Advanced Protective Gear and Armor

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Additional segmentations and data sets available upon request. Email custom@bccresearch.com.

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Introduction

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Chapter 1: Introduction

Study Goals and Objectives

Advanced protective clothing and associated gear is an industry sector that has a critical role in the protection of firefighters, police officers, military personnel and industrial workers. Concerns for general worker safety, including protection from death and disabling injuries and illnesses, as well as protection from the specific threats of chemicals, biological agents, fire, bullets and fragmentation particles, have yielded an industry solely devoted to personal protective equipment and gear. This equipment includes items from chemical protective garments and suits to firefighter turnout gear and industrial fire retardant garments to bullet-resistant vests and respirators and more. Military armor for vehicles and, to a greater extent, for personnel, has become another advanced segment within the industry.

While the protective gear and armor industry has assumed some new standards and regulations, there have been significant revisions and additions to current standards for worker-protective clothing. These changes have occurred in the areas of chemical protection, fire protection and bullet-resistant garments.

This report provides an overview of major trends within the personal protective equipment industry and market analyses for each end-use segment, focusing on the advanced materials in use. Historical data, as well as forecasts for the years 2023 through 2028, are provided to express market sizes, changes and dynamics.

Reasons for Doing This Study

This report updates a previous BCC report published in 2015. Protective apparel and associated gear are undergoing growth in many sectors because of terrorist activities and various related geopolitical events. Tracking and predicting growth related to these events, as well as examining offsetting growth factors, are major reasons for doing this study. Terrorism is unlikely to cease within the five-year horizon of this report or in the 21st century. Concentrations of individuals in ever more complex urban situations will continue and within this, the occurrence of fires, either structural or wildlands, will continue. The numbers and types of toxic materials in the workplace will continue or increase. Greater protection is deemed necessary for armed forces personnel, first responders and industrial workers.

Manufacturers, compelled by revisions made to existing standards, have changed some materials used in the production of some forms of personal protection equipment. The failure of some older materials to perform over the long term has initiated their withdrawal from the market. There is a constant struggle to achieve a balance of mobility vs. protection. While many segments of the personal protective clothing market have experienced growth, the number of players in some industry segments is decreasing because of acquisitions.

This study also incorporates a detailed analysis of the key dynamics and the technological advancements in the overall market.

This study assesses the protective gear and armor industry, its major participants, advanced materials and future growth potential as well as the technologies and standards crucial to the understanding of the industry. This report does not assess sports equipment and gear related to recreational activities.

Common causes of setting a fire industrial apparel include ignition of flammable liquids and/or other flammable materials spilled on the garment, contact with or proximity to molten metals, sparks and slag from flame cutting or welding, or any contact with open flames. Other dangerous fire situations include high-energy electrical discharges or other electric arc events, the explosion of vapors from volatile liquids or from flammable gases and the ignition of combustible dusts. Firefighters, whether in structural or wildland environments, along with other first responders require a higher level of thermal protection and fire-resistant garments.

Scope of Report

The protective clothing, gear and armor markets represent a fragmented industry. There are significant and specific segments of the protective clothing, gear and armor industry. Within each of these segments are a variety of players, including government organizations that create, develop and enforce regulations and standards, raw material suppliers, fiber and fabric manufacturers, mills and fabric producers, finished goods manufacturers and suppliers and distributors. As a result of the complexity, supply chains sometimes may be difficult to understand.

This report focuses on the major material types and the designers of the products instead of on product distributors. One large corporation, through many of its parts, may be involved in all sectors of the supply chain.

This study focuses on the following major sectors of the global advanced protective gear and armor market:

- Heat- and flame-resistant clothing, including firefighters' turnout gear for structural, proximity and wildlands fire service, as well as industrial fire-resistant garments for use in electric and gas utilities or in industrial applications in which electric arc and flash fire are hazards.

- Chemical protective garments and equipment, including chemical-resistant clothing, chemical or biological warfare and protective suits and gloves used in industrial applications. Much of this same gear can be used for biological protection.

- Respirators and ancillary components for fire and chemical/biological situations.

- Body and vehicular armor, including bullet and fragmentation-resistant garments used in law enforcement and military applications.

- Body armor, including bullet-resistant garments used in law enforcement and military applications. This includes the retrofitting of vehicles using the same types of materials and some of the newer engineered in-place vehicle armor.

- Sports protective gear is excluded in this report.

This report discusses the chemical/biological, fire and projectiles/explosives segments, including the regulations, raw materials, technologies, market size and anticipated growth. Manufacturers are evaluated and listed at the conclusion of each of the appropriate sections.

The market estimates and forecasts are based on a thorough analysis of the annual sales, market dynamics, product penetration as well as several other factors.

Nuclear protective gear is excluded from discussion because no truly protective clothing exists for severe nuclear threats such as battlefield nuclear explosions or Chernobyl-level nuclear accidents. Respirators and clothing can help, but the best solution is situational awareness.

What's New in this Update?

The latest version of the study incorporates additional details and analysis in the following sections:

- Global market for advanced protective gear and armor-fire resistance.
- Latest technological advancements in the market.
- Market dynamics, market trends, drivers, challenges, Porter's five forces and emerging trends.
- Sustainability/ESG considerations.
- Impact of COVID-19.
- Impact of war in Ukraine.
- Added company profiles and financials.

Methodology

A structured approach is based on optimal use of BCC Research's own databases and proprietary information, as well as primary and secondary research techniques and methodologies. The material researched and presented in this technical market report is based on information gathered from personal contacts within government agencies, individuals involved in materials and manufacturing and industry consultants.

Additional data was obtained from reviews of secondary sources, such as trade publications, trade-associated company literature, government documents and patents. This was done to supplement the application, market and trend data gathered from primary sources. All monetary projections presented in this report are reported in constant U.S. dollars. A targeted and selective analysis of recent patents was encompassed in the document.

Information Sources

The report encompasses a blend of data from primary as well as secondary sources such as company annual reports, trade associations. press releases & websites, government information, industry & financial sources, and an exhaustive review of technical literature.

Data from the following associations, databases and government organizations were also referred to:

- U.S. Department of Defense
- International Association of Firefighters (IAFF)
- Occupational Safety and Health Administration (OSHA)
- National Fire Protection Association (NFPA)
- Company websites & annual reports
- Research publications
- And others.

Geographic Breakdown

Segmentation Breakdown

Chapter 2

Summary and Highlights

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Chapter 2: Summary and Highlights

Market Outlook

Market Size	Overall, the global advanced protective gear and armor/fire resistance market was valued at $10.7 billion in 2022 and should reach $15.4 billion through 2028.
CAGR	The global market for advanced protective gear and armor/fire resistance market is expected to grow at compound annual growth rate (CAGR) of 6.3% from 2023 through 2028.
High Growth Region	North America contributes over 54% in terms of value followed by Europe and Asia Pacific.
Market Drivers / Opportunities	• Increasing awareness about the fire safety. • Rising demand from the military and defense sector. • Upsurge in the industrial and infrastructure development. • Security standards raised and cross-border conflicts.
Restraints / Challenges	• Lack of training and education. • Cost constraints. • Low safety compliance in the construction industry.
Emerging Technologies	• Nanotechnology usage. • Lightweight composites materials usage. • Smart textile usage.
Top Vendors	• 3M. • ArmorSource LLC. • Avon Protection. • DuPont De Nemours Inc. • Honeywell International Inc. • MSA Safety Inc.

Market Summary

This market research report focuses on protective gear, clothing and armor worn by personnel in law enforcement, the military, fire services and all other first responders and industrial workers.

The largest single sector of this market includes ancillary components such as protective gloves, helmets, eye wear and respirators. Many industrial or utility workers may need only minimal protection as compared to the more expensive and complex bunker gear of firefighters. Bunker gear, often known as turnout gear, is the personal protective equipment (PPE) firefighters are required to wear on the job.

CBRN is the fastest-growing segment within the global market during the forecast period.

The following table summarizes the major market sectors of advanced protective gear and armor.

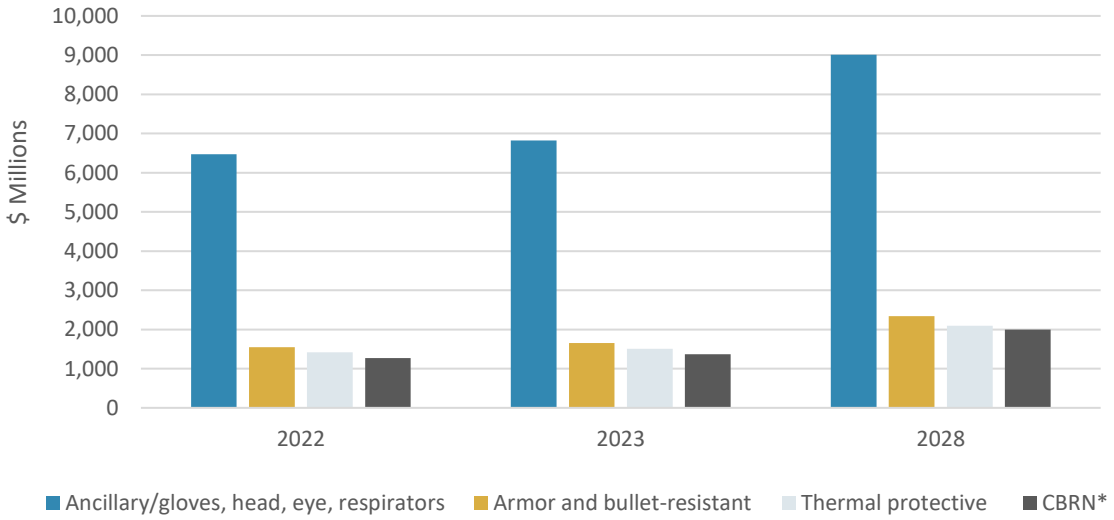
Summary Table:
Global Market for Advanced Protective Gear and Armor, by Sector, Through 2028
($ Millions)

Sector	2022	2023	2028	CAGR% 2023–2028
Ancillary/gloves, head, eye, respirators	6,469.4	6,823.6	9,010.6	5.7
Armor and bullet-resistant	1,546.5	1,655.7	2,337.3	7.1
Thermal protective	1,414.9	1,507.0	2,091.9	6.8
CBRN*	1,267.8	1,364.7	1,994.3	7.9
Total**	10,698.5	11,351.1	15,434.0	6.3

*Chemical/Biological/Radiological/Nuclear
**Note: Totals in this report's tables and figures might not match exactly due to rounding.

Source: BCC Research

Summary Figure:
Global Market for Advanced Protective Gear and Armor, by Sector, 2022–2028
($ Millions)



Source: BCC Research

Chapter 3

Market and Technology Background

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Chapter 3: Market and Technology Background

This business opportunity report addresses personal protective fire gear, chemical and biological protective gear. This also includes some ancillary and personal gear, such as helmets and gloves and vehicle armor in both military and civilian applications. Sports protective gear is excluded.

Some protective clothing and equipment are employed by both civilians and military organizations. This is particularly true in some body armor and ancillary equipment in which civilian law enforcement and military requirements are similar. The difference in the two sectors is scale; the military requirement in active combat situations compared to civilian need, which is growing. The civilian sector requires the highest levels of protective gear as border security and terrorist activity increasingly assume clear and present dangers within the U.S.

Market Environment

Protective gear is a niche market impacted by the demands of the war fighter, homeland security requirements, and growing numbers of domestic law enforcement and first responder personnel. As a result, demands are growing for material and design improvements, combined with production capability, to meet industry needs.

The Afghanistan and Iraq wars boosted the growth of the armor industry in a way not seen since the conversion of the domestic U.S. industrial base into military production at the outset of World War II.

The Army and the Marines struggle to field both improved vehicles and body armor on a timely basis. Increasing force protection demands have added much weight to the body armor that today's soldier or marine wears about 100 pounds of armor and equipment, probably the maximum feasible for the average dismounted man on foot patrol. Vehicle armor is improved, but it is approaching feasible limits in terms of protection considered against weight and transportability.

In civilian industrial and firefighting gear requirements, the growth of industry, population and associated development are pushing demand for additional services and more personnel. Severe drought in some parts of the country has escalated the number of wildland fires, increasing the need for more and better protective clothing for firefighters.

In the civilian sector, the demand for an improved or higher level of protection for police has increased significantly. For fire-protective gear, demand continues to grow due to increases in urban density and the increase in wildland fire events.

Flame Retardant Materials for Garments

Many polymers make up the backbone of the flame retardant garment industry. For the most part, the makers of these polymers, fibers and technical textiles are not the producers of the garments. The

weavers of technical textiles often develop their own unique blends and methods for creating the textiles. Few companies are engaged in designing and selling their garments.

There would be no garments to meet most of the flame retardant standards if the technical polymers did not exist. Apparel manufacturers can create custom or unique technical textile products using a combination of several polymers. Several ballistic textile fibers are used to manufacture fire retardant textiles. Technical yarns are produced and used in the form of multifilament, monofilament, continuous tapes and split films as well as staple spun products. These are made from all the major textile polymer systems, including polyester, polyamide, polyolefin, imides, viscose and acrylic as well as a number of high-performance or specialty materials, such as the aramids, carbon fibers, high molecular weight polyethylene, polytetrafluoroethylene (PTFE), polyphenylene sulphide (PPS), polybenzimidazole (PBI), novoloid (phenolic) fibers, polyetheretherketones (PEEK), elastane's, polyvinyl alcohol (PVA) and polyvinyl chloride (PVC), or some combinations of these polymers as composites.

Materials for the construction of fire retardant gear need to resist molten metal spatter and burning embers. Breathability of the moisture barrier is important, as is good visibility and mobility. Often there are tradeoffs between price and performance. Higher design standards lead to higher costs of firefighter apparel. Garment design criteria are, for the most part, dictated by the needs and severity of the fire service environment's need.

Meta-aramids

The meta-aramids (m-aramids) are among the most popular and serviceable of all the flame retardant polymers. This sector of the aramid family has been described as polyamidimides and as polyamide/imides. The aramids are a family of aromatic type nylons. Nomex meta-aramid or polymeta-phenyleneisophthalamide is prepared from meta-phenylenediamine and isophthaloyl chloride in an amide solvent. This results in a long chain polyamide in which at least 85% of the amide linkages are attached directly to two aromatic rings. The meta-oriented (1,3- attachments) phenylene form bends in the polymer chain, reducing chain rigidity as compared to the para-orientation (1, 4-attachments) in the chemically similar, yet different, Kevlar chain. This flexible polymer chain gives DuPont's Nomex or Teijin's Teijinconex more textile-like qualities while retaining high temperature-resistant properties.

These meta-aramids have outstanding retention of fiber properties, high resistance to long-term heat exposure, heat-insulating resistance, high flame resistance, good abrasion resistance and are strong and self-lubricating.

In 1977, the Federal Trade Commission (FTC) distinguished these fibers from conventional aliphatic polyamide fibers known as nylons by using the term aramid. The special configurations are important in that aliphatic polymers make up the families of nylons. The aromatic aramids differ in the position of the linkages through the aromatic ring structure. Nomex uses linkages in the 1,3- aromatic ring positions (meta) to link the backbone and contribute to something of a zigzag structure.

Aramids can be used in many applications, from woven filters, nonwoven filters, gaskets, ropes and marine composites to flame retardant clothing. They are suitable for catering for the requirements arising in the biological and chemical exposure clothing segment. This family consists of staple fibers, continuous filament yarns, paper and spunlaced fabrics. Uses for staple, yarn and spunlaced fabrics include apparel fabrics to protect against flash fire and electric arc exposure and firefighter garments. In addition, there are fabrics and spun yarns for filtration applications, insulation in fire-resistant thermal

protective apparel, rubber reinforcement and in textiles used in the transportation industry, such as airline carpeting.

Teijinconex

Teijinconex m-aramid fibers are a meta-linked polymeta-phenyleneisophthalamide, more commonly known as Conex. The material is known for a combination of heat resistance and strength and is relatively soft. Teijinconex begins to decompose and carbonize at about 400°C (732°F) and has a limiting oxygen index (LOI) of 30. A white, highly functional technical fiber, it can be used for applications from clothing to industrial materials. It is available in apparel or industrial grade as fabric, spun yarn or staple fiber.

Warwick Mills uses Conex fiber to enhance the performance of several products. Conex, depending on its use, resists temperatures of 100°C to 250°C (212°F to 482°F). Better known applications are to help strengthen hose and diaphragm construction. Other variations belong to the aramid fiber range, which are mostly the co-polyamides known as Technora. Technora is the branded product name of the aromatic p-polyaramid from Teijin Aramid, which is made by a simpler process using only one amide solvent and spinning that can be done after the polymer production. Fatigue resistance is good and thermal decomposition threshold is about 500°C (932°F).

The polymer can be used in heat protection products and to reinforce hoses, transmission belts and numerous composites and engineering plastics. According to the company, ongoing cost-saving programs and other efficiency optimization measures have been unable to offset the extreme rise in costs involved in the production and transportation of aramid products.

Nomex

According to DuPont, its m-aramid Nomex is a poly (meta-phenyleneisophthalamide) prepared from meta-phenylenediamine and isophthaloyl chloride in an amide solvent. This yields a long chain polyamide in which at least 85% of the amide linkages are attached directly to two aromatic rings. The meta [1,3-] oriented phenylene form bends in the polymer chain, reducing chain rigidity as compared to the para-1,4- orientation in the chemically similar Kevlar chain. This flexible polymer chain gives Nomex more textile-like qualities and high temperature-resistant properties like those of Kevlar.

A complex polymer like Nomex comes in an entire 400 series (410, 4100, 414, etc.), E-series and the 900 series (992, 993, 994). The latter are mostly paper products and find uses in high-temperature electrical insulation and pressboard. The 430, 450, 455 and N104 plus several others are the Nomex materials for thermal protective apparel. Nomex IIIA has a static dissipative added to the fibers that helps control static electricity in certain applications in which even a small electrical discharge could cause an ignition source. Nomex IIIA maintains its static dissipation qualities even in low humidity conditions in which 100% cotton fabric may not provide as much antistatic protection. This is because 100% cotton relies on the absorption of moisture/humidity to help eliminate the static buildup. When subject to low humidity conditions, cotton will not be able to provide the same protection as the Nomex IIIA due to moisture loss.

In addition to its flame retardant applications, Nomex is also used in press-board products such as spacers and barriers in transformers and in a variety of laminated flame retardant products and papers. Nomex fibers are used as components in aircraft and helicopters. Firefighter bunker gear, laboratory coats, EMS coveralls and flight suits all contain Nomex.

Table 1
Applications for Meta- and Para-Aramids

Composition	Application	Type	Description
100% Nomex	Filtration	E-88	
	Apparel		
	Business machines	E-88C	Calendered
	Shielding tapes	E-140	Calendered high density
	Electrical insulation		
Nomex and Kevlar blends	Apparel liners	E-89	Nomex E-89
	Moisture barrier		
	Substrate		
100% Kevlar	Fire blocking	Z-11	Narrow width tapes
	Calender roll	Z-11	
Quilted fabrics	Transportation	E-92	Multilayer quilts with woven fabric facing
	Seat fire blocking		
	Thermal Liners		

Source: DuPont

Some uses for m-aramid paper product include insulation in electric motors and transformers, wire wrapping and honeycombed strength members in aircraft. The inherent flame-resistant property of m-aramid fibers such as DuPont's Nomex does not diminish the life of the fiber. The material's low stiffness and high elongation give it textile-like characteristics that allow processing on conventional textile equipment. Nomex will self-extinguish when removed from a heat source and starts carbonizing at about 380°C (716°F). The m-aramid-type fiber fabric becomes almost insignificant as a protective shield after about 10 seconds of continuous exposure to heat at or above 315.5°C (600°F).

However, these desirable properties have a downside: once the fabric has charred, cracked and begun to decompose, holes may develop through which flames and heat can pass. After exposure to dry air at 500°F (260°C) for 1,000 hours and then returned to room temperature, the breaking strength and toughness of Nomex is approximately 65% of that exhibited before exposure to the dry air. According to DuPont, Nomex's unique combination of flame protection, durability and mobility protects 3 million firefighters. Nomex is also used in apparel worn by military pilots and combat vehicle crews, auto racing drivers, pit crew members and track officials and industrial workers at risk from flash fire and electric arc hazards. Troops in Iraq are being outfitted with Nomex-containing apparel to protect them from burns caused by roadside bombs or improvised explosive devices (IEDs).

Nomex on Demand
One of the newest DuPont products is Nomex on Demand, which provides up to 20% more thermal insulation as a thermal liner when needed. Designated as a "smart" technology, Nomex on Demand will automatically activate in temperatures at 250°F or higher and expand to trap more air for superior thermal insulation. During more routine conditions, Nomex on Demand remains a thin, breathable and flexible liner for mobility and comfort.

Modacrylic/Aramid Fiber Blends
To overcome the shortcomings of flame retardant textiles, some woven fabrics used in fire retardant garments are made of composites. Some composites contain viscose rayon, m-aramid, p-aramid and carbon fibers. A twill weave of 75% Nomex and 25% Kevlar is supple and soft, and it has a higher thermal damage tolerance than Nomex IIIA, which is a 93% Nomex, 5% Kevlar and 2% antistatic fiber blend. The retail price of twill weave material is set between the price of Nomex and the Kevlar/PBI blend.

Type 462 staple is a blend of Nomex and Kevlar brand fibers and P-140, a proprietary static dissipative fiber. When converted to fabric, it is known commercially as Nomex IIIA and used for thermal protective apparel. It offers all the features of Type 455 staple plus a higher level of static dissipation in fabric form. The P-140 fiber dissipates static generated from fabric-to-fabric and fabric-to-surface rubbing, minimizes the contribution of clothing to static hazards and reduces apparent electric field strength and nuisance static. The staple is dye mergeable and can be package-dyed as yarn for use in knit goods or sewing threads, or piece-dyed as baric for civilian protective apparel. Except for the static dissipative properties of Nomex IIIA, all other properties are essentially the same for Nomex III.

A novel flame retardant finished Nomex/cotton blend fabric for protective clothing was developed by Charles Q. Yang and Hui Yang, in the Department of Textiles, Merchandising and Interiors at the University of Georgia. The principle driving this innovation was the excellent fire retardant property of Nomex which would have wider use if the high cost could be lowered.

Nomex's low comfort level is a drawback. Blending Nomex with cotton not only reduces the cost but also improves moisture regain, absorbency and flexibility of the fabric. Because cotton is a highly flammable fiber, cotton/Nomex blend fabrics containing more than 20% cotton are not self-extinguishable, therefore require flame retardant finishing treatment. Researchers have found that the flame retardant finishing of the cotton/Nomex (65/35) blend fabric treated using a hydroxyl-functional organophosphorus oligomer (HFPO) as the flame retardant finishing agent, 1,2,3,4-butanetetracarboxylic acid (BTCA) as the bonding agent and triethanolamine (TEA) as the additive, was fine.

The addition of TEA to the finishing system improves the hydrolysis resistance and laundering durability of HFPO due to formation of a HFPO/BTCA/TEA cross-linked network on the fabric. TEA enhances the flame retardant performance of HFPO by means of phosphorus-nitrogen synergism. TEA reduces the deposit of calcium salt formed on the treated cotton/Nomex blend fabric during laundering procedures by esterifying the free carboxylic acid group of BTCA on cotton and minimizes the interference of calcium salt deposit to the flame retardants.

The cotton/Nomex blend fabric treated with the HFPO/BTCA/TEA system yielded a high flame retardant performance and good laundering durability at relatively low add-on levels (around 12% weight of fabric, for example). The cotton/Nomex blend thus treated is a completely formaldehyde-free flame

retardant fabric with good hand property and is a new flame retardant textile material suitable for use in protective clothing.

The term “stretch broken” refers to a process in which fibers are hot-stretched and broken to produce short fiber lengths, rather than cutting, to prevent some of the damage done by the cutting process. A blended yarn is produced that has at least one component fiber type being made of stretch broken fibers, preferably of a stretch broken high-performance fiber, along with multi-end yarns containing the blended yarn, composite yarns having at least one component being the blended yarn and articles made from the blended, multi-end or composite yarn.

Nomex Limitedwear

Nomex Limitedwear for military applications is a contemporary innovation from DuPont as a lightweight limited-use garment that helps protect service personnel from fires. The garments are especially useful for those who need intermittent flame protection. The limited use garments offer lightweight protection that fits over a battle dress uniform (BDU). Nomex Limitedwear for military garments can be laundered like any other uniform without affecting its fire-resistant integrity.

Nomex Limitedwear is certified as compliant with NFPA 2112 by Underwriters Laboratories. Because it comes in a simple coverall design, Nomex Limitedwear can be worn directly over cotton street clothes. When worn as intended, Nomex Limitedwear offers the same flame retardant protection as Nomex for use as a short-term garment. This limited-use garment weighs about half as much as traditional flame retardant apparel. They can also be used for contract employees and flash fire protection in industry. It is cost-effective for temporary workers. DuPont Protective Apparel sells this product.

Members of the Brand Preferred Program

In the DuPont Brand Preferred Program, some manufacturers of Nomex and Kevlar include:

- Cairns Protective Clothing.
- Fire-Dex.
- Globe.
- LION.
- Quaker Safety.
- TotalFire.
- Sperian Fire.
- Argus-Hazco.

Flame Retardant Cotton

The danger posed by combustible textiles led to the development of flame-resistant cotton. As early as 1735, Obadiah Wyld received a patent in Great Britain for developing a flame retardant mixture of alum, ferrous sulfate and borax. Studies continued in the 19th century in which various agents were used in the search for flame resistance. While some success was achieved, most attempts eventually failed because most of the agents, often inorganic salts, were water-soluble and would wash out of the fabric.

Cotton is made of cellulose fibers and is the most flammable of all natural and synthetic fibers. It ignites easily and burns with a hot flame, posing significant danger in situations in which the wearer comes into contact with a flame or heat source. Because cotton is soft, washable and comfortable, it is widely used for many types of clothing, including uniforms, work clothes and babies’ and young children’s clothes.

The initial impetus for research at the Southern Regional Research Center into flame-resistant cotton fabrics came from the Army's Quartermaster Corps, which sought fire retardant uniforms. Simultaneously, leaders in the cotton industry understood consumer demand would be high for flame retardant textiles that were also durable but not typically stiff and abrasive to the skin. Aware of the prevalence of burn victims injured by wearing cotton garments, the U.S. Congress passed the Flammable Fabrics Act in 1953, requiring cotton uniforms, work clothing and children's sleepwear to be fire-resistant. The standards were also extended to carpets, rugs and mattresses, but not to other home textiles, such as curtains.

The weight and weave of the fabric will affect how easily the material ignites and burns. Recommended fabrics are materials with a tight weave. Heavy, tight weave fabrics will burn more slowly than loose weave, light fabrics of the same material. The surface texture of the fabric also affects flammability. Fabrics with long, loose, fluffy pile or "brushed" nap will ignite more readily than fabrics with a hard, tight surface and in some cases will result in flames flashing across the fabric surface.

There are difficulties in meeting the specific requirements of cotton when flame-retarding the fabrics. The most stringent difficulty is the need to withstand 50 hot alkaline launderings, in both soft and hard water. Another requirement is to obtain cotton that does not lose much of its tensile, tear and burst strengths as well as its abrasion resistance. Another consideration is not to lose cotton fabric's high air permeability because of deposits of the chemicals needed to impart flame retardancy. According to the National Cotton Council of America, children's sleepwear is now manufactured with fabric made from molecularly altered cotton fibers. This new variety of cotton has been made fire-resistant without adding chemicals.

It is desirable to preserve the soft hand of the cotton fabric. It is important not to bring about a change in the outward appearance and aesthetics of the fabric and this means not to change the hue of the dye and/or the fabric's ability to be dyed. Another issue is not to cause medical problems from the additives, such as any toxicity or skin irritation. There should be no mutagenic or carcinogenic materials present in the flame retardant additive. Not to be overlooked is the requirement for low cost, which is essential in the manufacturing of flame retardant textiles. The textile industry does not seem to be inclined to support any new machinery that would add to higher costs to provide flame redundancy.

Reactive treatments in which the fire retardant chemicals reacted with the cotton, such as phosphorylations, were generally stable in soft water launderings but did not withstand hard water launderings. These chemicals also brought about a weakening of the fabrics. Sulfation treatments with urea sulfamates yielded fabrics that withstood 50 hard and soft water launderings; however, weakening of the fabric and afterglow occurred. Simultaneous sulfation and phosphorylation treatments eliminated the afterglow, but weakening of the fabrics was still observed. The cost of chemicals themselves is relatively low. A satisfactory, durable, flame retardant treatment for cotton remains a challenge.

Cotton remains a material of choice to wear under fire protective gear as underwear. Proban, an example of a fire retardant or treated cotton, was developed in 1955 by Rhodia to provide protection for children's sleepwear. It is produced with the gaseous ammonia or ammonia cure reaction. Proban fabrics are adapted to metal industries and electrical utilities and systematically depend on the flame retardant standards in use in the specific country or industry.

Firewear fabric made by Springfield LLC is a 55% fibrous flame retardant fiber and 45% combed pima cotton fiber that is not treated with flame retardant. It is sold as fire wear and is not recommended for flash fire protection.

Lenzing FR is a flame retardant viscose with properties similar to cotton. The fiber contains flame retardant additives. Lenzing of Austria produces the heat protection fiber, which reduces the risk of second- and third-degree burns. For industrial protective clothing, Lenzing FR is commonly blended with other fibers such as the meta- or para-aramids or with PBI. Garment cost varies depending on the fabric weight and blend level. Lenzing FR is used as an aramid enhancer in a 50-50 combination. Moisture and heat management properties are enhanced.

Westex launched a major R&D program and in 1987 introduced its Indura flame retardant cotton. A proprietary multi-step fabric softening process gives Indura Ultra Soft a unique balance of chemical and mechanical properties.

FR8, a flame retardant treatment for 100% cotton, is designed to reduce injury risk during exposure to aluminum splash. FR8 uses a system of antimony oxide and bromide compounds bound to the cotton fiber by a special latex binder.

Water-Resistant and Flame-Resistant Materials for Garments
The outer shell of a garment made according to the present invention can retain its primary water-resistant properties even after undergoing 30 laundry cycles.

Protective garments worn by firefighters are designed to perform several functions. Of these, protection from heat and flame is the most important characteristic of the garments. The garments, however, should also be as light as possible, should provide some breathability and should not encumber the wearer.

Conventional firefighter garments are generally constructed having a number of discrete layers. Typically, these layers include an outer shell, a moisture barrier layer, a thermal barrier layer and an inner lining. The layers are typically made from the appropriate thermally resistant materials to provide protection against heat and flame.

How to prevent protective garments from absorbing and retaining moisture is a design challenge. Protective garments worn by firefighters usually become exposed to water from extinguishing water, rain or building sprinkler systems. They can also become wet due to the absorption of perspiration. The absorption of moisture by a protective garment can adversely affect its characteristics and properties, including rendering the garment significantly heavier.

The presence of moisture within a protective garment can also adversely affect the thermal properties of the garment, rendering the garment less effective in shielding its wearer from thermal heat. Water is a far better heat conductor than air and the rate of heat transfer through the garment increases. It has been discovered that as water heats up in a protective garment, it can turn to steam under exposure to more heat and burn the wearer. Ultimately, when such protective garments become wet or soaked with water or other fluids, the garments become hot and uncomfortable due to both the increased weight and increased rate of heat transfer through the garment. Consequently, the possibility of heat stress can limit the amount of time a wearer can use the garment.

Conventionally applied water-resistant treatments to firefighter garments degrade significantly when garments are washed. Some water-resistant treatments begin to degrade only after five laundry cycles and typically lose most of their effectiveness after 10 laundry cycles. In accordance with the present invention, a durable water-resistant treatment is incorporated into the outer shell, such that the outer shell maintains a spray rating of at least 70 even after 30 laundry cycles and, in some applications, even after 50 laundry cycles. In an alternative preferred embodiment of the present invention, the outer shell is constructed to maintain a spray rating of at least 80 after 20 laundry cycles.

Construction of Structural Firefighter Garments
A firefighter's gear essentially consists of three layers: the outer shell, the moisture barrier and the thermal barrier. The moisture barrier and the thermal barrier may be combined into a single layer. Miscellaneous items such as trim and identification letters may be used or required by local specifications.

Structural firefighter garments are constructed to achieve minimal weight while providing comfort and excellent protective qualities. Cost and lifetime serviceability are key factors to be considered while purchasing. A series of measurements has been conducted to assess the thermal properties of materials used in firefighter thermal protective clothing. The thermal property measurements are used in heat transfer model computations.

NIST 7467 describes the "Full Ensemble and Bench Scale Testing of Fire Fighter Protective Clothing." The TPP test was developed to quantify the performance of firefighter protective clothing ensembles under an intense thermal exposure. This test method has helped to improve the thermal protection of firefighter protective clothing.

Outer Shell
The main function of the outer shell is to provide protection against direct flame and heat without losing its physical integrity and breaking open. The outer shell also needs to resist water absorption. The polymer or material of construction might be the same as for other parts of the garment, but the composition and way in which the barrier is constructed may be different. NFPA 1971 requires the outer shell to have reflective trim, which enhances the visibility of the protective garment. Sewing or gluing commonly affixes reflective trim.

The outer shell blends Nomex and Kevlar as well as PBI and Basofil materials. As an example, an outer shell may have a mix of 40% Basofil and 60% Kevlar. These materials of construction are discussed elsewhere in this report. The outer shell must not only be flame retardant, but must also resist most acids, bases, fuels and solvents and must resist abrasions and cuts. .

DuPont uses some of these materials in its own line of protective garments. Other companies may make their own blends. In one way or another, nearly all the blends use some Kevlar or equivalent for the outer shell. Many of the garment manufacturers have the option to weave their own textile and design in their own firefighter garments to meet industry standards. PBI is the polymer typically used without blending for the outer shell and is one of the more expensive options. Often blends are the solution to lower cost and greater serviceability.

Each of the polymers used for the elements of structural firefighter/proximity garments, wildlands firefighter garments or industrial fire-protective garments have many other applications. Most technical textiles use a p-aramid, typically Kevlar, to blend with other fibers for the outer shell. PBI costs nearly

twice as much as an m-aramid such as Nomex but is widely specified in some percentage for use in outer shells of structural firefighter garments.

The weaving and blending of the various polymer fibers and yarns into fabrics and technical textiles has become an art, a science and often a proprietary or patented process. The technical textile manufacturer becomes as important a part of the PPE industry as the manufacturer of the garment or the producer of the polymer fiber. Flame-resistant properties must be combined with wearability, serviceability, duty hazards and cost.

The inner liner and the moisture barrier are detachable from the outer shell so as to be wearable under any clothing. Thus, it becomes an inner surface of the outer shell. The protective garment with the surface of high visibility facing outwardly and with the inner liner and the moisture barrier worn within the outer shell should conform to the NFPA standard for "Protective Clothing for Structural Fire Fighting."

In terms of heat resistance, flame resistance and tear strength, each shell should conform to all applicable standards of NFPA 1971 for outer shells of protective clothing. In terms of thermal protection performance, the protective garment should conform to all applicable standards of NFPA 1971 for all layers of protective clothing. The protective garment should conform to the standards of NFPA 1971, no matter which shell faces outward when the protective garment is worn, except that the shell of low visibility does not have trim that is reflective, fluorescent or both.

Moisture Barriers

Fire protective gear typically has an outer shell, a moisture barrier and a thermal layer. The latter two layers might be sewn together or otherwise combined in some manner. The moisture barrier should be breathable. A microporous membrane meets the requirements. The moisture barrier must act as a liquid barrier (water, chemicals and bloodborne pathogens), but it must also meet the intrinsic flame- and heat-resistance requirements and contribute to the thermal insulation for firefighter safety in hostile environments. The moisture barrier must meet all of the criteria applied to other layers and still function as a breathable liquid barrier. Some bi-component elements combine membrane and monolithic technologies and use either polyurethane or expanded PTFE/polyurethane materials. The moisture barrier might be the most fragile protective component in the gear.

Moisture barriers are the second layer in bunker gear and are composed of a film or coating applied to a substrate. The film or coating is either semipermeable (breathable) or impermeable (nonbreathable). The substrate is either a woven fabric, such as Nomex ripstop, or is a nonwoven fabric, such as E-89 aramid spunlace. CrossTech is an example of a breathable moisture barrier. Neoprene on polyester/cotton construction is an example of a nonbreathable moisture barrier.

Breathable monolithic moisture barrier products use hydrophilic polymers, a water-loving material that has a strong affinity for water and the ability to absorb it, which permits water vapor transfer (breathability) through molecular diffusion. Once water vapor contacts the hydrophilic polymer, it permeates through the polymer one molecule at a time.

The most common orientation of breathable moisture barriers is with the substrate toward the outer shell and the breathable film toward the thermal barrier and the body of the wearer. This orientation provides better protection for the fragile moisture barrier film as well as increases the moisture vapor (i.e., perspiration) transmission potential of the moisture barrier film.

The moisture barrier is the second line of defense of a firefighter garment. This barrier provides some burn protection because of the insulation value of the substrate as well as the ability of the film/coating to reduce the passage of hot gases or liquids. The primary function of the moisture barrier is to increase firefighter comfort and to protect against hot liquids reaching the firefighter's skin.

The essence of a breathable barrier layer is a microporous polymer membrane. Microporous membranes or membrane-like constructions operate on a size exclusion principle and are termed breathable constructions. Membrane moisture barriers can handle a finite amount of moisture vapor on the order of 3 liters/square meters to 4 liters/square meters of surface area per 24 hours. When this limit is reached, the membrane wets out, is saturated and moisture vapor begins to condense on the inner surface of the barrier. This condensed moisture vapor increases the resistance of the moisture barrier to the transport of moisture vapor across the membrane. Perspiration will begin to accumulate in the thermal barrier.

Gore Chempak Selectively Permeable Fabric is constructed with a unique non-carbon-based laminate that is both liquid-proof and air-impermeable, which protects the user against liquid, aerosol and vapor toxic industrial chemicals and chemical warfare agents. At the same time, this barrier fabric contributes to total heat loss by allowing moisture vapor from perspiration to escape from the garment, thereby reducing potential heat stress for the firefighter.

The Gore family of products for the fire service industry also includes Gore Chempak ultra barrier fabric, CrossTech moisture barriers and other CrossTech products used for personal protective equipment. Gore's RT7100 moisture barrier is a cost-competitive alternative to the CrossTech barrier. The RT7100 is designed to meet the performance needs and cost considerations of rural and suburban fire departments by combining a less costly membrane with a less expensive textile substrate. The CrossTech products provide blood and body fluid resistance to penetration and are premier products for structure firefighting and emergency medical service (EMS) gear. The CrossTech moisture barrier membrane products were introduced in 1993.

Polytetrafluoroethylene Membranes

Gore-Tex's CrossTech product is the best-known example of polytetrafluoroethylene (PTFE) films. PTFE films have a chemical resistance to a wider range of substances and a higher melting point than polyurethane films. However, the relevance to firefighter safety of this wider chemical resistance and higher melting point is not immediately obvious in the context of bunker gear. A significant difference between the polyurethane, various rubber compounds and the use of PTFE moisture barriers is price. PTFE barriers are more expensive.

Polyurethane or Polyester Membranes

Polyurethane and polyester microporous membranes are made by controlled phase separation. The phase that is richer in polymer is solidified after the phase separation to form microporous membranes. For textile applications, the separation is usually induced by solvent extraction and solvent evaporation. The micropores are produced by selective removal of the solvent of prepolymers and nonsolvent (water). The micropores are in the range of 1 micron to 3 microns in diameter. Crosslinked polyurethane polymers are found in monolithic moisture barriers used by the fire service.

Foam

A flame-resistant foam should have evenly spaced apertures to trap air and allow permeation of body heat. It should also be water-resistant so it can be placed between the moisture barrier and outer shell

barrier, which protects the moisture barrier from heat and allows body heat to get beyond the moisture barrier more efficiently. This may be one of the more inexpensive constructions. Earlier specifications were written in such a way that this lower-cost product meets the specifications.

Objections to foam are that it does not breathe and can become hot. Offgassing and collapse of the foam structure are also possible. Embrittlement could occur at temperatures much lower than that for other parts of the gear. Foam is often used in knee, elbow and shoulder reinforcements.

Non-wovens and Battings

The thermal barrier can be made of battings, which are composed of fibers that are entangled by needling machines. The fibers are run through a series of many needles. This process blends the fibers and creates a soft assembly. The air between the needled fibers forms the insulating barrier. Most thermal barriers employ a non-woven batting to provide the bulk of the thermal resistance. The thermal resistance is partly a result of the type of fiber and partly a result of the dead air spaces in the batting.

Both the U.S. Army and Navy sought materials to replace the needled Nomex batting (MIL-B-81813). The goal was to find a batting that was more thermally efficient and lighter in weight and which had better FR protection, compressional recovery, wet loft retention and water-repellent capabilities. The Army Soldier Systems program evaluated both commercially available and developmental battings. Two battings were identified that merited further investigation: a P84 (polymide)/polyester blend developed under an Army contract and a Curlon/Polyester blend developed under a Navy contract.

Unlike batting, the fibers in spunlaced nonwovens are aligned and then needle-punched. This process can use water jets instead of steel needles for punching. The goal is to create a non-woven material of nominally consistent weight and thickness. When new, there is little air inside the non-woven material. More air is contained after washing; a large portion of the insulating value of non-woven liners comes from the air space between the layers. This type of liner system normally has multiple layers of insulating fabrics.

Trim Elements

The purpose of trim on turnout gear, helmets and other gear is to provide day/night visibility and quickly identify the firefighters by trim alone or with the visibility of lettering/numerals. Turnout gear also features retro-reflective and fluorescent trim to make the firefighter more visible. NFPA 1971 mandates that both retro-reflective and fluorescent trim be used on turnouts. Trim is optional on wildlands and EMS gear. Trim is not used on proximity gear. Scotchlite is available from Amazon and several other well-known companies.

Retro-reflective trim reflects light that strikes the trim back to the viewer, while fluorescent trim gives off light of its own when light falls on it. In the fire service industry, major types of trim include Scotchlite Reflective Materials from 3M and the 50mm by 2m Reflective Materials from Reflexite Corp. Reflexite trim is composed of cube-corner microprism reflective elements and is available in solid lime or yellow.

According to Reflexite Corp. and Flexcon , the polyester construction of Reflexite's microprismatic product line is flexible and durable. Reflexite films retain their photometric performance, even after being impacted, and meet all appropriate ASTM standards. The product line includes Flexcon's selection of adhesives and release liners.

Scotchlite reflective material, the most used material for retro-reflective application, is made of millions of tiny microspheres. Half of each sphere has a mirror coating. When light hits a microsphere, it is refracted through the surface and sent back out toward the light source. While this form of trim is generally considered more durable than other types of trim, it tends to lose some of its retro-reflective effectiveness when wet. Reflexite reflective material is either a glass bead system or microprisms. The material reflects in wet or dry conditions. Reflexite's retro-reflective trims are weather-resistant and comply with ANSI/ISEA 107-1999. The trims are made with enclosed microprismatic technology that enables them to reflect in daytime. They are designed to resist soiling and abrasion, and they reflect when wet.

The NFPA has minimum specifications for fire protective equipment such as tapes and reflective materials. The organization establishes electric codes and is involved in planning for and the response to issues involving Homeland Security.

Major End-Use Markets

This sector of clothing and armor protects military, industrial workforce, firefighters, law enforcement personnel, first responders and security personnel from dangers associated with their work environments. The industry has grown rapidly and should continue expanding over the forecast period.

Military Protective Clothing

The demand for personal and vehicle protection of military troops has escalated. The emergence of suicide bombers, improvised explosive devices (IED), explosively formed projectiles (EFP) and other deadly threats have raised the demand for body armor and vehicle armor. In addition, there remains some need for fire-resistant clothing and chemical/biological protective gear in-theater as well as in home bases.

Domestic Protective Clothing

First Respondents

On the domestic side, law enforcement and first responders are increasingly wearing fire-protective and flame-resistant clothing gear as it becomes more comfortable and affordable. Chemical and biological gear may seemingly be a discretionary item, but in reality, the situation and standards of protection often dictate and mandate the wearing of the appropriate level of protection. For flame-resistant clothing, the garment resist ignition and the spread of flames over the entire apparel. Flame-resistant garments do not provide significant protection from burn injury in the immediate area of contact with the fire source. Flame-resistant garments do provide protection against total clothing ignitions and sustained flame spread.

Post-creation of the Department of Homeland Security (DHS), a concerning pattern emerged. American law enforcement agencies, funded by DHS grants, started procuring equipment they had no real need for, seldom put into use and would have struggled to afford without readily available grants. Consequently, a significant portion of this equipment remained unused, collecting dust on storage shelves. However, police chiefs could often counter criticism by asserting the necessity of their forces being prepared for potential terrorist threats. The scramble for DHS grants resulted in a competitive environment among different jurisdictions. The usage, distribution of grants and equipment allocations shifted in response to economic fluctuations and the availability of protective gear.

In some large cities, the chemical/biological or hazmat gear remains on the desired list of equipment. In the hands of a trained individual, chemical and biological terror weapons are easy enough to produce and disperse.

A lack of funds has also constrained market growth. As the economy turned into a recession, cities and states lacked money to purchase basic gear and equipment. Bailout monies flowed freely to Wall Street banking institutions and to the automobile industry. As those sectors regained some control over their behavior and products, many cities and states were going bankrupt and still needed protective gear. In time, either federal money or reduced local services or a combination of these should help resolve this situation.

Other Civilian Workers

Protective clothing also holds high significance for other civilian workers, such as miners, electricians and refinery workers. It plays a vital role in offering safety under hazardous conditions, preventing injuries, illnesses, infection control and in reduction of liability. Key advantages of protective clothing for other civilian workers include protection against electrical hazards, heat and cold, dust, contamination, chemicals, falling objects and others.

Application and Technologies

Thermal and Fire Protection

Regarding fire-resistant gear and attire, the fire service sometimes undermines its own safety. This concern does not revolve around the clothing they wear but rather pertains to the use of seat belts when riding in vehicles. In several states, there is a legal exemption for emergency responders, including firefighters, which exempts them from wearing seat belts. However, this exemption, while in place, tragically results in the loss of lives among firefighters.

There has been a popular “systems” approach that has created incentives for manufacturers to create new designs for improved protection against hazardous substances.

These designs include the International Association of Firefighters (IAFF) Total Fire Group’s Project Heroes ensemble and Globe Firefighting Suits CB Ready concept. Improved integrity of garments without loss of structural firefighting capabilities should reduce firefighter exposure to a variety of hazardous materials often encountered at fire sites.

Grant funds that are available to firefighters typically are tied to compliance with existing standards. While some grant programs have slowed down, many departments are able to submit and gain new equipment through these programs.

Electrical protection is crucial for workers in multiple industries where there is large exposure to electrical hazards. It is vital to offer protection against electrical shocks, arc-flash, arc blast and others. An arc flash is an electrical breakdown of the resistance of air, resulting in an electric arc that can occur when there is sufficient voltage in an electrical system and a path to ground or lower voltage. There are many methods of protecting personnel from arc flash hazards. This can include personnel wearing arc flash PPE or modifying the design and configuration of electrical equipment. Both the Occupational Safety and Health Administration (OSHA) and the National Fire Protection Association (NFPA) have written standards and regulations that build on one another and help keep all workers safer from

electrical hazards in the workplace. Every three years the NFPA publishes a major update to its electrical safety codes, called NFPA 70E. The standard covers the full range of electrical safety issues, including safety-related work practices, maintenance, special equipment requirements and installation.

According to Lab Safety Supply most people working with electricity only require clothing that meets Category 1 or 2 protection characteristics. NFPA 70E standards are aimed more towards those workers who work in Category 3 or 4 hazard situations. Their clothing must meet APTV rating minimums throughout the life of the garment. The ATPV value represents the amount of incident energy that would cause the onset of second-degree burns.

Table 2
Personal Protective Clothing Characteristics

Hazard/Risk Category	Clothing Description	APTV Rating Cal/cm2	Lab Safety Supply Products
0	Untreated cotton-wool-rayon-silk or blend. Fabric weight >4.5oz/Yd2 (1 layer)	N/A	See Catalog
1	FR* shirt and FR pants or FR coverall (1 layer)	4	25270, 105037, 105041
2	Cotton underwear plus FR shirt and FR pants (1 or 2 layers)	8	105131, 92492, 105396
3	Cotton underwear plus FR shirt and FR pants plus FR coverall, cotton underwear plus 2 FR coveralls (2 or 3 layers)	25	92496, 105398
4	Cotton underwear plus FR shirt and FR pants plus multilayer flash suit (3 or more layers)	40	92501, 105401, 105199

* FR = flame retardant

Source: Lab Safety Supply

There is some misinformation in the definitions and market assumptions for flame-resistant wear. Items can be labeled “FR” that meet general wearing apparel standards or standards that are only applicable to upholstery or curtains. ASTM F 2302-08 is the standard performance specification for labeling protective clothing as heat- and flame-resistant. This specification includes requirements that define heat- and flame-resistance of materials used in protective clothing in a manner to limit the contribution of the clothing for causing injury to the wearer when exposed to high heat or flame. This specification does not pertain to materials and clothing that are addressed in other standards.

Specification for labeling protective clothing as heat- and flame-resistant is the minimum required standard for labeling these protective clothing as heat-and flame-resistant. This standard requires an after-flame time of no more than 2.0 seconds and char length of less than 6.0 inches when tested in accordance with ASTM Test Method D 6413 (vertical flame resistance). No melting or dripping of the specimens is allowed during the test. The fabric should not ignite, melt, drip, separate or shrink more than 10% when exposed in a forced air oven at 500°F for five minutes.

ASTM F1958 is the Standard Test Method for ignitability of non-flame-resistant material for clothing that may have electric arc exposure. Mannequins are used for the test. ASTM F1959 is the standard test to determine the arc thermal performance value for materials used in clothing. Arc ratings are expressed in cal/cm2 and are derived from the Arc Thermal Performance Value (ATPV) or Breakopen Threshold Energy (EBT).

BACKGROUND

Flame-protective apparel users include the structural/proximity firefighters, wildlands firefighters and parts of the industrial sector that includes electrical and utility workers, chemical process industry (CPI) workers, oil field service and any in-plant fire service workers. EMS workers may have use for all types of fire protective clothing, chemical/biological protective clothing and respirators. A special sector is the offshore oil and gas industry and the support firefighting segment of the onshore oil and gas production fields that invest heavily in this type of equipment and clothing. Respirators for use with fire service and for chemical/biological protection are considered in a separate section in this report.

The word garment usually refers to an article of clothing. The word clothing includes all types and segments of apparel and in the context of this chapter are garments and equipment for those in the firefighting service industry. This would include gear for structural firefighters, wildfire or wildland firefighters and their proximity gear, as well as industry workers and those in recreational activities such as racecar driving.

Some materials used in the manufacture of the fire and flame-protective garments for each of the primary sectors (structural/proximity, wildlands, industrial) are similar but may have different weaves and constructions. Some manufacturers may manufacture for all three sectors, but there may be different market leaders in a different sector. The leading materials and designers are covered in the firefighter turnout gear. Some of the technical aspects of gear components and market leaders for a different category appear under separate headings.

Since 2006, changes have occurred in the fire-protective clothing standards and recommendations. New editions of NFPA 1994 established the drag rescue device as part of firefighter coats. Other improvements have been made to garments, helmets, gloves and footwear. Changes are designed to improve breathability of the garment and mobility for the user. Grant funds are being tied to compliance with improved standards.

Chemical, Biological, Radiological and Nuclear

Chemical, Biological, Radiological and Nuclear (CBRN) continues to be an axiom in the emergency response industry. CBRN is a replacement for the Cold War era's term NBC, which became the abbreviation for nuclear, biological and chemical. This should probably be changed. The CBRN acronym is misleading because it seems to equate the threats as equals. This is not the case; they are dissimilar. The threat posed by nuclear radioactivity is different from that posed by chemical or biological hazards, which are, when detected, defensible with appropriate protective clothing and equipment. A true CBRN incident differs from a hazardous material incident in effect and scope.

In its most dangerous form, continued gamma radiation as the nuclear threat is not defensible. The new NFPA 1971 contains a CBRN option that allows an entire clothing ensemble, including self-contained breathing apparatus (SCBA), to be certified for additional protection against chemical, biological and radiological particulate hazards. (Note: This is for particulates, not radiation).

Impact/Bullet Protection and Ancillary

The application of advanced protective armor and gear for bullet protection is critical in a variety of fields and scenarios that have risk of firearm-related threats. It is designed for specialized units, first responders, security personnel, military and law enforcement and for personal protection. The type of advanced protective armor and gear worn depends on the wearer's needs. For example, soldiers typically wear full-body armor to protect themselves from all sides. Law enforcement officers typically wear vests and helmets to protect themselves from gunfire from the front. Security personnel typically wear vests and helmets to protect themselves from ballistic threats from all sides. It is an essential piece of equipment for personnel who operate in environments where a risk of ballistic threats exists.

Regulations and Standards

Important agencies involved in setting protective gear standards are summarized in the following table.

Table 3
Agencies Involved in Setting Protective Gear Standards

Agencies
American Society for Testing Materials/ASTM International
American National Standards Institute (ANSI)
Underwriters Laboratories Inc. (UL)
Department of Homeland Security (DHS)
National Institute of Justice (NIJ)
National Institute of Standards and Technology (NIST)
National Institute for Occupational Safety and Health (NIOSH)
Occupational Safety and Health Administration (OSHA)
Department of Defense (DoD)
Environmental Protection Agency (EPA)
Numerous State and Local Agencies and Jurisdictions
National Fire Protection Association (NFPA)
American Industrial Hygiene Association
U.S. Army Corps of Engineers
American Society of Safety Engineers
American Public Health Association

Source: BCC Research

National Institute of Standards and Technology
The National Institute of Standards and Technology (NIST) is a non-regulatory agency that operates as a subordinate element of the U.S. Department of Commerce. NIST's mission is the development and promotion of measurement standards and technology to enhance productivity, facilitate trade and improve the quality of life.

NIST has four cooperative programs: the NIST Laboratories, which conduct research aimed at advancing the U.S. technology infrastructure; the Baldrige National Quality Program, which conducts outreach programs for manufacturers, educational institutions and others; the Manufacturing Extension Partnership, a grouping of local centers offering technical assistance to manufacturers; and the Advanced Technology Program, which co-funds R&D partnerships with the private sector.

NIST funds industrial and academic research in a variety of ways. The Small Business Innovation Research Program Funds R&D proposals from small businesses. NIST offers other grants to encourage work in specific fields: precision measurement, fire research and materials science. In February 2009, President Obama signed the American Recovery and Reinvestment Act of 2009 (ARRA). The act includes funding for NIST. Facing a new fiscal year, it is still uncertain which NIST programs will be funded through the act.

National Institute for Occupational Safety and Health
National Institute for Occupational Safety and Health (NIOSH) operates under the direction of the Department of Health and Human Services (HHS) and the Centers for Disease Control and Prevention (CDC). Its central mission involves overseeing issues and some standards for safety and health, including chemical safety, emergency response resources, respirators, traumatic injuries and several other industrial areas concerned with workplace safety and health.

In this report, we discuss only the respirator segment as part of the protective clothing and equipment issue. NIOSH lists innumerable safety and health topics related to protective gear and clothing as well as the dangers of drugs and body art. Of special interest for this report is a set of concise pocket documents including the electronic library of construction safety and health and the pocket guide to chemical hazards, including exposure limits.

The CDC, a part of NIOSH, awards about 85% of its budget through grants and contracts to help accomplish its mission to promote health and improve quality of life by preventing and controlling disease, injury and disability. Contracts procure goods and services used directly by the agency and grants assist other health-related and research organizations that contribute to CDC's mission through health information dissemination, preparedness, prevention, research and surveillance.

Occupational Safety and Health Administration
OSHA is a subordinate element of the U.S. Department of Labor. Its mission is to assure the safety and health of America's workers by setting and enforcing standards, providing training, outreach and education, establishing partnerships and encouraging continual improvement in workplace safety and health.

OSHA's relevance to this report stems from its associations and alliances with industry, including some involved in the production and use of protective clothing and equipment, generally used in industry for safety purposes.

OSHA and its state partners have approximately 2,100 inspectors, plus complaint discrimination investigators, engineers, physicians, educators, standards writers and other technical and support personnel spread over more than 200 offices throughout the country. This staff establishes protective standards, enforces those standards and reaches out to employers and employees through technical assistance and consultation programs.

In March 2002, OSHA created the Alliance Program. This cooperative program enables organizations committed to safety and health to work with OSHA to prevent injuries, illnesses and fatalities in the workplace. OSHA and Alliance Program participants work together to reach out, educate and lead the nation's employers and their employees in advancing workplace safety and health. Groups that can form an Alliance with OSHA include employers, labor unions, trade or professional groups and educational institutions.

OSHA Standards

OSHA is well-known government regulatory agency that develops a wide range of standards. Although stated in terms of chemical protection, the same clothing and equipment are used, with some modification, for biological agent protection; therefore, this report does not differentiate between these. The purpose of chemical protective clothing and equipment is to shield or isolate individuals from the chemical hazards that may be encountered during hazardous materials operations. During chemical operations, it is not always apparent when exposure occurs. Many chemicals pose invisible hazards and offer no warning.

OSHA's guidelines describe the various types of clothing that are appropriate for use in a range of chemical operations and provide recommendations related to their selection and use. The final paragraph discusses heat stress and other key physiological factors that must be considered in connection with protective clothing use. Interpretations provide a comprehensive and easy-to-use resource for current OSHA standards and enforcement-related information. Laws, regulations and interpretations, enforcement guides and related information will be interlinked with regulatory requirements using hypertext links. Not all interpretations that have been issued by OSHA are included on its "Laws, Regulations and Interpretations" page. Ongoing maintenance is designed to provide the most up-to-date OSHA standards and interpretations of employee safety and health issues, while reducing the duplication of information and removing outdated guidance.

It is important that protective clothing users realize that no single combination of protective equipment and clothing can protect against all hazards. Thus, protective clothing should be used in conjunction with other protective methods. For example, engineering or administrative controls to limit chemical contact with personnel should always be considered as an alternative measure for preventing chemical exposure. The use of protective clothing can itself create significant wearer hazards, such as heat stress, physical and psychological stress, in addition to impaired vision, mobility and communication. In general, the greater the level of chemical protective clothing provided, the greater the associated risks. For any given situation, equipment and clothing should be selected that provide an adequate level of protection. Overprotection, as well as under protection, can be hazardous and should be avoided.

OSHA has the following flame retardant garment standards in place:

OSHA 29 CFR 1910.132

OSHA's General Duty Clause 29 CFR 1910.132 for Personal Protective Clothing plays a part in this industry, although it does not specify what types of clothing should be worn for which industry. These

standard states that personal protective equipment (PPE) should be provided when necessary and that the employer must pay for the PPE. Protective equipment, including personal protective equipment for eyes, face, head and extremities, protective clothing, respiratory devices and protective shields and barriers, shall be provided, used and maintained in a sanitary and reliable condition wherever it is necessary by reason of hazards of processes or environment, chemical hazards, radiological hazards or mechanical irritants encountered in a manner capable of causing injury or impairment in the function of any part of the body through absorption, inhalation or physical contact.

OSHA 1910.269 Electric Utility "Maintenance Standard."

This standard aims to reduce the risks associated with electrical work and protect employees from electrical hazards. It mandates proper training for workers to ensure they are aware of the potential dangers and know how to perform their tasks safely.

OSHA CFR 29 1910.269

OSHA's CFR 29 1910.269 deals with protection for utility workers or employees who are exposed to flash fires and electric arcs. While most of this regulation deals with proper training and hazard avoidance, there is some information about protective clothing in 1910.269 (1)(6)(ii-iii). This states: (ii) the employer shall train each employee who is exposed to the hazards of flames or electric arcs in the hazards involved and (iii) the employer shall ensure that each employee who is exposed to the hazards of flames or electric arcs does not wear clothing that, when exposed to flames or electric arcs, could increase the extent of the injury that would be sustained by the employee.

The paragraph states that clothing made from nylon, acetate, polyester and rayon, either alone or in blends, is prohibited by OSHA, unless the employer can demonstrate that the fabric has been treated to withstand the conditions that may be encountered or that the clothing is worn in a manner that will eliminate any perceived hazard that is involved. However, since this regulation does not have any performance characteristics about what fire retardant (FR) clothing should be able to withstand, there are a few other industry standards that must be met and considered by manufacturers of materials and garments, as well as by users of the equipment.

Regulations for thermal protective clothing

Passing vertical flammability requirements is an essential criterion for protective clothing fabrics, but it is only one of a battery of tests that fully describe the protective characteristics. After a material has demonstrated that it has self-extinguishing characteristics both initially and throughout the garment service life, additional specific tests can be employed to determine the protective capabilities to exposures such as electric arc, flash fire and molten metal splash.

The flammability of fabric can be drastically reduced through the use of fire retardant chemicals and treatments. This may lead to special handling and washing instructions. Many natural fibers, including cotton, can be topically treated with chemicals that reduce the fabric's flammability to the extent that it becomes nearly noncombustible. During a fire, the chemical reacts with the gases and chars generated by the fabric, converting the gases and tears to carbon char, thus drastically slowing the fabric's burning rate. Aramid polymers are inherently more flame retardant and resistant to combustion than chemically treated add-on materials.

A summary of the ASTM standards relating to textiles is given in the following table.

Table 4
Referenced ASTM Standards Relating to Textiles

Standards	
D123	Terminology Relating to Textiles
D4391	Terminology Relating to the Burning Behavior of Textiles
D6413	Test Method for Flame Resistance of Textiles (Vertical Test)
E171	Specification for Atmospheres for Conditioning and Testing Flexible Barrier Materials
F1002	Performance Specification for Protective Clothing for Use by Workers Exposed to Specific Molten Substances and Related Thermal Hazards
F1358	Test Method for Effects of Flame Impingement on Materials Used in Protective Clothing Not Designated Primarily for Flame Resistance
F1494 g	Terminology Relating to Protective Clothing
F1506	Performance Specification for Flame Resistant Textile Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards
F1891	Specification for Arc and Flame-Resistant Rainwear

Source: ASTM

"Normal" Flammability

Work clothes and everyday wearing apparel have some standards of regulation by the Consumer Products Safety Commission adopted in 1954 as CS 191-53. On a national basis, this standard regulates the flammability of textiles for clothing use. This is not flame-resistant clothing, but the standards that everyday materials must meet. This is summarized in the following table:

Table 5
Classes of Fabric Flammability

Class	Flammability	Description
Class 1	Normal flammability	Flames spread in four seconds or more and may or may not ignite.
Class 2	Intermediate flammability	Flames spread in four to seven seconds and the base fabric ignites.
Class 3	Rapid, intense	Flames spread in less than four seconds. Unsuitable for clothing and is dangerously flammable. Not allowed for clothing use in the U.S.

Source: Consumer Products Safety Commission

NFPA 70E Standard for Electrical Safety in the Workplace states that non-melting, flammable fiber undergarments may be used in conjunction with flame-resistant garments. Flame-resistant tee shirts, Henleys and base layer garments can provide additional protection. Heavyweight untreated 100% cotton fabrics may be more difficult to ignite than some synthetics but can and will ignite and continue to burn if exposed to an ignition source.

FLAME RESISTANCE

Flame resistance is the characteristic of a fabric that causes it not to burn in air. Flame resistance is often confused with flame retardant, which is a term used to describe a chemical substance that imparts flame resistance on fabric. The most common test method for measuring flame-resistant (FR) fabrics is ASTM D6413* Standard Test Method for Flame Resistance of Textiles (Vertical Test) (formerly; Method 5903.1 of Federal Test Method Standard 191A). The test uses an enclosed cabinet in which 12-inch-long specimens are suspended vertically over a controlled flame which is impinged on the bottom edge of the fabric for 12 seconds. From this exposure several responses are possible.

- Char length: The length of fabric destroyed by the flame so that it will readily tear by application of a standard weight (average of five specimens each; warp and fill).

- After flame: The number of seconds during which there is a visible flame remaining on the fabric after the ignition source has been removed.

- Afterglow: The number of seconds during which there is a visible glow remaining on the fabric after all flaming has ceased.

The vertical flame test ASTM D6413 is a test method with no pass/fail requirements. Industry established standards range from 4 in. to 6 in. (100 mm to 150 mm) maximum char lengths. However, a lower char length does not necessarily correlate to enhanced protection.

FIRE (OR FLAME) RETARDANCY

Fabric that is certified as fire or flame retardant (FR) has been topically treated in an immersion process with a chemical fire retardant after the fabric has been woven. All cottons and other natural fibers certified as flame retardant are FR topically treated. Some synthetic fabrics are also topically treated.

Because the treatment is topical, it will wear out in time and repeated cleanings will cause the flame retardancy to dissolve sooner. Most flame-proofing chemicals are water soluble and will also dissipate through dry cleaning. Draperies made from FR fabrics should be retested periodically for flame retardancy, as retreatment may be required. For this reason, “FR” flame retardancy is certified for only one year. A certificate of flame retardancy is furnished to customers upon request.

Inherently or permanently fire retardant fabric (IFR or PFR) is fabric woven from fibers that are noncombustible for the life of the fabric. For this reason, the fire retardancy of IFR and PFR fabrics will last for the life of the fabric and will not dissipate after cleaning. A certificate of fire redundancy is furnished upon request.

A fabric that cannot be treated for fire retardant (CBFP) should not be used in public venues. Types of fabrics that cannot be made fire retardant include certain synthetic and/or metallic fabrics.

NFPA 701 Test

Fabrics used in most public spaces (including schools, churches, auditoriums, theaters and more) are required by law in many states and cities to be certified as flame retardant according to standards developed by the NFPA. The NFPA has various standards depending on how the fabric will be used. In the case of draperies, curtains and similar hanging textiles, the standard that applies is NFPA 701: Standard Methods of Fire Tests for Flame Propagation of Textiles and Films. This test measures the flammability of a fabric when it is exposed to specific sources of ignition.

NFPA 701 (Small Scale) testing measures the ignition resistance of a fabric after it is exposed to a flame for 12 seconds. The flame, char length and flaming residue are recorded. The fabric will pass the test if all samples meet the following criteria.

- An after flame lasts less than 2.0 seconds.
- The char length is less than 6.5 inches.
- The specimen does not continue to flame after reaching the floor of the test chamber.

Fabric certified as flame retardant is certified to have been tested and passed the NFPA 701 test.

Flame retardant fabrics are textiles that are more resistant to fire than other textiles through chemical treatments or manufactured polymer fireproof fibers. Fire retardant means there is a reduced fire hazard. All textiles will burn under certain circumstances. A textile or garment may respond to flame resistance tests, which in general measure the resistance to propagation of combustion.

NFPA codes and standards are available on its website or can be purchased.

The term “fire retardant” refers to a fabric, felt, yarn or strand that is self-extinguishing and that will not burn.

The term “thermal protective performance” (TPP) relates to a fabric’s ability to provide continuous and reliable protection to a person’s skin beneath a fabric when the fabric is exposed to a direct flame or radiant heat.

The TPP measurement, which is derived from a mathematical formula, is often converted into an SFI rating, which approximates the time it takes before a standard quantity of heat causes a second-degree burn to occur. The term “limiting oxygen index” (LOI) defines the minimum concentration of oxygen necessary to support combustion of a particular material. The LOI is primarily a measurement of flame retardancy rather than temperature resistance.

Temperature resistance is typically measured as the “continuous operating temperature,” a term that measures the maximum temperature, or temperature range, at which a particular fabric will maintain its strength and integrity over time when exposed to constant heat of a given temperature or range. A fabric that has a continuous operating temperature of 400°F can be exposed to temperatures of up to 400°F for prolonged periods of time without significant degradation of fiber strength and fabric integrity and provides continued protection for the user.

The term “SFI Rating” is a measurement of the length of time it takes for someone wearing a specific fabric to suffer a second degree burn when the fabric is exposed to a standard temperature. The SFI

Rating is printed on a user's suit. The SFI Rating is not only dependent on the number of fabric layers in the garment, but also on the LOI, continuous operating temperature and TPP of the fabric or fabrics from which a garment is manufactured.

A secondary test for flame retardancy is the after-flame test, measuring the length of time it takes for a flame retardant fabric to self-extinguish after a direct flame that envelopes the fabric is removed. The term "after-flame time" is the measurement of the time it takes for a fabric to self-extinguish. According to SFI standards, a fabric must self-extinguish in 2.0 seconds or less to pass and be certifiably "flame retardant."

The term "tensile strength" refers to the maximum amount of stress that can be applied to a material before rupture or failure. The "tear strength" is the amount of force required to tear a fabric. In general, the tensile strength of a fabric relates to how easily the fabric will tear or rip. The tensile strength may also relate to the ability of the fabric to avoid becoming permanently stretched or deformed. The tensile and tear strengths of a fabric should be high enough to prevent ripping, tearing or permanent deformation of the garment in a manner that would significantly compromise the intended level of thermal protection of the garment.

Tenacity is the tensile stress at rupture of a fiber expressed in grams force per denier. Tenacity relates to the breaking strength of fibers and is not confused with modulus, which relates more directly with a fiber's ability to resist stretch. Denier is the weight in grams of 9,000 meters of a given yarn. A higher denier signifies a heavier fiber. Flex strength is the ability of a fiber to retain its strength after being folded back and forth. Flex strength is commonly expressed as loss in breaking strength after flutter testing.

Initial modulus describes a material's inherent ability to resist stretch. Initial modulus is usually expressed as grams of load per unit of stretch for a certain amount of fiber weight. The higher the initial modulus, the less the fiber will stretch. Modulus will change with age.

Ultraviolet (UV) resistance measures the effect of sunlight on textile or fiber. UV resistance is expressed as the time it would take for a material exposed to sunlight to lose half of its breaking strength.

The term "abrasion resistance" refers to the tendency of a fabric to resist fraying and thinning during normal wear. Although related to tensile strength, abrasion resistance also relates to other measurements of yarn strength, such as shear strength and modulus of elasticity, as well as the tightness and type of the weave or knit. Cut resistance refers to the tendency of yarn or fabrics to resist being severed when exposed to a shearing force.

The term "thread" describes the continuous or discontinuous elongated strands formed by carding or otherwise joining together one or more different kinds of fibers. The term "thread" differs from the term "filament."

FIREFIGHTING ENVIRONMENT

The nature of firefighting has changed over the years. Urban fire departments report that only about 2% to 3% of all calls actually involve structural building fires. Vehicle extrication and emergency medical service (EMS) may be inadequate for rescue requirements. Terror threats and response are an active part of training. The NFPA reports that stress is the leading cause of death among firefighters, not the fire itself.

Increasing firefighter mobility and comfort are now considered important elements for decreasing stress. This aspect interrelates to the department's own procedures, the physical conditioning and age of firefighters, types of calls per year and the distribution of calls between summer and winter.

Terroristic events can involve toxic materials issues as well as fire and stress issues.

ENVIRONMENTAL ISSUES WITH FLAME RETARDANT CHEMICALS

To make garments and other products fire retardant, chemicals may be used that are generally considered environmentally unsafe. Chemicals used in the manufacture of fire retardant products can adversely affect the environment. Brominated flame retardants, the major type of chemical flame retardants, are very effective in plastics and textile applications. They are applied to prevent electronics, clothes and furniture from catching fire. These add-ons chemical flame retardant additives are not permanently chemically bonded into their product substrates and could leach into the environment when the products containing them are discarded. This is a different chemistry than fabrics/fibers/polymers that are inherently flame retardant or fire-resistant, such as the aramids.

ENVIRONMENTAL ISSUES

Environmental problems are not seen as a common problem for firefighting equipment and garments, but the possibility exists. Most thermally protective gear does not use chemical additives; instead, materials that are inherently flame-, chemical-, biological- or impact-resistant are used. There are no perfect solutions to a fire problem in an imperfect world. The problem with restricting the use of all chemicals that potentially harm the environment or threaten human health is that most of the chemicals proposed or used are designed to be better than the products now in use.

As an example, the former Great Lakes Chemical Corp., now Chemtura, stopped producing penta- and octa-brominated diphenyl ether flame retardants in December 2004. A previous agreement with the EPA had been reached to replace those chemicals voluntarily, which are claimed to cause harm to human health and the environment. Chemtura is a major producer of flame retardants, including an array of bromide-, phosphorus- and antimony-based compounds.

A room fire can very quickly escalate to the point at which enough heat is generated that all combustible material in the room bursts into flames. This situation is known as flashover and can occur in a matter of minutes from ignition. Brominated flame retardants slow the initial burn rate and thereby can help increase the time to flashover, allowing occupants more time to escape. Brominated chemicals have come under increasing criticism for their use in household furnishings and in products children may come into contact with. Some scientists believe the chemicals, including polybrominated diphenyl ethers (PBDE), could have harmful effects on humans and animals. Concern has prompted some European countries to ban some of them, following the precautionary principle more common in Europe.

CLEANING AND REPAIRING GEAR

Bunker gear and turnout gear are expensive equipment made of special materials that require care. Some firefighters use the manufacturers' recommendations and closely follow them. Other stations or organizations might choose to rent gear and still another option is to contract out the cleaning, repairing and inspection of firefighter gear. Much depends on the specific contract as to which approach is most cost-effective in a specific situation.

As an example, Old Firefighter Gear (www.oldfirefightergear.com) offers a 72-hour turnaround time for cleaning personal protective equipment. The company uses a special wet wash method, the Check6 Aerospace cleaning agent together with a state-of-the-art industrial-size washer/extractor. Bunker gear should be washed once every six months. It also has to be washed before it can be inspected. Washing bunker gear more often than is necessary may damage its fire-protective integrity. Care must be taken that no manufacturers' warranty is voided.

Special attention before inspection must be paid to the Velcro enclosures, moisture barriers, reflective trim, any burn holes and the knee and shoulder pad reinforcements. NFPA guidelines commonly dictate when bunker gear should be inspected. Because a firefighter wears the gear, he or she conducts the routine inspections and is trained to look for problem areas.

Fire gear needs special attention. A trusted professional group that focuses on the safety of firefighters and the care of the ensemble is probably a better investment than a washer in the fire station. According to Shamrock Gear and Repair fire gear inspections are the heart of firefighter safety. If the moisture barrier, outer shell or thermal liner of fire gear is in poor repair, the firefighter could die.

Department Of Defense

The Department of Defense (DoD) is a major user and funder of the protective clothing and equipment sector. With 1.4 million personnel serving in the Army, Navy, Marine Corps and Air Force, the department plays a major role in the research, development, testing and evaluation (RDTE) of military-unique clothing and equipment standards and as a user of protective clothing and personal body and vehicle armor.

Every major base or post has its own fire and EMS department and requirements for both fire retardant and hazmat clothing and equipment. The Base Realignment and Closure Commission's activities may reduce some requirements. DoD's major role for purposes of this business opportunity report, however, is as an originator of needs and standards unique to the military and as a primary user of personal protective body armor and vehicle armor.

Environmental Protection Agency

The Environmental Protection Agency's (EPA) mission is to protect the environment and in this role it has some impact on the protective clothing and equipment industry, although perhaps less than other federal agencies and departments. The EPA has marginal enforcement powers, stemming partly from its lack of enforcement staffing. In the summer of 2010 the EPA, partly because of the huge BP oil spill in the Gulf of Mexico, announced that it would take action on chemicals used in dyes, flame retardants and industrial detergents to limit exposure and reduce the harm to people. The EPA released action plans to address the potential health risks of benzidine dyes, hexabromocyclododecane (HBCD) and nonylphenol (NP)/nonylphenol ethoxylates (NPEs). The chemicals are widely used in both consumer and industrial applications, including dyes, flame retardants and industrial laundry detergents. The plans identify a range of actions the agency is considering under the Toxic Substances Control Act (TSCA).

Non-Government Entities

Many agencies, departments and other entities—federal, state, local and otherwise—are to some degree involved in the business of protective clothing and equipment. These entities may have differing

agendas, with some involved in regulation and standards and others playing the roles of consumer, user or funding source. Both the executive and legislative arms of government at federal and state levels are involved, as are local jurisdictions and numerous non-governmental organizations and institutions, some of which are the primary regulatory players in these fragmented niche markets.

Each state has its own versions of major federal agencies and departments involved in regulatory, management and funding efforts. Others have charters that proclaim oversight or monitoring responsibilities. What most states lack, however, is an enforcement capability, except for law enforcement. First responders such as those involved in hazmat, EMS and similar efforts fall into a different category.

Many of the above responsibilities devolve upon local jurisdictions, major cities, counties and towns. Their requirements for protective clothing and equipment remain tied to evolving increases in population, development and the resulting requirements.

Standards pertaining to fire-resistant garments are formulated by the NFPA and the American Society for Testing Materials (ASTM), to which the manufacturers of polymers, materials and finished garments must adhere if workers are to wear their finished garments and be fully protected.

National Fire Protection Association

The NFPA is the primary U.S. standards setter for fire retardant clothing and equipment. It is the basic authority on fire, electrical and building safety. An international nonprofit association, its mission is to reduce the worldwide burden of fire and other hazards on the quality of life by providing and advocating scientifically based consensus codes and standards, research, training and education. NFPA membership totals more than 75,000 individuals from around the world and more than 80 national trade and professional organizations.

NFPA, established in 1896, is the world's leading advocate of fire prevention and is an authoritative source on public safety. NFPA's 300 codes and standards influence every building, process, service, design and installation in the U.S., as well as many of those used in other countries. NFPA's focus on consensus helps the association's code-development process earn accreditation from the American National Standards Institute (ANSI).

National Fire Protection Agency FR Garment Standards

NFPA 2112

NFPA 2112 applies to the area of flash fire exposure. NFPA 2112 this Standard on Flame-resistant Garments for Protection of Industrial Personnel against Flash Fire. It specifies the minimum design, performance and test methods for new flash fire protective garments. NFPA 2112 first discusses the criteria for garments to provide protection to personnel who could be exposed to a flash fire. The garments addressed in NFPA 2112 do not apply to protection from electric arc hazards.

The standard includes a significant section requiring third-party certification of garments that are made of flame-resistant fabrics or materials that have been treated with a flame retardant by a competent organization.

NFPA 70E

NFPA 70E deals with electrical protective clothing and, to a major extent, the determination of arc hazard. This regulation provides a section on clothing with a job-specific table on clothing requirements.

Neither NFPA 2112 nor NFPA 70E regulations are required to be followed by any law at the present time.

NFPA 1971

NFPA Standard 1971 was, as modified over the years, the basic standard governing structural and proximity fire firefighting gear (turnout or bunker gear) for individual structural firefighters. The present edition and the standard upgraded, including several new requirements for both structural and proximity protective gear.

The most obvious of these is the Drag Rescue Device (DRD) that is mandated to be part of every turnout coat under the new edition. This system is intended to make it easier to rescue downed firefighters in difficult structural fire environments.

Most of the changes taking effect under the 2013 revision of NFPA Standard 1971, Protective Ensemble for Structural Fire Fighting are not obvious to the first-time reader. One of the major changes is the matter of consolidating two protective clothing standards into one. The official name of the new standard is NFPA 1971, Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting. The separate standard for proximity gear, NFPA 1976, no longer exists.

Several other improvements have been made for garments, helmets, gloves and footwear used as part of the turnout gear ensemble. Generally, these include changes to improve breathability and mobility, both reducing firefighter stress without sacrificing any protection.

The standard specifies minimum requirements for the design, performance, testing and certification of the elements of the protective ensemble, including coats, trousers, helmets, gloves, footwear and interface items for protection from the hazards of structural and proximity firefighting operations.

NFPA 70E Standard for Electrical Safety in the Workplace.

This standard provides guidelines and requirements for electrical safety practices in the workplace, with a specific focus on protecting workers from electrical hazards.

NFPA 1977 Wildland Fire Fighting Standard.

This standard establishes requirements for the design and performance of protective clothing and equipment used by wildland firefighters.

NFPA 1971 Structural Fire Fighting and Proximity Fire Fighting.

This standard establishes the needs for the design & performance of protective clothing and equipment used by firefighters in structural fire-fighting and proximity fire-fighting environments

NFPA 1975 Station/Work Uniforms for Fire and Emergency Services

This standard provides guidelines and requirements for the design, performance and maintenance of station and work uniforms worn by fire and emergency services personnel.

ASTM International Standard

ASTM International, originally known as the American Society for Testing and Materials (ASTM), was formed more than a century ago. ASTM International is one of the largest voluntary standards development organizations in the world. The organization remains a trusted source for technical

standards for materials, products, systems and services. ASTM publishes an Annual Book of ASTM Standards each year.

Some of the important tests and standards related to this business opportunity report are summarized below.

ASTM STANDARD D6413

ASTM D6413 is the Standard Test Method for Flame-Resistance of Textiles (Vertical Test). This is a commonly used test method for measuring the effectiveness of flame-resistant fabrics. The test measures three sets of data to determine how flame-resistant a given fabric is. The criteria include (1) char length, which is the length of fabric destroyed by a flame so that it will readily tear by application of a standard weight; (2) after flame, which is the number of seconds during which there is a visible flame remaining on the fabric after the ignition source has been removed; and (3) afterglow, which is the number of seconds during which there is a visible glow remaining on the fabric after all flaming has ceased.

Referenced documents include ASTM Standards:

- D123 Terminology Relating to Textiles.
- D1776 Practice for Conditioning and Testing Textiles.
- D4391 Terminology Relating to The Burning Behavior of Textiles.

ASTM1506

ASTM 1506 is the Standard for Flame-resistant Clothing and has two basic requirements. The first is that a fabric sample must self-extinguish within less than two seconds after flame and a less than 6-inch char length according to ASTM Test Method D6413. The second requirement is that the sample must be tested for Arc Thermal Performance according to ASTM Test Method F1959.

This standard is a pass/fail standard with requirements for reporting information not considered for the pass/fail criteria. All garments that meet the requirements of ASTM F1506 must state on a garment label.

ASTM F1506 Standard for FR Clothing for Utility Workers.

This standard outlines the needs as well as performance criteria for FR clothing used in numerous industries, principally in the utility sector where workers may be subjected to electrical hazards, arc flashes and other fire-related risks.

ASTM F1959

ASTM F1959 is the Standard Test Method for Determining Arc Thermal Performance of Textile Materials for Clothing by Electric Arc and Related Thermal Hazards. This test method is used to calculate quantitative results for fabrics relating to how they perform in an electric arc environment. It determines how much heat a certain fabric will block from an electric arc before the onset of second-degree burns for the wearer. The amount of energy blocked by the fabric is reported as the Arc Thermal Performance Value. This test also determines the Heat Attenuation Factor, which is the percentage of total heat blocked by the fabric from reaching the sensor.

ASTM F1958

ASTM F1958 is the Standard Test Method for Determining Ignitability for Clothing by Electric Arc Exposure Using a Mannequin. This method is used to determine whether a specific non-flame-resistant fabric will ignite and continue to burn in an arc. Referenced documents and ASTM Standards are:

- D123 Terminology Relating to Textiles.
- D4391 Terminology Relating to the Burning Behavior of Textiles.
- F1494 Terminology Relating to Protective Clothing.
- F1506 Performance Specification for Textile Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards.
- F1959/F1959M Test Method for Determining the Arc Thermal Performance Value of Materials for Clothing.

ASTM F1891

ASTM F1891 is the Standard Specification for Arc and Flame-resistant Rainwear. It has two basic requirements. The first is that a sample of fabric must self-extinguish in less than two seconds after the flame source is removed and it should have a less than a 6-inch char length according to ASTM Test Method D6413. The second requirement is that the fabric sample must be tested for Arc Thermal Performance according to ASTM Test Method F1959.

This standard is a pass/fail standard with requirements for reporting information not considered for the pass/fail criteria. All garments that meet the requirements of ASTM F1891 must state this on the garment label.

American National Standards Institute

The American National Standards Institute, founded in 1918, oversees the creation, promulgation and use of thousands of norms and guidelines that directly impact businesses in nearly every sector, from acoustical devices to construction equipment, from dairy and livestock production to energy distribution and many more. ANSI is also actively engaged in accrediting programs that assess conformance to standards, including globally recognized cross-sector programs such as the ISO 9000 (quality) and ISO 14000 (environmental) management systems. The institute is a private, not-for-profit organization.

ANSI's mission is "to enhance both the global competitiveness of U.S. business and the U.S. quality of life by promoting and facilitating voluntary consensus standards and conformity assessment systems and safeguarding their integrity." Information powered by ANSI web resources includes the NSSN Search Engine for Standards and the Homeland Security Standards Database.

Underwriters Laboratories Inc.

Underwriters Laboratories Inc. (UL) is an independent, not-for-profit product safety certification organization that has tested products and writing standards for safety for more than a century. UL evaluates more than 19,000 types of products, components, materials and systems annually with 21 billion UL marks appearing on 71,000 manufacturers' products each year. UL's worldwide family of companies and network of service providers includes 66 laboratory, testing and certification facilities serving customers in 104 countries.

Chapter 4

Market Dynamics

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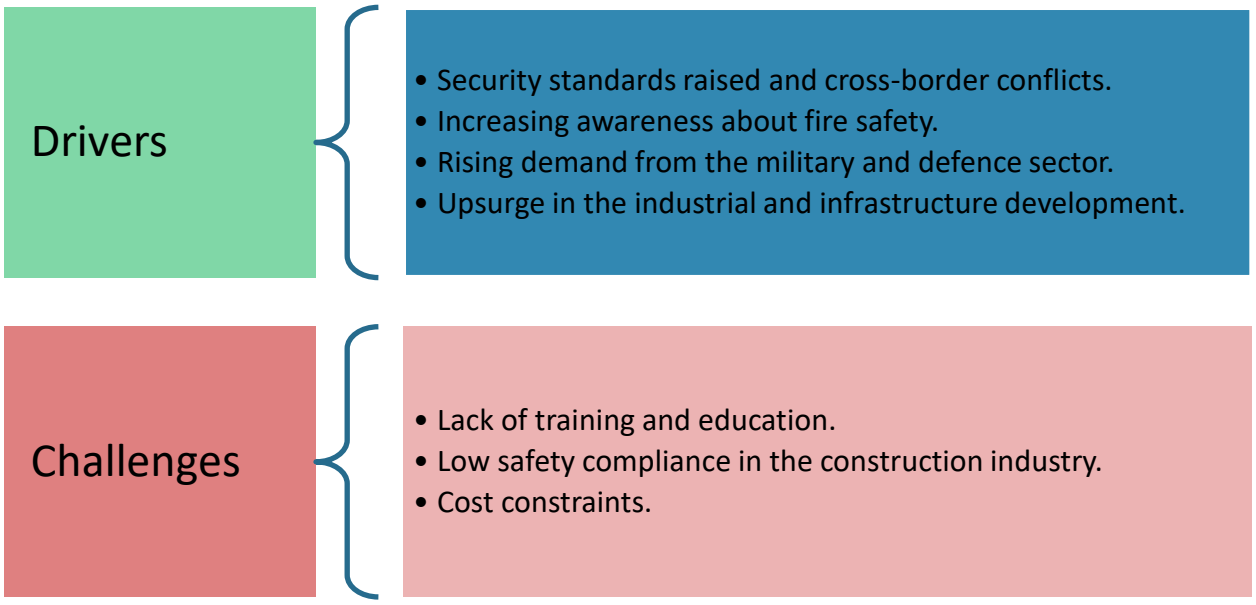
Chapter 4: Market Dynamics

Drivers and Challenges

The key factors influencing the market growth of advanced protective gear and armor – fire resistant market globally are described in the figure below

Figure 1
Drivers and Challenges of Advanced Protective Gear and Armor/Fire Resistant Market



Source: BCC Research

Drivers

Tightened Regulatory and Cross-Border Conflicts

These two factors play a crucial role in driving the market for advanced protective gear and armor/fire resistance:

- Raising security standards includes regulatory compliances, health safety and public awareness and accountability. Governments and regulatory bodies regularly update and improve the safety and security standards for several industries, including defense, public safety and industrial sectors.

- Ongoing cross-border conflicts and geopolitical tensions drive the requirement for more advanced protective gear for military personnel. Fire-resistant armor is essential in such conflicts

to protect soldiers from threats such as explosions and incendiary devices. The pressure of addressing developing threats in cross-border conflicts prompts mounted investment in R&D to design innovative fire-resistant armor that can efficiently counter new types of hazards.

Increasing Awareness About Fire Safety
Many companies are running awareness campaigns about safety, specifically in hazardous environments, contributing to the increasing demand for protective gear. These campaigns highlight the significance of gear usage properly, which should stimulate market growth.

Increasing awareness about fire safety is driving growth of the advanced protective gear and armor-fire resistance market. For example, during the past five years, the National Fire Protection Association (NFPA) estimates an average of 343,100 home fires in the U.S. each year. These fires cause an estimated $7.6 billion in property damage and 2,610 deaths.

In October 2022, the New York City Fire Department and the New York City Department of Housing Preservation and Development celebrated the development of their joint campaign, which spread fire and house safety awareness to more than 60,000 people.

These factors impact the growth of the protective gear and armor market.

Increasing Demand from the Military and Defense Sector
Defense organizations globally are investing in advanced protective gear and armor. As military technology evolves, a constant necessity arises for better fire-resistant gear to protect soldiers in combat situations. Increased defense spending and the need for enhanced protection for military personnel is driving innovations in fire retardant armor. Globally, military organizations are investing in R&D to improve the protective capacities of gear.

Upsurge in Industrial and Infrastructure Development
Using protective gears and armor in the building and construction industry can boost fire safety protection of workers and maintenance employees. It can also play a key role in reducing the escape time in the event of a fire.

For building materials to meet relevant fire safety standards and norms, their application is critically necessary. In addition to building materials, furniture (such as foam, upholstered furniture and carpets), electronic and electrical equipment and transportation products can also use fire retardants.

In industries such as construction, manufacturing and oil and gas, workers often face hazardous environments involving heat, chemicals and fire risks. Protective gear with fire-resistant properties becomes crucial to safeguarding their safety and reducing the risk of workplace accidents.

Challenges

Lack of Training and Education
Manufacturers and safety organizations are training users about the benefits of advanced protective gear and armor. Consumers may not know how to choose the appropriate protective gear and armor for their needs. Without proper training and education, consumers may not be aware of the different types

of protective gear and armor or their features when making a purchase and usage. This could lead to consumers choosing the wrong product for their needs, which could compromise their safety.

Lack of training and education leads to the following challenges:

- Ineffective use.
- Maintenance issues.
- Risk of safety if not used properly.

Low Safety Compliance in the Construction Industry
Low safety compliance in the construction industry is a major concern that has negative impacts the advanced protective gear and armor-fire resistance market. Construction workers are at high risk of injuries and death due to the nature of their work and low safety compliance only increases these risks.

Construction sites are known for their inherent hazards, including fire, heat, falling debris and other risks. As per OSHA in 2020, 4,764 workers lost their lives while on the job, resulting in a fatality rate of 3.4 per 100,000 full-time equivalent workers. Notably, workers in the transportation and material moving occupations and construction and extraction occupations jointly accounted for almost half of all fatal occupational injuries, or 47.4%. This statistic translates to 1,282 workplace deaths in the transportation and material moving occupations and 976 in the construction and extraction occupations. Effective protective gear is essential to ensure the safety and wellbeing of construction workers.

Cost Constraints
The protective gear and armor for fire resistance are manufactured from costly materials such as aramid fibers and carbon fibers. For instance, Nomex, a popular fire-resistant fabric, comprises aramids, a kind of synthetic fiber that is difficult and costly to produce. Such raw materials have the ability to sustain high temperatures and offer protection against flames, heat and other hazardous conditions.

COVID-19 Impact

The COVID-19 pandemic also led to several challenges for the market, such as increased demand for advanced protective gear product, supply chain disruptions and government regulations. The outbreak pushed governments worldwide to implement severe lockdowns and mandate social-distancing practices to limit the spread of the virus. As a result, the supply and demand for industrial-grade advanced protective gear were interrupted substantially. The private and commercial security industries were one of the most harshly affected industries by the epidemic and witnessed a drop of investments initially.

However, the market is expected to continue to grow during the forecast period as people become more aware of the importance of personal safety and security.

Russia-Ukraine War Impact

The Russia-Ukraine war has positively impacted the advanced protective gear and fire-resistant armor market. The conflict has escalated demand for these products from military and civilian customers.

On the military side, the demand for advanced protective gear for troops employed in Ukraine such as body armor, helmets and other gear designed to protect against bullets, shrapnel and other threats has surged.

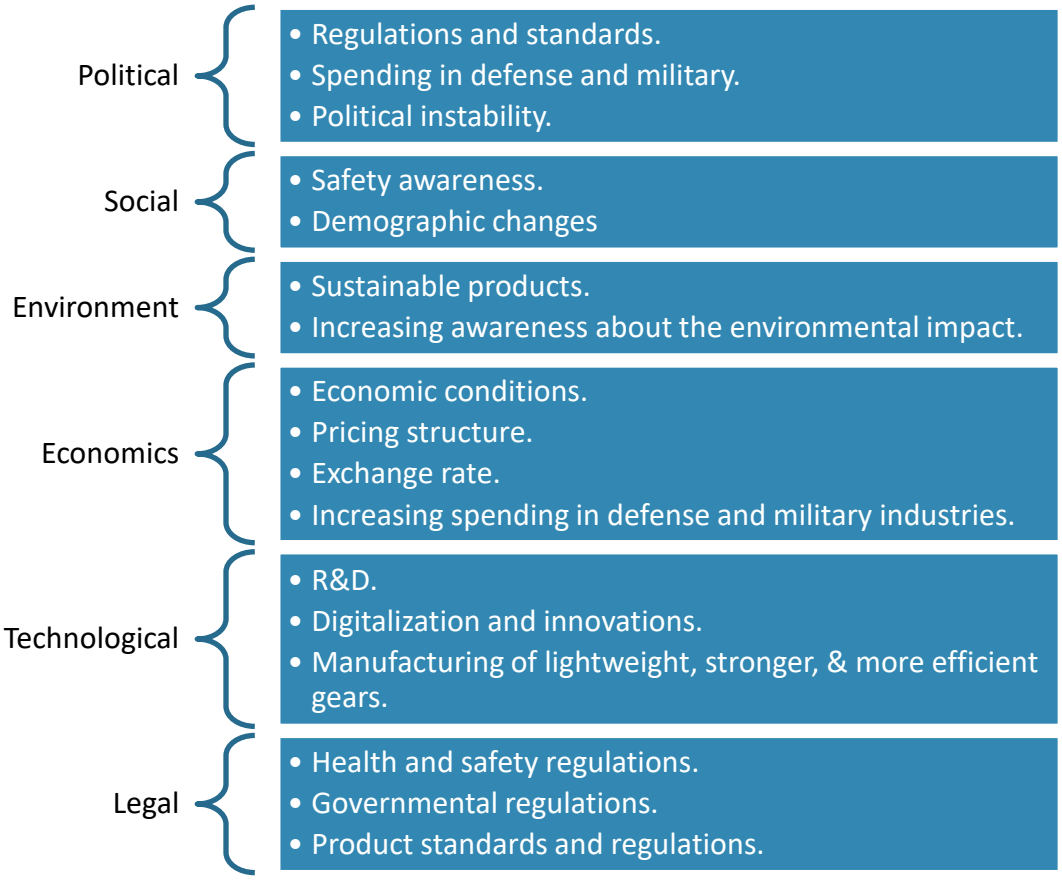
The civilian side has also experienced increasing demand for advanced protective gear. This is due to the fear of Russian cyberattacks and other threats. People are purchasing body armor, helmets and other gear to protect themselves in the event of an attack. In June 2022, UARM U.S.A Corp, National Body Armor, Armored Republic and Spartan Armor Systems reported a surge in sales of body armors following the mass shootings in Buffalo, Uvalde, New York and Texas.

The Russia-Ukraine war is projected to significantly impact the advanced protective gear and armor/fire resistance market. Increased demand is anticipated to lead to growth in the market in the coming years. The effect will spur increased investment in R&D and the manufacture of fire-resistant protective gear and armor.

PESTEL Analysis

PESTEL analysis as described in the figure below is a strategic framework used to analyze the external macro-environmental factors that may impact the overall operations and decision-making of key players.

Figure 2
PESTEL Analysis



Source: BCC Research

Chapter 5

Emerging Trends

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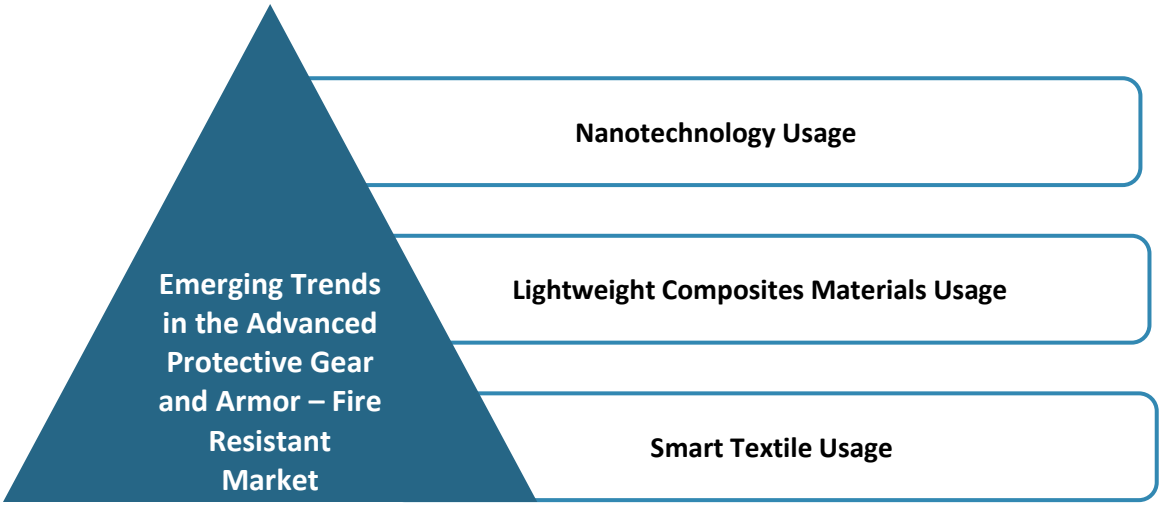
Chapter 5: Emerging Trends

Emerging Trends

The advanced protective gear and armor – fire resistant market has a broad range of applications and uses. The market is continuously expanding due to increasing demand from end-use industries. Key industry players are also continuously trying to improve their products and services to meet rising demand.

Figure 3
Emerging Trends



Source: BCC Research

Nanotechnology Usage

Nanotechnology has an important impact on the development of advanced protective gear and armor that is fire-resistant. By manipulating materials at the nanoscale level, researchers and manufacturers have been able to enhance the performance of protective equipment in terms of both fire resistance and overall functionality. Nanotechnology has facilitated the creation of flame-resistant materials that offer advanced protection against heat and flames. Nanofibers and nano-coatings can be applied to textiles to enhance their fire resistance properties without compromising comfort and flexibility. These materials can withstand higher temperatures and provide a longer window of protection, giving wearers more time to escape hazardous situations.

In addition, carbon nanotube (CNT) fibers are woven into bulletproof vests and explosion-proof blankets which offer excellent strength, absorption, flexibility and thermal insulation. CNT fibers are mainly produced by chemical vapor deposition (CVD). CNT fibers can be either single-walled or multi-walled, depending on the number of layers of graphene that comprise the cylinder.

Nanotechnology is being used to create new fire-resistant materials that are lighter, stronger and more flexible than conventional materials. Nanoparticles can be dispersed throughout a material to offer additional protection against heat and flames. They can also be applied to create new materials with unique fire-resistant properties. The nanoparticles provide additional protection against heat and flames, making the fabric more fire resistant. For example, DuPont has developed a nano-enabled fire-resistant fabric called Nomex III. This fabric is used in firefighter turnout gear and other applications where high levels of fire protection are required.

Lightweight Composite Material Usage

Composite materials have been extensively utilized in the development of advanced protective gear and armor that are fire-resistant. These materials combine different components with distinct properties to create a material that offers enhanced strength, durability and fire resistance while maintaining lightweight characteristics. They are also stronger and more durable, enabling them to better withstand the impact of bullets and other projectiles. Composite materials are a valuable element in the development of advanced protective gear and armor/fire-resistant products. Composite materials offer enhanced fire resistance, customizable, highly durable and are thermally insulated. They offer many advantages over traditional materials, making them ideal for use in high-risk environments.

Composites materials commonly used in manufacturing advanced protective gear and armor include:

- **Aramid fiber:** This fiber is used to manufacture armors which are lightweight, flexible and highly resistant to fire and bullets.
- **Carbon fiber:** This fiber is used for the helmet design which offers the following features lightweight and strong, making it ideal for protecting the head from impact.
- **Glass fiber:** This fiber is used for shield designing making it ideal for protecting the body from impact. It is also fire resistant, making it safe to use in high-risk environments.
- **Polyurethane:** Polyurethane padding is made with a soft, flexible material that is ideal for absorbing shock. It is often used in helmets, gloves and other protective gear to provide comfort and protection.

Smart Materials

Smart textiles are playing an increasingly important role in the development of advanced protective gear and armor that is fire-resistant. These textiles integrate technology and functional elements directly into the fabric, enhancing the performance and capabilities of protective equipment. Smart textiles can include built-in temperature sensors that monitor the wearer's body temperature and the external temperature. This information can provide early warnings of potential heat-related issues. Fire-resistant textiles can include thermochromic materials that change color when exposed to high temperatures. This visual indicator can alert the wearer to the presence of flames or extreme heat.

3M is an example of a company that develops a wide range of products, including smart textiles for fire resistant applications. One of their products is a conductive textile that can be used to detect heat and activate fire resistant properties. This can be used to create garments that automatically extinguish themselves when they are exposed to fire.

Chapter 6

Market by Sectors

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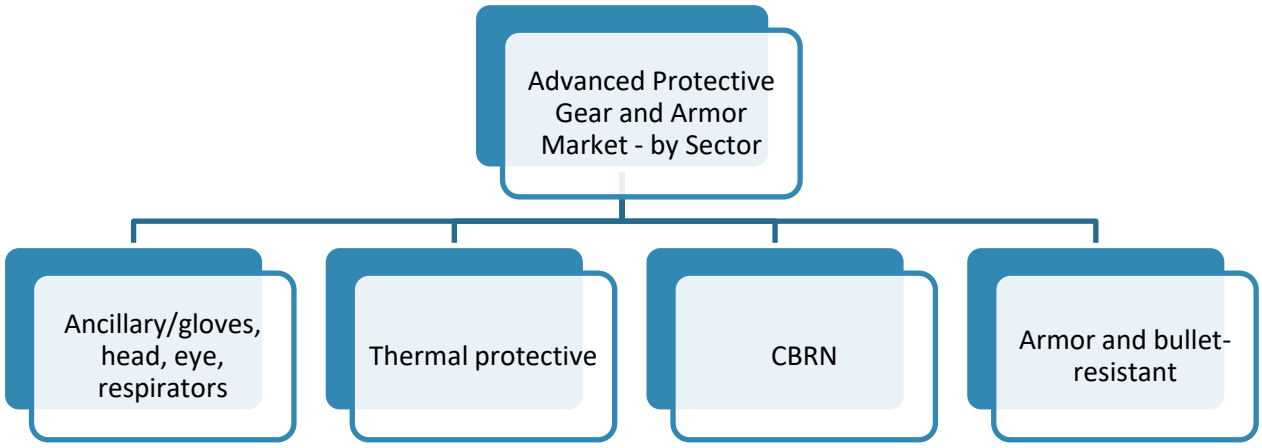
Chapter 6: Market by Sectors

Major Sectors of Flame-Resistant/Fire-Protective Apparel

The advanced protective gear and armor market is divided into four major sectors, such as:

Figure 4
Global Advanced Protective Gear and Armor Market, by Sector



Source: BCC Research

Global Market

The advanced protective gear and armor market is poised to expand significantly until 2028, driven by a amalgamation of various factors such as safety consciousness, technological advancements and growing industrial and social needs. Some of the factors for the growth are as follows:

- Increasing awareness of safety products.
- Tighter government regulations.
- Increasing defense spending.

The table below forecasts market growth based on key sectors. Among all sectors, CBRN is projected to register the highest growth rate. CBRN protective gear plays a vital role in safeguarding individuals from

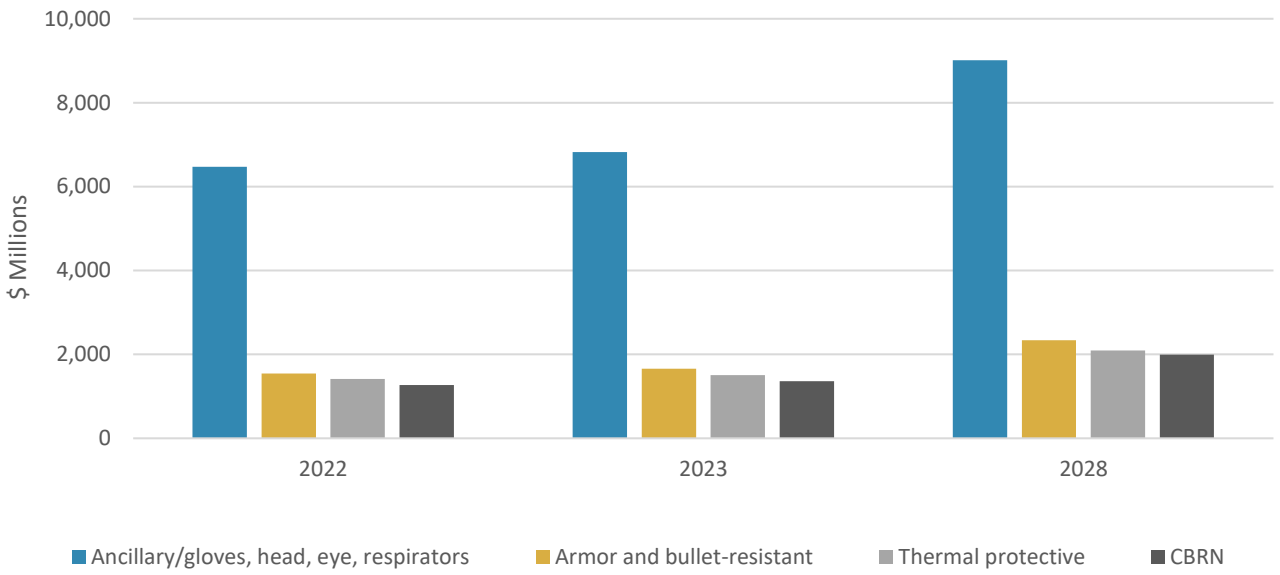
the unique and potentially catastrophic hazards posed by chemical, biological, radiological and nuclear agents. Its design, development and application are driven by the imperative to provide effective protection while allowing wearers to perform their duties as safely and efficiently as possible. The CBRN protective gear market is expected to grow at a CAGR of 7.9% during the forecast period. Key growth factors include increasing expenditures by the military and defense sectors, tighter regulatory guidelines and increasing awareness about fire-resistant apparel.

Table 6
Global Market for Advanced Protective Gear and Armor, by Sector, Through 2028
($ Millions)

Sector	2022	2023	2028	CAGR% 2023–2028
Ancillary/gloves, head, eye, respirators	6,469.4	6,823.6	9,010.6	5.7
Armor and bullet-resistant	1,546.5	1,655.7	2,337.3	7.1
Thermal protective	1,414.9	1,507.0	2,091.9	6.8
CBRN	1,267.8	1,364.7	1,994.3	7.9
Total	10,698.50	11,351.1	15,434.0	6.3

Source: BCC Research

Figure 5
Global Market for Advanced Protective Gear and Armor, by Sector, 2022–2028
($ Millions)



Source: BCC Research

Ancillary/Gloves, Head, Eye and Respirators

Ancillary protective gear for the civilian market includes respirators, gloves and head protection that in turn includes helmets and face and eye protection. Each of these pieces of equipment can be worn separately or is often worn as a component of a complete gear set, whether intended for industrial safety, firefighting, or chemical/biological hazards, with the exact gear set depending on the hazard faced. Each hazard—firefighting, industrial safety (non-bio/chem), bio/chem (industrial, hazmat responder) —normally requires either specialized or modified equipment based on the situation and hazard. For first responders, the general rule is to respond to the scene wearing the maximum level of protection if the hazard is unknown. In effect, this would be a closed protective system, including breathing, ingestion, chemical contact, flame, impact, ballistic and all other hazard protection.

The major hazards that require personal protection involve human body vulnerabilities, including the eyes, skin, lungs, central nervous system and vital organs subject to hazard-induced trauma. Excluded from this discussion are sports gear and specialized infectious disease equipment needs.

Respirators are key protective components of gear sets in the fire-protective and chemical/biological protective gear industry. Most respirators are either air-purifying or atmosphere-supplying. This report considers both categories but does not discuss sub-types and multiple-use types, such as those used in the medical sector.

Gloves as a piece of needed protective equipment have been around a long time. They have been used for various purposes throughout various cultures as well as time periods. Although U.S. government standards are discussed elsewhere in this report, note that three major organizations are largely responsible for setting the standards for the types of ancillary equipment discussed: OSHA, NFPA and ANSI. The University of Chicago Library provides several research guides for chemical safety. NIOSH also makes recommendations for chemical protective clothing.

The industrial and construction sectors are two of the largest end-users of fire-resistant products. This is due to the high risk of fire in these sectors, as well as the increasing number of regulations that require workers to wear fire resistant personal protective equipment (PPE).

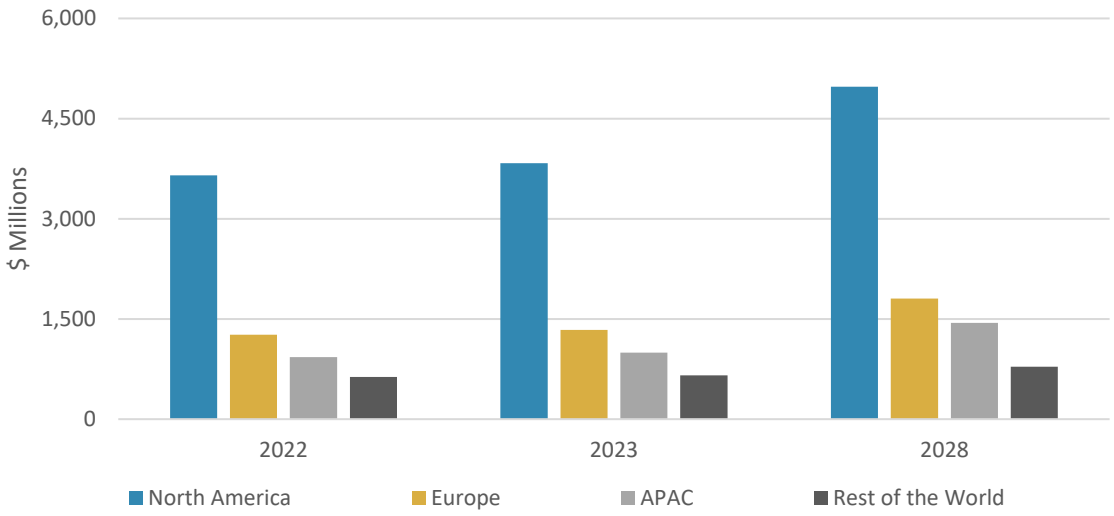
Regional market forecasts were based on trends, drivers, product penetration and sales data specific to each region.

Table 7
Global Market for Advanced Protective Gear and Armor
for Ancillary/Gloves, Head, Eye, Respirators, by Region, Through 2028
($ Millions)

Region	2022	2023	2028	CAGR% 2023–2028
North America	3,648.2	3,834.7	4,975.6	5.3
Europe	1,262.4	1,337.2	1,803.5	6.2
APAC	927.6	996.7	1,443.9	7.7
RoW	631.2	655.0	787.6	3.8
Total	6,469.4	6,823.6	9,010.6	5.7

Source: BCC Research

Figure 6
Global Market for Advanced Protective Gear and Armor
for Ancillary/Gloves, Head, Eye, Respirators, by Region, 2022–2028
($ Millions)



Source: BCC Research

Among all regions, APAC is projected to achieve the highest growth rate, 7.7%, during the forecast period. The region's expanding industrialization and urbanization are increasing its number of factories and construction sites, both of which are considered as high-risk areas for fire accidents. APAC's construction industry is thriving also due to urbanization and infrastructure development. Workers engaged in construction activities require fire-resistant PPE to mitigate risks associated with welding, cutting and other processes that generate heat and sparks.

Thermal Protective

Fire protective clothing includes a variety of materials, weaves and apparel types. These materials and types may be produced by both specialty firms or by firms that make basic polymeric. What gear is needed or used depends on the type of fire suppression or rescue operation to be performed and in what environment. There are companies that make a flame retardant fiber, there are companies that weave the fiber or combinations of fibers into technical textiles, there are the companies that design and produce the various types of protective fire protective clothing and then there is the distribution chain. All this fragmentation complicates the entire value chain for the industry. There is some vertical integration and some horizontal integration in the industry and there is a great deal of fragmentation that is tending toward some modest degree of consolidation. The entire distribution chain presents another range of complex options.

A basic understanding of where, how and when flame resistance is needed and how this is measured is important to the industry or those that would enter the industry. Common industry standards and the requirements of the standards related to specific activities, such as power generation and distribution, or in petroleum refining, are important.

Table 8
Referenced ASTM Standards Relating to Textiles

Grade	Description
D123	Terminology Relating to Textiles
D4391	Terminology Relating to the Burning Behavior of Textiles
D6413	Test Method for Flame Resistance of Textiles (Vertical Test)
E171	Specification for Atmospheres for Conditioning and Testing Flexible Barrier Materials
F1002	Performance Specification for Protective Clothing for Use by Workers Exposed to Specific Molten Substances and Related Thermal Hazards
F1358	Test Method for Effects of Flame Impingement on Materials Used in Protective Clothing Not Designated Primarily for Flame Resistance
F1494 g	Terminology Relating to Protective Clothing
F1506	Performance Specification for Flame Resistant Textile Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards
F1891	Specification for Arc and Flame-Resistant Rainwear

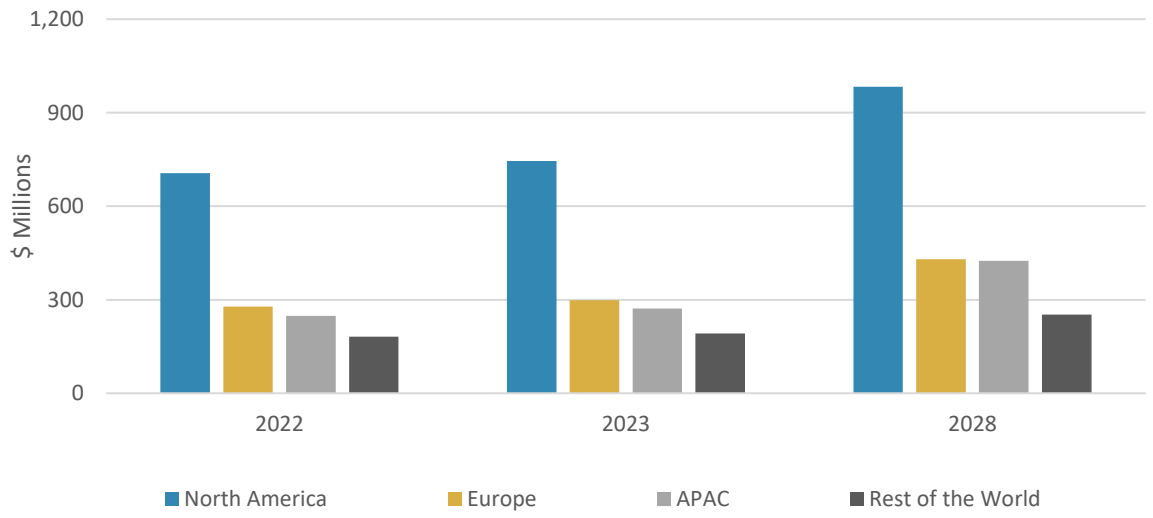
Source: ASTM

Table 9
Global Market for Advanced Protective Gear and Armor for Thermal Protective, by Region, Through 2028
($ Millions)

Region	2022	2023	2028	CAGR% 2023–2028
North America	706.1	744.8	983.5	5.7
Europe	278.2	298.6	430.3	7.6
APAC	248.7	271.5	425.3	9.4
RoW	181.9	192.2	252.8	5.6
Total	1,414.9	1,507.0	2,091.9	6.8

Source: BCC Research

Figure 7
Global Market for Advanced Protective Gear and Armor for Thermal Protective, by Region, 2022–2028
($ Millions)



Source: BCC Research

The North American market is dominating the thermal protective apparels market in the fire-resistant market. North America is known for having well-defined and strictly enforced occupational safety

regulations and standards. These regulations mandate the use of thermal protective equipment in industries where workers are exposed to heat and fire hazards, driving widespread adoption.

CBRN

CBRN continues as a buzzword in the emergency response industry. CBRN is a replacement for the Cold War era's term NBC, which became the abbreviation for nuclear, biological and chemical. This should probably be changed. The CBRN acronym is misleading since it seems to equate the threats as equals. This is not the case and they are dissimilar. The threat posed by nuclear radioactivity is different from that posed by chemical or biological hazards, which are, when detected, defensible with appropriate protective clothing and equipment. A true CBRN incident differs from a hazardous material incident in effect and scope.

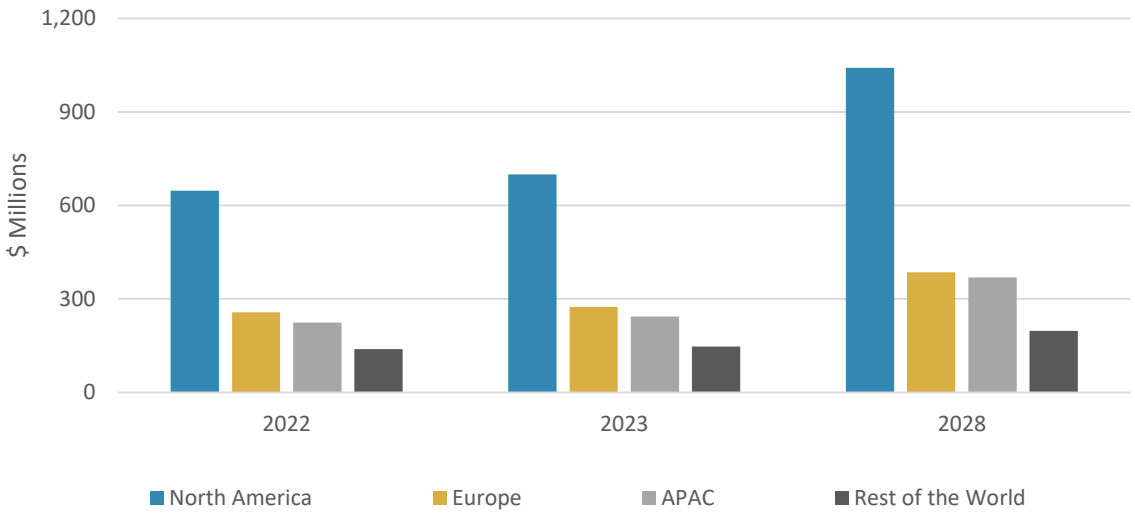
In its most dangerous form, continued gamma radiation as the nuclear threat is not defensible. The new NFPA 1971, however, contains a CBRN option that allows an entire clothing ensemble, including SCBA, to be certified for additional protection against chemical, biological and radiological particulate hazards. This "systems" approach has created incentives for manufacturers to create new designs for improved protection against hazardous substances.

Table 10
Global Market for Advanced Protective Gear and Armor for CBRN, by Region, Through 2028
($ Millions)

Region	2022	2023	2028	CAGR% 2023–2028
North America	647.3	699.4	1,041.8	8.3
Europe	256.8	274.3	386.0	7.1
APAC	224.7	243.6	369.3	8.7
RoW	139.1	147.4	197.2	6.0
Total	1,267.8	1,364.7	1,994.3	7.9

Source: BCC Research

Figure 8
Global Market for Advanced Protective Gear and Armor for CBRN, by Region, 2022–2028
($ Millions)



Source: BCC Research

Armor and Bullet Resistant

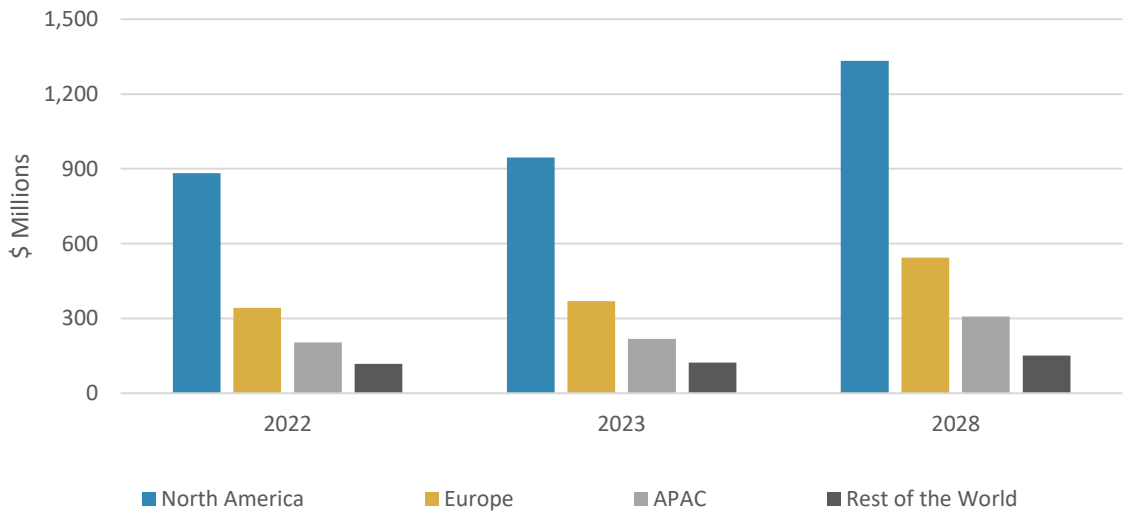
Armor includes body armor—bullet-resistant vests (outer tactical vests), hard body armor, or inserts (small arms protective inserts or SAPI plates) and associated helmets, ballistic eye protection, fire resistant gloves and vehicle armor and protection of vehicles against both ballistic and explosive threats. The armor industry is not exclusive to the military market—law enforcement, certain high profile corporate or government employees and homeland security requirements are significant, but the largest single necessity for armor remains the military ground forces.

Table 11
Global Market for Advanced Protective Gear and Armor
for Armor and Bullet Resistant, by Region, Through 2028
($ Millions)

Region	2022	2023	2028	CAGR% 2023–2028
North America	882.6	945.2	1,333.5	7.1
Europe	342.4	369.5	544.2	8.1
APAC	203.8	218.1	308.1	7.2
RoW	117.7	123.0	151.4	4.2
Total	1,546.5	1,655.7	2,337.3	7.1

Source: BCC Research

Figure 9
Global Market for Advanced Protective Gear and Armor
for Armor and Bullet Resistant, by Region, 2022–2028
($ Millions)



Source: BCC Research

Bullet-resistant vests are manufactured to offer key protection for law enforcement, military personnel, security professionals and individuals facing potential ballistic threats. Their fundamental goal is to lower the risk of injury from firearm projectiles. The bullet-resistant vests market plays a vital role in offering protective solutions to individuals and professionals facing ballistic threats. Advancements in materials, design and technology persist to shape this market, increasing the safety and security of those who rely on such protective gear.

Chapter 7

Market by Region

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Chapter 7: Market by Region

Global Market

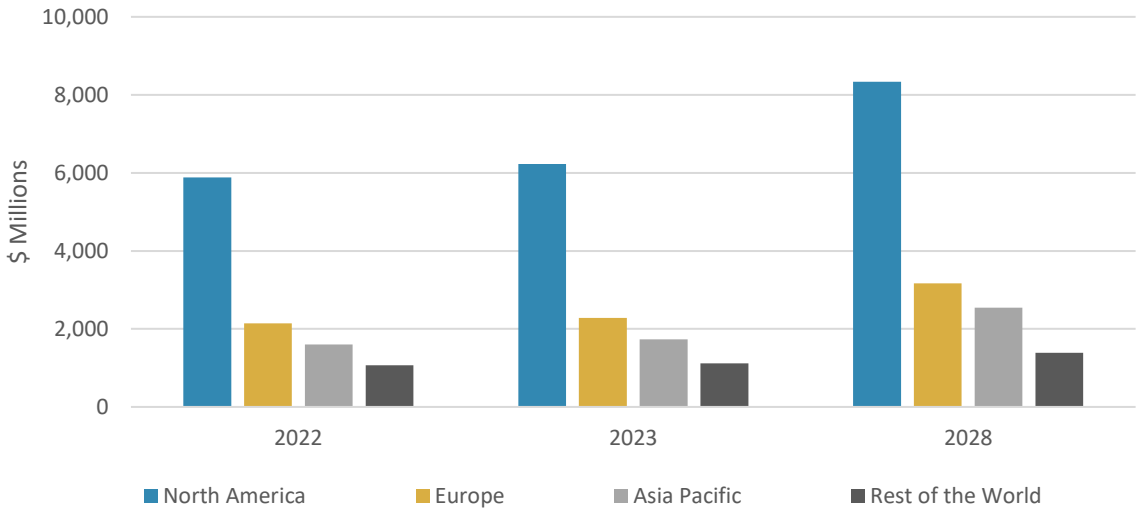
The advanced protective gear and armor market should grow substantially through 2028. The North America region accounts for largest market of advanced protective gear and armor, followed by Europe and Asia-Pacific. The Asia-Pacific region is the fastest growing because economies are driving investment in infrastructure and manufacturing, which is creating demand for advanced protective gear and armor.

Table 12
Global Market for Advanced Protective Gear and Armor, by Region, Through 2028
($ Millions)

Region	2022	2023	2028	CAGR% 2023–2028
North America	5,884.2	6,224.1	8,334.4	6.0
Europe	2,139.7	2,279.6	3,164.0	6.8
Asia-Pacific	1,604.8	1,729.9	2,546.6	8.0
RoW	1,069.9	1,117.6	1,389.1	4.4
Total	10,698.5	11,351.1	15,434.0	6.3

Source: BCC Research

Figure 10
Global Market for Advanced Protective Gear and Armor, by Region, 2022–2028
($ Millions)



Source: BCC Research

North American Market

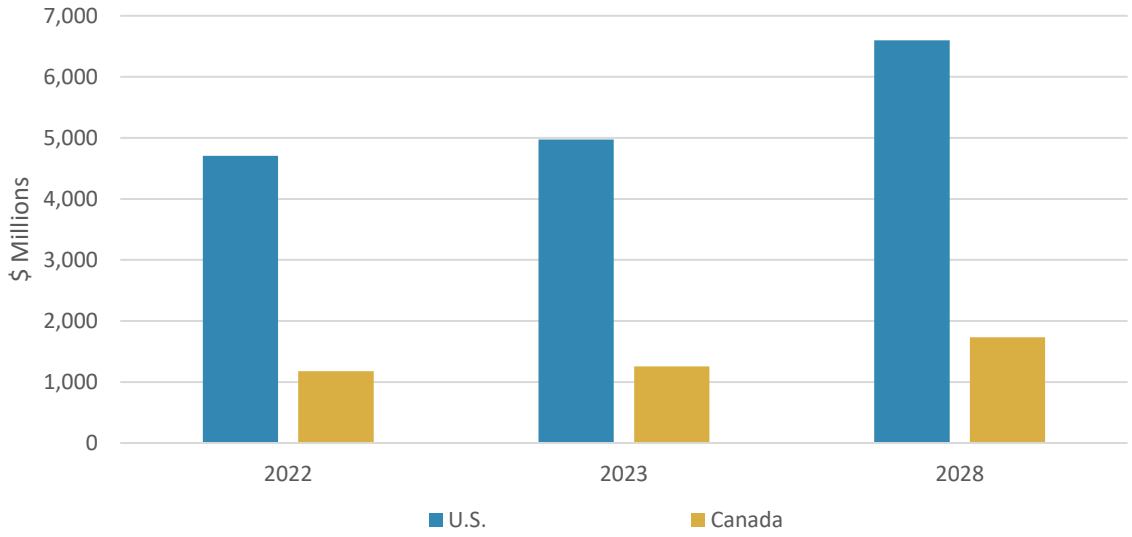
In 2021, fire departments in the U.S. responded to over 1.3 million fire-related incidents that caused more than 3,500 deaths and 15,000 injuries. The number of fire-related accidents and damage is increasing, pushing demand for enhanced protective gear and armor. The U.S. government has regulations that require employers to provide personal protective equipment (PPE) to their employees who are exposed to hazards in the workplace.

Table 13
North American Market for Advanced Protective Gear and Armor, by Country, Through 2028
($ Millions)

Country	2022	2023	2028	CAGR% 2023–2028
U.S.	4,707.4	4,970.9	6,600.8	5.8
Canada	1,176.8	1,253.1	1,733.6	6.7
Total	5,884.2	6,224.1	8,334.4	6.0

Source: BCC Research

Figure 11
North American Market for Advanced Protective Gear and Armor, by Country, 2022–2028
($ Millions)



Source: BCC Research

In Canada, an increased focus on safety is growing demand for advanced protective gear and armor. Employers are seeking more ways to protect their employees from hazards: advanced protective gear and armor is one way to do this. The growth of this market is determined by factors such as increasing demand for fire resistant gear from end-users such as firefighters, law enforcement personnel and industrial workers, growing government regulations on workplace safety and technological improvements in the manufacturing of fire-resistant gear.

European Market

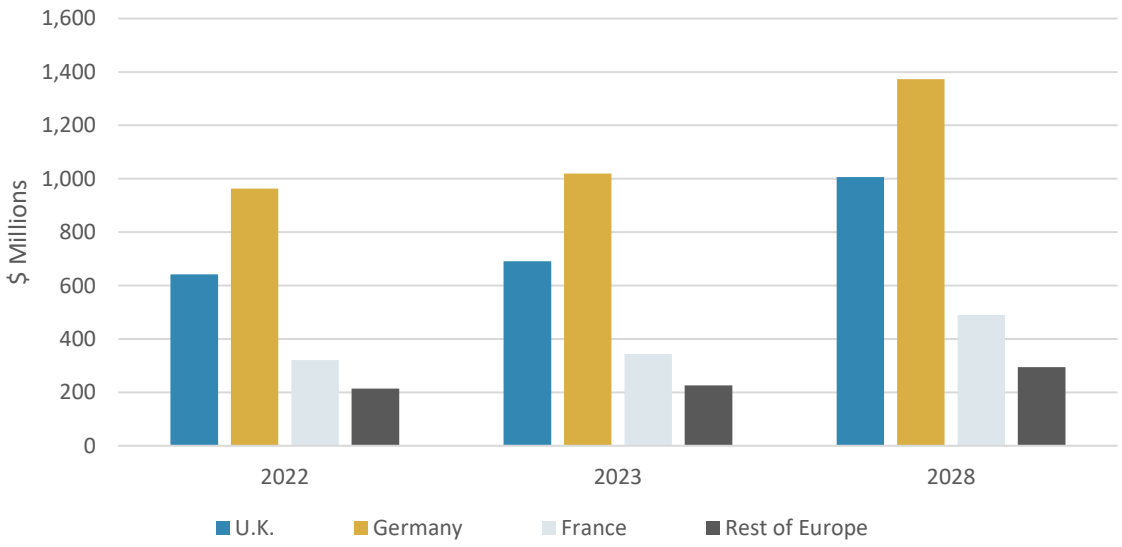
In Europe, market growth was bolstered by the Russia-Ukraine war, which has led to increased fire risks in Ukraine and other parts of Europe. The war is predicted to substantially impact the European market of advanced protective gear and armor fire resistant. The war is estimated to lead to an upsurge in demand for fire resistant gear, increased prices for fire resistant gear, shortages of fire-resistant gear, improved focus on R&D and new opportunities for European companies.

Table 14
European Market for Advanced Protective Gear and Armor, by Country, Through 2028
($ Millions)

Country	2022	2023	2028	CAGR% 2023–2028
U.K.	641.9	690.6	1,006.1	7.8
Germany	962.9	1,019.6	1,373.2	6.1
France	321.0	343.8	490.4	7.4
RoE	214.0	225.6	294.3	5.5
Total	2,139.7	2,279.6	3,164.0	6.8

Source: BCC Research

Figure 12
European Market for Advanced Protective Gear and Armor, by Country, 2022–2028
($ Millions)



Source: BCC Research

In Europe, Germany is a key market in the region's advanced protective gear and armor/fire resistant market. Germany has a sound industrial base, advanced manufacturing capabilities and a strong focus

on workplace safety. Germany is known for its strong industrial sector, involving manufacturing, engineering, chemicals and more. These industries require high-quality protective gear for workers who may be exposed to fire and other hazards. The U.K. is the second-largest market for advanced protective gear and armor in Europe, after Germany.

Asia-Pacific Market

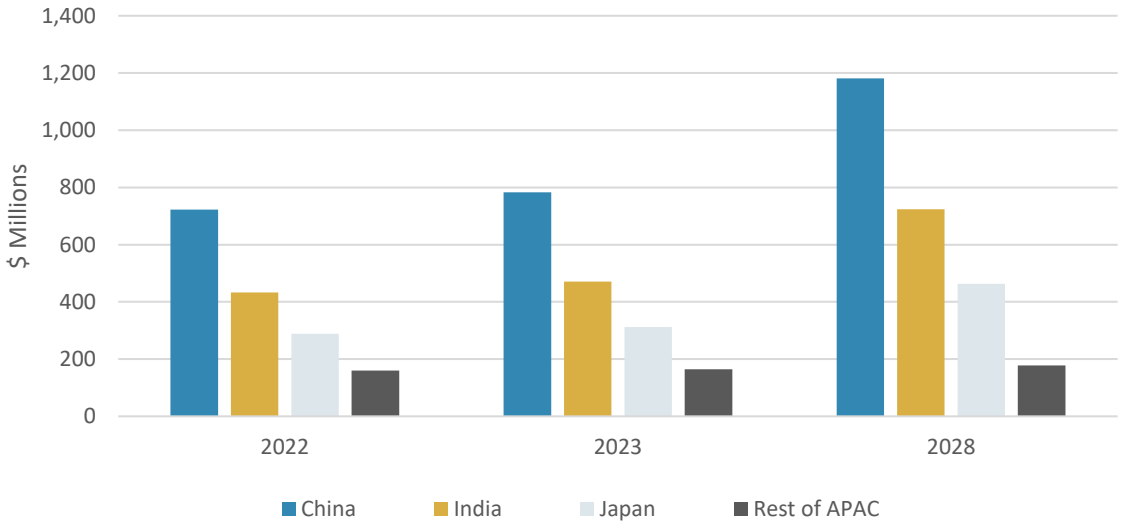
Asia-Pacific region is home to many large and growing economies, such as China, India and Japan. These economies are driving investment in infrastructure and manufacturing, which is creating demand for advanced protective gear and armor. Governments across Asia-Pacific are enacting regulations on workplace safety that mandate the use of advanced protective gear and armor by workers in high-risk industries.

Table 15
Asia-Pacific Market for Advanced Protective Gear and Armor, by Country, Through 2028
($ Millions)

Country	2022	2023	2028	CAGR% 2023–2028
China	722.2	782.5	1,181.6	8.6
India	433.3	471.0	723.2	9.0
Japan	288.9	312.0	463.5	8.2
Rest of APAC	160.5	164.5	178.3	1.6
Total	1,604.8	1,729.9	2,546.6	8.0

Source: BCC Research

Figure 13
Asia-Pacific Market for Advanced Protective Gear and Armor, by Country, 2022–2028
($ Millions)



Source: BCC Research

China is the largest market for advanced protective gear and armor in Asia-Pacific. China is also home to a large and growing manufacturing sector, a key driver of growth in the Asia-Pacific regional market. The Chinese manufacturing sector is characterized by many small and medium-sized enterprises (SMEs), which are often more likely to adopt new technologies and products than larger enterprises. This makes China an attractive market for advanced protective gear and armor manufacturers.

In India, rapid industrialization and infrastructure development have increased the demand for fire-resistant gear to protect workers from fire hazards and other risks associated with industrial processes. The Indian government has implemented stricter safety regulations and standards in industries such as oil and gas, petrochemicals and construction. Compliance with these regulations necessitates the use of advanced protective gear.

Rest of the World Market

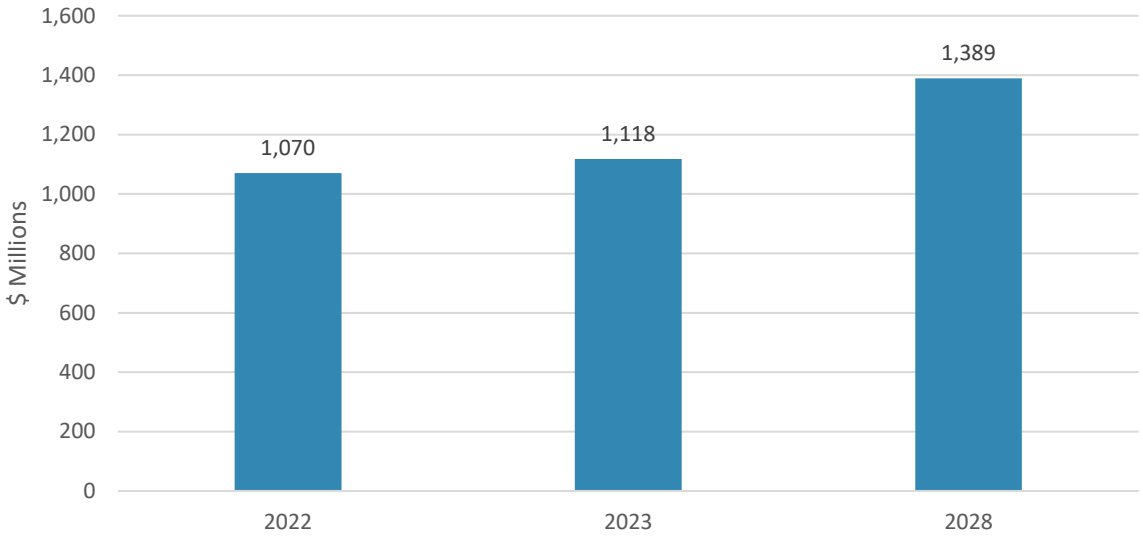
In the RoW market, there is growing adoption of modern fire-resistant protective gear and armor products. A growing number of industries require fire-resistant gear tailored for their own associated risks and hazards. In the RoW region, the MEA countries have undergone significant industrial growth, particularly in its oil and gas, construction and manufacturing sectors. Stringent regulations and safety standards imposed by governments and industry bodies have necessitated the use of high-quality fire-resistant protective gear.

Table 16
RoW Market for Advanced Protective Gear and Armor, Through 2028
($ Millions)

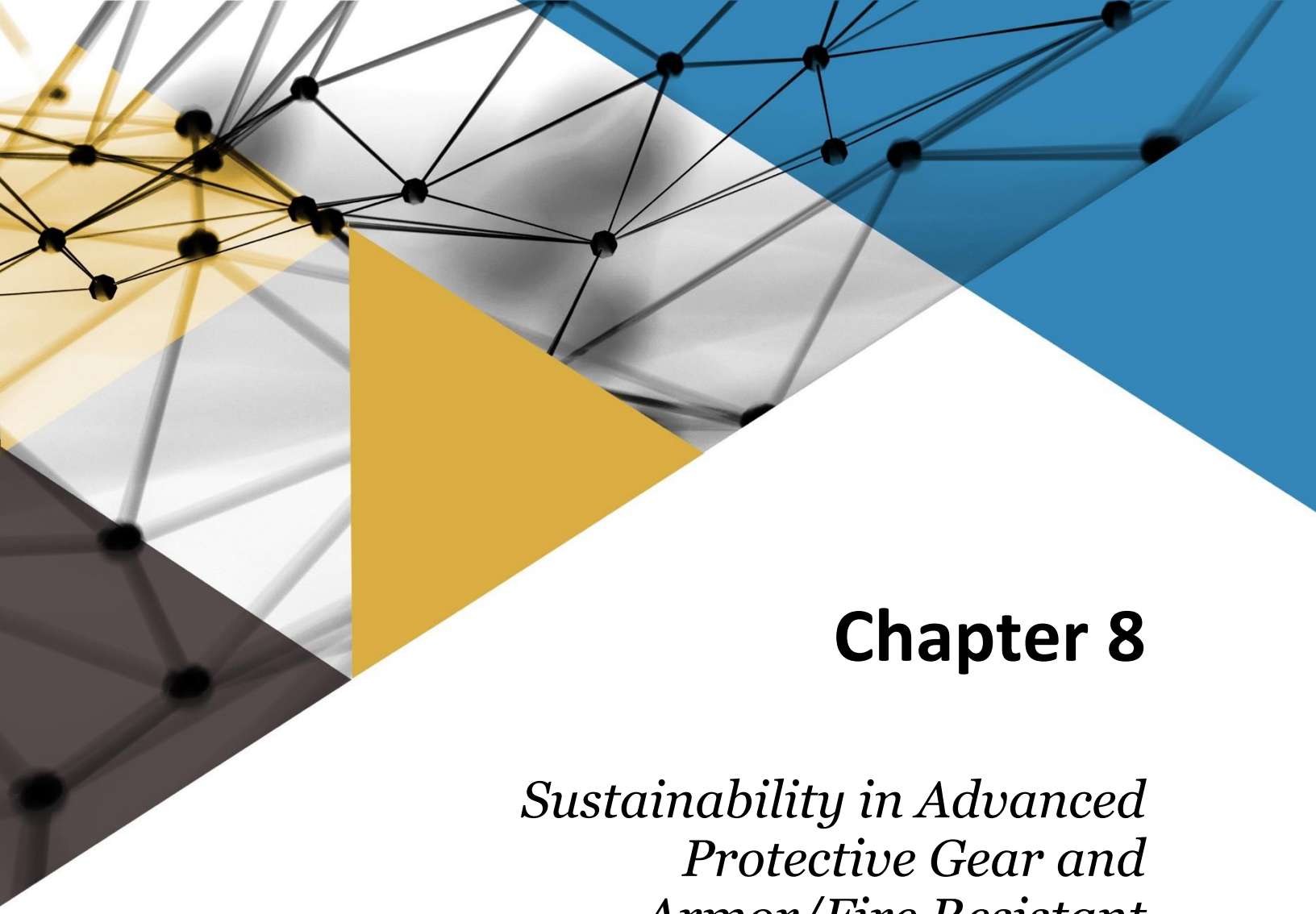
	2022	2023	2028	CAGR% 2023–2028
RoW	1,069.9	1,117.6	1,389.1	4.4

Source: BCC Research

Figure 14
RoW Market for Advanced Protective Gear and Armor, 2022–2028
($ Millions)



Source: BCC Research



Chapter 8

Sustainability in Advanced Protective Gear and Armor/Fire Resistant Global Market

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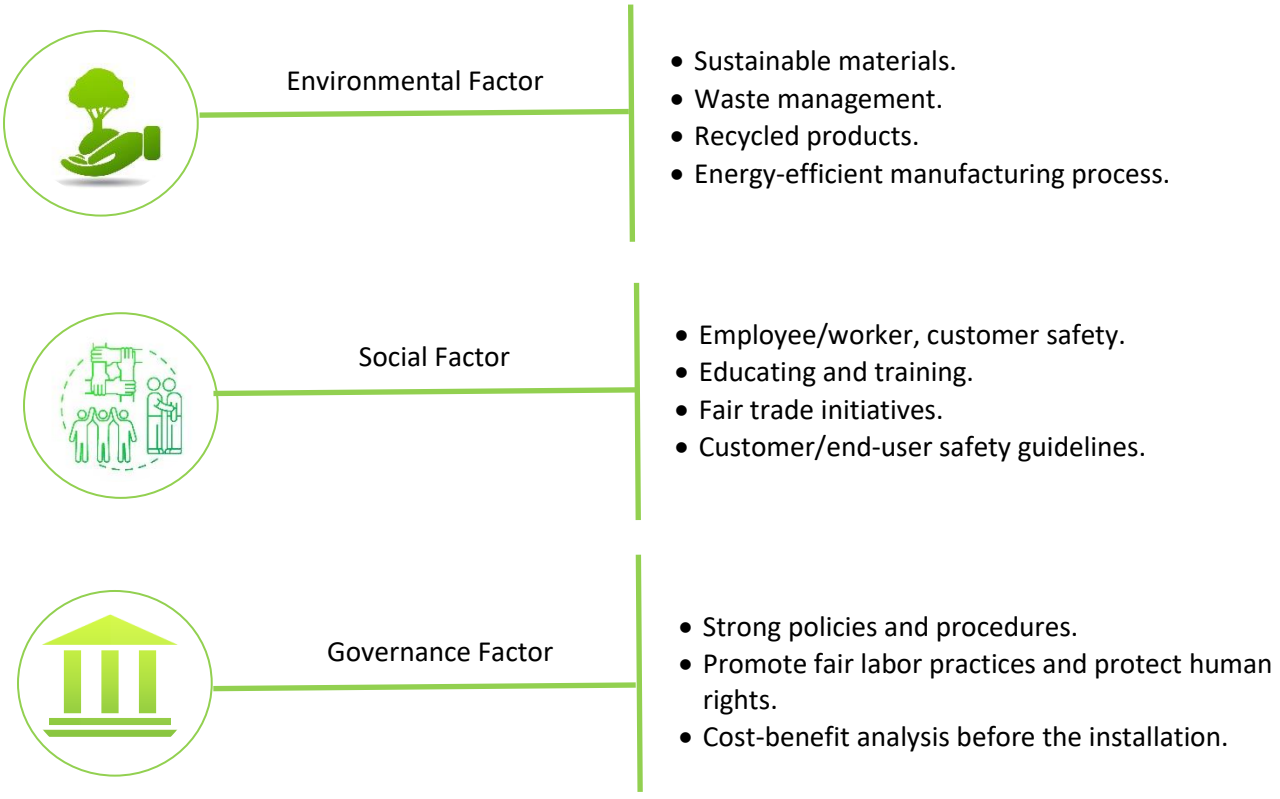
Chapter 8: Sustainability in Advanced Protective Gear and Armor/Fire Resistant Global Market

Sustainability in Advanced Protective Gear and Armor/Fire Resistant Market

Environmental, Social and Governance (ESG) factors are becoming more important for companies and investors. In the advanced protective gear and armor/fire resistant market, ESG considerations can play a significant role in determining which products and services are chosen.

Figure 15
ESG Factors for Advanced Protective Gear and Armor Market



Source: BCC Research

ESG considerations for advanced protective gear and armor fire resistant systems contain the ESG aspects of the system. By certifying that the system is designed, installed and maintained in a way that is environmentally liable, socially aware and financially sustainable businesses can help abate their impact on the environment, confirm the safety of people and attain long-term financial value.

ESG Compliance of Selected Companies in Advanced Protective Gear and Armor/Fire Resistant Market

This report covers all the major manufacturers of advanced protective gear and armor/fire resistant market present in the market. The market's wide range of companies has fragmented it. As such, we have covered key manufacturers and their ESG risk ratings, as shown in the table below. ESG risk ratings primarily measure the extent to which an organization's economic value is at risk driven by key ESG factors or the scale of a company's unmanaged ESG risks.

Table 17
ESG Compliant Companies Risk Rating

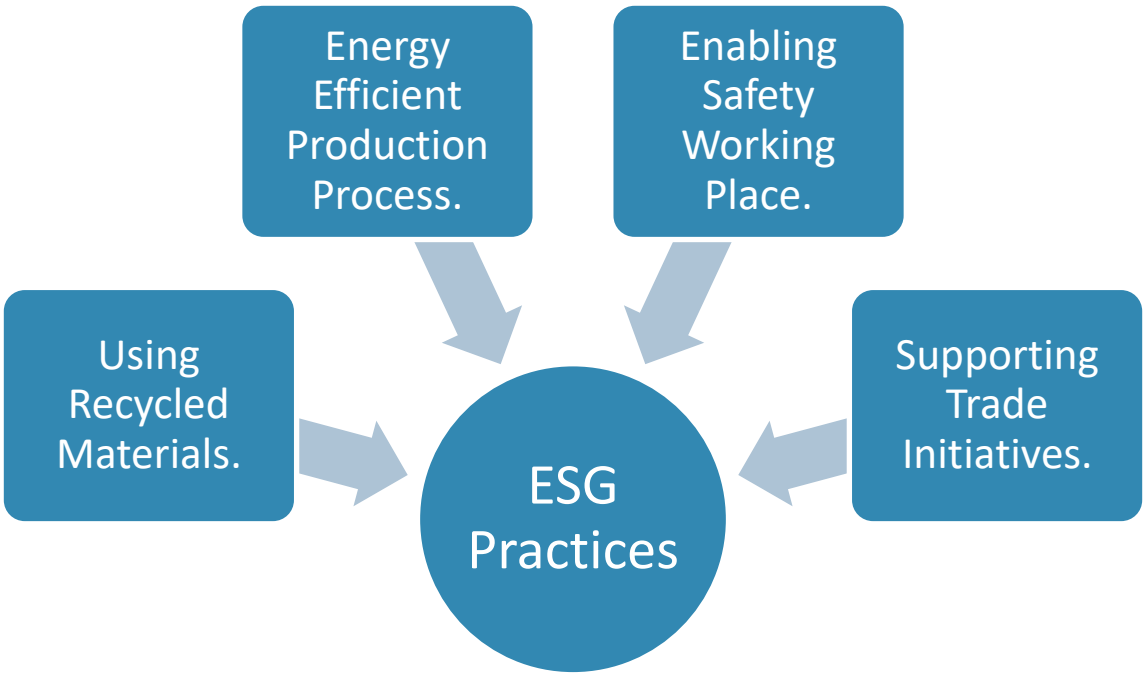
Company Name	ESG Risk Rating
3M Co.	34.90
Avon Protection	33.00
BAE Systems	26.15
DuPont De Nemours Inc.	28.81
Honeywell International Inc.	28.62
MSA Safety Inc.	19.12
Kimberly-Clark	21.94

Source: PitchBook Data, Inc.

ESG Practices by Advanced Protective Gear and Armor/Fire Resistant Manufacturers

There are various type of ESG practices in advanced protective gear and armor/fire resistant that companies can apply to foster sustainability and social responsibility.

Figure 16
ESG Practices of Players in the Advanced Protective Gear and Armor Market



Source: BCC Research

3M
Key ESG practices followed by 3M include:

- 3M uses recycled materials in the production of some of its advanced protective gear and armor/fire resistant products, such as its 3M Scotchgard Fire Resistant Fabric.
- It uses a variety of energy-efficient manufacturing processes, such as variable speed drives to control the speed of motors, which reduces energy consumption and helps heat recovery systems to capture and reuse waste heat.
- 3M ensures its employees work in safe conditions by providing proper safety equipment and training. This helps to protect employees from injuries and illnesses.
- Company has many fair-trade partnerships in place, including partnerships with suppliers of recycled materials, organic cotton and cocoa. These partnerships help ensure that 3M's advanced protective gear and armor - fire resistant products are made with ethically sourced materials.

Honeywell
Key ESG practices followed by Honeywell include:

- Honeywell uses recycled materials in the production of some of its advanced protective gear and armor - fire resistant products, such as its Nomex 510FR Fabric. Honeywell has many recycled content goals in place for its advanced protective gear and armor - fire resistant products. For example, the company has a goal of using 50% recycled content in its Nomex 510FR Fabric by 2025.

- Honeywell is committed to providing a safe and healthy work environment for its employees. The company is engaged in training employees, auditing fire related incidents and avoiding the fire incidents.

Chapter 9

Patent Analysis

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Chapter 9: Patent Analysis

Patent Analysis

The tables given below lists few of the recent published patents by some of the leading market players related to advanced protective gear and armor/fire resistant market. Key focus areas of major patents provided below are related to protection garments, helmet retention systems, flame resistant yarns and others.

Table 18
Patents on Advanced Protective Gear and Armor Market

Patent No.	Year Published	Year Expiration	Assignee	Abstract
U.S.-11700902-B2	18-Jul-23	25-Jun-41	ArmorSource LLC	Helmet Retention System.
U.S.-11672290-B2	13-Jun-23	20-Sep-41	Dupont	Protective Glove.
U.S.-11103017-B2	31-Aug-21	10-Jul-39	Dupont	Protective Garment with harness access.
JP-6685071-B2	22-Apr-20	14-Sep-35	Dupont	Crimped aramid staple fiber, high strength spun yarn made of the same, fiber structure and protective material.
JP-6704209-B2	3-Jun-20	24-Feb-35	Dupont	Flame retardant protective textile.
U.S.-11077325-B2	3-Aug-21	14-Nov-38	Dupont	Flame and particulate resistant knit article.
EP-2861789-B1	9-Sep-20	11-Jun-33	Dupont	Flame resistant spun staple yarns made from blends of fiber derived from sulfonated naphthalene poly-oxadiazole polymers.
U.S.-11213089-B2	4-Jan-22	7-Jun-39	MSA Safety	Protective helmet with face protection shields and linkage mechanism.
U.S.-11185723-B2	30-Nov-21	24-Jan-40	MSA Safety	Bypass knob for breathing apparatus pressure regulator.
U.S.-11137231-B2	05-Oct-2021	13-May-39	Point Blank Enterprises	Soft armor fabrication.

Source: PitchBook Data, Inc.

Chapter 10

Company Profiles

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Chapter 10: Company Profiles

3M CO.

3M Corporate Headquarters
3M Center
St. Paul, MN 55144-1000
Tel: 800/328-6276
Website: www.3m.com

3M is an American multinational conglomerate founded in 1902 and formerly known as Minnesota Mining and Manufacturing Company. The company produces more than 60,000 products, including adhesives, abrasives, laminates, passive fire protection, dental products, electronic materials, electronic circuits and optical films.

The company operates in more than 70 countries. Overall, 60% of the company's sales are in markets outside of the U.S. 3M employs 94,987 people worldwide. In 2022, 3M had revenues of $34.2 billion.

The company leverages significant crossover among its various target industries to help drive sales and bolster its brand recognition. Brand recognition, alongside an expansive range of product lines, has helped the company to drive significant commercialization success across many segments. A full list of 3M products is outside the scope of this report. However, key facets include automotive equipment and aftermarket sales, printing and paper, food and beverage, construction products, various industrial products including tapes, nonwovens, adhesives, abrasives, ceramics, sealants, separation products, purification products and various components for other machinery including automotive equipment, aircraft equipment, marine systems and others.

Within the fire suppression industry, the company is well known for its fire suppression consumables, or fire suppressants. Examples include the 3M Novec 1230 Fire Protection Fluid, which is a clean-agent type fire extinguishant. Developed as a halon replacement and/or a hydrofluorocarbon (HFC) alternative, the product belongs to a family of chemicals called halocarbons, a group which includes HFCs and fluoroketones. Novec 1230 fluid is a fluoroketone. In contrast, other well-known chemical clean agents including FM-200 and ECARO-25 are HFCs (HFC-227ea, HFC-125). Novec 1230 fluid has a global warming potential (GWP) of less than one, while competing HFCs have a GWP of more than 3000, a significant benefit to its consumers. Novec 1230 fluid also has the highest margin of safety for human occupancy among clean agents, including inert gas. Key benefits of the Novec system include:

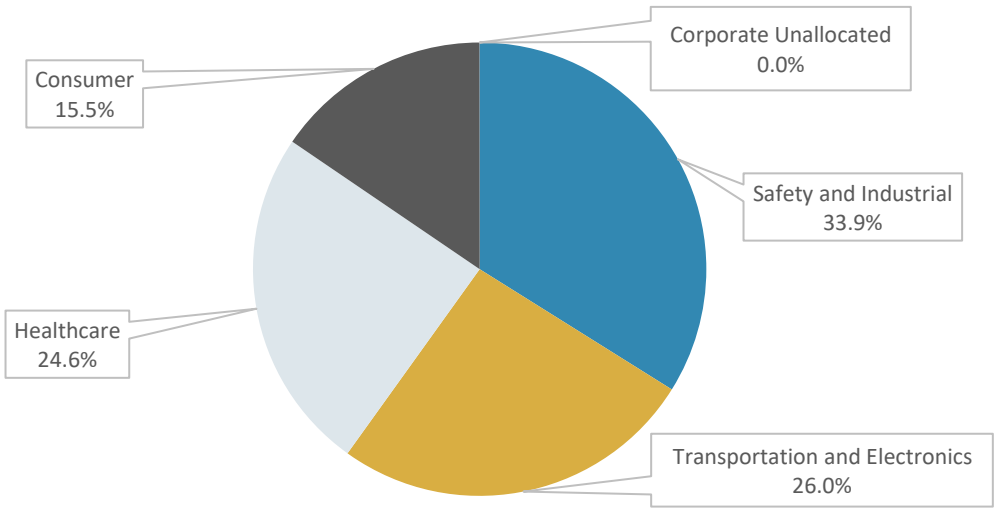
- Rapid extinguishing, often in seconds, compared to water-based systems.
- As a waterless solution, it protects irreplaceable paper documents and electronics.
- Electrically nonconductive and thus compatible with electrical fires.
- Highest margin of safety for human occupancy of any clean agent solution.
- Not subject to the Halon 1301 phaseout or HFC phasedown under any global regulatory body, including the Montreal Protocol.
- Global environmental warranty included — the 3M Blue Sky Warranty.
- Stored as a liquid and discharged as a gas, saving space.
- Appropriate for Class A, B and C fire hazards.

Table 19
3M: Financial Performance, Through 2022
($ Millions/%)

	2020	2021	2022	CAGR% 2020–2022
Net sales	32,184	35,355	34,229	3.1
Net income/loss	5,449	5,921	5,777	3.0
Net income/loss as a percentage of sales (%)	16.9	16.7	16.8	--

Source: BCC Research

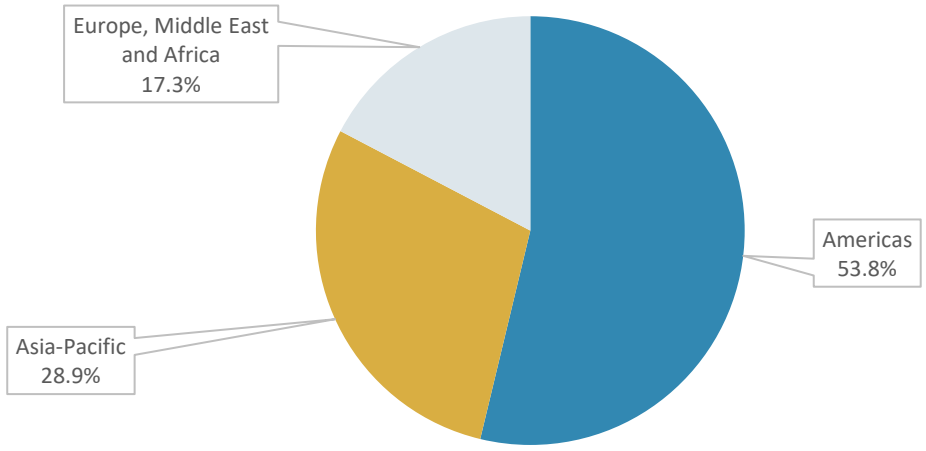
Figure 17
3M: Revenue Share, by Segment, 2022
(%)



*Elimination of Dual Credit is not adjusted in the pie chart

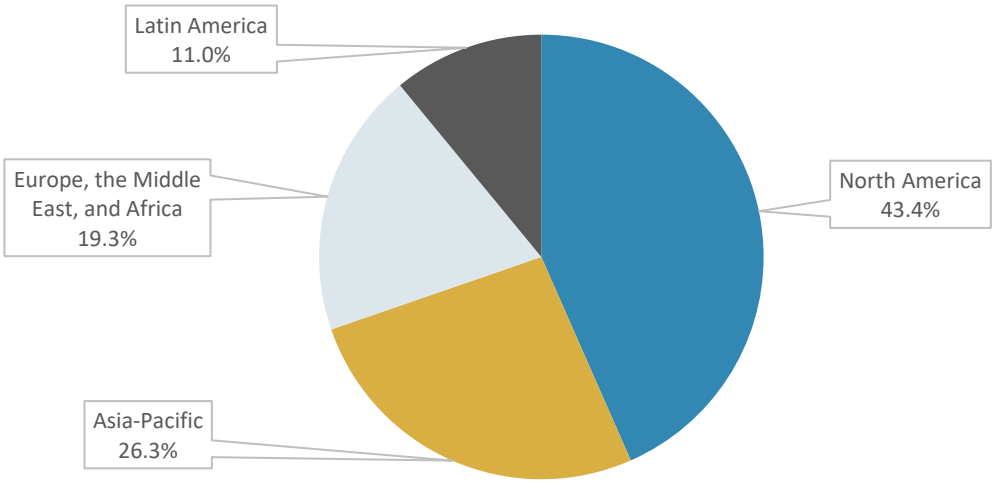
Source: BCC Research, company website/financial filings

Figure 18
3M: Revenue Share, by Region, 2022
(%)



Source: BCC Research, company website/financial filings

Figure 19
3M: Revenue Share, by Region, 2028
(%)



Source: BCC Research, company website/financial filings

ARMORSOURCE LLC

3600 Hebron Road
Hebron, OH 43025
Tel: 740/928 0070
Website: www.armorsource.com

ArmorSource LLC designs, manufactures and supplies advanced protective gear and armor for law enforcement, firefighters, military personnel and other professionals engaged in working under dangerous environments. Founded in 2005 and headquartered in Hebron, Ohio, ArmorSource is a privately held company. The company that specializes in designing and manufacturing advanced ballistic helmets and body armor for military, law enforcement and other tactical applications.

News/Key Developments

Table 20
ArmorSource LLC: News, 2023

Month, Year	Strategy	Development
April, 2023	New Product	The company launched a head protection gear which offers lightweight protection using composite material, i.e., aramid fiber. It offers approximately 20% weight savings without compromising product performance.
Jan., 2023	New Product	Introduced a new line of advanced hole-free head protection solutions i.e., Next Generation Aire System, a full spectrum for military, law enforcement and special forces personnel.
Dec., 2021	New Product	Launched a new Next Gen II helmet that performs efficiently under pressure with enabling the most vital feature of lightweighting the product for end user.

Source: Company Website

AVON PROTECTION

Hampton Park West
Semington Road, Melksham
Wiltshire, SN12 6NB
U.K.
Tel: +44 0 1225 896800
Website: www.avon-protection-plc.com

Avon Protection LLC is a leading player that designs, develops, manufactures and supplies protective systems for defense and security markets. The company's products include respiratory protection, ballistic protection, CBRN protection and thermal imaging systems. Avon Protection offers products for respiratory protection and head protection.

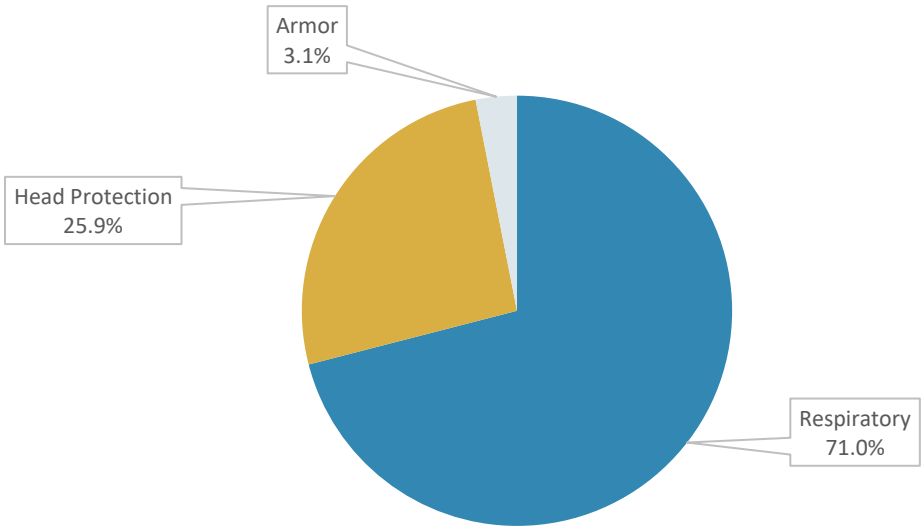
Avon Protection's respiratory protection products include SCBAs, airline respirators and powered air purifying respirators (PAPRs). The company's head protection products include ballistic helmets, fire helmets and bump caps. Avon Protection's fire resistant respiratory and head protection products are designed to protect users from a variety of fire hazards, including heat, flames and smoke. The products are made from high-performance materials that can withstand high temperatures and flames.

Table 21
Avon Protection: Financial Performance, 2021 and 2022
($ Millions)

	2021	2022
Net sales	248.3	271.9
Net income/loss	-5.6	-24.5

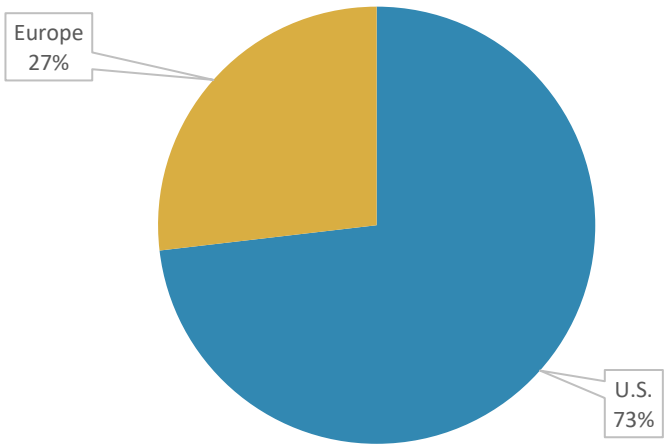
Source: BCC Research

Figure 20
Avon Protection: Revenue Share, by Segment, 2022
(%)



Source: BCC Research, company website/financial filings

Figure 21
Avon Protection: Revenue Share, by Country/Region, 2022
(%)



Source: BCC Research, company website/financial filings

BAE SYSTEMS PLC

6 Carlton Gardens
London, SW1Y 5AD
U.K.
Tel: +44 0 1252 373232
Website: www.baesystems.com

BAE Systems provides advanced protective gear and armor for military personnel, law enforcement officers and other high-risk users. The division's products include hard armor plates, soft vests, helmets, vehicle armor and ground vehicle seating systems. The company's protective gear and armor, designed to meet the needs of modern warfare, are lightweight, comfortable and provide the highest level of protection possible.

BAE Systems offers three lightweight armor variants: X Small Arms Protective Insert (XSAPI), a torso plate that defends against threats and two side plate variants; X Side Ballistic Insert (XSBI); and Enhanced Side Ballistic Insert (ESBI), which improve the protection afforded by the torso plates. The ESBI plates offer the same level of ballistic performance as earlier generations but are at least seven percent lighter, decreasing the load on the warfighter.

DUPONT

2211 H.H. Dow Way
Midland, MI 48674
Tel: 989/636-1000
Website: www.dupont.com

DuPont merged with Dow Chemical in August 2017. The company, after its merger, was split into publicly traded companies that focus on agriculture, materials science and specialty products. The agriculture division is called Corteva. The materials science spin-off is called Dow Inc. The specialty products division is called DuPont, the latter being relevant to this study. DuPont employs 23,000 people worldwide and had revenues of $13.0 billion in 2022.

DuPont current focuses on chemicals and specialty products business lines applicable to electronics and imaging, transportation and industrial, nutrition and biosciences and safety and construction, with the latter relevant to fire protection and suppression. DuPont's Advanced Fiber Systems Division includes Kevlar, which is used in ballistic resistant garments and fire protective garments and Nomex, which is used in fire protective garments. Nomex in industrial protective garments offers flame resistance as well as thermal protection, comfort and durability. Nomex resists electric arcs, flash fires and sparks. Nomex is combined with Kevlar for firefighter protective gear and is used in race driver protection.

DuPont also offers a variety of other fire-resistant protective gear, including helmets, gloves, boots and eyewear. This gear is designed to protect workers from a variety of fire hazards, including flash fires, arc flashes and molten metal splashes.

In addition to protective gear, DuPont also manufactures a variety of fire-resistant materials to make for custom protective equipment. These materials include fabrics, composites and coatings. DuPont works with customers to design and manufacture protective gear that meets their specific needs.

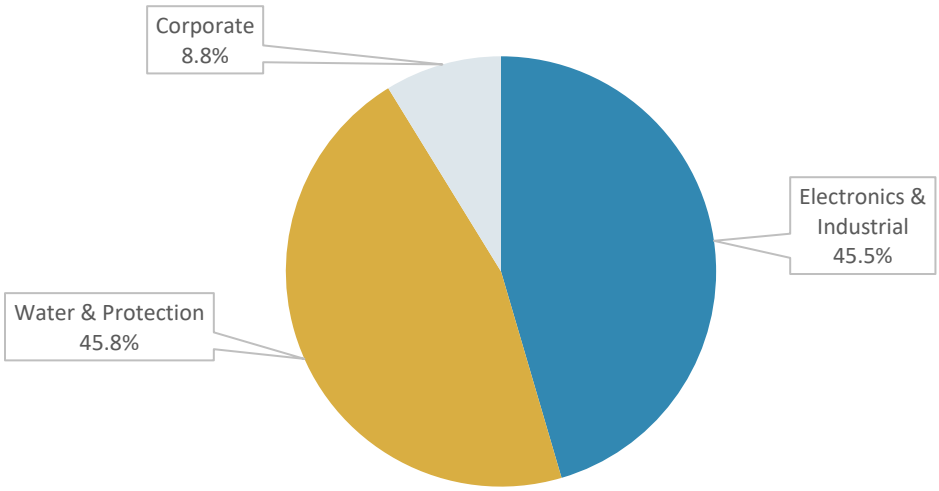
DuPont's advanced protective gear and armor is designed to keep workers safe in fire hazard environments. Made with high-performance fibers and materials, these products can withstand high temperatures and flames. DuPont also offers a variety of custom solutions to meet the specific needs of its customers.

Table 22
DuPont: Financial Performance, Through 2022
($ Millions/%)

	2020	2021	2022	CAGR% 2020–2022
Net sales	11,128	12,566	13,017	8.2
Net income/loss	-2,951	6,467	5,868	--
Net income/loss as a percentage of sales (%)	--	51.4	45.1	--

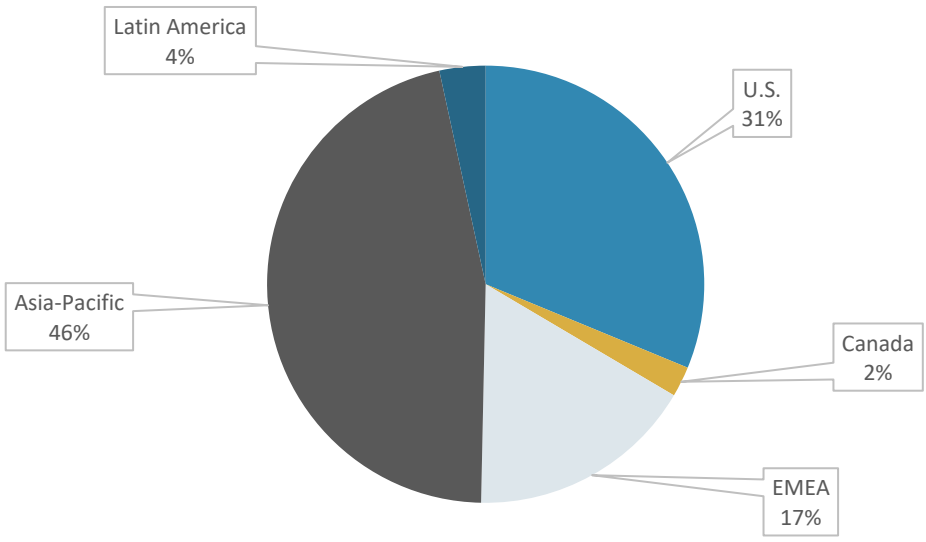
Source: BCC Research

Figure 22
DuPont: Revenue Share, by Segment, 2022
(%)



Source: BCC Research, company website/financial filings

Figure 23
DuPont: Revenue Share, by Country/Region, 2022
(%)



Source: BCC Research, company website/financial filings

HONEYWELL INTERNATIONAL INC.

855 S. Mint St.
Charlotte, NC 28202
Tel: 877/841-2840
Website: www.honeywell.com

The company designs and manufactures a range of branded products for the PPE market. Products include the general industrial sector, fire service and respirators for use in many different situations. The company emerged out of the Norton Company, Safety Product Division. It was acquired by Norcross in 1998 and later by Honeywell in 2008. The company has a strong presence in fire-protective gear and in respirators, but its hand protection gear gives it a niche in chemical/biological protection gear.

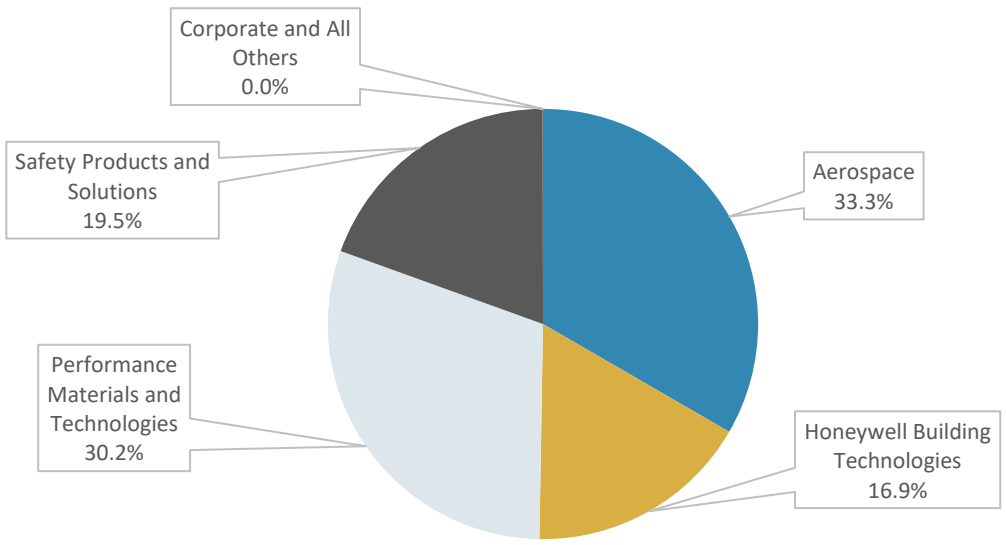
Honeywell's fire protection gear is designed to meet the highest safety standards. Made of high-quality materials, they are constructed for durability.

Table 23
Honeywell: Financial Performance, Through 2022
($ Millions/%)

	2020	2021	2022	CAGR% 2020–2022
Net sales	32,637	34,392	35,466	4.2
Net income/loss	4,865	5,610	4,967	1.0

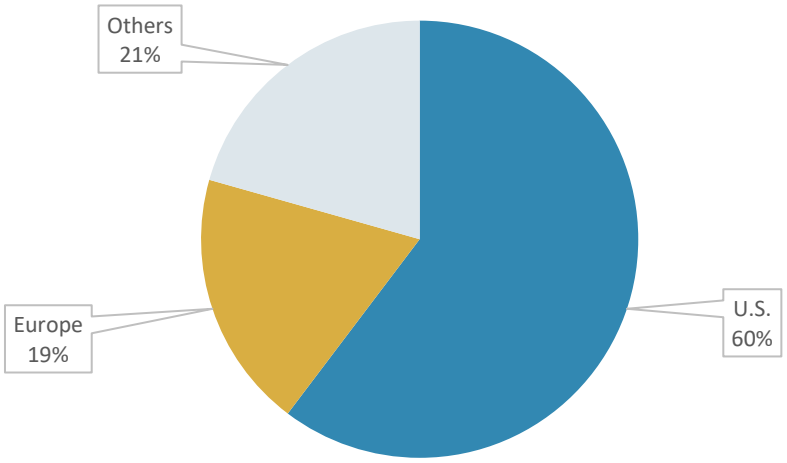
Source: BCC Research

Figure 24
Honeywell: Revenue Share, by Segment, 2022
(%)



Source: BCC Research, company website/financial filings

Figure 25
Honeywell: Revenue Share, by Country/Region, 2022
(%)



Source: BCC Research, company website/financial filings

KIMBERLY CLARK PROFESSIONAL

1400 Holcomb Bridge Road
Roswell, GA 30076
Tel: 800/241-3146
Website: www.kcprofessional.com

Kimberly-Clark Professional (KC Professional), a business unit of Kimberly-Clark Corporation, provides various products to help businesses create safer, healthier and more productive workplaces. The company's product portfolio includes protective equipment, hygiene and sanitation products, workplace consumables and workplace safety solutions. Under the personal protective equipment, it offers glasses, gloves, respirators, hearing protection and other products that protect workers from hazards.

MSA SAFETY INC.

1000 Cranberry Woods
Drive Cranberry Township, PA 16066
Tel: 800/672-2222
Website: se.msasafety.com

MSA Safety Inc. was founded in 1914 by James H. Davis and John T. Ryan. The company's first product was a flameproof helmet for miners. MSA has since expanded its product line to comprises a wide range of safety products, including SCBAs, portable gas detection instruments, fixed gas and flame detection systems, industrial head protection products, fire and rescue helmets and fall protection devices:

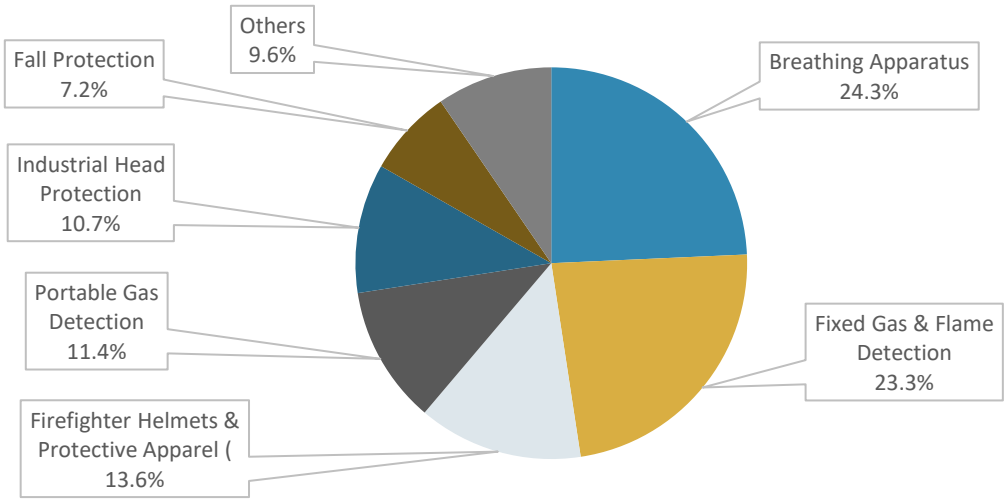
- **SCBA:** SCBAs offer breathable air to workers in hazardous atmospheres. SCBAs are key for firefighters, industrial workers and others who may be exposed to toxic gases or fumes.
- **Fixed gas and flame detection systems:** These systems detect and warn of hazardous gases and flames. Fixed gas and flame detection systems are used in an array of industries, including oil and gas, chemical and manufacturing.
- **Portable gas detection instruments:** These instruments, which measure the concentration of hazardous gases in the air, are employed in many industries, including construction, mining and manufacturing.
- **Industrial head protection products:** These products include hard hats, safety glasses and face shields.
- **Fire and rescue helmets:** These helmets are designed to protect firefighters and other first responders from the heat, flames and debris of a fire.
- **Fall protection devices:** These protection devices are essential for workers in fabrication, construction and other industries where there is a risk of falls.

Table 24
MSA Safety Inc.: Financial Performance, Through 2022
($ Millions/%)

	2020	2021	2022	CAGR% 2020–2022
Net sales	1,348.2	1,400.2	1,527.9	6.5
Net income/loss	125.1	21.8	179.6	19.8

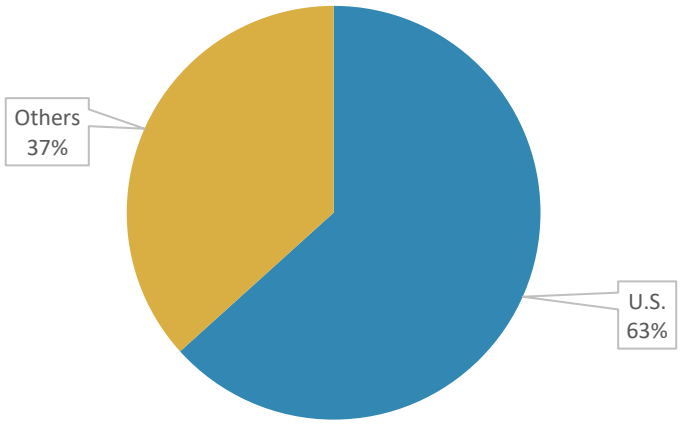
Source: BCC Research

Figure 26
MSA Safety Inc.: Revenue Share, by Segment, 2022
(%)



Source: BCC Research, company website/financial filings

Figure 27
MSA Safety Inc.: Revenue Share, by Country/Region, 2022
(%)



Source: BCC Research, company website/financial filings

POINT BLANK ENTERPRISES INC.

2102 Southwest 2nd St.
Pompano Beach, FL 33069
Tel: 800/413-5155
Website: www.pointblankenterprises.com

Point Blank Enterprises (PBE) Inc. develops, manufactures and distributes a wide range of protective solutions for military, law enforcement and other public safety personnel. PBE is the global leader in the development, producing and supplying of high-performance, federal agencies, protective solutions for the U.S. Military and Department of Defense and both domestic and international law enforcement and improvements in professionals.

The company's range of protective products include body armor, ballistic vests, plates, helmets, shields and other PPE.

Appendix

Abbreviations

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Appendix: Abbreviations

Table 25
Abbreviations

Abbreviation	Meaning
CBRN	Chemical, biological, radiological and nuclear
NBC	Nuclear, biological and chemical
U.S.	United States
U.K.	United Kingdom
APAC	Asia-Pacific
CAGR	Compounded annual growth rate
PPE	Personal protective equipment
PTFE	Polytetrafluoroethylene
IED	Improvised Explosive Devices
EFP	Explosively Formed Projectiles
FR	Flame Retardant
MEA	Middle East & Africa
ASTM	American Society for Testing Materials
ESG	Environment, Social and Governance
RoE	Rest of Europe
RoW	Rest of World

Source: BCC Research

About BCC Research

BCC Publishing

About BCC Research

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Intended Audience

This business opportunity report provides an analysis of the advanced protective clothing and equipment global market, by application, through the year 2028 with some speculative analysis for the years beyond. Under applications, the technologies, materials, standards, market participants, anticipated expansions and growth factors are included.

The report explains the structure of each industry and provides company profiles of major industry. The report is directed to decision-makers in the industrial, commercial, fire service and law enforcement sectors whose personnel are engaged in processes and operations involving the potential hazards associated with chemicals, fire and bullets.

This report is designed to provide an assessment of the advanced personal protective clothing industry for companies currently involved in the industry, or for those that are considering entering the marketplace. This includes protective clothing producers and distributors, textile and textile-related manufacturers, material suppliers and fabric mills. Companies with large numbers of personnel who are routinely exposed to workplace situations involving potential heat, flame, chemical and personal protection risks associated with bullets and other projectiles should also find this report useful use when identifying and comparing products and manufacturers. and sifting through the massive amount of personal protective industry regulations and standards.

This study should serve as an analytical and informational business tool for examining the growth in the marketplace and the increasing hazardous situations faced by first responders. There are numerous changes affecting the regulations associated with the forms of personal protective clothing. These areas are covered in terms of applications and end use. The report makes distinctions between estimates, projections and facts or statistical data. When possible, sources are identified.

Analyst's Credentials

BCC Research Team possesses expertise and experience in life and physical science domains. They specialize in offering valuable business insights, including industry analysis, competitor intelligence, strategic and financial analysis, and opportunity assessment. The team has in-depth knowledge of various sectors, including healthcare, biotechnology, pharmaceuticals, IT, automation, advanced materials, and energy. They are proficient in qualitative and quantitative market intelligence providing clients with actionable insights. With a vast understanding of the competitive landscape, the team can support clients in making data-driven decisions to help them achieve a competitive edge in their respective markets.

BCC Custom Research

Our experts provide custom research projects to those working to identify new markets, introduce new products, validate existing market share, analyze competition and assess the potential for products to impact existing markets. With impressive academic credentials and broad and deep knowledge of global industrial markets, our independent analysts and consultants develop the facts, figures, analysis and assessments to inform the decisions that will move your company ahead. Confidential inquiries to: custom@bccresearch.com or 781-205-2427.

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- CHM133B *Fire Suppressing Equipment and Consumables*.
- AVM177A *Global Markets for Flame-Resistant Polyurethanes*.
- CHM014Q *Flame Retardant Chemicals: Technologies and Global Markets*.

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December 2023