How well are you protected? What healthcare workers need to know about gown standards and selection considerations

Selcen Kilinc-Balci, PhD.

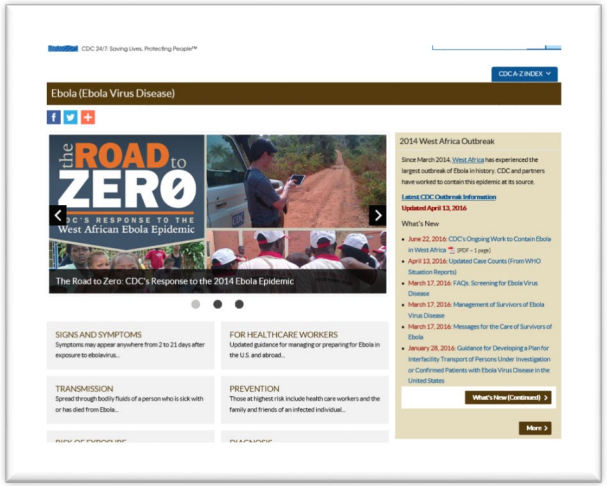
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
National Personal Protective Technology Laboratory

Photo Credit: CDC PHIL 19199

Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

Minnesota Department of Health
November 20, 2018 11:00AM CT

Outline

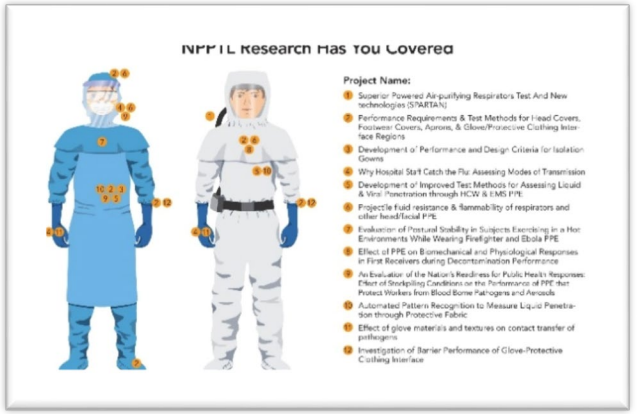


CDC's Ebola PPE recommendations

Protective clothing selection process and important considerations

Photo credit: NIOSH EPRO

Current healthcare protective clothing standards



Ongoing NIOSH research projects with gowns

Photo credit: NIIOSH NPPTL

NPPTL
National Personal Protective Technology Laboratory

Background

- The 2014 Ebola epidemic in West Africa was the largest in history

2014 Ebola Epidemic Facts:

>28,500 cases
>11,000 deaths

>900 healthcare worker cases
>500 healthcare worker deaths

Photo credit: CDC PHIL 17848

- In the country most affected, the confirmed Ebola incidence rate was over a hundredfold higher in healthcare workers (HCWs) than the general population

http://aps.who.int/ebola/current-situation/ebola-situation-report-30-march-2016
http://www.who.int/csr/resources/publications/ebola/personal-protective-equipment/en/.
CDC [2016]: 2014 Ebola Outbreak in West Africa - Case Counts. http://www.cdc.gov/vhf/ebola/outbreaks/2014-west-africa/case-counts.html
Kilmarx, PH., et al.[2014]: Ebola Virus Disease in Health Care Workers — Sierra Leone. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm649a6.htm

CDC's Recommended Protective Clothing for Healthcare Workers

- Single-use (disposable) fluid-resistant gown/coverall: Recommended while evaluating and managing persons under investigation (PUIs) for Ebola who are clinically stable and do not have bleeding, vomiting, or diarrhea (at a minimum)
- Single-use (disposable) impermeable gown/coverall: Recommended when caring for a patient with confirmed Ebola or unstable PUI

Table: Specifications for fluid-resistant and impermeable gowns and coveralls

	Gown	Coverall
Fluid-resistant	Surgical or isolation* gown that passes: • ANSI/AAMI PB70 Level 3 requirements or • EN 13795 high performance surgical gown requirements	Coverall* made of fabric that passes: • AATCC 42 ≤ 1 g and AATCC 127 ≥ 50 cm H_20 or EN 20811 ≥ 50 cm H_20 or • ASTM F1670 (13.8kPa) or • ISO 16603 ≥ 3.5 kPa
Impermeable	Surgical or isolation* gown that passes: • ANSI/AAMI PB70 Level 4 requirements	Coverall* made with fabric and seams/closures that passes: • ASTM F1671 (13.8kPa) or • ISO 16604 ≥ 14 kPa

*Testing by an ISO 17025 certified third party laboratory is recommended.

Source: http://www.cdc.gov/vhf/ebola/healthcare-us/ppe/guidance.html (Updated on August 27, 2015)

NPPTL
National Personal Protective Technology Laboratory

Protective Clothing Selection Process

Conduct Hazard Assessment

- Source
- Modes of transmission
- Pressure and type of contact
- Duration and type of tasks
- Stage of disease
- Severity of symptoms

Identify Standards or Specifications

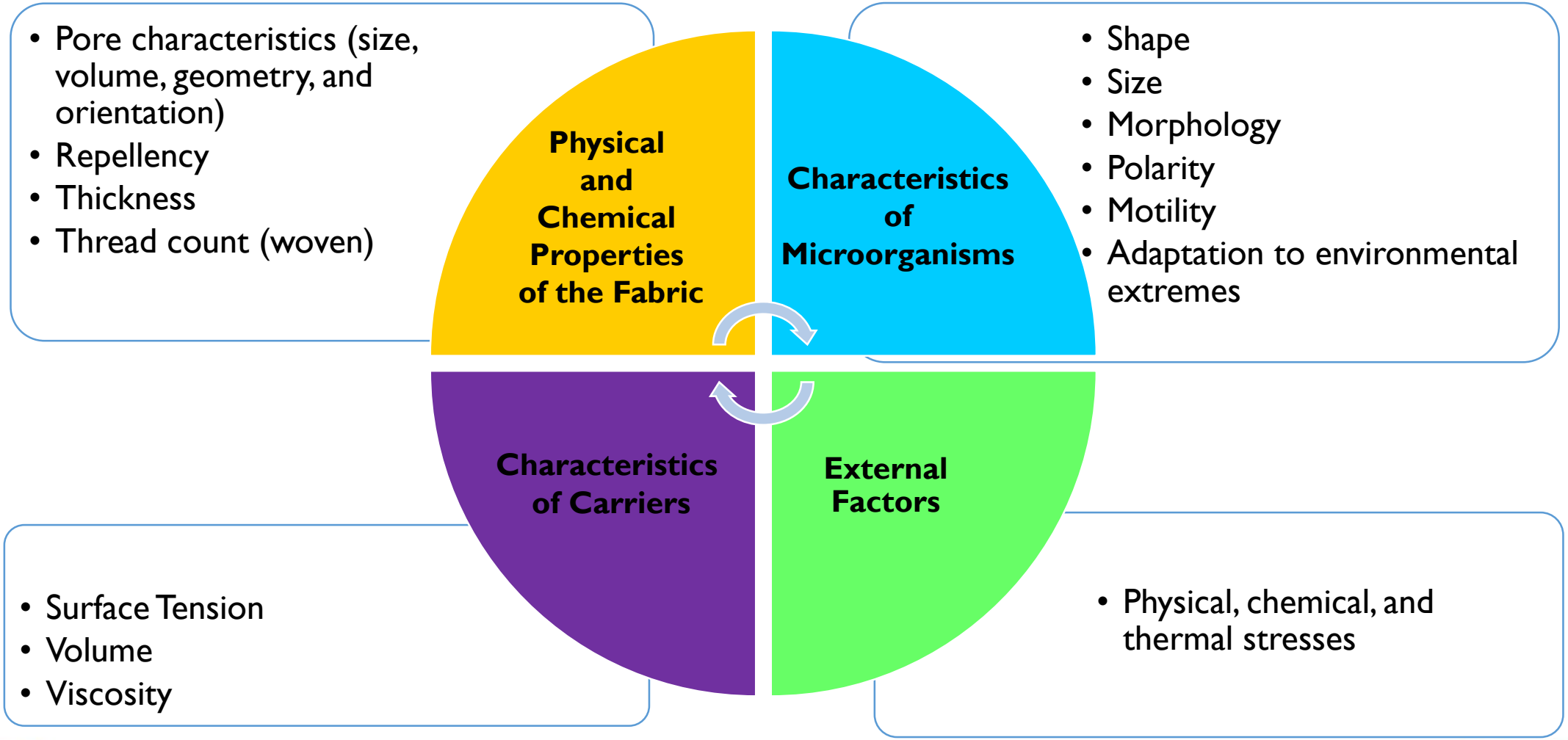
- HCW gown and coverall classification standards, specifications, test methods
- National, international

Select Appropriate Protective Clothing

- Regulations
- Practices

Photo Credit: CDC PHIL 10816

Microorganisms' Movement through Protective Clothing Materials



Bloodborne Pathogen Strikethrough

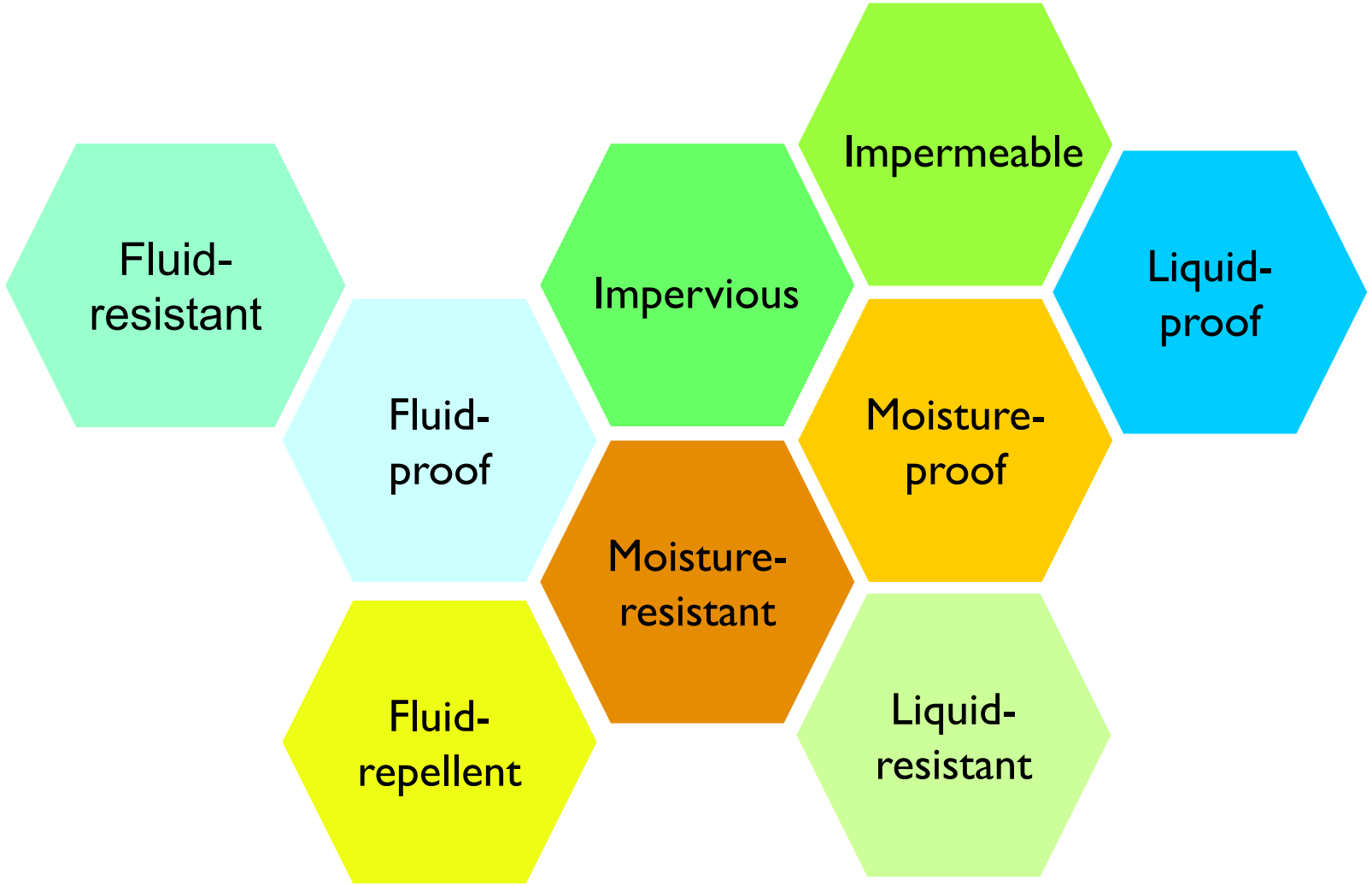
- Microorganisms are transported by carriers such as body fluids, sloughed skin cells, lint, dust, and respiratory droplets. A significant number of microorganisms can be carried in a very minute volume of blood or body fluids, which may not be visible to the naked eye.

Volume of strike-through (1)	100 µL	10 µL	1 µL	0.1 µL
size				
Number of bloodborne pathogens (2)				
HBV	10,000,000	1,000,000	100,000	10,000
HCV	100–100,000	10–100,000	1–1,000	0.1–100
HIV	6–700	0.6–70	0.06–7	0.006–0.7

(1) Volume of red 40 dyne/cm synthetic blood delivered to white blotter paper.
(2) Based on documented whole blood concentrations of infected patients.

Adapted with permission from ANSI/AAMI PB70:2012, "Liquid barrier performance and classification of protective apparel and drapes intended for use in health care facilities."

Terminology



Considerations for Protective Clothing Selection

- **Design of protective clothing**
  - No clinical studies have been done to compare the efficacy of gowns vs. coveralls
  - Coveralls: provide 360 degree protection
  - Gowns: relatively easier to put on/remove, and more familiar to HCWs, hence more likely to be used and removed correctly. The level of heat stress generated is also expected to be less compared to coveralls
- **Critical fabric and clothing properties**
  - Strength properties of the fabric and seams (e.g., tensile strength and seam strength)
  - Barrier properties of seams/closures
  - Size of the garment
- **Donning and doffing features of protective clothing**
  - The ease or difficulty with which PPE is put on and removed may affect its effectiveness and the potential for self-contamination
- **Other factors**
  - These include factors such as compliance with regulatory agencies, durability (abrasion resistance), comfort (breathability, air permeability), flammability, electrostatic properties, cost, availability, ergonomics/human factors, and integration with other types of PPE

Photo credit: CDC PHIL 18351, 17843, 17842

Current Healthcare Protective Clothing Standards and Specifications

NFPA®

ASTM INTERNATIONAL

ISO

ANSI

AAMI

AATCC®

Standards and Specifications for Gowns

- ANSI/AAMI PB70 - Liquid barrier performance and classification of protective apparel and drapes intended for use in healthcare facilities
  - Applies to surgical gowns and isolation gowns
- EN 13795 - Surgical drapes, gowns, and clean air suits, used as medical devices for patients, clinical staff, and equipment. General requirements for manufacturers, processors and products, test methods, performance requirements and performance levels.
  - Applies to surgical gowns
- ASTM F2407- Standard specification for surgical gowns intended for use in healthcare facilities
  - Applies to surgical gowns

Photo Credit: Shutterstock

Photo Credit: NIOSH EPRO

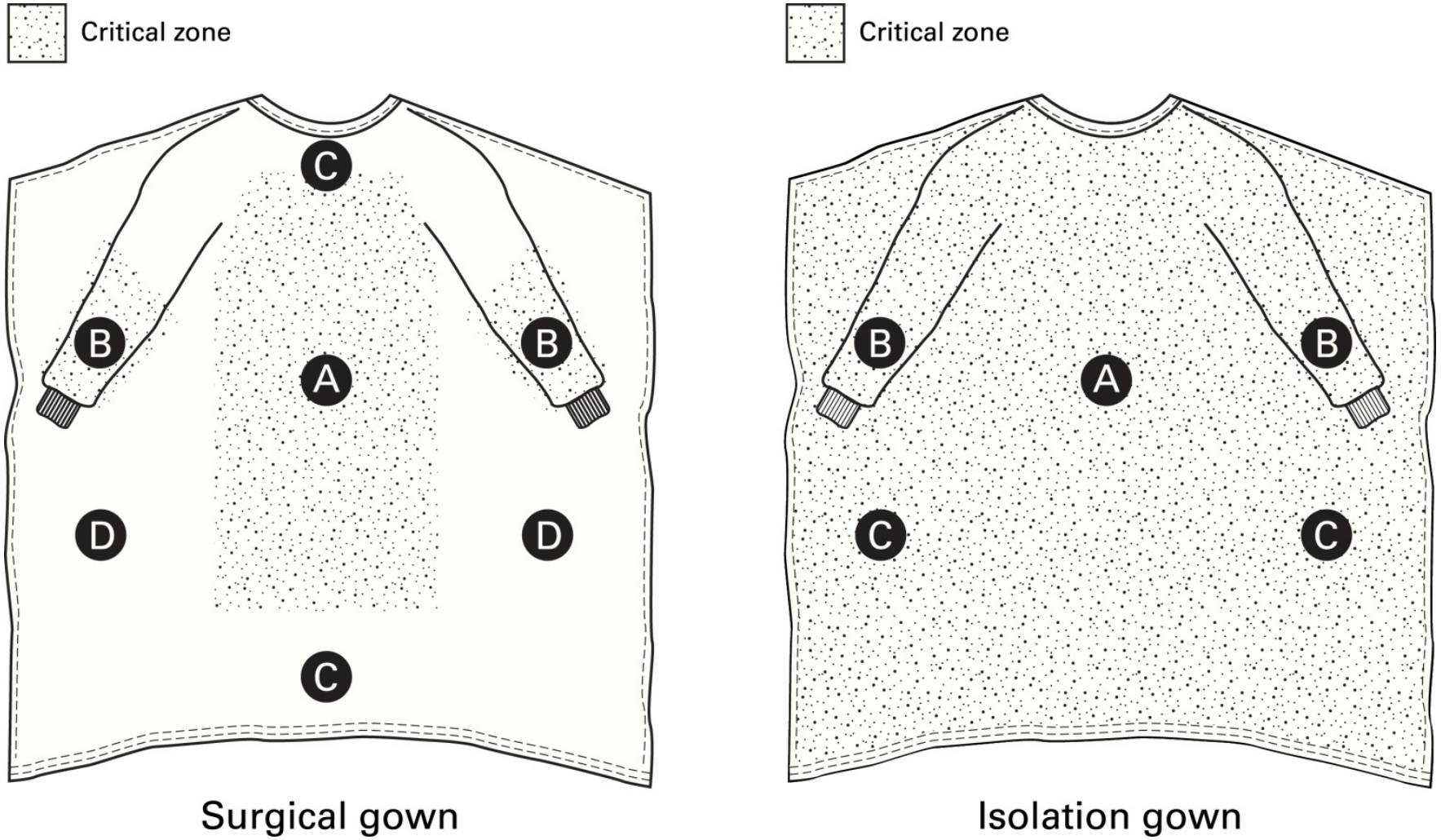
ANSI/AAMI PB 70:12 Classification Requirements

Protection Level

Level	Test	Liquid Challenge	Result*	Expected Barrier Effectiveness
1	AATCC 42	Water	≤ 4.5 g	Minimal water resistance (some resistance to water spray)
2	AATCC 42 AATCC 127	Water Water	≤ 1.0 g ≥ 20cm	Low water resistance (resistant to water spray and some resistance to water penetration under constant contact with increasing pressure)
3	AATCC 42 AATCC 127	Water Water	≤ 1.0 g ≥ 50cm	Moderate water resistance (resistant to water spray and some resistance to water penetration under constant contact with increasing pressure)
4	ASTM F1670 (for surgical drapes) ASTM F1671 (for surgical gowns and other protective apparel)	Surrogate blood Bacteriophage Phi-X174	Pass Pass	Blood and viral penetration resistance (2 psi)

All have an Acceptance Quality level (AQL) of 4% and Rejectable Quality Level (RQL) of 20%

ANSI/AAMI PB70 Critical Zones for Gowns



Surgical gown

Isolation gown

Adapted with permission from ANSI/AAMI PB70:2012, "Liquid barrier performance and classification of protective apparel and drapes intended for use in health care facilities"

NPPTL
National Personal Protective Technology Laboratory

Standard Test Methods to Evaluate the Resistance of Fabrics to Water

Barrier Property	AATCC Test Methods	ISO Test Methods
Water Resistance – Impact Penetration	**AATCC 42** Determines the ability of a material to resist water penetration under spray impact	**ISO 9073-17** Determines the ability of a material to resist water penetration under spray impact
Water Resistance – Hydrostatic Pressure	**AATCC 127** Determines the ability of a material to resist water penetration under constant contact with increasing pressure	**ISO 9073-16** Determines the ability of a material to resist water penetration under constant contact with increasing pressure

Note: These tests are typically conducted on fabrics, but they can be conducted on the garment seams/closures as well

Barrier Performance Test Methods - Impact Penetration Test

AATCC 42: Water Resistance: Impact Penetration Test

- Used to determine the ability of a material to resist water penetration under single spray contact
- Sample is oriented at a 45 degree angle and clamped in place over a piece of preweighed blotter paper
- Water is released from a funnel
- Blotter is weighed again
- Weight gain ↓ resistivity ↑

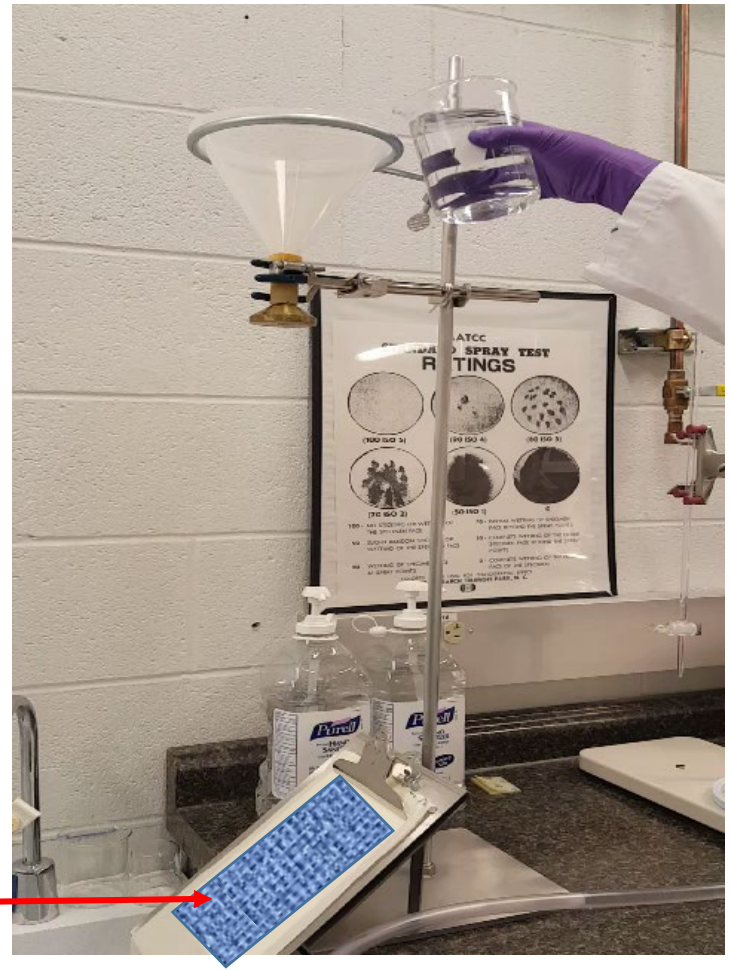


Photo Credit: NIOSH NPPTL

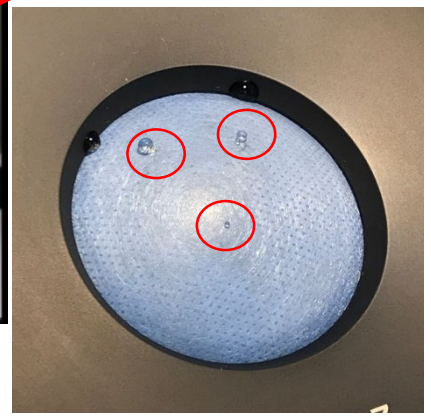
Barrier Performance Test Methods – Hydrostatic Pressure Test

AATCC 127: Water Resistance: Hydrostatic Pressure Test

- Used to determine the ability of a material to resist water penetration under constant contact with increasing pressure
- Sample is clamped in place horizontally, and the hydrostatic pressure is steadily increased by raising the height of the water column
- Terminated when visible penetration of water droplets occurs
- Hydrostatic pressure ⬆ resistivity ⬆

Photo Credit: NIOSH NPPTL

Test Fabric



Standard Test Methods to Evaluate the Resistance of Fabrics to Synthetic Blood & Virus Penetration

Barrier Property	ASTM Test Methods	ISO Test Methods
Synthetic Blood Penetration	**ASTM F1670 —** Standard test method for resistance of materials used in protective clothing to penetration by synthetic blood	**ISO 16603 —** Determination of the resistance of protective clothing materials to penetration by blood and body fluids—Test method using synthetic blood
Viral Penetration	**ASTM F1671—** Standard test method for resistance of materials used in protective clothing to penetration by bloodborne pathogens using Phi-X174 bacteriophage penetration as a test system	**ISO 16604 —** Determination of resistance of protective clothing materials to penetration by bloodborne pathogens— Test method using Phi-X174 bacteriophage

Note: These tests are typically conducted on fabrics, but they can be conducted on the garment seams/closures as well

Barrier Performance Test Methods – Viral Penetration Test

ASTM F1671, Standard Test Method for Resistance of Materials Used in Protective Clothing to Penetration by Blood- Borne Pathogens Using Phi-X174 Bacteriophage Penetration

- Used to determine the ability of a material to resist the penetration by bloodborne pathogens using a surrogate virus under continuous liquid contact
- A specimen is subjected to a nutrient broth containing a virus for a specified time and pressure sequence
- Phi-X174 is used
- Time and temperature are specified at 6 minutes, 2.0 psi for 1 minute, and atmospheric pressure for 54 minutes
- Terminated if visible liquid penetration occurs before or at 60 minutes
- This is a pass/fail test
- Primary bloodborne pathogens included in the test method are Hepatitis B Virus, (HBV), Hepatitis C Virus (HCV), and Human Immunodeficiency, Virus (HIV). Other microorganisms must be considered on a case-by-case basis

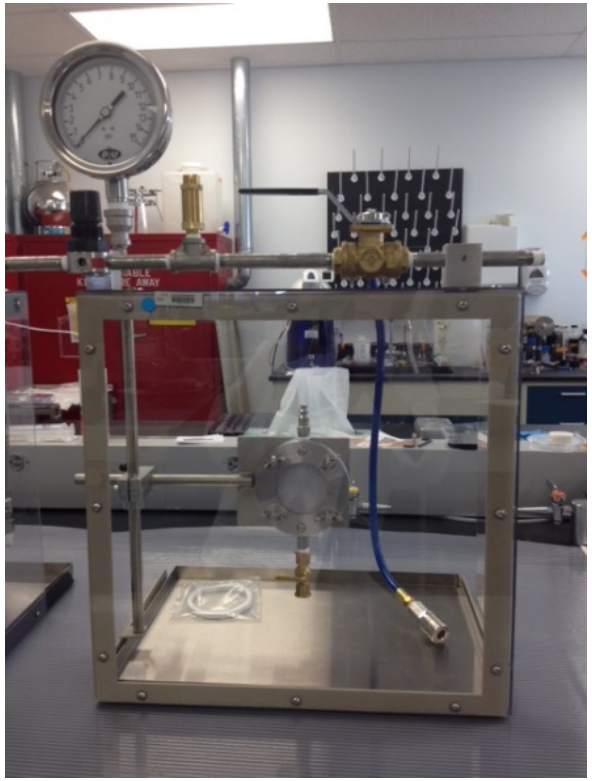
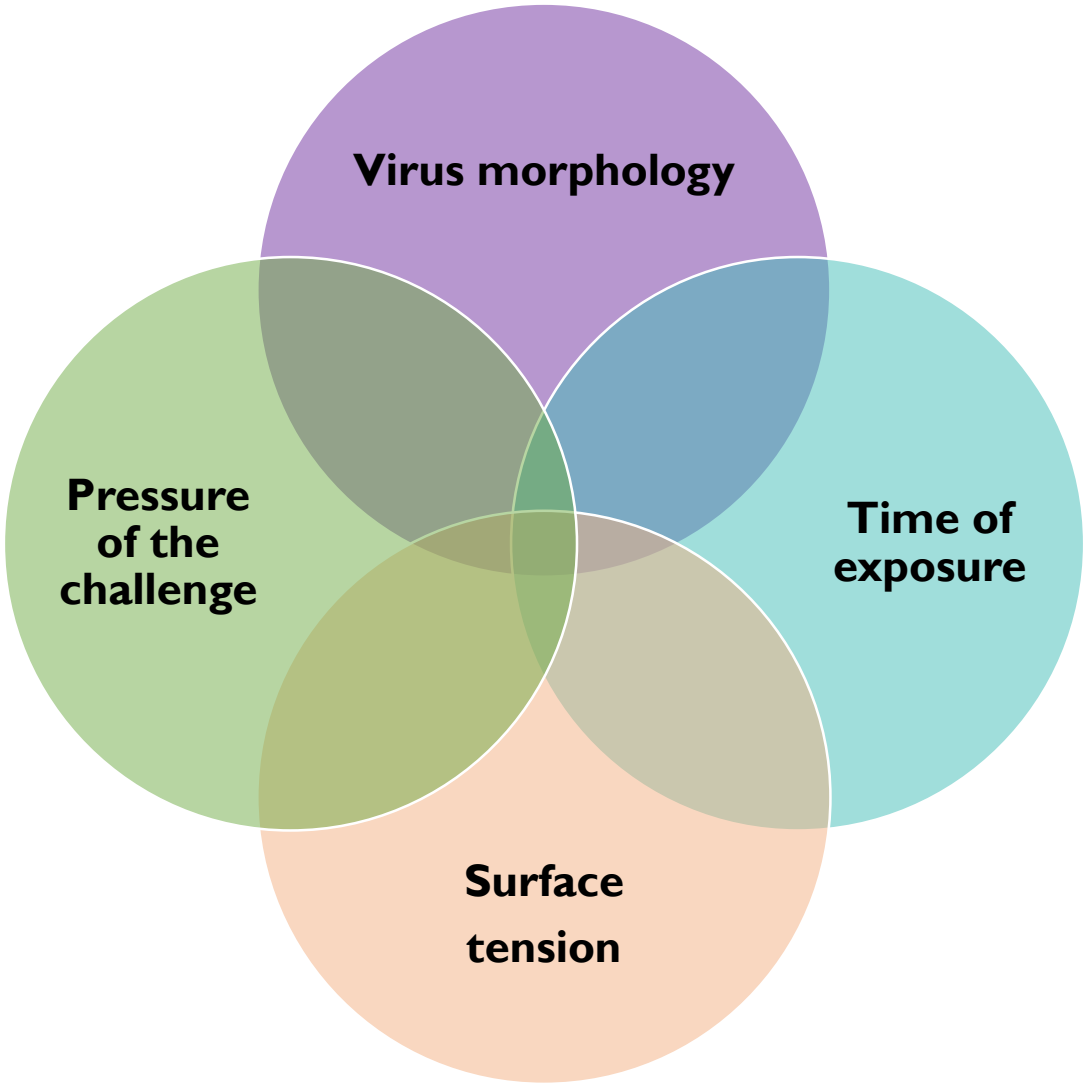
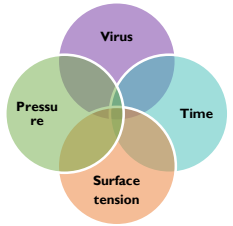


Photo Credit: NIOSH NPPTL

Critical Parameters of Blood and Viral Penetration Resistance Tests

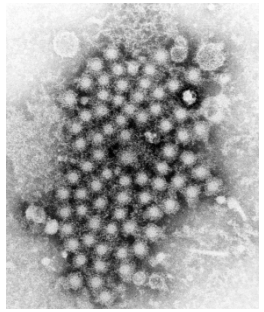




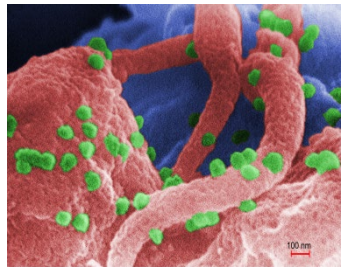
Virus Morphology

ASTM/ISO Test Methods

Phi-X174 : spherical, ~27 nm in diameter



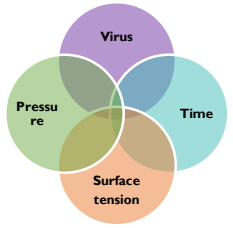
HCV: spherical, ~30 nm in diameter



HIV: spherical, 100-120 nm diameter

Ebola Virus: filamentous, ~80 nm in diameter

Photo Credit: CDC PHIL 8153, 11279, 10815

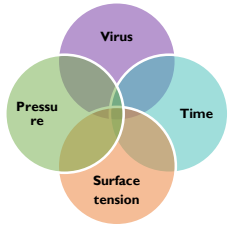


Surface Tension of the Challenge Liquid

Surface tension values for water, synthetic blood, and human blood and body fluids(1)				
	Surface Tension (N/m)			Temperature (°C)
	Average	**Min.**	**Max.**	
Water [Randall and Calman 1954]	0.072	—	—	25
Synthetic Blood	0.042 ± 0.002	—	—	25
Blood				
[Attinger et al. 2013] (review)	—	0.027	0.058	37
[Hrncir et al. 1997]	0.056	—	—	22
Saliva				
[Kazakov et al. 2009]	0.042	—	—	not specified
[Geigy Scientific Tables, 1984]	0.015-0.026	—	—	not specified
Gastric juices				
[Spychal et al. 1990]	0.047	—	—	Ambient
[Aburub et al. 2008]	—	0.035	0.045	not specified
Duodenal and Jejunal fluids				
[Fuchs and Dressman 2014]	—	0.028	0.041	not specified
Sweat				
[Bothorel et al. 1992]	0.0383	—	—	20-Healty
[Bothorel et al. 1992]	0.0418	—	—	20-Atopic
[Geigy Scientific Tables, 1984]	0.069-0.070	—	—	37–38

(1) Vomit is usually gastric juice, although in extreme cases intestinal juices can be included. Diarrhea is just the opposite—it is predominantly intestinal juices

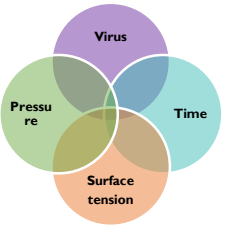
NPPTL
National Personal Protective Technology Laboratory



Pressure Type and Level

- Pressing and leaning in surgery 1 to 60 psi(1)
- Leaning against the operating table 0.52 psi(2)
- Reaching for an instrument <0.70 psi(2)
- Most pressures applied to the front of surgical gowns <2.9 psi for <15 seconds(3)
- Representative abdominal pressure during surgical procedures 0.25-2.0 psi(2)
- ASTM F1670 and ASTM F1671 use 2 psi (13.8 kPa) hydrostatic pressure
- ISO 16603 and ISO 16604 use incremental hydrostatic pressure levels, 0 psi up to 2.9 psi
- Hydrostatic vs. mechanical pressure

(1) Altman KW, McElhaney JH, Moylan JA, Fitzpatrick KT [1991]. Transmural surgical gown pressure measurements remits in the operating theater. Am J Infect Control 19(3):147–155
(2) Smith JW, Nichols RL [1991]. Barrier efficiency of surgical gowns: are we really protected from our patients' pathogens? Arch Surg 126(6):756–763
(3) Smith JW, Tate WA, Yazdani S, Garcia RY, Muzik AC, Nichols RL [1995]. Determination of surgeon-generated pressures during various surgical procedures in the operating room. Am J Infect Control 23(4):237–246



Time

- Time of exposure to pressurized liquid challenge another factor that might affect the results. This time is now set to one minute in the ASTM F1670 and ASTM F1671 test methods

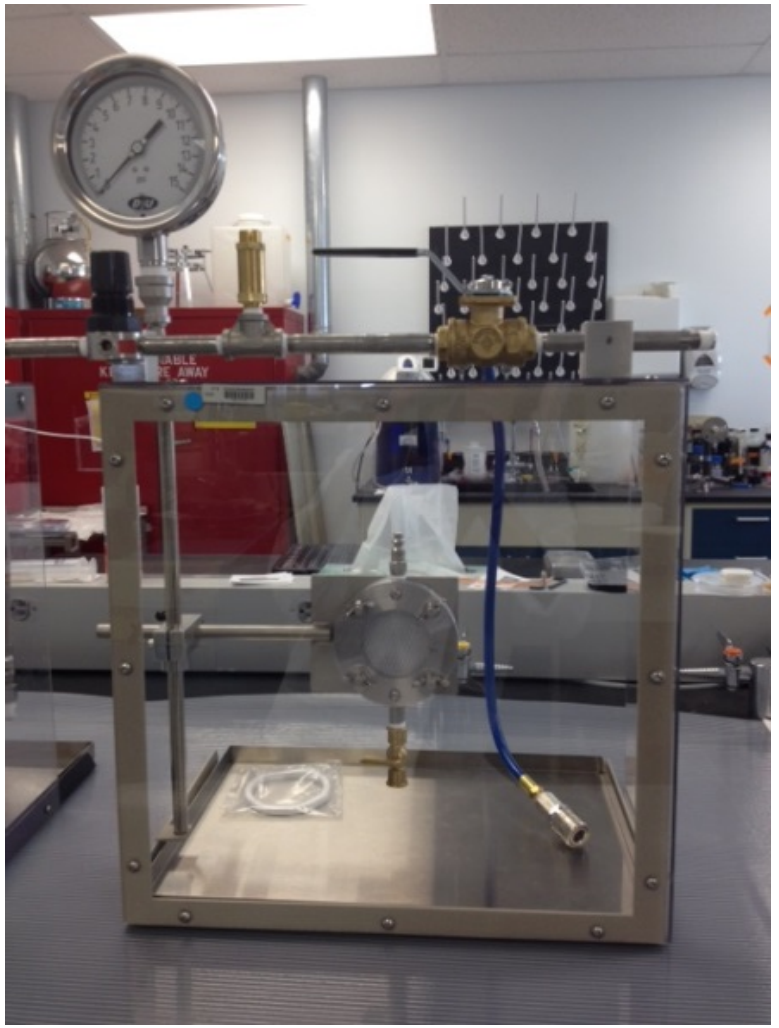


Photo Credit: NIOSH NPPTL

Standards and Classifications for Coveralls

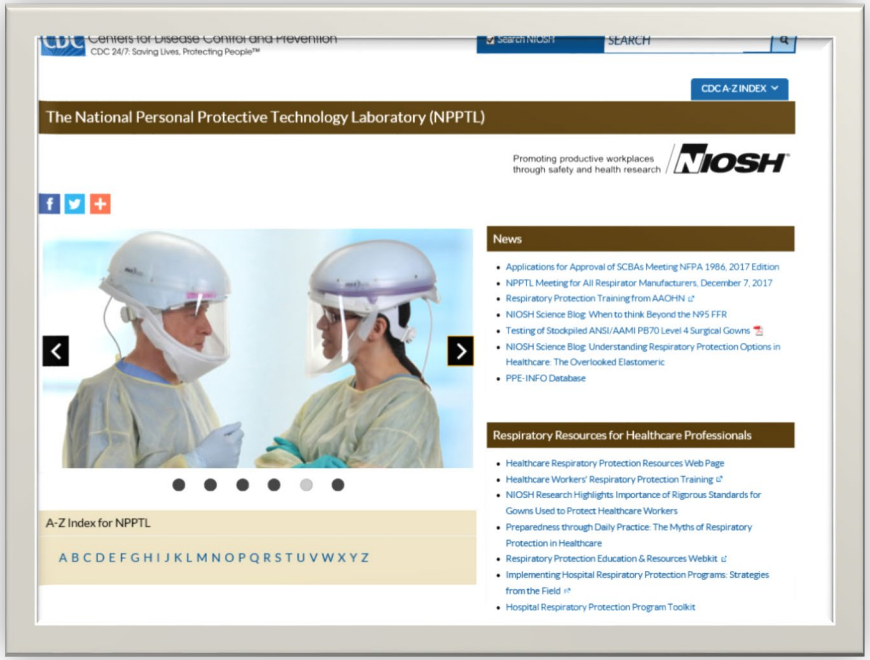
- EN 14126—"Performance requirements and test methods for protective clothing against infective agents"
- NFPA 1999—"Standard on Protective Clothing for Emergency Medical Operations"

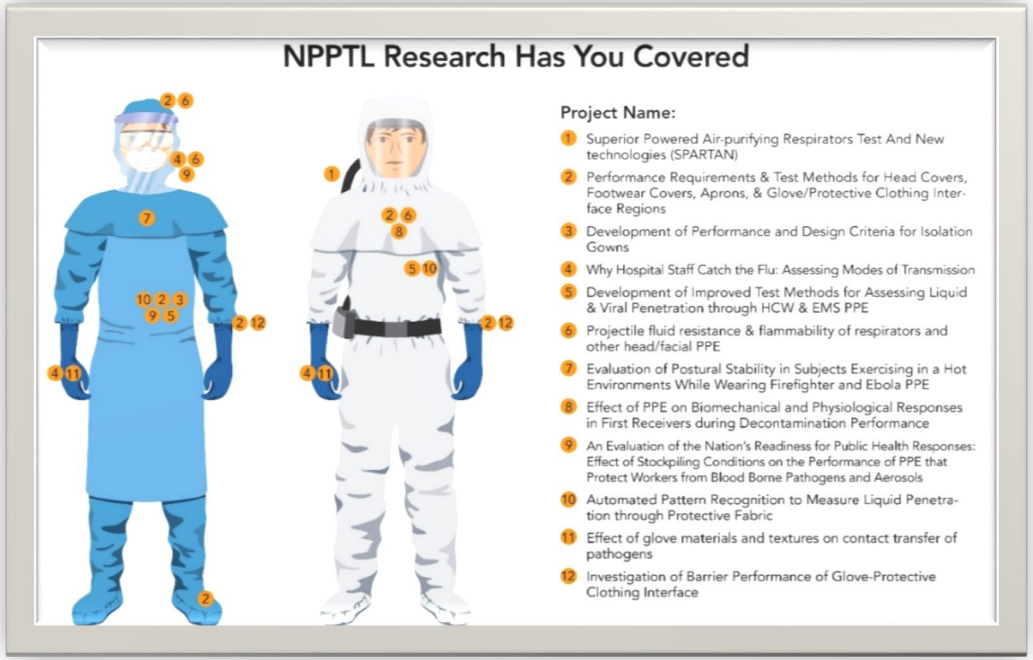
Photo Credit: CDC PHIL 18149

Photo Credit: MSA

Photo Credit: DuPont

Ongoing and Completed Research Projects with Gowns and Gloves at National Personal Protective Technology Laboratory (NPPTL)





NPPTL
National Personal Protective Technology Laboratory

Ongoing/Completed Ebola Response Research Projects at NPPTL

Testing PPE Performance	• Elbow Lean Study • Glove Strength Study • Stockpile Study
Development of Performance and/or Design Criteria	• Isolation Gown Project • PPE Elements Project (head covers, aprons, footwear covers)
Development of New Test Methods	• PPE Elements Project (glove/protective clothing interface) • Liquid and Viral Penetration Tests Project

Evaluation of Gowns and Coveralls against Simulated Bodily Fluids Using a Rapid Elbow Lean Test

Objective

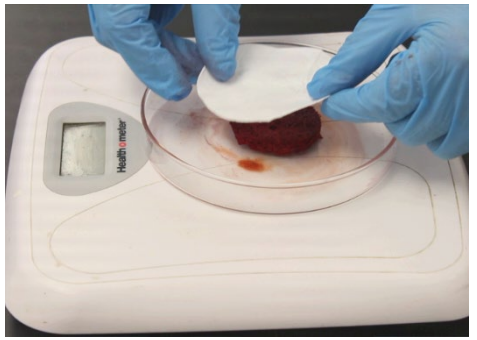
To quickly evaluate simulated bodily fluid penetration of protective clothing under mechanical pressure that demonstrates actual use conditions

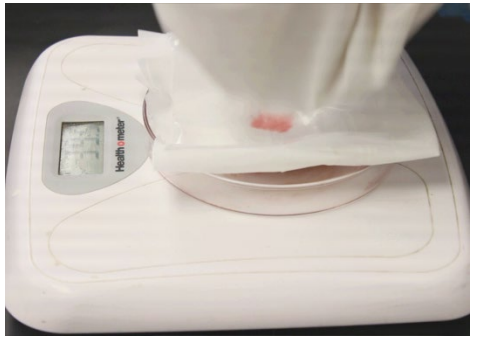
Methods

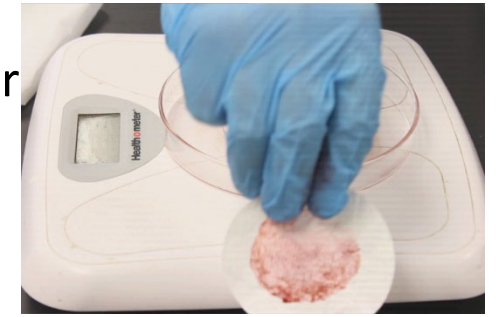
- Elbow Lean Test was used to obtain a visual semi-quantitative measure of the resistance of garments to the fluid penetration
- Two bodily fluid simulants (colored water and synthetic blood)
- Five gowns and four coveralls, continuous and discontinuous regions, multiple elbow pressure levels (2-44 PSI)

Findings

- No strikethrough at continuous regions of one gown & two coveralls
- Only the same gown consistently resisted strike-through at discontinuous areas
- Fluid strikethrough increased with higher applied elbow pressure, was higher for lower fluid surface tension, and was higher for the discontinuous regions of the protective garments (exception of one garment)







Jaques, P.A., Gao, P., Kilinc-Balci, S., Portnoff, L., Weible, R., Horvatin, M., Strauch, A. and Shaffer, R., 2016. Evaluation of gowns and coveralls used by medical personnel working with Ebola patients against simulated bodily fluids using an Elbow Lean Test. Journal of occupational and environmental hygiene, 13(11), pp.881-893.

Photo Credit: NIOSH NPPTL

Effect of Multiple Alcohol-based Hand Rub Treatments on Tensile Strength and Elongation of Medical Exam Gloves

Objective

Provide HCWs with useful information on the selection of medical exam gloves and understand the effect of alcohol based hand rubs (ABHR) on gloves (during doffing of PPE used for protection against the Ebola virus based on the CDC guidance)

Methods

- Five Latex and eight nitrile medical gloves
- Ethanol-Based and Isopropanol-Based Hand Rubs (EBHR and IBHR)
- Six applications (similar to CDC PPE doffing recommendations for Ebola)

Findings

- Both ABHRs decreased tensile strength while slightly increasing elongation
- Generally, the effect was greater on the nitrile than the latex gloves
- All tested gloves still met NFPA 1999 glove requirements for tensile strength up to six applications, except for two brands of relatively thin nitrile gloves
- Results show that multiple EBHR applications on the latex gloves and some of the nitrile gloves tested should be safe for Ebola PPE doffing based on the CDC guidance. Some of the results are available on CDC website at http://www.cdc.gov/vhf/ebola/healthcare-us/ppe/faq.html

Photo Credit: NIOSH NPPTL

Gao, Pengfei, et al. "Effect of Multiple Alcohol-Based Hand Rub Applications on the Tensile Properties of Thirteen Brands of Medical Exam Nitrile and Latex Gloves." Journal of occupational and environmental hygiene (2016) 13(11): 881-93

Effect of Stockpiling Conditions on the Performance of Particulate Air-Purifying Respirators and Surgical Gowns

Objectives

- Provide stockpile facilities, manufacturers, and regulators with evidence-based recommendations for particulate air-purifying respirators (APR) and Level 3 and 4 surgical gowns by evaluating shelf life and storage practices (humidity, temperature, light exposure) and sampling and testing PPE from 10 stockpile facilities with various conditions.

Photos courtesy of NIOSH NPPTL

Photos courtesy of Shutterstock

Photos courtesy of Moldex,

Progress

- 7/10 facility visits complete; 2,488 respirators tested

Next Steps

- Respirator testing (including quantitative fit testing): September 2017 and June 2019
- Surgical gown testing: August 2018 - March 2019

Expected Outputs

- Information to PPE manufacturers and stockpile managers on:
  - Guidance on practical/resource-driven decision-making related to stockpile conditions
  - Tips for inventory sampling to improve quality assurance activities
  - Low cost tips for environmental monitoring

PI: Lee Greenawald ilv1@cdc.gov

NPPTL
National Personal Protective Technology Laboratory

Development of Performance & Design Criteria for Isolation Gowns

Objective

Collaborate with ASTM F23 to develop standard specification that defines minimum performance and design requirements for isolation gowns

Progress

- 13/22 disposable gown models met AAMI liquid barrier performance standard
- Preliminary findings were incorporated into CDC Ebola PPE guidance and supported FDA's new guidance document http://www.fda.gov/ucm/groups/fdagov-public/@fdagov-meddev-gen/documents/document/ucm452804.pdf
- 9 models of reusable isolation gowns from 5 manufacturers were evaluated for performance before and after maximum laundering cycles (72-100). 3/9 models met AAMI liquid barrier performance standard
- ASTM draft standard to establish a new isolation gown standard that lists the minimum performance requirements including tensile strength, tear resistance and seam strength

Photo Credit: NIOSH NPPTL

Next Steps

- Evaluate the comfort properties of isolation gowns using benchtop &manikin testing
- Publish findings with disposable and reusable gowns

– *Cloud, Rinn, et al. "Isolation Gown Use, Performance and Potential Compliance Issues Identified by Infection Control Professionals." American Journal of Infection Control 40.5 (2012): e74-e75.*
– *Kilinc, F. Selcen. "A Review of Isolation Gowns in Healthcare: Fabric and Gown Properties." Journal of Engineered Fabrics & Fibers (JEFF) 10.3 (2015).*
– *Balci, F. Selcen Kilinc. "Isolation gowns in health care settings: Laboratory studies, regulations and standards, and potential barriers of gown selection and use." American journal of infection control 44.1 (2016): 104-111*

ASTM INTERNATIONAL

NPPTL National Personal Protective Technology Laboratory

Performance Requirements and Test Methods for Head Covers, Footwear Covers, Aprons, and Glove-Protective Clothing Interface Regions

Objectives

Determine the minimum performance and design requirements for three PPE elements (head covers, aprons, footwear covers)

Develop a new standardized test method for assessing the liquid penetration through glove/protective clothing interface, and design advanced protective clothing to eliminate/minimize the leakage through glove-protective clothing interface

Photo Credit: NIOSH NPPTL

Progress

- Head cover testing ongoing
- Testing procedure was developed and impact of the test parameters on the fluid penetration was analyzed (paper in press)
- Surgical settings and isolation settings were simulated (paper was submitted)


Photo Credit: CBS News/60 Minutes

Next Steps

- Test the PPE elements and develop minimum performance requirements
- Simulate decontamination settings, conduct testing of several protective clothing + glove combinations and determine the leakage and develop a standard test method to assess the leakage on glove-protective clothing interface

Kilinc-Balci, F. Selcen, Zafer Kahveci, and Patrick L. Yorio. "Novel Test Method for the Evaluation of Fluid Leakage at the Glove-Gown Interface and Investigation of Test Parameters." Journal of the American College of Surgeons (2018).

Development of Improved Test Methods for Assessing Liquid and Viral Penetration through Healthcare Worker and Emergency Medical Service PPE

Objectives

- To develop improved test methods for assessing liquid and viral penetration through healthcare worker and emergency medical service protective clothing
- To evaluate the attributes that affect penetration and rank their importance so that test methods reflect the primary factors affecting penetration

Progress

- After research showed that ASTM test methods did not properly characterize the test fluid, we published a paper and the committee amended ASTM F1670 and F1862
- After research showed that test results depended on a loosely specified screen design, we developed an improved prototype and the committee amended ASTM F903

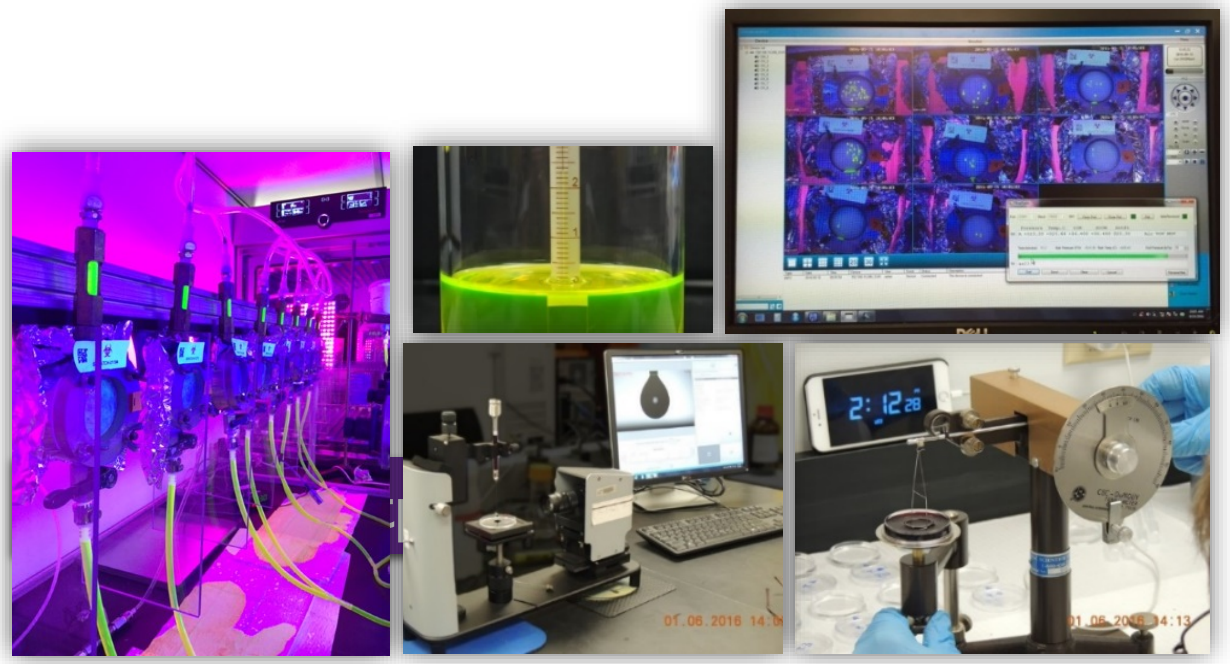


Photo Credits: NIOSH NPPTL

Next Steps

- To continue to amend current liquid penetration test methods by improving the test apparatus, such as replacing manual valves with precise electronic pressure control
- To develop the next generation of liquid and viral penetration testing standards

PI: Lee Portnoff xda3@cdc.gov

NPPTL
National Personal Protective Technology Laboratory

Summary

- Several fluid-resistant and impermeable protective clothing options are available in the market place for HCWs
- A key step in the protective clothing selection process is to understand the relevant standards and test methods
- Multiple test methods and classification standards exist to determine the barrier effectiveness of gowns and coveralls. There is room for improvement in some of the test methodologies.
- NPPTL plans to continue research to better understand the factors affecting barrier performance of protective clothing materials against bloodborne pathogens and use that information to validate/improve current test methods
- NPPTL plans to expand its work for determination of the minimum performance requirements for other PPE elements, such as hoods, aprons, footwear covers, and interface regions
- NPPTL will continue supporting CDC by generating technical documents for all types of PPE used by HCW and emergency responders to protect against microorganisms in blood and body fluids

Some NIOSH NPPTL Resources

- Considerations for Selecting Protective Clothing used in Healthcare for Protection against Microorganisms in Blood and Body Fluids

http://www.cdc.gov/niosh/npptl/topics/protectiveclothing/

- Fighting Ebola: A Grand Challenge for Development – How NIOSH is Helping Design Improved Personal Protective Equipment for Healthcare Workers

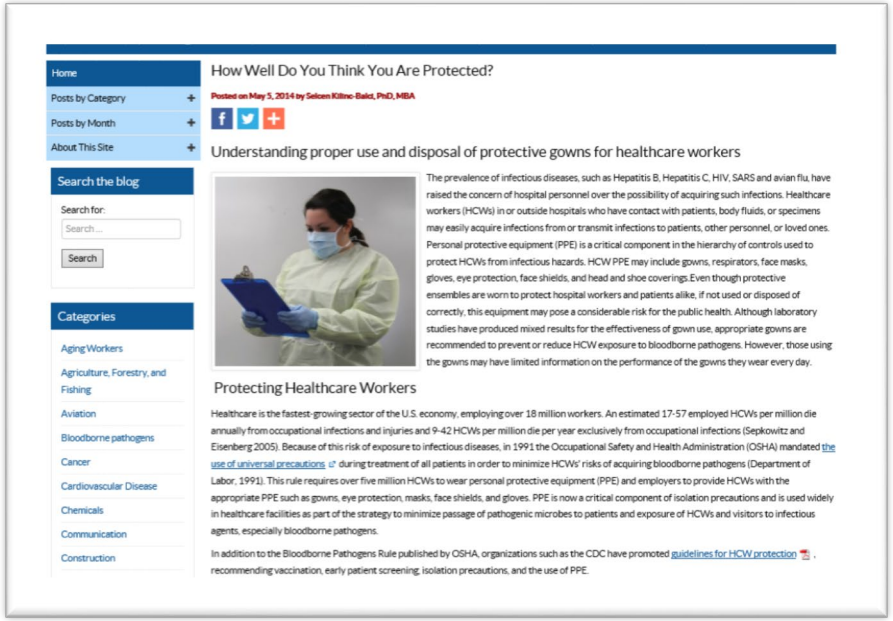
https://blogs.cdc.gov/niosh-science-blog/2015/02/05/ebola-ppe/

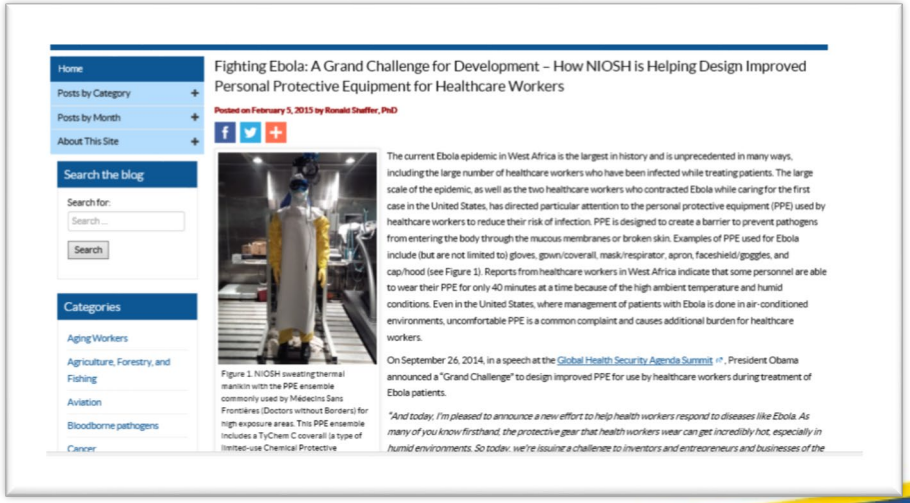
- How Well Do You Think You Are Protected? Understanding proper use and disposal of protective gowns for healthcare workers

https://blogs.cdc.gov/niosh-science-blog/2014/05/05/gowns/

- NIOSH Research Highlights Importance of Rigorous Standards for Gowns Used to Protect Healthcare Workers

https://blogs.cdc.gov/niosh-science-blog/2015/07/22/isolation-gowns/





NPPTL
National Personal Protective Technology Laboratory

Quality Partnerships Enhance Worker Safety & Health

Visit us at: http//www.cdc.gov/niosh/npptl

Photos courtesy of MSA, Kimberly Clark, and North

Disclaimer: The findings and conclusions in this report are those of the author(s) and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. Mention of a company or product name does not constitute endorsement by NIOSH.

Contact Information

F. Selcen Kilinc-Balci, Ph.D.

Phone: 412-386-4086

Email: JCQ8@cdc.gov