent penetration of diluted chemicals and biological contaminants Materials should not retain contaminants following clean water rinsing

Table 6 (Continued)

Swift Water Rescue Ensemble
Clothing and Equipment Design or Performance Needs

Clothing/Equipment Item	Design or Performance Needs
Protective Gloves	Should be of 5-fingered design
	Should cover wearer's hands to one inch above the wrist
	Should be available in at least 3 sixes
	Should limit water penetration to hands
	Materials should provide insulation from cold water exposure for at least one hour
	Materials should resist tearing, cutting, and punctures due to physical environment
	Materials should be breathable and comfortable to wear for extended periods of time
	Should offer adequate dexterity and grip to tie knots and operate a knife
	Should not slip off wearer's hand if inner glove is worn
	Retention straps should not become loosened in use
	Metal parts should not corrode or rust
	Materials should prevent penetration of diluted chemicals and biological contaminants
	Should not retain contaminants following clean water rinsing

* Existing performance specifications will be used for clothing or equipment item

Table 6 (Continued)

Swift Water Rescue Ensemble
Clothing and Equipment Design or Performance Needs

Clothing/Equipment Item	Design or Performance Needs
Protective Booties	Should cover wearer's feet to one inch above the ankle
	Should limit water penetration to feet
	Materials should provide insulation from cold water exposure for at least one hour
	Materials should resist tearing, cutting, punctures, and abrasion due to physical environment
	Soles should be slip-resistant and provide good traction under wet conditions
	Should accommodate swimming fins
	Retention straps should not become loosened in use
	Metal parts should not corrode or rust
	Materials should prevent penetration of diluted chemicals and biological contaminants
	Should not retain contaminants following clean water rinsing
Swimming Fins	Should allow wearer to walk normally

* Existing performance specifications will be used for clothing or equipment item

Table 6 (Continued)

Swift Water Rescue Ensemble
Clothing and Equipment Design or Performance Needs

Clothing/Equipment Item	Design or Performance Needs
Helmet*	Should cover top of wearer's head Should resist impact on top and sides from floating or stationary objects when struck Should be ventilated to allow passage of water Should not have brim or other surfaces suspectable to swift water forces Metal parts should not corrode or rust
Knife*	Should be single edged Should remain in sheath when inverted and shaken
Whistle*	Should be non-metallic Should not include a pall

* Existing performance specifications will be used for clothing or equipment item

Contaminated Water Diving

Current Protection Strategies. In spite of the potential for exposure to severe hazards, the protection typically used for contaminated water diving is simply an adaption of traditional SCUBA gear [5]. Due to the high cost of recommended equipment the equipment chosen can vary dramatically from rescue team to rescue team, from recreational SCUBA outfits to state-of-the-art protective clothing. One manufacturer estimated that, due to the monetary constraints, perhaps 50% of USAR teams do not have access to the best protective clothing [13]. However, as far as possible, the diver's gear is selected to minimize diver exposure to any chemical or biological hazards. A typical ensemble might include:

- a neoprene or vulcanized rubber dry suit with attached booties;
- mating dry gloves or mittens;
- a full face mask;
- a SCUBA system;
- swimming fins;
- a diving tether; and
- a line signal communications system.

Protection Needs and Priorities. The principal hazard encountered during contaminated water diving is exposure to dangerous biological or chemical agents. While some contaminants present may be so diluted that the risks associated with them are small, others such as PCB's may be immediately dangerous even at very high dilution [6, p. 12] Some materials may not dissolve in water; thus, these could be encountered as pockets of highly concentrated material in bottom sediment or as slicks on the water's surface [3]. Therefore, for maximum safety, the diver must be completely isolated from the water environment. Under certain conditions, when only a moderate biological hazard exists (such that only temporary illness could result), a lesser degree of protection may be sufficient [6, p.55]. In general, because not all hazards may be apparent, the prudent decision is to use the equipment giving the highest level of protection.

For the highest level of protection, the diver should be fully encapsulated. The core of this type of protective clothing ensemble is the dry suit with mating dry gloves or mittens. To avoid compromise of the entire system if the gloves or mittens become damaged, they should not be vented to the suit [6, p.35]. According to most experts, vulcanized rubber is the preferred material for dry suits, particularly because it is more readily decontaminated then other materials such as neoprene [6, p.31]. However, depending upon the chemical agents present, another material might be advisable [6, p.32]. Similarly, all parts of the ensemble, including equipment valves, etc, must be resistant to the hazards present.

The diver's head and respiratory system are best protected by a diving helmet (which mates directly to the dry suit) used with a surface supplied air system. Preventing the backflow of contaminants into the helmet requires a "double" or "stacked" exhaust system (two exhaust valves in series) [4]. Care must be taken to ensure that the diver's air is not contaminated by fumes from the contaminated area. In situations in which lesser protection is deemed sufficient for the diver's safety, a full face mask and integrated SCUBA system might be substituted for the helmet and surface-supplied air [6, p.55]. In all cases, the other members of the rescue dive team must be suitably equipped to avoid contamination. Their level of protection generally need not be as high as the diver's [4]. In addition, provisions must be made for appropriate decontamination.

Aside from the possible chemical and biological dangers, other likely hazards include thermal stress and physical hazards, such as underwater debris. Thermal stress caused by diving in exceptionally hot or cold water can be minimized by appropriate choice of dry suit underwear and, in some cases, by use of the suit-under-suit (SUS) ensemble [6 p.36]. This concept has also been employed in the U.S. Navy's Chemical Warfare Protective Dive Suit developed for diving in a wide variety of hazardous environments [14-153. In hot weather, the fully encapsulated diver may need to be shaded or sprayed with cool water to avoid heat stress while out of the water 16, pp.6-17].

Physical hazards include entanglement of the diver or his umbilical in underwater debris or compromise of the diver's suit through tears or punctures. These physical hazards are compounded by the probability of extremely poor visibility in the water [6, p.64]. Therefore, the diver's suit must be as resistant as possible to punctures or tears. In addition, to lessen the chance of entanglement, the diver must be versed in recommended strategies for maneuvering around underwater obstacles, and he should carry a knife and wire cutters for freeing himself from entanglements [6, pp.40,73,77,88]. In addition, slack in the umbilical should be minimized [6, p.73]. Because of the wide range of possible hazards, a reliable communications systems is imperative for ensuring diver's safety [6, p.77].

The ensemble for contaminated water diving must provide protection against the following threats as prioritized by the ERURC:

1. integrity of breathing air supply;
2. integrity of overall system to water penetration;
3. insulation from cold water exposure;
4. physical hazard protection (abrasion, tearing, cuts, and punctures);
5. garment form, fit, and mobility (design and comfort);
6. chemical protection; and
7. biological fluid protection.

Since the responder is immersed in the potentially hazardous environment, the different types of protection need to be provided to all parts of the body. The ERURC weighed these protection needs equally. Table 7 shows the relationship of these protection needs to various parts of the body.

<u>The Contaminated Water Diving Ensemble.</u> A fully integrated ensemble is needed to provide protection to the responder in contaminated water diving operations. Two different ensemble configurations should be considered: one employing an integrated self-contained underwater breathing apparatus (SCUBA), and a second, using a surface supplied air system. Both ensembles are defined below and should include the following clothing and equipment:

Table 7

Emergency Responder Protection Needs for Contaminated Water Diving

Protection Needed	Portions of Body to be Protected					
	Head/ Neck	Torso/ Limbs	Hands	Feet	Respiratory System	Eyes
Breathing Air Supply					X	
Water Penetration	X	X	X	X		X
Cold Water Exposure		X	X	X		
Physical Hazards	X	X	X	X		X
On-Site Visibility		X				
Thermal Comfort		X	X	X		
Chemical Exposure		X	X	X		X
Biological Fluid Exposure		X	X	X		X

SCUBA-based Ensemble

- a hooded dry suit or dry suit with attachable hood;
- dry suit underwear (for insulation and buoyancy);
- dry suit gloves or mittens;
- connected boots or booties;
- swimming fins;
- full face mask;
- SCUBA system with bailout system;
- a diving tether;
- communications system;
- a sheathed knife; and
- wire cutters.

Surface Air Supplied Ensemble

- a dry suit with a helmet specific neck ring;
- dry suit underwear (for insulation and buoyancy);
- dry suit gloves or mittens;
- connected boots or booties;
- swimming fins;
- a diving helmet (which mates specifically to the dry suit);
- a compressed air supply with bail-out system;
- a diver's air manifold box;
- a diver's umbilical;
- a pneumofathometer;
- a diver's bailout system;
- weight belts or harnesses;
- a buoyancy compensator;
- a communications system;
- sheathed knife; and
- wire cutters.

General performance recommendations for each of these items are given in Table 8. Unlike other urban search and rescue protective ensembles, protective clothing and equipment used in contaminated water diving must be fully integrated. Essentially, the ERURC believes that the ensemble must provide a complete envelope around the diver to equally protect all parts of his or her body. Many of the requirements for equipment items such as the diving helmet and breathing air supply components are design-oriented in nature. The ERURC recommends that existing specifications from Navy or the commercial diving industry be used for these items.

Table 8

Contaminated Water Diving Ensemble
Clothing and Equipment Design or Performance Needs

Clothing/Equipment Item	Design or Performance Needs
Protective Dry Suit	Should cover wearer's upper and lower torso, arms, legs, and feet
	Should be hooded or have attachable hood
	Should prevent water penetration to parts of body covered (should include wrist, foot, and neck seals)
	Materials should provide insulation from cold water exposure for at least one hour
	Materials should be rugged and strong
	Materials should resist tearing, snagging, and abrasion due to physical environment
	Wrist, ankle, or neck seal materials should be adjustable for sizing
	Wrist, ankle, or neck seal materials should resist cuts and punctures
	Should be reinforced at elbows and knees
	Seam and closure strength should be equal to material
	Should provide high visibility at night
	Materials should prevent penetration of diluted chemicals and biological contaminants
	Materials should not retain contaminants following clean water rinsing

* Existing performance specifications will be used for clothing and equipment

Table 8 (Continued)

Contaminated Water Diving Ensemble
Clothing and Equipment Design or Performance Needs

Clothing/Equipment Item	Design or Performance Needs
Protective Gloves	Should mate directly to the dry suit Materials should prevent penetration of diluted chemicals and biological contaminants Materials should provide insulation from cold water exposure for at least one hour Materials should resist cuts, punctures, and abrasion due to physical environment Should offer adequate dexterity and grip to tie knots and operate a knife Should not retain contaminants following clean water rinsing
Protective Booties	Should be a part of the drysuit (directly attached) Materials should prevent penetration of diluted chemicals and biological contaminants Materials should provide insulation from cold water exposure for at least one hour Materials should resist tearing, cutting, punctures, and abrasion due to physical environment Sole materials should resist puncture and wear due to abrasion Should have slip resistant soles Should not retain contaminants following clean water rinsing
Swimming Fins*	Should be resistant to diluted chemicals

* Existing performance specifications will be used for clothing and equipment

Table 8 (Continued)

Contaminated Water Diving Ensemble
Clothing and Equipment Design or Performance Needs

Clothing/Equipment Item	Design or Performance Needs
Helmet*	Should cover entire head and neck
	Should mate directly to the dry suit with safety mechanism to avoid accidental removal
	Should be neutrally buoyant in water
	Should include non-return valve in breathing system
	Should include emergency valve for connecting bail-out system
	Should have double exhaust (for demand diving helmets)
	Should have defogging mechanism
	Should have shatter resistant face piece
	Should have equalizing device (to equalize air pressure in ears)
	Should include integrated communications system
	Should not retain contaminants following clean water rinsing

* Existing performance specifications will be used for clothing and equipment

Table 8 (Continued)

Contaminated Water Diving Ensemble
Clothing and Equipment Design or Performance Needs

Clothing/Equipment Item	Design or Performance Needs
Full Face Mask*	Should enclose eyes, nose, and mouth
	Should include integral second stage regulator
	In surface-supplied mode, should be used with bail-out block
	Should have equalizing device
	Should have automatic defogging mechanism
	Should have earphone pockets
	Should have low volume
	Should have large buckles and wide straps
	Should have modular communications components
	Should not retain contaminants following clean water rinsing
Dry Suit Underwear	Should provide insulating performance even when wet
	Must not produce lint

* Existing performance specifications will be used for clothing and equipment

Table 8 (Continued)

Contaminated Water Diving Ensemble
Clothing and Equipment Design or Performance Needs

Clothing/Equipment Item	Design or Performance Needs
Communications System*	May be hard-wire or wireless system Should be constructed of rugged materials Should have mechanism to attach electronics housing to tank harness or buoyancy compensator Exposed parts should be able to be decontaminated Should include back-up systems (line pull signals)
Compressed Air Supply*	Should be a low pressure (175 - 250 psi) compressor or series of high-pressure bottles Should include emergency air supply for diver (bail-out system)
Air Manifold Box*	Should monitor air-pressure to diver Should regulate high-pressure air to proper pressure for the diver Should provide connection for top-side emergency air supply
Pneumofathometer*	Should usually be contained in the air manifold box Should be accurate to 0.25% of the gauge's full scale

* Existing performance specifications will be used for clothing and equipment

Table 8 (Continued)

Contaminated Water Diving Ensemble
Clothing and Equipment Design or Performance Needs

Clothing/Equipment Item	Design or Performance Needs
Umbilical*	Should be at least 25O'long Air supply hose should have minimal length change when pressurized Air supply hose should be at least 318" diameter Air supply hose should have rated pressure at least 50% higher that maximum pressure required by regulator or maximum diving depth Should resist kinking Should include air-tight fittings Should include strong diving tether Should have individual umbilical components (hose, communications wire, etc) connected with plastic cable ties Should include stainless steel ring to attach air supply hose to diver's harness

* Existing performance specifications will be used for clothing and equipment

Table 8 (Continued)

Contaminated Water Diving Ensemble
Clothing and Equipment Design or Performance Needs

Clothing/Equipment Item	Design or Performance Needs
Weight belt/harness*	Materials should be compatible with diluted chemicals Materials should not retain contaminants following clean water rinsing Should be plastic or rubber for easier decontamination Should include minimum amount of weight possible Should be able to be quickly ditched in emergency Should not include ankle weights
Diving Tether*	Should be attached to harness Should be polypropylene or other synthetic line compatible with diluted chemicals Should be strong enough to bear weight of diver Should not retain contaminants following clean water rinsing
SCUBA system*	Materials should be compatible with diluted chemicals Should include bail-out block mounted on diver's harness Should include bail-out air bottle with first-stage regulator Should not retain contaminants following clean water rinsing

* Existing performance specifications will be used for clothing and equipment

Table 8 (Continued)

Contaminated Water Diving Ensemble
Clothing and Equipment Design or Performance Needs

Clothing/Equipment Item	Design or Performance Needs
Bail-Out System*	Should include five-minute supply of air Should include bail-out bottle, diver's harness, first-stage regulator, relief valve, submersible pressure gauge, quick disconnect whip/low pressure whip
Knife and Wire Cutter*	Should be single edged Should be sheathed Should not fall out of sheath when inverted

* Existing performance specifications will be used for clothing and equipment

METHOD OF DEVELOPING PERFORMANCE REQUIREMENTS

A number of clothing or equipment items identified by the ERURC appeared to be suitably covered by existing performance standards. For example, NFPA 1974, which covers structural fire fighting boots, provides the majority of requirements necessary for technical rescue protective footwear. Likewise, ANSI 287.1 provides a number of requirements needed for protective goggles/eyewear. These standards were examined and ERURC identified performance areas were matched with requirements contained in existing clothing/equipment standards. No effort was expended in these areas beyond acknowledging the potential use of these standards.

Priority Protective Clothing and Equipment

For items where current criteria did not exist, and there was a strong, evident need for specific clothing/equipment items in urban search and rescue operations, specific clothing specifications were developed. The ERURC assigned the following priorities for developing performance criteria to clothing and equipment items in each of the three areas:

Technical Rescue Ensemble

1. Protective garment/hood
2. Protective gloves
3. Protective boots (partial requirements needed)
4. Helmet (partial requirements needed)
5. Goggles (requirements exist in ANSI 287.1)
6. Air-purifying respirator (use NIOSH requirements)
7. Ear protectors (requirements exist in ANSI 287.1)

Swift Water Rescue Ensemble

1. Full body dry suit
2. Protective gloves
3. Dive booties
4. Swimming fins
5. Vented protective helmet (UIAA requirements exist)
6. Personal flotation device (one additional requirement needed)
7. Sheathed knife (design criteria only)
8. Whistle (design criteria only)

Contaminated Water Diving Ensemble

1. Protective dry diving suit
2. Protective gloves or mittens
3. Protective booties
4. Dry suit underwear

5. SCUBA or surface-supplied air system (use existing Navy requirements where possible; also beyond scope of contract)
6. swimming fins
7. full face mask or helmet (use existing Navy requirements where possible; beyond the scope of the contract)
8. knife and wire cutters (design criteria only)
9. communications system (use existing Navy requirements where possible; beyond the scope of the contract)

In those cases where specific performance or design criteria could not be recommended, appropriate guidelines were provided that could be added to the specification. These guidelines recommend specific factors to be considered in selecting the item and reference where additional information can be obtained.

Test Method Selection

Incumbent to the development of performance criteria was the ability to measure the needed performance. Following the first ERURC meeting, suitable test methods were identified and proposed for measurement of each identified performance areas. These recommendations appear in Tables 9, 10 and 11. The following criteria were used in selecting test methods:

- The test method should simulate the performance area as closely as possible;
- The test method should be capable of accommodating a wide range of potential products or materials (i.e., it should not bias a particular class of materials or products); and
- The test method should provide either a quantitative or pass/fail determination.

Most test methods are either ASTM Methods, or procedures which are part of NFPA clothing/equipment standards. This approach took advantage of prior work done by consensus standards groups in validating the test method for its accuracy and precision.

A few areas were identified where test methods were not currently available. In these cases, two alternatives were available:

- design new test methods (or modifying existing test methods); or
- develop design criteria.

Developing new test methods was preferred over establishing design criteria because that approach allows latitude for the manufacturer to provide innovative materials and designs. However, for some protection areas such as reinforcement of garment knees and elbows, it was necessary to use design requirements. A number of areas such as clothing sizing, comfort, fit, and integrity may warranted consideration of both alternatives.

Table 9

Recommended Test Methods for Measuring Performance of Technical Rescue Ensemble Protective Clothing and Equipment Items

Clothing/Equipment Item	Design or Performance Needs	Proposed Test Method
Protective Garment	Areas of body coverage	Design requirement; Human subject test (to be developed)
	Material physical hazard resistance: Tensile strength Tear resistance Snag resistance Abrasion resistance	 ASTM D 1682 ASTM D 1424 ASTM D 2582 ASTM D 4157
	Knee/elbow reinforcement	Design requirement
	Seam/closure performance Breaking strength Closure design	 ASTM D 751 MS 27980F (snaps) ML-F-21840G ("Velcro") FED-V-F-106E (zippers)
	Garment visibility Amount of retroreflective trim Brilliance of retroreflective trim	 Design requirement ASTM E 508 (NFPA 1971, Section 5-6)
	Material breathability Total heat loss	 NFPA 1971, Appendix B
	Material flame resistance	FTMS 191A,5903
	Material heat resistance	NFPA 1971, Section 5-4
	Material heat insulation Thermal protective performance Radiant reflectance	 NFPA 1971, Section 5-2 NFPA 1977, Section 3-3.2

Table 9 (Continued)

Recommended Test Methods for Measuring Performance of Technical Rescue Ensemble Protective Clothing and Equipment Items

Clothing/Equipment Item	Design or Performance Needs	Proposed Test Method
Protective Garment	Material thermal shrinkage resistance	NFPA 1971, Section 5-3
	Material cleaning shrinkage resistance	NFPA 1971, Section 5-9
	Material static charge resistance	ASTM F 23.20.05(draft)
	Hardware corrosion resistance	ASTM B 117
	Supplemental liner barrier performance Material chemical resistance Material biological resistance	 ASTM F 903 ASTM ES 22
Protective Hood	Areas of head coverage	Design requirement
	Material breathability Total heat loss	 NFPA 1971, Appendix B
	Material flame resistance	FTMS 19IA, 5903
	Material heat resistance	NFPA 1971, Section 5-4
	Material heat insulation Thermal protective performance Radiant reflectance	 NFPA 1971, Section 5-2 NFPA 1977, Section 3-3.2
	Material thermal shrinkage resistance	NFPA 1971, Section 5-3
	Material cleaning shrinkage resistance	NFPA 1971, Section 5-9
	Material static charge resistance	ASTM F 23.02.05(draft)
Protective Gloves	Areas of hand and wrist coverage	Design requirement
	Inclusion of wristlet	Design requirement

Table 9 (Continued)

Recommended Test Methods for Measuring Performance of Technical Rescue Ensemble Protective Clothing and Equipment Items

Clothing/Equipment Item	Design or Performance Needs	Proposed Test Method
Protective Gloves	Minimum sixes	Design requirement
	Material physical hazard resistance Cut resistance Puncture resistance Abrasion resistance	 NFPA 1973, Section 3-7 ASTM F 1342 ASTM D 4157
	Material breathability Total heat loss	 NFPA 1971, Appendix B
	Hand function Dexterity Grip	 NFPA 1973, Section 3-9 NFPA 1973, Section 3-10
	Material flame resistance	ASTM F 1358 (modified)
	Material heat resistance Convective Conductive	 NFPA 1971, Section 5-4 NFPA 1973, Section 3-4
	Material heat insulation Thermal protective performance Radiant reflectance	 NFPA 1971, Section 5-2 NFPA 1977, Section 3-3.2
	Material thermal shrinkage resistance	NFPA 1977, Sections 6-3.4
	Material electrical current insulation	ASTM D 120
	Liner barrier performance Material chemical resistance Material biological resistance Overall water-tight integrity	 ASTM F 903 ASTM ES 22 ASTM D 5151

Table 9 (Continued)

Recommended Test Methods for Measuring Performance of Technical Rescue Ensemble Protective Clothing and Equipment Items

Clothing/Equipment Item	Design or Performance Needs	Proposed Test Method
Protective Boots	Areas of foot and ankle coverage	Design requirement
	Restriction of exposed metal parts	Design requirement
	Use of ladder shank and toe cap	Design requirement
	Minimum number of stud hooks and strength	Design requirement; NFPA 1977, Section 5-4.6
	Upper material physical hazard resistance Cut resistance Puncture resistance Abrasion resistance	 NFPA 1973, Section 3-7 ASTM F 1342 ASTM D 4157
	Sole material physical hazard resistance Puncture resistance Abrasion resistance Slip resistance	 ANSI 241, Section 5.3 FIA Test Method 301 ASTM F 489
	Toe impact and compression resistance	ANSI 241, Section 1.4
	Material flame resistance	ASTM F 1358 (modified)
	Material heat resistance Convective Conductive	 NFPA 1971, Section 5-4 NFPA 1973, Section 3-4
	Material heat insulation Thermal protective performance Radiant reflectance	 NFPA 1971, Section 5-2 NFPA 1977, Section 3-3.2
	Boot flex fatigue resistance	NFPA 1977, Section 5-3.7

Table 9 (Continued)

Recommended Test Methods for Measuring Performance of Technical Rescue Ensemble Protective Clothing and Equipment Items

Clothing/Equipment Item	Design or Performance Needs	Proposed Test Method
Protective Boots	Boot electrical current resistance	ASTM F 1116
	Liner barrier performance Chemical resistance Biological fluid resistance Overall water-tight integrity	 ASTM F 903 ASTM ES 22 ASTM D 5151 (modified)
Protective Helmet	Areas of head coverage	Design requirement
	Weight and shape	Design requirement
	Provision of headbands, crown straps, chin straps, and accessories	Design requirement
	No openings in helmet	Design requirement
	Material flame resistance	FTMS 191A, 5903 (modified)
	Material heat resistance	NFPA 1971, Section 5-4 (modified)
	Helmet impact resistance	NFPA 1972,Section 5-6
	Helmet penetration (physical) resistance	NFPA 1972, Section 5-8
	Helmet electrical current insulation	NFPA 1972, Section 5-9
	Suspension system separation resistance	NFPA 1972, Section 5-15
	Helmet retention and chip strap efficiency	New method
	Headlamp vibration stability	NFPA 1981, Section 5-10
	Headlamp power supply and weight	Design requirement

Table 9 (Continued)

Recommended Test Methods for Measuring Performance of Technical Rescue Ensemble Protective Clothing and Equipment Items

Clothing/Equipment Item	Design or Performance Needs	Proposed Test Method
Protective Helmet	Helmet Visibility Amount of retroreflective trim Brilliance of retroreflective trim	Design requirement ASTM E 508
Goggles	Areas of face and eye coverage Impact resistance Particulate penetration resistance	ANSI 287.1 requirements
Air-Purifying Respirator	NIOSH-certification Particulate filtration efficiency	29CFRl34 requirements
Ear Protectors	Overall performance	ANSI requirements

Table 10

Recommended Test Methods for Measuring Performance of Swift Water Rescue Ensemble Protective Clothing and Equipment Items

Clothing/Equipment Item	Design or Performance Needs	Proposed Test Method
Personal Flotation Device	Bouyancy, other requirements	Coast Guard Type III or V
	Life line hardware Attachment strength	Design requirement; Tensile strength test
Protective Dry Suit	Areas of body coverage	Design requirement
	Overall integrity	MIL-W-85365
	Adjustable neck, wrist, foot seals	Design requirement
	Material thermal insulation/breathability Insulation from cold Heat loss	 ASTM D 1518 NFPA 1971, Appendix B
	Material physical hazard resistance: Tensile strength Tear resistance Snag resistance Abrasion resistance	 ASTM D 1682 NFPA 1971, Section 5-5 ASTM D 2582 ASTM D 4157
	Knee/elbow reinforcement	Design requirement
	Seam/closure performance Breaking strength Closure design	 ASTM D 751 Federal Specifications
	Suit visibility Amount of retroreflective trim Brilliance of retroreflective trim	 Design requirement ASTM E 508

Table 10 (Continued)

Recommended Test Methods for Measuring Performance of Swift Water Rescue Ensemble Protective Clothing and Equipment Items

Clothing/Equipment Item	Design or Performance Needs	Proposed Test Method
Protective Dry Suit	Material barrier resistance Chemical penetration Biological penetration	 ASTM F 903 ASTM ES 22 (modified)
	Material contaminant retention	New test method
	Material cleaning shrinkage resistance	NFPA 1971, Section 5-3
	Hardware corrosion resistance	ASTM B 117
	Garment donning efficiency	New test method
Protective Gloves	Areas of hand and wrist coverage	Design requirement
	Material physical hazard resistance Cut resistance Puncture resistance Abrasion resistance	 NFPA 1973, Section 3-7 ASTM F 1342 ASTM D 4157
	Glove retention on hand	Design requirement and new test method
	Hand function Dexterity Grip	 NFPA 1973, Section 3-9 NFPA 1973, Section 3-10
	Material barrier resistance Chemical penetration Bacterial penetration	 ASTM F 903 ASTM ES 22 (modified)
	Material chemical retention	New test method
	Hardware corrosion resistance	ASTM B 117

Table 10 (Continued)

Recommended Test Methods for Measuring Performance of Swift Water Rescue Ensemble Protective Clothing and Equipment Items

Clothing/Equipment Item	Design or Performance Needs	Proposed Test Method
Protective Booties	Areas of foot and ankle coverage	Design requirement
	Overall integrity	ASTM D 5151 (modified)
	Material barrier resistance Chemical penetration Biological penetration	 ASTM F 903 ASTM ES 22
	Material cold insulation heat loss	 ASTM D 1518
	Material physical hazard resistance Cut resistance Puncture resistance Abrasion resistance	 NFPA 1977, Section 6-3.8 ASTM F 1342 ASTM D 4157
	Sole slip resistance	ASTM F 489
	Bootie retention on foot	New test method
	Accomodation of swimming fins	Design requirement
	Hardware corrosion resistance	ASTM B 117
Swimming Fins	No restriction in walking	Method to be developed
Protective Helmet	Areas of head coverage Impact resistance Penetration requirement	ASTM F32.01 (draft) or UIAA requirements
	Water drainage	New test method
	Hardware corrosion resistance	ASTM B 117

Table 10 (Continued)

Recommended Test Methods for Measuring Performance of Swift Water Rescue Ensemble Protective Clothing and Equipment Items

Clothing/Equipment Item	Design or Performance Needs	Proposed Test Method
Sheathed Knife	Single-edged Retention in sheath when inverted	Design requirements
Whistle	Non metallic No pall	Design requirements

Table 11

Recommended Test Methods for Measuring Performance of Contaminated Water Diving Ensemble Protective Clothing and Equipment Items

Clothing/Equipment Item	Design or Performance Needs	Proposed Test Method
Protective Dry Suit	Areas of body coverage	Design requirement
	Overall integrity	MIL-W-85365
	Neck, wrist, foot seals	Design requirement
	Material cold insulation	ASTM D 1518
	Material physical hazard resistance:	
	Tensile strength	ASTM D 1682
	Burst strength	ASTM D 751
	Tear resistance	NFPA 1971, Section 5-5
	Snag resistance	ASTM D 2582
	Abrasion resistance	ASTM D 4157
	Knee/elbow reinforcement	Design requirement
	Seal material physical hazard resistance	
	Cut resistance	NFPA 1973, Section 3-7
	Puncture resistance	ASTM F 1342
	Seam/closure performance	
	Breaking strength	ASTM D 751
	Closure design	Federal Specifications
	Material barrier resistance	
	Chemical penetration	ASTM F 903
	Bacterial penetration	ASTM ES 22 (modified)
	Material contaminant retention	New test method
	Hardware corrosion resistance	ASTM B 117

Table 11 (Continued)

Recommended Test Methods for Measuring Performance of Contaminated Water Diving Ensemble Protective Clothing and Equipment Items

Clothing/Equipment Item	Design or Performance Needs	Proposed Test Method
Protective Gloves	Areas of hand and wrist coverage	Design requirement
	Attachment to dry suits	Design requirement
	Water tight integrity	ASTM D 5151
	Material cold insulation	ASTM D 1518
	Material physical hazard resistance Cut resistance Puncture resistance Abrasion resistance	 NFPA 1973, Section 3-7 ASTM F 1342 ASTM D 4157
	Hand function Dexterity Grip	 NFPA 1973, Section 3-9 NFPA 1973, Section 3-10
	Retention of contaminant	Method to be developed
Protective Boots	Areas of foot and ankle coverage	Design requirement
	Attachment to dry suit	Design requirement
	Water-tight integrity	ASTM D 5151 (modified)
	Material cold insulation	ASTM D 1518
	Upper material physical hazard resistance Cut resistance Puncture resistance Abrasion resistance	 NFPA 1973, Section 3-7 ASTM F 1342 ASTM D 4157

Table 11 (Continued)

Recommended Test Methods for Measuring Performance of Contaminated Water Diving Ensemble Protective Clothing and Equipment Items

Clothing/Equipment Item	Design or Performance Needs	Proposed Test Method
Protective Boots	Sole material physical hazard resistance Abrasion resistance Puncture resistance	 FIA Test Method 301 ANSI 241, Section 1.4
	Sole slip resistance	ASTM F 489
	Retention of contaminant	New test method
Swimming Fins	Material chemical resistance	ASTM F 23.30.03(draft)
Protective. Helmet	Areas of head coverage Attachment to dry suit Neutral bouyancy with return valve Emergency valve for bail-out system Defogging mechanism Impact resistance Equalizing device Integrated communications system	Navy requirements
	Material chemical resistance	ASTM F 23.30.03(draft)
	Material chemical retention	Method to be developed

Table 11 (Continued).

Recommended Test Methods for Measuring Performance of Contaminated Water Diving Ensemble Protective Clothing and Equipment Items

Clothing/Equipment Item	Design or Performance Needs	Proposed Test Method
Full Face Mask	Areas of face coverage Integral second stage regulator Bail-out block Equalizing device Defogging mechanism Earphone pockets Low volume Large buckles and wide straps Modular communications components	Navy requirements
	Material chemical resistance	ASTM F 23.30.03(draft)
	Material chemical retention	Method to be developed
Dry Suit Underwear	Insulation from cold temperatures	ASTM D 1518
	Water absorptive	ASTM D 1117
Communications System	Rugged with back up system Attachment point to harness Ease of decontamination	Navy requirements
Compressed Air Supply	Low pressure Emergency air supply	Navy requirements
Air Manifold Box	Pressure measurement Regulation of pressure Connection to emergency air supply	Navy requirements
Pneumofathometer	Accuracy of pressure measurement	Navy requirements

Table 11 (Continued)

Recommended Test Methods for Measuring Performance of Contaminated Water Diving Ensemble Protective Clothing and Equipment Items

Clothing/Equipment Item	Design or Performance Needs	Proposed Test Method
Umbilical	Length and diameter Dimension changes when pressurized Rated pressure Kinking resistance Fittings integrity Tensile strength Types of components	Navy requirements
	Chemical resistance	Method to be developed
	Chemical retention	Method to be developed
Weight Belt/Harness	Maximum weight Method of release	Navy requirements
Diving Tether	Harness attachment point Load bearing capacity	Navy requirements
	Chemical resistance	ASTM F 23.30.03
	Chemical retention	Method to be developed
SCUBA System	Bail out block and bottle	Navy requirements
	Chemical resistance	Method to be developed
	Chemical retention	Method to be developed
Bail-Cut System	Air supply Configuration	Navy requirements
Sheathed Knife and Wire-Cutters	Single-edged Retention in sheath when inverted	Design requirements

Test Plan Development

ERURC members reviewed and approved test method recommendations for each of the performance areas. To support the development of performance criteria, it was essential that data be generated using the selected methods and used to:

- Verify that the chosen procedures meet the project criteria for test method selection; and

- Accumulate data that allows selection of minimum acceptable performance levels.

In previous meetings, the ERURC was asked to distinguish between:

- clothing/equipment offering accentable performance; and

- clothing/equipment offering unacceptable performance.

The purpose of making this distinction was to establish which clothing would be used for testing, and thus support further establishment of performance requirements.

Test plans were developed for priority clothing items. These test plans identified:

- the selected test methods;
- test conditions (where appropriate);
- test materials; and
- methods of documenting results.

Test plans were not necessary in some areas because performance requirements were established based on existing criteria found acceptable to the ERURC members. Test plans developed for verification and documentation testing are provided in Appendix A.

TECHNICAL RESCUE ENSEMBLE REQUIREMENTS

The basis for many of the suggested requirements for technical rescue protective clothing and equipment comes from the proposed standard, NFPA 1977, on wildlands fire fighting protective clothing. Technical rescue has many similarities with wildlands fire fighting. Both applications require an ensemble that can be worn for extensive periods of time, providing the wearer with relative mobility and comfort. While emergency responders for both applications may face severe hazards, typically their efforts involve more physical work than actual exposure. This is in contrast to structural fire fighting where emergency responders expect to encounter hazards on each response. Nevertheless, the ensemble must offer minimum protection against a variety of different hazards.

Protective Garment/Hood

The ERURC determined the need for a number of requirements for a technical rescue protective garment. Some needs were found to best be addressed as design requirements. Some of these were taken directly from NPPA 1977, while others were developed as part of the study. The garment itself must be defined as providing complete coverage of the wearer’s torso, arms, and legs, and head and neck when a protective hood is worn in conjunction with the garment. This specification should allow either one- (coverall) or two-piece designs (trousers and shirt/coat).

Other design requirements were recommended to address:

- collar orientation;
- sizing tolerance;
- pocket design;
- use and orientation of closures;
- hardware;
- knee and elbow reinforcement; and
- minimum amount of reflective trim (for visibility).

Performance requirements have been proposed to address resistance to thermal, physical, chemical, and biological hazards. Methods for evaluating these properties have been adopted from other existing or proposed NPPA standards including NFPA 1971 (structural fire fighting protective clothing), NFPA 1977 (wildlands fire fighting protective clothing), NFPA 1992 (liquid splash-protective suits), and NPPA 1999 (emergency medical protective clothing).

To support the selection of minimum performance requirements, 10 fabrics were evaluated for 7 key properties:

- tensile strength;
- tear resistance;
- snag resistance;
- thermal protective performance;

- radiant protective performance;
- flame resistance; and
- total heat loss.

The fabrics tested were considered to be potential candidates by ERURC members for use in technical rescue garments. Only "outer shell" materials were tested. No attempt was made to evaluate the performance of potential liner materials for limited chemical and biological resistance. Results of this testing are provided in Tables 12-14.

In nearly all cases, the ERURC opted to accept the existing NFPA criteria instead of setting different performance limits. The principal exception was the requirement for flame resistance, where the ERURC chose the more stringent 4 inch char length over the 6 inch char length originally proposed for NFPA 1977. Chemical and viral penetration requirements are similar to those proposed for structural fire fighting protective clothing, and are taken in part from NFPA 1992, Standard on Liquid Splash Protective Suits for Hazardous Chemical Emergencies, and NFPA 1999, Standard on Protective Clothing for Emergency Medical Operations. The static charge accumulation resistance requirement is based on a proposal under consideration for hazardous chemical protective clothing in chemical flash fire environments. Table 15 shows how the tested materials fare against proposed minimum performance criteria.

For protective hoods, the ERURC recommends using existing NFPA 1971 requirements. It was felt that hoods currently on the market, which are compliant' to NFPA 1971, offer acceptable performance. Therefore, the NFPA 1971 requirements were adopted verbatim. An additional requirement for static charge accumulation resistance was added. The committee also did note the need for hoods with improved stretch fatigue resistance, but no requirement was developed.

Protective Gloves

In considering adequate glove performance for technical rescue missions, the ERURC indicated the need for a balance between dexterity and physical hazard resistance as the top priorities. The example cited by ERURC members as an "ideal" glove was a Nomex based flight glove, where the principal physical protection is found on the palm of the glove, the main area of the hand which is subjected to physical hazards. This need indicated a new means for defining hand protection different from NFPA 1973 (structural fire fighting gloves) or 1977 (wildlands protective fire fighting protective clothing). It was accommodated by establishing a "wear surface" for the gloved hand and applying different requirements to respective parts of the glove.

Only a few other design requirements were found necessary. These apply to the minimum area of hand coverage by the glove, minimum sizing, glove design for non interference with other clothing, and minimization of hazard effects through proper design. These requirements were taken directly from NFPA 1977.

As with garments, many of the same requirements and test methods apply to gloves. These include the performance areas:

Table 12

Summary of Physical Property Test Results
For Technical Rescue Garment Materials

Fabric	Unit Area Weight (oz/yd^2)	Tear Resistance (lbs)		Snag Resistance (lbs)		Total Heat Loss (W/m^2)
		Warp	Text	Warp	Fill	
Nomex Breezetone	5.7	23.4	15.9	11.2	17.1	645
Military W. Weave	5.1	9.4	6.6	NT		NT
Flamex	6.0	6.9	6.0	8.2	9.6	671
PBI/Kevlar	6.0	> 56.3	>56.3	39.6	39.6	NT
FR Cotton	6.8	10.3	6.6	8.3	11.2	NT
Nomex III (Pants)	8.6	20.3	12.9	NT		569
PBI/Kevlar	7.5	>56.3	>56.3	39.6	39.6	560
Flamex	8.0	5.3	4.1	10.1	10.8	NT
Twill	7.3	15.1	8.7	NT		NT
FR Cotton	9.5	6.0	7.2	10.4	12.3	600

Tear resistance tests per ASTM D 1424 (Elmendorf)
Snag resistance tests per ASTM D 2582 (Puncture Propagation Tear)
Total heat loss testing per NFPA 1971, Appendix B

Table 13

Summary of Thermal Protective Performance Results for Technical Rescue Garment Materials

TPP Rating

Exposure	**50% Conv./50% Radiant**		**100% Radiant**			
Load (Cal/cm^2*sec)	2.0		1.0			0.5
Orientation	Horizontal		Horizontal		Vertical	
Spacer-Present	No	Yes	No	Yes	No	No
Fabric (Weight)						
Nomex Breezetone	5.2	13.5	6.0	9.7	7.2	8.8
Military W. Weave	7.6	12.0	5.1	8.5	5.8	6.5
Flamex (6.0)	7.1	7.7	6.1	7.6	6.4	7.1
PBI/Kevlar (6.0)	8.4	13.6	4.9	10.3	7.1	7.5
FR Cotton (6.8)	8.4	7.3	7.0	8.6	6.4	7.3
Nomex Pant (8.6)	11.1	16.8	6.2	14.1	8.6	9.5
PBI/Kevlar (7.5)	8.3	13.8	5.2	13.6	7.3	8.0
Flamex (8.0)	8.5	8.9	5.2	10.6	8.0	8.7
Twill (7.3)	10.0	14.4	6.7	12.4	7.2	7.9
FR Cotton (9.5)	10.8	9.8	7.7	10.9	9.2	10.0

Tests performed per NFPA 1971, Section 5-4 (as modified by stated conditions)

Table 14

Summary of Flame Resistance Test Results for Technical Rescue Garment Materials

Fabric	Weight (oz/yd^2)	No Conditioning		After 5 Washings	
		Machine	X-Machine	Machine	X-Machine
Nomex Breezetone	5.7	3.0	2.9	2.4	2.5
Military W. Weave	5.1	1.7	1.6	2.3	2.2
Flamex	6.0	4.8	4.0	4.9	4.3
PBV/Kevlar	6.0	0.4	0.5	0.4	0.4
FR Cotton	6.8	3.2	2.9	2.8	2.5
Nomex (Pant)	8.6	2.2	2.1	2.3	2.4
PBI/Kevlar	7.5	0.5	0.5	0.4	0.4
Flamex	8.0	4.7	3.7	4.6	3.8
Twill	7.3	1.7	1.6	1.5	1.5
FR Cotton	9.5	2.7	2.7	2.2	2.3

Flame resistance tests per FTMS 191A, 5903.1; Char length is reported

Table 15

Comparison of Selected Garment Materials With Recommended Minimum Performance Requirements

Fabric	Weight (oz/yd²)	Tear Resistance (lbs)*	Snag Resistance (lbs)*	Thermal Protective Performance	Radiant Reflectance	Char Length (inches)	Total Heat Loss (W/m²)
MINIMUM REQUIREMENT	**None**	**8.0**	**11.0**	**12.0**	**7.0**	**4.0**	**450**
Nomex Breezetone	5.7	23.4/15.9	11.2/15.9	13.5	7.2	2.4/2.4	645
Military W. Weave	5.1	9.4/6.6	NT	12.0	5.8	2.3/2.2	NT
Flamex	6.0	6.9/6.0	8.219.6	7.7	6.4	4.9/4.3	671
PBI/Kevlar	6.0	>56.3	39.6	13.6	7.1	0.4/0.4	NT
FR Cotton	6.8	10.3/6.6	8.3/11.2	7.3	6.4	2.8/2.5	NT
Nomex	8.6	20.3/12.9	NT	16.8	8.6	2.3/2.4	569
PBV/Kevlar	7.5	>56.3	39.6	13.8	7.3	0.4/0.4	560
Flamex	8.0	5.3/4.1	10.1/10.8	8.9	8.0	4.6/3.8	NT
Twill	7.3	15.1/8.7	NT	14.4	7.2	1.5/1.5	NT
FR Cotton	9.5	6.0/7.2	10.4/12.3	9.8	9.2	2.2/2.3	600

* First measurement is warp direction value; Second measurement is fill direction value
Shaded blocks show compliance with recommended performance requirement

- material radiant reflectance;
- material thermal protective performance;
- material flame resistance;
- material heat resistance;
- material abrasion resistance;
- liner chemical penetration resistance; and
- liner biopenetration resistance.

In all cases, the same performance criteria as used for garments were adopted. However, due to the nature of glove design and configuration of glove materials, subtle variations are required in some of the test methods. Requirements unique to protective gloves included:

- material conductive heat resistance;
- material cut resistance;
- material puncture resistance;
- glove integrity;
- glove electrical current leakage;
- glove dexterity; and
- glove grip.

The precedents for minimum performance for these requirements were established in both NFPA 1973 (structural fire fighting gloves) and NFPA 1977 (wildlands fire fighting protective clothing). Glove puncture and cut resistance minimum values were lowered to reflect the needs for increased dexterity and grip. Several gloves were tested for puncture resistance and compared against a qualitative ranking of glove dexterity (see Table 16). Gloves providing "acceptable" dexterity were used to set the minimum in material puncture resistance performance.

Protective Boots

The ERURC recognized the predominance of two different boot types throughout the fire fighting industry: leather or rubber type boots. Both types of boots can potentially be certified to NPPA 1974, ***Standard on Protective Footwear for Structural Fire Fighting.*** In addition, both types of boots offer advantages and disadvantages to the emergency responder; however, the distinctions between these boot types are rapidly diminishing as boot manufacturers attempt to overcome the inherent limitations for each type. Proposed requirements in NFPA 1977 dictate a leather, lace-up type boot. The basis for this requirement is better ankle support generally provided by leather boots (Leather boots are more easily designed so that they can conform tighter around the wearer's ankle, thus providing better ankle support [16]). Ankle support is considered to be a major need for emergency response, particularly for long duration activity over rough surfaces. On the other hand, rubber footwear is deemed to offer better overall integrity and resistance to liquid penetration. Using both philosophies, the ERURC decided to use design requirements developed for NFPA 1977, while maintaining NFPA 1974 performance for overall boot integrity.

Table 16

Comparison of Puncture Resistance Test Results for Selected Protective Gloves

Glove	Puncture Resistance (lbs)	Qualitative Dexterity (see key)
Genco leather glove with Kevlar liner	30.0	Low
Genco NFPA 1973 glove with Gore-Tex liner	24.2	Low
FDNY leather glove	26.6	Moderate
CMC Rescue rappelling glove	26.9	Moderate
CMC Rescue deerskin glove	12.8	Moderate
Flight Suits Ltd. Nomex flight glove	3.9	High

Glove dexterity based on average ratings of three test subjects

Other design requirements are suggested for the construction and configuration of the boot in terms of:

- minimum height;
- heel configuration;
- inclusion and position of top cap;
- minimum available sizes;
- metal part penetration;
- minimum number of stud hooks; and
- construction materials for eyelets.

The same philosophy used in developing performance criteria for technical rescue gloves was used in a similar fashion for protective boots. That is, a number of identical technical rescue garment requirements were used in combination with key requirements from NFPA 1974 (structural fire fighting protective footwear) and NFPA 1977 (wildlands fire fighting protective clothing). Some proposed requirements are similar to those used in defining glove minimum performance:

- upper material cut resistance;
- upper material puncture resistance;
- boot overall integrity; and
- boot electrical current leakage.

Most unique boot suggested requirements pertain to the sole or other special aspects of boot construction. These included:

- sole abrasion resistance;
- sole puncture resistance;
- sole flex fatigue resistance;
- stud hook detachment strength; and
- metal part corrosion resistance (although also cited for technical rescue garments).

The majority of recommended performance criteria in these areas were selected from either NFPA 1974 or NFPA 1977.

Helmet

The ERURC modelled many of its requirements for a protective helmet on hard hat type products found to offer acceptable performance in the industry, e.g.,the Bullard Advent helmet. As with the gloves and boots, many of the requirements for a protective helmet were adopted from the draft NFPA 1977, Standard on Protective Clothing for Wildlands Fire Fighting. This included criteria for both design and performance. Design criteria included:

- use of non-skin irritating materials;
- maximum weight;

- helmet configuration;
- ventilation between shell and headband;
- helmet shape and dome material of construction;
- requirement for removable, replaceable, and sized headband;
- requirement for removable and replaceable sweatband;
- requirement for crown straps;
- requirement, minimum width, and quick release feature for chin straps;
- minimum reflective trim area;
- requirements for accessories (i.e., face/neck shrouds, winter liners, lamp brackets); and
- method for affixing labels.

The performance requirements for helmets are somewhat similar to hard hats, but are different in many aspects due to the helmet's configuration and overall function. As with clothing, performance criteria address flame and heat resistance. Additional requirements are provided for:

- helmet impact resistance;
- helmet penetration (physical) resistance;
- helmet electrical insulation;
- suspension system separation resistance;
- retention system separation resistance; and
- trim luminous intensity.

In addition, it is suggested that helmets meet the criteria in ANSI 289.1-1986 for either Class A or B requirements.

Goggles

The majority of technical rescue goggle performance needs are addressed by ANSI 287.1 (1989 edition), ***Practice for Occupational and Educational Eye and Face Protection.*** Section 10 in the standard specifically addresses different types of goggles and includes requirements for:

- flame resistance;
- high mass impact;
- high velocity impact;
- minimum lens thickness; and
- lens penetration (puncture) resistance.

Optional requirements and test methods are provided for:

- prismatic power;
- refractive power;
- light definition;
- haze;
- light transmittance;

- corrosion resistance; and
- cleanability.

All applicable requirements are recommended for inclusion in specifications for goggles.

In addition, technical rescue goggles should resist adverse effects when exposed to hot convective and radiative heat environments. The heat resistance requirement and method recommended for the garment and other technical rescue clothing can be adopted to meet this need.

Keeping particulates from getting into the eyes is the only need not addressed. This form of protection is probably best met through guidance to the user emphasizing proper fit. Like respirators, good fit of goggles is important to the protection it offers.

Air-Purifying Respirator

In most emergency response activities, self-contained breathing apparatus (SCBA) is mandated for respiratory protection. In technical rescue, a variety of respiratory hazards may be encountered, dictating a range in respiratory protection devices. While SCBA provide the highest personal protection factors, they are also limited in their duration and are relatively heavy (up to 35 lbs.). Most ERURC members indicated the need for specific protection from particulates in certain emergency environments. Both the National Institute for Occupational Safety and Health (NIOSH) and the American Industrial Hygiene Association recommend air purifying respirators equipped with high efficiency particulate cartridges (filters) as an acceptable form of respirator protection from particulates.

Air-purifying respirators providing protection from particulates must be NIOSH certified to the appropriate sections of 29 CFR 134. The NIOSH certification entails a number of performance-based tests and criteria to demonstrate respirator effectiveness in protecting against particulates. However, air-purifying respirators are not evaluated for thermal properties such as heat or flame resistance.

While the ERURC considers air-purifying respirators as part of the technical rescue ensemble, it recognizes that appropriate respiratory protection must be worn commensurate with the hazards of the response. In some cases, SCBA might be deemed appropriate. In other cases, an air-purifying respirator would, be an acceptable choice. Some technical rescue mission may require no respiratory protection. In all cases, the ERURC recommends:

- Respirators be selected per NIOSH or AIHA guidance criteria [17];

- SCBA, if used, should meet the requirements of NFPA 1981, Standard ***for Open-Circuit, Se&Contained Breathing Apparatus*** (this includes NIOSH certification); and

- Air-purifying respirators, if used, should be NIOSH certified and should only be used for particulate protection, and in atmospheres defined to have no oxygen deficiency or chemical contamination. Air-purifying respirators should be equipped with a high efficiency particulate canister.

It is suggested that this information should be included in the standard as guidance. Specification of air-purifying respirators within the standard may falsely indicate to the user that only air-purifying respirators may be worn during technical rescue responses.

Ear Protectors

A variety of ear protection devices are available to the emergency responder. They range from basic ear plugs to ear muffs. Hearing protection is governed by OSHA's 29 CFR 1910.95, ***Occupational Noise Standard.*** Requirements for determining the effectiveness of ear protectors are provided in ANSI S31.19 (revised July 1984) which is cited in the OSHA regulations.

In addition to meeting noise protection requirements, the ERURC recommends that externally mounted ear protectors withstand high heat conditions, and that ear protectors not interfere with other clothing or equipment.

Summary of Requirements

Table 17 provides a summary of all requirements, indicating the recommended criteria, and origin for each different criterion. Appendix B, Chapter 4 provides the list of recommended design and performance requirements.

Table 17

Basis of Recommended Performance Criteria for Technical Rescue Protective Clothing and Equipment

Performance Need	Test Method	Recommended Criteria	Basis for Criteria
Protective Garment			
Radiant Protective Performance	NFPA 1977, Section 3-4.10	RPP rating > 7.0	Same as NFPA 1977
Thermal Protective Performance	NFPA 1971, Section 5-2	TPP rating > 12.0	ERURC proposed criteria
Flame Resistance	FTMS 191A,5903.1	Char length < 4.0 inches After flame time < 2.0 seconds No melting or dripping	Same as NFPA 1971
Thermal Shrinkage Resistance	NFPA 1971, Section 5-3	Shrinkage < 10.0%	Same as NFPA 1971/1977
Heat Resistance	NFPA 1971, Section 5-4	No melting, dripping, separation or ignition	Same as NFPA 1971/1977
Total Heat Loss	NFPA 1971, Appendix B	Total heat loss > 450 W/m^2	Same as NFPA 1977
Tear Resistance	ASTM D 1424	Tear strength > 8.01bs	ERURC proposed criteria
Snag Resistance	ASTM D 2582	Puncture force > 11.01 lbs	Same as NFPA 1992
Abrasion Resistance	ASTM D 4157	No wear through after 500 cycles	ERURC proposed criteria
Cleaning Shrinkage Resistance	NFPA 1971, Section 5-9	Shrinkage < 3.0%	Same as NFPA 1977
Static Discharge	ASTM F 23.20.05(draft)	Charge < 350 V after 5 seconds	Proposed NFPA 1992 requirement
Seam Strength	ASTM D 1683	Outer scam strength < 150 lbs Inner seam strength < 75 lbs	Same as NFPA 1977
Closure Strength	ASTM D 751	Closure strength < 150 lbs	Consistency with seam strength
Thread Heat Resistance	FTMS 191A, 5134	No melting at 500°F	Same as NFPA 1971/1977

Table 17 (Continued)

Basis of Recommended Performance Criteria for Technical Rescue Protective Clothing and Equipment

Performance Need	Test Method	Recommended Criteria	Basis for Criteria
Protective Garments (Continued)			
Hardware Corrosion Resistance	ASTM B 117	No corrosion after 24 hours	Same as NFPA 1971/1977
Trim Retroreflectivity	ASTM E 809	CPL > 90 cp/ft-c/ft^2	Same as NFPA 1977
Chemical Penetration Resistance	ASTM F 903 (5 chemicals)	No penetration in one hour (liner only)	Same as NFPA 1992
Biopenetration Resistance	ASTM ES 22	No penetration in one hour (liner only)	Same as NFPA 1999
Protective Hood			
Thermal Protective Performance	NFPA 1971, Section 5-2	TPP rating > 12.0	Consistency with garment
Flame Resistance	FTMS 191,5903.1	Char length < 4.0 inches After flame time < 2.0 seconds No melting or dripping	Same as NFPA 1971
Thermal Shrinkage Resistance	NFPA 1971, Section 5-3	Shrinkage < 10.0%	Same as NFPA 1971
Heat Resistance	NFPA 1971, Section 5-4	No melting, dripping, separation or ignition	Same as NFPA 1971
Total Heat Loss	NFPA 1971,Appendix B	Total heat loss > 450 W/m^2	Consistency with garment
Cleaning Shrinkage Resistance	NFPA 197 1, Section 5-9	Shrinkage < 3.0%	Same as NFPA 1971
Static Discharge	ASTM F 23.20.05	Charge < 350 V after 5 seconds	Consistency with garment
Thread Heat Resistance	FTMS 191A,5134	No melting at 500°F	Same as NFPA 1971

Table 17 (Continued)

Basis of Recommended Performance Criteria for Technical Rescue Protective Clothing and Equipment

Performance Need	Test Method	Recommended Criteria	Basis for Criteria
Protective Gloves			
Radiant Protective Performance	NFPA 1977, Section 3-4.10	RPP rating > 7.0	Consistency with garment
Thermal Protective Performance	NFPA 1971, Section 5-2	TPP rating > 20.0	Consistency with garment
Flame Resistance	FTMS 191A, 5903.1	Char length < 4.0 inches After flame time < 2.0 seconds No melting or dripping	Consistency with garment
Heat Resistance	NFPA 1971, Section 54	No melting, dripping, separation or ignition	Consistency with garment
Conductive Heat Resistance	NFPA 1973, Section 3-4	Time to 2nd degree bum > 7 sec Time to pain > 4 seconds	Same as NFPA 1977
Cut Resistance	NFPA 1973, Section 3-7	Cut force > 18 Ibs	Same as NFPA 1973/1977
Puncture Resistance	ASTM F 1342	Puncture force > 10 lbs	Same as NFPA 1977
Electrical Current Leakage	ASTM D 120	Current leakage < 3 mA	Same as NFPA 1973
Abrasion Resistance	ASTM D 4157	No wear through after 500 cycles	ERURC proposed criteria
Dexterity	NFPA 1973, Section 3-9	Gloved time < 120% bare-handed time	Same as NFPA 1973
Grip	NFPA 1973, Section 3-10	Glove capacity > 80% bare-handed capacity	Same as NFPA 1973/1977
Chemical Penetration Resistance	ASTM F 903	No penetration in one hour (liner only)	Same as NFPA 1992

Table 17 (Continued)

Basis of Recommended Performance Criteria for Technical Rescue Protective Clothing and Equipment

Performance Need	Test Method	Recommended Criteria	Basis for Criteria
Protective Gloves (Continued)			
Biopenetration Resistance	ASTM ES 22	No penetration in one hour (liner only)	Same as NFPA 1999
Overall Water-Tight Integrity	ASTM D 5151	No observed leakage	Same as NFPA 1999
Protective Boots			
Radiant Protective Performance	NFPA 1977, Section 3-4.10	RPP rating > 7.0	Consistency with garment
Thermal Protective Performance	NFPA 1971, Section 5-2	TPP rating > 12.0	Consistency with garment
Flame Resistance	FTMS 191A, 5903.1	Char length < 4.0 inches After flame time < 2.0 seconds No melting or dripping	Consistency with garment
Heat ‘Resistance	NFPA 1971, Section 5-4	No melting, dripping, separation or ignition	Consistency with garment
Conductive Heat Resistance	NFPA 1973, Section 3-4	Time to 2nd degree bum > 7 sec Time to pain > 4 seconds	Consistency with glove
Upper Cut Resistance	NFPA 1973, Section 3-7	Cut force > 18.0 lbs	Consistencv with glove
Upper Puncture Resistance	ASTM F 1342	Puncture force > 13.2 lbs	Same as NFPA 1974/1977
Sole/Heel Abrasion Resistance	NFPA 1974, Section 4-l .9	NBS index > 65	Same as NFPA 1974/1977
Sole/Heel Puncture Resistance	NFPA 1974, Section 4-l. 10	Puncture force > 272 lbs	Same as NFPA 1974/1977
Sole Flex Fatigue Resistance	NFPA 1977, Section S-3.7	Cut growth < 350%	Same as NFPA 1977

Table 17 (Continued)

Basis of Recommended Performance Criteria for Technical Rescue Protective Clothing and Equipment

Performance Need	Test Method	Recommended Criteria	Basis for Criteria
Protective Boots (Continued)			
Sole Slip Resistance	ASTM F 489	Friction coefficient > 0.75 (dry); > 0.5 (wet)	Proposed NFPA 1992 requirement
Electrical Current Leakage	ASTM F 1116	Current leakage < 3 mA	Consistency with glove
Stud Hook Detachment Strength	NFPA 1977,Section 5-3.6	Detachment strength > 66 lbs	Same as NFPA 1977
Metal Corrosion Resistance	ASTM B 117	No corrosion resistance after 24 hr	Consistency with garment
Chemical Penetration Resistance	ASTM F 903	No penetration in one hour (liner only)	Consistency with garment
Biopenetration Resistance	ASTM ES 22	No penetration in one hour (liner only)	Consistency with garment
Overall Water-Tight Integrity	ASTM D 5151 (modified)	No observed leakage	Consistency with glove
Protective Helmet			
Flame Resistance	FTMS 191A, 5903.l(moditied)	Afterflame time > 5.0 seconds	Same as NFPA 1977
Heat Resistance	NFPA 1971, Section 5-4 (modified)	Deformation of brim < 25%	Same as NFPA 1977
Top Impact Resistance	NFPA 1972, Section 5-2	Transmitted force C 850 lbs	Same as NFPA 1977
Physical Penetration Resistance	NFPA 1972, Section 5-8	Penetration < 0.375 inches	Same as NFPA 1977
Electrical Current Leakage	ASTM F 1116 (modified)	Current leakage < 3 mA	Consistency with glove
Suspension System Separation	NFPA 1972, Section 5-15	Separation force > 5 lbs	Same as NFPA 1972/1977

Table 17 (Continued)

Basis of Recommended Performance Criteria for Technical Rescue Protective Clothing and Equipment

Performance Need	Test Method	Recommended Criteria	Basis for Criteria
Protective Helmet (Continued)			
Retention System Efficiency	NFPA 1977 design requirement	No failure after 20 operations	Same as NFPA 1977
Vibration Resistance	NFPA 1981, Section 3-10	No separation or damage	Same as NFPA 1981
Trim Retroreflectivity	ASTM E 809	CPL > 90 cp/ft-c/ft^2	Consistency with garment
Protective Goggles			
General Performance	ANSI 287.1	Series of requirements	Existing standard
Heat Resistance	NFPA 1971, Section 5-4 (modified)	No deformation > 25%, melting, or ignition	Consistency with helmet
Air-Purifying Respirator			
General Performance	29 CFR 134	Series of requirements	Existing standard
Ear Protectors			
General Requirements	ANSI S3.19	Series of requirements	Existing standard
Heat Resistance	NFPA 1971, Section 5-4	No melting, dripping, or ignition	Consistency with helmet

SWIFT WATER RESCUE ENSEMBLE REQUIREMENTS

The development of requirements for the swift water rescue ensemble was primarily based on the assessment of protection needs conducted in the early part of the project. There were few model documents to follow, except in the case of head protection and personal flotation devices. The American Society for Testing and Materials (ASTM) F32 Committee on Search and Rescue has established a draft standard for rescue helmets which appears to offer many of the performance objects set by the ERURC. Specifications for personal flotation devices are already set by the Coast Guard.

Full Body Dry Suit

The choice of a dry suit over a wet suit was predicated on two key reasons:

1. Many flooding situations involve water near freezing temperatures; and
2. Water may be contaminated by a number of substances such as sewage and chemicals.

Based on these needs, requirements were established addressing insulation of the garment along with limited protection for resistance to penetration by common chemical and biological challenges. At the same time, emergency responders recognize that much of their time may be spent on the surface, that is, outside of the flood. Use of “impermeable” materials can cause undue heat stress on responders. For this reason, the ERURC considered breathable dry suits as offering the advantages for insulation and barrier protection, while still providing a relatively high level of comfort.

A limited number of design requirements were considered necessary. These are suggested to address areas of garment construction which could not be specified through performance requirements. Design requirements are proposed for:

- areas of dry suit coverage;
- use of size adjustable wrist, ankle, and neck seals;
- closures which afford easy donning and doffing;
- prohibiting metal part or closure contact with the wearer’s body; and
- reinforcement of knee and elbow areas of the garment.

To assist in the development of garment material requirements, 12 materials were obtained, including both wet and dry suit material candidates, and were tested for key properties. One of the dry suit materials was a microporous film based product which offers some level of breathability. Several of materials traditionally used in contaminated water diving were also included to support related efforts in setting requirements for that type of ensemble. The twelve materials are described in Table 18. The emphasis of this testing was in performance areas where the ERURC had difficulty in assigning minimum performance limits, namely, material physical properties. Materials were evaluated for:

Table 18

Dry/Wet Suit Materials Selected for Evaluation

Material	Description	Application	Thickness (mil)	Unit Area Weight (osy)
DUI CP2OOX Heavy Duty Neoprene*	Black spongy fabric; internal neoprene coating	Dry suit material	90	38.14
DUI TLS Laminate*	Navy fabric with inner elastomer laver	Dry suit material	12	8.08
DUI Vector Laminate*	Black fabric with inner elastomer layer	Dry suit material	15	11.32
DuPont Polyethylene Coated Tyvek	Yellow coated nonwoven textile	Disposable material	5	2.10
Henderson Neoprene (3 mm)	Orange/pink spongy fabric	Wet suit material	98	18.22
Henderson Neoprene (6 mm)	Green/orange spongy fabric	Wet suit material	250	43.36
Kokatet Gore-Tex Laminate	Yellow fabric with microporous film	Breathable dry suit material	19	7.48
Kotatet Urethane Laminate	Aqua fabric with light plastic coating	Specialized dry suit material	7	4.97
Parkway Nylon II (l/8")	Black spongy fabric	Wet suit material	130	27.02
Parkway Nylon II (l/4")	Navy spongy fabric	Wet suit material	248	46.89
Viking Pro Vulcanized Rubber*	Red elastomer coated fabric	Dry suit material	47	35.56
Viking Heavy Duty Vulcanized Rubber*	Red elastomer coated fabric	Dry suit material	62	49.59

* Also considered as prospective material in contaminated water diving applications

- tensile strength;
- tear resistance;
- burst strength;
- abrasion resistance;
- puncture propagation tear (snag) resistance;
- puncture resistance; and
- cut resistance.

These results are shown in Tables 19-21.

The ERURC decided to use the Kokatet GoreTex material-based dry suit as a model for setting performance requirements. Those ERURC members experienced in swift water rescues found this garment to offer the appropriate balance of insulation, physical hazard resistance, and comfort. Minimum performance limits were therefore set to include this material's measured values. A composite table showing a comparison of recommended minimum values with each of the tested fabrics is shown in Table 22. However, one exception was applied to abrasion resistance. In the study approach, abrasion resistance was measured in terms of total mass lost and percent mass loss. The ERURC suggested that abrasion resistance be measured, instead, based on loss of barrier resistance. This means that material would first be abraded, and then subjected to a barrier test such as chemical or biopenetration resistance. If the barrier resistance was maintained, the material would be considered to "pass" the test.

Materials were not evaluated for chemical or bacterial resistance since the ERURC was able to establish a requirement objectively based on rescue mission profiles. In these cases, the suggested requirement is similar to that currently proposed for structural fire fighting gloves: no visual penetration within one hour for the following chemicals:

- AFFF concentrate;
- battery acid (37% w/w sulfuric acid);
- gasoline;
- hydraulic fluid; and
- swimming pool chlorine additive.

Similarly, the ERURC set a one hour limit for hold out of biological challenges. The recently adopted ASTM ES 22, ***Standard Test Method for Resistance of Protective Clothing Materials to Blood Borne Pathogen Using a Viral Penetration System,*** was adopted but modified to replace the bacteriophage challenge (viral model) with serratia (a bacterial model). The bacterial challenge was thought to be more representative of the biological hazards faced by responders in swift water rescue.

The last area investigated pertained to material insulation and breathability. Material total heat loss was measured using the test procedures established in Appendix B of NFPA 1971, ***Standard on Protective Clothing for Structural Fire Fighting.*** Results from this testing are shown in Table 23. In this testing, both the material's thermal resistance and average total heat loss were determined. The first measurement relates to how well the material acts as an insulator; the second demonstrates how effectively the material releases heat to

Table 19

Summary of Physical Property Test Results for Swift Water Rescue Garment Materials (Set I)

Material	Unit Area Weight (oz/yd^2)	Tensile Strength (lbs)		Tear Resistance (Ibs)	
		Warp	Fill	Warp	Fill
DUI CP2OOX Heavy Duty Neoprene	38.14	315	244	65.1	54.7
DUI TLS Trilaminate	8.08	310	262	13.2	10.5
DUI Vector Bilaminate	11.32	542	362	27.6	16.6
DuPont Polyethylene Coated Tyvek	2.10	44	50	6.5	14.6
Henderson Neoprene (3 mm)	18.22	96	94	25.3	24.8
Henderson Neoprene (6 mm)	43.36	121	89	25.9	32.1
Kokatet Gore-Tex	7.48	239	224	40.3	28.7
Kokatet Urethane Laminate	4.97	268	190	11.2	6.3
Parkway Nylon II (1/8”)	27.02	129	99	36.8	38.8
Parkway Nylon II (1/4”)	46.89	133	114	33.3	39.8
Viking Pro Vulcanized Rubber	35.56	226	175	65.2	48.1
Viking Heavy Duty Vulcanized Rubber	49.59	226	182	75.8	53.3

Tensile Strength Tests per ASTM D 751 (Grab Strength Technique)
Tear Resistance Tests per NFPA 1971, Section 5-5 (Trapezoidal Tear)

Table 20

Summary of Physical Property Test Results for Swift Water Rescue Garment Materials (Set II)

Material	Unit Area Weight (oz/yd^2)	Burst Strength (lb)	Abrasion Resistance Weight Loss (gm)			Abrasion Resistance Weight Loss (gm)		
			Warp Initial	Weight Loss	Percent Change	Fill Initial	Weight Loss	Percent Change
DUI CP2OOX Heavy Duty Neoprene	38.14	330	8.32	0.07	0.8	8.75	0.11	1.3
DUI TLS Trilaminate	8.08	423	2.92	0.01	0.3	2.97	0.03	1.0
DUI Vector Bilaminate	11.32	534	4.23	0.02	0.5	4.29	0.03	0.7
DuPont Polyethylene Coated Tyvek	2.10	100	*			*		
Henderson Neoprene (3 mm)	18.22	78	8.32	0.07	0.8	8.75	0.11	1.3
Henderson Neoprene (6 mm)	43.36	91	16.56	0.07	0.4	17.23	0.06	0.3
Kokatet Gore-Tex	7.48	301	2.97	0.36	12.2	2.94	0.38	12.9
Kokatet Urethane Laminate	4.97	245	1.84	0.04	2.2	1.85	0.02	1.1
Parkway Nylon II (l/8”)	27.02	112	10.66	0.08	0.8	10.21	0.06	0.6
Parkway Nylon II (l/4”)	46.89	118	18.35	0.13	0.7	17.35	0.23	1.3
Viking Pro Vulcanized Rubber	35.56	304	12.63	0.48	3.8	12.89	0.65	5.0
Viking Heavy Duty Vul. Rubber	49.49	304	18.32	0.62	3.4	17.92	0.59	3.3

Burst Strength Tests per ASTM D 751 (Ball Burst Technique)
Abrasion Resistance per ASTM D 4157 (Wyzenbeek): 5 lb head wt; 3.5 lb tension wt; 100 cycles; 80 grit abrandant
* Material wore completely through as result of abrasion

Table 21

Summary of Physical Property Test Results for Swift Water Rescue Garment Materials (Set III)

Material	Unit Area Weight (oz/yd^2)	Puncture Propagation Tear Resistance (lb)		Puncture Resistance (lb)	Cut Resistance (lb)
		Warp	Fill		
DUI CP200X Heavy Duty Neoprene	38.14	212.3	337.6	10.4	19.5
DUI TLS Trilaminate	8.08	9.9	11.9	13.2	10.0
DUI Vector Bilaminate	11.32	18.2	27.4	10.6	19.5
DuPont Polyethylene Coated Tyvek	2.10	13.7	7.2	1.1	NT
Henderson Neoprene (3 mm)	18.22	84.8	106.2	6.4	NT
Henderson Neoprene (6 mm)	43.36	105.6	145.3	6.3	NT
Kokatet Gore-Tex	7.48	11.8	19.7	6.4	10.5
Kokatet Urethane Laminate	4.97	7.7	9.6	4.7	8.0
Parkway Nylon II (1/8”)	27.02	99.1	177.6	5.1	9.5
Parkway Nylon II (1/4”)	46.89	138.0	303.8	6.0	14.0
Viking Pro Vulcanized Rubber	35.56	71.4	83.6	6.8	12.0
Viking Heavy Duty Vulcanized Rubber	49.59	91.0	117.5	7.2	12.0

Puncture Propagation Tear Resistance tests per ASTM D 2582
Puncture Resistance tests per ASTM F 1342
Cut Resistance tests per NFPA 1973. Section 3-7

Table 22

Comparison of Selected Dry/Wet Suit Materials with Recommended Material Performance Requirements

Material	Thermal Insulation (clo)	Total Heat Loss (W/m^2)	Tensile Strength* (lbs)	Tear Resistance* (lbs)	Snag Resistance (lbs)
Recommended Minimum Requirements	**0.120**	**450.0**	**150**	**20**	**11**
DUI CP200X Heavy Duty Neoprene	0.271	150.2	315/244	65.1/54.7	212.3/337.6
DUI TLS Laminate	0.084	216.4	310/262	13.2/10.5	9.9/11.9
DUI Vector Laminate	0.090	215.4	542/362	27.6/16.6	18.2/27.4
DuPont Polyethylene Coated Tyvek	NT	NT	44/50	6.5/14.6	13.7/7.2
Henderson Neoprene (3 mm)	NT	NT	96/94	25.3/24.8	84.8/106/2
Henderson Neoprene (6 mm)	NT	NT	121/89	25.9/32.1	105.6/145.3
Kokatet Gore-Tex Laminate	0.135	482.7	239/224	40.3/28.7	11.8/19.7
Kotatet Urethane Laminate	NT	NT	268/190	11.2/6/.3	7.7/9.6
Parkway Nylon II (1/8")	0.471	96.6	129/99	36.8/38.3	99.1/177.6
Parkway Nylon II (¼")	0.922	54.6	133/114	33.3/39.8	138.0/303.8
Viking Pro Vulcanized Rubber	0.116	199.0	226/175	65.2/48.1	71.4/83.6
Viking Heavy Duty Vulcanized Rubber	0.116	195.2	226/182	75.8/53.3	91.0/117.5

* First value given is property measured in machine direction/second value in cross machine direction
Shaded blocks meet recommended requirement

Table 23

Summary of Insulation and Total Heat Loss Test Results for Swift Water Rescue Garment Materials

Material	Unit Area Weight (oz/yd^2)	Thermal Resistance (m$^{2.0}$C/W)	Thermal Resistance (clo)	Permeability Index	Avg. Total Heat Loss (W/m^2)
DUI CP200X Heavy Duty Neoprene	38.14	0.042	0.271	0.041	150.2
DUI TLS Trilaminate	8.08	0.013	0.084	0.025	216.4
DUI Vector Bilaminate	11.32	0.014	0.090	0.030	215.4
DuPont Polyethylene Coated Tyvek	2.10	NT			
Henderson Neoprene (3 mm)	18.22	NT			
Henderson Neoprene (6 mm)	43.36	NT			
Kokatet Gore-Tex	7.48	0.021	0.135	0.345*	482.7
Kokatet Urethane Laminate	4.97	NT			
Parkway Nylon II (1/8”)	27.02	0.073	0.471	0.016	96.6
Parkway Nylon II (1/4”)	46.89	0.143	0.922	**	54.6
Viking Pro Vulcanized Rubber	35.56	0.018	0.116	0.028	199.0
Viking Heavy Duty Vulcanized Rubber	49.59	0.020	0.116	0.031	195.2

Total Heat Loss tests per NFPA 1971, Appendix B
* Calculated with isothermal data
** Evaporative resistance of material beyond capability of measuring device

the outside environment via sweat evaporation. The highest thermal insulations were obtained with wet suit materials. These materials were the thickest of all materials tested. On the other hand, the GoreTex based material showed by far the greatest total heat loss. The selected minimum requirements suggested for a garment specification are based on the results for the latter material.

Protective Gloves

The ERURC accepted major compromises in developing requirements for swift water rescue gloves. This compromise was recognizing that sufficient insulation for protecting hands from cold temperatures could not be achieved without a significant reduction in dexterity. The loss of dexterity would pose serious safety risks to responders, and was considered an unacceptable tradeoff. For this reason, no minimum insulation requirement was established. In fact, many of the glove products currently accepted for this application do not cover the entire hand. The preferred gloves are generally heavy duty water skiing gloves which provide a relatively large improvement in grip, allow good dexterity, and stay on the hands. Yet, these "open" style gloves freely permit contact with water. Notwithstanding the insulation loss, use of water skiing type gloves provides no protection from chemical or biological contaminants as required for the garment. One solution proposed to overcome this problem was the wearing of thin, tight-fitting rubber gloves underneath the water skiing type glove. This two glove combination would keep the hand dry and protected from chemicals or bacteria, without loss of wearer dexterity and grip. A series of requirements was therefore proposed by the ERURC following this thinking.

Design requirements were very limited, and simply addressed:

- areas of hand coverage;
- minimum interference with hand movement; and
- glove availability in a minimum of three separate sizes.

Recommended performance requirements include some of the same requirements for garment materials such a abrasion, chemical and bacterial penetration resistance. Other requirements were added to deal with:

- cut resistance;
- puncture resistance;
- dexterity; and
- grip.

The palm areas of three different gloves were evaluated for puncture resistance with the results given below:

Glove	Thickness (mil)	Puncture Force (lbs)
Thunderwear - Double Thick	60	8.7
Thunderwear' - Single Thick	30	4.8
Nevin Power Wrap	125	15.6

Of these, the ERURC was able to borrow minimum requirements from those developed for technical rescue with the exception of grip. The ERURC felt that a higher level of grip was needed while wearing gloves during swift water rescue. Whereas, the grip requirement for the technical rescue glove permit no degradation of grip worse than 80% of bare-handed capability, the specification for the swift water glove requires that the glove improve upon the bare-handed capability.

Dive Booties

Dive booties are intended to be part of the ensemble when the rescuer enters the water. Most emergency responders are likely to wear standard ankle support boots prior to this activity, and boots meeting the requirements of the technical rescue boot would be acceptable for this purpose. Dive booties may include the so called "aqua socks" used in sport activities. Unlike protective gloves, booties can be insulated to obtain some cold water protection without sacrifice of foot function. For this reason, booties use nearly all the same requirements as gloves plus the insulation requirement employed for the protective dry suit. One additional requirement is slip resistance for the bootie sole.

Swimming Fins

No specific requirements were developed for swimming fins which may be worn alone on the feet or in conjunction with dive booties. Guidance is suggested that recommends selection of shorter length fins to allow the wearer to walk relatively easier than with the standard length fins.

Vented Protective Helmet

As already stated, ASTM F32 Committee on Search and Rescue has prepared a draft standard, F32.01, ***Standard Practice for Testing Rescue Helmets,*** that provides a series of requirements defining their performance. Several tests are listed, including:

- vertical energy absorption;
- penetration (physical) resistance;
- middle frontal energy absorption; and
- helmet chin strap retention.

Performance limits are set for each of the test methods. In addition, certain design parameters are recommended such as:

- helmet ventilation;
- arrangement of the inner helmet harness;
- finish quality of shell; and
- overall helmet mass.

Since the ASTM draft standard provides two different options for providing helmet ventilation, ERURC members indicated a strong need that the helmet not collect water and that the helmet be vented by means of holes. To ensure this performance, a requirement was added to measure the rate of water drainage from the protective helmet.

One other supplemental requirement is that helmets not have a brim. Experienced swift water rescue personnel find that brims can provide a surface for rushing water to exert against.

Personal Flotation Device

Personal Flotation Devices (PFDs) are approved by the U.S. Coast Guard under 46 CFR 160. There are five types of PFDs for which different specifications apply:

Type	Description
I	Life preserver (off-shore life jacket)
II	Buoyant vest (near-shore buoyant vest)
III	Flotation aid
IV	Life ring buoys (throwable device) Buoyant cushions (throwable device)
V	Work vests (special use device)

PFDs are classified by their function and have different performance characteristics. The federal regulations specify needed performance for each type of PFD. Generally these requirements pertain to the overall weight, amount of buoyancy and the freedom of movement provided by the design.

ERURC members consider Type III or V PFD's to provide adequate floatation during most swift water rescue applications. One need specific to swift water rescue is for a harness or point of attachment that allows attachment of a life line. One design requirement was added for providing this means of attachment, while a performance requirement was recommended for the strength of the attachment point. The physical strength requirement of the attachment was based on the tensile strength required for descent device hardware, as taken from NFPA 1983, ***Standard on Life Safety Rope, Harnesses, and Hardware.***

Sheathed Knife

Knives are an important part of the swift water rescue protective ensemble. To prevent accidental injury under emergency conditions, they should have a single cutting edge and remain in a sheath that will hold the knife, even when inverted.

Whistle

ERURC members found two important features for a whistle:

1. They should be non-metallic. Metal whistles get colder faster than plastic whistles. They may also rust.

2. They should have no pall. The pall is the ball inside some whistles. Under certain water forces, the pall may dislodge and make the whistle inoperative.

Summary of Requirements

Table 24 provides a list of swift water rescue ensemble requirements for each specified clothing and equipment item. This table also summarizes the recommended criteria and describes the basis for its selection. Appendix B, Chapter 5 provides the list of recommended design and performance requirements.

Table 24

Basis of Recommended Performance Criteria for Swift Water Rescue Protective Clothing and Equipment

Performance Need	Test Method	Recommended Criteria	Basis for Criteria
Personal Flotation Device			
General Requirements	46 CFR 160	Type III or V	Exiting standard
Hardware Tensile Strength	NFPA 1983, Section	Tensile strength > 5000 lbs	Same as NFPA 1983
Hardware Corrosion Resistance	ASTM B 117	No corrosion after 24 hours	Same as NFPA 1983
Protective Dry Suit			
Overall Water-Tight Integrity	MIL-W-85365	No leakage	ERURC proposed criteria
Thermal Insulation	ASTM D 1518	Clo > 0.12	ERURC proposed criteria
Total Heat Loss	NFPA 1971, Appendix B	Total heat loss > 450 W/m^2	Same as NFPA 1977
Tensile Strength	ASTM D 1682	Tensile strength > 150.0 lbs	ERURC proposed criteria
Tear Resistance	NFPA 1971, Section 5-5	Tear strength > 20.0lbs	ERURC proposed criteria
Snag Resistance	ASTM D 2582	Puncture force > 11.0 lbs	Same as NFPA 1992
Abrasion Resistance	ASTM D 4157/F 903	No penetration after 200 cycles	ERURC proposed criteria
Cleaning Shrinkage Resistance	NFPA 1971, Section 5-9	Shrinkage < 3.0%	Same as NFPA 1977
Seam Strength	ASTM D 1683	Seam strength < 150 lbs	Consistency with base material
Closure Strength	ASTM D 751	Closure strength < 150 lbs	Consistency with seam strength
Chemical Penetration Resistance	ASTM F 903 (5 chemicals)	No penetration in one hour	Same as NFPA 1992
Bacterial Penetration Resistance	ASTM ES 22 (modified)	No penetration in one hour	ERURC proposed criteria

Table 24 (Continued)

Basis of Recommended Performance Criteria for Swift Water Rescue Protective Clothing and Equipment

Performance Need	Test Method	Recommended Criteria	Basis for Criteria
Chemical Retention Resistance	New test method	No observed chemical	ERURC proposed criteria
Hardware Corrosion Resistance	ASTM B 117	No corrosion after 24 hours	Same as NFPA 1971
Trim Retroreflectivity	ASTM E 809	CPL > 90 cp/ft-c/fi^2	Same as NFPA 1971/1977
Donning Efficiency	New test method	Donning time < 3 minutes	ERURC proposed criteria
Protective Gloves			
Overall Water-Tight Integrity	ASTM D 5151	No leakage	Same as NFPA 1999
Cut Resistance	NFPA 1973,Section 3-7	Cut force > 18 lbs	Same as NFPA 1973/1977
Puncture Resistance	ASTM F 1342	Puncture force > 1Olbs	Same as NFPA 1977
Abrasion Resistance	ASTM D 4157/F 903	No penetration after 200 cycles	Consistency with garment
Dexterity	NFPA 1973, Section 3-9	Gloved time < 120% bare-handed time	Same as NFPA 1973
Grip	NFPA 1973, Section 3-10	Glove capacity > 120% bare-handed capacity	ERURC proposed criteria
Chemical Penetration Resistance	ASTM F 903	No penetration in one hour	Consistency with garment
Bacterial Penetration Resistance	ASTM ES 22 (modified)	No penetration in one hour	Consistency with garment
Chemical Retention Resistance	New test method	No observed chemical	Consistency with garment
Hardware Corrosion Resistance	ASTM B 117	No corrosion after 24 hours	Consistency with garment
Closure Tensile Strength	New test method	Tensile strength > 50 lbs	ERURC proposed criteria

Table 24 (Continued)

Basis of Recommended Performance Criteria for Swift Water Rescue Protective Clothing and Equipment

Performance Need	Test Method	Recommended Criteria	Basis for Criteria
Protective Booties			
Overall Water-Tight Integrity	ASTM D 5151 (modified)	No leakage	Consistency with garment
Thermal Insulation	ASTM D 1518	Clo > 0.12	Consistency with garment
Cut Resistance	NFPA 1973, Section 3-7	Cut force > 18.0 lbs	Consistency with glove
Puncture Resistance	ASTM F 1342	Puncture force > 10.0 lbs	Consistency with glove
Abrasion Resistance	ASTM D 4157/F 903	No penetration after 200 cycles	Consistency with garment
Sole Slip Resistance	ASTM F 489	Friction coefficient > 0.75 (dry); > 0.5 (wet)	Proposed NFPA 1992 requirement
Chemical Penetration Resistance	ASTM F 903	No penetration in one hour	Consistency with garment
Bacterial Penetration Resistance	ASTM ES 22 (modified)	No penetration in one hour	Consistency with garment
Chemical Retention Resistance	New test method	No observed chemical	Consistency with garment
Hardware Corrosion Resistance	ASTM B 117	No corrosion after 24 hours	Consistency with garment
Closure Tensile Strength	New test method	Tensile strength > 50 lbs	Consistency with glove
Protective Vented Helmet			
General Performance	ASTM F32.01	Meets all requirements	Existing standard
Water ventilation	New test method	Drain time < 10 seconds	ERURC proposed criteria
Hardware Corrosion Resistance	ASTM B 117	No corrosion after 24 hours	Consistency with garment

CONTAMINATED WATER DIVING ENSEMBLE REQUIREMENTS

As discussed in previous chapters, contaminated water diving represents a unique extreme of potential hazards to the emergency responder. Most contaminated water diving protection research has been undertaken by the Navy. In their clothing development programs, they devised a suit-in-suit concept to minimize any contact of contaminated water with the diver. This suit used in conjunction with the Mark 12 Navy diving helmet and system of weights is likely too expensive and cumbersome for emergency responder applications. As with any protective applications, no one suit or ensemble will protect against all hazards, but in this case, the ERURC sought to define performance for a diving suit ensemble that would offer minimum protection in the majority of all responses.

Some of the work undertaken to support development of requirements for swift water rescue protective clothing enabled the recommendation of requirements for contaminated water diving protective clothing. In general, many of the same performance requirements were adopted; however, more rigorous minimum requirements were often set for the contaminated water diving application. One may argue that the physical environment is essentially the same. Similar hazards exist for abrasion, tearing, cuts, and punctures. Nevertheless, the consequence of failure in contaminated water diving is likely to be more severe as compared to swift water rescue: a puncture in a dry suit during a dive in contaminated water will result in direct exposure to the diver. Additionally, there is greater concern for chemical or biological agent exposure. Whereas penetration resistance was deemed adequate in swift water rescue, permeation resistance is appropriate for contaminated water diving. Lastly, the interfaces between protective items, such as:

- dry suit to helmet,
- dry suit to gloves, and
- dry suit to dive booties or boots,

are imperative for achieving overall diver protection.

Protective Dry Diving Suit

As determined by the ERURC, a protective dry diving suit must possess overall water-tight integrity. For this reason, a number of design attributes were considered important for achieving overall performance:

- Complete body coverage must be attained by the dry suit in combination with gloves, boots, and a helmet;
- Suit interfaces with other components (gloves, boots, and helmet) must be water-tight and mated for specific items;
- A single closure should allow easy suit entry and exit along the suit's shoulders;
- No contact of metal parts with diver should occur; and
- Suit knees and elbow should be reinforced with an extra layer of material.

Selected physical properties of contaminated water dry diving suit materials were evaluated along with those for swift water rescue protective dry suits. These results are shown in Tables 19-21. Of these, 5 were dry suit materials conventionally used in commercial diving applications (as opposed to sport diving). From the expertise and experience of the ERURC, the Viking Pro dry suit was set as the minimum protective dive suit capable of withstanding the physical hazards most likely encountered in contaminated water diving. Physical property requirements were therefore based on that assumption and are represented in Table 25.

As with the swift water protective dry suit, the same requirements for bacterial penetration resistance apply. Bacteria can only be transported through a material by means of a liquid. The increased concern for chemical contact should be met with a permeation resistance requirement. The ERURC suggests a requirement of no permeation breakthrough in one hour as the minimum performance for material barrier protection. This property was investigated in a limited permeation study with testing against 5 chemicals diluted to saturation in water:

- Acetone
- Dichloromethane
- Hexane
- Sulfuric Acid
- Toluene

These chemicals were selected from the 15 liquids listed in ASTM F 1001, ***Standard Guide on the Selection of Test Chemicals to Evaluate Protective Clothing Materials.*** Results for permeation testing against the five chemicals are provided in Table 26.

Recognizing some of the same problems that confront emergency responders in hazardous materials incidents, the listing of chemicals will determine which materials pass and which fail. The ERURC was faced with a decision on selecting a wide range of chemicals or chemicals likely to be encountered in diving situations. ASTM F 1001 includes a wide range of chemicals representing a variety of chemical classes and challenges. However, some chemicals are very volatile and will evaporate quickly (e.g. carbon disulfide). Some chemical are lighter than water and will float on the surface. Other chemicals have about the same specific gravity as water, becoming diluted as they mix with the water. Lastly, chemicals which are denser than water will sink and may remain concentrated. Table 27 examines these properties for ASTM F 1001 liquids.

After evaluating this information, the ERURC decided to establish its criteria that could be applied to limit the chemical list to those chemicals that are most likely to be encountered in contaminated water diving. Chemical were selected which:

- Have vapor pressures less than 250 mm Hg (chemicals with higher volatility will evaporate and not mix with water;

- Are not water reactive; and

Table 25

Comparison of Selected Diving Suit Materials with Recommended Material Performance Requirements

Material	Thermal Insulation (clo)	Tensile Strength* (lbs)	Burst Strength (psi)	Tear Resistance * (lbs)	cut Resistance (lbs)	Puncture Resistance (lbs)	Snag Resistance (lbs)
Recommended Minimum Requirements	**1.0****	**150**	**300**	**20**	**12.0**	**6.0**	**11.0**
DUI 0200X Heavy Duty Neoprene	0.271	315/244	330	65.1/54.7	19.5	10.4	212.3/337.6
DUI TLS Laminate	0.084	310/262	423	13.2/10.5	10.0	13.2	9.9/11.9
DU1 Vector Laminate	0.090	542/362	534	27.6/16.6	19.5	10.6	18.2/27.4
Fairprene Viton/Nylon/ Chlorobutyl	NT	158/152	306	NT	NT	NT	17.2/16.7
Viking Pro Vulcanized Rubber	0.116	226/175	304	65.2/48.1	12.0	6.8	71.4/83.6
Viking Heavy Duty Vulcanized Rubber	0.116	226/182	304	75.8/53.3	12.0	7.2	91.0/117.5

* First value given is property measured in machine direction/second value in cross machine direction
Shaded blocks meet recommended requirement
** Measured in conjunction with underwear material

Table 26

Summary of Chemical Permeation Resistance Test Results for Selected Contaminated Water Diving Dry Suit Materials

Material	Permeation Breakthrough Time in Minutes (Permeation Rate in ug/cm2min)				
	Acetone	Dichloromethane	Hexane	Sulfuric Acid	Toluene
DUI TLS Trilaminate	> 180	76-88 (0.48-0.56)	4-12 (5.4-13.0)	120 (0.34-11)	< 4-4 (6.5-16.0)
Fairprene Viton/Nylon Chlorobutyl Laminate	> 180	>180	> 180	> 180	> 180
Henderson Neoprene (6 mm)	8-12 (10-20)	8-12 (5.8-7.0)	(6.5:12.0)	> 180	>180
Parkway Nylon II (l/4")	84-96 (5.7-7.4)	12-16 (8.5-10.0)	24-32 (7.6-14.0)	> 180	8-44 (37-160)
Viking Pro Vulcanized Rubber	60-64 (1.7-2.1)	24-28 (5.7-6.4)	(35-140)	>180	12-16 (2.7-8.6)
Viking Heavy Duty Vulcanized Rubber	140-160 (0.19-0.29)	(3.3-3.8)	(17-72)	> 180	28-36 (2.9-3.3)

Permeation resistance testing per ASTM F 739, at 25°C for 3 hour period;
All chemicals diluted in distilled water at concentration of 25%

Table 27

Selected Properties of ASTM F 1001 Liquid Chemicals

Chemical	Class	Vapor Pressure* (mm Hg)	Specific Gravity*	Water Solubility* (Percent)	Hazards**
Acetone	Ketone	266	0.791	Miscible	Potentially harmful
Acetonitrile	Nitrile	73	0.783	Miscible	Toxic
Carbon Disulfide	Sulfur Compound	300	1.261	0.2	Toxic
Diethylamine	Amine	195	0.172	Miscible	Corrosive, Harmful
Dichloromethane	Chlor. Hydrocarbon	350	1.336	1.3	Harmful, Carcinogen
Dimethylformamide	Amide	2.7	0.945	Miscible	Harmful
Ethyl Acetate	Ester	76	0.901	8.7	Potentially harmful
Hexane	Hydrocarbon	124	0.659	0.014	Harmful
Methanol	Alcohol	97	0.792	Miscible	Toxic
Nitrobenzene	Nitrogen Compound	<< 1	1.203	Reacts	Toxic
Sodium Hydroxide	Inorganic Base	≅ 0	2.130	50	Highly corrosive
Sulfuric Acid	Inorganic Acid	<0.001	1.834	Miscible	Highly corrosive
Tetrachloroethylene	Chlor. Hydrocarbon	14	1.624	0.015	Harmful, Carcinogen
Tetrahydrofuran	Ether	145	0.888	Miscible	Harmful
Toluene	Aromatic	22	0.866	0.05	Harmful

* Properties at 20°C (75°F)

** Hazard classifications from Forsberg and Mansdorf, ***Quick Selection Guide to Chemical Protective Clothing,*** Van Nostrand Reinhold, New York, 1989

Chemicals in bold type selected for test battery

- Have measurable solubility or are miscible in water.

When these criteria are applied, the list is decreased from 15 to 11 chemicals. Since miscible chemicals have infinite solubility in water, an arbitrary volumetric concentration of 10 percent was chosen to represent the extreme exposure. It is possible that certain chemicals which have relatively large or small specific gravities may tend to "pool" either at the surface or water bottom. Nevertheless, the concentration for these chemicals is still likely to be low.

A number of requirements were expanded to address dry suit components. For example, both seams and closures are evaluated for strength. While the overall suit water-tight integrity is intended to assess the entire construction of the suit, the ERURC recommends seams and secondary materials be evaluated for chemical resistance. Seal areas which act as interfaces for either gloves, boots, or the helmet should meet a separate set of physical property requirements.

Protective Gloves

Many of the same requirements that apply to swift water rescue protective gloves were used for contaminated water diving protective gloves. Exceptions included:

- Allowing 2- and 3-fingered mitts in addition to 5-fingered gloves;
- Adding a minimum glove material insulation valve;
- Specifying an insulative inner liner for addition cold temperature protection;
- Requiring a positive mated interface to the dry suit;
- Lowering the grip requirement; and
- Replacing chemical penetration resistance with permeation resistance.

Protective Boots

The recommended protective dive boot specifications use many of the same requirements as for dry suit garments and gloves:

- thermal insulation;
- cut resistance;
- puncture resistance;
- abrasion resistance;
- chemical permeation resistance;
- bacterial penetration resistance; and
- chemical retention resistance.

A number of specific performance areas are suggested that are specific for boots, particularly pertaining to the boot sole:

- sole abrasion resistance;
- sole puncture resistance; and
- sole slip resistance.

Design requirements relate to boot coverage of the foot and ankle, availability of sixes, and metal part penetration through boot materiaIs.

Dry Suit Underwear

Dry suit underwear is strictly used for providing additional insulation. The only requirements which are recommended for this ensemble component involve material thermal insulation, material water absorption capacity, and garment areas of body coverage.

Other Equipment

The scope of the contract did not permit a full investigation -into the variety of supporting equipment used in contaminated water diving. However, Table 11 provides an extensive list of design and performance considerations for all the items expected to form part of the contaminated water protective diving ensemble.

Summary of Requirements

Table 28 gives a complete listing of all performance needs, selected test methods, and recommended criteria for each clothing and equipment item covered in this study. In addition, the basis for each requirement is stated.

Table 28

Basis of Recommended Performance Criteria for Contaminated Water Diving Protective Clothing and Equipment

Performance Need	Test Method	Recommended Criteria	Basis for Criteria
Protective Dry Suit			
Overall Water-Tight integrity	MIL-W-85365	No leakage	ERURC proposed criteria
Thermal Insulation	ASTM D 1518	Clo > 1.0 (with underwear)	ERURC proposed criteria
Tensile Strength	ASTM D 1682	Tensile strength > 150.0 lbs	ERURC proposed criteria
Tear Resistance	NFPA 197 1, Section 5-5	Tear strength > 40.0lbs	ERURC proposed criteria
Snag Resistance	ASTM D 2582	Puncture force > 60.01bs	ERURC proposed criteria
Burst Strength	ASTM D 751	Burst strength > 300 psi	ERURC proposed criteria
Abrasion Resistance	ASTM D 4157/D 751	Burst strength > 80% original value after 200 cycles	ERURC proposed criteria
Cut Resistance	NFPA 1973, Section 3-7	Cut force > 12.0 lbs	ERURC proposed criteria
Puncture Resistance	ASTM F 1342	Puncture force > 6.01 lbs	ERURC proposed criteria
Seam Strength	ASTM D 1683	Seam strength < 150 lbs	Consistency with base material
Closure Strength	ASTM D 751	Closure strength < 150 lbs	Consistency with seam strength
Chemical Permeation Resistance	ASTM F 739 (11 chemicals)	Breakthrough time > 1 hour	Same as NFPA 1991
Bacterial Penetration Resistance	ASTM ES 22 (modified)	No penetration in one hour	ERURC proposed criteria
Chemical Retention Resistance	New test method	No observed chemical	ERURC proposed criteria
Hardware Corrosion Resistance	ASTM B 117	No corrosion after 24 hours	Same as NFPA 1971

Table 28 (Continued)

Basis of Recommended Performance Criteria for Contaminated Water Diving Protective Clothing and Equipment

Performance Need	Test Method	Recommended Criteria	Basis for Criteria
Protective Gloves			
Overall Water-Tight Integrity	ASTM D 5151	No leakage	Consistency with garment
Thermal Insulation	ASTM D 1518	Clo > 1.0 (with liner)	Consistency with garment
Cut Resistance	NFPA 1973, Section 3-7	Cut force > 12 lbs	Consistency with garment
Puncture Resistance	ASTM F 1342	Puncture force > 6 lbs	Consistency with garment
Abrasion Resistance	ASTM D 4157/D 751	Burst strength > 80% original value after 200 cycles	Consistency with garment
Dexterity	NFPA 1973, Section 3-9	Gloved time < 120% bare-handed time	Same as NFPA 1973
Grip	NFPA 1973, Section 3-10	Glove capacity > 80% bare-handed capacity	Same as NFPA 1973
Chemical Permeation Resistance	ASTM F 739 (11 chemicals)	Breakthrough time > 1 hour	Consistency with garment
Bacteria1 Penetration Resistance	ASTM ES 22 (modified)	No penetration in one hour	Consistency with garment
Chemical Retention Resistance	New test method	No observed chemical	Consistency with garment
Hardware Corrosion Resistance	ASTM B 117	No corrosion after 24 hours	Consistency with garment
Protective Boots			
Overall Water-Tight Integrity	ASTM D 5151 (modified)	No leakage	Consistency with garment
Thermal Insulation	ASTM D 1518	Clo > 1.0 (with sock)	Consistency with garment
Upper Cut Resistance	NFPA 1973, Section 3-7	Cut force > 12.01 lbs	Consistency with garment

Table 28 (Continued)

Basis of Recommended Performance Criteria for Contaminated Water Diving Protective Clothing and Equipment

Performance Need	Test Method	Recommended Criteria	Basis for Criteria
Protective Boots (Continued)			
Upper Puncture Resistance	ASTM F 1342	Puncture force > 6.0 lbs	Consistency with garment
Upper Abrasion Resistance	ASTM D 4157/D 751	Burst strength > 80% original value after 200 cycles	Consistency with garment
Sole/Heel Abrasion Resistance	NFPA 1974, Section 4-1.9	NBS rating > 65	Same as NFPA 1974
Sole/Heel Puncture Resistance	NFPA 1974,Section 4-1.10	Puncture force > 272 lbs	Same as NFPA 1974
Sole Slip Resistance	ASTM F 489	Friction coefficient > 0.75 (dry); > 0.5 (wet)	Proposed NFPA 1991 requirement
Chemical Permeation Resistance	ASTM F 739	Breakthrough time > 1 hour	Consistency with garment
Bacterial Penetration Resistance	ASTM ES 22 (modified)	No penetration in one hour	Consistency with garment
Chemical Retention Resistance	New test method	No observed chemical	Consistency with garment
Hardware Corrosion Resistance	ASTM B 117	No corrosion after 24 hours	Consistency with garment
Dry Suit Underwear			
Thermal Insulation	ASTM D 1518	Clo > 0.8	ERURC proposed criteria
Water Absorption	ASTM D 1117	Percent absorption > 20%	ERURC proposed criteria

ADDITIONAL RESEARCH NEEDS

Many of the proposed requirements are based on similar requirements from other standards. In some cases, new requirements have been set based on "acceptably performing" garments already used in emergency response. Some requirements remain untried and may only be validated through field testing. The ERURC makes the following recommendations to help further the development of standards on urban search and rescue protective clothing:

1. ***Evaluate potential technical rescue garment liners for chemical penetration resistance, biopenetration resistance, and physical properties.*** Their inclusion in the suggested specifications was a relatively late addition as part of the garment requirements.

2. ***Construct prototype technical rescue garments and evaluate in field testing.*** There was no opportunity in the study to actually fabricate garments which meet the proposed requirements. Field tests of garments which are designed to meet these requirements would help validate their efficacy and identify any needed additions or changes.

3. ***Develop a performance requirement forfootwear ankle support.*** Many of the leading injuries for emergency responders are strains and sprains, often of the ankle. Close fitting boots can prevent ankle injuries, but currently, short of very specific sizing specifications, there is no way to require ankle support either via design or performance tests.

4. ***Assemble a complete technical rescue ensemble and evaluate infield triaIs by one or more of the proposed FEMA regional urban search and rescue response teams.*** Integration and overall protection issues cannot be addressed by specifications for individual clothing and equipment items. FEMA's establishment of regional response teams for urban search and rescue will require extensive outfitting or response personnel. This FEMA study should be tied to that effort by having at least one team acquire and evaluate the technical rescue ensemble.

5. ***Investigate swift water rescue glove designs which will afford greater hand insulation against cold water temperatures.*** The ERURC accepted the limitation of glove insulation in favor of maintaining greater hand dexterity and grip. A compromise was made for using a thin, lightweight glove underneath for barrier protection, but the two glove system still does not provide sufficient thermal insulation for the hand. New technology being considered in similar applications should be examined for possible relevance in this area.

6. ***Validate the new F32 standard on rescue helmets.*** The majority of helmet requirements for swift water rescue are based on the draft F32 standard. A number of new and modified test methods are proposed in this standard and should be validated through round robin testing.

7. ***Encourage the U.S. Coast Guard to allow modifications of personal flotation devices for incorporating life line attachment hardware.*** Current Coast Guard specifications do not allow putting hardware onto the personal flotation device for purposes of attaching a life line. While design and performance requirements are recommended for meeting this need, it is doubtful the Coast Guard would certify PFDs as compliant with federal specifications when modified to accept life line hardware.

8. ***Conduct a field trial with all swift water rescue ensemble protective clothing and equipment.*** Again, the entire ensemble should be evaluated under simulated use conditions to determine needed changes and the proper interface between clothing and equipment.

9. ***Further research dive suit material chemical resistance requirements to determine a suitable list of chemical challenges.*** While some findings were obtained in this study about different chemical challenges faced by contaminated water divers, more information is needed to set a realistic and practical battery of chemicals for evaluating dive suit materials.

10. ***Develop a series of requirements for diving support equipment beyond the clothing items covered in this study.*** A series of qualitative requirements have been developed for each and every item of the contaminated water diving protective ensemble. However, this study focused only on the clothing components of that ensemble. Further work is needed to compile existing specifications by the U.S. Navy and other sources for diving helmets, umbilicals, and dive equipment. The need for an integrated system of components requires close attention to and evaluation of alternative approaches.

11. ***Continue support for adoption of a standard for urban search and rescue protective ensembles with the National Fire Protection Association. The*** real product of this study are recommended requirements which hopefully and ultimately will become the foundation for an NFPA standard. As part of this effort, the NFPA has been petitioned for a new standard on protective clothing for urban search and rescue. As of December 1992, they have accepted this petition pending reorganization of the Technical Committee on Fire Service Protective Clothing and Equipment. In order for this goal to be achieved, the U.S. Fire Administration should continue its support and assistance in the standards development/approval process. This support could take the form of reinstituting the ERURC and soliciting their support on the responsible NFPA subcommittee.

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APPENDIX A

TEST PLANS FOR DEFINING URBAN SEARCH AND RESCUE PROTECTIVE CLOTHING PERFORMANCE

Study 1 - Technical Rescue Protective Garments

Objective: To establish performance levels for "acceptable" technical rescue clothing and determine tradeoffs between comfort and heat/flame resistance, wear/durability properties.

Materials: The ERURC has indicated that physical protection is foremost as balanced with comfort. Flame/heat resistance is desired but a secondary property. Materials will be selected to represent a range of acceptable and unacceptable clothing currently in use by the fire service for this application. For example, fire fighter turnout clothing may represent one extreme in maximum performance but offering little comfort. Prospective materials include different weaves and weights of Nomex, PBI/Kevlar, and FR Cotton. In addition, some prototype materials will be included. A total of 8-10 materials will be selected.

Test Methods:

Property Type	**Property**	**Test Method**	**Laboratory**
Heat/Flame Resistance	Thermal Protective Performance	NFPA 1971; Section 5-3	Biotherm
	Vertical Flame Resistance	FTMS 191A,5903	TRI
	Convective Heat Resistance	NFPA 1977; Section 3-3.4	Biotherm
	Radiant Protective Performance	NFPA 1977; Section 3-3.1	Biotherm
Comfort	Thermal Heat Loss	NFPA 1977; Section 3-3.5	KSU
Wear/Durability	Tensile Strength	ASTM D1682	TRI
	Tear Strength	NFPA 1971; Section 5-4	TRI
	Snag Resistance	ASTM D2582	TRI
	Abrasion Resistance	ASTM D4157	TRI

Study 2 - Technical Rescue Protective Gloves

Objective: To establish performance levels for "acceptable" technical rescue gloves using the preferred urban search and rescue gloves ("flight" gloves) as a model of acceptable performance.

Materials: The ERURC has indicated that flight gloves typically made out of Nomex material with a leather palm offer superior performance in meeting hand protection needs. These needs are primarily physical protection, followed by dexterityr (as a measure of comfort and function), and flame/heat resistance. Examples of traditional fire fighter gloves (with and without liners), proposed Wildland fire gloves, regular work gloves, and the flight gloves will be considered in this study. A total of 6-8 gloves will be evaluated.

Test Methods:

Property Type	Property	Test Method	Laboratory
Heat/Flame Resistance	Thermal Protective Performance	NFPA 1971; Section 5-3	Biotherm
	Vertical Flame Resistance	FTMS 191A,5903	TRI
	Conductive Heat Resistance	NFPA 1977; Section 3-3.4	Biotherm
Comfort	Dexterity	NFPA 1977; Section 6-3.10	Biotherm
Wear/Durability	Cut Resistance	NFPA 1977; Section 6-3.8	Biotherm
	Puncture Resistance	ASTM F1342	T R I
	Abrasion Resistance	ASTM D4157	T R I

Study 3 - Swiftwater Rescue Protective Dry Suits

Objective: To establish performance levels for swiftwater rescue dry suits that clearly eliminate conventional wet suits balancing physical, barrier, and comfort properties. The "model" product is a dry suit composed of a rugged textile in combination with a microporous "breathable" film.

Materials: Two conventional wet suit materials will be chosen including those made from neoprene and natural rubber. Similarly, typical dry suit materials will also be selected representing different textiles and thicknesses. Lastly, newer generation materials will be included in the selection of materials which involve "breathable", but water resistant layers.

Test Methods:

Property	**Test Method**	**Laboratory**
Thermal Heat Loss	NFPA 1977, Section 3-3.5	KSU
Tensile Strength	ASTM D751 (Grab)	TRI
Tear Resistance	NFPA 1971, Section 5-4	TRI
Snag Resistance	ASTM D2582	TRI
Cut Resistance	NFPA 1977, Section 6-3.8	Biotherm
Abrasion Resistance	ASTM D4157	TRI
Puncture Resistance	ASTM F1342	TRI
Water Penetration	ASTM D751 (Hydrostatic)	TRI
Chemical Penetration	ASTM F903, Procedure D 4 chemicals: gasoline, hydraulic fluid, battery acid, pool chlorine additive	TRI
Biological Penetration	ASTM F23.40.02(modifkd using E. Coli simulant)	TRI

Study 4 - Swiftwater Rescue Protective Gloves.

Objective: To establish performance levels for swiftwater rescue gloves in the area of physical properties and comfort only. The “model” product is a 1/8 inch Neoprene/nylon glove.

Materials: Three to four glove materials will be chosen to determine baseline performance. Selected glove materials will primarily be “sport” type gloves that emply different fabrics and constructions.

Test Methods:

Property	**Test Method**	**Laboratory**
Cut Resistance	NFPA 1977, Section 6-3.8	Biotherm
Abrasion Resistance	ASTM D4157	TRI
Puncture Resistance	ASTM F1342	TRI
Dexterity	NFPA 1977, Section 6-3.10	Biotherm
Grip	NFPA 1977, Section 6-3.11	Biotherm

Study 5 - Contaminated Water Diving Rescue Protective Dry Suit

Objective: To establish performance levels for contaminated water diving protective dive suits which define acceptable performance for barrier protection and physical durability/wear resistance. Emphasis in this study will be place on discriminating materials which clearly prevent chemical/biological permeation and resist physical hazards. The intent will be to show how conventional wet suit and dry suit material fail to offer adequate barrier and physical protection. Materials will also be evaluated for stiffness at various temperature.

Materials: Conventional wet and dry suit materials will be chosen including those used in sport and commercial applications. These materials are generally used by a limited number of manufacturers including Viking and DUI. Likely materials for this investigation will be a range of Neoprene and heavy duty vulcanized rubbers. Insulation values will be investigated using a standard underwear material.

Test Methods:

Property	**Test Method**	**Laboratory**
Thermal Heat Loss	NFPA 1977, Section 3-3.5	KSU
Tensile Strength	ASTM D751 (Grab)	TRI
Tear Resistance	NFPA 1971, Section 5-4	TRI
Snag Resistance	ASTM D2582	TRI
Cut Resistance	NFPA 1977, Section 6-3.8	Biotherm
Abrasion Resistance	ASTM D4157	TRI
Puncture Resistance	ASTM F1342	TRI
Water Penetration	ASTM 0751 (Hydrostatic)	TRI
Chemical Permeation	ASTM F739, 5 chemicals diluted to saturation in water: acetone, dichloromethane, hexane, sulfuric acid, and toluene	TRI
Biological Penetration	ASTM F23.40.02 (modified using E. Coli simulant)	TRI
Ease of Decontamination	Procedure to be developed	TRI

APPENDIX B

DRAFT STANDARD ON PROTECTIVE CLOTHING AND EQUIPMENT FOR URBAN SEARCH AND RESCUE

STANDARD ON PROTECTIVE CLOTHING AND EQUIPMENT FOR URBAN SEARCH AND RESCUE

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.

Information on referenced publications can be found in Chapter 8.

CHAPTER 1 ADMINISTRATION

1.1 Scope

1-1.1* This standard specifies minimum documentation, design criteria, performance criteria and test methods for protective clothing and equipment used in urban search and rescue.

1-1.2* This standard does not apply to protective clothing used for structural fire fighting, proximity fire fighting, wildlands fire fighting, and hazardous materials response.

1-1.3* This standard does not provide criteria for protection from radiological or cryogenic agents, hazardous chemicals, or flammable or explosive atmospheres.

1-1.4* This standard is not intended to be utilized as a detailed manufacturing or purchase specification, but can be referenced in purchase specifications as minimum requirements.

1.2 Purpose

1-2.1 The purpose of this standard is to provide minimum requirements for protective clothing and equipment items forming protective ensembles for technical rescue, swift water rescue, and contaminated water diving designed to minimize exposure to hazards encountered by urban search and rescue missions.

1-2.1.1 Hazards in technical rescue operations include physical hazards such as sharp objects or rough surfaces, flame impingement, and incidental contact with hazardous chemicals or blood borne pathogens.

1-2.1.2 Hazards in swift water rescue operations include physical hazards such as sharp objects or rough surfaces, loss of buoyancy, cold temperature exposure, and liquid contact with hazardous chemicals and biological agents.

1-2.1.3 Hazards in contaminated water diving operations include physical hazards such as sharp objects or rough surfaces, loss of buoyancy, cold temperature exposure, and liquid contact with hazardous chemicals and biological agents.

1-2.2 Controlled laboratory tests used to determine compliance with the performance requirements of this standard shall not be deemed as establishing performance levels for any situations to which personnel may be exposed.

1.3 Definitions

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction. * The "authority having jurisdiction" is the organization, office or individual responsible for "approving" equipment, an installation or a procedure.

Biological Agents. Biological materials that are capable of causing a disease or long term damage to the human body.

Body Fluids. Fluids that the body makes including, but not limited to, blood, semen, mucus, feces, urine, vaginal secretions, breast milk, amniotic fluid, cerebrospinal fluid, synovial fluid, and pericardial fluid.

Boot. A protective clothing item designed to protect the wearer's feet.

Bootie. A sock-like extension of the garment leg designed to protect the wearer's feet when worn in conjunction with an outer boot.

Certification/Certified. A system whereby a certification organization determines that a manufacturer has demonstrated the ability to produce a product that complies with the requirements of the standard, authorizes the manufacturer to use a label on listed products that comply with the requirements of this standard and establishes a follow-up program conducted by the certification organization as a check on the methods the manufacturer uses to determine compliance with the requirements of this standard.

Certification Organization. An independent, third party organization that determines product compliance with the requirements of this standard with a labeling/listing/follow-up program.

Compliant. Meeting or exceeding all applicable requirements of this standard.

Cryogenic Agents. Low temperature materials that are capable of causing acute or long term freeze bum damage to the human body.

Flammable or Explosive Atmospheres. Atmospheres containing substances or gases at concentrations that will bum or explode if ignited.

Follow-Up Program. The sampling, inspections, tests, or other measures conducted by the certification organization on a periodic basis to determine the continued compliance of labeled and listed products that are being produced by the manufacturer to the requirements of this standard.

Garment. An item of clothing that covers any part of the wearer's skin except accessory items like gloves or face protection devices.

Garment Closure. The garment component designed and configured to allow the wearer to enter (don) and exit (doff) the emergency medical garment.

Garment Closure Assembly. The combination of the garment closure and the seam attaching the garment closure to the garment, excluding any protective flap or cover.

Garment Label. A label affixed to the garment by the manufacturer containing general information, warnings, care, maintenance, or similar data. This garment label is not a certification organization's label or identifying mark.

Glove. A protective clothing item designed to protect the wearer's hands.

Glove Label. A label affixed to or imprinted on the glove by the manufacturer indicating compliance with this standard. This glove label is not a certification organization's label or identifying mark.

Hazardous Chemical. Any solid, liquid, gas or mixture thereof that can potentially cause harm to the human body through respiration, ingestion, skin absorption, or contact.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Liquid Borne Pathogen. An infectious bacteria or virus carried in human, animal or clinical body fluids, organs or tissues.

Listed.* Equipment or materials included in a list published by an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

Radiological Agents. Radiation associated with x-rays, alpha, and gamma emissions from radioactive isotopes or other material in excess of normal radiation background levels.

Seam. Any permanent attachment of two or more garment or glove materials, excluding external fittings, gaskets, and garment closure assemblies, in a line formed by joining the separate material pieces.

Shall. This term indicates a mandatory requirement.

Should. This term, as used in the Appendix, indicates a recommendation or that which is advised but not required.

[ABOVE SECTIONS TO BE DEVELOPED BY NFPA SUBCOMMITTEE]

1-4 Units

1-4.1 In this standard, values for measurement are followed by an equivalent in parentheses, but only the first stated value shall be regarded as the requirement. Equivalent values in parentheses shall not be considered as the requirement as these values might ‘be approximate.

CHAPTER 2 CERTIFICATION

2-1 General

2-1.1 Urban search and ‘rescue protective clothing and equipment that are labeled and listed as being compliant with this standard shall meet or exceed all applicable requirements specified in this standard and shall be certified.

2-1.2 All certifications shall be performed by a certification organization.

2-1.3 Compliant technical rescue protective clothing and equipment shall be labeled and listed. Such clothing and equipment shall also have a garment label that meets the requirements specified in Section 2-5 of this Chapter.

2-1.4 Compliant swift water rescue protective clothing and equipment shall be labeled and listed. Such clothing and equipment shall also have a glove label that meets the requirements specified in Section 2-6 of this Chapter.

2-1.5 Compliant contaminated water diving protective clothing and equipment shall be labeled and listed. Such clothing and equipment shall also have a face protection device label that meets the requirements specified on Section 2-7 of this Chapter.

2-2 Certification Program

2-2.1* The certification organization shall not be owned or controlled by manufacturers or vendors of the product being certified. The certification organization shall be primarily engaged in certification work and shall not have a monetary interest in the product’s ultimate profitability.

2-2.2 The certification organization shall refuse to certify products to this standard that do not comply with all applicable requirements of this standard.

2-2-3* The contractual provisions between the certification organization and the manufacturer shall specify that certification is contingent on compliance with all applicable requirements of this standard. There shall be no conditional, temporary, or partial certifications.

2-2.4* For certification, laboratory facilities and equipment for conducting proper tests shall be available, a program for calibration of al instruments shall be in place and operating, and procedures shall be in use to ensure proper control of all testing. Good practice shall be followed regarding the use of laboratory manuals, form data sheets, documented calibration and calibration routines, performance verification, proficiency testing and staff qualification and training programs.

2-2.5 Manufacturers shall be required to establish and maintain a program of production inspection and testing.

2-2.6 The manufacturer and the certification organization shall evaluate any changes affecting the form, fit or function of the certified product to determine its continued certification to this standard.

2-2.7* Product certifications shall include a follow-up inspection program, with at least 2 random and unannounced visits per 12 month period.

2-2.8 The certification organization shall have a program for investigating field reports alleging malperformance or failure of listed products.

2-2.9 The operating procedures of the certification organization shall provide a mechanism for the manufacturer to appeal decisions. The procedures shall include the presentation of information from both sides of a controversy to a designated appeals panel.

2-2.10 The certification organization shall be in a position to use legal means to protect the integrity of its name and label. The name and label shall be registered and legally defended.

2-3 Inspection and Testing

2-3.1 Sampling levels for testing and inspection shall be established by the certification organization and the manufacturer to assure a reasonable and acceptable reliability at a reasonable and acceptable confidence level that products certified to this standard are compliant. This information shall be included in the manufacturers technical data package.

2-3.2 Testing for determining material and component compliance with the requirements specified in Chapters 4,5, and 6 of this standard shall be performed on samples representative of materials and components used in the actual construction of urban search and rescue protective clothing and equipment. The certification organization shall also be permitted to use sample materials cut from representative clothing and equipment items.

2-3.3 Any combination of materials used in urban search and rescue protective clothing and equipment that is needed to meet any of the performance requirements specified in Chapters 4, 5, and 6 of this standard, shall also be required to meet all the requirements for that particular segment of the clothing or equipment item unless otherwise specified.

2-4 Manufacturer's Quality Assurance

2-4.1 The manufacturer shall provide and maintain a quality assurance program that includes a documented inspection and product recall system. The manufacturer shall. have an inspection system to substantiate conformance to this standard.

2-4.2 The manufacturer shall maintain written inspection and testing instructions. The instructions shall prescribe inspection and test of materials, work in process, and completed articles. Criteria for acceptance and rejection of materials, processes and final product shall be part of the instructions.

2-4.3 The manufacturer shall maintain records of all pass/fail tests. Pass/fail records shall indicate the disposition of the failed material or product.

2-4.4 The manufacturer's inspection system shall provide for procedures that assure the latest applicable drawings, specifications, and instructions are used for fabrication, inspection, and testing.

2-4.5 The manufacturer shall, as part of the quality assurance process, maintain a calibration program of all instruments used to ensure proper control of testing. The calibration program shall be documented as to the date of calibration, and performance verification.

2-4.6 The manufacturer shall establish and maintain a system for identifying the appropriate inspection status of component materials, work in process, and finished goods.

2-4.7 The manufacturer shall maintain a system for controlling non-conforming material, including procedures for the identification, segregation, and disposition of rejected material. All non-conforming materials or products shall be identified to prevent use, shipment, and intermingling with conforming materials or products.

2-4.8 The manufacturer's quality assurance systems and procedures shall be audited by the third party certification agency to determine that the system is sufficient to ensure continued compliance to this standard.

2-5 Technical Rescue Protective Clothing and Equipment Labelling

[TO BE DEVELOPED]

2-6 Swift Water Rescue Protective Clothing and Equipment Labelling

[TO BE DEVELOPED]

2-7 Contaminated Water Diving Protective Clothing and Equipment Labelling

[TO BE DEVELOPED]

CHAPTER 3 DOCUMENTATION REQUIREMENTS

3-1 Technical Data Package

[ABOVE SECTIONS TO BE DEVELOPED BY NFPA SUBCOMMITTEE]

CHAPTER 4 TECHNICAL RESCUE PROTECTIVE ENSEMBLE

4-l Protective Garment

4-1.1 Design Requirements

4-1.1.1 All collars shall remain upright after extension into a vertical position.

4-1.1.2 Protective garments shall not have turn-up cuffs. Sleeve cuffs shall have a closure system that can be adjusted to provide a snug and secure fit around the wrist while wearing a technical rescue glove.

4-1.1.3 Inseam lengths shall be provide in lengths from 26 to 35 inches in 1.0 inch increments or cut to order. Inseam length shall finish to lengths specified within tolerance of +0.5/-0.0 inches.

4-1.1.4 Patch pockets and upper torso inserted pockets shall have cover flaps with a closure system.

4-1.1.5 Pass through openings of coveralls or jumpsuits shall have a closure system that can be easily secured or opened by the wearer.

4-1.1.6 Bottoms of upper torso garments shall be flat without curving upwards at the side seams.

4-1.1.7 All hardware finish shall be free of rough spots, burrs, or sharp edges.

4-l.1.8 All snaps shall meet the requirements of MS 27980F Fastener, Snap.

4-1.1.9 All fastener tape shall beet the requirements of MIL-F-218406, Fastener Tapes, Hook and Pile, Synthetic.

4-1.1.10 All zippers shall meet the requirements of FED-V-F-106E, Fasteners, Interlocking, Slide.

4-1.1.11 All upper torso garments shall have a closure systems at the neckline.

4-1.1.12 One-piece garment torso closure systems shall be continuous from the top of crotch area to top of garment at neck.

4-1.1.13 Two-piece garments shall be designed to provide at least a 2 inch overlap when the wearer raises his or her arms above their head and during extended arm side stretches.

4-1.1.14 Any metallic closure systems shall not come in direct contact with the body.

4-1.1.15 Any metal components of the garments shall not come in direct contact with the body.

4-1.1.16 Garment knees and elbows shall be reinforced with an additional layer of material.

4-1.1.17 Protective garment trim shall have not less than 80 sq. in. (520 sq. cm) of fluorescent area.

4-1.2 Performance Requirements

4-1.2.1 Textile fabrics used for protective garments or protective garment composites shall have an average Radiant Protective Performance (RPP) of not less than 7.0 when tested as specified in Section 7-1 of this standard.

4-1.2.2 The composite of fabrics used in the construction of the protective garment shall have a thermal protective performance (TPP) of not less than 12.0 when tested as specified in Section 7-2 of this standard.

4-1.2.3 Textile fabrics and linings used for protective garments shall be individually tested for flame resistance and shall have an average char length of not more than 4 in. (108 mm), an average after-flame of not more than 2 seconds, and shall not melt or drip when tested as specified in Section 7-3 of this standard.

4-1.2.4 Textile fabrics and linings utilized in protective garments shall be individually tested for thermal shrinkage resistance and shall not shrink more than 10.0 percent in any direction when tested as specified in Section 7-4 of this standard.

4-1.2.5 Textile fabrics, linings, and other materials used in garment construction - including but not limited to padding, reinforcement, wristlets, collars, garment labels, hanger hooks, buttons, fasteners and closures, but excluding hook and pile fasteners and trim when not in direct contact with the skin - shall be individually tested for heat resistance in their original form and shall not melt, drip, separate, or ignite when tested as specified in Section 7-5 of this standard.

4-1.2.6 The composite of fabrics used for protective garments or protective garment composites shall have a total heat loss of not less than or equal to 450 W/m^2 when tested as specified in Section 7-6 of this standard.

4-1.2.7 Textile fabrics and linings used for protective garments shall be tested for tear resistance and shall have a tear resistance of not less than 8 lb (3.63 kg) when tested in as specified in Section 7-7 of this standard.

4-1.2.8 Outer textile fabric used for protective garments shall be tested for snag resistance and shall have a puncture propagation tear resistance of 11 lb (5.5 kg) when tested as specified in Section 7-8 of this standard.

4-1.2.9 Outer textile fabric used for protective garments shall be tested for abrasion resistance and shall show no wear through after 500 cycles when tested in as specified in Section 7-9 of this standard.

4-1.2.10 Textile fabrics and linings used for protective garments shall be individually tested for cleaning shrinkage resistance and shall not shrink more than 3.0 percent in any direction after five wash cycles when tested as specified in Section 7-10 of this standard.

4-1.2.11 The outer textile fabrics used for protective garments shall be individually tested for rate of static electric discharge and show a voltage of 350 volts or less, 5 seconds after termination of charge generation when tested as specified in Section 7-11 of this standard.

4-1.2.12 All seams shall demonstrate a sewn seam strength equal to or greater than that stipulated for each seam type listed below when tested as specified in Section 7-12 of this standard.

4 Composite or outer textile fabric seams shall have a minimum of either 80% seam efficiency of fabric strength or 125 lbs. force, whichever is lower.

b) Separate liner seams shall have a minimum of either 80% seam efficiency of fabric strength or 50 lbs., whichever is lower.

4-1.2.13 All closures shall be tested for crosswise strength and have a breaking strength of 125 lbs. force when tested as specified in Section 7-13 of this standard.

4-1.2.14 All thread used in protective garments shall be tested for heat resistance and shall not melt when tested as specified in Section 7-14 of this standard.

4-1.2.15 All metal hardware and hardware that includes metal parts shall be tested for corrosion resistance as specified in Section 7-15 of this standard. Metals inherently resistant to corrosion, including but not limited to stainless steel, brass, copper, aluminum, and zinc shall show no more than light surface-type corrosion or oxidation. Ferrous metals shall show no corrosion of the base metal.

4-1.2.16 Reflective trim used on protective garments shall be tested for coefficient or retroreflectivity (CPL) and shall have coefficient or retroreflectivity (CPL) of not less than 90 cp/ft-c/ft^2 when tested as specified in Section 7-15 of this standard.

4-1.2.17 Supplemental liners, if provided with the protective garment for chemical protection, shall show no chemical penetration when tested as specified in Section 7-17 of this standard.

4-1.2.18 Supplemental liners, if provided with the protective garment for biological fluid protection, shall show no viral penetration when tested as specified in Section 7-18 of this standard.

4-2 Protective Hoods

4-2.1 Design Requirements

4-2.1.1 The protective hood shall be designed to cover and provide the limited protection specified within this section to the head, face, and neck, which are not protected by the protective coat, helmet, or respirator facepiece.

4-2.1.2 The protective hood shall be designed to contact the sides of the respirator facepiece, when worn, to cover all exposed facial areas. The protective hood shall be designed so that it does not interfere with the proper use of respirator and the respirator facepiece-to-face seal, as specified by the respirator manufacturer.

4-2.1.3 The protective hood shall be designed so that it does not interfere with the proper use and fit of helmets, as specified by the helmet manufacturer.

4-2.2 Performance Requirements

4-2.2-1 The protective hood shall have a thermal protective performance (TPP) of not less than 12.0 when tested as specified in Section 7-2 of this standard.

4-2.2.2 The protective hood material(s), including labels, but excluding hook and pile fasteners and elastic when not placed in direct contact with the body, shall be individually tested for flame resistance and shall have an average char length of not more than 2.0 sec, and shall not melt or drip when tested as specified in Section 7-3 of this standard. Garment labels not meeting the specimen size requirements for the procedure specified in Section 7-3 of this standard shall be sewn to a support fabric of required size.

4-2.2.3 The protective hood material(s), including labels, but excluding hook and pile fasteners and elastic when not placed indirect contact with the body, shall be individually tested for thermal shrinkage and shall not shrink more than 10.0 percent in any direction when tested as specified in Section 7-4 of this standard.

4-2.2.4 The protective hood material(s), including labels, but excluding hook and pile fasteners and elastic when not placed in direct contact with the body, shall be individually tested for heat resistance and shall not melt, separate, or ignite when tested as specified in Section 7-5 of this standard.

4-2.2.5 The protective hood material(s) shall have a total heat loss of not less than or equal to 450 W/m^2 when tested as specified in Section 7-6 of this standard.

4-2.2.6 The protective hood material(s), including labels, but excluding hook and pile fasteners and elastic when not placed in direct contact with the body, shall be individually tested for cleaning shrinkage resistance and shall not shrink more than 5.0 percent in any direction when tested as specified in Section 7-10 of this standard.

4-2.2.7 The protective hood material(s) used for protective garments shall be individually tested for rate of static electric discharge and show a voltage of 350 volts or less, 5 seconds after termination of charge generation when tested as specified in Section 7-11 of this standard.

4-2.2.8 All thread utilized in the construction of the protective hood shall be tested for heat resistance and shall not ignite, melt, or char when tested as specified in Section 7-14 of this standard.

4-3 Protective Gloves

4-3.1 Design Requirements

4-3.1.1 Protective gloves shall be designed with a cut and puncture resistant palm area to minimize the effects of flame, heat, sharp or abrasive objects, hand tool operation and other hazards that are encountered during technical rescue. Protective gloves shall have a wristlet that allows the glove material to fit closely around the wearer's wrist.

4-3.1.2 Gloves shall be designed to minimally interfere with physical movement in the use of technical rescue tools and equipment.

4-3.1.3 Glove body shall be designed such that they are closely conforming or adjustable at the wrist and shall extend a minimum of 1.0 inch past the wrist crease.

4-3.1.4 In order to label or otherwise represent that a glove is compliant with the requirements of this standard, the manufacturer shall provide gloves in not less than five (5) separate and distinct sizes. The manufacturer shall provide the purchaser with the hand dimension ranges when measured as specified in Section 7-1 8A of this standard.

4-3.2 Performance Requirements

4-3.2.1 Outer glove materials shall have an average Radiant Protective Performance (RPP) of not less than 7.0 when tested as specified in Section 7-1 of this standard.

4-3.2.2 Glove material composites shall be tested for thermal protective performance and have an average TPP of not less than 12.0 when tested as specified in Section 7-2 of this standard.

4-3.2.3 Glove materials shall be tested for flame resistance and shall not melt or drip, shall not have any afterflame of more than 2.0 seconds, and shall not have any char length exceed 4.0in. (10.16 cm) when tested as specified in Section 7-3 of this standard.

4-3.2.4 Sample gloves shall be tested for heat resistance and shall not separate, melt, ignite or drip when tested as specified in Section 7-5 of this standard. The glove shall be measured in both length and width and shall not shrink more than 10 percent in either direction. The glove shall be measured form the tip of the middle finger to the bottom of the glove body and the width shall be from side to side. If the glove is made with a wristlet of a different material, the wristlet shall be measured separately.

4-3.2.5 Sample gloves shall be tested for conductive heat resistance and shall have a second degree bum time of not less than 7 seconds, and the pain time shall not be less than 4 seconds when tested as specified in Section 7-19 of this standard.

4-3.2.6 Glove palm materials shall be tested for cut resistance and shall not be cut through under an applied force of 18 lb. (8.2 kg) when tested as specified in Section 7-20 of this standard.

4-3.2.7 Glove palm materials shall be tested for puncture resistance and shall not puncture under an applied force of 10 lb. (4.6 kg.) average when tested as specified in Section 7-21 of this standard.

4-3.2.8 Sample gloves shall be tested for electrical conduction and any electrical leakage shall not exceed 3 milliamperes when tested as specified in Section 7-22 of this standard.

4-3.2.9 Outer glove palm materials shall be tested for abrasion resistance and shall show no wear through after 500 cycles when tested as specified in Section 7-9 of this standard.

4-3.2.10 Sample gloves shall be tested for dexterity. Dexterity test timing shall not exceed 120 percent of baseline time when tested as specified in Section 7-23 of this standard.

4-3.2.11 Sample gloves shall be tested for grip and have a weight pulling capacity shall not be less than 80 percent of the bare hand control values when gloves are tested as specified in Section 7-24 of this standard.

4-3.2.13 Supplemental liners, if provided with the protective glove for chemical protection, shall show no chemical penetration when tested as specified in Section 7-17 of this standard.

4-3.2.14 Supplemental liners, if provided with the protective glove for biological fluid protection, shall show no viral penetration when tested as specified in Section 7-18 of this standard.

4-3.2.15 Supplemental liners, if provided with the protective glove for overall water tight integrity, shall show no water penetration when tested as specified in Section 7-25 of this standard.

4-4 Protective Footwear

4-4.1 Design Requirements

4-4.1.1 Protective footwear shall be of the front lace configuration and consist of a sole with heel, upper, insole, and shank.

4-4.1.2 Protective footwear shall not be less than 8.0 in. (20.3 cm) in height when measured from the heel breast at the top of the welt line directly to the top line and eyebrow intersection as measured on sample lot size 9D or 9 medium.

4-4.1.3 Heel breast shall not be less than 0.5 in. (1.27 cm). Heel breasting angle shall not be less than 90 degrees nor more than 135 degrees.

4-4.1.4 Protective footwear shah have a toe cap not less than 2.0 in. (5.0 cm) from the front edge of the footwear.

4-4.1.5 Protective footwear shah be available in all the following sizes;

Mens:	5 - 13, including half sixes, and a minimum of 2 widths
Womens:	5 - 10, including have sizes, and a minimum of 2 widths

4-4.1.6 Manufacturers shall be required to be to establish and provide, upon requires, a size conversion chart for each model or style of protective footwear based on toe length, arch length, and food width as measured on the Bannock Foot Measuring Device.

4-4.1.7 Metal parts shall not penetrate from the outside into the inside at any point, unless covered.

4-4.1.8 When used, there shall be a minimum of four (4) metal stud hooks on each side of the eyebrow.

4-4.1.9 Eyelets, if used, shah be constructed of coated steel, solid brass, brass coated nickel or nickel.

4-4.2 Performance Requirements

4-4.2.1 Outer footwear materials shall have an average Radiant Protective Performance (RPP) of not less than 7.0 when tested as specified in Section 7-1 of this standard.

4-4.2.2 Footwear material composites shall be tested for thermal protective performance and have an average TPP of not less than 20.0 when tested as specified in Section 7-2 of this standard.

4-4.2.3 Footwear materials shall be tested for flame resistance and shall not melt or drip, shall not have any afterflame of more than 2.0 seconds, and shall not have any char length exceed 4.0 in. (10.16 cm) when tested as specified in Section 7-3 of this standard.

4-4.2.4 Footwear shall be tested for heat resistance as specified in Section 7-5 of this standard. No part of footwear, except laces, shah melt and all accessories shall remain functional.

4-4.2.5 Protective footwear upper shall be tested for abrasion resistance and shall show no wear through after 500 cycles when tested as specified in Section 7-9 of this standard.

4-4.2.6 Sample footwear shall be tested for conductive heat resistance and shall have a second degree bum time of not less than 7 seconds, and the pain time shall not be less than 4 seconds when tested as specified in Section 7-19 of this standard.

4-4.2.7 Protective footwear upper shall be tested for cut resistance and shall not be cut through with an applied force of 18 lb (8.2 kg) when tested as specified in Section 7-20 of this standard.

4-4.2.8 Protective footwear upper shall be tested for puncture and shall have a puncture force of at least 13.2 lbs when tested as specified in Section 7-21 of this standard.

4-4.2.9 Protective footwear sole and heel shall be tested for abrasion resistance and have an abrasion-resistance rating of not less than 65 NBS Index when tested as specified in Section 7-26 of this standard.

4-4.2.10 Protective footwear sole and heel shall be tested for penetration (physical) resistance and have a puncture force of not less than 272 lbs (123 kg) when tested as specified in Section 7-27 of this standard.

4-4.2.11 Protective footwear outersole shall be tested for flex fatigue resistance and shall not exceed 350% cut growth when tested as specified in Section 7-28 of this standard.

4-4.2.12 Protective footwear outersole shall be tested for slip resistance and show a friction coefficient of not less than 0.75 under dry conditions and 0.50 under wet conditions when tested as specified in Section 7-30 of this standard.

4-4.2.13 Protective footwear shall be tested for electrical conduction and any electrical leakage shall not exceed 3 milliamperes when tested as specified in Section 7-22 of this standard.

4-4.2.14 Metal parts of protective footwear shall be examined for corrosion resistance when tested as specified by Section 7-16 of this standard. Metals inherently resistant to corrosion, including but not limited to stainless steel, brass, copper, aluminum and zinc shall show no more than light surface type corrosion or oxidation. Ferrous metals shall show no corrosion of the base metals. Accessories shall remain functional.

4-4.2.15 Stud hooks shall have a minimum detachment strength of 66 lbf (30 kgf) when tested as specified in Section 7-29 of this standard.

4-4.2.16 Supplemental liners if provided with the protective footwear for chemical protection shall show no chemical penetration when tested as specified in Section 7-15 of this standard.

4-4.2.17 Supplemental liners if provided with the protective footwear for biological fluid protection shall show no viral penetration when tested as specified in Section 7-16 of this standard.

4-4.2.18 Supplemental liners, if provided with the protective footwear for overall water tight integrity, shall show no water penetration when tested as specified in Section 7-25 of this standard.

4-5 Protective Helmet

4-5.1 Design Requirements

4-5.1.1 All materials used in the construction of the helmet that are designed to come in contact with the wearer's head or skin shall be known to be nonirritating to normal skin.

4-5.. 1.2 The total mass of the complete helmet, exclusive of accessories, shall not exceed 1.43 lbs (0.65 kg).

4-5.1.3 Helmets shall be of either the hat type or the cap type. Hat type helmets shall have a full brim. Cap type helmets shall have no brim, but shall be permitted to include a peak.

4-5.1.4 Helmets of both types shall be designed to consist of a shell and a means of absorbing energy within the shell. Provisions shall be made for ventilation between the headband and the shell.

4-5.1.5 The shell shah be generally dome shaped. The area under the peak or the front of the brim shall be permitted. to be covered with a nonconducting, non-flammable, anti-glare material.

4-5.1.6 There shall be no openings penetrating the shell other than those provided by the manufacturer for mounting energy absorbing systems, retention systems, and accessories.

4-5.1.7 Headbands shall be provided and shall be removable and replaceable. Headbands shall be adjustable in at least l/8 hat size increments. The size range that can be accommodated shall be marked on a product label. When the headband is adjusted to the maximum designated size, there shall be sufficient clearance between the shell and the headband to provide ventilation.

4-5.1.8 A sweatband shall be provided that shall cover at least the forehead portion of the headband. Sweatbands shall be either removable and replaceable, or shall be integral with the headband.

4-5.1.9 Crown straps shall be provided and, when assembled, they shall form a cradle for supporting the helmet on the wearer's head. The crown straps shall be designed so that the distance between the top of the head and the underside of the shall be adjusted to less clearance that the manufacturer's requirements for that specific helmet.

4-5.1.10 Chin straps shall be provided and shall be attached to the helmet shell. Nape straps shall also be permitted. Both chin and nape straps shall not be less than 12.7 mm (0.5 in.) in width.

4-5.1.11 Helmets shah have retroreflective markings on the exterior of the shell. A minimum of 4 sq. inches (103 cm^2) retroreflective markings shall be visible when the helmet is viewed from either side or rear.

4-5.1.12 A face and neck shroud, when provided, shall meet the requirements specified in Section 4-2 of this standard.

4-5.1.13 Winter liners shall not be required, but shall be permitted to provided by the manufacturer.

4-5.1.14 Lamp brackets, when provided, shall be constructed of a suitable, material and design to properly hold the lamp.

4-5.1.15 Lamp power supplies shall provide power to sustain the lamp for a minimum of 2 hours.

4-5.1.16 Accessories shall be permitted to be mounted through the use of openings in the shell, when provided, shall be designed with an inner wall that shall extend below the electrical test line as determined in Section 7-22 of this standard.

4-5.1.17 The openings in helmet shells provide for mounting of accessories shall be permitted to be filled by gasketing or other means provided the helmet will continue to meet the requirements specified in Section 7-3 of this chapter.

4-5.1.18 Product labels and any other identification labels or markers used on shells shall be affixed without making holes through the shell and without the use of any metal parts or metallic labels.

4-5.1.19 Helmets must meet the appropriate requirements of ANSI Z89.1.

4-5.2 Performance Requirements

4-5.2.1 Helmets shall be tested for flame resistance and any afterflame shall not have a duration greater than 5.0 seconds when tested as specified in Section 7-3 of this standard.

4-5.2.2 Any anti-glare material, when used, shall be tested for flame resistance and any afterflame shall not have a duration grater than 5.0 seconds when tested as specified in Section 7-3 of this standard.

4-5.2.3 Helmets shall be tested for heat resistance and any deformation of the brim or peak shall not exceed 25 percent of its length when measured from junction of the crown with the brim or peak when tested as specified in Section 7-5 of this standard.

4-5.2.4 Helmets shall be tested for top impact resistance and shall transmit an average force of not more than 850 lb (3781 N) when tested as specified by Section 7-31 of this standard, No individual sample specimen shall transmit a force of more than 1000 lb (4450 N). Disengagement of, deformation of, or damage to the helmet shall or component parts shall not of itself constitute failure.

4-5.2.5 Helmets shall be tested for penetration (physical) resistance and any penetration shall not pierce the helmet shell be more that 3/8 in (9.5 mm) when tested as specified in Section 7-32 of this standard.

4-5.2.6 Helmets shall be tested for electrical insulation and any electrical leakage shall not exceed 3 milliamperes when tested as specified in Section 7-22 of this standard.

4-5.2.7 Helmets shall be tested for suspension system separation and the minimum force required to separate any individual attachment point of the suspension assembly from the helmet shell shall be no less than 5 lbs (2.27 kg) when tested as specified in Section 7-33 of this standard.

4-5.2.8 Helmets shall be tested for retention system and chin strap efficiency and shall show no failure when tested as specified in Section 7-34 of this standard.

4-5-2.9 Helmets and accessories shall be tested for vibration resistance and shall show no separation or damage when tested as specified in Section 7-35 of this standard.

4-5.2.9 Helmet retroreflective markings shall be tested for coefficient or retroreflectivity (CPL) and shall have coefficient or retroreflectivity (CPL) of not less than 90 $cp/ft\text{-}c/ft^2$ when tested as specified in Section 7-15 of this standard.

4-6 Protective Goggles

4-6.1 Goggles shall meet ANSI 287.1 requirements.

4-6.2 Goggles shall be tested for heat resistance and shall show no deformation greater than 25 percent and textile materials shall not melt or ignite when tested as specified in Section 7-5 of this standard.

4-7 Air-Purifying Respirator

4-7.1 If used, air purifying respirators shall be certified by the National Institute for Occupational Safety and Health for high efficiency particulate removal in accordance with 29 CFR 134.

4-8 Ear Protectors

4-8.1 Ear protectors shall meet ANSI S3.19 requirements.

4-8.2 Ear protectors shall not interfere the proper wearing or function of any other component of the technical rescue ensemble.

4-8.3 Ear protectors shall be tested for heat resistance and shall not melt, drip, or ignite when tested as specified in Section 7-5 of this standard.

CHAPTER 5 SWIFT WATERRESCUE PROTECTIVE ENSEMBLE

5-l Personal Flotation Device

5-1.1 Design Requirements

5-1.1.1 Personal flotation devices shall be Coast approved Type III or V approved.

5-1.1.2 Personal flotation devices shall be designed with a harness arrangement which allows the attachment of a lifeline.

5-1.2 Performance Requirement

5-1.2.1 The harness to lifeline point of attachment shall be tested for tensile strength and have a tensile strength of 5000 lbs (2270 kg).

5-1.2.2 All metal hardware and hardware that includes metal parts shall be tested for corrosion resistance as specified in Section 7-15 of this standard. Metals inherently resistant to corrosion, including but not limited to stainless steel, brass, copper, aluminum, and zinc shall show no more than light surface-type corrosion or oxidation. Ferrous metals shall show no corrosion of the base metal.

5-2 Protective Dry Suit

5-2.1 Design Requirements

5-2.1.1 The dry suit shall be constructed such that it covers the wearer's body including torso, arms, wrists, legs, and ankles.

5-2.1.2 Neck, wrist, and ankle seals fabricated from elastomeric material shall be provided. These seals shall be adjustable to size of the wearing by trimming.

5-2.1.3 Wrist and Ankle openings shall provide a means that allow securing loose material at the opening close around the wrist or ankle.

5-2.1.4 The dry suit shall have a closure that allow easy donning and doffing.

5-2.1.5 Any metallic closure systems shall not come in direct contact with the body.

5-2.1.6 Any metal components of the protective dry suits shall not come in direct contact with the body.

5-2.1.7 Protective dry suit knees and elbows shall be reinforced with an additional layer of material.

5-2.1.8 Pockets on the outside of the protective dry suit, which are not water tight, shall have a means of drainage.

5-2.1.9 Protective dry suit trim shall have not less than 80 sq. in. (520 sq. cm) of fluorescent area.

5-2.2 Performance Requirements

5-2.2.1 Complete protective dry suits shall be tested for overall water tight integrity and show no leakage when tested as specified in Section 7-36 of this standard.

5-2.2.2 Protective dry suit materials shall be tested for thermal insulation and shall have a clo value of 0.12 or greater when tested as specified in Section 7-37 of this standard.

5-2.2.2 Protective dry suit materials shall have a total heat loss of not less than or equal to 450 W/m^2 when tested as specified in Section 7-6 of this standard.

5-2.2.3 Protective dry suit materials shah be tested for tensile strength and shall have a tensile strength of not less than 150 lb (68.1 kg) when tested in as specified in Section 7-38 of this standard.

5-2.2.4 Protective dry suit materials shall be tested for tear resistance and shall have a tear resistance of not less than 20 lb (8.0 kg) when tested in as specified in Section 7-39 of this standard.

5-2.2.5 Protective dry suit materials shall be tested for snag resistance and shah have a puncture propagation tear resistance of not less than 11 lb (5.0 kg) when tested in as specified in Section 7-8 of this standard.

5-2.2.6 Protective dry suit materials shall be tested for abrasion resistance and shall have a abrasion resistance of not less than 200 cycles when tested in as specified in Section 7-9 of, this standard.

5-2.2.7 Protective dry suit materials shall be individually tested for cleaning shrinkage resistance and shall not shrink more than 3.0 percent in any direction after five wash cycles when tested as specified in Section 7-10 of this standard.

5-2.2.8 All seams shall be tested for strength and shall demonstrate a sewn seam strength of 150 lbs (68.1 kg) or greater when tested as specified in Section 7-12 of this standard.

5-2.2.9 All closures shall be tested for crosswise strength and have a breaking strength of 150 lbs (68.1 kg) force when tested as specified in Section 7-13 of this standard.

5-2.2.10 Protective dry suit materials shall be tested for chemical protection and shall show no chemical penetration when tested as specified in Section 7-17 of this standard.

5-2.2.11 Protective dry suit materials shall be tested for biological fluid protection and shall show no bacterial penetration when tested as specified in Section 7-41 of this standard.

5-2.2.12 Protective dry suit materials shall be tested for chemical retention and retain no chemical retainage when tested as specified in Section 7-42 of this standard.

5-2.2.13 All metal hardware and hardware that includes metal parts shall be tested for corrosion resistance as specified in Section 7-15 of this standard. Metals inherently resistant to corrosion, including but not limited to stainless steel, brass, copper, aluminum, and zinc shall show no more than light surface-type corrosion or oxidation. Ferrous metals shall show no corrosion of the base metal.

5-2.2.14 Reflective trim used on protective dry suits shall be tested for coefficient or retroreflectivity (CPL) and shall have coefficient or retroreflectivity (CPL) of not less than 90 cp/ft-c/ft^2 when tested as specified in Section 7-15 of this standard.

5-2.2.15 Protective dry suits shall be evaluated for donning efficiency and shall be donned within 3 minutes when evaluated as specified in Section 7-43 of this standard.

5-3 Protective Gloves

5-3.1 Design Requirements

5-3.1.1 Protective gloves shall be of a five-fingered design.

5-3.1.2 Gloves shall be designed to minimally interfere with physical movement in the use of swift water rescue tools and equipment.

5-3.1.3 Glove body shall be designed such that they are closely conforming or adjustable at the wrist and shall extend a minimum of 1.0 inch past the wrist crease.

5-3.1.4 In order to label or otherwise represent that a glove is compliant with the requirements of this standard, the manufacturer shall provide gloves in not less than three (3) separate and distinct sizes. The manufacturer shall provide the purchaser with the hand dimension ranges when measured as specified in Section 7-18A of this standard.

5-3.2 Performance Requirements

5-3.2.1 Sample glove liners shall be tested for overall water-tight integrity and shall show no leakage when tested as specified in Section 7-25 of this standard.

5-3.2.2 Glove materials shall be tested for cut resistance and shall not be cut through under an applied force of 18 lb. (8.2 kg) when tested as specified in Section 7-20 of this standard.

5-3.2.3 Glove materials shall be tested for puncture resistance and shall not puncture under an applied force of 10 lb. (4.6 kg.) average when tested as specified in Section 7-21 of this standard.

5-3.2.4 Outer glove materials shall be tested for abrasion resistance and shall show no wear through after 200 cycles when tested as specified in Section 7-9 of this standard.

5-3.2.5 Sample gloves shall be tested for dexterity. Dexterity test timing shall not exceed 120 percent of baseline time when tested as specified in Section 7-23 of this standard.

5-3.2.6 Sample gloves shall be tested for grip and have a weight pulling capacity shall not be less than 120 percent of the bare hand control values when gloves are tested as specified in Section 7-24 of this standard.

5-3.2.7 Glove liner materials shall be tested for chemical protection and shall show no chemical penetration when tested as specified in Section 7-17 of this standard.

5-3.2.8 Glove liner materials shall be tested for biological fluid protection and shall show no bacterial penetration when tested ‘as specified in Section 7-41 of this standard.

5-3.2.9 Glove materials shall be tested for chemical retention and retain not more than 100 ppm chemical when tested as specified in Section 7-42 of this standard.

5-3.2.10 All metal hardware and hardware that includes metal parts shall be tested for corrosion resistance as specified in Section 7-15 of this standard. Metals inherently resistant to corrosion, including but not limited to stainless steel, brass, copper, aluminum, and zinc shall show no more than light surface-type corrosion or oxidation. Ferrous metals shall show no corrosion of the base metal.

5-3.2.11 Glove closure systems shall be tested for tensile and shear strengths and shall show strengths of 50 lbs. (22.7 kg) or greater when tested as specified in Section 7-44 of this standard.

5-4 Protective Booties

5-4.1 Design Requirements

5-4.1.1 Protective booties shall not be less than 8.0 in. (20.3 cm) in height when measured from the bottom of the sole.

5-4.1.2 Protective booties shall be available in a minimum of 5 sizes.

5-4.1.3 Metal parts shall not penetrate from the outside into the inside at any point, unless covered.

5-4.1.4 Protective booties shall accommodate the wearing of swimming fins.

5-4.2 Performance Requirements

5-4.2.1 Protective booties shall be tested for overall water tight integrity, shall show no water penetration when tested as specified in Section 7-25 of this standard.

5-4.2.2 Bootie materials shall be tested for thermal insulation and shall have a clo value of 0.12 or greater when tested as specified in Section 7-37 of this standard.

5-4.2.3 Bootie materials shall be tested for cut resistance and shall not be cut through under an applied force of 18 lb. (8.2 kg) when tested as specified in Section 7-20 of this standard.

5-4.2.4 Bootie materials shall be tested for puncture resistance and shall not puncture under an applied force of 10 lb. (4.6 kg.) average when tested as specified in Section 7-21 of this standard.

5-4.2.5 Outer bootie materials shah be tested for abrasion resistance and shall show no wear through after 200 cycles when tested as specified in Section 7-9 of this standard.

5-4.2.6 Protective bootie outersoles shall be tested for slip resistance and show a friction coefficient of not less than 0.75 under dry conditions and 0.50 under wet conditions when tested as specified in Section 7-30 of this standard.

5-4.2.7 Protective bootie materials shall be tested for chemical protection shah show no chemical penetration when tested as specified in Section 7-15 of this standard.

5-4.2.8 Protective bootie materials shall be tested for biological fluid protection shah show no bacterial penetration when tested as specified in Section 7-16 of this standard.

5-4.2.9 Protective bootie materials shall be tested for chemical retention and retain not more than 100 ppm chemical when tested as specified in Section 7-42 of this standard.

5-4.2.10 All metal hardware and hardware that includes metal parts shall be tested for corrosion resistance as specified in Section 7-15 of this standard. Metals inherently resistant to corrosion, including but not limited to stainless steel, brass, copper, aluminum, and zinc shall show no more than light surface-type corrosion or oxidation. Ferrous metals shall show no corrosion of the base metal.

5-4.2.11 Protective bootie closure systems shall be tested for tensile and shear strengths and shall show strengths of 50.0 lbs (22.7 kg) or greater when tested as specified in Section 7-44 of this standard.

5-5 Protective Helmet

5-5.1 Design Requirements

5-5.1.1 Protective helmets shall meet the requirements of ASTM F32 (draft).

5-5.1.2 Protective helmets shall not have a brim.

5-5.2 Performance Requirements

5-5.2.1 Protective helmets shall be tested for water ventilation and shall drain within 10 seconds when tested as specified in Section 7-45.

5-5.2.2 All metal hardware and hardware that includes metal parts shall be tested for corrosion resistance as specified in Section 7-15 of this standard. Metals inherently resistant to corrosion, including but not limited to stainless steel, brass, copper, aluminum, and zinc shall show no more than light surface-type corrosion or oxidation. Ferrous metals shall show no corrosion of the base metal.

5-6 Knife

5-6.1 Knives shall be single edged.

5-6.2 Knife sheaths shall have a means for securing the knife in the sheath when the sheath and knife are inverted.

5-7 Whistle

5-7.1 Whistles shall be non-metallic.

5-7.2 Whistles shall have no pall.

CHAPTER 6 CONTAMINATED WATERDIVING PROTECTIVE ENSEMBLE

6-1 Protective Dry Suit

6-1.1 Design Requirements

6-1.1.1 The dry suit shall be constructed such that it covers the wearer's body including torso, arms, wrists, legs, and ankles.

6-1.1.2 The dry suit shall be outfitted with means of interfacing other clothing and equipment items, including but not limited to gloves, boots, and helmet. The provided interfaces shall be water-tight as determined in Section 6-1.2.1 of this standard.

6-1.1.3 If wrist, ankle, or neck seals are used, these shall be fabricated from elastomeric material shall be provided. These seals shall be adjustable to size of the wearing by trimming.

6-1.1.4 The dry suit shall have a closure which allow entry of the suit through the shoulders. The length of the closure shall be sufficient to permit easy donning and doffing.

6-1.1.5 Any metallic closure systems shall not come in direct contact with the body.

6-l. 1.6 Any metal components of the protective dry suits shall not come in direct contact with the body.

6-1.1.7 Protective dry suit knees and elbows shall be reinforced with an additional layer of material.

6-1.2 Performance Requirements

6-1.2.1 Complete protective dry suits shall be tested for overall water tight integrity and show no leakage when tested as specified in Section 7-36 of this standard.

6-1.2.2 Protective dry suit materials, except wrist, ankle, or neck seal materials, in conjunction with underwear materials, shall be tested for thermal insulation and shall have a clo value of 1.0 or greater when tested as specified in Section 7-37 of this standard.

6-1.2.3 Protective dry suit materials, except wrist, ankle, or neck seal materials, shall be tested for tensile strength and shall have a tensile strength of not less than 150 lb (68.1 kg) when tested in as specified in Section 7-38 of this standard.

6-1.2.4 Protective dry suit materials, except wrist, ankle, or neck seal materials, shall be tested for tear resistance and shall have a tear resistance of not less than 40 lb (18.1 kg) when tested in as specified in Section 7-39 of this standard.

6-1.2.5 Protective dry suit materials, except wrist, ankle, or neck seal materials, shall be tested for snag resistance and shall have a puncture propagation tear resistance of not less than 60 lb (27.2 kg) when tested in as specified in Section 7-8 of this standard.

6-1.2.6 Protective dry suit materials, except wrist, ankle, or neck seal materials, shall be tested for burst strength and shall have a burst strength of 300 psi (21.0 kg/cm^2) when tested as specified in Section 7-40 of this standard.

6-1.2.7 Protective dry suit materials, except wrist, ankle, or neck seal materials, shall be tested for abrasion resistance and shall have a abrasion resistance of not less than 200 cycles when tested in as specified in Section 7-9 of this standard.

6-1.2.8 Protective dry suit material shall be tested for cut resistance and shall have a cut resistance of 12.0lb (5.4 kg) when tested as specified in Section 7-20 of this standard.

6-1.2.9 Protective dry suit material shall be tested for puncture resistance and shall have a puncture resistance of 6.0 lb (2.7 kg) when tested as specified in Section 7-21 of this standard.

6-1.2.10 All seams shall be tested for strength and shall demonstrate a sewn seam strength of 150 lb (68.1 kg) or greater.

6-1.2.11 All closures shall be tested for crosswise strength and have a breaking strength of 50 lb (22.7) force when tested as specified in Section 7-13 of this standard.

6-1.2.12 Protective dry suit materials shall be tested for chemical protection and shall show breakthrough times of one hour or greater when tested as specified in Section 7-45 of this standard.

6-1.2.13 Protective dry suit materials shall be tested for biological fluid protection and shall show no bacteria penetration when tested as specified in Section 7-40 of this standard.

6-1.2.14 Protective dry suit materials shall be tested for chemical retention and retain not more than 100 ppm chemical when tested as specified in Section 7-41 of this standard.

6-1.2.15 All metal hardware and hardware that includes metal parts shall be tested for corrosion resistance as specified in Section 7-15 of this standard. Metals inherently resistant to corrosion, including but not limited to stainless steel, brass, copper, aluminum, and zinc shall show no more than light surface-type corrosion or oxidation. Ferrous metals shall show no corrosion of the base metal.

6-2 Protective Gloves

6-2.1 Design Requirements

6-2.1.1 Protective gloves shall be of two, three, or five-fingered designs.

6-2.1.2 Protective gloves shall be designed to minimize the effects of sharp or abrasive objects, hand tool operation and other hazards that are encountered during contaminated water diving.

6-2.1.3 Gloves shall be designed to minimally interfere with physical movement in the use of contaminated water diving tools and equipment.

6-2.1.4 Gloves shall extend a minimum of 1.0 inch past the wrist crease.

6-2.1.5 Gloves shall be designed such that they can mate directly to the dry suit with the interface providing water-tight integrity as determined by Section 6-2.2.1.

6-2.1.6 An inner insulative glove shall be provided.

6-2.1.7 In order to label or otherwise represent that a glove is compliant with the requirements of this standard, the manufacturer shall provide gloves in not less than three (3) separate and distinct sixes. The manufacturer shall provide the purchaser with the hand dimension ranges when measured as specified in Section 7-18A of this standard.

6-2.2 Performance Requirements

6-2.2.1 Sample gloves shall be tested for overall water-tight integrity and shall show no leakage when tested as specified in Section 7-25 of this standard.

6-2.2.2 Glove materials in conjunction with insulative liner shall be tested for thermal insulation and shall have a clo value of 1.0 or greater when tested as specified in Section 7-37 of this standard.

6-2.2.3 Glove materials shah be tested for cut resistance and shall not be cut through under an applied force of 12 lb (5.4 kg) when tested as specified in Section 7-20 of this standard.

6-2.2.4 Glove materials shall be tested for puncture resistance and shall not puncture under an applied force of 6 lb (2.7 kg) average when tested as specified in Section 7-21 of this standard.

6-2.2.5 Outer glove materials shall be tested for abrasion resistance and shall show no wear through after 200 cycles when tested as specified in Section 7-9 of this standard.

6-2.2.6 Sample gloves shall be tested for dexterity. Dexterity test timing shall not exceed 140 percent of baseline time when tested as specified in Section 7-23 of this standard.

6-2.2.7 Sample gloves shall be tested for grip and have a weight pulling capacity shall not be less than 80 percent of the bare hand control values when gloves are tested as specified in Section 7-24 of this standard.

6-2.2.8 Protective glove materials shall be tested for chemical protection and shall show breakthrough times of one hour or greater when tested as specified in Section 7-44 of this standard.

6-2.2.9 Glove materials shall be tested for chemical retention and retain not more than 100 ppm chemical when tested as specified in Section 7-41 of this standard.

6-2.2.10 All metal hardware and hardware that includes metal parts shall be tested for corrosion resistance as specified in Section 7-15 of this standard. Metals inherently resistant to corrosion, including but not limited to stainless steel, brass, copper, aluminum, and zinc shall show no more than light surface-type corrosion or oxidation. Ferrous metals shall show no corrosion of the base metal.

6-3 Protective Boots

6-3.1 Design Requirements

6-3.1.1 Protective boots shall be designed to minimize the effects of sharp or abrasive objects, hand tool operation and other hazards that are encountered during contaminated water diving.

6-3.1.2 Protective boots shall not be less than 8.0 in. (20.3 cm) in height when measured from the heel breast.

6-3.1.3 Protective boots shah be designed such that they can mate directly to the dry suit with the interface providing water-tight integrity as determined by Section 6-3.2.1.

6-3.1.4 An inner insulative sock shall be provided.

6-3.1.5 The manufacturer shall provide boots in not less than three (3) separate and distinct sizes.

6-3.1.6 Metal parts shall not penetrate from the outside into the inside at any point, unless covered.

6-3.2 Performance Requirements

6-3.2.1 Sample boots shall be tested for overall water-tight integrity and shall show no leakage when tested as specified in Section 7-25 of this standard.

6-3.2.2 Boot materials in conjunction with the insulative sock shall be tested for thermal insulation and shall have a clo value of 1.0 or greater when tested as specified in Section 7-37 of this standard.

6-3.2.3 Boot upper materials shall be tested for cut resistance and shall not be cut through under an applied force of 12 lb (5.4 kg) when tested as specified in Section 7-20 of this standard.

6-3.2.4 Boot upper materials shall be tested for puncture resistance and shall not puncture under an applied force of 6 lb (2.7 kg) average when tested as specified in Section 7-21 of this standard.

6-3.2.5 Boot upper materials shall be tested for abrasion resistance and shall show no wear through after 200 cycles when tested as specified in Section 7-9 of this standard.

6-3.2.6 Boot sole and heel shall be tested for abrasion resistance and have an abrasion-resistance rating of not less than 100 NBS Index when tested as specified in Section 7-26 of this standard.

6-3.2.7 Boot sole and heel shall be tested for puncture resistance and have a puncture resistance of not less than 272 (123 kg) when tested as specified in Section 7-27 of this standard.

6-3.2.8 Boot outersoles shall be tested for slip resistance and show a friction coefficient of not less than 0.75 under dry conditions and 0.50 under wet conditions when tested as specified in Section 7-30 of this standard.

6-3.2.9 Protective glove materials shall be tested for chemical protection and shall show breakthrough times of one hour or greater when tested as specified in Section 7-44 of this standard.

6-3.2.10 Glove materials shall be tested for chemical retention and retain not more than 100 ppm chemical when tested as specified in Section 7-41 of this standard.

6-3.2.11 All metal hardware and hardware that includes metal parts shall be tested for corrosion resistance as specified in Section 7-15 of this standard. Metals inherently resistant to corrosion, including but not limited to stainless steel, brass, copper, aluminum, and zinc shall show no more than light surface-type corrosion or oxidation. Ferrous metals shall show no corrosion of the base metal.

6-4 Dry Suit Underwear

6-4.1 Design Requirement

6-4.1.1 Dry suit underwear shall be constructed such that it covers the wearer's body including torso, arms, wrists, legs, and ankles.

6-4.2 Performance Requirement

6-4.1.1 Dry suit underwear material shall be tested for thermal insulation and shall have a clo value of 0.8 or greater when tested as specified in Section 7-37 of this standard.

6-4.1.2 Dry suit underwear material shall be tested for water absorption and absorb 20% water or more by weight when tested as specified in Section 7-47 in this standard.

CHAPTER 7 TEST METHODS

7-1 Radiant Reflective Performance

- Adopt test method described in NFPA 1977, Section 3-4.10
- Remove requirement for abrasion preconditioning
- Provide sampling procedures for garments, hoods, gloves, and boots

7-2 Thermal Protective Performance

- Adopt test method described in NFPA 1971, Section 5-2
- Provide sampling procedures for garments, hoods, gloves, and boots
- Require testing of garment and glove materials following 5 cycles of home laundering per AATCC 135, machine cycle 1, wash temperature V, and drying procedure Ai

7-3 Flame Resistance

- Use FTMS 191A,5903 as modified in NFPA 1977, Section 3-4.3
- Provide modifications to address gloves, boots, helmets and helmet components
- Provide sampling procedures for garments, hoods, gloves, boots, and helmets
- Require testing of garment and glove materials following 5 cycles of home laundering per AATCC 135, machine cycle 1, wash temperature V, and drying procedure Ai

7-4 Thermal **Shrinkage Resistance**

- Adopt test method described in NFPA 1971, Section 5-3
- Provide sampling procedures for garments and hoods
- Require testing of garment and glove materials following 5 cycles of home laundering per AATCC 135, machine cycle 1, wash temperature V, and drying procedure Ai

7-5 Heat Resistance

- Adopt test method described in NFPA 1971, Section 5-4
- Provide sampling procedures for garments, hoods, gloves, boots, helmets, goggles, and ear protectors
- Require testing of garment and glove materials following 5 cycles of home laundering per AATCC 135, machine cycle 1, wash temperature V, and drying procedure Ai

7-6 Total Heat Loss

- Adopt test method described in. NFPA 1977, Section 3-4.5
- Provide sample procedures for garments and hoods

7-7 Tear Resistance (Elmendorf)

- Use ASTM D 1424, *Test Method for the Tear Resistance of Woven fabrics by Fall Pendulum (Elmendorf) Apparatus*
- Provide sampling procedures for garments

7-8 Snag Resistance

- Use ASTM D 2582, *Test Method for Puncture Propagation Tear Resistance of Plastic Film and Thin Sheeting*
- Provide sampling procedures for garments

7-9 Abrasion Resistance

- Use ASTM D 4157, *Test Method for Abrasion Resistance of Textile Fabrics (Oscillatory Cylinder Method)*
- Provide sampling procedures for garments, gloves, and boots
- Set the following test conditions:
  - 5 lb. head weight
  - 3.5 lb. tension weight
  - 80 grit abradant, trimite D-weight open coat
- Specify number of cycles for particular application
- Require penetration testing following abrasion for swift water rescue applications
- For contaminated water diving applications, measure burst strength using mullen-based procedure in ASTM D 751, *Methods of Testing Coated Fabrics*
- Establish passing performance as:
  - No wear through (technical rescue)
  - No penetration within one hour (swift water rescue)
  - 80% retention of original burst strength (contaminated water diving)

7-10 Cleaning Shrinkage Resistance

- Adopt test method described in NFPA 1971, Section 5-9
- Provide sampling procedures for garments and hoods
- Require testing of garment and glove materials following 5 cycles of home laundering per AATCC 135, machine cycle 1, wash temperature V, and drying procedure Ai

7-11 Static Charge Accumulation Resistance

- Use draft ASTM F 23.20.05, *Test Method for Measuring Triboelectric Charge Generation on Protective Clothing materials*
- Set the following conditions:
  - Teflon felt wheel
  - 77°F and 50% relative humidity
- Provide sampling procedures for garments and hoods

- Require measurement of material charge (voltage) at 5 seconds after applying initial charge

7-12 Seam Strength

- Use ASTM D 1683, *Test Method for Efficiency of Woven Textile Seams*
- Provide sample procedures for garments

7-13 Closure Strength

- Use modified form of test method described in Section 7-12 above or ASTM D 751, *Methods for Testing Coated Fabrics*
- Provide sample procedures for garments

7-14 Thread Heat Resistance

- Use FTMS 191A,5134
- Examine thread at 500°F to determine compliance

7-15 Trim Luminous Coefficient

- Use ASTM E 810, *Test Method for Coefficient of Retroreflection of Retroreflective Sheeting*
- Provide sample procedures for garment and helmet trim

7-16 Hardware Corrosion Resistance

- Adopt test method described in NFPA 1971, Section 5-13
- Provide sample procedures for garment hardware

7-17 Liner Chemical Penetration Resistance

- Use ASTM F 903, *Test Method for Resistance of Protective Clothing Materials to Penetration by Liquids,* Procedure C
- Conduct testing against following liquids:
  - AFFF concentrate
  - battery acid (37% sulfuric acid)
  - gasoline
  - hydraulic fluid
  - swimming pool chlorine additive
- Provide sampling procedures for garments, gloves, and boots

7-18 Liner Biopenetration Resistance

- Use ASTM ES 22, *Test Method for Resistance of Protective Clothing Materials to Penetration by Blood Borne Pathogens using Viral Penetration as a Test System*

- Provide sampling procedures for garments, gloves, and boots

7-18A Glove Size Determination

- Adopt procedures described in NFPA 1973, Paragraph 2-2.1

7-19 Conductive Heat Resistance

- Adopt test method described in NFPA 1973, Section 3-4
- Provide sampling procedures for gloves

7-20 **Cut Resistance**

- Adopt test method described in NFPA 1973, Section 3-7
- Provide sampling procedures for gloves and boots

7-21 Puncture Resistance

- Use ASTM F 1342, *Test Method for Resistance of Protective Clothing Materials to Puncture*
- Provide sampling procedures for gloves and boots

7-22 Electrical Current Resistance

- Use the Electrical Requirements (Section 9) in ASTM D 120, *Standard Specification for Rubber Insulating Gloves* and ASTM F 1116, *Standard Test Method for Determining Dielectric Strength of Overshoe Footwear*
- Incorporate modifications for helmet evaluation
- Provide sampling procedures for gloves, boots,and helmets

7-23 Dexterity

- Adopt test method described in NFPA 1973, Section 3-9
- Provide sampling procedures for gloves

7-24 **Grip**

- Adopt test method described in NFPA 1973, Section 3-10
- Provide sampling procedures for gloves

7-25 Overall Glove or Boot Water-Tight Integrity

- Use ASTM D 5 151, *Test Method for Detection of Holes in Medical Gloves*
- Provide modifications to address testing of boots
- Employ dye in test to enhance detection of leaks
- Develop more stringent criteria for integrity check by extending test time to at least one hour

- Provide sampling procedures for gloves and boots

7-26 Sole Abrasion Resistance

- Adopt test method described in NFPA 1974, Section 4-1.9
- Provide sampling procedures for boots

7-27 Sole Puncture Resistance

- Adopt test method described in NFPA 1974, Section 4-1. 10
- Provide sampling procedures for boots

7-28 Boot Flex Fatigue Resistance

- Adopt test method described in NFPA 1977, Section 5-3.7
- Provide sampling procedures for boots

7-29 Boot Stud Hook Detachment Strength

- Adopt test method described in NFPA 1977, Section 5-3.6
- Provide sampling procedures for boots

7-30 Boot Sole Slip Resistance

- Use ASTM F 489, *Test Methodfor Static Coefficient of Friction of Shoe Sole and Heel Material as Measured by the James Machine*
- Require measurement of friction coefficient in both dry and wet conditions
- Provide sampling procedures for boots

7-31 Helmet Top Impact Resistance

- Adopt test method described in NFPA 1972, Section 5-6
- Provide sampling procedures for helmets

7-32 Helmet Penetration Resistance

- Adopt test method described in NFPA 1972, Section 5-8
- Provide sampling procedures for helmets

7-33 Helmet Suspension Separation Resistance

- Adopt test method described in NFPA 1972, Section 5-15
- Provide sampling procedures for helmets

7-34 Helmet Retention and Chip Strap Efficiency

- Helmet suspension system and chin strap system shall be secured and unsecured 20 times

- Failure to operate or diminished performance shall constitute failure

7-35 Helmet Vibration Resistance

- Adopt test method described in NFPA 1981, Section 3-10

7-36 Overall Garment Water-Tight Integrity

- Use MIL-W-85365

7-37 Temperature Insulation

- Use modified form of procedure described in this standard, Section 7-6
- Measure material heat transfer under dry conditions only
- Alternative method is ASTM D 15 18, *Test Method for Thermal Transmittance of Textile Materials*

7-38 Tensile Strength

- Use ASTM D 1682, *Test Method for Tensile Strength of Woven Fabrics*
- Provide procedures for sampling garments

7-39 Tear Resistance (Trapezoidal)

- Adopt test method described in NFPA 1971, Section 5-5
- Provide procedures for sampling garments

7-40 Burst Strength (Ball)

- Use ASTM D 751, Method for Testing Coated Fabrics, Ball Burst Technique
- Provide procedures for sampling garments

7-41 Bacterial Penetration Resistance

- Use procedures described in Section 7-18 of this standard
- Substitute the bacterium Serratia for bacteriophage

7-42 Chemical Retention Resistance

- Expose material samples to selected chemicals
- Decontaminate samples through water and detergent washing following by water rinsing and air drying
- Extract samples for chemical retainage

7-43 Garment Donning Efficiency

- Use three test subject fitted to appropriate size of garment
- Have test subject put on garment unassisted
- Have test subjects practice putting on garment until the donning time varies no more than 10% between donning trials
- Conduct three separate trial and measure average donning time

7-44 Glove and Boot Strap Tensile Strength

- Use tensile testing machine and measuring breaking strength of securing system for gloves and boots

7-45 Helmet Drainage

- **One liter of water will be poured into the rescue helmet**
- **The time required for complete dramage of the water shall be measured**

7-46 Permeation Resistance

- Use ASTM F *739, Test Method for Permeation Resistance of Protective Clothing Materials to Liquids and Gases*
- Evaluate all materials to chemical resistance of following selected chemicals for three hours:
  - Acetone
  - Hexane
  - Sodium Hydroxide
  - Sulfuric Acid
  - Toluene
- Use the breakthrough time at one hour to determine compliance

7-47 Underwear Water Absorption

- Use ASTM D 1117, *Method for Testing Nonwoven Textile Materials*

CHAPTER 8 REFERENCED PUBLICATIONS

[List of test methods and other documents to be compiled]

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