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TECHNICAL REPORT

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PROTECTIVE CLOTHING AND LIFE SUPPORT EQUIPMENT FOR EXPLOSIVE ORDNANCE DISPOSAL PERSONNEL

by

Vincent D. Iacono, Jr.

Advanced Projects Branch

Clothing and Equipment Systems Division

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Clothing and Personal Life Support Equipment Laboratory
US ARMY NATICK LABORATORIES
Natick, Massachusetts 01760

FOREWORD

This report describes an advanced design for a Chemical and Biological (CB) Protective Clothing System for Explosive Ordnance Disposal (EOD) personnel. This protective clothing system will permit EOD personnel to perform their mission in CB-contaminated environments and provide them with complete thermal protection over a wide climatic range of -40°F to +110°F.

The design and engineering of this protective clothing system was performed under an exploratory development program, Pron. No. A18Z?5831F1GG. This work was directed by U. S. Army EOD Center, Picatinny Arsenal, Dover, N. J., with Mr. Lester E. Poese as project monitor.

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ABSTRACT

The design and engineering of a special protective clothing system for personnel who are required to dispose of toxic munitions are discussed. The various components comprising the overall system and their specific protective requirements are described. Performance characteristics of functional systems built to date are discussed.

PROTECTIVE CLOTHING AND LIFE SUPPORT EQUIPMENT FOR EXPLOSIVE ORDNANCE DISPOSAL PERSONNEL

1. Introduction

The chemical and biological protective clothing system discussed in this report was designed and engineered for the Explosive Ordnance Disposal (EOD) Center, Picatinny Arsenal, New Jersey.

The problem of protecting Army EOD personnel against contaminated working environments has existed since 1950 when the EOD Center was assigned responsibility for the removal of damaged nuclear weapons. Today, there are additional requirements imposed by the disposal of chemical and biological munitions.

The present M-3 toxicological protective suit used by EOD specialists (Figure 1) is unsatisfactory in that it requires assistance in donning and doffing, and allows a "stay-time" in the contaminated area of less than 15 minutes. It is presumed that contamination will be limited, and that the environment can be controlled. The problem of staying in the present suit in hot weather has not been effectively resolved. At best, the suit is uncomfortable and of course efficiency drops with an increase in discomfort.

Therefore, in November 1963, the U. S. Army EOD Center decided that current Army developments in the area of chemical and biological (CB) protective clothing for EOD personnel were not keeping pace with EOD requirements and a project was initiated to:

a. Establish EOD needs for protective clothing.
b. Determine state-of-the-art in this area.
c. Study the feasibility of developing a suit which would meet EOD needs for the next 10 years.

As a result of this project, the EOD Center selected the Thermalibrium System developed by the U. S. Army Natick Laboratories (NLABS) as the concept design that would most effectively meet specific requirements of EOD personnel operating in toxic or hazardous environments. A prototype of the Thermalibrium suit system is shown in Figure 2.

This clothing assembly with its heat regulation device is capable of isolating the soldier from CB-contaminated environments as well as providing him with complete thermal protection over a wide climatic range of -40°F to +110°F. A spin-off development from this concept is shown in Figure 3, the Man-Lock Thermal Protective Coverall, which was designed and fabricated by NLABS for the NASA Manned Spacecraft Center, Houston, Texas.

Figure 1. M-3 Toxicological Protective Suit

Figure 2. Thermalibrium Suit System

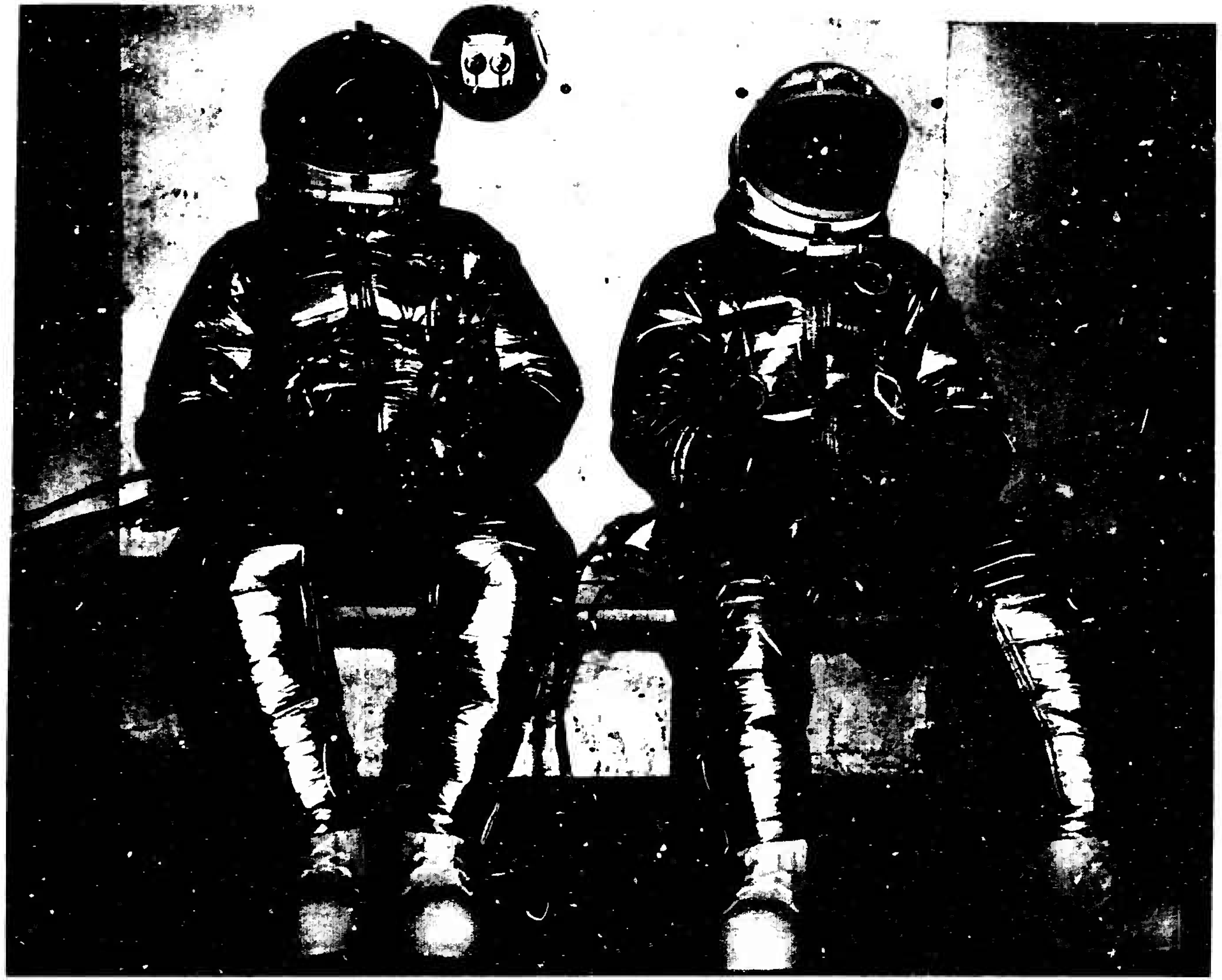

Figure 3. Man-lock Thermal Protective Coverall

This clothing system was designed to meet a chamber pressure of 5 psia and temperatures of -90°F to +190°F. It has the versatility of operating off the chamber environmental control system via an umbilical hose (closed loop) and/or a portable liquid oxygen cryogenic backpack. As part of the preacceptance testing, these clothing systems were tested for physiological adequacy at temperatures of -70°F and +165°F and 20 percent R.H.

The experience gained in the development of these systems has been drawn upon in selecting materials and hardware, and in establishing overall system designs for the EOD protective clothing system.

2. <u>Design Requirements</u>

The general design requirements for the EOD protective suit are:

a. The suit must provide toxicological protection to personnel while they work in contaminated environments on the neutralization of unexploded missiles, rockets, bombs and other explosive ordnance.

b. The thermal insulation of the clothing must be effective from -40°F to +110°F.

c. The suit must be capable of performing at its nominal design performance for a mission of two hours minimum (four hours design goal) without resupply (also for repeated mission reuse).

d. All closures, hardware and relief valves must be protected against direct liquid splash of CW agents and decontamination solutions.

e. The quick-disconnect ports in the system must be capable of interfacing any of the following life-support equipment:

    (1) Battery-powered breathing and ventilating backpack (filtered air).

    (2) Liquid air cryogenic backpack.

    (3) Umbilical hose.

f. The ventilation system must be capable of removing 700 to 1500 Btu/hr of heat.

g. The system must be capable of being repaired in the field.

h. The life-support system must have a secondary emergency breathing system as a backup to the primary system in the event of a malfunction.

i. Pressure drop across the suit and the air filter system is not to exceed 4 inches of water pressure at a flow rate of 18 cubic feet per minute.

j. The suit assembly must have some type of integrated quick-doffing overgarment which will provide flame-resistant protection and abrasion protection to the impermeable suit layer.

k. The material used must be able to withstand decontamination and/or cleansing with solvents and/or water-detergent solutions.

l. The helmet configuration must permit the use of personal spectacles.

m. The communication system must be an integral part of the overall system.

n. Boot designs must accommodate the thermal insulation as well as provide for toxicological resistance.

These factors have been considered in the design and fabrication of four functional prototype systems. These assemblies will be tested for reliability and performance under simulated environmental and operational conditions.

3. Description of Suit Design

The basic design of both the protective suit and the Thermalibrium system is a multilayered clothing system which uses a counter current flow of the ventilating air. Figure 4 shows a schematic drawing of the proposed EOD protective suit. The suit contains all the necessary components and subcomponents required to encapsulate the user and isolate him from a contaminated environment of toxic agents, as well as provide adequate thermal protection against the extremes of the imposed ambient temperatures.

The complete suit assembly consists essentially of a comfort liner, a vent distribution layer, a vent gas separator, an exhaust vent layer, a gas-sealing layer, and an expendable Nomex* cover layer (high-temperature nylon). Ancillary components to the suit are thermal underwear, thermal footwear, handwear, helmet, communication and life-support equipment.

The design of this clothing system is unique in that it provides a high degree of mobility, sizing versatility, a counter current flow distribution of the suit's environmental control air, and accommodation of the life support system variations.

*Trade Name for high-temperature resistant Nylon, DuPont

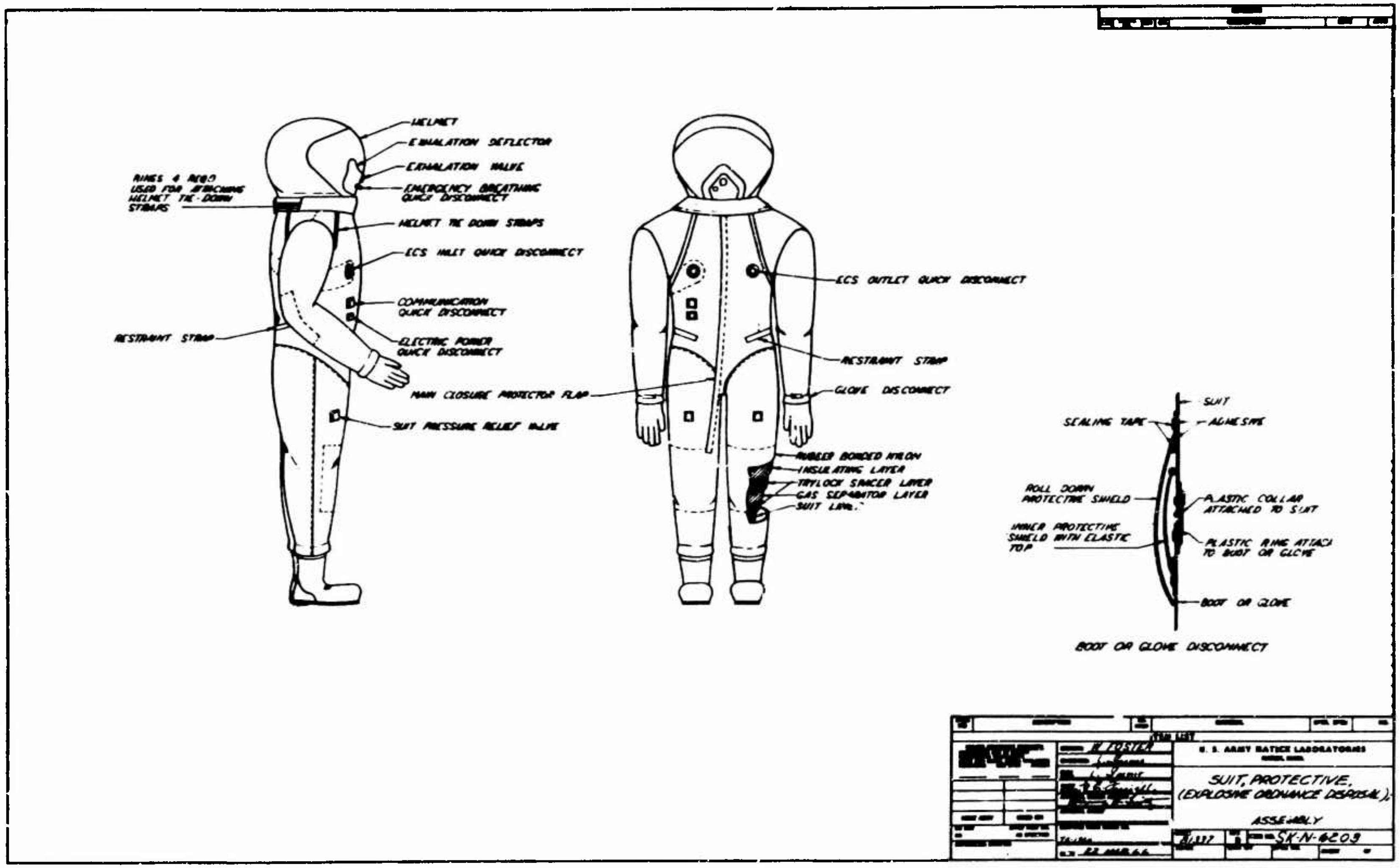

Figure 4. Proposed EOD Protective Suit

The breathing and ventilating air supplied from the life-support equipment enters the suit's manifold through two inlet disconnects. The manifold directs approximately 1/3 (6 CFM) of the clean and/or conditioned air to the helmet and the remaining 2/3 (12 CFM) to the suit.

Figure 5 shows the flow pattern of the ventilating air through the suit's layer system. This method of air distribution operates on the same principle as a double-walled heat exchanger. The ventilation air in the suit diffuses over the torso, arms and legs between the impermeable vent air separator wall and the underwear. The ventilating gas flows parallel to the body down to the extremities. At these points the vent gas reverses its direction of flow and diffuses between the impermeable gas sealing layer and vent gas separator wall. The exhaust gas is now flowing parallel to the body and counter current to the vent gas and is discharged outside the suit through the exhaust valves.

The method of counterflow distribution of the suit's ventilaing air assures that a highly turbulent ventilating air will come in contact with the body. The high turbulence achieved increases the overall heat and mass tr isfer coefficient prevailing on the skin surfaces, and thereby increases the effectiveness of heat regulation. The partitioned exhaust air which flows counter current to the ventilating air serves as a buffer layer between the outside environment and gas flowing directly over the body. The advantages of a buffer air layer are as follows:

1. The buffer air layer reduces the temperature gradient between the outside environment and the gases flowing in contact with the body surface.

2. The buffer air layer provides an extra safety mechanism against any in-board leakage of toxic agents through tears or punctures in the outer protective layer of the suit by discharging through these openings, thus preventing toxic gases from entering the suit and contaminating the ventilating and/or conditioned gas that is in contact with the skin surface.

3. The gas separator wall is a lightweight. butyl-coated, nylon rip stop fabric that maintains a balanced flow of ventilating air over the body, even when the outer impermeable gas layer is punctured; it also serves as a second toxicological protective layer.

A high degree of flexibility is achieved in this suit through the use of stretchable fabrics and special fabrication techniques. The gas-sealing layer is fabricated from a special material developed by NLABS for its thermalibrium system. The unique

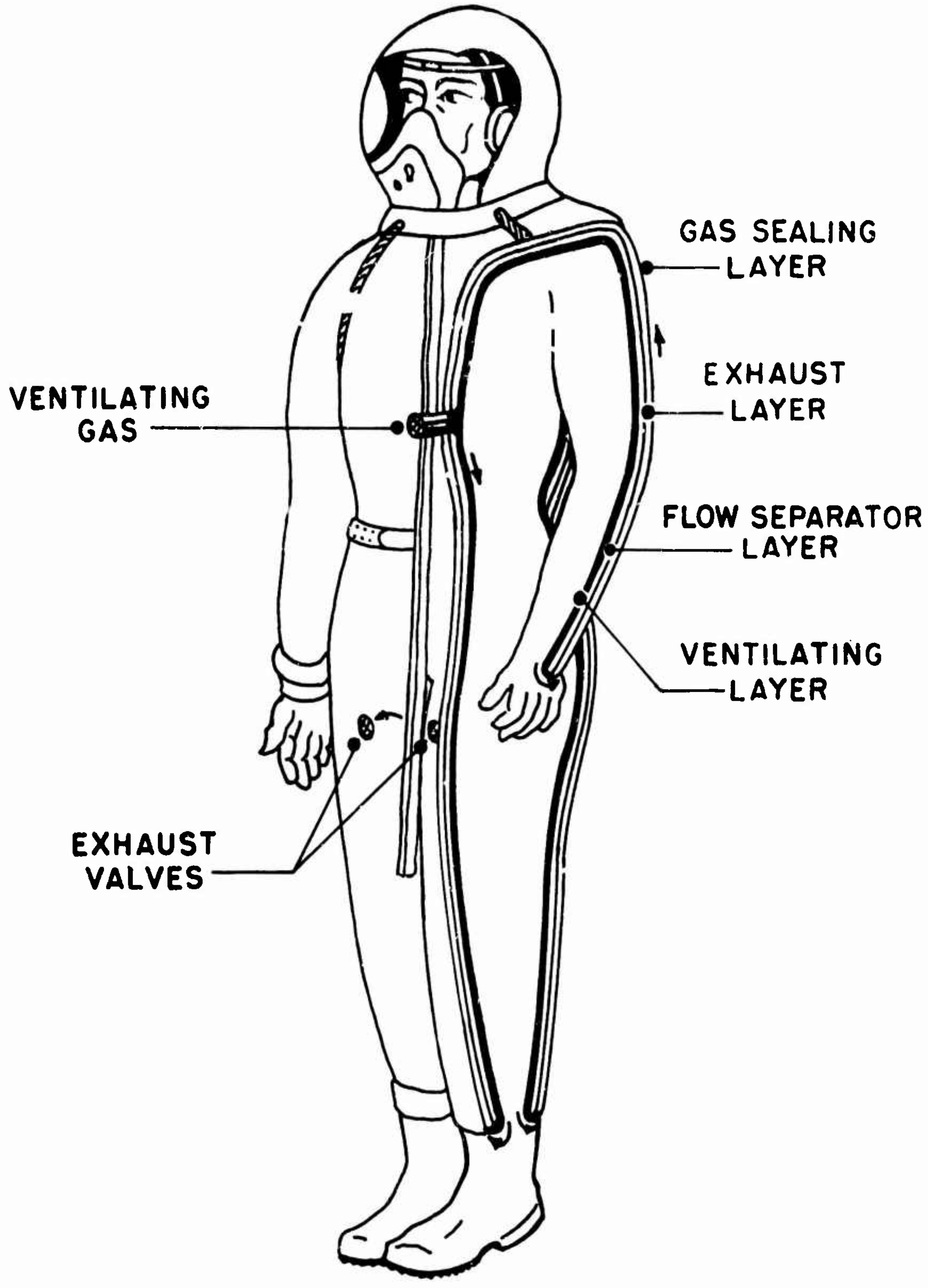

Figure 5. Counterflow Air Distribution

characteristics of this material are its lightweight and stretch properties. Limited testing of production samples has shown it to have good chemical and biological resistance. More extensive testing is planned for this coated fabric to determine more about its physical characteristics and toxicological resistance.

Connection of handwear and footwear to the suit is achieved by plastic disconnects. A gas-sealing zipper is used for the main closure of the suit. All hardware connectors and closures are shielded with a flap or cover made of the same material as the gas-sealing layer of the suit for protection against direct liquid splash.

The outer cover layer is fabricated from a single layer of Nomex nylon. In the event of an excessive splash of toxic agents, this layer can be easily removed and, at the discretion of the user, can be either destroyed or decontaminated. The layer is a two-piece garment and is sized and graded to fit over the life-support pack. It serves as a pressure restraint layer, and protects the gas-sealing layer against abrasion, direct splash of toxic agents and flash fire. The main closure entrances are designed to permit self-donning and doffing without disconnecting the life-support pack.

The EOD protective system components are shown in Figure 6. Figure 7 shows a prototype chemical and biological protective system.

4. Description of Helmet Design

The helmet design configuration is shown in Figure 8. This helmet consists of a rigid shell with a large clear area to provide nearly unrestricted visibility. The helmet shell is made in two halves by vacuum-forming clear polycarbonate plastic. The unclear portion of the helmet is painted with a white epoxy paint for chemical resistance. The helmet is supported on the shoulders and has an adjustment on either side to control the raising and lowering of the helmet for better fit.

The vent air for cooling the head and defogging the visor enters the helmet air channel through an interface connector in the neck ring and is directed through the air channel over the head, discharging across the visor.

At the base of the visor area is an oral-nasal deflector for directing carbon dioxide and moisture-laden exhaled gases away from the visor, thereby eliminating visor fogging and carbon dioxide buildup in the helmet.

The deflector is currently being redesigned to permit direct breathing from various types of emergency breathing life-support equipment.

Another design configuration (Figure 9) will permit the helmet to be used separately from the suit and will provide isolated protection

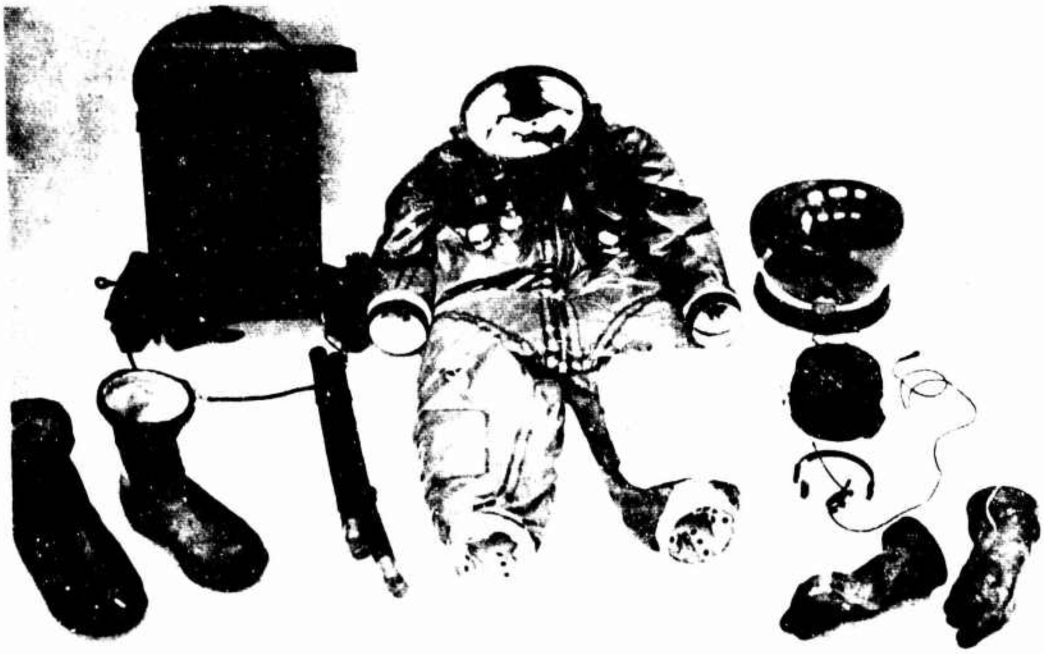

Figure 6. EOD Chemical and Biological Protective System

Figure 7. Prototype Chemical and Biological Protective System

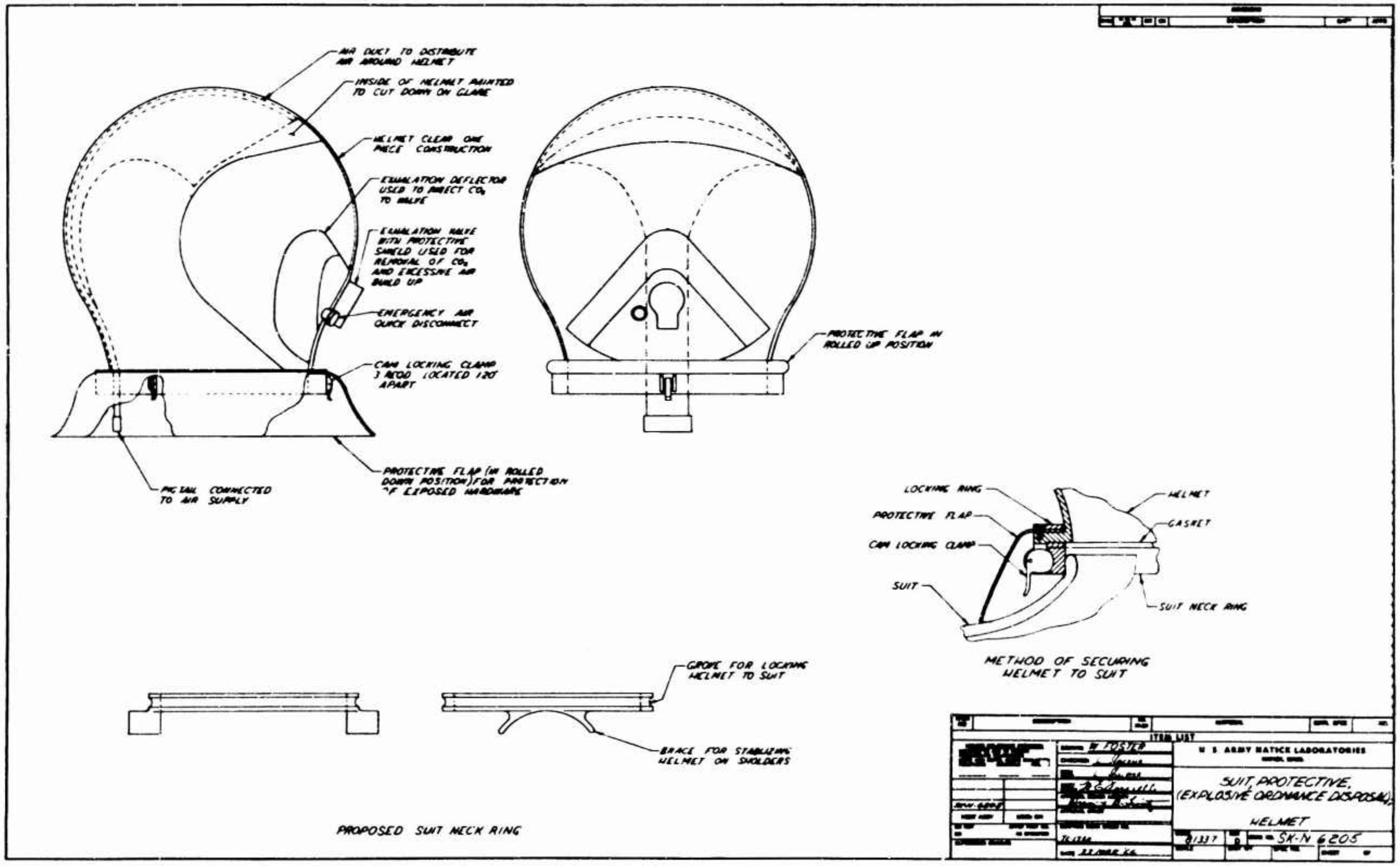

Figure 8. Helmet Design Configuration

to the head area only. Forced ventilation of approximately 5 CFM will be supplied inside the helmet by a battery-powered air filter pack.

5. Description of Boot Design

Figure 10 shows a schematic outline of the insulated boot which was specially developed for this sytem. It has the same material construction as the suit and uses a dead air space for thermal insulation.

6. Life-Support System

The connecting link between the man-suit and the environment is the life-support pack. The unit is capable of supplying 18 CFM of filtered ambient air to maintain a temperature and humidity balance inside the protective suit system.

The operating time for the powerpack of rechargeable Ni-CD batteries is two hours. The batteries are carried in two pouches supported on a belt around the waist. They are accessible for quick changing in a contaminated area.

The disposable filter canister is connected to the inlet side of the motor blower unit by means of a gas-tight quick disconnect. The ambient air is first drawn through the filter media and then blown into the suit. The filter (Figure 11) is capable of purifying ambient air containing CBR agents at the same level established for the M-17 Field Protective Mask. For normally encountered field concentrations of CBR agents, the filter will provide more than four hours protection. However, a self-contained air supply system will be provided in place of the filter for use in the presence of propellent vapors and high concentrations of CB agents.

Power Supply Requirements For Air-Filtered Backpack

Batteries	Ni-Cd
Voltage/cell	1.25 DC
Nominal Capacity (to 1.1 volts) (rated at 700 milliamperes)	7 ampere-hours
Average Weight/cell	15.7 oz.
Number of cells required	10
Operating time/cycle	2 hr.
Cell Dimensions	
Height	4-1/32"
Width	1-9/16"
Depth	1-41/64"

7. Communication System Concept Design

Three discrete activities should occur while deactivating munitions in the field. They are:

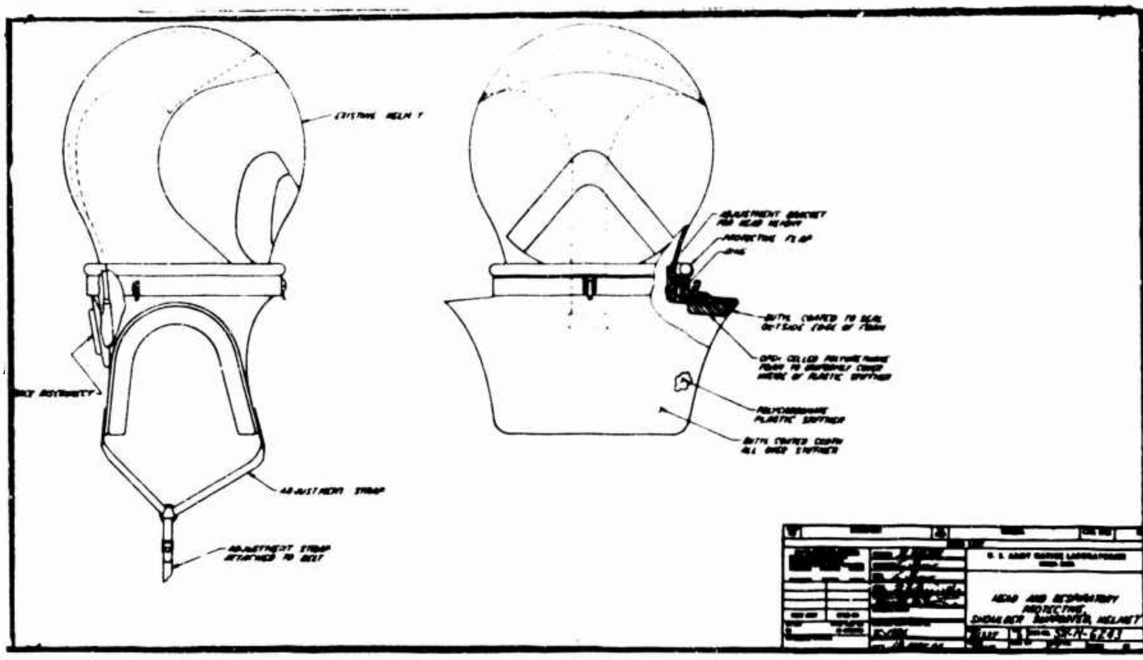

Figure 9. Helmet Design Configuration for Head Protection Only.

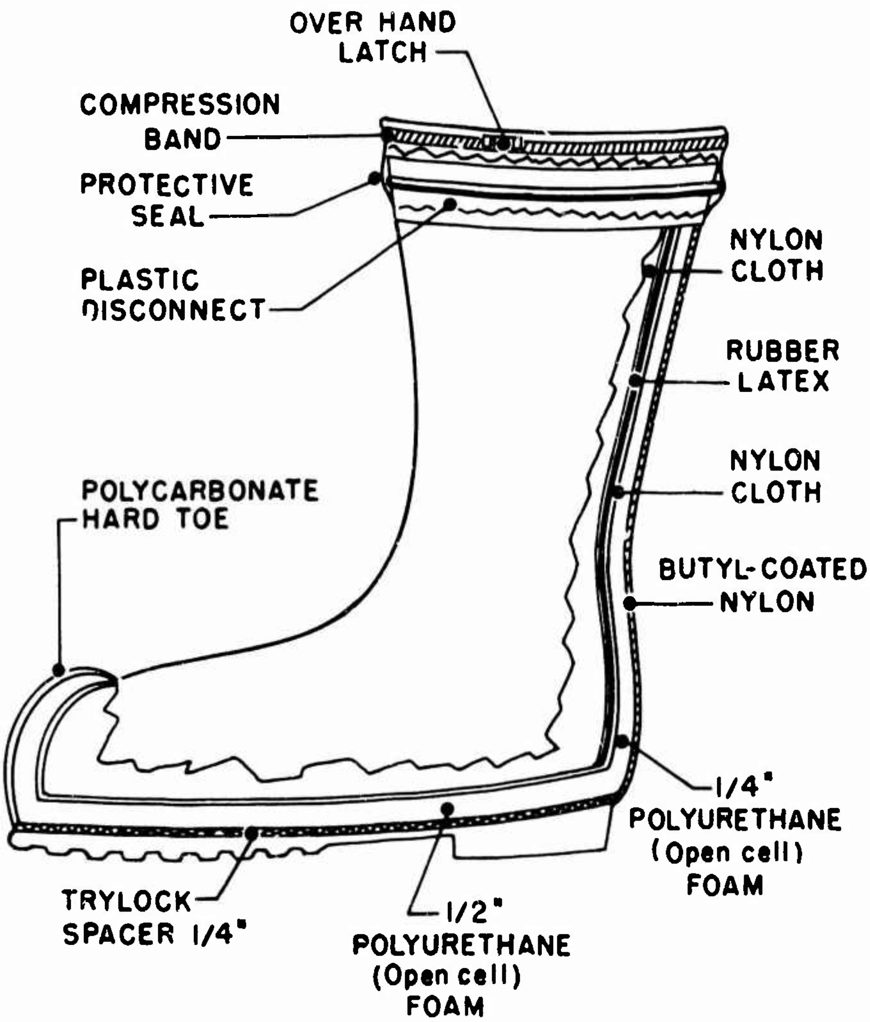

Figure 10. Boot Design Configuration

1. Reel time communication should be possible between members of the deactivation team.

2. The employment of auxiliary instruments (electronic stethoscope) to aid in deactivation should be convenient.

3. Information should be recorded as deactivation proceeds.

A system concept which implements the above functions is shown in Figure 12. This system uses the two-conductor field wire between the control center and the other stations manned by the deactivation team. Headsets which can simultaneously transmit and receive are worn by the lead man at the point of incidence by his assistants 20 feet on either side by two standby operators at a remote point 1000 feet from the point of incidence, and by the control center operator. Each headset is electrically connected to the field wire through a 4-wire to 2-wire conversion circuitry. This system allows the operators to monitor the deactivation with an electronic stethoscope, permits on line communication between all operators on the deactivation team, and records all verbal communication between operators. The system is portable and battery-operated for remote field operation.

CBR Protective Suit (EOD) - Weight Breakdown

1. Sub-Components

Sub-Components	Weight/lb
Helmet	3.2
Protective Suit and Hardware	13.7
Nomex Cover-Layer	1.3
Toxicological Protective Glove (Pair)	0.7
Toxicological Protective Insulated Boot (Pair)	3.9
	22.8

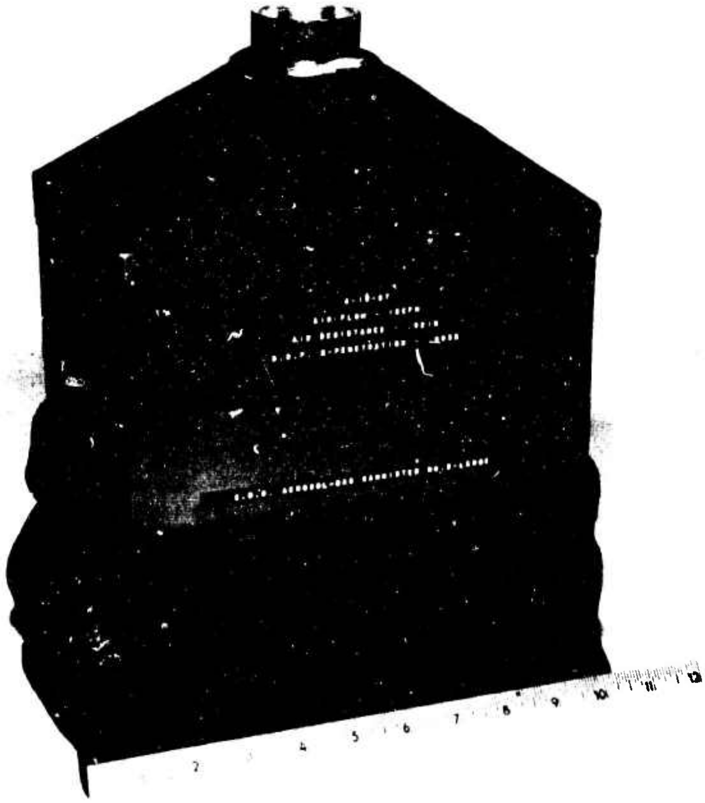

Figure 11. Chemical and Biological Air Filter

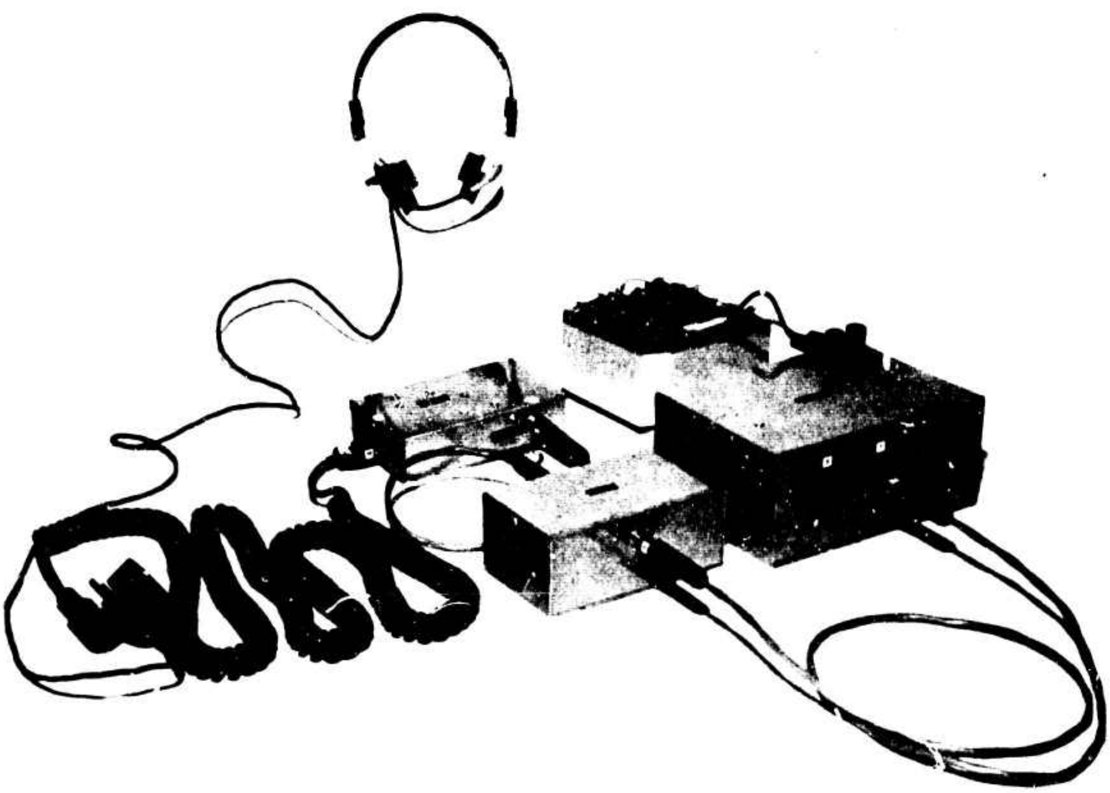

Figure 12. Communications System

2. <u>Life-Support Pack</u>

Filter Canister	4.8
Ni-Cd Rechargeable Batteries (10)	10.0
Motor Blower Unit & Housing	4.3
Operating Time 2 to 2-1/2 Hours (12 Volt DC; 12,000 RPM; 28 Watts)	19.1
Total System Weight	41.9 lb

Suit air-flow resistance and filter at 18 CFM: 3 to 4 inches of water. Suit operating pressure: 0.1 to 0.15 psi.

8. <u>Conclusion</u>

The U. S. Army Natick Laboratories has built four functional Chemical and Biological Protective Clothing Systems for the Explosive Ordnance Disposal Center at Picatinny Arsenal.

These clothing systems will permit EOD personnel to perform their missions in all environments contaminated with chemical and biological agents. The operating time of the EOD specialist in hot environments has been extended by these protective systems from 15 minutes to 2 hours. The operating time can be further increased to 8 hours by selecting a different power source. Other types of power sources which can be phased into the system as soon as they become operationally reliable and economically feasible are now being evaluated.

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13. ABSTRACT

The design and engineering of a special protective ensemble for personnel who are required to dispose of toxic munitions are discussed. The various components comprising the overall system and their specific protective requirements are described. Performance characteristics of functional systems built to date are discussed.

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Army personnel	9		4			
Heat	5					
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Contaminants	5		4			
Biological agents	5					
Chemical warfare agents	5					
Thermalibrium clothing system	10		9			
Protective clothing	10		9			
Explosive ordnance disposal	4		4			
Design			8			
Components			8			
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Human factors engineering			8			