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Project Summary

The Selection and Measurement of Physical Properties for Characterization of Chemical Protective Clothing Materials

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Chemical protective clothing (CPC) must possess certain physical properties if it is to function as an effective barrier to chemicals. The physical characteristics of CPC materials have gone largely unstudied; most attention has been focussed on chemical resistance. Physical property tests have been surveyed for their applicability to CPC materials, and those tests, which appeared to be most pertinent, were applied to ten fabrics and three visor materials. From statistical analysis of the results and experience gained in performing the tests, a minimum battery of tests is recommended. The battery contains nine primary test methods that will allow the measurement of puncture, puncture-propagation tear, burst, abrasion, accelerated aging, and electrostatic charge accumulation for CPC fabrics, and abrasion resistance, deviation in line-of-sight, and impact for the CPC visor materials. Further development of a cut test is recommended before it is added to the battery.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Along with engineering controls and safe work practices, protective clothing is an important means for minimizing or preventing the contact of workers with potentially harmful chemicals. Such contacts can occur in settings which include industrial plants, waste sites, and uncontrolled spills. Those persons responsible for worker protection must have available and specify the most appropriate clothing for the particular situation. Chemical Protective Clothing (CPC) selection, procurement, and specification require information on the potential severity of the chemical contacts, the tasks to be performed, the skill levels of the workers, the performance characteristics and limitations of the protective clothing, and the effect of the clothing on worker performance.

Much has been written on the chemical resistance of protective clothing materials, and standard test methods have been promulgated. Of equal or perhaps greater importance than the chemical resistance of CPC is that the clothing remain intact during the work assignment. The clothing must resist tears, punctures, cuts, abrasion, and other physical stresses. Although scores of standard tests exist for measuring physical properties of the materials from which clothing is fabricated, there have been no studies directed towards evaluating the applicability of these tests to CPC. Consequently, there has been no basis on which to specify either physical property testing or the minimum performance in such testing for CPC.

The purpose of this study was to evaluate published physical property tests and to recommend a battery of tests that could be used in CPC specification and selection. The study was directed towards tests for materials used for garments, in contrast to the materials used in the fabrication of gloves, boots, and respirators. Tests were sought that are applicable over the broad range of material types, able to discriminate the performances of different materials, and relatable to field failure mechanisms.

Although this study necessarily produced quantitative physical property data, no attempt has been made to set minimum acceptable values for the results of any of the tests. Minimum acceptable values are dependent on the specific application of the clothing. For example, the physical property requirements for clothing used in laboratory applications may be significantly different from those for clothing used during entry of confined spaces that contain unknown chemical wastes.

The recommended battery of tests does, however, provide both users and manufacturers of CPC with a means to compare and evaluate the performance of CPC. This battery is preliminary in nature, as it is used and more data are generated, the battery will be modified and expanded. Additionally, use of the battery and response from the field will aid in the development of minimum acceptable performance values.

Procedure

Materials

Ten fabrics used to fabricate pants, jackets, coveralls, or full body encapsulating ensembles, and three clear plastics used to fabricate visors were used in this study (Table 1). Garments fabricated from these materials range in price from less than $10 to over $3000.

Candidate Test Methods

Sources of the standard test methods used in this study included American Society for Testing and Materials (ASTM), Federal Standards, Military Standards, American National Standards Institute (ANSI), National Fire Protection Association (NFPA), and the American Association of Textile Chemists and Colorists (AATCC). Approximately 50 methods having potential applicability to the objectives of this study were identified, and 14 were selected for laboratory examination. Brief synopses of the 14 methods follow:

ASTM F23.20.1-Test Method for Resistance to Cut (draft 4) — The specimen is mounted on a holder and pulled by hand at a nominal rate of 25 cm/min beneath a single-edged, industrial razor blade which has been loaded with a known weight. The minimum weight that produces a cut completely through the specimen is recorded. Cut is detected by the completion of an electrical circuit between the razor blade and an aluminum foil placed under the fabric.

NFPA 1973 Gloves for Structural Fire Fighters (Section 3-2.7)- Puncture Resistance Testing — A machined, 2.03-mm diameter stainless steel stylus, having a tip radius of 25 mm, is pushed through a specimen at a rate of 127 cm/min. The force required to puncture the fabric is recorded.

ASTM D1424-Tear Resistance of Woven Fabrics by Falling-Pendulum (Elmendorf) Apparatus* — A 12 x 12-mm notch is cut out of the center of one edge of a 75 x 75-mm specimen. One side of the specimen is clamped and the other side is fixed to a pendulum of known weight. A 2-cm slit is cut into the center of the notch and the pendulum is released causing the specimen to tear. The tearing force is calculated from the weight of the pendulum and the distance that the pendulum travels.

ASTM D2261-Tearing Strength of Woven Fabrics by the Tongue (Single Rip) Method (Constant-Rate-of-Extension Tensile Testing Machine) — A 8.9-cm long slit is cut length-wise in the center of a 76 x 203-mm specimen. The fabric on each side of the slit is fastened into the jaws (180° opposed) of a tensile testing machine and the jaws are separated at 5 cm/min. The tear resistance is the force required to separate the jaws.

ASTM D2582-Puncture- Propagation Tear Resistance of Plastic Film and Thin Sheeting-- A carriage of known weight and holding a 0.32-cm diameter, conical tipped probe is released from a standard height such that the probe impacts, punctures, and tears the specimen. The tear length, carriage weight, and release height are recorded and used to calculate the tear resistance.

ASTM D3884-Abrasion Resistance of Textile Fabrics (Rotary Platform, Double-Head Method) — This method is also known as the Taber test. The speci is rotated under two abradant wh under a specified load. The parameters are the coarseness of abradant wheels, the arm weight, anc number of cycles. In this study, an weight of 1,000 g was usec combination with an H22 vitrified wl Upon completion of the abrasioı permeation test, ASTM F739, performed on each abraded specime determine the effect of abrasion chemical resistance.

ASTM D4157-Abrasion Resistanc Textile Fabrics (Oscillatory Cylii Method) — This method is also know the Wyzenbeek test. An abradan secured to a barrel (i.e., the cylinder) the specimen is secured at a kn tension in a holder above the cylir The fabric is lowered onto the oscilla abradant and held there unde predetermined load for a predeterm number of cycles (or double rubs). In study the tension was 2.3 kg, the loac kg, and the abradant was #80 grit s paper. Similar to the Taber tes permeation test was used as the endp test.

ASTM D751-Coated Fabrics, Brea Strength, Cut Strip Method — A 2 100-mm specimen is clamped in the j of a tensile testing machine and pu apart at a rate of 30 cm/min. The f required to break the specimen and elongation at break are measured.

ASTM D751-Coated Fabrics, Burs Strength — A 2.5-cm diameter spher pushed at a rate of 30 cm/min throug 4.5-cm diameter specimen usin tensile testing machine. The fc required to break the specimen measured.

ASTM G26-Operating Light-Expos Apparatus (Xenon-Arc Type) with without Water for Exposure Nonmetallic Materials — A specime subjected to periodic exposure ultraviolet light and rain under condit of elevated temperatures and humidi In this study, a four week expos period was used; the exposure cycle 51 minutes at 90+ %RH and 6 followed by 9 minutes of rain at 3 Simultaneously the specimens w continuously exposed to a 6000W Xe Arc lamp operating at 4950W. Specim were observed for visual changes tested for changes in breaking stre and elongation at break as describe ASTM 751.

NASA MMA-1985-79-Evaluating Tr electric Charge Generation and Deca A 190 x 190-mm specimen is rubbed a polytetrafluoroethylene (PTFE)

*Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

overed wheel rotating at 200 rpm under 1.36 kg load for 10 seconds. The harge (i.e., voltage) on the specimen is neasured immediately (i.e., the peak oltage) and 0.5, 1, 2, 3, 4, and 5 seconds thereafter.

ASTM D881-Deviation of Line-of-Sight – A 150 x 150-mm specimen of a visor naterial is held in a position normal to a ne-of-sight established between a fixed elescope and target. The angular eviation caused by the visor material is etermined from the apparent shift of the rosshairs of the telescope, the distance etween the specimen and the target, nd the spacing of the lines on the target. or this investigation, the target consisted vertical lines spaced 0.25 cm apart ith the target set 340 cm from the pecimen.

ASTM D1044-Resistance of Transarent Plastics to Surface Abrasion Haze) — This test is identical to the aber Abrasion test, however, a finer bradant is typically used at fewer ycles. A CS10 abrading wheel was used an arm weight of 1,000 grams for 10, 5, and 50 cycles. The loss in light ansmittance at 550 nm was measured.

ASTM D3029-Impact Resistance of igid Plastic Sheeting — A 5 x 5-cm pecimen is held in an aluminum clamp hich has a 3.8-cm diameter hole in it. A 5-gram dart is released from a known height (2.5 cm to 175 cm) and allowed to impact the specimen. The mean failure energy is calculated from the weight of the dart and height at which 50% of the specimens failed. A failure was defined as visually (unaided) detectable cracks in the specimen.

Results and Discussion

The results for all tests, except the abrasion tests, are summarized in Tables 2 and 3. The content and organization of Table 2 warrants discussion. Mean values for each test of each fabric are reported along with the standard deviation (in parentheses). The number of replicates, n, is designated beneath each column heading. The upper case letter to the right of the standard deviation is either the Duncan's or the Tukey's Grouping Letter (DGL or TGL, respectively). Within each test, the letters designate results that are statistically similar or dissimilar at the 95% confidence level. For example under puncture, the result for the supported butyl fabric (DGL = A) is significantly different from that of the supported PVC (DGL = B) but the result for the supported CPE (DGL = C) is not significantly different from that for the Viton-Nomex-Chlorobutyl (DGL = C).

Table 3 for the visor materials is organized in a similar manner with the exception that no statistical analysis was performed.

Cut — Cut resistances of the fabrics ranged from 365 g to 1265 g. The method was easy to perform and the apparatus relatively inexpensive to build. The draft method, however, has several shortcomings which must be corrected before the method can be considered as part of a standard test battery. These shortcomings include: lack of a standardized industrial razor blade, the absence of a means for controlling the rate at which the fabric holder is pulled under the razor blade, the large weight increments that prevent differentiation of some fabrics, and the means by which test results are generated that renders them difficult to analyze by common statistical methods. This latter shortcoming prevented analysis of the data by Duncan's multiple range test; thus the DGLs are absent from Table 2. Questions exist as to the applicability of the method to all garment materials and the relationship of the test to field scenarios.

Puncture — The resistance of the fabrics to puncture ranged from 3.3 to 19.4 kg_f. The puncture test has good precision; the relative standard deviation was less than 10% for each fabric. Whether this test is representative of field puncture scenarios is open to discussion.

***Table 1**. Test Materials*

Material	*Description*	*Source*	*Weight,* g/m²*	*Thickness, + mm*
Fabrics				
Butyl Rubber (supported)	*Butyl -Nylon Fabric -Butyl*	*Fyrepel Products Inc.*	428	0.37
Challenge 5200®	*Teflon-Nomex-Teflon*	*Chemical Fabrics Corp.*	528	0.26
Chemrel®	*Multilayer Plastic Film-Fabric*	*Chemron, Inc.*	145	0.27
CPE	*Chlorinated Polyethylene*	*ILC Dover*	698	0.52
CPE (supported)	*CPE-Polyester Fabric-CPE*	*Standard Safety Equipment Co.*	743	0.60
PE-Tyvek®	*Polyethylene-Tyvek*	*Kappler, Inc.*	76	0.14
PVC (supported)	*Polyvinyl-Chloride-Polyester Fabric*	*Standard Safety Equipment*	898	0.76
Saranex®- Tyvek	*Saranex-Tyvek*	*Kappler, Inc.*	126	0.19
Viton®-Nylon- Chlorobutyl	*Viton-Nylon Fabric-Chlorobutyl*	*Life-Guard, Inc.*	584	0.44
Viton-Nomex®-Chlorobutyl	*Viton-Nomex-Chlorobutyl*	*Fairprene, Inc.*	683	0.42
Visor Materials (flat)				
FEP (film)	*Fluorinated ethylene propylene copolymer*	*Chemical Fabrics Corp.*	-†	0.25
Polycarbonate				
Melamine-coated		*General Electric*	--	1.02
Uncoated		*Sheffield*		0.76
PVC (flexible)	*Polyvinyl chloride*	*Standard Safety Equipment Co.*	--	1.02

**Average of 5 measurements.*
+ Average of 20 measurements.
†Not measured.

Table 2. *Fabrics Test Results and Duncan's or Tukey's Multiple Range Analysis**

Material	Cut, g_f (n=3)	Puncture kg_f (n=5)	Tear			Tensile		Burst kg_f (n=5)	Triboelectric charge after 5s,V (n=5)
			Elmendorf, g_f (n=3-12)	Tongue, g_f (n=5)	Puncture-propagation, Kg_f (n=5)	Breaking strength, Kg_f (n=5)	Elongation, % (n=5)		
Butyl Rubber (supported	365(0)	19.4(0.33)A	-- +	5605(375)B	8 2(0.17)D	82.3(1.72) B -18.8†	33.3(3.4)B -18.8†	329(16)A	-15907(2164)A
Challenge 5200	1265(0)	10.1(0.62)D	1722(114)B	2639(296)C,D	5.8(0.47)E	94.1(4.37) A -18.9	7.9(0.1)C -15 2	143(28)D	-7847(1330)A
Chemrel	465(0)	4.4(0.39)F	422(40)D	889(186)G	33(0.23)G	20.8(0.69) F -76.1	44.8(1.1)B -66.5	49(8)F	20287(2170)A
CPE	365(0)	9.19(0.25)E	--	843(94)G	26.1(1 1)A	20.3(0.97) F 7.2	275(31)A 15.0	75(8)E	< 100(0)D
CPE(supported)	465(0)	15.7(0.94)C	3200(0)A	6567(308)A	11.5(0.43)C	37.8(1.71) E 6.1	15.4(1.0)C 7.8	78(4)E	1703(652)B
PE-Tyvek	365(0)	3.3(0.55)G	--	1360(173)F	3.0(0.63)G	5.1(0.59)G 13.0	5.0(1.2)C 100.0	15(2)G	< 100(0)D
PVC(supported)	365(0)	17.6(1.15)B	--	2340(135)D,E	17.1(1.0)B	2.4(44)D -18.2	16.4(0.8)C 1.2	91(10)E	< 100(0)D
Saranex-Tyvek	365(0)	4.2(0.35)F	1216(369)C	1633(299)F	4.8(1.1)F	6.8(0.32)G -48.3	8.2(1.0)C -59.8	17(1)G	< 100(0)D
Viton-Nylon-Chorobutyl	665(0)	16.2(0.89)C	1109(33)C	2059(41)E	5.6(0.32)E	68.0(2 9)) C -8.6	35.5(6.1)B 3.4	166(2)C	1397(3680)B,C
Viton-Nomex-Chlorobutyl	565(0)	10.5(0.77)D	--	2703(207)C	5.8(0.45)E	70.3(4.5)C -8 5	34 2(3.2)B -14.9	182(5)B	-457(116)C

* Results are reported as: Mean (standard deviation) Duncan's or Tukey's Grouping letter. Tukey's analysis was performed only on the Tensile and the Elmendorf data.
\+ Not tested.
† Percent change in property due to four weeks aging average of two specimens.

Puncture is in part determined by the speed at which an object impacts a fabric ınd the freedom that the fabric has to ılongate upon the impact. These parameters have not been studied in ıither the laboratory or the field.

Tear — This study included the nvestigation of three tear tests: Elmendorf, tongue, and puncture-propagation.

Both the Elmendorf and the tongue ∍ar tests begin with a fabric specimen which has been slit. Thus, these tests do ot measure the resistance of the fabric ɔ tear initiation, rather, they measure nly the resistance to tear propagation. ince the CPC issued to workers is resumed free of cuts, tears, holes, and o forth, these tests may not fully ∍present field failure mechanisms. urthermore, the Elmendorf test yields nly the maximum value of the tear ısistance for a fabric and the tear attern exhibited by the nonwoven pecimens was not consistent with the ıquirements of the method. The types of ısults produced by the Elmendorf pparatus varied with the type of fabric ıpport (woven vs. nonwoven) and may ot be comparable. The values in Table 2 re mean tearing forces.

More representative of a field tear, the uncture-propagation tear simulates a ondition of snag. The force required to itiate and propagate a tear is measured. his test was applicable to all fabrics and precision, as judged by a comparison relative standard deviations, was onsiderably greater than those of the lmendorf and tongue tear tests.

Abrasion — Several abrasion rocedures were investigated in an tempt to identify a method that would representative of field conditions. In is study, ASTM F739 was used to easure the effect of abrasion on the emical resistance of the fabric. cetone was used as the chemical allenge for all permeation tests. The ect of abrasion on a material was dged by the change in breakthrough ne of the acetone.

Abrasion testing is generally cognized as semi-quantitative in haracter; reproducibility is difficult to hieve. The actual abrading action on he fabric is dependent on the oarseness of the abradant, the weight pplied to the abradant, and the number f abrasion cycles as well as the tautness f the fabric. Fabric tautness may change uring the procedure as the fabric heats nd stretches due to the abrasion ocess and may vary from fabric to bric. A general rule of thumb is that the reproducibility of the abrasion increases as the number of cycles is increased and as the coarseness of the abradant is decreased.

For the Wyzenbeek abrader, the breakthrough times for acetone and the Viton-Nylon-Chlorobutyl fabric remained relatively stable for 25, 50, 75, and 100 cycles, then dropped precipitously at 250 cycles. Even 25 cycles was sufficient to cause immediate breakthrough of acetone through the Saranex-Tyvek material. Breakthrough of acetone through Challenge 5200 remained above two hours even after 400 cycles.

Midway through the study consideration of the Wyzenbeek test was discontinued in favor of the Taber test for three reasons. One, the Taber abrasion pattern is more uniform. Two, the Wyzenbeek apparatus is no longer commercially available. Three, the lack of its commercial availability would seem to suggest that the Wyzenbeek method has previously not been found useful by the textile fabric test community. The Taber test, on the other hand, is widely performed and the apparatus is readily available.

Five hundred Taber cycles caused immediate breakthrough of acetone through the Chemrel fabric but had minimal (if any) effect on the supported CPE and no apparent effect on the Challenge 5200.

Abrasion testing with a permeation endpoint test was successfully used to discriminate the performances of CPC fabrics. This study, however, has not resolved precision shortcomings that are characteristic of abrasion testing nor have test conditions (e.g., abradant coarseness and load) been defined that represent field scenarios.

Tensile Strength and Elongation at Break — These common tensile tests were applied to new fabrics and to fabrics that had been subject to accelerated aging. The results are summarized in Table 2 in a format that has the initial values on one line and the percent change in the values due to the aging immediately underneath. These measurements are easily performed with equipment that is commercially available. Good precision was found and the tests were applicable to all fabrics.

Static Charge Accumulation — As is evident from Table 2, the fabrics exhibited a wide range of abilities to hold and dissipate voltages produced by rubbing the fabrics with a PTFE wheel. In reviewing the data, one must bear in mind that the absolute value of the reported result, not its sign, is important. This characteristic should be considered when selecting or specifying CPC since static charges could lead to sparking with disastrous consequences in certain situations involving chemicals.

This method is applicable to all types of CPC materials and appears to enable discrimination of the results.

Deviation in Line-of-Sight — This test is designed to measure the deviation in the line-of-sight caused by a clear plastic. To be useful, the results must be obtained with the plastic in its use configuration; in the case of visors, this typically means curved. If the deviation in line-of- sight becomes noticeable, users of the visor materials will have difficulty manipulating objects which they are focusing on.

Table 3 summarizes the limited results generated during this investigation. Of the four materials tested, only the PVC caused any measurable deviation in the line-of-sight. The method is easy to perform and appears to be applicable to all visor materials.

Haze — The Taber test conditions used in this study were arbitrary but provide comparative data on the abrasion resistance of visor materials. Visor abrasion can occur during suit use, decontamination and storage.

Table 3 summarizes the measured decrease in light transmission. The Melamine-coated polycarbonate retained the highest amount of light transmission at 50 cycles. The results show good precision and it is apparent from the differences in the results that the method can discriminate among the performance of different visor materials.

This test is quick and easy to perform but requires the use of a spectrophotometer. The only apparent limitation to this method is that it can only be used on flat specimens.

Visor Impact — The test simulates the impact of a small diameter, semi-sharp projectile with a visor. Direct relation of the results to the field, however, is complicated by the fact that the impact during testing can only occur within the diameter of the specimen holder. The size of the holder restricts the potential for deflection and flexing in the specimen.

Table 3 summarizes the results of the impact test for the four materials tested. The FEP was the only material made to fail by this method. The limitations of our apparatus were a maximum drop height of 175 cm and a maximum dart weight of 315 gram.

The test is easy to perform and applicable to all types of flat visor materials. Some ambiguity exists in selecting the correct number of test specimens. The endpoint of the test is reached when 50% of the specimens fail.

Statistical Analysis

As discussed above, the results from each of the fabric tests were subjected to either a Duncan's or Tukey's analysis in order to demonstrate the degree to which the test could be used to discriminate between the performances of the fabrics. Another objective of the study was to identify and eliminate those tests that seemed to be redundant. A minimum battery of tests was desired that would provide broad perspective on the physical characteristics of protective clothing materials.

Test method redundancy was investigated by applying the Spearmen's Rank Correlation Coefficient (SRCC) procedure. If the rank orders of the two lists were exactly the same the coefficient would be 1, if the rankings were exactly opposite then the coefficient would be -1. A coefficient greater than 0.65 is indicative of a pair of lists in which the rank orders are in relatively good agreement.

Strong correlations were found between the rank orders of the fabrics for the burst strength/break strength pair (SRCC = 0.92) and the burst strength/puncture strength pair (SRCC = 0.84). Good correlations were found between the rank orders of the puncture resistance/tongue tear pair (SRCC = 0.70) and the puncture strength/break strength pair (SRCC = 0.72), and between the tongue tear/burst strength pair (SRCC = 0.67) and the tongue tear/break strength pair (SRCC = 0.65).

Conclusions and Recommendations

Recommended Test Battery

The standard tests and conditioning methods listed in Table 4 are recommended as the minimum battery of procedures for characterizing or specifying the physical properties of chemical protective clothing materials. These standards can be supplemented with others, dependent on the needs of each specific application of the clothing.

The puncture-propagation tear test was selected over the Elmendorf and tongue tear tests because it appears to yield unambiguous results for all fabrics and because it appears to most closely represent field failure mechanisms for garment materials.

The burst test is recommended over the more commonly performed tensile test because the burst test is easy to perform and is not subject to the confounding problems of jaw breaks, fabric slippage, or fabric orientation. Furthermore, from the Spearmen's analysis, the tensile test appears to be redundant of the burst test.

The Taber abrasion test was selected over the Wyzenbeek test because of availability problems of the Wyzenbeek apparatus and because it can produce specimens of suitable size and quality for endpoint testing. The permeation test is recommended as the endpoint test assessing the effects of abrasion chemical resistance. Although investigated in this study, the effects abrasion on the physical integrity of fabric could be measured by the b test.

Accelerated aging followed by same endpoint tests as for the abra test is recommended for those clot use scenarios that include a signifi amount of reuse or extensive stor periods.

The triboelectric charge test has ticular applicability to work scena involving flammable or explosive erials. Such clothing should also subject to flammability or flame re tance testing. Flammability testing beyond the scope of this study consequently there is no specific recommendation herein; other refere should be consulted.

Although the authors believe a cu should be part of a minimum test ba none is included because the pres available methods have been ju inadequate. Further work in this ar recommended. Further work is recommended pertinent to the abr test. Finally, efforts should be under to develop case history files of failures due to tear, cut, puncture, and so forth in order to establish a base for minimum performance spe tions for each of the tests.

The full report was submitt fulfillment of Contract No. 68-03-32 Arthur D. Little, Inc., under sponsorship of the U.S. Environn Protection Agency.

Table 3. *Visor Materials Test Results*

Material	*Thickness*, cm*	*Deviation of line of sight, +, min*	*Haze, % transmission @ 550 nm abrasion cycles*				*Impact strength, j*
			0	*10*	*25*	*50*	
FEP (film)	*0.025*	*--†*	*89(1)*** *(1/3)††*	*72(3)* *(3/3)*	*72(2)* *(3/3)*	*67(2)* *(3/3)*	*1.98++* *(22)****
Polycarbonate							
Melamine-coated	*0.102*	*0*	*88(1)* *(1/3)*	*84(6)* *(1/3)*	*83(2)* *(1/3)*	*73(2)* *(1/3)*	*>5.43* *(10)*
Uncoated	*0.076*	*0*	*88(3)* *(1/3)*	*72(2)* *(2/3)*	*62(2)* *(2/3)*	*58(2)* *(2/3)*	*>5.43* *(10)*
PVC (flexible)	*0.102*	*3.1*	*85(1)* *(1/3)*	*73(3)* *(3/3)*	*62(3)* *(3/3)*	*53(4)* *(3/3)*	*>5.43* *(10)*

* *Average of 20 measurements.*
\+ *Maximum deviation measured in three specimens.*
† *Not tested.*
** *Average % transmission (standard deviation).*
++ *Average impact strength.*
†† *Number of specimens tested/number of measurements made on each specimen tested.*
*** *Number of specimens tested.*

Table 4. *Recommended Physical Property Test Methods For Chemical Protective Clothing*

Fabrics	
Puncture resistance	*NFPA 1973- Paragraph 3-2.7*
Puncture-propagation tear resistance	*ASTM D2582*
Abrasion resistance endpoint tests:	*ASTM D3884* *Permeation–ASTM F739* *Burst Strength–ASTM D 751*
Bursting resistance	*ASTM 751*
Accelerated aging endpoint tests:	*ASTM G26* *Permeation–ASTM F739* *Burst Strength- ASTM D751*
Electrostatic charge	*NASA MMA–1985-79*
Visor Materials	
Deviation in line-of-sight	*ASTM D881*
Haze-abrasion resistance	*ASTM D1044*
Impact resistance	*ASTM D3029*

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***Michael D. Royer** is the EPA Project Officer (see below).*
The complete report, entitled "The Selection and Measurement of Physical Properties for Characterization of Chemical Protective Clothing Materials," (Order No. PB90-188-731/AS; Cost: $17.00 subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
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Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
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