



AEROSPACE INFORMATION REPORT

AIR4362**REV. A**

Issued 2008-08

Stabilized 2014-07

Superseding AIR4362

NBC Protection Considerations for ECS Design

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1. SCOPE

This SAE Aerospace Information Report (AIR) provides Nuclear, Biological and Chemical (NBC) protection considerations for environmental control system (ECS) design. It is intended to familiarize the ECS designer with the subject in order to know what information will be required to do an ECS design where NBC protection is a requirement. This is not intended to be a thorough discussion of NBC protection. Such a document would be large and would be classified. Topics of NBC protection that are more pertinent to the ECS designer are discussed in more detail. Those of peripheral interest, but of which the ECS designer should be aware are briefly discussed. Only radiological aspects of nuclear blast are discussed. The term CBR (Chemical, Biological, and Radiological) has been used to contrast with NBC to indicate that only the radiological aspects of a nuclear blast are being discussed. This is actually a more accurate term to describe the subject of this paper, but NBC has become more widely used in the aircraft industry.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

ARP780 Environmental Systems Schematic Symbols

2.1.2 U.S. Government Publications

Available from the Document Automation and Production Service (DAPS), Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6257, <http://assist.daps.dla.mil/quicksearch/>.

MIL-STD-1472F Human Engineering Design Criteria for Military Systems, Equipment, and Facilities, Department of Defense, August 23, 1991

Available from the Army Publication Directorate, <http://docs.usapa.belvoir.army.mil/ordering/>.

FM 3-11.5 Multiservice Tactics, Techniques, and Procedures for Chemical, Biological, Radiological, and Nuclear Decontamination, April 4, 2006

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FM 8-9, NAVMED P-5059, AFJMAN 44-151 NATO Handbook on the Medical Aspects of NBC Defensive Operations, AMedP-6(B), Departments of the Army, the Navy and the Air Force, Washington, DC, February 1, 1996

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Southern Research Institute, [1984], Absorption/Desorption and Permeation Tests of Sealant Materials for Human Engineering Laboratory," Report Nos. SORI-EAS-84-818, ADD750736, CB-010905, for the U.S. Army Human Engineering Laboratory, Aberdeen, MD.

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2.3 Related Publications

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2.4 Definitions

ABSORB: To penetrate the surface of a material and intermix with the material.

ADSORB: To adhere to or become attached physically by adhesion forces on a surface.

AIRWASH: Exposure to a flow of air.

ASPHYXIATING TOXIC AGENTS: See CHOKING AGENTS.

BLISTERING TOXIC AGENTS (VESICANTS): These agents include sulfur mustard (H/HD) and nitrogen mustard (HN), arsenicals such as lewisite (L), and, phosgene oxime (CX). Mustard agents are also known by the French name yperite. Characteristic of these agents is their capacity of injuring skin integuments with the formation of abscesses and ulcers. However, they are all cell poisons, and accordingly they also affect the organs of vision, respiration, and all internal organs.

BLOOD AGENTS: Hydrogene cyanide (AC), cyanogen chloride (CK), arsine (SA). These agents affect the body functions preventing the normal transfer of oxygen from the blood to the body tissue.

CHOKING AGENTS: These agents include Phosgene (CG), Diphosgene (DP) and Chlorine (CL). Also known as lung or asphyxiating agents, they injure the respiratory tract, particularly the lungs. Death results from pulmonary edema.

CONTAMINANT: A chemical or biological agent or radioactive material posing a threat to equipment or personnel.

DANC SOLUTION: A decontaminant that consists of the chemical RH 195 dissolved in acetylene tetrachloride (tetrachloroethane); RH 195 is a white to cream-colored powder that decomposes gradually, giving off a chlorine-like odor. This decontaminant is obsolete.

DECONTAMINANT: Anything used to perform decontamination.

DECONTAMINATION: Process of sufficiently reducing the hazard caused by NBC contamination in order to allow the mission to be accomplished. Hazard may be reduced by chemical neutralization or by removing, destroying, or covering the contamination.

DETOXIFICATION: To remove a poison or toxin or the effect of such from the body.

EDEMA: An abnormal accumulation of fluid in tissue or a body cavity.

G-AGENTS: A family of neuromuscular toxic (nerve) agents that includes sarin (GB), soman (GD) and tabun (GA).

IMPERMEABLE: Not allowing passage, as of a liquid, through its substance; pertaining to materials-through which penetration of chemical agents is not possible.

INCAPACITATING AGENTS: Agents intended for disorganizing enemy forces by physical (nausea, vision impact) or mental (behavioral disturbances) impairment. This group includes the psychochemical agents.

IRRITANT TOXIC AGENTS (STERNITES): These agents include diphenylchlorarsine, diethyl-phenylarsine, adamsite. They irritate the mucous membranes of the upper respiratory tract and cause irrepressible sneezing, pains of chest, vomiting, and other morbid phenomena. Irritant toxic agents are intended to weaken the fighting capacity of troops and produce their physical exhaustion. These chemicals are also used by the police and for training purposes.

LACRIMATORY (LACRIMATION): The secretion of tears especially when abnormal or excessive.

LUNG AGENTS: See CHOKING AGENTS.

MISSION-ORIENTED PROTECTIVE POSTURE (MOPP): A flexible system of command calling for chemical agent protection during chemical warfare to facilitate mission accomplishment. The system gives the commander and staff a range of choices as dictated by the situation.

NEUROMUSCULAR TOXIC AGENTS (NERVE POISONS): G-agents, V-agents, and other organic derivatives of phosphoric and alkyl phosphoric acids. These toxic agents cause disturbances of functions of the nervous system, muscular convulsions and paralysis.

NEUTRALIZATION: The chemical process by which a decontaminant reacts with a chemical agent to produce less hazardous products.

NONPERSISTENT AGENTS: These agents may include nonpersistent nerve agents, choking agents or various combinations, which are usually disseminated in a vapor or aerosol state. They are quickly diffused or dissipated in the atmosphere and primarily intended to cause casualties by entry through the respiratory tract.

OFF GASSING RATE: The rate at which agent that has been adsorbed by a material is vaporized and released due to changes in conditions surrounding the material such as temperature and pressure.

OVERPRESSURE (POSITIVE PRESSURE): Pressure that is greater than that of the prevailing outside atmosphere.

PANTOTOXIC AGENTS: These agents include hydrocyanic acid, cyanogen chloride, arsenic hydride, phosphorus hydride, carbon monoxide, and organo-fluorine compounds. They cause general poisoning of the organism, although the mechanism of their action and character of affection are completely different.

PERCUTANEOUS: Effected or performed through the skin.

PERMEABLE: Having pores or small openings that allow liquids or gases to penetrate.

PERSISTENT AGENTS: These agents may include persistent nerve agents, blister agents, or a combination of both. They have a more permanent lingering effect and are used to contaminate equipment and terrain and to cause casualties through the skin absorption route.

PSYCHOCHEMICAL AGENTS: These agents include diethylamide of lysergic acid, mescaline, pilocine, benzilic acid derivatives, and others. They cause disturbances in the action of the central nervous system with the symptoms of psychic affections.

SLURRY: Suspension of a solid in a liquid; in general, it is a mixture of a decontaminating agent with water for use as a decontaminating solution.

SORB: To absorb or adsorb.

TACTICAL CLASSIFICATION: A classification that subdivides toxic agents according to their effect on the organism. The following three groups are usually distinguished: lethal, incapacitating, herbicides.

TEAR-PRODUCING TOXIC AGENTS (LACHRYMATORS): These toxic agents include chloracetophenone, bromobenzyl cyanide, and chloropicrin. They irritate the mucous membrane of eyes and upper respiratory pathways, causing a profuse flow of tears and intense smarting of eyes and nose. They are and primarily used for mob and riot control and not for NBC warfare.

V-AGENTS: A family of neuromuscular toxic (nerve) agents that includes O-ethyl S-diisopropylaminomethyl methylphosphonothiolate (VX).

VOICEMITTER: Device enabling voice transmission outside of a mask.

VOMITING AGENTS: These agents include Diphenylchloroarsine (DA), Adamsite (DM), Dyphenylcyanoarsine (DC). They are disseminated as an aerosol and primarily used for mob and riot control and not for NBC warfare.

2.5 Abbreviations

AC: Hydrogen cyanide

CB: Chemical and biological

NBC: Chemical, biological, and radiological. This is used to contrast with NBC to indicate only that the radiological aspects of a nuclear blast are being discussed.

CG: Phosgene

CK: Cyanogen chloride

CL: Chlorine

CT: Cumulative concentration multiplied by time (actually the time integral of concentration)

CW: Chemical warfare

CX: Phosgene oxime

DA: Diphenylchloroarsine

DC: Dyphenylcyanoarsine

DM: Adamsite

DP: Diphosgene

ECS: Environmental control system

GA: Tabun

GB: Sarin

GD: Soman

H/HD: Sulfur Mustard

HEPA: High efficiency particulate air (usually in reference to a filter)

HN: Nitrogen Mustard

L: Lewsite

MOPP: Mission-oriented protective posture

MMD: Mass mean diameter

NBC: Nuclear, biological, and chemical

PSA: Pressure Swing Adsorption

SA: Arsine

TSA: Temperature Swing Adsorption

VX: O-ethyl S-diisopropylaminomethyl methylphosphonothiolate

WCG: Water cooled garment.

3. THREAT

As with other military weapon systems, NBC weapons have as their goal harming the opponent. The wide range of threats and effects, both offensive and defensive, of these weapons is what sets NBC weapons apart from others. Effects can vary from the destruction associated with nuclear weapons to a famine associated with biological agents. The examples show that the time required for NBC weapons to affect their intended targets can vary from immediate to months. Some of these weapons can be tailored to be non-lethal, but still cause intensive casualties, thus decreasing overall combat effectiveness. The threat and the effects of these weapons will be discussed in aircraft operational terms, in flight, as on a mission, or on the ground where the aircraft would be serviced.

3.1 Types of Threat

- a. **NUCLEAR** - A nuclear device produces immediate blast, heat and radiation effects. The ECS is not capable of dealing with the blast, heat effects or the radiation that can penetrate the aircraft structure. Following a nuclear detonation, radioactive residue forms a cloud that moves with the wind, creating both an atmospheric and ground hazard. If the aircraft encountered a radioactive cloud, radiation in the form of alpha and beta particles and gamma radiation would be encountered. This radiation results from the decay of radioactive particles making up the cloud. Crew and equipment exposure would result from the ingestion of radioactive materials into the vehicle through the bleed system and ECS. While the radiation levels would be lower than that of the blast area, the crew effects from prolonged exposure, particularly if the particles are inhaled or ingested, could be severe. Avionics equipment could also be affected. The vehicle, its crew and its subsystems would require detection of the radiation and decontamination after recovery to protect the crew and allow for normal maintenance activities.
- b. **BIOLOGICAL** - The means of dispensing various agents is provided in Table 1. In flight, the biological agents would be ingested into the pressurized zones of the aircraft through the bleed system and ECS. The high temperature encountered in the engine and bleed system would provide some destruction of the agents in flight, but due to short dwell times in the bleed air system, some contamination must be assumed to pass through to the ECS. Bleed air temperatures of most aircraft on the ground are generally not high enough to destroy any agent. There would be no immediate effect on the crew because of the time required for the biological agent to act. Table 1 provides the exposure time and lethality of the various agents. Again, exposure of the vehicle to biological agents must be detected. The crew would require medical attention, and the vehicle must be decontaminated prior to servicing and reuse.
- c. **CHEMICAL** - Like biological agents, chemical materials can be dispensed as aerosols and would be ingested into the bleed air system. Again, some of the agents would be destroyed by oxidation with the bleed air at high temperature in flight; however, the remaining agent would go through the ECS to the pressurized zone. The effects on an unprotected crew could be immediate or take up to days to be observed, depending on agent type. Air-cooled equipment would also be contaminated, requiring care in servicing. As with biological agents, any contamination of the vehicle would have to be decontaminated prior to ground service and reuse.

3.2 Detail Threat

The various military services have established detailed threat information for various operational areas. This information, which is generally classified for specific threats, provides the expected concentration levels for various agents. This information is required prior to starting a detail design of an NBC protection system. For each of the threats defined in 3.1, properties are examined in general terms, and the relative difficulty of protecting aircraft from each is discussed.

3.2.1 Nuclear Agents

The radioactive particles of most concern are dust particles thrown or sucked up by surface or near-surface bursts and contaminated with radioactive fission fragments. These particles range in diameter from less than 1 μm to more than 100 μm . Inhalation of radioactive particles can be more serious. Although the nose effectively filters particles with diameters greater than 5 μm , particles with diameters on the order of 1 μm are deposited in the alveolar (air) cells. Radioactive dust must be excluded from the crew compartment.

3.2.2 Biological Agents

Potential biological warfare agents are shown in Table 1, along with their type, incubation period, and approximate human mortality rate. Biological agents and toxins are generally solids and are disseminated as aerosols of particles having a mass mean diameter (MM D) smaller than 10 μm . They can also be disseminated in liquid solutions or slurries. Solid agents dispersed in this manner remain as solid residue after the liquid carrier evaporates.

TABLE 1 - BIOLOGICAL WARFARE AGENTS FROM ARMY FM 8-9 [1996]

Group	Disease	Likely Methods of Dissemination	Incubation* Time	Duration of Illness	Lethality
Bacteria	(Inhalation) Anthrax	Spores in aerosols	1-6 days	3-5 days	High
	Brucellosis	1. Aerosol 2. Sabotage	Days to months	Weeks to years	Low
	Cholera	1. Sabotage 2. Aerosol	1-5 days	1 or more weeks	Moderate to high
	Melioidosis	Aerosol	Days to years	4-20 days	Variable
	(Pneumonic) Plague	1. Aerosol 2. Infected vectors	2-3 days	1-2 days	Very high
	Tularemia	Aerosol	2- 10 days	2 or more weeks	Moderate if untreated
Rickettsiae	Typhoid Fever	1. Sabotage 2. Aerosol	7-21 days	Several weeks	Moderate if untreated
	Epidemic Typhus	1. Aerosol 2. Infected vectors	6-16 days	Weeks to months	High
	Q-Fever	1. Aerosol 2. Sabotage	10-20 days	2 days to 2 weeks	Very low
	Rocky Mountain Spotted Fever	1. Aerosol 2. Infected vectors	3-10 days	2 weeks to months	High
	Scrub Typhus	1. Aerosol 2. Infected vectors	4-15 days	Up to 16 days	Low
Chlamydia	Psittacosis	Aerosol	4-15 days	Weeks to months	Very low
	Coccidioidomycosis	Aerosol	1-2 weeks	Weeks to months	Low
	Histoplasmosis	Aerosol	1-2 weeks	Weeks to months	Low
Viruses	Chikun-Gunya Fever	Aerosol	2-6 days	2 weeks	Very low
	Crimean-Congo Hemorrhagic Fever	Aerosol	3-12 days	Days to weeks	High
	Dengue Fever	Aerosol	3-6 days	Days to weeks	Low
	Eastern Equine Encephalitis	Aerosol	5-15 days	1-3 weeks	High

* Incubation applies to infectious disease. With toxins, its application refers to the period between exposure and appearance of the symptoms and signs of poisoning.