DESIGN - QUALITY FACTOR FOR PROTECTIVE CLOTHING

BY

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Abstract. Starting from the motto: “Comfort is a pleasant state of physiological, psychological and physical harmony between a human being and the environment” ([11] Slater, 1985), this paper aims to have a deeper look on what these concepts imply in the context of protective clothing design as a merger between worker protection needs and employee organizational needs. The substance of this definition of comfort is best understood in the context of protective clothing, since especially in this case the design needs to take into consideration all of body’s functions, physical and mental aspects. This paper is a synthesis of the correlation of constructive design of regular clothing – patterns, size, and colour – with design elements filtered through the requirements of protective clothing – protection, comfort and aesthetics – in the production process.

Key words: protective clothing, personal protective equipment, risk assessment, constructive design, design features.

1. Introduction

The focus point in design has shifted in the past years to include new elements previously ignored or dismissed as non-important. From the standpoint of the Romanian researchers, it was obvious that a new vision of constructive elements has been increasingly used by producers of protective clothing within the past twenty years as they came onto the Romanian protective clothing market. From having as the only essential element of design the fulfilment of the protection function, comfort and aesthetical principles, now the list of requirements protective clothing has to satisfy has expanded [1]. The underlying needs that led to this change were:

- The need to correlate design requirements for specific uses with the need to ensure freedom of movement to an appropriate degree;
- Technological evolution of fabric-making for protective clothing, in
terms of both protection performance and aesthetics and comfort. Main changes were observed in specific weight, softness, range of colours:

− Increase of the automatization and mechanization degree of the technological process;

− Application of study results with regard to workplace stress, particularly of the colour theory where certain colours’ use increases psychological comfort;

− Improvement of living conditions and implicitly of the individual needs regarding the use at the workplace of protection clothing that answers aesthetic and comfort demands as well. These translate through reduced weight, permeability to water vapours, permeability to air, diverse colour palette.

Correlation of individual needs of various organizations, that is, creating models used only by certain companies (such as: E-on, Transgaz, Petrom etc.), not just to market the brand, but also out of practical organizational reasons pertaining to ensuring discipline in the factory/compound/on the facility grounds, to the personnel fluctuations, distinguishing personnel by department and attributions.

In fulfilling the above requirements, the main role is played by constructive design. This ensures:

a) The making of protection wear in a wide range of sizes, as adapted as possible to the field of use, including the correlation between the constructive dimensions of the product with the anthropometric dimensions of the users and the actual wearing conditions [2]. Example: the clothing for protection against toxic chemicals with limited usage numbers. It can be used only once in cases such as nuclear contamination or biological risks, or, more than once and until cleaning/washing of the clothing is needed, in fields as spraying with pesticides or in dye works. Usually these products are made out non-woven fabrics, one of the most famous such fabrics being Tyvek [3]. These materials have low mechanical resistance, hence the inability to wash them and the futility of having a wide size range. Narrow size options still allow the needs for protection as well as the anthropometric correspondence. In adopting a narrower size range companies also consider the reduction in costs for the design of tailoring patterns and of manufacturing.

b) Creation of clothing models ensuring the requirements of protection for a particular work environment [4]. Some examples are the using of the raglan or kimono style of tailoring in workplaces where ample arm movements are needed or tailoring clothing elements around the neck or the wrists for workplaces with risk of spraying of toxic chemicals.

c) Creation of specialised clothing types which allow the wearing of other personal protective equipment (e.g. respiratory system protection devices, integrated safety belts, protection devices for body parts as knee pads, shoulder pads.

d) Creation of personalised products according to the field of use (combinations of colours, logos, etc.) and devised with functional elements (pockets, tool straps).
c) Ensuring the hygienic function of protective clothing by allowing ventilation, through holes or aeration openings, or of devices that allow ventilations [5] (e.g. one-way airing valves for intervention wear in chemical environments).

With regard to the above in the scientific literature there are studies, but they usually focus on only one feature and do not give an overall view of the factors influencing the protection clothing comfort. This is why this paper presents all the features that need to be considered when designing and making models of protective clothing with a maximum possible level of comfort. Between the features discussed there cannot be a clear hierarchy of their importance, since they are interdependent and all contribute to satisfying the protection and comfort parameters for the protection user. Nonetheless, we have tried here to summarize/outline the importance of each of these elements.

2. Sizing Chart

The issue with producing protective clothing in a large range of sizes, as adequate as possible to the type of protective clothing and which guarantees the consistency between the final dimensions of the product and the body size of the wearer is one of the most difficult, since in the current context of demand to comply with EU standards, the protective clothing producers did not understand or can not align themselves to the standards’ provisions out of several reasons:

The users of protective clothing are used to the system of sizes for regular clothing and the orders are placed according to this system;

The basic standard that regulates the requirements with regard to the size chart is EN 340 and relates to the series EN 13402 (European standard for size designation of clothes, especially part 3 - Measurements and intervals). This standard imposes only basic limits, leaving the creation of the size system to the discretion of the producer. The producer can choose whether they respect the classic size distribution, with intervals of two (four cm) between sizes, or adopt their own size distribution with larger intervals of four or eight (eight or sixteen cm). For example, the classic system is applicable especially for products that are used only as summer or winter underclothes, which needs to fit better the wearer [6]. Clothing that does not need to fit the wearer so closely, or that will be used by more than one person, benefits from a narrower size range; for example are parts used over the other protective clothing or garments used in special conditions, such as multilayered protective clothing against cold or intervention costumes in noxious environments.

The correct design of a model of protective clothing depends on the selection of the sizing chart. By doing so a number of issues are solved:

− The main and secondary sizes that will be used to design the protective clothing model;

− The constructive and comfort add-ons that have to be considered for the respective model, including the add-ons necessary for technological movements, which have been set through dynamic anthropometry studies.
According to the model of protective clothing there can be different size ranges, even when the same type of protection is provided. For example:

- Signalling clothing: it can take the shape of a waistcoat or a tabard, which are usually done in a limited range of sizes (S, M, L and XL), units or coveralls or types of protective clothing that ensure protection against other risks as well: weather, cold, toxic substances [7]. In this latter case, the size range can be of the type S, M, L… or based on the bust circumference 42 to 62;

- Protective clothing against the cold which can be composed out of various parts for which a range of sizes can be adopted: vests, jackets, suit, overalls.

- Equipment against dangerous substances for which there are two main categories: reusable and with limited number of uses. For reusable clothing the size range is usually based on the semi-circumference of the bust. On the other hand, for models with limited number of uses, the system used if of the type S, M, L…

Problems arise from the fact that these systems can be different from one producer to another, from one country to another. The main problem of all is having an insufficient number of producers that explain the size range for their products, despite this being required by standards of protective clothing design. If they choose a personalized size range, where the baseline and the intervals are unknown to the user, this can lead to confusions. In this circumstance it is hard for the user to choose their size; hence fitting issues and restriction of movement appear. A correct size chart should explain the number of sizes that it includes, to whom it is addressed (men, women, children) and at least the main body sizes of the users.

The correct description of a size range has to be done similarly to the images below (Figs. 1 and 2).

![Fig. 1 − Sizing chart description used by Helly Hansen company.](image-url)
3. Models Design

The design of protective clothing has to ensure the correlation of physiological, psychological comfort and protection parameters according to workplace conditions, so that wearing the protective clothing should not impact negatively on the health of the users. This result is obtained through the joining of the technical characteristics of the materials with constructive design principles. Through constructive design we understand respecting the constructive requirements according to the risks against which protection is provided, including the additional add-on elements for special cases: special tailoring lines, ventilation or airing systems, functional and comfort elements. The role of the elements is to allow maintaining of the state of health of the wearer through maintaining the psychological, physiological and motor abilities in the work process and allowing for precision and coordination of movements [8].

From the standpoint of constructive design of the protective clothing models, new technology and production evolution of textile fabrics, of auxiliary materials and specialized accessories' according to types of protection has lead to enhancing the protection performance, to the diversification and standardization of protective clothing types according to the workplace [9]. To illustrate this spectacular evolution of constructive design, next we present models from a number of companies where the constructive elements that contribute to ensuring comfort in wearing can be observed (Table 1).

1 For example: protective materials against toxic substances or thermal risks, fire-resistant zippers, waterproof zippers.
### Table 1

**Examples of Multirisk Protective Clothing**

<table>
<thead>
<tr>
<th>Model</th>
<th>Requirements Protection Type</th>
<th>Particular features of the model</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN 343</td>
<td>conductive carbon in membrane lining Polyester reflective tape taped seams double storm flap with zipper and Velcro closure detachable hood with draw cord adjustment and Velcro top adjustment hood made for helmet draw cord adjustment at waist and hern elastic cuffs with Velcro adjustment extended back (optional)</td>
<td>– 55% modacryl + 45% cotton mass: 345 g/m² two chest pocket with zipper closure mobile pocket with pen pocket on right chest – two hand pockets under flaps with zipper closure map pocket under storm flap thumb slits inside zipper for enter inside of the jacket</td>
</tr>
<tr>
<td>EN 471</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN 1149-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN 531</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AB1C1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN 62482-2-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>class 1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 2

**Examples of Features Optimization of Protective Clothing**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zipper/storm fly front seals out wind, rain, and contaminants.</td>
<td>Full corduroy collar with hood in collar construction for comfort and convenience.</td>
</tr>
<tr>
<td>Full-vented cape back for improved air circulation.</td>
<td>D-ring access for fall protection harness.</td>
</tr>
</tbody>
</table>
4. Typing Patterns

Another important aspect to be considered in the design of protective clothing is the one regarding the standardization of the product’s points of reference. This occurred so that a client can compose the desired model in the shortest time possible, according to the points of reference in Table 2.

**Table 3**
*Examples of Typing Patterns of Protective Clothing*

<table>
<thead>
<tr>
<th>Model</th>
<th>Features of models</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Model Image" /></td>
<td>front zipper covered by storm flap with snap closure&lt;br&gt;right chest pocket with zipper, phone pocket with Velcro closure and pen pocket&lt;br&gt;left chest pocket with zipper closure&lt;br&gt;2 skewed front pockets with snap closure&lt;br&gt;click-on loops for additional accessories under waist flaps&lt;br&gt;Easy access inside pocket with zipper closure for notebook etc.&lt;br&gt;Velcro adjustment at sleeve&lt;br&gt;draw cord adjustment at hem with inside cord attachment&lt;br&gt;extended back</td>
</tr>
<tr>
<td><img src="image2" alt="Model Image" /></td>
<td>2 hanging front nail/screw/ tool pockets&lt;br&gt;2 bellowed front pockets&lt;br&gt;broad belt tunnel in back for extra strength and stability&lt;br&gt;click-on loops for additional accessories at front and sides&lt;br&gt;belt loops with regular click-on loops for additional accessories at back&lt;br&gt;extra strong loops with double Velcro closure on both sides for hammer holders&lt;br&gt;2 bellowed back pockets; 1 with flap and Velcro closure&lt;br&gt;bellowed thigh pockets with flap and Velcro closure for accessories/tools additional space for carpenter’s pencil&lt;br&gt;knee pockets for optional knee</td>
</tr>
</tbody>
</table>

As it is observed from the models in the Table 3, according to the client’s needs a model can be composed with:

− In a various range of colours or uncoloured;
− With various constructive elements that ensure ease during wear (gusset, size-increasing pleats and so on);
− With diverse closing/zipping, calibration and adjustment systems;
− With various functional elements (pockets, tool straps).

5. Colour

After many years when the colour of protective clothing was chosen as dark/sober and resistant to dirt, today we are assisting to a real colour revolution in the manufacturing of protective clothing [10]. Colours are chosen according to:
− Necessity to represent the brand of the company, for commercial purposes, to advertise the quality of the products or the type of services provided by the company (oil extraction and refinement companies usually use orange, or orange-blue clothing), as well as to separate the company’s employees from those in a similar company (Coca-Cola company dresses it’s bottling or distribution employees in red all over the world, while Pepsi Cola dresses workers in blue);
− Necessity to recognize special attributions’ workers that confers them authority (such as ambulance workers or intervention teams);
− Necessity to signal the presence of personnel to avoid accidents (e.g. workers for public roads);
− Necessity to promote order and discipline in the company and avoid undesirable accidents, product contamination, disease spreading.

Moreover, colour choice relies on studies made on the effect it can have over the human psyche. Thus, the application of these studies has led to the creation of clothing coloured in a way that should reduce the stress as a body of effects that the environment can have over the psyche of the worker. For example in work in narrow spaces, like pipes or canals, the protective clothing used is in colours or combinations that stimulate human psyche such as green, yellow or light blue. These colours can reduce the sensation of isolation of the employee, besides acting to make the worker observable in low visibility conditions. A secondary and crucial effect of increased visibility of the employee is the sense of security the worker has knowing they can be more easily rescued. In turn the sense of security increases the productivity of the worker compared to the person who is stressed psychologically by the concern of a potential catastrophe.

Another eloquent example is the protective clothing against bad weather or water drops used by personnel on fishing boats, pleasure cruise vessels, which has seen an increase in orange and yellow use.

Regulation of colour usage within a company notably increases the discipline within. This is why more and more companies choose a distinctive colour, such as dark red, yet protection equipment and especially protective clothing has various elements - collars, basque, and flaps – from a different colour that marks the management personnel, maintenance personnel and so on. This way indiscipline acts in terms of movement through forbidden zones,
leaving work post to do unrelated activities or substitution of a qualified worker for a non-qualified worker are avoided.

6. Conclusions

From the above it can be concluded that for protective clothing the planning stage has a vital importance in ensuring not only the protective performance but also providing the comfort quality necessary to maintaining the overall state of comfort of the employee and to avoid any potential refusal to wear the clothing.

In the protective clothing planning stage it is necessary to join scientific and aesthetic criteria to obtain all the elements that form a superior quality model of protective clothing. This starts with the selection of materials and of the accessories corresponding to the level of protection desired and ends with the functional and aesthetic elements necessary to carry out work attributions while supporting mental and physical health of the employee [11].

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DESIGNUL – FACTOR VITAL PENTRU ÎMBRĂCĂMINTEA DE PROTECȚIE

(Rezumat)

Lucrarea are drept scop explicitarea conceptului de design pentru îmbrăcămintea de protecție, punând în legătură necesitățile protecției muncitorului și cerințele organizației economice. Substanța acestui concept este bine înțelesă în acest context, dacă se iau în discuție cerințele proiectării, care țin cont de funcțiile corpului, aspectele fizice și mentale ale acestuia.

Lucrarea este o sinteză a corelației dintre designul îmbrăcămintei obișnuite cu designul elementelor cerute de îmbrăcămintea de protecție – protecție, confort, estetic – în procesul de producție.