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THE DESIGN AND EVALUATION OF DISPOSABLE PROTECTIVE COVERALLS FOR PESTICIDE APPLICATORS IN AGRICULTURE

BY

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ABSTRACT

The Design and Evaluation of
Disposable Protective Coveralls for
Pesticide Applicators in Agriculture

by

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Although the use of disposable garments has been determined to be a feasible method to reduce exposure to pesticides, currently available disposable coveralls are not well suited for the agricultural worker who works on and around farm equipment.

The purpose of this study was to design (following the functional apparel design process) and evaluate two disposable garments for use by agricultural pesticide applicators. These garments, along with a recently-developed Kimberly-Clark design, were evaluated for functional fit and comfort by 39 male farmers of medium build.

The functional apparel design process was employed for this research because its open, step-by-step approach

encourages a thorough investigation of the design problem before a prototype is developed. The Scheffé paired comparison design was utilized as it lends itself to evaluations involving more than two garments.

Evaluation was done under controlled conditions. Subjects rated the functional fit and comfort of the coveralls while working through predetermined activities around a tractor and boom sprayer, simulating pesticide application practices.

Analysis of variance and the Scheffé multiple comparison test were used in the statistical analysis. Attitudes and beliefs were found not to be confounding factors biasing responses of subjects. Significant differences in component parts of functional fit among garment styles were found, but garment style did not influence comfort ratings.

The raglan sleeve design was rated highest for functional fit when donning and doffing, as well as during simulated pesticide application in the following anatomical areas: shoulders, upper arm and leg length. The separate hood (of the square armhole design) was rated the highest for functional fit. The final coverall recommendations were derived from a composite of positive attributes of each design.

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CHAPTER I

INTRODUCTION

The use of pesticides has enabled agriculturalists to protect crops against animals, insects, weeds and plant diseases. Historically, pure elements such as copper and mercury had been used as fungicides, effective in curing various diseases found among plants. Arsenic, on the other hand, had been known as a poison since ancient times, but its effectiveness as an insecticide was not known until the 1860s. Under the name of Paris Green, it became available to control the Colorado potato beetle.

The full potential of chemicals in agriculture was not realized until the second world war when interests in chemical warfare provided incentive for research into a great number of chemicals. Dichlorophenyltrichloroethane (DDT) was synthesized in 1874 by the German chemist, Zeidler. It was, however, not fully recognized as an insecticide until 1939 when it was used to protect soldiers from yellow fever, the plague and malaria. By the early 1950s, agriculturalists had adopted DDT for regular use. Its popularity rose tremendously as its use helped to produce notable increases in crop yield. It was then found to cause toxic build-up and its use was banned in the

1960s. Since then, many new pesticides have been introduced and their individual combined effects on the environment, including human health, continue to be investigated. "Approximately 4 billion pounds of pesticides are used annually worldwide, with 1 million pounds in the United States alone (Moses, 1983, p. 547)." A report released in the late 1970s om the United States Congress's Office of Technology Assessment stated:

> If all farmers gave up pesticides, commercial production of apples, lettuce, and specialty crops, such as strawberries, would cease. Insects, weeds, and plant disease would ruin enough corn, wheat, and soybeans to boost prices 60 percent (Boraiko, 1980, p. 162).

Pesticide poisoning in agricultural workers was, at first, not fully recognized. Because the severity of the health risk is not only related to the chemical make-up of the pesticide, but also its concentration, the length of human exposure and environmental conditions during application, it remains a challenge to determine potential health hazards. Furthermore, many of he early symptoms of pesticide poisoning are either nonspecific or similar to those of common illnesses and there is often a delay in onset of symptoms after exposure. For example, victims of herbicide poisoning might complain only of weakness while victims of insecticide poisoning might suffer from headaches, loss of appetite and nausea (Ontario Pesticides Advisory Committee, 1977, pp. 41, 45).

There are three ways through which pesticides may enter the body: 1) inhalation (of airborne chemicals), 2) ingestion, and 3) transcutaneous (dermal) absorption; however, the transcutaneous route of entry has been found to be the major one. Research has shown that the dermal absorption rate varies according to body part exposed. For example, in a study by Maibach, Fieldman, Milby, and Serat (1971) where the effect of C Parathion absorption for topical anatomic regions was quantified, it was found that the forearm absorbs up to 8.6% while the scrotum may absorb up to 100%.

Given this information, it is important to identify the body regions being exposed the most in the various pesticide related activities. Deposition pattern studies, such as that by DeJonge, Ayers, and Branson (1985), were a primary step in developing protective clothing. Other related areas of research include user surveys (Perkins, 1988; Rucker, Branson, Nelson, Olson, Slocum & Stone, 1988; Rigakis, Martin-Scott, Crown, Kerr & Eggertson, 1987; Hussain, 1983; Murray, 1982; Henry, 1980; Kuzyk, 1979), studies of pesticide penetration through fabric (Martin-Scott, 1987; Raheel, 1987; Branson, Ayers & Henry, 1986; Leonas, 1985; Orlando, Branson, Ayers & Leavitt, 1981) and studies of laundering of contaminated fabrics (Nelson &

Fleeker, 1988; Rigakis et al., 1987).

It has been determined that the use of protective clothing is a feasible method to reduce or avoid pesticide poisoning; however, protective clothing is often considered to be uncomfortable to wear, and as a result, compliance with appropriate use of the garments is limited (Boraiko, 1980). Henry (1980) found that although Michigan farmers were aware of the value of protective garments, they considered the garments too hot and uncomfortable.

It has become clear that many pesticides cannot effectively be extracted from the regular clothing of agricultural workers during common laundry procedures (Rigakis et al., 1987). Consequently, concern has been expressed not only for the farm laborers working with the pesticides, but also for members of their families who might come in contact with contaminated clothing by other means.

> These clothes are not only a source of exposure to the farmer and farm workers, but also result in the exposure of other family members. For example, children may play in areas where the clothes are stored (i.e. mud rooms), and thus be exposed, or laundering the clothes results in the exposure of those involved in the laundering process. Laundering may not remove all pesticides from clothing and the laundering of

contaminated with non-contaminated clothing may result in pesticide residues in all of the clothing (Ontario Centre for Toxicology, 1985, Appendix 6).

The use of disposable garments is now being considered as an additional means of protection over common workwear. In order to provide workers with increased mobility and thermal comfort, garments constructed of nonwoven, lightweight, vapour permeable fabrics are the focus of recent studies. Perkins, Crown, and Martin-Scott (1988) examined the durability of a spun-bonded 100% polypropylene disposable coverall. Results revealed garment design problems that resulted in tearing in the crotch area. The narrow range of available sizes of disposable coveralls (small, medium, and large) accommodates only those farmers who are of an average height:build ratio. Those who do not fit into this limited range find the coveralls either too short or too long which often leads to restrictions in the wearers' mobility.

PROBLEM STATEMENT

Very little work has been carried out on the effect of garment design of protective clothing. Currently-marketed disposables are of particular concern. It has been suggested that the lack of a systematic approach to the design process of protective garments is a contributing factor to their poor acceptance (Branson, 1982; Murray, 1982; Henry, 1980; Orlando, 1979).

The purpose of this study was to follow the functional apparel design process in the production and evaluation of two different disposable garments for use by agricultural pesticide applicators. These designs, along with a recently-developed Kimberly-Clark design were evaluated for functional fit and comfort.

This study is part of ongoing research in protective clothing for pesticide applicators in the department of clothing and textiles at the University of Alberta. It contributes to the North Central Regional Pesticide Research Project NC-170.[1]

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[1]. The North Central Regional Pesticide Research Project, NC-170: "Reducing Pesticide Exposure of Applicators Through Improved Clothing Design and Care," whose new mandate runs from October 1, 1987 to September 30, 1992, is made up of researchers at the following institutions: University of Alberta, University of California, University of Georgia, University of Illinois, Iowa State University, Kansas State University, University of Maryland Eastern Shore, Michigan State University, University of Nebraska, North Dakota State University and Oklahoma State University. (A regional U.S. Agriculture Experiment Station Project.)

OBJECTIVES

The objectives of the study were as follows:

1a. To employ the functional apparel design process in the development of two disposable protective garments for use by agricultural pesticide applicators.

b. As part of the functional apparel design process, to determine what is currently available to potential consumers of disposable protective garments for pesticide protection and to choose a manufacturer's garment for comparative purposes.

2a. To develop a questionnaire for administration to volunteer pesticide applicators residing in Ontario and in Alberta, in order to collect subjective data on functional fit and comfort.

b. To have the three designs evaluated by the subjects (both in Ontario and Alberta) for functional fit and comfort under controlled conditions, through a series of closely-monitored prescribed movements simulating activities common to pesticide application.

NULL HYPOTHESES

To meet objective 2b, the following hypotheses were tested:

1. There will be no significant differences in assessment

of functional fit among garment styles.

2. There will be no significant differences in assessment of comfort among garment styles.

3. There will be no significant differences in either

   (a) beliefs about disposable coveralls or

   (b) attitudes towards wearing disposable coveralls

   among respondents wearing the three styles.

DEFINITIONS

Anatomical position: A position the body takes "in which the individual stands in an erect position with legs straight, feet flat on the floor, head erect, and arms hanging straight down beside the body with the palms forward" (Watkins, 1984, p. 146). Movement is defined in relation to the anatomical position in kinesiology.

Attitude: A person's judgement that performing the behavior is good or bad, that he is in favor of or against performing that behavior (Ajzen & Fishbein, 1980, p. 56). Attitudes were measured through the responses given to questions 1 through 8 in the General Questionnaire (Appendix E). These questions were in the form of statements with responses recorded on a seven-point scale (from +3 to -3, including zero as the neutral value).

Measured attitude towards the coveralls was analyzed as a composite attitude score (q2a + q2b + q2c + q2d). Calculated attitude was defined as the sum of the products of each belief times the corresponding evaluation of the beliefs.

Belief: Refers to a person's perceived likelihood that performing a behaviour will result in a given outcome (Ajzen & Fishbein, 1980, p. 66). Beliefs were measured through responses given to the six component parts of question 1 in the General Questionnaire (Appendix E). These questions were in the form of statements with responses recorded on a seven-point scale (from +3 to -3, including zero as the neutral value).

Comfort: "is a mental state of physical well-being expressive of satisfaction with physical attributes of a garment such as air, moisture and heat transfer properties and mechanical properties such as elasticity and flexibility, bulk, weight, texture and construction" (Sontag, 1985, p.10). Comfort was operationally defined by responses to question 11 of the Coverall Evaluation. Subjects rated the "overall general comfort" on a seven-point scale ranging from extremely comfortable (1) to extremely uncomfortable (7).

Functional (Apparel) Design Process: "A holistic approach to creating functional apparel. The process is based on a strategy control system, whereby each step serves as a built-in check in exploration of problem boundaries followed by the definition of the problem structure and critical factors' assessment and analysis. Design specifications are then developed and analyzed for interrelatedness and priority. These specifications become the design criteria used for developing the prototype [and for] eventually evaluating its success" (Orlando, 1979).

The following steps, which are not mutually exclusive, outline the functional design process:

1. Request for the design
2. Exploration of the design situation
3. Problem structure perceived
4. Specifications described
5. Design criteria established
6. Prototype developed
7. Design evaluation

Functional Apparel: Clothing that is designed to meet the physical, social, psychological, and aesthetic needs of potential users (Murray, 1982).

Functional Fit: A combination of body measurements of a person in the anatomical position and the ease allowance necessary for movement to perform the required activities. This is estimated through activity and movement assessments in the Functional Apparel Design Process (Chapter III) but its ultimate effectiveness is through objective assessment by the garment's intended user.

Functional fit was operationally defined by responses to questions 1 through 10 of the Coverall Evaluation and was broken down into four components: 1) overall functional fit, 2) functional fit by activity, 3) functional fit by body part, and 4) damage.

Overall functional fit was scored by adding all "fits quite well" responses in all body parts, across all activities to gain a singular score for each coverall evaluation.

Three different "functional fit by activity" scores were calculated by:

i) adding all "fits quite well" responses across all body parts,

ii) adding all "fit too tight/too short" responses across all body parts, and

iii) adding all "fit too loose/too long" responses. across all body parts for each activity.

Three different "functional fit by body part" scores were calculated by:

i) adding all "fits quite well" responses across all activities,

ii) adding all "fit too tight/too short" responses across all activities, and

iii) adding all "fit too loose/too long" responses across all activities for each body part.

Damage was recorded objectively by the researcher, indicating areas of damage for each coverall. A damage score was determined for each garment by adding the number of observed damaged sites.

Pesticides: A general term which describes chemicals that are intentionally used in the practice of pest control. Examples of pesticide groups commonly used in agriculture include insecticides, herbicides, and fungicides which control insects, weeds and plant diseases respectively.

LIMITATIONS

1. As the study was conducted with volunteer farmers, these participants did not necessarily represent a random sample of pesticide applicators.
2. The fabric of the coveralls used in this study was 100% spun-bonded polypropylene.
3. The garment designs used in this study were limited to coveralls.

ASSUMPTIONS

1. Volunteers gave valid and honest assessments of the garments they tested.
2. The instruments used in this study provided a valid measurement of the variables.

OUTLINE OF THESIS

Chapter II contains a summary of literature related to this research: pesticide exposure, legislation for pesticide control, protective clothing, garment design, functional fit and evaluation. Chapter III is devoted to the functional apparel design process. This includes historical highlights, a general description of the step-by-step approach, and finally, a detailed account of its use in this study. Because the design of the coveralls preceded the evaluation process, results of the functional apparel design process are included in this chapter. The methods for evaluating the coveralls are discussed in Chapter IV. The requirements and mode of sample selection are outlined, the research design described, the third commercially designed coverall introduced and finally, the structure of the evaluation and procedures for data analyses are explained. Chapter V contains the statistical analysis of results (including testing of the null hypotheses) as well as discussion of these results. A summary of the study, conclusions and recommendations are presented in Chapter VI.

CHAPTER II

REVIEW OF LITERATURE

The literature review has been divided into six sections. The first, pesticide exposure, deals with the toxicity of pesticides to humans. The section on legislation for pesticide control provides the reader with an understanding of the laws governing pesticide use and handling in Canada, particularly within the provinces of Alberta and Ontario where the garment evaluations took place. Clothing as a means of protection is introduced in the third section and gar[illegible]sign research is reviewed in the next. Due to thei[illegible] interrelatedness, fit, sizing and ease are discussed together in the section on functional fit. The final section emphasizes the importance of the evaluation process in the development of functionally designed clothing. A more extensive review of literature on the functional apparel design process is reviewed in Chapter III.

PESTICIDE EXPOSURE

The major source of occupational exposure to toxic chemicals is in agriculture (Moraski & Nielsen, 1985). According to Maibach et al. (1971), of the three possible routes of entry of chemicals into the human body (inhalation, ingestion and dermal absorption), the dermal route accounts for as much as 87% of total absorption. Moraski and Nielson (1985) found that skin contact with chemicals constitutes the major source of exposure--90%.

Absorption of pesticides by humans causes a wide range of health problems: mild, short-term illnesses, neurological disorders, sterility, cancer, etc. (Murray, 1982). Hoar, Blair, Homes, Boysen, Robel, Hoover, and Fraumeni (1986) found that those who work with the herbicide 2,4-D, without wearing protective clothing, increase their risk of developing lymph cancer. Kilgore and Akesson (1980) revealed that ground applicators are more at risk than any other pesticide related occupation.

Toxicity levels of pesticides vary; generally speaking, rodenticides are the most toxic to humans while herbicides are considered the least toxic. However, exposure levels are important factors to consider. ". . . herbicides are the most extensively used pesticides in agriculture, their use in North America exceeding that of insecticides and fungicides combined" (McEwen & Stephenson, 1979).

PESTICIDE LEGISLATION

All pesticides, whether imported into, used or sold in Canada must be first registered by Agriculture Canada under the Pest Control Products Act (PCP Act) and assigned a registration number. Agriculture Canada is also responsible for the product's labelling.

Control of pesticide use in Canada is a provincial responsibility. In Alberta, the Agricultural Chemicals Act (which falls under the Department of Environment), consists of two regulations: 1) Pesticide applicator licensing and, 2) Pesticide sales (use and handling). Although general safe handling of pesticides is encouraged, the use of protective clothing is not mandatory. In addition, those who apply pesticides on their own land (or neighbor's land without charge) are not required to hold a pesticide applicator's license. This may well exclude them from valuable instruction on proper handling and personal safety practices that would otherwise be introduced to them in a training course. Those interested, however, may seek information from district agriculturalists, district home economists, neighbors, and through the media. Government agencies promoting safe practices for pesticide use through education are Alberta Environment, Alberta Advanced Education and Manpower, Alberta Agriculture and Alberta Community and Occupational Health (Government of the

Province of Alberta, 1984).

Ontario's legislation is directed under the Pesticides Act through the Minister of the Environment's Ontario Pesticides Advisory Committee (Government of the Province of Ontario, 1987). It regulates a chemical's dispersion, availability and use in Ontario by assigning it to one or more of six classification schedules on the basis of the chemical's "toxicity, environmental or health hazard, persistence of the active ingredient or its metabolites, concentration and usage" (Ontario Ministry of the Environment, 1987). As is the case in Alberta, licensing is necessary for those interested in applying pesticides on a commercial basis. In addition, interested students are supplied with study packages in preparation for sitting the Ministry examinations. News bulletins, information sheets, displays and conferences provide the general public and those working in pesticide-related fields the opportunity to be kept up-to-date with changing pesticide regulations.

The Farm Safety Association Inc. in Ontario (one of many provincial safety associations) was founded for the purpose of reducing the number of injuries and accidents on Ontario farms. This association also acts as an educating body to promote safety, including lessening incidents of agricultural pesticide poisoning.

CLOTHING AS A FORM OF PESTICIDE PR''TECTION

Properly designed protective clothing has been deemed to be an adequate barrier between the pesticide chemicals and their handlers (Hoar et al., 1986, Moraski & Nielsen, 1985; Davies, Freed, Enos, Duncan, Barquet, Morgade, Peters & Danauskas, 1982). However, due to factors such as inadequate design, thermal and dexterity discomfort, and the inability to safely remove residues through laundering procedures, workers tend not to wear the garments or wear them incorrectly (Moraski & Nielsen, 1985; Henry, 1980). Thus, a systematic approach to the design process, taking these factors into account, should be a valuable tool in the development of a functional protective garment (Branson, 1982; Murray, 1982; Henry, 1980; Orlando, 1979).

Laundry studies as summarized by Nelson and Fleeker (1988) have revealed that certain pesticides are not fully extracted from the clothing in the laundering process and additional washing treatments such as pre-treatment and consecutive washings are recommended. Even though these treatments did help, pesticide residues were still left in the fabric.

The extent of protection has been examined in recent years. Studies on pesticide penetration through a variety of fabrics have also been completed (Martin-Scott, 1987; Branson, Ayers et al., 1986; Orlando et al., 1981).

Contamination in laundry areas and exposure of family members could become a problem. Because of these factors, the use of disposable coveralls has become a consideration as an additional means of protection (Rigakis et al., 1987, Martin-Scott, 1987).

A number of disposable or limited-use garments for chemical protection are presently available to Canadian consumers. Kimberly-Clark and E.I. Dupont de Nemours produce material for protective garments. Kimberly-Clark, manufactures a 3-layer, meltblown, spunbonded polypropylene fabric which is treated to resist liquid penetration and is referred to as their EP® (extra protection) fabric. It is promoted as breathable and comfortable, with the look and feel of cloth ("KleenGuard® coveralls," 1986). Dupont's competing coverall fabric, Tyvek®, is 100% spunbonded olefin. Another material, an impermeable and chemically resistant, polyethylene coated Tyvek®, is also manufactured by Dupont. Due to its incapacity to allow body moisture and heat to escape, it is recommended by Dupont for short-term protective wear such as during mixing or loading of pesticides.

GARMENT DESIGN

Very little research has been undertaken in the area of garment design for protective clothing for pesticide applicators despite recommendations for further research by professionals in the field (Nielsen & Moraski, 1986; Moraski & Nielsen, 1985; DeJonge, 1983; Staiff, Davis & Stevens, 1982). Responses from wear tests have also revealed a need for design modifications in presently-marketed disposable protective garments (Perkins et al., 1988).

Coveralls or one-piece jumpsuits have been used in a number of pesticide studies because of the design's intrinsic nature of limiting exposure to the midriff area (McConville, 1986; Crow & Dewar, 1986; Murray, 1982; Branson, 1982). Industrial coveralls have also been found to be chosen by farmers (Rigakis et al., 1987) in addition to jeans and a chambray shirt (Branson et al., 1986).

Two fabrics with excellent pesticide resistance, along with another fabric, were tested with three separate designs by Branson (1982). Fabric, not design, greatly influenced subjects' responses to therma mfort measures for the tested garments. Subjects who ˀvethylene coated Tyvek® had higher skin temperatu ˀose who wore Gore-Tex®.

Under mild conditions, (temperatu. tely 20 degrees celsius), a study of pesticide applicators in Alberta revealed that there was a positive response towards Kimberly-Clark EP® disposable coveralls (Crown, Perkins & Tremblay, 1988). The coveralls are resistant to chemicals and because they are to be discarded after use, recontamination is minimized. However, visual examination of the disposable coveralls after use revealed that rips were repeatedly found in the crotch area (Perkins et al, 1988). Questions were raised as to the possible cause of the problem and it was speculated to be due to design and/or sizing problems.

FUNCTIONAL FIT

Fit requirements of garments differ depending on the intended purpose of the garment. As an example, a given item of women's evening wear might require that the dimensions of the prospective wearer be exact or nearly exact to those of the dress form for which it was made. Excessive movement in this type of apparel is generally not expected. Alternatively, a football shirt, would need to accommodate sufficient movement of the wearer while participating in the sport. This might be achieved by designing a loose fitting, straight-cut style in a stretchable knit which would cover a much broader range of body dimensions and might be available to the consumer in sizes small, medium, large and extra-large.

Adding more ease in a garment for sports or workwear might be seen as a solution for all design problems where extensive movement is required. However, for protective clothing used in agriculture, the garment must accommodate mobility requirements of the farmer without contributing to farm-machinery accidents (Branson, 1982). The direct conflict between required ease and limiting fabric for safety are challenging design problems.

In addition, it should be noted that the fabric used for disposable garments does not possess the inherent ease or "give" of woven fabric commonly found in workwear. For instance, when stress is placed on a spun-bonded material, fibers may tear away from each other and the resulting damage is permanent. Although other factors are involved (such as fiber content, yarn twist, fabric weave and finish) yarns in woven fabric have the ability to stretch, shift and share stress and partially, if not fully, recover from the strain.

"Manufacturers of protective items often try to fit everyone into a limited set of sizes, sometimes only three--small, medium, and large. Yet, to protect effectively and function well, the items must often fit better than street clothing" (Robinette, 1986).

In recent years, with the increased interest in protective clothing, some research has been carried out in anthropometric sizing and fit testing for military uniforms in the United States and Canada. Robinette (1986) maintains that traditional sizing practices are inadequate for many protective garments and that in many circumstances, an anthropometric sizing analysis of the target group is necessary. A sample of 1330 U.S. army women were classified into subgroups according to stature and weight. The finer dimensions of these women were then analyzed and the variability summarized. Each subgroup was treated separately and design specifications drawn up specifically to the needs of each subgroup.

Another study involving anthropometric sizing and fit of women in the military included a single sizing system for both men and women for a U.S. Army's battledress uniform. The result was a 20-size shirt and trouser system (Gordon, 1986).

As it has been determined that it is normally the male members of the farming family who do the pesticide spraying Rigakis et al., 1987; Henry, 1980), garments have generally been designed according to male sizing systems. Measurement data are available through data banks of anthropometric surveys of military and civilian populations (McConville, 1986) or through government publications, such as standards for men's industrial coveralls (Canadian Government Specifications Board, 1972). These systems are merely guidelines to be followed at the discretion of the manufacturer.

The amount of ease required in garments is also left to the discretion of the manufacturer. Mobility analysis is therefore an essential step in the functional apparel design process (Branson, 1982) to determine actions specific to the needs of the target group.

Kirk & Ibrahim (1966) in their study of stretch garments revealed the critical strain areas of the body to be the knee, seat, back and elbows. Crow and Dewar (1986) devised thin rubber coveralls with alternating rows of slits to identify locations of stress in clothing. As the subjects moved or stretched, the slits gaped in the stressed areas. They found that the stance causing the most stress to the coverall upper back was "crossing the arms in front with the hands on the opposite shoulders . . . " while " . . . sitting with the knees and hips fully bent and the legs spread apart or squatting", putting strain on the buttocks, crotch and inner leg regions. Nestler and Schlegel (1978) noted that donning and doffing the garment put considerable strain on clothing.

EVALUATION

As part of the larger project, "Design and Evaluation of Functional Clothing for Agricultural Workers" at the University of Tennessee, Murray's (1982) research involved the user evaluation of prototypes. She maintained that in every product development process, evaluation is necessary as the final step in the functional apparel design process before the product becomes available to the public in order to determine and correct possible negative qualities.

McConville (1986) stressed the importance of an anthropometric fit test in the early stages of the design process, for the success of a design or sizing system. There are three phases in the fit test: 1) pretest preparation, 2) testing and evaluation, and 3) analysis and reporting. At least three to five subjects for each size of the test garment should be employed. Similar to the Robinette (1986) study, he stressed using stature and weight as key variables in the sizing process. The subjects were chosen to represent the sizing range of the user population and were checked on a bivariate frequency table of 2420 British military men. Two questionnaires were used. One was completed by the researcher to gather basic personal information on each subject, record measurements and sizes and enter results of any specialized tests (eg. mobility tests); and the other was filled out by the subject to determine the user's perception of the garment. "Although the major concern of the test revolves around fit, function and integration, the subjects' comments regarding comfort and preference are also of concern" (McConville, 1986).

SUMMARY

Protective clothing, in general, and more specifically, disposable garments, are seen as an important solution towards increased protection from pesticide poisoning. However, those garments available for pesticide applicators are often inadequate in the areas of fit, sizing and ease necessary for specific activities. The functional apparel design process encourages a thorough investigation of the design problem towards the final step--the garment's evaluation by the intended wearer. It is for this reason that the process was used in this research.

CHAPTER III

THE FUNCTIONAL APPAREL DESIGN PROCESS

The functional apparel design process served as the conceptual framework for this research. This process is an externalized, systematic, holistic approach to clothing design used primarily in the development of special purpose apparel. Based on a strategy control system, the designer works through the step-by-step process from the initial idea for the design through to the garment's completion and evaluation.

This chapter will explain the functional apparel design process in detail. Historical aspects of the process will be highlighted, followed by a description of the process in general terms. Then, by elaborating on the individual steps which make up the process, an explanation of how each step was interpreted to meet the needs of this research will be presented.

The functional design process followed for this research was first developed by Case and Orlando in 1979 at Michigan State University by adopting the design process of Christopher Jones (1970). The objective was to integrate design methods from the disciplines of clothing, interiors and housing into one framework, thus breaking down the boundaries between the disciplines and allowing for a wider range of design alternatives towards solutions for energy conservation design problems.

Jones commented that designing is often confused with art, science and mathematics. However, he saw design as not being associated with strictly one discipline but as a "hybrid" of all three. Designers need to treat future possibilities as real and specify ways in which the designed object can be made to exist. In studying a problem before predicting the future, signers borrow the trained skepticism and doubt from scientists as well as their ability to set up and analyze results of controlled experiments. Artistic ability is required to quickly and accurately depict design ideas. A mathematician's method of using symbols to state assumptions and find solutions through symbol manipulation is borrowed when the problem is stable and assumptions are not likely to change.

Jones further explained that there are three ways in which to approach design. In the first approach, the designer as a magician or black box designing, suggests that the most valuable part of the process goes n in the designer's head. Branson defines it in the following way: " . the design process traditionally used for apparel is one based on the creative inward assimilation of inputs in the designer's head. The design solution emerges as a mysterious output of the designer's brain." (Branson, 1982,

p. 18). The second approach and the extreme opposite of the "black box" approach is referred to as the designer as a computer or the glass box approach. This system is considered to be systematic and objective. The third approach, the designer as a self-organizing system combines these two extremes--one part carries out the search for the design and the other provides structure. It is through this final approach that the functional apparel design process has grown.

Jones observed that in the 1950s and 1960s, a number of design methods were evolving and developing in many disciplines such as engineering, business and communication. In spite of the obvious differences in the disciplines, they all had one thing in common: the design process had been "externalized". Because the process is written out or in diagram form, it has become possible for others to better understand and follow it, make suggestions or question areas of doubt.

Since 1979, a number of researchers have used this process or stressed the need for its use in functional apparel studies. It has also been refined, manipulated and developed by them to suit a variety of research needs (Branson, 1982; Case & Orlando, 1979; Gay, 1986; Henry, 1980; Murray 1982). Although its basic concept among the studies remains the same, obvious differences appear in flow chart layout and presentation. The functional design process is also referred to in apparel research as the functional "clothing" design process (DeJonge, 1984) or the functional "apparel" design process (Branson, 1982).

Interestingly, many of the researchers worked in the area of protective clothing for pesticide applicators. Branson (1982), developed a variation of the process in order to design garments for pesticide users and to assess thermal responses of subjects wearing the garments.

The purpose of Murray's (1982) research, was to contribute to the functional design process through the evaluation of prototype spray garments developed for pesticide applicators. Murray also promoted the functional design process in her belief that "the product must be evaluated prior to market introduction in order to identify any design deficiencies, hazards of use, and marketing problems before introducing the product for public consumption" (Murray, 1982, p. 2).

Henry (1980) questioned the effectiveness of the process and maintained that it could not be declared a success until the product had received acceptance in the marketplace. Henry's contribution to the process was embodied in its expansion to include an investigation of the intended user's perceptions.

THE PROCESS IN GENERAL

The functional design process, as outlined by Case and Orlando (1979) is a multi-step process. The first, request for the design, is stated in general terms outlining the nature and purpose of the garment. The design situation is thoroughly explored to identify as many areas of relevance as possible.

These areas are studied throughout the process in the ensuing steps through a number of possible research investigation methods and are initially examined in the next step: exploration of the design situation. This exploration acquaints the designer with the specific problem and the needs of the intended user through informal user interviews, literature reviews of the areas considered to be important and examination of inconsistencies of garments in use. For instance, as the user's near environment plays an important role in the safety and comfort of the user, thermal testing would be considered a critical factor to investigate.

Problem structure perceived is the more formal step in the research process. Assessments or studies developed from the critical factors (eg. thermal, activity, movement, impact and socio-psychological factors) which have been considered to be vital to the success of the garment's design are undertaken. However, these factors and the degree to which they are investigated will depend on the nature of the problem. Orlando (1979) regarded this step as "a transformation from the entire spectrum opened through divergence to focal areas of design concern" (p. 128). These individual assessments may be time-consuming, expensive or require the attention of, or consultation with, specialists in a particular field. It may, on the other hand, be quite sufficient to use the information obtained from a literature search if the results from a recent study suit the needs of the current design problem.

When the assessments have been completed, the findings are pulled together, the strategies converge and the problem is redefined. Design specifications are drawn from these results. These may be written in point form but should be specific for design purposes. For example, if findings indicate that there has been a concern about loose fabric around machinery, a design specification may include: "control fullness in trunk and limbs to lessen chances of fabric catching on machinery."

Design criteria are established and ranked by referring to design specifications to establish points representative of design specifications in order to chart and rank them according to priorities for the garments' designs. An interaction matrix outlines the areas of conflict between the specifications. Converting this matrix into interaction nets further clarifies the areas that need special attention in determining the outcome of the garment design. By manipulating the criteria in this way, the list of design specifications can be revised, ready for prototype development.

During the "Prototypes are developed" stage, garment construction techniques are tested, work-flow diagrams are developed and markers are plotted before the actual garments are made.

The designer may be interested in answering a number of questions in the final step of design evaluation. Does the garment allow for the required ease of the wearer? Has a new construction technique solved a particular problem which appeared in ready-to-wear garments? The evaluation process as well as the instruments for gathering the data should be devised in order to provide answers to all questions raised at the beginning of the design process.

OPERATIONAL DESIGN PROCESS

Figure 1 represents a model developed to meet the needs of the particular design problem of this research. Two of the three garments were designed using this method.

REQUEST FOR THE DESIGN
- general objective

EXPLORATION OF THE DESIGN SITUATION
(in order to identify critical factors)

interviews	literature review	examination of ready-to-wear garments
-Farm Safety Assoc.	-workwear	-available disposable protective coveralls
-researchers	-pesticides	
-farmers	-CGSB standard sizes	

PROBLEM STRUCTURE PERCEIVED
(critical factors--developed into individual studies)

user survey	material analysis	market analysis	activity analysis
-farmers	-100% spun-bonded polypropylene	-safety supply stores	-pesticide application films
		-catalogues	-movement assessment

DESIGN SPECIFICATIONS
relating to safety, fit, mobility, comfort, production and cost

DESIGN CRITERIA RANKED
determining areas of interaction (conflicts, compromises) relating to safety, fit, mobility, comfort, production & cost

PROTOTYPES DEVELOPED
through computer-aided design

EVALUATION
by potential users in a controlled, simulated condition through questionnaires

Figure 1. Functional apparel design process.

Request for the design

The following statement outlined the nature and purpose of the garment (also stated as objective 1a in this research): to design two disposable protective garments for use by agricultural pesticide applicators.

Exploration of the design situation

This step acquainted the designer with the specific problem and needs of the intended user group through informal interviews with farmers and those working in research to lessen the hazards of pesticide contact. Discussion with professionals in occupational medicine and the Farm Safety Association in Ontario provided some initial background for the design endeavour. A thorough literature review on pesticide exposure, pesticide legislation, clothing as a form of protection, fit, garment design and sizing was performed at this point and provided the background for the study.

Workwear in general, CGSB standard sizes, and ready-to-wear disposable protective garments were then examined. During these investigations, brainstorming sessions (with researchers, members of the Farm Safety Association and users) produced three lists: design needs, activities of wearer, and complaints of existing garments (Figure 2).

These initial notes were related to the wearer's health, thermal comfort, socio-psychological needs and

Design needs

- disposable
- cover most of body to protect against pesticides
- compatible with goggles, respirator, gloves & boots
- comfortable
- aesthetically pleasing
- able to be worn over workwear
- allows for mobility
- convenient to donn and doff
- suitable for mass production
- inexpensive

Activities of wearer

- bending
- climbing on machinery
- sitting
- walking
- squatting
- turning
- donning and doffing

Complaints of existing disposable garments

- underarm tears
- crotch tears
- poor fit
- elastic not secure
- elastic too tight
- seam ruptures
- no pockets
- too hot
- hood does not fit well
- hood obstructs vision when turning head

Figure 2. Exploration of the design situation: Initial considerations for garment designs.

movement requirements. From these considerations, the following studies were deemed important: 1) a user survey of similar garments to determine socio-psychological beliefs and behaviors, 2) a material analysis to determine the fabric to be used in the new designs, 3) a market analysis to investigate positive and negative attributes of other chemically resistant disposable garments and, 4) an activity analysis to determine specific movements of the pesticide user.

Problem Structure Perceived

DeJonge (1984) stated, "It is not always possible to enter the functional clothing design process from the first step and proceed through it . . ." (p. xi). There are occasions when the problem has already been structured or specifications have already been designated. In this situation, two of the studies deemed important for this project--user survey and a material analysis--were conducted by other researchers before this project began.

Kimberly-Clark's EP[R], 100% spun-bonded polypropylene fabric would be used as the fabric for the new coverall designs. Previous testing of this fabric (Martin-Scott, 1987; Perkins et al., 1988) found it to have favorable attributes for disposable garments for pesticide users. The fabric is lightweight, disposable and possesses a high degree of resistance to chemical penetration.

The results of Perkins' (1986) pilot study determining attitudes of farmers and their behaviour towards the Kimberly-Clark EP KleenGuard® coverall, provided this study with complaints and appraisals of a similar-use coverall and some suggestions for a better garment. This earlier KleenGuard® coverall had raglan sleeves, attached hood and zipper front closure. To control fullness and limit pesticide entry, elastic was sewn around the wrist and ankle openings, around the face opening on the hood and along the sides and back waist. Seams were limited to decrease pesticide penetration and reduce production costs. The following is a list of seams in the KleenGuard® coverall: hood seam along the top and back of hood, hood to trunk seam, raglan sleeve to trunk seam, raglan sleeve seam along shoulder to wrist, centre back seam to crotch point and front crotch point to base of zipper.

A market analysis of disposable chemical resistant garments conducted by the author revealed similar styles. The one-piece coverall design was the most prevalent garment design, although some two-piece outfits were available. Hoods were primarily attached to the coveralls, although one coverall was designed with a small stand-up collar allowing for the option to buy a separate hood. Except in one case, all coveralls examined had elastic around the face on the hood, and at wrists and ankles. Elastic at the waist was not common.

An activity analysis provided the background for incorporating the necessary ease requirements into the garments. This was done through direct field observation and by viewing a number of films on weed control and pesticide application (Dupont Canada, 1979; May and Baker, 1966; South Dakota State University, 1970; United States Department of Agriculture, 1964). Diagrams of the specific activities were drawn (Figure 3) and notes were taken to describe the actions.

To determine the amount of extra fabric needed to allow for specific movements, a movement assessment was also performed. This was done by measuring a subject of the required stature and build in the anatomical position and again in one of the extreme positions commonly found during pesticide application. The difference between the two measurements was considered to be an approximation of the necessary ease needed in the garment. For instance, a measurement was taken from the centre back neck to waist while the subject was in the anatomical position and the second measurement while the subject simulated the action of crouching to see the nozzle of the boom. The difference between the two measurements represented the maximum length the torso of the coverall would have to be to accommodate this movement.

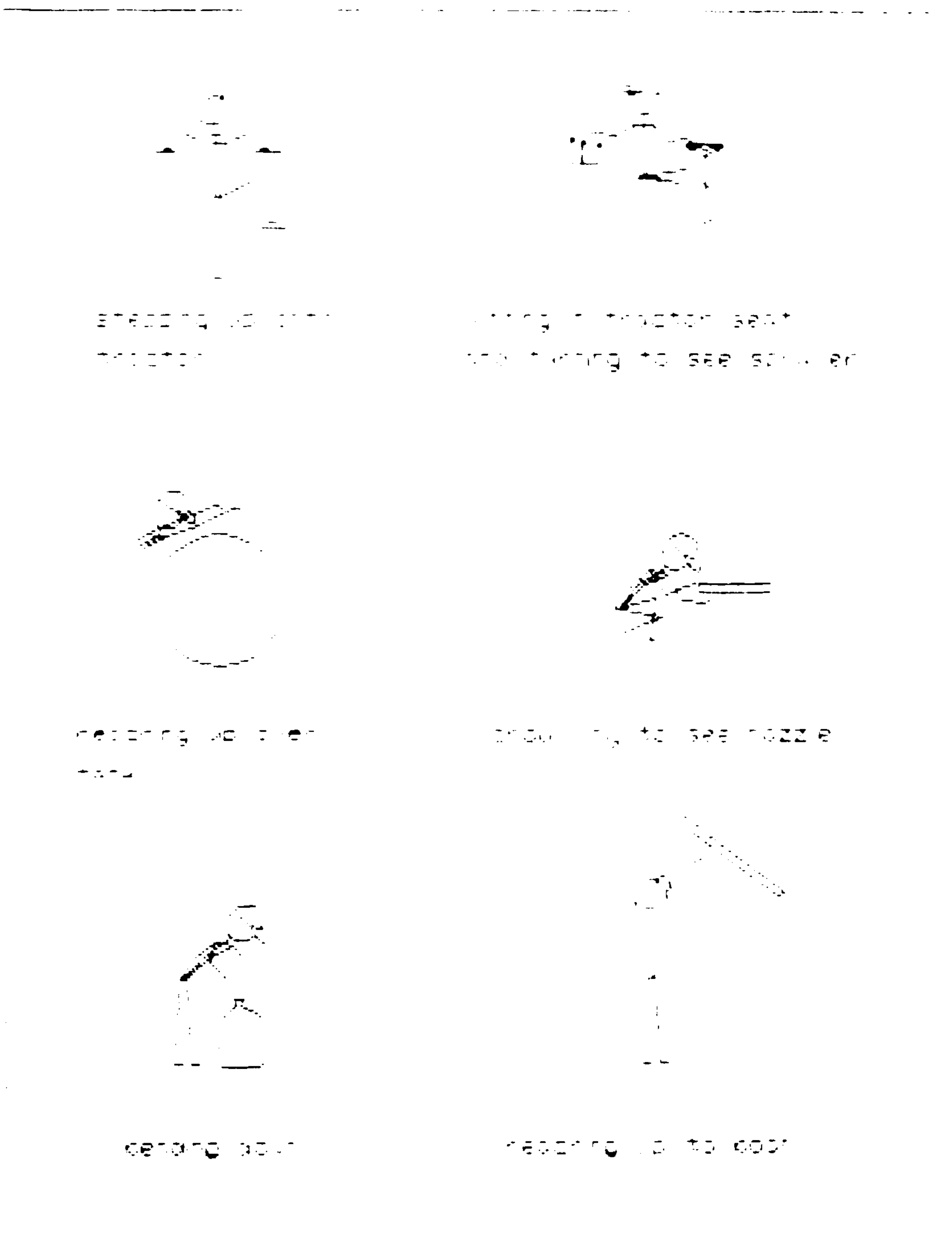

Figure 3. The activity analysis revealed typical activities of a pesticide applicator.

Design specifications

Specifications were determined from the results of each study, but arranged according to the headings of safety, fit, mobility, and production and cost (Figure 4). These were listed specifically to "externalize" all of the features considered to be desirable for a protective coverall design. Each point was deliberated to determine ways in which these specifications could be incorporated into the designs. The specifications list was revised numerous times. Figure 4 represents the final draft.

As a means of manipulating the design specifications to determine and better understand their compatibility, a list of 15 design criteria were established. These criteria were drawn from the initial draft of the design specifications but include other factors that were considered important to the success of the designs, such as the wearer's comfort, his aesthetic considerations and his ease of donning and doffing. These were listed in random order in an interaction matrix and examined for interrelatedness (Figure 5).

Design criteria ranked

The chart was further developed into accommodation and conflict interaction nets (Figure 6). Although the term "ranked" used in the functional apparel design process might imply that criteria can be placed in priority rating,

Safety
- provide continuous body cover (head to ankles & wrists, excluding face).
- control fullness in trunk to lessen chances of fabric catching on machinery.
- provide head covering that does not obstruct vision.
- incorporate protective strip over/under zipper to lessen pesticide penetration.

Fit
- evaluate one size of each design (size medium).
- allow for movement as determined by movement assessment.
- use CGSB standard size measurements, industrial coveralls.
- use elastic to control fullness and fit wrists and ankles.
- choose a drafting system designed for outerwear in order to fit over workwear.
- choose designs without specific shoulder lines, waist lines or body contouring to fit a wide range of male physiques.

Mobility

Incorporate the following measurement increases into designs:
- centre back measurement to increase approximately 18 cm. (7") when subject is in a crouched position.
- measurement from waist (side seam) to wrist (along underarm seam) to increase by 25.5 cm (10") when subject reaches up.
- vertical measurement from waist to ankle over buttocks to increase approximately 7.5 cm. (3") when subject steps up.

Production and Cost
- limit yardage used per garment to reduce cost.
- limit number of seams to reduce cost.
- pre-test construction techniques.
- produce work-flow diagrams and markers.

Figure 4. Final draft of design specifications determined from results of each study.

(Numbers correspond with criteria list at left)

The garment(s) should . . .	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. allow for mobility		A	A	A	A	N	N	N	N	N	N	A	A	A	A
2. fit & cover trunk			N	N	N	N	N	N	N	N	N	A	A	N	N
3. cover arms to wrists				N	N	N	N	N	N	N	N	A	A	N	N
4. cover legs to ankles					N	N	N	N	N	N	N	A	A	N	N
5. cover head and neck						N	A	C	A	N	N	A	A	N	A
6. fit wrists & ankles snugly							A	N	N	A	N	A	A	N	N
7. be comfortable								N	N	N	N	A	A	A	N
8. be aesthetically pleasing									N	A	N	N	N	N	N
9. be easy to donn & doff										N	N	N	N	N	N
10. be inexpensive to produce											N	N	N	N	N
11. be suitable for mass production												N	N	N	N
12. be produced in a maximum of 4 sizes													A	N	A
13. fit a wide range of male physiques														N	A
14. fit over a pair of pants and shirt															A
15. be safe to wear when working with machinery															

KEY:
C = conflict (specifications in direct conflict)
A = accommodation (specifications that require accommodation in the same design)
N = no conflict (specifications that create no conflict when grouped together)

Figure 5. Interaction matrix of criteria, representative of the design specifications.

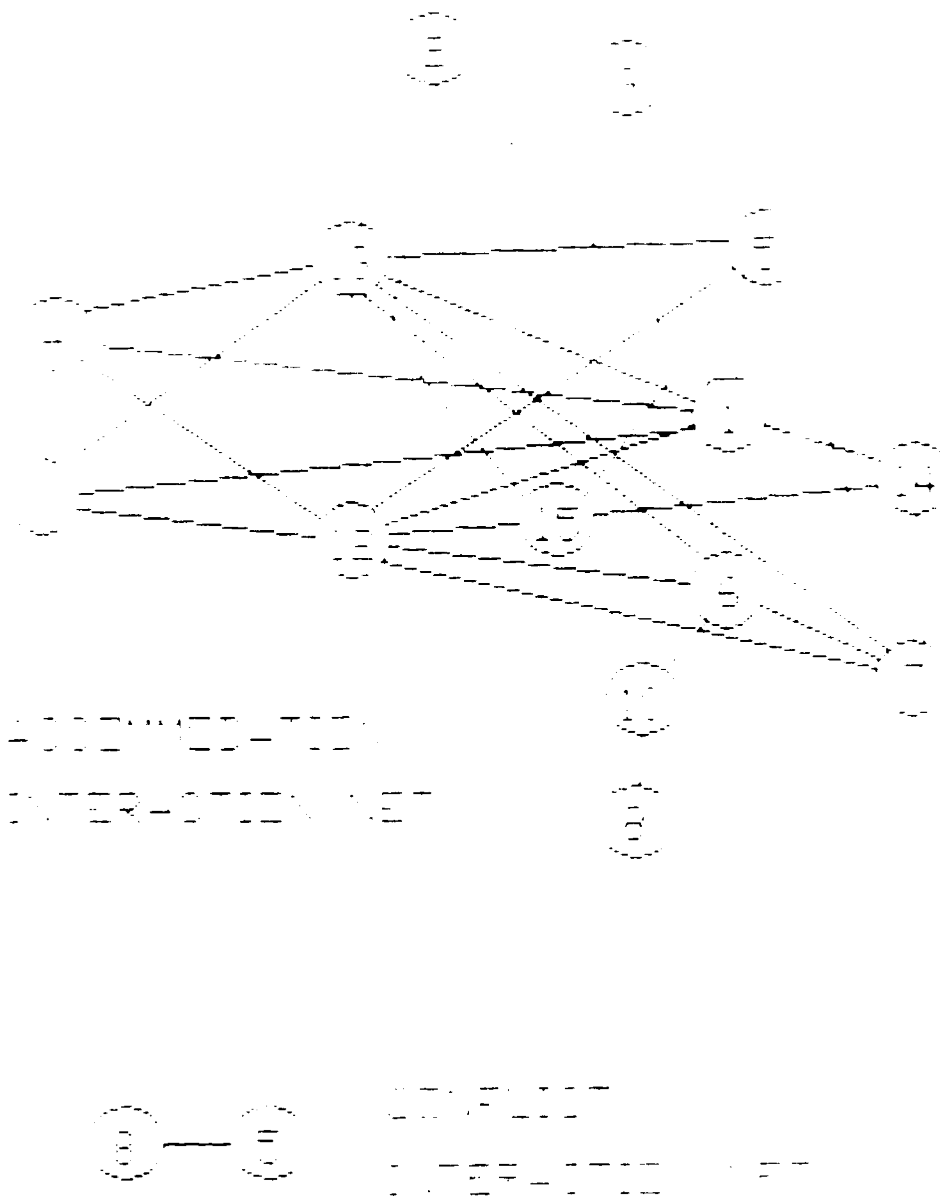

Figure 6. Accommodation and conflict interaction nets--numbers correspond with criteria listed in Figure 5.

it is not as simple as that. Many of the criteria overlap in their importance to the design. For this reason, displaying the criteria graphically provided a clear image of the relationships among them. Because it was felt that the attached hood could not be produced to meet everyone's aesthetic preferences without jeopardizing safety, the relationship between "cover head and neck" (5) and "be aesthetically pleasing" (8) was defined as a direct conflict--one criterion was chosen over the other in the coverall design process. In other words, although it may be considered that a hood was not aesthetically pleasing and should be omitted, a hood, nevertheless, would be part of the coverall design in the interest of safety.

The relationships among the other criteria represented in the interaction matrix were studied to determine how the right balance of compromise could be met. Some were difficult to incorporate into two designs while others required little consideration in problem solving. The criterion, "allow for mobility" (1) needed a great deal of consideration to accommodate it and others such as "fit and cover trunk" (2), "cover arms to wrists" (3), "cover legs to ankles" (4), "cover head and neck" (5), as well as, "able to be produced in a maximum of four sizes" (12), "fit a wide range of male physiques" (13), and "fit over a pair of pants and shirt" (14). When considering ways in which to allow for mobility all of these criteria had to be considered at the same time. For instance, if the solution for allowing for mobility in crouching was to lengthen the trunk, the garment would be too long in the crotch when standing and would therefore, not accommodate criteria 2, 4 and 13 sufficiently.

Diagrams (Figure 7) clarify the design features of each coverall. Coveralls (as opposed to a two-piece suit), with raglan sleeve (design 1) or square armhole (design 2) application, were chosen for roominess around the shoulder and armhole region in order to accommodate criteria 1, 7, 9, 10, 11, 12, 13 and 14. A centre back inverted box pleat was drafted into Design 2 for added controlled expansion during movement. Elastic was chosen to accommodate criteria 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, and as a means to control excess fullness in the trunk area (criterion 2). The length of the elastic at wrists and ankles was kept the same as that of the tested Kimberly-Clark garment since there were no complaints about wrist and ankle fit in the field study (Perkins, 1988). A tie inside a casing was chosen for the hood opening as a possible solution to the non-adjustable elastic length. Because of the complaint that the attached hood obstructed vision when turning the head, a separate hood was designed for independent movement from the suit. This would be worn with the stand-up collar of the square armhole suit.

To lessen pesticide penetration, seams were eliminated

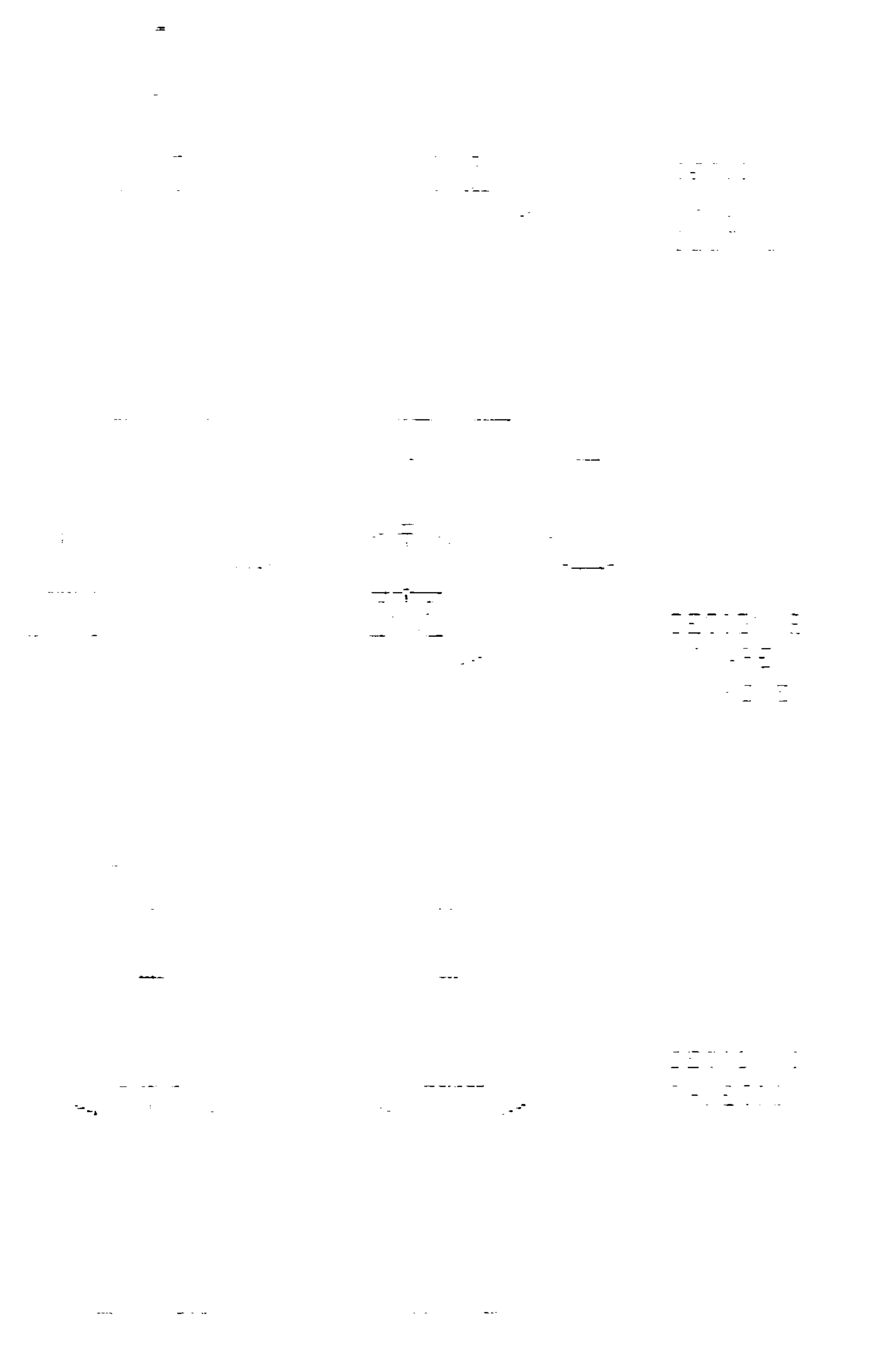

Figure 7. The three designs.

wherever possible, particularly on top of the head, on the shoulders and upper arms where pesticide drift might settle. Although it was not possible to eliminate the shoulder seams on the square armhole design, this area was covered by the separate hood. Two different styles of pesticide barrier flaps were incorporated into the zipper opening: the raglan design had two flaps, behind and in front of the zipper for optimum pesticide block, and the square armhole design had only one in front.

Prototypes developed

Drafting instructions for men's outerwear garments were used for the two designs and were based on size 43 LONG of the Kawashima (1977) suit and coat measurement chart with adjustments to accommodate the movement assessment. This drafting size was chosen as size medium in the CGSB standard sizes (1972) encompassed chest sizes 40 to 42. Size 41 was therefore considered to be the average size in this grouping and this was increased two sizes as required by the Kawashima (1977) method of drafting when designing for outerwear. Drafting instructions for a "LONG" size 43 was chosen due to the wide range of subjects' heights involved in the evaluation.

Pant drafts and coverall transformation were based on the Roberts & Onishenko (1985) method of men's pattern drafting. The Auto-CAD® computer program (Auto Desk, Inc.,

1988) was used as the drafting tool throughout the pattern-making process and as a mechanism to plot markers for each design. A chart of the three designs based on measurements as outlined by CGSB standards (CGSB, 1972) for men's industrial coverall dimensions is found in Appendix F.

All seams were serged while casings, elastic and zippers were sewn down with a straight stitch. Red thread was used for both designs in keeping with that of the third garment (a new Kimberly-Clark design), which was evaluated in this study. Sewing techniques were tested and work flow diagrams produced for efficiency prior to mass production of the garments.

Evaluation

The evaluation process of the two styles designed through the functional apparel design process, as well as a third coverall design manufactured by Kimberly-Clark, is discussed in Chapters IV (Evaluation) and Chapter V (Results).

SUMMARY

This design process should be thought of as a set of guidelines on which to base a design problem. Along with every new challenge faced by a designer of functional apparel, comes a new set of choices of strategy in order to effectively solve the problem. In some instances, and as DeJonge stated (1984), the problem may already be defined by a client or the project may be well into the design matrix before the functional design researcher becomes involved.

This process encourages the researcher to take that "step backward"--to review, clarify, recheck and confirm information before proceeding to the successive steps. By employing this investigative process and thereby having a thorough knowledge of the subject, the designer is better equipped to produce a useful effective garment.

CHAPTER IV

EVALUATION METHOD

This chapter delineates the final step, the evaluation, of the functional apparel design process. It outlines the requirements and mode of selection of the sample of volunteers who took part in the evaluation process, describes the research design and introduces the third coverall which was tested. The structure of the evaluation is then explained, followed by the procedure for data analyses.

This study is a portion of ongoing research in protective clothing for pesticide applicators which is presently underway in the department of clothing and textiles at the University of Alberta. Due to the relocation of the author from Edmonton to Toronto, the evaluation portion of the functional apparel design process was conducted under controlled conditions both at the University of Guelph in Guelph, Ontario at its annual open house, College Royal, and at the University of Alberta, Edmonton, by researchers working in the area of protective clothing for pesticide users.

SELECTION OF SAMPLE

Subjects were of average build and expected to meet three requirements in order to be accepted: 1) a chest measurement of at least 99 cm. (39") and no more than 109 cm. (43"); 2), a height measurement of at leas [illegible] cm. (5'7") and no more than 188 cm. (6'2"); and, 3) experience in applying pesticides using boom sprayers on field crops.

The sample was selected differently at the two evaluation sites. The initial evaluation took place on the weekend of College Royal's open house (March 12/13, 1988) at the University of Guelph. The history of College Royal goes back to 1925 when the [illegible]io Agricultural College was the major agricultural scho[illegible] in Ontario. It has continued to attract rural families from the surroundin[illegible] with an annual attendance estimated at over 30,000. It was therefore anticipated that the event would draw the required number of volunteers to the evaluation site which was set up in one of the exhibition buildings. Interest was encouraged and initiated through notices posted on the University of Guelph campus, advertisements in the Guelph and area newspapers and in the College Royal booklet (Appendix A).

The subjects who took part in the Alberta evaluation were informed through radio announcements and solicited by telephone through referrals from Alberta district home economists. After ensuring they were within the required body measurement range, an appointment was set up for the volunteer to evaluate the coveralls at the University of Alberta farm where the evaluation site was assembled.

RESEARCH DESIGN

The Scheffé paired comparison design (Table 1) was found to be particularly suited to this study. Fuzek and Ammons (1977) commented that in a subjective evaluation involving more than two garments, this method is recommended; each participant is issued only two garments for comparison, making the evaluation process easier. Ten to 15 replications of each pair of garments are usually used. In this study, where three garments were tested, 30 participants were needed in order to randomly assign the treatment for 10 replications per garment. Initially 60 volunteers (30 at each location) were expected in order to use the study for geographical comparative purposes. However, only nine Alberta subjects participated, giving a total of 39 volunteers. This provided 13 replications of the Scheffé design with 26 subjects evaluating each coverall style.

Table 1

Research Design: Scheffé Paired Comparison Method

	COVERALL STYLE		
WEARER	1	2	3
A	X	X	
B	X		X
C		X	X

THE GARMENTS

Designs 1 and 2 were developed using the functional apparel design process (Chapter III). The Kimberly-Clark EP "T-design" disposable coverall was chosen as the third coverall design for the study (Figure 7). Size large was used because the internal coverall measurements, as outlined by the Canadian Government Specifications Board (Appendix F), were closer to those of designs 1 and 2 than a size medium. As its name suggests, the design is T-shaped when laid flat, with an attached hood, zipper front closure and extended shoulder/armhole seams. Elastic is sewn around the wrists and ankle openings, around the face opening on the hood and along the back waist seam to the sides. Seams are serged around the waist and neck, armhole, centre back to crotch, base of zipper to crotch, centre back on hood and underarm/side seam to waist.

At the time of the evaluation, this newly designed coverall had yet to be marketed. Although the style had changed from its tested predecessor, the KleenGuard® EP coverall (Martin-Scott, 1987; Perkins, 1988), the fabric remained the same. Spun-bonded polypropylene fabric had been deemed favorable for pesticide protection due to its resistance to penetration by a wide range of liquid chemicals, low specific gravity, low manufacturing cost, and its ability to transmit moisture vapour from the skin to the surface of the fabric where it escapes (Fiedler & Baker, 1977; Martin-Scott, 1987; Perkins, 1988).

All three designs were constructed of this fabric using the same seam finish (serging) in order to keep production cost and seam strength as similar as possible. Clothing worn under the coveralls was also standardized to reduce variability in the evaluation process.

STRUCTURE OF THE EVALUATION

Farm equipment (a tractor and boom sprayer) routinely used in field crop pesticide application in Ontario were set up in an area accessible to visitors of the open house.

Interested persons were briefed on the purpose of the project, the amount of time required of them and what was to be expected during the session (Appendix B). An instructional video depicting how each evaluator was to move around and on the machinery visually explained what was required in order to evaluate the coveralls. If a subject agreed to participate, his chest circumference and height were first measured to ensure compliance with requirements. He was then asked to sign a consent form (Appendix C) before engaging in any further involvement in the study.

Volunteers were required to wear one layer of their own clothing (eg. trousers and a shirt or light sweater) and were provided with the assigned disposable coveralls, respirator, gloves and boots worn during the evaluation process.

Their remaining measurements (waist circumference and trunk length) and weight were taken. The trunk length was obtained by measuring the length of the subject's back while he was in an upright seated position, from the chair (where a measuring tape was secured) to the subject's prominent cervical vertebrae at the neck. All other measurements were taken by conventional standard methods. Room temperature and relative humidity were also recorded at this time. The subjects then wore each pair of coveralls while performing the pre-determined battery of movements on and around the machinery, simulating activities common to pesticide application. The activities or actions included 1) donning and doffing the coverall, 2) stepping up onto the tractor, 3) sitting in the tractor seat and turning to see the sprayer, 4) walking to the end of the boom and crouching next to a nozzle, 5) reaching up to the [illegible] and, 6) reaching over the tank. These represented the results of the activity analysis (Figure 3) and are listed as separate sections in the Coverall Evaluation (Appendix D).

After each action, the subject was asked questions by his accompanying interviewer regarding perceptions of functional fit of the coverall and the evaluator recorded the responses on the Coverall Evaluation (Appendix D). The subject was required to mark a position on a seven-point rating scale to indicate his perception of comfort (Appendix D, question 11). Each participant was required to evaluate two garments in this manner. The General Questionnaire (Appendix E) was completed at the end of the session by the volunteer and handed in to the researcher upon its completion.

These sessions were videotaped and photographed. The reason for this form of record-keeping was threefold. Videos acted as verification of potential fit problems and provided references and documentation for research reports.

Lastly, videotapes and photographs aided in replicating the research site in Edmonton. Details of the evaluation described above were all repeated at the Edmonton site.

DATA ANALYSES

Descriptive data about the sample were obtained by determining frequencies, means and standard deviations. Null Hypotheses 1 and 2 were tested using one-way and two-way analyses of variance (SPSS Inc., 1986). When significant differences were found using analysis of variance, the Scheffé Multiple Comparison Test (Norusis, 1986, p. B-156) determined which pairs of garments differed. The level of significance was set at .05 for analysis of variance and at .10 for the Scheffé test. Null Hypothesis 3 was tested using one-way analyses of variance. Findings of these analyses were complemented by the visual component of videotapes and photographs.

CHAPTER V

EVALUATION RESULTS AND DISCUSSION

This chapter includes a description of the volunteers by outlining their ages, some of their farming and pesticide application practices, the protective clothing and equipment they usually wear and the environmental conditions under which they tested the coveralls. A review of the sample's anthropometric measurements is then presented, followed by comments on specific design features of each of the styles and testing of the null hypotheses.

DESCRIPTION OF THE SAMPLE

The University of Guelph's annual open house, College Royal, attracted the required 30 male volunteers who were familiar with the application of pesticides using boom sprayers. Researchers at the Alberta site, however, were able to secure only nine volunteers during the limited time available as seeding had begun. This caused farmers to be reluctant to leave their farms and travel to the University of Alberta farm where the evaluation took place. Because the Alberta sample was too small to stand alone in a geographical comparison, the subjects of the two studies were combined giving a total of 39 volunteers. This allowed thirteen replications of the Scheffé design (Table 1) with 26 subjects evaluating each coverall style.

Age

The majority of subjects were under 34 years of age. Of these, 17 subjects were under the age of 25 and 10 were between the ages of 25 to 34. There were five volunteers in each of the "35 to 44" and "45 to 54" age groups and two were between 55 and 64 years of age.

Pesticide spraying

Most subjects sprayed less than 300 acres of land with pesticide, while seven of the nine Alberta farmers sprayed more than 400 acres of their own land. Grain corn, oats, barley, soybeans, sweet corn, potatoes, wheat, canola and beans were the crops sprayed.

Protective clothing and equipment worn

Clothing reported as usually worn during spraying consisted mainly of regular coveralls (56.4%) but jeans/ pants and a shirt (20.5%) and jeans/pants and a t-shirt (10.3%) were also worn. Disposable coveralls were worn by two of the subjects and another two usually wore both disposable and regular coveralls. Goggles were regularly worn by 38.5%; respirators, by 43.6%; and rubber gloves by 61.5% of the subjects. Even though not questioned, three subjects volunteered the information that they wore hard hats during crop spraying.

Environmental conditions

The room temperature during the evaluation at the Ontario site rose progressively from 23° C on Saturday morning to 26° C by Sunday afternoon at closing. The Alberta site range was recorded at 16° C to 21° C. Relative humidity ranged from 35% to 41% at the Ontario site and 31% to 39% at the Alberta site.

ANTHROPOMETRIC MEASUREMENTS OF THE SAMPLE

Subjects were of average build and were expected to meet two size requirements in order to be accepted: 1) a chest measurement of at least 99 cm (39 inches) and no more than 109 cm (43 inches) and, 2) a height measurement of at least 179 cm (5'7") and no more than 188 cm (6'2"). Those interested in volunteering at the University of Guelph location were measured before beginning the coverall evaluations to ensure compliance of requirements. As researchers at the University of Alberta located volunteer farmers through Alberta Agriculture's district home economists and a radio announcement, initial screening was done by telephone, when subjects were asked their measurements. This was to be confirmed at the time of the evaluation. Three Alberta volunteers proved to have slightly smaller chest measurements than they had claimed but were accepted for the study on the basis of the researchers' judgement that they were of "average build". Some volunteers who appeared for the study but were too large were not included. There were no significant differences in subjects' measurements among the wearers of the three styles.

Table 2 outlines for the various body areas measured, the range of the volunteers' measurements, means, standard deviations and modes.

For the purpose of variance analysis, the anthropometric measurements of chest and waist size, height, weight and trunk length were recoded and clustered into two categories as outlined in Table 3. Rather than splitting the subjects into equal groups, the division between the two groups was made at approximately the midpoint of the actual range for each measurement area.

Table 2

Physical measurements of volunteers (n=39)

Area Measured	Range	Mean	Std. Dev.	Mode
Chest (cm)	16 (93-109 cm.)	102.3	[illegible].4	99
Height (cm)	18 (170-188 cm.)	179.7	4.5	180
Waist (cm)	33 ([illegible]9-112 cm.)	92.5	6.8	91
Weight (kg)	39 (5-105 kg.)	83.5	7.6	84
Trunk (cm)	12 (6- 78 cm.)	73.0	2.8	74

Table 3

Anthropometric measurement groups

Measurement area	Low range	High range
Chest (cm)	93.0 - 101.9 (small) (n=23)	102.0 - 109.2 (large) (n=16)
Height (cm)	170.0 179.9 (short) (n=17)	180.0 - 188.0 (tall) (n=22)
Waist (cm)	78.0 - 91.9 (narrow) (n=22)	92.0 - 111.8 (wide) (n=17)
Weight (kg)	65.0 - 84.9 (light) (n=23)	85.0 - 105.0 (heavy) (n=16)
Trunk (cm)	66.0 - 71.9 (short) (n=11)	72.0 - 77.5 (long) (n=28)

COMMENTS ON DESIGN FEATURES

Solicited comments on each of the three designs (Questions 1m, 1n, 7 and 8, Appendix D) follow:

Raglan sleeve design: Solicited comments

To limit pesticide penetration, the zipper on the raglan sleeve design was sandwiched between the right and left centre front edges to create two protective flaps. Of those 26 subjects who evaluated the raglan sleeve design, 14 found the zipper to have no problems when zipping it up and down, 10 found that the underflap caught in the path of the zipper, one reported it to be worse than the zipper on the previous style he tested (square armhole design) and one thought the tab needed to be bigger.

The tie on the hood was found to be awkward by 11 subjects; seven found there to be no problem with it. Two other comments included "difficult to find" and "irritates chin". The remainder of singular comments about the tie were more closely related to the hood in general: "does not fit with glasses", "too close around the face", "obstructs vision", "pulls over chin" and "pulls over eyes". When asked whether the hood obstructed their vision, 19 subjects indicated it did. Only one subject of the 26 found the elastic around the wrists too tight.

Square armhole design: Solicited comments

The square armhole design had only one protective flap over the zipper. Twenty-three subjects found no problems with this type of application while three found the zipper to catch on the fabric. Nine subjects had no complaints about the tie on the separate hood, eight found it awkward, one found it difficult to find and another found it too thin. Again, comments also included those having more to do with the hood than the tie: "close around face" (two cases) and "obstructs vision" (one case). One subject felt he needed a mirror in order to tie it and another simply did not like it. Eighteen subjects felt that the hood did not obstruct their vision in any way. Elastic around the wrists was found to be too tight by one subject and too loose by another; the remaining evaluators found the elastic to fit well.

T-Design: Solicited comments

The zipper on this coverall design was applied in a similar way to the square armhole design and no complaints were recorded. Twenty of the 26 subjects reported no vision obstruction caused by the attached hood. Except for one complaint, elastic at the wrist was thought to fit well by all subjects.

Likes and dislikes of each style

Table 4 represents frequency of mentioned comments of subjects by style in response to Questions 9 and 10 of Appendix D. Subjects were encouraged to provide two for each style but the topics were unsolicited.

Table 4

Frequency of Mentioned "Likes" and "Dislikes" by Style

Comments	Raglan	Sq. armhole	T-design
Likes			
hood general	-	1	2
hood comfortable	-	-	2
hood not restrictive	-	3	1
hood elastic	-	-	2
hood separate	-	2	-
arms not restricting	1	1	-
legs not restricting	2	1	-
legs long	-	1	-
generally not restrictive	4	1	1
waist not restrictive	-	-	1
body length	2	2	2
arms long	1	-	2
shoulders roomy	1	-	-
hips roomy	-	2	-
fabric light weight	3	5	5
fabric cool	2	1	-
fabric color	1	-	-
fabric breathable	-	1	1
fabric disposable	1	1	-
fabric weak for safety	-	1	-
fabric strong	-	1	-
generally fit well	2	2	3
generally comfortable	1	1	3
generally roomy	2	2	2
one-piece coverall	1	-	2
easy to put on	1	-	-
zipper	-	1	1
elastic at ankle	-	1	-

Table 4 (cont'd.)

Comments	Raglan	Sq. armhole	T-design
Dislikes			
hood in general	4	8	1
hood attached	-	-	1
hood tight	4	1	1
hood loose	1	2	-
hood obstructs vision	2	1	-
hood too close to eyes	1	-	-
hood hot	-	1	-
hood elastic	-	-	1
tie on hood	3	-	-
body short	4	13	5
body loose	2	1	-
body long	-	-	1
arms short	1	3	-
arms tight	-	3	4
legs short	-	-	3
shoulders tight	1	2	8
generally tight	2	-	1
generally short	-	1	-
zipper poor	1	-	-
difficult to donn & doff	-	-	2
no pockets	1	-	-
knees thin	-	1	-
goggles interfere with hood	1	-	-

The results from Table 4 could not be used for comparative purposes among the designs as the responses were unstructured. Rather, this form of questioning provided the subject with an opportunity to either comment on positive attributes of the coveralls or unforeseen difficulties that were not covered in the preceding more structured questioning. The comments offered, however, provide some face validity to the more structured component of the functional fit evaluation, in that they tend to reflect the points covered.

TESTING OF NULL HYPOTHESES

Null Hypothesis 1: There will be no significant differences in assessment of functional fit among garment styles.

Overall functional fit

A composite score reflecting the responses to questions on functional fit was calculated. "Fits quite well" responses (questions 1 to 5 of Appendix D) were scored by adding all such responses in all body areas across all activities to gain an overall score for each coverall evaluated. The maximum possible score for each coverall was 36. The mean value for this composite score for each coverall design is given in Table 5.

The differences in the mean composite scores for functional fit for the three coverall designs were not significant. Functional fit was next broken down into two elements: 1) fit by each activity and, 2) fit for each body part.

Table 5

Composite Score for "Fits Quite Well" Responses, Analysis of Variance

Total group mean (n=78)	Treatment Means Raglan (n=26)	Sq. Armhole (n=[illegible])	T-Design (n=26)	F (Sig.)
25.64	27.15	25.46	24.31	2.313 (.106)

Functional fit by activity

The "fits quite well" responses were added across all body parts for each activity. Analysis of variance (Table 6) revealed a significant difference among the mean scores of subjects wearing each of the three designs in donning and doffing the coverall ($p < .01$) and reaching up to the boom ($p < .01$).

It is important to note that the maximum possible score for "fits quite well" responses varied according to activity. This is due to the fact that not all body areas were considered to be potential problem areas for each activity. For instance, a total of 12 body areas were considered in donning and doffing but only four areas for stepping up onto the tractor (Appendix D).

Table 6

Mean Total Scores for "Fits Quite Well"

Responses by Activity, Analysis of Variance

Activity (Maximum Possible Score)	Total Group Mean (n=78)	Treatment Means Raglan (n=26)	Sq. Armhole (n=26)	T-Design (n=26)	F (Sig.)	
Donning (12)	9.3	9.9	9.6	8.4	6.379 (.003)	**
Stepping (4)	2.6	2.9	2.7	2.1	2.597 (.081)	
Sitting (7)	5.9	6.2	5.	5.6	1.624 (.204)	
Crouching (7)	4.5	4.7	4.6	4.2	0.748 (.477)	
Reaching (6)	4.0	4.1	3.3	4.8	6.969 (.002)	**

** $p < .01$

The Scheffé Multiple Comparison Test revealed that the T-design was significantly more difficult to donn and doff than either of the other two designs ($p < .05$): while the ragl sleeve design and the square armhole design were not significantly different from one another. For reaching up to the boom, the Scheffé test revealed a significant difference in mean scores between the square armhole and the T-design ($p < .05$) with the T-design being the best.

Thus, the T-design provided better freedom of movement than the square armhole design when reaching up while the raglan and square armhole designs were both easier to don and doff than the T-design.

Next, the "fits too tight/too short" responses were added across all body parts for each activity. Mean total scores for each coverall are listed for each activity in Table 7.

Table 7

Mean Total Scores for "Fits Too Tight or Too Short" Responses by Activity, Analysis of Variance

Activity (Maximum Possible Score)	Total Group Mean (n=78)	Treatment Means Raglan (n=26)	Sq. Armhole (n=26)	T-Design (n=26)	F (Sig.)
Donning (12)	1.5	0.9	1.3	2.2	7.974 (.001) ***
Stepping (4)	1.4	1.1	1.2	1.9	2.913 (.060)
Sitting (7)	1.1	0.8	1.1	1.3	1.204 (.306)
Crouching (7)	2.5	2.2	2.4	2.8	0.933 (.398)
Reaching (6)	1.5	1.1	2.3	1.1	9.746 (.000) ***

*** p<.001

Analysis of variance revealed a significant difference among the groups of subjects wearing each of the three designs based on their response of "fits too tight" short" in donning and doffing the coverall and reaching up to the boom ($p<.001$). The Scheffé multiple comparison test confirmed the T-design to be significantly tighter during the activity of donning and doffing than both the raglan sleeve design and the square armhole design. During the activity of reaching up to the boom, the square armhole design was found to be significantly tighter than both the raglan sleeve design and the t-design ($p<.05$).

In summary, the T-design was considered more restrictive than either of the other designs during donning and doffing the coverall and the square armhole design was significantly more restrictive than either of the other designs when reaching up to the boom.

ally, "fits too loose/too long" responses were added across all body parts for each activity. Very few such responses were recorded (Table 8). This may be due to two possible reasons. The research was done in a controlled environment and not during actual spraying operations when loose clothing may be perceived as a problem around working machinery. In addition, both the raglan and square armhole designs (fuller in the stomach/seat area than the T-design) had fullness controlled by vertical strips of elastic in the front and back. As expected these may have controlled billowing at the front waist area when sitting down.

Table 8

Mean Total Scores for "Fits Too Loose or Too Long" Responses by Activity, Analysis of Variance

Activity (Maximum Possible Score)	Total Group Mean (n=78)	Treatment Means Raglan (n=26)	Sq. Armhole (n=26)	T-Design (n=26)	F (Sig.)
Donning (2)	0.9	1.1	1.2	0.4	4.457 (.015) *
Stepping (4)	0.0	0.0	0.0	0.0	0.500 (.609)
Sitting (7)	0.0	0.0	0.0	0.1	1.000 (.373)
Crouching (7)	0.0	0.1	0.0	0.0	1.000 (.373)
Reaching (6)	0.2	0.3	0.4	0.0	5.857 (.004) **

* $p < .05$
** $p < .01$

Again, there was a significant difference among the scores recorded by the subjects wearing the three designs based on their response of "fits too loose/too long" in: 1) donning and doffing the coveralls ($p < .05$) and, 2) reaching up to the boom ($p < .01$). The Scheffé test revealed that both the raglan and square armhole designs were given significantly higher mean scores than the T-design for both activities. These results reflect the results obtained when examining the "fits quite well" and "fits too tight/too short" responses, confirming the impression that the T-design coverall is restrictive when donning and doffing in comparison to both of the other designs and that the T-design is better than the square armhole when reaching up to the boom.

Functional fit by body part

Next, the "fits quite well" responses were added across [illegible] activities performed for each body part.

There is a significant difference among the mean scores for the subje[illegible] [illegible]ing [illegible]e three designs for the following body parts: a[illegible] [illegible] shoulders ($p < .05$), around the upper [illegible] ($p = .000$), i[illegible] [illegible] hood ($p = .01$), in the body length [illegible] in leg length ($p < .05$) and in arm length ($p < .01$ [illegible] [illegible]e 9).

Table 9

Mean Total Scores for "Fits Quite Well" Responses by Body Part, Analysis of Variance

Body Part (Maximum Possible Score)	Total Group Mean (n=78)	Treatment Means: Raglan (n=26)	Treatment Means: Sq. Armhole (n=26)	Treatment Means: T-Design (n=26)	F (Sig.)
Shoulders (5)	3.2	3.7	3.2	2.6	4.2[illegible]9 (.017) *
Stomach (4)	3.9	3.8	3.9	3.9	0.872 (.422)
Hips (3)	2.6	2.7	2.5	2.6	0.698 (.501)
Arms (5)	3.6	4.2	3.9	2.5	12.015 (.000) ***
Thighs (4)	3.5	3.4	3.6	3.5	0.494 (.612)
Wrist elastic	0.9	0.9	[illegible]	0.9	0.543 (.583)
Ankle elastic (1)	1.0	1.0	1.[illegible]	1.0	0.500 (.609)
Hood (3)	2.1	1.9	2.6	1.7	4.945 (.010) **
Body length (5)	2.7	3.0	2.0	3.2	4.866 (.010) **
Leg length (1)	0.8	0.9	0.9	0.6	3.391 (.039) *
Arm length (2)	1.6	1.7	1.2	1.8	6.178 (.003) **

* $p < .05$
** $p < .01$
*** $p < .001$

The Scheffé multiple comparison test revealed that the raglan design fit significantly better in the shoulders ($p<.05$) and in the leg length ($p<.10$) than the T-design and both the raglan and the T-design rated significantly better in body and arm length when compared to the square armhole design ($p<.05$). A significantly better fit was also found in the square armhole's separate hood than in that of the T-design's attached hood ($p<.05$) and both the raglan and the square armhole designs fit significantly better than the T-design around the upper arms ($p<.05$).

The "fits too tight/too short" responses were also added across all activities performed for each body part (Table 10). Analysis of variance showed significant differences among the groups of subjects wearing each of the three designs based on their response of "fits too tight/too short" across the shoulders ($p<.01$) around the upper arms ($p=.000$), in the hood ($p=.001$), in the body length ($p<.0$[illegible]) in leg length ($p=.000$) and in arm length ($p=.000$) confirming the findings of "fits quite well" responses outlined above.

Table 10

Mean Total Scores for "Fits Too Tight or Too Short" Responses by Body Part, Analysis of Variance

Body Part (Maximum Possible Score)	Total Group Mean (n=78)	Treatment Means: Raglan (n=26)	Sq. Armhole (n=26)	T-Design (n=26)	F (Sig.)	
Shoulders (5)	1.8	1.2	1.8	2.4	5.128 (.008)	**
Stomach (4)	0	0.0	0.0	0.0	0.000 (1.000)	
Hips ([illegible])	0.[illegible]	0.3	0.4	0.2	0.839 (.436)	
Arms (5)	1.3	0.[illegible]	1.0	2.4	14.309 (.000)	***
Thighs (4)	0.4	0.5	0.4	0.4	0.353 (.704)	
Wrist elastic (1)	0.1	0.0	0.1	0.1	0.207 (.814)	
Ankle elastic (1)	0.0	0.0	0.0	0.0	0.500 (.609)	
Hood (3)	0.7	0.8	0.2	1.2	8.196 (.001)	***
Body length (5)	2.2	1.8	3.0	[illegible].8	5.405 (.006)	**
Leg length (1)	0.1	0.0	0.0	0.4	13.235 (.000)	***
Arm length (1)	0.4	0.2	0.8	0.2	8.762 (.000)	***

** $p < .01$
*** $p < .001$

The Scheffé test revealed that the T-design was rated significantly tighter in the shoulders than the raglan and also tighter than both the raglan and square armhole designs around the upper arms ($p < .05$). It was also considered significantly shorter in leg length than both the raglan and square armhole designs and tighter in the hood than the square armhole design's separate hood. The square armhole design was found to be significantly shorter in body and arm lengths than both the raglan design and T-design.

Overall, the T-design was rated as being significantly more restrictive in a number of body areas. These included across the shoulders, around the upper arms, in the leg length, as well as, in the hood. The square armhole design rated the most restrictive in body and arm lengths.

Lastly, the responses to "fits too loose/too long" were added across the activities for each body part (Table 11). Analysis of variance revealed no significant differences among the three garments at the .05 level.

Table 11

Mean Total Scores for [illegible]s Too Loose or Too Long" Responses by Body Part, Analysis of Variance

Body Part (Maximum Possible Score)	Total Group Mean (n=78)	Treatment Means Raglan (n=26)	Sq. Armhole (n=26)	T-Design (n=26)	F (Sig.)
Shoulders (5)	0.0	0.0	0.0	0.0	-- (--)
Stomach (4)	0.1	0.1	0.0	0.1	0.528 (.592)
Hips (3)	0.1	0.0	0.1	0.2	1.087 (.342)
Arms (5)	0.1	[illegible]	0.1	0.0	1.862 (.163)
Thighs (4)	0.1	0.1	[illegible]	0.1	0.152 (.860)
Wrist elastic (1)	0.0	0.0	0.1	0.0	1.027 (.363)
Ankle elastic (1)	0.0	0.0	0.0	0.0	-- (--)
Hood (3)	0.2	0.3	0.3	0.0	3.037 (.054)
Body length (5)	0.1	0.2	0.0	0.0	0.765 (.469)
Leg length (1)	0.1	0.1	0.2	0.0	0.962 (.387)
Arm length (2)	0.0	0.0	0.0	0.0	0.500 (.609)

In terms of functional fit by body part, each style was noted to have particular strengths. The raglan sleeve design fit very well across the shoulders and in leg length; the T-design was preferred for its ease of movement in both body and arm length; the square armhole design's separate hood was rated the highest for hood fit. In addition, both the raglan and square armhole designs rated very well in the upper arms.

Damage

Damage was determined objectively by recording areas of rips and stress upon inspection of each garment after the evaluations were completed. Damage was noted for each of the following areas: under the arms, the seat, crotch and the tie at the neck (Table 12).

Table 12

Objective Functional Fit--Damage

Frequency Distribution across all tyles

Site of damage	Number of garments (n=78)	Styles Raglan (n=26)	Sq. Armhole (n=26)	-Design (n=26)
Seat	5	3	1	1
Underarm	26	14	8	4
Crotch	6	1	1	4
Hood at tie	15	3	12	--

A total score for damage was calculated for each coverall taking into consideration all the sites of damage excluding the damage found on the hood at the tie. Due to the fact that the T-design did not have a tie and could not have any of the associated damage, the tie site was excluded in calculating overall damage. Analysis of variance of the mean scores revealed a significant difference in the amount of damage observed among the three styles (Table 13).

Table 13

Site of Damage by Style, Analysis of Variance

Site	Total Group Mean (n=78)	Treatment Means: Raglan (n=26)	Sq. Armhole (n=26)	T-Design (n=26)	F (Sig.)	
All sites (excl. tie)	0.5	0.7	0.4	0.4	744 (.071)	
Seat	0.1	0.1	0.0	0.0	0.840 (.436)	
Underarm	0.3	0.5	0.3	0.2	4.750 (.011)	*
Crotch	0.1	0.0	0.0	0.2	1.630 (.203)	
Tie (n=52)	0.3	0.1	0.5	--	8.544 (.005)	**

* $p < .05$
** $p < .01$

Scores for damage at the individual sites were then compared among designs. The Scheffé test revealed that the raglan design incurred significantly more damage under the arms than the T-design and that the square armhole design incurred significantly more damage at the tie than the raglan design.

Comparison of damage among subjects in different anthropometric measurement groups revealed significant differences between the small and large chest size groups (Table 14). This damage was more common among subjects with large chest measurements.

Table 14

Damage by Anthropometric Size

Body Measurement	Low Range	High Range	F (Sig.)	
Chest (cm)	.54 (small) (n=23)	.84 (large) (n=16)	3.845 (.05)	*
Height (cm)	.56 (short) (n=17)	.75 (tall) (n=22)	1.538 (.22)	
Waist (cm)	.59 (narrow) (n=22)	.76 (wide) (n=17)	1.267 (.26)	
Weight (kg)	.57 (light) (n=23)	.81 (heavy) (n=16)	2.566 (.11)	
Trunk length (cm)	.55 (short) (n=11)	.71 (long) (n=28)	0.981 (.33)	

* $p < .05$

Further analysis of variance revealed significantly different damage scores among styles for large-chested individuals. At the .05 level, the Scheffé test indicated that the raglan design incurred significantly more damage than the T-design and when set at the .10 level, both the raglan and square armhole designs scored significantly higher than the T-design.

The above analyses of variance provide evidence that there are a number of areas (damage, functional fit by activity and functional fit by body part) where significant differences appear among garment styles. Null Hypothesis 1 is, therefore, rejected.

Null Hypothesis 2: There will be no significant differences in assessment of comfort among garment styles.

A frequency distribution of responses for the comfort rating scale by subjects is shown in Table 15. The mean rating was 3.1, with standard deviation of 1.3.

Table 15

Comfort Frequency Distribution across all Styles

Value Label	Value	Frequency (n = 78)
extremely comfortable	1	7
comfortable	2	22
somewhat comfortable	3	24
neutral	4	11
somewhat uncomfortable	5	12
uncomfortable	6	2
extremely uncomfortable	7	0

Table 16 shows the results of analysis of variance in comfort scores by garment style. There is no significant difference in the overall comfort scores recorded by subjects wearing the different coverall styles. It was thought, however, that there may be a relationship between anthropometric size and comfort scores. Analysis of variance confirmed a significant difference in comfort scores recorded by "tall" and "short" individuals (Table 17), with the shorter group rating garments as more comfortable.

Table 16

Comfort by Style, Analysis of Variance

Total group mean (n=78)	Treatment Means Raglan (n=26)	Sq. Armhole (n=26)	T-Design (n=26)	F (Sig.)
3.06	2.9	3.2	3.1	0.283 (.754)

Table 17

Comfort by Anthropometric Size, Analysis of Variance

Measurement Area	Mean comfort scores: Low range group	Mean comfort scores: High range group	F (Sig.)
Chest	2.98 (small) (n=23)	3.19 (large) (n=16)	0.499 (.482)
Height	2.74 (short) (n=17)	3.32 (tall) (n=22)	0.046 (.046) *
Waist	2.86 (narrow) (n=22)	3.32 (wide) (n=17)	2.514 (.117)
Weight	2.89 (light) (n=23)	3.31 (heavy) (n=16)	2.063 (.115)
Trunk	2.95 (short) (n=11)	3.11 (long) (n=28)	0.221 (.639)

* $p < .05$

Because of the difference between the two height groups, individual groups (short and tall) were analyzed for differences in mean scores. No significant differences in the mean comfort scores across the styles for either short (p=.89) or tall (p=.51) individuals were evident.

Further 2-way analyses of comfort scores showed interactions between style & chest (Table 18), even though there were no significant differences in mean scores for comfort across the chest measurement groups (Table 17).

Table 18

Two-way Analysis of Variance:

Comfort by Garment Style by Anthropometric Size

Variables	F	Signif. of F
style	0.289	.750
chest	0.499	.482
interaction	4.515	.014 *
style	0.189	.828
waist	2.255	.138
interaction	0.840	.436
style	0.251	.778
trunk	0.154	.696
interaction	1.663	.197
style	0.306	.737
weight	2.136	.148
interaction	2.856	.064
style	0.462	.632
height	4.337	.041
interaction	C.364	.696

* p<.05

The F value associated with the interaction of style and chest is 4.515; the observed significance level of F is .014 (Table 18). Therefore, there is an interaction between the variables. The mean scores for comfort relate not only to the style of the garment and to the chest size of the individual but also to the particular combination of values for style and chest size. Large-chested individuals rated the square armhole style as the most comfortable (2.73 mean score), whereas small-chested subjects rated the T-design the most comfortable (2.53). Thus, the comfort ratings of various styles depended on the chest size of the respondent. The two variables, chest size and style, jointly affect comfort. Figure 8 provides a graphic depiction of the interaction of comfort and style.

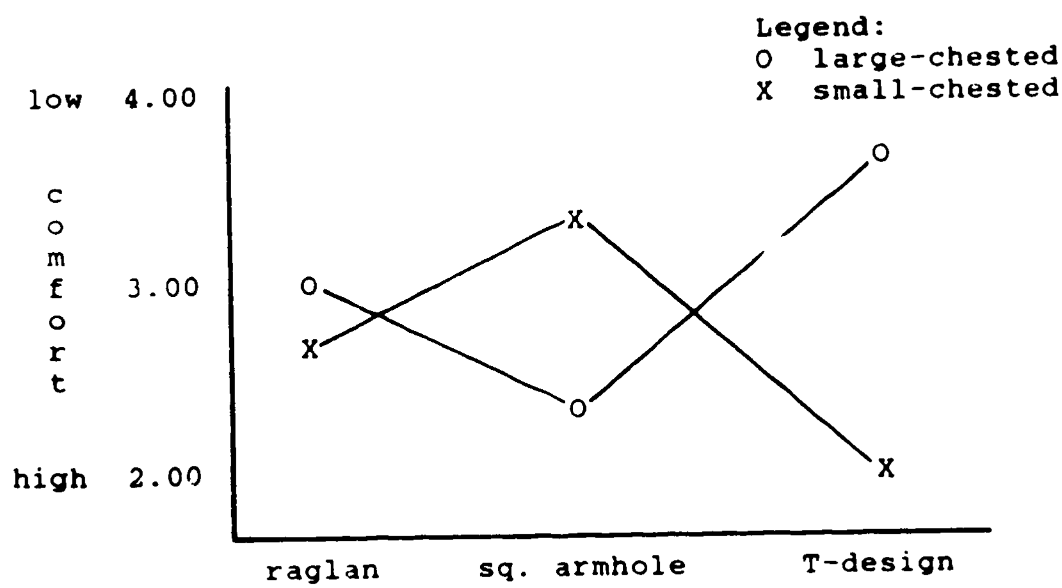

Figure 8. Two-way interaction of style & chest size on comfort, analysis of variance.

When comparing mean scores of comfort for each of the three styles (Table 16), no significant difference in overall perception of comfort was detected ($p<.75$). However, when comparing mean scores of comfort for "tall" and "short" individuals, taller individuals generally found the coveralls to be less comfortable (Table 17). The two-way interactions between style and height, however, revealed no significant interaction (Table 18). This leads one to conclude that irrespective of style, short individuals found the coveralls to be more comfortable than did tall individuals and that the different styles did not influence this difference in any way.

In summary, the T-design was considered more comfortable than the other two designs by individuals with smaller chests, whereas, the square armhole design was rated as a more comfortable design by individuals with larger chest measurements.

The above results of analysis of variance provides sufficient evidence that there is a significant difference in comfort among garment styles, when considering chest size and taking two-way interactions into account. Therefore, Null Hypothesis 2 is partly rejected.

Null Hypothesis 3: There will be no significant differences in either (a) **beliefs** about disposable coveralls or (b) **attitudes** towards wearing disposable coveralls among respondents wearing the three styles.

Beliefs and attitudes (measured through the responses given to questions 1 through 8 in the General Questionnaire, Appendix E) were analyzed in a number of different ways to determine if there were any significant differences among respondents wearing the three styles. All beliefs and attitudes were first analyzed separately. Measured attitude towards the coveralls was also analyzed as a composite attitude score (q2a + q2b + q2c + q2d). Calculated attitude [Σ(belief X the corresponding evaluation of belief)] was then computed and analyzed.

The question regarding the consideration of purchasing the specific coverall being evaluated (question 12 in the Coverall Evaluation) was found to be ambiguous. Because of this, this question was not considered for analysis.

Composite scores and scores for individual attitudes and beliefs were analyzed by analysis of variance to compare these values among the subjects wearing each coverall design style. There were no significant differences at the .05 level in any of the belief or attitude scores among the subjects wearing the different coverall styles (Table 19).

Table 19

Beliefs and Attitudes by Style, Analysis of Variance

	Total Group Mean (n=78)	Treatment Means: Raglan (n=26)	Sq Armhole (n=26)	T-Design (n=26)	F (Signif.)
Beliefs					
Protect better	2.9	2.9	[illegible]	2.9	0.111 (.895)
Feel hot	-2.1	-2.1	[illegible]	-2.1	[illegible] (.818)
Feel wet	-2.0	-2.1	-1.8	-2.1	[illegible] (.611)
Restrict mobility	-2.3	-2.2	-2.2	-2.5	0.553 (.578)
Spending money	-1.3	-1.3	-1.4	-1.2	0.048 (.953)
Ease of care	2.4	2.4	2.6	2.2	1.206 (.305)
Measured attitudes					
Good idea	2.7	2.7	2.8	2.7	0.051 (.950)
Necessary	2.3	2.1	2.3	2.4	0.503 (.607)
Sensible	2.8	2.8	2.8	2.8	0.072 (.930)
Pleasant	0.9	0.8	1.1	0.9	0.449 (.640)
Composite measured attitude[1]	8.7	8.4	9.0	8.8	0.391 (.678)
Calculated Attitude [Σ(belief X evaluation of belief)][2]					
	4.4	3.0	4.0	6.2	0.399 (.672)

[1] Measured Attitude = q2a + q2b + q2c + q2d

[2] Calculated Attitude = (q1a X q3) + (q1b X q6) + (q1c X q4) + (q1d X q5) + (q2e X q7) + (q1f X q8)

Based on these findings it can be safely assumed that attitudes and beliefs were not significantly different among the subjects evaluating the different coverall designs. One would therefore not be concerned that beliefs and attitudes were a confounding factor biasing responses of subjects regarding comfort and functional fit of the three designs.

Null Hypothesis 3, stating that there will be no significant differences in either beliefs about disposable coveralls or attitudes towards wearing disposable coveralls among respondents wearing the three designs is, therefore, accepted.

CHAPTER VI

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

SUMMARY

The purpose of this study was to follow the functional apparel design process to produce and evaluate two different disposable garments for use by agricultural pesticide applicators. As part of the process these garments, along with a recently-developed Kimberly-Clark garment, were evaluated for functional fit and comfort by male farmers.

The use of disposable garments has been determined to be a feasible method to reduce exposure to pesticides. This is particularly true in rural farming situations where all members of the family could come in contact with contaminated clothing. Currently available disposable coveralls are, however, not designed specifically for the agricultural worker who needs to work on and around farming equipment.

The functional apparel design process is particularly suited to designing clothing for special needs. This open, step-by-step approach encourages a thorough investigation of the design problem before the actual prototype is developed. Analysis of variance with the Scheffé paired comparison method of evaluation was utilized in the final step of the functional apparel design process as it lends itself to evaluations involving more than two garments.

The three coverall styles were evaluated by 39 volunteers under controlled conditions on and around a tractor and boom sprayer. Subjects rated the functional fit and comfort of each of the assigned coveralls while working through a number of predetermined activities simulating typical pesticide application.

Different design styles did not influence comfort ratings except when style by small and large chest size interactions were taken into account. Taller subjects found all of the coveralls to be less comfortable than did shorter subjects, regardless of style. Rip or stress damage were also more prevalent on garments worn by taller men.

The raglan sleeve design received the highest rating for functional fit during donning and doffing and across all activities in the shoulder area and in leg length. Both the raglan and square armhole designs rated very well around the upper arms.

Among those who tested the square armhole design, th highest comfort rating was given by large-chested subjects. It was also rated highly in donning and doffing but was rated the poorest of the three designs in reaching up to the boom and had the lowest rating in functional fit in body length and arm length.

The T-design was rated the poorest in comfort by large-chested subjects and the best by small-chested subjects. It received the highest functional fit rating in reaching up to the boom and the lowest rating for donning and doffing and stepping up onto the tractor. Functional fit complaints were noted across the shoulders, around the upper arms, in leg length and in the hood, while for functional fit in body length and arm length, it was rated the best of the three garments.

The separate hood of the square armhole design was rated the highest for functional fit; the attached hood of the raglan was rated the next best, and the T-design's hood, the least popular.

Rip and stress damage was found most often under the arms of the raglan sleeve design. Damage was also frequently noted at the hood tie of the square armhole design.

These findings provided the basis for recommendations for the development of the final garment design.

CONCLUSIONS

The study

A review of the objectives of this study on the functional apparel design process reveals three distinct, yet progressive phases. Although not listed specifically as a separate objective, the planning stage was a vital part of the project. Planning or mapping out the flow chart provided the organizational structure for the study

In phase two (objective 1a), the activity analysis and the development of two new coverall designs to be evaluated formed the basis for the researcher's specific contribution. Decisions for choosing the styles were based on the findings of the activity analysis, market analysis (objective 1b) and comments about designs and design features from users who took part in a previous pilot study (Perkins, 1986). This investigative process was extremely important as a prelude to design decisions. The styles that were ultimately used in the project were roomy, simple, as well as easy and inexpensive to construct. The decisions made in merging styles with specific design features were made so that as many design features as possible could be tested.

The object was not to determine that one of the styles was the perfect coverall but to determine different "winning aspects" in each of the three designs which could then be incorporated into a final design. The final recommended garment design should, therefore, be better than any one of the designs tested. In addition, it was also important to identify poor design features, such as the double flap zipper application (Chapter V, Raglan

Sleeve Design: solicited comments) and to eliminate these as considerations for the final design.

More of this type of analysis could have been done. For instance, it would have been helpful to incorporate the vertical elastic in only one of the designs in order to determine whether this elastic really made a difference in controlling fullness. Nevertheless, very few subjects found the larger garments "too loose", so the elastic likely played some role in controlling fullness.

The third and final phase combined the planning of the evaluation process, the development of the instrument and the execution of the evaluation (objectives 2a & 2b). The controlled conditions proved to be valuable in testing coverall design. Activities, time and environmental conditions were kept constant: each evaluator performed the same activities, was given the same amount of time in which to do them, and used the same equipment. In this way differences in the perceptions of the fit and comfort were dependent on garment style. As a research assistant accompanied the subject throughout the evaluation, constant questions about the fit and comfort forced the subject to concentrate on the coverall. Specific comments were solicited while the subject was still performing that activity or holding a particular position. Questionnaires filled in after the evaluation process--even immediately after--are very dependent upon the evaluator's recall of perceptions of fit and comfort. Videotapes and photographs were also valuable to confirm functional fit problems and provided additional documentation of the study.

Raglan sleeve design

This design proved to be the easiest to put on and take off and was the most suitable for a wide range of chest sizes and torso lengths. It provided "continuous fullness" or the ability to shift in the shoulder area thus accommodating a variety of activities involving the upper body and upper arm area. It was evident from viewing videotape footage of the raglan sleeve tests that the subject's back length and upper back width increased considerably while crouching down next to the end of the boom and hunching over to see the nozzle. In addition, due to the unstructured nature of the raglan sleeve, the shoulder area of the garment shifted over the shoulders to the back to provide the needed ease for the curved back.

The major problem encountered with the raglan style was that several garments ripped under the arms during reaching up or forward. This was considered to be a design deficiency. In an attempt to minimize pesticide penetration and reduce construction costs, side seams on both the raglan and square armhole designs were eliminated. This resulted in a weak area at the intersection of the underarm point of the trunk piece and the end of the underarm seam. Although eliminating seams may reduce production costs, the side seam perhaps should not have been eliminated in this case, because it may have served to strengthen this area. Stress may then have been distributed along the underarm/side seam instead of being concentrated at a single point. It [illegible] uld also be noted, however, that stitches produce needle holes in spunbonded material and may add to seam weakening problems.

Square armhole design

This design had the lowest armhole which provided additional chest room. Although there were no significant differences in "fit too loose" responses among respondents wearing the three designs, small-chested individuals considered this roomy coverall the least comfortable. These small-chested subjects also rated the small fitting t-design as being the most comfortable. This leads one to believe that general comfort rating may have been a better characterization of fit in this situation than the nebulous comment, "too loose".

This design proved to be the least accommodating to movement. It is interesting to note that in spite of the fact that the raglan and square armhole designs were drafted from the same block, the square armhole design was rated substantially lower in functional fit in arm length and particularly, body length. This can only be attributed to the armhole style.

The separate hood of this design was rated particularly well, both in not obstructing vision when turning, and in functional fit ratings. This was achieved by shaping the back of the hood with two seams instead of just one centre back seam.

T-design

Functional fit ratings revealed that this design was overall "close-fitting", particularly around the upper arm and shoulders. The close-fitting nature, also made donning, doffing and stepping up difficult. This was evident in comments of "too short" in the leg length and "too tight" in the hood. Movements involving reaching up were, however, not hindered by the garment because of its relatively long underarm/side seam.

Individual design features

The single-flap zipper application was most satisfactory. Although the second underflap might prevent pesticide from entering through the zipper, there is a risk that the zipper may catch on the flap, tear and result in even greater risk of contamination.

A tie on the hood seemed a logical option to attempt to rectify the complaints of past coverall users that they were unable to adjust elastic around the faces. It was not, however, an improvement. Another similar design feature which was pretested by sewing a sample was a zig-zag stitch casing over the tie. This revealed a worse problem in that the mouth of the casing tore when the tie was pulled in to form a bow. The explanation lies with the weakness of the spun-bonded material compared to a woven fabric structure. Concentrated stress (eg. at the mouth of the casing) can be shared among yarns in woven fabrics, whereas, the spun-bonded material remains vulnerable and rips. Although evaluators complained that the elastic pulled in too much and obstructed their vision when turning, ties were a nuisance to tie, often ripped at the casing mouth and are more costly in materials and to construct.

As there were few complaints from previous users of similar coveralls, the length, type and application of the elastic around wrists and ankles was kept the same among the three designs. Only one subject from each coverall design group reported the wrist elastic to be too tight. Elastic at the ankles was not evaluated as the coveralls were pulled over the boots and it was thought that a sensation of tightness could not have been easily detected.

The incorporation of vertical lengths of elastic on the front and back sections of both the raglan and square armhole designs was intended to control fullness or excess torso length that could otherwise result in a sagging crotch for the shorter man. It would also hold the waist line at the proper position as well as act as an expansion feature for the back when the subject was bending or crouching. Since both garments were constructed in this manner, it is difficult to make the comparison between having the elastic or not. However, on examination of the documenting videotapes, this elastic application did appear to control the fullness.

RECOMMENDATIONS

The final design

The final design should be a composite of the positive attributes of each design. As evident from conclusions drawn about each of the designs, overall, the raglan sleeve design was considered to be the most favorable.

It is recommended that the underarm be raised by two inches bringing it closer to the body, thus lengthening the underarm/side seam to provide better reaching capacity. In addition, in place of the underarm seam, a dart could extend down to the waist and past the waistline elastic. Further testing would reveal whether the stitching in such a dart would add weakness, or if the seam would add strength through distributing the stress.

Elastic in the hood should replace the troublesome casing and drawstring application. Because the hood of the square armhole design was rated favorably, it is recommended that the raglan coverall should be available in both an attached and separate hood version. The attached hood would be of the same style as the separate hood with the two seams shaping the contour of the head. The coverall with the separate hood should have a band collar with the top of the zipper ending at the top edge of the collar.

Since visual observations confirmed the effectiveness of the vertical lengths of elastic on the raglan and square armhole designs, these should be incorporated into the final design. It should be noted, however, that production costs would increase if this elastic application and the two-seam hood construction were accepted. The manufacturer of the coveralls would have to determine the feasibility.

Due to the functional fit complaints among men at the larger end of the sizing scale, the recommended limit for size medium would be set at: chest sizes 99 cm. (approximately 39 inches) to 107 cm. (approximately 42 inches) and height measurements of 179 cm. (approximately 5'7") to 182 (approximately 6') inclusive.

Recommendations for future research in protective clothing for pesticide users

As this study was exploratory in nature, the researcher recommends the following for future research:

1. A further study should include testing the recommended final design under the controlled conditions of this study and again in field trials.
2. Additional research into the development of protective handwear and footwear would also expand the use of the functional apparel design process for designing protective clothing.
3. A survey of anthropometric measurements of farmers and farm laborers should be conducted in order to provide a more accurate sizing system for protective workwear.

Recommendations for future research using the functional apparel design process

1. The functional apparel design process could be used for other areas such as clothing for the aged or handicapped. This would improve and refine the process and lead to a more thoroughly tested design process.

Recommendations to manufacturers

1. Careful fit considerations should be made in the "S, M, L & XL" sizing system. Although the first two designs were drafted for a size medium (from a men's outerwear drafting system), a size large Kimberly-Clark T-design was chosen for this study because its measurements were closer to those of the other two designs. In spite of this allowance, results revealed that the T-design was still rated as a tighter (smaller) fit than the other two.

2. As the use of disposable coveralls is expanding into a number of chemical handling fields, manufacturers should become more aware of the movement requirements specific to these jobs in order to incorporate these requirements into garment designs.

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'DIX A

News Release ng evaluation site at the Univer y of Guelph, Ontario (A similar news release was used in Alberta for the radio announcement.)

NEWS RELEASE

PROTECTIVE CLOTHING FOR PESTICIDE USERS

Protective clothing, worn while handling pesticides, is the best way to reduce or avoid pesticide poisoning. Many farmers are concerned both for themselves and their families as they become more aware of the hazards of contact with contaminated clothes in the home. The use of **disposable** coveralls is now being considered as an extra layer of protection.

The Department of Consumer Studies at the University of Guelph and the Department of Clothing and Textiles at the University of Alberta are involved in a joint project in the design and evaluation of disposable protective coveralls for pesticide applicators in agriculture with the support and assistance of the Farm Safety Association in Ontario and Alberta Agriculture.

We are looking for volunteers with the following characteristics who would like to become involved in the evaluation process during College Royal:

* **Men who apply pesticides with boom sprayers and who are of average build (chest sizes ranging from 39 to 43 inches) and heights ranging from 5'7" to 6'2".**

For more information on the project or to volunteer as an evaluator, please contact Holly van Schoor or Marjorie Wall at 824-4120, ext. 2416.

We'll be set up in the north end of the Engineering Building (main floor) during College Royal's open house at the University of Guelph on Saturday and Sunday (March 12-13). You will recognize our exhibit with the tractor and pesticide sprayer.

We look forward to seeing you there.

APPENDIX B

Evaluation Brief

for potential subjects interested in becoming

involved in the evaluation

THE DESIGN AND EVALUATION OF DISPOSABLE PROTECTIVE COVERALLS FOR PESTICIDE APPLICATORS IN AGRICULTURE

Who may participate:

In order to participate, your measurements must conform to the body measurements on the sign. As you have seen on the posters, you will be allowed to keep the respirator and safety goggles supplied during the coverall evaluation. We will also be presenting you with a folder of farm safety literature.

Participants' involvement:

Each participant will be testing two garments. If you agree to participate, you will be expected to wear a shirt or sweater and pants. We will then take some basic measurements including your waist and weight. (This information is confidential.)

You will then put on one of the pairs of coveralls, a respirator, goggles, gloves and boc and perform various activities on and around the machi These are all movements that simulate normal wor We will show you what is expected.) We will be videotaping while you are going through the routine. This will help us later on if adjustments are needed to the designs by showing us, for example, where stress is being put on the coveralls. As you are walking around and on the machinery, you will be asked a series of questions during each activity.

When you have finished evaluating both pairs of coveralls, we have a general questionnaire we would like you to complete about your views on protective clothing. We will take up approximately a half hour of your time.

APPENDIX C

Agreement and Consent Forms

for volunteers

I.D. #: ____________

AGREEMENT AND CONSENT

I, ________________________________, volunteer to participate in a research study on the evaluation of disposable protective coveralls for pesticide use in agriculture at the University of Guelph. The research goal is to determine which coverall design would best suit the safety, comfort and mobility needs of a farmer spraying pesticides.

I understand that during my participation in the study, I will be observed, photographed and videotaped. I realize that public reports, articles and presentations might be made of this research but I am aware that they are for educational purposes only. I consent to this as well as to the use of photographs and videotapes of my involvement.

Although I am familiar with the use of the farm machinery that will be used in this study, I understand that I will not be driving or operating the machinery or working with pesticides of any kind and that there is no normal risk associated with these activities. I am aware that this machinery has been washed and decontaminated of pesticides before my involvement in this research project.

I understand that I may withdraw from the study at any time.

________________________________ ____________________________

signature date

If you are interested in receiving a brief summary of the research results, please fill in your address:

Address: ____

____

You may also contact me regarding my possible involvement this spring for further evaluation of these coveralls on my own farm. This evaluation would involve my wearing each garment for one day of spraying with my own equipment.

________________________________ ____________________________

signature date

Address: ____

______________________________ Telephone number: ______________

Approximate date of spring spraying season: ____________________

I.D. #__________

AGREEMENT AND CONSENT

I, ______________________________ volunteer to participate in a research study on the evaluation of disposable protective coveralls for pesticide use in agriculture at the University Farm at Ellerslie. The research goal is to determine which coverall design would best suit the safety, comfort and mobility needs of a farmer spraying pesticides.

I understand that during my participation in the study, I will be observed and may be photographed. I realize that public reports, articles and presentations might be made of this research but I am aware that they are for educational purposes only. I consent to this as well as to the use of photographs of my involvement.

Although I am familiar with the use of the farm machinery that will be used in this study, I understand that I will not be driving or operating the machinery or working with pesticides of any kind and that there is no normal risk associated with these activities. I am aware that this machinery has been washed and decontaminated of pesticides before my involvement in this research project.

I am willing to participate ______________ (day) May ____, at ________ (time).

I understand that I may withdraw from the study at any time.

______________________________ signature

______________________________ date

If you are interested in receiving a brief summary of the research results, please fill in your address:

Address: ____

____

- -

You may also contact me regarding my possible involvement this spring for further evaluation of these coveralls on my own farm. This evaluation would involve my wearing each garment for one day of spraying with my own equipment.

______________________________ signature

__________ ______________ date

Address: ______________________________ __________

______________________________ Telephone Number __________

Approximate date of spring spraying seasons: __________ __________

Type of pesticides that will be applied: ______________ __________

APPENDIX D

Coverall Evaluation

I.D. #: ___________

COVERALL EVALUATION

INSTRUCTIONS:

[To be read to the volunteer after he has seen the video and before he puts on the first coverall.]

You have watched the short video of the route we will be taking during the evaluation of the garments. It was intended to give you an idea of the route but I'll be directing you throughout so don't worry about the sequence. It is important that once we start, we move as efficiently as possible and not get side-tracked during the evaluation.

The questions are about how the garment fits. As an example, I will be asking you whether you feel the coverall is "too tight", "too loose", or "fits quite well" across the shoulders. I'll be recording your answers here on my chart so you'll have to speak up in order for me to hear you through your respirator.

Do you understand what is expected or would you like to have a quick look at the equipment or ask any questions before we begin?

. . . then let's begin.

1. Action: donning and doffing coveralls

Directions

- Please sit down and take off your shoes (boots). Here is the first coverall.
- Pull on the pant legs and pull the elastic up to your knees to make it easier to pull on the boots. (While he is doing that, ask him what boot size he takes and place them in front of him.)
- Now, stand up facing me and pull the coveralls on.
- Before you zip it up, turn to the fence (pause until in place), take it off your shoulders again (pause) and then pull it back on.
- Okay, now turn to face me again and put on the hood. (Help him if he is taking too long or if he is having trouble with the tie but give him a chance to do it by himself first.)

Questions

Using the phrases, "too tight", "too loose" or "fits quite well", rate the coveralls as I prompt you.

	too tight	too loose	fits quite well
a) across the shoulders			
b) around the stomach			
c) across the hips			
d) around the upper arms			
e) around the thighs			
f) elastic on hood ___ check if no elastic			
g) elastic at the wrists			
h) elastic at the ankles			
i) the hood			

Using the phrases, "too short", "too long" or "fits quite well", rate the coveralls as I prompt you.

	too short	too long	fits quite well
j) body length Does it pull or sag in the crotch? (pull in crotch = too short sag in crotch = too long)			
k) leg length			
l) arm length			

m) Do you have any complaints about the zipper? yes____ no____

If yes, what is the problem? ______________________________

n) [If there is a tie.] Do you have any complaints about the tie on the hood?

yes___ no ___ If yes, what is the problem? _______________

____

<u>Directions</u>

Hand him the . . .

- . . . respirator (assist him)
- . . . goggles (assist him)
- . . . gloves (hand him the medium size first) Do they fit or do you need a smaller or larger pair?

2. Action: <u>stepping up onto the tractor</u>

Directions

- Please walk around to the other side of the tractor.
- Put one foot on the first step and hoist yourself up so that you are standing next to the seat and stop there while I ask you questions.

Questions

Using the phrases, "too tight", "too loose" or "fits quite well", rate the coveralls as I prompt you.

	too tight	too loose	fits quite well
a) across the shoulders			
d) around the upper arms			
e) around the thighs			

Using the phrases, "too short", "too long" or "fits quite well", rate the coveralls as I prompt you.

	too short	too long	fits quite well
j) body length Does it pull or sag in the crotch? (pull in crotch = too short sag in crotch = too long)			

3. Action: <u>sitting in tractor seat and turning to see sprayer</u>

Directions
- Now, manoeuver yourself into the tractor seat.
- Put your left hand on the steering wheel and keep it there.
- Turn to your right and put your right hand on the sprayer controls while keeping your left hand on the wheel.
- Stay in that position while I ask you questions.
  [Walk around to stand beside the PTO.]

Questions
Using the phrases, "too tight", "too loose" or "fits quite well", rate the coveralls as I prompt you.

	too tight	too loose	fits quite well
a) across the shoulders			
b) around the stomach			
c) across the hips			
d) around the upper arms			
e) around the thighs			
i) the hood			

Using the phrases, "too short", "too long" or "fits quite well", rate the coveralls as I prompt you.

	too short	too long	fits quite well
j) body length Does it pull or sag in the crotch? (pull in crotch = too short sag in crotch = too long)			

4. Action: <u>walking to end of boom and crouching next to nozzle</u>

<u>Directions</u>

- [Interviewer lead.] Climb down from the tractor and walk over to the end of the boom and stand by the chalked-in footprints #1.
- Squat down as you would to look at the nozzle.
- Now, stand up and repeat this on the second set of footprints (#2) and examine it from both sides.
- Please stay where you are (in the squatting position) while I ask you the questions.

<u>Questions</u>

Using the phrases, "too tight", "too loose" or "fits quite well", rate the coveralls as I prompt you.

	too tight	too loose	fits quite well
a) across the shoulders			
b) around the stomach			
c) across the hips			
d) around the upper arms			
e) around the thighs			
i) the hood			

Using the phrases, "too short", "too long" or "fits quite well", rate the coveralls as I prompt you.

	too short	too long	fits quite well
j) body length Does it pull or sag in the crotch? (pull in crotch = too short sag in crotch = too long)			

5. Action: <u>reaching up to the boom</u>

Directions

- Stand up and walk over to the raised boom where footprints #3 are.
- Reach up and handle the nozzle.
- Hold this position while I ask you the questions once more.

Questions

Using the phrases, "too tight", "too loose" or "fits quite well", rate the coveralls as I prompt you.

	too tigh	too loose	fits quite well
a) across the shoulders			
b) around the stomach			
d) around the upper arms			
f) around elastic on hood ___ check if no elastic			

Using the phrases, "too short", "too long" or "fits quite well", rate the coveralls as I prompt you.

	too short	too long	fits quite well
j) body length Does it pull or sag in the crotch? (pull in crotch = too short sag in crotch = too long)			
l) length			

6. Action: <u>reaching up over tank</u>

<u>Directions</u>

- Now go over to the tank.
- Take off the lid and look inside.

<u>Question</u>

Do you notice any difference in the fit from the last action you did? ____ no ____ yes

If yes, specify____

____

Please meet me back where we started.

Now I have a few general questions I would like to ask you.

7. Did you find that the hood obstructed your vision in any way? ____ yes ____ no

8. Did you find the elastic on the wrist . . .
_____ too tight, _____ too loose or _____ fit you quite well"?

9. Please tell me what you liked about these coveralls.

1) ______________________________

Anything else?
2) ______________________________

10. . . . and what you disliked about these coveralls.

1) ______________________________

Anything else?
2) ______________________________

11. Now that you have had a chance to wear these coveralls around the machinery, I'd like you to rate their overall general comfort. On a scale of one to seven, with one being comfortable, seven being uncomfortable, and four being neutral, how would you rate their comfort? Place a check mark on one of the seven points.
[Hand clip board and [illegible] to volunteer to place the check.]

extremely comfortable _____:_____:_____:_____:_____:_____:_____ extremely uncomfortable
(1) (2) (3) (4) (5) (6) (7)

12. If available for $10 or less, would you consider buying these disposable coveralls for use while applying pesticides.
_______ yes _______ no

To say to subject only after first coverall evaluation is completed: Now we will go through the same process with the second coverall.

APPENDIX E

General Questionnaire

I.D. #: ____________

GENERAL QUESTIONNAIRE

Instructions:

Most of the following questions require the use of a seven-point rating scale. Where indicated, place a check mark ( ) on the space which best describes your opinion. Be sure to answer all items and ensure the check marks are placed in the middle of the space provided.

An example:

If you think the rain fall last year was quite low, you would fill out the following scale as follows:

extremely high ____:____:____:____:____:__✓__:____ extremely low

---

1. a) Providing better protection from pesticides is:

   good ____:____:____:____:____:____:____ bad

   b) Feeling hot is:

   pleasant ____:____:____:____:____:____:____ unpleasant

   c) Feeling wet from perspiration is:

   pleasant ____:____:____:____:____:____:____ unpleasant

   d) Restricting my mobility while working is:

   good ____:____:____:____:____:____:____ bad

   e) Spending a lot of money on work coveralls is:

   good ____:____:____:____:____:____:____ bad

   f) Eliminating the need to launder contaminated work coveralls is:

   good ____:____:____:____:____:____:____ bad

2. Wearing a disposable protective coverall while I apply pesticides is

a) a good idea ____:____:____:____:____:____:____ a bad idea

b) unnecessary ____:____:____:____:____:____:____ necessary

c) sensible ____:____:____:____:____:____:____ foolish

d) unpleasant ____:____:____:____:____:____:____ pleasant

3. Wearing a disposable protective coverall provides the best protection from pesticides.

strongly agree ____:____:____:____:____:____:____ strongly disagree

4. Wearing disposable protective coveralls will make me feel wet from perspiration.

strongly agree ____:____:____:____:____:____:____ strongly disagree

5. I will be prevented from moving freely while working if I wear disposable protective coveralls.

strongly agree ____:____:____:____:____:____:____ strongly disagree

6. Wearing disposable protective coveralls will make me feel hot.

strongly agree ____:____:____:____:____:____:____ strongly disagree

7. Buying disposable protective coveralls will mean spending a lot of money.

strongly agree ____:____:____:____:____:____:____ strongly disagree

8. Wearing disposable protective coveralls means I do not need to take special care of my pesticide contaminated work clothes.

strongly agree ____:____:____:____:____:____:____ strongly disagree

9. While applying pesticides, I usually wear the following:

_____ jeans/pants and shirt
_____ jeans/pants and sweat shirt
_____ jeans/pants and t-shirt
_____ regular work coveralls
_____ goggles
_____ respirator
_____ rubber gloves
_____ disposable coveralls
_____ other (please specify) ____________________

10. I spray the following field crops with pesticides:

_____ grain corn
_____ oats
_____ barley
_____ soybeans
_____ sweet corn
_____ potatoes
_____ wheat
_____ other (please specify) ____________________

11. The total acreage sprayed on my farm is:

_____ under 50
_____ 50 - 99
_____ 100 - 199
_____ 200 - 299
_____ 300 - 399
_____ 400 - 499
_____ 500 - 999
_____ 1,000 - 1,999
_____ 2,000 and over

12. My age falls into the following age group:

_____ under 25
_____ 25 - 34
_____ 35 - 44
_____ 45 - 54
_____ 55 - 64
_____ 65 and over

After completing this questionnaire, please hand it to your interviewer.

Thank you for taking the time to participate in our study.

APPENDIX F

Comparative Measurement Chart of the Three Designs

based on
Canadian Government Specifications Board Standards for:
Coveralls, Men's Industrial, Dimensions
(CGSB, 1972)

COVERALL MEASUREMENTS IN CENTIMETERS
(inches in brackets)

Garment Measurements	Styles		
	Raglan	Sq. Armhole	T-Design
Chest	125.00 (49 1/4)	125.00 (49 1/4)	125.00 (49 1/4)
Waist (with elastic pulled)	125.00 (49 1/4)	125.00 (49 1/4)	125.00 (49 1/4)
Waist (with elastic at rest)	97.00 (38 1/8)	100.00 (39 3/8)	96.00 (37 3/4)
Seat	127.00 (50)	127.00 (50)	123.00 (48 1/2)
Wrist to wrist across back	178.00 (70)	186.00 (73 1/4)	179.00 (70 1/2)
Wrist to waist	88.00 (34 5/8)	74.50 (29 1/4)	90.00 (35 1/2)
Trunk	194.00 (76 3/8)	194.00 (76 3/8)	196.00 (77 1/8)
Armhole circumference	69.00 (27)	61.00 (24)	42.00 (16 1/2)
Sleeve length	64.50 (25 3/8)	52.00 (20 1/2)	54.50 (21 1/2)
Sleeve aperture	32.00 (12 1/2)	32.00 (12 1/2)	32.00 (12 1/2)
Leg inseam	87.00 (34 1/4)	87.00 (34 1/4)	72.50 (28 1/2)
Leg aperture	56.00 (22)	56.00 (22)	51.00 (20)
Hood length	41.00 (16 1/8)	-- --	35.00 (13 3/4)
Hood aperture	69.00 (27 1/8)	77.00 (30 1/4)	70.00 (27 1/2)

METHOD OF MEASURING COVERALLS
(for preceding chart, Appendix F)

The following method of measuring was based on standards for men's industrial coveralls (CGSB, 1972). As the three designs differ from that specified as standard for industrial coveralls, some measurements were omitted and others adapted. All measurements were taken with coveralls placed on a flat surface.

Chest: Twice the distance across the closed coveral at chest level.

Waist: Two measurements were taken: 1) Twice the distance across the closed coveralls along elastic level with the elastic pulled so that the coverall lies flat and, 2) Twice the distance across the closed coveralls along elastic level with elastic at rest.

Seat: Twice the distance across the coveralls measured at a position 11 cm (4 3/8) up from crotch point.

Wrist to wrist across back: Twice the distance across the coveralls from centre back to sleeve edge. This measurement replaces the back width measurement of the CGSB standards as the styles do not have a common sleeve design. The internal measurements of the inverted box pleat at centre back on the square armhole style are also included.

Wrist to waist: The distance from wrist edge along underarm seam to waist at elastic.

Trunk: Twice the distance from the fold of the shoulder at the neck seam to the fold of the crotch, measured with crotch fully extended. Both the raglan and square armhole designs are measured with elastic pulled so that fabric lies flat.

Armhole circumference: Twice the distance from the underarm point to a point perpendicular to the overarm fold line.

Sleeve length: The distance from the underarm point (base of the armhole) to the bottom of the sleeve measured along the underarm seam.

Sleeve aperture: Twice the distance across the end of the sleeve with elastic pulled so that sleeve lies flat.

Leg inseam: The distance from the crotch seam along the leg seam to the bottom edge of the leg.

Leg aperture: Twice the distance across the end of the leg with elastic pulled so that fabric lies flat.

Hood length: The distance from neck edge to the top fold at a position half way across the hood (an approximate point where shoulder seam would be). The length of the separate hood of the square armhole design was not measured as there is no neck edge from where to measure.

Hood aperture: Twice the distance from top of zipper to top fold of hood. The T-design is measured with elastic pulled so that hood lies flat.