PPE Cleaning Validation

Verification of Cleaning, Decontamination, and Sanitization of Fire Fighter Garments

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SUPPLEMENT C: Investigation of Simulated Fire Ground Exposures

Jay Tarley
NIOSH NPPTL
Morgantown, West Virginia

July 2019

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Part 4 of 9

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Final Report by:

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1 Batterymarch Park, Quincy, MA 02169-7417, USA

Email: foundation@nfpa.org | Web: nfpa.org/foundation

Foreword

Fire fighter exposure to personal protective equipment (PPE) that is dirty, soiled, and contaminated is an increasing concern for long-term fire fighter health. Cancer and other diseases resulting from chronic exposures has become a leading issue and is presumed to be associated with fireground exposures relating to protection/hygiene practices and persistent harmful contamination found in fire fighter PPE.

While general cleaning procedures have been established in NFPA 1851, *Standard on Selection, Care, and Maintenance of Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting*, there are no requirements that demonstrate whether current cleaning practices will adequately remove contaminants from fire fighter PPE. Many manufacturer gear cleaning recommendations are vague and most cleaning product/process claims are unsubstantiated regarding contaminant removal effectiveness. Prior studies have identified persistent chemical and biological contaminants in structural firefighting PPE. Therefore, industry methodologies and practices are needed that can promote safe cleaning techniques so that fire fighters are not continually exposed to unclean or inadequately cleaned gear. It also important to set cleanliness criteria for the continued use of fire fighter protective clothing.

This project has established a relevant and credible procedure to validate "how clean is clean?" for fire service contaminated gear, and in doing so has addressed the primary goal of reducing fire fighter exposure to harmful contaminants in PPE. This includes the establishment of a repeatable and reproducible standardized method that can be used to determine the decontamination effectiveness of cleaning methods, and establish the needed fire service guidance for maintaining contaminant-free PPE as well as show that cleaning processes do not damage clothing. The project deliverables directly support efforts to update NFPA 1851 and other information that ensures consistent, effective cleaning processes of fire service gear.

This report is part four of a nine-part series on this topic of "PPE Cleaning Validation", with this part titled "*Supplement C: Investigation of Simulated Fire Ground Exposures*". The following are all the reports in this series:

1. Master Report
2. Supplement A: Annotated Bibliography
3. Supplement B: Preliminary Work for Assessing PPE Cleaning Procedures
4. Supplement C: Investigation of Simulated Fire Ground Exposures
5. Supplement D: Evaluation of Outer Shell Liquid Retention Properties
6. Supplement E: Report of Semi-Volatile Organic Chemical Contamination, Extraction, and Analysis Procedures
7. Supplement F: Report of Heavy Metals Contamination, Extraction, and Analysis Procedures
8. Supplement G: Report of Biological Contamination, Extraction, and Analysis Procedures
9. Supplement H: Evaluation of Microbial Cleanliness of Selected ISP Advanced Cleaning Procedures

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Project Technical Panel

David Bernzweig, Columbus Fire Department (OH)
Ken Block, Edmonton Fire/Rescue & Metro Chiefs Representative (AB)
Ken Brown, NVFC & VA State Firefighter's Association (VA)
Roger Curtis, ECMS Curtis & Sons (CA)
Paul Curtis, ECMS Curtis & Sons (CA) (Alt to Roger Curtis)
Steve Lakey, Northwest Safety Clean (WA)
Mark Lambert, WV Fire Academy & NAFTD (WV)
Ed McCarthy, Boston Fire Department (MA)
Andy Oliver, Verified Independent Service Providers Association (WI)
Bryan Ormond, NCSU (NC)
Russ Osgood, Firefighter Cancer Support Network (NH) (Alt to Keith Tyson)
Larry Petrick, IAFF (DC)
Jim Riley, Boston Fire Department (MA) (Alt to E. McCarthy)
Molly Riley, Virginia Beach Fire Dept. (VA)
Thomas Smith, FDNY (NY)
Bruce Toliver, Phoenix Fire Dept. (AZ)
Tim Tomlinson, Gear Cleaning Solutions (TX)
Robert Tutterow, NFPA Fire Service Section (NC)
Dick Weise, SAFER (CA)
Keith Tyson, Firefighter Cancer Support Network (FL)
Ken Wiles, LA County Fire Dept. (CA)

Phase 1 Project Contacts (Supplement B)

Steve Allison, Fire-Dex (OH)
Jack Binder, Edmar Chemical Company (OH)
Bill Brooks, Alliance Corp. (WI)
Charlie Dunn, TenCate Protective Fabrics (GA)
Chris Farrell, NFPA & Staff Liaison for NFPA 1851 (MA)
Rob Freese, Globe Manufacturing (NH)
Pat Freeman, Globe Manufacturing (NH) (Alternate to Rob Freese)
Diane Hess, PBI Performance Products (NC)
Karen Lehtonen, LionFirst Responder Products (OH)
Dan Silvestri, 9-1-1 Safety (PA)

Project Liaisons

Eric Guillaume, Efectis & Liaison for ISO TC92/SC3 (France)
Bill Haskell, NIOSH NPPTL (MA)
James Hoar, Boston Fire Department (MA)
Steve King, Past Chair NFPA 1851 (NY)
Fanny Rieunier, Ministry of Interior & Liaison for ISO TC92/SC3 (France)

Core Research Team

Jason Allen, Intertek (NY)
Daniel Farcas, NIOSH HELD (WV)
Crystal Forester, NIOSH NPPTL (WV)
Lee Greenawald, NIOSH NPPTL (WV)
Bill Lindsley, NIOSH HELD (WV)
Stephen Martin, NIOSH DRDS (WV)
John Noti, NIOSH HELD (WV)
Marni Schmid, Fortunes Collide & Secretary NFPA 1851 (MI)
Jeff Stull, International Personal Protection (TX)
Jay Tarley, NIOSH NPPTL (WV)

Additional Research Team Support

Francoise Blachere, NIOSH HELD (WV)
Renee Dotson, NIOSH HELD (WV)
James Harris, NIOSH NPPTL (WV)
Ryan Lebouf, NIOSH DRDS (WV)
John Powers, NIOSH (WV)
Heather Reed, NIOSH NPPTL (PA)

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About the Fire Protection Research Foundation

The Fire Protection Research Foundation plans, manages, and communicates research on a broad range of fire safety issues in collaboration with scientists and laboratories around the world. The Foundation is an affiliate of NFPA.

About the National Fire Protection Association (NFPA)

Founded in 1896, NFPA is a global, nonprofit organization devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards. The association delivers information and knowledge through more than 300 consensus codes and standards, research, training, education, outreach and advocacy; and by partnering with others who share an interest in furthering the NFPA mission. All NFPA codes and standards can be viewed online for free. NFPA's membership totals more than 65,000 individuals around the world.

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Investigation of Large and Small Scale Burn Approaches for the Consistent Contamination of Fire Fighter Protective Clothing Fabric Samples

Jay L. Tarley

Physical Scientist

National Institute for Occupational Safety and Health

National Personal Protective Technology Laboratory

Evaluation and Testing Branch

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Introduction

There was a requirement within the project to establish controlled laboratory-based contamination methods that could generate samples representative of field-soiled fire fighter turnout gear. An essential part of this assessment was to determine how firefighter clothing and materials subject to artificial soiling procedures compared samples contaminated under real world conditions. This methodology was needed to provide samples that could then be subjected to cleaning processes to determine their effectiveness in removing specific contaminations.

Initially, NIOSH planned to use fire fighter gear donated by various fire departments throughout the United States to the Fire Protection Research Foundation (FPRF). The original plan was to analyze portions of this clothing to determine contamination levels. However, it was decided that this approach would create a highly varied range of identified contaminants and levels making it difficult to compare to the laboratory contaminated samples. Instead, a large scale, controlled burn procedure was developed to produce contaminants that would be expected to be found in a house fire, which in turn would have the capabilities to contaminate entire fire fighter ensembles under more realistic firefighting conditions consistent with fire fighter working positions and activities. Similarly, a small scale chamber was designed and engineered to mimic the conditions and contaminants in the large scale burn with the collaboration of the WVU Fire Academy. This small scale chamber named the Mountaineer Contamination Chamber (MCC), was developed to allow for a repeatable, consistent, and less labor intensive sample contamination.

Experiments

Large Scale Burn Experiment

A large scale burn took place in a metal shipping container that was roughly $9' \times 20'$ with double doors on one end. A fuel package was constructed in a pile and secured in place with a galvanized metal frame and 2×4 boards that are included in the fuel package. The fuel package consisted of components that would typically be found in a residential house fire (see Table 1). The fuel package materials were researched to ensure that the burn provided the full spectrum on contaminants that would be present from a residential fire (see Appendix A). The pile was ignited with an alcohol burner and was monitored by staff to ensure that all of the fuel package was consumed. Ventilation was conducted by adjusting the door opening of the metal shipping container to ensure the fire remained in an active stage of evolvement to allow for the longest burn time possible.

Table 1: Material Items Used in Large Scale Burn

Item	Quantity	Dimensions
Copper tube	1	36″ × 0.5″
Pizza pan	1	12″ × 0.5″
Tube fittings	5	~6.5″ × 1.5″
Galvanized metal scrap	1	117″
Cake pan	2	9″ × 1.5″
Nonstick aluminum alloy sauté pan	1	9.5″
Mangled piece of metal	1	
Stranded copper insulation wire	1	100′
AAA batteries	4	Standard
9V battery	2	Standard
Aluminum	1	15′
Wood laminate	2	See box
Laminate underlay	1	6′
Shredded foam	2 bags	0.75 ft^3
Vinyl tiles	5	Standard
Carpet squares	4	
Black roofing paper	1	45′
Black shingles	10	
Household electrical wire	1	100′
Fabric coated with protector	1	2.2 yards
Scented candle	1	20 oz.
Scented candle	1	11.5 oz.
Styrofoam	1	30″ × 18″
Silicone sealant	2 tubes	
Moth balls	2 packs	
Household cleaning product	2 packs	
Vinyl siding	1	Standard size cut in half
2″ × 4″ wood	1.5	
Pressure treated 2″ × 4″ wood	1.5	
Pine plywood	0.5 sheet	
USB board	0.5 sheet	
Drywall	1 sheet	
PCP pipe coated with pipe cement	1	10′ × 1″
Wood glue	1 tube	
Fiber glass insulation batts	2	
Spoon set	1 pack	4 spoons

A hole was cut in the rear of the box approximately 7″ × 20″. Fabric panels were hung roughly 18-inches from the ceiling in front of the hole cut in the back of the box due to be in the path of exiting smoke from the fire. The material was pinned to a metal chain strung between each side. Ventilation of the container was controlled at the front of the box with the double entry doors and the hole cut in the back. The overall configuration of the large scale burn container is shown in Figure 1. Figure 2 provides a photograph showing the arrangement of fire load materials.

Figure 1: Configuration of large scale burn in metal shipping container

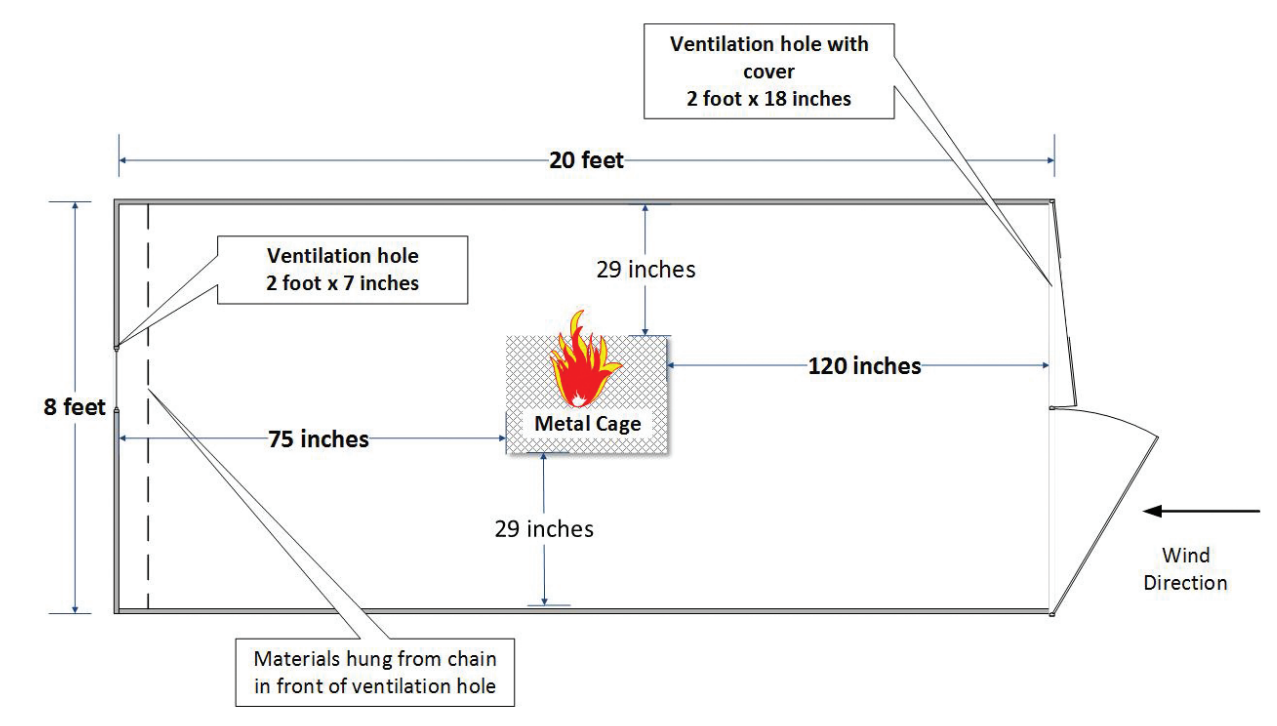

Figure 2: Layout of fire load materials inside metal shipping container (fabric panels are seen at back of box covering ventilation hole)

During the large scale experiment, the burn was ended after approximately 17 minutes as it was found that the fire growth was too hard to control and the exterior of the container caught on fire (see Figure 3). Figure 4 shows the metal shipping container interior following the burn. In this test, the fabric panel samples were heavily damaged during this evolution (embrittled to the extent of material loss) as shown in Figure 5.

Figure 3: Large scale burn extinguished just after the outside of the metal shipping container caught on fire

Figure 4: Fire load materials after burn in metal shipping container

Figure 5: Deteriorated fabric samples affected by extensive heat in large scale burn

Small Scale Burn Experiment

The large scale burn was determined to not be feasible for ease of repeatability and sample preservation. The project team met after the large scale burn and developed a combustion chamber in the collaboration with the Fire Protection Research Foundation. This chamber was designed to burn the same materials (in smaller portions) as the large scale burn and be controlled by one person. The chamber included a specimen frame that held nine fabric samples that were contaminated through smoke emanating through the exit section of chamber ducting. The overall configuration of the small scale burn chamber, dubbed the "Mountaineer Combustion Chamber" or MCC, is shown in Figure 6. The finished chamber is shown in Figure 7.

Experiments were carried out with the MCC to determine if more controllable and uniform conditions for exposing fabric samples to smoke contaminants could be achieved. Figure 8 shows the configuration of fire load materials inside the chamber, while the condition of these materials after a small scale burn experiment is seen in Figure 9. Figure 10 provides a view of a large fabric sample that was placed on the horizontal grill above the burning fire load materials and indicates a wide range of smoke particle deposition across the sample surface.

Figure 6: Diagram of MCC

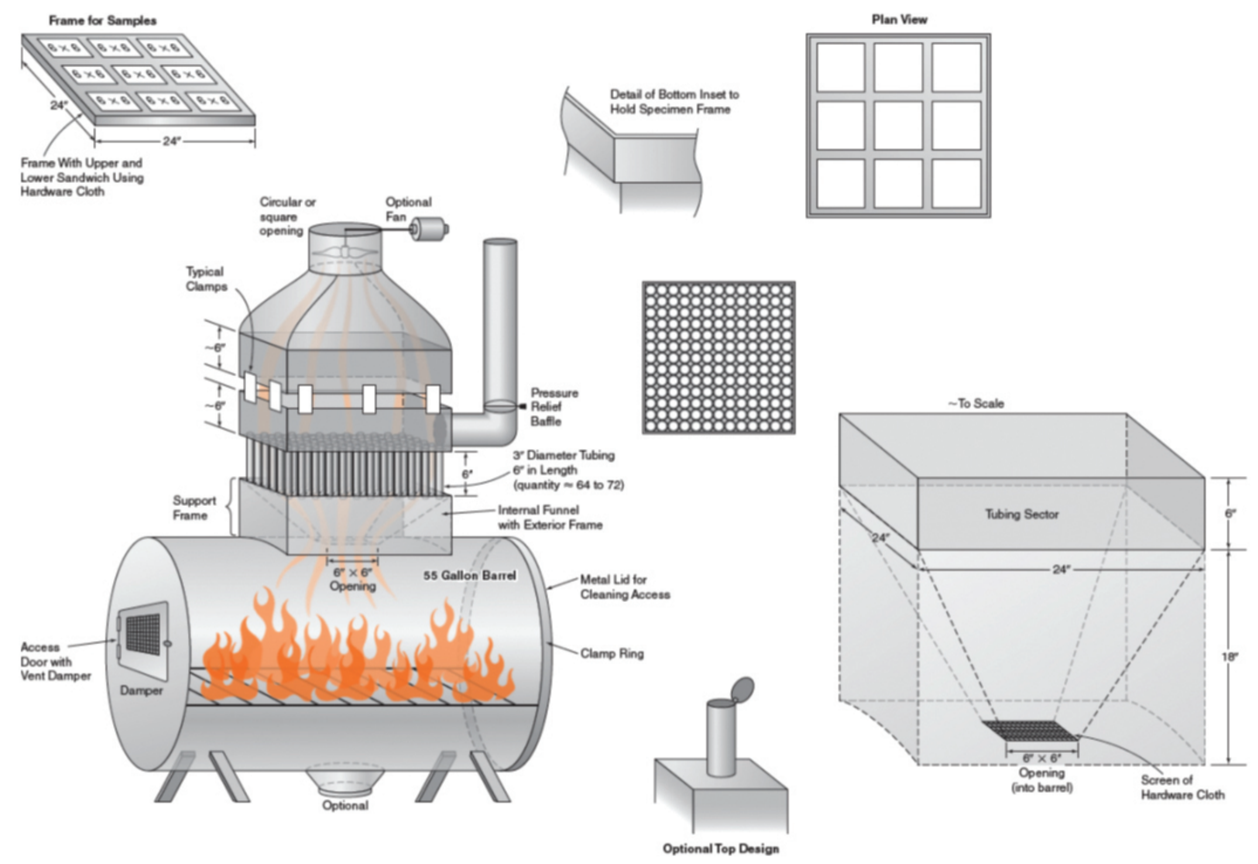

Figure 7: MCC after construction

Figure 8: Layout of fire load materials inside MCC

Figure 9: Fire load materials after burn in MCC

Figure 10: Inconsistent smoke deposits on sample material after MCC burn

Discussion

This project had an original objective for developing a technique that would consistently contaminate clothing fabric samples in a manner representative of field exposure. It was determined to design a burn utilizing props that are familiar to the fire service, such as a metal shipping container, could provide one means for realizing this goal. The metal shipping container was chosen because it was large enough to hold building materials and other fire load material that would be found in a normal house fire. The size of the metal shipping container was also large enough to allow for the possibility to contaminate full ensembles when positioned to simulate fire fighters engaged in fire suppression operations. It was further thought that by placing fabric samples in the burn box, samples would easily be contaminated by direct gas/vapor contact and through the deposition of soot. The first and only large scale burn experiment in the metal shipping container proved to be a relatively dynamic and uncontrollable event. Further, it was determined that the large scale burn was not a cost-effective procedure and would require multiple personnel to control the growth of the fire to operate safely. Of greatest significance, it was determined that the results could not be repeatable even with significant efforts for instituting greater levels of control over the fire load materials and burn conditions.

The small scale burn approach was developed to allow for more controllable and repeatable burn conditions for contaminating gear fabric samples using the same realistic materials found in a common house fire. The concept of the Mountaineer Contamination Chamber was intended to be a small scale experiment that could be operated by one person, be more cost effective, and still allow for the use of typical fire ground materials. The chamber was further designed to keep the flame and extreme heat from the samples, but still allow for the fire gases and smoke soot to contact the gear fabric samples for their contamination. Yet, while fire grown in the Mountaineer Contamination Chamber was easier to control, the dispersion of the combustion products from the fire did not contaminate the samples evenly or effectively.

Conclusions

Live-burn evolutions are dynamic events which are unpredictable. These fires and the resulting products of combustion are difficult to control as an approach for contaminating fire fighter clothing fabric samples, particularly for maintaining sample integrity and attaining consistent, repeated contamination. Although live-burn evolutions represent a more realistic exposure for contamination, the results are not reproducible. From this investigation, the project team shifted its activity to identifying and developing reliable methods for consistently contaminating fire fighter clothing fabric samples for allowing development of techniques for evaluating the effectiveness of fire fighter clothing cleaning.

Appendix A: Target Fireground Contaminants, Sources, and Fire Load Material Examples

Table 2: Examples of Contaminants, Sources, and Fire Load Materials

Contaminants	Sources	Fire Load Material Examples
Inorganic Chemicals (heavy metals)		
Aluminum	Aluminum cans, cookware, drain cleaner, sheetrock, roof coating, printer powder, aluminum nails	Food cans, aluminum pots & pans, Gypsum panels (3%), Aluminum roof coating (10–30%), Color Imaging Drums (95–98%)
Antimony	Flame retardants, batteries, solder	95/5 lead-free plumbing solder (1–5%), 60/40 Rosin Core Solder (2%)
Arsenic	Treated lumber, combustion of fossil fuels	Pressure treated wood, particle board, paneling
Silver	Jewelry, coins, burn creams, antibacterial textiles, solder	Lead-free Plumbing Solder (1–5%)
Boron	Glass, fire retardants, some laundry soaps (20 borax), glass wool, ant baits, some welding flux	20 borax, all-purpose cleaner, foaming glass cleaner
Barium	Drilling mud, rat poison, latex paints, epoxy, makeup	All Surface Enamel Acrylic Latex Primer, white (3%), Epoxy Steel Resin and Hardener (20–30%), Epoxy Weld Bonding Compound, liquid makeup
Beryllium	Occupation specific . . . minimal risk otherwise	
Cadmium	Ni-Cad Batteries, PVC plastics electronics, phosphate fertilizers, tires, tobacco smoke, concrete, oil, craft paints	PVC plastic, tires, other rubber, batteries, electronic devices, TVs, High mileage motor oil, Liquid cement colors, all colors except charcoal
Chromium (hexavalent)	Treated lumber, antifreeze, Portland cement, coal fly ash, tires	Treated lumber, tires, other rubber
Cobalt	Cobalt sulphate: linoleum, storage batteries, varnishes, paints	Dishwasher detergent, Nickle Metal Hydride Batteries (5–10%)
Copper	Pipe, wire, brass, bronze, treated wood, craft paint, plant pesticide.	Pressure treated wood, copper pipe, Oil colors-copper (30–50%)
Mercury	Batteries, tires, caulk, concrete, old thermometers	Tires, electronic devices/TVs, liquid cement colors, all colors except charcoal, Tub & Tile Adhesive Caulk all colors
Lithium	Lithium ion batteries	Lithium 9-Volt Battery

Contaminants	Sources	Fire Load Material Examples
Manganese	Matches, aluminum cans, fertilizer, concrete, batteries	Liquid cement colors, all colors except charcoal, Nickle Metal Hydride Batteries (1–5%)
Molybdenum	Lubricants, corrosion inhibitors, flame retardants, fossil fuel combustion, some pigments, engine antifreeze	Metal Repair paste (<5%)
Nickel	Magnets, cheap jewelry, Ni-Cad batteries, stainless steel cooking and eating utensils, joint compound	Nickle Metal Hydride Batteries (55–70%), Electrical Joint compound (18–20%), Liquid cement colors, all colors except charcoal, Metal Repair paste (10%)
Lead	Pipes and fittings, lead solder, rechargeable batteries, leaded glass, brass or bronze objects, radiators, tires	Leaded Solid Wire (30–60%), batteries, tires, electronic devices/ TV's, leaded paint, High Mileage Motor Oil 10W30
Selenium	Electronics, feed additive for poultry, pigments used in plastics, paints, enamels, inks and rubber, gun bluing, antidandruff shampoos	Shampoo
Strontium	Paint pigments, fluorescent lights, fabric softener	Fabric Softener, Moisture Absorber pellets (1%)
Tin	Soldering material, can linings for food and beverages, brass, bronze and pewter materials, dyes and coloring agents	Lead-Free Plumbing Solder (60–100%), food cans
Thallium	Exposure to thallium occurs mainly from eating food. Low levels found in cigarette smoke; electronic devices, switches and closures for the semiconductor industry. Hasn't been produced in the US since 1984.	N/A
Thorium	Used to make ceramics (<20%), lantern mantels, glass polish, vacuum tubes and welding rods (<0.05%)	Some ceramic glazes
Titanium (dioxide)	Pigments (white), sunscreen, varnishes, paper and plastics, toothpaste, makeup, concrete pavers (noxer blocks)	Adhesive Putty (5–10%), Interior Latex Semi Gloss Enamel extra white (13%), Acrylic latex for exterior house paint, liquid foundation makeup
Uranium		N/A
Vanadium	Fuel oil combustion, cigarette smoke	
Zinc	Anti-rust coatings, dry cell batteries, brass & bronze alloys, paints, rubber, dyes, wood preservatives, ointments	Organic rich Primer (72%), Electrical Grade Lubricant (27%)
Inorganic Chemicals		
Cyanide	Nylon, wool, polyurethane, styrene, acrylic carpeting, anything with nitrogen in their structure, glues	Nylon upholstery, Glue
Inorganic acids (mineral acids)	Strong inorganic acids –HCl, HNO_3, H_2SO_4; weak inorganic acids –HCN or H_2S (corrosives)	Formed by water reacting with building materials like concrete and mortars, gypsum

(continues)

Contaminants	Sources	Fire Load Material Examples
Inorganic bases	Compound that produces OH ions when dissolved in water, i.e., ammonia (NH_3), potassium hydroxide (KOH), calcium hydroxide or caustic lime (Ca_2OH), and sodium hydroxide or caustic soda (NaOH)	Sodalime, marble chips
Hydrogen chloride	Produced when burning PVC	
Phosgene	Produced when burning PVC	Building insulation (fiberglass, styrofoam), Electrical wiring insulation
Semi-Volatile Organic Chemicals		
2-methyl-napthalene (PAH)	PVC plastics, toilet deodorant blocks. It was once the primary ingredient in mothballs, although its use has largely been replaced in favor of alternatives such as 1,4-dichlorobenzene.	Moth Flakes (99%), Moth balls (99%)
Acenaphthylene (PAH)	Crude oil, coal tar, tobacco smoke, burning organic matter (carbon), soot, asphalt, charcoal	Asphalt shingles, treated wood
Anthracene (PAH)		
Phenanthrene (PAH)		
Fluoranthene (PAH)		
Pyrene (PAH)		
Benzo[a]anthracene (PAH)		
Benzo[b]-fluoranthracene (PAH)		
Benzo[k] fluoranthracene (PAH)		
Benzo[a]pyrene (PAH)		
Indeno[1,2,3,cd]pyrene (PAH)		
Dibenz[a,h]anthracene (PAH)		
Chrysene (PAH)		
Benzo[g,h,i]-perylene (PAH)		
Acetophenone	Used mainly as a fragrance, food flavoring agent, and as a solvent for plastics and resins. It is also found naturally in small quantities in foods such as bananas, apples, and beef. Used as fragrance ingredient in soaps, detergents, creams, lotions & perfumes.	High Acid Bowl Cleanse
Di-2-ethylhexyladipate (DEHA)	Used in adhesives and sealants, paints & coatings, electrical and electronic products, food packaging, toys, plastic & rubber products, cleaning products, building & construction products, arts & crafts materials. used primarily as a plasticizer in the flexible vinyl industry and is widely used in flexible poly (vinyl chloride) (PVC) food film (cling film).	PVC Cling wrap

Contaminants	Sources	Fire Load Material Examples
Di-n-octyl phthalate (DNOP)	Used as a plasticizer in plastic and rubber, used as an insecticide repellant in clothing	Carpet backing, hairspray, insect repellents
Butylbenzylphthalate	Mostly used in vinyl tile flooring. Can also be found in PVC for manufacturing conveyor belts, carpet, weather stripping, vinyl gloves, and adhesives.	Polyurethane Roof & Flashing Sealant (10–30%), Caulk (10–30%)
Di-n-butyl-phthalate	Plasticizer used to make carpet backings, paints, glue, insect repellents, hairspray, most common phthalate added to nail polish	Nail polish, DAP Wood dough
Di-2-ethylhexyl-phthalate (DEHP)	Primarily used as a plasticizer to increase flexibility of a material. Most manufactured DEHP (95%) is used to produce PVC. Soft toys, upholstery, tablecloths, raincoats, adhesives, glue, food containers, carpet, vinyl tiles, wire & cables, shoes, tubing. DEHP is highly lipophilic (fat soluble). When used in PVC plastic, DEHP is loosely chemically bonded to the plastic and readily leaches into blood or other lipid-containing solutions in contact with the plastic.	Soft children's toys, carpet, vinyl tiles, PVC materials, water hose, raincoats, tubing (20–40% by weight)
Phenol	Phenol is used primarily in the production of phenolic resins and in the manufacture of nylon and other synthetic fibers. Also used as a bactericide, disinfectant, and antiseptic. Phenol is a constituent of coal tar and creosote. The smoke from 1 non-filter cigarette contains 60–140 ug of phenol. o-cresol extracted from coal tar and mainly a precursor to other compounds such as herbicides (dinitrocresol). 2,4-dimethylphenol used in making insecticides, fungicides, dye stuffs, rubber chemicals and plastics. Cresols *(chemical classification: phenols/phenolic acid)* are found in many foods and in wood and tobacco smoke, crude oil, coal tar, and in chemical mixtures used as wood preservatives.	Synthetic fabrics, air fresheners, disinfectant, Contact Cement
2-methylphenol (o-cresol)		
4-methylphenol (p-cresol)		
2,4-dimethylphenol		
4-chloro-3-methylphenol		
Polybrominated diphenyl ethers (PBDEs)	PBDEs are used as flame retardants in a number of applications, including textiles, plastics, wire insulation, and automobiles. PBDEs are released from products when TVs or computers heat up, while sleeping on mattresses, or when the products degrade. There are over 209 different PBDE compounds, and the three most common commercial formulations are deca, octa, and penta. Deca accounts for 80 percent of the PBDEs currently produced and is composed of around 97 percent pure brominated diphenyl ether. It is used primarily as an additive in electronics, electronic equipment, and textiles, and it is commonly found in mattresses and TVs.	Upholstered couches, chairs, etc., Mattresses
Vinyl chloride (a chemical intermediate gas)	Primarily used to make PVC found in toys, food containers, credit cards, blinds, flooring, siding, shower curtains. Smaller amounts of vinyl chloride are used in furniture and automobile upholstery, wall coverings, housewares, and automotive parts.	PVC piping, wire coatings, plastic kitchenware
Volatile Organic Chemicals		
Acrolein	Acrolein is mainly used as a contact herbicide to control submersed and floating weeds, as well as algae, in irrigation canals. Also found in cigarette smoke and some furniture products.	Upholstery, plastic items, PVC pipe, furniture, nylon clothing
Benzene	Natural constituent of crude oil and a component of gasoline.	Tires, asphalt shingles, paints, motor oil, varnishes, paraffin wax candles, Liquid Wrench, 3-in-1 Household oil

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Contaminants	Sources	Fire Load Material Examples
Methanol	Wood alcohol, primarily used for the manufacture of chemicals and as a fuel source. About 40% of methanol is converted into formaldehyde and from there into products as diverse as plastics, plywood, paints, explosives, and permanent press textiles. Methanol is used as a solvent and as an antifreeze in pipelines and windshield washer fluid.	Windshield Washer Antifreeze (99%)
Naphthalene (PAH)	Derived from coal tar, naphthalene is used mainly as a precursor to other chemicals. Naphthalene sulfonic acids are used in the manufacture of naphthalene sulfonate polymer plasticizers (dispersants), which are used to produce concrete and plasterboard (wallboard or drywall). They are also used as dispersants in synthetic and natural rubbers, and as tanning agents (syntans) in leather industries, agricultural formulations (dispersants for pesticides), dyes and as a dispersant in lead–acid battery plates. Naphthalene has been used as a household fumigant.	Moth Flakes (99%), Moth balls (99%), Heavy Duty Construction Adhesive
Styrene	Over half of all styrene becomes polystyrene. Solid and film polystyrene, used in rigid foodservice containers, CD cases, and appliance housings. Polystyrene foam, used in food service products and building insulation. Styrene-based latex (SBL) used in many paper coatings and in more than 90% of the broadloom carpeting made in the United States to attach carpet fibers to a backing material.	Tires, fiberglass, and styrofoam building insulation
Toulene	Toluene is widely used as an industrial feedstock and a solvent. Toluene occurs naturally at low levels in crude oil. Toluene is a common solvent, e.g., for paints, paint thinners, silicone sealants, many chemical reactants, rubber, printing ink, adhesives (glues), lacquers, leather tanners, and disinfectants. Toluene can be used as an octane booster in gasoline fuels.	Paraffin wax candles, Lacquer Thinner (20–30%), spray paint, Frosted Glass Finish (50%)
Complex Organic Chemical Mixtures		
Gasoline	Gasoline	Gasoline
Hydraulic fluid	Three of the most common types of hydraulic fluids used today: (1) mineral oil, (2) organophosphate ester, and (3) polyalphaolefin. Mineral oil hydraulic fluids are produced from crude oil. Organophosphate ester and polyalphaolefin hydraulic fluids are synthetic.	Many types
Diesel oil	Standard diesel fuel obtained from petroleum distillation. It comes in two grades: Diesel #1 (or 1-D) and Diesel #2 (or 2-D). Diesel #2 is less volatile but more viscous.	Many types
Other Substances		
Total particulate matter		Anything we burn will have PMs
Asbestos fibers	Not going to use for this burn	
Soot	A mass of impure carbon particles resulting from the incomplete combustion of hydrocarbons.	Anything we burn will create soot
Diesel engine exhaust		
PAHs	Incomplete burning of wood, coal, oil, garbage, etc.	Burning of organic materials

Contaminants	Sources	Fire Load Material Examples
PCBs (polychlorinated biphenys)	The manufacture of PCBs was stopped in the U.S. in 1977. Products made before 1977 that may contain PCBs include old fluorescent lighting fixtures and electrical devices containing PCB capacitors, and old microscope and hydraulic oils.	N/A
Dioxin	More than 90% of human exposure is through food. Dioxins are unwanted by products of a wide range of manufacturing processes including smelting, chlorine bleaching of paper pulp, and the manufacturing of some herbicides and pesticides.	Building insulation such as styrofoam, fiberglass, Electrical wiring insulation, Nylon upholstery, PVC plastics
Formaldehyde	Household products such as glues, permanent press fabrics, paints and coatings, lacquers and finishes, and paper products. Resins used in the manufacture of composite wood products (i.e., hardwood plywood, particleboard, and medium-density fiberboard). Building materials and insulation. Fertilizers and pesticides. It is a by-product of combustion and certain other natural processes, and so is also found in: Emissions from unvented, fuel burning appliances, like gas stoves or kerosene space heaters, cigarette smoke.	Upholstery, plywood/wood, particle board, paneling, nylon clothing, foam insulation, wood glue Laminate flooring
Acetaldehyde	Acetaldehyde is a significant constituent of tobacco smoke. Sources of acetaldehyde include fuel combustion emissions from stationary internal combustion engines and power plants that burn fossil fuels, wood, or trash, oil and gas extraction, refineries, cement kilns, lumber and wood mills and paper mills. Acetaldehyde is also created by thermal degradation or ultraviolet photodegradation of some thermoplastic polymers during or after manufacture.	Caulking
1,3-butadiene	A chemical made from the processing of petroleum. About 75% of the manufactured 1,3-butadiene is used to make synthetic rubber.	Tires on cars and trucks. Also used to make plastics including acrylics. Small amounts are found in gasoline
Creosote	Creosote is the name used for a variety of products: wood creosote, coal tar creosote, coal tar, coal tar pitch, and coal tar pitch volatiles. These products are mixtures of many chemicals created by high-temperature treatment of beech and other woods, coal, or from the resin of the creosote bush. Coal tar creosote is the most widely used wood preservative in the United States. Coal tar, coal tar pitch, and coal tar pitch volatiles are used for roofing, road paving, aluminum smelting, and coking.	Pressure treated wood
Nitrile		
Acrylonitrile	Acrylonitrile is used to make other chemicals such as plastics, synthetic rubber, and acrylic fibers.	Tires, plastics
Acetone cyanohydrin	The major use of acetone cyanohydrin is in the production of methacrylic acid and its esters; the latter are used for the production of plexiglass. Also has been known to be used in manufacturing of insecticides, flavoring agents, and pharmaceuticals among others.	Plexiglass

(continues)

Contaminants	Sources	Fire Load Material Examples
Carbonyl		
Fufural	An organic compound derived from a variety of agricultural by-products, including corncobs, oat, wheat bran, and sawdust (waste biomass). Used especially in making furan or phenolic resins, nylons, and as a solvent.	Oat hulls is one of the most popular ways to make fufural. Products it is used in include weed killer, fungicide, and solvent.
Furan		
Furan (VOC)	Furan is found in heat-treated commercial foods and is produced through thermal degradation of natural food constituents. Obtained from wood oils of pines or made synthetically. Dioxins and furans have never been manufactured deliberately, except in small amounts for research purposes. They are unintentionally created in two major ways: (1) by the processes used to manufacture some products, for example, certain pesticides, preservatives, disinfectants, and paper products; (2) when materials are burned at low temperatures, for example, certain chemical products, leaded gasoline, plastic, paper, and wood.	Treated wood, burning PCBs and PBBs, PVC
Dimethyl furan	2,5-Dimethylfuran forms upon thermal degradation of some sugars and has been identified in trace amounts as a component of caramelized sugars. Also found as one of the components of cigar smoke.	Electrical wiring insulation
Hydrocarbons		
Nonane	Nonane is a component in automotive fuel and in jet fuel. Nonane is also used as a solvent, distillation chaser, fuel additive, and a component in biodegradable detergents.	Kerosene
Octane	Octane is a component of gasoline.	Gasoline
Pentane	Pentanes are some of the primary blowing agents used in the production of polystyrene foam and other foams. Pentanes are components of some fuels and are employed as specialty solvents in the laboratory.	Polystyrene foam
N-butane	Fuel, lighter fluid, paints, solvents, deodorant spray, flea spray (used as an aerosolizer in sprays)	Lighters, paint, insulating foam Sealant, Air freshener (20%), Body Spray (30–60%)
Heptane	Used as an aerosol vehicle in sprays, construction adhesives	Spray adhesive (10–30%), Quickbond Waterproof Tileboard Adhesive (10–15%), Dirt & Dust Resistant Dry Lube (70–80%), Outdoor Carpet Adhesive (30%)
Hexane	Used as an aerosol vehicle in sprays, construction adhesive	Aerosol Spray (15–40%), Nail Subfloor & Deck construction adhesive