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Limited-Use Chemical Protective Clothing for EPA Superfund Activities

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LIMITED-USE CHEMICAL PROTECTIVE CLOTHING FOR EPA SUPERFUND ACTIVITIES

by

Jack C. Sawicki, Carla Mond, and Arthur D. Schwope
Arthur D. Little, Inc.
Cambridge, MA 02140-2390

and

Susan Watkins
Dept. of Design and Environmental Science
Cornell University
Ithaca, NY 14853-4401

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Project Officer

Michael Gruenfeld
Releases Control Branch
Superfund Technology Demonstration Division
Risk Reduction Engineering Laboratory
U.S. Environmental Protection Agency
Edison, NJ 08837-3679

RISK REDUCTION ENGINEERING LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OH 45268

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, threaten both public health and the environment. The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

This study was undertaken to better understand the limitations and potentials of limited-use chemical protective clothing used in Superfund activities. The findings are directly applicable to pesticides and toxic substance operations.

E. Timothy Oppelt, Director
Risk Reduction Engineering Laboratory

ABSTRACT

Because contractor field personnel complained about the poor durability and fit of limited-use chemical protective clothing (CPC) most commonly used at hazardous waste site operations, the U.S. Environmental Protection Agency (EPA) initiated a study to

- characterize use of CPC
- determine problems encountered
- develop solutions to problems, and
- communicate results in publications and procurement guidelines.

Personnel at two Superfund hazardous waste sites were surveyed about CPC problems. Poor fit of coveralls and lack of fabric durability resulted in garment failures, especially in the seat, crotch, and underarms. Some fabrics were identified that provided improved performance.

The commercial market was surveyed, and commercial fabrics for limited-use CPC were identified and obtained. In addition, two experimental fabrics were obtained. All available fabrics were tested for breaking strength and flexibility. Based on these tests and the field survey, acceptable minimum values for breaking strengths of coated and uncoated fabrics and acceptable maximum values for stiffness were determined. One of the experimental fabrics, DuPont Tyvek® 1445 coated with polyethylene, was found to be especially promising when compared with these values.

Available standards and specifications describing size and fit parameters for limited-use CPC were identified and reviewed relative to EPA Superfund CPC needs. None of the standards were found to be fully acceptable. American National Standards Institute (ANSI) Standard 101-1985, however, provided a satisfactory baseline for further standards development. Problems with CPC were analyzed and suggested changes to ANSI 101 were developed as a proposed procurement guideline. This information was presented to the Industrial Safety Equipment Association, which developed the ANSI standard.

This report was submitted in fulfillment of Contract 68-03-3293, Work Assignment 3-60.1, by Arthur D. Little, Inc., under sponsorship of the U.S. Environmental Protection Agency. This report covers the period from September 1988 through September 1989.

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ACKNOWLEDGMENT

The authors would like to acknowledge the Engineered Nonwoven Structures Division, DuPont Co., Inc., Durafab, Inc., and Kappler, Inc., for their assistance.

SECTION 1

INTRODUCTION

With the promulgation of the Resource Conservation and Recovery Act of 1976 (RCRA), the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA, A.K.A. "Superfund"), and the Superfund Amendment and Reauthorization Act of 1986 (SARA), the Environmental Protection Agency (EPA) has been tasked with the lead responsibility for management of hazardous substances/hazardous waste (HS/HW) mitigation activities in the United States and its territories. The EPA has been involved in thousands of HS/HW actions since 1980.

HS/HW include gases, liquids, and solids that may be flammable, reactive, corrosive, or toxic. In many cases, the composition of the waste or substance is unknown. Furthermore, the waste or substance may present multiple hazards.

Consequently, personnel involved in HS/HW mitigation activities are potentially at risk. To address these risks to personnel, the Occupational Safety and Health Administration (OSHA) promulgated 29 CFR 1910.120, Hazardous Waste Operations and Emergency Response in 1988. This regulation, based largely on the EPA manual Health and Safety Requirements for Employees Engaged in Field Activities, requires special training, supervision, procedures and personal protective equipment (PPE) to be provided to workers involved in HS/HW activities.

In EPA operations, the determination of the appropriate PPE to be utilized for each operation is the responsibility of the on-scene coordinator (OSC) and the site safety officer (SSO). To assist such personnel in making these critical decisions, the EPA has sponsored research into various aspects of PPE. This study focuses on chemical protective clothing (CPC) that is designed to be discarded after becoming contaminated or a few uses, known as limited-use CPC.

While strictly speaking, any CPC must be considered disposable in cases where effective decontamination is impossible, CPC priced up to approximately $100 is generally termed "limited-use" by the HS/HW community, and this value was used as a guide for selecting the clothing evaluated in this study.

It is estimated from interviews with OSCs that nearly all EPA hazardous waste operations use CPC consisting of a coverall constructed of a coated fabric, with approximately

90% costing less than $20, and most of the balance costing from $20 to $100. Less than 1% of EPA operations appear to require the use of CPC costing in excess of $100; these are almost exclusively Level A suits used for emergency response applications.

PURPOSE

The purposes of this study were to:

- identify and characterize representative usage of limited-use CPC by the EPA and its contractors who are responsible for investigation and mitigation of HS/HW;
- identify and document the problems with limited-use clothing experienced by on-site personnel;
- hypothesize and investigate solutions to these problems; and
- communicate solutions to the HS/HW community through publication of the results and promulgation of a guideline document to be utilized in procurement applications.

It is anticipated that this study will result in safer and more efficient HS/HW operations for the EPA.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

Improvements described for both fabrics and coverall sizing are considered a starting point for continuing efforts to provide improved protective clothing for EPA hazardous waste workers. It is hoped that this study will give direction for manufacturers both to improve current products and develop new products that provide superior performance.

This study has resulted in the production of a new fabric, DuPont Tyvek 1445/PE, that appears to have improved physical performance over those Tyvek materials previously utilized for limited-use garments. In addition to DuPont, many other manufacturers are currently continuing research and development in this area, and it is hoped that a commercial fabric with similar or better physical characteristics will result. Identification of other new fabrics that provide better performance, including enhanced chemical resistance and increased breaking strength, is promising. However, the increased stiffness of these fabrics over those currently considered acceptable requires further evaluation to determine the compatibility with field work assignments. Interviews clearly demonstrated the importance of human factors in the selection of protective clothing by field personnel.

The data developed has been presented to the Industrial Safety Equipment Association (ISEA) committee responsible for ANSI 101. It is hoped that the information will be useful in the current efforts to revise and upgrade the standard.

During this study, several questions were identified which could not be readily answered.

One was the role of fabrics which provide various degrees of liquid and vapor resistance (especially uncoated nonwovens such as Tyvek and Kleenguard) in providing effective protection from chemicals. Another was the protection provided by seams and closures of various types to similar threats. While it can be assumed that coated fabrics, baffled closures, and sealed seams provide superior protection, the level of acceptable protection has not been defined. Evaluation of various fabrics and designs using available spray and liquid resistance test methods is certainly indicated.

Another area where little is currently known is flame resistance. Many EPA waste sites contain solvents and petroleum products that are flammable or combustible, yet most limited-use fabrics are not considered flame resistant. While proposed NFPA standards address flame resistance for fire fighters emergency response operations, identification of test methods appropriate for EPA operations has not yet been done. Again, additional research is indicated.

Effective transfer of information regarding protective clothing is another area which should be addressed. Many OSCs and SSOs noted that current 40 hour courses that are utilized to fulfill requirements of 29 CFR 19101.120 do not provide up-to-date information regarding personal protective equipment. One OSC suggested that a "hotline" should be established for EPA activities to provide state-of-the-art information regarding protective clothing and equipment selection and use.

While many questions remain regarding limited-use protective clothing, one point was made very clear during the field investigations. Workers at EPA hazardous waste activities utilize limited-use protective clothing for protection from many potentially dangerous chemicals that can cause severe injury--or even death--upon exposure. It is critical that these workers are provided clothing that they can rely on to provide effective protection.

SECTION 3

FIELD EXPERIENCE WITH LIMITED-USE CPC

BACKGROUND

Problems being encountered with limited-use CPC were identified at an EPA workshop on PPE held for OSCs at Edison, New Jersey in 1986. OSCs commented that failures of limited-use CPC were common at EPA operations. They reported that coveralls were tearing at stress points, such as the underarms, crotch, across the back, and at the neck and hood. Particular problems occurred with coveralls constructed of uncoated Tyvek[1] 1422 spunbonded polyolefin. Coveralls constructed of Tyvek 1422 coated with polyethylene (PE) or laminated to Saranex 23-P[2] were judged to be somewhat more durable, but were still not as tough as desired. It was noted that these coveralls were typically discarded after each shift or workday. At a 1989 PPE workshop, some OSCs reported that coveralls constructed of Kleenguard[3], another brand of nonwoven fabric, provided more acceptable durability than uncoated Tyvek 1422. However, Kleenguard is not available in coated form, and is thus considered unsuitable for those HS/HW applications where hazardous liquids are encountered.

The OSCs identified additional problems relating to coverall fit. In particular, with large persons, or when coveralls are worn over winter clothing or other PPE such as hard hats and cooling vests, binding occurred in the hood, chest, back, seat, armholes, and thighs, even with the largest available sizes of coveralls.

Because of these complaints, it was decided to do the following: (a) investigate the problems identified; (b) investigate limited-use CPC sizing and fabric durability; and (c) devise practical, cost-effective solutions that could be implemented to provide better protection to field personnel.

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1 Registered trademark of DuPont, Inc.

2 Registered trademark of Dow Chemical, Inc.

3 Registered trademark of Kimberly-Clark, Inc.

FIELD INVESTIGATION

Procedure

In order to better understand the problems faced by EPA field personnel, several EPA Superfund sites were visited. Hazardous waste mitigation workers at each site were asked to fill out a questionnaire regarding their experience with limited-use CPC. Information collected was evaluated to determine the extent and nature of the problems encountered with limited-use CPC.

Based on the experience with the questionnaire/interviewing process, a more structured questionnaire was developed and is recommended for similar information gathering activities in the future. The proposed questionnaire is presented in Appendix A.

Results

In general, most workers reported very similar experiences. The 24 survey forms returned indicated that: 100% of the workers had trouble with sizing and found their garments, including hoods, to fit poorly, and used duct tape to seal and/or tailor their garments; and 96% of the workers surveyed found that their garments tear frequently in the crotch, arms, and seat. However, most workers seemed unaware of the fabrics being utilized or available for use, the manufacturers or sizes of their garments, the costs of purchase or disposal or any other factors associated with their CPC. To gather more information, interviews were conducted with workers at two Superfund sites.

The first site visited was Seaway Boats, Inc., in Winthrop, Maine, a former boat yard which constructed fiberglass boats. On the day of the visit, air temperatures were between 0° and 10°F, and workers were wearing winter clothing (thermal underwear, flannel shirts, denim jeans, sweatshirts, and insulated coveralls) beneath their CPC. PPE in use was Level C, with coveralls with attached or separate hoods constructed of uncoated Tyvek 1422, from several different suppliers. Work being performed on the site included heavy equipment operation, soil removal, and overpacking of drums. Garment failures were observed during the site visit, including tears in stress areas at the crotch, buttocks, underarms, and back (Figures 1 and 2).

The garments were examined to determine the mode of failure. The tears consisted of separation of fabric, not seam failures (although one worker commented that Tyvek 1422/PE garments were prone to failure at the seams). Workers noted that the most common failures were in the crotch when coveralls were donned over safety shoes, which were worn except when actually in contaminated areas, when rubber boots were donned. Some coveralls in use on the site did not include hoods, which were purchased separately and duct taped to the garments. The reason given for this was that attached hoods were too small to don over hard hats and respirators. It was also noted that hoods with elastic edges were unacceptable, as they interfered with visibility and the fit of the respirator facepiece. Elastic cuffs on sleeves and legs were also undesirable due to difficulty in donning and doffing. Workers noted that

Figure 1. Limited-use coverall seat failure

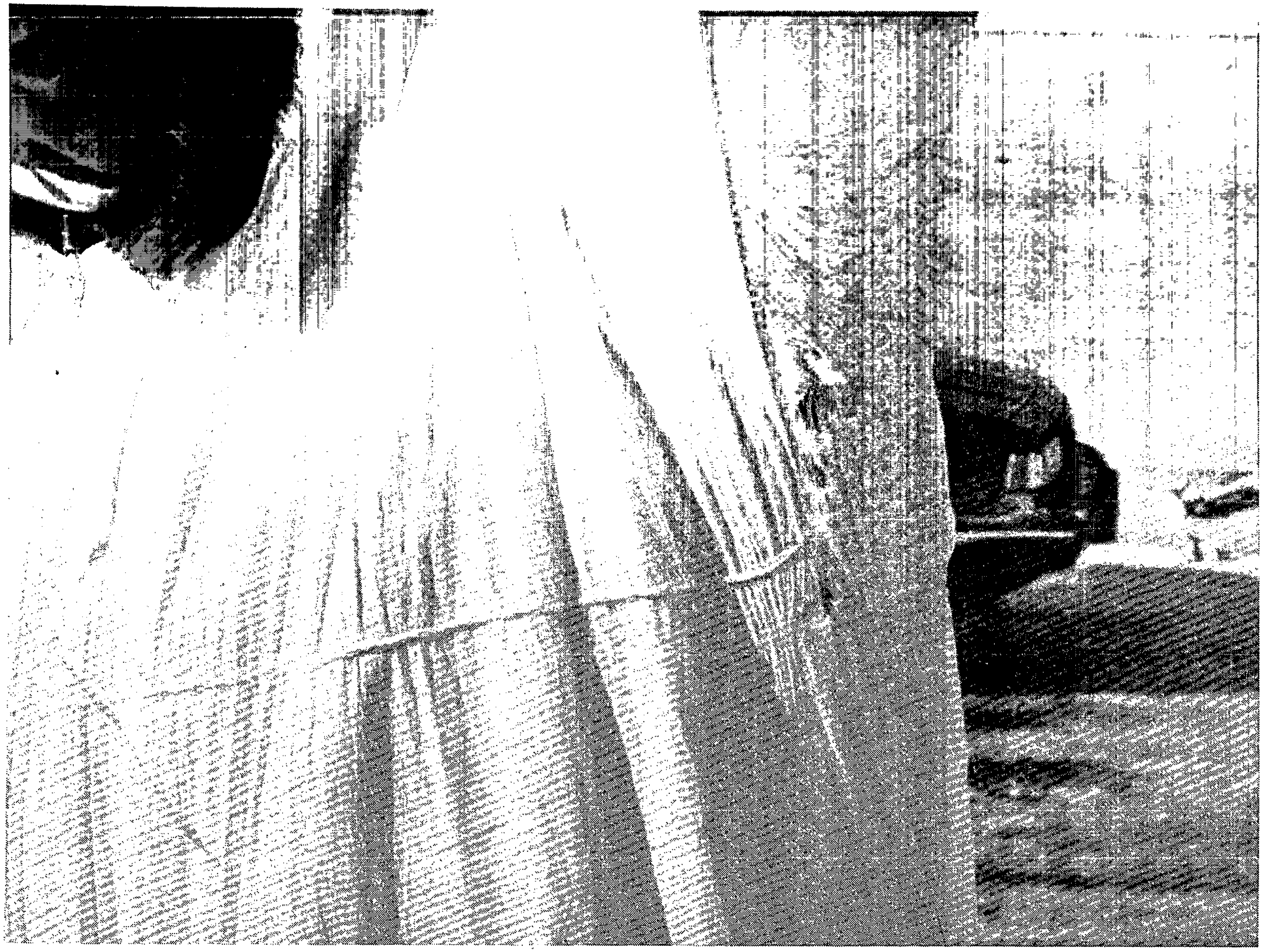

Figure 2. Limited-use coverall armpit failure

cuffs and ankles were usually cut to proper length and fastened with duct tape. Duct tape was also used to alter the fit of coveralls if sizes that were too large were issued.

Worker comments indicated that it is apparently a common practice to order only one size of coverall, usually extra- or extra-extra-large, and expect workers of all sizes to fit into it, using duct tape around the waist to adjust sizing. While several workers noted that this was acceptable (they would rather have garments too big than too small) others, particularly smaller persons, stated that this practice resulted in a very poor fit that interfered with ability to work and made it difficult to see the ground, thus creating a hazard. Many workers noted that the currently available coveralls were not sized properly between the body and the sleeves and legs to allow winter clothing to be worn, even if oversize garments were chosen. Larger workers, with large torsos or protruding abdomens complained that this was a particular problem for them, noting that there was inadequate room in the seat. One female worker noted that the bust in smaller coveralls was not sized properly for females.

The primary chemicals present on this site were epoxy resins and solvents, especially acetone. The manufacturer's product information for uncoated Tyvek 1422 does not recommend its use for protection from acetone or other solvents. Interviewees gave insights into their choice of fabric. One stated that they were almost always issued Tyvek 1422 garments, no matter what chemicals were present on a site (most of the workers generically referred to chemical protective clothing as "Tyveks"). One worker commented that he preferred Tyvek 1422 due to its greater comfort, which he attributed to its light weight and "breathability," when compared to coated fabrics. The site safety officer was questioned regarding the selection of CPC for use at the site. He indicated that Tyvek 1422 was utilized as he believed that the chance of contact with significant levels of solvent was low due to the characteristics of the site and the cold weather, and noted that workers were told to change clothing immediately if any contamination occurred. He stated that uncoated Tyvek worked well due to its flexibility and low bulk, and especially when larger sizes were rolled up and taped to fit. He further observed that coated fabrics were less adaptable to this practice due to lower flexibility and higher bulk.

The second Superfund site was on South Street in Walpole, Massachusetts. On the day of the visit, temperatures were between 30° and 40°F, and again workers were wearing winter clothing under their CPC. Garments constructed of Tyvek 1422/PE fabric were in use. Work being performed included drilling and sampling. No failures of the clothing were observed during the visit but workers commented that failures occurred with both Tyvek 1422/PE and Tyvek 1422/Saranex 23-P. The most common area of coverall failure was again the crotch, when coveralls were donned while wearing safety shoes. Comments regarding poor fit were made, with larger workers again having more problems, particularly with binding in sleeves and legs when garments were worn over winter clothing. Sizes available on the site included both large and extra-large. Tailoring was accomplished with duct tape, although the OSC noted that this took a lot of time to do properly and "was a real pain". One worker stated that when oversize garments were tailored with tape, squatting and kneeling caused the leg inseams to tear when moving. Several workers commented that metal zippers on some coveralls jammed repeatedly and constituted a real hazard, as the garments could not be doffed quickly if required due to chemical splash or fire.

Telephone interviews were also conducted with two EPA OSCs and several OSCs and SSOs for EPA contractors. In general, these interviews amplified the comments made during the site visits.

An EPA OSC with extensive emergency response experience, particularly at transportation incidents, noted that the newer limited-use fabrics such as Barricade[4], Responder[5], and Chemrel Max[6] were creating a new type of CPC consisting of a fully encapsulated disposable suit that was not operated under positive pressure; he believed that these garments should be termed encapsulating Level B, rather than Level A. These new materials were also available in Level B and Level C coveralls. He stated that these new fabrics were much stiffer than Tyvek-based fabrics and could not be tailored with duct tape, and thus required more sizes to adequately fit personnel.

The same OSC also noted that Sijal Chemtex[7], a coated, woven fabric, provided superior field durability, although it was heavier and less comfortable than the coated nonwoven fabrics. He stated that Chemtex coveralls were routinely cleaned and reused. These garments were also too heavy and bulky to tailor with duct tape. He stated that what was required was a fabric that was as light and flexible as uncoated Tyvek 1422, but which was as durable as Chemtex.

An OSC stated that he used a policy similar to that practiced at the Seaway site. Uncoated Tyvek 1422 coveralls were sometimes worn even when not a recommended application for this fabric, and workers were required to change them immediately if contamination occurred. He noted that this was the only way he could do required work in the tropical climate where his last site was located (Puerto Rico) due to problems with heat stress associated with coated fabrics.

An EPA contractor SSO commented that he utilized uncoated fabrics (Tyvek 1422 and Kleenguard) only for applications where contaminated soil and dust were the main hazard, and noted good results with Tyvek 1422/PE for aqueous chemicals and Tyvek 1422/Saranex 23-P for oil-based toxic materials (such as PCBs) and for non-flammable solvents. For strong acids and bases he preferred Chemtex coveralls, decontaminating them daily and discarding after each job. Noting that no coated limited-use garments are flame resistant, he utilized

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[4] Proprietary product of DuPont, Inc.

[5] Proprietary product of Lifeguard, Inc.

[6] Proprietary product of Chemron, Inc.

[7] Registered trademark of Bata, Inc.

PVC or neoprene-coated garments for flammable materials due to their relative flame resistance, even if not recommended for the chemicals involved.

Discussion

The survey findings indicate considerable problems with limited-use garments utilized in the field in the area of durability. Complaints regarding tearing are most often directed at uncoated Tyvek 1422, but were also registered for coated, nonwoven fabrics.

The survey also indicates a common discontent with the fit of limited-use coveralls. Almost all workers surveyed found fit problems that they believe interfere with their safety, productivity, or comfort. In part this situation is due to the common practice of stocking only one or two sizes. However, the survey findings also suggest that the current sizing in the industry is inadequate, especially in ease in leg and sleeve holes.

Cost is a very significant factor in the selection of fabrics and garments. As noted previously, most garments now utilized in EPA activities cost less than $20. The evidence collected in this study suggests that $40 suits are reused routinely, thus there appears to be a price point somewhere between $20 and $40 above which disposal after use is prohibitive and discouraged in actual practice. Consequently, improvements to limited-use coveralls that increase costs above this price range may be resisted. However, consistent complaints of fabric failures during routine use require that more durable materials be identified or developed.

SECTION 4

LABORATORY INVESTIGATION

Due to the problems with both fit and durability noted in the field investigation, limited-use fabrics and coveralls were obtained for evaluation in the laboratory.

PROCEDURE

Physical properties of fabrics are related to both durability and comfort. Durability is critical to the safety as well as the usefulness of CPC worn while performing such arduous tasks as sampling, drum handling, spill cleanup, and heavy equipment operation, as fabric failure could directly expose the wearer to hazardous chemicals. A basic measure of fabric durability is breaking strength. Failures in fabrics at EPA sites showed breaks nearly identical to those that occur with standard textile breaking strength tests. For this reason, breaking strength was selected for measurement in laboratory evaluations. Since increasing breaking strength generally requires increases in weight and stiffness which are detrimental to comfort and ease of motion, these physical properties were also examined. Twenty fabrics meeting the cost requirement defined for limited-use garments (i.e., approximately $100 or less) were selected and are listed in Table 1.

RESULTS

Fabrics that could be obtained were tested for breaking strength and flexibility using American Society for Testing and Materials (ASTM) methods (Table 2). The results of these tests are presented in Table 3.

The uncoated fabrics (Kleenguard, Tyvek 1422, Enhance) were the lightest in weight, ranging from 1.24 to 1.88 ounces/square yard. Coated fabrics constructed of nonwoven fabrics ranged from 2.14 ounces/square yard for Tyvek 1422/PE, to 8.23 ounces/square yard for Responder. Woven fabrics were heavier; for example, Chemtex weighed 9.52 ounces/square yard. Field data suggested that lighter fabrics were preferred to heavier fabrics, but as workers had little experience with the intermediate weight fabrics (those greater than 3.6 but less than 9.52 ounces/square yard) conclusions regarding the maximum acceptable weight of fabrics were impossible to make. However, workers considered the heavier woven fabrics significantly more uncomfortable than the lightweight nonwoven fabrics.

TABLE 1. LIMITED-USE CHEMICAL PROTECTIVE CLOTHING FABRICS

Fabric/Garment	Manufacturer	Composition	Price, $*
Tyvek 1422	DuPont	Polyethylene (PE) nonwoven (NW)	5-10
Kleenguard LU	Kimberly-Clark	Polypropylene (PP) NW	5-10
Kleenguard	Kimberly-Clark	PP NW	5-10
Enhance	Abandaco	PE NW	5-10
Tyvek 1422/PE	DuPont	PE NW/PE coating	10-15
Tyvek 1443**/PE	DuPont	PE NW/PE coating	10-15
Tyvek 1445**/PE	DuPont	PE NW/PE coating	10-15
Encase II	Abandaco	PP NW/PE coating	10-15
Chemtuff	Chemron	Proprietary, coated NW	15-20
PP/Saranex 23-P	Abandaco	PP NW/Saranex 23-P film	15-20
Tyvek 1422/ Saranex 23-P	DuPont	PE NW/Saranex 23-P film	15-20
Chemrel	Chemron	Proprietary, coated NW	30-40
Barricade	DuPont	Proprietary, coated NW	40-50
Chemrel Max	Chemron	Proprietary, coated NW	40-50
Greengard	Mine Safety Appliance	Woven nylon-polyvinyl chloride (PVC) coating	40-50
Chemgard	Rainfair	Woven nylon/PVC coating	40-50
Chemtex	Bata-Sijal	Woven nylon/PVC coating	40-50
Neonyl	Rainfair	Woven nylon/neoprene coating	50-50
Responder	Lifeguard	Proprietary, coated NW	60-70
Blue Max	Mine Safety Appliance	Proprietary, coated NW	60-70

* Approximate price of Level C coverall with hood.

** Experimental fabric provided by DuPont.

TABLE 2. STANDARD TEST METHODS FOR EVALUATING CHEMICAL PROTECTIVE CLOTHING FABRICS

Test Number	Test
ASTM* D 1682	Breaking Load and Elongation of Textile Fibers
ASTM D 1388	Stiffness of Textile Fabrics
ASTM D 3776	Mass per Unit Area of Textile Fabrics

* American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103

TABLE 3. PHYSICAL CHARACTERISTICS OF LIMITED-USE CHEMICAL PROTECTIVE CLOTHING FABRICS

Fabric	Weight* (SD++)	Breaking Strength** (SD, SD)	Bending Length+ (SD, SD)
Uncoated Nonwovens			
Enhance	1.88 (0.2)	9.5 x 9.8 (0.9, 0.9)	1.7 x 2.15 (0.15, 0.1)
Kleenguard	1.85 (0.1)	9.8 x 12.2 (0.7, 1.2)	1.65 x 1.6 (0.05, 0.05)
Kleenguard LU		Sample not received	
Tyvek 1422	1.24 (0.15)	5.2 x 7.5 (0.2, 0.6)	1.15 x 1.3 (0.05, 0.05)
Coated/Laminated Nonwovens			
Barricade	6.39 (0.45)	24.9 x 31.4 (6.1, 4.0)	5.95 x 4.2 (0.35, 0.2)
Blue Max		Received insufficient sample for testing	
Chemrel	4.08 (0.45)	27.6 x 15.0 (1.1, 1.0)	5.2 x 3.3 (0.6, 0.2)
Chemrel Max	5.19 (0.6)	44.9 x 33.1 (3.1, 5.5)	>10.0† x 3.0‡ (NA, 1.0)
Chemtuff	3.60 (0.35)	41.6 x 51.2 (2.9, 4.7)	5.2 x 4.5 (1.35, 1.4)
Encase II	2.33 (0.3)	11.1 x 13.8 (2.0, 2.4)	1.1 x 1.65 (0.2, 0.15)
Greenguard		Sample not received	
PP/Saranex 23-P	3.53 (0.25)	16.0 x 10.1 (1.7, 1.9)	1.85 x 1.85 (0.1, 0.15)
Responder	8.23 (0.9)	40.3 x 34.8 (4.9, 4.4)	4.5 x 4.35 (0.4, 0.35)
Tyvek/Saranex 23-P	3.60 (0.2)	13.6 x 13.6 (1.5, 1.4)	1.85 x 2.2 (0.2, 0.25)
Tyvek 1422/PE	2.14 (0.15)	11.7 x 12.5 (1.8, 1.1)	1.65 x 1.80 (0.25, 0.25)

(continued)

TABLE 3 (Continued)

Fabric	Weight* (SD++)	Breaking Strength** (SD, SD)	Bending Length+ (SD, SD)
Tyvek 1443/PE	2.18 (0.2)	12.7 x 13.9 (1.2, 1.1)	1.75 x 1.90 (0.15, 0.3)
Tyvek 1445/PE	2.23 (0.25)	14.2 x 15.6 (1.2, 2.2)	1.85 x 2.1 (0.45, 0.3)
<u>Coated Wovens</u>			
Chemgard	10.40 (1.1)	115.8 x 91.7 (9.5, 5.9)	1.85 x 1.5 (0.1, 0.15)
Chemtex	9.52 (1.2)	61.2 x 70.0 (2.8, 9.3)	1.9 x 1.0 (0.1, 0.05)
Neonyl	15.19 (0.6)	130.4 x 104.13 (12.7, 9.0)	1.62 x 1.53 (0.2 x 0.1)

* ASTM D 3776, option C; ounces/square yard.

** ASTM D 1682, rate of extension, 5 inch/minute; pounds, direction A x direction B, where direction A is 90° to direction B.

\+ ASTM D 1388, option A; inches, direction A x direction B, where direction A is 90° to direction B.

++ Standard deviation, n=5.

† Samples curled upward through full range of apparatus.

‡ Samples curled downward without flexing.

Examination of laboratory breaking strength data for uncoated fabrics provides some explanations for the field preferences and performances. The fabric most commonly found to fail in the field, Tyvek 1422, showed the lowest breaking strength of any fabric tested, 5.2 x 7.5 pounds. (Fabric strength was measured with specimens cut at a 90°angle to one another, hence the convention of reporting the results as A x B.) Kleenguard, the other commonly utilized uncoated fabric, which was reputed to provide better durability, tested at 9.8 x 12.2 pounds. Enhance, which has not yet been widely used in the field had a breaking strength of 9.5 x 9.8 pounds.

The most commonly used coated fabric, Tyvek 1422/PE, had a breaking strength of 11.7 x 12.5 pounds, while the next most commonly used fabric, Tyvek 1422/Saranex 23-P, measured 13.6 x 13.6 pounds. Encase II, and the same polypropylene base fabric laminated to Saranex 23-P, measured 11.1 x 13.8 pounds, and 10.1 x 16.0 pounds, respectively.

The experimental fabrics, Tyvek 1443/PE and Tyvek 1445/PE, showed higher breaking strengths of 12.7 x 13.9 and 14.2 x 15.6, respectively, compared to Tyvek 1422/PE.

The flexibility test selected uses relative bending performance as a means of comparison; more flexible fabrics show a lower bending length. The uncoated fabrics exhibited high flexibility, with bending lengths of 1.15 x 1.3 inches for Tyvek 1422, 1.6 x 1.65 inches for Kleenguard, and 1.7 x 2.15 inches for Enhance.

The coated fabrics showed a much wider range of flexibility, with bending lengths ranging from 1.65 inches for Encase II to over 10 inches for Chemrel Max. The most commonly utilized, Tyvek 1422/PE showed a bending length of 1.65 x 1.80 inches. The two experimental coated fabrics, Tyvek 1443/PE and 1445/PE, showed somewhat increased stiffness of 1.75 x 1.9 and 1.85 x 2.1 inches, respectively. The heavier Tyvek 1422/Saranex 23-P measured 1.85 x 2.2 inches.

The coated, woven fabrics, Chemtex, Chemgard[8], and Neonyl[8] exhibited breaking strengths ranging from 61.2 to 130.4 pounds. Compared to the coated nonwoven fabrics, the coated, woven fabrics are more flexible, with bending lengths ranging from 1.0 to 1.9 inches, but this is offset by their higher weight (9.52 to 15.19 ounces/square yard). These characteristics were noted in interviews with field personnel; in the words of one OSC, "It's heavy, but doesn't rip on every twig or nail."

DISCUSSION

While garments with greater flexibility are preferred by workers surveyed, limited experience with garments constructed of the stiffer fabrics makes it difficult to accurately determine acceptable flexibility parameters. However, examination of the laboratory data

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[8] Registered trademark of Rainfair, Inc.

suggest that the fabrics tested can be divided into two distinct categories: those with bending lengths of 2.2 inches or less; and those with bending length of 4.2 inches or greater. Since a lower bending length is indicative of a more flexible fabric, field personnel would be expected to prefer clothing of fabrics from within the first grouping.

There is not an overall correlation of stiffness with fabric weight. The lightest and the heaviest fabrics have similarly low stiffness. Among the fabrics based on nonwoven fabrics, however, those fabrics with weights under approximately 3.5 ounces per yard have bending lengths less than 2.2 inches and those fabrics over approximately 3.5 ounces per yard have bending lengths greater than 4.2 inches.

Relative to fabric weight, breaking strengths seem to be in three groups. Fabrics with weights less than approximately 3.5 ounces per yard have breaking strengths less than 20 pounds. The heavier nonwovens (i.e., from about 3.5 to 8.5 ounces per yard) have breaking strengths in the range of 20-45 pounds. Finally, the three woven fabric based materials, which are the heaviest, have strengths greater than 60 pounds, in two cases > 100 pounds.

It is tempting to conclude that fabrics selected for use should have the light weight and high flexibility found in the first grouping and the high strength found in the second, or as one OSC said: "give me something as light as Tyvek and as strong as Chemtex." It is apparent from the data, however, that none of the current nonwoven, limited-use fabrics possess these characteristics.

The production of the experimental Tyvek 1445/PE fabric demonstrates that approximately 30% greater strength can be achieved with an increase of less than 10% in weight and stiffness compared to the standard Tyvek 1442/PE. This suggests that additional fabric engineering, such as changes in machine speed or web construction, or substitution of a higher-strength polyethylene or polypropylene resin for the nonwoven base fabric, could increase strength, while minimizing increases in stiffness, weight, and cost. It is also possible that proper engineering of a lightweight knit base fabric (e.g., 15 denier nylon tricot) might allow construction of a coated fabric with improved performance.

SECTION 5

EVALUATION OF FIT AND SIZING

In response to the problems with fit identified in the field study, further investigation of garments and garment specifications and standards was performed.

EXISTING STANDARDS

Limited-use garments currently purchased by EPA are, in many cases, designed to meet the requirements of American National Standards Institute (ANSI) Standard 101-1985, Men's Limited-Use and Disposable Protective Coveralls-Size and Labeling Requirements.[9] This voluntary standard was developed by the Industrial Safety Equipment Association (ISEA) and is utilized by many of the major manufacturers to define minimum dimensions for coveralls.

ANSI 101 defines seven dimensions for five sizes: small through extra-extra-large. These dimensions and sizes are listed in Table 4.

TABLE 4. ANSI 101-1985 MINIMUM REQUIREMENTS

Size*	Chest	Leg Inseam	Sleeve Outseam	Body Length	Sleeve Opening	Leg Opening	Front Opening Length
Small	21½	27½	31½	35	6½	9½	29½
Medium	23½	28	32½	36	7	10	29½
Large	25½	29	33½	37	7	10	30
X-Large	27½	29½	35	38½	7	10	30½
XX-Large	29½	30	36½	39	7	10	31

* All dimensions in inches.

[9] American National Standards Institute, 1430 Broadway, New York, New York 10018.

Measurements for these dimensions are taken from the finished garment in the following manner:

- The chest is measured from one inch below the base of the armhole, across the chest from folded edge to folded edge.
- The leg inseam is measured from the center of the crotch seam, down the leg inseam, to the leg bottom.
- The sleeve outseam length is measured from the center back point to the top of the neckline at the center back point to the top edge of the sleeve hem.
- The body length is measured from the top of the neckline at the center back point to the crotch seam with the coveralls flat and front side up.
- The sleeve opening is measured from one folded edge to the other folded edge at the sleeve end with the sleeve flattened.
- The leg opening is measured from one folded edge to the other at the leg end with the leg flattened.
- The front opening length is measured from the center back point to the bottom of the front opening with the coverall flat and the front side up.

To determine the extent of compliance with this standard, 10, size large, coveralls were purchased from several manufacturers, including some of the manufacturers whose garments were encountered on EPA sites. Five Tyvek 1422 and five Tyvek/Saranex 23-P composed the sample. Each garment was measured according to ANSI 101. Results are given in Table 5. Only one of the commercial coveralls met or exceeded all the minimum dimensions specified in ANSI 101.

One Tyvek 1422/PE and one Tyvek 1422/Saranex 23-P coverall were measured multiple times to determine if there were significant variations in measuring technique. Results are presented in Table 6. The data indicate that, in the worse case, the standard deviations are only 2% of the average value.

Two military specifications for limited-use coveralls were identified: MIL-C 29133A, Coveralls, Disposable, General Purpose and MIL-C 87069A, Coveralls, Disposable. MIL-C 29133A is otherwise similar in design to commercial coveralls utilized by the EPA and one of the fabrics used by the military for this coverall is Tyvek 1422/PE. MIL-C 87069A was not analyzed as it does not have a front closure and is made of other types of fabrics. Examination of the size and measurement chart contained in MIL-C 29133 shows compliance with ANSI 101 in the listed dimensions. To determine actual concurrence of the military garments with all ANSI 101 requirements, a coverall was manufactured in accordance with MIL-C 29133A and was measured. Results are presented in Table 7.

TABLE 5. MEASUREMENTS OF TEN COMMERCIAL LIMITED-USE COVERALLS

Dimension	Minimum ANSI 101	Tyvek 1422 Manufacturer					Tyvek 1422/Saranex 23-P Manufacturer				
		1	2	3	4	5	1	2	3	4	5
Chest	25.5*	26.2	28.8	25.2	26.8	27.0	26.4	26.0	29.2	28.0	27.0
Leg inseam	29.0	29.0	30.2	27.0	29.2	29.2	26.5	28.5	30.2	27.0	28.5
Sleeve outseam	33.5	34.5	34.0	33.5	33.0	36.0	33.4	33.8	36.2	37.0	40.0
Body length	37.0	36.1	37.5	40.2	40.2	35.0	40.7	36.8	39.0	43.0	38.8
Sleeve opening	7.0	7.5	6.2	7.2	8.2	6.8	7.9	7.0	7.8	7.2	6.2
Leg opening	10.0	11.0	9.0	10.2	10.8	9.5	11.0	11.0	11.5	11.5	11.5
Front opening	30.0	29.8	28.0	29.8	30.8	28.0	28.9	30.0	30.2	26.5	29.5
Hood width	**	9.6	12.75	11.0	9.0	11.0	11.0	11.0	11.75	10.0	9.8
Hood length	**	14.7	14.0	15.3	15.0	14.75	15.2	15.5	14.5	15.5	15.5

* All measurements in inches.

** Not a requirement.

TABLE 6. REPRODUCIBILITY OF MEASUREMENTS OF TWO, COMMERCIAL, LIMITED-USE COVERALLS

Coverall	Chest	Leg Inseam	Sleeve Outseam	Body Length	Leg Opening	Sleeve Opening	Front Opening
Tyvek 1422	25.75*	29.00	33.50	37.50	6.50	10.00	32.00
	26.20	28.75	33.50	37.00	7.00	10.00	31.50
	26.00	28.25	33.25	36.75	7.00	10.00	30.75
	25.75	28.50	33.00	36.50	7.00	10.25	30.50
	25.50	28.50	33.25	36.00	7.00	10.00	30.25
Average	25.84	28.60	33.30	36.75	6.90	10.05	31.00
Standard Deviation	0.24	0.10	0.19	0.50	0.20	0.10	0.65
Tyvek 1422/	26.75	26.75	33.25	40.75	8.00	10.75	28.75
Saranex 23-P	26.50	26.50	33.25	40.50	7.50	11.00	28.75
	26.25	26.25	33.25	40.75	8.00	11.25	29.00
	26.25	26.50	33.50	40.75	8.00	11.00	29.00
	26.50	26.50	33.50	40.75	8.00	11.00	29.00
Average	26.45	26.50	33.35	40.70	7.90	11.00	28.90
Standard Deviation	0.19	0.16	0.12	0.10	0.20	0.16	0.12
ANSI 101 Minimum Requirement	25.50	29.00	33.50	37.00	7.00	10.00	30.00

* All measurements in inches.

TABLE 7. MEASUREMENTS OF MILITARY COVERALL (SIZE LARGE)

Coverall	Chest	Leg Inseam	Sleeve Outseam	Body Length	Sleeve Opening	Leg Opening	Front Opening
MIL-C-299B3A	27.00	35.00	35.00	37.25	7.50	10.00	26.50
ANSI 101 Minimum Requirement	25.50	29.00	33.50	37.00	7.00	10.00	30.00

These results indicate that with the exception of front opening length, the military coveralls meet the requirements of ANSI 101. Subsequent conversations with the manufacturer and the specification agency (U.S. Navy Clothing and Textile Research Facility) suggest that this military design is essentially equivalent to those commercial models now utilized by the EPA.

A General Services Administration (GSA) schedule for limited-use coveralls was identified. The May 1, 1989 Federal Supply Schedule (FSS) lists these items under Group 84, Part II, Section B, Class 8435. However, the GSA FSS does not include an actual specification, but rather vendors that are authorized as sources for government purchases of commercial coveralls. Not surprisingly, the vendors identified included those that were found to have supplied the garments that were examined in the field and laboratory studies.

The National Fire Protection Association (NFPA) is currently preparing a standard on certain limited-use coveralls to be used by firefighters during decontamination at emergency response operations. The scope of this standard, however, may not apply to EPA operations.

Because of the lack of definitive data suggesting that any available standards or specifications provide superior fitting coveralls compared to the currently available commercial garments constructed to meet ANSI 101, garment design was investigated to determine:

- the impact of sizing dimensions on the types of coverall failures encountered in the field.
- alternative sizing dimensions that could be utilized to minimize such failures.

ANSI 101 was used as a starting point for the investigation, with the hope that results could be useful in efforts to update the standard.

STANDARDS MODIFICATION

Since the field survey indicated that larger workers had difficulty fitting into currently available extra-extra-large coveralls, an expansion of the current five sizes to six sizes to address this problem was investigated. Changes in the measurement technique and definition of current sizing parameters were also considered, as described below.

In most clothing items, strain in the crotch area tends to be due to two actions: bending of the leg at the hip, causing the length of the buttocks to increase, and raising the arms, causing the length of the torso to increase. Adding additional clothing layers for winter wear would be equivalent to both of these actions. In addition, with coveralls, bending and climbing place considerable stress over the back of the hip. The field data suggest that insufficient back body length exists in present coverall designs. Since ANSI 101 specifies front body length but not back body length, the standards cannot define additional ease in the area where it is required. Since there is approximately a 45% increase in length directly over the buttocks when the hip is fully bent, additional length is required for back body length over front body length. ANSI 101 should be modified to include dimensions for back body length. Back body length should be measured from the top of the neckline at the center back collar seam to the crotch seam. Front body length should be measured from the top of the neckline at the center back point to the crotch seam with the coveralls flat and front side up.

Tearing under the arm may be related to inadequate back width and armhole width. Most coveralls do not allow enough width across the shoulder blades to allow for the full range of motion required for all work activities, from arms at sides, through arms fully outstretched forward, to arms extended fully overhead. Based on the field failures, the area in which width needs to be increased is midway between the current ANSI 101 chest measurement and the neckline, that is, the area over the shoulder blades. It is difficult to establish standard measurement procedures for the chest, however, because the landmarks for the measurement are different for each pattern style. For example, both raglan and set-in sleeves may be used, and even the slant of the raglan line may vary considerably. Thus, there is no alternative at present to using the base of the armhole as a reference point, even though it may not always accurately describe the area in question. Using the armhole itself is preferred to the current one inch below the armhole, as it is closer to the ideal. To allow for female bustlines and persons with larger chests, abdomens, or torsos, it is advantageous to specify requirements for both front and back dimensions. Based on these factors, and using the ANSI 101 chest width as a starting point, an increase in the difference between front and back width will increase range of motion. Additional back width will reduce garment stress associated with forward reach, and will assist in reducing stress in the underarm area. Adding additional width to the back will not interfere with movement except with very stiff fabrics. Front chest width should be measured from the base of the armhole across the front chest to the base of the other armhole. Back width should be measured from the base of the armhole across the back to the base of the other armhole, including all of the fullness that lies between these two points. If there is no underarm seam on either sleeve or body of coverall, lay the sleeve and body of coverall at an angle where both are flat and establish an underarm point at the juncture of the sleeve and torso.

The primary importance of armhole width is to allow room for garments worn underneath to fit in the coverall without placing stress on the underarm area. One of the key factors in this is the circumference of the armhole of the largest garments to be worn over the coverall. For example, a size large, cotton or cotton/polyester coverall (of the type favored by EPA workers) has a 26-inch external circumference. Assuming that an extra-large size limited-use coverall would be worn over this garment in winter, additional ease for this dimension is required. To determine armhole width, establish a line from the base of the armhole which is parallel to the center front. Measure up from the armhole base to the top of the sleeve with the coveralls stretched flat.

Improved sleeve outseam and leg inseam measurements are relatively easy to establish. Additional length increases the range of fit. To decrease costs, smaller sizes can use slightly smaller lengths. Sleeve outseam is measured from the center back point to the top of the sleeve at the wrist edge. Leg inseam is measured from the crotch seam down the leg inseam to the bottom edge.

Little problem with the size of the sleeve opening seems to exist with the current ANSI 101 requirement of seven inches, however, some gradation of sleeve opening over the sizes specified would serve to reduce bulk from hindering smaller sizes (generally persons with relatively small hands), and allow easier doffing for the larger persons. To measure sleeve opening, flatten sleeve at wrist end. Measure from one folded edge to the other.

Leg opening size represents more of a problem, as workers universally noted problems with crotch tear-out when donning and doffing coveralls over safety shoes. An increase in this dimension will provide a wider range of fit. As with sleeve openings, gradation of the leg opening over the size range is desirable. To measure leg opening, flatten leg at bottom and measure from one edge to the other.

While coverall front opening length is essential to allow easy donning and doffing, the current ANSI 101 requirement appears to be generally adequate. However, an increase in range will accommodate up-sizing. Front opening length is measured from the center back collar base to the bottom of the front opening with the coverall flat and front side up.

ANSI 101 does not currently include hood dimensions; however, hoods are considered desirable for EPA activities, and must fit when worn over hard hats. Communication with manufacturers indicates that most have not understood this requirement, and suggests that they are readily able to supply attached hoods that fit over hard hats. Measurement of hard hats as worn were taken to establish dimensions that should allow wearing the hat without raising the coverall on the shoulder or hindering the turning of the head. This requires a surprisingly large hood. To measure hood opening length, flatten the hood along the center seam so that the sides are superimposed. Measure on a flat vertical line that extends upward from the neckline seam to the highest point on the top of the hood. To measure hood depth, flatten the hood along the center seam so that the left and right sides are superimposed. Measure on a horizontal line from the center front (face) edge to the back of the hood at the point of greatest depth.

An associated dimension to allow full coverage of the neck when a respirator is worn, is the neckline length. This is also critical when winter clothing is worn. To measure neckline length, stretch neckline seam flat with the coverall facing up. Measure from one end of seam to the other.

Using the measurement dimensions and procedures discussed above, requirements were developed for six sizes of limited-use coveralls. These sizes include extra-small, small, medium, large, extra-large and extra-extra-large. The measurement values are presented in Table 8. The procedure for taking these measurements is summarized in Appendix B.

The six sizes developed add an additional size to current ANSI 101 requirements. In the new sizing system, extra-small and small have been optimized for females, medium represents a compromise for larger females and smaller than average males, large represents a slightly larger than average male, and extra-large and extra-extra-large are optimized for upper-percentile-size males. It is anticipated that extra-extra-large will fit a 95th percentile worker wearing typical temperate winter clothing. While the coveralls specified are upsized from the current standard, the dimensions of critical body fit areas have also been modified, so the current practice of selecting a larger size garment to allow for freedom of movement should no longer be required.

TABLE 8. PROPOSED MINIMUM FINISHED DIMENSIONS FOR LIMITED-USE COVERALLS

		Size					
	Dimension*	XS	S	M	L	XL	XXL
A.	BACK BODY LENGTH	38	39	40	41	42	43
B.	FRONT BODY LENGTH	33	34	35	36	38	40
C.	ARMHOLE WIDTH	12	13	13	14	14	15
D.	SLEEVE OUTSEAM	31	32	33	34	35	37
E.	SLEEVE OPENING	6	6	7	7	8	8
F.	FRONT CHEST	22	23	24	26	28	30
G.	BACK CHEST	23	24	26	29	32	34
H.	LEG INSEAM	28	29	30	31	32	33
I.	LEG OPENING	13	13	14	14	15	15
J.	FRONT OPENING LENGTH	29	30	30	30	31	32
K.	HOOD LENGTH	16	16	17	17	18	18
L.	HOOD DEPTH	11	12	12	13	13	14
M.	NECKLINE LENGTH	16	16	18	19	20	20

* All measurements in inches.

APPENDIX A

PROPOSED USER QUESTIONNAIRE FOR LIMITED-USE COVERALLS

INTRODUCTION

The purpose of this questionnaire is to obtain information on the nature and extent of problems experienced by individuals wearing limited-use coveralls. Please complete the following questions and add any comments you might have that would further describe your experiences while wearing these types of coveralls. Please check off as many responses as are appropriate for the multiple choice questions.

REGION ________________________	SITE NAME ____________________
AGE __________________________	GENDER _______________________
HEIGHT ________________________	WEIGHT _______________________
JOB DESCRIPTION _______________	YEARS ON JOB __________________
______________________________	DATE _________________________
______________________________	EMPLOYER _____________________

1. How often do you wear limited-use coveralls

   ______daily
   ______two or three times weekly
   ______weekly
   ______other

2. What size coverall do you wear in the winter?

______x small
______small
______medium
______large
______x large
______xx large
______xxx large

2.1 Do you wear the same size in the summer?

______yes
______no

2.2 If not, what size do you wear in the summer?

______x small
______small
______medium
______large
______x large
______xx large
______xxx large

3. What is the name of the manufacturer or brand of the garments you wear?

____

______unknown

3.1 Have you ever worn garments made by other manufacturers/brands?

______yes, name of manufacturers ____________________________________
______no

3.2 Why did you switch manufacturers?

______sizing was a problem
______garment frequently tore
______garment unavailable in a suitable range of sizes
______cost
______availability
______don't know (organization I work for makes decision)
______other ______________________________

3.3 How long have you been using this brand of coveralls?

____

4. What kinds of problems do you encounter when wearing uncoated limited-use coveralls?

______tearing and ripping
______excess material bulk
______restricted overhead reach
______restricted forward reach
______restricted kneeling
______restricted climbing
______discomfort from tight fit
______no problems experienced
______too hot in summer
______hard to put boots through legs

5. If you do not encounter problems with your coveralls, could you please offer your opinion as to why this is the case?

____
____
____
____

6. Do you use duct tape to tailor your coveralls?

______yes
______no

6.1 Where do you apply the duct tape?

______waist
______wrist
______ankles
______other ______________________________

7. Do you believe that using oversized garments and tailoring them with duct tape eliminates the occurrence of problems associated with tearing?

______yes
______no

8. How often do you change your coveralls each day?

______once
______twice
______not at all
______more often than twice a day, If so, how many? __________

9. How often do your coveralls rip?

______daily
______twice a day
______other ______________________________

10. When your coveralls rip, do you change them?

______immediately
______at your next convenient break
______not at all
______not at all, but you tape over the torn part

11. Do you have more problems with garments tearing during the winter?

______yes
______no

12. Do your coveralls have a hood attached to them?

_______yes
_______no

13. Does the hood adequately cover your head? In particular, does it fit over winter hats and hard hats?

_______yes
_______no

Additional comments

____

14. Have you found that the coveralls you wear currently have fewer problem s associated with the fit of the hoods?

_______yes
_______no

15. How are your coveralls procured?

____
____
____
____

16. How much do you pay for coveralls?

____
____
____
____

17. How are your coveralls disposed of?

____
____
____
____

APPENDIX B

PROPOSED LIMITED-USE COVERALL PROCUREMENT GUIDELINES

1. DEFINITIONS

Coverall. A garment, with a front closure extending from the crotch to the neck, designed to provide protection for the torso, neck and head (with the exception of the face), arms (with the exception of the wrists and hands), and legs (with the exception of the ankles and feet).

2. DESIGN. Coveralls shall meet the following requirements:

2.1 Sleeve and leg hems unhemmed such that they may be cut to correct length and taped to gloves and boots.

2.2 Front closure with full-length nylon- or polyester-coil zipper and pressure-sensitive tape-sealed splashflap that completely covers closure when fastened.

2.2.1 On garments constructed of coated fabric, seam affixing flap to coverall shall be sealed.

2.3 Hood with drawstring, fastened to the collar for its full length, and suitable for wear over a protective helmet with front brim and with a full-face respirator.

2.4 When hood and front closure are properly fastened the neck shall be completely covered to immediately beneath the chin.

3. FABRIC. Fabric shall meet the following requirements:

3.1 Breaking strength when tested in accordance with ASTM D 1682:

Uncoated fabrics: not less than 9.0 pounds
Coated fabrics: not less than 12.0 pounds

3.2 Stiffness when tested in accordance with ASTM D 1388-1975 of not more than 2.5 inches in any direction.

4. SEAMS. All seams shall meet the following requirements:

4.1 Breaking strength when tested in accordance with ASTM D 1683 of not less than 75% of the fabric breaking strength.

4.2 On garments constructed of coated fabrics, seams shall be bonded, heat-sealed, or sewn and taped.

4.3 Stitched with not less than 6 nor more than 10 stitches per inch.

5. SIZING. Coveralls shall be offered in not less than 6 sizes with minimum dimensions as described in Table B-1. Measurements for determining dimensions shall be made in accordance with Table B-2.

6. LABELING. All garments shall have a label attached or printed on the inside near the collar. The following information shall be provided:

6.1 Manufacturer's name and address

6.2 Size

6.3 Statement of compliance with this guideline

6.4 "WARNING: WHEN USING THIS GARMENT FOR PROTECTION FROM CHEMICALS, CONSULT THE MANUFACTURER REGARDING THE SUITABILITY OF THE FABRIC FOR THE INTENDED USE."

TABLE B-1. PROPOSED LIMITED-USE COVERALL MEASUREMENT PROCEDURES

A.	BACK BODY LENGTH. Measure from the top of the neckline at the center back collar seam to the crotch seam.
B.	FRONT BODY LENGTH. Measure from the top of the neckline at the center back point to the crotch seam with the coveralls flat and front side up.
C.	ARMHOLE WIDTH. Establish a line from the base of the armhole that is parallel to the center front. Measure up from the armhole base to the top of the sleeve with the coveralls stretched flat.
D.	SLEEVE OUTSEAM. Measure from the center back point to the top of the sleeve at the wrist edge.
E.	SLEEVE OPENING. Flatten sleeve at wrist end, completely stretching elastic if present. Measure from one folded edge to the other.
F.	FRONT AT CHEST. Measure from the base of the armhole across the front chest to the base of the other armhole. If there is no underarm seam on either sleeve or body of coverall, lay the sleeve and body of coverall at an angle where both are flat and establish an underarm point at the juncture of the sleeve and torso.
G.	BACK AT CHEST. Measure from the base of the armhole across the back to the base of the other armhole, including all of the fullness that lies between these two points. If there is no underarm seam on either sleeve or body of coverall, lay the sleeve and body of coverall at an angle where both are flat and establish an underarm point at the juncture of the sleeve and torso.
H.	LEG INSEAM. Measure from the crotch seam down the leg inseam to the bottom edge.
I.	LEG OPENING. Flatten the leg at the ankle end, completely stretching elastic if present. Measure from one folded edge to the other folded edge.
J.	FRONT OPENING LENGTH. Measure from the center back collar base to the bottom of the front opening with the coverall flat and front side up.
K.	HOOD OPENING LENGTH. Flatten the hood along the center seam so that the sides are superimposed. Measure on a flat vertical line that extends upward from the neckline seam to the highest point on the top of the hood.

(continued)

TABLE B-1 (Continued)

L.	HOOD DEPTH. Flatten the hood along the center seam so that the left and right sides are superimposed. Measure on a horizontal line from the center front (face) edge to the back of the hood at the point of greatest depth.
M.	NECKLINE LENGTH. With front of coverall facing up, stretch neckline seam flat. Measure from one end of seam to the other.

TABLE B-2. PROPOSED MINIMUM FINISHED DIMEMSIONS FOR LIMITED-USE COVERALLS

		Size					
	Dimension*	XS	S	M	L	XL	XXL
A.	BACK BODY LENGTH	38	39	40	41	42	43
B.	FRONT BODY LENGTH	33	34	35	36	38	40
C.	ARMHOLE WIDTH	12	13	13	14	14	15
D.	SLEEVE OUTSEAM	31	32	33	34	35	37
E.	SLEEVE OPENING	6	6	7	7	8	8
F.	FRONT CHEST	22	23	24	26	28	30
G.	BACK CHEST	23	24	26	29	32	34
H.	LEG INSEAM	28	29	30	31	32	33
I.	LEG OPENING	13	13	14	14	15	15
J.	FRONT OPENING LENGTH	29	30	30	30	31	32
K.	HOOD LENGTH	16	16	17	17	18	18
L.	HOOD DEPTH	11	12	12	13	13	14
M.	NECKLINE LENGTH	16	16	18	19	20	20

* All measurements in inches.

*U.S. Government Printing Office: 1992 — 648-003/40724

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