NEW DEVELOPMENTS IN FIBERS, FABRICS AND APPLICATIONS FOR PROTECTIVE CLOTHING

INDUSTRIAL FABRICS ASSOCIATION INTERNATIONAL

NEW DEVELOPMENTS IN FIBERS, FABRICS AND APPLICATIONS FOR PROTECTIVE CLOTHING

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PROTECTIVE CLOTHING MARKET

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INTRODUCTION

The purpose of the IFAI Conference on Protective Clothing is to acquaint you with this growing and exciting market, and to present some of the latest "happenings" in the field. In the very short time we have, you will hear presentations by leaders in the various facets of the protective clothing industry, from fibers and fabrics to end uses. In several of the IFAI programs, papers related to protective clothing have been given. It is, indeed, a field generating a lot of interest.

Our protection needs are quite sophisticated. We've always had heat, fire, and cold to contend with, but we discovered that exposure to certain chemicals, gases, radiation, mechanical hazards, and the like, some of which are new or didn't exist until just recently, are harmful to our health/safety. There are many areas where we must protect the things we make and use from being contaminated by humans. We are finding increased need for more effective and functional protection that will allow workers to safely work around and with certain products.

DEFINITION

Protective clothing doesn't mean the same to all people. In a real sense, clothing or garments of any type are protective in nature; they protect us from the sun, from routine cold, from rain, from spills, etc.

Our definition of protective clothing refers to those more sophisticated needs. It includes those garments, or fabric related items that are worn, that prevents one from coming in contact with, that protects from, and/or reduces the risk of exposure to hostile elements or environments. We are concerned with life threatening situations or risk of severe injury or damage.

CATEGORIES

We can categorize our concerns for protective clothing into several general areas:

* Protection from extreme cold
* Protection from outer space environments
* Ballistic and mechanical protection
* Protection from radiation
* Bacteria/Viral protection
* Protection from extreme heat and/or fire
* Protection from harmful chemicals
* Protecting delicate items in manufacture

There may be other concerns, but the above list covers most concerns for which products have been, or are being developed. We will cover several of these in presentations by our speakers. We will briefly discuss these areas.

COLD

Protection from cold is one of our oldest needs for clothing. We use animal skins, high bulk fabrics, layers of clothing, etc. Protection from extreme cold is similar but greater effectiveness is needed.

The best insulation has always come from down, the fine underside and neck fowl feathers, usually from geese. We have attempted to emulate the insulating properties of down, with varying degrees of success. These include all manners of "fiber-fill", high bulk products. New developments include different fiber cross sections as well as hollow fibers with different internal cross sections. All try to increase the air space with as little weight and bulk as possible, since air space provides the insulating mechanism. Among the most successful products include blends of coarse and very fine fibers; 3M's Thinsulate™ (65% olefin fibers/35% polyester) is perhaps the best known of these products.

SPACE

While an interesting subject, protection from space environments aren't likely to involve many of us directly. Yet, the demands of survival and doing useful work in the hostile space environment has led to some interesting developments.

Newer and better pressurized suits and extra vehicular activity garments have many applications in chemical, fire, underwater, and other high-hazard areas. Development work is being done that will give us better materials, construction techniques, less stressful garments, better joints for increased maneuverability and mobility, etc.

BALLISTIC/MECHANICAL

This area includes protection not only from bullets or other projectiles, but also from various cut and/or slash hazards, such as chain saws, meat cutter's knives, those working with jagged metal or glass, etc.

The most significant development in this area has been the application of Kevlar™ para-aramid fiber. This ultra-high strength material is used in "soft" body armor as well as in "semi-rigid" composite structures, such as helmets.

A new development that promises to challenge Kevlar is the use of HDPE fibers such as Allied's Spectra™. Spectra-Shield™ is a new matrix comprised of uni-directional fiber in a moldable resin. A 33% lighter product, the matrix is more effective than Kevlar fabric at equivalent weights. The product can also stop oblique impacts and can be molded to complex shapes.

RADIATION

Most of the work in this area involves protection from particulate or fall-out. A simple polyethylene coated woven slit film polypropylene fabric has been found by the military to be an effective barrier for personnel and equipment. More complex coated products are being studied and used for protection from radioactive isotopes as may be encountered by those working in nuclear plants, etc.

Other work is being done to provide protection from ionizing radiation such as may be encountered by X-Ray technicians, those working with radiation treatment or research with cancer. Fibers impregnated with lead, boron, or other products are being studied.

Non-ionizing radiation, as may be found around microwave or high-voltage power transmission lines, are other areas of increased interest. Electromagnetic shielding suits of conducting and dissipating metal coated fibers/fabrics are being developed.

A new area is of great concern, exposure to low level of non-ionizing radiation while working around CRT's, computers, and other high-powered electronic equipment. No one yet knows how important this hazard may be, especially to pregnant women. Special shielding is used, including work on workers garments providing dissipating and attenuation of the radiation. One special product involves a silver coated nylon fabric.

BACTERIAL/VIRAL

While the medical field has been a major user of protective clothing, the AIDS concern is creating a lot of attention toward developing better products. With more people wearing protection, this business is growing rapidly. Barrier fabrics, coated fabrics, and anti-bacterial treatments are some of the approaches.

Additional work is being done on anti-odor products. Union Carbide has Abscents™, a molecular sieve product effective in combating odors in the medical field. The increased use of laser surgery has created flammability and other problems for curtains and garments normally used in the operating room. Significant opportunity exists for new flame resistant products in the medical area.

THERMAL

Protection from fire and extreme heat, and the need to work around fire and heat has long provided a need for protective clothing. Our primary concern has been for the fireman, those working in primary metal industries with molten metal, and similar areas of high heat.

The development of the heat resistant fibers (Nomex, Kevlar, PBI, FR rayon, pre-oxidized PAN based fibers, among others) have made possible far more effective garments for protection from heat. Extensive use of FR treated cotton is found in primary metal industries as well as a number of other, less critical areas where lower cost may be a major factor.

Protection from heat exposure involves more than just the resistance to heat of the fibers/fabrics involved. What type heat are we talking about? What type risk factors are involved? Different materials are often used and/or required for high risk areas, such as fire entry or fuel fires. Whether the risk involves conductive, radiant, or convective heat are factors. For instance, metallized film laminated to fabric reflects up to 90% of the radiant heat, but may need more to protect against conductive and/or convective heat.

Construction of the garment is paramount importance. Layers and ensembles are often used to provide greater Thermal Protection Performance (TPP).

We must also be concerned about heat stress created while working in various garments. This can be as a limiting factor as the garment materials. The garment must provide breathability and moisture protection and moisture vapor transmission for longer work periods.

More about thermal protection from our speakers.

CHEMICAL

The chemical area is also quite complex. While high performance fibers are used in this area, the emphasis is on the use of sophisticated chemistry in the coating and laminating area, and in the garment manufacture, sealing, and total encapsulation suits with self contained breathing apparatus.

The choice of materials for this area is quite extensive, and depends on the exposure involved. No one product or garment is best for every hazard. It is not uncommon for Haz-Mat response teams to carry several types of garments and use the one(s) required at the scene. The different levels of protection range from A for almost complete protection to D which is basically a pair of coveralls and boots for the least protection.

The most commonly used materials involve DuPont's spunbonded olefin, Tyvek™, plain or coated. New products are being developed, fueled by a shortage of Tyvek. These include DuPont's Barrier™, Chemron's Chemrel™, and other coated non-woven products. These are in addition to some expensive ($3000) garments made from sophisticated coated fabric, fabricated into total encapsulating suits for Level A protection.

CLEAN ROOM

The area here is equally complicated. Here, we are trying to protect the worker, but, more often as not, we are protecting the environment and the product being manufactured. These include medicines, computer chips, etc. The protective garments have to be lint free and static resistant, among other requirements.

Four major types of fabrics are used: 1) continuous multifilament fabrics, 2) spunbonded olefins, 3) polymeric film materials, and 4) inherently antistatic fabrics. Most garments are of non-woven materials.

Some concerns in selecting proper garments include the cleanability, can it be disinfected, garment construction, seam sealing, permeability, breatheability, the barrier protection level, chemical resistance, among others.

MARKET SIZE

The protective clothing business is highly fragmented, secretive, and difficult to pin down precisely. Specific market information not easily come by and not usually shared. Studies are being conducted to determine accurate information, and will be availabale on a subscription basis. Some general information can be shared.

One source puts the protective apparel market to be in excess of 100 million square yards of fabric, with 65% being non-woven, 30% woven, and 5% knit. This does not include medical apparel (250 million square yards, with 60% non-woven) and work gloves (30 million square yards). Growth is projected to be at least 10% in the fire and chemical areas, and higher in the medical and clean room areas.

NEEDS

Perhaps the biggest need in the PC market, aside from better base materials, is the need for understanding the problem and better, more universally accepted and followed standards and specifications. In many cases, the problems are not well studied, tested, understood, and defined. Often we have no real basis for comparing different materials. Many claims just don't hold up. The National Fire Protection Association (NFPA), ASTM, National Bureau of Standards, ANSI, and the EPA are among those trying to develop and adopt standards. Much work needs to be done.

Other needs include more effective materials, materials that provide greater protection against high temperature over a longer period of time, materials with better TPP ratings, better resistance to chemical degradation and permeation, materials that provide protection over a greater range of hazards (chemical AND thermal protection, for instance), and garments with greater comfort and less stress on the wearer.

CONCLUSION

The protective clothing market is one receptive to continual innovation and development. The market may be the profitable niche that many are looking for in the industrial fabrics area.

The market has not been a major target for imports to this point, but that could change rapidly. Much new and innovative work is being done overseas. If we are to maintain our lead, and to supply a global need, we must continue to be innovative in our development of new and better products.

We must be on the leading edge of applying new technology in this area. There are long lead times and much expense involved in bringing products to market. The fact is, though, we cannot afford to not have the new ideas and products.

I hope this overview has been helpful in putting the market in perspective for you. Our speakers will go into much greater detail on many of the market we have discussed.

ADVANCES IN HIGH PERFORMANCE FIBERS, YARNS AND FABRICS FOR THERMAL PROTECTIVE CLOTHING

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1. INTRODUCTION

Conventionally, garments made from asbestos fiber were used as Thermal Protective garments. The asbestos fiber provided the required Heat and Flame Resistance, Thermal Insulation and Protection from Molten Metal Splashes. However, asbestos fiber is considered to be a serious health hazard. Therefore, later on, natural fibers such as Cotton and Wool with flame retardant topical treatments were used in the garments for less severe thermal exposures. The challenge persisted for higher heat and flame resistant garments. The man-made fiber industry has responded to this challenge and has developed various inherently flame and heat resistant fibers such as flame retardant Cellulosics and Acrylics, Aramids, Phenolic, PBI, Sulfur, Fluorocarbons, Carbon, Glass and Metallic fibers. The yarn and fabric converters have developed various hybrid materials using these fibers and have successfully designed a new generation of High-Tech Thermal Protective fabrics. This paper will review various Thermal Protective Clothing requirements in relation to the high heat and flame resistant state of the art fibers, yarns and fabrics.

2. PERFORMANCE REQUIREMENTS FOR THERMAL PROTECTIVE CLOTHING

"THE END USE AND ITS REQUIREMENTS NEARLY ALWAYS DICTATE THE DESIGN AND THE FIBER SELECTION OF THE TEXTILE SUBSTRATE, ITS CONSTRUCTION METHOD AND ITS FINISHING CHARACTERISTICS. IGNORANCE OF THE RELATIONSHIP BETWEEN ..... APPLICATION AND SUBSTRATE, AND ITS PREPARATION, WILL LEAD TO FAILURE, IF NOT OUTRIGHT DISASTER." This is very true for Thermal Protective Clothing. The assessment of the performance requirements is quite critical for selecting the right type of fiber/s and the development of the Thermal Protective Clothing.

2a) THERMAL PROTECTION REQUIREMENTS

To understand the application demands for Thermal Protection, we will categorize the Thermal Protective Clothing into various categories such as:

I. Radiant Heat Exposure

II. Molten Metal Splash Exposure

III. Direct Contact Heat Exposure (Conductive Heat)

IV. Hot Ambient Air Exposure (Convective Heat)

V. Exposure to Flames

I. RADIANT HEAT EXPOSURE

Radiant Heat is defined as Heat Transmitted by Radiation. A very simple example of Radiant Heat exposure is the sunlight. We have all experienced that on a hot summer day, avoiding direct sunlight prevents skin burns. Generally, the Radiant Heat energy of the sunlight varies between 0.4 to 0.85 kW/meter square (much lesser than one kilowatt per square meter). Similarly, a person standing one meter away from a one meter by one meter size fire pool experiences a Radiant Heat flux of 20 kW/meter square. A Steel Industry worker standing three meters away from half meter diameter furnace heated to 2800^{O}F. is subjected to a Radiant Heat flux of 4.2 kW/meter square - more than twice the heat energy required to give severe skin burns!

Therefore, the selection of the Thermal Protective Clothing for Radiant Heat exposure should take into account the type and the intensity of Radiant Heat flux. The behavior of textile materials subjected to intense heat depends in part on the reflectivity of the material and the nature of the exposure. Conventionally, textile materials have very high absorption in the infrared region, therefore, the amount of Radiant Heat absorbed is determined by the reflectivity of the surface of the textile material. Normally, more reflective the surface, more Radiant Heat it will reflect back. The reflectivity of textile substrates is achieved by the applications of polished metal films such as gold and aluminum to the outer surface. Although, metalized fabrics reflect about 90% of the Radiant Heat, the remaining energy is absorbed by the substrate material itself, resulting in the degradation of the substrate material depending on the exposure periods. Therefore, the selection of the fibers for the substrate fabric should be done carefully to provide maximum safety to the wearer. The fibers that melt, stick or soften at elevated temperatures should be avoided in the design of the substrate fabrics for the Radiant Heat exposure.

For high Radiant Heat exposures of 1500-3000^{O}F., the metalized substrate fabrics incorporate such fibers as Flame Retardant Cellulosics and Acrylics, Aramids, Phenolic, PBI, Glass and Carbon. For workers in the Steel Industry presently, metalized substrate fabrics containing corespun Hybrid yarns consisting of Partially Carbonized PAN and Aramid fibers are used costeffectively. These fabrics are marketed under the brand name Nor*Fab Series 900.

II. MOLTEN METAL SPLASH EXPOSURE

In addition to the Radiant Heat, workers who are around blast furnaces, pouring platforms, continuous casters and melt shop pits in the Metals Industry are also exposed to Molten Steel and Aluminum Metals. The temperature of molten iron varies from 2750°F. to 2850°F. and the temperature of molten aluminum varies from 1200°F. to 1300°F.. Molten iron and aluminum, when poured onto metalized low temperature thermoplastic substrate fabrics, would have a tendency to adhere to the fabrics resulting in a higher heat flux through the substrate material causing severe burn injuries. Therefore, the selection of the fibers should take into account such factors as charring, thermal shrinkage, melting and transition temperatures, dripping, flame resistance, etc.. The fabric design also plays a very important role in fabric perforation, metal adherence and total heat transfer.

Subjecting various aluminized substrate fabrics to the standard Molten Metal Splash testing of primary Protective Clothing materials, it was learned that in comparison with a 100% Permanently Flame Resistant (PFR) Cellulosic fibers and 100% Aramid fibers, an optimal performance balance was achieved utilizing Corespun Hybrid Partially Oxidized PAN and Aramid fibers. This Patented optimal combination of fibers was developed by Amatex Corporation.

III. DIRECT CONTACT HEAT EXPOSURE (CONDUCTIVE HEAT)

Heat transfered from the outer surface of a Thermal Protective garment to its inner surface, is the Conductive Heat. All of us have experienced the intensity of contact heat by mistakenly holding a hot pot and burning our fingers. In most cases, the temperature of the hot pot ranges from 300-600^{O}F.. To avoid these types of burn injuries, we wear cooking mittens or gloves. Similar situation prevails in the Metal Casting Industry. Workers handle hot casts which are well above 1800^{O}F. - 2000^{O}F.. Without the appropriate Thermal Protective gloves, these workers will suffer severe burn injuries due to contact-conductive heat. The heat transfered by conductance is directly dependent on the rate at which it is absorbed through the fabric. The rate of heat transfer is also controlled by the thickness, density, thermal conductivity, specific heat capacity, thermal shrinkage and the softening temperatures of the fabrics used in the construction of Thermal Protective gloves. Depending on the exposure parameters such as the surface temperature of the hot material in contact, exposure time, pressure on the fabric surface in contact and the nature of hot material in contact; the selection of the types of fibers and yarns and fabric construction including liner materials, plays a very important role.

Reviewing the performance of available products in the Metals Casting Industry, it was concluded that 100% PFR Cellulosic and Aramid fiber fabrics provided poor results, whereas fabrics containing PBI fibers provided good results. Also, inorganic compound coated fiberglass fabrics such as Vertex Glass provided good results.