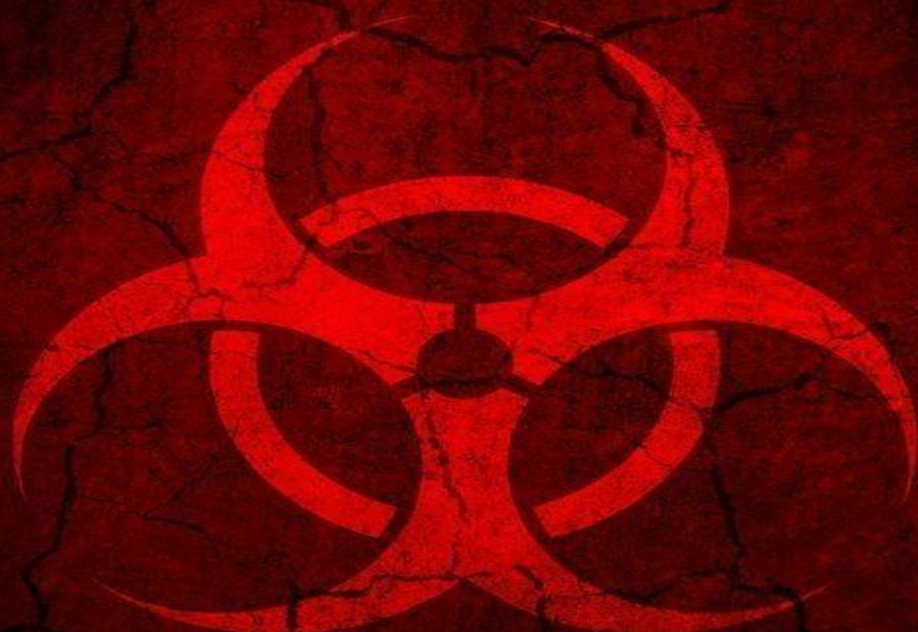
Take a Deep Breath...

P.P.E. for Haz.Mat operations & C.B.R.N.E. incidents



JOHN S. RETSIOS

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P.P.E. for Haz.Mat operations and C.B.R.N.E. incidents, part I

Personal protective equipment, or P.P.E., **is designed to provide protection from serious injuries or illnesses** resulting from contact with **chemical, radiological, physical, electrical, mechanical, or other hazards**.

Careful selection and use of adequate P.P.E. should protect individuals involved in chemical emergencies from hazards effecting the respiratory system, skin, eyes, face, hands, feet, head, body, and hearing.

No single combination of protective equipment and clothing **is capable of protecting against all hazards**.
Thus, P.P.E. should be used in conjunction with other protective methods, including exposure control procedures and equipment.

In this article I will describe P.P.E. needed for **Haz.Mat** operations and **C.B.R.N.E.** incidents.

P.P.E. Main Categories

- **S.C.B.A. = Self Contained Breathing Apparatus**

The breathing apparatus must be approved according to **EN 137 (2006) type 2.**

All components of the S.C.B.A. must be arranged to minimize interference when maneuvering in confined spaces and when passing through small openings. Also, the components of the S.C.B.A. must be easily removed for routine service and maintenance. The breathing apparatus should accept a range of compressed air cylinders *(steel, aluminum, carbon composite, or fully synthetic type 4)* and have the option of twin cylinder configurations.

The back plate usually is a two-piece, anti-static composite construction with ergonomic design to evenly distribute the weight of the SCBA over the user's lumbar region, hips, and shoulders. Some back plates have a **3 or 4 position multi height adjustment** to customize the back plate to the wearer torso.

The back plate waist belt must be designed to move in a vertical up and down movement to provide **maximum movement when bending forward and stretching**. The waist comfort pad is automatically set in the correct donning position.

The waist pad is best to swivel from side to side by approximately 30 degrees to **increase comfort and stability** when moving. The shoulder and waist padding must be constructed from a high abrasion resistant, high puncture resistant, slip resistant chloroprene rubber outer layer. The shoulder and waist padding shall be chemical resistant and fire retardant.

The harness webbing shall be constructed of a heavy duty, high temperature resistant type material.

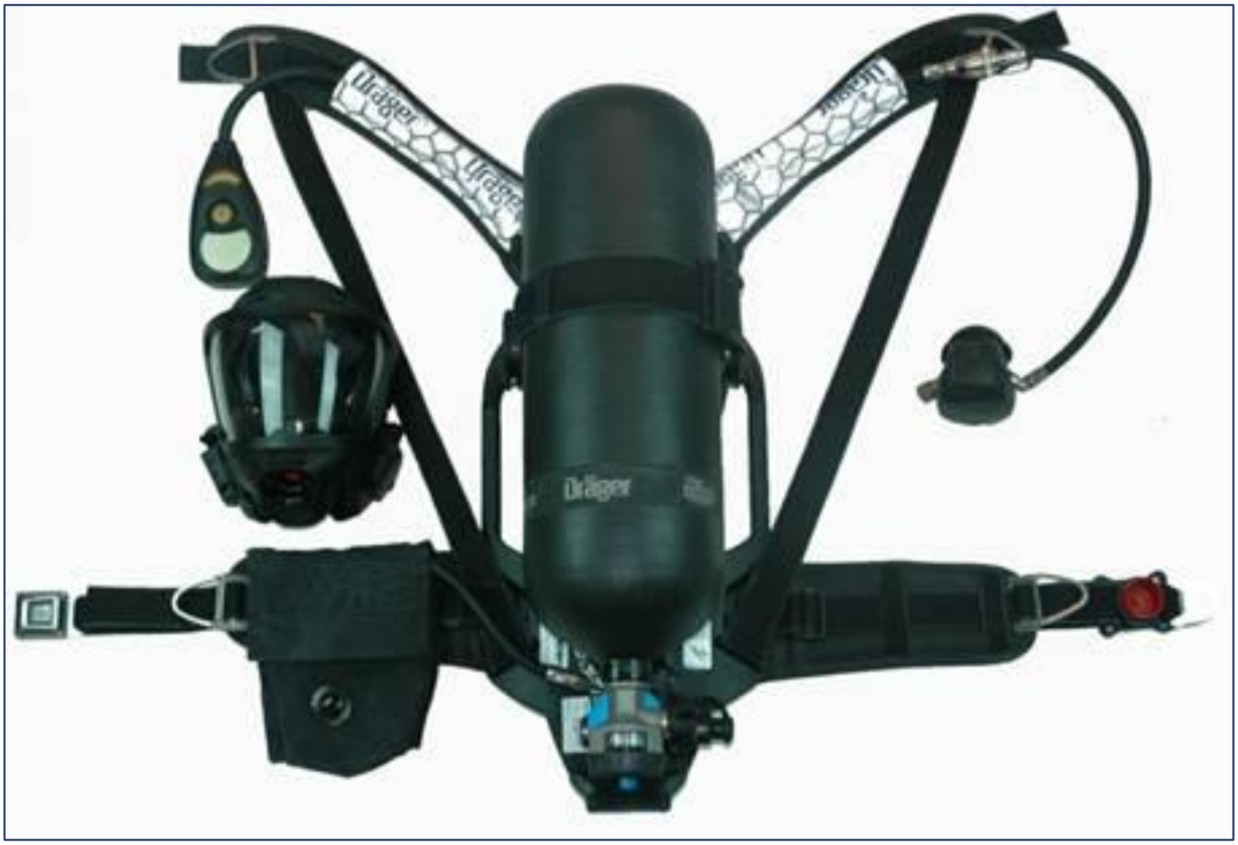
The shoulder pads must be designed with an ergonomic body contoured comfort style to maintain shape when worn, providing comfort and freedom of movement for the users. Wide for optimal support. Shoulder and waist belt harnessing must be independently adjustable.

Shoulder and waist adjustment friction buckles must be made of stainless-steel construction. Each shoulder and waist harness padding must be easily detached from the back plate by a quick release button only. This will allow for easy cleaning and disinfection of the harness if required without the use of tools.

A cam-lock mechanism will be used to secure the cylinder strap in place to ensure simple and secure operation.
The cylinder strap accommodates a complete range of sizes of cylinders **without the use of tools.**

The pneumatic system is usually easy to detach from the back plate and harness.

Medium and High-pressure hoses **must be routed in hose channels inside the back plate to eliminate snag potential.**



The S.C.B.A. has a first stage reducer which is connected directly to the backplate (described above) via quick fit connection for easy fitting and removal of the pressure reducer assembly from the backplate without tools. The first stage reducer has a standard **DIN G 5/8-cylinder valve** thread connection, or a cylinder quick connect coupling for 300 bar cylinders. (In case of 200 bars an alternative coupling must be selected)

The failure mode of the first stage reducer must be such that the reducer fails safe and always delivers air to the user.
As an optional an airline secondary supply connection **must be available to use S.C.B.A.** as a supplied air respirator or use it as an emergency escape system.

The S.C.B.A. utilizes a mask mounted L.D.V. (Lung Demand Valve). The regulator must be capable of being reset to the donning mode while connected to the S.C.B.A. to allow the user always to keep the mask in a ready position.
The Lung Demand Valve is preferred to be a plug-in version and positive pressure. Although there are other types of L.D.V's in Europe, **75% use plug-in version.**
I strongly suggest the use of a specialized membrane on the L.D.V. according to **BS 8468-1** or **NFPA C.B.R.N.** standards.
The use of an L.D.V. holder will give the user the necessary space to secure the L.D.V. when it's not in use.

The full-face mask of the S.C.B.A. set is something simple but must be selected carefully. One of the factors to be considered is the approvals according **EN 136 class 3**, and in case of C.B.R.N. use I suggest following the **BS 8468-1**.

The new full-face masks have different sizes in the main body and at the inner mask. So, it's up to you to select a full-face mask with one size fitted all or different sizes.

New full-face masks have also a COM system attached giving the user the ability to connect to a group of users raising the safety awareness during the incident.

C.P.S. = Chemical Protection Suits or C.P.C. = Chemical Protective Clothing

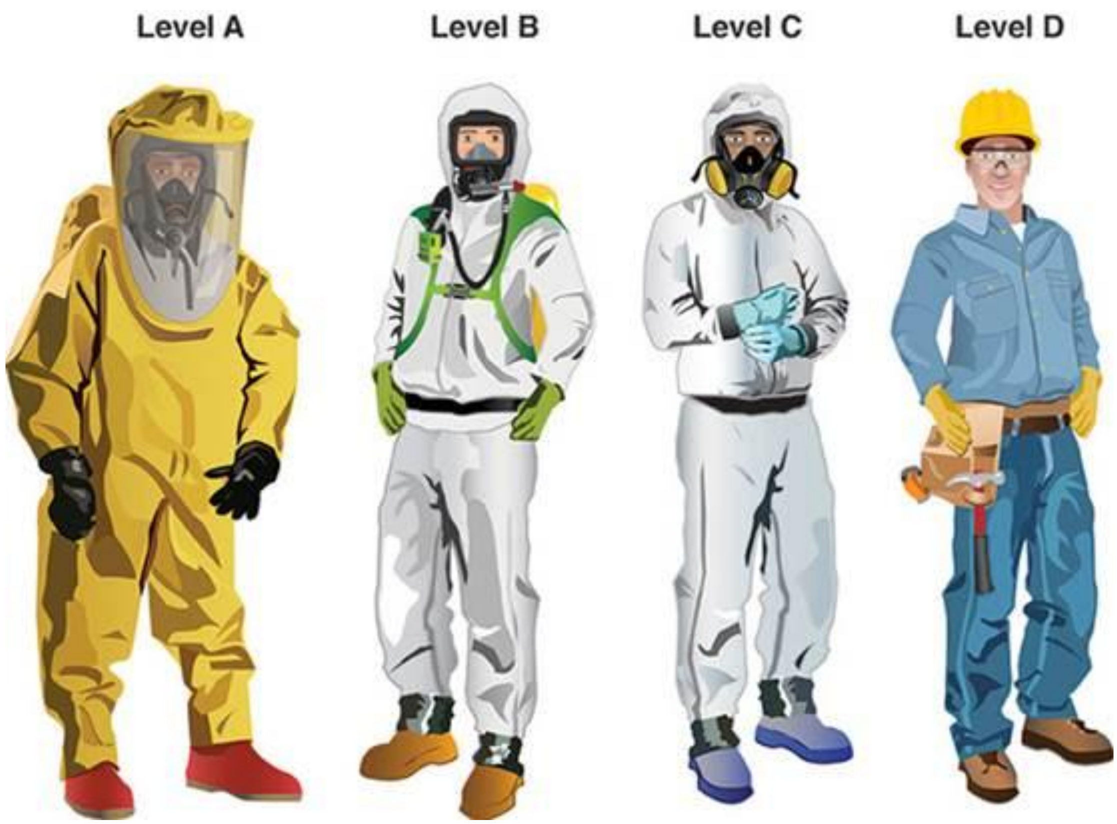
Levels for C.P.S. according to OSHA (A-D)

To help users choose a total P.P.E. package, OSHA offers guidance on determining the **four levels of chemical risks**. These levels are adopted from the Environmental Protection Agency (EPA) and give a range from unknown or highly hazardous, which requires complete protection, to non-hazardous, which requires only basic work attire.

Level A protective equipment provides the **highest level of skin and respiratory protection** available. This type of protection must be **gas-tight, vapor-tight and splash resistant**. It is worn when there is a possible threat to life and health, such as during spill response and cleanup.

<u>The minimum Level A equipment consists of</u>:

- Positive pressure, self-contained breathing apparatus (S.C.B.A.) or positive pressure supplied air respirator with escape S.C.B.A.
- Totally-encapsulating chemical-protective suit
- Chemical-resistant inner and outer gloves
- Chemical-resistant bootswith steel toe and shank



Level B protective equipment offers **chemical splash protection** but does **not prevent exposure to gases or vapors**. As with Level protective clothing, an S.C.B.A. is used for respiratory protection. The C.P.C. may or may not be completely encapsulating since a lower level of skin protection is required.

<u>The minimum Level B equipment consists of</u>:

- Positive pressure, self-contained breathing apparatus (S.C.B.A.) or positive pressure supplied air respirator with escape S.C.B.A.
- Hooded chemical-resistant clothing (overalls and long-sleeved jacket; coveralls; one or two-piece chemical-splash suit; disposable chemical-resistant overalls)
- Chemical-resistant inner and outer gloves.
- Chemical-resistant boots with steel toe and shank.

Level C protective equipment features the **same type of clothing as Level B** but has a lower level of respiratory protection. An air-purifying respirator is used in place of an S.C.B.A. This level is used when the chemicals are known, and it has been established that an air-purifying respirator is appropriate protection for the hazard.

Level D protective equipment offers the **lowest level of protection** and is used when no potential or actual hazard exists. It consists of a normal work uniform (long sleeve coveralls, safety shoes, goggles, etc.), offering minimal protection for nuisance exposure. Additional information on the four protection levels is given in **OSHA 29 CFR 1910.120 Appendix B.**

Note: In **European Union** mostly there is a **different level of protection** which means must be in accordance mainly with **EN 943 regulation**, let's see what the levels are according to EU.

Levels for C.P.S. according EN (1 – 6)

Type 1 C.P.S., gas tight suits, are divided into several sub-types. Type 1a has a breathable air supply inside the chemical protective suit. The air supply can be e.g., self-contained open circuit compressed air breathing apparatus. In type 1b the breathable air supply is worn outside the C.P.S. In type 1c, a positive pressure of breathable air can be provided via air lines. Types **1a-ET and 1b-ET** are meant for emergency teams. Type 1 C.P.S. may be needed for example against dimethyl sulphate, ammonia, chlorine, cyanogen chloride, hydrogen cyanide, Sulphur mustard, or Sarin.

The leak tightness for type 1a, and for types 1b in which the facemask is permanently joined to the suit, is ensured with a test that measures how pressurized air is held by the suit. Type 1b suits which have facemasks that are not permanently joined to the suits must be tested with the same pressure test but also inward leakage test.
The inward leakage shall not be greater than 0.05% when measured in the ocular cavity of the mask. Inward leakage test is also used for type 1c and type 2 suits.

Type 2 C.P.S. are not gas tight and a positive pressure of breathable air is provided into the suit e.g., via air lines.
The suits can be used against aerosols, sprays, or gases, for instance in the manufacture of drugs or other hazardous materials, if the task requires that the employee stands still. *(Type 2 is currently out of EN 943 so we do not count this type anymore)*

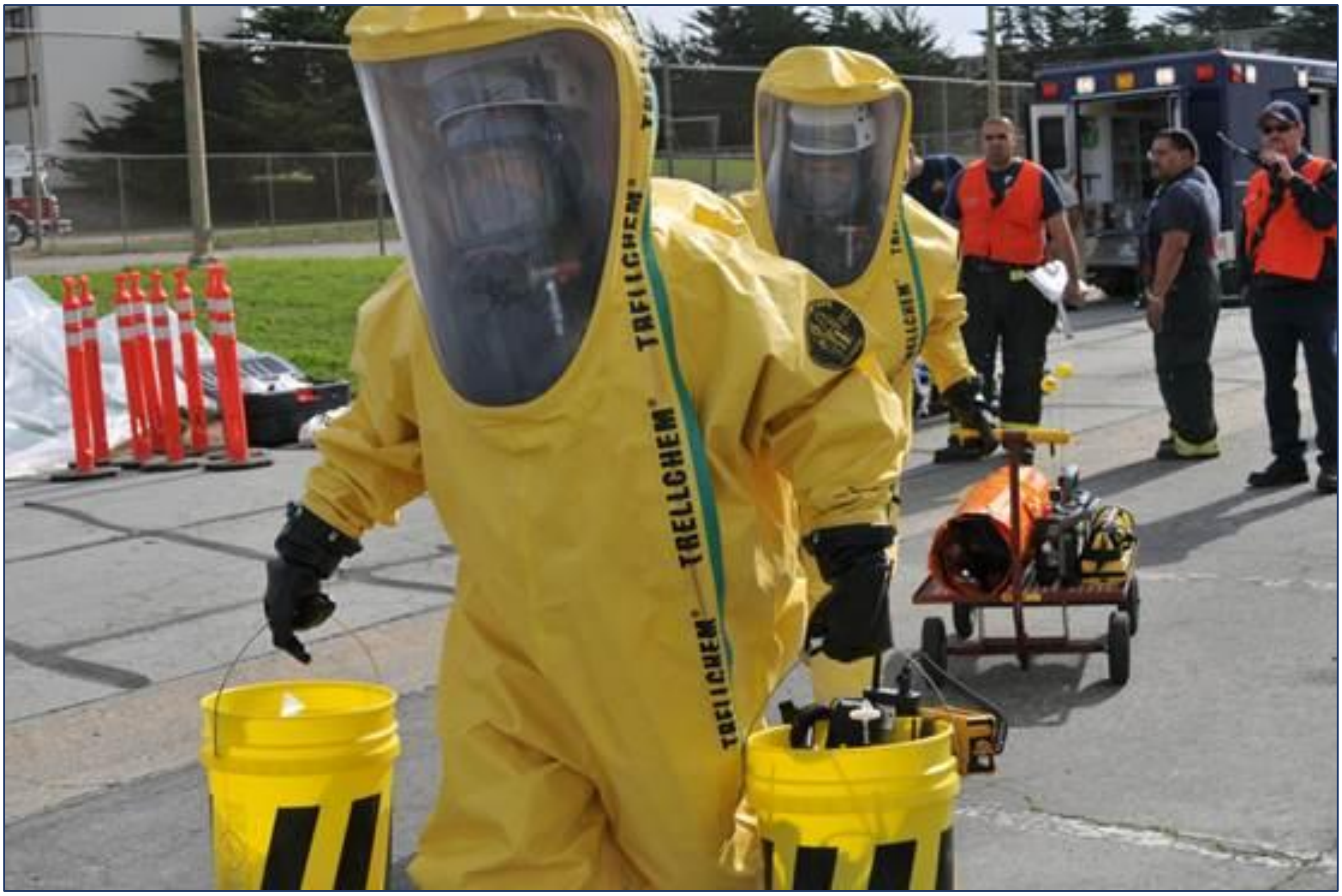
Type 3 S.P.C. (Splash protection coverall) has liquid-tight connections between different parts of the clothing.
The S.P.C. can be used in tasks **where the contaminants are not airborne**, chemicals may splash under pressure, or the workspace is confined, and the employee has to lean on contaminated surfaces. The type 3 SPC is not tested for leakage of a gas or particles, but it is tested for leaks by compressed jets of water. The materials can be the same or different as those used in type 1 or 2 C.P.S.

Type 4 S.P.C. has spray-tight connections between different parts of the clothing. The S.P.C. can be used in tasks **where the contaminants are not air-borne**, there is a risk of small splashes of chemicals, and the workspace is not confined. The type 4 S.P.C. is tested by spraying it with water. The materials can be the same as for the type 5, but the seams are taped.

Type 5 S.P.C. is intended for use **against air-borne solid particles**. It is often used to lessen the respiratory exposure such as those encountered in asbestos work and other tasks with hazardous dusts. The leak tightness of the suit is evaluated through two criteria. One special test is for the total inward leakage (TIL), i.e. the overall mean penetration through the suit while worn by test persons in sodium chloride aerosol atmosphere.

The TIL can be used as laboratory-based efficacy measure for the S.P.C.
For the type 5 S.P.C. the TIL has to be less than 15% for 8 test persons out of 10.
This is a factor to be seriously considered while selecting the type 5 clothing against hazardous chemicals.

Type 6 S.P.C. is meant for tasks where limited protection against liquid chemicals is needed. The overall efficacy of the clothing is tested with a similar spray test as used in type 4 C.P.S., but with only 10% of the liquid load. The material efficacy against chemicals is measured in percentages, while the types 1–4 are classified in units of micrograms per square centimeters. The type 6 C.P.C. **should be only used against small and rare splashes of irritant substances.**



Testing Differences

Emergency responders and industrial employees throughout the world, prepare for similar real-life situations and as a result, many of the tests performed **under EN 943 and NFPA 1991** certification are similar, including those for gas-tight integrity, flame resistance, and chemical permeation against many of the same toxic chemicals and gases.
These tests seek to simulate actual scenarios, such as emergency responses, fires, chemical spills, and terrorist incidents with the release of poisonous gases or chemicals.

However, when comparing the two certifications, **it is important to understand the different test methodologies and minimum performance requirements to ensure a suit provides the maximum protection for an intended application.**

Detailed comparison of the test requirements results in five key areas of performance evaluation:

1. Chemical permeation testing. For chemical permeation testing, EN 943 and NFPA 1991 use the same test methodology. However, EN 943 has a less severe minimum permeation detection level of 1.0mg/cm^2/min versus the NFPA 1991 level of 0.1mg/cm^2/min. In addition, NFPA 1991 requires preconditioning prior to chemical permeation testing, while EN 943 testing does not. This means that NFPA 1991-certified materials are subjected to the physical stresses of both flexing and abrasion of outer surface with coarse sandpaper repeatedly before actual permeation testing. High-performance protective suits are NFPA 1991 certified, having been put through this rigorous abrasion preconditioning before chemical permeation testing, but other suits rely on an aluminum oversuit or cover to meet this requirement.

2. Gases and chemical warfare agents. NFPA 1991 chemical testing covers a much broader spectrum of chemicals than EN 943. It covers all the chemicals listed in EN 943 except for heptane and additionally specifies only one-tenth chemical permeation detection level requirements. NFPA 1991-certified suits are tested against 19 toxic industrial chemicals, six gases, and two warfare agents, while EN 943 covers 12 toxic industrial chemicals and three gases and does not test at all for chemical warfare agents.

3. Pressure testing. Gas-tight integrity — vital for any protective suit that may come into contact with toxic chemicals and gases — can be determined only by performing a pressure or inflation test and a leak detection test of the protective suit. This ensures not only that base suit material is gas-tight, but also that all seams and joints are equally gas-tight. This test typically involves closing off suit exhalation valves and inflating the suit to a specified pressure to observe whether or not the suit holds that pressure for a designated period of time. Both tests involve pre-inflating the suit at an elevated pressure; while this is only one minute for NFPA 1991, it is 10 minutes under the EN standard. More importantly, EN 943 features a six-minute test period at 1650 Pa (6.6 inches water pressure), while the NFPA 1991 test is for four minutes' duration at 1000 Pa (4 inches water pressure). The standards are similar in not allowing any more than 20 percent loss of starting pressure during the test period, although actual results on suits in use should be well above these thresholds for maximum reliability.

4. Flame and flash resistance. EN 943 certification does not include any test for flash fire resistance and only requires very limited flame resistance (1 second). NFPA 1991 certification involves more rigorous flame and burn testing and has the optional test of flash fire resistance. Interestingly, some suits that meet the requirements of EN943-2 do not meet the NFPA 1991 standard unless they are equipped with a second aluminized oversuit, which significantly reduces comfort and dexterity and increases weight and bulk. Flash fire resistance is an optional requirement met by some suits. The test method includes putting the ensemble onto a mannequin in a sealed, propane-filled flash chamber. The suit is then subjected to a remotely ignited, six- to eight-second burn and must exhibit airtight integrity, thermal insulation, and visual acuity following the exposure to meet minimum standards, all in addition to the requirement for no after flame.

5. Hand protection. Protective suit accessories, such as visors, seams, and gloves, also need to be manufactured using highly protective textiles and materials. Both NFPA 1991 and EN 943-2 certifications require gloves to meet a high level of chemical and permeation resistance. NFPA 1991 has set much higher standards for cut and puncture resistance, which require that an outer glove be worn in addition to the chemical barrier glove. In most cases, two barrier gloves (a film inner and elastomer outer glove) are worn to obtain the full range of chemical protection and breakthrough times.

However, innovative solutions are able to offer this puncture resistance and chemical permeation resistance in a single-piece construction.

Though unintentional, chemical industrial disasters and incidents happen and **unfortunately C.B.R.N. terrorist acts are a real and ongoing reality**. As a result, there is a wide variety of innovative protective suits and equipment on the market meeting a range of safety and performance standards.

To keep emergency responders and industrial employees safe in the event that the use of P.P.E. becomes necessary, **it is critical to understand the various certifications, testing, and performance requirements**.

These factors will assist emergency service professionals and procurement groups to determine which suit is most appropriate for their needs, ensuring that emergency response teams and employees are able to do their jobs as safely and effectively as possible, EN 943 and NFPA 1991 are widely considered to be the global gold standards in P.P.E. performance for gas and liquid-tight chemical protective clothing, but key differences need to be clearly understood.

In order to ensure maximum protection that provides the highest level of safety for hazmat and emergency personnel, organizations and companies should specify suits that meet both EN 943 and NFPA 1991 and certification requirements.

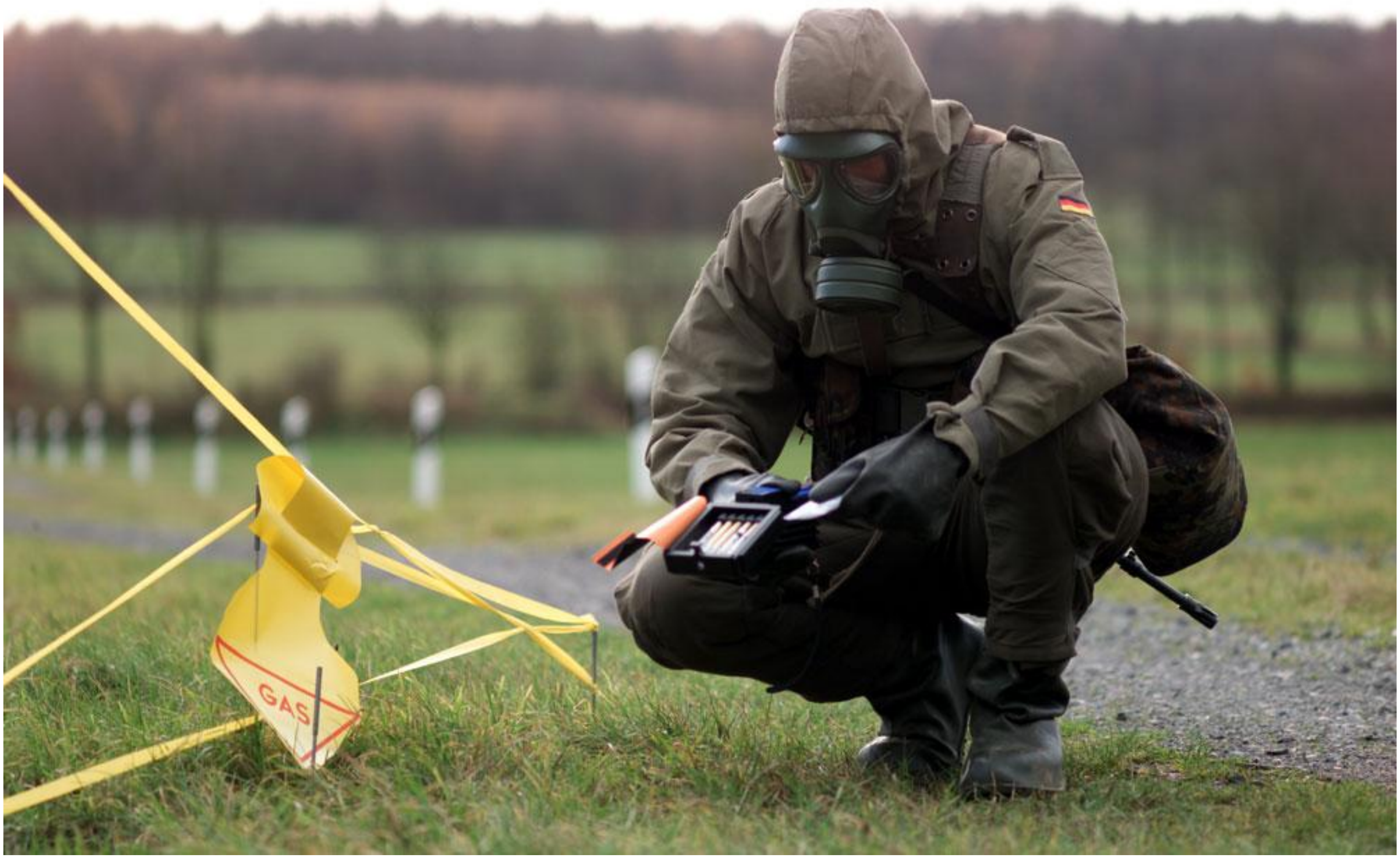
Donning and Doffing

Proper donning and doffing of C.P.S. will preserve the integrity of the P.P.E. and protect the wearer from chemical exposure.

Level B, general advice.

- Receive medical check (Optional)
- Verify that all PPE is ready and, in the dress, out area
- Perform an operational check of the SCBA (High pressure leak test etc.)
- Remove watches, jewelry, leather shoes and other personal items
- Don inner suit (Optional or comfort vest)
- Inspect suit
- Don Level B suit to waist.
- Don chemical resistant boots with boot covers.
- Conduct entry briefing.
- Don inner glove (Usually white cotton gloves)
- Don middle glove (if necessary)
- Insert arms into the sleeves of the suit and pulling it over shoulders.
- Gloves will be turned inside out over the thumb and palm of hand, then carefully taped making sure to stretch the elastic as far as possible and folded back over suit.
- Don chemical resistant outer gloves, and tape seam (preferred chemtape) between glove and suit leaving a tab
- Don facepiece. (Please use manufacturer instructions for secure fitting)
- Don attached hood of suit, zip up front zipper, attach zipper flap and tape flap leaving a tab.
- Don SCBA.
- Conduct a positive and negative pressure check of respirator facepiece.
- Don hardhat, if required (tape if needed).
- Assign suit number. (left arm, right foot, back)
- Rapid Intervention Team/Decon people to decon line.
- Connect regulator (LDV) to face piece and enters Hot Zone after Decon line is ready and IC approves.
- Ensure wearer is breathing air and indicates readiness with a thumbs-up sign.

P.P.E. for HazMat operations and C.B.R.N.E. incidents, part II



Chemical Suits Donning & Doffing Procedures in Detail

The following are instructions for donning and doffing of **Type 3 & 4** chemicals suits to minimize the risk of contamination. These instructions can apply to any similar suit. Both donning and **especially doffing is easier and safer if assisted by a colleague**.

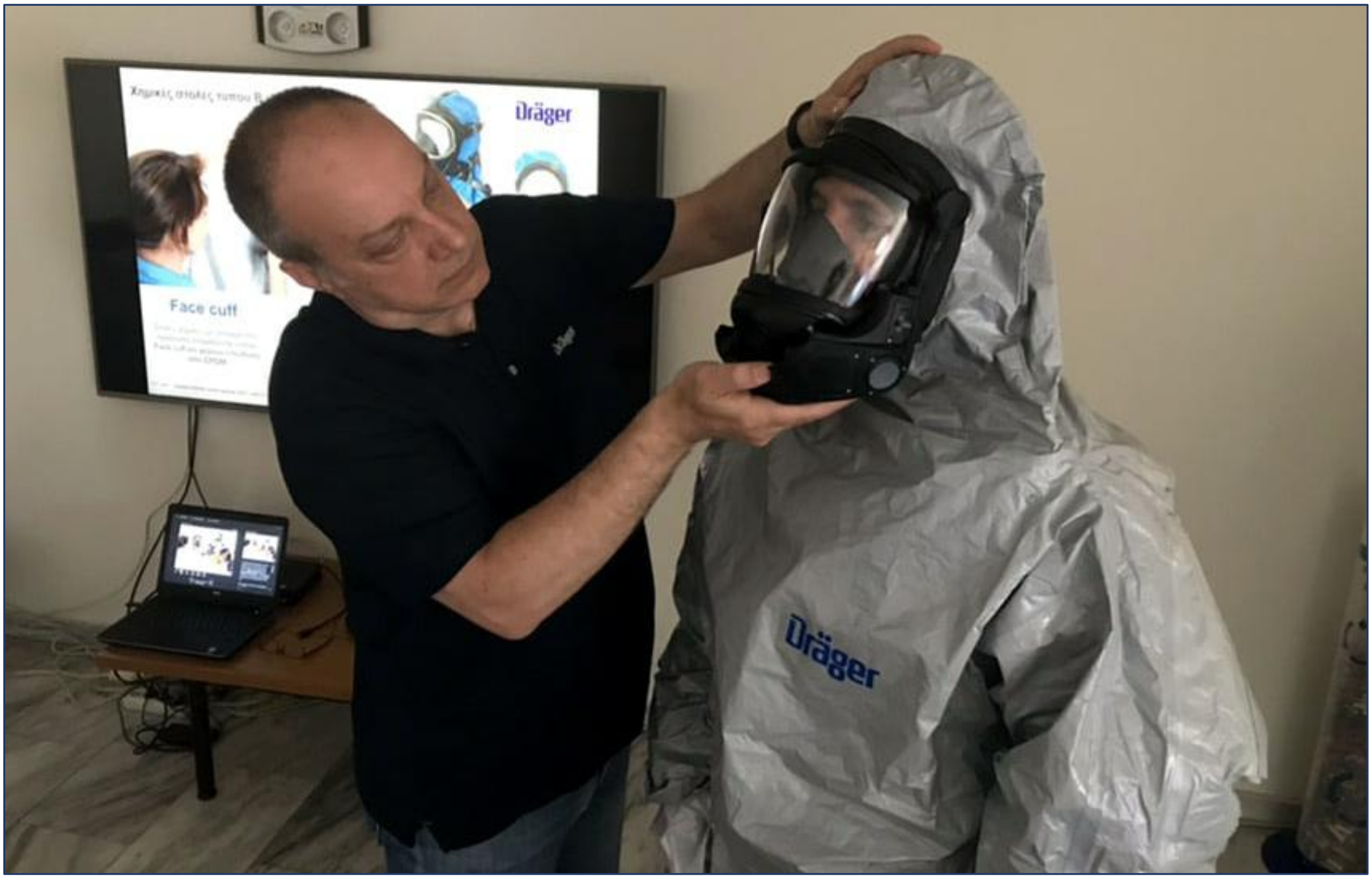
Note: Do not try to remove a garment contaminated with chemicals without assistance.

Donning 1.

1. Remove the garment from its bag and unfold carefully, ideally on a smooth surface **avoid rough surfaces that may scratch or damage the garment fabric**.
2. Careful open the outer zip flap by unfastening the Velcro, **inserting a finger behind the top and sliding the finger down to the bottom**. Fully unzip the outer and then the inner zip.
3. **In a sitting position** remove shoes or boots. (Donning the coverall with boots on risks damaging the suit unnecessarily).

4. Whilst sitting, open the garment and insert one leg after the other into the garment legs, **carefully pulling the legs up over the feet**. Once the legs are fully donned it is a good idea at this stage to replace shoes or boots.
5. For garments with attached feet / boot flaps the attached feet **should slide into the chemical boot**. (a woolen sock pulled over the feet can assist and add comfort if required). The boot flap is pulled over the outside of the chemical boot.
6. Stand and pull the garment up the body, placing each arm into a sleeve one after the other, and ensuring the garment is comfortably sitting on the shoulders.
   - For garments with attached gloves **ensure the hands are fitted** into the gloves properly
   - For garments with double cuffs: pull the outer sleeve back and seat the inner sleeve to the wrist; pull on the glove then pull the outer cuff over the gauntlet of the glove. **This process will be much easier with assistance**
7. From this point it is better **to have a colleague assist** and perform the remainder of the procedure. Pull the inner zip up about three quarters by holding the bottom of the zip with one hand and sliding the zip up with the other. **Take care not to trap fabric in the zip**. Further adjust the garment if required.
8. If a face mask is to be worn, don it now ensuring it is properly seated and comfortable. If an air supply is required as part of the mask switch it on or ensure breathing is normal if a filter mask is used.
9. Carefully pull the hood over the head, seating the elasticated edge to any face mask as required. Pull the inner zip up to the neck. **Ensure the zip is fully closed.** Ensure the hood edge is seated properly against the face mask or face as required.
10. Fold the inner flap into the flap housing and then slide the outer zip up carefully ensuring the inner flap folds back on itself and taking care not to trap the flap fabric in the zip. Slide the outer zip to the neck and ensure it is fully closed.
11. **To fasten the outer flap**:
    - **For Velcro versions**: carefully attach the Velcro at the neck first and gradually press together down the garment ensuring there are no folds or gaps left in the Velcro join.
    - **For adhesive tape versions:** carefully remove the backing of the tape on the flap from the top by peeling it down carefully. Ensure the exposed tape does not become damaged or dirty. Fasten the tape at the top first by pulling the flap across the neck of the garment, then carefully press the tape into place all the way down, again ensuring there are no folds or creases.
    - At this stage **your colleague should again check to ensure zips are fully closed**, and the outer flap is fully sealed with no gaps, creases, or holes.
12. Once the suit is donned and seated properly, make any final adjustments, and conduct a further visual check to ensure the hood is suitably seated to face mask or face and that there are no tears or damages in the fabric or seams of the suit.
13. Finally, at this stage further sealing of the joins between parts of the PPE ensemble may be made – hood to facemask, sleeve to glove, ankle to boot. This can be done using **a suitable chemical tape**. Doffing chemical protective garments are designed to protect against splashes and sprays of chemicals. They are not intended for long term or extended exposure to chemicals and as such when contaminated during use should be removed as quickly as possible and disposed of accordingly.

Any contaminated suit must be removed with the help of a qualified assistant. The assistant should be wearing suitable PPE subject to the chemical contaminant such as gloves, coverall, face mask etc. The key task is to ensure that any chemical on the outside of the suit does not come into contact with the wearer or the assistant.



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- Heavily contaminated suits **should be de-contaminated first** by the use of a suitable method such as a decontamination shower.
- The assistant should carefully remove the hood from the wearer, **turning the hood inside out** to prevent contamination contacting the wearers head. Any face mask can then be removed.
- The assistant should then open the outer zip flap to expose the outer zip and using the zip pull slide the zipper down to the bottom.
- The inner flap and zip can be opened in the same manner – ensuring the body of the garment is folded outwards and away from the wearer's body in the process.
- With wearer standing with arms slightly back, the assistant then stands behind the wearer and pulls the cuff of the garment over the wearer's hands. He can then gently slide the shoulders off the body of the wearer, the wearer withdrawing his arms at the same time, again, turning the sleeves and body inside out in the process.
- The body of the garment can then be removed back and down the legs of the wearer.
- With the wearer sitting, any boots should be removed, and the garment legs can be pulled over the wearer's feet.
- The contaminated suit should be folded inside out **and placed in a suitable bag for disposal garments** are generally manufactured from polypropylene, polyethylene, or similar polymers.

There are no known hazards from incineration or from placement in landfill. Uncontaminated suits can therefore be disposed of in the normal manner **depending on local laws and regulations**.

However contaminated suits must be disposed of in a manner suitable given consideration of the chemical contaminant. This will depend on the chemical itself and on local legal requirements. Companies will normally have their own procedures for disposal of chemical contaminated equipment.

Chemical Suits Level A

Donning & Doffing Procedures in Detail

Good safety practices require an assistant to help you don and doff the suit. This is easier and quicker, **and you will avoid stumbling or tripping** which may result in personal injury or damage to the suit.

Follow these steps in putting on the suit:

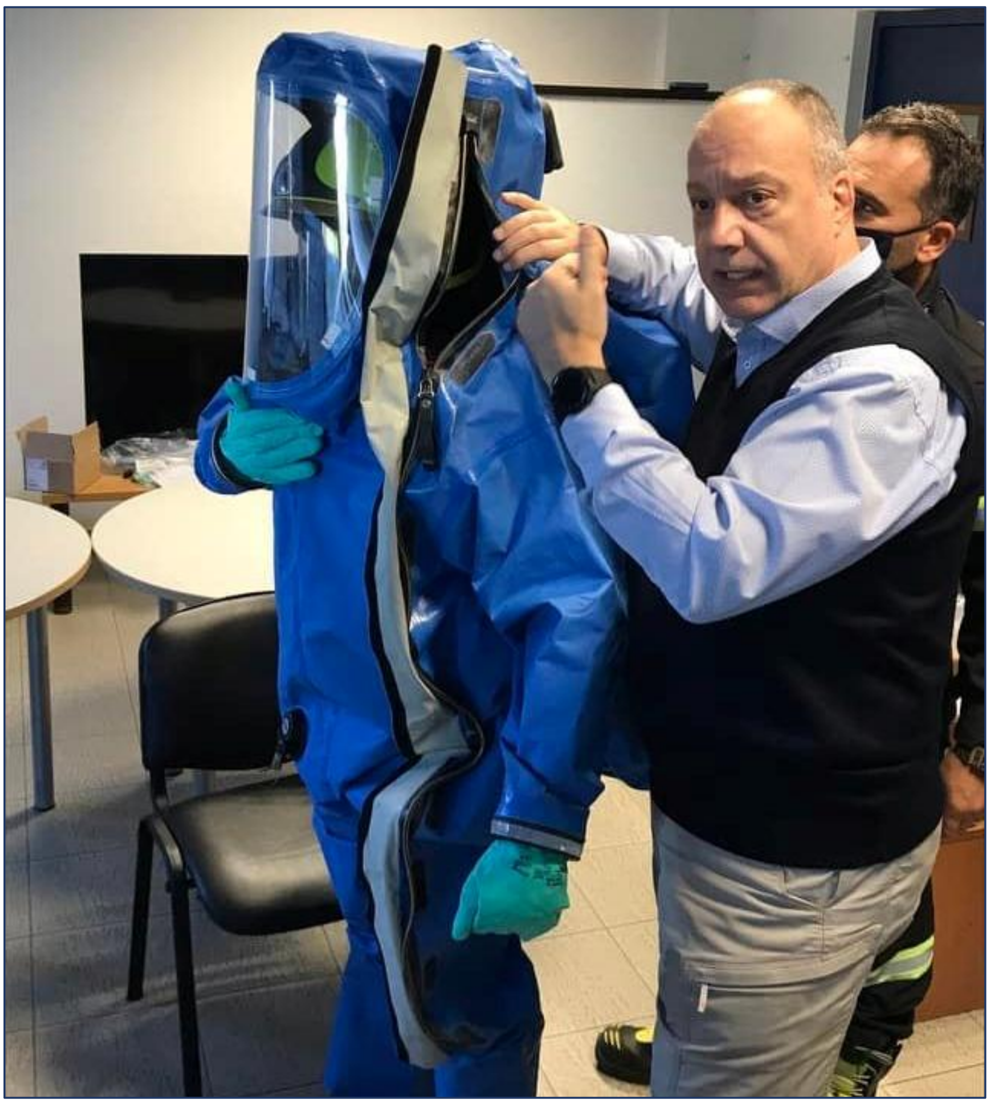
1. **Make sure** the suit has been visually inspected, air pressure tested and is free from defects. Also make sure the correct suit has been selected for the intended use.
2. Underclothing should be worn under the chemical suit. As a minimum, a long sleeve shirt and long pants or **"long underwear" are recommended**.
3. **Remove all personal affects** which might result in damage to the suit (e.g. pens, badges, jewelry, etc.).
4. **Remove shoes.** Most boots don't allow street shoes.
5. Tuck pant cuff **into socks to make donning** of suit legs and sock boot easier.
6. Using a SCBA (Self Contained Breathing Apparatus), check the level of air, complete all connections, make all adjustments in accordance with the manufacturer's procedures. Do not put the face piece on, yet, unless required by the design of the SCBA.
7. While seated place both legs into the suit. (Preferably start with right leg) Stand up and attach the internal waist belt. Belt is intended to help adjust the fit of the suit. In case there is a height adjustment system please adjust it accordingly.
8. Turn on the air supply, put on facepiece, and **make sure air supply system** is working properly.
9. Place your right arm and the head inside the suit, then the left arm, close the zipper, then Velcro shut the fly over the top of the zipper. (Be careful not stretching the zipper stop at the end, some manufacturers have very strict rules and instructions regarding this) Always leave about 20cm the zipper open **to maintain communication with the user** and when you are ready close tight **and give a thump up**. (Zipper close from bottom to the hood)
10. The person assisting should check to make sure the zipper covers are completely closed, all airline connections are tight, and suit appears to be working properly.

Note: Do not try to remove a garment contaminated with chemicals without assistance.

Doffing Procedure

The person assisting in the doffing procedure should be wearing the appropriate attire selected by Qualified Safety Personnel. (It is suggested that the assistance must be fully trained in A type suits)

1. The person assisting should open the zipper flaps by separating the velcro attached to the fly and open the zipper by pulling the zipper tab at the opening of the zipper.
2. The user should pull their arms back into the body of the suit, remove their safety helmet, and hand safety helmet to the assistant (this will prevent the assistant from touching the inner suit with their gloves that may be wet or contaminated. (Pay attention to the zipper, handle with care)
3. Carefully remove the head and arms from the suit.
4. Loosen the air supply mask (allow the mask to hang around the neck until the air supply has been cut off. Remove the air system per the instructions provided with that particular system.
5. Loosen the suit belt and allow suit to fall. Assume a sitting position for stability. The assistant should remove the outer boots and hold the bottom of each leg to allow the user to remove legs from the suit more easily.



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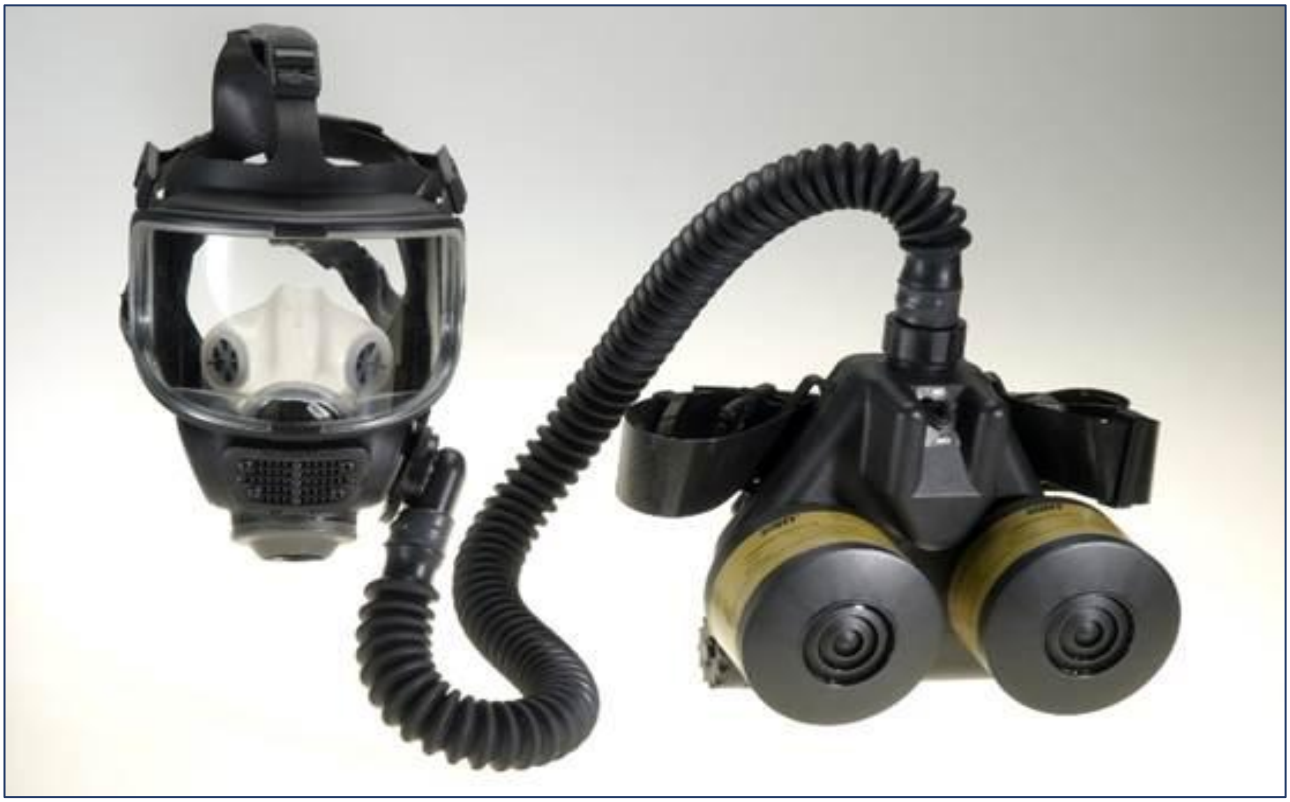
P.A.P.R. = Powered Air Purifying Respirator

A **powered, air-purifying respirator** (P.A.P.R.) is a type of personal protective equipment used to safeguard workers against contaminated air. P.A.P.R.s consist of a respirator in the form of a hood, or full-face mask, which takes ambient air that is contaminated with one or more type of pollutant or pathogen, actively removes (filters) a sufficient proportion of these hazards, and then delivers the clean air to the user's face and/or mouth. P.A.P.R.s are sometimes called **positive-pressure masks**, **blower units**, or just **blowers**.



How does a P.A.P.R. work?

- With a Mask & Filter combination the wearer has to "pursue" the air to pass the filter.
  This leads to an uncomfortable effect: **Breathing resistance!**
- A P.A.P.R. operates with a fan/blower unit which is powered by a battery.
  The blower unit pulls the air through the filter and blows it through an outlet.
- In most cases the air outlet of the P.A.P.R. unit is connected to a headpiece by a hose
- The headpiece can be the same full-face mask like used for mask & filter combination, but due to the high airflow other headpieces like hoods, helmets, visors or welding visors are possible as well.

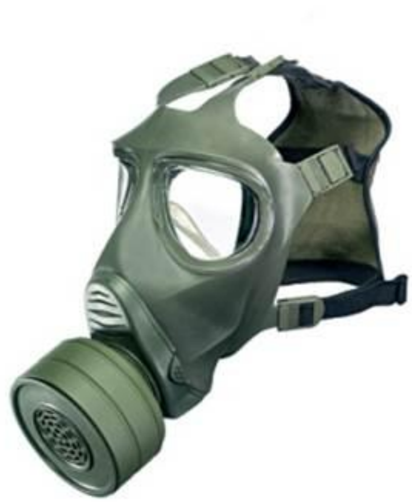
F.F.M. = Full Face Masks or G.M. = Gas Masks

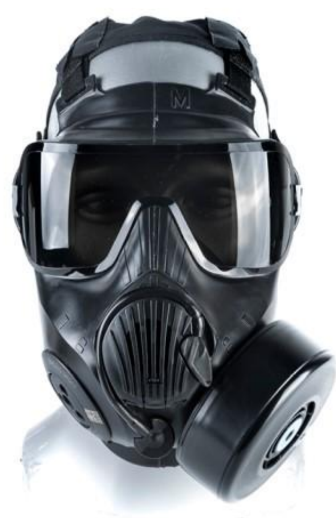
A full-face mask or a gas mask is a device **designed to protect the wearer from noxious vapors, dust, and other pollutants.** Masks may be designed to carry their own internal supply of fresh air, or they may be outfitted with a filter to screen out harmful contaminants. The latter type, known as an **Air Purifying Respirator** (A.P.R.), consists of a tight-fitting face piece that contains **one or more filter cartridges**, an exhalation valve, and transparent eye pieces.

The first A.P.R. was patented in **1914** by **Garret Morgan** of Cleveland, Ohio, an African American inventor also credited with major improvements in the traffic signal. When the Cleveland Waterworks exploded in 1916, Morgan showed the value of his invention by entering the gas-filled tunnel under Lake Erie to rescue workers. Morgan's device later evolved into the gas mask, **used in World War I** to protect soldiers against **chemicals used in warfare**.

Since that early time, there have been significant advances in gas mask technology, particularly in the area of new filtration aids. In addition, masks have been made more comfortable and tighter fitting with modern plastics and silicone rubber compounds. Today APRs are used to filter many **undesirable airborne substances, including toxic industrial fumes, vaporized paint, particulate pollution, and some gases used in chemical warfare**.

These masks are produced in several styles, some that cover only the mouth and nose (half masks) and others that cover the entire face, including the eyes. They may be designed for military as well as industrial use but, even though the two types are similar in design, the military masks must **meet different standards than those used in industry**.

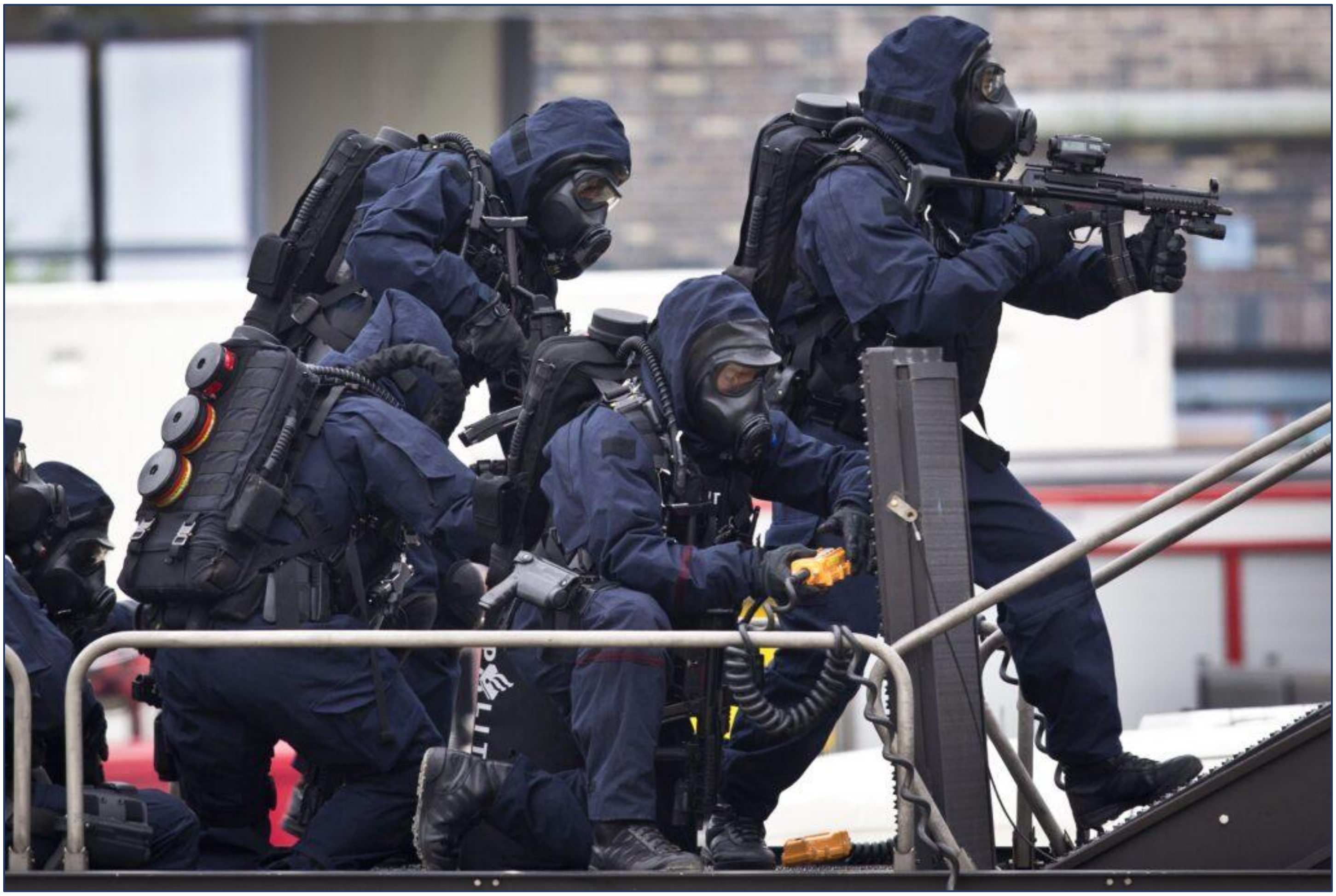




The gas mask usually utilizes two independent sealing edges, providing three sealing rings. The face mask must be available **in 3 different sizes** (S, M, L) or one size fits all usually that refers to M2 size (Medium mask, size no 2 inner mask)

Head harness can be directly applied to the sealing edges to minimize deformation of the seal and prevent leakage.
The visor of the full-face mask must have an effective field of vision based on a three-dimensional shape and designed in a way so that air from the cylinder passes over the mask lens prior to inhalation **to prevent fogging** on the inside of the visor. It is optional but a good choice always to have the full-face mask with an anti-scratch coating.

P.P.E. for HazMat operations and C.B.R.N.E. incidents, part III

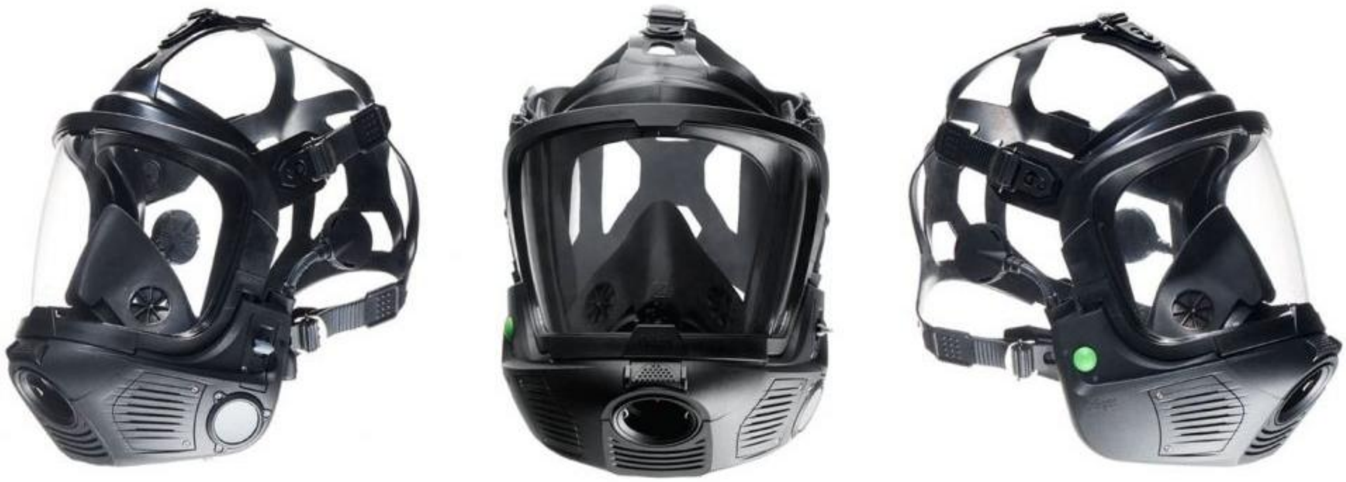


New generation Full Face Masks

The newly developed communication systems optimally adapt to the design and ergonomics of the mask. Depending on what is required, **it can be chosen with different modules and offers the optimal solution** for each communication in the field. Whether radio, voice amplifier or head-up display, everything can be directly integrated into the mask and it is easy to use.

*For missions requiring respiratory protection **you have to expect extreme conditions**: thick smoke and noise obstacles that not only cause stress but also significantly hinder any form of communication. This is even more difficult if a chemical protective suit is required: these suits restrict movement and suppress your voice.*

Each communication system (such as Drager FPS COM 7000) has an integrated P.T.T. button (push-to-talk) to operate a radio that can be connected as an option. You can communicate using a tactical radio by pressing just one button.
The tactical radio can be connected with a cable or Bluetooth. That means that there are no cables that could become entangled reducing the risk of snagging.



The communication system allows **fast and efficient communication** within one group or among different ones. And it works without pressing a single button. This improves your safety by not distracting you from your task. The voice-activated function also provides full-duplex communication. This means that you can talk and listen at the same time – as if you were on the phone. If there is only one radio for the entire group, the system allows the automatic transfer of the received instructions for up to ten group members via short-range radio. This means that only one member of the group needs a tactical radio while everyone is still informed immediately.

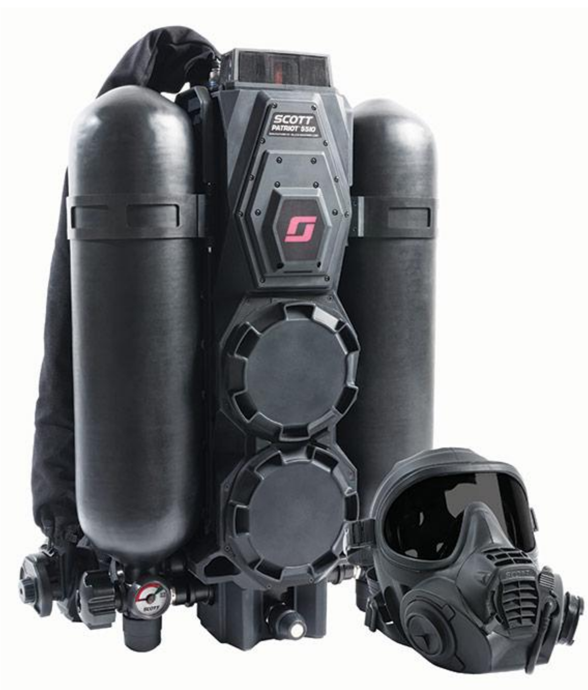
Hybrid Masks for C.B.R.N.

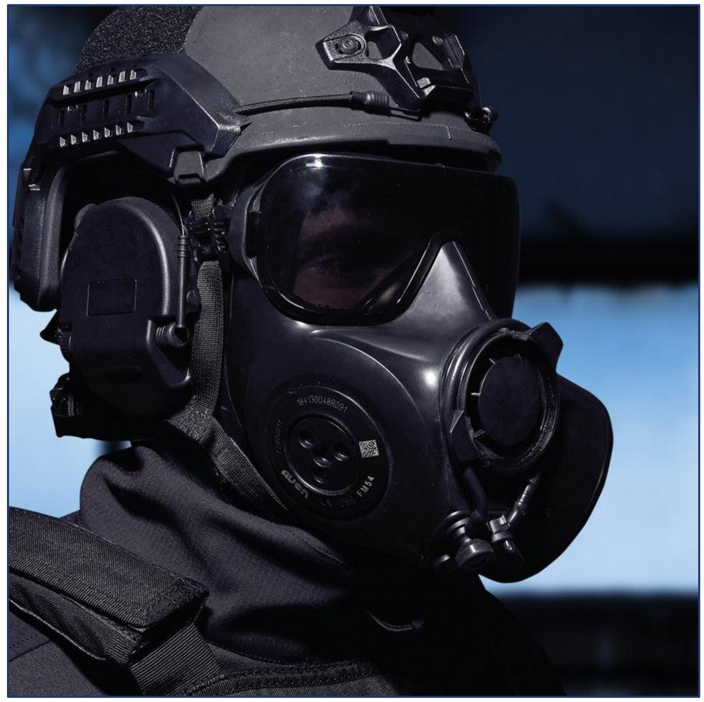
Hybrid Masks are engineered for **ultimate protection** in a variety of hazardous environments, reducing cost of ownership by supporting **A.P.R, P.A.P.R. and S.C.B.A.** applications. High versatility supports **C.B.R.N.E.** and long-duration missions The hybrid mask is ideal protection for personnel who face potential **C.B.R.N.E.** operations or long-duration missions. Based on newly designed systems can be used in three modes of operation with the same face piece: air purifying respirator (A.P.R.), powered air purifying respirator (P.A.P.R.), or self-contained breathing apparatus (S.C.B.A.).

The mask works either in positive pressure mode as a S.C.B.A. or in normal pressure mode as an A.P.R. or P.A.P.R. Switching between these modes is as simple as flipping a switch. The fact that can be used as a C.B.R.N. gas mask, **C.B.R.N. P.A.P.R**, or a C.B.R.N. S.C.B.A. means that the user only has to carry a single mask.
It also means less time required for pre-op preparation and gear maintenance.

Additionally, it is only necessary to purchase one mask for three modes, rather than a separate mask for each mode. The hybrid mask has a triple sealed edge, as well as an impact-resistant lens which provides a field of vision that is greater than 90 percent for optimal situational awareness.

The system usually if required, offers a hydration device which can be connected to a canteen or a Camelback. An optional communication system, which has a microphone that is inserted into the mask, an ear speaker (or two) for clear reception of messages, and a push-to-talk button that is connected to the radio to ensure understanding of messages between teammates.





Gas Masks and filter cartridges

A full-face gas mask consists of a filter cartridge, flexible face covering piece, transparent eye lenses, and a series of straps and bands to hold the device snugly in place. The filter cartridge is a plastic canister 8-10 cm across and 2.5 cm deep, which contains a filtration aid. Carbon based filtrants are commonly used because they **can adsorb large quantities of organic gases, especially high molecular weight vapors** like those used in chemical warfare.

However, inorganic vapors are not usually strongly adsorbed on carbon. The adsorptive properties of carbon can be enhanced by impregnating the particles with specific reactants or decomposition catalysts. Such chemically treated carbon is known as “activated carbon.”

The type of activated carbon employed in a given filter cartridge depends on the specific type of industrial contaminant to be screened. For example, carbon treated with a combination of chromium and copper, known as **“Whetlerite carbon,”** has been used since the 1940s to screen out hydrogen cyanide, cyanogen chloride, and formaldehyde.

Today, due to concerns about chromium toxicity, a combination of molybdenum and triethylenediamine is used instead.

Other types of activated carbon employ silver or oxides of iron and zinc to trap contaminants. Sodium-, potassium- and alkali-treated carbon are used to absorb sewage vapors (hydrogen sulfide), chlorine, and other harmful gases.

The face-covering piece, of the mask is used to hold the other components in place and to provide a secure seal around the face area. Depending upon mask design, an exhalation valve may be inserted in the face piece. This one-way valve allows exhaust gases to be expelled without allowing outside air into the mask.

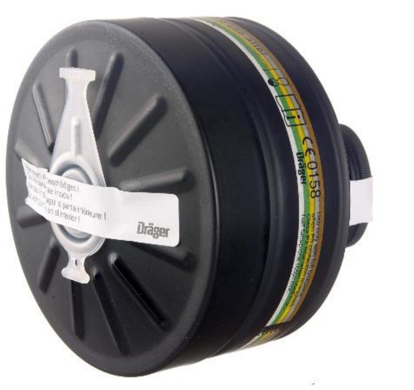
The eyepieces used in gas masks are chemically resistant, clear plastic lenses. Their main function is to ensure the wearer's vision is not compromised. Depending on the tactical environment in which the mask is to be used, the eyepieces may have to be specially treated to be shatterproof, fog resistant, or to screen out certain types of light (laser beam etc.). The elastic straps that hold the mask on the face are typically made of silicone rubber, EPDM or other suitable material. Supplementary straps (neck strap) may be added to allow the mask to be comfortably hung around the neck during breaks at work.

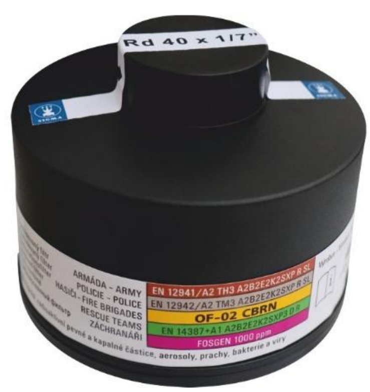
Chemical Filters

Chemical filters are used on respirators to help **remove and lower worker exposures** to harmful gases and vapours in the workplace.

There are several types of chemical filters:

- **Organic vapour.**
- **Inorganic vapour.**
- **Acid gases.**
- **Ammonia**
- **Formaldehyde**
- **Merculy vapour.**





Cleaning & Disinfection for PPE

In this chapter we will present only the methods for cleaning since disinfection is a procedure which needs practical experience and the user must be trained by an instructor for this purpose.

Procedure for Cleaning your Mask

1. Remove filters, cartridges, or canisters. Disassemble facepieces by removing speaking diaphragms, lung demand and pressure- demand valve assemblies, hoses, or any components recommended by the manufacturer. Discard or repair any defective parts.

2. Wash components in warm (30 deg.maximum) water with a mild detergent or with a cleaner recommended by the manufacturer. (e.g., Sekusept by Ecolab) A stiff bristle (not wire) brush may be used to facilitate the removal of dirt or a hard sponge.

3. Rinse components thoroughly in clean, warm (30 deg. C maximum), preferably running water. Drain.

4. When the cleaner used does not contain a disinfecting agent, respirator components should be immersed for two minutes in one of the following:

5. Hypochlorite solution (50 ppm of chlorine) made by adding approximately one milliliter of laundry bleach to one liter of water at 30 deg. C or,

6. other commercially available cleansers of equivalent disinfectant quality when used as directed, if their use is recommended or approved by the respirator manufacturer.

7. Rinse components thoroughly in clean, warm (30 deg.C maximum), preferably running water. Drain.
   The importance of thorough rinsing cannot be overemphasized. Detergents or disinfectants that dry on facepieces may result in dermatitis. In addition, some disinfectants may cause deterioration of rubber or corrosion of metal parts if not completely removed.

8. Components should be hand-dried with a clean lint-free cloth or air-dried. (not high pressure)

9. Reassemble facepiece, replacing filters, cartridges, and canisters where necessary.

10. Test the respirator with an appropriate testing device for leakages to ensure that all components work properly.

Maintenance and cleaning of your Chemical Protective Suit

Due to the vast number of chemicals and their different properties, **no general decontamination procedure exists**. The best way to decontaminate must be decided for the specific chemical encountered. This decision may only be taken by people educated for this task and with good knowledge of chemistry. Different CPS manufacturers may be contacted for advice.

*As a first rule a pre-decontamination must **always be performed before doffing the suit** – the safety of the wearer is the most important! This predecontamination should include rinsing with large amounts of water, if possible, containing a detergent.*

After this initial procedure the real decontamination can take place and since all chemicals can be divided into groups, depending on chemical and/or physical properties, the following three groups are the most relevant when it comes to decontamination:

- **Volatile**
- **Soluble or reacts with water**
- **Insoluble in water**

Depending on which group a chemical falls into, the decontamination procedure will be different. A special group of chemicals are the chemical warfare agents, for which we recommend a special decontamination procedure.

NOTE: There are many effective cleaning and decontamination agents available on the market. However, some of them contains corrosive chemicals which may affect the suit materials or components after long time use or repeated use. Therefore, if you are unsure, always contact CPS manufacturer for advice before use.

VOLATILE CHEMICALS

Chemicals that have lower boiling temperature than 80 °C are regarded as volatile. These are typically solvents like ethyl acetate, heptane, benzene, chloroform, acetone, and many others.

To decontaminate a suit which has been in contact with a volatile compound you air the suit outdoors or in a well-ventilated area, if possible, at a slightly elevated temperature (30-40 °C).

Hang the suit with the zipper fully open and enough space around it, so that the air can flow freely around the suit.
The required time for ventilating the chemicals depends on the temperature and airflow rate around the suit. After having aired the suit check for odour/smell of the chemicals and test the air for residual chemicals by using simple gas detecting tubes.

WATER SOLUBLE CHEMICALS

Chemicals that have higher solubility than 60 g/l water are regarded as water soluble. Also, the solubility is dependent on the temperature; an increase in temperature increases the solubility. Examples of water-soluble chemicals are: phenol, ethylene glycol, sodium, all acids and alkali.

When decontaminating a suit which has been in contact with a water-soluble compound you rinse the suit thoroughly with water, preferably with some added detergent. To further enhance the solubility, you can use warm water (30 °C).

Acids and alkali

Examples: sulphuric acid, hydrochloric acid, sodium hydroxide, ammonium hydroxide.

Since both acids and alkali are soluble in water, a suit which has been in contact with either one of them should be rinsed with water. Residual acid may first be neutralized with a dilute solution of alkali and vice versa for residual alkali. Afterwards, rinse thoroughly with water with some added detergent. The pH should be checked during the decontamination, when the pH is neutral the decontamination is finished. pH can easily be checked with a pH-stick.

WATER INSOLUBLE CHEMICALS

Chemicals that are not water soluble are soluble in some type of solvent, for example alcohol or white spirit. Chemicals that have lower solubility than 60 g/l water are regarded as water insoluble.

Examples are: styrene, pyridine, nitrobenzene, diesel and crude oil.

If the suit has been in contact with a water insoluble compound, you wipe the suit thoroughly with a cloth soaked in alcohol or white spirit (depending on what solvent will solve the chemical). Afterwards, rinse thoroughly with water with some added detergent.

There are chemicals that are so sticky that it is more or less impossible to get the suit completely clean.
If this occurs the suit must be scrapped.

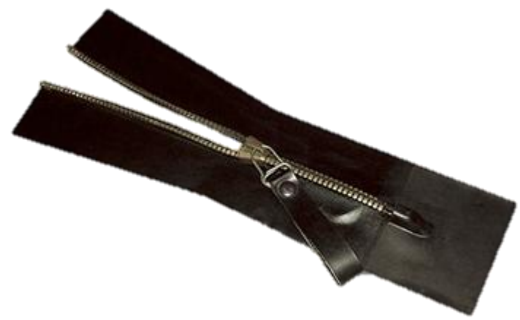
CHEMICAL WARFARE AGENTS

To decontaminate chemical – and also biological – warfare agents it is recommended using a 30% water slurry of calcium hypochlorite (also known as chloride of lime or HTH). The suit is washed with the slurry and the slurry is allowed to react with the agents for about 15 minutes before it is washed off with water. After this procedure the suit is washed thoroughly with lots of water, preferably with some added detergent.

*Once again if you are unsure, **always contact CPS manufacturer for advice before use.***
My suggestion is that if a chemical protection suit encounters heavy chemical warfare agents the percentage of successful decontamination of the material is about 30%.

Zipper Special Caution

DYNAT-slide fasteners are hermetically sealed and used as conventional zippers.



They are used wherever people need to be safeguarded by special protective clothing against unfavourable or even harmful factors in their environment, i.e. in the fields of **chemical protection**, **diving**, **surface watersport**, **survival** and **offshore-industry** as well as for technical applications like **special packaging's**.

The fastener system has been **developed especially for chemical protective suits.** Generally, the additional seals make mobility more difficult in comparison to zip fasteners on normal clothing. To prevent folds forming on the fastener system, the open section of the fastener system must be free of tension and operated without being twisted. At the same time, the closed area must be held tight with the hand. The protective suit wearer should be standing upright when opening and closing the fastener system. To avoid damage to the fastener system, **both halves of the zip must be parallel and unstressed**. Do not use force when opening and closing the fastener system or jerk the zipper. Fastener systems without sufficient lubrication are more difficult to operate. This can result in damage to the fastener system. Lubricate the fastener system using the grease stick supplied by your manufacturer.

Opening the fastener system

- Fully open the fastener system.
- Always pull the zipper tab in the direction of the zipper mechanism, never pull diagonally!
- Do not use force. Zip elements can become bent!
- If the zipper tab gets caught, pull it back and push it forward again.

Closing the fastener system

- When closing the fastener system, avoid diagonal forces on the zip.
- Pull the fastener chains together by hand.
- Then the zip will slide more easily along the section that is being pulled together.
- Foreign objects, such as shirt, jacket, threads, etc. must not be trapped between the zip elements.

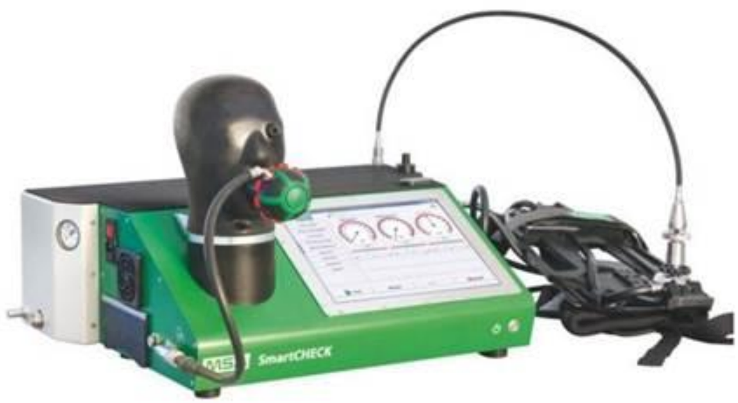
***Don't forget** to maintain your zipper with the special grease from **DYNAT**.*

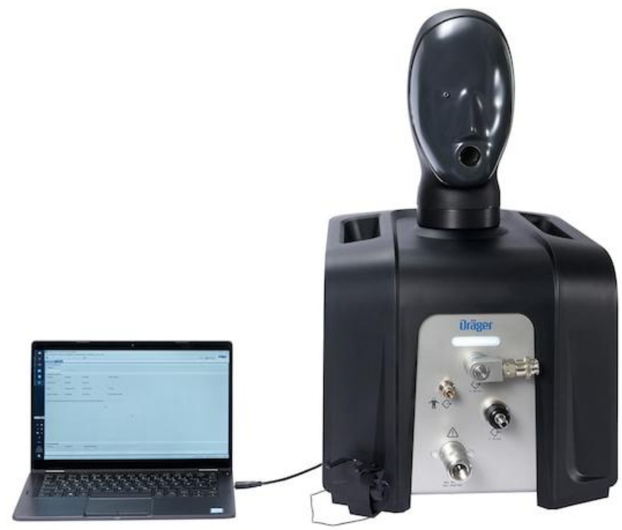
Testing Devices for PPE

There are several different devices for testing P.P.E. some of them are directly from the manufacturer of the product others from independent laboratories.

With these devices you can test for leakages, low pressure tests etc. It is really important after each cleaning of your mask or your suit to test it according to the guidelines of the manufacturer. Usually, the test devices do not occupy much space and can be integrated smoothly into your workshop.

*It is **strongly recommended** that the users of the testing devices should be fully trained by the manufacturer understanding the parameters of each P.P.E. and the tolerances of each test.*





Testing possibilities

- Full face masks
- Lung demand valves
- Pressure reducer (medium pressure function)
- Compressed air breathing apparatus
- Chemical protection suits (level 1A – 1B)
- Complete SCBA

It is important to decide before you purchase one if your testing device will be capable of completing dynamic tests not just static. This is essential especially for the lung demand valves which most of them need every year a dynamic test.

Another important factor is the possibility of connection via USB cable with a desktop pc or a laptop for easier measurement and tests according to each manufacturer instructions.

International & European Regulations

Depending on where they are sold, chemical protective suits must comply with specific regional standards that ensure they meet stringent performance requirements. For example, EN certification is required in Europe, while NFPA is the primary certification standard for protective suits and equipment in the United States and Canada. To meet these standards, protective suits and equipment are exposed to harsh conditions simulating the actual threats responders might face in the field, such as extreme temperatures, chemical exposure, and abrasion.

While both **EN and NFPA** standards provide a guaranteed level of safety and performance, it is important to note they are not the same. Each certification requires different testing procedures, each with its own methodology to simulate real-life hazmat incidents. In order to ensure they procure the best equipment for their emergency response teams, it is essential that organizations and companies understand the two main international certifications in hazmat suits, EN 943 and NFPA 1991, as well as the differences between them, including the tests performed and minimum performance requirements.

Chemical protective suits (CPS) are **essential for CBRN severe situations** while working with unknown and dangerous chemicals and substances as well as during decontamination. The new gas-tight CPS are especially designed for assignments under these extreme conditions. The suit material offers comprehensive protection from a wide variety of toxic industrial chemicals, chemical agents und biological hazardous substances liquefied gasses, and bursts of flames.

New suit materials protects during work in potentially explosive atmospheres as well as with the handling of frozen substances and hazardous substances at temperatures down to – 80°C. The suit even retains its protective effect if the surface is damaged. Material combinations of a double-sided sturdy elastomer layer and chemically resistant laminate layer plus a tear proof textile ensures this.

Exceeds international standards

Numerous international and national standards, for example the European **EN 943-2**, the **EN 1073-2** and the British **CBRN Standard BS 8467** specify the safety standards for chemical protection suits. Due to the new textile materials, CPS not only meets all the specified standards for reusable protection suits, but also exceeds the requirements for emergency teams and CBRN-Units from fire services, civil defense, and civil protection as well as the military.

Regulations regarding breathing protection

- **EN 137:2006 type 2** (Self Contained Breathing Apparatus)
- **EN 136 class 3** (Full face masks)
- **BS 8468-1:2020** Respiratory protective devices for use against chemical, biological, radiological and nuclear (CBRN) agents Positive pressure, self-contained, open-circuit breathing apparatus.
- **BS 8468-2:2020** Respiratory protective devices for use against chemical, biological, radiological and nuclear (CBRN) agents Negative pressure, air purifying devices with full face mask.
- **EN 529:2006** Respiratory Protective Devices
- **EN 12245:2022** Transportable gas cylinders – Fully wrapped composite cylinders
- **EN 12021:2014** Respiratory protective devices – Compressed gases for breathing apparatus
- **2014/68/EU** Pressure Equipment
- **EN 14593-1:2018** – Respiratory protective devices – Compressed air line breathing devices with demand valve – Part 1: Devices with a full-face mask – Requirements, testing and marking
- **EN 14594:2018** – Respiratory protective devices – Continuous flow compressed air line breathing devices – Requirements, testing and marking

Regulations regarding body protection

- **EN 943-1:2015+A1:2019** – Protective clothing against dangerous solid, liquid and gaseous chemicals, including liquid and solid aerosols – Part 1: Performance requirements for Type 1 (gas-tight) chemical protective suits
- **EN 943-2:2019** – Protective clothing against dangerous solid, liquid and gaseous chemicals, including liquid and solid aerosols – Part 2: Performance requirements for Type 1 (gas-tight) chemical protective suits for emergency teams (ET)
- **EN 1073-1:2016+A1:2018** – Protective clothing against solid airborne particles including radioactive contamination – Part 1: Requirements and test methods for compressed air line ventilated protective clothing, protecting the body and the respiratory tract
- **EN 1073-2:2002** – Protective clothing against radioactive contamination – Part 2: Requirements and test methods for non-ventilated protective clothing against particulate radioactive contamination
- **EN 14605:2005+A1:2009** – Protective clothing against liquid chemicals – performance requirements for clothing with liquid-tight (Type 3) or spray-tight (Type 4) connections, including items providing protection to parts of the body only (Types PB [3] and PB [4])
- **EN 14126:2003** – Protective clothing – Performance requirements and tests methods for protective clothing against infective agents
- **EN 1149-5:2018** – Protective clothing – Electrostatic properties – Part 5: Material performance and design requirements
- **ISO 16602:2007** – Protective clothing for protection against chemicals — Classification, labelling and performance requirements

Important issue for PPE products

Sometimes users are combining parts from different manufactures in order to cover the lack of one component e.g., Lung demand valve. You must be careful since each part component carries a unique certification, and the total amount of products creates a new certification which is valid **only if they are coming from the same manufacturer** – brand name.

*In case of an accident, **you will find yourself in lot of trouble if you have made a puzzle SCBA** from different manufacturers since there **will be no certification** for the overall SCBA.*

Epilogue

Closing this e-book, I would like to thank all my instructors, my friends, my students and the people who believed in me, for the valuable information and experiences provided me in my career.

And don't forget, **our greatest glory is not in never falling, but in rising every time we fall…**

John S. Retsios

**John Retsios is a professional trainer for Haz.Mat and C.B.R.N.E. P.P.E.*

You can read more articles from the author in www.fire.gr (online encyclopedia)

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- TESIMAX – Altinger GmbH
- DYNAT Verschlußtechnik GmbH
- Avon Protection
- CEN, the European Committee for Standardization

Acronyms

- **C.B.R.N.E. :** Chemical Biological Radiological Nuclear and Explosive
- **P.A.P.R. :** Powered Air Purifying Respirator
- **S.C.B.A. :** Self-Contained Breathing Apparatus
- **C.C.B.A. :** Closed Circuit Breathing Apparatus
- **L.D.V :** Lund Demand Valve
- **C.P.S. :** Chemical Protective Suit

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