ACCIDENTAL EXPOSURE OF ATOMICS INTERNATIONAL
FILM BADGES DURING THE LATTER PART OF NOVEMBER, 1962

SUMMARY

Investigation has revealed that the major portion of the Atomics International December 1 film badges was exposed during the four-day Thanksgiving weekend while the film was on the receiving dock in close proximity to a box of radioactive material. Personnel badge exposures ranged from approximately 100 mR to 1200 mR, with the average exposure being approximately 350 mR. Visitor badge exposures ranged from approximately 100 mR to 10,000 mR, with the average being approximately 750 mR. This incident has revealed a need for improved methods of handling film of all types and for more careful quality control in our film badge program. The personnel badge exposures, which in general were not excessive, will be entered in personnel exposure records except where actual personnel exposures can reasonably be determined.
Introduction

At the present time 2500 film badges are used monthly in the personnel monitoring program at Atomics International. Approximately 1250 of these film badges are issued routinely to personnel and are referred to as personnel badges. About 1050 additional badges, referred to as visitor badges, are distributed to various locations for use by visitors and contractors and by Atomics International personnel who have an infrequent need for film badges. Badges from this group are also used whenever it is felt that, for radiation monitoring purposes, a person should wear one or more in addition to, or instead of, his normally assigned personnel badge. Also, approximately 300 badges are used as location badges; i.e., they are routinely placed at fixed locations in various radiation areas.

Sets of calibration film are developed each week, and control films are developed each time film badges are processed. The calibration film is normally exposed and furnished to Atomics International by the vendor, R. S. Landauer, Jr. and Company. A supply of control film, furnished by this vendor with each new film emulsion, is stored in a refrigerator in the Health and Safety Laboratory darkroom.

Film badges, except those worn or used for some special purpose or project, are sent to the vendor for processing. Special badges are processed at Atomics International, since the exposure levels recorded on these films are generally of immediate interest in the day-to-day planning of operations, and the exposure levels are obtainable much more rapidly if the badges are processed at Atomics International.

On December 7, 1962, twelve special badges were received and processed by the Health and Safety Laboratory. These badges, which had been worn on December 4 and 5 during work assignments requiring cell entries at the Component Development Hot Cell (CDHC), indicated gamma exposure ranging generally from 3 to 5 roentgens. The Laboratory Supervisor was immediately notified, and the exposures were discussed. The values were not believed to represent true personnel exposures because cell entry at CDHC had, in the past, generally resulted in exposures which included a large beta component, while these film badges indicated only high energy gamma. As further indications that these were not valid personnel exposures, readings from dosimeters worn by the people ranged only from 110 to 320 mr, and the film badge exposures were not commensurate with exposures determined from measured dose rates and occupancy times. The indium foils on the badges were monitored and the badges smeared; results were negative. The exposures were treated as personnel
exposures since they could not be immediately proved otherwise.
The Chief of Health and Safety and the Manager of the Canoga Park
Area Office of the AEC were notified; however, it was made clear
that considerable evidence indicated that these were not personnel
exposures.

Because of the unusual nature of these exposures (i.e., only
by high energy photons), it was decided to examine a number of
additional badges from CDHC. Sixteen used and four unused film
badges were obtained from CDHC and immediately processed together
with a calibration set and a control film. These films indicated
exposures ranging from 1.2 to 6.0 roentgens. Six film badges from
Headquarters were immediately processed; they indicated exposures
ranging from 0.47 to 2.3 roentgens. Three personnel badges which
should not have received any exposure were also processed; they
indicated 0.50, 0.34 and 0.36 roentgens. Now it appeared that all
film badges in use had been exposed and that, indeed, the exposures
reported were not valid personnel overexposures. R. S. Landauer Jr.
& Company in Culver City (the local office of our present film badge
supplier) was requested to be prepared to supply a complete set
(2600) of film packets. The Culver City office notified the main
plant in Matteson, Illinois, and preparations were made to fill
this order.

On the morning of December 8, the Landauer Company in Matteson,
Ill. was contacted, both to confirm the order and inform them of
the urgency. During that day the Landauer Company prepared the
film packets, dated them December 10 to distinguish them from the
exposed film dated December 1, and shipped them air express at
approximately 6:00 PM Central Standard Time. The film arrived at
Los Angeles International Airport at approximately 10:00 PM Pacific
Standard Time. It was picked up by a Landauer employee and delivered
to Atomics International about midnight. Arrangements were made on
December 8 for a number of Atomics International Health and Safety
personnel to work on Sunday, December 9, to exchange the exposed
film by Monday, December 10. On December 9, all available film
badges dated December 1 were recovered and unloaded. All of the
new personnel film was loaded into film holders, as was much of
the visitor film. Samples of the new film were processed to
ensure that it, too, was not exposed. Of the exposed December 1
badges, approximately 95%, 90% and 75% of the location, visitor and
personnel badges, respectively, were recovered during this day.
Signs requesting that all badges dated December 1 be exchanged
for those dated December 10 were posted at time clocks, building
entrances, change room entrances and Atomics International entry
gates.
On Monday, December 10, the request to turn in December film badges was made over the public address system at Headquarters and Santa Susana. The film exchange continued throughout the week. By Thursday, December 13, 99%, 98% and 98% of the location, visitor and personnel badges, respectively, had been exchanged. The December film collected through this date was then sent to Landauer for processing. The remainder of the film is being collected and will be submitted to Landauer for processing as soon as possible.

Investigation

History of the December 1 Film

The film for the December exposure period was shipped from Landauer in Matteson, Illinois to Landauer in Culver City, California in a large shipment prior to November 19, 1962. On November 19 and 20, all but approximately 100 of the December film for Atomics International was loaded into the film holders. The North American Aviation Science Center film was also loaded on these dates. At 9:30 AM, on November 21, the first 2500 Atomics International December film badges, packed in two cardboard cartons, were picked up by an Atomics International truck which, after several other stops, returned the badges to Atomics International, arriving at 2:50 PM. (The remaining 100 Atomics International badges and the Science Center badges were not shipped until November 26, as will be discussed later.)

Upon arrival at Atomics International the badges were removed from the truck, taken into a receiving area and returned to the shipping dock shortly thereafter. The badges were placed in the Building #4 accumulation box (the box in which incoming items addressed to Building #4 are placed until in-plant delivery), where they remained over the four-day Thanksgiving weekend. The badges were delivered to the Health and Safety Laboratory on November 26.

The remaining 100 badges that had not been shipped to Atomics International were picked up by an Atomics International truck on November 26, returned to Atomics International and delivered late that day to the Health and Safety Laboratory. The Science Center badges were picked up by a Science Center truck on November 26 and delivered to the Health and Safety representative at the Science Center on that day.

On November 27 and 28, all the December badges except about 40 visitor badges and the 100 badges mentioned above were prepared for distribution to the Health and Safety Operations Units. The December badges for Santa Susana were shipped to the Santa Susana Health and Safety Operations Unit on November 28. The Headquarters badges were delivered to the Headquarters Health and Safety Operations Unit by noon, November 30. All of the December film badges
were placed on the film badge racks during the afternoon of November 30. After finding on December 7 that the December film was exposed, preparations were made to replace the exposed film. Exposed badges were collected during the next several days and nearly all of them were sent to Landauer for processing on December 13.

By the morning of December 10, it had definitely been determined that the source was one of high photon energy. The exposure could have occurred at any one of eight points in the history of the film from its storage at Matteson, Illinois to discovery of the exposure on December 7 (See Figure I). Chronologically, these would be as listed below.

1. At R. S. Landauer Jr. & Company in Matteson, Illinois.
2. Transit from Matteson, Illinois to Landauer Co., Culver City, California.
3. Final processing at Culver City (November 19 and 20).
4. Transit from Culver City to the Atomics International receiving dock (November 21).
5. On the receiving dock (November 21-26).
6. Transit from the dock to the Health and Safety Laboratory (November 26).
7. In the interim between receipt by the Health and Safety Laboratory and distribution to the Health and Safety Operations Units (November 26-28).
8. In the interim between distribution to the Operations Unit and the film exchange (November 28-December 9).

Items 1 and 2 were eliminated since the visible darkening under the lead filter indicated exposure after loading, and the film was loaded in Culver City.

The 100 Atomics International badges and the Science Center badges do not indicate any exposure. As their history differed from that of the exposed film only to the extent that they were shipped November 26, rather than November 21, exposure at Culver City (Item 3) was eliminated as a possibility.

The Atomics International truck which picked up the film badges at Culver City made six additional stops before returning to Atomics International. A thorough investigation indicated no reason to suspect exposure at any of these locations or en route.

The possibility of exposure from radiographic operations on or near the dock, incoming or outgoing radioactive material shipments, and intra-plant radioactive material shipments during the period November 21 through November 26 was thoroughly investigated. This investigation revealed a box of radioactive material which appeared to be the source of the exposure. The investigation concerning this box will be described in greater detail subsequently.
The film shipment was transferred to the Health and Safety Laboratory during the morning of November 26 by an in-plant delivery vehicle. The nature of other items delivered at this time to other departments is unknown; however, the magnitude of exposure is not compatible with the short time interval between leaving the dock and final delivery. Had a source of sufficient intensity to expose the film in this short time interval been transported with this film or passed en route, there would have been an indication by some of the RAS detectors, counting systems, background monitoring systems, or the film badges of those personnel near the source as it passed. No such indication was discovered. Thus Item 6 was eliminated.

November personnel and location badges used in or near the Health and Safety Laboratory were processed; they indicated that the December 1 film badges could not have been exposed in the Laboratory. This was further verified by processing a few of the 100 December 1 visitor badges mentioned earlier which had been received in the Laboratory on November 26.

Personnel and visitor badges are distributed to approximately 50 film badge racks at Headquarters and Santa Susana. Due to this wide distribution it is virtually impossible that all the film could have been exposed while on the racks. Thus Item 8 was eliminated.

Description and History of the Box of Radioactive Material

The box of radioactive material (hereafter referred to as Box A) contained 40 samples which were irradiated in a Battelle Memorial Institute reactor. Nearly all of the samples consisted of iron or aluminum (2EC or 6061) base metals, coated with any of several organic or inorganic materials. After irradiation, the samples were shipped to Atomics International.

Box A weighed 3½ pounds with external dimensions of approximately 7" high x 8" wide x 13" long. A Group I or II, Class D poison label was attached to the box. Dose rates measured at Atomics International on November 20 were 50 mr/hr near the surface and 8 mr/hr at 1 meter. By December 14 the dose rate at a meter had decreased to approximately 1.5 mr/hr (See Figure III).

Once the measurements of interest had been made, it was felt that no further requirement existed for the contents of Box A to remain in their original configuration. The box was opened, the contents were inventoried and measurements of the inner secondary container were made. The secondary container, holding the irradiated samples, was approximately 7" wide x 7" long x 6" high. Within the secondary container were found 40 cylindrical metal canisters,
1" diameter x 1-1/16" high. Each canister was numbered, each number being prefixed by a letter. Each letter prefix designated the base metal (A...6061 aluminum, B...2024 aluminum, C...1113 iron). Another prefix "I" was used for a few samples having SnO₂ or Cu bases. The "G" series samples were the most radioactive. The activity of these was primarily Fe²⁹ (1.1 Mev and 1.3 Mev).

On November 19, Box A was received at Atomics International and transferred to the SS Vault, and on November 20, at approximately 3:30 PM, it was monitored prior to delivery to the consignee. Shortly thereafter it was transferred to the receiving dock and placed under the Radiological Alarm System detector and next to the Building #4 accumulation box, to await pickup by the in-plant delivery vehicle.

The routing ticket which had been placed on Box A at the SS Vault indicated, in pencil, that the box was to be delivered to Building #4, Room 1616. This notation had been written over in ink to indicate "Room 416-16" since "Room 1616" is an improper Building #4 address. Indications are that an attempt was made on November 21 to deliver the box to Building #4, Room 416-16 (also an improper address) and that it was returned to its original location on the receiving dock, where it remained over the four-day Thanksgiving weekend. Another notation on the routing ticket indicates that the box was returned from the dock to the SS Vault. According to the vault custodians, the box arrived at the vault on November 26. Therefore, we conclude that Box A remained on the dock and in close proximity to the December 1 film during the entire four-day weekend.

The previous discussion of the history of both the exposed film and Box A indicate that Box A was the source of exposure since:

1. both Box A and the two cartons containing the film which became exposed were on the receiving dock from the afternoon of November 21 to the morning of November 26;
2. during this period Box A was located no more than a few feet from the film and was very possibly located immediately adjacent to the film;
3. the dose rate from Box A was sufficient to cause this exposure; and
4. the gammas emanating from Box A were largely of a high energy.
Corroborative Measurements

In order to show that, under certain conditions, Box A could have caused the exposure of the December 1 badges, the following investigations were made.

First, film badges were attached in various positions to Box A and removed at various times in order to obtain a range of exposures similar to those received by the December 1 film. These badges were then processed, and the densities under the various filters were compared with December 1 film which had received nearly the same exposure. Both the experimental and December 1 films indicated a gamma energetic enough to produce a considerable amount of pair production in the lead filter. Some of the experimental films also indicated a small amount of beta, while the December 1 films did not. This is attributed to the fact that the experimental badges were placed on the outside of the box, while the December 1 badges were shielded by their own boxes and, in most cases, by other badges within the boxes. The similarity between the exposures can be seen in Figure II. The upper-left portion shows density under the lead and aluminum filters for the December 1 film badges. The lower-right portion compares these data with similar data obtained from film badges experimentally exposed to Box A.

Second, Box A was monitored on December 14 to determine dose rates as a function of distance. Isodose curves in three perpendicular planes through the center of the box were found to be nearly circular, except at very close distances. A composite isodose curve is shown in Figure III. Since at least one short-lived isotope (Fe\textsuperscript{59}) was present, the dose rates presented here are obviously less than those during the period November 21-26.

Third, Box A was placed near the Radiological Alarm System detector on the dock, where the exposure occurred, to see if it could have been there without causing a noticeable increase on the RAS console meter in the Industrial Security Control Center. The increase was not measurable; therefore, the box could have been on the dock during this period.

Fourth, the gamma energy spectrum was examined to further prove the existence of high energy photons. Isotopes identified were Fe\textsuperscript{59} (1.1 and 1.3 MeV), Ag\textsuperscript{110} (0.66 MeV and others), Mn\textsuperscript{54} (1.84 MeV) and possibly Zn\textsuperscript{65} (1.1 MeV). Half-lives of these isotopes range from 245 to 300 days except for Fe\textsuperscript{59} which has a 45-day half-life. A number of the canisters in the box were examined individually. It was found that the isotopic content varied somewhat between canisters. This is probably due to the variety of elements contained as trace impurities, both in the base metals (iron and aluminum) and the coating materials applied to the base metals.
Our conclusion that Box A caused the exposure of the December 1 film badges was confirmed by the fact that 1) the quality of the radiation was the same, 2) the dose rate was sufficient and 3) the box could have been on the dock without being detected by the Radiological Alarm System detector.

Corrective Action

This incident and the subsequent investigation have revealed the need for some improvement in our film handling procedures. Specifically, special methods should be developed for the handling of film of any type prior to delivery to the ultimate user. Existing radioactive material handling procedures appear to be adequate for the purposes of personnel protection and accountability, but they may not provide complete safeguards against incidents of this type. In addition, Health and Safety Laboratory procedures should include adequate quality control measures for both incoming and outgoing film badge shipments.

In order to improve our operations, the following action is planned.

1. A formal procedure for the handling of all types of film, prior to delivery to the ultimate user, will be developed. Considered in the development of this procedure will be (a) labeling of incoming film, (b) notification to user of receipt, (c) expedited delivery and (d) handling methods on vehicles and the receiving dock.

2. Existing radioactive material handling procedures will be reviewed and, if necessary, modified to ensure compatibility with the new film handling procedure.

3. Health and Safety Laboratory procedures will be expanded to provide adequate quality control measures. This will include processing representative film badges to detect accidental exposure or other anomalies that might have occurred prior to their receipt or shipment.

Treatment of Personnel Exposure

One hundred and thirty-nine of the December 1 film badges were processed at Atomics International as a part of the investigation. The remainder, approximately 2350, were returned to Landauer for processing. Exposure results are presented in Figures IV and V. Figure IV shows the frequency distribution of exposure levels of personnel badges, unused visitor badges and used visitor badges.
Figure V shows a summation of the Figure IV data expressed as a percentage of the number of badges in each of the three groups. It can be seen that 95% of the personnel badges received exposures of 800 mr or less and that 95% of the visitor badges received exposures of approximately 5600 mr or less. It should be noted that with a few exceptions the personnel badges had been packed in one carton while the visitor badges had been packed in the second for shipment from Landauer at Culver-City to Atomics International on November 21, as mentioned earlier. The difference in exposure level on personnel and visitor badges is attributed to this separation.

Upon examination of the exposure data it was decided to assign to each person the exposure indicated by his December 1 film badge since the exposures were not excessive in most cases. The exposure and a note of explanation will be entered in each person's exposure record.

For the individuals in the cases listed below, every effort will be made to determine the actual dose received. These doses and appropriate explanations will be entered in the individual's exposure record.

1. Employees absent from Atomics International during the entire period from distribution to collection of their December 1 film badges. (For example, a person on leave of absence, away on business, absent due to illness.)

2. Employees whose exposures can be determined from other monitoring data, such as dosimeters, radiation surveys.

3. Employees whose exposures are approaching the maximum permissible exposure.

Isodose Curves Showing Maximum, Minimum, and Average Distance to Obtain Indicated Dose Rate (measured 17 Dec. 1962)