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to Meet the Threats of the 21st Century

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OF THE REQUIREMENTS FOR THE DEGREE OF  
MASTER OF MILITARY STUDIES

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## *Executive Summary*

**Title:** Recommendations to Improve the Current NBC Ensemble to Meet the Threats of the 21st Century

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**Thesis:** For Marines to survive in 21st century warfare, the Department of Defense must immediately conduct a comprehensive re-engineering effort that uses updated requirements and realistic testing to redesign the currently-issued, outdated, and ineffective NBC protective ensemble to ease respiration, increase time to failure, enhance individual cooling, improve ergonomics and integration with weapons, and address the range of the complex NBC and HAZMAT-threat environments that they can expect to encounter.

**Discussion:** Aspects of future amphibious operations outlined in *Expeditionary Force 21* will be conducted in the littoral zones around the world. These amphibious operations could encompass everything from humanitarian assistance up to and including full combat operations. Within these coastal zones, resides the majority of the world's population and many are living in megacities. The current chemical protective ensembles are designed to protect the wearer from traditional Soviet/Warsaw pact traditional chemical aerosol threats in open battlespace delivered by traditional delivery methods. Current terrorist/insurgents operating in the megacities of littoral zones, will take advantage of the air flow characteristics and enhanced "containment" offered by the "urban canyons" of these coastal cities to magnify the concentration and duration of NBC threats. The enemy will employ these agents with the intent of terrorism, impacting the continuity of legitimate government, inflicting mass casualties along with area denial and anti-access. These threat agents can be employed as gases, vapors, aerosols, particulates, liquids, and solids. Marines will face not only the traditional Nuclear, Biological and Chemical war agents but will be subjected to the threats of infectious disease pathogens, dispersed radioactive isotopes, toxic industrial chemicals and toxic industrial materials deployed with ingenious and commonly available dispersal devices. Our NBC equipment must be redesigned to reflect our anticipated battle space along with its attendant hybrid and asymmetrical conditions.

**Conclusions:** The recommendations contained herein will help to equip the 21st Century U.S. Marine, civil first responder, acquisition specialist and requirements writers with the knowledge necessary to plan the improvements in NBC equipment, tactics, techniques and procedures, and will offer the opportunity of an increased force protection quotient as well as extended and enhanced combat efficiency and endurance in all contaminated environments.

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*Table of Contents*

	Page
DISCLAIMER.....	i
PREFACE AND ACKNOWLEDGEMENTS.....	iii
I – INTRODUCTION.....	1
II - GENERAL ISSUES REGARDING RESPIRATORY PROTECTION .....	5
III - FILTERS, POWERED-AIR PURIFYING RESPIRATORS (PAPR), AND COMBINATION UNITS.....	11
IV - MASK FACE BLANKS.....	12
V - CHEMICAL PROTECTIVE OUTER GARMENTS (CPOG).....	14
VI - DECONTAMINATION.....	18
VII - ACQUISITIONS.....	19
VIII - CONCLUSION.....	20
APPENDIX A: CYANOGEN CHLORIDE TESTING DATA.....	23
ENDNOTES.....	25
BIBLIOGRAPHY.....	27

## *Preface and Acknowledgements*

As a Marine NBC Defense Officer, my interest in nuclear, biological and chemical warfare is professional, after retirement and on joining Marine Corps Systems Command, I was assigned duties as a science advisor to the USMC Chemical, Biological Incident Response Force (CBIRF). During my decade of duties at CBIRF I have had the honor to participate in the Anthrax and Ricin cleanups in the National Capital Region, represent CBIRF at numerous foreign government briefings, Federal, State and local events, standard writing organizations, and liaison with civil first responder organizations. I have operated in all levels of protective equipment in live nerve and blister agent in open and confined spaces and have supervised several historically significant Human Use and material testing protocols in both military and civilian laboratories and in open proving grounds. By invitation, I have shared my observations with the DOD, Industry, universities, requirements writers, acquisition personnel and research, development and testing experts.

I would like to recognize the sacrifice, patriotism and valor of a number of individuals from many organizations who have contributed greatly towards the expanded operational competence of the USMC and the Marine Corps Systems Command, especially Dr. Jon Kaufman of Naval Air Systems Command, Mr. Christopher Karwacki, Mr. Richard Newton and Dr. Pete Stopa of Edgewood Chemical Biological Command, the dedicated Americans of the National Institute of Occupational Safety and Health (NIOSH) at the Briceston center in Pittsburgh, Pennsylvania, Dr. Christina Baxter and Mrs. Beth Lancaster of the Technical Support Working Group (TSWG) in Crystal City, Virginia, Mr. Bruce Teal and the staff of the National Fire Protection Association (NFPA) in Quincy, Massachusetts, Mr. Kent Hofacre and Mr. Aaron Richardson of Battelle Memorial institute Columbus, Ohio, and the members of the Inter Agency

Board (IAB). I would also especially like to thank my Marine Corps Command and Staff College conference group military faculty advisor, LtCol Steven Wallace, my expert writing coach, Ms. Andrea Hamlin, from the Marine Corps University's Leadership Communications Skills Center, the leadership of CBIRF, Col T.X. Hammes, Col Ike Trafton, LtCol Scott Graham, Maj Ron Dahart, and the courageous U.S. Marines and sailors of CBIRF at Naval Surface Warfare Center, Indian Head, Maryland.

## *Introduction*

The proliferation and availability of Nuclear, Biological and Chemical weapons, common precursor materials, radioactive isotopes, simple aerosol dual use delivery techniques and devices would be sufficient in and of themselves, in order to compel a revisit of issued NBC respiratory and dermal protective equipment. Many of the design features of current issue NBC equipment has at its inception, a genesis in the cold war era with an accommodation toward the most likely threat of the day; Soviet doctrine, threat agents, tactics and delivery techniques. Post mortem examinations of Soviet armor destroyed by Israel in the 1973 Yom Kippur war revealed the Soviets were prepared to fully function on a modern NBC contaminated battlefield and had invested in the overpressure and filtration systems necessary to ensure survivability of their crews. This mindset has continued more or less unchanged up to the current time period and manifests itself in the end state design, objective and thresholds established in the test and evaluation master plans (TEMP) for NBC equipment. While many military thinkers are fully aware of the textbook effects of traditionally delivered NBC (nuclear, biological, chemical) agents, very few have any real experience wearing these protective ensembles in live agent performing their normal military occupational specialties for any extended periods of time; as a result, most are oblivious to the sensory deprivation, core temperature rise, labored breathing and in general, the arduous nature of operations in elevated levels of NBC protective equipment. Most have no first-hand knowledge of the impact of poor design features of and the strength sapping and sensory deprivation characteristics of current NBC protective ensembles. As a result, the “projected” operational life spans of our NBC gear in the contaminated zones are in large measure, wishful thinking; our real down range combat effective endurance times are fractions of what is postulated and published.

For the sake of brevity and clarity, the term “NBC agents” will be used to describe the threat from these pernicious but traditionally ignored “options” of modern warfare and terrorism. With regard to the physical characteristics of the agents themselves, they may take the form of solids, liquids, gases, aerosols, particulate and vapors. These agents can be delivered overtly via well-known delivery techniques that would leave little doubt of their employment. Conversely, they can also be delivered covertly or in a concealed/veiled manner, where their use would never be suspected and only confirmed by the ensuing “spike” in casualty rates that would only then, precipitate deliberate sampling and analysis. It must be noted that this delay between delivery of the agent(s) and the correct diagnosis in the affected population(s) with the prescribed medical course(s) of action would, have an adverse effect on the victim’s survival rates. The gestation periods of many of the biological pathogens, along with the delayed effects of ionization of human tissues by radioactive isotopes and blistering from the “mustard” agents are but a few examples of delayed physiological symptoms.

While many military NBC warfare planners appear to be fixated on the old “Soviet/Warsaw pact” threat list, delivery techniques and the Communist tactics techniques and procedures; many civilian first responders are concerned with terrorist use of traditional NBC agents along with toxic industrial materials that transit our highways and rail systems in massive quantities on a daily basis. The enterprising terrorist will make use of field expedient, commercially available (TICs) toxic industrial chemicals and (TIMs) toxic industrial materials, as well as the precursor ingredients to “locally manufacture” a wide variety of threat agents and deliver them with equally available “dispersal apparatus” also of local manufacture and purchased or acquired on the open market.<sup>1</sup>

While we may not admire the savage barbarity and determination displayed by traditional enemies, transnational threats, hybrid warriors, criminal groups or Islamic fundamentalist groups to dominate the world; we should respect their determination and take it as prima facie evidence of the motivation that drives this current, clear and obviously effective threat to the World. Cyberspace, the internet and social media provide instant communications in a manner that was non-existent a decade ago, technological innovations like the recent widespread use of “drones” be they, unmanned aerial vehicles or of a terrestrial design, add another dimension of command, control and delivery options that this ingenious and technically proficient enemy has at his disposal<sup>2</sup>. It is not “if” but rather “when” the enemy’s preparation and opportunity intersect; it is at these intersections that we will see the use of NBC weapons within the Continental United States (CONUS) and/or outside CONUS (OCONUS) scenarios<sup>3</sup>.

Since the disastrous events of 9-11, and the anthrax and ricin incidents in the National Capital Region there have been moments of concentrated national clarity regarding NBC readiness. Unfortunately and in large measure, these moments of clarity and the technical progress made in the wake of these weapons of mass destruction incidents within the continental United States have faded into history. As is usually the case, the rapid development of NBC protective ensembles has been largely transitory and is bound to and limited by the funding and thought patterns that are chronologically tied to the surprise and our collective state of unreadiness in preventing and responding to these events and the management of their ensuing consequences. With the passage of time, unfortunately their importance, potential “probability,” urgency and funding fade as well; along with the essential and pertinent tactical and strategic lessons of history that are so often overlooked by successive generations of Americans.

Equally apparent is the fact that any complete review must also include an extensive assessment of tactics techniques and procedures (TTPs) that fully explore the full range of military and civil operations that we will be called on to perform in this hostile and arduous toxic environment. It should be apparent to all, that the forward edge of the battlefield is no longer exclusively outside of the confines of the continental United States; equally apparent is the fact that the effects of weapons of mass destruction within CONUS may require the unique depth, capacity and endurance of the U.S. military in order to restore essential civil infrastructure as well as Federal, State and local government functionality.<sup>4</sup> It is essential that all involved understand that these operations will require extended periods in elevated levels of protective posture; equipment design features must incorporate the ergonomic changes necessary to physiologically accommodate these exhausting operations. Any changes, be they design or TTP related that contribute to increased or extended mental acuity and physical endurance will, at the end of the day increase our operational efficiency in the NBC environment.

The threats, which are historically known, may be deployed by ingenious and innocuous delivery methods that may be disguised as normal commercial conveyances, these methods will provide many detection challenges to military personnel and civil first responders. Some emerging “next generation” threat agents pose a different set of challenges related to lethality, detection, decontamination and medical treatment. It is also remarkable and of interest, that many of these agents can be delivered as gases, vapors, aerosols, liquids, particulates and solids; giving them the increased capacity to permeate, penetrate and migrate “normal issued sorptive” chemical protective over garments and their closure and interface points with mask, boots and gloves. All agents, traditional and emerging, require a complete understanding of their physical characteristics and behavior in the environment in order to effect complete protection, detection

and decontamination. The newer threat agents require some special TTPs (tactics, techniques and procedures) in order that they do not migrate, reoff and cross contaminate during the decontamination process where the protective posture is compromised for hasty or deliberate decontamination. This danger would be most acute in the decontamination process for the walking wounded and non-ambulatory patients that are in various stages of reduced protective posture due to their state of undress.<sup>5</sup>

### ***General Issues Regarding Respiratory Protection***

There is no doubt of the superior protection factor (PF) of a supplied air system. These systems have been around for quite some time, they would include tethered air systems (air line), self-contained breathing apparatus (SCBA) with pressurized air bottles (open circuit), and rebreather systems (closed circuit). All of these respiratory air systems, unless certified as such, are not to be considered as NBC hardened and suitable for use in NBC threat environments. These supplied air systems provide the engineering potential for a superior respiratory protection factor, and are in common use by specialized military units, with specialized support equipment but are logistically intensive for the DOD at large and for the purposes of this thesis are considered an untenable and unsustainable option for general issue.<sup>6</sup>

As a result, this leaves us with one type of respiratory protection option to be considered and that is the option of the Air Purifying Respirator (APR). The APR is a mask with a filter system and is usually negative pressure, that is to say it is operated on the natural breathing process so that the action of the human lungs draw in the inspired air thru the filtration mechanism. On the other hand, the APR may be powered by fans that mechanically assist in the drawing of air thru the filtration mechanism; these powered APRs are commercially known as a

Powered Air Purifying Respirators (PAPR). As one might imagine, the positive pressure PAPR has lowered breathing resistance when compared to any negative pressure APR system.

Historically and for general issue purposes the DOD has chosen the negative pressure APR, colloquially known as the “Gas Mask” or more correctly the Field Protective Mask (FPM). I must note that in order for any APR (positive or negative pressure), there must be not less than 19.5% oxygen available in the atmosphere that is filtered, in order to sustain life at sea level.

With regard to NBC operations, the containment and confined space possibilities of military operations in urban terrain and urban canyons could overwhelm any filter system unless the physiology of the individual, environmental conditions and threat characteristics of the agents used are accurately predicted. The mask face blanks should have some design features that I will discuss later but the filters and the purified air they produce are the essential purpose of the mask, while other design features are important and contribute significantly to the serviceability of the mask, they are secondary concerns when compared with filtration. Filters have some physical limitations that are not generally known to the uninitiated and they include particulate loading of the media (increasing the breathing resistance) internal airflow characteristics, filter bed depth and surface area, tranquil migration of adsorbed contamination through the filter bed, most filter media are very hydroscopic and draw moisture out of the air, that preferentially takes up space in the filter media. Contaminated inspired air must have sufficient “residence time” within the filter media in order for adsorption to take place via mechanical, electrical or chemical removal, this residence time is shortened by the increasing volume and velocity of the inspired air. The higher the respiratory demand, the greater the volume and velocity of the inspired air impacting the filter media, the lower the residence time and the sooner the filter will fail and allow contamination to pass to the wearer.<sup>7</sup>

Historically, the military tests respiratory protection (of air purifying respirator filters) at 32 liters per minute (LPM) in a constant flow, few others have been evaluated at 64 LPM, a flow rate that is indicative of resting and light work rate respirations.<sup>8</sup> Striking, is the fact that there is and has been for a long time sufficient evidence that human respirations indicative of combat and moderate to heavy work rates can easily approach and exceed 300 LPM in peak inhalation air flows (PIAF).<sup>9</sup> Unfortunately the resultant published failure times of the filters tested at the lower flow rates (32 LPM) therefore have little connection to realistic filter failure times in Combat or Rescue operations. Apparently there is little incentive to design filters that provide a realistic level of protection in the 21st Century and we seem to be stuck in the cold war mindset of the threat from the Soviet Union. This is in spite of recognition by the Marine Corps Operational Test and Evaluation Activity of the merits of filter improvements suggested by CBIRF, MCSC and Edgewood.<sup>10</sup>

Consider the filter performance of the C2A1 canister, outlined in Appendix A, when exposed to the blood agent cyanogen chloride (CK) at three human cyclic respiratory rates, humidities and at two challenge concentrations. This data is extracted from the Progress report 9-19 Dec 2002 evaluation of the chemical removal performance of C2A1 canister at high flow rates; protection against CK.<sup>11</sup>

The blood gases hydrogen cyanide (AC) and cyanogen chloride (CK) are admittedly “bad actors” when it comes to filtration but illuminate the effects of increased respiratory rates, increased concentrations and the effects of exposure to humidity. All of the CWAs and TICs evaluated at the higher respiratory airflows gave different results because of the chemical structures involved but displayed a similar negative impact on the filter life due to the same environmental and physiological conditions illustrated in Appendix A. Filter life is dependent on

several factors they are the specific chemical in the inspired airstream, its concentration in that inspired airstream, the relative humidity in that airstream and the respiratory rate that brings that airstream with its volume and velocity into contact with the filter media. All things being equal, the higher the respiratory rate, the higher the concentration of the contaminant and the higher the humidity is, the sooner the filter will have a break through (failure).<sup>12</sup>

There are some engineering enhancements that can be used in the production of filters to improve their functionality, they include use of cylindrical shaped filter canisters (avoiding peculiar shaped filters that can not evenly distribute air over the filter media this may cause a “blow thru” of the filter media just under the intake openings, wasting, via airflow bypass, and premature failure much of the media), pre-filters, electrostatic enhancements, intake air baffles that evenly distribute the airflow over the entire filter surface area, dimpling of interior canister surfaces to enhance even internal air flow characteristics, usable filter life indicators, layering and shaping of the filter bed and increasing the filter bed depth.<sup>13</sup>

It follows that if a filter system is to be used, we must have the greatest filter surface area and bed depth evenly available, but the more filter media used (weight), the breathing resistance (pressure drop) increases, and the greater the bed depth, the greater the chances that the “longer” filter may leverage the mask and affect the fit factor and sealing capacity of the mask on the face. During my decade long tenure as a science officer in the technical cell at CBIRF, I gained first hand live agent experience in all personal protection ensembles in use by the DOD and civil first responders. Heavily involved with the Anthrax and Ricin clean-up operations in Washington DC during this period, my duties also compelled a routine and regular familiarity with the testing laboratories at Edgewood Chemical Biological Command, Edgewood Maryland, Naval Air Systems Command Human Physiology laboratory at NAS Patuxent River Maryland, the

Defense Research Directorate of Canada (DRDC) Suffolk, (Medicine Hat) Alberta, The Danish State Serum institute, Copenhagen Denmark, and Underwriters laboratories in Raleigh, North Carolina.

It was sobering to realize that in the U.S. the testing and evaluation of all personal protective equipment (PPE) is performed in a piecemeal or partial manner by many organizations that often deliver mediocre, confusing and incomplete guidance. This guidance is more often the result of the need for an ease of performance duplication in a laboratory setting, or simply the differences between civil and military approaches. The morphing and melding of military and civil NBC/HazMat first response operations and missions, highlights the need to morph and meld equipment research development and testing. Historical research development and testing has been fire service centric and much of civil first response cultural tactics, techniques and procedures and gear development have only recently begun to take this mission creep into account. An example of the civil/military cultural, legal and institutional morphing that must also accompany the operational mission creep is the possession of CWA's. The lawful and statutory use and possession of many traditional chemical warfare agents has been traditionally restricted to government laboratories, making civilian industrial testing very cumbersome and costly. This situation could be easily overcome with statutory change.

Development of acceptable simulants for NBC testing and evaluation is another avenue that has yielded some acceptable alternatives to some live agents. Unfortunately far too many test and evaluation master plans (TEMPs) usually have little or no connection to the physiological and atmospheric validation realities and conditions of men wearing these ensembles in contaminated environments for extended periods of time under rigorous, demanding conditions that are sometimes in remote locations. In short, we have far too many

clinical, laboratory personnel designing gear for operational personnel that are functioning in “inconceivable” conditions and there is far too little incentive or opportunity for them to communicate or to interact with each other in the design phases. Complicating the issue, is the fact that there are a number of fire service centric “standards writing organizations” that are geared towards civil use or commercial industrial conditions (OSHA, NFPA, NIOSH, IAFF). There is much confusion and often, for example, a NIOSH “manufacturing standard” is often misunderstood to be an “operational parameter”.

With regard to respiratory protection in the civil world, NIOSH is the authority, but with APRs, all published effective durations are “escape times”, industrial civilians must retreat from the atmospheric threat immediately (from the respiratory protection standpoint this is prudent and safe sided in the extreme for industrial civilians). Conversely, the DOD by practice and in accordance with its concepts of operation and employment advance with their APRs into deadly atmospheric threats routinely. It is the threat of weapons of mass destruction (WMDs) since 9-11 that has ignited some degree of cooperation between civil agencies and military agencies, melding in a prudent manner, civil SOPs, guidance and law with military SOPs, guidance and law. This is largely because the threat of NBC warfare is no longer “exclusively” at some far flung location outside the United States. Civil first responders have begun to realize that they, very likely, will be the first troops on scene and will have to deal with the consequences of what we would formerly be considered a “military NBC attack” in their local municipal and state venues.<sup>14</sup> The DOD will have to adapt to the use of not only “traditional” NBC agents but the enemy use of toxic industrial chemicals and materials (TIC and TIM) that would formerly be considered a civil HAZMAT response.<sup>15</sup> Civil and Military NBC operators and operations are no longer separated by the threats or theaters of operations. Civil and Military leadership,

operators, their requirements writers, standards writers, testing and evaluation personnel, acquisition personnel and the extensive laboratory complex within the United States must cooperate, associate, invest and interact freely, each with the other, routinely in order to provide efficient and effective NBC ensembles needed for the threats of the 21st Century in the United States and overseas.

### ***Filters, Powered-Air Purifying Respirators (PAPR), and Combination Units***

***“If everybody is thinking alike, then somebody isn’t thinking.”***

***- General George S. Patton***

In consideration of previously outlined and suggested filter design enhancements and improvements. It can be stated without exception, that filtration physics support the use of a stout performing “cylindrical” filter with a 40 m/m thread canister of at least 180 to 200 grams of carbon in a bed that has a volume of at least 280 cm<sup>3</sup> ( note the moderately adequate C2A1 has 115 grams and a volume of 161 cm<sup>3</sup>). These 40 m/m thread, cylindrical canisters should all be equipped with intake covers in order to reduce the degrading effect of humidity exposure when not in use and should never be taken from their hermetically sealed containers until respiratory protection is needed.

If one accepts the fact that with any air purifying respirator (filter) system, to achieve true down range endurance means a need for increased filter surface area and bed depth.<sup>16</sup> Albeit, with the negative but attendant physics of increased breathing resistance and the danger of mask seal loss due to weight and leverage of filter affecting mask face seal and fit factor. Then we, logically, must consider a multiple filter manifold of some description. A PAPR equipped with either variable speed or breath responsive capability, and either chest, back or belt mounted multiple 40 mm canisters connected to the face blank by 40 mm flexible intake line(s) should be

considered. The manifold of the filter mounting must be engineered to have equal distant tidal volumes (plenums), so that the filters are all utilized (inspired from) in an equal manner. This is to avoid overloading one or two of them and causing a blow through filter failure (physically using all of the filter media and bed depth equally and concurrently via an equal spread loading of the powered inspiration strokes across the entire array of multiple filters). It should be noted that, current Joint Services General Purpose Mask (JSGPM) filters approved and delivered by the Joint Program Office, Chemical Biological Defense are not Standard NATO Agreement (STANAG) 40 mm and have a “pork chop” like shape that is not conducive to even air flow over filter surface area and their thin bed depth allows for an even more rapid failure than the cylindrical and more robust STANAG 40 mm C2A1 canister.

### ***Mask Face Blanks***

In considering the design of respiratory mask face blanks, one would not suppose to know the thought patterns of the designers or the requirements of every mask ever manufactured.<sup>17</sup> As counterintuitive as it might seem, many design features of some DOD masks defy all operational logic and occasionally attempt to show the same disregard for the laws of physics. Perhaps it is due in some measure, to the insulation and isolation of the designers and requirements writers from the operators, their environment and their experiences. Civilian masks to some degree can also fall into this category but perhaps for different reasons that are sometimes related to marketing or finance. In short, it is apparent that the design features of some military and civilian APR do not lend themselves well to functionality. Occasionally APR in their final configurations are manufactured in a manner that is inconsiderate of basic principles of proper internal airflow and exhaust patterns necessary to

reduce humidity and fogging. Also, there is an occasional disregard for design of proper valves, valve seats and valve placement, good drainage and fluid expulsion, sealing surfaces, field of view, and proper head harness affairs that draw the mask onto the face evenly and comfortably seal and hold it in place.<sup>18</sup> Experienced operators would recommend that the outer surface (shell) of the mask face blank for the 21st century be manufactured of a flexible but impermeable/impervious material (possibly of butyl or butyl/polymer mixed rubber); because of their placement on the “clean side” of the filter, select internal surfaces (i.e. nose cups & sealing surfaces) could be made of softer more pliable materials (possibly a silicone rubber). The mask should accommodate at least two STANAG 40 mm apertures for filter or hose attachment, these apertures should allow of either right or left mounting of filter/intake hose or use of both for dual filter mount or dual hose mount. In the event only one mount is used for filter/hose intake the opposing mount could be used to affix an additional voice emitter, sealing this orifice from the environment and enhancing communication potential.

The mask face blank should be designed to function in either positive or negative pressure applications and have a side sealing surface that is broad and convex in its shape. This one mask therefore could accommodate the use of filters, PAPRs, SCBA, combination PAPRs/SCBAs and or Rebreathers (if and when they become approved for NBC use). The economy of effort, the individual pride of ownership and confidence of functionality of one mask face blank for all respiratory protection issued to the individual Marine or First Responder should not be underestimated. This in no way would negate or reduce the requirement for annual vacuum testing and maintenance surveillance efforts carried out by serious users of their respiratory protection devices. It would however increase the personal responsibility, familiarity, and confidence level of the operators and their life support equipment. Additional items

necessary in the mask face blank to accommodate the longer durations of 21st century operations must include a rehydration capability, an external mounted voice amplifier attachment (that does not violate mask seal integrity) in order to provide clear instructions in full personal protective equipment (PPE), also a sufficient field of view (FOV) is necessary to maintain situational awareness and operate ancillary equipment while down range. All of these aforementioned features must not interfere with function and or operation of other gear or weapons that are worn or used by Marines or First Responders. In contrast to these aforementioned principles, the current Joint Program Office issue JSGPM face blank is possessed of bad drainage characteristics that promote lens fogging, the exhaust valve placement is not at a low point to enhance fluid expulsion, it is designed with very poor performing filters with a peculiar non-STANAG thread mounting filter connector, and is not well adapted to the telescopic sight on the M4 Carbine, in that proper eye relief is unattainable and the scope blacks out when the JSGPM worn by the shooter. Units that depend on effective respiratory protection like the USMC CBIRF and the National Guard Civil Support Teams refused to accept this mask for obvious reasons.

### ***Chemical Protective Outer Garments (CPOG)***

***“My mental faculties remained in suspended animation while I obeyed orders of the higher-ups. This is typical with everyone in the Military.”***

***- General Smedley D. Butler***

The CPOG of the DOD general issue ensemble is an air permeable affair that is designed to defend against vapors and aerosols via absorption into graphite or carbon media woven in the textile. This design is rooted in Soviet and Warsaw pact NBC threats and delivery systems deployed on the open terrain of Eastern Europe where maintaining lethal concentrations would

prove very challenging to maintain. This technology is an ergonomic improvement over the previous technologies that utilized underwear with chlorine impregnated paraffins (XXCC3)<sup>19</sup> worn under impermeable rubber outer garments. The thermal load on the individual operator wearing this heavy gear is extreme so much so that periodic cooling showers in the contaminated area were needed to reduce core temperature rise during any operation.

Most of the current issue disposable, two-piece, air-permeable, sorptive-technology garments perform adequately for vaporous chemical threat agents. These sorptive garments allow some airflow but possess traits that are moderately insulating and therefore add some thermal load of the wearer. Conversely, they are less than adequate for particulate (dry, dusty agents, fallout) and liquid contamination. The air permeation allows for minimal evaporative cooling but also transfers and spreads contamination via the bellows effect inside the garment resulting from normal human dynamic movement in combat and rescue operations. Civilian first responders use protective outer garments that fall into one of three categories of descending orders of “written and descriptive” protection levels. Experienced operators would suggest that a more effective category assignment would use actual verified “protection factors” of the candidate ensembles rather than a written description of what the ensemble must contain. The current issue Joint Program Office Chemical/Biological defense Joint Integrated Lightweight Suit Technology (JLIST) garment does not meet even the lowest level of protection garments. These textiles and the ensembles (respiratory protection piece, suit, boots and gloves that are ultimately made from the fabrics) are tested largely but not completely in a static manner. Often pieces of the ensemble are tested in isolation from the remaining components of the total ensemble and or against a “short list” (incomplete) of the total possible threat agents. Swatches of the specific textile are usually evaluated for penetration and permeation and this is important

testing germane to the fabric itself, but cannot provide the total ensemble “protection factor” with all interfaces and closure systems “in play” in live agent or simulant on a living breathing, sweating operator performing relevant tasks at realistic physiological rates. Occasionally, disjointed and isolated, “man in simulant testing” (MIST) is performed on some components of the total ensemble as well, some “articulated manikin” testing. These preliminary tests provide valuable insights into the textiles and characteristics of pieces of the ensemble but are incomplete; when in the final analysis, it is revealed that in none of the tests, were any completed garments evaluated in an dynamic manner in a contaminated environment at the expected concentration of threat agent or its approved simulant and the anticipated atmospheric conditions, with all closure and interface surfaces for the mask, boots and gloves being evaluated for a protection factor as an operator would wear them while performing his normal tasks.

It is fortunate that currently there are a number of advanced textiles with impermeable and or selectively permeable “sandwiched” membranes that are available in fabric weights that are suitable for rugged use and abrasions, others are thin barrier materials designed to promote conductive cooling and provide superior protection factors.<sup>20</sup> All have closure and interface surfaces that also provide protection factors far in advance of current issue CPOG.

In short, the current methodology for testing and evaluation of NBC gear utilizes a yardstick that is not connected to current, likely realistic threat agents, threat concentrations and the threat state of matter; which are inextricably bound to the threat agent deposition, efficacy and duration characteristics on and in personnel, terrain, vehicles and facilities. Consideration of the effects of high wind or rotor/propeller/jet blast energetics on the multitude of threat agents, operational environments and durations that we need for functionality and mission accomplishment require further evaluation.<sup>21</sup> We must verify and validate the efficacy all

protective garments with all current threats (not just convenient ones that provide flattering test results), in the expected concentrations, atmospheric conditions and in the physical forms of matter that they will be employed against us. This situation can be corrected by a consistent, collegial, collaboration of true subject matter experts from civil and military backgrounds, requirement writers, standard writers, manufacturers and laboratory experts in testing and evaluation.

It is important to mention the efforts conducted by CBIRF, Marine Corps Systems Command and Naval Air Systems Command to reduce the impact of thermal loading on the individual Marines in elevated levels of chemical protective gear; these efforts include evaluation of tube suits that are cooled by ice, air flow, liquid nitrogen, and polyethylene glycol and phase change materials. CBIRF noticed that an hour of moderate exercise in elevated levels of PPE exhausted the Marines to such a degree that their stress levels measured by weight loss due to perspiration, salivary amylase enzymes and written stress testing indicated that full recovery took at least eight hours, it was apparent that operators needed to reduce the core temperature rise.<sup>22</sup>

All of examined technologies failed to retard core temperature rise, in fact some appear to have cooled the skin and constricted the blood vessels at the surface and exacerbated the rise of core temperature while giving a false feeling of well-being due to cooling of the skin surface.<sup>23</sup> As peculiar as it might appear, the CBIRF cooling Study of May 2001 directed CBIRF to explore TTP options that led to the cooling trials of Dec 2008 which in turn, moved CBIRF towards a work rest cycle TTP change, the cool water immersion of the hands and forearms via conductive cooling of the AVA vascularity found in the human hands and feet.<sup>24</sup> This immersion was conducted while the individuals were in elevated levels of PPE as a work rest cycle intervention

and was the only method found to reduce the core temperature rise of Marines in elevated levels of PPE while performing rigorous tasks over extended periods of time.<sup>25</sup>

### ***Decontamination***

***“A good plan violently executed now is better than a perfect plan executed at some indefinite time in the future.”***

***- General George S. Patton***

It is clear to most military thinkers that operations other than war are continuing to be assigned to the military. When one considers decontamination of humans in a humanitarian assistance scenario or a consequence management scenario after a WMD incident as a result of conflict, the necessity to execute decontamination will be acute and will require some forethought and preparation.<sup>26</sup> This planning is acutely important if decontamination of aircraft and personnel is to be conducted aboard ship because of operational necessity.<sup>27</sup> The USMC CBIRF probably has the most experience in handling decontamination of both ambulatory and non-ambulatory personnel in the nation. CBIRF’s capacity to handle ambulatory casualties is a little more than twice that of its capacity to handle non-ambulatory casualties; this fact must be recognized in the light that these Marines work together with some specialized decontamination technology and routinely exercise this capacity. The use of less experienced personnel would extend the duration and time lines to greater parameters. The efficacy of the decontamination would likely also suffer and result in additional casualties and longer execution windows for operations. Leadership must consider the impacts and aspects of wind direction and wind speed and casualty movement downwind to upwind, from dirty to clean. The medical stabilization and triage must occur on dirty side of the Liquid control line, requiring medical personnel to perform triage in an elevated level of personal protection. Consider the wisdom of using decontamination

tents that contain, to some degree, the cross contamination and blow back from decontamination hoses and shower heads. Use elevated platforms in the decontamination tents to keep personnel out of the contaminated “grey water” that accumulates in the sumps that are integral to most decontamination tents available on the open market. Use of stout submersible sump pumps and control of contaminated runoff must be considered. The adherence to host nation regulations with regard to disposition of hazardous waste/contaminated clothing/possessions and human remains will have to be considered and addressed. Clean clothing issue after completed decontamination on the upwind side of the vapor control line. Logistical use of NBC mendicants (possible Authorized Medical Allowance Lists modifications), acute care/stabilization and transfer to follow on long term care will require careful consideration and planning.

### *Acquisitions*

Title 50 of the US Code has given overall responsibility for Chemical and Biological defense equipment procurement to the Army.<sup>28</sup> This means that there is usually an Army-centric “flavor” to these acquisition programs, with a “one size fits all” type of mindset that does not take into account unique USMC concepts of operations or employment (e.g. amphibious assault, fighting with “open-hatch” from armored vehicles, etc.). As the JPO, the Army must consider all of the services’ common and unique requirements. Additionally, these acquisition teams have little or no practical experience in actual NBC or combat operations and engage in little interaction with operators who might be able to illuminate on operationally relevant, realistic NBC issues. This is especially true if “outside” experts give observations and recommendations that run counter to the paths of a particular program that scientific evidence shows have pursued thoughtless, capricious, or uninformed designs. Recognition of design

mistakes is avoided at all costs because it highlights incompetence, waste and hubris, when this occurs the bureaucracy, because careers are on the line, typically go into full self-defense mode rather than make the design changes and move on. The programmatic personnel (military and civilian) that lead these acquisition efforts, in many cases struggle with layers of bureaucracy, piled on by well intentioned “acquisition reform,” that simply add more convoluted “layers of process with the attendant layers of process people,” this proclivity equates to increased time, schedule and cost to the taxpayer but delivers little in the way new equipment to the warfighter. One could argue that “groupthink” and repetitive episodes of the “Emperor's New Clothes” are the order of the day; this means the focus is on careerism rather than improving the gear issued to the warfighter.<sup>29</sup> Initial Product Teams should be carefully formed with well integrated expertise across the full range of technical and operational disciplines and experiences with the focus on delivery of tested, verified and validated gear in response to disciplined, vetted requirements documents. In this author’s view, only Congressional intervention and regular and routine GAO audits of military acquisition programs are capable of bringing order in accountability, spiraling processes, schedule and costs across a vast Federal bureaucracy.

### ***Conclusion***

***“We have met the enemy and he is us.”***

**- “Pogo” by Walt Kelly**

A new century with expanded obligations, new threats and technology will require a reconsideration of tactics, techniques and procedures. In accordance with the thesis the author has given recommendations for design changes to NBC Equipment that makes up our “ensemble.” These challenges are daunting, but pale in comparison to the related challenges that face the USMC with regard to statutory and entrenched cultural barriers between the services,

acquisition agencies, requirements writing organizations, contracting and budget/ finance bureaucracies.

The implications of Islamic Terrorism, technical advancements in NBC agents, widespread use of drones and cyber connectedness provide for the conscious among us, the intent, means and ability for gruesome assault, we are awaiting the “opportunity” to intersect, and we will then see another “incident.” *Expeditionary Force 21* has us consider a pivot to the Pacific and speaks of NBC operations, humanitarian operations and threats that are OCONUS as well as the full and the massive implications of a greatly increased Range Of Military Operations. Not addressed in *Expeditionary Force-21* is the possibility of disaster relief and humanitarian assistance operations in CONUS requiring the depth and endurance of the US Military (specifically decontamination operations). Increased urbanization, megacities and littoralization, old and new threats, with familiar and unfamiliar delivery techniques (fourth generation agents, dusty agents, TIC, TIM) gases, vapors, aerosols, liquid, particulate & solids provide the challenges that also need to be addressed. The NBC impact on all operations and our operational need to increase our combat efficiency in this facet of the modern battlefield is painful and complicated but unavoidable as military and civilian NBC, HAZMAT, decontamination, humanitarian assistance and government restoration operations expand and morph into the military realm. U.S. industry, federal, state and municipal governments are ready to be part of the solution and stand ready to assist and share in any way. Those in the military must reach out to those responsible for NBC issues and act as partners in the expanding efficiency in conducting a Global War on Terror. This partnership must be shared with regard to research and development, funding and common requirements that will stimulate civil

manufactures and markets. These collegial efforts must become regular and routine in order to maximize the fullest potential.

The regular and routine cooperation between civil and military operators, the industrial base, standards writers, requirements writers, SMEs and Testing and Evaluation personnel will increase our collective operational competency. Our expanding obligations across the full range of military and civil operations must match and be synchronized with our collective capacity for providing effective, relevant, low cost NBC personal protective gear that is designed to address the contemporary and mid-term NBC threats and our current military/civilian concepts of employment and operations as outlined in *Expeditionary Force-21*.

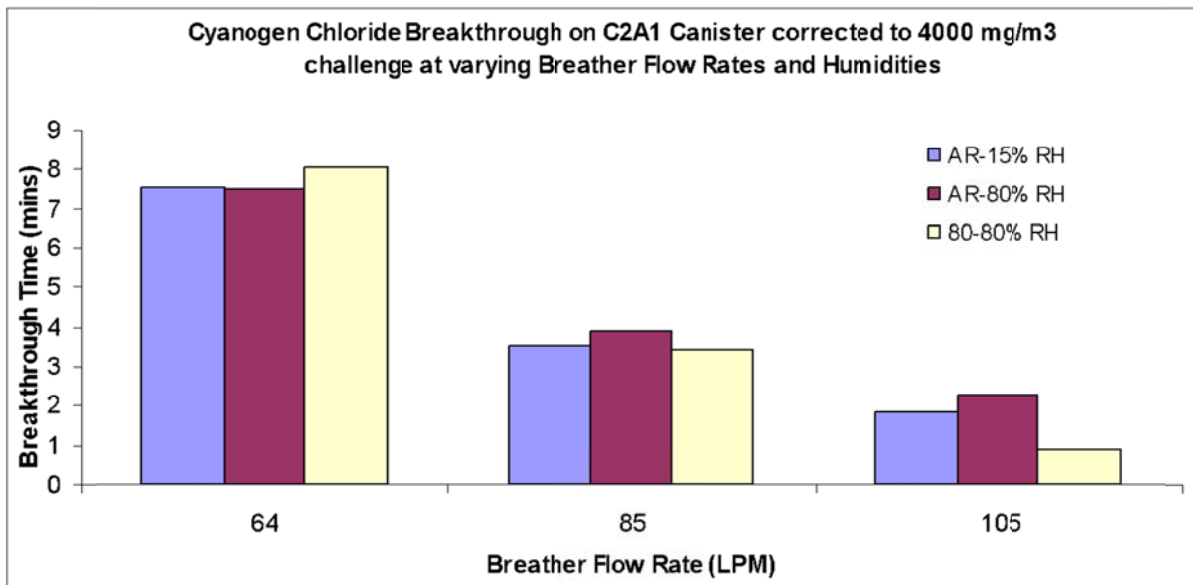
## APPENDIX A

### Cyanogen Chloride Testing Data

	Flowrate	Breath Rate	Tidal Volume	Rel Humidity	Feed	Break Time (8 mg/m3)	Corrected Break Time	SP			
<u>Canister</u>	<u>(LPM)</u>	<u>(BPM)</u>	<u>(L)</u>	<u>(%)</u>	<u>(mg/m3)</u>	<u>Time (min)</u>	<u>(min)</u>	<u>(mg-min/m3)</u>	<u>File</u>	<u>System</u>	
C2A1	64	40	1.6	AR-15	3603.97	8.5	7.658	30633.745	021210B	1	
C2A1	64	40	1.6	AR-15	3603.97	8.7	7.839	31354.539	021210B	1	
C2A1	64	40	1.6	AR-15	3966.3	7.1	7.040	28160.73	021212A	1	
C2A1	85	36	2.361111111	AR-15	3988.93	3.6	3.590	14360.148	021210A	1	
C2A1	85	36	2.361111111	AR-15	3988.93	2.5	2.493	9972.325	021210A	1	
C2A1	85	36	2.361111111	AR-15	3904.47	4.5	4.393	17570.115	021212B	1	
C2A1	105	42	2.5	AR-15	3899.15	2.4	2.339	9357.96	021210C	1	
C2A1	105	42	2.5	AR-15	3899.15	1.7	1.657	6628.555	021210C	1	
C2A1	105	42	2.5	AR-15	3914.03	1.7	1.663	6653.851	021212C	1	
C2A1	64	40	1.6	AR-80	4051.08	8	8.102	32408.64	021210F	1	
C2A1	64	40	1.6	AR-80	4051.08	6.5	6.583	26332.02	021210F	1	
C2A1	64	<b>36</b>	1.777777778	AR-80	3817.35	8.1	7.730	30920.535	021212G	1	
C2A1	85	36	2.361111111	AR-80	4056.66	3.9	3.955	15820.974	021210E	1	
C2A1	85	36	2.361111111	AR-80	4056.66	3.8	3.854	15415.308	021210E	1	
C2A1	85	<b>39</b>	2.179487179	AR-80	3986.54	3.8	3.787	15148.852	021212F	1	
C2A1	105	42	2.5	AR-80	3933.15	3.1	3.048	12192.765	021210D	1	
C2A1	105	42	2.5	AR-80	3933.15	2.1	2.065	8259.615	021210D	1	
C2A1	105	42	2.5	AR-80	3807.78	2.1	1.999	7996.338	021212D	1	
C2A1	105	<b>39</b>	2.692307692	AR-80	3866.22	2	1.933	7732.44	021212E	1	
C2A1	64	40	1.6	80-80	3985.52	8.7	8.669	34674.024	021211A	1	
C2A1	64	40	1.6	80-80	3985.52	7.5	7.473	29891.4	021211A	1	
C2A1	85	36	2.361111111	80-80	3926.78	3.1	3.043	12173.018	021211B	1	
C2A1	85	36	2.361111111	80-80	3926.78	3.9	3.829	15314.442	021211B	1	
C2A1	105	42	2.5	80-80	3940.59	0.3	0.296	1182.177	021211C	1	
C2A1	105	42	2.5	80-80	3940.59	1.5	1.478	5910.885	021211C	1	
C2A1	64	36	1.777777778	AR-15	1082.64	25.9	28.040	28040.376	021216A	1	
C2A1	64	36	1.777777778	AR-15	1082.64	24.8	26.849	26849.472	021216A	1	
C2A1	85	39	2.179487179	AR-15	1169.86	14.6	17.080	17079.956	021216B	1	
C2A1	85	39	2.179487179	AR-15	1169.86	14.2	16.612	16612.012	021216B	1	
C2A1	105	39	2.692307692	AR-15	965.45	11.3	10.910	10909.585	021216C	1	

C2A1	105	39	2.692307692	AR-15	965.45	12.2	11.778	11778.49	021216C	1	
C2A1	64	36	1.777777778	80-80	1068.02	50	53.401	53401	021213B	1	
C2A1	64	36	1.777777778	80-80	1068.02	53.5	57.139	57139.07	021213B	1	
C2A1	85	39	2.179487179	80-80	1015.36	29.4	29.852	29851.584	021213A	1	
C2A1	85	39	2.179487179	80-80	1015.36	26.3	26.704	26703.968	021213A	1	
C2A1	105	39	2.692307692	80-80	1045.31	16.5	17.248	17247.615	021213D	1	
C2A1	105	39	2.692307692	80-80	1045.31	17.8	18.607	18606.518	021213D	1	

The above shows C2A1 canister filter performance at 3 different breather air flows, 3 different humidities and 2 different concentrations of Cyanogen Chloride (CK) with the breakthrough times in minutes.



The above is a bar graph illustration of previous data. But only illustrates the higher challenge concentration of CK (4000 mg/m<sup>3</sup>), note: that AR-15 % RH means tested “as received” with 15% humidity in the airstream, AR-80% means tested “as received” with 80% relative humidity in the airstream and 80-80% RH means filters are pre equilibrated for 8 hours to 80% relative humidity and then tested with 80% relative humidity in the airstream.

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