DEPARTMENT OF THE ARMY
ASSISTANT SECRETARY OF THE ARMY
RESEARCH, DEVELOPMENT, AND ACQUISITION
WASHINGTON, D. C. 20310



# NUCLEAR PROTECTION FOR THE SOLDIER



FINAL REPORT OF THE

AD HOC COMMITTEE OF THE

ARMY SCIENTIFIC ADVISORY PANEL



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The vulnerability of the soldier to the effects of ionizing radiation is well established. The potential threat against the US military forces was reviewed and a variety of means of providing protection against the effects of nuclear radiation on the battlefield were analyzed. The findings, conclusions and recommendations of the Ad Hoc Group are presented for consideration and possible implementation in the future.

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**DEPARTMENT OF THE ARMY**
**ARMY SCIENCE BOARD**
**OFFICE OF THE ASSISTANT SECRETARY**
**WASHINGTON, D.C. 20310**

27 JUL 1979

SUBJECT: ARMY SCIENCE BOARD (ASB) REPORT ON "NUCLEAR PROTECTION FOR THE SOLDIER"

SEE DISTRIBUTION

Enclosed report has been prepared and submitted in accordance with the Terms of Reference dated 15 April 1977, for Army Scientific Advisory Panel (ASAP) Ad Hoc Group on Nuclear Protection for the Soldier. Reorganization within DA led to the discontinuation of the ASAP and the Ad Hoc Group was instructed to cease its effort at that time. However, due to the nature and importance of the subject, the Ad Hoc Group has on its own initiative completed the report.

A review of the report was made and comments provided by the Office of the Deputy Chief of Staff for Operations and Plans (ODCSOPS). Those comments are included with the report. In subsequent discussions with the ODCSOPS action officer, it was agreed that the report contains research material which may be beneficial to agencies involved in this subject area.

The report is being provided for information.

Joseph H. Yang

Inclosure
As stated

JOSEPH H. YANG
Executive Director
Army Science Board

# Preface

This final report has been prepared and submitted in accordance with the Terms of Reference, Ad Hoc Group on Nuclear Protection for the Soldier. An oral, summary report was presented to the Army Scientific Advisory Panel at its last meeting, 31 October-1 November 1977. Reorganization within DA led to the discontinuation of the Army Scientific Advisory Panel and the Ad Hoc Group was instructed to cease its efforts at that time. However, due to the nature and importance of the subject, the Ad Hoc Group has on its own initiative prepared this limited report which it is hoped may be useful to the Army Science Board and other Department of Army agencies for planning purposes.

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## Background and Terms of Reference

Terms of Reference
ASAP Ad Hoc Group on
Nuclear Protection for the Soldier

15 April 1977

1. Background:

The level of hardening of materiel to nuclear weapons effects is determined by the capability of the human operator to withstand the effects. If techniques can be established to improve the ability of man to withstand nuclear effects then the potential exists for raising the Army's overall capability to operate in a nuclear environment. Conceptually, this increase in the "nuclear hardness" of a soldier on the battlefield could be established by providing a protected environment or by medically treating the man to decrease his inherent vulnerability.

Recent emphasis on providing protection against CW/BW agents could well have applicability to the nuclear hardening question. For example, a shelter that has an air filtration system designed to keep out chemical and biological agents that may be in the atmosphere should provide comparable protection against nuclear fallout.

A number of new Army systems have been developed but there has been no consideration of the degree of nuclear protection these systems provide to the operator or how this level of protection could be increased without seriously impacting the cost of operating characteristics of the systems.

Although the hardening of man himself has been studied extensively in the past, it would be worthwhile to review past results to determine if such work should receive increased or decreased emphasis.

2. Terms of Reference:

Specifically the Ad Hoc Group is asked to:

Recommend approaches the Army should pursue that will lead to improved protection for the soldier on the nuclear battlefield.

This should primarily emphasize techniques to provide a practical protection environment for the soldier.

Recommendations on the practicability of improving the soldiers inherent ability to withstand nuclear radiation effects are also requested.

3. Termination of Effort:

The Chairman of the Ad Hoc Group is requested to conclude his efforts within five months. A final report should be published not later than 30 September 1977.

Membership, Ad Hoc Group on Nuclear Protection of the Soldier

DEPARTMENT OF THE ARMY
ARMY SCIENTIFIC ADVISORY PANEL
Washington, DC 20310

15 April 1977

Membership
AD HOC GROUP
on
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* NOTE: Due to conflicts during the early meeting dates, Dr. Smith was unable to participate in the study and asked to be relieved of this responsibility.

LTC William E. Woodward from the US Army Medical R&D Command was assigned to serve as Military Staff Assistant to the study group. LTC Woodward was most helpful throughout the study and in the preparation of this report.

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EXECUTIVE SUMMARY

## SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND CONCERNS OF THE AD HOC GROUP

As stated elsewhere in this report, nuclear protection of the soldier is but one element of military medical combat support, which in turn is but one of the many complex functions of Command. Mission accomplishment is the overall responsibility of Command. Viewed in this context, it should be recognized that as destructive and devastating as nuclear weapons may be, there is always a peripheral zone in which lethality is not inevitable and where graded incapacitation will be encountered. The medical mission is to minimize the nuclear effects and to widen this zone by every possible means -- and thereby to enhance the prospects of personnel survival and mission completion. It was also recognized by the Ad Hoc Group that there are other measures which are of equal or greater importance than the biomedical which need to be applied in order to provide maximal nuclear protection to troops in the field. However, because of the complexity of the interaction between radiation effects and the effectiveness of individuals and units on the battlefield, it is impossible to state at this time how important any given degree of protection or dose reduction might be. Nevertheless, on the basis of its study the Ad Hoc Group believes that there are a number of medical and physical protective measures which might be available or developed to support operations in a nuclear environment. The principal conclusions and recommendations of the Ad Hoc Group are given below. Additionally, attention is drawn to some concerns which need consideration.

### CONCLUSION 1:

Soviet and Warsaw Pact Forces are equipped to deal with some degree of effectiveness, with the effects of radiation on the battlefield. Their doctrine and their exercises reveal that use of nuclear weapons in tactical situations is an integral part of their military planning. US tactical nuclear doctrine envisions use of nuclear weapons in a defense mode, often in close proximity to friendly troops. Some US nuclear weapon systems are incorporating enhanced radiation warheads, further increasing the importance of nuclear radiation as a battlefield effect. Therefore, the US Army should be thoroughly prepared to deal with the effect of nuclear radiation on the tactical battlefield. An integral part of this need is an ability, to the extent practical, to integrate radiation effects from individual soldiers and to deal effectively with radiation casualties.

### RECOMMENDATION 1:

That the Army undertake a comprehensive, in depth review of its capabilities in this area, and to implement, in an integral way, measures which could be developed, including those discussed in various sections of this report.

CONCLUSION 2:

There are practical physical measures which can be applied to provide some protection to the soldier in the nuclear environment. These relate to thermal and flash as well as to blast and radiation effects which threaten the troops.

RECOMMENDATION 2:

The Ad Hoc Group recommends augmentation of efforts to develop and evaluate physical protective measures, and that improvements be incorporated promptly into troop equipment and training.

RECOMMENDATION 3:

That there be established appropriate linkage of the Night Vision Program of the Army and Flash Blindness Protection Program of the Air Force.

RECOMMENDATION 4:

That there be established an appropriate program or tasking to develop means of providing and testing the usefulness of smoke in flash/thermal protection. This should be linked with the DA program on SMOKE.

RECOMMENDATION 5:

That there be established an appropriate linkage to the Chemical Decontamination/Contamination Avoidance program of efforts to improve field Nuclear Fallout Decontamination capability.

CONCLUSION 3:

There are several medical measures which could afford some protectior of soldiers to the effects of irradiation. These include dietary constituents and drugs for reducing radiation injury effects. In addition, there are potentially useful medical approaches to the prevention, delay, or amelioration of acute symptoms associated with radiation injury, that is, nausea, vomiting, and diarrhea. For delayed severe radiation injury to the bone-marrow, medical developments offer promise for survival from bone-marrow transplantation, along with improvements in blood banking support of such patients with red blood cell, white blood cell, and platelet transfusions. The more severe the radiation injury, the less likely becomes survival, and the more complex becomes the treatment effort while the logistical burden of therapy increases exponentially.

Thus, physical measures to protect soldiers should be maximized at all times. Medical support and prophylactic measures should, however, also be maintained at their highest possible level. Even so, the combat situation may result in radiation exposure with which the commander and his troops will need to contend in the performance of their mission. The medical measures that are available or potentially available will, to a considerable extent, help delimit the amount of exposure that would be "acceptable" to mission accomplishment.

RECOMMENDATION 6:

It is not possible to estimate the military impact that would result from the various aspects of medical efforts to increase radiation protection of the soldier. For this reason, the Ad Hoc Group recommends incorporation of biomedical factors in a variety of scenarios in order to arrive at a more meaningful assessment of such factors. The findings should be useful for planning purposes and to assist in ordering priorities of the military biomedical R&D effort.

RECOMMENDATION 7:

Similar scenarios should be directed toward assessment of trade-offs which will result from avoidance, alleviation, and decontamination of fallout effects, and of these parameters in combinations with biomedical factors.

RECOMMENDATION 8:

The prophylactic drug program should be resumed and maintained along the lines described herein.

RECOMMENDATION 9:

The prophylactic potential of dietary factors should be explored and this should be linked with the programs of the Army Nutrition Laboratory.

RECOMMENDATION 10:

Medications should be developed to delay onset or suppress acute responses of radiation injury -- namely, nausea, vomiting, and diarrhea. Some candidate drugs are suggested.

RECOMMENDATION 11:

In order to establish the safety of drugs to be employed as in 9 and 10 above, at some point in the R.D.T.& E. of preventive, protective, or treatment measures, it becomes necessary to utilize human subject volunteers. For this reason, it is recommended that a DA or DOD level "Human Use Committee" be established to provide criteria for protocols, safety factors, monitoring of studies for compliance, with assurance of informed consent of participant volunteers as well as consideration of the moral and ethical aspects involved.

RECOMMENDATION 12:

Much relevant information to 10 above could and should be obtained through an active liaison with civilian medical radiation treatment centers. (The Director of the Armed Forces Radiobiology Research Institute indicated that DNA does not permit such liaison arrangements.) (This kind of information can only be obtained from human subjects. The mechanism by which such information is to be obtained would need to be approved by the "Human Use Committee" recommended in 11 above.)

RECOMMENDATION 13:

It is recommended that R&D for the cryopreservation of blood components be continued and integrated into the medical and logistical plans for the support of combat forces which have suffered radiation injury. (This should also be coordinated with the Dept. of Navy Blood Preservation Research Program.)

RECOMMENDATION 14:

It is further recommended that research on bone-marrow preservation and transplantation be incorporated into the overall effort to improve medical support of the soldier exposed to radiation injury on the battlefield. (This should also be coordinated with the Dept. of Navy Blood Preservation Research Program.)

RECOMMENDATION 15:

As a corollary, it is recommended that comparative assessments be made of the logistical costs/burden and medical outcome of blood/blood products transfusions and bone-marrow transplantation in forward areas vs prompt evacuation of radiation-injured troops to designated treatment sites.

CONCLUSION 4:

Appropriate dosimetry is crucial to analysis of the radiation factor in a combat situation. Commanders and medical personnel would need to know doses received by troops in order to use resources effectively, but no individual dosimeter exists which is suitable for widespread use. A number of possible approaches could be considered but definition of requirements is lacking. Such requirements should be developed to address, for example:

(a) whether reusability is required,

(b) desirability of threshhold vs continuous reading, and over what range,

(c) cost,

(d) read-out requirements: Should the exposed individual be able to read the dose himself or not?

The Ad Hoc Group finds that there is need for a major effort to improve and field individual, unit, and area dosimeters of radiation activities. Some promising possibilities are cited.

RECOMMENDATION 16:

It is recommended that high priority be given to further definition of requirements and the development of radiation dosimetry instrumentation for utilization in the field.

RECOMMENDATION 17:

Fallout can now be measured and mapped to terrain in near real-time with airborne equipment. A prototype system exists in the Department of Energy's NEST/SANDS equipment. It is recommended that this capability be rapidly developed and adapted for field use.

CONCERNS:

During the course of its deliberations, a number of areas of concern became apparent to the Ad Hoc Group. Several of these were discussed during the meeting of 11-12 August, 1977 at Las Vegas. They range from specific to general in nature, and while not necessarily related to the terms of reference of this review, the concerns are relevant to the Services' overall capabilities to deal with the problems of the soldier in the nuclear battlefield. The following list of concerns was prepared, on request, by one of the consultants who participated at the Las Vegas meeting of the Ad Hoc Group:

1. A foremost concern is that none of the Services has a nuclear warfare organizational unit. Clearly there are pros and cons regarding this issue, but basically it seems unreasonable to expect line organizations to give proper priority to the demands and needs of the Armed Forces in this classified technical field.

2. The diminished interest of the Services in this field is perhaps illustrated by noting that both the Naval Radiological Defense Laboratory (NRDL, Hunters Point, San Francisco) and the Army's Nuclear Defense Laboratory (NDL, Edgewood Arsenal) have been phased out of existence.

3. There does not appear to be any high level officer in any Service with responsibility for nuclear medicine or radiation protection.

4. The R&D effort in the civilian nuclear biomedical field does not address the specific and special problems in this field that should be of concern to the Armed Forces. The same situation obtains in the radiation protection field. Basically, in both fields, the thrust is towards understanding and measuring low doses and low dose rate effects.

Spin-off from the civilian R&D is, however, directly applicable in many instances to the military, but there is little effort expended by the Services to remain knowledgeable or to direct the R&D into areas of specific interest to the military.

5. Young officers, MDs or health physicists no longer spend a tour of duty at LASL, and presumably this is also true at Livermore.

6. Somewhat along the same lines as item 5 is the apparent discontinuance of the university graduate programs in radiation protection for military personnel.

7. The Army's field manuals on nuclear warfare, unless they have been completely revised within the last six years, are of questionable value.

8. The response of the Armed Forces to the demands of the Eniwetok Cleanup Project would indicate that:

o Trained teams of health physicists and radiation monitors are not readily available.

o Radiation monitoring instruments and the capability to maintain and calibrate the instruments are not readily available.

o Field facilities for radiochemistry and radioactivity counting for evaluation of biological or environmental samples are not readily available and may not be available at all.

o Authoritative briefing on health and safety procedures for troops engaged in a radiation field is not available.

9. A final item, but one of major concern, is the lack of any apparent capability for the Army to advise and control the civilian population in case of nuclear war or a major nuclear incident. One has to suspect that the state of readiness on the part of the Army, National Guard, and Civil Defense to handle such a situation is less than desirable or prudent.

In the interim a number of the concerns expressed above may have already been addressed and resolved. The Ad Hoc Group is aware that recently there have been some important organizational changes in the US Army Nuclear Agency. The Ad Hoc Group now perceives a Defense Nuclear Agency (DNA) with a Defense level research facility (AFRRI) and individual service (Army, Navy, and Air Force) research programs. DNA is now in an improved position to collate the service requirements and to designate which requirements are to be supported and accomplished by

Defense agencies and which by the individual services. The interrelationships of many separate elements as noted in this report necessitate highest level coordination not only for the problems attendant to the use of nuclear weapons but also to defense against chemical and biologic agents.

NOTES OF 5 MEETINGS HELD BY AD HOC GROUP

## Summary of Meetings Held by Ad Hoc Group on Nuclear Protection of the Soldier*

First meeting.

3 June 1977 at Armed Forces Radiobiology Research Institute (AFRRI), Bethesda, MD. The Ad Hoc Group was briefed by COL LaWayne R. Stromberg, Director of AFRRI.

Second meeting.

28-29 July 1977 at Forrestal Building, Washington, DC. Briefings were provided by staff members of the Foreign Science and Technology Center (FSTC), the Defense Nuclear Agency (DNA), the Medical Intelligence and Information Agency (MIIA), and by the Division of Medicinal Chemistry, Walter Reed Army Institute of Research (WRAIR).

Third meeting.

11-12 August 1977 at the Nevada Operations Office of the Energy Research and Development Administration (ERDA) at Las Vegas. Briefings were made by representatives from the Nevada Operations Office, the Los Alamos Scientific Laboratory and the Lawrence Livermore Laboratory.

Fourth meeting.

25-26 August 1977 at the Lawrence Livermore Laboratory, Livermore California. Briefings were provided by staff members from the US Army Nuclear and Chemical Agency, the Lawrence Livermore Laboratory, and the Los Alamos Scientific Laboratory.

Fifth meeting.

5-6 October 1977 at the Armed Forces Radiobiology Research Institute 5 Oct for briefing by new Director, and for report working session on 6 October.

No further meetings were held as per instructions from the ASAP office pending administrative and budgetary changes associated with plans to transfer its activities to a new Army Science Board.

* Memoranda for Record of each meeting may be found at APPENDIX A.

## THE THREAT

**THE THREAT.** Introductory statement of Ad Hoc Group.

At its June 28, 1977 meeting, the Ad Hoc Group received classified briefings on the nuclear threat and the capabilities of potential enemies of the United States. The presentations were provided by staff members of the Foreign Science and Technology Center (FSTC), and representatives from the Medical Intelligence and Information Agency (MIIA) were available for questioning. These briefings were very helpful in providing an informative and timely review of the threat situation. However, the Ad Hoc Group believes that for the purposes of this report, an unclassified statement of the threat will suffice. Accordingly, the following material is provided to indicate the magnitude and formidable reality of the nuclear threat.

## THE THREAT

Numerous studies and documents deal with the nuclear weapons threat to US Military Forces and their Allies. The Chairman of the Joint Chiefs of Staff has published a general analysis of the United States Military Posture for FY 1978 in which the nuclear threat is included in an overview of all elements of military threat to our nation.[1] As with conventional weapons, the nuclear threat is primarily that of the USSR and the Warsaw Pact countries, with specific implications of concern for the US and its NATO allies. To the threat of strategic use of nuclear weapons has now been added the threat associated with the tactical use of such weapons, particularly those with more selective destructive capabilities (i.e., neutron weapons).

The rationale behind the tactical use of nuclear weapons is given by GEN Brown:

"A theater nuclear capability is indispensable to successful deterrence and defense. Theater nuclear forces complement general purpose forces and provide a continuum between conventional and strategic nuclear forces.

"In the event aggression cannot be contained conventionally, theater nuclear forces provide the capability to terminate, if necessary, a conflict at less than a strategic nuclear level of intensity, on terms acceptable to the United States and its allies. Tactical nuclear weapons are deployed as an integral part of our theater forces to strengthen the deterrent effect of forward defense and to provide immediately available combat power to augment conventional forces. In the case of a Warsaw Pact attack which allows NATO little time for preparation or mobilization, NATO conventional forces would be greatly disadvantaged. A credible option for selective employment of theater nuclear weapons can contribute to deterrence and also provide augmentation should conventional means be found insufficient.

"The conventional balance in Europe is such that if the Warsaw Pact forces are able to mass secretly and apply armored pressure to a given point in the defense line, NATO's ability to defend with conventional forces would be greatly weakened. Selective employment of nuclear weapons against armored thrusts could greatly contribute to theater deterrence and provide an intermediate option between conventional warfare and a general nuclear war.

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[1] United States Military Posture for FY 1978, by Chairman of The Joint Chiefs of Staff, General George S. Brown, USAF. 20 January 1977.

"The Soviets currently possess a tactical nuclear capability which could serve as a significant reinforcement to their offensive operations in Europe."

USSR

"The Soviets have a significant number of nuclear missiles with which they could launch an attack on the Eurasian continent. Their peripheral missile attack force consists of MRBMs (1,050 nm range) and IRBMs (2,200 nm range) located in the western USSR. In addition, some of their ICBMs are capable of being fired to short range and can be retargeted. This ability increases their capability to attack either Western Europe or China.

"The Soviet Union has deployed a large number of nuclear-capable tactical missiles and rockets -- primarily the SCUD short-range (85-160 nm) tactical ballistic missile, the FROG, a surface-to-surface unguided rocket and the SCALEBOARD, a longer range surface-to-surface missile.

"The Soviet SS-4 and SS-5 missile force has been slightly reduced this year with the deactivation of some SS-4 launchers.

"As stated last year, the Soviets began testing a new mobile solid propellant IRBM, the SS-X-20 in the fall of 1974. R&D flight testing of this missile, which is a two-stage derivative of the 3-stage SS-X-16 ICBM, is now essentially complete. The flight test program has proceeded at a rapid pace and has been highly successful. Flight testing has featured all of the milestones of a typical R&D program.

"Initial deployment of the SS-X-20 is expected to occur in the near future.

"The Soviets have also continued active training in nuclear delivery techniques with the tactical aircraft assigned to frontal aviation. The most frequently used aircraft on nuclear delivery training missions are MIG-21/FISHBED-Js, -Ks, and -Ls; SU-7 and SU-17/FITTERS; MIG-23/FLOGGERS; and various medium-range bombers. The SU-19/FENCER is expected to be an excellent aircraft for this type of mission."

UNITED STATES

"The US inventory does not contain any ballistic missiles in the MR/IRBM class. US theater nuclear forces consist of nuclear-capable cannon artillery, tactical surface-to-surface missiles, nuclear-armed strike aircraft, nuclear air defense, atomic demolition munitions and ASW nuclear systems. Additionally, a substantial number of POSEIDON SLBM warheads are committed to support the Supreme Allied Commander, Europe (SACEUR). The 8-inch and 155 mm nuclear artillery projectiles constitute the nuclear artillery stockpile. A new 8-inch nuclear projectile is now in engineering development. This new projectile will provide about 50 percent improvement in effectiveness and an 80 percent reduction in collateral damage over the current 8-inch projectile. Funds are also being requested to begin development of an improved 155 mm projectile. The 155 mm projectile is critical for support of NATO allies who are in the process of standardizing the 155 mm howitzer as their predominant artillery weapon and to ensure appropriate density of nuclear firepower across NATO's front.

"PERSHING and LANCE are the principal tactical surface-to-surface missiles. SERGEANT and HONEST JOHN are being replaced by LANCE although some HONEST JOHNs will be retained for the foreseeable future in support of certain allies. Improved versions of gravity bombs are being deployed to theater forces, thus providing an enhanced air delivery capability. Additionally, standoff weapons technology is being investigated for possible application to tactical air delivered nuclear weapons." . . .

SUMMARY

"In summary, our current inventory of tactical nuclear weapons is becoming obsolete since these weapons represent essentially the technology of the 1950s and 1960s. It is essential that we modernize the theater nuclear force capability as these weapons play an important role in our deterrent strategy.

"We must maintain our qualitative advantages by providing an improved tactical nuclear stockpile with greater accuracy and enhanced security devices. Our modernization efforts include major improvement in response time, flexibility in employment, lower collateral damage and enhanced security. It is important that technological advances and theater nuclear force modernization continue so that the United States maintains a viable option between conventional warfare and strategic nuclear warfare."

<u>CONCLUSION</u>. <u>THE THREAT</u>.

The Ad Hoc Group concludes that the nuclear threat is real and of formidable magnitude.

CONTEXT OF STUDY

APPROACH OF THE AD HOC GROUP

## APPROACH OF THE AD HOC GROUP.

Nuclear protection of the soldier is but one element of military medical combat support, which in turn is one of the many complex functions of Command. The ultimate emphasis required of and by Command is mission accomplishment. Viewed in this perspective, it must be recognized that as destructive and devastating as nuclear weapons may be, there will always exist a peripheral zone in which lethality is not inevitable and where graded incapacitation may be encountered. The medical mission is to minimize the nuclear effects and to widen this zone by any means possible. This will be of critical importance in relation to the combat environment in which tactical nuclear weapons are employed. However, it is further recognized by the Ad Hoc Group that there are other measures which are of equal or even greater importance than the biomedical which must be considered and applied appropriately in order to provide maximal nuclear protection to troops in the field. These other measures will also be addressed briefly in an effort to achieve balance of emphasis with respect to the recommendations which ensue in this report.

# PROTECTION OF THE SOLDIER

Protection of the Soldier.

a. Physical Measures.

1. Introduction.

Advantage should be taken of every means of protection that can be afforded the soldier in a radiation environment. To this end, numerous analyses of the radiation shielding characteristics of various physical measures, as well as resistance to thermal and blast effects have been made over the years. Enormous amounts of data have accumulated, but have been of limited usefulness in planning, training, and implementation--possibly constrained in part because of the existing conceptualization of strategic employment of nuclear weapons. The newer recognition of the potential for tactical employment of nuclear weapons has pointed to the need for re-assessment of existing protective concepts and measures and more sharply focuses on associated military R&D requirements. For example, analysis of the radiation shielding characteristics of many combat vehicles has been accomplished (USA Ballistics Research Laboratory, US Army Armament Research and Development Command, Aberdeen Proving Ground, Maryland. BRL Report No. 1998, August 1977). It has been shown, for example, that the Neutron Protection Factor (NPF) afforded by the M60A1 tank essentially represents the degree of protection against initial radiation. NPFs averaged 1.3, 2.0, 1.8 and 3.9 for the commander, gunner, loader, and driver, respectively. Sensitivity analyses found NPFs to be insensitive to source/vehicle range and vehicle configuration, but mildly sensitive to source/vehicle orientation. The M60A1 tank was found to provide only a moderate amount of crew member protection in an initial radiation environment. Similar analyses will undoubtedly be accomplished with newer generation combat vehicles. Such tests should also address potential measures for enhancement of NPFs, e.g., boron shielding, distribution of on-board water supply in protective configuration--that is, for neutron capture, etc. Obviously weight/benefit ratios and other factors will need to be addressed.

While much data exists regarding the shielding characteristics of vehicles, bunkers, trenches, fox-holes, etc., the major problem appears to be lack of ability to integrate the data with field activities in a practical and meaningful way. The Ad Hoc Group believes that a severe limiting factor has been the absence of radiation dosimetry that would provide prompt intelligence for rational actions in the nuclear battlefield environment. This factor is discussed elsewhere in this report.

The importance of practical measures for the protection of personnel in tactical nuclear environments is illustrated by the following edited excerpts from a report (Appendix B) which was prepared for the Ad Hoc Group by Dr. Donald Blumenthal:

Personal Casualty Mechanisms.

"The magnitude and nature of the problems regarding protection of troops in the field may be emphasized by noting briefly the mechanisms by which nuclear weapons cause casualties.

"Immediate casualties are caused by three distinct aspects of nuclear weapons:

(1) thermal radiation can cause serious burns at levels as low as 2-5 cal/cm$^2$;

(2) blast and dynamic wind can hurl missiles and will destroy many structures at overpressures of 2-10 psi;

(3) nuclear radiation will cause immediate incapacitation with 3,000-10,000 rads.

"In addition to the immediate effects, long-term effects include:

(1) nuclear radiation of 500 rads will ultimately cause death;

(2) fallout and rainout which can contaminate large areas with radioactive debris.

"A Corps level simulation employing up to 28 weapons in the 100 KT yield range is illustrated in Figure 1. It suggests that thermal protection of 50 cal/cm$^2$ is required to reduce vulnerability to levels comparable with blast and radiation.

"These simulations assume that the attack was a 'surprise' and that no one was able to 'take shelter' during the period of about one second duration of the thermal and nuclear radiation, or, prior to arrival of the blast.

"The general trends of variation with weapon yield of these effects is illustrated in Figure 2 for weapons in the range 1 KT - 1 MT. Thermal radiation effects dominate the threat to exposed personnel at yields greater than about 10 KT."

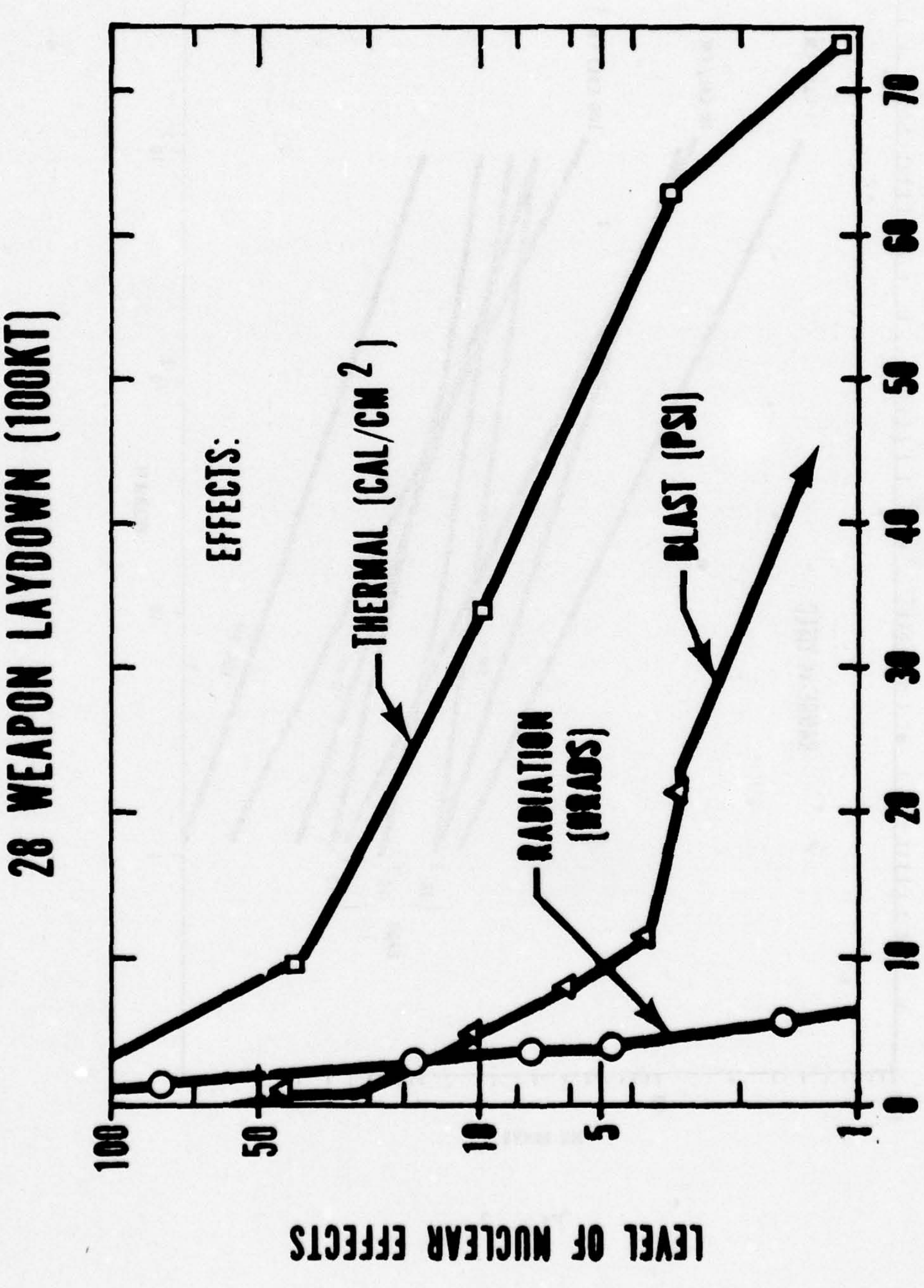
28 WEAPON LAYDOWN (100KT)
EFFECTS:
THERMAL (CAL/CM 2)
BLAST (PSI)
RADIATION (KRADS)
0
10
20
30
40
50
60
70
U.S. CORPS PERSONNEL AFFECTED (%)
100
50
10
5
1
LEVEL OF NUCLEAR EFFECTS

Fig. 1

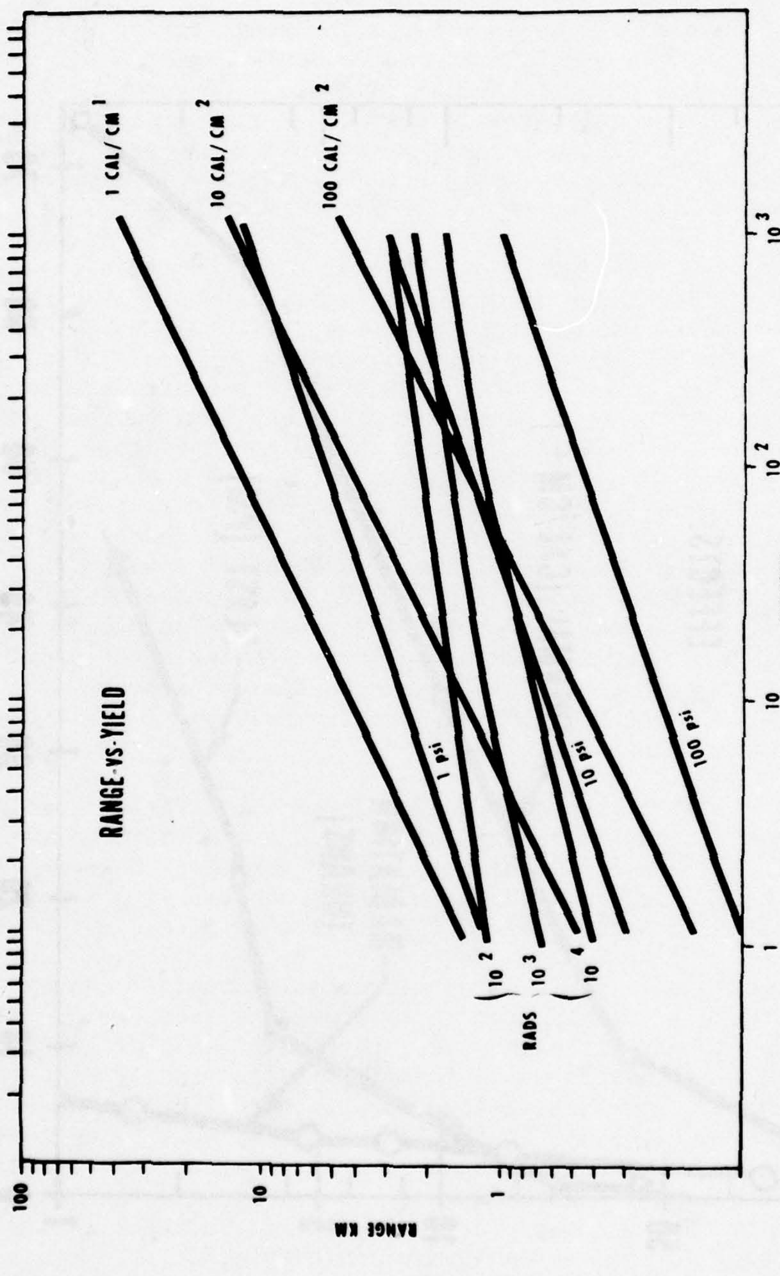
RANGE-VS-YIELD
1 CAL/CM 1
10 CAL/CM 2
100 CAL/CM 2
1 psi
10 psi
100 psi
RADS
10 2
10 3
10 4
RANGE KM
100
10
1
YIELD(KT)
1
10
10 2
10 3

Fig. 2

Field Expedient Protective Measures.

"For avoidance of all three effects: thermal burns, blast, and nuclear radiation, the single most important field expedient measure is effective protection against thermal radiation. Beyond the 'core' of approximately a 2 km radius from a 100 KT low air burst, the predominant casualty mechanism is thermal burns of exposed personnel. Burn casualties require extensive medical care, thus having a major impact on combat effectiveness for corps casualty levels of 20-30%.

"Conversely, shielding against thermal flash burns is the easiest to achieve since a thin layer of opaque material can intercept the thermal 'light' flash - even though that layer may ultimately be destroyed. Even heavy smoke, rain or fog would provide substantial protection. Forests or heavy vegetation would also be effective in reducing the thermal flux. However, ignition of these materials may be a serious problem. In a tactical environment it is likely that any given target location will be alerted by a prior nuclear detonation at a more distant location. This suggests that a large proportion of a corps level force could take cover from a pulse of weapons - if such shelter is nearby. For the larger yield weapons the thermal flash duration of a weapon is significant - about one second for 100 KT and five seconds at 1 MT. Thus a prompt 'reflex' action such as falling prone and shielding face and hands is advisable. Individual protective clothing might provide a factor of 3-5 in thermal flux tolerance. It might also be worthwhile to consider 'thermal modifications' of shelter halves, sleeping bags, protective masks and gloves.

"Group protection is probably a more practical field expedient than individual protection. This appears to be the kind of thinking behind the Soviets' BMP mechanized infantry combat vehicle. However, simple thermal shelters, such as might be put on troop-carrying trucks, require much less shielding than required for small arms fire.

"One concept is to replace certain existing vehicle canvas with a cover which could be easily removed to provide a local group thermal shelter. For example, it might take the form of an aluminum or fiberglass half-cylinder about 8 feet in diameter and 12 feet long. When properly anchored, and perhaps covered with dirt, it could also help shield against missiles driven by blast winds as well as conventional shell fragments. Depending on availability of earth moving equipment and/or time for manual trenching, such shelters could facilitate construction of 'bunker complexes'. Protection to blast levels of 10 psi and factors of 5 for radiation appear achievable.

". . . another example of a field expedient concept (is) an individual automatic smoke system for protection against thermal flash burns. This concept is based on the knowledge that it takes about a second to deliver the thermal burn from a 100 KT blast. It is questionable whether an unwarned individual can take any evasive action in that interval. This is particularly true of people such as truck drivers whose movement options are limited.

"Suppose that it is possible to make a light, cheap, automatic sensor of the prompt pulse in coincidence with the primary flash of light. This detection could trigger the release of gas driven smoke jets (analogous to auto air bags). Within vehicles this could serve as a 'shutter' to reflect or absorb the following thermal flash. (This is the same problem as with fighter pilots.)

"Suppose the principle is extended to place such a device in belts and/or helmets with multiple jets directed to surround soldiers with an 'instant smoke screen.' The jet duration could be as long as the five second duration of a 1 MT burn so that smoke dispersed by wind would be continually replaced. A dense smoke driven by a $CO_2$ cartridge might be effective in shielding individual soldiers from most of the thermal flash. . .

"Such concepts are speculative, but they illustrate the possibility of relatively simple protective devices."

Organizational and Procedural Factors.

"Even without equipment changes, it seems probable the nuclear vulnerability of personnel can change by a factor of two or three as a result of options in behavior. One way to maintain operable personnel is to keep them sheltered. Suppose one thinks in terms of well dug-in combat positions at a density such as in the Korean War, but being subjected to nuclear attacks. Because of troop safety considerations, the attacker cannot be very close at the actual time of the burst. Thus, if one keeps most of the people sheltered most of the time they can survive to fight when the conventional forces attack. The procedure might be implemented as a maximum allowable number being 'outside' at any time except when actually required.

"Personnel in vehicles require special attention to field expedient survival procedures. Sitting in the back of an open moving truck is probably the worst possible location in that:

(1) You get maximum thermal radiation with minimum chance of getting prone on the ground by reflex action.

(2) The blast effect may roll the truck over at levels which wouldn't otherwise be much threat to an isolated individual. (It probably doesn't make much sense to put seat belts, air bags and roll bars in the truck.)

(3) The truck driver may receive enough exposure through the windows to lose control and wreck the truck.

"A procedural policy when attack is imminent, requiring gloves, protective masks and no exposed skin - just as in anticipation of chemical attack - for drivers would lessen the problem.

"It is apparent that there are, indeed, a number of inexpensive expedient methods that can be developed and implemented to mitigate the effects of nuclear weapons, but more importantly our soldiers must be trained in their effective use to the point of becoming a sixth sense. Once this is achieved survivability becomes both attainable and believable."

Flash blindness may incapacitate troops during either daytime or nighttime detonation of nuclear weapons. It is believed that retinal damage will not be enhanced in those wearing night vision instruments, however, flash blindness per se could temporarily disable large numbers of troops. In this connection, the Ad Hoc Group wishes to note progress made by the US Air Force in the development of protective treatment for lenses with substances that change almost instantly on flash exposure in order to prevent eye damage from light.

The Air Force is currently producing a material for goggles which is issued to pilots and crew members for protection from flash blindness caused at detonation of nuclear weapons. This material is called PLZT and works on a molecular change basis in that it causes a reorientation of the polarity of the molecules by application of a voltage.

The material will rotate the polarity of light as a function of the voltage. The PLZT is placed between two wafers of orthogonally polarized material. When the voltage is applied the polarity is changed to shut out light. This change occurs within 150 microseconds. The open state of the material is 22% and will close to an optical density of 4.

These goggles are provided in the helmet version to pilots, copilots, tailgunners of the B-52 and to the boom operators of KC 135 tankers, as well as all other crew members unable to "button up". A smaller, lighter version is under development for issue to tactical fighter crews.

These goggles currently cost about $3,000 a copy, including a minicomputer with a feedback loop controlling the degree to which the system will reopen after exposure to the nuclear event. They can be used at night and have been night-tested in all modes.

CONCLUSION. There are practical physical measures which can be applied to provide protection to the soldier in the nuclear environment. These relate to thermal and flash as well as to blast and radiation effects which threaten the troops.

RECOMMENDATIONS.

1. The Ad Hoc Group recommends augmentation of efforts to develop and evaluate physical protective measures, and that improvements be incorporated promptly into troop equipment and training;

2. that there be established appropriate linkage of the Night Vision Program of the Army and Flash Blindness Protection Program of the Air Force;

3. that there be established an appropriate program or tasking to develop means of providing and testing the usefulness of smoke in flash/thermal protection. This should be linked with the DA program on SMOKE;

4. that there be established an appropriate linkage to the Chemical Decontamination/Contamination Avoidance program of efforts to improve field Nuclear Fallout Decontamination capability.

Protection of Soldier.

b. Medical Measures.

1. Introduction.

The biomedical effects of radiation have been extensively studied and are well-documented. This is particularly true of gamma radiation while the biologic effects of neutron radiation have not been as extensively studied. However, it appears that for practical purposes the biomedical effects of neutrons are comparable with some exceptions. For example, it appears that neutron radiation is associated with an increased incidence of cataract formation by a factor of 10 over gamma rays. Also, there is some evidence that neutrons are less effective in producing behavioral incapacitation than are gamma photons. On the other hand, with respect to lethality or cancer induction, neutrons have greater biological effectiveness.

Aside from the foregoing observations, there are two key facts which have emerged from studies in recent years that have important bearing on the current Ad Hoc Group review report. The first is that the limiting factor for survival of man appears to be approximately 1,000 rad total body irradiation. Evidence from bone marrow transplantation studies in leukemic human subjects revealed that radiation damage to lungs is the limiting factor, relative to survival, rather than bone marrow damage as was previously thought. Evidence has accumulated to indicate that the severe acute illness from radiation is associated with release of histamine. These observations provide some limits within which guidelines for treatment may be established as well as pointing to areas of needed research emphasis.

It should also be recalled that while emphasis here is placed on the effects of radiation injury, there are complicating factors associated with non-radiation effects of nuclear weapons, namely, burns, infection, fractures and stress. It appears that these all interact and apparently enhance the amount of damage from radiation significantly over that which would occur from the same dose given to a normal, inactive subject. Therefore, physical protective measures against blast and thermal effects have a much greater importance than their induced injuries would have if there were no associated radiation. It is of paramount importance, therefore, that field measures be devised and utilized to provide protection against the non-radiation forces released on the detonation of nuclear weapons. This aspect of protection has been considered in the preceding section of this report.

2. <u>Prophylactic drugs</u>.

Some years ago there was an R&D program at the WRAIR which was directed toward the systematic development of drugs that would be protective against radiation injury. That program produced a number of candidate compounds, which provided 1 or 2 $LD_{50}$ protection in experimental animals. At the time, this degree of protection was not considered significant enough--an opinion which was probably influenced by the then-existing belief that nuclear weapons would be used, if at all, in a strategic manner with massive "over-kill" doses of radiation. The recent emergence of the concept for tactical use of nuclear weapons poses new conditions and new requirements which need to be considered. Thus, even 1 or 2 $LD_{50}$ prophylaxis from drugs, along with other measures noted in this report, may be additive to the point of decisiveness on the field.

Review of the WRAIR program reveals that the protective compounds had a serious drawback in that they were effective only when injected. They were not absorbed when administered orally. Obviously, in a field situation, prophylactic medications should be effective when taken by mouth, so that they could be taken by the individual soldier himself. Fortunately, in the interim since the program at WRAIR was discontinued, there have been new developments in pharmaceutical technology which give promise that such compounds can be made to be absorbable following oral administration.

The Ad Hoc Group *recommends resumption* of the drug program along the following lines. The program should incorporate newer pharmacologic methodology and should explore additional compounds to those derived from the earlier efforts.

In this connection, a recent study was based on the hypothesis that histamine-terminal peptides might exhibit radioprotective activity.[1] Initial tests with the simplest such compound (glycylhistamine dihydrochloride) demonstrated significant protection when given intraperitoneally or subcutaneously to mice exposed to 850 R. Oral tests of the compound were not reported. The compound was not significantly toxic to mice. Thus, more extensive studies of glycylhistamine and other procamine analogs are warranted. It is also recommended that some tests be repeated with those compounds already shown to provide some protection --and that the histology of lungs as well as other organs be included in the studies. The question which needs to be addressed is whether 1 or 2 $LD_{50}$ (or more) drug protection applies to all tissues and organs, or is selective, for example, to protect bone marrow or lungs, or the gastrointestinal tract.

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1 Peck, M.L., <u>et al</u>.: Radioprotective Potential and Chelating Properties of Glycylhistamine, An Analog of Histamine Terminal Peptides Found in Bee Venom. Toxicon, <u>16</u>:690-694, 1978.

3. Prophylactic diet.

That dietary constituents may play a significant protective role against the effects of radiation has been experimentally demonstrated by Canadian investigators.[2] Rats were exposed to 700 rads of $^{60}Co$ gamma irradiation. Only 1 of 16 rats fed the usual food pellets survived this dose of radiation and the mean survival time was 9 days. In contrast, 11 of 15 rats fed an experimental elemental diet for a week before irradiation survived, and the mean survival time was 59 days. It was of no value to begin the experimental diet after the irradiation exposure. It appeared that the experimental elemental diet was associated with an enhanced cellular proliferation in the blood-forming tissues and also a better response to antigen stimulation.

It is recommended, therefore, that this finding be tested for validity, and if confirmed, further exploration of this and other experimental diets be undertaken. This effort should be linked with the Army R&D Nutrition activities at Natick--and indeed current troop rations could (should) be assessed in this regard as well.

A dietary constituent, namely Vitamin E, has also been demonstrated to provide some radioprotective effect in experimental animals.[3] This study was based on the knowledge that radiation damage to tissues is partially mediated through formation of free radicals. Since Vitamin E is a free radical scavenger, it was tested for its ability to protect against the lethal effect of total body irradiation in mice. There were some important dose relationships, but the findings were suggestive that Vitamin E should be studied further for its potential value in lessening the toxicity of acute radiation exposure.

4. Treatment after Radiation Injury.

(a) Delay of Onset and/or Suppression of Symptoms.

Once a soldier has been exposed to radiation, what can be done in the way of treatment? It will be recalled that radiation does its greatest damage to rapidly proliferating tissues, such as the bone marrow and the epithelium of the gastrointestinal tract. The radiation

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[2] Pageau, R., Lallier, R.; and Bounous, G.: Systemic Protection Against Radiation. I. Effect of an Elemental Diet on Hematopoietic and Immunologic Systems in the Rat. Rad. Res., 62(2):357-363, 1975.
[3] Londer, H.N. and Myers, C.E.: Radioprotective Effect of Vitamin E. Clin. Res., 26:284A, 1978 (April).

damage to these tissues, then, leads to nausea, vomiting, and diarrhea and to anemia, bleeding, and infection. The more acute symptomatic effects occur on the gastrointestinal system and they may quickly incapacitate the exposed soldier. The principal symptoms are nausea, vomiting, and diarrhea. Their onset and severity are to a considerable degree dose-related and may be expected to occur within the first few hours of exposure. These effects would obviously interfere promptly with soldier and unit performance. Thus, it would be of considerable importance to mission accomplishment if these attacks could be prevented or, if not prevented, at least ameliorated and delayed in onset. Regrettably, there is little understanding as to the mechanisms by which nausea and vomiting are induced.

Nevertheless, a good deal of information is available which provides a reasonable basis for the empirical biomedical response to radiation injury. Glasstone and Dolan[4] have concisely summarized the initial, latent, and final phases of illness induced by radiation as follows:

"No single source of data directly yields the relationship between the physical dose of ionizing radiation and the clinical effect in man. . . Individuals receiving acute whole-body doses of ionizing radiation may show certain signs and symptoms of illness. The time interval to onset of these symptoms, their severity, and their duration generally depend on the amount of radiation absorbed, although there may be significant variations among individuals. Within any given dose range, the effects manifested can be divided conveniently into three time phases: initial, latent, and final.

"During the initial phase, exposed individuals may experience nausea, vomiting, headache, dizziness, and a generalized feeling of illness. The onset time decreases and the severity of these symptoms increases with increasing dose. During the latent phase, exposed individuals will experience few, if any, symptoms and most likely will be able to perform useful tasks. The final phase is characterized by illness that requires hospitalization of people receiving the higher doses. In addition to the recurrence of the symptoms noted during the initial phase, skin hemorrhages, diarrhea, and loss of hair may appear, and, at higher doses, seizures and prostration may occur. The final phase is consummated by recovery or death.

"With the foregoing in mind, Table 12.108 is presented as the best available summary of the effects of various whole-body dose ranges of ionizing radiation on human beings. Results of radiological studies are generally reported in terms of the (VERTICAL) midline tissue dose in rads. This dose is lower than the dose that would be measured by

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[4] Glasstone, S. and Dolan, P.J. Eds.: Effects of Nuclear Weapons, Revised edit. DA Pamphlet 50-3, 1977.

instruments (and the dose that would be absorbed by tissue) near the surface of the body by a factor that depends upon the energy of the radiation and the size of the individual. . . .For consistency, the data in Table 12.108 are the dose (in rems) equivalent to the absorbed doses (in rads) in tissue at the surface of the individual. For gamma rays, these absorbed doses are essentially equal to the exposures in roentgens. For nuclear weapons radiation, the midline tissue dose for average size adults would be approximately 70% of the doses in the table."[5]

As noted above, it is now recognized that histamine which is released consequent to irradiation plays a major role in the systemic manifestations of radiation injury. In this regard, it may also be noted that it has long been known that histamine will induce gastric acid secretion and this knowledge has been utilized to devise a test for the determination of gastric acid production in certain clinical conditions. It has also been known that widely used "antihistamine" drugs do not block or prevent this effect of histamine on gastric secretion. Research in recent years has produced evidence that there are at least two types of receptors for histamine in the body. The sites which conventional "antihistamine" drugs affect are now designated "$H_1$ receptors," and those in the gastric mucosa are "$H_2$". Of importance to this report is the fact that several new drugs are available which block the $H_2$ receptors of histamine and could, therefore, inhibit gastric secretion that would normally ensue from histamine released in the irradiated situation. What is not known is whether the blocking of $H_2$ receptors will affect radiation-induced nausea and vomiting. The Ad Hoc Group recommends that $H_2$ blocking drugs be evaluated in experimental animals for possible ameliorative action on both the systemic and gastric effects of histamine. The two most widely used $H_2$ receptor antagonists are cimetidine (Tagamet[R]) and metiamide. These are effective orally and their use in a field situation would be feasible. Still another experimental drug, "Nabilone" (Eli Lilly & Co) has been found in relation to cancer chemotherapy to provide protection from vomiting which appears to be better than other anti-nausea drugs.[6]

Another pharmacologic group, namely the prostaglandins, also need to be explored for potential usefulness in connection with the gastrointestinal effects of radiation. There is evidence that prostaglandin inhibition of gastric secretion is not related to interference with the $H_2$ receptor.[7] Thus, the possibility that there may be additive or synergistic effects of these newer compounds needs to be evaluated as well.

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5 See footnote preceding page.

6 Montgomery, B.J.: High Interest in Medical Uses of Marijuana and Synthetic Analogues. JAMA, 240(14):1469-1470, 1978. (Sep 29)

7 Wollin, A.; Code, C.F.; and Dousa, T.P.: Evidence of Separate Histamine and Prostaglandin Sensitive Adenylate Cyclases (AC) in Guinea Pig Gastric Mucosa. Clin. Res., 23:260A, 1974. (Apr)

## Table 12.108

### SUMMARY OF CLINICAL EFFECTS OF ACUTE IONIZING RADIATION DOSES

| Range | 0 to 100 rems Subclinical range | 100 to 1,000 rems Therapeutic range | | | Over 1,000 rems Lethal range | |
|---|---|---|---|---|---|---|
| | | 100 to 200 rems | 200 to 600 rems | 600 to 1,000 rems | 1,000 to 5,000 rems | Over 5,000 rems |
| | | Clinical surveillance | Therapy effective | Therapy promising | Therapy palliative | |
| Incidence of vomiting | None | 100 rems: infrequent<br>200 rems: common | 300 rems: 100% | 100% | 100% | |
| Initial Phase | | | | | | |
| Onset | — | 3 to 6 hours | ½ to 6 hours | ¼ to ½ hour | 5 to 30 minutes | Almost immediately** |
| Duration | — | ≤ 1 day | 1 to 2 days | ≤ 2 days | ≤ 1 day | |
| Latent Phase | | | | | | |
| Onset | — | ≤ 1 day | 1 to 2 days | ≤ 2 days | ≤ 1 day* | Almost immediately** |
| Duration | — | ≤ 2 weeks | 1 to 4 weeks | 5 to 10 days | 0 th 7 days* | |
| Final Phase | | | | | | |
| Onset | — | 10 to 14 days | 1 to 4 weeks | 5 to 10 days | 0 to 10 days | Almost immediately**. |
| Duration | — | 4 weeks | 1 to 8 weeks | 1 to 4 weeks | 2 to 10 days | |
| Leading organ | Hematopoietic tissue | | | | Gastrointestinal tract | Central nervous system |
| Characteristic signs | None below 50 rems | Moderate leukopenia | Severe leukopenia; purpura; hemorrhage; infection. Epilation above 300 rems. | | Diarrhea; fever; disturbance of electrolyte balance. | Convulsions; tremor; ataxia; lethargy. |
| Critical period post-exposure | — | — | 1 to 6 weeks | | 2 to 14 days | 1 to 48 hours |
| Therapy | Reassurance | Reassurance; hematologic surveillance. | Blood transfusion; antibiotics. | Consider bone marrow transplantation. | Maintenance of electrolyte balance. | Sedatives |
| Prognosis | Excellent | Excellent | Guarded | Guarded | Hopeless | |
| Convalescent period | None | Several weeks | 1 to 12 months | Long | — | |
| Incidence of death | None | None | 0 to 90% | 90 to 100% | 100% | |
| Death occurs within | — | — | 2 to 12 weeks | 1 to 6 weeks | 2 to 14 days | < 1 day to 2 days |
| Cause of death | — | — | Hemorrhage; infection | | Circulatory collapse | Respiratory failure; brain edema. |

*At the higher doses within this range there may be no latent phase.

**Initial phase merges into final phase, death usually occurring from a few hours to about 2 days; this chronology is possibly interrupted by a very short latent phase.

Diarrhea associated with radiation injury may also be mitigated by medical means. Experimental evidence suggests that certain resins, e.g., sequestrene (Questran[R]) and cholestyramine, will bind bile acids which are associated with diarrhea, including diarrhea from radiation injury.[8]

The Ad Hoc Study Group recommends that efforts be undertaken to evaluate these and other drugs for their ability to suppress or delay onset of nausea, vomiting, and diarrhea consequent to radiation injury. It would seem that much relevant information could be obtained by an active liaison with civilian medical radiation treatment centers. However, on direct question the Director of the AFRRI indicated that DNA does not permit such liaison arrangements. This issue should be resolved in order that incidental but important clinical information obtained in civilian medical studies may be made available in timely fashion to the military medical services.

(b) Medical Treatment to Correct Consequences of Bone Marrow Damage from Radiation.

Destruction of bone-marrow cells leads to marked decrease in white blood cells (leukocytes), platelets, and later of the red blood cells. The full blown clinical picture may include anemia, bleeding manifestations, and infections as a result of radiation damage.

Advances in blood banking technology provide prospect for replacement transfusions of red blood cells (to correct anemia), platelets (to stop bleeding) and white blood cells (to combat infectious complications). The Medical Department of the Navy has provided leadership in the development of technology for the freezing of red blood cells, allowing indefinite storage, and availability in acute, emergency situations. Progress is rapidly being made also in the application of freezing technology to the preservation of white blood cells and platelets.

Availability of ample supplies of frozen blood cell components will be essential to prompt medical support of radiation injured soldiers.

It is recommended that R&D support for the freezing and storage of blood components be continued and integrated into the medical and logistical plans for the support of combat forces which have suffered radiation injury.

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8 (a) Berk, R.N. and Seay, D.G.: Cholerheic Enteropathy as a Cause of Diarrhea and Death in Radiation Enteritis and Its Prevention with Cholestyramine. Radiol., 104:153-156, July 1972.
(b) Parkinson, T.M. and Drake, N.A.: Protection Against Gastrointestinal Effects of Whole-Body X-Irradiation by a Bile Acid Sequestrant in Rats. Experimentia, 28:553-554, 1972.

Other medical advances raise the possibility that bone-marrow transplantation may provide restoration of marrow function. Although this is technically feasible, bone-marrow transplantation as now performed is not a practical solution to this problem. Somewhat less than 400 bone-marrow transplants have been done in the US civilian medical community since inception of the program. Matching tests to find suitable donors and other requirements are such that transplantation has to be individualized. Even in the most experienced hands, obtaining the donor marrow alone requires some two hours time in the operating room, and overnight hospitalization of the donor. It is highly unlikely that the technology could be logistically adapted to a mass casualty situation--as one would anticipate from tactical employment of nuclear weapons. Thus, some further possibilities should be explored. For example, recent developments suggest other promising approaches to bone-marrow restoration following radiation injury from combat exposure to tactical nuclear weapons. There are two lines of investigation that should be examined:

(1) The first is an extension of cryogenic efforts to preserve bone-marrow for indefinite periods--from individuals at risk--for subsequent administration. This is already technically feasible and has been utilized successfully both in radiation injured animals and in patients with cancer. This approach would require collection and storage of bone-marrow from individual soldiers at a time prior to their deployment. The bone-marrow would be stored frozen in a safe depot, for use in the same soldier at any subsequent time it might be needed. (Autogeneic bone-marrow transplantation.) Although there are obvious logistical factors to be assessed in connection with this approach, they do not appear as formidable as those which attend bone-marrow transplantation from other donors--especially under mass casualty situations. It is recommended, therefore, that research on bone-marrow preservation be incorporated into the over-all medical effort to improve the medical support of the soldier exposed to radiation injury on the battlefield. As a corollary, it is recommended that comparative logistical costs and medical outcome tests be undertaken through war-gaming scenarios involving various circumstances of radiation injury.

(2) A longer term area of research promise is that which is directed to the identification, isolation, and *in vitro* growth of "stem cells" from human bone marrow. Since these cells give rise to all of the normal blood cellular elements, it is theoretically attractive to pursue their production in the expectation that cultures could be grown to supply bone-marrow regeneration capacity to large numbers of individuals. Even though this avenue of investigation might be fruitful, there is still the possible drawback that immune mechanisms will react to the stem cells and cause either "rejection" of the cells by the recipient's body tissues or a "graft vs host" reaction where the stem cell derivatives

might produce antibodies against the recipient's tissues. Although testing of this approach is not currently feasible, it is recommended that it be closely monitored and supported within the total nuclear medical R&D effort.

## CONCLUSION.

There are several medical measures which could afford some protection of soldiers to the effects of irradiation. These include dietary constituents and drugs for reducing radiation injury effects. In addition, there are potentially useful medical approaches to the prevention, delay, or amelioration of acute symptoms associated with radiation injury, that is, nausea, vomiting, and diarrhea. For delayed severe radiation injury to the bone marrow, medical developments offer promise for survival from bone-marrow transplantation, along with improvements in blood banking support of such patients with red blood cell, white blood cell, and platelet transfusions. The more severe the radiation injury, the less likely becomes survival, and the more complex becomes the treatment effort while the logistical burden of therapy increases exponentially.

Thus, physical measures to protect soldiers should be maximized at all times. Medical support and prophylactic measures should, however, also be maintained at their highest possible level. Even so, the combat situation may result in radiation exposure with which the commander and his troops will need to contend in the performance of their mission. The medical measures that are available or potentially available will, to a considerable extent, help delimit the amount of exposure that would be "acceptable" to mission accomplishment.

## RECOMMENDATIONS.

1. It is not possible to estimate the military impact that would result from the various aspects of medical efforts to increase radiation protection of the soldier. For this reason, the Ad Hoc Group recommends incorporation of biomedical factors in a variety of scenarios in order to arrive at a more meaningful assessment of such factors. The findings should be useful for planning purposes and to assist in ordering priorities of the military bio-medical R&D effort.

2. Similar scenarios should be directed toward assessment of trade-offs which will result from avoidance, alleviation, and decontamination of fall-out effects, and of these parameters in combinations with biomedical factors.

3. The prophylactic drug program should be resumed and maintained along the lines described herein.

4. The prophylactic potential of dietary factors should be explored and this should be linked with the programs of the Army Nutrition Laboratory.

5. Medications should be developed to delay onset or suppress acute responses of radiation injury--namely, nausea, vomiting, and diarrhea. Some candidate drugs are suggested.

6. In order to establish the safety of drugs to be employed as in 4 and 5 above, at some point in the R.D.T.& E. of preventive, protective, or treatment measures, it becomes necessary to utilize human subject volunteers. For this reason, it is recommended that a DA or DOD level "Human Use Committee" be established to provide criteria for protocols, safety factors, monitoring of studies for compliance, and assurance of informed consent of participant volunteers as well as consideration of the moral and ethical aspects involved.

7. Much relevant information to 5 above could and should be obtained through an active liaison with civilian medical radiation treatment centers. (The Director of the AFRRI has indicated that DNA does not permit such liaison arrangements.) This kind of information can only be obtained from human subjects. The mechanism by which such information is to be obtained would need to be approved by the "Human Use Committee" recommended in 6 above.

8. It is recommended that R&D for the cryopreservation of blood components be continued and integrated into the medical and logistical plans for the support of combat forces which have suffered radiation injury. (This should be coordinated with the Dept. of Navy Blood Preservation Research Program.)

9. It is further recommended that research on bone-marrow preservation and transplantation be incorporated into the overall effort to improve medical support of the soldier exposed to radiation injury on the battlefield. (This should also be coordinated with the Dept. of Navy Blood Preservation Research Program.)

10. As a corollary, it is recommended that comparative assessments be made of the logistical costs/burden and medical outcome of blood/blood products transfusions and bone-marrow transplantation in forward areas vs prompt evacuation of radiation-injured troops to designated treatment sites.

DOSIMETRY

Dosimetry.

Useful dosimetry is the key to analysis of the radiation situation and appropriate response, whether military or medical and whether it applies to the individual, the unit or area.

The Ad Hoc Group finds that there is need for a major effort to improve and field individual, unit, and area dosimeters of radiation activity. Most civilian emphasis has naturally been directed to the production of dosimeters that detect minute amounts of radiation and warn against low level exposure. These also have their usefulness in certain military settings, but would not be sufficiently informative in a nuclear combat environment. For the latter situation, the need is for dosimeters that give gross readings indicative of dangerous exposure--up to incapacitiating levels. Measurement of selected levels of radiation exposure would provide the basis for Command and medical decisions regarding individual and unit disposition, movement, evacuation, and so on. In this regard, the Ad Hoc Group learned that a dosimeter system for determining neutron dosage received by human beings was developed, tested, and patented by the US Government in 1966. (Appendix C) The instrument was portable, relatively inexpensive, and capable of rapid and field operation. It is recommended by the Ad Hoc Group that this and other radiation dosimetry instrumentation be reviewed, assessed and further developed if necessary for utilization in the field.

Area dosimetry is also badly needed, especially for the commander of troops in the nuclear battlefield. Lacking to date has been the capability to provide to Command at or near real-time intelligence regarding radiation activity, its nature, amount, and distribution. In this connection the Ad Hoc Group believes that there are several recent hardware developments that are very promising in this regard: Fallout can now be measured and mapped to terrain in near real-time with equipment carried by helicopter or light aircraft. A prototype of such a system exists in the Department of Energy's NEST/SANDS equipment. This capability needs to be rapidly developed and adapted for field use. It has obvious implications with respect to Command decisions regarding troop disposition, lines of movement--e.g., for avoidance of heavy radiation fallout, etc. Important progress is also being made in the development of the data base and methodology which could provide the field Commander with greater predictive capability with meteorological data including rainout at or near real-time. The major effort in this program is that known as The Atmospheric Release Advisory Capability sponsored by ERDA.[1] (Appendix D) This program, too, needs prompt integration and development for its potential contribution of timely information for decision-making by the Commander.

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1 Dickerson, M.H. and Orphant, R.C.: Atmospheric Release Advisory Capability. Nuclear Safety, 17:281-289, 1976 (May-June).

CONCLUSION. Appropriate dosimetry is crucial to analysis of the radiation factor in a combat situation. The Ad Hoc Group finds that there is need for a major effort to improve and field individual, unit and area dosimeters of radiation activities. Some promising possibilities are cited.

RECOMMENDATIONS.

1. It is recommended that high priority be given to further development of radiation dosimetry instrumentation for utilization in the field.

2. Fallout can now be measured and mapped to terrain in near real-time with airborne equipment. A prototype system exists in the Department of Energy's NEST/SANDS equipment. It is recommended that this capability be rapidly developed and adapted for field use.

## WARSAW PACT NATION CONCEPT OF PROTECTION

Warsaw Pact Nation Concept of Protection

As noted in the section on Threat, both the United States and the Soviet Union possess a variety of nuclear weapons and delivery systems which are available for use in Western Europe. Reviews of Soviet doctrine suggest that nuclear attacks may be used to "soften up" areas designated for "breakthrough" operations and to attack priority rear area targets such as nuclear storage facilities and headquarters units. Also, the sophisticated level at which Soviet forces are trained and equipped in chemical warfare indicates that they are prepared to survive and effectively wage war in an integrated chemical-nuclear environment. It is of relevant interest, therefore, to consider information regarding nuclear protection measures for troops in Warsaw Pact countries.

The German Democratic Republic Handbook "Nuclear Weapons and Protection Against Nuclear Weapons" provides some insight into their understanding of the hazards of nuclear warfare, and of the status of their efforts to protect their military personnel or to minimize the associated casualty effects. The following excerpts from the Handbook will serve to illustrate their views and efforts in this connection: "Thus, it was established, that for an instantaneous radiation burden, the lethal dose ($LD_{100}$) is 600R. For a uniform distribution over one month, on the other hand, the lethal dose is about 1500R.

"Since the general biological effects of residual nuclear radiation have already been described in section 5.3.3.2, in connection with the immediate nuclear radiation, there is no need to study these questions once more.

"Table 7.17 gives the maximum permissible nuclear radiation doses, (MPD) for external radiation as a function of the duration of combat operations in the activated areas. These values must be interpreted as being such that if maintained, no immediate casualties have to be expected through radiation diseases. However, the idea that in such cases it is a question of 'harmless' radiation doses is wrong because it is directly opposed to the requirement that each combat mission be undertaken with the minimum radiation burden, and also because it does not correspond to the biological position.

"Conserving the forces of the troops assumes that in every situation all available possibilities of protection against external radiation is utilized to the maximum extent. The purpose is not merely not to exceed prescribed highest doses, but rather to retain as far as possible below the maximum permissible doses.

Table 7.17 - Maximum permissible nuclear doses (MPD) for combat conditions

| Conditions of the radiation effect | | MPD |
|---|---|---|
| For single absorption | in 4 days | up to 50R |
| For repeated absorption | in 10 days | up to 100R |
| | in 3 months | up to 200R |
| | in 1 year | up to 300R |

Remark: The maximum permissible nuclear radiation doses defined for longer periods assume that the doses fixed for the shorter periods are not exceeded.

"These goals are achieved with both technical and semistrategic measures, which are referred to here, as a whole, as field measures of protection against nuclear radiation, even though they are naturally, essentially measures of protection against weapons of mass destruction in general, and it is possible to define clear limits between it and the other measures of protection."

Pages 641-659 quoted from the same document follow:*

8. Protection against Nuclear Weapons as Integral Part of the Protection of Troops against Mass Destruction Weapons.

8.1. Summary of the most Important Protective Measures for Troops against Nuclear Weapons.

"In the Introduction to the text-book, it had been stated that protection of troops against nuclear weapons is an integral part of the protection of troops against mass destruction weapons and must be organized in all types of combat, and in any situation, with the purpose of preventing the use of mass destruction weapons, reducing the effects of enemy attacks, maintaining or rapidly restoring combat fitness of troops and securing the accomplishment of the combat mission.

* Because of poor reproducibility, the material has been re-typed. Some spelling and punctuation corrections were made, and actual graphs are omitted because of lack of clarity--however, the legends are shown to provide information as to the scope of the data given.

"It may be seen from this definition of purpose that there is only one protection of troops against mass destruction weapons, whose planning, organization and implementation is the mission and work of all commanders and staffs, as well as all branches of the armed forces, even before the enemy has begun to use them.

"Securing constant protection of troops against mass destruction weapons is a most creative task, requiring thorough evaluation of the situation, ability for quick decision, a show of great initiative, and without any regular model.

"The practice, which is still partly followed, of dividing the protective measures for troops against mass destruction weapons into so-called active and passive ones is, for the least, inconvenient because it does not give due importance to each individual measure, and above all, wrong in its fundamental orientation.

"The most important measures of protection against nuclear weapons for troops is given once again in the form of summary and survey in Table 8.1. However, since these measures have already been described in detail in the previous sections, there is no need for further statements.

"The external conditions and phenomena of a missile warfare lead to extraordinary high psychological, moral and physical burdens for the commanders, staffs and troops, caused by the simultaneous effect of a number of causes. These include sudden and great changes in the situation as a result of enemy attacks with mass destruction weapons, results in total losses, forced stay in areas with high dose rates, necessity for quick decisions even without an overall picture of the new situation, repeated and long operation with protective equipment and many other problems discussed in the previous sections.

Table 8.1 Review of the most important protective measures for troops against nuclear weapons.

| Measures | Essence of Measures |
| --- | --- |
| Timely reconnaissance of enemy's preparation for use of mass destruction weapons, and prevention of their use. | --coordinated, continous use of all reconnaissance units of the branches of the services, special troops and services;<br>--reconnaissance of shifting, or movement and firing of nuclear weapon launching equipment, sites of preparation of nuclear charges; |

| | |
|---|---|
| | --immediate destruction of objects detected, using all available means, such as missile units and artillery, *air force, special reconnaissance* and destruction units. |
| Prior determination of activated area, and specification of areas in which extensive destruction, fires, and floods occur when nuclear weapons are used. | --evaluating the actual possibilities of use of nuclear weapons by the enemy on the basis of the actual situation (*nuclear weapon launching equipment* ranges, detonation intensities, explosion types, targets);<br>--possibilities of causing in particular, ground and underground explosions (nature of operations, weather situation, areas where nuclear mines are laid, nuclear radiation position to be expected);<br>--evaluating particularly dangerous directions and areas (cities, forests, dams, lake areas, impracticable sections of the terrain, sections of introduction and deployment of 2 echelons and reserve, forcing(?) sections, etc).<br>--consideration of the consequences of the evaluation of the situation when making decisions and assigning missions to troops;<br>--foresight in evaluation of the effects of enemy's nuclear attacks on the accomplishment of the assigned missions, and range of measures to eliminate the consequences. |
| Continuous organization and implementation of reconnaisance | --constant reconnaissance of the most important areas, sections, marching routes and directions by structural and non-structural nuclear radiation and chemical agents reconnaissance units;<br>--establishing essential points of |

| | |
| --- | --- |
| | reconnaissance, proper distribution of forces and equipment, timely assignment of missions to the reconnaissance forces, securing stable guidance and connections;<br>--undertaking calculation of probable radiation burden of troops. |
| Timely warning to troops and services behind the lines of activation | --utilization of connections and means of communications;<br>--establishing uniform signals and sequence for transmission of warnings;<br>--foresight in evaluation of direction of propagation of radioactive explosion products;<br>--timely transmission and evaluation of reconnaissance data on the nuclear radiation situation. |
| Decentralization and camouflage of troops and services behind the lines | --complete utilization of available area for accommodation and deployment of troops;<br>--maintenance of required distances spacing and safety distances;<br>--prevention of non-authorized concentration of troops when introducing the 2nd echelon and reserves in river crossing and at road junctions;<br>--implementation of measures of camouflage, apparent concentration areas; concealment of troop movements, making use of the night for regrouping, limiting time of stay; |
| Changing the quarters of the troops, air force bases, and position of ships | --disorientation of enemy reconnaissance by concealed arrangements of troops, and very versatile operations;<br>--study of possibilities of enemy reconnaissance and removal of troops from dangerous areas;<br>--irregular changing of quarters, bases and position |

| | |
|---|---|
| Use of personal protective equipment, and utilization of the properties of the combat vehicles, terrain and shelters | --ensuring a high level of protection training and constant readiness for use of protective equipment; utilization of the terrain to accommodate troops and for movement on the battlefield; remaining in combat vehicles, positions and shelters. |
| Preparation of troops for maneuvers and engineering layout of areas occupied by troops | --evaluating possible changes according to terrain of effects of nuclear enemy attacks (possibility of negotiating roads and paths, bridges, possible flood and fire areas, etc);<br>--reconnaissance of street and path system, implementing repair works, reinforcing the bearing capacity of bridges, camouflage of roads and paths;<br>--construction of positions and shelters (protective units) and constant increase of the degree of protection units with maximum use of natural possibilities of protection of the terrain, the built up area, etc. |
| Correct operations in activated areas | --strict observance of protective measures and rules of behavior while in the activated terrain;<br>--limitation of time of stay in zones of high dose rate or detour around such zones, or waiting for the radiation to attenuate before passing through them. |
| Undertaking dosimetry and nuclear radiation monitoring | --constant prior calculation of troop radiation burden to be expected; regular evaluation of dosimetry (measurement, detection, evaluation of possible effects on combat fitness, conclusion about further use;<br>--recording of immediate reports for high dose absorption or daily total reports according to orders; |

| | |
|---|---|
| | --undertaking nuclear radiation monitoring after leaving an activated area or after complete deactivation;<br>--regular checking of troop supplies; such as provisions, water, clothing and equipment for possible activation (taking of samples, carrying out laboratory tests). |
| Carrying out hygiene and prophylactic measures | --preventing incorporation of radioactive substances (restricting use of captured provisions, local supplies, water taken from unauthorized source, etc);<br>--undertaking strict rationing of water and provisions;<br>--administration of radiation protection agents. |
| Timely and constant supply of protective equipment to troops | --establishing sequence and main points of supply;<br>--time, type and place of supply;<br>--storage of troop supplies and reserves;<br>--use of local means after authorization. |
| Rapid elimination of the consequence of enemy's use of mass destruction means | (this question was studied separately in section 8.2.) |

"Taking into consideration the fact that troop direction is above all the directing of men, and even in the most complicated situations, unity of political and military direction must be assured, the protection of troops against mass destruction means cannot be considered merely as a sum of individual measures, decision and orders, but it must be understood, and hence can be planned, organized and carried out only on the basis of a concrete and purposeful political work in combat. Here it must be recalled that constant and direct threat to life may cause individual reactions such as fear and thought inhibition, combined with a decrease in physical fitness, as well as collective reactions such as anxiety and panic.

"Among the factors limiting the possibilities of panic, the political-moral condition of the troops and knowledge of the justness of the cause for which they are fighting, assumes the first place. Nevertheless, a concrete knowledge of the danger, as well as the counter measures to be undertaken, also play an important role.

"Hence the troops must be prepared for the requirements of a missile warfare. In this connection, inadmissible simplifications are just as harmful as uncritical considerations. There is no need to have a more detailed basis for the fact that narrow limits are imposed on the training for visualization and presentation of a missile war launched by the imperialists. However, great importance must be given to training and preparation of troops in near-combat conditions. Its implementation would require above all:

--securing a high theoretical training level;

--a consistent struggle against simplifications and easier combat training;

--the realization of the fact that practical exercise cannot be considered as the only criterion;

--the consideration of the basic laws and norms of troop protection against mass destruction weapons not merely as quantitative requirements, but also the qualitative need;

--to make maximum utilization of the training base and time for training in near-combat conditions;

--create constantly, during the entire training, complicated initial situations, whose mastery will require the highest physical and psychological requirements.

"Only the rigid spur of political motivation for combat missions and military mastery will guarantee the accomplishment of the military mission. This political-moral training promotes not for the least the collective adjustment of every member of the Army, forms qualities of character and will, and assures the superiority of the personality of the socialist soldier. In this connection, prominent importance should be given to decisiveness, self-control, and confidence in victory in all superiors, and the effect of their example in every situation, which would act as a stimulus to the subordinates' operations. The need of psychological preparation is to overcome the demoralizing effects of the surroundings in combat and the man-equipment problem. An important goal is to develop an active behavior, i.e., to prevent any passive, patient and long-suffering attitude. In this respect, the relationship of trust between superior and subordinates is essential. It must be developed to such an extent that even in complicated situations the subordinate is convinced that the superior is doing all in his power to achieve victory over the enemy, maintain readiness for combat of all the troops under him, and avoid meaningless sacrifice.

"These psychological aspects must be considered by creating situations as realistic as possible in combat training. Hence, those practical elements requiring continuous mastery of fear and anxiety, are of great educational value. This is possible without creating really dangerous situations in combat training if required safety and protective measures are implemented and maintained consistently, and these requirements correspond to the training level.

"In conclusion, it may be stated that the following steps be taken to secure high level of training of troops in matters of protection against mass destruction means:

--utilize all possibilities of politico-moral influences being imbued in training;

--develop ingenuity in creating or describing situations coming close to those of modern combat;

--give systematic training in all rapid and 'autometized' maneuvers and operations in combat.

<u>Test questions</u>

8.1 Name and discuss the most important protective measures against nuclear weapons.

8.2 Why is protection against nuclear weapons an essential component of protection against mass destruction weapons as a whole?

8.3 On the basis of Table 8.1, attempt to work out a few basic points for the protection of troops against nuclear weapons according to the different types of combat. Why is it not correct to speak of peculiarities in this connection?

8.4 What is the meaning of "implementation of unity of political and military direction" in conditions of use of mass destruction weapons by the enemy?

8.5 What personal conclusions did you draw for your own work from the study of problems of nuclear weapons, and protection against them?

8.6 How far is it possible and necessary to create the basis for a general successful implementation of protection of troops against nuclear weapons in the training of commanders, staffs and troops?

8.2. Duties of commanders and staff in the evaluation of the position after nuclear attacks by the enemy, and in organizing and implementing the elimination of consequences. The main duty of commanders and staffs, even after enemy nuclear attacks, is to secure continued accomplishment of the combat missions. To what extent this is possible depends naturally on the real effects of the enemy's actual nuclear attacks.

"By a thorough evaluation, directed to essential points of the situation, the necessary assumptions must be secured to restore combat fitness of the units and platoons affected within the shortest possible period.

"Eliminating the consequences of nuclear attacks by the enemy includes in particular:

--restoring troop direction;

--rescue work, medical treatment, and removal of wounded;

--special treatment (deactivation and sanitary treatment);

--clearance and reorganization of the marching routes, restoring or building of shelters and obstacles as well as extinguishing and containing fires impeding troop operations;

--nuclear radiation monitoring and dosimetry;

--deactivation of troop supplies especially provision and treatment of water.

"Restoring troop direction is the requisite and basic condition for the solution of all further problems. This is because, among other things, after an enemy nuclear attack, the situation is not as a rule clear, and incoming reports and information may be contradictory. Nevertheless the decisions of commanders and staffs cannot wait until there is complete survey of the situation, nor can the assignment of missions. Hence, in such a position, all considerations, estimates, and calculations must be based on the most unfavorable version.

"Taking into account the combat missions assigned to the troops, the enemy's operations, the position of the troops at the time of the attack, the actual terrain and meteorological conditions, the commanders and staffs must evaluate the probable losses, possible psychological effects on the units affected directly or indirectly, because of shock and panic, as well as terrain-dependent effects of nuclear explosion and their influence on the fulfillment of the combat missions. How far this is possible depends on the available initial data. If no information is at hand, preliminary estimates must be made on the basis of a ground explosion.

"It had been stated, that under conditions, the terrain-dependent effects of nuclear explosions can be very great. This includes not only large and highly activated craters, but also surface fires, debris zones, road blocks, floods because of dyke breaks and river damming, valleys and gullies becoming impracticable.

"The evaluation of these problems will give not only results for the consequences for the further course of the combat, but also affect the extent and complexity of the rescue works to be undertaken.

"Further difficulties arise when intense terrain activation must also be expected.

(Figure 8.1)

Fig. 8.1 Radii of the destruction zones as
as function of the state of protection (L)
atmospheric explosion; (E)-ground explosion;
if the difference in the destruction radii
is low, both values are combined.

a. destruction zone radii/km b. area of destruction zone/$km^2$ c. detonation intensity/kg d. outside shelters (L) e. outters (E) f. in trenches (L&E) g. tank crews (L&E) h. in underground light shelters i. in underground shelters of heavy type.

"Because of the justified assumption that the enemy will always seek to exploit to the maximum extent the results of the nuclear attack he has launched, great attention must be given to the quick restoration of the fire and obstacle system. In this connection increased significance must also be attached to the clearing of important marching routes, and restoring of column paths; to secure freedom of maneuvers, particularly of the second echelon and reserves.

"The rescue works in explosion areas include:
--searching for the wounded and their rescue from the combat vehicles as well as from destroyed and damaged units;
--administration of first-aid;
--removal of the wounded for further medical treatment to assembly points.

(Figure 8.2)

Fig. 8.2 Radii of destruction zones for
combat vehicles and combat equipment.

a,b,c, see Fig. 8.1 d. radar station with parabolic tower (E) like light motor vehicle (E) e. radar stations with parabolic tower (L) like boot of light motor vehicle (L) f. munition dumps with fuel containers (E) like armored personnel carrier (E) g. munition dumps with fuel containers (L) like medium and heavy tanks (L&E) h. heavy and medium tanks (L&E) i. boot light motor vehicle (L) radio station (L). Other items illegible.

"It is characteristic of the course of rescue works that as a rule operations for removal of debris, fire-fighting, and clearing of marching routes must be undertaken simultaneously. Moreover, the corresponding terrain activation can have considerable effect on the course on the rescue works.

(Figure 8.3)

Fig. 8.3 Radii of destruction zones in forests and cities, as well as various means of transport

a. detonation intensity b. cities c. damages d. traffic obstructions e. medium to light destruction f. heavy to total damage g. fire area h. railway (E) i. railway (L) and dams (E) j. dams (L) k. steel bridges of more than 100m span (E) cities impracticable l. steel bridge of more than 100m span (L) concrete bridges of more than 20m (E) m. concrete bridge of more than 20m (L) n. forests o. wood fires p. slight destruction q. pontoon bridge (L) r. auxiliary bridge (L) s. pontoon and auxiliary bridge (E)

"The combined nature of the damages, injuries, and destruction arising as a result of nuclear explosions requires the timely implementation of rescue and salvage operations, geared to the essential needs and whose severity and extent would correspond to the problems to be solved. The practical realization of such a requirement, particularly in massed enemy attacks, is however not always fully possible. This is not the least of the reasons why self-help and mutual help must be organized to restore readiness for combat in the units and platoons affected directly, and eliminating effects of nuclear attacks must be begun in a suitable manner without waiting for help and support from the superiors. The earlier one starts removing the effects, the less the secondary losses to be expected, and the quicker the demoralizing effects stopped, the rise to panic and anxiety can be fought against.

"It is unquestionable that even the best organization of protection of troops against mass destruction weapons cannot prevent great losses and casualties. But it is quite possible to reduce the absolute quantity of losses by the commanders and staff being fully prepared theoretically and practically for the problems to be solved in protecting troops against mass destruction weapons.

"In his speech to the members of the National People's Army, the First Secretary of the Central Committee of the German Socialist United Party at Rugen in January 1972 declared: 'In a world changed and changing to an ever increasing extent through the force of socialism in our days, imperialism can no longer achieve its goals as they could 30 or even 50 years ago. Nevertheless, it remains aggressive, crafty and dangerous. As shown by the barbaric war adventures in Vietnam, Cambodia, Laos and the Arab countries, the enemy will not be afraid to allow arms to speak, wherever and whenever he sees the slightest prospect of achieving his plans of aggression.

" 'We have therefore every reason not to abandon for a minute our political and military guard. The picture of the enemy is correct. There is nothing to change in this picture for the enemy himself does not change.' "

Test questions

8.7 What are the measures covering elimination of consequences of nuclear attacks by the enemy?

8.8 What are the peculiarities of the elimination of consequences in case of high terrain activation?

8.9 What problems have to be solved by rescue and salvage units? Derive from them the proper constitution of forces and means.

Remarks on Chapter 8

1. Compare: Christian, K., Remarks on General Measures of Troop Protection Against Mass Destruction Weapons, 'Militarwesen' (1961) p. 175-184; Nadirov, Yu, S., et al., Zascita podrazdelenij ot oruzja massovogo porazdenija, Publishers of the USSR Defense Ministry, Moscow, 1966, p. 1219.

2. Compare: in this connection, among others: Gillert, H. The Panic Problem in Modern Combat, 'Militarwesen' (1962) 1, p. 51-62; Koniezny, Panic in War, 'Militarwesen' (1963) 6, p. 843-854.

3. According to the chosen classification of this textbook, it is not the intention to treat this topic completely and systematically. Rather, a few brief remarks will be expressed. Hence, this section must be studied together with the statements of Sections 2.3, 3.5, 4.3, 5.3, 6.3, and 7.4.

4. DV-36/1, p. 45 ff.

5. The term 'affected area' in this context not applicable to the situation since it is not only a question of nuclear radiation reconnaissance, but a comprehensive reconnaissance of the general situation arising after nuclear weapon attacks! Nevertheless, it is retained in the interest of uniform formulations.

6. Cited according to the Republic Issue of the "Neues Deutschland" of 1-7-1972, p. 3."

<u>CONCLUSION</u>. <u>WARSAW PACT NATION CONCEPT OF PROTECTION</u>.

Nuclear protection measures for troops have been extensively studied by the USSR and the other Warsaw Pact countries. This matter continues to receive high priority as judged from documents available to the Ad Hoc Group.

# REFERENCES

## REFERENCES


1. Department of the Army Pamphlet No. 50-3, The Effect of Nuclear Weapons, Revised Edition, March 1977 - Compiled and Edited by Samuel Glasstone and Philip S. Dolan.

2. Department of the Army Technical Manual 8-215, Nuclear Handbook for Medical Service Personnel, April 1969.

3. Department of the Army Field Manual 8-9, NATO Handbook on Medical Aspects of NBC Defense Operations, AMedP-6, August 1973.

4. Department of the Army Field Manual 100-5, Operations, July 1976.

5. Douglass, Joseph D., Jr., The Soviet Theater Nuclear Offensive, Vol. 1, Studies in Communist Affairs.

6. Defense Intelligence Agency Publication DST-1640H-040-76, Nuclear Defense Equipment-Communist Countries (U): (S)

7. Nuclear Notes, Numbers 1 - 6, US Army Nuclear and Chemical Agency, Ft Belvoir, VA.

   No. 1. The Electromagnetic Pulse, June 1974
   No. 2. The Army Nuclear Survivability Program, October 1974
   No. 3. The New Nuclear Radiation Casualty Criteria, May 1975
   No. 4. Nuclear Blackout of Tactical Communications, August 1974
   No. 5. Rainout, December 1976
   No. 6. A Primer on Nuclear Weapons Capabilities, June 1977

APPENDICES

APPENDIX A

# DEPARTMENT OF THE ARMY

**U.S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND**
**WASHINGTON, D.C. 20314**

REPLY TO
ATTENTION OF:

SGRD-PL

MEMORANDUM FOR RECORD

SUBJECT: First Meeting - ASAP Ad Hoc Group on Nuclear Protection for the Soldier

1. The first meeting of the Ad Hoc Group on Nuclear Protection for the Soldier was held at 0900 hrs, 3 June 1977 in the Commander's Conference Room, Armed Forces Radiobiology Research Institute (AFRRI), Bethesda, MD.

2. Attendees:

(a) Committee:

| | |
|---|---|
| Dr. Chris J. D. Zarafonetis | Chairman |
| Dr. Herbert L. Ley, Jr. | Member |
| Dr. Richard L. Wagner, Jr. | Member |
| LTC William E. Woodward | Military Staff Asst. |

(b) Briefers:

| | |
|---|---|
| COL LaWayne R. Stromberg | AFRRI |
| COL D. W. McIndoe | AFRRI |

3. Proceedings:

a. Dr. Zarafonetis introduced the group and discussed the terms of reference. He emphasized that the group was to investigate all aspects of protection for the soldier in the nuclear environment and make recommendations to the Army Scientific Advisory Panel for "hardening" man against the adverse effects of nuclear radiation.

b. Dr. Stromberg discussed the role of AFRRI in the protection of the soldier. His discussion included an historical summary of the Defense Nuclear Agency (DNA) from the time of the Manhattan Project thru the formation of the Armed Forces Special Weapons Project (AFSWP) and the Atomic Energy Commission. The Defense Atomic Support Agency (DASA) replaced AFSWP in 1959 and subsequently became the DNA in 1971. AFRRI was

VANGUARD OF FREEDOM UNITED STATES ARMY



AMERICAN REVOLUTION BICENTENNIAL 1776-1976 established as an element of the Navy in 1962 and was transferred to DASA in 1964. The mission of the AFRRI shall be to conduct scientific research in the field of radiobiology and related matters that are essential to the medical support of the Department of Defense. The AFRRI is a DOD laboratory which responds to requirements of all three services. As an example, the Army, through the Army Nuclear Agency (ANA) prepares annually the Qualitative Research Requirements (QRR), a document which includes biomedical requirements. Other services have similar vehicles. All requirements are presented to AFRRI at the long range planning meeting in the spring of each year. AFRRI evaluates these requirements, sets priorities and then establishes work units or contracts for the work. AFRRI also responds directly to the requirements of DNA and from the Board of Governors. At present there is only one extramural contract. All other research is conducted in house. Except for one small project at the School of Aerospace Medicine no other radiobiology research is being conducted within the DOD. There is one project in radiation research being conducted at the US Army Medical Institute of Infectious Disease but funded by the US Army Medical Research and Development Command. The response AFRRI makes to requirements may be technical reports, articles in the open literature, the AFRRI annual report or the data base of DD Forms 1498 from the Defense Documentation Center.

c. Recent evidence indicates that some of the bioeffects data now recorded may be in error. It is apparent that man will be incapacitated at doses lower than previously suggested, but this incapacitation may not be immediate. The severity of the incapication is dose dependent. Any protection which may reduce the effective dose or delya the onset of symptoms will be beneficial. It has been demonstrated that even a delay of 10 minutes may be essential for mission completion. AFRRI is now looking at bioeffects of doses below 1000 R. Evidence indicates this to be the area of prime concern. Research has been conducted on a wide variety of animal species with major emphasis on the Rhesus monkey. It now seems that the Rhesus was a poor choice because of a unique mechanism of histamine release demonstrated by that animal. As new methods of research and different animal models emerge, it becomes necessary to replicate former experiments to validate the data.

d. With renewed concern about the use of chemical agents, there is now a concerted effort to study the combined effects of chemical/nuclear agents on biological systems. The AFRRI has an ad hoc group currently studying such combined injuries.

e. A major issue for commanders in the field is troop safety. Troop Safety Criteria, for protection of our troops from effects of our weapons, needs to be re-studied. Fallout and subsequent operations in and around contaminated areas presents other very realistic problems. Several questions, listed below, relating to troop safety, and troop protection were posed. No quick answers were readily available.

1. How do we protect our troops from 100 R produced by our own weapons?

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2. Can we provide protection to air crews flying thru radioactive clouds?

3. What protection can be afforded our troops moving thru our fall-out?

4. Are our units in Europe protected?

5. Do these units have any protected relocation areas?

f. It was pointed out at this meeting that over the past several years the Department of Defense has minimized research and training in all areas of NBC defense. The Surgeon General of the Army recently stated at a meeting of the Board of Governors, AFRRI, that corporate money for such matters was no longer available. The training programs which were readily available during the 60's have disappeared and he noted that it is now imperative that these programs be re-established. He requested that AFRRI establish such a program for military physicians.

g. There was general discussion about documents pertaining to radiation protection which revealed that there are numerous manuals addressing this subject. Included are TM8-215, Nuclear Handbook for Medical Service Personnel; FM 8-9, NATO Handbook on the Medical Aspects of NBC Defensive Operations; and FM 100-5 Operations, and Minutes of the 142d meeting of the JMRC. It was requested that members of the group be provided copies of each of these as well as the AFRRI annual report and other pertinent documents which might be available. Dr. Stromberg stated that Dr. Lushbaugh, Oak Ridge National Laboratory, had data on approximately 2000 accident victims which might be beneficial to the group.

h. The following list of pertinent research projects which would be of benefit to DOD was compiled. There was a discussion on the need to do more research in several areas:

1. Perform studies in the $LD_5$ range.

2. Make further determinations for troop safety and collateral damage.

3. Provide protection against endotoxin.

4. Protect against infection in conjunction with radiation injury.

5. Provide better, more comprehensive training in NBC defense for the troops.

6. Coordinate with Human Engineering Laboratory (HEL) and the Army Research Institute (ARI) to evaluate human factors.

7. Concentrate our efforts at the 1000R dose and lower range.

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8. Evaluate current therapy measures.

9. Study marrow transplant and the related problems of pulmonary failure.

10. Through intelligence channels, determine the organization and doctrine for NBC defense, and protection affored troops from WARSAW Pact.

11. Provide an integrative dosimeter that will not be discarded and which cannot be altered by the soldier.

12. Provide medical training for military physicians to handle casualties resulting from NBC operations.

13. Study the data available on accident victims in an effort to make better predictions.

WILLIAM E. WOODWARD
LTC, MSC
Military Staff Assistant

**DEPARTMENT OF THE ARMY**
**U.S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND**
**WASHINGTON, D.C. 20314**

REPLY TO
ATTENTION OF:

SGRD-PL

MEMORANDUM FOR RECORD

SUBJECT: Second Meeting - ASAP Ad Hoc Group on Nuclear Protection for the Soldier

1. The second meeting of the Ad Hoc Group on Nuclear Protection for the Soldier was held on 28-29 July 1977 at the Forrestal Building, Washington, DC.

2. Attendees:

(a) Committee:

| | |
|---|---|
| Dr. Chris J. D. Zarafonetis | Chairman |
| Dr. Herbert L. Ley, Jr. | Member |
| Dr. Donald M. Kerr, Jr. | Member |
| LTC William E. Woodward | Military Staff Asst. |

(b) Briefers:

<u>28 Jul</u>

| | |
|---|---|
| Mr. Frank O'Leary | Foreign Science & Technology |
| Mr. Max Klugerman | Center (FSTC) |
| Mr. Keywood Cheves | FSTC |
| CPT Michael E. Montie | Defense Nuclear Agency (DNA) |

<u>29 Jul</u>

| | |
|---|---|
| LTC David E. Davidson | WRAIR |
| Dr. Thomas R. Sweeney | WRAIR |
| Dr. Melvin H. Heiffer | WRAIR |
| Dr. Takeru Higuchi | Univ. of Kansas |
| Dr. David P. Jacobus | Jacobus Pharmaceutical Co. |

(c) Observers:

| | |
|---|---|
| COL Charles M. Dettor | USAMBRDL |
| COL Phillip E. Winter | USAMRDC |
| Mr. Ronald L. Adams | MIIA |
| Mrs. Carolyn E. Stettner | MIIA |
| Mr. Richard L. Torian | MIIA |

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SUBJECT: Second Meeting - ASAP Ad Hoc Group on Nuclear Protection for the Soldier

| | |
|---|---|
| LTC G. Dunham | ACSI |
| CPT Bruce Leibrecht | USAMRDC |
| MAJ Wallace Dean | MIIA |
| CPT Jurgen Von Bredow | WRAIR |
| Miss Marie M. Grenan | WRAIR |
| LTC (P) Kenneth E. Kinnamon | USUHS |
| COL Gale Demaree | WRAIR |

3. Proceedings:

(a) Three staff members of the Foreign Science and Technology Center (FSTC) presented classified briefings on the NBC threat and capability of potential enemies of the United States.

Mr. Keywood C. Cheeves discussed the potential of offensive use of tactical nuclear weapons against US forces as well as the defensive capabilities of others should the US defend with such weapons.

Mr. Klugerman presented an intelligence overview of the potential use of chemical weapons/agents against US forces. There was an in-depth discussion of the offensive and defensive capabilities of potential enemies with respect to the use of chemical weapons, organization and training for chemical operations, and decontamination procedures and equipment available to these forces. There was some discussion of the comparative capability and organization of US forces for similar operations.

Mr. Frank O'Leary continued the program with a similar discussion of the use of biological agents on the battlefield during any future conflict. The potential for use of biological agents in future conflicts is more difficult to examine since the arena for conflict may be a determining factor, the mode of delivery is more sensitive to the operation, and the objectives of the operation may preclude the use of biologicals.

Due to the classification of the FSTC discussion and the travel requirements of the speakers, it was necessary to defer questions. Representatives from the Medical Intelligence and Information Agency (MIIA) were available for questions after this briefing.

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SUBJECT: Second Meeting - ASAP Ad Hoc Group on Nuclear Protection for the Soldier

(b) CPT Michael Montie, Headquarters, Defense Nuclear Agency (DNA), presented an overview of the organization and functions of that agency. This discussion covered, in a broad manner, the overall functions of DNA and did not deal with specific functions related to protection of maneuver forces. It was noted that the Armed Forces Radiobiology Research Institute (AFRRI), the research laboratory for DNA, is the only Department of Defense laboratory addressing radiation biology, dosimetry, or biomedical effects of energy radiation.

(c) On the following day, the group met with members of the Division of Medicinal Chemistry, Walter Reed Army Institute of Research (WRAIR) to discuss the former WRAIR program in chemoprophylaxis against effects of ionizing radiation. Attached is a modified staff study discussing alternatives in the development of a chemical compound to protect against ionizing radiation with a recommendation for possible future programming, a flow chart to show time requirements and milestones in development, and cost analyses for two alternatives in the staff study. (Incl 1)

Dr. Thomas Sweeney presented a historical review of the chemical synthesis program, emphasizing the major classes of compounds and their relative effectiveness in protection. LTC David Davidson presented the review of the biological testing of these compounds, showing the protective capabilities in differing animal species as well as differing routes of administration of drugs. It is important to note that the major problem has been the inability to produce a compound which is absorbed orally in large animals.

Dr. Melvin Heiffer presented the historical review of pharmacological problems encountered in testing compounds and the recent pharmacologic breakthrough in formulation which may allow for oral absorption of radioprotective compounds. Dr. Heiffer then introduced Dr. Takeru Higuchi, a Defense contractor from the University of Kansas who has been instrumental in this breakthrough. Dr. Higuchi discussed the methodology of this pharmaceutical formulation and indicated that it seemed feasible to consider the antiradiation compounds toward this end.

Dr. David P. Jacobus, Jacobus Pharmaceutical Company, who was formerly at the WRAIR, discussed the potential for sulfur compounds as antiradiation agents. Dr. Jacobus is an expert in medicinal uses of sulfur compounds and maintains a high degree of interest in the antiratiation program.

1 Incl

William E. Woodward
WILLIAM E. WOODWARD
LTC, MSC
Military Staff Assistant

"Hardening the Soldier to the Nuclear Battlefield Environment"

Problem

The Department of Defense does not have a radioprotectant drug today that could be manufactured, distributed to troops in the field, and used in a practical manner in the event of a nuclear attack. The Army program on Prophylaxis and Therapy Against Ionizing Radiation was designed to develop prophylactic and/or therapeutic measures which would prevent or reduce the incapacitating effects of ionizing radiation on U.S. troops in the event Nuclear Weapons were used on the battlefield. While medicinal agents were developed that effectively protected subhuman primates against ionizing radiation when these drugs were administered intravenously, the program was terminated before an orally effective drug could be developed that would offer protection.

Assumptions

1. Nuclear weapons may be used in certain potential battlefields and our possession of radioprotectants can serve to deter armed aggression by a potential enemy.
2. The Army has a requirement for a practical and effective radioprotective agent with highest DCS OPS Priority assigned to the Medical Corps (Army Science and Technology Objective Guide, FY 1978).
3. Drugs effective in protecting subhuman primates will be effective in protecting man if appropriately delivered. Using modern techniques, better oral absorption can be obtained in monkeys and man.

Incl 1

Facts Bearing on the Problem

1. The tactical scenario for war in Europe published in 1971 indicated the following: Fully deployed, dispersed, and reinforced Army units in Europe would constitute 732,235 troops. Over 700,000 of these troops would be blast survivors in the event of nuclear attack. Depending on the type of burst, up to 300,000 of these survivors would be exposed to radiation, half of whom would receive fatal doses. Radioprotectant drugs with dose reduction factors of 2 would reduce fatalities by 15%, or 22,000 soldiers, and drugs with dose reduction factors of 3 would reduce this by 22%, or 34,000 soldiers. The number of survivors could be further increased by effective physical protection. (DADA17-70-C-0068, Final Report, October 1971.)

2. Incapacitation due to radiation sickness from sublethal radiation would be significantly reduced by the appropriate administration of an antiradiation agent.

3. Antiradiation agents also prevent or delay the immediate complete neurological incapacitation which normally would be expected to follow if soldiers were exposed to supralethal radiation, thus enabling them to complete short term retaliatory missions. (J.C. Sharp, et al., "The Radio-Attenuating Effects of n-Decylaminoethanethiosulfuric Acid in the Rhesus Monkey," 1968.)

4. Drugs were developed by the U.S. Army in the 60's that protected subhuman primates from ionizing radiation when these agents were administered intravenously (dose reduction factors were not calculated). These drugs were not effective when administered orally.

5. One of these drugs (WR 2721) provided a dose reduction factor of 2.7 when administered parenterally to mice.

6. It may now be possible to achieve effective protection with oral dosage forms. Technology in the field of experimental formulation to improve oral bioavailability now exists. The methods of formulating medicinal chemicals and producing prodrugs and our ability to exploit these processes has markedly improved since the program was terminated in 1972. There are current USAMRDC programs utilizing these techniques.

7. The amounts of these drugs in our current inventory are insufficient to support the proposed research and development effort; however, the methods of synthesis of these drugs are known, allowing for pilot plant production at a relative low cost.

8. WRAIR does not have a radiation facility currently available to support efficacy studies of these new formulations in primates. Experienced personnel are still present in WRAIR.

9. The bioavailability of drugs when administered orally to man can be confirmed in an existing Phase I facility.

10. IND's on three compounds have already been filed. They are WR 2721, WR 638 and WR 2529.

Discussion

It would appear that the Army has the following choices:

Alternative 1: Do nothing at this time.

Advantages: 1. No commitment of resources.

Disadvantages: 1. This would delay the delivery of a practical radioprotectant to the field indefinitely.

Alternative 2: Start a major radioprotectant drug development program.

Advantages: 1. Superior radioprotectants may be identified.

Disadvantages: 1. Most costly of all alternatives.

2. Personnel and other resources would have to be diverted from existing missions.

Alternative 3: Stockpile existing radioprotectants for intravenous use in an emergency.

Advantages: 1. Little additional work needs to be performed.

Disadvantages: 1. This is not a very practical method of administering a drug in the field.

2. Storage and distribution of sterile dry products, sterile water and syringes would create a logistical problem.

Alternative 4: Initiate a limited program to develop an oral dosage form from one or more existing drugs.

Advantages: 1. The probability of achieving this objective is high.

2. The cost is not prohibitive and resources are committed for short terms only.

3. The expertise presently exists both in the Army intramural and extramural programs.

4. A practical oral radioprotectant could also be used to protect civilian populations.

Disadvantages: 1. Diverts personnel and resources from existing missions.

Considering worldwide nuclear capabilities of many countries, we can ill-afford not to try to develop a practical radioprotectant. Our NATO allies in the field (AC225/Panel VI EGEC) have minor capabilities for drug development and are unlikely to produce an effective solution to the problem within the foreseeable future.

Conclusion:

Alternative 4 is the least costly and has the highest probability of early success.

Recommendation:

Action be initiated to implement Alternative 4 as soon as possible.

# DEPARTMENT OF THE ARMY

**U.S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND**
**WASHINGTON, D.C. 20314**

REPLY TO
ATTENTION OF:

SGRD-PL

MEMORANDUM FOR RECORD

SUBJECT: Third Meeting - ASAP Ad Hoc Group on Nuclear Protection for the Soldier

1. The third meeting of the Ad Hoc Group on Nuclear Protection for the Soldier was held on 11-12 August 1977 at the Nevada Operations Office of the Energy Research and Development Administration (ERDA), Las Vegas, NV.

2. Attendees:

a.

| | |
|---|---|
| Dr. Chris J. D. Zarafonetis | Chairman |
| Dr. Donald M. Kerr, Jr. | Member |
| Dr. Richard Wagner, Jr. | Member |
| LTC William E. Woodward | Military Staff Assistant |

b. Participants:

| | |
|---|---|
| Dr. Roger Ray | Nevada Operations Office, ERDA |
| Dr. Savino Cavender | Nevada Operations Office, ERDA |
| Dr. Payne Harris | Los Alamos Scientific Laboratory |
| Mr. Harry Jordan | Los Alamos Scientific Laboratory |
| Mr. Donald Blumenthal | Lawrence Livermore Laboratory |

3. Proceedings:

a. Dr. Roger Ray presented an overview of the cleanup activities on Eniwetok. He showed slides of the operation and discussed the problems encountered in that job. He further discussed the aerial surveys of the island and showed maps and overlays which outlined the contour lines of the contamination as detected in the survey. There was general discussion about the response of the military in general and the Army in particular to this particular cleanup operation. There is inadequate command/control of the health physics problems, and the overall organization of the activity appears in disarray. Each service has an individual element with no one service charged with overall command. The Army has one radiation safety officer assigned there but the Army Service Element has no organic health and safety resources to work in the operation. There is very little training provided to the personnel. The Air Force troops are given 40 hours of instruction in Hawaii prior to arrival on Enewetak, but that is insufficient. The troops are afraid of the hazard and, because of the lack of coordination,

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SUBJECT: Third Meeting - ASAP Ad Hoc Group on Nuclear Protection for the Soldier

different groups are equipped differently for similar operations. There is an overall fear of personal injury, e.g., leukemia and sterility, resulting from exposure to the radiation contamination which is present.

b. Two contractors, Mr. J. P. Stewart and Mr. Jack Doyle, reviewed the development and operation of the motorized survey vehicle, the IMP, which can provide area monitoring on the ground using monitors on a 30 foot boom on the vehicle. The IMP is used by ERDA for monitoring contamination and locating sources of radiation. It, in conjunction with aerial surveys, can be used in the event of terrorist activities which may use radiation devices. There was a recent training exercise in Idaho for the purpose of using, testing and evaluating these methods of survey and the response capability of government agencies in emergencies.

c. Mr. Harry Jordan discussed a list of concerns which indicate a general lack of emphasis within the Department of Defense (DOD) in preparation for hostilities involving the use of nuclear weapons. This list is attached as Inclosure 1. He further discussed a dosimetry device which was patented in 1966 but which has not been adopted for general use. This device could possibly be valuable assistance in the field. The patent and description are attached as Inclosure 2.

d. There was discussion concerning the apparent overall apathy of the DOD over the past 8-10 years regarding devense against nuclear weapons. Dr. Payne Harris and Dr. S. Cavender, both formerly involved with DOD aspects of nuclear weapons defense, discussed the historical milestones of DOD in nuclear weapons defense and development. They were able to review the military posture of the 60's and compare that period to the current military preparedness for nuclear conflict. Both Dr. Harris and Dr. Cavender showed great concern over the fact that the Army has not kept up its expertise in nuclear weapons effects.

e. There was discussion among members of the Ad Hoc Group as to how the Army could make use of the new methods of area survey, aerial and ground, which have been developed in recent years. The sensitivity of these surveys would allow field commanders to have almost immediate battlefield contamination information. The areas of conflict could then be mapped to allow troops to either avoid areas of significant contamination or to traverse these areas rapidly. These maps and the survey information could be of value to field commanders as planning tools for subsequent operations.

William E. Woodward

2 Incl
as

WILLIAM E. WOODWARD
LTC, MSC
Military Staff Assistant

# DEPARTMENT OF THE ARMY

**U.S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND**
**WASHINGTON, D.C. 20314**

REPLY TO
ATTENTION OF:

SGRD-PL

MEMORANDUM FOR RECORD

SUBJECT: Fourth Meeting - ASAP Ad Hoc Group on Nuclear Protection for the Soldier

1. The fourth meeting of the Ad Hoc Group on Nuclear Protection for the Soldier was held on 25-26 August 1977 at the Lawrence Livermore Laboratory, Livermore, CA.

2. Attendees:

(a) Committee:

| | |
|---|---|
| Dr. Chris J. D. Zarafonetis | Chairman |
| Dr. Donald M. Kerr, Jr. | Member |
| Dr. Herbert L. Ley, Jr. | Member |
| Dr. Richard L. Wagner, Jr. | Member |
| LTC William E. Woodward | Military Staff Assistant |

(b) Briefers:

| | |
|---|---|
| Dr. Charles N. Davidson | US Army Nuclear & Chemical Agency |
| Mr. Donald K. Blumenthal | Lawrence Livermore Laboratory |
| MAJ T. Tobin | Lawrence Livermore Laboratory |
| Dr. E. Mendelsohn | Lawrence Livermore Laboratory |
| Mr. Robert Gard | Lawrence Livermore Laboratory |
| Mr. K. Froeschner | Lawrence Livermore Laboratory |
| Dr. Eugene Goldberg | Lawrence Livermore Laboratory |
| Dr. K. Joseph Knox | Lawrence Livermore Laboratory |

(c) Observers:

| | |
|---|---|
| Dr. Marve Gustavson | Lawrence Livermore Laboratory |
| Dr. George L. Voelz | Los Alamos Scientific Laboratory |
| Dr. Richard R. Sandoval | Los Alamos Scientific Laboratory |

3. Proceedings:

a. Dr. Charles Davidson, US Army Nuclear and Chemical Agency (USANCA), formerly the Army Nuclear Agency, gave a briefing on the roles and missions of the USANCA. He discussed the interaction of his agency and the Defense Nuclear Agency, the Air Force and the Navy. He explained the mechanisms of development of the Qualitative Research Requirements, how these requirements are submitted within the Army, and what responses are made toward meeting these requirements. He included a comprehensive discussion on shielding provided by US armored vehicles with comparative data on US armor and other armored vehicles. He showed the group a new videotape, produced by USANCA, illustrating shielding properties of armored vehicles. This videotape may be incorporated as a training aid in the TRADOC schools. It is but one of a series of videotapes to be produced and used as training aids.

b. Mr. Don Blumenthal gave a general briefing on weapons effects which will be encountered in the event nuclear weapons are used on the battlefield. The discussion centered around tactical weapons with little emphasis placed on strategic uses of high yield weapons. There was some general discussion of weapons incorporating the enriched radiation phenomena and the overall effects of such weapons. There are still some major questions to be answered about these weapons and the differences in defending against their use when compared to other types of nuclear devices.

c. MAJ Tobin's briefing on effects of rainout indicated the importance of knowing and predicting the weather during the use of nuclear weapons. Precipitation will play an important role in the distribution of fallout from nuclear weapons. He pointed out that considerable improvement has been made in meteorological prediction and that this can have a major impact on the planning aspects of using nuclear weapons as well as predicting effects while defending against their use. It was suggested that the military study these newer methods and possibly incorporate them into the intelligence gathering network.

d. Dr. Mendelsohn's presentation on shielding considerations was particularly aimed at protecting troops in the field, newer and more accurate means of calculating protection and/or transmission coefficients of various shielding materials, buildings, and vehicles, and the benefits to be derived from field fortifications which the individual soldier can provide for himself. Because of the general elimination of training for nuclear defense in recent years, a recommendation to once again incorporate this training in DOD schools was voiced.

e. There were two demonstrations made for the group. The first was led by Mr. Gard in the DWEEPS program illustrating the means of using the computer to establish a battlefield and then, through a selection process,

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SUBJECT: Fourth Meeting - ASAP Ad Hoc Group on Nuclear Protection for The Soldier

determine the type of weapon(s) to be employed and, playing the battle at the console, to evaluate the effects of the weapons, casualties produced and area of terrain affected by the weapons. Members of the Ad Hoc Group were allowed to play the game by making weapons selections at the console and then see the printouts showing the casualties. There was a visual display on the console showing the extent of damage caused by the weapons. The second, Project JEREMIAH, was discussed by Mr. Froeschner and displayed on a large screen. This is a computer application of conventional warfare simulating a battlefield situation and showing the effects of a two sided exercise using conventional weapons preprogrammed into the game. The demonstration used was one showing the employment of ground to ground missles against ground troops and armor.

1 Incl
1. Agenda

WILLIAM E. WOODWARD
LTC, MSC
Military Staff Assistant

# DEPARTMENT OF THE ARMY
## U.S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND
## WASHINGTON, D.C. 20314

REPLY TO
ATTENTION OF:

SGRD-PL

MEMORANDUM FOR RECORD

SUBJECT: Fifth Meeting - ASAP Ad Hoc Group on Nuclear Protection for the Soldier

1. The fifth meeting of the Ad Hoc Group on Nuclear Protection for the Soldier was held on 5-6 October 1977 at the Armed Forced Radiobiology Research Institute (AFRRI), Bethesda, MD.

2. Attendees:

(a) Committee:

5 Oct

| | |
|---|---|
| Dr. Chris J. D. Zarafonetis | Chairman |
| Dr. Herbert L. Ley, Jr. | Member |
| LTC William E. Woodward | Military Staff Assistant |

6 Oct (Working Session)

| | |
|---|---|
| Dr. Chris J. D. Zarafonetis | Chairman |
| Dr. Richard Wagner | Member |
| LTC William E. Woodward | Military Staff Assistant |

(b) Briefer (5 Oct):

COL D. W. McIndoe — AFRRI

(c) Participant (6 Oct ):

Mr. Donald K. Blumenthal — Lawrence Livermore Lab

3. Proceedings:

a. Since the first meeting of the Ad Hoc Group, 3 Jun 77, Dr. McIndoe has become the Director of the AFRRI. The change in directors was a result of the unexpected retirement of Dr. L. R. Stromberg. Dr. McIndoe discussed with the committee his perception of the mission of the AFRRI, the means by which he expects to address this mission and the areas of research he hopes to emphasize in the near future.

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SUBJECT: Fifth Meeting - ASAP Ad Hoc Group on Nuclear Protection for the Soldier

b. Dr. McIndoe sees a definite need to improve dosimetry for the field soldier. For the field commander, it is of extreme importance to have knowledge of radiation exposure of individuals for determination of capability in future operations. From a medical standpoint, it is necessary to have a means of predicting absorbed doses of radiation for planning the medical impact on future operations which may produce radiation casualties. There may well be a need for providing more than one type of individual dosimetry. There have been discussions, also, about the feasibility of providing dosimetry which cannot be directly interpreted by the individual. There was general discussion among members of the Ad Hoc Group and Dr. McIndoe in the areas of therapy for the radiation casualty, combined injuries, ranges of effects, dose response curves, and the general lack of confidence in extrapolation of animal data to man.

c. Dr. Thomas Contreras presented data on his research in blood preservation and elutriation of white cells. There has been general interest in these areas, especially as a therapeutic means, e.g., bone marrow banks and platelet transfusions. It has been suggested that studies be initiated to determine the validity and feasibility of such therapeutic measures.

William E. Woodward
WILLIAM E. WOODWARD
LTC, MSC
Military Staff Assistant

APPENDIX B

PROTECTION OF PERSONNEL IN TACTICAL NUCLEAR ENVIRONMENTS

I. Introduction

Both the United States and the Soviet Union possess a variety of nuclear weapons and delivery systems which are available for use in Western Europe. (See Appendix A, "The Military Balance 1977-1978," p. 77 ISSS, London.) NATO theater nuclear weapons number about 7000 with yields predominantly in the low kiloton range. The 3500 estimated Soviet warheads are in the high kiloton to megaton range.

Reviews of Soviet equipment and doctrine suggest that nuclear attacks may be used to "soften-up" areas dedsignated for "break-through" operations and to attack priority rear area targets such as nuclear storage facilities and headquarters units. Also, the sophisticated level at which Soviet forces are trained and equipped in chemical warfare indicates that they are prepared to survive and effectively wage war in an integrated chemical-nuclear environment. Appendix B is a recent comparison between NATO and Soviet/Warsaw Pact forces (Armed Forces Journal, September 1977, p. 30) and provides a "raw numbers feeling" for the military odds NATO faces as well as emphasizing NATO's need to develop and implement field expedient survivability techniques as a means of countering any future nuclear-conventional-chemical integrated threat.

II. Personnel Casualty Mechanisms

Immediate casualties are caused by three distinct aspects of nuclear weapons:

- thermal radiation can cause serious burns at levels as low as 2-5 $cal/cm^2$;
- blast and dynamic wind can hurl missiles and will destroy many structures at overpressures of 2-10 psi;
- nuclear radiation will cause immediate incapacitation at 3000-10,000 rads.

In addition to the immediate effects, long term effects include:

- nuclear radiation of $>$ 500 rads will ultimately cause death;
- fallout and rainout which can contaminate large areas with radioactive debris.

A Corps level simulation employing up to 28 weapons in the 100 kt yield range is illustrated in figure 1. It suggests that thermal protection of $\sim$50 $cal/cm^2$ is required to reduce vulnerability to levels comparable with blast and radiation.

These simulations assume that the attack was a "surprise" and that no one was able to "take shelter" during the period of about one second duration of the thermal and nuclear radiation, or, prior to arrival of the blast.

The general trends of variation with weapon yield of these effects is illustrated in figure 2 for weapons in the range 1 kt - 1 Mt. Thermal radiation effects dominate the threat to exposed personnel at yields greater than about 10 kt.

## III. Field Expedient Protective Measures

For avoidance of all three effects: thermal burns, blast, and nuclear radiation, the single most important field expedient measure is effective protection against thermal radiation. Beyond the "core" of approximately a 2 km radius from a 100 kt low air burst, the predominate casualty mechanism is thermal burns of exposed personnel. Burn casualties require extensive medical care, thus having a major impact on combat effectiveness for corps casualty levels of 20-30%.

Conversely, shielding against thermal flash burns is the easiest to achieve since a thin layer of opaque material can intercept the thermal "light" flash - even though the layer may ultimately be destroyed. Even heavy smoke, rain or fog would provide substantial protection. Forests or heavy vegetation would also be effective in reducing the thermal flux. However, ignition of these materials may be a serious problem. In a tactical environment it is likely that any given target location will be alerted by a prior nuclear detonation at a more distant location. This suggests that a large proportion of a corps level force could take cover from a pulse of weapons - if such shelter is nearby. For the larger yield weapons the thermal flash duration of a weapon is significant - about one second for 100 kt and five seconds at 1 Mt. Thus a prompt "reflex" action such as falling prone and shielding face and hands is advisable. Individual protective clothing might provide a factor of 3-5 in thermal flux tolerance. It might also be worthwhile to consider "thermal modifications" of shelter halves, sleeping bags, gas masks and gloves.

Group protection is probably a more practical field expedient than individual protection. This appears to be the kind of thinking behind the Soviets' BMP mechanized infantry combat vehicle. However, simple thermal shelters, such as might be put on troop-carrying trucks, require much less shielding than required for small arms fire.

One concept is to replace certain existing vehicle canvas with a cover which could be easily removed to provide a local group thermal shelter. For example, it might take the form of an aluminum or fiberglass half-cylinder about 8 feet in diameter and 12 feet long. When properly anchored, and perhaps covered with dirt, it could also help shield against missiles driven by blast dynamic winds as well as conventional shell fragments. Depending on availability of earth moving equipment and/or time for manual trenching, such shelters could facilitate construction of "bunker complexes." Protection to blast levels of 10 psi and factors of 5 for radiation appear achievable.

Appendix C gives another example of a field expedient concept - an individual automatic smoke system for protection against thermal flash burns. Such concepts are speculative but they illustrate the possibility of relatively simple protective devices.

## IV. Organizational and Procedural Factors

Even without equipment changes, it seems probable the nuclear vulnerability of personnel can change by a factor of two or three as a result of options in behavior. One way to maintain operable personnel is to keep them sheltered. Suppose one thinks in terms of well dug-in combat positions at a density such as in the Korean War, but being subjected to nuclear attacks. Because of troop safety considerations, the attacker cannot be very close at the actual time of the burst. Thus, if one keeps most of the people sheltered most of the time they can survive to fight when the conventional forces attack. The procedure might be implemented as a maximum allowable number being "outside" at any time except when actually required.

Personnel in vehicles require special attention to field expedient survival procedures. Sitting in the back of an open moving truck is probably the worst possible location in that:

1) You get maximum thermal radiation with minimum chance of getting prone on the ground by reflex action.

2) The blast effect may roll the truck over at levels which wouldn't otherwise be much threat to an isolated individual. (It probably doesn't make much sense to put seat belts, air bags and roll bars in the truck.)

3) The truck driver may receive enough exposure through the windows to lose control and wreck the truck.

A procedural policy when attack is imminent, requiring gloves, gas masks and no exposed skin - just as in anticipation of chemical attack - for drivers would lessen the problem.

It is apparent that there are, indeed, a number of inexpensive expedient methods that can be developed and implemented to mitigate the effects of nuclear weapons, but more importantly our soldiers must be trained in their effective use to the point of becoming a sixth sense. Once this is achieved survivability becomes both attainable and believable.

## V. Summary

The current perspective of the nuclear battlefield has been unduly influenced by a mirror-imaging of our tactical nuclear stockpile of low yield weapons. This has led to lack of concern and respect for thermal as a casualty mechanism.

Field expedient protective measures for individuals and groups could contribute dramatically to force survivability in both the nuclear and intense conventional environments.

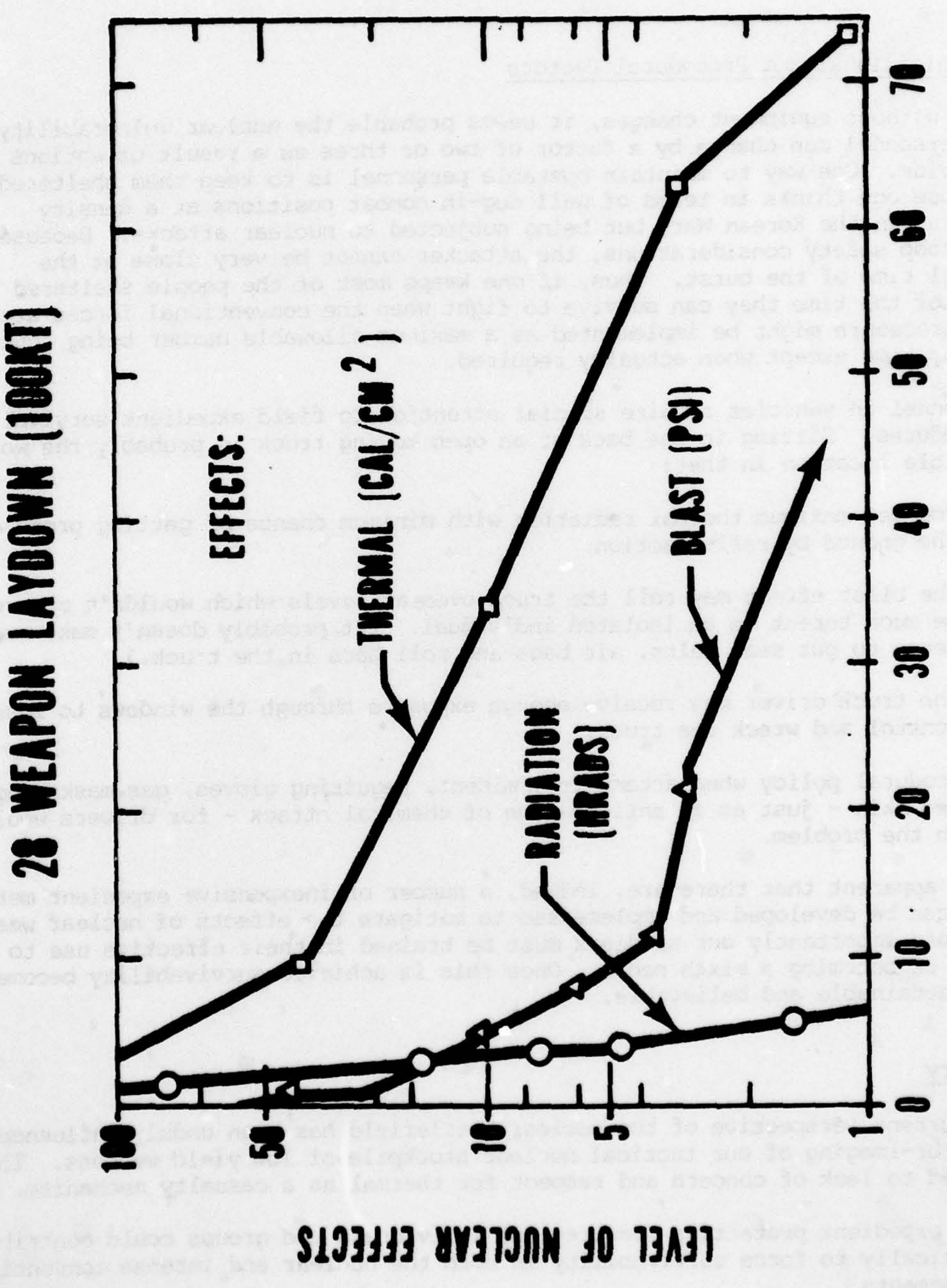
28 WEAPON LAYDOWN (100KT)
EFFECTS:
THERMAL (CAL/CM 2)
RADIATION (KRADS)
BLAST (PSI)
U.S. CORPS PERSONNEL AFFECTED (%)
0
10
20
30
40
50
60
70
LEVEL OF NUCLEAR EFFECTS
100
50
10
5
1

Fig. 1

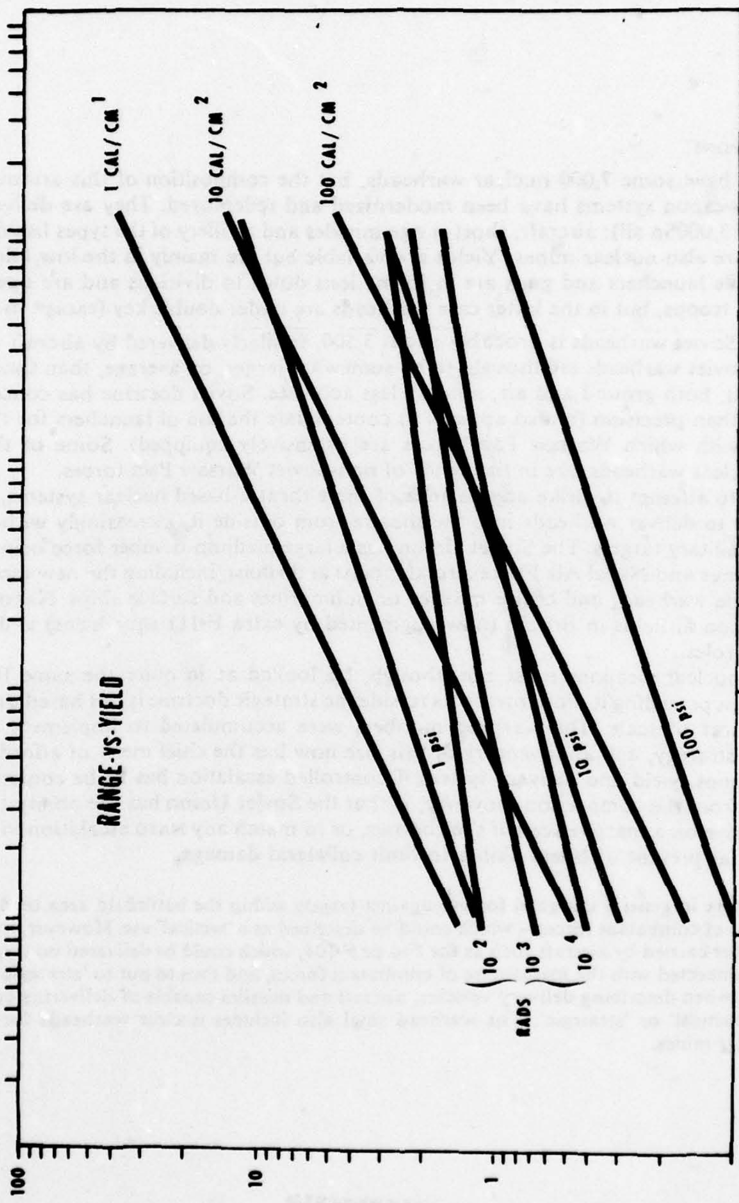
RANGE-VS-YIELD
1 CAL/CM²
10 CAL/CM²
100 CAL/CM²
1 psi
10 psi
100 psi
RADS
10²
10³
10⁴
YIELD(KT)
10
10²
10³
RANGE KM
100
10
1

Fig. 2

THEATRE NUCLEAR WEAPONS

NATO has been said to have some 7,000 nuclear warheads, but the composition of this armoury has undoubtedly changed as weapon systems have been modernized and redeployed. They are deliverable by a variety of vehicles (over 3,000 in all): aircraft, short-range missiles and artillery of the types listed in Table 1 on pp. 77–81.[m] There are also nuclear mines. Yields are variable but are mainly in the low kiloton range. The ground-based missile launchers and guns are in formations down to divisions and are operated both by American and allied troops, but in the latter case warheads are under double key (except in the case of France). The figure for Soviet warheads is probably about 3,500, similarly delivered by aircraft and missile systems (see Table 1). Soviet warheads are thought to be somewhat larger, on average, than those of NATO, and the delivery systems, both ground and air, notably less accurate. Soviet doctrine has concerned itself more with area targets than precision (it also appears to contemplate the use of launchers for the delivery of chemical weapons, with which Warsaw Pact forces are extensively equipped). Some of the delivery vehicles, but not the nuclear warheads, are in the hands of non-Soviet Warsaw Pact forces.

It is not appropriate to attempt to strike any balance of these theatre-based nuclear systems, since each side also has the ability to deliver warheads into the theatre from outside it, increasingly with accuracies and yields suitable for military targets. The Soviet Union has a large medium-bomber force being equipped with *Backfire*; Long-Range and Naval Air Force aircraft; IRBM and MRBM, including the new mobile SS-20, with its accurate multiple warhead; and cruise missiles on submarines and surface ships. NATO has strike aircraft on carriers and on airfields in Britain (now augmented by extra F-111 squadrons) and could use SLBM for certain theatre roles.

This comparison of nuclear weapons must not, though, be looked at in quite the same light as the conventional comparisons preceding it, since on the NATO side the strategic doctrine is not based on the use of such weapons on this sort of scale. The warhead numbers were accumulated to implement an earlier, predominantly nuclear, strategy, and an inventory of this size now has the chief merit of affording a wide range of choice of weapons, yield and delivery system if controlled escalation has to be contemplated. A point that does emerge from the comparison, however, is that the Soviet Union has the ability to launch a battlefield nuclear offensive on a massive scale if she chooses, or to match any NATO escalation with broadly similar options, though at present with less ability to limit collateral damage.

[m] These nuclear weapons are in general designed for use against targets within the battlefield area or directly connected with the manoeuvre of combatant forces – which could be described as a 'tactical' use. However, the warheads include a substantial number carried by aircraft such as the F-4 or F-104, which could be delivered on targets outside the battlefield area or unconnected with the manoeuvre of combatant forces, and thus to put to 'strategic' use. There is inevitably some overlap when describing delivery vehicles, aircraft and missiles capable of delivering conventional or nuclear warheads as 'tactical' or 'strategic'. The warhead total also includes nuclear warheads for certain air defence missiles and nuclear mines.

# 1. NUCLEAR DELIVERY VEHICLES: COMPARATIVE STRENGTHS AND CHARACTERISTICS

## (A) UNITED STATES AND SOVIET UNION

(i) *Missiles and Artillery*

| | Category[a] | United States: Type | Range (mi)[b] | Warhead yield range[c] | Throw-weight range[d] (000 lb) | First deploy-ment | Number deployed (7/77) | Soviet Union: Type[e] | Range (mi)[b] | Warhead yield range[c] | Throw-weight range[d] (000 lb) | First deploy-ment | Number deployed (7/77) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ICBM | *Titan II* | 7,000 | 5–10 MT | 7.5 | 1962 | 54 | SS-7 *Saddler* | 6,900 | 5 MT | 3–4 | 1961 | 109 (SS-7 and SS-8) |
| | | *Minuteman II* | 7,000 | 1–2 MT | 1–1.5 | 1966 | 450 | SS-8 *Sasin* | 6,900 | 5 MT | 3–4 | 1963 | |
| | | *Minuteman III* | 7,500 | 3 × 170 KT | 1.5–2 | 1970 | 550 | SS-9 *Scarp* | 7,500 | 18–25 MT or 3 × 5 MT[f] | 12–15 | 1965 | 238 |
| | | | | | | | | SS-11 *Sego* | 6,500 | 1–2 MT or 3 × KT[g] | 1.5–2 | 1966 | 840 |
| | | | | | | | | SS-13 *Savage*[h] | 5,000 | 1 MT | 1 | 1968 | 60 |
| | | | | | | | | SS-17 | 6,500 | 4 × KT or 1 × 5 MT[i] | 6 | 1975 | 40 |
| | | | | | | | | SS-18 | 7,500 | 15–25 MT or 8 × MT[j] | 15–18 | 1975 | 50 |
| | | | | | | | | SS-19 | 6,500 | 6 × KT or 1 × 5 MT[i] | 7 | 1975 | 140 |
| Land-based | M/IRBM | | | | | | | SS-4 *Sandal* | 1,200 | 1 MT | n.a. | 1959 | 500 |
| | | | | | | | | SS-5 *Skean* | 2,300 | 1 MT | n.a. | 1961 | 100 |
| | | | | | | | | SS-20 | 3,000 | 3 × KT[k] | 1.2 | 1977 | (20) |
| | SRBM | *Pershing*[l] | 450 | high KT | n.a. | 1962 | 108[m] | SS-1b *Scud A*[l] | 50 | KT | n.a. | 1957 | (750) (SS-1b, SS-1c, SS-12) |
| | | *Lance*[l] | 70 | low KT | n.a.[n] | 1972 | 36[m] | SS-1c *Scud B*[l] | 185 | KT | n.a. | 1965 | |
| | | *Honest John*[l] | 25 | KT | n.a. | 1953 | n.a. | SS-12 *Scaleboard* | 500 | MT | n.a. | 1969 | |
| | | | | | | | | *FROG 7*[l] | 10–45 | KT | n.a. | 1957–65 | (450) |
| | LRCM | | | | | | | SS-N-3 *Shaddock* | 450 | KT | n.a. | 1962 | (100) |
| Sea-based | SLBM | *Polaris A3* | 2,880 | 3 × 200 KT | 1,000 | 1964 | 160 | SS-N-4 *Sark* | 350 | 1–2 MT | n.a. | 1961 | 27 |
| | | *Poseidon C3* | 2,880 | 10 × 50 KT[o] | 2,000 | 1971 | 496 | SS-N-5 *Serb* | 750 | 1–2 MT | n.a. | 1964 | 54 |
| | | | | | | | | SS-N-6 *Sawfly*[e] | 1,750 | 1–2 MT or 3 × KT[p] | 1,500 | 1969 | 544 |
| | | | | | | | | SS-N-8[q] | 4,800 | 1–2 MT | 1,500 | 1972 | 284 |
| | SLCM | | | | | | | SS-N-3 *Shaddock*[r] | 450 | KT | n.a. | 1962 | 324 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air-launched | ALCM | *Hound Dog* | 600 | KT | n.a. | 1961 | (400) | AS-3 *Kangaroo* | 400 | KT | n.a. | 1961 | n.a. |
| | | | | | | | | AS-4 *Kitchen* | 450 | KT | n.a. | 1962 | (800) |
| | ALBM | SRAM | 150 | KT | n.a. | 1972 | 1,500 | | | | | | |
| Artillery | SP | M-110 203mm how[f] | 10 | KT | — | 1962 | 200[m] | | | | | | |
| | | M-109 155mm how[f] | 10 | 2 KT | — | 1964 | 300[m] | | | | | | |
| | Towed | M-115 203mm how[f] | 10 | KT | — | 1950s | n.a. | M-55 203mm gun/how[f] | 18 | KT | — | 1950s | n.a. |

(ii) *Aircraft*[t]

| | United States | | | | | | Soviet Union | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Category[t] | Type | Range (mi)[u] | Speed (Mach no.) | Weapons load (000 lb) | First deploy-ment | Number deployed (7/77) | Type[v] | Range (mi)[u] | Speed (Mach no.) | Weapons load (000 lb) | First deploy-ment | Number deployed (7/77) |
| Long-range bombers | B-52D | 11,500 | 0.95 | 60 | 1956 | 373[w] (B-52D–B-52G-H) | Tu-95 *Bear* | 8,000 | 0.78 | 40 | 1956 | 100 |
| | B-52G-H | 12,500 | 0.95 | 70 | 1959 | | Mya-4 *Bison* | 6,000 | 0.87 | 20 | 1956 | 35[x] |
| Medium-range bombers | FB-111A | 3,800 | 2.5 | 37.5 | 1969 | 68 | Tu-16 *Badger*[y] | 4,000 | 0.8 | 20 | 1955 | 740[v] |
| | | | | | | | Tu-? *Backfire* B | 5,500 | 2.5 | 20 | 1974 | 65[v] |
| Land-based strike (incl short-range bombers) | F-105D | 2,100 | 2.25 | 16.5 | 1960 | | Il-28 *Beagle* | 2,500 | 0.8 | 4.85 | 1950 | (1,000)[m] (Il-28 *Beagle*–Su-19 *Fencer* A) |
| | F-4C-J | 2,300 | 2.4 | 16 | 1962 | (350)[m] | Su-7 *Fitter* A | 900 | 1.7 | 4.5 | 1959 | |
| | F-111A/E | 3,800 | 2.2/2.5 | 25 | 1967 | | Tu-22 *Blinder* | 1,400 | 1.5 | 12 | 1962 | |
| | A-7D | 3,400 | 0.9 | 15 | 1968 | | MiG-21 *Fishbed* J/K/L | 1,150 | 2.2 | 2 | 1970 | |
| | | | | | | | MiG-27 *Flogger* D | 1,800 | 2.5 | 2.8 | 1971 | |
| | | | | | | | Su-17-20 *Fitter* C | 1,100 | 1.6 | 5 | 1974 | |
| | | | | | | | Su-19 *Fencer* A | 1,800 | 2.3 | 8 | 1974 | |
| Carrier-based strike | A-4 | 2,055 | 0.9 | 10 | 1956 | | | | | | | |
| | A-6A | 3,225 | 0.9 | 18 | 1963 | | | | | | | |
| | A-7A/B/E | 3,400 | 0.9 | 15 | 1966 | (200)[m] | | | | | | |
| | F-4 | 2,000 | 2.4 | 16 | 1962 | | | | | | | |

[a] ICBM range = 4,000+ statute miles; IRBM range = 1,500–4,000 miles; MRBM range = 500–1,500 miles; SRBM range = under 500 miles; LRCM range = over 350 miles.
[b] Statute miles. Operational range depends upon the payload carried; use of maximum payload may reduce missile range by up to 25 per cent.
[c] Estimated maxima; warhead yields vary greatly. KT range = less than 1 MT.
[d] Figures given are estimated maxima. Throw-weight is the weight of the post-boost vehicle (warheads, guidance systems, penetration aids) that can be delivered over a given range. At maximum range throw-weight will be less than shown here.





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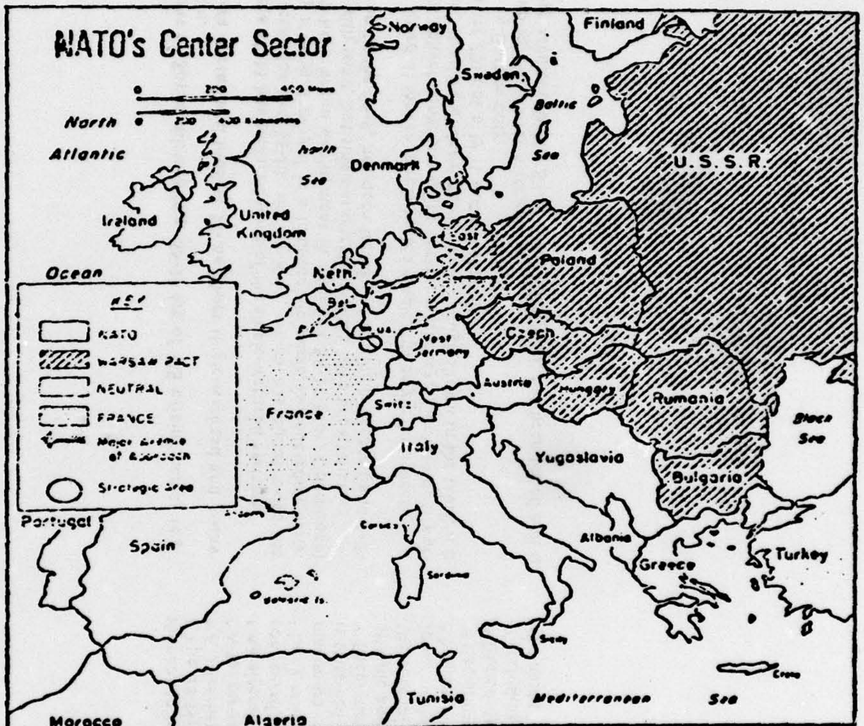
[e] Numerical designations of Soviet missiles (e.g. SS-9) are of US origin; names (e.g. *Scarp*) are of NATO origin.
[f] The SS-9 exists in three operational modes; 18- or 25-MT single-warhead and 3 MRV of 4–5 MT each.
[g] A 3-MRV version of the SS-11 has replaced some of the single-warhead systems.
[h] A solid-fuel replacement for the SS-13, the SS-X-16, which has about twice the throw-weight and may also be deployed in a land-mobile mode, is undergoing tests.
[i] The SS-17 and SS-19 have begun deployment in modified SS-11 silos. Operational missiles are equipped with MIRV, but single-warhead versions have been tested.
[j] The SS-18, a follow-on to the SS-9, has been tested in two single-warhead and 5–8-MIRV versions.
[k] The SS-20 has been tested at longer ranges with a single, lower-yield warhead.
[l] Dual-capable (able to deliver conventional or nuclear warheads). Conventional warheads for US *Lance* and *Pershing* under development. Though shown in the table, it is uncertain whether Soviet 203mm arty is nuclear-capable.
[m] Figures for systems in Europe only.
[n] *Poseidon* can carry up to 14 RV over a reduced range.
[o] A solid propellant replacement for the SS-N-6, the SS-NX-17, has been tested and is thought to be capable of deploying MIRV.
[p] The SS-N-6 has been tested with new single warhead (MT range) and with 3 MRV.
[q] A 3-warhead MIRV replacement for the SS-N-8, the SS-NX-18, has been tested.
[r] A longer-range version of the SS-N-3, the SS-X-12, is reportedly under development.
[s] All aircraft are dual-capable, but some in the strike aircraft categories are not presently configured for the nuclear role.
[t] Long-range bomber = maximum range 6,000+ miles; medium-range bomber = maximum range 3,500–6,000 miles, primarily designed for bombing missions. *Backfire* is classified as a medium-range bomber on the basis of reported range characteristics.
[u] Theoretical maximum range in statute miles, with internal fuel only, at optimum altitude and speed. Ranges of strike aircraft assume no weapons load. Especially in the case of strike aircraft, therefore, range falls sharply for flights at higher speeds, lower altitude or with full weapons load.
[v] Names of Soviet aircraft (e.g. *Bear*) are of NATO origin.
[w] Excluding aircraft in storage or reserve.
[x] Excluding approximately 45 Mya-4 configured as tankers.
[y] Including aircraft in the Naval Air Force (some 280 Tu-16 and 30 *Backfire*) but excluding Tu-16 tankers.




**LATEST COMPARISON** of Soviet and Warsaw Pact forces in Central Europe credits Pact with 141⅔ divisions, against 45⅓ NATO divisions *measured in Warsaw Pact division equivalents*. Those forces exclude Soviet forces outside Europe or in the Caucasus, but include reserves immediately available to both sides (and for NATO, assumes availability of 9 French mechanized and 1 airborne divisions). Professor John Erickson provided the numbers in his chapter on "The Warsaw Pact" in a new British book, "The Soviet War Machine," released by Salamander Books through The Hamlyn Publishing Group. Erickson says those forces would pit about 27,000 Pact tanks supported by 8-9,000 artillery tubes against 10-11,000 NATO tanks and 6,000 artillery pieces. Pact now has under arms about 1,240,000 men, NATO about 1,200,000—but Erickson says the Warsaw Pact capability for mobilization would give Pact a three-to-one superiority in fighting troops after three weeks of mobilization, whereas it would take NATO an additional month to close that gap. Warsaw Pact forces deployed opposite NATO's vital central sector total 48 divisions available without additional reinforcement—about 200 battalion-size combat groups, 8,700 tanks and 1,750 tactical aircraft. Some 50 additional divisions could be committed in the first 30 days of operations. ■ ☆ ■

APPENDIX C

AUTOMATIC SMOKE SYSTEMS

It takes about a second to deliver the thermal burn from a 100 kt blast. It is questionable whether an unwarned individual can take any effective evasive action in that interval. This is particularly true of people such as truck drivers whose movement options are limited.

Suppose that it is possible to make a light, cheap, automatic sensor of the prompt pulse in coincidence with the primary flash of light. This detection could trigger the release of gas driven smoke jets (analogous to auto air bags). Within vehicles this could serve as a "shutter" to reflect or absorb the following thermal flash. (This is the same problem as with fighter pilots).

Suppose the principle is extended to place such a device in belts and/or helmets with multiple jets directed to surround soldiers with an "instant smoke screen." The jet duration could be as long as the five second duration of a 1 Mt burn so that smoke dispursed by wind would be continually replaced. A dense smoke driven by a $CO_2$ cartridge might be effective in shielding individual soldiers from most of the thermal flash. Such a device could be simple, reliable, and cost effective.

United States Patent Office

3,230,369

Patented Jan. 18, 1966

1

# 3,230,369
# RADIATION DOSIMETER SYSTEM USING CADMIUM-BACKED COPPER FOIL

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Filed Sept. 11, 1962, Ser. No. 222,976
4 Claims. (Cl. 250—83.1)

This invention relates to a dosimeter system and more particularly to a method for determining the neutron dose received by human beings from radiation incidents.

Does of radiation sufficient to cause death within weeks may not produce symptoms in human beings for many hours after exposure to the radiation. Furthermore, the accurateness, severity, and type of symptomatology are not always of prognostic value. Adequate personnel dosimetry is, therefore, a requisite when early mass casualty assessment is required such as in military and civilian defense applications. Since nuclear weapon and reactor explosions and criticalities involve the radiation of neutrons and gamma rays, both of which are capable of producing injury in humans, a dosimeter system for mass casualty assessment must be capable of measuring both gamma and neutron doses in the characteristic mixed radiation field.

Gamma dosimeters for this purpose are in a much more refined state of the art than either the neutron or gamma-neutron dosimeters.

There has been recent recognition of the value of body sodium activation measurements in assessing a received neutron dose. One device accomplishes such measurements by use of a well type scintillation counter which involves the drawing, centrifugation, and counting of blood serum samples for $Na^{24}$ activity. Another method is the use of the human whole-body counter and also by the use of a large scintillation crystal gamma spectrometer assembly. All of these devices have inherent disadvantages for mass casualty assessment work in the field, such as lack of portability, time consuming testing procedures, high level of training necessary for operators as well as relative expense of the system. For mass casualty assessment work, a dosimeter system should be portable, relatively inexpensive, and capable of rapid and fairly untrained operation.

It is, therefore, an object of the present invention to provide a dosimeter system for determining neutron dosage received by human beings exposed to radiation incidents.

It is another object of the present invention to provide a portable dosimeter system for determining the neutron dosage received by human beings exposed to radiation incidents.

It is still another object of the present invention to provide a rapidly operable dosimeter system for determining neutron dosage received by human beings exposed to radiation incidents.

It is a further object of the present invention to provide a dosimeter system for measuring the neutron dosage received by human beings from a mixed radiation field.

It is a still further object of the present invention to provide a method for measuring the neutron dose received by a human being from a radiation incident by measurement of body sodium.

It is yet a further object of the present invention to provide a method of determining the statistical average neutron energy of the incident dose received by a human being.

It is a further object of the invention to provide a neutron dosimetry system which directly measures human body and clothing induced radiation and which does not require the attachment of badges or other forms of dosimeters to the clothing.

It is yet another object of the invention to provide, by electronic circuitry, a means of estimating body sodium activity at the time of exposure without resorting to tables or calculations.

Other objects and a fuller understanding of the invention may be had by referring to the following description and claims taken in conjunction with the accompanying drawings in which:

FIGURE 1 shows an elevation view, partially in cross section, of the body sodium activity detector unit utilized in the method of the present invention.

FIGURE 2 is a schematic diagram, partially in block form, of the rate meter circuitry used in conjunction with the detector unit of FIG. 1.

FIGURE 3 is a drawing of the battery operated $Na^{24}$ detector unit.

FIGURE 4 is a graph indicating the correction value to be applied to the microammeter reading vs. Na/Cu ratio.

FIGURE 5 shows three views (*a*, *b*, and *c*) of the cadmium-backed copper foil badge of this invention. FIGURE 5*a* is a three-quarter sectional view of the foil badge, while FIGURE 5*b* is a cross-sectional view. FIGURE 5*c* is an illustration of a human being wearing four of the badges at cardinal (NSEW) points in a belt.

The novel method of the present invention to determine the neutron dose received by an individual is based upon the measurement of induced body sodium activity and the relation of the ratio of body sodium activity to the activity of a copper foil worn on or about the body as a function of incident neutron energy which permits an estimate of body dose to be made.

The principles underlying the present invention may be stated as follows:

(1) The amount of damage (tissue dose) produced in the body depends upon the number and energy of the incident neutrons.

(2) The activation of body sodium-23 to radioactive sodium-24 depends upon the number and energy of the incident neutrons.

(3) The activation of a copper foil worn on the body to radioactive copper-64 depends upon the number and energy of the incident neutrons.

(4) Sodium-24 decays with a 14.8 hour half life emitting gamma rays that can be detected by holding a rate meter-probe assembly against the back of the individual exposed.

(5) Copper-64 decays with a 12.8 hour half life emitting gamma rays that can be detected by placing the copper foil on a rate meter-probe assembly.

(6) Tissue dose, body sodium activity, and copper foil activity increase directly and proportionally with the number of incident neutrons.

(7) Both tissue dose and body sodium activity increase with increasing neutron energy; however, the increases are not proportional to neutron energy and neither do they increase to the same amount nor at the same rate with increasing neutron energy.

(8) The activity of a copper foil worn on the body decreases with increased neutron energy; however, the decrease is not inversely proportional to the neutron energy except over a small range.

(9) The ratio of body sodium activity to copper foil activity is characteristic of a certain average incident neutron energy.

(10) In order to determine the tissue dose both the sodium activity produced and the average incident neutron energy which produced it must be known.

Jan. 18, 1966 — E. R. BALLINGER ETAL — 3,230,369

RADIATION DOSIMETER SYSTEM USING CADMIUM-BACKED COPPER FOIL

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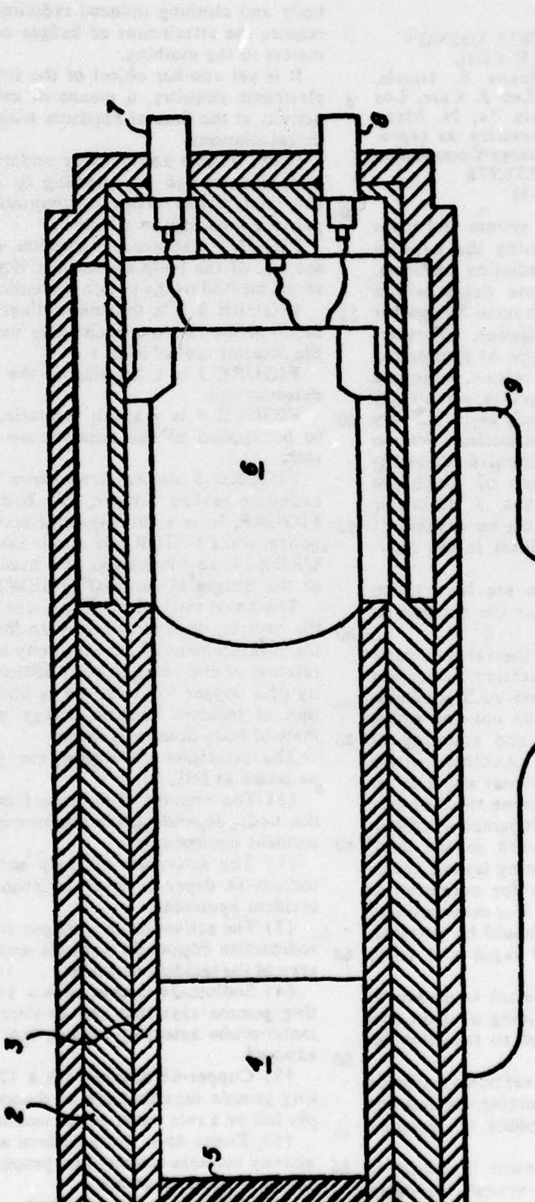


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RADIATION DOSIMETER SYSTEM USING CADMIUM-BACKED COPPER FOIL

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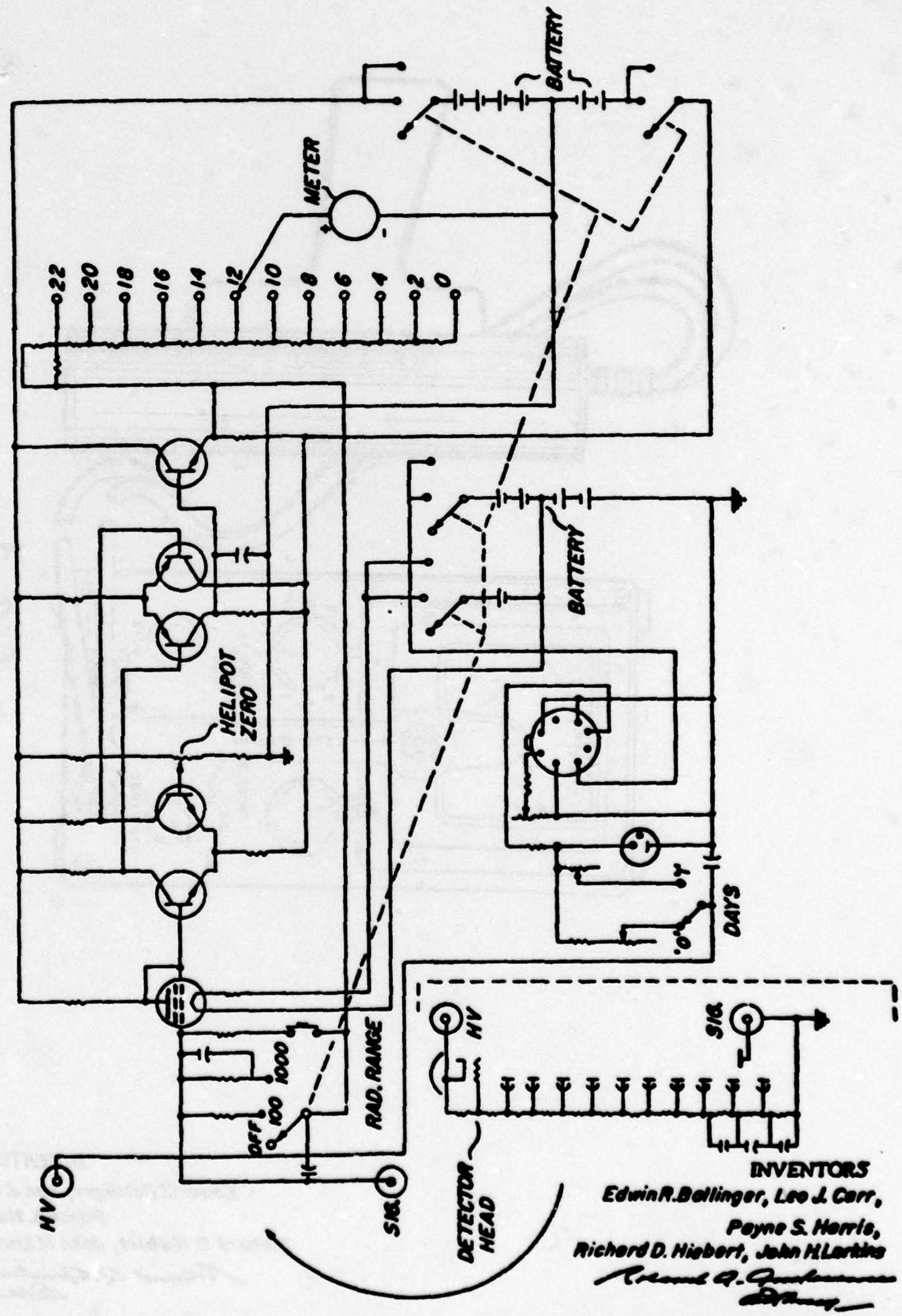


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RADIATION DOSIMETER SYSTEM USING

CADMIUM-BACKED COPPER FOIL

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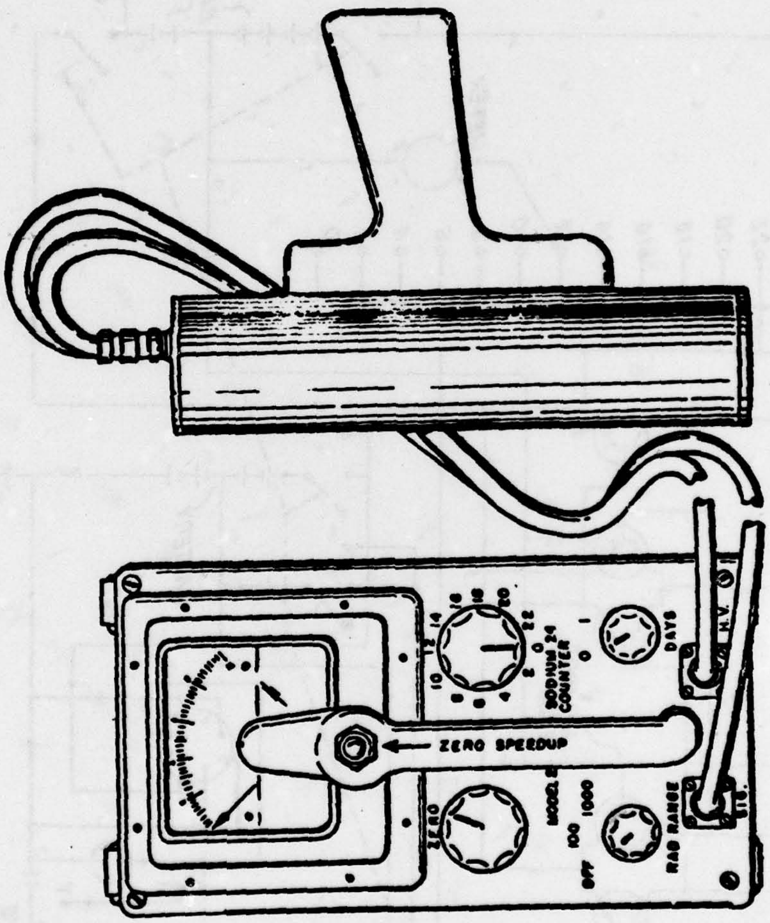


*Fig. 3*

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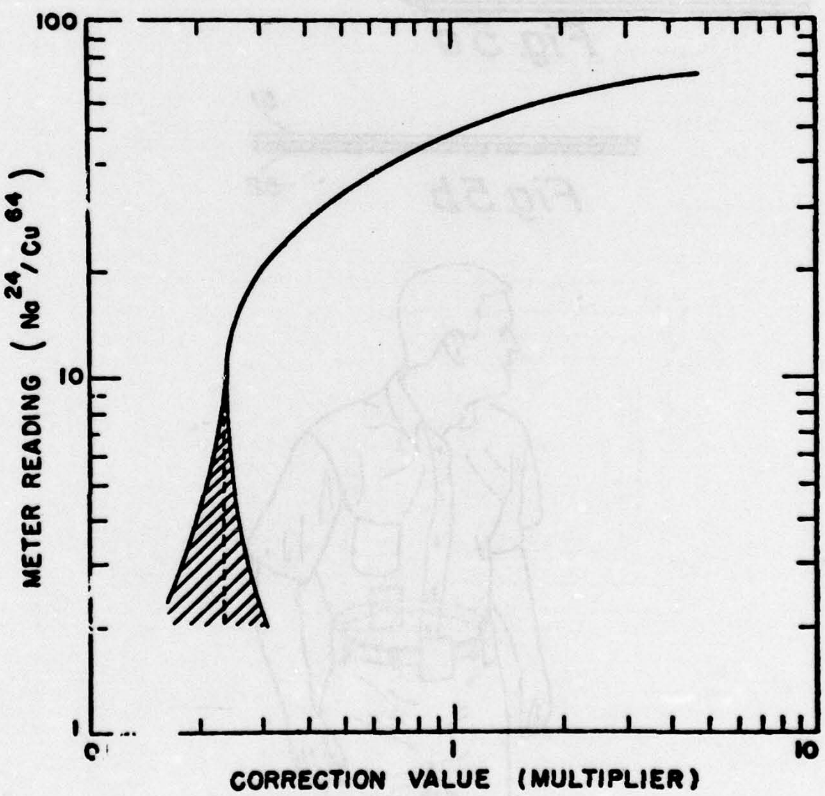


*Fig. 4*

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RADIATION DOSIMETER SYSTEM USING CADMIUM-BACKED COPPER FOIL

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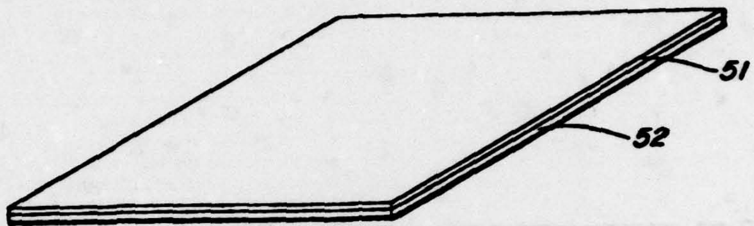


Fig. 5a

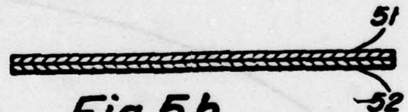


Fig. 5b

Fig. 5c

INVENTOR

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BY

Attorney

The present invention measures the body sodium activity by means of a special rate meter-probe assembly held against the back of the exposed individual.

The present invention provides an estimate of average neutron energy by comparing the observed body sodium activity with the activity of a copper foil worn on the body. The ratio of these two activities as a function of neutron energy has been experimentally and theoretically determined by the inventors of the present invention.

A device in accordance with the present invention is shown in FIGURE 3. The device is physically in two parts, a detector probe and a rate meter box.

The detector probe is shown in FIGURE 1 and consists of a NaI crystal 4 mounted on a photomultiplier tube 6 wrapped with conetic material 3 to reduce local environmental magnetic effects and with lead 2 to reduce environmental radiation background effects. This unit is encased in aluminum 1, capped at both ends (10 and 1), and equipped with a piston grip handle 9 for convenience of operation. In operation, the detector probe unit is held firmly against the body of the individual to be checked, preferably over the lumbar area where the adjacent rich blood supply and heavy bone structure insures a high concentration of body sodium. The gamma radiation from the decaying body sodium-24 produces light pulses in the NaI crystal in proportion to the activity observed. The light pulses are detected and amplified as electrical pulses in passage through the photomultiplier tube.

The photomultiplier tube output is fed by coaxial cable 7, FIGURE 1, to the rate meter box where the signal is further amplified in the circuitry shown in FIGURE 2. The amplified signal passes then to a microammeter which has been calibrated in rads of incident neutrons of 2 mev. energy required to produce the $Na^{24}$ activity observed. Detailed descriptions of the components of the rate meter box shown in FIGURE 2 are as follows:

(1) A power supply unit of a compact self contained type for portable operation supplies the necessary operating voltages for both the rate meter box components and the photomultiplier tube in the detector unit 8, FIGURE 1.

(2) Rate meter circuitry is divided into three main stages: A combination input-amplifying stage; an amplifying stage; and a combination amplifier-output stage.

Any well known amplifying stage circuitry can be utilized; however, the use of transistorized circuitry is preferred to minimize power and space requirements and provide a compact and portable unit. The signal output from the photomultiplier tube is conducted through a coaxial cable shown in FIGURE 3 to a coaxial input socket on the meter box unit, and thence to the first input amplifying stage. The signal is further amplified in the remaining two stages and is then presented to a load consisting of the series combination of a current-limiting tapped resistance network and finally to the microammeter. The amount of output current passing through the microammeter varies in accordance with the input signal derived from the sodium activity of the individual examined by the detector probe unit.

(3) Decay correction circuitry: To allow the correction of readings taken longer than 22 hours post exposure a series of voltage dropping resistors can be selectively switched to regulate the high voltage output to the photomultiplier tube. The value of these voltage dropping resistors is such as to provide 24 hour increments of logarithmic decay which would thereby, in combination with the tapped resistance network (shown in FIGURE 2), allow correction in 2 hour increments of meter readings obtained a matter of days after exposure. Full scale readings of 100 rads and 1000 rads have been found convenient and are selectable by a front panel switch which inserts different values of amplifier input resistors (see FIGURE 3).

To obtain an accurate indication of the neutron dosage received by the human body upon exposure to nuclear radiation a body activity reading taken some time after exposure must be related back to the time of exposure because the radioactivity of the body has been logarithmically decaying. The correction is accomplished electrically in the rate meter circuit by the tapped resistance network, the time since exposure being "dialed-in" by the operator. The relative values of the resistances between the taps of the network are selected to cause a logarithmic decrease in effective resistance, upon the successive selection of taps, in accordance with the logarithmic rate of decay of sodium-24. Since the half life of sodium-24 is known to be 14.8 hours, selection of the actual values of resistances between taps is relatively simple once the equivalent full scale indication in rads per hour has been specified. In the device, 12 taps are provided with the equivalent time between taps equal to 2 hours (see FIGURE 2). Hence, the operator may dial in the time since exposure in bihourly increments up to 22 hours and the meter reading will automatically be corrected to directly read the radiation absorbed by the human body.

(4) Background zero adjust circuitry: An additional circuit refinement is the inclusion of an adjustable voltage divider network in the amplifying stage to enable the canceling out of reasonable background radiation levels. In practice an attenuation plug, having attenuation characteristics identical to that of the human body would, preliminary to readings, be placed over the end of the detector unit and a reading taken in free air. Any meter indication could then be zeroed out by proper adjustment of the amplifying stage voltage dividing network.

As pointed out in item (10) of "principles underlying the present invention," in order to determine the tissue dose it is necessary to known both the body sodium-24 activity and the average neutron energy. The present invention has been deliberately calibrated to read the actual tissue dose received from approximately 2 mev. neutrons. If the average neutron energy is less than 2 mev., the microammeter on the rate meter box will read a larger dose than actually received by the individual. Conversely, if the average incident neutron energy is greater than approximately 2 mev., the reading will understate the actual dose received.

As pointed out in item (9) of "principles underlying the present invention," the ratio body sodium-24 activity to the activity of a copper foil worn on the body is characteristic of a certain incident neutron energy. The relation of these ratios vs. neutron energy was determined theoretically and checked experimentally. Similarly, the relation between body sodium-24 activity and neutron energy was determined. Thus, by obtaining the ratio of activities

$$\left(\frac{\text{body Na-24}}{\text{copper foil}}\right)$$

the corresponding average neutron energy is obtained, and by knowing the relation between body sodium-24 activity and neutron energy, the microammeter reading can be corrected accordingly to approximate the actual dose received. The correction values vs. Na/Cu ratio are indicated in FIGURE 4. Several features of the copper foils need to be stated.

The copper foils (see FIGURE 5a and b) used in the present invention measure ¾" x ¾" x 30 mil thick. The foils are backed with cadmium 52 measuring ¾" x ¾" x 30 mil thick. Cadmium is necessary to prevent neutrons scattered and reflected from the body from coming in contact with the copper foil 51 and thus contributing to the activation produced by incident neutrons from the radiation source. Four foils are worn at cardinal compass points (see FIGURE 5c) in clothing at the waistline of the individual to insure that at least one of the four copper foils will be directly exposed to the source of the radiation. In practice, these foils may be sewn into clothing belts (FIGURE 5c) worn by the individuals.

To render the method of the present invention usable for mass casualty assessment following a known or suspected radiation incident, it is assumed that the individuals to be examined will be wearing the four foil belt referenced previously.

The proposed procedure is as follows:

(1) The device is turned on, the time since suspected exposure dialed in, and the environmental background level zeroed out.

(2) Screening: Since the microammeter reading will be high if the average neutron energy is less than 2 mev. and since this probability is great, one would first perform a screening procedure by placing the probe over the lumber area of all individuals in rapid succession and eliminating from further consideraion all persons with readings less than 25 rad. This procedure may early indicate the number of probable neutron radiation casualties and such a procedure can be conducted at a rate of 4–6 persons/minute.

(3) Dose estimates: All individuals with screening readings greater than 25 rad having been assembled, the device is turned on and a favorable location for readings is determined by walking about the area to determine a spot with the lowest background reading. The attenuation plug having background attenuation characteristics comparable to that of a human body would be held over the detector unit and the microammeter adjusted to a zero needle reading by means of the zero adjust knob. The probe is then held over the lumber area of the back for 5–10 seconds or for long enough for the microammeter needle to come to rest. The reading is recorded and the copper foil belt is scanned for the foil with the highest relative activity. This foil will be the one which faced the radiation source and the orientation will be recorded. The microammeter needle will again be zeroed, this time without the attenuation plug and the most active copper foil will be removed from the clothing and placed on the face of the detector probe. The activity will be recorded and the ratio of the two readings determined

$$\left(\frac{\text{body Na-24}}{\text{copper foil}}\right)$$

Using the graph shown as FIGURE 4, a correction value will be obtained. This value, when multiplied by the body sodium reading will result in an approximation of the actual neutron dose received. This procedure of dose estimate can be conducted with a two man survey team (reader and recorder) at a rate of 1 estimate per 2 minutes.

A specific example of the aforementioned procedure is as follows: A dummy man with neutron response characteristics similar to a real man is exposed to radiation for four hours, the necessary time correction is dialed in on the counter-reader and a reading of 100 rads is obtained. A copper foil belt worn by the dummy man is then scanned by the counter probe and a reading of 4 rads is obtained. The sodium-24 to copper-24 ratio is 100 to 4 or 25. Looking at FIGURE 4 and reading across to where the sodium/copper value of 25 intersects the curve, a correction value of 0.38 is obtained. This correction value is multiplied by the 100 rads figure, which gives a resulting value of 38 rads. This measurement is the approximate true neutron radiation dose which the dummy has received. By a different and much more time consuming method called the Hurst Fission Foil System, a value of 45 rads was obtained, thus giving the applicants' measuring system an error of about 15%.

What is claimed is:

1. An improved dosimeter system having in combination means for indicating substantially the average radiation dose received by a human being within 48 hours of a radiation incident due to neutrons of various energies released during the said incident, said combination comprising a portable battery powered sodium-24 - copper-64 detector unit and a thin cadmium-backed copper foil placed strategically in the clothing of the said human being.

2. The dosimeter system of claim 1 in which said detector unit is comprised of a probe, an electronic means for adjusting the gamma radiation sensitivity of the said probe, and an electronic means for adjusting the gamma radiation signal of the detector so as to make the value of the signal time dependent.

3. The dosimeter system of claim 1 in which four cadmium-backed copper foils are worn at cardinal points at the waistline of the individual, said foils being each comprised of a copper plate of the dimensions three-quarters inch by three-quarters inch by 0.003 inch and being backed by a cadmium plate of the same dimensions.

4. The dosimeter system of claim 1 in which said detector unit is comprised of

(a) a probe that consists of a sodium iodide crystal mounted on a photomultiplier tube,

(b) said tube being wrapped with a conetic material and lead,

(c) said unit being encased in alminum and having a pistol grip handle, and

(d) said photomultplier tube being electrically connected to a meter box where the signal is further amplified and measured by a microammeter calibrated in rads.

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RALPH G. NILSON, *Primary Examiner*.

ARCHIE R. BORCHELT, *Examiner*.

APPENDIX D

Reprinted from

# NUCLEAR SAFETY

## Atmospheric Release Advisory Capability

By M. H. Dickerson* and R. C. Orphan†

A BIMONTHLY TECHNICAL PROGRESS REVIEW
prepared in cooperation with Nuclear Safety Information Center,
Oak Ridge National Laboratory,
for Division of Technical Information, ERDA

# General Safety Considerations

Edited by J. R. Buchanan

## Atmospheric Release Advisory Capability

By M. H. Dickerson* and R. C. Orphan†

**Abstract:** *The Atmospheric Release Advisory Capability (ARAC) is a concept for a service to facilities requiring a means of real-time prediction of the extent of health hazards that may result from a release of radionuclides and other toxic materials. The ARAC system, sponsored by the Energy Research and Development Administration (ERDA), consists of a network of serviced site facilities and a central facility located at the University of California, Lawrence Livermore Laboratory (LLL). Since 1973, when the concept was initiated, a joint feasibility study of the ARAC system has been conducted by LLL and Savannah River Laboratory (SRL). A system of three sites, LLL, SRL, and the Rocky Flats Plant, is being tested and evaluated during FY 1976. Plans are ready to implement the ARAC service for additional ERDA nuclear facilities over the next 3 years. This article briefly describes the ARAC concept, discusses the progress to date, and outlines future plans for developing the system.*

The nuclear industry faces a great challenge in minimizing damage that could result from toxic emissions during accidents and incidents. Continuation of a favorable nuclear safety record depends not only on strict adherence to standards and regulations but also on extensive effort at the local level to foresee potential occurrences and to plan protective emergency action guides. Although the nuclear power industry on the whole is engaged in this problem, the Energy Research and Development Administration (ERDA) nuclear sites (research and production facilities) have a special responsibility in this regard. In the execution of this responsibility, the ERDA nuclear sites are typically faced with a number of questions such as:

1. What health hazards to operating personnel and the public would result in the event of an accident or incident?
2. More specifically, how fast and to what extent will a release of hazardous materials diffuse under a particular set of circumstances and weather conditions?
3. What kind of predictive information can be derived to permit adequate decisions in an emergency?
4. How can routine releases of toxic emissions be planned so as to minimize potential impact on the surrounding environment?

ERDA is sponsoring a means of assisting the management at ERDA nuclear sites in responding to these types of questions. Under the cognizance of the Division of Biological and Environmental Research (DBER) program, the University of California, Lawrence Livermore Laboratory (LLL) has developed a centralized service to provide sites with real-time predictions of the consequences of an atmospheric release of toxic emissions. This service is called Atmospheric Release Advisory Capability (ARAC).[1] The ARAC concept is presently being tested and evaluated for application at ERDA sites throughout the nation. This article surveys the purposes of the ARAC

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service, the basis for its structure, the current status of development, and the projected plans for implementation.

## PURPOSE OF ARAC

The chief purpose of ARAC is to provide responsible site officials with estimates of the effects of accidental or routine atmospheric releases of hazardous materials as rapidly and as accurately as possible. To do this, ARAC would develop a series of advisorie containing projections based on monitored environmental and other input data from the site. Central to the ARAC concept are the numerical models that provide real-time regional assessments of release consequences using the localized site data. These models vary in complexity from a simple-trajectory model to an interfaced set of advanced regional transport and diffusion models covering distances of ~10 to 100 km. The models, combined with other technologies for dose conversion, data handling, and communication, permit a means for predicting the effects of release of toxic materials of any sort.

The primary function of ARAC is to assist a site in emergency response, but there are other routine uses intended for this service. Some examples are:

1. To calculate and maintain a record of the inventory of radioactivity in the source.
2. To maintain an updated record of the inventory of routine releases of materials and their concentration in the environment.
3. To calculate doses from routine releases.
4. To perform sensitivity studies to ascertain changes in the biological impact possible from changes in site operations and in site locations for projected facilities.

When implanted, the ARAC would support ERDA in assisting the operating sites in several ways. These include, but are not limited to, the following:

1. The quality of information and predictive advisories from ERDA would be improved because of the availability of real-time data and regional information.
2. The predictions of off-site toxic effects would have a basis in transient regional transport processes.
3. Any off-site countermeasures and postemergency cleanup operations would have a basis for iterative improvement as actual monitored information is received.
4. ARAC would serve as a focal point to develop future improvements in the assistance and advisories provided by ERDA.

## COMPONENT PARTS OF ARAC

The ARAC concept is built upon a communication and data-acquisition network that allows each user to have rapid access to the central advisory products, which in turn are based on environmental data from the local site. Figure 1 shows the component parts of the ARAC system. Any number of nuclear or chemical facilities or sites within the United States can be serviced within the network. The meteorological service, provided by the National Weather Service (NWS) and the Air Force Global Weather Central (AFGWC), supplies the meteorological data (observational data, analyses, and forecasts) that are used in each assessment. The ARAC central facility, through data and voice telecommunication links, provides the sites with the regional assessments that are calculated on the CDC 7600 class computers. The remainder of this section discusses the manner in which the site receives the regional assessment calculations, the design and function of the central facility's data-acquisition and communication system, and the use of the national meteorological services. Aspects of the regional modeling calculations and advisories are discussed in the following section.

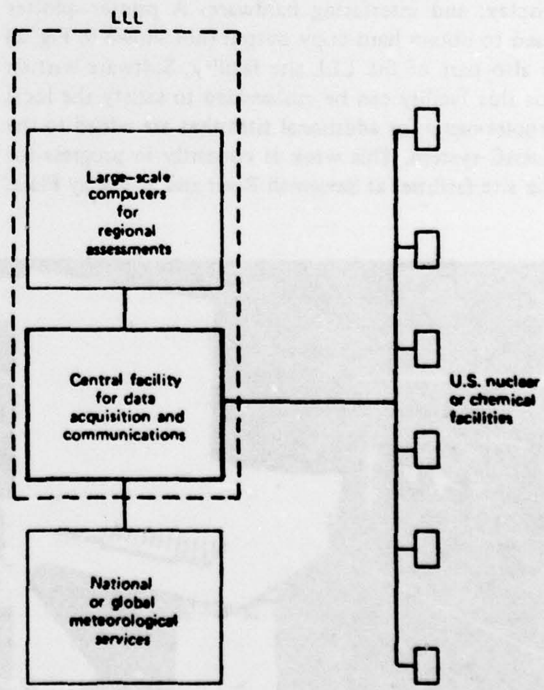


Fig. 1 Component parts of the ARAC system.

## Site Facility

Each ARAC-serviced site will have a minicomputer, which is referred to as a site facility, that furnishes local data-acquisition, assessment, and communication capabilities. Some specific functions of the site facility are:

1. It multiplexes the environmental sensors.
2. It provides local data quality control.
3. It calculates and displays Gaussian diffusion estimates for close-in distances (out of approximately 5 km) using latest local meteorological data.
4. It transmits local environmental monitoring measurements to the central facility.
5. It receives and displays regional calculations from the central facility.

Since the site facility can perform certain functions without a direct data link to the central facility, this part of the system was the first to be designed and tested. Late in 1974 the hardware was purchased and the software development initiated for the first operating ARAC site facility, which is also located at LLL. The site equipment, shown in Fig. 2, is being used in a research environment; it consists mainly of the minicomputer with core memory, interactive graphics display, and interfacing hardware. A printer–plotter used to obtain hard copy output (not shown in Fig. 2) is also part of the LLL site facility. Software written for this facility can be customized to satisfy the local requirements for additional sites that are added to the ARAC system. This work is currently in progress for the site facilities at Savannah River and at Rocky Flats.

The interactive operating system for the site facility is designed to provide the user with a selection of advisories based on different levels of complexity. Examples of the capabilities available on the LLL site facility in May 1975 are shown in Figs. 3 to 7. These figures show the cathode-ray tube (CRT) screen and should be interpreted as illustrations of the site facility's functions. Figure 3 shows the "menu" listing the options that are available to the user on the graphic display of the minicomputer. With a light pen or keyboard, a user can select items 1 to 10 for display on the screen. For example, if one is interested in the normalized Gaussian diffusion calculation, based on the latest meteorological data from the tower and superimposed on the 5-km radius map of the area surrounding LLL, he selects numbers 7 and 5. This calculation is shown in Fig. 4. At the time this picture was taken the contour labels were not included; these will be added in the final version.

Figure 5 shows the 100-km radius map of the Livermore region that is used as a reference for the trajectory and regional model calculations. The cross surrounded by the dash–dot square and solid diamond follows the light pen and allows the user to select and magnify the portion of the area enclosed by the square. This scaling also applies to the calculations that are overlaid on the map for reference. The user has the scale options listed at the bottom of the figure. Figure 6 shows a scale of 100 km selected from this list, and Fig. 7 shows an example of a trajectory computed and overlaid on this region. The trajectory is the line originating at LLL, with the labels A, B, D, and

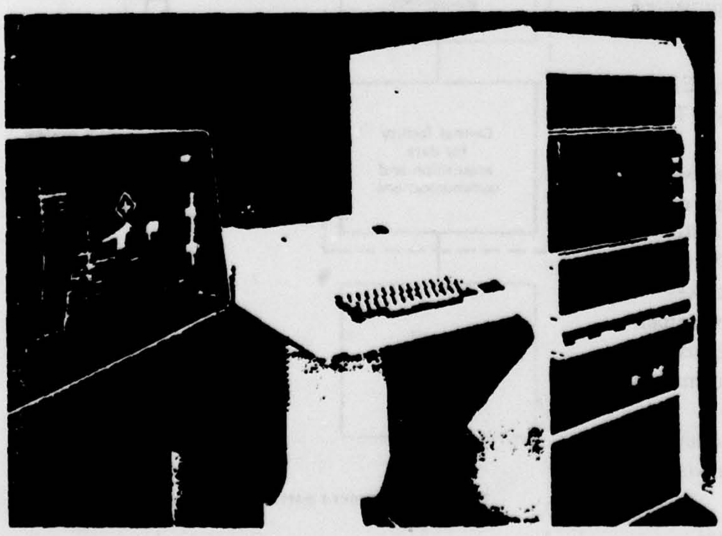

**Fig. 2 Hardware used in the LLL prototype ARAC site facility.**

- 1. Set parameters
- 2. Wind rose
- 3. Meteorological data
- 4. Site map 1 km
- 5. Site map 5 km
- 6. Regional map
- 7. Gaussian diffusion
- 8. Trajectory model
- 9. Regional model calculations
- 10. Local weather information
- 11. Central system communication
- 12. Release notification
- 13. Cancel release notification
- 14. Plot
- 15.
- 16.

**Fig. 3 "Menu" showing a list of optional displays and commands presently available at the LLL site facility.**

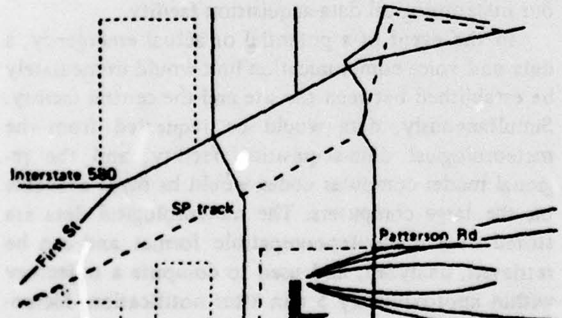


**Fig. 4 Gaussian diffusion calculation overlaid on a map of the area within 5 km of LLL.**

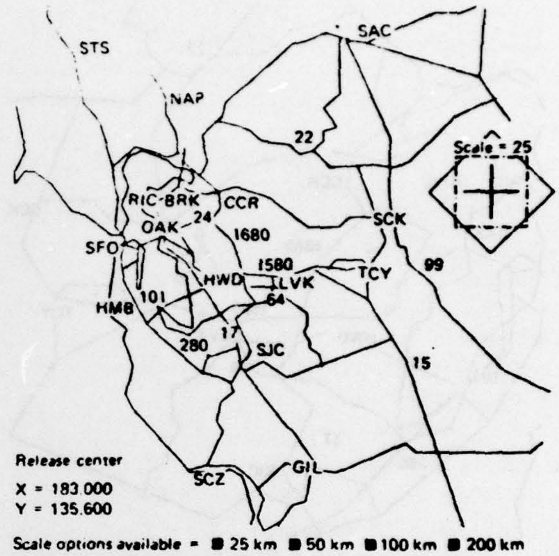


**Fig. 5 Map of the area within a 100-km radius of LLL. The cross surrounded by the dash–dot square and solid diamond is used to select an area of the map for magnification.**

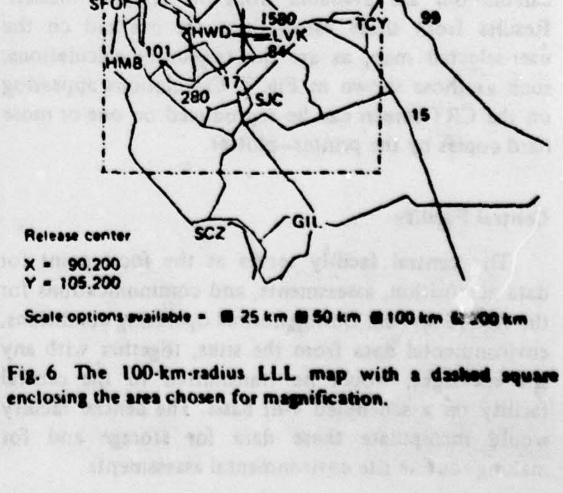


**Fig. 6 The 100-km-radius LLL map with a dashed square enclosing the area chosen for magnification.**

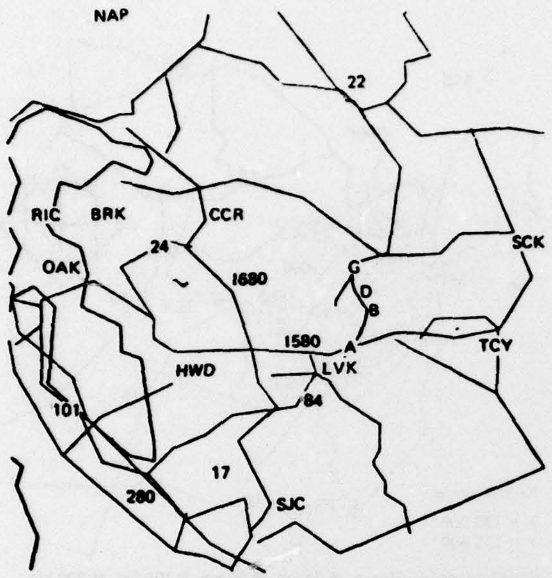


**Fig. 7 A computed trajectory (the line originating at LLL with the A, B, D, and G labels) overlaid on the map selected from the dashed square shown in Fig. 6.**

G representing the locations of a hypothetical release after 1, 2, 4, and 7 hr, respectively. Data used to calculate this trajectory were selected from a hypothetical data set and are used for purposes of illustration only.

To view advisories from the regional model calculations received from the central facility, a user selects number 9, and a "submenu" appears on the graphical display listing the output options that are available. Within 30 to 40 min after notification of a release, the calculations are available from the regional models. Results from these calculations are overlaid on the user-selected map, as are the trajectory calculations, such as those shown in Fig. 7. Calculations appearing on the CRT screen can be reproduced on one or more hard copies by the printer–plotter.

### Central Facility

The central facility serves as the focal point for data acquisition, assessments, and communications for the ARAC service. During normal operating conditions, environmental data from the sites, together with any site messages, would be transmitted to the central facility on a scheduled 4-hr basis. The central facility would manipulate these data for storage and for making routine site environmental assessments.

Meteorological data from the NWS and the AFGWC would be received by the central facility minicomputer on a routine and special-request basis. These data would be stored and printed on hard copy for analysis; certain data would be selected and formatted as input data for the trajectory calculation and the regional models. The LLL is now serviced by NWS; we anticipate that our meteorological data-acquisition facility will link to AFGWC to obtain grid-point-forecast meteorological data from their fine-mesh and boundary-layer models. The design of the AFGWC meteorological data network is such that a minicomputer can receive, analyze, display, and store the meteorological data. This feature improves the efficiency of manipulating and using large amounts of weather data.

During the next several years, the NWS data will be received on facsimile charts and teletype output. These data will be used to supplement and back up the data that we receive from the AFGWC. However, NWS plans to automate its meteorological service with the Automation of Field Operations and Services (AFOS) system within the next several years. When this system becomes operational, we plan to include it as part of our meteorological data-acquisition facility.

In the event of a potential or actual emergency, a data and voice communication link would immediately be established between the site and the central facility. Simultaneously, data would be requested from the meteorological data-acquisition facility, and the regional model computer codes would be made available on the large computers. The meteorological data are stored in a computer-compatible format and can be retrieved, analyzed, and used to compute a trajectory within approximately 5 min after notification. Meteorological data would then be transmitted to the large computers and used for the regional model calculations, which would be available about 35 min after the trajectory calculation. These calculations would be repeated with updated environmental measurements and transmitted to the site until the requirement no longer exists. During the postemergency period, more detailed numerical model calculations can be made to assess the total environmental consequences of the toxic material release.

Although ARAC trial exercises have so far been conducted in a prototype configuration, a separate LLL central facility is scheduled for July 1976. The minicomputer and associated equipment are now undergoing checkout; software will be written during FY 1976. Communications to the ERDA sites—LLL, Savannah River Plant (SRP), and Rocky Flats Plant

(RFP)—will be established early in FY 1977. By FY 1979 we plan to have the central facility staffed 24 hr/day. During the interim 3-year period, we will staff the central facility on a limited basis, with the personnel on call during the off hours.

## NUMERICAL MODELING AND ENVIRONMENTAL ASSESSMENT

In the preceding section, we discussed and gave an example of the Gaussian diffusion estimate calculated at the site facility and based on the latest available meteorology measured at the local site. This calculation gives the site personnel a quick estimate of expected normalized concentrations and/or doses for distances out to 5 km. This section deals with advisories that are calculated at the central facility, transmitted to the site facility, and used to make regional assessments out to 100 km from the site.

For detailed regional assessments, we presently have three-dimensional numerical transport and diffusion models that can be used to estimate regional air concentrations and ground deposition from a continuous or instantaneous point source or sources.

A meteorological adjustment model has been developed to provide a pollutant transport model (see ADPIC, below) with input wind fields that are mass-consistent (nondivergent), three-dimensional, and representative of the available meteorological measurements. Interpolated three-dimensional winds are adjusted in a weighted least-squares sense to satisfy the continuity equation within the volume specified.[2,3] The upper and lateral boundaries above topography are assumed to be open air and thus allow mass flow through the boundaries. The bottom boundary (assumed to be solid) is determined by the topographic elevations of the area of interest.

The theoretical basis for this model was developed by Sasaki.[4-6] The model minimizes the deviation of the adjusted wind field from the measured field subject to the constraint that the adjusted field is nondivergent. The observed data needed for the adjustment are provided by an interpolation–extrapolation scheme using information available at a given site to determine the observed velocity components at each grid point above the topography. These observed velocities are assumed to be a fair and reasonable representation of the actual wind field and only need to be minimally adjusted to significantly reduce the remaining divergence.

The current implementation of this model, known as MATHEW, adjusts the three-dimensional winds at approximately 30,000 grid points in 2 to 5 min of CDC 7600 computer time. The actual running time depends on the complexity of the topographic boundary. It must be emphasized that MATHEW does not forecast the wind fields but instead uses existing wind measurements over the region to produce wind fields based on persistence.

Research is under way at LLL as well as at other laboratories and agencies over the United States to develop fine-mesh meteorological predictive models. As these models are validated and become available, they are to be included as an integral part of the model options available in the ARAC central facility. In the interim, we plan to use forecasts that are available from NWS or AFGWC to help predict changes in the meteorological conditions that might occur.

The ADPIC[7-9] is a hybrid, Lagrangian–Eulerian, three-dimensional, particle-in-cell code for calculating the transport and anisotropic diffusion of a pollutant from its source to its temporal and regional distribution at arbitrary times. The code can simulate the transport and diffusion of pollutants under prescribed conditions of speed and directional wind shear; occurrence of calms; space-variable surface roughness; wet and dry deposition; radioactive decay; gravitational settling; space- and time-dependent eddy diffusion parameters; and single or multiple sources of either continuous or instantaneous nature. The code solves the three-dimensional advection diffusion equation in flux-conservative form using a pseudovelocity technique for a given regional mass-consistent advection field (supplied by MATHEW) in three-space dimensions and in time.

In this method the Lagrangian particles represent the activity distribution and concentration associated with the aerosol within the structure of an Eulerian grid. The chief advantages of this approach are (1) the artificial diffusion inherent in purely Eulerian finite-difference codes is practically eliminated and (2) the Lagrangian particles can be tagged with their coordinates, mass or activity, age, and other properties that a particular pollutant might exhibit.

The ADPIC code has undergone validation tests against closed analytic solutions and also regional tracer studies. Figure 8 is a summary of the results from three validation tests run against methyliodide tracer studies at the Idaho National Engineering Laboratory, Idaho Falls, Idaho, and $^{41}$Ar plumes at the Savannah River Plant, Aiken, S. C.[9] The latter data are from a joint SRL-LLL 1974 test, the results of which are scheduled for publication.[10] The measurements shown in Fig. 8 were made at 5 to 80 km from the

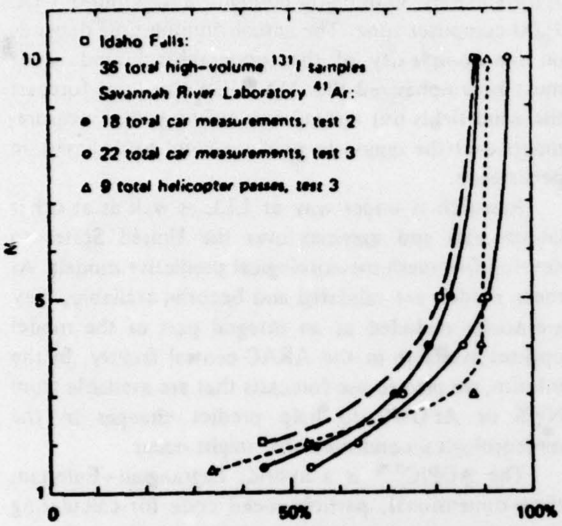


**Fig. 8 Percentage of cases in which ADPIC results are within a factor N of field data.**

point or points of release. For these tests, ADPIC concentrations were within a measured factor of 2 for 60% of the time and over 90% of the time were within an order of magnitude. Three additional long-range (out to 80 km) validation tests are planned at SRL which include $^{41}$Ar and $SF_6$ as tracers. We hope to conduct tracer experiments at other ERDA sites in the future. Further details of the numerical models and their validation may be found in the references cited for the MATHEW–ADPIC computer codes (Refs. 3, 7, and 9).

The conversion to dose levels of the ADPIC-calculated regional distribution of surface air concentrations and surface deposition of specific radionuclides is currently under development.[7] On completion, we expect the dose-conversion code (DOSCON) to be capable of estimating the whole-body or organ doses via the inhalation, external, and ingestion pathways. For the inhalation pathway, we plan to incorporate the ICRP Task Group on Lung Dynamics Model[11] to compute the dose to various organs of the respiratory tract. However, this requires a knowledge of the aerodynamic particle size and the chemical and physical characteristics of the specific radionuclides. We plan to use the EXREM-III computer code developed by Trubey et al.[12] for the external pathway. This code is capable of estimating the exposure due to gamma and beta radiation during cloud passage and to surface deposition. The calculation of dose from food ingestion requires the use of concentration factors and transfer coefficients to determine the activity of specific radionuclides in each food. These may be obtained from the data of Thompson et al.[13] By using these data, in conjunction with the internal dose model developed by Ng et al.,[14] we expect to have the capability of estimating the ingestion dose for each radionuclide of interest through specific food-chain pathways.

## ARAC IMPLEMENTATION PLAN AND ASSOCIATED COSTS

The initial three-phase study started at LLL in FY 1973 provided for concept, prototype, and implementation of ARAC. The prototype phase ended in FY 1975, and an implementation phase is now in progress. In FY 1976 we plan to activate the LLL central facility and the initial ERDA site facilities at LLL, SRP, and RFP. The 3-year plan calls for an incremental building of the component parts of the ARAC system until a fully operating network of ERDA nuclear sites and the LLL central facility would be complete by FY 1979.

Table 1 summarizes the LLL costs estimated for the 3-year plan. ERDA funding will be budgeted by

**Table 1 Estimated LLL Costs for 3-Year ARAC Implementation Plan**

| | Operating costs, \$10³ | | | Capital equipment costs, \$10³ | | |
|---|---|---|---|---|---|---|
| Fiscal year | Research | Operations | Total | Research | Operations | Total |
| 1976 | 525* | 135† | 660 | 170 | 50 | 220 |
| 1977 | 610 | 305‡ | 915 | 60 | 100 | 160 |
| 1978 | 600 | 400‡ | 1000 | 50 | 100 | 150 |
| Total | 1735 | 840 | 2575 | 280 | 250 | 530 |

*Includes site customizing for SRL.
†Includes site customizing for RFP.
‡Includes site customizing for two additional ERDA sites as yet not specified.

LLL with one exception. Each user site will have to fund the one-time operating costs for customizing the installed ARAC equipment at the site.

At some point in the future, each user site will bear its proportion of the recurring annual operations-related costs for the central facility. For FY 1979 and subsequent years, these annual costs are estimated at $630,000 (plus inflation), plus about $200,000 of ERDA funding for continuing research-related activity on improving ARAC and modeling capability. The estimated ARAC costs to an ERDA site for the service are summarized in Table 2.

In addition, the site will bear the costs for installing and operating the environmental monitoring network that furnishes the basic input source data. The latter costs would be variable, depending on each site; however, operating costs to maintain the ARAC site equipment are estimated at $10,000 per year.

**Table 2 Details of Estimated ARAC Costs for an ERDA Site (FY 1976 Dollars)***

| | Cost, $$10^3$ |
|---|---|
| One-time costs | |
| Capital equipment (ERDA funded) | |
| Minicomputer with core memory, graphic display, tape, teletype | 32 |
| Interface to weather data equipment | 4 |
| No-fail power supply | 4 |
| Printer–plotter | 10 |
| Total | 50 |
| LLL customizing and software (user funded) | 75 |
| Recurring costs (annual) | |
| Site operating expenses | |
| Lease of telephone lines, data set, acoustic coupler unit | 1 |
| Communication charges | 4 |
| Computer system maintenance | 5 |
| Total | 10 |
| Approximate user share in ARAC operations-related costs after FY 1978 | |
| For 7 sites | 90 |
| For 20 sites | 30 |

*Not included are the inflation factors or the costs of establishing and operating an environmental monitoring network.

## CONCLUSION

It should be recognized that ARAC represents a concept that is in the initial stages of implementation as an operational system. This emerging nature of ARAC means that changes can be expected before it reaches its final form. However, the concept of ARAC is fully developed and was successfully demonstrated[11] during a feasibility study conducted in FY 1974 as a joint effort between SRL and LLL. The concept also received a realistic check in May 1974, when SRP experienced a relatively low-level atmospheric release of tritium.[15,16] Although the feasibility tests were not completed at that time, the real-time meteorological data link between SRL and LLL was established. Meteorological measurements from the instrumented television tower near SRP, coupled with calculations based on simple LLL models, provided SRL personnel with supplemental information that was used in assessing the potential hazard from the release.

In this article, we have attempted to provide sufficient data on the concept, current status, and future plans of ARAC to demonstrate the potential of ARAC. ARAC would offer a number of advantages for emergency and routine planning by site officials. The ARAC site facility would provide a means for locally applying atmospheric modeling techniques for close-in distances. The central facility would provide the results of newly developed regional modeling techniques and predicted real-time dose calculations; access to large-scale computers and data handling would permit improved emergency planning based on data not normally available at an individual site. Although our immediate goal is the application of ARAC to assist a limited number of ERDA sites, the system is designed with sufficient flexibility to permit expanding the service to a larger number of nuclear or chemical sites.

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