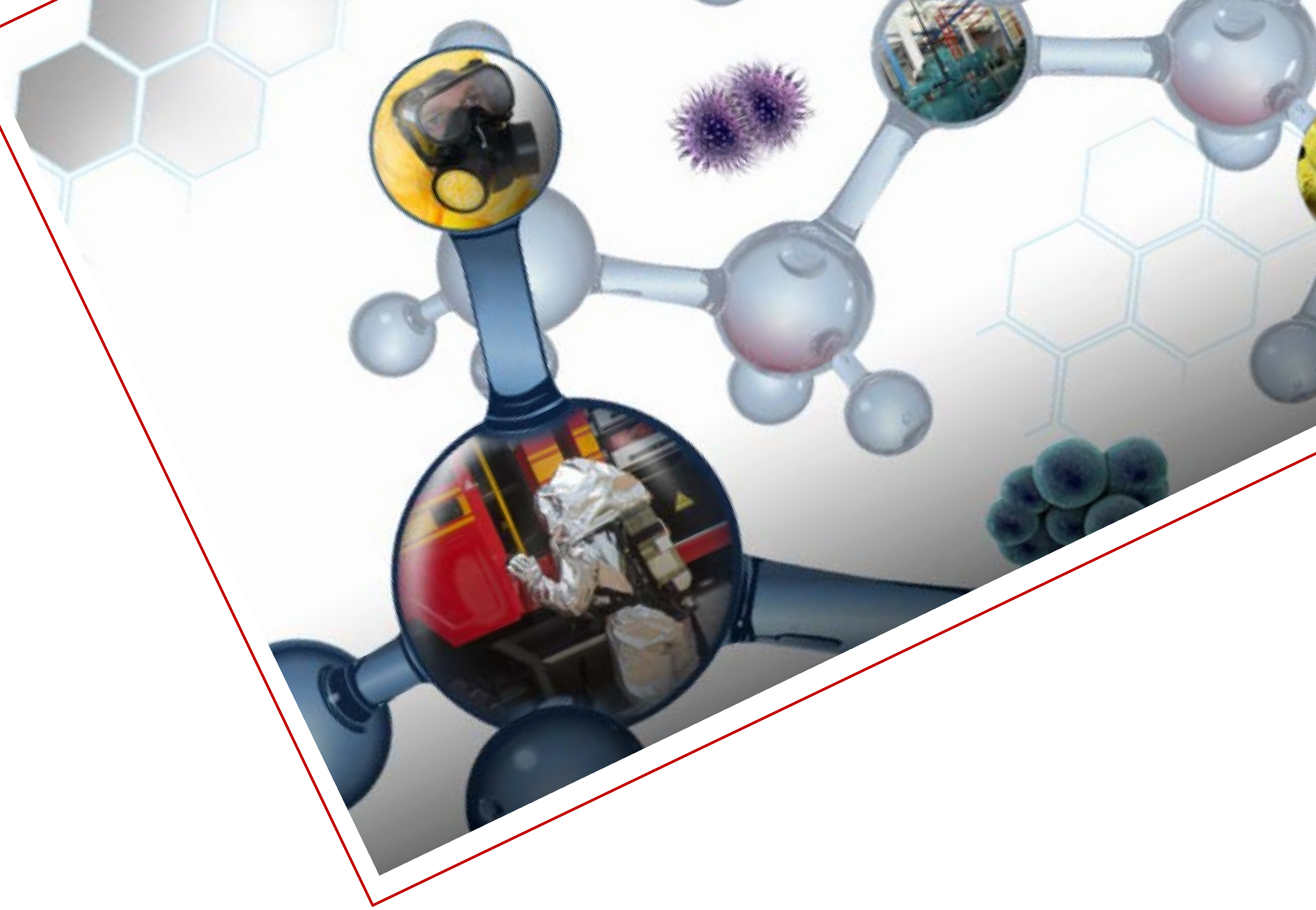

STANDARDIZED CHEMICAL LISTS FOR SELECTING CHEMICAL PROTECTIVE ENSEMBLES

Standards add value to ensure adequate protection against a broad range of chemicals

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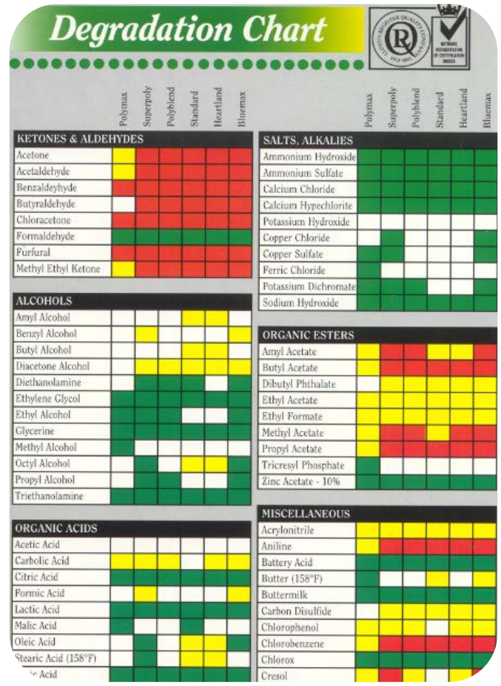
KEY TAKEAWAYS FROM THIS PAPER

By going through this paper, you will:

1) ***Understand why it is important to use protective ensembles that comply with NFPA standards***
2) ***Recognize why standardized chemical batteries are particularly relevant to broad chemical resistance claims***
3) ***Become aware of how having a long list of chemical permeation data on a clothing product does not establish the relative safety of a full ensemble***



There is a common misconception within parts of the hazardous materials response community that large chemical lists with permeation breakthrough data are the best way to demonstrate the protective qualities of chemical clothing products. Most of these lists provide information only on the principal barrier material (usually the most protective part of the clothing) while ignoring interface materials, seams, and visors (that tend to be the least protective parts of an ensemble). While such lists can sometimes be helpful, this approach ignores the overall systems approach for how clothing provides protection where it is more important to test all parts of the ensemble and apply standardized lists or batteries of chemicals used for demonstrating clothing barrier qualities for a larger array of chemicals.

How Large Chemical Permeation Data Lists Can Be Misleading

On August 12, 1983, a tank car loaded with dimethylamine located on an industrial rail track in Benicia, California, began leaking products from its sample line. The responsible chemical company called in the local fire department, which dispatched its hazardous materials response team. Three firefighters wearing chemical protective suits climbed on the tank car and installed a clamp to stop the leak. However, 30 minutes later, the clamp began to leak, and the response team made a second attempt at the repair. During this second exposure to the dimethylamine, the responders noted that suit facepieces began to cloud over, crack, and melt, reducing their visibility. Leaks also developed in the seams of the suits, and one responder’s facepiece shattered, exposing him to the chemical. This incident ultimately exposed several first responders to dimethylamine, even though the manufacturer recommended the use of their suits for the chemical involved.

An investigation of the accident by the U. S. National Transportation Safety Board (NTSB) revealed that the information on the chemical compatibility of the suit with dimethylamine was relevant to the suit material only; *__it did not apply to the visor or seams.__* As result of their investigation, NTSB recommended the development of standards for protective clothing used for protection from hazardous chemicals. The U. S. Department of Transportation (DOT) also issued a position paper that requested the private sector to undertake writing standards for hazardous chemical protective clothing and asked other governmental agencies to assist and participate in the private sector standards development system. The DOT at this time also directly requested that the NFPA develop documents on hazardous chemical protective clothing. The International Association of Fire Chiefs, U. S. Environmental Protection Agency, U. S. Coast Guard, Federal Emergency Management Agency, and Occupational Safety and Health Administration either adopted position statements modeled after the DOT position or endorsed the DOT position. This effort was heavily supported by the International Association of Fire Fighters for improving the health and safety of its members, which constituted a significant portion of the hazardous materials response teams around the country.

Figure 1: Situation Representative of Benicia Incident with Photographs of Damaged Suit Visor

How Ensembles Provide Protection

To protect the wearer, clothing must provide a barrier that prevents or impedes exposure to the chemical. While many believe that the principal barrier qualities of chemical protective clothing arise from the materials of construction only, it is the combination of clothing design, its integrity, and material chemicals resistance that are the principal drivers of protection.

Chemicals take the path of least resistance, whether this be a gap between the interface of sleeve and glove, an inadequate closure system, or poorly constructed seams.[1] More often than not, the elasticized coverall hood opening as a suit interface with the respirator facepiece is likely to provide a more likely pathway for liquid or vapor penetration than the chemical having to go directly through the material. The use of chemical resistance tape is not a viable means to correct for this interface deficiency.

Thus, it is first integrity through suitable ensemble design, then the barrier properties of the material, seams, and closure, and then other design/material attributes of the clothing items that affect its durability, function, and comfort that define the protective capabilities of the ensemble.

Only comprehensive standards that fully address all of these attributes can properly establish appropriate levels of protection. Reliance on a single measure, such as chemical permeation resistance only, does not address the most important clothing features for defining protection. The NFPA 1991, 1992, and 1994 standards are representative of the few comprehensive standards that fully account for all essential attributes.[2,3,4]

Chemical Permeation and Penetration Resistance as a Form of Material Barrier Performance

Chemical permeation resistance testing evaluates how easily chemicals pass through a material (or seam or closure) on an "invisible" molecular level. This testing involves putting the chemical in contact with the clothing material and measuring the amount and rate at which chemical passes through the material as captured in a collection medium – either air or water. This form of evaluation is in contrast to penetration, which for liquids, is the visual observation of bulk liquid chemical passing

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[1] Stull, J. O. and D. F. White. (1992). "Selecting Chemical Protective Clothing on the Basis of Overall Integrity and Material Performance Tests." American Industrial Hygiene Association Journal, Vol. 53, No. 7, pp. 455-462.
[2] NFPA 1991, Standard on Vapor-Protective Ensembles for Hazardous Materials Emergencies and CBRN Terrorism Incidents; NFPA 1992, Standard on Liquid Splash-Protective Ensembles and Clothing for Hazardous Materials Emergencies; and NFPA 1994, Standard on Protective Ensembles for First Responders to Hazardous Materials Emergencies and CBRN Terrorism Incidents (available at www.nfpa.org).
[3] The NFPA provides an overview of these standards and the selection HazMat/CBRN PPE in "Risk-Based Selection of Chemical Protective Clothing" on their website at: https://www.nfpa.org/-/media/Files/white-papers/WhitePaperRiskBasedSelectionOfChemicalProtectiveClothing.pdf.
[4] Additional tutorial information explaining these standards and their individual requirements in "Risk-Based Selection of PPE" is available at https://www.resonatelearning.com/demo/PPE/.

through the material. In either case, the barrier performance of the clothing material is judged as ability to prevent the passage of chemical, either molecularly (permeation) or in bulk (penetration).

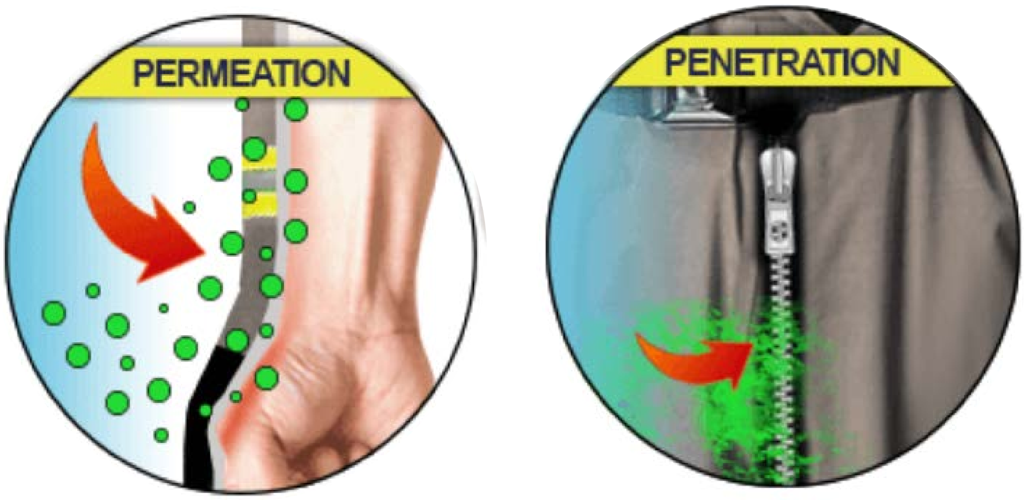

Figure 2: Visualization of permeation and penetration

Permeation resistance is primarily applied in NFPA 1991 and 1994, where extended liquid or vapor contact are possible, whereas penetration resistance is used in NFPA 1992 for demonstrating liquid splash protection. Both types of barrier performance are illustrated above.

Several references provide an in-depth review of chemical permeation and penetration resistance testing methods and their applications.[5,6,7,8]

Measuring Protection: Permeation Breakthrough Time versus Cumulative Mass

It is important to understand why cumulative permeation is a better, more practical metric as compared to breakthrough time. The NFPA 1991 and 1994 hazmat standards made this change in 2016 and 2012, respectively.

Historically, chemical permeation resistance information for protective clothing was presented as breakthrough times. Breakthrough times indicate the elapsed time between initial contact of the chemical with clothing material and the elapsed time for its passage through the material as detected at a specified concentration or rate (usually reported in minutes).

[5] Module 2, "Material Barrier Performance" in "Risk-Based Selection of PPE" is available at https://www.resonatelearning.com/demo/PPE/.

[6] Henry, N. W. III & Stull, J. O. (2003) "Test Methods and Standards." In Chemical Protective Clothing, Second Edition. American Industrial Hygiene Association, Anna, D. H. (Ed.). Available at: https://online-ams.aiha.org/amsssa/ecssashop.show_product_detail?p_mode=detail&p_product_serno=1153.

[7] Schwope, A. D., Goydan, R., Reid, R. C., & Krishnamurthy, S. (1988). "State-of-the-art review of permeation testing and the interpretation of its results." American Industrial Hygiene Association Journal, 49(11), 557-565.

[8] Stull, J. O., White, D. F. & Greimel, T. C. (1992). "A Comparison of the Liquid Penetration Test with Other Chemical Resistance Tests to Determine the Performance of Protective Clothing," In.Performance of Protective Clothing: Fourth Volume, ASTM STP 1133 (J. P. McBriarity and N. W. Henry, eds.), ASTM International, pp. 123-138.

Contrary to what many first responders are taught, the breakthrough time is not the same as protection time since chemical may permeate before the manufacturer-reported breakthrough time. As currently defined and applied, breakthrough time is the time to when the measured permeation reaches a certain prescribed rate (that is not related to exposure safety but for consistency of testing). Thus, breakthrough times only serve as a benchmark for comparing material performance.

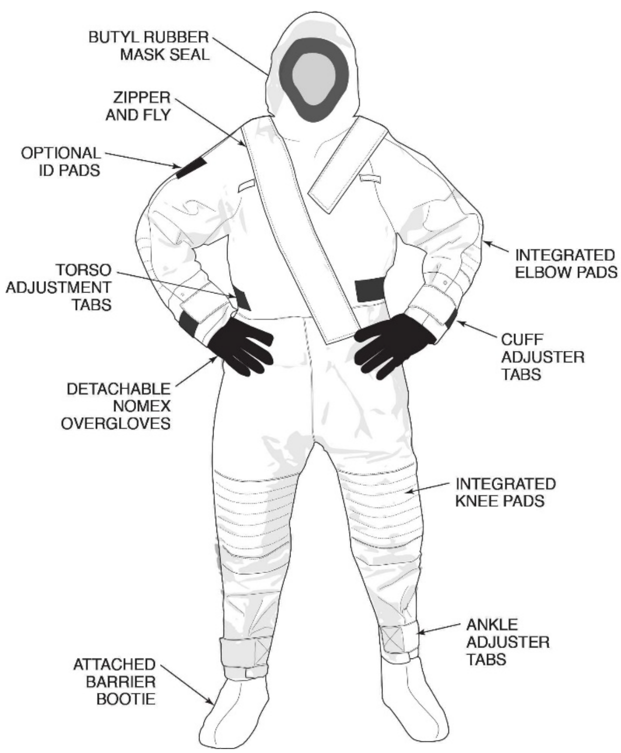

Figure 3: Different areas of ensemble must be tested to fully evaluate its barrier properties.

Cumulative permeation mass is the amount of chemical that passes through the clothing material in a given time frame (usually reported as microgram per square centimeter of material). This is considered more relevant information for understanding protection because this measurement indicates the amount of chemical that the wearer is potentially exposed to akin to a "dose." Consequently, the reporting of cumulative permeation mass allows a determination of safe levels of chemical to which first responders can be exposed, which is not possible with breakthrough time measurements. Lastly, research has demonstrated a greater likelihood for using cumulative permeation data for modeling the permeation resistance of chemical protective clothing.[9]

Unlike most manufacturer chemical resistance breakthrough charts, the NFPA 1991 and 1994 standards specify performance of chemical protective ensemble materials based on the use of cumulative permeation mass. These standards further define meaningful performance levels for garment material and seams, visors, gloves, footwear, and some interfaces, with some testing after simulated wear and tear. Unless otherwise stated, nearly all manufacturer chemical resistance charts for non-NFPA products exclusively report the chemical permeation data for the principal barrier material only, not including seams or other ensemble materials.

[9] Goydan, R., Schwope, A. D., Reid, R. C., Krishnamurthy, S., & Wong, K. (1988). "Approaches to Predicting the Cumulative Permeation of Chemicals through Protective Clothing Polymers." In Performance of Protective Clothing: Second Symposium. ASTM International. pp. 257-268.

ENSEMBLE AREAS SUBJECT TO NFPA BARRIER TESTING

The Establishment of Standardized Chemical Lists ("Batteries") for Barrier Testing

It is impractical to evaluate all parts of the protective ensemble (garment/suit, visor, gloves, footwear, and seams) for every anticipated chemical exposure. There are simply too many different chemicals encountered in a range of concentrations, in various combinations as mixtures, under different environment conditions, and during different types of response operations, all of which affect wearer exposure to the respective chemical(s).

In the mid-1980s, a standard list of chemicals (ASTM F1001) was established to identify key substances that could be used to both represent a range of commonly encountered chemicals as well as offering a basis for predicting generalized, broad material barrier performance of chemical protective clothing.[10] The 15 room temperature liquids and 6 gases in this list were selected based on the following factors:[11]

- The representation of different chemical classes
- Consideration of both organic and inorganic chemicals
- Relative volumes of chemical use or transport (potential for release)
- Hazards posed by chemicals in laboratory testing (requiring surrogates)
- Known effects of chemical on common protective clothing materials

In general, the chosen chemicals were smaller molecules of each represented class as lower molecular weight chemicals permeate many clothing materials more easily and thus serve as aggressive chemical challenges.

NFPA 1991 uses the ASTM F1001 list plus five chemicals specifically used for CBRN protection for the evaluation of permeation resistance of vapor-protective ensembles.[12] NFPA 1991 further requires using this chemical battery in the permeation testing of all major ensemble components including base materials, seams, and interfaces.

NFPA 1994 Class 1 non-encapsulating HazMat/CBRN protective ensembles use a subset of the chemicals in the NFPA 1991 test battery that focuses on those chemicals that are more likely to be encountered during emergency responses and at high challenge levels. This is an important distinction

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[10] ASTM F1001, Standard Guide for Selection of Chemicals to Evaluate Protective Clothing Materials, available at www.astm.org.

[11] Stull, J.O. (1996). "A Review of the ASTM F1001 Battery of Chemicals and Its Effect on the Chemical Protective Clothing Industry," In Performance of Protective Clothing: Fifth Volume, ASTM STP 1237 (J. S. Johnson and S. Z. Mansdorf, eds.), ASTM International, pp. 110-122.

[12] These additional chemicals include Acrolein, Acrylonitrile, Dimethyl Sulfate, Distilled Mustard (HD), and Soman (GD).

because many chemicals in the NFPA 1991 battery have high vapor pressures, meaning they will readily evaporate very early during the response lowering the potential for first responder exposure. The annex of NFPA 1994 further explains the choice of Class 1 chemicals where information from a comprehensive U. S. Department of Defense study[13] for the prioritization of skin-absorptive exposure chemicals was used and further identifies the characteristics of an "ideal" chemical battery as:

1) Within the constraints of the testing environment, each battery chemical provides test data that is of sufficient quality to allow for the assessment of material barrier performance. The quality of data is defined in terms of its corresponding accuracy, reproducibility, and utility.
2) The battery incorporates the necessary range of chemical classes and reactivity in order to estimate the probability of minimal performance against the diverse population of untested chemicals with an appropriate degree of confidence consistent for providing intended level of protection.
3) Battery representative chemicals possess physical and chemical properties consistent with the exposure scenario for which the material is intended to provide protection.
4) Representative chemicals pose a reasonable hazard to the safety of the end user or the integrity of the protective ensemble system.

As with NFPA 1991, chemical warfare agents Distilled Mustard (HD) and Soman (GD), a more persistent and less volatile nerve agent than Sarin (GB), supplement the selected industrial chemicals creating a 12 chemical battery that is used for evaluating the permeation resistance of all of the principal ensemble components.

A subset of the above 12 NFPA 1994 Class 1 chemicals is used as the NFPA 1994 Class 2 and 3 test batteries for evaluating moderate and low level threat HazMat and CBRN protective ensembles. This smaller list entails chemical threats believed to best characterize lesser HazMat and CBRN operational exposures as one would expect during decontamination, investigation, evacuation, and other HazMat/ CBRN operations.

Whereas ASTM F1001, NFPA 1991, and NFPA 1994 chemical batteries are based on using standardized lists primarily aimed at establishing material and seam barrier performance against a wide range of chemicals threat that can be in either gas/vapor or liquid states, a separate battery of liquid chemicals was established for splash-protective ensembles in NFPA 1992 where liquid penetration resistance testing is used. Important factors used in selecting the 10 chemicals in this battery were:

1) Chemicals were included from the ASTM F1001 list if the chemical was a low-volatility liquid with a vapor pressure less than 5 mm Hg at 20°C; more volatile chemicals were excluded if they had known skin absorption toxicity (being outside the scope of NFPA 1992).

[13] Sutto, T. E. (2011). "Prioritization and sensitivity analysis of the inhalation/ocular hazard of industrial chemicals," NRL/FR/6364--11-10,211. Naval Research Laboratory, Materials Science and Technology Division, Washington, DC. Accessed at: https://apps.dtic.mil/sti/pdfs/ADA552552.pdf.

2) Lower vapor pressure substitutions of the same classification were made for some ASTM F1001 chemical. This was because lower volatility chemical are easier to observe for failure during liquid penetration testing.
3) Some of the chemicals were chosen to represent different characteristics such as known decontamination agents (e.g., bleach) or their ability represent a wider range of chemicals that impact liquid penetration resistance of NFPA 1992 ensemble materials.

The NFPA 1992 chemical battery is used in evaluating the penetration resistance of key liquid splash protective ensemble or clothing materials. A smaller subset of these chemicals is used specifically for evaluating ensemble seams.[14]

Figure 4: The selection of chemicals for standardized batteries must reflect a range of factors including likelihood of contact, chemical properties, permeation aggressiveness and ability to represent other chemicals that are not always tested.

The following chart summarizes these chemicals as well as three relevant properties that characterize different aspects for how they were selected.[15]

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[14] NFPA 1992 chemicals used for evaluating seams and closures include Fuel H (42.5% toluene, 42.5% iso-octane, 15% ethanol), Methyl Isobutyl Ketone, and Sulfuric Acid.

[15] The room temperature state indicates whether the "bulk" chemicals is a gas or liquid under ordinary circumstances. Vapor pressure is a measure the likelihood for the chemical to evaporate, particularly under warmer conditions. In the NFPA standards, chemicals with a vapor pressure of greater than 5 mm Hg at 20ºC are considered volatile. Surface tension is related to ability of liquids to penetrate small pores or imperfections in materials, or through seams, closures, or interfaces. Lower surface tensions represent chemicals are more likely to have better penetrating qualities.

Table 1: Standardized List (Batteries) of Chemicals

Chemical	Class	Room Temp. State	Vapor Press. (mm Hg)	ASTM F1001	NFPA 1991	NFPA 1992	NFPA 1994 Class 1	NFPA 1994 Class 2 & 3
Acetone	Ketone	Liquid	231	◆	◆			
Acetonitrile	Nitrile	Liquid	91.1	◆	◆			
Acrolein	Aldehyde	Liquid	210		◆		◇	◇
Acrylonitrile	Nitrile	Liquid	83		◆		◇	◇
Ammonia	Inorganic gas	Gas	7600	◆	◆		◆	◆
1,3-Butadiene	Halogenated hydrocarbon	Gas	2100	◆	◆			
Butyl Acetate	Ester	Liquid	15			◆		
Carbon Disulfide	Sulfur chemical	Liquid	360	◆	◆			
Chlorine	Inorganic gas	Gas	5830	◆	◆		◆	◆
Dichloromethane	Halogenated hydrocarbon	Liquid	435	◆	◆			
Diethylamine	Amine	Liquid	237	◆	◆		◇	
Dimethylformamide	Amide	Liquid	3.87	◆	◆	◆		
Dimethyl Sulfate	Sulfur chemical	Liquid	0.677		◆		◆	◆
Distilled Sulfur Mustard (HD)	Blister agent	Liquid	0.11		◆		◆	◆
Ethyl Acetate	Ester	Liquid	93.2	◆	◆		◇	
Ethylene Oxide	Heterocyclic compound	Gas	0.882	◆	◆			
Fuel H (42.5% toluene, 42.5% iso-octane, 15% ethanol)	Hydrocarbon mixture	Liquid	59.3			◆		
Hexane	Aliphatic hydrocarbon	Liquid	153	◆	◆			
Hydrogen Chloride	Inorganic acid	Gas	35424	◆	◆			
Isopropyl Alcohol	Alcohol	Liquid	45.4			◆		
Methanol	Alcohol	Liquid	127	◆	◆			
Methyl Chloride	Halogenated hydrocarbon	Gas	4300	◆	◆			
Methyl Isobutyl Ketone	Ketone	Liquid	19.9			◆		
Nitrobenzene	Nitrogen chemical	Liquid	0.284	◆	◆	◆		
Sodium Hydroxide (50%)	Inorganic base	Liquid	0	◆	◆	◆		
Sodium Hypochlorite (10%)	Inorganic salt	Liquid	12.1			◆		
Soman (GD)	Nerve agent	Liquid	0.41		◆		◆	◆
Sulfuric Acid (93.1%)	Inorganic acid	Liquid	3.4	◆	◆	◆	◆	
Tetrachloroethylene	Halogenated hydrocarbon	Liquid	18.5	◆	◆	◆	◆	
Tetrahydrofuran	Heterocyclic compound	Liquid	162	◆	◆			
Toluene	Aromatic hydrocarbon	Liquid	28.4	◆	◆		◆	

◆ Part of chemical battery; ◇ Part of chemical battery but tested as a vapor

Predictive Capabilities for Battery Chemicals

The general principle in applying a standardized list of chemicals is to use a representative set of substances for evaluating all primary parts of the ensemble to enable confidence in decisions for using the ensemble in operational exposures involving chemicals that might not be in the list. The premise of this approach is grounded in the following knowledge:

- It is impractical to test each and every chemical. In some responses, multiple chemicals may be involved or mixtures of different chemicals can be present. End users generally cannot rely on having the exact data they need to support deployment decisions for specific HazMat and CBRN responses.
- Even when specific chemicals are evaluated, actual exposure levels to first responders are typically much less than the chemical challenge levels used in testing, creating a "margin of error" that further ensures a sufficient level of safety for the first responder.
- NFPA-specified barrier testing employs preconditioning by repeated abrading and flexing of materials to simulate practical wear and use for predicting barrier performance. None of the regular chemical resistance data provided by manufacturers includes these preconditions.
- By evaluating the other elements and components of the ensembles such as glove and boot materials, seams, and interface, battery-based testing is likely to identify vulnerable or "weak links" in the barrier performance offered by the ensemble. Thus, passing performance for all of these materials and seams (including the applied preconditions such as abrasion and flexing to represent wear & tear during use) provides a stronger case for relying on a finite battery of chemicals for evaluating permeation or penetration resistance.
- When battery chemicals are judiciously selected to represent a range of potential aggressive chemicals as in the case of NFPA 1991 and 1994, the prospects for optimally addressing broad-based permeation or penetration resistance are increased. The application of an open and transparent process during the standards development process in combination with comprehensive research to choose representative chemicals also helps to better meet end user expectations for protection.
- Acceptable barrier performance against several of the battery chemicals can be inferred to predict acceptable performance for certain related chemicals that are of the same chemical class or are structurally similar. The diagram on the following pages shown an example of how one chemical (acrolein) can be used in represent other chemicals in the same general class. Table 2 provides some examples of possible inferences that can be made about chemicals used in the NFPA 1994 Class 1 chemical battery for permeation resistance.[16]

[16] Inferences of one chemical representing other potentially related chemicals can be made on a detailed examination of broad chemical resistance data between the battery chemical and the associated chemicals by examination comprehensive data sources found in Forsberg, K., Van den Borre, A., Henry III, N., & Zeigler, J. P. (2020). Quick Selection Guide to Chemical Protective Clothing. John Wiley & Sons and Forsberg, K., & Keith, L. H. (Eds.). (2019). Chemical Protective Clothing: Permeation and Degradation Compendium. Routledge.

Figure 5: Representation of One Chemical for Other Chemicals for Barrier Performance

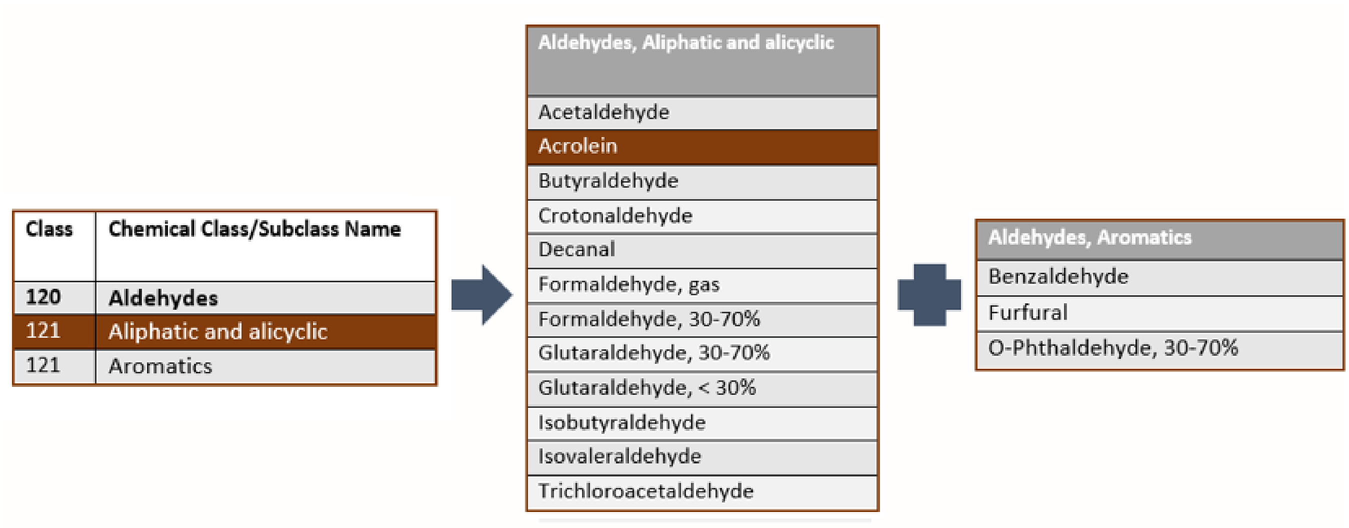

Table 2: Inferred Chemical Resistance for NFPA 1994 Class 1 Chemicals

Chemical	Class	Highly Likely Inferences	Possible Examples
Acrolein	Aldehyde	Other aldehydes and amides	Acrylamide, Benzaldehyde, Dimethylformamide, Formaldehyde, Glutaraldehyde
Acrylonitrile	Nitrile	Other nitriles and aromatic nitrogen compounds	Acetone Cyanohydrin, Acetonitrile, Benzonitrile, Nitrobenzene
Ammonia	Inorganic gas	Other reduced inorganic gases	Hydrogen Cyanide, Methane
Chlorine	Inorganic gas	Other oxidized inorganic gases and related compounds	Boron Trifluoride, Nitrogen Oxide, Phosgene, Phosphorous Oxychloride
Diethylamine	Amine	Other primary, secondary, and tertiary amines	Aniline, Butylamine, Dimethylamine, Morpholine, Trimethylamine
Dimethyl Sulfate	Sulfur chemical	Limited other sulfur compounds	Chlorosulfonic Acid, Dimethyl Sulfoxide, Sulfuryl Chloride
Distilled Sulfur Mustard (HD)	Blister agent	Other blister agents	Lewisite (L), Nitrogen Mustard (HN)
Ethyl Acetate	Ester	Other esters; ketone, and carboxylic acids	Acetic Acid, Benzyl Acetate, Diethyl Phthalate, Ethyl Acrylate, Methyl Ethyl Ketone
Soman (GD)	Nerve agent	Other nerve agents	Sarin (GB), Tabun (GA), VX
Sulfuric Acid (93.1%)	Inorganic acid	Most inorganic acids, bases, and salts, except for Nitric and Hydrofluoric Acids	Hydrochloric Acid, Hydrogen Cyanide, Phosphoric Acid, Potassium Hydroxide, Sodium Hydroxide, Sodium Hypochlorite, Sulfur Dioxide
Tetrachloroethylene	Halogenated hydrocarbon	Unsaturated chlorinated hydrocarbons	Chlorobenzene, Trichloroethylene, Vinyl Chloride
Toluene	Aromatic hydrocarbon	Large aliphatic hydrocarbons (>C8); aromatic hydrocarbons; certain mixtures	Benzene, Cumene, Diesel Fuel, Isooctane, Jet Fuel, Styrene, Xylene

Synopsis of Key Findings

1) ***Use of protective ensembles compliant with NFPA standards establishes broad chemical resistance claims*** –Confidence for the use of specific ensembles in protecting first responders from chemical exposures is best achieved when all of the different materials, seams, and interfaces are evaluated against sets of chemicals in combination with other criteria applied to the whole ensemble as part of its design and integrity.

2) ***The NFPA chemical batteries are particularly relevant to broad chemical resistance claims*** – The specific use of standardized chemical lists or batteries is an essential way of demonstrating broad chemical resistance, particularly when the testing of the ensemble is applied to all primary materials and seams used in its construction and further coupled with preconditioning of materials to simulate wear and tear during use to add an additional safety factor for exhibiting appropriate levels of safety.

3) ***Protection against other chemical can be inferred from test results for NFPA battery chemicals*** – Testing of the same battery chemicals does offer a means of extrapolating protection against many chemicals that are not specifically tested since the selected chemicals involve relatively aggressive permeating or penetrating substances that are either representative of other chemicals or structurally similar to chemicals in the same general functional class. This ability to infer broader protection further results from other safety factors where chemical test concentrations and conditions are most often worse than actual exposure conditions.

RETHINK LEVEL A

ASSESS. SELECT. DEPLOY.

AN OVERDUE MODERNIZATION OF HAZMAT PPE