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RADIATION EXPOSURE RATES IN THE 222-S

PROCESS CONTROL LABORATORY

by

G. L. Helgeson

Radiation Monitoring
Separations Section
Manufacturing Department

April 1, 1953

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I INTRODUCTION

In performing a routine analysis of a radioactive sample the laboratory assistant is exposed to varying exposure rates and these exposures to different portions of the body. Since their prime responsibility is to perform analytical work, it is difficult for them to accurately self monitor their work. It is not economically feasible to employ additional Radiation Monitoring personnel to follow this work on a round-the-clock basis. For these reasons there has been little accurate daily recording of exposure estimates in the Process Control Laboratories.

II OBJECTIVE

The objective of this study is to provide a simple method for calculating exposures for the various laboratory procedures which involve penetrating radiations. With this method it will be possible to evaluate and record on a day to day basis the total exposure received during laboratory work. It will also provide reliable information for exposure investigations.

III SUMMARY

The various exposure rates found in the laboratory are summarized in Table I. Table II in the appendix presents the average exposure rates and the results of statistical analysis of the data. In general, more frequent radiation monitoring and subsequent housekeeping, plus additional shielding in some cases will help to reduce the exposure rates found in this study. It is recognized that these exposure rates can be reduced if these precautions are taken, in which case the study can be re-evaluated, allowing more available time for radiation zone work for laboratory personnel.

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TABLE I
SUMMARY OF DATA ON LABORATORY EXPOSURES

<u>Operation</u>	<u>Hand Rate</u> <u>mrep/min</u>	<u>Body Rate</u> <u>mrep/min</u>	<u>Recommended</u> <u>Allowable</u> <u>Hood Bkg.</u> <u>mrep/hr</u>	<u>Equivalent</u> <u>Scale Reading</u> <u>on Open</u> <u>Window</u> <u>C.P.</u>
<u>Primary Sampling</u>	2.0	0.9	25	6
DZ-1a(doorstops)	1.0	1.7	15	4
(bayonets)	0.7	0.4	15	4
<u>PuA-6b*</u>	0.7	0.5	6	1
<u>PuA-20a*</u>	0.7	0.5	6	1
<u>UF-1b</u> (initial dilutions only)	0.7	0.5	6	1
<u>HV-1a</u>	1.8	negligible	6	1
<u>HV-1a</u>	1.8	negligible	6	1
<u>Glassware Slurping</u>	2 times body rate	as measured with C.P.	25	8
<u>Bayonet Base Slurping</u>	2 times body rate	as measured with C.P.	25	8
<u>Doorstop Slurping</u>	2½ times body rate	as measured with C.P.	25	8
General Flash Dose Per Doorstop	2.0 mrep	2.0 mrep		
<u>Work at Hood 13 and</u> <u>Hood #6</u>	2½ times body rate	as measured with C.P.	25	6
<u>Any Other Work</u>	1.0 mrep/hr	1.0 mrep/hr	<1	<1

* See discussion of these procedures

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III SUMMARY (Cont'd.)

By the use of the monthly Radiation Exposure Estimate Card it will be possible to keep a strict account of an individual's exposure. These cards have been adopted by the other Sub-Sections of the Manufacturing Department and have proved highly successful. By the use of them a record may be established of estimated radiation exposure received. At the present time this is impossible for laboratory personnel.

IV General Method of Obtaining Data and Calculation Involved

During the first week of this study a conventional Hanford Works model C.P. was used to determine exposure rates. It was soon realized that to accurately measure the lower exposure rates encountered in some operations, a more sensitive instrument would be required. Accordingly, a Tracerlab CP, Model SUIE was obtained from the Radiological Sciences Department. This instrument was modified to use a standard Hanford Works CP ionization chamber with the newly designed beta window. The ratio of beta to gamma response is approximately four to one with this new window. The full scale gamma sensitivity on Range X1 is 15 mr/hr (better than three times as sensitive as the standard CP) and the corresponding beta sensitivity is 59 mrep/hr. Thus, it is possible to accurately measure dosage rates as low as 1 mrep/hr.

Due to source size and geometry there were very few cases in which it was possible to determine field beta dosage rates in other than the standard method, i.e., observing the open window scale deflection minus the closed window scale deflection, reading the difference on the beta calibration graph and adding in the gamma.

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IV GENERAL METHOD OF OBTAINING DATA AND CALCULATION INVOLVED (Cont'd.)

Total exposure to hands and body were calculated from the exposure rate and the accurately timed exposure period. Each time there was a change in exposure rate, new rates were established and time on that rate started again. In a few instances, action was so rapid that average rates were used instead. However, this was not the general practice. Total sampling and/or exposure time was also recorded.

All observations on the same operation were summarized on a data sheet and averages and statistical deviations were determined. The best value for hand or body exposure rate in units of mrep/minute was based on the average rate for that operation plus the deviations from the average to include 90% of all observations. Therefore, it may be stated with considerable degree of reliability that the total exposure for any specific analysis will be correct, or on the safe side, and this will include all but 10% of the cases. Statistical formulae used in these calculations are shown in the appendix.

It should be noted here that it was not possible to correlate the total exposure per analysis and a side reading on the carrier. This is due principally to the fact that hood backgrounds were a major factor in determining total exposure. It is recognized that similar correlations are now in existence at other locations in the 200 Areas. If hood backgrounds could be reduced to negligible exposure rates, this conceivably could be investigated.

V GENERAL RECOMMENDATIONS APPLICABLE TO ALL PHASES OF LAB WORK

In several instances it was observed that personnel meters were worn in locations which were receiving little or no radiation while other portions

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V GENERAL RECOMMENDATIONS APPLICABLE TO ALL PHASES OF LAB WORK (Cont'd.)

of the body were receiving larger exposure rates. It is difficult to specify one location which will be satisfactory for all operations and all personnel. It is the writer's opinion that personnel meters should be worn on the lower portion of the chest for slurping operations such that they can "see" the entire hood opening just as that portion of the body "sees" it. On primary sampling work the meters should be worn in the vicinity of the left chest pocket. Under present conditions for PuA-6b, PuA-20a, etc., the meters should actually be on the knees, since this is the portion receiving the highest dosage rate. However, it is hoped that additional shielding will be added in these hoods, at which time the preferred location would be somewhere on the upper portion of the body. In general, the personnel meters should be worn at that body location which is receiving the highest dosage rate. This same principle holds for finger film, i.e., if the palm is receiving the highest rate, turn the film in toward the palm; if the back of the hand is receiving the highest, turn the film out.

When hood backgrounds which are greater than the allowable hood background but less than 100 mrep/hr (25 scale deflections on all work except slurping, where it is 35 scale deflections), are encountered, the supervisor may establish an exposure rate in the proper method (window open - window closed). When exposure rates are greater than 100 mrep/hr, monitoring assistance from Radiation Monitoring should be requested. This is in accordance with established procedures at other locations in the 200 Areas.

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VI GENERAL DISCUSSION OF INDIVIDUAL PROCEDURES

Rather than attempt to make a general evaluation for any and all procedures, the writer felt it of much more value to consider each one and obtain sufficient data on it to be able to examine it statistically, which would make the results independent, generally speaking, of the operator. With this in mind the following discussion is presented.

Primary Sampling - The best value to use for hand exposure rate is 2.0 mrep/min., and for body exposure rates is 0.9 mrep/min. No primary sampling should be done with a hood background greater than 25 mrep/hr. This dosage rate should be measured with a CP (window open, window closed) with the window end of the chamber at the front edge of the hood. The CP should be moved along the entire length of the hood and the dosage rate should be based on the maximum scale deflection. On the basis of several hundred individual exposure rate determinations, a ratio of the beta component to gamma component of 8.5 to 1 was found for body locations. Thus, by simple algebra one can find that an open window scale deflection of 6 divisions will be equivalent to 25 mrep/hr in the average case. (See appendix)

The maximum body exposure observed was 20.3 mrep obtained during a 14 min. period while making two 25 lambda dilutions on an H-7 sample. An exposure of 18.7 mrep to the hands was obtained during the dilution of the same sample. The maximum hand exposure observed was 42.2 mrep obtained during a one minute interval while making one 200 lambda dilution from an A-2 sample. These high exposures can be attributed principally to one cause: Poor housekeeping with essentially no regard for radiation level in the hood. A survey of the hood

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VI GENERAL DISCUSSION OF INDIVIDUAL PROCEDURES (Cont'd.)

Primary Sampling (Cont'd.)

conditions shortly after these high exposures were observed revealed damage rates of 3920 mrep/hr at 2" including 100 mr/hr at 4". The left wrist was exposed to this source of radiation in normal sampling operations. The right hand was routinely exposed to a radiation source of 3260 mrep/hr at 1" including 120 mr/hr at 3". The exposure rates to the operator in both of these cases were lower than these maximums. However, these maximums are pointed out as examples of poor housekeeping which lead to unnecessarily high exposures. See Figure 1 below.

VI GENERAL DISCUSSION OF INDIVIDUAL PROCEDURES (Cont'd.)

Primary Sampling (Cont'd.)

The dry waste carton is another potential source of high backgrounds. Dosage rates of 21 rep/hr including 4 r/hr at four inches were measured from a waste carton which was too full. This was discarded with exposure rates to the body of 1.4 rep/hr including 50 mr/hr and a total body dose of 11.36 mrep was received during a 35 second period. On another occasion the operator was more adept at covering the waste carton and was able to make the transfer in one second, but in doing so received 3.16 mrep with a body dosage rate of 11.3 rep/hr. Therefore, to limit the possibility of a high exposure and to keep a man available for work, it is recommended that waste cartons be changed when the dosage rate is 1 rep/hr as measured with an open window C.P. with the open window 2" from the top of the carton, or, when the general background is raised above 25 mrep/hr because of the waste carton. It is further recommended that personnel be trained in putting the covers on an ice cream carton with the use of the long tongs. Under no circumstances should the cover be put on with the gloved hand. In the event the cover cannot be put on at all, the ice cream carton should be filled with "Kleenex", or equivalent material, and discarded in the dry well.

During the study several operators questioned the writer on using shielded tweezers to wipe the sampling pipette. They felt that the shielded tweezers were an unnecessary burden, making the job more difficult. While it is recognized that the exposure rates to the unprotected wrist are almost the same as they would be to the unshielded hand, it is still vital to keep the

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VI GENERAL DISCUSSION OF INDIVIDUAL PROCEDURES (Cont'd.)

Primary Sampling (Cont'd.)

total radiation exposure at as low a level as possible. This is in keeping with plant policy. Therefore, it is recommended that the use of shielded tweezers be re-emphasized to laboratory personnel.

Many of the operators could reduce their hand exposure materially by using tongs to remove the sampling pipettes from the "Goldberg". At the present time it appears to be common practice with a number of individuals to grasp the pipette with only rubber gloves for hand protection. It is almost impossible to obtain accurate dosage rates from these pipettes, however, a typical dosage rate was measured as 210 mrep at one-half inch including 80 mr/hr at $2\frac{1}{2}$ inches. Due to the peculiar geometry, it would be difficult to calculate the true exposure rate. Therefore, the true hand dose is unknown in these cases. It is recommended that 6" tongs or tweezers of some type be used to install and remove the sampling pipette.

Determination of Specific Gravity by the Falling Drop Method, Room 4B

Hand exposures may be calculated by using the figure of 1.0 mrep/min; body exposure by using 1.7 mrep/min. These figures apply for highly radioactive samples (beta-gamma) only, such as doorstep samples. For "cold" samples, such as bayonet and bottle samples, hand exposures may be calculated from 0.7 mrep/min. and body exposures from 0.4 mrep/min. The background as measured at body locations should not exceed 15 mrep/hr. Using the same methods for determining beta to gamma ratios, it can be shown that a maximum open window scale deflection of 4 divisions will be equivalent to 15 mrep/hr in the average case.

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VI GENERAL DISCUSSION OF INDIVIDUAL PROCEDURES (Cont'd.)

Determination of Specific Gravity by the Falling Drop Method, Room 4B (Cont'd.)

Perhaps the reader is wondering why there is a higher body dosage rate than hand rate for doorstep work, while the body dosage rate is lower than the hand rate for "cold" samples. When the delivery pipette is in position over the tube to be used, there is a varying amount of sample exposed to the top of the head. This causes the average body dosage rate to be higher than the hand rate. Due to this fact a maximum exposure rate of 145 mrep/hr including 20 mr/hr at the operators forehead was recorded. (This exposure rate, of 145 mrep/hr, and the long exposure time at this rate, 14 minutes, contributed 33.9 mrep towards a total body exposure of 51.8 mrep for one analysis of an H-7 sample. The total sampling time was 45 minutes. However, it should be acknowledged that the presence of the writer appeared to make the operator more excited than normal.) Since 90% of the exposure rate to the head from this source is due to beta, a simple lucite shield one-fourth inch thick installed around the front of the opening would materially reduce the body exposure rates. Figure 2 shows a rough sketch of the shield:

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VI GENERAL DISCUSSION OF INDIVIDUAL PROCEDURES (Cont'd.)

Determination of Specific Gravity by the Falling Drop Method, Room 4B (Cont'd.)

A second source of high background is the wooden pedestal on which the doorstops are placed for sampling. Radioactive solutions have soaked into the wood to an extent that the background at the body 18" away remains at about 25 mrep/hr even after four washes with 6N HNO₃, water and acetone. However, it should be added that before cleaning, the background from the same source was on the order of 90 mrep/hr. Therefore, it is recommended that this wooden stand be replaced with a metal stand (such as stainless steel) so that it may be decontaminated readily.

A third source of high background is the highly radioactive solutions at the bottom of the tubes. Exposure rates of 20 mr/hr to the knees and 40 mrep/hr to the hands were recorded and a maximum dosage rate of 500 mr/hr at the lamp opening was observed on the same occasion. This condition exists mainly in tubes used for H-7 samples (tube 7 primarily, tubes 6 and 8 also). The writer was informed, however, that existing procedures called for the tubes to be slurped after each sample. If this established procedure were followed, this source of high background could be eliminated.

On several occasions the writer observed operators using poor working habits which led to increased exposure rates. In an attempt to do the job more rapidly, they left the cotton wipes on the tweezers so they could be used more than once. These were then left lying unshielded across the waste carton. On low level samples the writer can see no objection to this (other than the fact that this might increase the air contamination level). However, with doorstop

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VI GENERAL DISCUSSION OF INDIVIDUAL PROCEDURES (Cont'd.)

Determination of Specific Gravity by the Falling Drop Method, Room 4B(Cont'd.)

samples these wipes become extremely "hot" and lead to body exposure rates on the order of 200 mrep/hr. On each occasion the writer called this to the attention of the operator, who intimated he had "forgotten" and quickly remedied the problem. It is recommended that these wipes be discarded immediately after use, as called for by procedure.

A systematic procedure for checking the radiation level of waste traps and waste cartons should be established. It is recognized that the liquid waste trap does not fill rapidly enough (under present procedures) to be emptied daily. As a general rule of thumb, this should be emptied before the radiation level reaches values which result in very high exposure rates during removal. A figure of 100 mrep/hr is suggested as a top limit. Disposal of dry waste cartons should be governed by the same policy, i.e., do not allow the radiation level to build up to the point where exposure rates during removal are over 100 mrep/hr. A second rule of thumb governing removal of waste should be that the general background body exposure rate for routine operations does not exceed 15 mrep/hr.

PuA-6b and PuA-20a Procedures

Under the present conditions the best value for body exposure rate is 0.5 mrep/min. and for hand exposure rate is 0.7 mrep/min. However, it is the opinion of the writer that body exposure rates can be reduced about 75% by the use of additional lead shielding. At the present time the carrier containing two 10 ml volumetric flasks is placed just to the left of the center of the hood.

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VI GENERAL DISCUSSION OF INDIVIDUAL PROCEDURES (Cont'd.)

© PuA-6b and PuA-20a Procedures(Cont'd.)

Dosage rates of 200-250 mr/hr at two inches from the carriers are typical dosage rates. The resulting body exposure rates to the upper legs and knees are on the order of 15 to 35 mr/hr. These could be reduced materially by constructing a lead holder with one inch thick walls and bottom. Assuming the average effective energy of the gamma radiation is 1.5 Mev, one inch of lead will reduce the exposure rates by a factor of 4.4(1).

The maximum hand exposure observed was 16.8 mrep obtained during the analysis of a 6-3MS sample using the PuA-6b procedure. This was obtained during a 21 minute period. The maximum body exposure observed was 10.4 mrep obtained during the analysis of a 6-3MS sample by the PuA-6b procedure. This was obtained during a 22 minute period.

It was noted that some operators did not use shielded controls. The general reason for not using them was that "they were difficult to operate" and "most of the time would not operate at all due to poor mechanical fit". The writer observed that in some cases this was true, but feels that in many other cases the operator preferred to use an unshielded control mainly due to convenience. As in the use of shielded tongs as described above, there is appreciable exposure to the wrists. However, it should be re-emphasized to all lab personnel that exposure should be kept to a minimum through the use of shielded controls. In the writer's opinion there is little that can be done to reduce the hand and wrist exposure rates other than the use of shielded controls.

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VI GENERAL DISCUSSION OF INDIVIDUAL PROCEDURES (Cont'd.)

PuA-6b and PuA-20a Procedures (Cont'd.)

These same exposure rates apply to other procedures involving the same type carriers. For example, the first phase of the UF-1b procedure involves taking aliquots from the original dilutions and further diluting them. Exposures may be calculated using the same rates and appropriate exposure periods. The writer will not attempt to list the other procedures.

It should be pointed out that many operators do not use the proper method for moving the dilution carrier from one location to another, but rather, pick up the carrier at the side or top with resulting hand exposure rates in excess of 200-250 mr/hr and which may be as high as 800 mr/hr.(2) Therefore, it is recommended that all lab personnel be cautioned to follow the established procedure for handling these dilution carriers. It should be pointed out at this time that the carrier should be held at a safe distance from the body during transit. Any movement from one room to another should, of course, be done according to the established procedure of using a cart.

Since the dilutions are diluted even further during these analyses, the cotton wipes do not approach the high levels of contamination that occur in primary sampling. Because of this it is very seldom that the general hood background is over 6 mrep/hr. Nevertheless, the hood background should be checked prior to each analysis to ensure the operator that the standard exposure rates will be valid. Waste cartons should also be checked routinely and disposed of when they reach the limiting factor as described above.

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VI GENERAL DISCUSSION OF INDIVIDUAL PROCEDURES (Cont'd.)

PuA-6b and PuA-20a Procedures (Cont'd.)

During all the surveys of primary sampling and procedures in which these stainless steel dilution carriers are used the writer found no carrier which had a dosage rate over 300 mr/hr. However, should one be found, it is recommended that the analysis be carried out under SWP conditions rather than use the standard rates. (Please refer back to General Recommendations for the preferred procedure.)

HV-1a and HV-4a Procedures

The principal exposure rates in these procedures are to the hands. The best value is 1.8 mrep/min. The body is quite well shielded due to distance and the use of the lead buckets. However, the hand exposure rate could be reduced by one-third if there were provided a lead cover for these samples. Not only would it reduce hand exposure, but also would tend to eliminate any body exposure which might occur due to poor handling methods. As previously reported by Jech (3), lead covers would also help in reducing air contamination. The writer concurs with Mr. Jech.

Several operators were observed to remove the small beakers from the lead buckets to get better stirring action. This was done without the use of tongs, tweezers, or any method which might help in reducing the exposure rate. Other operators were asked about the efficiency of stirring in the lead bucket and it appears to be entirely satisfactory. Therefore, the writer strongly recommends that the beakers be left in the lead buckets.

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VI GENERAL DISCUSSION OF INDIVIDUAL PROCEDURES (Cont'd.)

Decontamination of Equipment, Room 2B

Since there are several phases of this work which have widely varying exposure rates, these were broken down and studied individually. Generally speaking, some strong measures must be taken to reduce personnel exposure since the average total body exposure to the operator performing the slurping operation is 60.3 mrep for only the first three hours of the day. Hand exposure is 86.8 mrep. See Page 21, Table II. These exposures are not always recorded on the badges and pencils due to the locations in which the meters are sometimes worn on the body. See previous discussion on this.

Of five different people performing slurping operations, only two wore plastic aprons. Therefore, the 20% reduction in beta radiation provided by the aprons was not applied to any of this work. Lab coats and coveralls showed no reduction in exposure rates.

Room 2B, Slurping of Glassware

The slurping of glassware is generally a low level job, relative to doorstep slurping. However, the average body exposure rate was found to be 25 mrep/hr. The highest average for one day for glassware slurping was 75 mrep/hr. It was not possible to arrive at a single value for a body exposure rate which would be applicable to all conditions. However, it was found that the correlation of the total observed body exposure and the calculated body exposure based on the hood background and total time for glassware slurping held up very well. See Figure 2. It is recommended, therefore, that the body exposure be calculated from the hood background and the total time for slurping glassware. The hand exposure has been shown to be very close to twice the body exposure. These

VI GENERAL DISCUSSION OF INDIVIDUAL PROCEDURES (Cont'd.)Room 2B, Slurping of Glassware (Cont'd.)

conditions hold with normal hood backgrounds and will apply up to hood backgrounds of 25 mrep/hr. By the method described above, an open window CP reading of 8 scale divisions will be equivalent to a dosage rate of 25 mrep/hr. If the hood background is greater than this, no slurping should be done until the rates are reduced to 25 mrep/hr or less by cleaning or removing high level sources.

It is the writer's opinion that occasionally some of the 10 ml. volumetric dilution flasks used in PuA-6b, PuA-20a, and similar procedures, are placed in with the rest of the glassware. This appears to be the only way to account for the occasional high gamma background from the glassware. It should be re-emphasized that there is no positive indication as to the origination of these volumetrics. However, lab personnel should be advised that this is definitely an undesirable condition which could lead to a high exposure to the slurping operator. It is recommended that all glassware to be returned to the decontamination room be checked for activity with an open window C.P. Anything which appears to be a potential hazard should be separated and plainly identified.

General levels could be reduced further by using separate slurping tubes. See next page for a more detailed description of a possible method. In addition it is recommended that the slurp tube be flushed frequently.

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TABLE II

AVERAGE EXPOSURES DURING SLURPING WORK*

Exposure received during slurping of:	Body mrep	Hands mrep
Glassware	12.3	14.3
Bayonets	9.3	21.2
Doorstops (except flash exposures)	17.2	23.2
Doorstop flash exposures (8.4/shift)	16.8	16.8
Hood 13 & Misc.	<u>4.7</u>	<u>11.3</u>
Totals	60.3 mrep	86.8 mrep

*These are the average exposures received during the first three hours of the day. According to the decontamination room personnel the remainder of the day is spent in low level work.

Room 2B, Slurping of Bayonets

Slurping of bayonet bases is also, generally, a low level job, relative to doorstop slurping. The average body exposures rate was found to be 25 mrep/hr. The highest average for one day for bayonet slurping was 41 mrep/hr. As in the slurping of glassware it was not possible to arrive at a single value for a body exposure rate which could be applicable to all conditions. However, it was found, as in glassware, that the correlation of the total observed body exposure and the calculated exposure based on hood background and total time for bayonet slurping held up very well. See Figure 3. It is recommended, therefore, that the body exposure be calculated from the hood background and the exposure time. The hand exposure, here also, was found to be very close

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VI GENERAL DISCUSSION OF INDIVIDUAL PROCEDURES (Cont'd.)

Room 2B, Slurping of Bayonets (Cont'd.)

to twice the body exposure. These conditions hold with normal hood backgrounds and will apply up to hood backgrounds of 25 mrep/hr. By the method described above an open window CP reading of 8 scale divisions will be equivalent to a dosage rate of 25 mrep/hr. If the hood background is greater than this, no slurping should be done until the rates are reduced to 25 mrep/hr or less by cleaning or removing high level sources.

Some operators have been observed to use excellent technique in slurping bayonets. Briefly it is as follows:

1. Place one or two trays of bayonet bases in the hood.
2. Open the row furthest from the body.
3. Slurp this row and remove glass inserts.
4. Cover this row, allowing slurp tube to flush while covering bases.
5. Uncover second row and continue with steps 3 and 4.

By slurping in this manner there is little possibility of unnecessary hand and wrist exposure, which occurs when one reaches over open bayonets to get to a back row. A wrist exposure rate of 455 mrep/hr including 20 mr/hr was received for three minutes by an operator who failed to recognize the hazard. The resulting exposure was 23 mrep and accounted for 58% of the total hand exposure for that day. It is easily recognized that if personnel were aware of this potential hazard that they would prefer the better and safer method.

As mentioned in the report of Mr. Jech (4) it is recommended that bayonet bases be checked for alpha and beta-gamma activity in a hood. Any transportation

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VI GENERAL DISCUSSION OF INDIVIDUAL PROCEDURES (Cont'd.)

Room 2B, Slurping of Bayonets (Cont'd.)

of bayonet bases outside of a hood before cleaning should be done with all bases covered, either by their own caps or by a large cover suitable for covering a whole tray at a time. These two steps would reduce the possibility of air contamination.

Room 2B, Slurping of Doorstops

This is the most hazardous of the various slurping operations. The average total body exposure for this operation alone is 34 mrep and the hand exposure is 40 mrep. This is based on an average of 8.4 doorstops per shift, 2.0 mrep flash exposure per doorstop, and 17.2 mrep and 23.2 mrep for general body and hand exposures, respectively.

Flash exposures received while the sample travels through the slurping tube averaged 0.9 mrep per doorstop. The best value to use is 2.0 mrep per doorstop. This value includes 90% of all observations made (78 in all).

Due to the high background, resulting in part from sample remaining in the slurping tube, the general hood background averaged 64 mrep/hr with a maximum of 235 mrep/hr. This maximum resulted from a poor operating practice and, it is hoped, was a one-time occurrence. For reasons unknown the operator had removed the one quart ice cream carton used for waste disposal from its stainless steel holder, which also acts as a beta shield. It was resting on the slurping cart next to an open doorstop just 18 inches from the operator's abdomen. It contained three tips from doorstops which had been slurped before the writer arrived on the scene. The slurp tube had not been flushed. The operator estimated she had been in this field for about 6 minutes resulting in an exposure of 23.7 mrep.

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VI GENERAL DISCUSSION OF INDIVIDUAL PROCEDURES (Cont'd.)

Room 2B, Slurping of Doorstops (Cont'd.)

General body exposure received for all doorstop slurping except the flash exposures may be calculated from the hood background dosage rate and the exposure time. It is recommended that hood background be held to 25 mrep/hr. In the present state of the art this will be difficult. Frequent flushing of the slurp tube with 6N HNO₃ and water will help markedly.

To reduce the hand and body exposure rates from doorstop slurping and, therefore, to allow the operator to do more productive work, it is suggested that a device be designed and fabricated to provide adequate shielding for this operation. Such a device could conceivably consist of a "lazy Susan" type of table on which is constructed a lead glass barricade. The doorstop is placed in a marked location on the table and the table is revolved such that the lead glass barricade effectively shields the operator. A remotely operated and completely shielded slurp tube removes the sample. Likewise, a two way remotely controlled valve provides alternately a nitric acid rinse and a water rinse. A suitable device could be developed to remove the tip and place it in the waste disposal carton. In a method similar to this the hand and body rates could be kept to as low a value as in the other slurping operations.

Referring to the report of Mr. Jech again (3), the writer also wishes to recommend that the removal of stainless steel inserts from doorstops be performed in a hood. This would eliminate the potential hazard of floor contamination and reduce the hand exposure obtained during transfer of the

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VI GENERAL DISCUSSION OF INDIVIDUAL PROCEDURES (Cont'd.)

Room 2B, Slurping of Doorstops (Cont'd.)

inserts. In addition this would reduce the possibility of air contamination. The writer has been informed that on occasions at 222B and 222T the inserts were removed in a hood (4). It would be desirable to re-establish this procedure.

Room 2B, Work at Hood 13 and Misc. Work

Aside from the slurping hood (#5), hood #13 is the "hottest" hood in 2B. The high background results from inserts, doorstops, and tongs which are cleaned and stored in this hood. Based on the many observations made of work around this hood it was found that body exposure could be best determined by measuring the hood background each time the operator performs work at this hood. The exposure is then calculated from the rate and total exposure time. From the same data it was found that hand exposures are $2\frac{1}{2}$ times body exposures. Figure 4 shows the correlation between actual body exposure and that calculated from hood background and total exposure time.

Slurping of organic samples and high level product samples is carried out in hood #6. Since this is adjacent to hood #5, (the hood used for doorstop, bayonet, and glassware slurping), there is sometimes a rather appreciable background exposure rate primarily due to hood #5. Also, the plastic tubing used to slurp organic waste has on occasions become contaminated up to 135 mrep/hr including 25 mr/hr. Therefore, body exposure may be calculated from the observed exposure rate and the exposure time. Hand exposures were found to be $2\frac{1}{2}$ times the body exposure.

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VII CONCLUSIONS

A comprehensive study has been made of laboratory exposure rates of penetrating radiations. Simple methods for calculating both body and hand exposures have been presented. The value of recording the day by day exposure on a permanent monthly exposure record card for future reference has been discussed briefly. Specific recommendations have been made which, in the writer's opinion, will help to reduce personnel exposure during routine work.

The writer wishes to thank Mr. R. J. Dorwart and Mr. D. C. Fleckenstein of Radiological Sciences for their assistance in providing the special monitoring instrument.

VIII LITERATURE CITED

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Figures 2 through 5 show the correlation between the actual body dose received and that calculated dose received based on the initial hood background level and the time spent in the particular operation. The broken line represents perfect correlation, or an "ideal" curve. The points to the upper left of this line are in the safe region. The solid line represents the average curve for that particular operation.

Fig. 2
Slurping of Glassware

Fig. 3
Slurping of Bayonet Bases

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All Doorstop Work Except Flash Exposures

Hood 13 and Miscellaneous Work

APPENDIX B

TABLE III, COMPLETE DATA FOR EXPOSURE INVESTIGATION

Procedure	Body Location	Dosage Rate, mrep/min			Best Value	Average Dose mrep	Average Time Min.
		Average	68.3% C.L.	90% C.L.			
Primary Sampling	Body Hands	0.36 0.81	0.29 0.11	0.48 1.17	0.9 2.0	4.2 15.4	11.2
DZ-1a Doorstops	Body Hands	0.79 0.14	0.55 0.53	0.90 0.88	1.7 1.0	9.7 5.6	19.5
DZ-1a "cold" Samples	Body Hands	0.25 0.35	0.12 0.25	0.20 0.43	0.4 0.7	4.9 4.5	17.6
HV-1a HV-1a	Body Hands	Negligible 1.53	-- 0.18	-- 0.30	Negligible 0.8	Negligible 9.4	Negligible 5.7
PuA-6b & PuA-20a	Body Hands	0.29 0.35	0.13 0.23	0.21 0.38	0.5 0.7	4.5 8.3	15.4
Glassware Slurping	Body Hands	0.62 0.86				12.3 14.3	20.5
Bayonet Base Slurping	Body Hands	0.37 0.78				9.3 21.2	26.8
All Doorstop Except Flash Exp.	Body Hands	0.61 1.41				17.2 23.2	19.3
Hood 13 & Misc. Work	Body Hands	0.40 0.74				4.7 11.3	17.6
Flash Exp. Based on 8.4 Doorstops Per Shift		0.9 mrep Per Doorstop	0.67	1.1	2.0	16.8 16.8	

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APPENDIX C

CALCULATION OF C.P. SCALE READINGS FOR ANY GIVEN DOSAGE RATE

The method used in this calculation is described as follows:

The sum of the beta components for a series of observations is determined. In this study approximately 200 observations were summarized. The same thing is done for the gamma component. The ratio of these two totals is the ratio of the beta component to the gamma component for that location. For primary sampling a ratio of 8.5 to 1 was found while in slurping operations the ratio was 4 to 1.

Therefore, let us calculate the number of scale divisions on a C.P. equivalent to 25 mrep/hr.

Let x equal the gamma dosage rate. Therefore, $8.5x$ is the beta dosage rate.

$$x + 8.5x = 25 \text{ mrep/hr}$$

$$x = 2.63 \text{ mrep/hr}$$

$$8.5x = 22.37 \text{ mrep/hr}$$

If C.P. beta to gamma ratio is 6:1, then 22.37 mrep/hr is equivalent to

$$\frac{22.37}{6} = 3.72 \text{ scale divisions}$$

Therefore, total scale deflections are $3.72 + 2.63 = 6.35$ divisions.

Therefore, the best value for 25 mrep/hr for primary sampling is 6 units.

In the same manner the equivalent scale readings for slurping operations is determined. For instance,

$$x + 4x = 25 \text{ mrep/hr}$$

$$x = 5 \text{ mrep/hr}$$

$$4x = 20 \text{ mrep/hr}$$

$$\frac{20}{6} = 3.67 \text{ scale divisions for beta component}$$

Therefore, $3.67 + 5 = 8.67$ scale divisions, or, taking the best value, 8 scale divisions are equivalent to 25 mrep/hr for slurping operations.

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APPENDIX D

STATISTICAL FORMULAE USED IN THIS STUDY (5)

1. Averages

$$\bar{x} = \frac{\sum x_1 f_1}{N}$$

where $\bar{x}$ is the mean value for N observations,
 x_1 is the individual observation,
 f_1 is the frequency of x_1 ,
N is the total number of observations.

2. Standard Deviation

$$s = \sqrt{m_2} = \sqrt{\frac{\sum (x_1 - \bar{x})^2 f_1}{N}}$$

where s is one standard deviation,
 m_2 is the second moment.

3. Error (or deviation from the mean) of the next single observation.

$$\text{Error} = k \sqrt{\frac{\sum (x_1 - \bar{x})^2 f_1}{N - 1}}$$

where k is 2.00 for 99% confidence level
1.96 for 95% confidence level
1.645 for 90% confidence level.

END

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