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The New
LASL

MASTER

Film

Badge

and

Personnel

Neutron

Dosimetry

Packet

LOS ALAMOS SCIENTIFIC LABORATORY of the
University of California, Los Alamos, New Mexico

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LOS ALAMOS SCIENTIFIC LABORATORY of the University of California LOS ALAMOS • NEW MEXICO

The New LASL Film Badge and Personnel Neutron Dosimetry Packet

by
Group H-1
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Over the years the Los Alamos Scientific Laboratory's Health Physics Group H-1 has had numerous inquiries about the proper use of film badges. These questions often come from persons who do not use the LASL film badge. The major users of the LASL film badge are the employees of LASL, The Zia Company, and the Los Alamos Area Office of the U.S. Atomic Energy Commission. If you are curious about the use and abuse of film badges for personnel radiation monitoring, or are a user of the LASL film badge, this bulletin is directed to you.

This pamphlet is being circulated at this time because of changes currently taking place in the LASL personnel dosimetry program. During 1968 the brass film badge, which has been in use since 1951, will be replaced by an improved film badge. At the same time, the red plastic-encased indium foil, which has been in use since 1959 for detecting exposure to a nuclear criticality accident, will be replaced by the new personnel neutron dosimetry (PND) packet.

Before discussing the new film badge and PND packet, it is desirable to acquaint the reader with some of the nomenclature used in personnel radiation dosimetry, the radiation protection standards, and methods of reducing radiation exposure. All recipients are encouraged to read these introductory sections. For completeness, technical details of the new LASL film badge are also presented. All users of the LASL film badge are especially requested to read the sections on FILM IDENTIFICATION, WHO SHOULD WEAR FILM BADGES, and FILM BADGE DOs AND DON'Ts.

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I. RADIATION EXPOSURE AND DETECTION

EXPOSURE TO RADIATION

The three basic ways to minimize occupational radiation exposure external to the body are: (1) to provide radiation shielding, (2) to increase the distance between the person exposed and the source, and (3) to limit the duration of the exposure. Insofar as possible, all work with radiation at LASL is preplanned, using shielding, distance, and time limitations to keep personnel exposure well below the permissible levels. Larger exposures occur as a result of accidents, unforeseen conditions, and negligent or careless disregard for established safeguards. To ensure adequate radiation protection and to detect unanticipated circumstances, film badges are issued to persons who work with various sources of radiation and to other persons who may visit or pass through areas where radiation is present.

RADIATION EXPOSURE UNITS

The quantity of ionizing radiation incident upon or absorbed by human tissue has been expressed in terms of erythema dose, Roentgen, n-unit, rep, neutron/cm², erg/g, rad, and rem. Several of these units are only of historical significance; others are interrelated by proportionality factors which depend upon the type and energy of radiation and upon the biological responses of the exposed organs. Only two of the units are used in radiation exposure records of the LASL H-1 Photodosimetry Section, the *rad* and the *rem*.

The *rad* is defined as the unit of absorbed dose and is equal to the absorbed dose of 100 erg/g in any material (usually human tissue).

The *rem* is the unit of dose equivalent, which is numerically equal to the dose in *rads* multiplied by a biological response (quality) factor.

In the records of the LASL H-1 Photodosimetry Section, the unit "rem" is used for penetrating or whole-body radiations, such as x and gamma rays, fast and thermal neutrons, and tritium internal-whole-body irradiations. The "total-rem" dose is the sum of the rem doses for all of these radiations. To distinguish external beta radiation, which exposes primarily the skin (because of its low penetrability), the unit "rad" is used. For the external beta radiation encountered at LASL, the quality factor is unity, so that numerically the beta-rad can be added to the total-rem (if the need arises to determine the total skin dose).

SOME BIOLOGICAL EFFECTS OF RADIATION

The harmful effects of large, relatively acute doses of radiation are well known. These effects depend upon several factors including the fraction and part of the body exposed, the penetrability of the radiation, the radiation dosage, and the length of time of the exposure. For instance, a 1,000-rad beta exposure (low penetrability) to the skin of the hand in less than one hour will usually result in only an erythema, which is similar to a mild sunburn. By contrast, a 250-rem exposure of penetrating gamma radiation over the entire body in less than an hour will probably result in an incapacitating form of radiation sickness and

possibly in death. The same 250-rem whole-body exposure delivered uniformly over a period of 50 years will cause *no observable* symptoms or damage to the person so exposed; the body continually replaces nearly all of the radiation-damaged cells and the physical manifestations of damage do not appear.

RADIATION PROTECTION STANDARDS

Using the wealth of information based on human experience and animal experiments, the International Commission of Radiological Protection (ICRP), the National Council on Radiation Protection and Measurements (NCRP), and the Federal Radiation Council (FRC) have recommended permissible levels of radiation exposure for the public and for persons who are occupationally exposed. Many of these recommendations have been adopted by the U.S. Atomic Energy Commission for use by its prime contractors and licensees. For employees of LASL, The Zia Company, and the AEC's Los Alamos Area Office, these radiation protection standards are given in AEC Manual Chapter 0524 (effective August 12, 1963) which supersedes all previous radiation exposure controls used at Los Alamos. Only exposure resulting from industrial or commercial uses of radiation is covered by these standards; i.e., no control is placed on naturally occurring background or medical exposures.

The following standards are currently in effect:

1. The accumulated whole-body (head and trunk, active blood-forming organs, gonads, or lens

of eye) exposure for an adult of age N should be no greater than $5(N-18)$ rem, and no more than 3 rem should be received during any calendar quarter (a predetermined period of 13 consecutive weeks).

2. To the skin of the whole body (and the thyroid gland), the permissible annual rate is 30 rem (rad), with the limit of 10 rem (rad) per calendar quarter.

3. To the hands and forearms and/or feet and ankles, the permissible annual rate is 75 rem, with the limit of 25 rem per calendar quarter.

It should be noted that AEC Manual Chapter 0524 specifies no weekly or monthly control levels.

Insofar as the $5(N-18)$ formula permits, an occupationally exposed person may accumulate a radiation dose at a rate not in excess of 3 rem per quarter. Thus, within the latitude of the AEC radiation protection standards, a person may be allowed a total occupational exposure of 12 rem in one year. To take advantage of this flexibility, the occupational exposure of the affected individual must be documented. The past and present LASL policy is to restrict the whole-body exposure of its employees to 5 rem per year because of the ease with which this policy can be administered. Exceptions to this policy have been and will be permitted if all three of the following conditions are met: (1) only when the accumulated exposure after the age of 18 is documented, (2) when previous exposure has not resulted from careless or injudicious actions, and (3) when, in unique and unusual instances, and after due consideration has

been given, strict adherence to the 5 rem/year limit would seriously impair the functions of LASL.

BACKGROUND RADIATION

The aim of all radiation protection organizations is to keep personnel exposure as low as practicable; i.e., well below the prescribed AEC limits. Because of cosmic radiation, radiation from naturally occurring radioisotopes in the earth's crust and atmosphere and contained within the human body, and radiation from fallout from atmospheric nuclear tests, it is impossible to eliminate all radiation exposure. At Los Alamos, these background radiations result in an exposure of about 0.2 rem/year (0.017 rem/month). At sea level the background is approximately 0.1 rem/year. The higher background radiation at Los Alamos is due to increased cosmic radiation at 7,300 feet elevation and a larger quantity of naturally occurring radioisotopes in the surrounding terrain than at most sea-level locations.

PERSONNEL RADIATION DOSIMETRY

Film Badges. Of the several personnel dosimeters in use today, film badges are the best understood and most responsive to the largest number of different types and energies of radiation. A film badge is a small, flat box-like object containing one or more photographic films (similar to dental x-ray film packets), an assortment of radiation absorbers (filters), and a means of identifying and dating film. After a possible radiation exposure, the films are removed from the badges and developed according to a carefully controlled

procedure. The amount of photographic darkening of the film (response) under the various absorbers is used to measure the exposure to several types and intensities of radiation. Thus, the developed film provides a permanent record of the radiation exposure received by the person wearing the film badge.

Who Should Wear Film Badges. The requirement for providing film badge service to LASL-associated personnel is stated in AEC Manual Chapter 0524: "Personnel monitoring equipment shall be provided each individual who receives or is likely to receive a dose in any calendar quarter in excess of 10% of the quarterly limit." Based on the radiation exposure at LASL over the past five years, strict adherence to this regulation would require less than 100 persons per month to wear film badges. However, because the persons receiving the exposures change from month to month, it would be impossible to assign the film badges to the "proper" 100 people.

LASL Group H-1 encourages the wearing of film badges, not only to ensure that the "proper" persons are covered, but also to provide a method for detecting unexpected or unnecessary sources of radiation exposure before a serious breach of AEC regulations occurs. To accomplish these objectives, the following guide is used by Group H-1 to establish who should wear film badges:

Film badges should be worn by all persons who:

1. Work on or in the vicinity of nuclear reactors (including critical assemblies), high-energy par-

ticle accelerators (including cyclotrons, Cockroft-Waltons, Van de Graaffs, and LAMPF devices) and other x-ray generating facilities (including x-ray machines, high voltage rectifiers, PHERMEX devices, betatrons, and Sherwood devices).

2. Work with or in the vicinity of radioactive material or sources.

3. Visit the areas covered by items 1 and 2 at a frequency of 6 or more times a year.

4. May be called upon to participate in emergency procedures in areas covered by items 1 and 2.

The radioactive materials mentioned in item 2 include all forms of plutonium on which chemistry or machining is done and all quantities of over 30 grams of depleted, natural, or enriched uranium, and over 10 grams of natural thorium, and fission-product samples. In determining who should wear a film badge a "radioactive source" is considered to be any laboratory-associated radioactive material which has a closed-shield (no beta) reading of more than 0.001 rem (rad or R)/hr, or an open-shield reading of more than 0.005 rem (rad or R)/hr with a portable detection instrument held in contact with the source of radioactivity. This definition includes sealed neutron or gamma sources, and spots of contamination of a gamma-and/or beta-active material.

Certain personnel from the following organizations are encompassed by items 1 and 2: CMF, CMB, J, H, P, MP, K, N, GMX, and W Divisions, the SS Accountability Group, and the Shop Department of LASL, and certain personnel of The

Zia Company. Item 3 includes some personnel from the Mail and Records Group, D Division, and the Engineering, Supply and Property, and Accounting Departments of LASL; The Mountain States Telephone and Telegraph Company; and certain AEC employees (particularly protective force personnel). Item 4 includes primarily AEC firemen and some Los Alamos Medical Center personnel.

It is not intended to limit film badge coverage to those persons covered by the four items above. Anyone associated with LASL activities who desires a regularly issued film badge may obtain the routine service by a telephone request to the H-1 Photodosimetry Section (7-4127). All persons receiving the LASL film badge service will be asked to supply the following information for record purposes: full legal name, Z-number (if any), birth date, and social security number.

II. THE NEW LASL FILM BADGE

The new LASL film badge is used to measure exposure to soft x rays or beta rays, gamma rays, and thermal and fast neutrons. The badge (illustrated on the cover and in Fig. 1 on the center fold) consists of a two-piece Cylolac plastic case, multielement filters, film packets, and identification plates. Each person receiving the routine monthly film badge service will be assigned a blue and a gray badge on alternate months. By issuing blue film badges for the odd numbered months and gray badges for the even numbered months, a quick visual indication is provided to determine when film badges are to be returned for processing.

The construction of both the blue and gray film badges is identical. Internally, in addition to two film packets, each badge contains a set of multielement filters, two lead identification strips, and a high-range glass dosimeter imbedded in modeling clay. The front of the badge is embossed with "Los Alamos Scientific Laboratory." On the back are tape labels containing the wearer's name, an identification number, and distribution information. The badges are kept closed by a captive Phillips screw. The standard method of attachment to the wearer is by means of a nickel-plated alligator clip, although other arrangements can be made with the H-1 Photodosimetry Section.

FILM PACKETS

The two film packets used with the LASL film badge are the DuPont Type 545 Dosimeter Film pack and the Kodak Personal Neutron Monitoring Film Type B pack. The DuPont pack contains a single gamma-sensitive film of type 555 emulsion in a light-tight wrapping. This film is used to measure the monthly exposures to x rays or beta, gamma, and thermal neutron radiation. The useful range depends upon the type and energy of the radiation. For hard gamma radiation (above 200 keV), the range is from about 0.03 to 10 rem; i.e., from twice one month's background exposure to twice the annual limit. The Kodak film packet contains a gamma-insensitive film, a nuclear track film, and two thin aluminum absorbers in a light-tight wrapping. The gamma-insensitive film (Kodak's Fine Grain Positive) has a useful range from about 10 to 1,000 rem. The nuclear track film (Kodak's NTA) is used in conjunction with aluminum absorbers to measure fast

neutron exposures from about 0.03 to 10 rem.

MULTIELEMENT FILTERS

The response of a bare film packet, such as the Dupont Type 545 packet, is independent of the energy of x- or gamma radiation above 200 keV (referred to as hard gamma). That is, the photographic densities (after development) of two films, one exposed to 1 rem of 300-keV x rays and the other to 1 rem of 1.33 MeV gamma rays, are the same. Below 200 keV, a 1-rem exposure will cause a greater photographic density by as much as a factor of 20, depending on the energy of the radiation. This overresponse can be corrected by a suitable choice of radiation absorbers. The multielement filters in the LASL film badge were designed to give a uniform film response within $\pm 30\%$ to any mixture of x- or gamma radiation from 40 keV to 1.33 MeV. This increased uniformity of response represents a significant improvement over the old brass film badge, since much of the x- or gamma radiation exposure at Los Alamos is in the energy range of 40 to 200 keV.

The multielement filters are so named because they contain copper, molybdenum, gadolinium, erbium, tantalum, lead, and gold. There are two types of these filters in each LASL film badge. Both types exhibit the same uniform energy response characteristics. One filter contains gadolinium, which has a large capture cross section for thermal (very low energy) neutrons. When thermal neutrons are captured by the gadolinium, gamma rays are emitted that expose the adjacent film. The other filter has a molybdenum foil with

a very small thermal-neutron capture cross section, which provides x- or gamma ray absorption equivalent to the gadolinium filter. By measuring the density difference of the film under the two types of filters, the thermal neutron exposure may be determined. Technical details concerning the design of the new LASL film badge are given in LA-3001.*

The thermal-neutron-sensitive filter consists of a copper cup in which is cemented a pressed-powder disk that contains gadolinium, erbium, tantalum, lead, and gold. This filter, marked "G", is located at the end of the film badge (Fig. 1). The other filter has a molybdenum foil cemented in a copper cup, and a pressed-powder disk (containing erbium, tantalum, lead, and gold) is cemented to the molybdenum foil. This filter, marked "M", occupies the center position in the film badge (Fig. 1). Pairs of each type of filter are arranged on opposite sides of the film (when the badges are closed) to reduce the front-to-back response variation of the film badge. It should be emphasized that the pressed-powder disks are fragile and subject to breakage upon impact. Although small hairline cracks in these disks will not greatly affect the response of the film badge, large cracks or shattering can cause significant errors in the measurement of the exposure.

*Ellery Storm and Simon Shlaer, "The Development of Film Badges Containing Multi-element Filters to Reduce the X-Ray Energy Dependence of Photographic Film," Los Alamos Scientific Laboratory report LA-3001, July 1961.

KODAK
NTA FILM
PACK

STEP #1 Place Kodak film packet into badge against identification plates, pebbled side up, as shown above.

STEP #2 Place DuPont film packet on top of Kodak packet, green tab up and to the right.

STEP #3 Close badge and tighten captive screw.

DuPONT
545 FILM
PACK

Figure 1. LOADING INSTRUCTIONS FOR NEW LASL FILM BADGE

OPEN WINDOW OF THE FILM BADGE

The new LASL film badge has an open window on the front side of the badge. This was necessary to meet the design criteria that the badge be of minimum size and weight, and that approximately the same film densities appear in the open-window area whether the badge is exposed from the front or the rear (uniform front-to-back response). To meet the first requirement, the two film packets were stacked, rather than being placed side by side. Because of the stacked-film arrangement, the second criterion dictated the nonsymmetrical appearance (single open window) of the film badge. Approximately uniform front-to-back response for beta radiation is achieved by placing the Kodak film packet directly under the open window and by putting the DuPont film packet between the Kodak packet and the back of the badge. The thickness of the back of the badge opposite the open window is such that it gives almost the same beta absorption as the Kodak packet. A correction for this beta absorption is applied during the exposure evaluation.

To better define the lightly filtered area under the open window, the outline of the copper ring (Fig. 1) is registered on the exposed film. The copper rings also provide improved directional response to low-energy x rays.

In the absence of beta radiation, the open-window area of the film is used to determine the exposure from x rays of energy less than 40 keV. Because the film response to x rays below 40 keV is strongly dependent upon the energy spectrum, special calibrations are used for certain sources

encountered at LASL.

Because the appearance of the developed film is not definitive in determining whether an exposure is due to beta rays or to low-energy x rays, it is desirable to determine (at the time of original issue of a film badge) the most probable type of exposure anticipated. Usually this decision is made by the H-1 Photodosimetry Section from knowledge of the LASL group with which the person intends to work. If you have any reason to believe that your film badge is not being properly evaluated, call the H-1 Photodosimetry Section Leader (7-4127).

FAST NEUTRON EVALUATION

X-ray, gamma, beta, and thermal-neutron exposures are determined from the density of the developed film. Fast neutrons (with energy greater than 1 MeV) do not directly react with film emulsions because they lack electric charge. However, fast neutrons are scattered to an appreciable extent by hydrogen atoms, and in this scattering process they can impart a significant fraction of their kinetic energy to hydrogen nuclei (protons). When these energetic protons pass through NTA film emulsion, each of them produces ionization along its path. After the film is developed, these proton recoil tracks can be seen as a row of silver grains and can be counted with the aid of a high-power microscope. The number of proton recoil tracks per unit area is directly proportional to the fast neutron dose.

The process of counting proton recoil tracks in the developed NTA film through a microscope

is a time-consuming job, requiring a minimum of six minutes per film. This can be compared with a half minute for determining the density in the three filter areas of the DuPont film. Neither personnel nor facilities permit the H-1 Photodosimetry Section to analyze all the NTA films which are issued; however, all issued NTA films are developed and stored. In many laboratory areas a detectable number of fast neutrons does not exist, and the NTA films worn in these areas are not evaluated. In general, only those NTA films worn by persons suspected of having received significant fast neutron exposure are evaluated; these are approximately 10% of all the NTA films issued.

FILM IDENTIFICATION

Two perforated lead strips are incorporated in each badge on both sides of the multielement filters, as shown in Fig. 1. One strip bears the wearer's name and identification number; the other, a binary code of the identification number. Prior to being unloaded and developed, each film badge is x-rayed through the area of the identification plates. (The filter areas are completely shielded from these x rays and record only the radiation exposure during the period of issue.) Upon photographic development the images of the identification information appear on the film, providing a permanent record of the wearer's identification.

Each developed DuPont film is placed in the H-1 automatic densitometer. The binary coded identification number is electro-optically decoded, and the number is punched on an IBM card along with values representing the film densities under

the three filter areas. Misinterpretation of the identification number can result from multiple images of the binary coded number. Since occupational exposures also expose the film in the identification area, it is imperative that the position of the films within the badge not be altered.

The new film badge will be a novelty, and some users will insist upon examining it more closely. To ensure that the films will be reloaded properly, the following instructions are supplied:

1. Use a small Phillips screwdriver to loosen the captive screw. Care should be taken to avoid removing the screw past its captive position (to prevent losing the screw).
2. Counterrotate the two badge halves.
3. The film may be removed by gentle prying.
4. Further disassembly of the badge should not be attempted. If you wish to inspect any of the other badge components, please see the H-1 Photodosimetry Section Leader, Administration Building (SM-43), Room A-122A.
5. Figure 1 illustrates the correct procedure for reloading the film badge. It should be followed carefully to ensure the proper orientation of the films.

III. TABULATION OF FILM BADGE EXPOSURES

Film badges are routinely evaluated after a one-month issue period. The developed films are

stored in compliance with current AEC regulations. A record of the measured exposures (including "zero" exposures) is maintained in the H-1 Photodosimetry Section.

LASL Group H-1 is charged with overseeing the radiation protection of LASL employees. In fulfilling this obligation, members of Group H-1 review monthly the measured exposures of LASL employees and other persons who use the LASL film badge service.

A summary tabulation of film badge results is prepared monthly. Group H-1 uses this tabulation to determine where additional radiation controls may be needed. Quarterly tabulations are submitted to the various group and division offices of LASL, The Zia Company, and the Los Alamos Area Office of the AEC. Reports are not routinely made to individual users of the film badge service because it is assumed that quarterly reports are further distributed to all interested persons. Anyone who desires to know his own radiation exposure may call the H-1 Photodosimetry Section (7-4127) for this information. If a written statement of the exposure is desired, a written request to the H-1 Group Office is required.

IV. FILM BADGE DOs AND DON'Ts

The basic purpose of the film badge is to measure the radiation exposure received by the person who wears the film badge. To prevent errors in this measurement, the film badge should be used in the proper manner. Group H-1 recommends the following *dos* and *don'ts*:

1. DO WEAR YOUR FILM BADGE VISIBLY EXPOSED, WITH THE FRONT SIDE OUT, ON THE FRONT OF YOUR PERSON BETWEEN THE WAIST AND NECK.

The film badge should be worn this way so that health physics personnel in the various radiation areas will not be obliged to bother you with a request to see the badge. "Front side out" is requested because the film badge is calibrated in this orientation, and small (but avoidable) errors will result in the interpretation of exposure if the film badge is reversed. The request implies that the film badge be worn on outer clothing unshielded by pens, pencils, metal rulers, and security badges.

2. DO WEAR YOUR REGULAR-ISSUE FILM BADGE AT ALL LASL SITES IN LOS ALAMOS COUNTY DURING ALL WORKING HOURS.

The interpretation of film densities depends upon the types of radiations encountered and, sometimes, upon the laboratory area in which the film badge was worn. However, in the case of significant exposures that differ from the usual pattern, an investigation is made to ascertain that the film badge is properly interpreted for the type of radiation received. Therefore, if you are regularly issued a film badge, avoid the use of visitor badges at sites where you do not normally work.

3. DO PROTECT YOUR FILM BADGE FROM TEMPERATURES ABOVE 100° F, WETTING, CHEMICAL VAPORS, TRITIUM GAS, EXCESSIVE PRESSURE, AND ANY OTHER FORM OF PHYSICAL ABUSE.

Undeveloped photographic film is sensitive to many effects. Prolonged exposure of film to temperatures above 100° F sensitizes the emulsion and causes an increased density upon photographic development. Serious loss of film badge data has occurred repeatedly when persons leave their film badges in closed vehicles. If you are issued a film badge, keep it with you during all working hours, and do *not* leave it in your automobile or truck even during nonworking hours.

The effects of allowing the film badge to become wet are twofold: (a) water will soften and tend to decompose the multielement filters and (b) water dampens the light-tight film wrapping, which sticks to the film after it dries and prevents proper development. If the badge is accidentally dropped in water, immediately remove it from the water, open the badge, wipe dry the film packets and badge, and reload them according to the instructions in Fig. 1. Then call the H-1 Photodosimetry Section (7-4127) for a replacement badge and send in the once-wet film badge for early processing.

Highly concentrated vapors from nitric acid, acetic acid, Formalin, hydrogen peroxide, mercury, ammonia, and hydrogen sulfide adversely affect films. Therefore, try to prevent your film badge from being exposed to these and other chemical vapors which could affect the film. The film badge should also be prevented from being immersed in these materials.

Tritium gas (the radioactive isotope of hydrogen) will diffuse through the paper wrapper of the film packet and cause photographic fogging

of the film. This fogging renders the film useless for recording external radiation exposure. If you work in an area where tritium gas is present (and wear a film badge), inform the H-1 Photodosimetry Section (7-4127) of this fact. Thereafter, your film badge will be sealed in a plastic envelope, which will appreciably reduce the diffusion of tritium gas.

Pressure on a film can cause the film to become desensitized, resulting in a false interpretation of the developed film. Writing on the film packets with a pencil or ball-point pen can cause such damage.

The following abuses of film badges have been experienced and should be avoided: allowing the film badge to be used as a teething ring for babies, using the film badge as an object to pry or hammer with, sending the film badge through your home laundry or the commercial contaminated laundry, using the film badge for pistol and rifle targets, and for exercising heavy-duty staplers.

4. DO PROMPTLY RETURN YOUR OLD FILM BADGE FOR PROCESSING UPON THE ISSUE OF YOUR REPLACEMENT FILM BADGE NEAR THE END OF EACH MONTH.

An effort is made to prepare a tabulation of the previous month's film badge exposures by the 15th of each month. In a three-week period (last week of previous month and first two weeks of current month) all 3,000 film badges must be exchanged, the returned films developed, the density read, the nuclear tracks counted, the exposures

calculated, and tabulations of the results prepared. Three weeks is ample time to accomplish this job only if all film badges are returned promptly.

5. DO REQUEST AN IMMEDIATE REPLACEMENT BY CALLING THE H-1 PHOTODOSIMETRY SECTION (7-4127) IF YOU LOSE YOUR FILM BADGE.

All persons who lose their film badges are required to fill out a short questionnaire.

6. DO REQUEST AN IMMEDIATE BADGE REPLACEMENT BY CALLING THE H-1 PHOTODOSIMETRY SECTION (7-4127) IF YOUR FILM BADGE IS ACCIDENTLY EXPOSED TO RADIATION WHILE NOT ON YOUR PERSON.

Accidental exposures of your film badge while you were not wearing it should be reported immediately to H-1 to ensure that the recorded exposure will not be charged to your record. Unless such immediate notice is supplied to Group H-1, all exposures recorded by a film badge will be assumed to have been received by the person to whom the film badge was issued and will be added to that person's radiation exposure record.

7. DO WEAR GLASS SAFETY GLASSES WHEN WORKING WITH BETA EMITTERS AND SOFT X RAYS (LESS THAN 50 KILOVOLTS PEAK POTENTIAL) TO REDUCE THE EXPOSURE TO YOUR EYES AND TO FACILITATE THE ADMINISTRATION OF THE CONTROL OF RADIATION EXPOSURE.

If the lenses of the eyes are shielded, the exposure recorded by the film badge as low energy x-ray or beta exposure can be assumed to expose

only the skin of the body because these radiations do not penetrate the body to the blood-forming organs or gonads. Thus, the allowable limit per calendar quarter would be 10 rem for beta or soft x rays if the eyes are protected by glass safety glasses (glass is specified because it is more effective than plastic in absorbing beta rays and soft x rays). Without glass safety glasses, the permissible level is 3 rem per quarter.

8. DO REQUEST ANY ORGANIZATION OTHER THAN LASL (SUCH AS NTS, NRDS, SANDIA, ORNL, OR LRL) THAT ISSUES YOU A FILM BADGE TO SUBMIT A REPORT OF THE EXPOSURE TO: LASL GROUP H-1, P.O. BOX 1663, LOS ALAMOS, N. M., 87544.

To ensure that the exposure records at LASL are complete and up-to-date, the exposures received at other installations must be included. Some organizations (such as NTS and NRDS) submit the exposure reports to LASL without being requested, but others do not.

9. DON'T USE YOUR REGULARLY ISSUED FILM BADGE FOR EXPERIMENTAL PURPOSES.

Whenever you wish to know the radiation output from a device or source, ask your nearest H-1 health physics surveyor, or call the H-1 Group Office (7-5296). If you disbelieve the measurement made for you, do *not* use your regularly issued film badge to determine the exposure. If you would like to make an independent determination with a film badge, call the H-1 Photodosimetry Section (7-4127) and request an experimental film badge. Similarly, do *not* use

your regularly issued film badge to determine the x-ray output of a color television set; instead, request an experimental badge.

10. **DON'T STORE YOUR FILM BADGE (DURING NONWORKING HOURS) NEAR RADIOACTIVE MATERIAL, SUCH AS DEPLETED OR ENRICHED URANIUM, LUMINOUS WATCH AND CLOCK DIALS, CERTAIN COLORED POTTERIES WHICH CONTAIN URANIUM, AND PORTABLE MONITORING INSTRUMENT CHECK-SOURCES.**

Several times a year someone carelessly stores his film badge near such radioactive materials, and frequently an extensive investigation is required to determine how the large exposure was received. Make certain that your film badge is stored during nonworking hours in an area relatively free of radiation. If you do not know whether your proposed storage place is free of radiation, contact your local H-1 health physics surveyor, or call the H-1 Group Office (7-5296).

11. **DON'T ATTEMPT ANY REPAIRS ON YOUR FILM BADGE.**

Most attempted repairs of film badges result in mutilation of the film badge and/or destruction of the film. The H-1 Photodosimetry Section has the proper tools and know-how to repair the film badges, and all damaged film badges should be called to their attention.

12. **DON'T WEAR YOUR REGULARLY ISSUED FILM BADGE DURING MEDICAL OR DENTAL X-RAY PROCEDURES.**

If you want to measure the exposure you receive during a dental or medical x-ray procedure, request an experimental film badge for this purpose.

13. **DON'T LEAVE YOUR FILM BADGE AT HOME OR IN YOUR OFFICE WHEN YOU VISIT RADIATION AREAS AND EXPECT TO OBTAIN A VISITOR BADGE AT SUCH AREAS.**

Experience has shown that visitor film badges usually do not receive sufficient exposure to exceed the lower limit of detection, partly because the film badge does not reliably detect or measure exposure of less than 0.03 rem for hard gamma radiation. Thus, a person could receive 0.02 rem at two different locations on two different film badges, and have an erroneously recorded exposure of 0.00 rem. Had that person worn his regularly issued film badge on both occasions, the correct exposure of 0.04 rem would have been recorded.

14. **DON'T TAKE YOUR LASL FILM BADGE WITH YOU ON TRIPS TO OTHER INSTALLATIONS (ESPECIALLY NTS AND NRDS).**

Non-LASL installations, at which radiation exposure is probable, will issue you one of their film badges. If you also wear your LASL film badge, double your actual exposure will be recorded when the report from the other installation has been received. In general, each installation is better equipped to measure the radiation exposures received at their location than is LASL Group H-1.

V. THE PERSONNEL NEUTRON DOSIMETRY (PND) PACKET

The PND packet was designed to comply with the requirement for personnel neutron dosimetry as stipulated in the April 20, 1966, AEC Manual Chapter 0545 on the nuclear accident dosimetry program. The packet, as illustrated on the cover, consists of a bare indium foil, a cadmium-covered indium foil, a cadmium-covered copper foil, and a sulfur pellet, all encased in a clear plastic wafer. When these packets are exposed to a spectrum of neutrons, several activities are induced in the foils. Upon counting the foils and pellet, the rad dose of the neutron exposure may be estimated in several neutron-energy bands.

Initially, PND packets will be issued to persons working in areas where a nuclear criticality accident is possible; eventually, PND packets will be issued to all AEC security badge holders.

In the event of a nuclear criticality accident, the PND packets of all potentially exposed persons will be "read" by LASL Group H-1 with a closed-shield Geiger-Müller instrument. Those packets indicating significant exposure will be collected and identified as to the person wearing it at the time of the accident. The collected packets will be taken apart and the foils will be counted as soon as possible. Packets considered to have received significant exposure, when the foils are individually counted, will indicate a neutron exposure greater than:

0.2 rad for 0.02 to 0.3 eV neutrons,

0.3 rad for 0.3 to 2.0 eV neutrons,

0.13 rad for 2 eV to 1 MeV neutrons,

0.58 rad for 1 to 2.9 MeV neutrons, and

1.3 rad for 2.9 to 9.0 MeV neutrons.

For exposures below 10-rad fast neutrons and gamma exposure less than 5 rem, the NTA film in the film badge will give additional data. Similarly, for less than 5 rad of thermal-neutron exposure, the film badge will give additional data. However, exposures exceeding the range of the film badge can occur, and the PND packet will be used to estimate the neutron exposure.

To complement the PND packet in the event of extremely high neutron exposure, use will be made of the glass rod contained in each film badge. The glass rod has a range from 50 to 100,000 rem, and responds to gamma radiation as well as thermal neutrons.

If you would like more details on the matters treated in this pamphlet or have questions about the material, please feel free to contact James N. P. Lawrence at 7-4316.