Self-Contained Atmospheric Protective Ensemble (SCAPE)
Propellant Handlers Ensemble (PHE)

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SCAPE-PHE

- Self Contained Atmospheric Protective Ensemble (SCAPE)
  - Predates Shuttle Operations (1960s)
  - Equipment has evolved to accommodate the needs for all programs
  - Current SCAPE (Propellant Handlers Ensemble (PHE)) have been in use since 1987
  - Used in IDLH Environments

SCAPE-PHE Modes

- Available in two modes
  - Category I: Self Contained Environmental Control Unit (ECU)
    - Mobile; not attached to an external air source
    - Internal Cryogenic Air Supply, ECU
  - Category IV: Airline Supplied
    - Airline Supply Required
    - Portable Air Supply Required for Ingress/Egress

SCAPE-PHE Features

- Features of the SCAPE-PHE
  - Detachable, variable sized boots and gloves
  - "Bubble" or Flat Visor
  - Internal Air Distribution System

Category I SCAPE-PHE

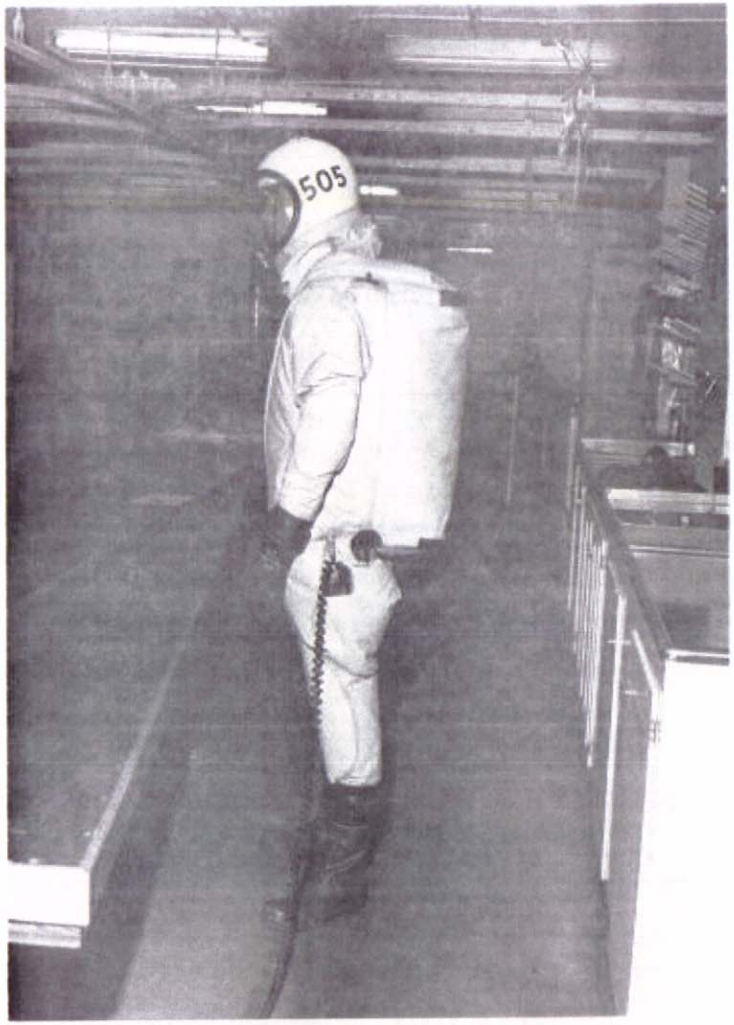

Figure 1a

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Category I SCAPE-PHE

Ancillary Equipment of Category I SCAPE-PHE

- Environmental Control Unit
  - Utilizes Locally Manufactured Liquid Air (20% - 30% Oxygen)

Category IV SCAPE-PHE

Category IV SCAPE-PHE

Specification of the SCAPE-PHE

- Research for an improved ensemble began in late 1970s and was driven by:
  - NIOSH (78-172 and 76-149) recommended changes in Allowable Exposure Limits for fuels and oxidizer used by NASA and the Air Force
  - An incident involving a Rocket Fuel Handler's Coverall (RFHCO) in an Air Force TITAN Missile Silo and personnel injury

Specification of the SCAPE-PHE

- Design Challenges and Design Requirements
  - Single Point Failure Mode
  - Glove and Boot Disconnects and Seals
  - Visor
  - Vent Valves
  - Suit Fabric
  - Gloves
  - Torso Closure
  - Communications
  - Emergency Air Supply

Specification of the SCAPE-PHE

- Program Execution
  - Survey of users of protective suits in propellant operations and of suit/component manufacturers
  - Test program to evaluate propellant resistance and other characteristics of candidate materials and components for an improve suit
  - Specification prepared to define and describe an improved ensemble

Specification of the SCAPE-PHE

- Single Point Failure Mode
  - Prevent/Minimize circulation of toxic vapors in the head area (breathing zone) in the event of a puncture or tear of the suit material
    - Evaluated manual mode change to head-only air
    - Evaluated neck ring with air to head first
    - Evaluated automatic mode change to head-only air
    - Evaluated internal face mask
  - Design Preference
    - Manual Mode change to head-only air
    - Distribute 60% of air supply to head area at all times

Specification of the SCAPE-PHE

- Glove and Boot Disconnects and Seals
  - Prevent Liquid Impingement
  - Visual and mechanical indicators that ensure reliable connections
  - Design Preference
    - Aluminum Quick Disconnects with O-Ring Seal
- Gloves
  - Glove thickness limited dexterity and material became "sticky" when exposed to high concentrations of oxidizer
  - Design Preference
    - The current glove was selected because it was the only one that adequately resisted propellants

Specification of the SCAPE-PHE

- Suit Fabric
  - Develop a more "Robust" fabric
  - Improve Flammability
  - Improve Maintenance
  - Design Preference
    - Thicker Fabric developed which incorporates a wear-indicator
    - Validated protection through Permeation Testing and Physical Properties Testing
    - Reasonable flame resistance

Specification of the SCAPE-PHE

- Visor
  - Minimize/Prevent scratches
  - Improve Chemical Resistance
  - Design Preference
    - Polycarbonate material with Chemical Resistant Hard Coating

Specification of the SCAPE-PHE

- Vent Valves
  - Prevent vapor migration under steady state venting and negative pressure scenarios
  - Testing performed in the NASA Lab using Helium to determine flow characteristics
  - Design Preference
    - Implemented a diaphragm-type exhaust valve with a relief valve cover to direct air flow and provide impingement protection

Specification of the SCAPE-PHE

- Torso Closure
  - Current closure design worked against the positive pressure of the suit
  - Design Preference
    - Selected a zip-lock style closure with zipper reinforcement

Specification of the SCAPE-PHE

- Communications
  - Focus on standard system that would be common to all users
  - Design Preference
    - Selected a headset and connecting cable to a bulkhead feedthrough on the garment fabric
    - External bulkhead connector allows for adaptation to other communications systems

Specification of the SCAPE-PHE

- Emergency Air Supply
  - Provide egress capability in the event of breathing air supply failure
  - Design Preference
    - Internally worn Emergency Air Supply with SCUBA mouthpiece originally designed
    - Unit increased ensemble weight and was discontinued
    - Egress capability accomplished through SCAPE Ventilators

Performance Validation of the SCAPE-PHE

- Protection factor testing
  - Overall Protection Factor of 50,000 for preoperational and operational exercises in Category I and Category IV Modes
- Physiological Testing
  - High and Low Temperature Operation Tests
  - Manned and Unmanned Carbon Dioxide Tests
  - ECU Testing in non-vertical attitudes
- Other Testing
  - Liquid Impingement Testing of ensemble from all attitudes
  - Ensemble Exposure Testing
  - Ensemble Fire Testing

Maintenance Testing of the SCAPE-PHE

- Maintenance testing validates continued performance:
  - Light Inspection (small holes)
  - Visual Inspection - Material degradation and damage identified
  - Ensemble Leak Test
  - Airline Flow Test
  - Exhaust Valve Reverse Flow (Leak) Test
  - Quality Inspection/Verification
  - Boots and Gloves tested individually