

More Time in the Hot Zone: CBC Develops Lighter, Longer-Lasting Respiratory Protection System

更長的熱區作業時間：
化學生物中心發展更輕、更持久的呼吸防護系統(譯)

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Editor's Note 編註

All quotes in this article were obtained from a personal interview with Mr. Jonathan D. Sampson at the U.S. Army Combat Capabilities Development Command (DEVCOM) Chemical Biological Center (CBC), Aberdeen Proving Ground, Maryland, on 17 September 2019.

本文中所有引述內容來自於 2019 年 9 月 17 日在馬里蘭州亞伯丁試驗場 (Aberdeen Proving Ground) 的美國陸軍戰力發展司令部 (DEVCOM) 化學生物中心 (CBC) Jonathan D. Sampson 先生的個人訪問。

When an industrial accident releases toxic industrial chemicals in the United States, the first responders usually consist of the

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particular state's Army National Guard civil support team. Team members suit up in full-body protective gear and enter the hot zone. One of the major challenges that they face is the length of time that their respiratory protection systems allow them to stay there.

在美國發生工業意外事故釋放毒性化學物質時，第一線應變人員通常由特定州的國民兵民事支援隊所組成。組員們穿上全身防護服進入熱區時，所面對的主要挑戰其一是呼吸防護系統限制他們待在熱區的作業時間。

Responders currently tend to rely on closed-circuit, self-contained breathing apparatuses as part of their full protective ensembles. Use of the breathing apparatus requires the wearing of a bubble suit, which restricts motion and increases the weight and thermal burden on the user. The ensemble weighs 36 pounds, traps heat within, and does not allow for the wearer to drink while wearing it; it is heavy, hot, and "thirsty." In addition, there is a 4-hour usage limit.

應變人員現行使用封閉自給式呼吸器作為全裝防護的一部分，而全裝防護除封閉自給式呼吸器外，仍需要穿著密閉式防護服，這不僅限制了使用者的行動，亦增加重量及熱負荷。全裝重達 36 磅，既悶熱又不允許人員在著裝下飲水；這對人員而言，它又重、又熱、又「令人口渴」。此外，還有 4 小時的使用時間限制。

The “Closed System” 「封閉系統」

“The closed in closed system means that the user inhales and exhales on the same breathing loop; no exhalations are made to the outer environment. It comes with a 4-hour time limit,” said Mr. Sampson, a mechanical engineer at DEVCOM CBC. Mr. Sampson is the project team leader for research in designing a replacement system known as the Full-Spectrum Respiratory Protection System.

發展司令部化學生物中心的 (DEVCOM CBC) 機械工程師 Sampson 先生說：「封閉系統的封閉一詞(此封閉系統指封閉自給式呼吸器)，是指使用者在相同的呼吸循環中呼氣與吸氣，不與外部環境換氣。它有 4 小時的時間限制。」Sampson 先生是研究設計一種名為全方位呼吸防護系統以替代封閉系統的專案

組長。

“Civil support team responders have told us that the 4-hour time limit in the current system really reduces their effectiveness,” Sampson said. “When they suit up, they have to do equipment checks and then get to the mission site and, upon leaving the site, have to be decontaminated—all the while, using up time within that 4-hour window. On average, they have only 1 hour in the hot zone,” he added.

Sampson 先生說：「民事支援隊應變人員告訴我們，現行封閉系統 4 小時的時間限制確實降低了他們的效率。」他補充說：「他們著裝時必須檢查裝備，接著抵達任務地點，並且在離開前必須完成除污—這些同時都要在 4 小時內完成。」平均來說，他們在熱區只有 1 小時的時間。

Although the problem of heat stress in the current system can be reduced by using ice to cool the breathing loop, ice is very heavy, it is logistically complicated to supply, and it melts fast. Additionally, the need for rehydration during a mission is not addressed by the current system at all.

雖然使用冰能降低封閉系統內呼吸管路的溫度，進而減少熱負荷的問題，但冰很重，致使後勤支援困難，而且它融化快速，也依然沒有解決任務期間水分補充的需求。

A Better System 系統改良

Presented with these limitations, the DEVCOM CBC design team went to work. “We knew we had to center our solution around mission availability—more time in the hot zone. We also knew we had to reduce weight, lower the internal temperature, and get rid of the need for ice,” said Mr. Sampson, “So we teamed up with one of our sister Army research laboratories, the DEVCOM Soldier Center, and used a couple of their design innovations. These included adding a streamlined, body-forming uniform with built-in chemical agent protection and a tube for hydration to our system.”

面對這些限制，發展司令部化學生物中心的設計團隊開始進行呼吸防護系統的改良。Sampson 先生說：「我們知道提出的解決方案必須考量任務的實用

性，就是「更長的熱區作業時間」。我們也知道必須減輕重量、降低內部溫度及擺脫對冰的需求。所以我們與我們姊妹關係的陸軍研究實驗室(發展司令部士兵中心)合作，使用了一些他們創新的設計，包括在我們的系統上，使用輕便、符合人體且具化學防護及飲水管的服裝。」

Team members used existing technology to add a cooling plate to replace bags of ice. They even added miniature fans. They were able to further reduce weight by incorporating ultra-high-pressure gas cylinders, which hold the same amount of oxygen in a much smaller, lighter-weight container. All external parts were designed to fit together in a compact, easy-to-don and easy-to-remove backpack weighing only 24 pounds.

團隊成員運用現有技術以冷卻板來代替冰袋，增加微型風扇，在具備相同氧氣含量下，運用體積較小、重量較輕的超高壓氣體鋼瓶，能更進一步減輕重量。所有外部組件採壓縮式設計、易於穿著及脫卸，且採用背包容納所有組件，而背包的重量僅有 24 磅。

The real breakthrough, though, was the employment of two different respiratory protection modes in one system, making it a combined unit respirator. That advancement dramatically increased the time that civil support team members could spend on-site.

然而真正的突破是將兩個不同的呼吸防護模式融合在一個系統中，使人員依任務特性選擇適當模式。這個進展大幅增加民事支援隊在作業現場的時間。

When placed in powered air-purifying mode, a fan is used to push ambient air through the respirator filter, purifying the air as it enters the suit and maintaining positive pressure. The respirator can be operated for 8 hours in power air-purifying mode. Adding a powered air purifying respirator to the closed-circuit capability affords operators up to 12 hours of protection.

系統在動力空氣淨化模式下，利用風扇抽取環境中的空氣並經過呼吸器過濾，以淨化進入防護服的空氣且保持正壓。系統在動力空氣淨化模式下可操作 8 小時。動力空氣淨化模式與下段敘述之封閉自給呼吸器模式成為新系統的兩種呼吸防護模式，能為操作手提供長達 12 小時的防護。

The closed-circuit, self-contained breathing apparatus mode uses the existing closed-circuit technology of carbon dioxide absorption from the breath stream combined with injections of oxygen to maintain optimal oxygen levels while keeping carbon dioxide levels to a minimum. In addition, it makes use of the M53 mask and hydration tube. Furthermore, ice is replaced with a much lighter-weight cooling plate. The respirator can be used for 3 hours in closed-circuit, self-contained breathing apparatus mode; but the design team is confident that, with some further design optimizations, the time can be extended to at least 4 hours.

封閉自給式呼吸器模式使用現有封閉式循環技術，此技術結合吸收呼氣中的二氧化碳並注入氧氣，以維持最佳的氧氣含量，並同時將二氧化碳的含量保持在最低。此外，它還使用了 M53 面罩及飲水管。不僅如此，還使用重量較輕的冷卻板取代冰，呼吸器可在封閉自給式呼吸器模式下使用達 3 小時，但設計團隊有信心能透過更進一步的改良設計，讓使用時間能延長至少 4 小時。

Switching between modes in response to the threat level around them prevents operators from using such a large percentage of available time for equipment checks, transportation to the site, and decontamination.

依據周圍的威脅程度切換不同模式，可以避免操作手耗費大量的時間在檢查裝備、抵達任務地點，以及實施除污作業。

Warfighter Testing 人員測試

The entire effort to improve the protective ensemble was funded by the Defense Threat Reduction Agency, which developed and executed the Chemical Biological Operations Analysis to test emerging chemical and biological defense technologies. The event was held at Camp Dawson, Kingwood, West Virginia, on 22 August 2019. Industry, academia, and government laboratories were invited to bring their latest chemical and biological defense prototypes for warfighter use in realistic missions. The military operators provided candid feedback on the usefulness of the prototypes and then recommended possible improvements.

改良全裝防護的全部工作由國防威脅防制局資助，該機構負責發展與執行化學及生物的作戰分析，以測試相關新興防禦技術。這項活動於西元 2019 年 8 月 22 日在西維吉尼亞州金伍德 (Kingwood) 的道森營區 (Camp Dawson) 舉行。產業界、學術界及政府部門實驗室受邀提供最新的化學及生物防禦技術產品原型供實際任務中測試。軍方代表操作人員則直接針對原型的實用性提供回饋，並建議可行的改進方案。

The 35th West Virginia National Guard Civil Support Team, St. Albans, West Virginia, was assigned to test the Full-Spectrum Respiratory Protection System prototype at the Chemical Biological Operations Analysis. The mission of the 35th was to support civil authorities at a domestic chemical, biological, radiological, nuclear, and explosives incident site by identifying agents and substances, assessing the consequences, advising on response measures, and assisting with requests for additional state and federal support. Two teams from the 35th practiced investigating an abandoned structure containing a series of rooms for the presence of chemical, biological, radiological, nuclear, and explosives materials. One of the teams wore the current closed-circuit, self-contained breathing apparatus system; the other wore the Full-Spectrum Respiratory Protection System prototype. The team wearing the Full-Spectrum Respiratory Protection System prototype had the advantages of a body-cooling system, no bubble suit, available drinking water, and more time on-site. Those operators reported that they were very satisfied with the advantages offered by the Full-Spectrum Respiratory Protection System and that they were very glad to have the longer duration to complete the mission.

位於西維吉尼亞州聖奧爾本斯的第 35 西維吉尼亞國民兵民事支援隊，被賦予在化學生物分析作業時，測試全方位呼吸防護系統(上述段落之二合一呼吸防護系統)的原型(如圖 1)。他們的任務是支援國內化學、生物、放射、核子及爆裂物事故現場的民政當局，鑑別戰劑和物質種類、作業評估、建議應變措施及協助請求其他州與聯邦政府協助。來自該隊中的兩組成員，演練調查一座廢棄建築物結構，包含許多存放化學、生物、放射、核子及爆裂物的房間。其中一組

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穿著現行封閉自給式呼吸器系統，另一組著全方位呼吸防護系統。穿著全方位呼吸防護系統的組別，具備身體冷卻系統、穿著較輕便之防護服、可於著裝下飲水及更多現場作業時間等優點(如圖 2)。這些操作人員表示，他們非常滿意全方位呼吸防護系統所提供的優點，亦高興能有更長的時間來完成任務。



圖 1 全方位呼吸防護系統原型²

資料來源：美國陸軍戰力發展司令部化學生物中心網站，瀏覽日期：110 年 10 月 12 日。



圖 2 國民兵民事支援隊演練調查廢棄建築結構³

資料來源：美國陸軍戰力發展司令部化學生物中心網站，瀏覽日期：110 年 10 月 12 日。

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2. 美國陸軍戰力發展司令部化學生物中心網站，
<https://www.cbc.devcom.army.mil/solutions-newsletter/more-time-in-the-hot-zone/>，瀏覽日期：110 年 10 月 12 日。
 3. 美國陸軍戰力發展司令部化學生物中心網站，
<https://www.cbc.devcom.army.mil/solutions-newsletter/more-time-in-the-hot-zone/>，瀏覽日期：110 年 10 月 12 日。

Next Steps 未來展望

With the first phase of prototype development complete, Mr. Sampson and his design team will work with manufacturers in private industry to develop a next-generation prototype that combines all of the innovations created thus far and further refinements based on the latest laboratory generated performance data. This next-generation prototype will be subjected to rigorous field testing, and that data will be incorporated into the design of the final system. Ultimately, Sampson looks forward to the widespread use of the system by Army National Guard civil support teams across the Nation.

隨著第一階段產品原型的開發完成，Sampson 先生和他的設計團隊將會與民營企業的製造商合作發展下一代的裝備原型，將結合迄今為止所有創新思維，並依據實驗室之測試數據進一步提升相關性能。這個下一代的裝備原型還會接受嚴格的野戰測試，這些數據也將被納入最終系統的設計中。最終，Sampson 先生期待全國陸軍國民兵民事支援隊能廣泛使用這套系統。

For more information about the DEVCOM CBC, visit the website at <<https://www.cbc.devcom.army.mil>>.

更多有關美國陸軍戰力發展司令部化學生物中心的訊息，請訪問 <<https://www.cbc.devcom.army.mil>>網站。