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LOS ALAMOS SCIENTIFIC LABORATORY

OF THE UNIVERSITY OF CALIFORNIA ○ LOS ALAMOS NEW MEXICO

HEALTH PHYSICS BIBLIOGRAPHY ON TRITIUM

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HEALTH PHYSICS BIBLIOGRAPHY ON TRITIUM

Compiled by

Donald A. McKown

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ABSTRACT

A list of 87 papers with abstracts is given. The papers were selected to cover those aspects of the subject which would be of interest to monitoring and health physics personnel involved in radiation protection work. A few bibliographies are listed.

ACKNOWLEDGEMENTS

I wish to thank James N. P. Lawrence, Jerome E. Dummer, Morris Engelke, and Dean D. Meyer for suggesting papers to include in this list. I also wish to thank Delores Morrow for typing and general assistance in assembling the bibliography.

PREFACE

There are several good tritium bibliographies in the literature. Some of these are quite exhaustive, listing hundreds of papers on the broad subject of tritium while others are limited to a narrow scope. This list is compiled to give a short and convenient representative coverage of those aspects of interest to personnel involved in radiation protection work.

The papers were roughly scanned to determine their suitability for this listing on the basis of the subject covered. There is no intent to infer that the included papers are superior nor that any which were not included are inferior.

The titles of the papers are arbitrarily broken into groups under 8 general headings. The headings are listed in alphabetic order according to the significant words in the title. All reports except three are unclassified.

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Detection, Counting, and Determination Techniques

BETAS AND BREMSSTRAHLUNG

KAPL - 1086 Dorfman, L. M. The Absorption of Tritium Beta-Particles in Hydrogen and Other Gases (March 1954) General Electric Company, Knolls Atomic Power Laboratory, Schenectady, New York

The absorption curves for tritium beta-particles in hydrogen and helium have been determined by using a spherical ion chamber in which the particular gas serves both as the absorber and the ionization medium. The absorption curves give half-thickness values of 0.031 mg/cm^2 for hydrogen and 0.061 mg/cm^2 for helium. From the saturation currents obtained with a given amount of tritium the relative energy requirement per ion pair has been measured for hydrogen, helium, oxygen, and argon. These values are compared with recent values in the literature.

Kuhn, W. "Continuous Measurement of the Concentration of Solutions by Means of Bremsstrahlung from Low-Energy Beta

Emitters." Chemie-Ingenieur-Technik, Vol. 32, pp. 747 - 749, (1960)

A measuring device is described which uses tritium adsorbed on zirconium as a β-ray source. The resulting γ-radiation is used for continuous absorption measurement of solutions. A continuous display of the data is provided.

CLM/R-11 Forrest, M. J., M. Hill, and B. M. White Film Calibrations and Absorption Curves for the X-Ray Bremsstrahlung of Low Energy (5-20 KeV) Electrons (September 1961) U.K.A.E.A. Research Group, Culham Laboratory, Culham

Film calibrations and absorption curves are presented for the X-ray Bremsstrahlung generated by monochromatic electrons with selected energies between 5 and 20 KeV. Results for stainless steel and tungsten targets are given. Absorption curves are shown for aluminum and copper absorbers using both target materials. Two isotope calibrations for higher energies are also included. The results are in a form which is convenient for X-ray studies in the C. T. R. field.

AERE-R-3086 Cameron, J. F., J. R. Rhodes, and P. F. Berry Tritium Bremsstrahlung and Its Applications (October 1959). Isotope Research Division, U.K.A.E.A. Research Group, Atomic Energy Research Establishment, Harwell

Convenient sources of electromagnetic radiation in the energy region 0-18 KeV are available in the form of tritium absorbed in a thin layer of titanium or zirconium. These sources emit a combination of bremsstrahlung and X-rays characteristic of the absorbing layer. Applications of these sources to fluorescence analysis and thickness measurement are described.

Westermark, T., L. Devell, and N. A. Ghanem "On the Use of Bremsstrahlung for the Determination of Tritium in Aqueous and Organic Systems," Nuclear Instruments and Methods, Vol. 9, 141 - 144 (1960)

The bremsstrahlung method for the determination of beta radioactivity without gamma radiation is extended to the case of tritium. Using cells made from light materials, excellent results and rough agreement with theoretical estimates were obtained for water containing millicurie amounts of tritium. Applications to self-diffusion studies on water and labelling experiments are briefly described.

BIBLIOGRAPHIES

NBS-5446 Johnson, Virginia R. <u>A Review of the Properties of Deuterium and Tritium Compounds</u>. (October 1957) Annual Bibliography 1955. National Bureau of Standards, Washington, D.C.

The references in the bibliography are arranged alphabetically according to the last name of the leading author. Each reference is numbered by a letter number symbol corresponding, respectively, to the first letter of the leading author's name and the numerical listing under that letter. The names of co-authors are listed alphabetically and cross-indexed. Compound and subject indexes are included for the convenience of the reader. This bibliography contains 455 references to published research on deuterium and tritium compounds and was compiled entirely from volume 49 (1955) of <u>Chemical Abstracts</u>. Research articles related to nuclear properties have been excluded, except where other pertinent information on deuterium or tritium was reported. Also the topic of isotope effects has been restricted primarily to the isotopes of hydrogen, whereas the topic of isotope separation still contains references to works on the separation of isotopes of various elements.

DP-511 (TID-4500, 17th Ed.) Feldman, Myra S. Techniques for the Determination of Tritium, A Literature Search June 1962, E. I. Dupont de Nemours & Co. Explosives Department -- Atomic Energy Division Technical Division -- Savannah River Laboratory

References on the quantitative determination of tritium were compiled and arranged in an annotated bibliography. The references are limited to those pertinent to the instrumentation and techniques for tritium determination.

UCRL-5069 Cason, Maggie Tritium (A Bibliography). (March 1957) University of California, Livermore Radiation Laboratory

This is a selective bibliography of books, periodicals, articles, and technical reports relating to tritium with special reference to urine analysis of tritium and metabolic experiments.

BIBLIOGRAPHIES (Continued)

Sources consulted include the library card catalog; the information division AEC card catalog; Chemical Abstracts, 1954 to 1955; Nuclear Science Abstracts, 1955 to 1956.

AERE - Bib. 132 Foskett, A. C. Tritium Detection and Measurement A Bibliography. (March 1961). Library Information Office, Atomic Energy Research Establishment, Harwell, Berkshire.

The bibliography contains 164 references covering published literature and reports up to the end of 1960. Since the very low energy (maximum 18 KeV) of the beta radiation from tritium causes special problems in counting, references have been selected which definitely refer to tritium, and no attempt has been made to cover the very much wider field of low-energy beta counting in general. Where appropriate, notes have been added to indicate the method of counting, sensitivity, range, and efficiency.

TID-3570 Bost, William E. Tritium Handling. A Literature Search (December 1961) Division of Technical Information, United States Atomic Energy Commission

BIBLIOGRAPHIES (Continued)

Included are 157 references to reports, journals, and other literature related to the problems and techniques of tritium handling. The subject scope embraces analytical monitoring procedures and instruments, physiological effects, and safety measures and standards.

CHEMICAL BEHAVIOR

HW-17318 Roesch, W. C. P-10 Chemical Equilibria (March 1950) Hanford Works, Richland, Washington

Some theoretical considerations of the exchange of tritium with hydrogen in water vapor and the effect of a catalyst are discussed.

ORNL-128 Ghormley, J. A. and A. O. Allen Decomposition of Tritium Oxide under Its Own Radiation (September 1948) Oak Ridge National Laboratory, Oak Ridge, Tennessee

The decomposition of tritium oxide by the action of the tritium betas was investigated. Tritium water was sealed in glass ampules and the decomposition was measured by observing the boiling point of the contained water. The difference in decomposition caused by alpha particles, beta particles, and gamma rays is discussed.

KAPL-900 Dorfman, L. M., and H. C. Mattraw The Exchange Reaction of Hydrogen and Tritium. (April 1953). General Electric Company, Knolls Atomic Power Laboratory, Schenectady, New York

The rate of the hydrogen-tritium exchange reaction

$$H_2 + T_2 = 2HT$$

initiated by the tritium beta-radiation has been investigated at room temperature using a mass spectrometer as the analytical instrument. The runs cover a pressure range of 59.0 to 399.9 mm with tritium pressures between 33.2 and 147.7 mm.

The progress of the reaction may be represented by the equation:

$$HT_\infty - HT_t = HT_\infty e^{-kt}$$

where HT_t and HT_∞ denote the concentrations of tritium hydride at time t and at equilibrium; k is a constant. The initial rate of exchange has been calculated from

$$\left(\frac{d\ HT_t}{dt}\right)_{t = o} = k\ HT_\infty$$

Over the conditions studied, half times ranging from 260 to 818 minutes have been obtained.

The fraction of the beta energy absorbed has been estimated, and G values as high as 450 molecules/100 ev have been obtained indicating the reaction to be a chain process. Correlation of the data shows that the initial rate of formation of HT is directly proportional to the product of the pressure and the square root of the absorbed intensity.

Dorfman, Leon M., and B. A. Hemmer. "Ion-Pair Yield of the Tritium-Oxygen Reaction," The Journal of Chemical Physics, Vol. 22, No. 9, 1555-1558. (September 1954)

The rate of reaction of tritium and oxygen, initiated by the tritium beta radiation, has been investigated at 25° C, in the absence of mercury vapor, by using a sensitive Bourdon gauge as the manometer. The rate is not linear with time, but shows a small continual decrease as the reaction proceeds. The initial reaction rate was found to be directly proportional to the tritium pressure, and hence proportional to the radiation intensity.

CHEMICAL BEHAVIOR (Continued)

It was independent of the oxygen concentration over the range investigated. The reaction rate shows a slight dependence on the isotopic composition of the hydrogen reactant, tending to rise with increase in the mole fraction of protium. The initial reaction rate may be represented by

$$R_0 = 1.19 \times 10^{-1} CT_2 \left(1 + 0.3m_H\right)$$

where CT_2 is the tritium concentration in moles/liter or other absolute concentration units, and m_H is the mole fraction of protium in the hydrogen reactant. On the basis of a requirement of 33 ev per ion pair in the reactant mixture, the initial ion-pair yield for tritium disappearance or water formation is $(M/N)_0 = 3.2$ for the reaction of pure tritium with oxygen. Material balance measurements indicate that little or no peroxide appears in the product.

Progress Report USNRDL-P-22 (Report Classified) Scientific Staff, P. C. Tompkins, Scientific Director <u>Quarterly Progress Report (1 Jan to 31 March 1960)</u> pp. 174 - 175 (Pages cited unclassified) "Self Induced Radiolysis Reactions of Tritium in Air" U. S. Naval Radiological Defense Laboratory, San Francisco, California

Progress Report USNRDL-P-23 (Report Classified) Scientific Staff, E. P. Cooper, Scientific Director <u>Quarterly Progress Report (1 April to 30 June 1960)</u> pp. 258 - 259 (Pages cited unclassified) "Self Induced Radiolysis Reactions of Tritium in Air" U. S. Naval Radiological Defense Laboratory, San Francisco, California

USNRDL-TR-565 Casaletto, G. J., L. H. Gevantman, J. B. Nash <u>The Self-Radiation Oxidation of Tritium in Oxygen and Air</u>, (May 1962). U. S. Naval Radiological Defense Laboratory, San Francisco 24, California

The rate of self-radiation oxidation of tritium has been studied in atmospheres of oxygen and air by direct analysis of products as a function of time.

Second-order dependence on tritium concentration was observed below 1 mc/ml. Rate constants were determined to be 1.2×10^{-3} ml/mc-hr in oxygen and 0.62×10^{-3} ml/mc-hr in dry air.

The reaction rate was found to be independent of oxygen concentration and surface area at constant total pressures above 100 mm but to drop off sharply below this value.

The rate in oxygen is increased threefold in the presence of water vapor. The rate in atmospheric air, although poorly reproducible, is essentially the same as in dry air.

USNRDL-TR-471 Yang, J. Y., and L. H. Gevantman Tritium β-Radiation-Induced Isotopic Exchange in the T_2-H_2O System (September 1960) U. S. Naval Radiological Defense Laboratory San Francisco 24, California

The conversion of tritium to tritiated water through its β-radiation-induced isotopic exchange with water vapor was investigated. It was found that, under simulated normal atmospheric conditions with tritium concentration in the range of 0.05 to 0.7 c/l, the rate of conversion of tritium to tritiated water is independent of the water vapor density. On the other hand, a second order dependency on the initial tritium concentration was observed. The isotopic exchange rate, R, expressed in mc/l/day may be approximated by the following equation:

$$R = 4 \times 10^{-5} \quad (T_2)_0^2$$

where $(T_2)_0$ is the initial tritium concentration in mc/l.

Results from X irradiation of the reaction mixture indicate that the exchange rate is essentially proportional to radiation absorption. Lowering of the reaction rate by dilution of tritium with protium was observed. The presence of a number of moderating gases was found to exert a small but apparently significant effect on the reaction rate. To account for the marked inhibiting effect of nitric oxide, a reaction mechanism involving radical intermediates is proposed.

DETECTION, COUNTING, AND DETERMINATION TECHNIQUES

GAS FLOW PROPORTIONAL COUNTERS AND GEIGER COUNTERS

Christman, David R. "Choosing a Method for Counting Soft Betas", Nucleonics, Vol. 19, No. 5., 51 - 55 & 64, (May 1961)

For counting the soft betas of C^{14}, S^{35}, or tritium you will use a solid counter, gas counter, ionization chamber or scintillator. Here are some criteria that will help you choose among them.

GAS FLOW PROPORTIONAL COUNTERS AND GEIGER COUNTERS (Continued)

Mon H - 448 Firminhac, R. H. Conversion of Air Proportional Counter Alpha Detection Instruments ("POPPY") to Detect C^{14} Contamination and Soft Beta Radiation. (January 1947), Monsanto Chemical Co., Clinton Laboratories, Oak Ridge, Tennessee

Alteration of the air proportional counters usually used for survey for alpha contamination, to detect soft beta radiation is described. This consists mainly of changing the gas used in the counter tube and changing the high voltage supply.

Rydberg, Jan "Determination of the Absolute Activity of Solid Tritium Samples", Acta Chemica Scandinavica, Vol. 12, 399 - 407 (1958)

It is shown that the absolute specific beta activity of tritium in solid samples of finite thickness can be accurately determined with 2 internal gas-flow counters. The effects of self-absorption and back-scattering of tritium betas are discussed.

GAS FLOW PROPORTIONAL COUNTERS AND GEIGER COUNTERS (Continued)

LA-1645 McClelland, Jean and Morris F. Milligan Determination of Tritium in Urine and Water. (March 1954). Los Alamos Scientific Laboratory of the University of California, Los Alamos, New Mexico

The sample, water or urine, is prepared for counting in a vacuum line. Urine or water is dropped onto metallic calcium, and hydrogen and tritium are evolved. The gas flowing into the evacuated system is passed through liquid nitrogen cooled traps to remove unreacted water and condensable gases. The gas is allowed to flow into a tube similar to a Geiger-Muller tube until a pressure of 15 cm of mercury is attained. Ethylene and argon are added to give a total pressure of 22 cm of mercury. The beta activity is counted with a scaling circuit having an input sensitivity of ¼ volt. A tube similarly filled with inert hydrogen is counted simultaneously to determine the environmental background. The background count is subtracted from the sample count to obtain the true sample count.

The method has a precision of 5% in the range of 1 to

250 μc of tritium per liter of sample. Samples with higher concentrations may be determined with appropriate dilutions. An experienced operator can do approximately 50 determinations per day. The tolerance used at LASL for tritium in urine is 250 μc/liter.

AERE-R-3092 Cameron, J. F., and B. J. Puckett Geiger Gas Counting Methods of Assaying Tritiated Hydrogen and Tritiated Water. (January 1960). Isotope Research Division, U. K. A. E. A. Research Group, Wantage Radiation Laboratory, Berkshire

Methods are described of assaying tritium in hydrogen, water vapor, butane and acetylene as part of the filling of a self-quenching geiger counter and it is concluded that the most satisfactory filling is tritiated hydrogen with toluene as a quenching vapor. Absolute measurements on tritiated water are carried out by reducing the water over zinc at 425° C and introducing the hydrogen into a counter with a known sensitive volume.

GAS FLOW PROPORTIONAL COUNTERS AND GEIGER COUNTERS (Continued)

DP-34 Karraker, D. G. <u>A Monitor for Surface Adsorbed Tritium</u> (December 1953) E. I. du Pont de Nemours & Co. (Inc.), Explosives Department - Atomic Energy Division Technical Division - Savannah River Laboratory

A monitor for detection of surface-adsorbed tritium beta particles has been developed. The detecting element is a windowless Geiger tube with the counting gas flowing through it. The normal limit of detection of a single-tube probe is 800 d/m of tritium, while a three-tube probe is probably limited to about 2000 d/m. Both probes have a counting efficiency of about 10% for tritium.

Wolfgang, Richard, and C. F. Mackay "New Proportional Counters for Gases and Vapors", <u>Nucleonics</u>, Vol. 16, No. 10, 69 - 73 (October 1958)

New proportional-counter designs simplify this inherently sensitive tool for assay of C^{14} and H^3 and extend its use to gas-flow applications. Comparison is made with the sensitivity and convenience of other systems.

Isbell, Horace, S., Harriet L. Frush, and Ruth A. Peterson "Tritium-Labeled Compounds I. Radioassay of Tritium-Labeled Compounds in 'Infinitely Thick' Films With a Windowless, Gas-Flow, Proportional Counter", Journal of Research of the National Bureau of Standards - A. Physics and Chemistry, Vol. 63A, No. 2, 171 - 175 (September - October 1959)

A simple, sensitive and reliable technique has been devised for the radioassay of non volatile, water-soluble tritium compounds. The substance to be analyzed is dissolved in an aqueous solution of a thickening agent, preferably sodium O-(carboxymethyl) cellulose or sodium alginate. The solution is placed in a shallow planchet, and after evaporation of the water, the resulting film, which is "infinitely thick" to tritium beta particles, is counted with a 2π, windowless, gas-flow, proportional counter. By means of an empirical factor, determined with a substance of known radioactivity, the counts are converted to micro-curies. In a film having a thickness of 0.7 mg/cm^2, the counting efficiency is about 4 percent; the standard deviation from the mean, obtained in a series of routine measurements, was less than 2 percent. An assay can readily be made with tritium-containing material having 0.01 microcurie of radioactivity. The method, which is applicable to nonvolatile, water-soluble solids, solutions or liquids, is suitable for routine analyses.

Driver, G. E., "Tritium Survey Instruments". The Review of Scientific Instruments, Vol. 27, No. 5, pp. 300 - 303 (May 1956)

Portable counters for the detection of surface and air tritium contamination are described. The surface monitor uses a sponge rubber seal to the surface with an argon-methane counting mixture being admitted during measurements. The air monitor mixes methane with the air before counting, and is capable of detecting a tritium concentration of 10^{-5} mc/cc of air.

DETECTION, COUNTING, AND DETERMINATION TECHNIQUES

ION CHAMBERS

Shaw, D. F., "An Automatic Monitor for Measuring Tritium

Contamination in Air", Journal of Scientific Instruments, Vol. 32, pp. 178 - 180 (May 1955)

This paper describes the design and principle of operation of an automatic monitor for testing air for contamination by tritium. The method of detection is based on the measurement of ionization in an air sample. A direct reading meter registers the level of radioactivity and provision is made for operating a recorder. The instrument was developed to test for tritium contamination but may be used to detect other airborne radioactive gases, e.g., $^{14}CO_2$ or radon.

AERE-M-429 Fry, R. M. The Calibration of Flow Ionization Chambers for Tritium Monitoring in Air. (August 1959) Health Physics Division, Atomic Energy Research Establishment, Harwell, Berkshire

A stream of air of known tritium (HTO) concentration is obtained by mixing dry air and air saturated with HTO vapor in known proportions.

This has been used to calibrate ion chambers for the monitoring of tritium in air. Particular attention is paid to the 1590A, a chamber designed at A.E.R.E. Harwell, and limitations in its use as an air monitor due to adsorption of HTO are briefly discussed.

LA-1683 Eutsler, B. C., R. N. Mitchell, and M. C. Robbins
Calibration of Tritium Monitoring Devices. (June 1954).
Los Alamos Scientific Laboratory of the University of California,
Los Alamos, New Mexico

The increased use of tritium monitoring devices has made it necessary to devise a scheme for the calibration of such instruments. Several methods for setting up known concentrations of tritium were considered. A dynamic system containing tritium as HTO vapor or gaseous HT was selected because of the ease of control of variables. The variables that have been considered are:

1. The effect of rate of air flow through the instruments.
2. The effect of humidity on instrument response.

3. The effect of ion collection ahead of the ion chamber.
4. The variation of "hold time" from the generation of tritium to its passage through the ion chamber.
5. The instrument response to several concentrations of tritium as HTO vapor and gaseous HT.

The following three types of monitoring devices have been calibrated:

1. Model 101 Sniffer of Group P-1.
2. CI-1 Vibrating Reed Electrometer of Group CMR-7.
3. Modified T1B of Group H-6.

Brinkerhoff, J., C. A. Ziegler, R. Bersin, and D. J. Chleck "Continuous Air Monitor for H^3", Nucleonics, Vol. 17, No. 2, pp. 76, 78, 81 (February 1959)

A continuous monitor has been developed capable of accurately indicating tritium concentrations of 0.1 - 100 times the maximum permissible concentration, with an estimated error over the range not exceeding ± 5%. The instrument uses a flow type ionization chamber. By means of a filter and ion-sweeper system, it is unreponsive to airborne sources of ionization other than radioactive gases. The theory of operation is discussed.

LA-1270 Deal, James B., Jr. Continuous Tritium Monitor. (February 1951) Los Alamos Scientific Laboratory of the University of California, Los Alamos, New Mexico

An instrument developed to continuously detect and measure the amount of tritium in the atmosphere consists of a Model 30 Vibrating Reed Electrometer manufactured by the Applied Physics Corporation and a Model CI-1 Ionization chamber designed for use with this electrometer.

An electric fan continuously sucks room air first through a filter element, then through an ionization chamber. Except for the particles removed by the filter element the air sample inside the ionization chamber is identical to the air in the room.

ION CHAMBERS (Continued)

The chamber has been calibrated by calculation. A tolerance concentration of tritium with an average Beta energy of 6 Kev in the one liter chamber will yield an ionization current of about 2.4 x 10^{-15} amperes. With the electrometer sensitivity set at 10^{-13} amperes full scale this reading will then be about 2.4% of full scale.

DP-150 Ryder, F. D. An Explosion Resistent Ion Chamber for the Measurement of Tritium (March 1960) E. I. du Pont de Nemours & Co. Explosives Department - Atomic Energy Division Technical Division--Savannah River Laboratory

An ion chamber was constructed to monitor gaseous tritium in hydrogen-oxygen mixtures that have a high relative humidity and that might fall within the explosive limits. In calibration tests the ion chamber responded linearly to tritiated water vapor in air, at concentrations from 10^{-5} to 10^{-4} microcurie per cubic centimeter. The chamber withstood deliberate internal explosion without detectable damage.

LA-1909 Eutsler, B. C., G. L. Evans, R. D. Hiebert,

ION CHAMBERS (Continued)

R. N. Mitchell, Chain Robbins, and R. J. Watts Instruments for the Monitoring of Tritium in the Atmosphere. (April 1955) Los Alamos Scientific Laboratory of the University of California Los Alamos, New Mexico

Three types of instruments, all operating on the same principle, are described. These are a battery operated type, an AC operated linear type, and an AC operated logarithmic type.

The current from a conductivity type chamber is monitored by a simple electrometer tube circuit. A warning bell is rung by means of sensitrol relay when ionization in the atmosphere produces a full scale reading. These instruments are intended for special situations where the environment can be controlled to some extent. They will respond to ionization arising from any source. A full scale reading on the most sensitive scale is equivalent to a current of 10^{-12} amp in the chamber.

Curves are given of the behavior of this type of instrument with flow rate, tritium concentration, equilibrium time, voltage ion traps, and tritium in the form of HT and HTO.

It is concluded that these instruments are satisfactory as warning devices but are of doubtful value as health tolerance meters.

HW-SA-2413 Little, G. A. Ionization Chamber Air Sampling System for Tritium (May 1962) General Electric Co., Hanford Atomic Products Operation, Richland, Washington

A rapid inexpensive air sampling system was devised which will detect one MPC (5×10^{-8} μc/cc) of tritium oxide in air. The system uses a one-liter ionization chamber for a sample collecting-measuring chamber and an ionization chamber pulse reader for sample activity measurements. Accuracy of the system is ± 25%. Concentrations of 5×10^{-6} μc/cc of tritium in air were measured, with results available in less than one hour after sample collection. The system has been in routine operation for several months. It has been reliable, and is faster than other available methods for tritium air sampling. The system has also been used for air sampling for other gaseous radio-isotopes.

UCRL-3499 Tolbert, B. M., Ionization Chamber Assay of Radioactive Gases. (March 1956) University of California Radiation Laboratory, Berkeley

A practical review is presented on ionization chamber assay of radioactive gases. The subjects covered include: Ion chamber theory, samples and sample preparation, combustion of organic compounds to CO_2, design and construction of ion chambers, measurement of ion chamber currents and approximate calibration data, and detailed procedure for C_{14} and tritium assay.

CRRD-858 AECL-1049 Cowper, G. and S. D. Simpson A Monitor for Airborne Tritium (July 1960) Atomic Energy of Canada Limited, Chalk River, Ontario

A monitor has been designed which is suitable for the measurement of concentrations of tritium in air in the presence of a fluctuating background of gamma radiation. It is therefore suitable for the measurement of the tritium hazard in the vicinity of a heavy water reactor. Whereas a simple ionization chamber through which ambient air is circulated would give equal response to a maximum permissible concentration of tritium and an external gamma radiation field of only 0.25 mr/hr, this apparatus using a pair of compensated ion chambers operates satisfactorily in gamma radiation fields of several milli-roentgens per hour without the use of shielding.

AERE-M-428 Fry, R. M. Monitoring of D_2O for Tritium Contamination (July 1959) Health Physics Division, U. K. A. E. A. Research Group, Atomic Energy Research Establishment, Harwell

A simple and rapid method for monitoring drums of D_2O for tritium contamination is described. DTO vapour above the heavy water surface is transferred to an ion chamber, the resulting ion current being a measure of the specific activity of the D_2O. The apparatus described can detect concentrations of 0.1 µc/gm.

Hoy, J. E. "Operational Experience with Kanne Ionization Chambers", Health Physics, Vol 6, pp. 203 - 210 (1961)

Operating experience with two types of Kanne ionization chambers is described. These chambers are used to monitor gaseous radioactive β-emitting contaminants released during the operation of heavy-water moderated reactors at the Savannah River Plant. Calibration results, γ sensitivity, the effects of β-energy on chamber sensitivity, and the effects of such variables as temperature, pressure and humidity on the operation characteristics of these chambers are discussed.

LA-1894 Eutsler, B. C., M. C. Robbins, and R. Hiebert A Portable Apparatus for the Determination of Tritium in Body Fluids and Aqueous Solutions (April 1955) Los Alamos Scientific Laboratory of the University of California, Los Alamos, New Mexico

This report supersedes LA-1678.

A small apparatus of adequate sensitivity and more portable than that described in Report LA-1678 has been developed for the determination of tritium in body fluids and aqueous solutions. The entire system is adaptable to operation by untrained personnel.

The small glass vacuum manifold and ionization chamber are evacuated by means of water aspiration and filled to atmospheric pressure with a mixture of hydrogen-tritium gas. The hydrogen-tritium mixture is evolved by dropping a liquid (sputum, urine, blood, or water) onto metallic calcium and passing the gas through a drying column filled with indicating Drierite. The current produced by the beta activity within the ionization chamber is measured with either an Applied Physics Corporation Vibrating Reed Electrometer or a battery powered ionization chamber current meter designed by Los Alamos Scientific Laboratory. The method has a range of 10 to 10,000 μc of tritium per liter of liquid, depending upon the size of the ionization chamber and the measuring instrument.

Anthony, J. D. "Portable Tritium Monitor Has Gamma Compensation", Nucleonics, Vol. 17, No. 4, pp. 110, 112, 114 (April 1959)

A tritium monitor is designed on the same air-sampling principle used in the Los Alamos Model 101 Sniffer and the Tracerlab Tritium-Flow Monitor. But it has an additional gamma-compensation chamber.

ION CHAMBERS (Continued)

DP-242 Colvin, D. W. A Simple Monitor for Tritium Contamination on Surfaces (October 1957) E. I. du Pont de Nemours & Co., Savannah River Laboratory

Surface contamination by tritium was measured with an open-end ionization chamber that was operated as a dosimeter. The chamber could detect 12,000 d/m of tritium with a signal-to-noise ratio of ten.

Ziegler, C. A., and A. Schwebel "Technique for Monitoring Tritiated-Water Vapor in Air" Nucleonics, Vol. 15, No. 1, 64 (1957)

A method for the determination of HTO concentration in air is described utilizing a 250 cm^3 ionization chamber with a vibrating-reed electrometer. The ionization chamber was calibrated by filling with known concentrations of HTO vapor in air and measuring the resulting electrometer drift rate.

Rieck, H. G., I. T. Myers, and R. F. Palmer "A Tritiated Water Standard" Radiation Research, Vol. 4, pp. 451 - 466 (1956)

A tritiated water sample has been prepared and its activity determined by three different independent methods. This sample is now in use as a standard. The error in the final activity is estimated to be 2%. Considerable care was taken throughout the standardization measurements in order to reduce isotope effects of tritium adsorption on apparatus surfaces.

AERE-HP/R-2858 Fry, R. M. Tritium in Urine Monitoring by the Acetylene Flow Ion Chamber Method (July 1959) U. K. A. E. A. Research Group Atomic Energy Research Establishment, Harwell, Berkshire

Using a 2 litre ion chamber enclosed in a 2" lead castle and a stable vibrating reed electrometer, the limit of detection of an acetylene flow method of measuring tritium in aqueous solutions has been found to be 0.001 μc/ml. Concentrations of 0.005 μc/ml can be measured to a relative accuracy of about ±10% in a quarter of an hour. Commercial acetylene is used as the flushing gas and for background determination.

Radon present in the calcium carbide introduces a constant zero error.

DETECTION, COUNTING, AND DETERMINATION TECHNIQUES

SCINTILLATION DEVICES AND TECHNIQUES

Langham, W. H., W. J. Eversole, F. N. Hayes, and T. T. Trujillo, "Assay of Tritium Activity in Body Fluids with Use of a Liquid Scintillation System", Journal of Laboratory and Clinical Medicine, Vol. 47, No. 5, pp. 819 - 825 (May 1956)

Simple and rapid methods have been developed for the determination of tritium water (HTO) in mammalian serum and urine. Mean recovery values obtained for tritiated blood serum and urine were at least 97% of the expected values and the error was relatively small (>3 percent).

In order to obtain consistent and reliable values for tritium activity, it was necessary to remove proteins and pigments from all samples. In human serum this was accomplished by the use of trichloracetic acid. Rat serum did not contain enough pigments to make decolorization necessary. Urine was decolorized by filtration through activated charcoal, and cleared urine was added directly to the scintillation solution. After centrifugation and decanting, the clear supernatant solutions were placed in optically clear glass counting bottles, chilled for one hour at 2 to 3° C., and counted.

These procedures were shown to be applicable to the study of water absorption and distribution studies in a normal human using HTO.

Horrocks, Donald L. and Martin H. Studier, "Determination of the Absolute Disintegration Rates of Low Energy Beta Emitters in a Liquid Scintillation Spectrometer". Analytical Chemistry, Vol. 33, No. 4, pp. 615 - 620 (April 1961)

Integral counting techniques using a liquid scintillation spectrometer for the determination of the absolute disintegration rate of β-emitters have been extended to the isotopes S^{35}, C^{14}, Sm^{151}, Ni^{63}, Ru^{106}, Pu^{241}, and H^{3}. Experimental results are compared with those expected from the theory of β decay and the statistical probabilities of scintillation counting. If the shape of the β spectrum is known, the absolute disintegration rate can be determined by integral counting and comparison of the extrapolated integral counting rates for single channel and coincidence systems. Some practical factors involved in obtaining a system with a high counting efficiency for low energy β emitters are discussed. The liquid scintillation spectrometer is shown to be stable, and can determine very small amounts of low energy β emitters.

Butler, Frank E. "Determination of Tritium in Water and Urine (Liquid Scintillation Counting and Rate-of-Drift Determination)." Analytical Chemistry, Vol. 33, No. 3, 411 - 414 (March 1961)

Two methods are presented for the accurate determination of tritium in urine and water. One method, liquid scintillation counting utilizes an improved scintillation mixture and disposable, low background, poly-ethylene vials. Untreated urine samples are assayed at tritium levels of 1 μc per liter after a 1-minute count. The lower limit of detection of tritium in water is 0.005 μc per liter, and 0.05 μc per liter can be determined with a relative standard deviation of less than 10% after a 30-minute counting period. Results are comparable with the second method of tritium determination, using a vibrating reed electrometer rate-of-drift determination. The vibrating reed procedure requires less expensive equipment and is suitable for analyzing 4 to 6 samples per day.

AERE R-3605 Hutchinson, W. P. <u>The Identification of Beta Emitting Isotopes by Liquid Scintillation Counting</u>. (October 1960). Medical Division, U.K.A.E.A., Research Group, Atomic Energy Research Establishment, Harwell

The average energy of a beta-emitting isotope, in micro-microcurie amounts, may be measured at room temperature by means of the system described. The apparatus is useful for rapid quantitative routine analysis of beta-emitters required for biological purposes.

The spectrometer which is briefly described is a simplified apparatus using standard Harwell equipment.

AERE R-3238 Hutchinson, W. P. <u>Liquid Scintillation Counting of Tritium at 22° C.</u> (January 1960). Medical Division, U.K.A.E.A.

Research Group, Atomic Energy Research Establishment, Harwell.

0.001 µc ±10% of tritium may be quantitatively estimated at room temperature. Two photomultiplier tubes are used working in coincidence.

Roucayrol, Jean-Claude, Eric Oberhauser and Richard Schussler "Liquid Scintillators in Filter Paper -- A New Detector", *Nucleonics*, Vol. 15, No. 11, pp. 104, 106, 108 (November 1957)

A convenient inexpensive scintillation method of assay for soft beta emitters on filter papers has been developed in which the papers are impregnated with a liquid scintillator and pressed against the end of the photomultiplier. A means of differentiation between different beta emitters is discussed as well as the effect of different papers.

AERE R-3716 Sandalls, J. *A Method for Routine Determinations of Tritium in Urine Using a Coincidence Liquid Scintillation Counter*. (June 1961) Medical Division, U.K.A.E.A. Research Group, Atomic Energy Research Establishment, Harwell

A sensitive and wide range method for the routine measurement of tritium in urine is described.

Urine, distilled in the presence of toluene, is assayed for tritium content by a liquid scintillation technique. Two 1" diameter matched E. M. I. type 9524 S/A photomultiplier tubes are connected through coincidence and discriminator units to a standard amplifier and scaler. The liquid scintillation counting is carried out at room temperature.

A tritium concentration of 1 x 10^{-3} μc/ml in urine gives about 160 counts per minute above a background of about 170 counts per minute. The counting efficiency is 7%. The absolute limit of detection of the method for tritium in urine is about 1.6 x 10^{-4} μc/ml, on the basis of two standard deviations.

UCLA 504 Myers, L. S., Jr., and Cynthia Rosenblum A Rapid Method for Determining Tritium Water in Urine Following Acute Exposure. (May 1962) University of California, Los Angeles School of Medicine, Los Angeles 24, California

HTO in the urine of exposed individuals can be determined within minutes after receipt of samples by use of a detergent-anthracene-scintillation counting method. The procedure consists merely of pipetting an aliquot of the sample onto detergent coated anthracene in a counting vial and counting in a liquid scintillation counter. Reproducibility, stability, and sensitivity are adequate to give reliable results with tritium concentrations well below the maximum permissible level of 28 μc/l. Yellow pigments decrease the counting efficiency according to Beer's law, and must be removed if a highly accurate analysis is required. However, for most bioassay purposes a correction based on an optical density measurement will give satisfactory results.

Boyce, I. S., J. F. Cameron, and K. J. Taylor "A Simple Plastic Scintillation Counter for Tritiated Hydrogen", The International Journal of Applied Radiation and Isotopes, Vol. 9, 122 - 123 (1960)

A plastic scintillation detector was designed to measure the tritium content of hydrogen coming from a palladium chromatography column.

Hodgson, T. S., B. E. Gordon and M. E. Ackerman "Single-Channel Counter for Carbon-14 and Tritium", Nucleonics, Vol. 16, No. 7, pp. 89, 90, 91, 92, 93, and 94 (July 1958)

An economical, room-temperature liquid scintillation counter was designed that is capable of counting carbon-14 activities of 10 cpm above background. Careful photomultiplier selection also provides adequate efficiency and stability for tritium assay.

Jeffries, T. O., "A Tritium Monitor", <u>Journal of Scientific Instruments</u>, Vol. 30, pp. 387 - 388 (October 1953)

A monitor which has been developed for recording continuously the tritium concentration in low pressure gas targets (containing about 2 μ. of tritium) is described in this note. The monitor consists of an E. M. I. type 6260 photomultiplier with a thallium activated potassium iodide phospher, in the form of a thin screen, mounted in contact with the glass window. The end of the multiplier is sealed into a chamber of fixed volume which is connected to the target by means of a flexible tube.

DIFFUSION AND PERMEABILITY IN THE ATMOSPHERE AND IN MATERIALS

TID-12350 Nussbaum, Elmer <u>Diffusion of Radon Through Semi-Permeable Materials</u> (Technical Progress Report). (March 1961) Taylor University, Upland, Indiana

Experiments have been conducted to investigate the rate at which radon is diffused through sheets of rubber vulcanates, plastic films and papers. A program has also been initiated to utilize tritium to study the transmission rate of this gas through similar semi-permeable materials.

DIFFUSION AND PERMEABILITY IN THE ATMOSPHERE AND IN MATERIALS (CONTINUED)

It is seen that the diffusion of radon through silicone rubbers proceeds at a rate six to eight times as fast as the diffusion of tritium through the same material (based on the time required for 30% transmission). It is of particular interest that tritium, an isotope of the lightest element diffuses through silicone rubbers more slowly than does radon which is the heaviest of the inert gases.

It is of further interest that tritium diffuses through some semi-permeable materials at a rate which exceeds that of radon. For example, five layers of wax paper will permit the transmission of 18% of the radon in 35 minutes while experiments currently in progress indicate that 36% of the tritium is transmitted through the same material in the same time.

Future experiments may shed further light upon the specific requirements of a material to serve as an effective barrier to tritium.

Hosler, E. R., J. F. Chivot, P. J. Korpi, and J. W. Westwater "Diffusion of Water Vapor in Plastic Laminates", Journal of Chemical and Engineering Data, Vol. 5, No. 2 (April 1960)

Diffusivities in each of the three principal directions were determined separately from unidirectional diffusion tests for three different phenol-formaldehyde plastic laminates. Two of these laminates were paper base and one was cloth base. The cloth base sample was more permeable than the two paper base samples. The effect is most pronounced for the directions parallel to the laminations. Some theoretical considerations are discussed.

Ayer, J. E., R. M. Mayfield, and D. R. Schmitt "The Engineering Aspects of the Water Vapor Permeability of Glove Materials", Nuclear Science and Engineering, Vol. 8, 274 - 276 (1960)

DIFFUSION AND PERMEABILITY IN THE ATMOSPHERE AND IN MATERIALS (CONTINUED)

Gloveboxes are frequently used for the protection of personnel and containment of an inert atmosphere within which operations upon pyrophoric or physiologically hazardous materials are performed. Leakage or diffusion of water vapor through gross leaks or through gloves may necessitate purification of the inert atmosphere. Since the required capacity of the purification system involves a summation of in-leakage from all sources, quantitative information on the role of the glove as a contributing factor is of importance. This paper is intended to indicate the engineering application of an investigation into the role of the permeability of glove materials.

Water vapor permeability through various glove materials has been determined mathematically as a function of film thickness, partial pressure of water vapor differential across the film, film surface area, and the permeability constants for a particular "compound."

Calculations indicate that a sample glove exposed to air at 75° F and 50% relative humidity on one surface and to a very low humidity on the other side will contribute 0.22 g of water vapor per day to a glovebox system. The same glove in use by an operator will contribute up to 2.8 g of water per day due to the increased partial pressure of water vapor differential between the two glove surfaces. These calculations allow the quantitative determination of water permeation through gloves and its effect upon the desired purity or operating dew point of the protective atmosphere system and its purification equipment.

DP-528 Symonds, A. E. Evaluation of Plastic Films for Protective Suiting. (Nov. 1960) Savannah River Plant, E. I. du Pont de Nemours and Company, Aiken, South Carolina

Four films, polyethylene, "Saran", "Saran"- PVC, and polyvinyl chloride were tested for permeability and diffusion of tritiated water vapor and the retention and decontamination of tritium activity. Relative ratings based on these tests are presented. For protective suiting "Saran" - PVC was rated best and polyvinyl chloride was rated poorest.

ANL-5743 Davis, D. A., J. E. Ayer, and R. M. Mayfield. Gloves for Protective Enclosures. (May 1957) Argonne National Laboratory, P. O. Box 299, Lemont, Illinois

A study of the glove problem has been made by the ANL Glove Committee as a necessary prerequisite to any attempt at coordination or standardization. This report consists of a compilation of the findings of the Committee and the resulting compromises which are felt necessary to the resolution of the problem.

Materials, methods of manufacturing and general properties of gloves are described. Glove design has been analyzed and suggestions are made in regard to an acceptable

DIFFUSION AND PERMEABILITY IN THE ATMOSPHERE AND IN MATERIALS (CONTINUED)

standard. Permeability characteristics of various glove compounds are reviewed and the effect of moisture contamination upon hypothetical systems is tabulated. An electrical test is proposed for the determination of glove soundness.

Butler, H. L., and R. W. Van Wyck "Integrity of Vinyl Plastic Suits in Tritium Atmospheres." Health Physics, Vol. 2, 195 - 198 (1959)

Significant amounts of tritium oxide penetrate vinyl plastic suits when exposed to high level concentrations. The degree of penetration can be estimated from data obtained during control tests. Exposures of personnel using the suits can be controlled by establishing working time limits based on the expected penetration. Laundering does not appear to affect the overall permeability of the plastic. The test data permit extensive use of the inexpensive two-piece suit, resulting in considerable cost savings in a tritium protection program.

Y-1075 Rowan, J. H. Moisture Permeability of Glove Materials for Controlled-Atmosphere Boxes. (May 1954) Carbide and Carbon Chemicals Company, A division of Union Carbide and Carbon Corporation, Y-12 plant, Oak Ridge, Tennessee

The permeability of Butyl-7, Butyl-6, Supreme-4, Supreme-2, U. S. Rubber-1, Neoprene-3, Surety-5, Kodapak-8, and Kodapak-9 was measured. Most of these materials were tested under 3 conditions: 24° C and 58% relative humidity, 24° C and 100% relative humidity, and 37° C and 100% humidity.

Of the samples of materials tested Butyl rubber appears to have a moisture permeability of about one-tenth that of the next best material. The results presented should be considered indicative only for presently marketed stocks.

Ayer, J. E., D. R. Schmitt, and R. M. Mayfield. "Permeation of Water Vapor Through Polymeric Films", Journal of Applied Polymer Science, Vol. III, Issue No. 7, 1 - 10 (1960)

DIFFUSION AND PERMEABILITY IN THE ATMOSPHERE AND IN MATERIALS (CONTINUED)

The use of gloves made of rubber or synthetically produced copolymers in protective atmosphere enclosures has focused attention upon the permeability of the film as a suspect area for the diffusion of water vapor as a contaminant into the protective gas system. This investigation was carried out to determine the role of the conditions affecting the permeability of glove materials. Particular attention was placed upon the system governing the permeation of water vapor through vinyl, Hycar, and milled and latex neoprene films. The investigation was carried out by a constant pressure technique conforming to Procedure B, ASTM Designation E96-53T. The rate at which water vapor permeates a film was studied in the light of two independent variables: film thickness and water vapor pressure differential across the film. Permeation rate was found to be inversely proportional to thickness to a constant exponent. The variation of permeation rate with vapor pressure drop across a membrane is not as sharply defined as the variation with thickness, but does vary semilogarithmically. It was found that water vapor permeation rate may be mathematically defined in terms of the controlling variables and three constants. The relationship between permeation rate and the independent variables influencing this rate can be expressed as $W/tA = Ke^{n\Delta p}/x^{m}$ where W is the weight of water permeating a film of area A area in time t. The film thickness is x, Δp is the difference in partial pressure of water vapor across the film, K is defined as the permeability constant, n is the partial pressure coefficient, and m is a thickness coefficient dependent upon the solution system employed for film manufacture. Characterization of a particular film with respect to its permeability is possible through the use of the permeability constants. The value of the thickness coefficient appears to be dependent upon the solution system employed in the manufacture of the film. The exponents of thickness are offered as 1.1 for an organic solvent dispersion system and 0.8 for an aqueous dispersion system. The value of the exponential constant dependent upon the vapor pressure differential and the value of the permeability constant are suggested as dependent upon the schedule of "compounding" and not readily predictable. They appear, however, to be well defined functions and, once determined for a particular composition, may be used to predict the permeability of that material as a function of the water vapor pressure differential across the film.

Daynes, H. A. "The Process of Diffusion Through a Rubber Membrane", Royal Society of London Proceedings, 97A, 286 - 307 (1920)

The theory of the diffusion of several gases through rubber membranes is discussed. The permeability of the rubber membranes to these gases was determined experimentally.

Morgan, P. W. "Structure and Moisture Permeability of Film Forming Polymers", Industrial and Engineering Chemistry, Vol. 45, No. 10, 2296 - 2306 (Oct. 1953)

The moisture permeabilities of over 100 film-forming polymers were determined at thicknesses in the range of 0.001 to 0.003 inch, at 39.5° C and a vapor pressure differential equivalent to 53 mm. of mercury. Of these materials only 20 had permeabilities below 50 grams of water vapor per 100 cm^2. per hour at a thickness of 0.002 inch.

The film-forming materials having low permeabilities were polyethylene, rubber hydrochloride, vinylidene chloride copolymers, polytetrafluoroethylene, polychlorotrifluoroethylene, and isobutylene-isoprene copolymers. The mechanism of permeation is discussed.

LA-2671 Engelke, Morris J. and Edwin A. Bemis, Jr. A Study of the Diffusion and Mixing of Tritium Gas in Air. (April 1962). Los Alamos Scientific Laboratory of the University of California, Los Alamos, New Mexico

The mechanism by which small amounts of tritium gas mix with air has been investigated. Interpretations have been applied to the diffusion process for a small-volume source in a homogeneous and stationary atmosphere. Results from strict diffusion considerations indicate that the concentration velocity of tritium in air has a practical maximum value of less than 0.4 cm/sec. However, effective concentration velocities depend almost entirely on the air motion in the room and are as much as three orders of magnitude greater than those indicated by diffusion theory. Therefore, to obtain a representative breathing-zone sample, the detector of a monitoring instrument should be placed as close to a worker's face as possible and in a position to take advantage of the air flow in the room.

DOSIMETRY

SCTM-406-59(33) Rarrick, H. L. and G. E. Tucker An Approximation of Radiation Dose Resulting from an Accidental Release of Tritium Gas. (December 1959) Sandia Corporation, Albuquerque, New Mexico

A simple method is developed for calculating the approximate radiation dose for personnel exposed to an accidental release of tritium gas.

AERE - M. 770 Gibson, J. A. B. Detection of Tritium with a Film Dosimeter (Nov. 1960). Health Physics Division, U. K. A. E. A. Research Group, Atomic Energy Research Establishment, Harwell

Exposure, at room temperature and 50% relative humidity, of the A. E. R. E. film dosimeter to tritium as HTO results in a film blackening which is proportional to the exposure dose of tritium and to the storage time after exposure before developing. From measurements of the blackening of the film and a knowledge of the storage time, the dose to the man wearing the film can be determined. Calibration of the films to an accuracy of ± 50% is given over the range 0.1 to 2.5 rem, corresponding to tritium in air activities in the range 150 to 20,000 pc per cm^3.

DOSIMETRY (CONTINUED)

LA - 2163 Lawrence, James N. P. Estimation of Whole Body Dose (REM) From Tritium in Body Water (November 1957) Los Alamos Scientific Laboratory of the University of California, Los Alamos, New Mexico

The most reasonable method of detecting tritium in the body is by urinalysis. A detailed procedure, in use at LASL since 1953, is given for estimating the whole body exposure from a known concentration of tritium in the body water. As presented it is based on 1956 accepted standards of a permissible body burden of 3.7 mc, a 43.4 kg critical organ (total body water), and a 1.7 RBE for tritium in the body.

GENERAL TRITIUM PROBLEMS

LAMS-2602 Engelke, Morris J. Health Problems Associated with the Acceleration of Tritons in a 2.5 Mev Van De Graaff (July 1961) Los Alamos Scientific Laboratory of the University of California, Los Alamos, New Mexico

The purpose of this document is to enumerate some of the health problems associated with the acceleration of tritons in a 2.5 Mev Van De Graaff. In the course of years of operation many procedures in the handling of tritium and tritium-contaminated components have been accumulated. Listing and recording of these experiences may prove of benefit to others. While there are potential dangers associated with tritium acceleration, reasonable precaution will prevent serious personnel exposures.

DP-367 Symonds, Albert E., Jr. Removal of Tritium Contamination from Surfaces of Metals (April 1959) E. I. du Pont de Nemours & Co., Savannah River Laboratory

Heat treatments greatly enhance the removal of tritium contamination from metals that have been exposed to heavy water used as a reactor moderator. Heat treatment for 30 minutes at 300° C has been found effective in removing general contamination. Quench treatments following the heating significantly improve the decontamination process.

The "smear" technique for the detection of tritium on surfaces is much more sensitive and reliable if the paper smear is wet with a compound of low volatility, e.g., oil or glycerol.

USNRDL-TR-505 Vaughan, B. E. and A. K. Davis Some Critical Observations Concerning the Handling of High Levels of Tritium Radioactivity. (April 1961) Naval Radiological Defense Laboratory, San Francisco, California

The data presented demonstrate substantial non-volatile transfer of tritium from contaminated surfaces to skin by direct contact. Since radioactivity on the contaminated surfaces is not necessarily detectable by gas-flow monitoring methods, this route of entry of tritium into body tissue must be considered an unrecognized, potential hazard, where the handling of apparatus exposed to high levels of tritium is concerned. The lability of contact-transferred tritium in skin, its chemical form and location within the skin, and the exact radioactivity content of the contaminated surfaces are peculiar problems remaining to be established by exact methods. The demonstration on non-volatile contact transfer is reported here because of its significance to health safety practice.

AECU-3394 Kingsley, W. H. and F. G. Hirsch Some Health Considerations in the Handling of Tritium (June 1956). Sandia Corporation, Albuquerque, New Mexico

A discussion is presented as to the possible hazards of tritium which may be used as a guide for those personnel who will be coming in contact with the material in small quantities.

DP-329 Butler, Harry L., and Robert W. Van Wyck A Synopsis of Studies Related to Tritium Monitoring and Personnel Protective Techniques. (February 1959). E. I. du Pont de Nemours & Co., Explosive Department, Atomic Energy Division, Technical Division, Savannah River Laboratory

GENERAL TRITIUM PROBLEMS (CONTINUED)

Information obtained from investigations pertinent to tritium monitoring and protective measures at the Savannah River plant are given. These findings were used to establish realistic protective techniques and consequently, to insure the safety of workers exposed to this hazard. Topics included are: Contamination, permeation of plastics and rubber, instrumentation, and biological and physical aspects.

Barker, Robert F. "Tritium Protection." Isotopics pp. 10 - 15 (January 1956)

Some of the practical aspects of tritium hazard control are discussed, as well as physiological significance of exposure and instrumentation. A bibliography of 45 references is given.

PHYSIOLOGICAL ASPECTS OF EXPOSURE

LA-1464 Pinson, Ernest A., The Absorption of Ingested Tritium Water and the Water Dilution Volume of Man (June 1952). Los Alamos Scientific Laboratory of the University of California, Los Alamos, New Mexico

Tritium activity in venous blood of humans increased linearly with time after ingestion of HTO. This increase in activity began 2 to 9 min. following ingestion and reached a maximum in about 40 to 45 minutes. The rate of appearance of tritium in the blood was essentially the same when the HTO was ingested in 100 ml of water or in 1000 ml of water. These studies suggested that water absorption from the gastrointestinal tract began 2 to 9 minutes after ingestion. They also suggested that the volume of water transferred from the gastrointestinal tract to the blood, by absorption or exchange was linear with time after ingestion and was proportional to the volume of water ingested within the range of 100 to 1000 ml. The time required for the complete absorption of 100 to 1000 ml of water from the gut was 40 to 45 min.

After reaching a maximum in about 45 min. the activity in venous blood usually declined slowly until equilibrium was reached at about 2 1/2 hours. From the equilibrium activity measured at 2 1/2 hours it was possible to determine the dilution volume for HTO in the body. The body dilution volume ranged from 57.6 to 67.3 percent of the body weight in five experiments on three men. The average of all determinations was 62.2 percent.

LA-1466 Pinson, Ernest A., Ernest C. Anderson, and Virginia Lotz Absorption of Liquid HTO and HTO Vapor Through the Skin of Man. (June 1952) Los Alamos Scientific Laboratory of the University of California, Los Alamos, New Mexico

When the arm of a man was exposed at 24° C for 15 minutes or longer to an atmosphere saturated with HTO vapor, it was found that an average of 0.019 $mg/cm^2/min$ of the HTO was transferred across the skin into the body. This rate of absorption was comparable to the rate of water loss at 24° C through the skin as insensible perspiration, i.e., the water loss through the skin when sweat glands are inactive. Both processes are concluded to be due to the diffusion of water vapor back and forth through the skin barrier and are dependent on vapor pressure.

The HTO vapor took 2 to 5 minutes to diffuse across what appears to be an inert barrier in the skin before coming in contact with diluting volumes from where it was picked up by the blood stream. The half-time of appearance in the blood ranged from 20 min. to 1 hour, depending on the circulation rate in the skin. The diluting volume between the outer inert layer of the skin and the circulating fluids appeared to be equivalent to a water layer only about 0.064 mm deep.

When the arm was immersed in liquid HTO at 34° C for periods of 5 min. or less, the rate of HTO water transfer across the skin ranged from 0.040 to 0.065 $mg/cm^2/min$. This rate of transfer was higher than could be accounted for by diffusion during the time of exposure due to vapor pressure alone. It was concluded therefore that there is a "blotter effect" in the outer skin layer that returned some of the HTO water per se in the skin after removal from the exposure solution. No significant reduction was made in the amount of HTO subsequently showing up in the general body fluids when the exposed area was rinsed and dried after exposure, or washed for 30 min. or rinsed, dried, and immersed in 100 percent alcohol for 30 minutes.

The absorption rate of HTO through the skin when the arm is immersed in liquid HTO for 10 min. or longer was less than that observed during shorter exposure periods and appeared to decrease with increasing lengths of exposure until the rate of transfer inward through the skin per unit of vapor pressure was comparable to that found during long exposures to HTO in the saturated vapor state.

The rates of transfer of HTO through the skin was compared with the absorption through the lung which has been reported (LA-1465). The comparison indicated that the tritium taken into the body through the total skin surface from an environment containing HTO or T_2O would approximately equal that absorbed via the respiratory tract when the possible but undetermined protective effect of clothing is ignored.

LA-1986 Trujillo, T. T., E. C. Anderson, and W. H. Langham
Biological Effects of Inhalation of High Concentrations of Tritium Gas (December 1955) Los Alamos Scientific Laboratory of the University of California, Los Alamos, New Mexico

The hazard resulting from inhalation of unoxidized tritium (T_2 or HT) in relatively high concentration was investigated. Mice were made to inhale an atmosphere containing 1 per cent tritium gas (20 curies per liter) and the rate of fixation of tritium as HTO in the body fluids was determined.

The animals fixed an LD_{50}^{30} dose of tritium as tritium water (1.5 mc./cc. of body fluids, equivalent to ~800 rep total body exposure) in about 45 minutes, during which time the calculated total dose to the lung surfaces was ~135,000 rep. No histological evidence of acute lung changes from the very high doses of beta radiation was observed. The 30 day survival curve of the mice inhaling 1 per cent tritium gas was compared with that of animals given tritium water (HTO) by intraperitoneal injection. The results showed no significant difference in the LD$^{30}_{50}$ of mice exposed by inhalation of tritium gas and mice that received equivalent amounts of HTO by injection. From these results it was concluded that the additional large beta radiation exposure of the alveolar surfaces resulted in no additional acute stress to the animal. It appears, therefore, that the fixation of tritium as HTO in the body fluids is the limiting factor with regard to acute inhalation exposure to tritium gas.

LA-1218 Pinson, Ernest A., and Ernest C. Anderson The Body Absorption, Distribution, and Excretion of Tritium in Man and Animals. (March 1951) Los Alamos Scientific Laboratory of the University of California, Los Alamos, New Mexico

A study has been made of the body absorption, distribution, and excretion of tritium in man and laboratory animals following exposure to tritium in the form of HT and HTO. Both respiratory and oral routes of exposure were studied. The results indicated that the major portion of tritium inspired as HTO was absorbed in the body. Very little tritium inspired as HT was absorbed. Both rat and man oxidized small amounts of HT to HTO.

From the results obtained it would appear that for man the maximum permissible level of tritium as HTO in inspired air should be $6 \times 10^{-5} \mu c/cc$. based on 0.3 rep/wk and a 40 hr/wk exposure. The maximum permissible level of tritium as HT in inspired air should 0.6 $\mu c/cc$. In the latter case radiation doses to the lungs is the limiting factor. The principal dilution volume of tritium as HTO in the body of both man and animals on short exposure was found to be the total body water. The rate of turnover of tritium from the body fluids following acute exposure was in keeping with the rate of turnover of total body water.

Mice excreted tritium from body fluids with a biological half-time of 1.5 to 2.0 days, rats 3 to 5 days, men 9 to 14 days.

Chronic exposure of mice to HTO over a period of 5 months resulted in tritium which has a biological half-time longer than one week becoming distributed in the body water and in some other undetermined body constituents. The study further showed that tritium concentration as HTO in all the body fluids and fluid excreta of man was essentially the same.

The rate of absorption of HTO through the gastrointestinal tract was linear with time when given amounts were ingested. Tritium excretion as HTO from the body fluids of man and animals was exponential with water turnover. Absorption of HTO through the skin of man was studied by immersion of the hand and forearm in water containing HTO. Absorption through the skin was found to be approximately equal to the rate of water loss by insensible perspiration.

HW-29615 (Report Classified) Thompson, Roy C., and Harry A. Kornberg Hazards of Exposure to Tritium and Tritium Oxide (January 1954) Hanford Works, Richland, Washington

The relative seriousness of exposure to elemental tritium and tritium oxide is discussed. Different modes of body entry are considered, as well as the distribution of tritium in the body and its elimination. Application to practical hazard control procedures is discussed.

LA-1465 Pinson, Ernest A., Ernest C. Anderson, and Virginia Lotz Lung Absorption of HTO by Man Upon Inspiration of HTO Water Vapor. (June 1952) Los Alamos Scientific Laboratory of the University of California, Los Alamos, New Mexico

Five experiments on three human subjects exposed to HTO water vapor in inspired air showed that between 98 and 99 per cent of HTO vapor inspired was absorbed through the respiratory system into the body and that only 1 to 2 per cent of the inspred HTO was expired during the exposure. Thus for radiation exposure purposes when estimating HTO uptake by men exposed to an atmosphere containing HTO vapor, one must assume that essentially all HTO inspired is absorbed into the body.

Twenty-five to 39 minutes was required for the HTO activity in expired air to come down to a level equal to that in the venous blood and urine. This sustained high activity in expired water vapor after exposure was thought to be due to adsorption of HTO on the lining of the upper respiratory tract during exposure where it comes into equilibrium slowly with other body fluids.

After exposure to HTO vapor in inspired air the activity in venous blood rose sharply for a few minutes and then declined exponentially in about 80 min to a level indistinguishable from ultimate equilibrium by the sensitivity of the analytical methods used. The half-time for the exponential decline in activity in venous blood was found to be about 12 min which indicated that 99 per cent of ultimate equilibrium would be reached in about 80 min.

With high rates of urine secretion after exposure to HTO vapor in inspired air the activity in urine showed the same pattern as that observed for venous blood. However, the activity in urine rose higher than that in venous blood and remained measurably higher for about 2 hours after exposure. The exponential decline in activity in urine at high rates of urine secretion had a half-time of about 20 to 22 min which indicated that about 2 1/2 hrs was required to reach 99 per cent of equilibrium. At slow rates of urine secretion the rise in activity with time following exposure was slow, and the maximal activity was recorded 25 to 40 min after exposure. After reaching this maximum, the activity declined slowly to equilibrium.

AECD-4207 DeLong, C. W. Percutaneous Absorption of Tritium Oxide. (July 1951) Hanford Works, Richland, Washington

Data are presented on the absorption of tritium oxide vapor through human skin. Under the experimental conditions used, the average rate constant was found to be 0.28 ± 0.08 μc/cm^2 skin/min per μc/cc of atmosphere for the forearm exposures, but some of the data suggested a higher rate constant for other portions of the body surface. The effects of various parameters on percutaneous absorption are discussed and the relationship of the data to estimation of maximum permissible limits is mentioned briefly.

DeLong, Chester W., Roy C. Thompson, and Harry A. Kornberg "Permeability of Excised Mouse, Rat, and Human Skin to Gaseous Tritium", Radiation Research, Vol. 1, 214 - 217 (1954)

The percutaneous absorption of tritium gas was studied using excised skin from mice, rats, and man. In terms of μc tritium absorbed/cm^2/min/μc tritium/cm^3 atmospheres, absorption rates found were, for mice $(254 \pm 44) \times 10^{-6}$; for rats $(207 \pm 26) \times 10^{-6}$; and for man, $(72 \pm 16) \times 10^{-6}$.

Although there is considerable uncertainty as to the applicability of these figures to intact animals, the relative permeability of human, rat, and mouse skins should be useful in the extrapolation of animal data to humans.

Pinson, Ernest A., and Wright H. Langham. "Physiology and Toxicology of Tritium in Man", Journal of Applied Physiology, Vol. 10, No. 1, 108 - 126 (January 1957)

Using tritium water as a tracer in man, water absorption through the gastrointestinal tract began in 2-9 minutes and was complete in 40-45 minutes. The volume of water transferred from the intestine to the blood was linear with time and proportional to the volume of water ingested, within the range of 100-1000 ml. When exposed to HTO vapor via inhalation, man absorbed through the respiratory system 98-99% of the activity inspired. The activity in venous blood increased sharply during and shortly after inhalation exposure, after which it declined exponentially to equilibrium with a half-time of about 12 minutes. The average dilution volume in five experiments on three normal males was 62.2% and the biological half-time of tritium in body water of eight males on ad libitum water intake averaged 11.5 days. At equal vapor pressures man absorbed HTO inward through the skin at a rate comparable to the rate of insensible perspiration. HTO appeared to diffuse across the inert barrier of the outer skin with a half-time of about 3 minutes. When man was exposed to an atmosphere containing HTO, the HTO entering the body through the total skin area was approximately equal to that entering through the lungs. Both man and rat slowly oxidized inspired HT to HTO. The radiation hazard from exchange of tritium with hydrogen of the tissues after chronic or acute exposure to HTO was small compared to the hazard from the amount of HTO necessary to induce the activity into tissue components. On the basis of human data, the maximum permissible body burden of tritium was calculated to be 3.7 mc, and the maximum permissible concentrations of tritium oxide in air and water for continuous 24-hour exposure was estimated at 5×10^{-8} µc/ml and 0.1 µc/ml, respectively.

Adoption of the 1956 recommendations of the International Commission on Radiological Protection will result in the division of the above values by three.

LA-1468 Pinson, Ernest A., Ernest C. Anderson, and Virginia Lotz The Specific Activity of Tritium in the Organic Components of the Skin and Fat of Man Following Eight Months Chronic Exposure to HTO in Body Fluids. (October 1952). Los Alamos Scientific Laboratory of the University of California, Los Alamos, New Mexico

A healthy 39-year-old male weighing 65 kg was exposed for a period of 8 months to varying levels of HTO. The average tritium activity in body fluids over the entire period was 23 μc/liter. A few weeks after exposure, when the HTO activity in body fluids had declined to about 0.2 μc/liter, a biopsy was performed on skin and fat taken from the region of the lower abdomen and the material was analyzed for tritium activity. The skin showed an average activity equivalent to 0.4 μc/kg of dry tissue and the fat about 0.3 μc/kg of dry tissue. The radiation dose per unit time from these activities was only 1 to 2 per cent of the radiation dose per unit time during the 8 month exposure period. It was concluded that the radiation hazard due to retention of tritium in the organic components of these tissues of man after chronic exposure was negligible compared to the radiation hazard from HTO activity in the body fluids which was necessary to induce the activity into the organic components. Comparable experiments on mice previously reported indicate that this conclusion may hold for all tissues in the body.

The water content of the skin and fat of man was found to be 71 per cent and 20 per cent, respectively, on the basis of the wet weight. The hydrogen content of skin was 7.6 per cent, and of fat 11.4 per cent, of the dry weight of the tissue.

LA-1469 Pinson, Ernest A., Ernest C. Anderson, and Virginia Lotz Theoretical Considerations of Acute Exposure of Man to HTO or T_2O Activity in the Atmospheric Environment.

(October 1952) Los Alamos Scientific Laboratory of the University of California, Los Alamos, New Mexico

The quantity of tritium taken into the body of man on exposure to an atmosphere containing HTO or T_2O vapor is proportional to the length of exposure and the activity of HTO or T_2O per unit volume in the atmosphere. The theoretical quantity of HTO or T_2O required to produce lethality can be introduced into the body of man in a few seconds of exposure or in the time required to take one breath if the atmosphere is saturated with T_2O vapor. It is indicated that personnel working with T_2O should be extremely cautious with procedures which might possibly lead to exposure to tritium water vapor.

LA-1646 Anderson, E. C., and Wright Langham <u>A Theoretical Consideration of the Hazards Associated with Acute Exposure to High Concentrations of Tritium Gas</u> (February 1954) Los Alamos Scientific Laboratory of the University of California, Los Alamos, New Mexico

PHYSIOLOGICAL ASPECTS OF EXPOSURE (CONTINUED)

Theoretical consideration of the hazards associated with acute exposure to high concentrations of T_2 gas indicates that a lethal radiation dose would result only from explosive oxidation of very rich T_2-air mixtures. If the gas remained as T_2, the dose rate to a 1 μ layer of the respiratory surfaces would be very high (thousands of rep/sec) but the effect of doses of this magnitude on a very thin layer of these surfaces is completely unknown. Other hazards considered are whole body radiation from dissolved T_2 in body fluids, biological oxidation of T_2 and subsequent absorption of the tritium water produced, auto-oxidation of the T_2 by the tritium beta rays and absorption of the tritium water, and Bremsstrahlung radiation of tissue surfaces. The orders of magnitude of these hazards are a few tenths rep/sec of exposure.