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MINUTES
NINETEENTH MEETING OF THE
PANEL ON RADIOLOGICAL INSTRUMENTS

14 - 15 May 1959

The meeting was called to order by the Chairman at 1000 hours, 14 May 1959, with the following voting members present:

Dr. G. Failla, Chairman - Columbia University
Dr. William F. Bale - University of Rochester
Dr. Francis R. Shonka - St. Procopius College
Dr. Wolfgang J. Ramm - Army (USASEDL)
Mr. George Mahaffey - Navy (BUSHIPS)
Lt Col L. T. Boatwright - Air Force (AFSWC)

The following member was absent:

Dr. George K. Green - Brookhaven National Laboratory

For the Defense Atomic Support Agency (DASA) Secretariat, the following person was in attendance:

Captain William D. Sheehan, USA, CmlC

The alternates and other interested persons listed below also attended the meeting:

Mr. Norris Sills - OCCmlO (Army Alternate)
CDR George Howe - CNO (Navy Alternate)
LtColonel Paul Cerar - OCCmlO
Mr. Abraham Cohen - USASEDL
Mr. Elmo DiIanni - NML

The summaries of discussion and Panel resolutions are as follows:

PANEL MEMBERSHIP AND CHARTER

The Chairman has recommended to the Chief, DASA, that Dr. Victor Bond, Brookhaven National Laboratory, be invited to join the Panel to replace Dr. G. K. Green who has submitted his resignation.

The Chief, DASA, asked the Chairman to consider the feasibility of enlarging the Panel to include five civilian members. The Panel voted to enlarge the Panel to include five civilian members and three Service

members. Various persons, representing the National Laboratories, civilian Universities and industry, were proposed to the Chairman as the fifth member. The Chairman took the list of names under advisement and if he does not nominate a fifth member by the next meeting, the nominees will be discussed at the 20th meeting.

RECOMMENDATIONS FROM THE 18TH PRI MEETING

The Panel presented three recommendations to the Chief, DASA, for forwarding to the Research and Development elements of the Services. The prepared letter was coordinated with the Panel. As for the recommendation on a tritium monitoring instrument, a further discussion was held on the feasibility of such an instrument and the consensus of opinion was that this recommendation was feasible for a go no-go type instrument. A possible situation where this instrument might not be feasible was discussed and as a result the Panel voted to add the following sentence to the current recommendations.

"The permissable concentration for a short exposure to tritium gas is assumed here to be 1×10^{-2} micro curies per cubic centimeter. Exposure for one hour at this concentration does not exceed the integrated 13 week exposure for occupational personnel allowed by the current (1959) International Commission on Radiological Protection (ICRP) recommendation."

Minor modifications to the wording of Na-24 body fluid assessment recommendation and the energy dependence summary were made. The Panel then coordinated on "Current Recommendation" letter.

STANDARD CALIBRATION SOURCES

The Navy member discussed the problems associated with alpha calibrators. Three problems in calibration sources were discussed; namely, reduce the swipe count hazard, reduce the variations in the prepared calibration sample and the procurement of Pu-239. The NML representative discussed his ideas and the Mound Laboratory method of calibration sample preparation. The OCCml0 member discussed some apparent procurement problems. After further discussion, the Panel made the following resolution:

> "The Panel recognizes the importance of having suitable primary alpha standards to calibrate alpha radiacs. Therefore, the Panel recommends that an accelerated effort be made to fabricate suitable alpha ray standards."

The Secretary indicated that the DASA will assist the Services in Pu-239 procurement if any difficulties in procurement are experienced. The Field Command, DASA, channel to obtain Pu-239 was discussed.

The Navy member discussed another aspect of standardization; that is, that the responsibility of the radiac standardization program was a Navy responsibility. He further discussed the specifications for dosimeters and field calibrators which he hoped would be standardized this year.

ENERGY DEPENDENCE

The question of the response of personnel dosimeters was again discussed. The energy response of dosimeters to initial, residual and laboratory irradiations were discussed and the Panel then made the following resolution:

> "The Panel recommends that for purposes of evaluation of the short term effects of whole-body exposure of military personnel in an extended fallout field, the energy dependence of personnel dosimeters should be adjusted to take into accout the lower efficiency of the less penetrating components of the gamma ray spectrum and beta rays in producing such effects. Presently available information indicates that for practical purposes this condition is fulfilled when the reading of the personnel dosimeter in an extended radiation fallout field represents:
>
> (1) 100% of the air dose in roentgens in the gamma ray energy range from 1.25 Mev (Co-60) to 80 Kev.
>
> (2) A gradually decreasing percentage of the air dose in roentgens below 80 Kev so that it is 50% at 50 Kev and no greater than 5% at 20 Kev. Allowable error limits should be stated in the detailed specifications of the procuring agency. A precision of $\pm$ 20% is suggested.
>
> The Panel also recommends that all dosimeters in the 0-200 mr and 0-5 r range and dosimeters of all ranges for technical and laboratory use, where the evaluation of possible long term hazard is the principal object be constructed so as to show essentially flat energy response from Co-60 radiation down to X-ray quantum energies of 20 kev with no peaking of response for quantum energies below this value."

EFFECTS INFORMATION

The DASA representative reviewed PLUMBBOB and HARDTACK results which have a bearing upon radiac instrument requirements. A discussion of the initial gamma ray spectrum and its application to dosimeters ensued.

FIELD TESTING

The testing of radiacs in simulated fields was discussed. The NML representative discussed depth-dose measurements and felt that phantom and depth-dose exposures to laboratory sources can be adjusted to duplicate field exposures. The USASEDL representative agreed with the ideas discussed but felt the problem of field testing was centered about the user's use of the instruments. The OCCmlO representative felt that although the radiological test area will be open for Service use, the bomb fallout spectrum would not be duplicated and thus a degree of confidence is lost. After further discussion, the Panel made the following resolution:

> "The Panel believes that field tests of radiac instruments designed for measurement of prompt radiation and radiation from fallout fields has been in the past unduly expensive in money and in the time of professional personnel because of a lack of facilities for preliminary testing of instruments under development under simulated field conditions. The Panel therefore recommends that facilities for simulated prompt field tests and extended fallout fields be made available for these purposes. For prompt radiation studies, the Panel recommends that a facility be provided for joint Service use in the study of radiac instrumentation and radiological effects based on a preliminary study to indicate whether one or more prompt radiation simulators are required for adequate scheduling of necessary tests for both purposes.
>
> The Panel understands that action has already been taken to provide an extended gamma radiation field at the Bugway Proving Ground, Nevada, which will be available for testing of radiac instruments. The Panel recommends that such facilities be supplemented to simulate more closely a radiation field."

BIOLOGICAL DOSIMETERS

The bodily effects of slow and fast neutrons were discussed. The subject of Cx-Reactive Protein (CxRP) response in rabbits given whole body X-irradiation was mentioned. The question of whether or not CxRP appearing in the blood serum as a biological dosimeter in addition to Na-24 was discussed.

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WD Sheehan

MINUTES
EIGHTEENTH MEETING OF THE PANEL ON RADIOLOGICAL INSTRUMENTS

First Day - 10 February 1959

The meeting was called to order by the Chairman at 0900 hours, with the following voting members present:

Dr. G. Failla, Chairman	Columbia University
Dr. William Bale	University of Rochester
Dr. Francis Shonka	St. Procopius College
Dr. Wolfgang Ramm	Army (USASEL)
Mr. George Mahaffey	Navy (BUSHIPS)
Lt Colonel L. T. Boatwright	Air Force (AFSWC)

The alternates and other interested persons listed below attended the meeting at the end of the Closed Session.

Mr. Robert Attmore, BuShips
CDR Gordon Bell, BuMed
Dr. Victor Bond, BNL
Lt Col Francis Bradley, OSD R&E
Major Heber Brill, CONARC
Mr. Louis Browne, USASEDL
Major William Bryan, AFSWC
Mr. Alvin Carriker, NRL
CDR Francis Chambers, NMRI
Mr. Irwin Cherrick, BuShips
Mr. Leland Clark, Sr., NML
Mr. Abraham Cohen, USASEDL
Dr. George Davis, NML
Mr. Elmo DiIanni, NML
Lt Col B. S. Evans, JTF-7
Lt Col James Hartering, SGO
Mr. Charles Hollander, BuShips
CDR George Howe, CNO (Navy Alternate)
Mr. Martin Jachter, USASEDL
Mr. Robert Jones, BuShips
Mr. Nathan Klein, CWL
Dr. S. Kronenberg, USASEDL
Colonel Ralph LeChausse, AFCSG
Capt Dale Lindall, AFSWC
Mr. Joseph Lindwarm, CWL
Mr. Joseph McGreevy, NML
Mr. Robert Martin, OCDM
Mr. Harry Murphy, USASEDL
Mr. A. H. Redmond, NRDL -

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John F. Bilek
DATE 5 Aug 94

Mr. Edward Saunders, OCDM
Dr. James Schulman, NBS
Mr. Norris Bills, OCDM10 (Army Alternate)
Mr. Kenneth Sinclair, NBS
Dr. Scott Smith, NBS
Mr. Herbert Talkin, AEC
Lt Colonel F. Timmerman, SCO
Lt Colonel Lowell Thompson, OCDM10
Lt Colonel Albert Voegli, AEC
Capt Clay Weight, AFSWC (Air Force Alternate)
Mr. Henry Whitten, OCDM
Dr. Harold Wyckoff, NBS

The following persons from Headquarters, Armed Forces Special Weapons Project were in attendance:

Captain William T. Sheehan, Secretary, Panel on Radiological Instruments
Major Phillip Dolan
Captain Thomas Provenzano

CLOSED SESSION

10 February 1959

1. A closed session of the Panel was held from 0900 to 1000 hours.

2. Dr. Failla was re-elected Chairman of the Panel for 1959.

3. The following members were absent:

Dr. Francis Shonka, St. Procopius College
Dr. George Green, Brookhaven National Laboratory

4. Captain Clay D. Weight was nominated and elected as an alternate member (U.S. Air Force) to the Panel.

5. The Chief, AFSWP, indicated to the Panel that the mission of AFSWP was being rewritten and that Chief, AFSWP, would be responsible to maintain current information as to the status of military research and engineering in the field of radiac instruments and to make recommendations to integrate

the efforts of Services research agencies." The Chief, AFSWP, also pointed out to the Panel that the Charter of the Panel would still be valid under the new mission and that the Panel would continue to advise the Chief, AFSWP.

OPEN SESSION

WELCOME - Dr. Failla, Chairman

On behalf of the Panel, I wish to welcome you to the 18th meeting. At this time, I would like to reiterate the five functions of the Armed Forces Special Weapons Project Panel on Radiological Instruments. The functions of the Panel are: (1) to periodically review the status of radiac instruments under development, (2) to review the implications of new weapons effects information upon radiac instrument requirements and design, (3) to provide a forum for the exchange between the R and D elements of the Services, (4) to render assistance to specific problems, and (5) recommend, where appropriate, changes or extensions in the research and development programs within the Services. The Open Session will now begin with the first presentation.

NEW MILITARY RADIAC REQUIREMENTS

ARMY - Major Heber C. Brill, CONARC

The Army has no specific new requirements. Time has been spent, since the last meeting, filling the old requirements.

One problem that arose and was felled during the year was the alpha survey meter. The Army bought JUNO (the standard range model). We like it and feel we are committed to it, although we are interested in the

PAC-3G and 1S.

The IM-108 for field survey is now being procured and issued. A version of this instrument - the Xe-4 - for aerial survey has been prepared and will be tested in April. A version for tanks is being tested now. The IM-93 is being issued.

One new requirement stated last year is still valid - the need for a gamma-neutron dosimeter. We prefer, of course, one instrument to do both.

We do have one thing that is new. CONARC's Dr. Browning and SGO's Colonel Maupin have approved the concept of administrative dosimeter for research only. We feel that if a device can be found that closely resembles the human body in response to radiation, it will be useful. None of the present dosimeters are considered to be suitable.

The 48E1a training device, which I mentioned last year, has been issued and used. This is a radio transmitter with signal strength meters made to resemble exactly the IM-108. We like it. It has a few bugs, but has proved to be very useful for training.

Our new requirements are conceptual rather than mechanical. We have found that our instruments give us all the information we can use. We now have a capability at least, in all the requisite phases. We have reached the first plateau, so to speak, and can take a look around. We are now concerned with what do we want from these instruments? What do we need to have them tell us? What should we expect them to do? Once we have decided these things, we can turn again to development.

NAVY - Mr. George Mahaffey, BUSHIPS

The Navy has need for Radiac Equipment for personnel to protect themselves from overexposure to ionizing radiations. Radiological measuring instruments, techniques, and procedures are required for the following five applications:

a. Nuclear weapons and weapons systems, wherein the use of nuclear weapons requires protection measures for personnel from ionizing radiations due to accidents or other incidents involving our own weapons and weapons delivery systems.

b. Atomic warfare, wherein Naval personnel are subjected to the radiological effects of hostile nuclear weapons.

c. Explosive Ordnance Disposal, wherein Naval personnel involved in deep sea diving and in salvage operations may not be overexposed to nuclear radiations.

d. Nuclear propulsion, wherein the presence of a nuclear reactor provides a radiological or possible radiological environment which must be known in order that personnel are not inadvertently exposed to nuclear radiations.

e. Health safety and regulatory purposes, wherein the use of radioisotopes requires precautions to protect personnel from undue exposure to ionizing radiations due to normal use of radioisotopes, contaminated materials or leaking sources.

It may be observed that all of the above are concerned with health safety; however, the approaches which must be used are frequently dictated by the application involved. In other instances, a single instrument type, properly designed, can be used in more than one application. Where practicable, the latter approach is used.

The requirements which equipments and techniques must meet are dynamic. The body of knowledge relating radiation to biological effects is constantly growing; because of their application, many radiac equipments must produce readings which can be quickly and easily correlated with these biological effects. Many tolerances are being revised, generally downward; therefore, equipments and techniques must be capable of measurements at the reduced levels. New weapons and systems for delivery are being evolved and suitable instruments for the protection of personnel during handling and delivery must be provided.

To insure the Naval Forces Afloat and Shore Establishments are in a state of readiness, radiac equipment to meet the Navy's requirements include: Survey Meters, Dosimeters, Monitors, Laboratory Equipment, Calibrators, and Accessories for existing equipment.

Radiacs presently in use in the Navy and types in development proposed for future adoption by the Navy are included in the List of Military Radiac Devices. Time will not permit discussing in detail each of these types. Many were presented and are covered in the minutes of the Sixteenth Meeting of the Panel. Some of the types in development will be described and models presented later in the meeting.

A requirement exists for a survey meter to determine the presence of ionizing radiation because of the increasing power of radar equipments. Personnel who service or bench test radar equipment may be exposed to ionizing radiation in addition to thermal damage due to microwaves, depending upon the radar in use. Some current Navy radar developments with 250,000 volt transmitting tubes require approximately one ton of lead shielding.

In summary, in some operations potential hazards to Navy personnel may occur from radioactive materials used and present in the environment.

SOLID STATE DOSIMETER SYSTEMS

The Navy member reviewed the use of thermoluminescence for radiation dosimetry. Results of investigations being conducted on radiation sensitive materials at the Naval Research Laboratory indicate that a special manganese-activated calcium fluoride phosphor permits detection of X-ray and gamma-ray doses in the milliroentgen range. This device offers promise as a replacement for the photographic film badge for health physics applications. In this method of dosimetry the sensitive element is a luminescent solid that stores part of the energy received from the radiation. This storage is generally due to the trapping of electrons, which have been freed by the radiation, at imperfections in the solid. When the phosphor is heated, the stored energy is emitted as luminescent light, and the amount of this light is proportional to the dose received. The reader used to measure the dose consists of a small light-tight furnace, a simple means of inserting and removing the dosimeter, a photomiltiplier tube that views the active surface of the dosimeter, and a conventional meter read-out system. After the dosimeter has been read, and subsequently cooled, it is again ready for use.

The Panel felt that it was worthwhile to investigate solid state dosimetry. However, no resolution was made to recommend an expanded effort.

QUARTZ-FIBER RATEMETERS

Dr. Shonka discussed his quartz-fiber ratemeter. It was pointed out that the 6 sec time constant was too long for military uses such as mobile operations in radiological fields.

OTHER BUSINESS

The Panel expressed a vote of thanks to Dr. Bale of the University of Rochester for the hospitality shown during the 19th meeting.

The Panel accepted Dr. Shonka's invitation to hold the next meeting at St. Procopius College. The Chairman suggested an October meeting and the date of the meeting would be held during the same week of the Radiological Society meeting at Chicago, Illinois.

The meeting was closed at 1400 hours on 15 May 1959 and the Panel was then given a conducted tour through the research facilities of the AEC project at the University of Rochester's School of Medicine.

William D. Sheehan

WILLIAM D. SHEEHAN
Captain, USA
Secretary, Panel on Radiological Instruments

In these situations, it is desirable and often mandatory to have information on dose and dose rate within an accuracy of ± 20 per cent.

AIR FORCE - Lt Colonel L. T. Boatwright, AFSWC

The various areas where the Air Force requires nuclear instrumentation are as follows: personnel dosimetry to include the present integrating instruments such as the DT-60, quartz-fiber dosimeters and film badges, and a new requirement exists for a suitable neutron dosimeter. The ideal personnel dosimeter would be one that gives a correct dose indication upon exposure to both gamma and neutrons over the entire energy spectrum.

Requirements for portable field survey instruments are for more reliable types which are easier to maintain and which have a simplified battery complement.

For air crew survival kits we need a miniature gamma rate instrument which should be rugged and capable of immediate operation after a long storage period.

Air Base monitoring requires a continuously operating instrument to give an alarm in case of unexpected radioactive fallout.

Special purpose instruments are required from time to time in the weapons test program and high altitude sampling projects. In this category we also include air samplers, calibration equipment, tritium monitors and analysers.

REPORT FROM TRIPARTITE CONFERENCE - Mr. Joseph Lindwarm, CWL

The 13th Tripartite Toxicological Conference on Chemical Warfare, Biological Warfare, and Radiological Defense was held 9 - 23 September 1958 at Suffield Experimental Station, Alberta, Canada. The Tripartite countries are US, UK, and Canada. This is a yearly, 2-week conference. The purpose is to coordinate the R&D efforts, exchange information, and arrive at a degree of standardization of equipment and techniques among the three countries.

Discussions in the field of Radiological Defense include: nuclear weapons radiation phenomenology, biological effects of radiation, radiation detection and measurement, protection (shielding) decontamination and simulation — all from both the technical and service aspect point of view.

This report will summarize the discussions, conclusions and recommendations of the conference which are of pertinent and immediate

interest to this group.

1. Nuclear weapons radiation phenomena--no new information or data were presented.

2. Biological effects of ionizing radiation--it was concluded that the two areas of greatest ignorance were: (a) dose versus acute effects of neutrons, (b) the effect of protraction and fractionation of the dose on the table of acute effects of radiation. It was further concluded that the effort being put into the neutron problem by the three countries is inadequate to produce solutions in a reasonable time. It was therefore recommended that action should be taken by all three countries to increase substantially the effort in this field. To insure that this would be effective, a meeting of experts in biology and medicine should be arranged to examine existing data and to recommend how the militarily significant problems could best be attacked. Further, that the three countries should examine means of setting up a working group which could plan an integrated program on biological effects for a weapons test devoted specifically to the acquiring of biological effects data.

3. Radiac Instrumentation.

a. Dosimeters. It was noted that currently available quartz fiber dosimeters, in all 3 countries, fail to meet present specifications on dose-rate and neutron response, particularly for low-yield, small-sized tactical weapons. Three recommendations were made: (1) the Services should conduct an operational analysis specifically directed towards evaluating the effect of these inadequacies on the ability of the commander to arrive at a "suitable estimate of the situation;" (2) present types of quartz-fiber and phosphate glass dosimeters should be retained until it is determined to what extent the neutron response and dose-rate characteristics of dosimeters can and should be improved; and (3) investigations on the design of dosimeters for measuring initial gamma radiation dose should continue in order to be prepared to meet a stricter specification on dose-rate dependence.

b. Water Monitoring. It was agreed that a level in drinking water of 3×10^2 uc/ml of recent fission products is one which can be consumed for several weeks without significantly increasing the likelihood of acute effects, and radiac instruments exist which can measure this level with sufficient accuracy.

c. Aerial Survey. It was noted that considerable progress has been made by the 3 countries in defining their operational requirements for aerial survey over friendly territory using low performance aircraft. Further, that the technical problems involved in the development of the associated equipment do not appear to be particularly difficult. Visual navigation and radio-telephone reporting appear to be acceptable;

- the improved accuracy obtainable with more sophisticated techniques does not appear to warrant the associated increased cost, greater complexity, and risk of failure due to destruction of the land-based components.

d. Surface Hazard Evaluation. It was concluded that to obtain a measure of the surface dose-rate at levels approaching the acute response of the skin would require a high dose-rate measuring instrument with a good beta capability. There was disagreement as to the actual need for such a measurement.

e. Radiac Units. It was agreed that although it is necessary for designers of radiac instruments and for radio-biologists to consider carefully the units and terms which they use, such as roentgen, rep, rad, gram-rad, rem, rbe, etc., and whether dose should be measured in air or in tissue, at the surface or at the center of the body, for isotropic or for uni-directional radiation, etc., the reading of the Service radiac instrument should be directly related to the information provided to the Services concerning physiological damage.

ALPHA CALIBRATION AND CAPABILITES OF METERS

Mr. Louis Browne, USASRDL

A requirement was established to determine the Alpha Calibration and capabilities of Juno radiacmeters SRJ-6 and HRJ-6. Seven accurately calibrated Pu-239 source plaques were prepared. The activity of the plaques ranged from 18×10^3 CPM to 58×10^6 CPM (the surface area of each plaque was 3"x4", as compared to the Juno window area of 3"x43/8".) Two SRJ's and four HRJ's were gamma calibrated on an AN/UDM-1 cobalt-60 calibrator at USASRDL. From the data, corrected accordingly [illegible], the following conclusions were drawn:

1. The Juno was insensitive to the gamma components or any beta contamination in the Pu-239 source plaques used.

2. For the SRJ, the full scale capabilities over an effectively "infinite" area of uniformly distributed Pu 239 are: for x1 range= 160,000 CPM; for x10 range=1, 600,000 CPM; for x100 range=16,000,000 CPM. Similarly, for the HRJ, for x1 range= 577,000 CPM; for x10 range= 5,770,000 CPM; for x100 range= 57,700,000 CPM.

3. Moving the Juno window 1/16" closer to or away from the alpha surface resulted in a 25% change in meter reading.

4. The Juno alpha response is linear across the scale on all ranges.

Resulting from this study, the Juno SRJ-6 was selected for interim Army use. A design was evolved and specification requirements were prepared for a Pu-239 source plaque and two attenuator masks. The arrangement will allow calibration of the SRJ-6 on each of its three ranges and the check of additional points across the scale.

ALPHA CALIBRATION

Robert Attmore, BuShips

The Navy, like other Services, is in the midst of a program to obtain suitable Plucon instrumentation. As an interim measure we are procuring the Eberline Instrument, PAC-3G gas flow proportional counters, and USNRDL has completed development of their RAS-10 scintillation type alpha survey meter. The Eberline instrument has an upper range of 100,000 counts per minute (cpm) corresponding to a plutonium contamination of about 100 micrograms per square meter (ug/m^2.) The NRDL equipment has an upper range of 10^6 counts per minute corresponding to plutonium contamination of 10,000 ug/m^2.

In order to assure to the extent practicable that the alpha sources to be used for calibration will be as versatile as possible in terms of accommodating probes of various types and form factors, we are calling for an active area of 10 cm x 20 cm; surrounded by a 3 cm inactive border for handling. Because of the high range on which the calibration must be accomplished, we are specifying plutonium as the active material. The sources are being procured in sets of four; with the respective sources in the set having activity as follows:

(a) 160 ug uniformly distributed to give concentration of 0.8 ug/cm^2 over the active area.

(b) 16 ug uniformly distributed to give concentration of 0.08 ug/cm^2 over the active area.

(c) 1.6 ug uniformly distributed to give concentration of 0.008 ug/cm^2 over the active area.

(d) 0.16 ug uniformly distributed to give concentration of 0.0008 ug/cm^2 over the active area.

The distribution of the active material is to be as uniform as practicable across the surface of the source, and total amount of each source is not to differ from the amounts specified by more than 5%. Residual energy of alpha particles is to be at least 4 Mev at the source.

The concentrations called for are intended to give an 80% reading on the corresponding ranges of the NRDL equipment.

The physical procedure of calibration will be simple. The ranges and meter indications of the RAS-10, for example have been selected so that a plutonium and concentration of 10,000 ug/cm^2 will give an indication of 10^6 cmp, a concentration of 1000 ug/cm^2 will give an indication of 10^5 cmp, etc.

In this manner, a meter reading can be easily converted to its equivilent of ug of Pu per m^2 (under ideal measuring conditions). To calibrate the equipment on the 100,000 cpm scale, the probe would be placed in the center of the active area of the .08 ug/cm^2 source so that the entire screen is covered, and the calibration potentiometer adjusted to give a reading of 80,000 cpm on the meter.

In using this equipment for applications, other than Plucon, it is desirable that the meter readings be easily interpreted in terms of disintergrations per minute rather than micrograms of material. If we assume a 2π geometry in the above calibration, we find that an area of about 15 cm^2, Plutonium contaminated at 1000 ug/m^2 will give 10^5 dpm in a 2π geometry, must be referred to 15 square centimeters of area.

This does not imply that the alpha window is 15 cm^2 in area, merely that the meter reading should be referred to that area. It does imply that the source must be extended (i.e.-cover all of the sensitive area), and that separate calibrations must be made for sources which are not extended.

INSTRUMENT DEVELOPMENT FOR PLUCON

Mr. Kenneth Sinclair, NRDL

Several separate instrument developments will be covered, with special emphasis on alpha instrumentation.

The Plucon problem has reemphasized the need for suitable field alpha instrumentation. The principal concern here is in estimating the quantity of alpha contaminated material available for inhalation. The best present means for accomplishing this kind of measurement is by means of an estimate of the surface contamination level, coupled with the use of a likely resuspension factor. This data is used in estimating the potential or long term health hazard resulting from an alpha contamination situation. For determination of immediate hazard, standard air monitoring techniques are employed. Here, interest is directed at the material actually suspended in the air at the time the measurement is made. For some time, it was hoped that some more direct means of getting at the material available for resuspension would be found. Some effort at NRDL was directed towards the development of a device

having an integral facility for mechanically establishing some standard particulate resuspension and then automatically measuring the amount of the material so suspended to provide a direct measure of the hazard. Further study, however, disclosed many difficult and apparently insoluble problems. Factors like the hour-to-hour moisture content of the soil in a given area could result in radically different readings from such a device. Cons quently, the existing method of determining potential alpha hazard by means of a direct surface measurement corrected for the type of surface and the expected resuspension factor must be employed. In order to provide a device suitable for military field use in determination of the alpha surface activity, NRDL undertook the development of a new alpha survey radiac. This instrument, known as the RAS-10 is a general purpose device utilizing scintillation detection and transistorized circuitry. It is intended to replace the existing military device, the AN/PDR-10, and, in addition, to provide a range capability consistent with present operational needs. The PDR-10 has an upper range capability corresponding to 5 micrograms per square meter of plutonium-239 without modification. Since the present military standard in plutonium alpha incidents does not require decontamination below 1000 micrograms per square meter, far greater range capability was indicated. The RAS-10 will, on its top range, give a full-scale indication for 10,000 micrograms per square meter. Its maximum full-scale sensitivity, on the other hand, will correspond to 10 micrograms per square meter. The major enviromental problem with the PDR-10, humidity sensitivity, is eliminated by this instrument. Packaging is consistent with the operational need, providing maximum flexibility. An integral Thorium metal source is provided for field check of over-all instrument performance. Plug-in printed wiring boards are used through-out, facilitating maintenance. Work is underway on an additional small area probe for personnel monitoring and inspection of wounds. The opaque covering on the zinc sulphide screen still leaves much to be desired and further work is planned to improve this situation, using two alternate lines of attack. Continuing effort will be directed at the development of a screen with an evaporated or transferred aluminum over-covering and, in addition, work is planned on coatings consisting of opaque particles in an epoxy binder.

Another recent Laboratory development is a new low-range beta-gamma survey instrument. This device, designated the RGG-10, is an all transistorized instrument operating from two standard type D flashlight cells. It covers the standard military low-range from .5 mr/hr full scale to 500 mr/hr full scale in four linear ranges. Important improvements are provided over the existing AN/PDR-27 series of radiacs. These include beta indication on all ranges, a side window beta capability on the two lower ranges, physical location of both GM tubes in the same assembly to eliminate confusion, considerable reduction in over-all size and weight, simplified battery complement, and high reliability circuitry employing a functional layout to permit easy maintenance.

The third device of interest is the AN/PDR-52 beta-survey radiac. This is a multi-purpose instrument, presently out on contract with the Maico Company in Minneapolis. Prototypes have been delivered for evaluation and test. The range covered by this instrument is from 2 rep/hr full scale to 1000 rep/hr full scale in four linear ranges. Three distinct measuring functions are provided: (1) beta only, (2) beta plus gamma, and (3) gamma only. To provide beta only measurements, the gamma cancellation technique is employed, using two essentially identical but oppositely polarized ionization chambers. This feature is extremely important in decontamination and recovery operations where a high ambient gamma field may not permit local contamination assessment. For beta measurements, the chamber is consistent with biological criteria. The window consists of 10 milligrams per square centimeter mylar and the chamber depth is about 1½ centimeters. The power supply is transistorized and two type D flashlight cells are used for primary power.

ABSORBED DOSE FROM INITIAL RADIATION

CDR Francis Chambers, NMRI

This discussion will consider the absorption of the integrated dose of the initial radiation rather than the prompt, because of its more practical application.

Looking at the absorption of the initial gamma radiation in the absence of neutrons, we find that the exit dose from an average size man is approximately 60-65% of the entrance dose. Comparison of field test data obtained in the laboratory shows that a 10 Mev Betatron produces approximately the same transmission curve as the weapons evaluated, which did not include thermo-nuclear detonations. The energy appeared not to change for the distances involved at the dose levels of interest, namely, up to 1000 roentgens.

The evaluation of the absorbed dose due to neutrons presents a considerable problem mainly because of the lack of (a) good instrumentation absorption measurements and (b) an adequate knowledge of the RBE for neutrons or the protons liberated by them. The instrumentation that is discussed is not field but laboratory instrumentation.

Processes involved in neutron absorption have been investigated and calculations have been made with regard to the LD_{50} (man) for neutrons of varying energies. The significant thermal neutron effects in tissue appear to be the

n,p reaction $N^{14} + n = C^{14} + p$ (0.61 Mev)

n,γ reaction $H + n = D + \gamma$ (2.2Mev)

The significant effect of fast neutrons appears to be the production of recoil protons. Calculations have been made by Cave in England for the LD_{50} (man) of various energy neutrons. They were based on the assumption that (a) the 50% lethal dose for X-rays is 400 roentgens, (b) the RBE for protons is 6.5, (c) the criterion for lethal effects is the equivalent amount of ionization produced in the whole body, and (d) the incidence of the neutrons is isotropic. The values vary from 1.6×10^{12} n/cm^2 at thermal energies to 1.7×10^{10} n/cm^2 for 3 Mev neutrons. These values agree within an order of magnitude with those given in the "THE EFFECTS OF ATOMIC WEAPONS."

Hurst and Rossi have developed methods for evaluating tissue dose for neutrons and mixed ionizing radiation which we hope to use, along with other detectors, in an attempt to correlate the physical measurements of absorbed dose for mixed ionizing radiation with biological effect in large, as well as in small, animals. The instrumentation problem for absorbed dose of mixed ionizing radiation in tissue at this time is one for the laboratory. Considerably more information, both physical and biological, will be needed before one could "set up" a good field project. In the meantime, the use of threshold and other presently available detectors for air measurements under various conditions of exposure would provide valuable information for future correlation and possible development of an integrating dosimeter for mixed ionizing radiation.

TRITIUM MONITORING EQUIPMENT

Captain James H. Scharff, AFSWC

1. This is a presentation on the tritium monitoring equipment presently in use by the USAF. This presentation includes some of the problems we have experienced with this equipment.

2. There are presently four items of equipment associated with tritium monitoring. These include a portable air monitor, the T-290; a semi-permanent air monitor, the T-289; a remote indicating alarm unit used with the T-289, the T-336; and a uranalysis kit, the T-329, also used in conjunction with the T-289.

3. The T-290 is a small portable unit weighing only 23 pounds and operates from a self-contained battery. The instrument provides full-scale sensitivity ranges from 12.5, 125, and 1250 micro curies per cubic meter of air. Major components making up the T-290 include the precipitation chamber, electrometer, amplifier, meter, alarm circuit, blower, and associated power supply. Ambient air is drawn through the precipitation chamber into the electrometer by the blower. Free ions present in the air sample are removed by the precipitation chamber before it enters the electrometer. Ionization then present results in a current established

in the electrometer which is proportional to the inoization level of the air sample. This current is then presented to the meter circuit. When the meter reaches full scale on any range selected, the alarm circuit is activated. The alarm is a transistor audio oscillator presenting a signal of approximately 1,000 cycles per second. The alarm circuit is self-holding and must be manually deactivated. The instrument is self-calibrating and very simple to operate. Adequate operating instructions are printed on a plate located on the side of the instrument. The battery power supply is made up of mercury cells and provides 6.3 volts to power the blower motor and audio oscillator and a 12.06 volt output for the electrometer circuit. An internal battery provides an operating life of approximately 50 hours at temperatures above 50°F. Since the life of mercury batteries is greatly dependent on temperature, an external battery is provided for operation below 50 degrees. This battery is contained in a holster which is worn next to the operator's body to maintain its operating temperature.

4. The semi-permanent monitor, the T-289, is made up of two sections, each weighing slightly over 100 lbs. The first, a pre-amplifier unit, contains the blower, precipitation chamber, electrometer and preamplifier circuitry. The unit is normally located in the area where monitoring is desired. The second section, the control amplifier unit, can be located either 10 or 50 feet from the pre-amplifier unit using cables provided. This unit contains the amplifier circuitry, operating controls, alarm circuit, and a recorder which provide a permanent record of instrument operation. The T-289 is also self-calbrating. When first turned on, the unit is unstable for a short period and this state is indicated by a buzzer. Once the unit stabilizes and is operating properly, the instrument is quiet. At any time the instrument reaches full scale on any range, a loud alarm is sounded. Full scale ranges for the T-289 are 1, 10, 100, and 1,000 micro-curies per cubic meter. This unit is normally used only in an area that is routinely occupied by personnel, such as assembly buildings. Other monitoring operations are covered by the T-290, such as checking storage igloos prior to entry, aboard aircraft, etc.

5. The third instrument, the T-336 Over-radiation Alarm, operates in conjunction with the T-289 and provides remote aural and visual indications of the three states of operating condition of the T-289. A buzzer and yellow light indicate the non-operative states; silence, and a green light indicate normal operation (at less than full scale); while a loud alarm and red light indicate a full-scale reading. The alarm condition of the T-289 is also self-holding and must be manually deenergized. The T-289 can accomodate either one or two T-336's without external power connections. If conditions require, a number of T-336 units may be controlled by a single T-289, provided proper power connections are made.

6. The final piece of monitoring equipment is the T-329 Uranalysis Kit. This unit consists of a gas generator jar, associated glassware for drying of the generated gas, precipitation chamber, electrometer, and a

vacuum pump. A urine sample from an individual suspected of tritium contamination is placed in the instrument. The urine sample is allowed to react with metallic calcium liberating free hydrogen and/or tritium ions. The resulting gas is dried and collected in the electrometer. The vacuum system is used to "power" this operation. The charged electrometer is then removed from the T-329 and placed in a T-289 for read-out.

EVALUATION OF BODILY EFFECTS OF FAST NEUTRONS

Victor P. Bond, M.D., Ph.D.

Brookhaven National Laboratory

Before beginning this presentation I would like to define a few terms that must be clearly understood for meaningful discussions. The terms are as follows:

1. "Air dose." This has been termed "air exposure dose," and the "dose measured free-in-air." With x-rays or gamma rays, it is expressed in roentgens, and is the dose measured free-in-air with the virtual absence of any scattering material near the measuring instrument.

2. "Incident dose." Air dose refers strictly only to x- or gamma rays and cannot be used in connection with neutrons because, while the mechanisms of absorption of x- or gamma radiations are not greatly different in air or tissue, they are vastly different in air and tissue in the case of neutrons. The incident dose then will be used to correspond to the air dose used with x- or gamma rays, and indicates the first collision neutron dose calculated from the neutron flux measured free-in-air, in the absence of significant amounts of scattering material.

3. "Tissue dose." This refers to x- or gamma radiation only, and is the air exposure dose measured in tissue. The ionization chamber, for instance a Victoreen chamber, is placed on the surface or in tissue, and the dose in the air contained within the instrument is measured at an exposure site within the tissue. This differs from the air dose above, principally, in that it takes into account scattered radiations from the tissue and the geometry of exposures. The tissue dose may differ in value from the air dose, and may be higher or lower by as much as a factor of 0.5. It is usually higher

than the air dose in the case of exposure of small animals such as mice; is usually lower than the air dose with large animal irradiation principally because of the geometry of exposure employed.

4. "Absorbed dose." This value is measured in rads, and represents the actual absorption in tissue rather than in air as with the air dose or the tissue dose. With x- or gamma rays, it is obtained from the air dose by multiplying by a factor of the order of 0.95. Thus numerically, under most conditions, it is essentially equal to the tissue dose.

5. "True RBE." The "true RBE," or the "intrinsic RBE" refer to the RBE obtained under conditions where the dose is measured in the biological specimen, and is essentially equal throughout the biological specimen. The RBE's obtained are presumably related to some intrinsic property of the radiations involved, probably principally on LET.

6. "Dose distributions." This refers to the depth dose pattern in tissue, principally in large animals in this discussion. Most radiations are absorbed rapidly, and the distribution of dose throughout the body is markedly inhomogeneous. The degree of inhomogeneity depends principally upon the energy of the radiation, and the geometry of the exposure.

7. "Apparent RBE." By apparent RBE I mean the term RBE used loosely to compare apparent differences in effectiveness of two radiations under conditions where the tissue dose either is not known with any degree of accuracy, is non-homogeneous throughout the tissue--or, both. Specifically here, apparent RBE will be used to compare effects on large animals or man in terms of the air dose or incident dose. The apparent RBE of different energy radiations for acute mortality in large animals can be quite large as indicated by the fact that in going from 250 KVP x-rays to 50 KVP x-rays, and studying acute mortality in dogs, the apparent RBE of the radiations can change by a factor of 20 or so. This apparent RBE is not related to the LET, or the intrinsic energy of the radiations, but is secondary to differences in, or the lack of penetration.

Under the usual conditions we have the air dose or the incident dose to work with. It is obvious that the biological effects however depend upon the tissue dose or absorbed dose and its distribution, and it is of great importance to determine the relationship between these factors if accurate prediction of biological effect is considered important.

One other point before we get to the data. Present instruments for neutron dosimetry read in terms only of the heavy recoil particles from the neutrons. They are calibrated in terms of the first colli-

sion dose for a "thin foil" of tissue to which generated gamma radiation is a minor contributor. This is excellent for the mouse. As we shall see, in man, fast neutrons are thermalized rapidly, and a great deal of gamma radiation is generated. This added dose, not measured by the instruments, is of considerable importance, and raises the question as to what should be considered the "neutron dose." Should neutron dose include the gamma radiation or only the heavy recoil particles.

In the course of field studies, it became apparent that neutrons were potentially of increasing importance, and thus preliminary attempts were made to measure neutron depth dose patterns in tissue. In collaboration with Dr. G. W. Hurst and R. Ritchie of Oak Ridge, preliminary studies were carried out using principally their fission foil detector system. (Some chemical dosimeters were used; however these functioned less satisfactorily.) This system allows one to measure the total neutron flux, and by a system of multiple threshold detectors, to break down the spectrum partially into energy intervals. From this flux the first collision dose can be calculated. The incident dose was obtained from the detectors, mounted essentially completely free in air, and absorbed doses in tissues were calculated from fluxes measured from instruments placed throughout tissue equivalent phantoms.

The phantoms consisted of polystyrine bottles, with diameters approaching that of the average man. The bottles were filled with a tissue equivalent fluid according to a formula provided by Dr. H. H. Rossi. Several phantoms are placed at a given distance from the source, and 1 to 3 of the instruments were mounted in each of the phantoms such that in the aggregate the dose was measured at several points from the front to the rear surface of the phantom. All instruments functioned well, and excellent results were obtained. In fact, on initial plotting of the data, irregularities beyond the expected accuracy of the instruments were first encountered. On re-checking, it was noted that because of the size of the instruments, some of the foils had been represented as being a few cm. from their true location of the phantom. When this correction was made, data obtained under different conditions essentially superimposed.

The depth dose curves obtained are shown in Fig. 1. The absorbed doses are expressed in terms of the incident dose. Please note that the entire curve of the absorbed dose lies well below the incident dose. The absorbed dose of the front surface is approximately 70%, and falls to less than 20% at the midline. The exit dose is of the order of 40%. These results are entirely consistent with separate directional flux measurements made by Hurst and Ritchie, indicating that the situation in the field is close to being isotropic. The curves obtained are analogous to those obtained with low energy x-rays, of the order of 100 KVP, given with bilateral exposure;

however it differs somewhat because more dose is incident on the front than on the back surface. We have broken this curve down into unilateral curves, that when added together would give the experimental curve. The unilateral curves correspond in their pattern to that obtained from the calculations of Snyder and Neufield for a monoenergic beam with an energy between 1 and 2.5 MeV, closer to the 1 MeV. With a changing energy spectrum in tissue, the effect of changing intrinsic RBE with neutron energy becomes of importance.

From neutron data, another point brought out by Dr. Failla becomes evident. The thermal neutrons contribute essentially nothing to the total dose in a mixed fast and thermal neutron flux. Thus any calculations of dose based only on thermal neutron flux will be accurate only under conditions in which the fast neutron spectrum, and its relationship to the thermal neutron spectrum are known with reasonable accuracy.

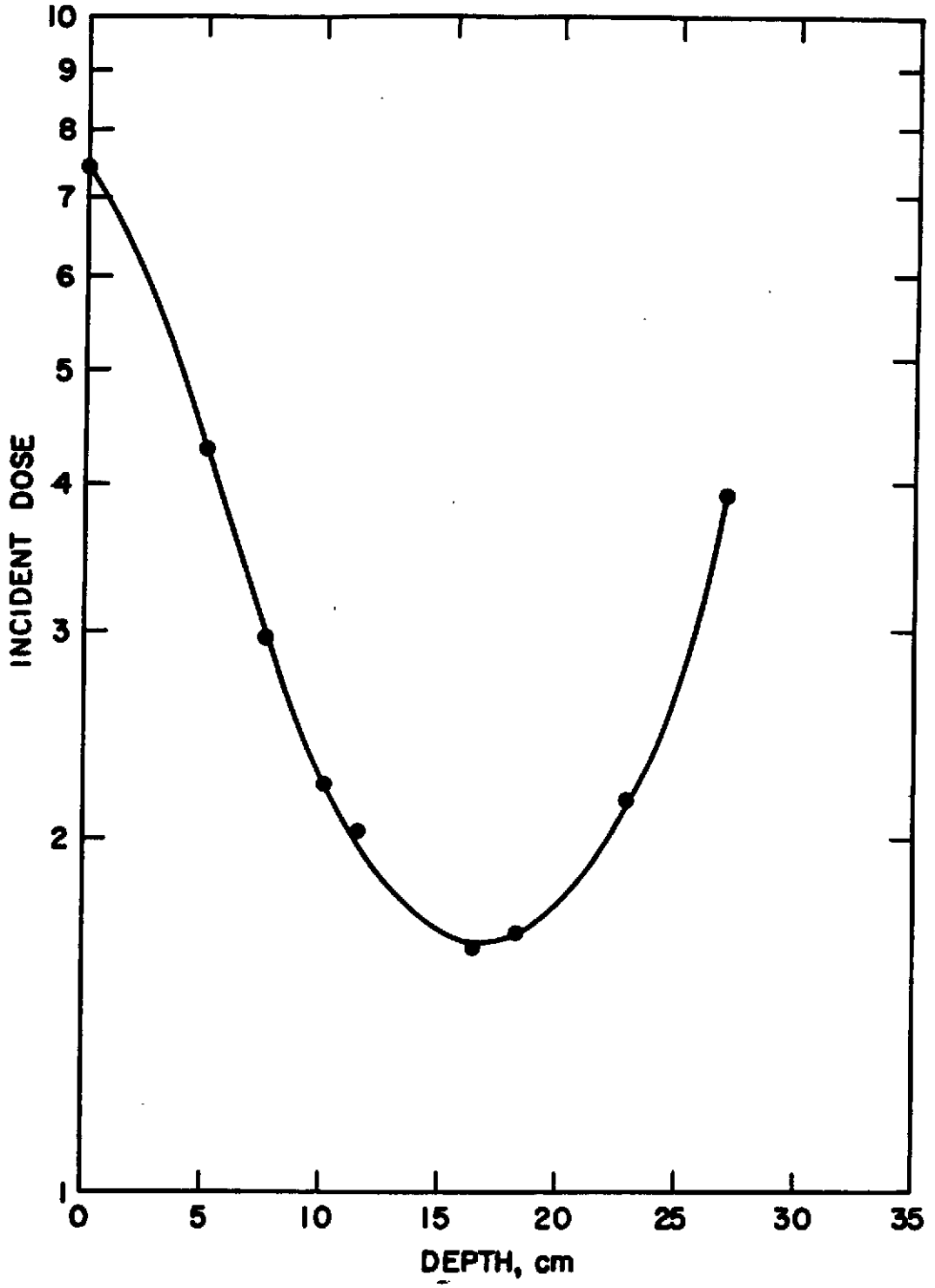
Before interpreting these results in terms of biological effects, I would like to diverge for a moment and discuss two separate laboratory experiments. The first relates to experiments done principally by Dr. Bateman in our laboratory, and have to do with the change in intrinsic RBE as a function of energy in the ranges of interest. Using the P,T reaction with a Van De Graaf machine, it is possible to expose mice to relatively monoenergic beams of neutrons ranging in energy from over 2 MeV down to 1/10th MeV or less by placing the animals at different angles with respect to the beam axis and the target. He has completed preliminary work on screen thymus weight with mice in the range of 2.2 MeV to 0.4 MeV. The intrinsic RBE appears to increase with decreasing energy in these ranges, and the overall magnitude of the effect is an increase of approximately 30%.

Secondly, I would like to refer to LD_{50} experiments on large animals, dogs, exposed to fast neutrons obtained from a cyclotron. I and my group first exposed dogs at the USNRDL to a high energy neutron beam, with approximately 90% of the neutrons above the 2.5 MeV point. The dogs were exposed bilaterally, and the dose distribution throughout the depth of the animal was equal within approximately 10 per cent. We can thus consider this essentially an intrinsic RBE. The intrinsic RBE, of course in terms of rads, was found to be unity. Dr. Alpen has since repeated this work, and has extended it to low energy beams and also finds the intrinsic RBE to be unity. Thus it seems apparent that with large animals, the intrinsic RBE for acute effects is lower than that obtained with mice, and can be taken as one.

Now if we can return to the neutron curves obtained in the field, and now we shall speak in terms of the apparent RBE, or the

apparent effectiveness of the neutrons expressed in terms of the incident and the air dose. It is not possible to say precisely what this figure would be, because a depth dose pattern like this has not been produced experimentally in the laboratory, and its biological effects noted. However it is apparent that most of the tissues of the animal is receiving 50% or less of the incident dose of neutrons. The intrinsic RBE for large animals as we noted is one. We therefore expect the apparent RBE of neutrons under these conditions to be smaller than one, probably 0.5 or less. I would presumably expect a value of approximately 0.3 to hold.

However another factor must be considered, mentioned earlier, and that is the gamma radiation generated by the thermal neutrons, not measured by the dosimetry devices employed. We have approximated this contribution by taking the flux energy intervals, and approxi-


INCIDENT DOSE
10
9
8
7
6
5
4
3
2
1
0
5
10
15
20
25
30
35
DEPTH, cm

TOXICITY OF TRITIUM

MC

Captain Dale R. Lindall, AFSWC

Tritium is a pure beta emitter with a half-life of 12.5 years. The energy of the emitted particle ranges from 5.7 to 18 Kev. The radiological hazard of tritium is the presence of tritium within the body. The half-life of tritium oxide (tritium water) in the body is 10 days, but this half-life can be decreased by the addition of water to the body. Since inhalation of tritium oxide vapor is the hazard, the detection of tritium is accomplished by sniffers which are special beta detectors.

Although tritium is potentially a highly hazardous substance, there are so many mitigating factors that the probability of serious radiation injury from tritium handling is extremely remote, providing a few basic facts of tritium chemistry, physiology, and health physics are known and applied.

DIRECT MEASUREMENT OF NEUTRON EXPOSURE

Lt. Col James Hartgering, WRAMC

Results of exposure of swine to neutron fluxes at Operation HARDTACK, Phase II, were presented. The dose received by the swine was determined by assaying the amount of Sodium-24 formed in the blood from the neutron-gamma reaction. The results of this technique compared favorable with other independent dose measurements. **

STATUS OF AIR FORCE DEVELOPMENT PROJECTS

Lt. Colonel L. T. Boatwright

The Air Force has an outstanding requirement for an alpha scintillation counter type survey instrument. One alpha instrument, the PAC-1S, a commercially developed instrument by the Eberline instrument Corporation, has a range up to two million counts per minute. We have subjected prototypes to the full range of enviromental conditions and have found they come closer to withstanding these severe conditions than any other instrument we have tested. The PAC-1S features a Mylar Dutch leaf covered sensitive area which is optically coupled to a photomultiplier tube. Complete transistorized circuitry amplifies the photomultiplier output and integrates the signal for presentation on a meter calibrated in counts per minute. It is powered by a four cell zinc silver oxide battery which operates the instrument for approximately 200 hours after

** Copies of this presentation, which is Confidential, may be obtained by request.

which it can be recharged. Present indications are that this battery can be recharged at least 50 or more times before requiring replacement. It can be supplied and stored in a dry charged state and in this condition has an extended shelf life. Most of the electronic components are mounted on three removeable cards which contain, respectively, power supply, amplifier circuit and trigger circuit. Calibration potentiometers are provided for each of the three ranges. The instrument meter has been Mil Spec. qualified. The gamma probe associated with the instrument contains a photomultiplier tube optically coupled to a scintillation crystal. Present efforts are towards getting a high range probe up to 200 r/hr and a lower range probe up to about 20 r/hr. This will be accomplished by varying the size and composition of the scintillation crystal.

A special alpha probe is being developed to give field personnel a capability for immediately ascertaining alpha activity from air samples.

The Air Force is presently using the PAC-2GA gas flow counter for its alpha survey needs. Although this instrument is relatively insensitive to humidity changes, it does require recalibration at different elevations. It performs much better than instruments which use an air chamber open to ambient pressure and humidity.

Next a development model of an instrument which will be used in air crew survival kits is being considered. It utilizes a modified quartz fiber dosimeter to indicate radiation rates up to 200 r/hr. It will have a self-contained power supply consisting either of solid state batteries or a friction charger. A contractor is developing this instrument under our supervision and guidance.

Finally, the fixed station monitor called the MG-3 will be discussed. The sensing element is an unsaturated ion chamber connected to the indicating unit by 100' to 500' of cable. Its range is up to 1,000 r/hr. This instrument can be set to give an alarm when the ambient radiation increases to about 1 r/hr. A recorder is provided as an accessory in order to provide a time history of the radiation. The MG-3 will operate continuously and unattended for more than six months, after which the batteries must be replaced. The clock driven recorder requires winding every 72 hours and normally is not used until after the instrument alarm has sounded.

RADIACMETER IM-133 AND RADIAC CALIBRATOR SET TS 784

Mr. Martin Jachter, USASRDL.

A logical extension of the IM-108, now in production to meet immediate needs of the Army, is to provide the equipment with an external ion chamber capability. The inherent simplicity of the circuit enables the operation of an ion chamber remotely by the additon of a connector and switches. A presettably relay to actuate an external

alarm is provided in addition to provision for external recording of radiation rate. An a.c. nickel cadmium battery supply has also been bread boarded which enables the instrument to operate continuously in fixed installations.

Two accessory ion chamber hardwares are being developed for use on aircraft (Low speed) and for use on tanks. Durability tests for the Tank accessory and Radiac have been performed.

Adding up all these changes in the basic IM-108 makes for a slightly different case design which in turn made necessary the new IM-133 nomenclature.

Radiac Calibrator TS-784 will be used to calibrate Radiac meters IM-108, IM-123 (CDV-720), IM-133, AN/PDR-39, and Radiac Dosimeters IM-9, IM-93, IM-147 and similar dosimeters. This has been made possible by the use of new jigs for the calibrator equipment.

The calibrator equipment itself has been modified with a new type source. The former Strontium salt has been replaced by Strontium incorporated in a melt of glass which is in turn, incorporated in a sealed mica aluminum container. This encapsulation technique has been evaluated over the last five years on an accellerated basis for the purpose of detecting surface leakage and none has been found.

SECONDARY ELECTRON MIXED RADIATION DOSIMETERS

Dr. Stanley Kronenberg - USASRDL

a. Introduction. Military characteristics for tactical fast-neutron dosimeters have existed since 1955. To satisfy these characteristics, USASRDL has worked for some time on the problem, largely with ion-chamber dosimeters. One of the chief difficulties with the ion-chamber dosimeters, however, is that of dose rate dependence, which becomes very serious at dose rates typical of nuclear detonations. Accordingly, we have suggested the SEMIRAD system for ultrahigh dose-rate measurements.

b. Description of SEMIRAD. In general construction, SEMIRAD has the same appearance as ion chambers. However, instead of being filled with air or other gas, SEMIRAD is evacuated to a very low pressure. As a consequence, little or no ionization is produced in SEMIRAD, and the entire response is due to secondary electron production.

When the wall of a SEMIRAD detecting chamber is irradiated with X-rays, gamma rays, or neutrons, a number of particles are ejected from the wall. In the case of X- and gamma rays, these particles are photo-electrons of 50 to 100-kev energy, and Compton electrons of a few hundred

to a thousand-kev. For very high-energy gammas these particles include both positrons and electrons from pair production. In the case of fast neutrons the ejected particles are mainly protons of energy averaging one-half that of the neutrons. When these ejected particles pass through the surface of the wall of the SEMIRAD chamber they cause secondary emission of low-energy electrons. Secondary electrons are also emitted when the high-energy Compton and photoelectrons or protons re-enter the opposite wall of the chamber.

If a positively charged electrode is placed within the chamber, the low energy secondary electrons are easily swept up and the total charge collected is proportional to the radiation dose received.

As in the ion chamber, the neutron sensitivity of SEMIRAD can be adjusted by varying the hydrogen content of the chamber walls. The neutron sensitivity of the SEMIRAD may be enhanced by increasing the amount of hydrogen contained in the wall material. In this way, readings of a mixed radiation dose can be made with two SEMIRAD; one with non-hydrogenous walls (very low neutron sensitivity) and one with hydrogenous walls. This technique enables determination of both the gamma and the neutron dose.

Since the energy of the secondary electrons is very low (on the order of a few ev), only a very low voltage need be applied to ensure complete collection. The primary particles (electrons and protons) are not collected because of their energy is much too high to be affected by the collecting potential.

Since SEMIRAD operation does not depend on the collection of relatively heavy positive and negative gas ions, recombination effects do not occur, and therefore SEMIRAD is inherently dose-rate independent. This is, perhaps, SEMIRAD's most outstanding feature. Furthermore, because of the rapid collection of the secondary electrons (7 milli-microseconds for an applied voltage of 45 volts and an electrode separation of 2 centimeters) the response time of SEMIRAD is approximately one millionth that of conventional ion-chamber dosimeters.

c. SEMIRAD Sensitivity. An unique feature of SEMIRAD is that we can vary the sensitivity of a given SEMIRAD detector over wide ranges without the necessity of changing the size of the detector (as is necessary in conventional ion-chamber detectors). The system as such is about 1000 times less sensitive than an ion-chamber dosimeter with a similar geometry. To reduce the sensitivity in ion-chamber dosimeters and so to make them suitable for higher dose readings, condensers are introduced between the collecting electrodes. The di-electric material in these condensers must be of highest quality; however, it is a source of many unwanted effects, explained by persistent internal polarization, which may make the dose readings unreproducible. Considerable research has been done on these effects. In the case of SEMIRAD, the sensitivity can be increased by using a large emitting surface coated with a high-

yield secondary-electron emitter (for example, MgO). To lower the sensitivity of the instrument, we use a very small emitter and a low-yield emitter coating (for example, aluminum).

Although low-energy secondary electrons are emitted from both the positive and the negative electrodes in a SEMIRAD, the presence of the electric field will cause the negatively charged electrons emitted from the positive electrode to return immediately to that electrode, and only the electrons emitted from the negative electrode will traverse the detector. Therefore, only the negative electrode plays an important part in SEMIRAD secondary-electron generation. In some respects, the negative electrode of a SEMIRAD is similar in action to that of the cathode of a thermionic diode. As a consequence, the sensitivity of a SEMIRAD is proportional to the product of the yield and the area of the emitting (negative) surface and unlike ion chambers is completely independent of the volume.

d. Vacuum Requirements. The vacuum in SEMIRAD serves two purposes: (1) it prevents gas ionization, and (2) it makes possible the collection of the low-energy secondary electrons. We can determine the vacuum requirements of SEMIRAD by considering these two purposes.

If we choose the arbitrary (but reasonable) limit for ion production in SEMIRAD of one ion pair for every 50 secondary electrons, then the response of the SEMIRAD by ionization will be no greater than 2 percent of the total response. To achieve this goal, the gas within the detecting chamber must be reduced in pressure until the sum of the production of ions by both primary radiation and by ion multiplication is less than 2 percent of the number of secondary electrons produced.

Research has been made on confinement of plastic materials in vaccum systems and the results show that the requirements can be met by using, for example, polyethylene.

e. Energy dependence of SEMIRAD. The conversion mechanism of fast neutrons to recoil protons and gammas to electrons that exist in the wall of SEMIRAD are the same that operate in the walls of ion chambers. The number of particles emitted from the wall of the detecting chamber is dependent on the energy and the flux of the radiation as well as on the geometry and wall material of the chamber. Therefore the energy dependence of SEMIRAD would be the same as in case of an ion chamber with negligible wall separation if the yield of secondary electrons would not depend on the energy of the primary particles. In this case the energy dependence is given by the Bragg-Gray theory for ion chambers which states that the measured current is proportional to the energy absorbed in the wall. In the case of SEMIRAD the yield is a function of energy but because the variation is slow, the Bragg-Gray theory gives a rather good approximation especially at energies above 1 Mev. In order to establish the energy dependence in an exact and absolute way, one has to know the distribution in energy of the eleetron and recoil protons leaving the emitter surface, as well as the function of secondary electron yield versus

energy of the primaries.

The total charge emitted as secondary electrons from the wall is then:

$$q(\bar{E}) \sim\sim \int_0^{\bar{E}} \frac{\partial N}{\partial E}(E)\ Y\ (E)\ dE \qquad (1)$$

where: q is the total charge emitted as secondary electrons.

$\frac{\partial N}{\partial E}$ is the energy distribution function of the primary electrons on recoil protons respectively emerging from the emitter.

Y(E) is the yield as function of energy for the wall material used.

and $\bar{E}$ is the maximum primary particle energy.

The function $\frac{\partial N}{\partial E} = f\ (E)$ is now being determined experimentally in USASRDL for gamma using phosphors and coincidence techniques.

f. SEMIRAD dose-rate limitations. Since SEMIRAD are electronic diodes in which the electrons are generated by high-energy radiation rather than by thermionic emission, the limitations on current that apply to thermionic diodes may be directly applied to SEMIRAD. These limitations are the result of space charge formation between the emitter and the collector, and are given by the Langmuir Formula for parallel-plate geometry. The limiting current in a SEMIRAD whose electrodes are parallel plates may be expressed as:

$$i = 2.334 \times 10^{-6} \frac{v^{3/2}}{A x^{-2}}$$

where: i is the maximum current (amps) through the SEMIRAD.
v is the voltage applied to the SEMIRAD (volts).
x is the plate separation (cm).
A is the area of one plate (cm^2).

g. Tests. Experimental SEMIRAD have been designed and tested for sensitivity and dose rate independence. The results show that the system can be applied in fountain pen dosimeters similar to the IM-93 by replacing the ion chamber with a SEMIRAD. The radiation delivered to the instrument will be measured independently of the dose rate for all tactical situations. Other tests have been made using the device as a dose rate meter on Godiva II.

CONDUCTING PLASTICS EQUIVALENT TO TISSUE, AIR, AND POLYSTYRENE

Dr. Francis R. Shonka, St. Procopius College

INTRODUCTION

The purpose of this paper is to describe the composition and production of a series of conducting plastic resins that have been developed which permit the direct measurement of absorbed dose in rads for photons and neutrons in muscle, bone, and polystyrene; rads for photons in muscle (insensitive to neutrons); and roentgens.

For practical applications in ion chambers, proportional counters, etc. intended for field as well as laboratory use, the components chosen for tissue, air, and polystyrene equivalent materials should result in a conducting blend with certain optimum mechanical properties which place severe limitations on the materials of choice. Thimble chambers and proportional counters for field use require materials of great stability, chemical as well as mechanical, thus precluding the choice of any material with an appreciable vapor pressure or sensitivity to temperature, water vapor, etc. Practical devices of this nature further require relatively high tensile strength, impact strength, and most especially low gas permeability with no selective adsorption of any one gas if they are to retain the gas compositions necessary to satisfy the Bragg-Gray cavity requirements. Obviously, moldability, low snrinkage, machinability, good electrical conductivity, and suitable densities are desirable properties all of which are obtainable with the herein described mixtures.

To obtain the optimum electrical conductivity in the mixtures of the materials of choice, namely combinations of the commercial plastics and additives, it was found experimentally that oil furnace black has a suitable structure to yield a maximum.

The free carbon content essential for suitable conductivity in each case varies in the different mixtures from 10 to 18.5%. The use of oil furnace black or other particulate matter with a finite particle size in a blend which is essentially a solution of the various resins introduces the problem of the range of the electrons within the particles at the plastic-gas interface in a Bragg-Gray cavity. An arbitrary choice was made in that it was assumed that a loss of 10% of the energy of the secondary electrons from within a particle would introduce an error that could be ignored.

The determination of energy absorbed in rads in the simulating mixture requires that for equal numbers of electrons there be equivalence in hydrogen and nitrogen content such that the same photoelectric absorption coefficients will result for low energy X rays as well as the same recoil production for fast neutrons as in the simulated material.

Thus the introduction of free carbon in the described mixtures results in chiefly, an oxygen or nitrogen deficiency which is compensated for by the addition of lesser amounts of calcium, silicon, and fluorine to match the radiation attenuation properties of the simulated tissues in each case.

MIXER

The high degree of dispersion and extreme uniformity essential in these conducting plastics could not be readily accomplished through the use of commercially available mixing equipment. From trials which envolved several designs, one was found to be relatively inexpensive to construct in a well equipped machine shop. The final design consists of two assemblies, one of which is held stationary, the other rotating within it.

TISSUE EQUIVALENT - MUSCLE

(for Photons and Neutrons)

Since there is little agreement in the literature on the composition of wet muscle, the decision was made to adopt the composition recommended by the International Commission of Radiological Units (ICRU). The percentage compositions by weight given therein yield the formula:

C	H	O	N	Na	Mg	P	S	K	Ca
1.024	10.2	4.556	0.25	0.0035	0.0008	0.0065	0.0156	0.0077	0.00017,

containing a total of 55.087 electrons.

Proper choice of materials results in a simulating blend that may be written as $(C)_a$ $(CH_2)_b$ $(C_6H_{11}NO)_d$ $(SiO_2)_e$ $(CaF_2)_g$, where the literal subscripts represent the number of molecules of each of the materials used in the TE-muscle. The values of a, b, d, e, and g are a=1.12; b=2.73; d=0.25; e=0.03734; and g=0.05116. One now obtains the percentages by weight of the materials which comprise the TE-muscle blend, consisting of carbon 13.5%, polyethylene 52.1%, nylon 28,22%, silica 2.2% and calcium fluoride 4.0%. Thus the chemical formulation is $C_{6.35}H_{10.2}O_{0.325}N_{0.250}F_{0.102}Si_{0.0373}Ca_{0.05116}$.

TISSUE EQUIVALENT - MUSCLE

(Insensitive to Neutrons)

If TE-muscle is to be insensitive to neutrons it may contain neither hydrogen, nitrogen nor any element with an appreciable cross

section for neutrons. The material of choice for a plastic compound which contains no hydrogen is Teflon, since the atomic numbers of its components bracket that of oxygen. In this case carbon and fluorine are balanced such that equal Compton and photoelectric absorption coefficients result. The resulting mixture when normalized at 15 kev consists of 43.87% carbon black and 56.13% Teflon. The chemical formulation then is $C_{5.384}$ $F_{2.538}$.

The resulting mechanical properties of this mixture are anything but ideal ----- the most that may be said is that it is superior to pure graphite in every respect.

TISSUE EQUIVALENT - BONE

(for Photons and Neutrons)

Adopting the ICRU composition of TE-bone the resulting calculations normalized for photoelectric absorption at 15 kev, yield carbon 14.0%, nylon 21.6%, polyethylene 30.0%, and calcium fluoride 34.4%, thus the chemical composition is

$$C_{4.49}H_{6.4}N_{0.193}O_{0.193}F_{0.8911}Ca_{0.4456}.$$

AIR EQUIVALENT

(Photons Only)

The conducting air equivalent (Air Eq.) material, useful for measuring the roentgen, consists of the following mixture: carbon 17.69%, nylon 67.23%, silica 15.08%; and the chemical composition is :

$$C_{136.9}\ H_{177.7}\ N\ 16.1\ O\ 29.78\ Si_{6.820}.$$

POLYSTYRENE EQUIVALENT

It is desirable in some cases to use the same materials of construction for certain parts of an ionization chamber, especially when the condenser is an integral part of the chamber. This avoids certain transition effects which are apparent with gamma radiation and neutrons. Since polystyrene is the usual choice for the insulating parts, a material that is suitably conducting has the same chemical composition and is compatible for molding with polystyrene consists of 72% CH, 15.1% CH_2, and 12.9% free carbon.

IMPROVED DT-60 SYSTEM

G. E. Davis
Naval Material Laboratory

The DT-60/PD personnel dosimeter consists essentially of a small square of phosphate glass of a definite basic formula, to which about 8 per cent of silver phosphate is added. This glass is housed in a plastic case. After exposure to X-rays or gamma rays, the silver phosphate fluoresces under radiation in the near ultraviolet, with intensity proportional to the X- or gamma-ray dose received. The intensity is indicated in roentgens of dose by "reader" with photocell receiver. The reading includes a "predose" value inherent in the unexposed glass and specified to fall in the range (37±7)r.

Some time after manufacture, a certain number of the dosimeters were found to give predose readings higher than the 44r permitted by specifications, and some readings showed a tendency to increase slowly with time. To determine the cause of this, a large number of samples from Navy stock and from widely separated Air Force bases were investigated under the following conditions: shelf life under room conditions, also at 45 degrees C and 20% R.H.; same, with glass removed from case and bare; exposure to ammonia vapor; exposure to high humidity. Examinations were made visually, under ultraviolet light; by spectroscopic analysis (surface brushings); by X-rays analysis (particles from some of the glass surfaces). A study was made to determine whether high predose was related to meteorological conditions at the Air Force stations from which samples had been received.

The findings were made partially indefinite by the inseparability of causative factors and by frequently inconsistent results as between individual samples. However, the following potential causes of high and variable predose were definitely indicated: (1) fluorescent contaminant or contaminants (visible on some glasses), mostly confined to the exit face of the glass and very probably from the cement used to secure the glass; (2) diffusion of a fluorescent component of the cement through the black paint on the bottom of the glass; (3) separation of the black paint from the glass (visible shiny spots); (4) variation in amount of ultraviolet and fluorescent light scattered at the ground or sandblasted entrance and exit surfaces of the glass, due mainly to the impossibility of exactly reproducing such surfaces and, to a lesser extent, to changes in these surfaces due to humidity, washing, etc. Also, variations in glass composition, chemical or physical, due to inadequate control during manufacture, may grossly affect the predose value.

It was found that washing, either by ultrasonic vibrations or by brushing or soaking in detergent solution, reduced the predose readings of more than 90% of the high-reading dosimeters to within the specified (37±7)r range.

As a result of these findings, the DT-60's have been partially re-designed to eliminate the effects of scattering from ground-glass surfaces, contamination by cement components, and separation of the black paint from the glass. The new glass squares are smooth-rolled on upper and lower surfaces, with edges sawed then ground smooth and polished. The glass is held by a plastic housing secured by two posts extending from an aluminum base (formerly plastic), passing through holes in the housing and swaged at the ends. No cement is used. Instead of black paint for a non-reflecting lower surface, a black-glass frit is fused to the phosphate glass. The two glasses form a permanent bond and the frit should be more highly non-reflecting than the black paint. The aperture for light entrance at the upper surface of the glass is reduced to eliminate possible internal reflection from the side faces.

These design changes have been made by the Specialty Engineering and Electronics Co., under Bureau-of-Ships contract. It is expected that the new design, plus greatly tightened manufacturing specifications, will result in highly stable predose readings and much greater uniformity in the readings of different dosimeters. The glass composition is unchanged except for omission of manganese, which was added by a manufacturer without permission. A group of 100 samples has been under observation at the Material Laboratory for about two months. No changes in predose have been observed.

The DT-60 system includes the reader. Three models, designed and built by Polaroid, Admiral and Specialty, respectively, are in use. These are quite satisfactory except for an occasional minor drift or fluctuation in the gain. A battery-operated reader is under development by Specialty.

MODIFICATION TO CP/95 READER

Major Bryan, AFSWC

The Air Force Special Weapons Center has made modifications in a CP-95A/PD Radiac Computer-Indicator which improve that instrument's discrimination against surface fluorescence which is one cause of high pre-dose readings of the DT-60/PD. The Center has negotiated a contract for the manufacture of six kits which will be used to modify other CP-95A/PD's in order to determine the reproducibility of initial results and to indicate the feasability of modifying other instruments.

The modification includes both optical and electrical changes. The electrical changes consist largely of a plug-in preamplifier and were made necessary by a loss in sensitivity caused by the optical changes.

One hundred seventy nine DT-60's which were rejected by Air Force units because of excess pre-dose and 104 DT-60's which were in possession

of troops or were collected. Statistical treatment here assumes a normal or Gaussian distribution and random sampling. We feel that the sampling was such that the rejected dosimeters were worse than typical and the others were better than typical.

In all cases the modified reader gave lower values for the mean and standard deviation than did the CP-95A, and that this result is most spectacular in the case of the rejects. The figures representing percentages that could be expected to fall between -15r and +15r, the present acceptable limits of predose in the Air Force, favors the modified Reader.

After the DT-60's were washed with tap water and dried, the readings were better than before washing but not as good as readings made with modified reader. Good results were not achieved by washing rejected DT-60's. The modified reader had its greatest effect on the highest pre-doses. The small degree of correlation between readers indicates that their difference depends upon a more or less random variable. We claim that variable to be surface fluorescence.

This comparison of frequency response of a modified CP-95A and a 62 cps signal shows a slight difference; however, it was demonstrated that the average effect of modified circuitry on readings of 50 dosimeters was only -1.2 r. We should like to find a means of increasing sensitivity that is better than increasing amplification. One requirement of the optical modification is the need for a flat, transparent exit face on the DT-60. The DT-60's reported on here had their exit faces made transparent by coating with clear lacquer or glycerin for reading in the modified reader. Obviously it was necessary to calibrate the reader with a dosed DT-60 similarly treated. We believe that polished exit faces would produce better results.

One can determine with this schematic and a straight-edge that no surface fluorescence can enter the photomultiplier tube.

RADIOLOGICAL TEST AREA AT DUGWAY PROVING GROUND

Lt. Col. Thompson, CMLC

The area will be a circle 200 yards in diameter, contaminated with approximately 2.2 curies of Co^{60} per square yard, to give an intensity of 100 R/hr at 2 feet above ground. The Co^{60} will be electroplated on soft steel wire and overplated with nickel to prevent loss of the Co^{60} by flaking or chemical action. The wire will then be cut into appropriate lengths and spread by a device similar to a seed drill. Pickup of the material, when required for reshaping of the radiation pattern, will be done by an electromagnetic pickup device. The contaminated circle will be surrounded by a one foot concrete curb,

a six foot moat, and an eight foot earth bank, in that order. A commercially available tractor, guided by remote control or electromagnetically along a buried wire, will be used to spread the contaminant, place and remove specimens and instruments, and remove the contaminant. Two view-ports, built into the wall of the earth bank and protected by concrete and lead glass windows, will be placed at a 90^0 angle from the center of the field to allow cartesian coordinate emplacement of specimens and instruments. The area will be protected by fences, guards, and automatic alarms.

The area will be used for test work involving larger area, high intensity radiation of approximately the same spectrum and energy as that of fallout. Shielding studies, depth dose measurements, instrument performance, and long term biological studies involving both chronic and acute radiation doses are some of the projects currently planned for this area.

LOW RANGE SELF INDICATING DOSIMETER-

Mr. Charles Hollander, BuShips

Today we can choose the method of dose measurement; for instance, the silver halide or film, colorimetric, radiophotoluminescent, or ionization methods. Of these, the most accurate, at least, in the lower range is probably the ionization type.

The ionization chamber type can be further divided into two categories, the self-indicating and the non-self indicating. Since the Navy is primarily interested in the self-indicating type it is this one that will be discussed, and more specifically the low range or 0-200mr.

Although the low range self-indicating dosimeter is the best instrument for accurately measuring X and gamma radiation, there are still undesirable features. To point out some of the causes of inaccuracies lets take a typical instrument apart. There are six basic components to the dosimeter; the charging end, electometer, chamber, optical system, insulator, and barrel.

(1) Charging mechanism (Sylfon bellows almost always used.)

(a) Interactions with other parts of the dosimeter causing shock problems.

(b) Mating problems between charger and dosimeter.

(2) Electrometer (Usually aluminum)

(a) Reproducibility problems (in production)

(b) Contributes to drop instability.

(3) Chamber (Phenolic)

(a) Sensitive to neutrons

(b) Long term stability questionable

(4) Optical System

(a) Focusing problems (clarity of image focus throughout range of scale-each unit must be focused)

(b) Alignment (Fiber with respect to reticle)

(5) Insulator

(a) Leakage problems

Other problems which do not relate to any one specific part of the formentioned are:

(a) Hermetic seal

(b) Kick

(c) Temperature effect

To attempt to eliminate the undersirable features of the current dosimeter the Navy has initiated a development program. The program consists of four phases:

(1) Study Phase- During this phase as many type low range ionization chamber dosimeters as were available were examined to pick out desirable features.

(2) Development Phase- The development phase, now underway, is being devoted to selecting materials, developing component parts, and developing fabrication techniques. One of the most important objectives of this program is to insure ourselves that production of the developed dosimeter will be feasible for any company in the dosimeter field.

(3) Construction Phase- This phase will be utilized to construct a quantity of dosimeters based on resultant data of Phase 2.

(4) Report Phase-The report phase will be devoted to writing techniques necessary to insure reproducibility in production quantities, making manufacturing drawings of the instrument and every associated test instrument.seemed necessary for

production control.

As stated, we are now in Phase 2 of the program. Material studies and/or development work is in process. Taking each component part mentioned earlier we have;

(1) Charging mechanism-Sixteen methods have been examined. We have now reduced this amount to three; the metal diaphragm, plastic diaphragm, and the bellow type.

(2) Electrometer- Examination of horseshoe types one of which is now commonly used; other electrometer suspensions such as Dr. Shonka's attraction bending, and torsion electrometers are being investigated.

(3) Chamber-Some of the materials being investigated are epoxy resins, phenolics, flourocarbon plastics, and thermoplastics.

(4) Optical System-Since the optical system is dependent on the electrometer characteristics, most of the work is still to be done. The basic problem in this system will be to increase the depth of focus thereby eliminating, to some extent, the criticality of focus and allowing for a sharp fiber image as it swings across scale.

(5) Insulator-Approximately 15 insulator materials have been evaluated. To date the most promising is the "Bendix Amber". However, materials as fused quartz, ceramics are still to be investigated.

USASRDL NEUTRON DOSIMETRY

Mr. Harry Murphy, USASRDL

This is a short report of what has happened in ion chamber neutron dosimetry at USASRDL during the last year.

The results of the Plumbbob field tests of the tissue equivalent ion chamber dosimeters were entirely unsatisfactory, and that the ion chambers indicated - at best - only a fraction of the total fast neutron dose as measured by such dose-rate independent systems as the Sigoloff Chemical dosimeter and fission foils.

Because of the many unknown factors that entered into the Plumbbob experiment, such as the effects of the nitrogen-14 gamma radiation, shock, the fallout and residual field, etc., as well as the unknown neutron and gamma delivery rates, it was impossible to determine the

exact cause of the poor results. However, USASRDL had an experiment scheduled at the Los Alamos Godiva II reactor which we hoped might clear up the reasons for the poor Plumbbob results.

Godiva II is a bare critical assembly of oralloy which is capable of producing pulses of fast neutron radiation lasting about 75 to 80 microseconds. In the absence of better information, we have concluded that Godiva II is a reasonable simulator of the fast neutron burst received at a distance of a few hundred yards from a typical fission weapon.

Two experiments were performed at Godiva II, one in January and one in July 1958. These experiments consisted of exposing calibrated ion chamber dosimeters from operation Plumbbob at different distances ranging from 70 to 500 centimeters from Godiva II for a total of 16 bursts.

The gamma standard used for these experiments were the NBS film pack loaded with a special low neutron sensitivity set of emulsions. The fast neutron dose was measured through the use of sulphur pellet threshold dosimeters whose induced activity was converted to total tissue dose through factors.

The results of the experiments are summed up in Table I and bear out the results of the Plumbbob experiment. For the dose range of 50 to 1050 rads, the ion chamber dosimeters read only 50 to 35 percent of the total fast neutron dose.

Table I

Comparison of experimental data to Boag's general recombination theory

NEUTRON DOSE	EQUIVALENT DOSE RATE	OBSERVED SENSITIVITY	CALCULATED SENSITIVITY
50 rads	0.5×10^6 rad/sec	0.55	0.75
300 rads	3.0×10^6 rad/sec	0.45	0.45
550 rads	5.5×10^6 rad/sec	0.38	0.35
900 rads	9.0×10^6 rad/sec	0.38	0.29
1050 rads	10.5×10^6 rad/sec	0.35	0.27

If one assumes that the fast neutron dose from Godiva II is delivered uniformly over a period of about 100 microseconds, then one can compare the results of the Godiva experiment with those predicted by the general recombination theory developed by Boag. The results of such a comparison is given in Table I with the theory adjusted to fit the results at a total dose of 300 rads. This comparison shows that the results of the Godiva II experiment follow generally the results of

the application of Boag's theory for a parallel-plate ion chamber with a plate spacing of 1.6 millimeters. This is a value of interelectrode spacing not greatly different from that used in the experimental ion chambers.

As a result of the Godiva experiments, it is concluded that the response of the ion chamber dosimeters at high dose rates is mainly controlled by simple general recombination, and that the results of the experiment at operation Plumbbob are mainly the result of recombination.

Since the dosimeter response seems to be so largely limited by dose rate dependence, we have made some simple calculations of the dose-rate limit that one might achieve through selection of very high collecting fields and very small interelectrode spacing. Using a field strength of 10,000 volts per centimeter and a parallel plate ion chamber spacing of one millimeter, using Boag's theory, the upper dose rate limit is about 3.5×10^7 rads/second. At this rate, such an ion chamber would have a loss in sensitivity due to dose rate limitation of about 10 percent.

Boag has made a similar calculation for parallel plate ion chambers and has concluded that the dose rate limit of ion chambers is about 6.4×10^7 rads per second; with a more practical limit, based on less stringent requirements of 1.5×10^6 rad/second.

Now, if you assume that the tactical neutron dose is delivered in 100 microseconds, and a 600 rad dose, then this would correspond to a dose rate of 6×10^6 rads per second. This dose rate lies just within the "Grey Area" of dose rate limitation mentioned above. This means that, considering simple recombination theory only, operation of tactical fast neutron ion chamber dosimeters probably is possible. However, this operation depends on the use of high collecting fields and very small electrode spacing.

So far only general recombination has been mentioned. However, there are other effects which can be added to those of general recombination; these are first, space charge, and second, insulator damage. The first effect is important when certain gases, such as ultra pure argon or neon are used in which ionization is the result of formation of positive ions and electrons only. For this condition, the electrons tend to be swept up immediately causing a positive space charge to remain which destroys the collecting field and results in further recombination. The second effect is that of transient damage in the insulators used in the ion chambers and has been observed at dose rates as low as 600 rads per second. This effect results in the transfer of charge to or from the collecting electrode of ion chambers and results in erratic readings not attributable to ionization in the detecting chamber. These effects were observed in field tests of ion chamber dosimeters and are reported in WT-1228 and ITR-1167.

As a result of these tests and the consideration of recombination theory, it appears impracticable to construct tactical tissue-equivalent ion chambers dosimeters that will measure fast neutron dose at the rates encountered in the field. Therefore all work along these lines at USASRDL has stopped .

Current investigations at our laboratories are being directed towards the use of the Semirad system of dosimetry which shows great promise and which appears to be entirely free from dose rate effects. However, much more research and development must be done before any field tests or Semirad tactical dosimeters can be considered.

STATUS OF CHEMICAL DOSIMETRY

Mr. Klein, CML

Research and development work in chemical dosimetry during the past year was reviewed. Work continued on the use of aqueous trichloroethylene solutions as dosimeters. The major effort has been directed toward measuring neutron response of the system. This was done with mono-energetic neutrons at 1, 2, 4, 6, 8, and 14 Mev. The system was shown to be energy independent in this range. Sensitivity which, unlike gamma response, is oxygen independent was determined: $G_{H^+} = 13.5$. Thermal neutron sensitivity was observed. It is felt, however, that this is not a property of the dosimetry system but is one to the fairly high B^{10} content of the glass used to contain the solution. The fact that G_{H^+} for thermal neutrons is dependent on oxygen content would tend to corroborate the assumption that a secondary gamma reaction such as that produced by B^{10} (n, α) Li^7 is occurring. The cross section of H (n, γ) D is too low to account for the observed effects. Irradiation containers free of B^{10} are currently being prepared to test this hypothesis.

The dosimetry system was used with some degree of success during Operation Hardtack although these data will not be finalized until neutron response of the system is more completely elucidated.

A tactical dosimeter has been designed and a prototype (Tactical Gamma-Neutron Dosimeter E-5) was shown. The E-5 records gamma and neutron dose in ranges of 0-50, 50-150, 150-300, 300-450, 450-600, and 600 + REM. A fast neutron RBE of 1.0 is used in the dosimeter. The complete dosimeter is made of molded plastic with the fine glass tubes permanently shock mounted in place. Dimensions are 3x2$\frac{1}{4}$x1 inches and weight is approximately 4 ounces.

CLOSED SESSION

11 February 1959

1. The following member was absent:

Dr. George Green, Brookhaven National Laboratory

2. The Panel discussed the problem of energy dependence in the response of personnel dosimeters, and the tentative resolution of the 17th Panel meeting on this subject. It was not clear to the Panel exactly how dosimeters were assumed to be calibrated in guidance given the Armed Forces by their medical staff with regard to predicted effects on service personnel from different radiation doses. These predicted dosage effects could be for the free air dose, for dosimeters calibrated in air but worn against the human body, or in terms of an assumed dose at some particular depth or site inside the human body. A representative from the AFSWP Medical Division, Captain Barton, stated that the military gamma dose criteria are in terms of the free air dose. The Navy member brought out the fact that the purpose of this resolution was to insure that the response of personnel dosimeters below 80 kev was not greater than 100% and, in that the resolution did not impose an undue hardship upon the manufacturer, it should seriously be considered as it will insure a better dosimeter for Service usage.

The Panel recognized the desirability of a very low or absent beta ray response in dosimeters to be utilized for evaluation of the short term effects of whole-body exposure of military personnel in an extended fall-out field. This is because substantial beta ray sensitivity in a fall-out field of mixed beta and gamma rays can lead to substantial over-estimates of effective dosage from the radiation of such fields. Ideally, radiation dosimeters should reduce beta ray sensitivity by shielding with a substance of an effective atomic number for radiation absorption similar to that of soft tissue. Such filters add unacceptable bulk to current dosimeters. Filters dense enough to have effective beta ray stopping power in an acceptable thickness also substantially reduce dosimeter response to soft gamma- and x-radiation.

After further discussion, the following resolution was proposed for adoption.

a. The Panel recommends that for purposes of evaluation of the short term effects of whole-body exposure of military personnel in an extended fall-out field, the energy dependence of personnel dosimeters should be adjusted to take into account the lower efficiency of the less penetrating components of the gamma ray spectrum and beta rays in producing such effects. Presently available information indicates that for practical purposes this condition is fulfilled when the reading of the

personnel dosimeter in an extended radiation fall-out field represents:

(1) 100% of the air dose in roentgens in the gamma-ray energy range from 1.25 Mev (Co-60) to 80 Kev.

(2) A gradually decreasing percentage of the air dose in roentgens below 80 Kev so that it is 50% at 50 Kev and no greater than 5% at 20 Kev. Allowable error limits are to be stated in the detailed specifications of the procuring agency. A precision of ±20% is suggested.

Further discussion by the Panel indicated general agreement that these were satisfactory energy response specifications for the use of dosimeters for the evaluation of short term fall-out hazards. However, it was pointed out that if dosimeters with these characteristics were used for other types of monitoring, for example, radiation hazards due to the rather soft x-rays generated in radar equipment, a very significant under-valuation of hazard from radiation exposure might occur.

For this reason no final action was taken by the Panel on this resolution.

3. Tritium monitoring requirements and tritium monitoring instruments were discussed. It was indicated to the Panel that these instruments were rather expensive and bulky. In that some monitoring requirements indicate frequent monitoring, the Panel adopted the following resolution:

a. The Panel recommends that a simple, rugged, economical device be developed to indicate the presence of tritium. This device should give a positive response at levels in the neighborhood of permissible concentrations for short exposure. One such simple device could be a quartz-fiber electrometer with associated ionization chambers or modifications of certain existing survey meters such as a beta radiac.

4. The problem of determination of prompt neutron dose was discussed. A satisfactory neutron dosimeter is not available. The Panel felt that continued work on neutron dosimeter should be performed in view of the Service requirement for a neutron detecting dosimeter. Concurrently with this effort, the Panel made the following recommendation:

a. Effort should be directed to the exploration of the possibility of the development of a portable, single channel analyzer, field detector which would enable the first echelons of medical service to determine the concentration of Na-24 in body fluids and thereby be able to make a quick assessment of the dosage received from prompt neutron radiation.

5. The status of gamma radiac development was discussed and the Panel made the following general ~~resolution~~ recommendation:

"a. The Panel recommends that a continuing program be pursued to develop a more reliable, simply operated and lower costing gamma radiac."

6. Other topics were discussed (alpha instrumentation, radiological test area, modifications to existing equipment, and Panel membership) but no additional resolutions were made.

7. Dr. Bale invited the Panel to hold the next working meeting at Rochester, New York. The Panel agreed to meet in Rochester in May 1959.

8. The meeting was closed at 1630 hours.

Following the meeting, Dr. Failla prepared a memorandum to supplement paragraph 2 above. It states,

The Panel wishes to point out that a dosimeter with these characteristics when suspended in air, in an extended fallout field, does not measure correctly the gamma ray "air dose" at that point; and when worn on the surface of the body in an extended fallout field, it does not measure correctly the gamma ray skin dose at that point in the body, since in either case the dosimeter does not respond fully to the low energy components of the gamma ray spectrum. (Furthermore, it does not register the beta ray dose). The adjustment represents an attempt to weight the different components of the gamma ray spectrum according to their potency in producing short-term effects, when the whole body is exposed in an extended fallout field. Presently available radiobiological information applicable to man is insufficient to permit an accurate weighting process, even for the restricted conditions stipulated above. However, since in an extended fallout field the low energy gamma ray components that pass through the shield required to absorb the beta rays, do not contribute much less to the body dose, an approximate weighting of the low energy gamma ray components is satisfactory. The particular choice of low energy gamma ray response recommended above is based in part on constructional considerations to meet general requirements of military instruments.

The Panel was told by Captain Barton that the military criteria for the evaluation of radiation injury in combat situations are based on gamma ray doses measured in air (i.e. not on the surface of the body or at some particular depth). It should be noted in this connection that an unbiased personnel dosimeter worn on the surface of the body in an extended gamma ray field measures the skin dose, which for gamma ray energies greater than 50 kev is about 80% of the air dose at the same point without the presence of the body. (This is based on approximate calculations). It may be expected that there will be a similar difference between the reading in air and on the surface of the body when the biased dosimeter is used in an extended fallout field. Therefore, measurements of the "body dose" made with the biased dosimeter (or any dosimeter, for that matter) worn on the surface of the body do not represent the doses used in establishing the military criteria. This matter deserves further study by those responsible for the military criteria.

The Panel wishes to point out also, that the use of the biased personnel dosimeter in radiation fields other than an extended fallout field may result in serious underestimation of the dose recieved by the individual wearing it. The obvious extreme case is the use of the biased dosimeter in a gamma ray beam with photen energies less than 20 kev, in which case the skin dose recieved by the individual would be more than 20 times that recorded by the dosimeter on the incidence side. If the biased dosimeter were used under these conditions as a monitor to comply with permissible limits of occupational exposure in peace time, the skin dose received by the individual over a period of years would greatly exceed the permissible limit and in time cancer might develop. Of course, such obvious misuse would not occur with a high range dosimeter (0-600r), but nevertheless, it would be well to label all biased dosimeters in a suitable manner to warn the inexperienced user. Since the scale is marked in roentgens, it is natural for the uninitiated to assume that the dosimeter measures doses from all gamma rays correctly.

The above example brings up the question as to whether low range personnel dosimeters (e.g. 0-200 mr) should be biased at all. Obviously, such low doses would be of concern only when chronic exposure is involved and the pertinent biological effects would then be long term ones (such as cancer or life shortening) rather than the short term effects envisaged in military operations, for which a suitably biased instrument seems desirable. This matter was not discussed by the Panel. Actually, the main considerations are biological and the decision should be made by the responsible medical authorities.

William D. Sheehan

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Captain, USA
Secretary, Panel on
Radiological Instruments