Technical Review of Dipped Products Limited (DPL) Products
- A Comparative Analysis

By

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DECLERATION

The project work described in this thesis was carried out at the marketing department of Dipped Products Limited (DPL) under the supervision of Mrs. S.E. Fernando and Prof. D.B.M.Wickramarathne. A report on this has not been submitted to any other university for another degree.

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AFFECTIONATELY DEDICATED TO

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List of Abbreviations

DPL	- Dipped Products Limited
CE	- Conformité Européenne
PPE	- Personal Protective Equipment
OSHA	- Occupational Safety & Health Administration
mm.	- mille meters
NBR	- Nitrile-Butadiene Rubber
SBR	- Styrene-Butadiene Rubber
PVA	- Polyvinyl alcohol
°C	- Celsius
PVC	- Polyvinyl Chloride
°F	- Fahrenheit
UHMWPE	- ultra high molecular weight polyethylene
PTFE	- polytetrafluoroethylene
CEN	- European Committee for Standardization
ASTM	- American Standards for testing materials
NFPA	- National Fire Protection Association
ANSI	- American National Standards Institute
ISEA	- International Safety Equipment Association
EEA	- European Economic Area
min.	- minutes
BTT	- Break through time
AQL	- Acceptable quality level
kV	- Kilo Volt
JIS	- Japanese Industrial Standards
GPa	- Giga Pascal
etc.	- etcetera
PU	- Poly-urethane
REACH	- Registration, Evaluation, Authorization and Restriction of Chemicals
COSHH	- Control of Substances Hazardous to Health Regulations
CEPA	- Canadian Environmental Protection Act
NICNAS	- National Industrial Chemicals Notification and Assessment Scheme

TECHNICAL REVIEW OF DIPPED PRODUCTS LIMITED (DPL) PRODUCTS – A COMPARATIVE ANALYSIS

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The global hand protection industry provides effective barriers for chemical, biological, mechanical and thermal hazards. The world chemical production, which currently exceeds 400 million tons per annum, has inevitably led to complex safety measures to cope with highly specific substances, or with a broad spectrum of chemicals combining multiple risks. Hence, today the gloves are being sold on technical points rather than cosmetic points where technical data on gloves has gained in importance in marketing products to the international community.

The objective of this study was to identify the chemical resistance profiles offered by the competitors' range of products and to make suggestions for improvement and development of products in the DPLs' range. In this regard, several parameters of glove performance in providing hand protection have been chosen for comparison.

For the purpose of comparative analysis, databases were prepared using the information available in the public domain for the range of products of the key competitors and for the chemical resistance profiles offered by their products. The similar products in the competitors' range for DPL products were identified and the technical information provided for the DPLs' products were compared with that of the main competition. From this comparative analysis, the range of chemicals needed to be tested against as well as the needs for development of new products and the improvements required for the current range were identified. In addition compliance to the different legislations in force governing Personal Protective Equipment (PPE) in the industrial segment in various countries were researched and gathered.

CHAPTER 1
INTRODUCTION

1.1 Company Profile

Dipped Products Ltd (DPL) is a seamless umbrella organization with their own rubber plantations, manufacturing facilities and customer relationship management services. It is the pioneer latex glove producer in Sri Lanka, which was established in 1976 and ranks amongst the larger global manufacturers of hand protection wear, presently producing over half a million gloves per day. Production is organized such that all factories are capable of making a range of core standard products whilst each factory is also capable of making specialty products for niche markets. Products conform to the CE standards both in intermediate and complex categories and to other international standards. (DPL Annual reports 2002 -2007)

The protective glove market worldwide may be broadly split into the medical/examination market which accounts for 85% and the non- medical sector making up 15%. DPL has hitherto focused on the non-medical rubber gloves segment. These products are meant for protection from chemical/biological and mechanical hazards. They have applications in general industry, in cleaning and janitorial applications, the food industry and in household. Product categories of the group fall broadly into unsupported and fabric supported gloves and use natural and synthetic polymers. The product range includes 40 categories and are produced in more than 225 versions differentiated by shape, grip, size and color.

1.2 Background

Increasingly, gloves are being sold on technical points rather than cosmetic points where technical data on gloves has gained in importance. Therefore, how DPL gloves compare with competition on selected technical points gives an edge to its marketing efforts, especially when selling gloves into the Industrial market segment. To cope with these demands as far as possible DPL has decided to carry out a research on the competitive glove manufactures products and to find out the strengths and weaknesses of the DPL's products compared to those of the key competitors. This will also assist DPL in identifying the need for further developments of its products. In this regard, several parameters of glove performance in providing hand protection have been chosen for comparison.

a. Chemical resistance
b. Mechanical resistance
c. Range

This information is vital in addressing the major questions that are raised by the customers at the global market. Namely;

What DPL glove provides a similar profile to a certain competitors' glove?
What are the gloves that offer protection against a particular chemical?
What is the range of chemical resistance offered by a particular glove?

In addition in the Industrial segment, compliance to the different legislations in force governing Personal Protective Equipment in various countries also gives DPL a marketing edge. For this purpose, legislations in countries where English is the official language would need to be researched and gathered. This would assist DPL to identify the rules and regulations that they are already in compliance with and those which are essential to be in compliance with.

1.3 Overall objective

To provide a global marketing edge for DPL products through the comparative analysis of the technical information of the major competitors products.

1.4 Specific objectives

(i) Studying the attributes of different types of gloves in the global market and search for different legislations pertaining hand protection equipment in various countries

(ii) Collecting data and preparing a database for the products of main competitors, which will provide all the information regarding a particular product i.e. product specifications, material, dimensions, applications, Extent of barrier protection provided, special product features, etc.

(iii) Analyzing the chemical recommendations for the above competitors' products by preparing a chemical recommendations guide for competitors' products and comparison of the chemical recommendations guide with that of the DPL products.

(iv) Identifying the key areas needed to be improved and developed with regard to DPL products and to make suggestions in order to provide better hand protection solutions

CHAPTER 2

LITERATURE SURVEY

2.1 The Hand Protection industry

Definition of Glove

A glove is an item which protects the hand or any part of the hand from hazards and hence essentially falls to the category of personal protective equipment. It may also cover part of the forearm and arm. (EC directive for PPE, 1989)

2.1.1 Major Product categories in the Hand Protection Industry

The Hand protection industry can be broadly classified into the following key categories owing to their differences in the production process.

i). Knitted gloves
ii). Cut and sewn gloves
iii). Supported gloves
iv). Unsupported gloves

2.1.2 Choosing the right glove

There are many types of gloves available today to protect against a wide variety of hazards. The nature of the hazard and the operation involved will affect the selection of gloves. There is no single glove which provides protection from all forms of hazards (Groce, 2002). The variety of potential occupational hand injuries makes selecting the right pair of gloves challenging. It is essential that employees use gloves specifically designed for the hazards and tasks found in their workplace because gloves designed for one function may not protect against a different function even though they may appear to be an appropriate protective device. *(OSHA standards, 2003)*

The following are examples of some factors that may influence the selection of protective gloves for a workplace.

- Type of protection required (Chemical, Mechanical, Thermal, Electrical, Ionization radiation, etc.)
- Nature of contact (total immersion, splash, etc.)
- Area requiring protection (hand only, forearm, arm, Fingertips, Palm only)
- Size, comfort and dexterity
- Duration of contact
- Grip requirements (dry, wet, oily)
- Cost, durability, packaging, Special issues such as allergy, etc.

2.1.2.1 Glove types

(a). Unsupported Gloves

In manufacturing these gloves, molds are dipped directly into the glove material, giving the wearer maximum dexterity. Offered as unlined or flock-lined with cotton or rayon polyester for improved comfort. Also examination and disposable gloves are offered in both powder-free and lightly powdered forms.

(b). Supported Gloves

Fabric knitted or cut and sewn inner liner covers the mold, which is then dipped into the glove material. This absorbent liner provides improved comfort during wear and adds strength and durability to the glove.

2.1.2.2 Glove Shape, Size and Length

(a). Shape

Anatomically shaped gloves are preferred in most applications as they provide greater dexterity, reduce hand fatigue over prolonged use and facilitate easy donning and removal. Ambidextrous gloves are interchangeable between left and right hands and are cost-effective and are recommended for short periods and one-off applications. Matching the shape of the glove fingers to the user's hand shape is desirable to improve sensitivity and dexterity, particularly in applications requiring greater precision.

(b). Size

The size of the glove needs to match the wearer's hand to optimize comfort, dexterity, safety and efficiency. The size range of the gloves is generally between 5 and 11 and corresponds to the circumference of the palm.

(c). Length

The glove length is determined by the extent to which the wearer's arms would require protection in the working environment. It must be selected according to the hazards incurred. In chemical applications, the depth to which the arms are immersed should be the deciding factor.

2.1.2.3 Glove Thickness

The thickness is crucial for the dexterity and performance of the glove. It is generally between 0.1 and 2.5 mm. The extent of chemical resistance offered by the glove strongly depends on the glove thickness.

2.1.2.4 Cuff Patterns

(a) **Straight Cuff:** This type offers additional length to trough, to protect from runoff and drips.

(b) **Rolled/ Beaded Cuff:** This offers drip protection for the forearm and increased glove strength when donning. Featured on surgical and examination gloves.

(c) **Pinked Cuff:** This style is used on unsupported and supported chemical resistant gloves and offers improved edge grip for ease of donning and glove removal.

(d) **Safety Cuff:** Also called a band top, this style helps protect from wrist injury, increases hand ventilation during wear, and speeds removal. Used for supported gloves.

(e) **Slip-On Cuff:** Offers easy donning and removal by standing away from the wrist. No seam between glove and cuff.

(f) **Knit Wrist Cuff:** This cuff type holds glove firmly to the wrist and improves fit and reduces glove slippage. Also prevents entry of debris and are used for supported gloves.

(g) **Gauntlet Cuff:** This type provides extended protection for forearm. Allows wearing over work clothes. Used for supported and unsupported gloves.

(h) **Fluted Cuff:** Provides additional length and reinforces cuff edge.

Fig 2.01: Cuff patterns of gloves
Source : www.dplgroup.com

2.1.2.5 Grip patterns

Grip patterns are designed to offer optimum wet and dry grip under general working conditions associated with each glove style. Trial usage is recommended to select the best grip for the intended application.

Following figure shows few frequently used grip patterns in gloves.

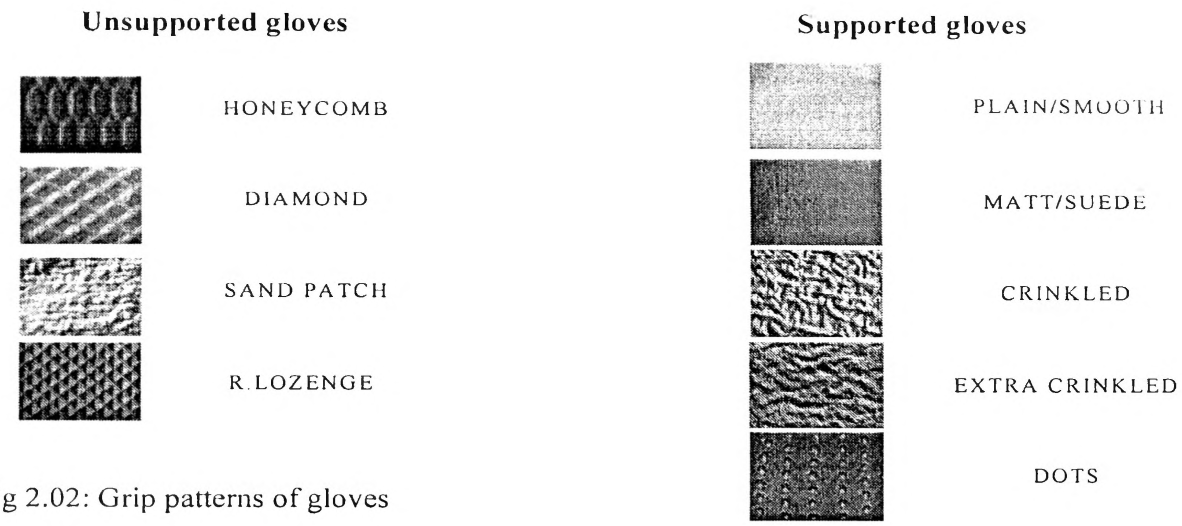


Fig 2.02: Grip patterns of gloves

2.1.2.6 Glove interior finishes

(a). Textile supported

Knitted or cut and sewn interior made from cotton or synthetic materials to increase comfort and absorbs sweat. These are particularly suitable for long-term work.

(b). Flocked

Cotton based textile fibers on the inside of the gloves, which provides extra comfort for wearer. Also these absorb perspiration and are suitable for extended use.

(c). Chlorinated

This is a powder-free treatment which helps when putting on and taking off the gloves without increasing the thickness. The chlorination reduces the risk of allergy from natural latex. Also, increases the chemical resistance profile of the glove up to some extent.

(d). Powdered

Powdered interior helps when putting on and taking off the gloves, without increasing its thickness. Usually medical and examination gloves comes with this finish.

2.1.3 Materials used in Glove manufacturing

Gloves made from a wide variety of materials are designed for many types of workplace hazards. In general, following elastomers are commonly used in the hand protection industry;

(a). Natural Rubber Latex

Natural rubber is a high molecular-weight polymer of isoprene, in which essentially all the isoprenes have the *cis-1,4* configuration, with a broad distribution of molecular weights. The outstanding source for natural rubber is the tree *hevea brasiliensis,* from which the latex is exuded from the bark when it is damaged. Natural latex is an aqueous dispersion of rubber containing 30 - 40% rubber hydrocarbon, stabilized by proteins, lipids and fatty acids in the serum. The latex collected from the trees is preserved by adding alkali and sent for further processing, such as centrifuging, compounding and vulcanization. (Bahadur and Sastry, 2005)

Fresh latex is not utilised in its original form due to its high water content and susceptibility to bacterial proliferation. The concentration of latex can be achieved by centrifuging, creaming or evaporation, where the aqueous part is reduced. Use of secondary preservative system such as a combination of a small amount of tetramethyl thiuram disulphide and zinc oxide allows a lower amount of ammonia to be employed which makes the processing for manufacturing easier. The centrifuged latex is matured for three to four weeks before compounding where the stability of the latex is increased by the hydrolysis of proteins and lipids in the serum. (Nethsinghe, 1986)

The material properties of natural rubber make it an elastomer and a thermoplastic. Vulcanised rubber has greater elasticity and tensile strength than crude rubber. Gloves are by far the largest market sector, consuming around 60% by weight. Something that limits the use of natural rubber are the allergic reactions, which have been reported due to extractable residual proteins in latex. (Beswick and Dunn, 2002)

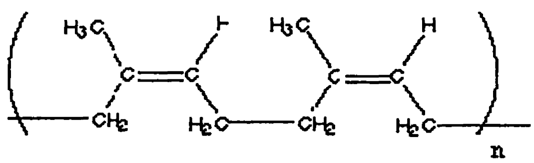
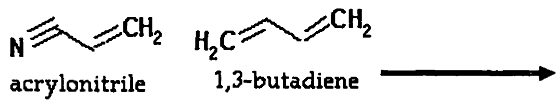


Fig 2.03: Structure of polyisoprene

(b). Synthetic Rubber: Nitrile (Nitrile-Butadiene Rubber)

Nitrile rubber is a synthetic rubber copolymer of acrylonitrile (ACN) and butadiene. Acrylonitrile butadiene rubber (NBR) is a family of unsaturated copolymers of 2-propenenitrile and various butadiene monomers (1,2-butadiene and 1,3-butadiene). Nitrile rubber contains approximately 55-82% butadiene and 45-18% acrylonitrile.The first commercial nitrile rubbers were made in Germany. Nitrile rubbers are prepared in emulsion systems. Because the monomer reactivity ratios are quite different, the compositions of the feed and the polymer differ markedly. This fact is usually taken into account by adjusting the monomer compositions during the polymerization to achieve the desired composition. The reaction for one possible portion of the polymer is shown below. (Billmeyer, 1994)



Acrylonitrile butadiene rubber

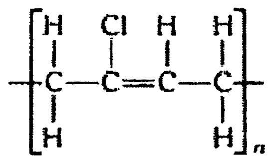
The yielded polymer latex is coagulated using calcium chloride, aluminum sulfate, and other coagulating agents in an aluminum tank. The coagulated substance is then washed and dried into crumb rubber.

Although its physical and chemical properties vary depending on the polymer's composition of acrylonitrile (the more acrylonitrile within the polymer, the higher the resistance to oils but the lower the flexibility of the material), this form of synthetic rubber is generally resistant to oil, fuel, and other chemicals. Its resilience makes NBR the perfect material for disposable lab, Industrial, and examination gloves. NBR's ability to withstand a range of temperatures from −40°C to +120°C makes it an ideal material for industrial applications. Compared to natural rubber, nitrile rubber is more resistant to oils and acids as well as improved abrasion and heat resistance, but has inferior strength and flexibility. Nitrile rubber is generally resistant to aliphatic hydrocarbons. However (like natural rubber), it can be attacked by ozone, aromatic hydrocarbons, ketones, esters and aldehydes. (Simpson, 2002)

(c). Synthetic Rubber: Neoprene (polychloroprene)

The term neoprene denotes rubber like polymers and copolymers of chloroprene, 2-chloro-1,3-butadiene. Neoprene was invented by DuPont scientists in 1931, who focused on monovinyl acetylene and reacted the substance with hydrogen chloride gas, manufacturing chloroprene. The neoprenes are produced by the emulsion polymerization. Polymerization appears to take place entirely in *trans*-1,4 form and as a result neoprenes are crystalisable elastomers.The vulcanization of neoprene is different from that of other elastomers in that it can be vulcanized by heat alone. ZnO and MgO are the preferred vulcanizing agents. (Billmeyer, 1994)

Neoprene processes very high tensile strength even without use of carbon black. Weathering resistance and ozone resistance are quite good. Neoprene is slightly inferior to nitrile rubber in oil resistance, but markedly better than natural rubber, butyl rubber or SBR. The dynamic properties of neoprene are superior to those of most other synthetics and only slightly inferior to those of natural rubber. (Davis and Berner, 2004)



Polychloroprene (neoprene) structural unit

Fig 2.04: Structure of polychloroprene

(d). Polyvinyl Alcohol (PVA)

Polyvinyl alcohol (PVOH, PVA, or PVAL) is a water-soluble synthetic polymer. Polyvinyl alcohol has excellent film forming, emulsifying, and adhesive properties. It is also resistant to oil, grease and solvent. It is odorless and nontoxic. It has high tensile strength, flexibility, as well as high oxygen and aroma barrier. However these properties are dependent on humidity, in other words, with higher humidity more water is absorbed. The water, which acts as a plasticizer, will then reduce its tensile strength, but increase its elongation and tear strength. (Kent, 1997)

Unlike most vinyl polymers, PVA is not prepared by polymerization of the corresponding monomer. PVA instead is prepared by partial or complete hydrolysis of polyvinyl acetate to remove acetate groups (Simpson, 2002). The vinyl acetate is dissolved in methanol, and is polymerised with the help of a catalyst forming polyvinyl acetate. Caustic soda is added to the methanol solution, bringing about saponificaion of the polyvinyl acetate to polyvinyl alcohol. PVA polymer is precipitated from the methanol solution, pressed and dried. (Davis and Berner, 2004)

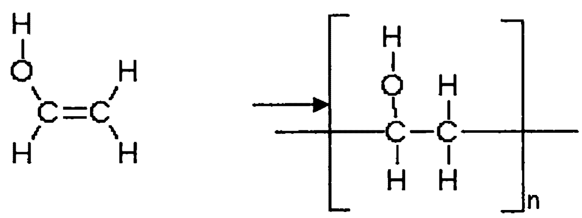


Fig 2.05: Structure of Polyvinyl alcohol

PVA is an atactic material but exhibits crystallinity as the hydroxyl groups are small enough to fit into the lattice without disrupting it. PVA has a melting point of 230 °c and 180–190 °c for the fully hydrolyzed and partially hydrolyzed grades. It decomposes rapidly above 200 °c as it can undergo pyrolysis at high temperatures

(e). Butyl rubber

Butyl rubbers copolymers of isobutylene with a small amount of isoprene added in order to make them vulcanizable. In a typical process, butyl rubber is manufactured by mixing isobutylene with 1.5-4.5% isoprene and methyl chloride as diluent. This mixture is fed in to stirred reactors cooled to -95°C by liquid ethylene. Catalyst solution is made by dissolving anhydrous aluminum chloride in methyl chloride. The extremely rapid reaction is completed in less than a second. Polymer forms at once as a finely divided product suspended in the reaction mixture. The reaction is exothermic and instantaneous where cooling is very essential. (Davis and Berner, 2004)

Butyl rubbers are amorphous under normal conditions, but crystallizes on stretching. The very low residual unsaturations of butyl rubbers lead to outstanding chemical inertness. A property of great importance in elastomers is aging in the presence of oxygen. These are less sensitive to oxidative aging than are most other elastomers except the silicones and become soft rather than brittle on oxidative degradation. Butyl rubber has much better ozone resistance than natural rubber and solvent resistance is typical to that of hydrocarbon elastomers, the acid resistance is quite good. (NIIR, 2001)

The stress-strain properties of butyl rubbers are similar to those of natural rubber and show the importance of crystallization in obtaining high tensile strength. Crystallization does not take place until higher elongations are reached. The tear resistance of butyl is quite good and is retained well at high temperatures for longer times, in contrast to natural rubber. The electrical properties are good as predicted by its non-polar, saturated nature. Rebound is slow and heat build up is high. (Billmeyer, 1994)

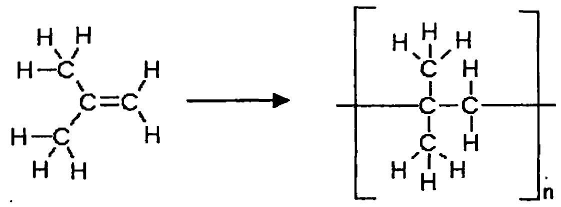


Fig 2.06: Structure of Butyl rubber

(f). Polyvinyl Chloride (PVC)

Over 80% of PVC is manufactured using suspension polymerization. Small amounts are made by solution, emulsion and bulk polymerization, despite difficulties resulted from the insolubility of the polymer in its monomer. Vinyl chloride is polymerised typically as an aqueous emulsion in autoclaves, under the pressure of 40-50 atm and a temperature of about 65 °C. The polymer forms a suspension in water, and is recovered by spray drying. (Davis and Berner, 2004)

PVC is a partially syndiotactic material, with sufficient irregularity of the structure that crystallinity is quite low. PVC is relatively unstable to heat and light. Stabilizers are almost invariably added to improve the heat and light stability of the polymer. It can be made softer and more flexible by the addition of plasticizers, the most widely used being phthalates. (Billmeyer, 1994)

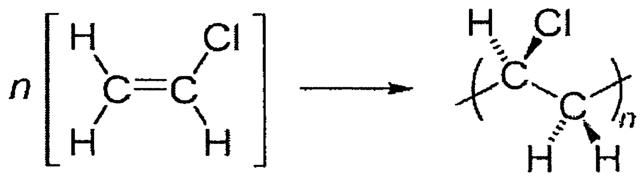


Fig 2.07: Structure of polyvinyl chloride

(g). Polyurethane (PU)

Polyurethane is a unique material that offers the elasticity of rubber combined with the toughness and durability of metal. Because urethane is available in a very broad hardness range (eraser-soft to bowling-ball-hard). It replaces rubber, plastic and metal with the ultimate in abrasion resistance and physical properties. Polyurethanes are typically formed through the reaction of a diisocyanate and a glycol. Coatings based on polyurethanes have very good resistance to abrasion and solvent attack plus good flexibility and impact resistance. They can be applied by dip, spray, or brush and adhere well to a wide variety of materials. These are suitable for applications in which unusual impact and abrasion resistance is required. (Billmeyer, 1994)

Urethanes have better abrasion and tear resistance than rubbers, while offering higher load bearing capacity. Compared to plastics, urethanes offer superior impact resistance, while offering excellent wear properties and elastic memory. Polyurethane has excellent resistance to oils, solvents, fats, greases and gasoline. Polyurethane has a higher load-bearing capacity than any conventional rubber. Tear-strength is far superior to rubbers. Polyurethane has outstanding resistance to oxygen, ozone, sunlight and general weather conditions. Continuous use above 225°F is not recommended nor is urethane recommended in hot water over 175°F. At low temperatures, polyurethane will remain flexible down to -90°F. A gradual stiffening will occur at 0°F, but will not become pronounced until much lower temperatures are obtained. (Bahadur and Sastry, 2005)

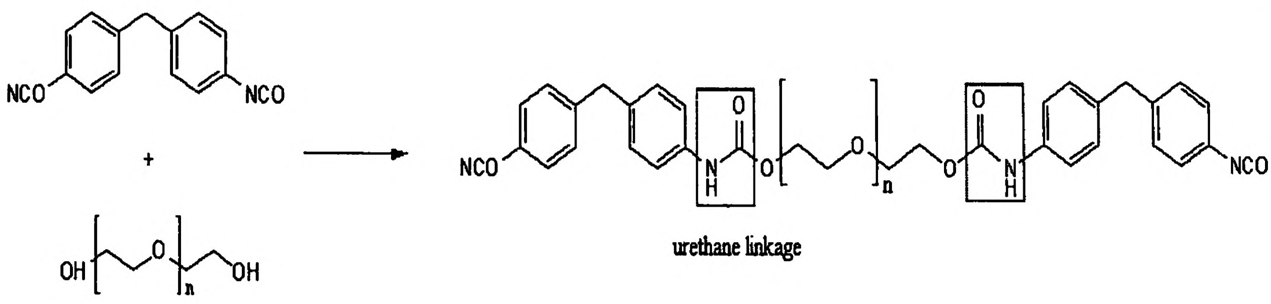


Fig 2.08: Structure of polyurethane
Source: www.ch.ic.ac.uk

(h). Polyamide (Nylon, Aramids)

A polyamide is a polymer containing monomers joined by peptide bonds. They can occur both naturally, examples being proteins, such as wool and silk, and can be made artificially, examples being Nylons and Aramids. (Davis and Berner, 2004)

Nylon is a generic designation for a family of synthetic polymers first produced on February 28, 1935 by Wallace Carothers at DuPont. Nylons are condensation copolymers formed by reacting equal parts of a diamine and a dicarboxylic acid, so that peptide bonds form at both ends of each monomer in a process analogous to polypeptide biopolymers. These are formed into monomers of intermediate molecular weight, which is then reacted to form long polymer chains. Nylon was the first commercially successful polymer and the first synthetic fiber to be made entirely from coal, water and air.
(Kent, 1997)

Nylon

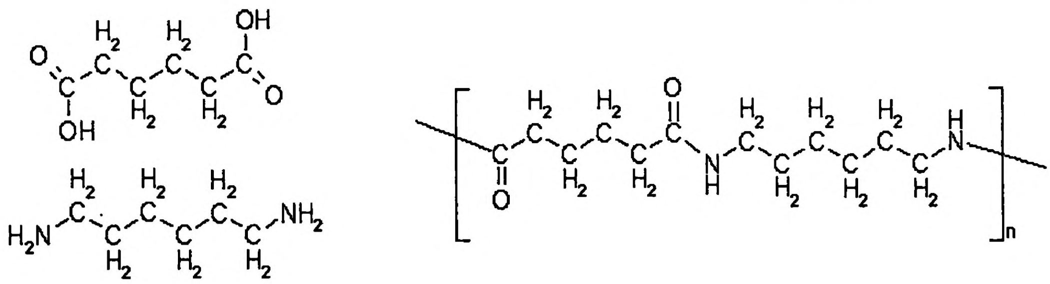


Fig 2.09: Structures of Nylon
Source : www.steve.gb.com

(j). **KEVLAR®**

Following the technological breakthroughs which led to the discovery of the liquid crystalline behaviour of Para-amides and a novel method for spinning anisotropic liquid crystalline polymer solutions, *Kevlar®* aramide fiber was produced and commercialized by the DuPont Company in1972. It is a member of the Aramid family of synthetic fibers. It can be spun into ropes or sheets of fabric that can either be used as-is, or used in the construction of composite components (Kent, 1997). *Kevlar* has high strength-to-weight ratio, *"...5 times stronger than steel on an equal weight basis..."*. *Kevlar* also have water resistant properties, but its most outstanding physical property is its high stiffness (17-127 GPa). (DuPont, 2007). There are three common grades of Kevlar: Kevlar, Kevlar 29 produced from poly(p-phenyllene terephthalamide) , and Kevlar 49 made by heat annealing of Kevlar 29. Kevlar 49 is considered to have the greatest tensile strength of all the aramids. The other members based on aromatic polyamide compositions are *Technora®* (Tenjin, Japan), *Teijinconex®* (Tenjin, Japan), *SVM®* (Russia) and *Twaron®* (Azko, Netherlands). (Kent, 1997)

Kevlar is synthesized from the monomers 1,4-phenylene-diamine (*para*-phenylenediamine) and terephthaloyl chloride in condensation reaction giving hydrochloric acid as byproduct. A mixture of N-methyl-pyrolidone and calcium chloride is used as the solvent for the polymerization.

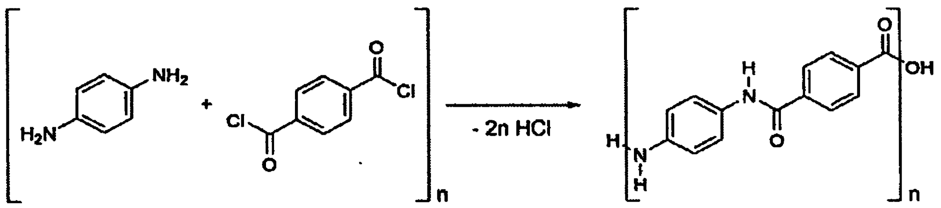


Fig 2.10: Synthesis of Kevlar

Fibers of *Kevlar* consist of long molecular chains produced from poly-paraphenylene terephthalamide. There are many inter-chain bonds making the material extremely strong. *Kevlar* derives a portion of its improved strength from inter-molecular hydrogen bonds formed between the carbonyl groups and protons on neighboring polymer chains and the partial pi stacking of the benzenoid aromatic stacking interactions between stacked strands. These interactions have a greater influence on *Kevlar* than van der Waals interactions and chain length that typically influence the properties of other synthetic polymers and fibers like *Dyneema*. *Kevlar*'s structure consists of relatively rigid molecules, which tend to form mostly planar sheet-like structures that have similarities to silk protein. (Kent, 1997)

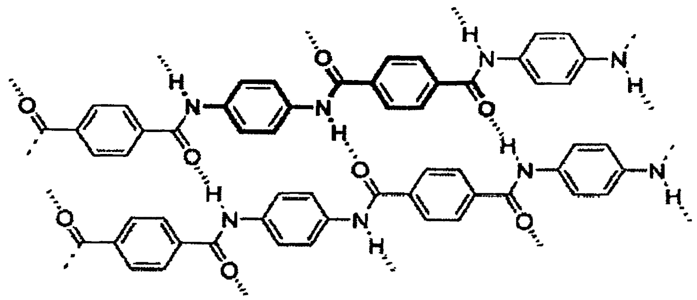


Fig 2.11: Structure of Kevlar

(k). High Performance Poly ethylene (*DYNEEMA®* and *SPECTRA®*)

Dyneema and *Spectra* are synthetic fibers based on ultra high molecular weight polyethylene (UHMWPE), also known as high modulus polyethylene (HMPE) or high performance polyethylene (HPPE) is a thermoplastic. This gives a strength/weight ratio as much as 15 times stronger than steel and up to 40% stronger than Aramid. *Dyneema* was invented by Royal DSM N.V., Netherlands in 1979. *Dyneema* fibers are made using a method called gel spinning. Honeywell developed a chemically identical product, which is sold under the brand name *Spectra*. (Kent, 1997)

The weak bonding between olefin molecules allows local thermal excitations to disrupt the crystalline order of a given chain piece-by-piece, giving it much poorer heat resistance than other high-strength fibers. Its melting point is around 144 - 152°C; it is not advisable to use UHMWPE fibers at temperatures exceeding 80 to 100°C for long periods of time. It becomes brittle at temperatures below -150°C. (Wikipedia-encyclopedia, 2007)

(k). Fluoropolymers (TEFLON®, VITON®)

Fluoroelastomers are a class of synthetic rubber which provide extraordinary levels of resistance to chemicals, oil and heat, while providing useful service life above 200°C. The outstanding heat stability and excellent oil resistance of these materials are due to the high ratio of fluorine to hydrogen, the strength of the carbon-fluorine bond, and the absence of unsaturation. (Kent, 1997)

Fluoropolymers were discovered accidentally by Plunkett in 1938. He was working on freon and accidentally polymerized tetrafluoroethylene. The result was polytetrafluoroethylene (PTFE), more commonly known as Teflon. PTFE is inert to virtually all chemicals and is considered to be the most slippery material in existence; it has the lowest coefficient of friction of any known solid material. (Drobny, 2006)

Fig 2.12: Structure of Teflon

In fluorocarbons, stability of the molecules is due to primary forces between carbon and fluorine. Fluorine forms much stronger bond to carbon than either hydrogen, chlorine, silicon or carbon to carbon and hens imparts the highest order of stability. Some of these rubbers retain their flexibility up to 500°C and resist even fuming nitric acid. They are the costliest among all the rubbers and have the best resistance of all the rubbers to heat, chemicals and solvents. The latest fluoropolymers have a much broader fluids resistance profile than standard fluoroelastomers, and are able to withstand strong bases and ketones as well as aromatic hydrocarbons, oils, acids, and steam. (Billmeyer, 1994)

2.2 Manufacturing process

2.2.1 Unsupported gloves - Unlined

Unsupported gloves are produced by dipping of the formers in a solution of the elastomers such as Natural latex, Nitrile, Neoprene, PVC, etc. These gloves are available in various finishes such as flocked, powdered, chlorinated and/or equipped with a synthetic inner-coating. The grip pattern of the glove is usually embossed on the former.

(a). Compounding

Rubber compounding is the art and science of selecting and incorporation of various compounding ingredients such as accelerators and anti-oxidants and their quantities to mix and formulate a useful rubber formulation that is processable and meets or exceeds the customers' final product requirements. The heart of rubber compounding is the formulation usually referred in the industry as a recipe. Every recipe contains a number of components, each having a particular function to perform either during processing, reinforcement or vulcanization and ultimately in the end use of the product. (Dick and Annicelli, 2001) Several chemical additives are often used in compounding process to provide some desired characteristics to the final product. For instance, antioxidants protects the polymer from chemical degradation by oxygen or ozone, ultraviolet stabilizers protect against weathering, Fillers are added to modify the strength and working properties while sometimes reducing costs, plasticizers make a polymer more flexible, lubricants reduce problems with friction, curing agents to form cross linking during vulcanization process and pigments or colorants add color to the polymer. Other additives like retardants, antistatics, antibicides and fragrances can also be used to provide specific features to the product. (Bahadur and Sastry, 2005)

(b). Dipping

Thousands of ceramic hand formers are first washed by dipping in hot water. They are then dipped into a coagulant tank that contains process chemicals. Finally they are ready for dipping in the latex tank. These formers then pass through an oven where the liquid latex forms into gel. (Nethsinghe, 1986)

(c). Leaching

The formers then run through pre-vulcanization leaching tanks to remove excess chemical residue and latex protein, with hot water counter-flowing continuously against the formers as they pass through. Then the leached formers undergo pre-drying process where the excess moisture is removed. (Nethsinghe, 1986)

(d). Vulcanization

Inside the vulcanization oven the heat removes moisture and the latex gel hardens to form into latex gloves. Either sulphur vulcanization or non-sulphur vulcanization can be utilized for this purpose. The hot vulcanization occurs at 120 -160 °C inside ovens in the presence of chemical agents called accelerators. The formers then pass through a post-vulcanization leaching tank, which is the most important step, but unfortunately not utilized by all manufacturers, to further remove latex protein and chemical residue. The gloves then pass through another drying oven before being stripped from the formers either by hand, or by an air-ejection machine. The gloves are last placed into tumble dryers for final vulcanization process. (Nethsinghe, 1986)
The diagram below illustrates the manufacturing process of unsupported gloves.

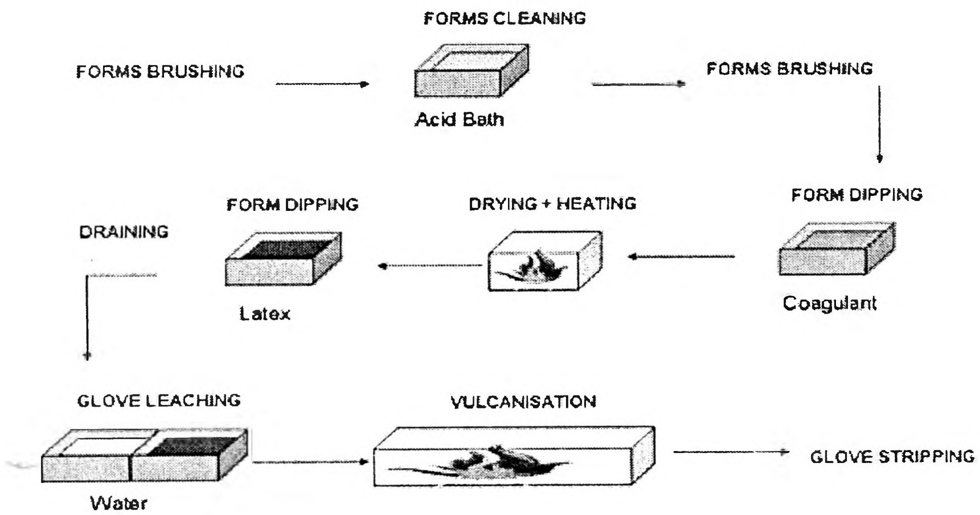


Fig 2.13: Manufacturing process of unsupported gloves
Source: www.anselleurope.com

2.2.1.1 The strengths of unsupported gloves

Unsupported gloves offer a broad spectrum of chemical resistance, according to the material used and materials can be blended to enlarge spectrum of performances. Formers used are ergonomically designed to fit the natural hand shape and to make gloves less tiring to wear. Glove dexterity, sensibility and comfort can be enhanced by Thin and flexible products. Extended choice of colours, lengths, type and patterns are available.

2.2.2 Supported gloves

Coating of the liner is performed as follows,

- The liner is loaded onto a metallic former.
- It is then dipped into a pre-selected compound (elastomer).
- The glove is vulcanized (or cured).

The diagram below visually illustrates the manufacturing process of supported gloves.

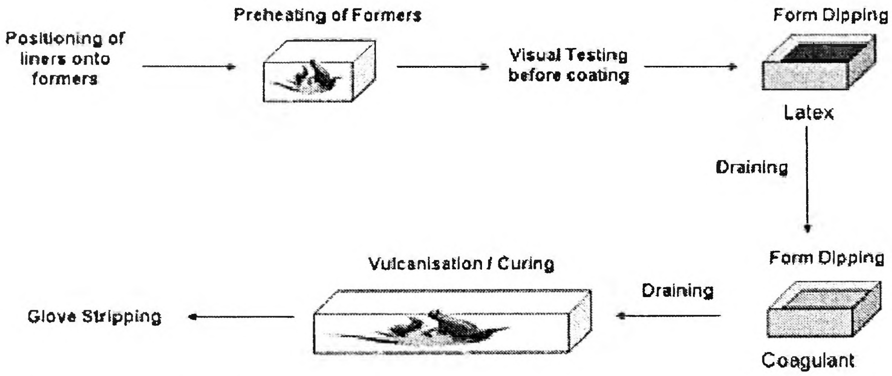


Fig 2.14: manufacturing process of supported gloves

Source: www.anselleurope.com

2.2.3 Medical and examination glove manufacturing

Following diagram illustrates the manufacturing process of Medical and examination gloves (powdered).

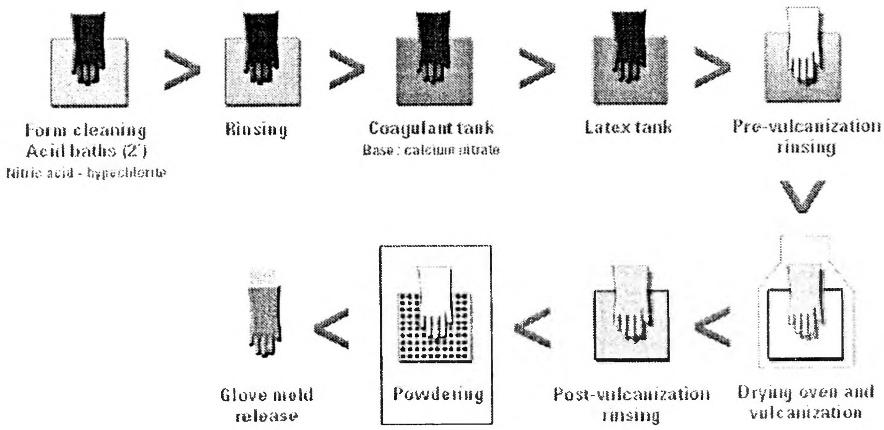


Fig 2.15: Manufacturing of powdered latex medical gloves

Source: www.anselleurope.com

2.3 International Standards and regulations pertaining gloves

The CEN Directives control whether a manufacturer can sell a product in the EC. Without the certified third party testing, documentation, and labeling for intended use and protection criteria, a glove cannot be sold in EC countries. There are several other organisations such as ASTM, NFPA, ANSI, COSHH and ISEA, who provide an incomparable wealth of information and tools to ensure worker safety. (Werner, 2007)

2.3.1 European community standards

The EC Directive 89/686/EEC on the approximation of the laws of Member States relating to personal protective equipment was adopted by the Council on 21 December 1989. In 2002, the Principal Regulations and the three amendments were consolidated into one document in the interests of providing clearer legislation and at the same time additional enforcement powers were extended to the Trading Standards Departments.

Failure to comply with these Regulations may mean that PPE may be prohibited from being placed on the Community /European Economic Area (EEA) market. If previously placed on the market in non-compliance, PPE may be forfeited. PPE complying with the PPE Directive's requirements may be supplied anywhere in the EEA.

2.3.1.1 EC standards for Personal protective equipment (PPE)

CE

CE category

The CE mark is a mandatory European marking for certain product groups to indicate conformity with the essential health and safety requirements set out in European Directives. The Directive provides exclusive lists of 'simple' and 'complex' design PPE. The responsibility for deciding whether a product is covered by the Directive and if so, to which category that PPE belongs rests with the manufacturer or his authorized representative in the Community.

Category I - Gloves of simple design - for minimal risk only

For gloves of simple design offering protection from low level risks, e.g. janitorial gloves, manufacturers are permitted to test and certify gloves themselves.

Category II - Gloves of intermediate design - for intermediate risk

Gloves designed to protect against intermediate risk, e.g. general handling gloves requiring good cut, puncture and abrasion performance, must be subjected to independent testing and certification by a Notified Body. Only these approved Bodies may issue a CE mark, without which the gloves may not be sold.

Category III - Gloves of complex design - for irreversible or mortal risk

Gloves designed to protect against the highest levels of risk, e.g. chemicals, must also be tested and certified by a Notified Body. In addition, the quality assurance system used by the manufacturer to guarantee homogeneity of production must be independently checked. The Body carrying out this evaluation will be identified by a number which must appear alongside the CE mark.

2.3.1.2 EN 420: 2003 - General Requirements for Protective Gloves

This standard defines the general requirements for glove design and construction, innocuousness, comfort and efficiency (sizing, dexterity), marking and information applicable to all protective gloves.

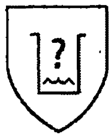
2.3.1.3 EN 374: 2003 – Protective Gloves against Chemicals and Micro-Organisms

EN 374-1: 2003 chemical resistance: terminology and requirements.

EN 374-2: 2003 resistance to penetration (3 levels).

EN 374-3: 2003 resistance to permeation (6 levels).

EN 374: 2003 - 1 - General chemical protection (low risk)



The 'Low Chemical resistant' or 'Waterproof' glove pictogram is to be used for those gloves that do not achieve a breakthrough time of at least 30 minutes against at least three chemicals from the defined list. If a glove is liquid proof according to EN 374-1, it will bear the pictogram "Liquid proof" or "basic chemical protection".

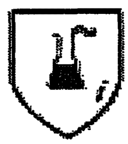
Penetration:

The ability of a chemical or micro-organism to pass through closures, porous layer, seams, pinholes or other material imperfections.

Degradation:

Change in one or more physical properties of the glove due to exposure with a chemical.

EN 374: 2003 – 3 - Specific chemical protection (high risk)



If a glove is liquid proof and has a level of performance in the permeation test according to EN 374-3 of 2 at least (>30 min.) for at least 3 of the chemicals listed in Annex A, then the (Erlenmeyer flask) pictogram can be used.

Permeation:

The gradual migration of a solvent through the glove at a molecular level is measured. The time taken by a chemical to break through the glove sample determines its permeation rating as per EN 374 standard.

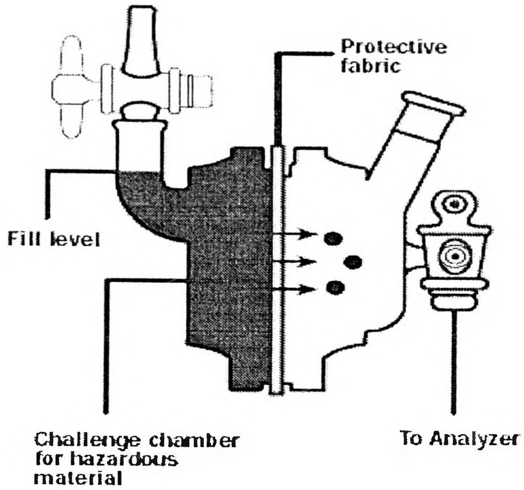


Fig 2.16: Permeation test cell (Introduced by ASTM in 1981)

Each chemical tested is classified in terms of Break through times for a given glove material (Performance level 0 to 6).

Table 2.01 Break through time (BTT) index

Protection index	BTT -Breakthrough time (min)
1	> 10
2	> 30
3	> 60
4	> 120
5	> 240
6	> 480

Table 2.02 Annex-A of EN 374-3 Chemical resistance index

Code	Chemical	CAS #	Class
A	Methanol	67-56-1	Primary Alcohol
B	Acetone	67-64-1	Ketones
C	Acetonitrile	75-05-8	Nitrile compounds
D	Dichloromethane	75-09-2	Chlorine based solvents

E	Carbon disulphide	75-15-0	Organic sulphur compounds
F	Toluene	108-88-3	Aromatic Hydrocarbons
G	Diethylamine	109-89-7	Amines
H	Tetrahydrofurane	109-99-9	Ethers
I	Ethyl acetate	141-78-6	Esters
J	n-Heptane	142-85-5	Aliphatic hydrocarbons
K	Sodium hydroxide 40%	1310-73-2	Inorganic Bases
L	Sulphuric acid 96%	7664-93-9	Inorganic mineral Acids

EN 374: 2003 - 2 - Gloves protecting against penetration by micro-organisms.

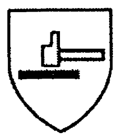
The 'Micro-organism' pictogram is to be used when the glove conforms to at least a performance level 2 for the Penetration test.

Table 2.03: Acceptable quality level (AQL) index

Performance level	Acceptable Quality level unit (AQL)	Inspection levels
Level 3	< 0.65	G1
Level 2	<1.50	G1
Level 1	< 4.00	S4

2.3.1.4 EN 388: 2003 Protective gloves against Mechanical Hazards

This standard applies to all kinds of protective gloves in respect of physical and mechanical aggressions caused by abrasion, blade cut, tearing and puncture. The 'Mechanical Risks' pictogram is accompanied by a 4-digit code:



a b c d

- **a.** Resistance to abrasion: based on the number of cycles required to abrade through the sample glove.
- **b.** Blade cut resistance: based on the number of cycles required to cut through the sample at a constant speed.
- **c.** Tear resistance: based on the amount of force (Newtons) required to tear the sample.
- **d.** Puncture resistance: based on the amount of force (Newtons) required to pierce the sample with a standard sized point.

Table 2.04: Mechanical performance index

Resistance to:	Units	Performance level					
		0	1	2	3	4	5
Abrasion **a**	cycles	< 100	100	500	2000	8000	-
Blade Cut **b**	cycles	< 1.2	1.2	2.5	5.0	10.0	20.0
Tear **c**	Newtons	< 10	10	25	50	75	-
Puncture **d**	Newtons	< 20	20	60	100	150	-

2.3.1.5 EN 407: 2004 Protective Gloves for Thermal Hazards

This standard specifies thermal performance for protective gloves against heat and/or fire.

abcdef

The 'heat and flame' pictogram is accompanied by a 6-digit number:

a. Resistance to flammability (performance level 0 - 4)

b. Contact heat resistance (performance level 0 - 4)

c. Convective heat resistance (performance level 0 - 4)

d. Radiant heat resistance (performance level 0 - 4)

e. Resistance to small splashes of molten metal (performance level 0 - 4)

f. Resistance to large splashes of molten metal (performance level 0 - 4)

a. Resistance to flammability:

Based on the length of time the material continues to burn and glow after the source of ignition is removed. The seams of the glove shall not come apart after an ignition time of 15 seconds.

b. Contact heat resistance:

Based on the temperature range (100-500 °C) at which the user will feel no pain for at least 15 seconds. If an level 3 or higher is obtained, the product shall record at least EN level 3 in the flammability test. Otherwise, the maximum contact heat level shall be reported as level 2.

c. Convective heat resistance:

Based on the length of time the glove is able to delay the transfer of heat from a flame. A level of performance shall only be mentioned if a performance level3 or 4 is obtained in the flammability test.

d. Radiant heat resistance:

Based on the length of time the glove is able to delay the transfer of heat when exposed to a radiant heat source. A performance level shall only be mentioned if a performance level 3 or 4 is obtained in the flammability test.

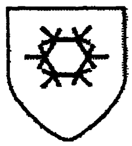
e. Resistance to small splashes of molten metal:

The number of molten metal drops required to heat the glove sample to a given level. A performance level shall only be mentioned if a performance level 3 or 4 is obtained in the flammability test.

f. Resistance to large splashes of molten metal:

The weight of molten metal required to cause smoothing or pin holing across a simulated skin placed directly behind the glove sample. The test is failed if metal droplets remain stuck to the glove material or if the specimen ignites.

2.3.1.6 EN 511: Protective gloves against Mechanical Hazards



This standard applies to any gloves to protect the hands against convective and contact cold down to –50 °C.

The 'cold hazard' pictogram is accompanied by a 3-digit number:

- **a.** Resistance to convective cold (performance level 0 - 4)
- **b.** Resistance to contact cold (performance level 0 - 4)
- **c.** Permeability by water (0 or 1)

a. Resistance to convective cold:

Based on the thermal insulation properties of the glove which are obtained by measuring the transfer of cold via convection.

b. Resistance to contact cold:

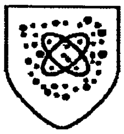
Based on the thermal resistance of the glove material when exposed to contact with a cold object.

c. Permeability by water:

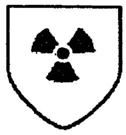
0 = water penetration after 30 minutes of exposure; 1 = no water penetration.

2.3.1.7 EN 421: 1994 Protective Gloves against Ionising Radiation and Radioactive Contamination

This standard applies to gloves to protect from Ionising Radiation and Radioactive Contamination. To protect from radioactive contamination, the glove has to be liquid proof and needs to pass the penetration test defined in EN 374.



Radioactive contamination



Ionising Radiation

To protect from ionising radiation, the glove has to contain a certain amount of lead, quoted as lead equivalence. This Lead Equivalence must be marked on each glove. Materials exposed to ionising radiation may be modeled by their behaviour to ozone cracking. This test is optional and can be used as an aid to selecting gloves which require resistance to ionising radiation.

2.3.2 **American Standards for testing materials** (ASTM International, 2007)

ASTM D5151 - Test Method for Detection of Holes in Medical Gloves

ASTM D3578 - Specification for Rubber Examination Gloves

ASTM D3577 - Glove tensile test, unaged - medical surgical gloves

ASTM D5250 - Specification for Poly(vinyl chloride) Gloves for Medical Application

ASTM F1342 - Glove puncture resistance

ASTM D5712 - Test Method for Analysis of Aqueous Extractable Protein in Natural Rubber and Its Products Using the Modified Lowry Method

ASTM D6124 - Test Method for Residual Powder on Medical

ASTM F739 - Standard Test Method for Resistance of Protective Clothing Materials to Permeation by Liquids or Gases under Conditions of Continuous Contact

ASTM D120 - Standard Specification for Rubber Insulating Gloves

ASTM D3767 - Practice for Rubber-Measurement of Dimensions

ASTM D412 - Test Methods for Vulcanized Rubber and Thermoplastic Elastomers – Tension

ASTM D6319 - Specification for Nitrile Examination Gloves for Medical Application Gloves

ASTM D6355 - Test Method for Human Repeat Insult Patch Testing of Medical Gloves

ASTM D6977-04 - Standard Specification for Polychloroprene Examination Gloves for Medical Application

ASTM D 6499 - Test Method for the Immunological Measurement of Antigenic Protein in Natural Rubber and its Products

ASTM D4679 - Specification for Rubber General Purpose, Household or Beautician Gloves

ASTM D7198-05 - Standard Specification for Disposable Embalming Gloves for Single-Use Applications

ASTM D7103-06 - Standard Guide for Assessment of Medical Gloves

ANSI/ISEA 105-2005 - The American National Standard for Hand Protection Selection Criteria

ASTM F1671, PB70 - Glove viral penetration

ASTM D573, NFPA 1999 - Test Method for Rubber-Deterioration in an Air Oven

2.3.3 Other standards

BS ISO 25518 - Dipped natural-rubber gloves for multipurpose application. Specification

BS 2606:1955 - Specification for X-ray protective gloves for medical diagnostic purposes up to 150 kV peak

BS IEC 61942:1997 - Live working. Gloves and mitts with mechanical protection

BS EN 60903:2003 - Gloves and mitts with mechanical protection for electrical purposes

BS 7971-6:2003 - Protective clothing and equipment for use in violent situations and in training. Gloves for protection against mechanical, thermal and chemical hazards. Requirements and test methods

ISO 11193-1:2002 - Single-use medical examination gloves - Part 1: Specification for gloves made from rubber latex or rubber solution

ISO 2859 - Sampling Procedures and Tables for Inspection by Attributes U.S. Pharmacopeia

ISO 10282:2002 - Single-use sterile surgical rubber gloves - Specification

CAN/CGSB 20.25-M91 - Sterile Surgical Rubber Gloves, Disposable

CAN/CGSB 20.35-2003 - Single-use Rubber Examination Gloves - Specification

AS/NZS 4179:1997/Amdt 1:1998 - Single-use sterile surgical rubber gloves – Specification

AS/NZS 2161.9:2002 - Occupational protective gloves - Method of measurement and evaluation of the vibration transmissibility of gloves at the palm of the hand

AS/NZS 2161.7.1:1998 - Occupational protective gloves - Protection against cuts and stabs by hand knives - Chainmail gloves and arm guards

JIS Z 4810:2005 - Protective rubber gloves for radioactive contamination

JIS T 8112:1997 - Rubber gloves for electrical insulation

JIS L 4131:2000 - Working gloves

JIS T 8114:2007 - Vibration isolation gloves

JIS T 8116:2005 - Protective gloves for use against chemicals

JIS T 9107:2005 - Single-use sterile surgical rubber gloves - Specification

JIS T 9115:2000 - Single-use rubber examination gloves

2.3.4 Latex allergies

Latex allergies are increasingly becoming a problem for people who are exposed to disposable non-sterile and sterile latex gloves, such as health care workers, patients, food service workers, manufacturers, hair dressers, child care workers, and children. There are three types of reactions that can occur in persons using latex products:

(1) Irritant contact dermatitis;

(2) Allergic contact dermatitis (delayed hypersensitivity) - Type IV allergy

(3) Immediate hypersensitivity latex allergy - Type I allergy

(Charous, 1998)

Reaction to latex may manifest through skin rashes, hives, itching, swollen skin, swollen lips and tongue, shortness of breath, dizziness, fainting, eyes or sinus symptoms, asthma and difficulty breathing, coughing spells, wheezing, and shock. (Reddy, 1998) In 1997, the National Institute for Occupational Safety and Health issued an alert concerning the danger of exposure to latex products and requested assistance preventing allergic reactions to natural rubber latex among workers who use gloves and other products containing latex. (OSHA regulations, 1997)

2.3.5 Latest trends in Hand protection industry

The shift in industry from production to service has created a similar shift in occupational hand protection requirements. Heavy, thick gloves, once considered a standard in hand protection, are being replaced with a variety of industry-specific products that offer protection while maintaining or improving worker productivity.

The recognition of potential musculoskeletal injuries from repetitive motion and vibration has identified a need in many industries for more ergonomically designed hand protection products. These products can be designed to provide support for different parts of the hand or wrist, or to provide cushioning for protection against impact. The challenge in the occupational glove industry is to design products that address specific worker needs for ergonomic design, fit and comfort and performance. (Nelson, 2006)

Advances in fibers and yarns, knitting technology and coating technology provide many options for material combinations to address specific hand protection requirements. Gloves made with high-performance fibers have provided unprecedented levels of protection against a range of hazards. Aramid fibers such as *Kevlar* and *Twaron* are known for their high strength and thermal stability. Polyethylene fibers such as *Spectra* and *Dyneema* also are known for their high strength, as well as for abrasion resistance and a cool feel on the hands; while research continues to identify other polymers that can be commercialized in fiber form. To assure gloves made with high-performance fibers or yarns are as comfortable as possible, manufacturers can employ a variety of knitting technologies. Plating is a knitting technology that allows insertion of a material inside the glove that is different than the material used on the outside. A *Kevlar* glove, for example, may be plated with a softer yarn to improve comfort and to encourage workers to wear the product for longer periods. (Smith, 2007)

CHAPTER 03

METHODOLOGY

Predominantly, a literature survey approach was followed, where information available in the public domain (product brochures, web sites) was researched to build up databases for fast access and comparison of DPL gloves with the main competition.

(a). The competitor products database was prepared

(b). Chemical resistance guide for competitors products was prepared

(c). Mechanical resistance guide for competitors products prepared

(d). The range of chemical and mechanical resistance offered by DPL products was analyzed

(e). The strengths and the weaknesses of DPL products regarding protection offered was identified by comparative analysis

(f). The key areas needed to be improved in order to provide better hand protection were identified

CHAPTER 04

RESULTS AND DISCUSSION

4.1 Similar products to the DPL product range identified in comparative analysis

Nova Fine

Manufacturer	Product name	Product code
Mapa	Solo Blue/ Solo Plus	995
	Solo Extra	998
Ansell	AccuTech® Ambi UltraGrip	91-104

Nova 38

Manufacturer	Product name	Product code
Sumirubber	SF-F-06 / EF-F-06	SF-F-06 / EF-F-06
Mapa	Vital	124
	Vital Eco	115/117

Nova Super 38

Manufacturer	Product name	Product code
Ansell	Econohands® Plus	87-190/87-195
	proFood® Re-usable Latex	87-315
	Universal™ Plus	87-650/87-660/87-665

Nova 45

Manufacturer	Product name	Product code
Sumirubber	LT-F-06	LT-F-06
Mapa	Classics	L-200/L-200LH/L-210
Ansell	FL100/FL200	155/188/198
	Tan Rubber	26-665
Marigold	3 colours	G12
	Red Lightweight	G10R
	Foodsure	U12B

Nova Super 45

Manufacturer	Product name	Product code
Rubberex	Multipurpose	RF1
Sumirubber	NT-F-06CS	NT-F-06CS

Nova 52

Manufacturer	Product name	Product code
Sumirubber	TD-F-01	TD-F-01
Rubberex	Extra Long/ Deep clean	LC21
Mapa	Medio	200/210
	Sure-Grip	LF-128
Ansell	AciTek	49-252
	Tan Rubber	26-685

Nova Super 52

Manufacturer	Product name	Product code
Ansell	Austral® Plus	87-800/87-805

Nova Super 55

Manufacturer	Product name	Product code
Ansell	Profil™ Plus	80-850

Nova Super 65

Manufacturer	Product name	Product code
Marigold	Suregrip	G04Y
Mapa	Alto	258/ 266

Nova 75

Manufacturer	Product name	Product code
Rubberex	Spong	RSL 80
Sumirubber	MT-F-09	MT-F-09

Nova Super 75

Manufacturer	Product name	Product code
Ansell	Orange Heavyweight	208
	Extra	87-950/87-955

Fathom 45

Manufacturer	Product name	Product code
Sumirubber	NT-U-06C	NT-U-06C
Rubberex	Satin Touch/ Soft touch	UC1
	Unlined semi- industrial	BK21
	Superfood	174/175/177
Ansell	Natural Blue™	356
	Technicians™	390
	DuraTouch	87-600
	proFood® Re-usable Latex	87-305

Fathom 50

Manufacturer	Product name	Product code
Rubberex	Superior touch	UC2R
Mapa	Sure-Grip	LF-128
Ansell	Canners and Handlers™	384/392/394/343

Barrier 100

Manufacturer	Product name	Product code
Sumirubber	ST-F-07 / ET-F-07	ST-F-07 / ET-F-07
Mapa	Industrial	299

Silver 50

Manufacturer	Product name	Product code
Rubberex	Silver/ Superior silver lined	SL1
Sumirubber	HD-S-07C	HD-S-07C

Workman 1.10

Manufacturer	Product name	Product code
Rubberex	Power Knight/ Black Knight Gauntlet	BK39-18
Mapa	Trident	285/286
	Industrial	297/ 298

Workman 1.30

Manufacturer	Product name	Product code
Marigold	Emperor Heavyweight	ME102/ ME105/ ME108

Fisherman 0.75

Manufacturer	Product name	Product code
Rubberex	Power Knight/ Black Knight Gauntlet	BK31-18
Marigold	Black Heavyweight	G17K
	Supaweight	G02T
	Emperor Lightweight	ME100/ME103/ME106

Fisherman 0.90

Manufacturer	Product name	Product code
Mapa	Trident	287

Fisherman 1.15

Manufacturer	Product name	Product code
Marigold	Emperor medium weight	ME101/ME104/ME107

Frontier 75

Manufacturer	Product name	Product code
Rubberex	Super Neoprene	NEO 400
Sumirubber	NP-F-07	NP-F-07
Mapa	Technic	420/450

Grandeur 70

Manufacturer	Product name	Product code
Sumirubber	CR-F-07 (0.75mm)	CR-F-07
	CB-F-09 (0.65mm)	CB-F-09
Rubberex	X'treme Tough	HD27NEO
Ansell	Neotop®	29-500

Rescuer II

Manufacturer	Product name	Product code
Mapa	Protector	AFR-282

Conqueror II

Manufacturer	Product name	Product code
Mapa	Duo-mix	405
Ansell	Chemi-Pro®	224

Skinsafe

Manufacturer	Product name	Product code
Sumirubber	UN-F-07C (0.45mm)	UN-F-07C

Interface Soft

Manufacturer	Product name	Product code
Rubberex	Satin Nitrile	RNU 9
Sumirubber	GI-U-01C	GI-U-01C
Mapa	Optinit	472
Ansell	Sol-Vex®	37-105
	Sol-Vex® Blue	37-510
	Sol-Vex® II	37-646
	Virtex™	79-700

Interface Plus 0.28

Manufacturer	Product name	Product code
Rubberex	Satin Nitrile	RNU 11
	Silken	SILKEN
Sumirubber	GC-F-09C	GC-F-09C
Mapa	Stansolv	A-10/A-10UN/A-30/A-10CR
	Ultrafood	486
	Ultranitrile	481
Marigold	G07B+	G07B+
	Greenfit™ Plus	79-300
	proFood® Re-usable Nitrile	79-340

Interface Plus 0.38

Manufacturer	Product name	Product code
Rubberex	Super Nitrile	RNF 15
	Sofie Skin	SOF 13
Sumirubber	GT-F-09C	GT-F-09C
Mapa	Stansolv	489/A-15/A-35
Marigold	G25G/ G26G / G915	G25G/ G26G / G915
Ansell	Sol-Vex®	37-155/37-175
	Sol-Vex® II	37-656
	proFood® Re-usable Nitrile	37-355

Interface Plus 0.45

Manufacturer	Product name	Product code
Sumirubber	GD-F-09C	GD-F-09C
Rubberex	Super Nitrile	RNF 18
Mapa	Stansolv	AF-18/ AF-38
	Ultrafood	497
Ansell	Sol-Vex® Premium	37-900
Marigold	Blue Nitrile	G25B

Interface Plus 0.55

Manufacturer	Product name	Product code
Mapa	Ultranitrile	480
Marigold	Long Nitrosolve	Z51G
Ansell	Sol-Vex®	37-165

Paragon

Manufacturer	Product name	Product code
Mapa	Enduro	330
	Harpon	320
Ansell	Golden Grab-It®	16-300
	Gladiator	16-500

Lite-it

Manufacturer	Product name	Product code
Mapa	Jersetlite	307
Marigold	Belmain Plus	

Hold-it

Manufacturer	Product name	Product code
Marigold	Comarex	35

Hand-it

Manufacturer	Product name	Product code
Sumirubber	RF4 SB	RF4 SB
Mapa	Jersette	300
Ansell	Hy-Care™	62-200

Max-it

Manufacturer	Product name	Product code
Ansell	Gladiator	16-650
Mapa	Blue-Grip	LL-301

Laurel

Manufacturer	Product name	Product code
Sumirubber	BF6 LB	BF6 LB
Mapa	Stansolv	AK-22
	Dextram	375 , 376
	Ultril	377
Marigold	Flexiproof	
Ansell	Sol-Knit®	39-112 / 39-122 / 39-124

Ze-nit

Manufacturer	Product name	Product code
Mapa	Dexilite	383
Marigold	Nitrotough	N110/ N130/ N205/ N210/ N230/
	Flexilight Tropique	
Ansell	EasyFlex	47-200
	Hylite®	47-400 / 47-402 / 47-800

Gra-nit

Manufacturer	Product name	Product code
Mapa	Titanlite	GPA-397
Marigold	Nitrotough	N630/ N650/ N730
Ansell	Hycron®	27-600 / 27-602
	Hyd-Tuf	52-502

Infi-nit

Manufacturer	Product name	Product code
Mapa	Titanlite	GPA-397
Marigold	Nitrotough	N640/ N660/ N740
Ansell	Hycron®	27-607 / 27-805
	Hyd-Tuf	52-507 / 52-547 / 52-590

Tuf-un

Manufacturer	Product name	Product code
Ansell	Golden Grab-It®	16-307

Viking

Manufacturer	Product name	Product code
Rubberex	Maxx Grip	DGNRC1
Marigold	K2000	K2000
Ansell	PowerFlex®	80-100
	Hyd-Tuf	52-507 / 52-547 / 52-590

Viking Plus

Manufacturer	Product name	Product code
Rubberex	Nitrile coated string knitted	NBRC1
Marigold	Flexilight	

Samurai

Manufacturer	Product name	Product code
Marigold	PGK10	PGK10
Ansell	Grab-It® Safe	28-310
	PowerFlex® +	80-600

In matching the competitors gloves with the DPL's product range following factors were considered;

For unsupported gloves,

- Material (Elastomer)
- Thickness
- Lining (flock lined / unlined)

For supported gloves,

- Material (Elastomer and liner)
- Type of cuff
- Thickness

Table 4.1 Database for product attributes of competitors range

Prod. name	Prod. code	Material	Lining	Thickness (mm)	Length (cm)	Grip pattern	Cuff	Finish	CE cat.	Applications	Special Remarks	Picture	Closest matching DPL product

Table 4.2 Chemical resistance data for DPL products derived by the comparative analysis

	Product references					
Chemical	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**
Acetaldehyde						
Acetic acid 50%				47	158	
Acetic acid 100%	< 5	8	23	3	9	11
Acetone **B**			< 5		15	< 5
Acetonitrile **C**						3
Acrylic acid						67
Acrylonitrile						
Ammonia(gas)						
Ammonium acetate						
Ammonium carbonate						
Ammonium hydroxide 28%					>480	
Ammonium hydroxide 50%					>480	>480
Amyl acetate						
Amyl alcohol						
Aniline						
Benzene						
Butanol / Butyl alcohol	< 5		24		>480	
n-Butanol						
t-Butanol						
2-Butoxyethanol				236		
Butyl acetate				25		
t-Butyl methyl ether						
Carbon disulphide **E**						
carbon tetrachloride						< 5
Chromic acid 50%						

4.2 Discussion

The chemical resistance data derived by comparative analysis can be used to get a useful idea about the chemical resistance profile of a similar glove, yet certain deviations with the actual performance of a glove is obvious. This can happen due to the changes in chemical composition of gloves, which results from differences in compounding, leaching and elastomer profiles. For example the composition of acrylonitrile in a nitrile glove can influence on its chemical resistance profile (18% moderately resistant to oils and 40% extremely resistant to oils). (Billmeyer, 1994)

One important point noted in the comparative analysis was that the competitors offer chemical resistance information on many specific chemicals other than the 12 chemicals mentioned in the EN 374-3 standard. This chemical resistance information is on specific chemicals which are used in particularly special industries. For example they provide information on resistance to hazardous chemicals such as White spirit, Methyl isobutyl ketone, methyl-t-butyl ether, N-methyl-2-pyrrolidone, diisobutyl ketone, methyl ethyl ketone, etc. which are used in production of paints, wood preservatives, lacquers, varnishes, and asphalt products. So a particular glove which offers resistance against these chemicals can be marketed as a specific glove for paint industry.

Research shows that the breaks through times are significantly reduced in actual applications of the glove; because, testing is carried out at 23°C but, gloves after few minutes in contact with hand are having temperature around 35°C. Therefore caution should be taken in actual applications.

Gloves used by workers today not only must meet performance criteria but also must fit well and provide sufficient levels of comfort, so workers will make a conscious choice to wear them. However, the requirements for performance, fit and comfort vary from one industry to another. For example, the material handling and product assembly sectors may require gloves that can protect against cuts, punctures and abrasions while providing high levels of dexterity and tactile sensitivity. Workers in the waste management industry must protect their hands from moisture, chemicals, micro-organisms and sometimes unknown substances. In the growing construction industry, workers need protection from abrasive surfaces, wood and metal splinters and injuries associated with repetitive motion and vibration.

According to Australian conservation foundation (ACF), "Hazardous chemical" is a general term including artificially manufactured substances or naturally occurring substances which cause or have potential to cause injury or damage to organisms or materials or the degradation of the ecosystems. The substances may have properties which are toxic, carcinogenic, mutagenic, teratogenic, corrosive, reactive flammable, explosive, bioaccumulative or otherwise directly or indirectly harmful. When providing chemical resistance data it would be useful to give information regarding chemicals that are identified as hazardous/harmful by the force governing authorities such as OSHA regulations in USA, REACH package of European chemical agency, Control of Substances Hazardous to Health Regulations (COSHH) in UK, CEPA of Canada and NICNAS, EHC acts of Australia.

Also it was identified that the competitors are responding to the world health crisis and are in-turn benefited from them. For example 'Gloves to protect against avian flu' information provided by Mapa-proffessional and 'Gloves to protect against Bird flu' by Ansell are aimed for the recent world health crisis due to "Bird Flu".

Also an eye should be kept on the new legislations and amendments effecting directly for glove industry. For example Canada prohibited the use of silicone in contact with food by an act in 2007 and there are several regulations regarding latex related allergies.

Competitors like Ansell and Mapaglove have a very informative technical database with a special focus on occupational ergonomics, supported by a dedicated technical team. For example they are answering the technical issues regarding there products on-line and information such as silicon-free, wax-free, plasticizers-free and special features of the products are provided in their product catalogues. They also have categorized their range of products according to different types of applications, supported by the chemical resistance data for those applications.

Competitors have specialty gloves made using special materials (elastomers and liners) and special blends in their product range, which are aimed for specific industries. For example;
Mapa-Professional's Topchem, Fluotex, Fluonit, Stanzoil, Chemzoil, Chemply, Trilites, Trionic, Ultrane-Grip, Krytech, etc.
Ansell's Alpha Tec, Barrier, Sol-vex, Safe-Knit® Kevlar XG, ThermaPrene, Vibra-Guard, Metalist, etc. and
Marigold's Master diver, Electrician, Vibra-plus, FS18KP, Comaprene, PX-Insulator, G60R, etc.

CHAPTER 05

CONCLUSION AND RECOMMENDATION

5.1 Suggestions for product Improvements and developments

It would be vital to have information of the actual applications/end-uses of products to identify the required barrier protection levels for a particular product. For this purpose glove research and development will need to rely on increased interaction with end-users to identify specific needs. For example knowing the range of chemicals that are handled in a particular industry will assist in providing chemical resistance information readily available for customers.

Also it is important to check the gloves against chemicals (E.g. carcinogens, bioaccumulative, mutagenic, toxic, etc.), which are identified as hazardous/harmful by the force governing authorities such as OSHA, European chemical agency, COSHH, CEPA, NICNAS and EHC . For example, natural rubber latex (NRL) is a substance hazardous to health as defined by the COSHH regulations and therefore advice that gloves made of natural rubber must be subjected to risk assessment. It is estimated that there are 20 million Americans who are allergic to the latex found in gloves.

New products made using special elastomers/coatings can provide enhanced barrier protection for special purposes. Addition of these special purpose gloves will surely add vitality to the DPLs' range of products. E.g. Electricians/linemans'gloves, Anti-vibration gloves, Magnetic radiation resistant gloves, etc. Also, natural and synthetic rubber blends at various ratios can be used to develop new products which provide enhanced levels of performance while cutting down the costs. E.g. Fluoroelastomers (Teflon, Viton), Poly-vinyl alcohol, Kevlar, Dyneema, Spectra, ThermaStat, PVC, PU, Gel-Foam and blends of elastomers. Competitors use layers of different elastomers to produce gloves with special barrier protection profiles to suit specific industries. E.g. Neoprene + PVA, Nitrile + Fluoroelastomer, Neoprene + Fluoroelastomer, etc.

There are material safety datasheets (MSDS) for special chemicals provided by testing laboratories, specifying brand names of competitors' gloves to use for protection against that chemical. For example, the material safety datasheets for Methylene chloride (dichloromethane) recommends the use of Fluoroelastomer (Viton) gloves such as Fluotex, Fluonit, Chemtec, etc, in the competitors range. DPL can also be benefited by publishing their product names in MSDSs.

Making chemical resistance information available as product-wise and chemical-wise will assist the customer in choosing the best glove for their hand protection requirements. These data are already being provided by the main competitors for their range of products. Because proper glove selection is a complex issue, employers and others responsible for selection will inevitably demand a simple, easy-to-read yet informative guide. Competitors have product sheets which are informative as well as attractive and downloadable, which assists the customer in choosing the right glove for their requirements.

Categorizing the products under different applications would assist customers in choosing the best hand protection solution. For this, information on actual environments of glove usages should be researched and gathered. Researchers have found that the same glove gives significantly different BTT for the same chemical in different applications. Hence this information will assist DPL to recommend there products as specific for a particular application.

Today people are searching for natural like or less synthetic products. So providing information such as silicon-free, wax-free, no-plasticizers, no-fillers, etc may be effective in competitive marketing of products. Also products such as Aloe Vera lined, Vanilla scented, fragranced, Absorbent cream lined, hypoallergenic etc. could be introduced to the range.

Today there are hundreds of rules and regulations which are directly or indirectly related to the marketing of gloves. Searching for these legislations and getting compliance with them will provide an edge in marketing DPL products. For example four states of United States have banned the use of latex gloves in contact with food and a Canadian court recently brought an act prohibiting the use of silicone treated gloves in food establishments. Awareness of such local regulations will assist in marketing products for use in food industry. Not only the product but legislations related to packing materials may also influence in global marketing of products.

An on-line answering system could be introduced to assist the technical issues experienced by the customers/end-users, which will in turn help the technical staff to get information regarding the product improvements which are required.

Studies show that workers are more likely to wear gloves and keep them on if they understand the product's purpose and why specific gloves were selected to assure their job safety. Competitors are now employing a variety of tools - from glove boards and brochures to training videos, online resources and newsletters - to educate workers.

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Appendix I

Product details of competitors range

Key :- Unsupported gloves
supported gloves

Product name	Product code	Material	Lining		Thickness +/-0.05mm	Length +/- 2% mm	Cuff
			Supported	Unsupported			
Alto	258	Natural latex		Flock-lined	0.60	320	
Alto	266	Natural latex		Flock-lined	0.60	370	
BioPro	860	Thermoplastic elastomer			0.50	310	
ChemPly	407	Neoprene		Unlined	0.75	355	
ChemPly	414	Neoprene		Unlined	0.75	455	
ChemZoil	339	Neoprene on Cotton Jersey	Knitted		1.35	355	
Cobra	466	Fluoroelastomer			0.35	280	
Cobra	467	Fluoroelastomer			0.65	355	
Dexilite	383	Nitrile on Cotton	Knitted		0.80	260	Knitwrist
Dextram	375	Nitrile on Cotton	Knitted		0.80	260	Pinked
Dextram	376	Nitrile on Cotton	Knitted		0.80	310	Pinked
Duo-mix	405	NR & neoprene blend		Flock-lined	0.70	330	
Duo-Nit	180	NR & nitrile blend		Flock-lined	0.40	310	
Enduro	330	Natural latex on Cotton liner	Knitted			240	Knitwrist
Fluonit	468	Fluoroelastomer			0.50	300	
Fluotex	344	Fluoroelastomer on Cotton liner	Knitted		1.50	370	Knitwrist
Gantex	520	Natural latex			0.40	335	
Gantex	540	Natural latex			0.40	320	
Harpon	319	Natural latex on Cotton liner	Knitted			250	Knitwrist
Industrial	297	Natural latex		Unlined	1.00	360	
Industrial	298	Natural latex		Unlined	1.00	420	
Industrial	299	Natural latex		Flock-lined	0.90	310	
Isomapa	343	Neoprene on Cotton Jersey liner	Knitted		1.65	330	Gauntlet
Jersetlite	307	Natural latex on Cotton liner	Knitted		0.75	310	Pinked
Jersette	300	Natural latex on Cotton liner	Knitted		1.15	310 - 330	Pinked
Jersette	315	Natural latex on Cotton liner	Knitted		1.25	370	Pinked
Krolite	820	para-aramide fibres (Kelvar® or Twaron®)	Knitted			280	
Kronit	386	Nitrile on Kelvar liner	Knitted			260	Knitwrist
Kronit	387	Nitrile on Kelvar liner	Knitted			310	Pinked
Krotech	830	para-aramide fibres (Kelvar® or Twaron®)	Knitted			260	Knitwrist

Competitors' product details used for the preparation of Database for range

- Product name
- Product code
- Material (Elastomer/Liner)
- Lining (Supported/Unsupported)
- Thickness
- Length
- Cuff
- Colour
- Grip pattern
- Finish
- Applications
- CE category
- EN ratings
    - EN 388 : Protective gloves against Mechanical Hazards
    - EN 374-1 : General chemical protection (low risk)
    - EN 374-2 : Protective Gloves against Micro-Organisms
    - EN 374-3 : Specific chemical protection (high risk)
    - EN 511 : Protective gloves against Mechanical Hazards
    - EN 407 : Protective Gloves for Thermal Hazards
    - EN 1149 : Protective Gloves against Ionising Radiation and Radioactive Contamination
    - Food safe
- Special remarks
- Picture
- Web link
- Closest matching DPL product (Product name/product code)

Appendix II

The Chemical resistance profiles for DPL products derived by comparative analysis

	Product reference					
Chemical	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**
Acetic acid 100%	8	166		24	135	
Acetone *B*		8	8	5	15	11
Acetonitrile *C*		10	17			
Acrylonitrile					10	
Ammonium hydroxide 28%		44			54	
Benzene		< 5			5	
Butanol / Butyl alcohol		49				
2-Butoxyethanol						
Butyl acetate		6		6	16	34
t-Butyl methyl ether				8		
Carbon disulphide *E*		< 5	< 5		< 5	
Chromic acid 50%						
cyclohexane				8		34
cyclohexanone	9			18	35	50
Dichloromethane *D*						
Diethylamine *G*					6	
N-N Dimethyl acetamide	14			34		197
Dimethylformamide(DMF)	12			28	91	32
Dimethyl sulfoxide(DMSO)				203		
Ethanol	14			20		70
Ethyl acetate *I*		< 5	5	3	14	
ethylene glycol		>480	>480		>480	
Ethylglycol acetate					29	
Formaldehyde 37%		>480			>480	
Formic acid 90%					58	
n-Heptane *J*						
Hexane					7	2
Hydrochloric acid 10%		>480		>480	>480	
Hydrochloric acid 35%	>480	>480		>480		>480
Hydrofluoric acid 50%			>480			
Hydrogen peroxide 30%		>480				
Isopropanol	15	47		42		64
Kerosene						
Methanol *A*	7	12	30	11	26	42
Methyl ethyl ketone (MEK)	2			5	8	11
Methyl isobutyl ketone (MIBK)				6	12	
Methyl methacrylate				5		
N-Methyl-2-Pyrrolidone	17			36		
Naptha				5		
Nitric acid 68%			> 480		>480	

Appendix III

Safety and risk phrases for chemicals

Chemical	CAS Nos	Risk & Safety Phrases
Acetaldehyde	75-07-0	R40
Acetic Acid (glacial)	64-19-7	R35
Acetone	67-64-1	S24
Acetonitrile	75-05-8	R24
Acrylic Acid	79-10-7	R34
Agrochemical (Aqueous)	38641-94-0	S37
Agrochemical (Solvent)	–	R38
Ammonium Hydroxide (0.88 S.G.)	1336-21-6	R21/34
Amyl Acetate	628-63-7	R38
Amyl Alcohol (Pentyl Alcohol)	71-41-0	R24
Anionic Surfactant (5% Aq. Potass. Oleate)	143-18-0	S24
Benzene	71-43-2	R24/45/48
Bisphenol A (20% in MEK)	80-05-7	R38
Butanol (Butyl Alcohol)	71-36-3	S24
Butyl Acetate	123-86-4	S24
Carbon Disulphide	75-15-0	R38/48
Cationic Surf. (5% Aq. Cetyl Pyridin. Chlo.)	123-03-05	R38
Cellosolve	110-80-5	R21
Cellosolve Acetate	111-15-9	R21
Chloroform	67-66-3	R38/40/48
Chromic Acid	1333-82-0	R35/43
Citric Acid (Satd. Aq. Soln.)	77-92-9	R38
Cyclohexanol	108-93-0	R38
Cyclohexanone	108-94-1	S24
Cyclohexylamine	108-91-8	R21/34
Diacetone Alcohol	123-42-2	S24
Dichloromethane (Methylene Chloride)	75-09-2	R40
Diesel Fuel	–	S37
Diethyl Ether	60-29-7	R21
Dimethyl Acetamide (DMAC)	127-19-5	R21
Dimethylformamide (DMF)	68-12-2	R21
Dioctyl Phthalate (DOP)	117-81-7	R38/45
Dioxane (1,4)	123-91-1	R38/40
Epichlorohydrin	106-89-8	R27/34/43/45
Epoxy Resin (Araldite Liquid Resin)	68609-97-2	R38/43
Ethanol (Ethyl Alcohol)	67-17-5	S24
Ethanolamine	141-43-5	R38
Ethyl Acetate	141-78-6	S24
Ethyl Acrylate	140-88-5	R38/43
Ethyl Lactate	97-64-3	S37
Ethylene Glycol	107-21-1	S24
Formaldehyde (40% Aq. Soln.)	50-00-0	R34/40
Formic Acid (90% Aq. Soln.)	64-18-6	R35
Furfural	98-01-1	R40/S24
Glycerol	56-81-5	S24

Safety and risk phrases

R21	Harmful in contact with skin
R24	Toxic in contact with skin
R27	Very toxic in contact with skin
R33	Danger of cumulative effects
R34	Causes burns
R35	Causes severe burns
R38	Irritating to the skin
R39	Danger of very serious irreversible effects
R40	Possible risk of irreversible effects
R43	May cause sensitisation by skin contact
R45	May cause cancer
R46	May cause heritable genetic damage
R47	May cause birth defects
R48	Danger of serious damage to health by prolonged exposure
S24	Avoid contact with skin
S37	Wear suitable gloves

Contd.

Chemical	CAS Nos	Risk & Safety Phrases
Heptane (-n)	142-82-5	S37
Hexamethylene Diisocyanate (HMDI)	5124-30-1	R38/43
Hexane (-n)	110-54-3	R48
Hydrochloric Acid (36% Aq. Soln.)	7647-01-0	R34
Hydrofluoric Acid (48% Aq. Soln.)	7664-39-3	R27/35
Hydrogen Peroxide (30% Aq. Soln.)	7722-84-1	R34
Hydroquinone (Satd. Aq. Soln.)	123-31-9	S24
Isopropanol (Isopropyl Alcohol, IPA)	67-63-0	S24
Jeffamine (An Epoxy Catalyst)	101-77-9	R21/43
Kerosene	8008-20-6	S24
Lubricating Oil	–	S37
Methanol (Methyl Alcohol)	67-56-1	S24
1-Methoxy-2-propanol	107-98-2	S24
Methyl Ethyl Ketone (MEK)	78-93-3	S37
Methyl Isobutyl Ketone (MIBK)	108-10-1	S37
Methyl methacrylate	80-62-6	R38/43
N-Methylpyrrolidone (NMP)	872-50-4	R38
Naphtha	8032-32-4	R45
Nitric Acid (50% Aq. Soln.)	7697-37-2	R34
Nitric Acid (70% Aq. Soln.)	7697-37-2	R34
Nonionic Surfactant (5% Aq. Dehydol)	–	–
Octane (Isooctane)	111-65-9	S37
Orthophosphoric Acid	7664-38-2	R34
Perchloroethylene	127-18-4	R40
Petroleum Ether (60/80)	8032-32-4	R38/48
Phenol (7% w/v Aqueous Solution)	108-95-2	R24/34
Phenol (Aq. 80% w/w)	108-95-2	R24/34
Picric Acid (Satd. Ethanol Solution)	88-89-1	R24
Potassium Hydroxide (50% Aq. Soln.)	1310-58-3	R35
Propanol (Propyl Alcohol)	71-23-8	S24
Pyridine	110-86-1	R21
Sodium Carbonate (Satd. Aq. Soln.)	497-19-8	–
Sodium Chloride (Satd. Aq. Soln.)	7647-14-5	R38
Sodium Hydroxide (50% Aq. Soln.)	1310-73-2	R35
Sodium Hypochlorite (Satd. Aq. Soln.)	7681-52-9	R34
Styrene	100-42-5	R38
Styrene Solution (polyester resin in 40% Styrene)	–	R38
Sulphuric Acid (50% Aq. Soln.)	7664-93-9	R35
Sulphuric Acid (98%)	7664-93-9	R35
Toluene	108-88-3	S24
Toluene Diisocyanate (TDI)	584-84-9	R38
Trichloroethylene	79-01-6	R40
Triethylamine	121-44-8	R21
Turpentine	8006-64-2	R21
Unleaded Petrol	–	S37
White Spirit	–	R21
Xylene	1330-20-7	R21

Source: http://www.marigold-industrial.com/ Chemical/MI_chemical_chart_EN.pdf

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