X-821

ORNL MASTER COPY

#1792

External Transmittal Authorized
Distribution Limited to Recipients Indicated

OAK RIDGE NATIONAL LABORATORY
Operated by
UNION CARBIDE NUCLEAR COMPANY
Division of Union Carbide Corporation
UCC
Post Office Box X
Oak Ridge, Tennessee

ORNL CENTRAL FILES NUMBER
61-8-30

COPY NO. 27

DATE: August 11, 1961

SUBJECT: Health Physics Problems Associated with Recent Accidents at Oak Ridge National Laboratory

TO: Distribution

FROM: Karl Z. Morgan

ABSTRACT

This is a review given by K. Z. Morgan on January 20, 1960 of some of the health physics problems associated with the three contamination accidents at ORNL within a period of three weeks in the fall of 1959.

#1792

HEALTH PHYSICS PROBLEMS ASSOCIATED WITH RECENT ACCIDENTS AT OAK RIDGE NATIONAL LABORATORY*

By

Karl Z. Morgan

Perhaps there is no laboratory in the country that has a greater diversity of radiation problems than is found at Oak Ridge National Laboratory. Some of our radiation problems have become routine and static, but many of them are unique and dynamic and change continually with the changing conditions of research experiments and with operating procedures. Because of this situation radiation problems or incidents of varying magnitude occur many times each day in various parts of our Laboratory. Some of the problems or incidents are "near misses" or "close calls" and do not actually result in radiation contamination, measurable exposure, or damage of any kind; however, we learn valuable lessons from these experiences. Some of the more serious incidents result in local contamination or in a high flux of ionizing radiation in a limited area, and usually the situation is rectified without appreciable personnel exposure or property damage and without any awareness on the part of most Laboratory employees.

There is no sharp distinction or suitable definition of when a radiation problem becomes an "incident" or when an incident becomes a radiation "accident". It always becomes a serious accident if it results in radiation damage to personnel or in radiation exposure in excess of the maximum permissible exposure limits. In addition and according to my definition, a radiation "incident" is a radiation accident if it results in a situation where there is potentially a large exposure to a few individuals or where there is potentially

---

*Presented at Health Physics Division Seminar, Oak Ridge National Laboratory, January 20, 1960.

a small but appreciable exposure to a large number of individuals. I am using this latter definition when I state that we had three radiation accidents at Oak Ridge National Laboratory in the latter part of 1959. Table I gives the date of occurrence and principal radionuclides involved in each of these accidents.

One cannot discuss the subject "Health Physics Problems Associated with Recent Accidents at Oak Ridge National Laboratory" without referring repeatedly to the very fine work by almost everyone in the Applied Health Physics Section. Some of these persons have shown great skill in the manner in which they have performed their functions, and many have worked 80 to 100 hours a week during this accident period without any reward other than the knowledge of a job well done. For fear of failure to give proper recognition to some of these men, I refer with pride to the 1959 organization chart of the Applied Health Physics Section, Table II.

Both accidents 1 and 2 resulted in the release of Ru^{106} into the environment. On October 28, 1959, unusually high levels of gross β activity were noted in the ORNL process waste water. This level increased progressively, and by November 1, 1959, it had reached the Health Physics emergency level of 1000 dis/m/ml (4.5×10^{-4} μc/ml) at the outflow from White Oak Creek Dam to the Clinch River, and as a result, Health Physics closed the gate of the dam. This gate was opened again on November 3, 1959, after assurances were made as follow

1. Numerous samples of the impounded water indicated that essentially all the radioactive contamination was due to Ru^{106}.

2. The source of Ru^{106}, i.e., certain operations in Building 3019, had been cut off.

3. The process water to Building 3019 was cut off.

UNCLASSIFIED
ORNL-LR-DWG. 45049

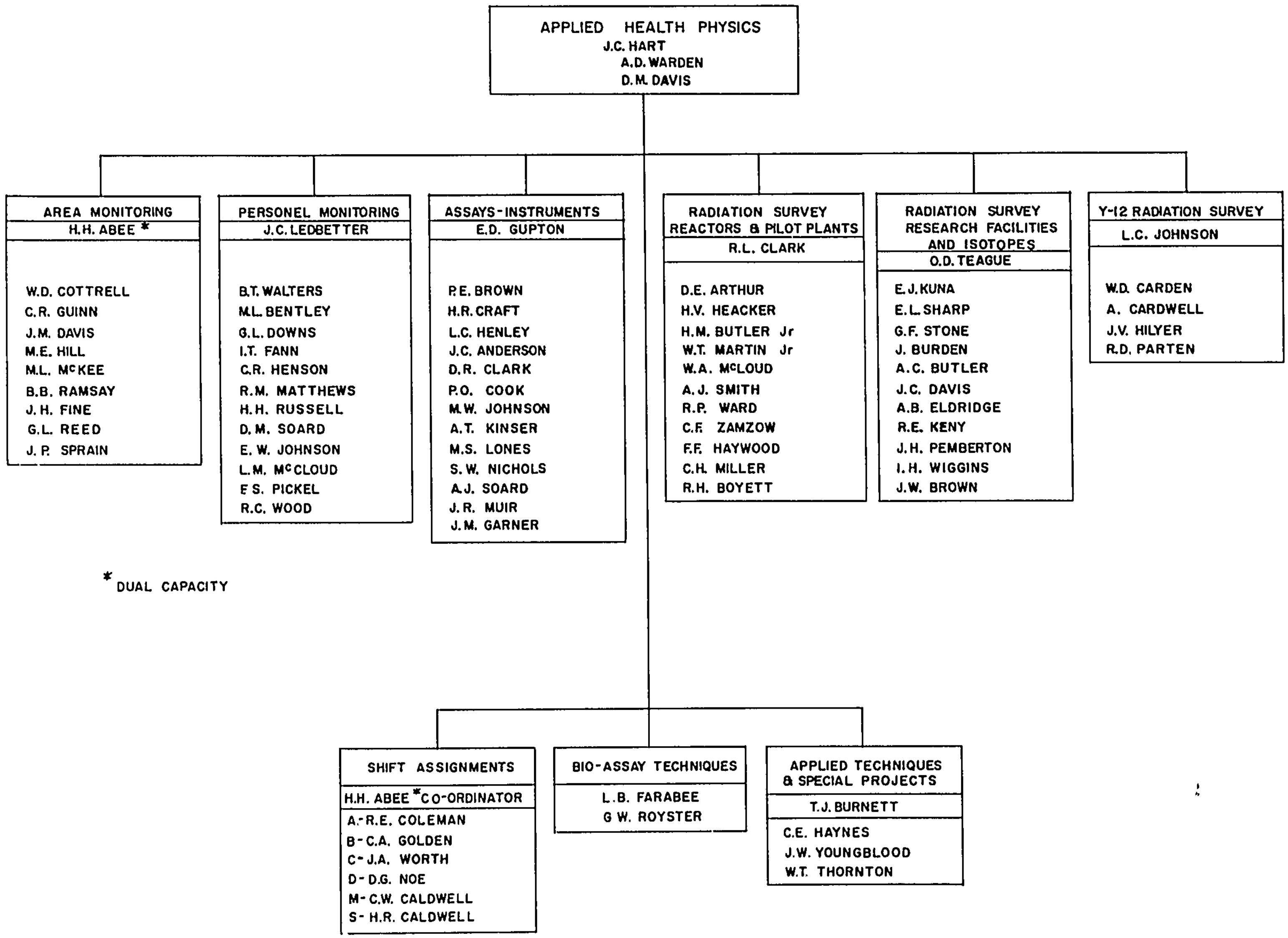
TABLE 1

ACCIDENTS AT ORNL DURING LATTER PART OF 1959

DATE	PRINCIPAL RADIONUCLIDES	REMARKS
OCT. 28 TO 31	Ru^{106}, Rh^{106} Ce^{144} Cm^{242}, Am^{242}	A LEAK OF AN EVAPORATOR IN BLDG. 3019 RESULTED IN AN ESTIMATED RELEASE OF 2000 C (MAINLY Ru^{106} AND Ce^{144}) TO WASTE SYSTEM. AN ESTIMATE OF 45 C OF Ru^{106}, 9C OF Ce^{144} AND 0.05 C OF ALPHA ACTIVITY WERE RELEASED TO THE CLINCH RIVER.
NOV. 11 AND 12	Ru^{106}, Rh^{106}	AN ESTIMATED 0.3 TO 15 C OF Ru^{106} ATTACHED TO PARTICLES WERE RELEASED UP THE RED BRICK STACK FOLLOWING MAINTENANCE OPERATIONS ON THE FAN AND DUCTS.
NOV. 20	Pu^{239}	AN ESTIMATED 40 MC OF Pu^{239} WAS RELEASED OUT-SIDE CELL 6 OF BLDG. 3019 AS RESULT OF A CHEMICAL EXPLOSION.

UNCLASSIFIED
ORNL-LR-DWG. 45059

TABLE 2



4. A pump was installed to pump waste water from Building 3019 directly to the hot waste system.

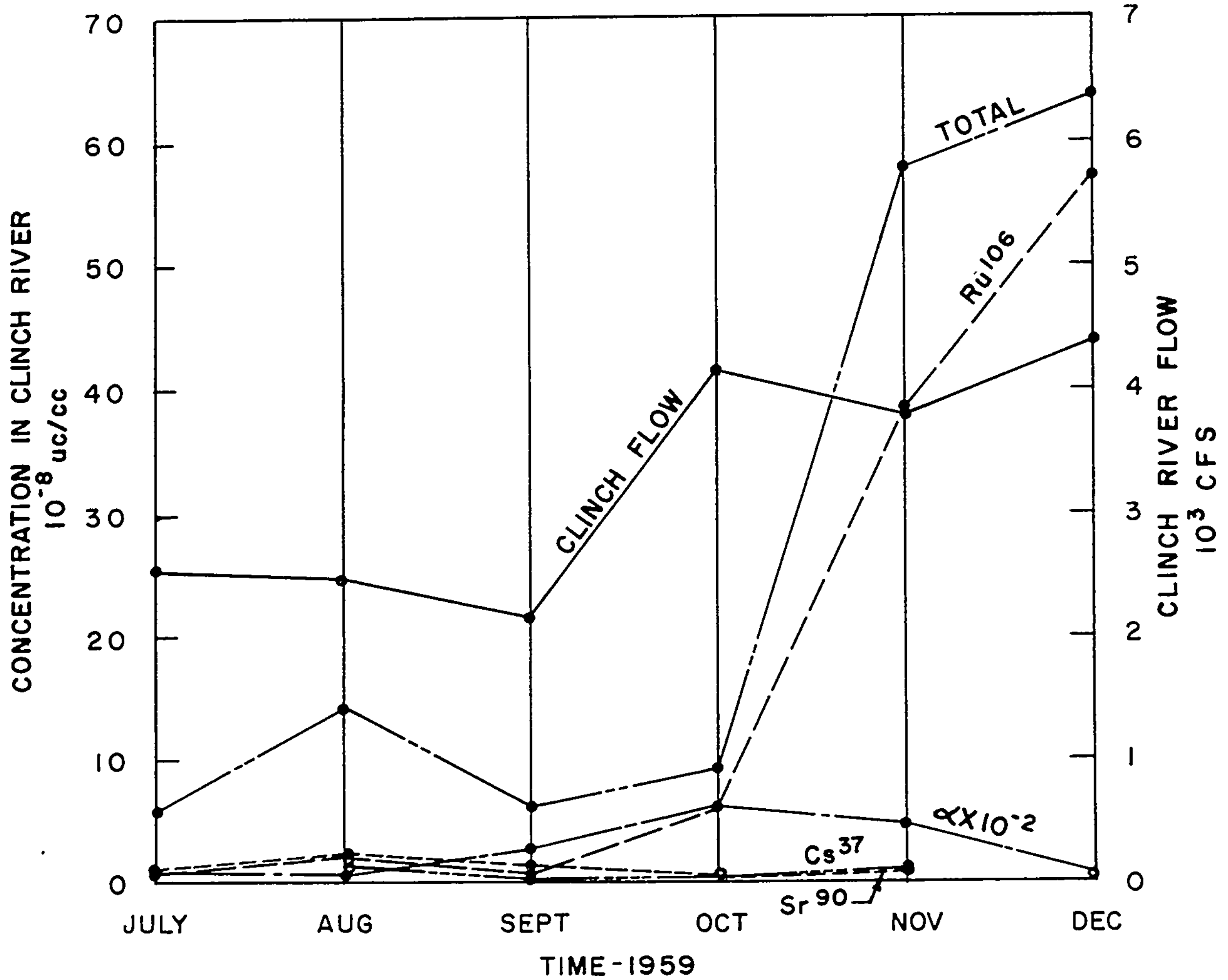
5. Predicted flow of Clinch River was sufficient to reduce the concentration of radioactive material discharged from White Oak Creek below 7×10^{-6} μc/cc. This value was the calculated MPC value applicable in the neighborhood of our controlled area for the experimentally determined radionuclide mixture that would be discharged from White Oak Lake to the Clinch River.

At the time the gate of White Oak Dam was opened the gross activity of the impounded water was about 5000 dis/m/ml (2.3×10^{-3} μc/ml), but the dilution available, assuming uniform mixing in the Clinch River, was such that the total activity in the river would not exceed about 10% of the tolerance level or 7×10^{-7} μc/ml as indicated by the experimental data plotted in Figure 1. It is interesting to observe also the relative contribution to the total contamination of the river by Sr^{90}, Cs^{137}, and α-emitting radionuclides. It should be noted also in Figure 1 that the flow rate of the river is an important factor in determining the quantities of radioactive material that can be discharged safely into the Clinch River. As shown in Figure 2, the MPC follows primarily the Sr^{90} curve and is influenced very little by the Ru^{106} because the MPC for Sr^{90} is 1/100 the MPC for Ru^{106}. In Figure 2 it is to be observed that, in spite of accident 1, Ru^{106} contributed only 22% toward the MPC or less than 10% of 22% of the MPC for the radioactive contamination of Clinch River during November* and that the principal contributor was Sr^{90}.

While discussing accident No. 1 and the problem of Ru^{106} in liquid waste, I would like to divert your attention momentarily to another Ru^{106} problem at ORNL. Table 3 indicates the Ru^{106} that is discharged to our earthen pits. Here we observe the startling fact that we discharged to the pits as much Ru^{106} in the first part of 1959 as in all previous years, and in the month of

*Since the time of this report (January 20, 1960), the values of percent contributing to the MPC in the Clinch River has been determined for December and plotted in Figure 2. During December 1959 and January the Ru^{106} contributed about 15% more to the MPC than did Sr^{90}. Since then the contribution of Ru^{106} to the MPC has diminished and now (September 1961) the contribution of Ru^{106} is about 50% less than that of Sr^{90}.

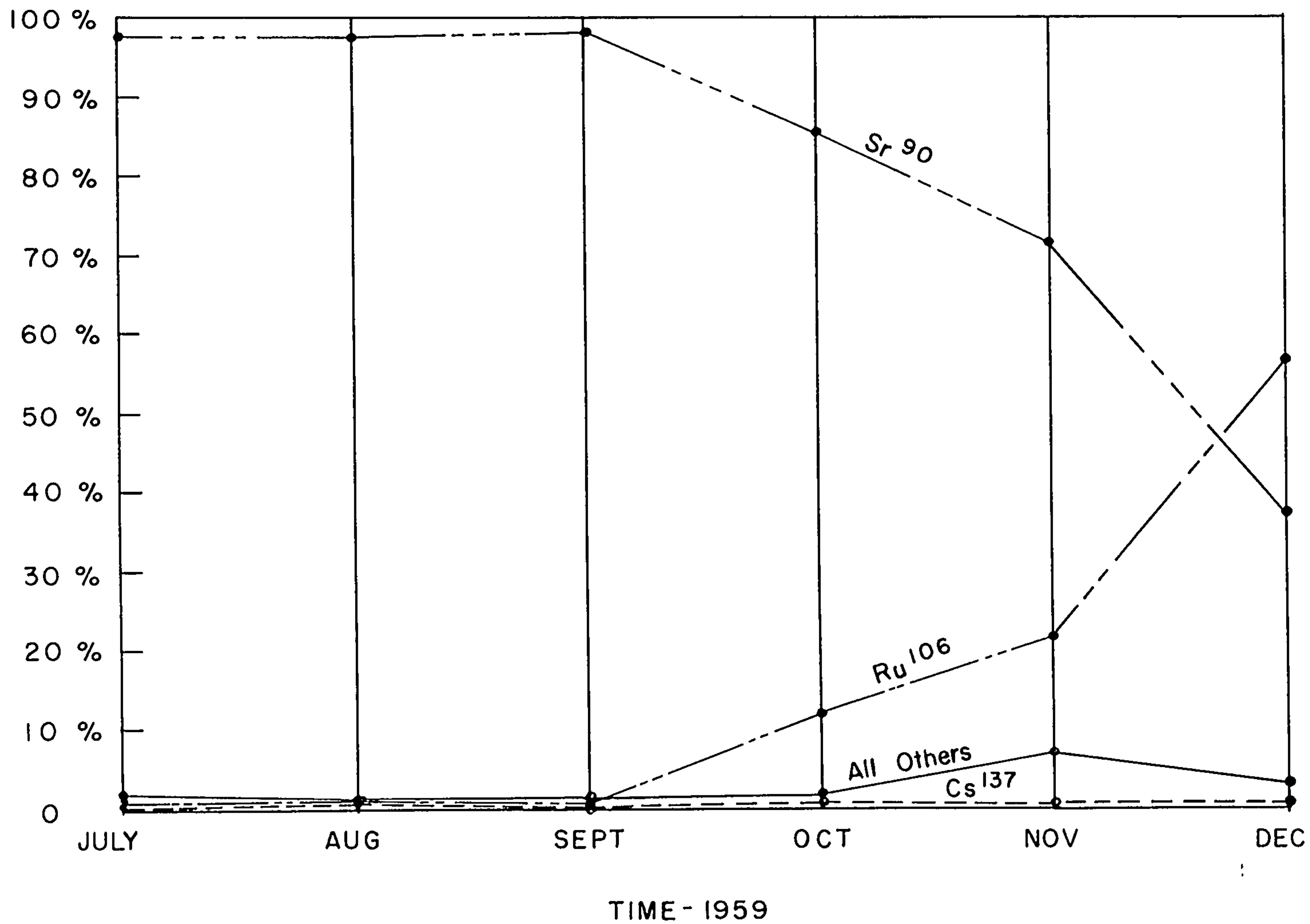
UNCLASSIFIED
ORNL-LR-DWG. 45055



CONCENTRATION IN CLINCH RIVER

Fig. 1.

UNCLASSIFIED
ORNL-LR-DWG. 45056R



PER CENT CONTRIBUTION TO MPCw
Figure 2

UNCLASSIFIED
ORNL-LR-DWG. 45050

TABLE 3

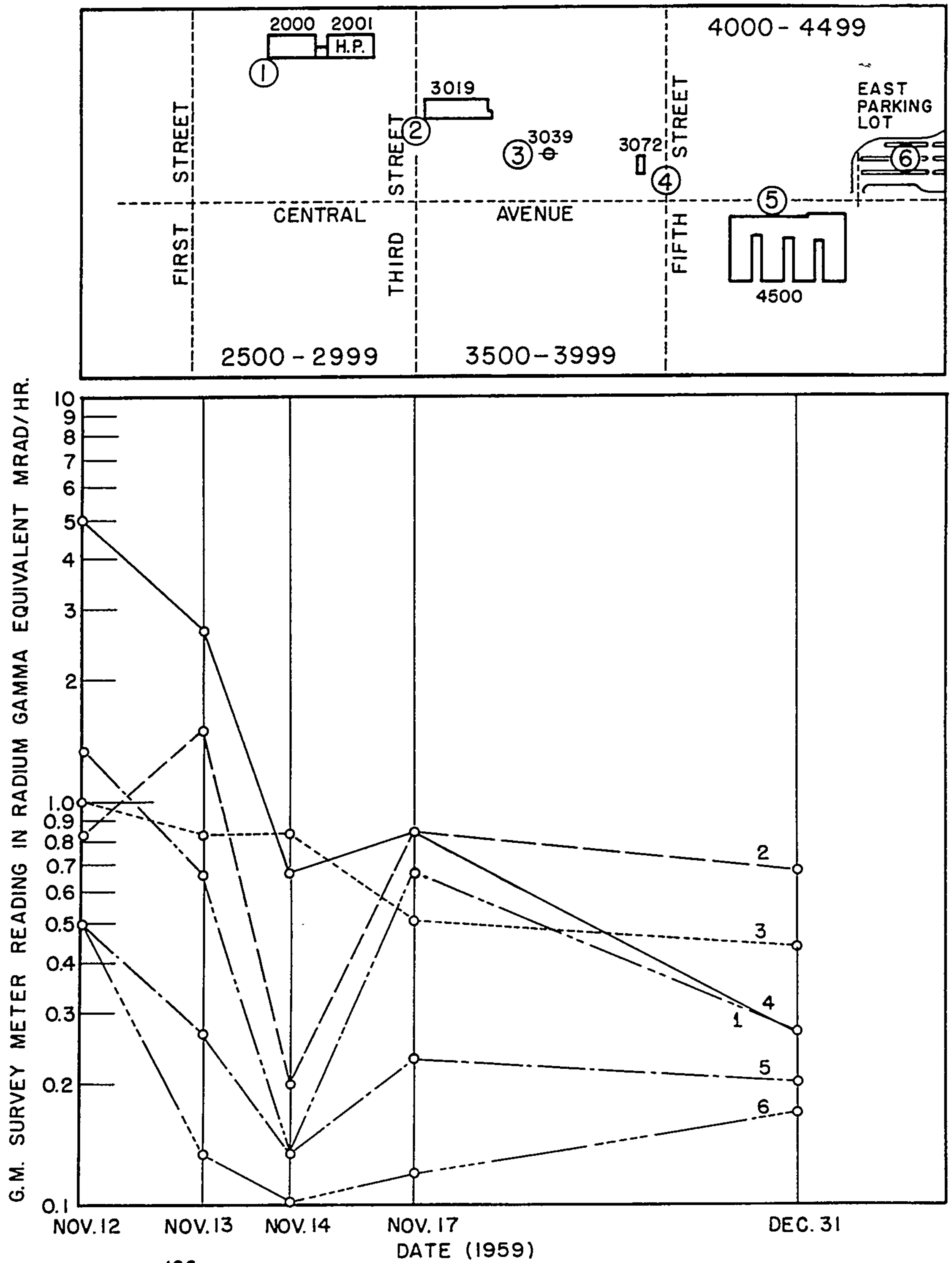
RUTHENIUM TRANSFER TO WASTE PIT SYSTEM

PERIOD	VOLUME OF DISCHARGE		Ru^{106} DISCHARGED	
	(gal/interval) $\times 10^6$	(cumulative gal) $\times 10^6$	(curies/interval)	(cumulative curies)
1952 THRU 1955	2.862		9,300	
1956	2.779	5.641	5,600	14,900
1957	2.902	8.543	4,500	19,400
1958	3.156	11.699	2,800	22,200
JAN. THRU AUG. 1959	2.525	14.224	24,000	46,200
SEPT. 1959	0.357	14.581	116,000	162,200

September alone we discharged over twice that in all the previous period. Until 1959 we had always regarded Ru^{106} as a very valuable asset to our pit program, because it served as a reliable tracer to indicate the direction of flow of water into the sampling wells that surround the pits. Now, however, this protective "instrument" has become one of the potential hazards and modifications in pit operation, e.g., the addition of iron to the pits, are being made to minimize this problem. Although in November probably 75% of the Ru^{106} activity in the Clinch River resulted from seepage from the pits, there is evidence that a considerable fraction - probably 16% - resulted from the delayed contribution of accident 1 and that a substantial contribution - probably 5% - resulted from accident 2.

As stated above, accident 2 on November 11 and 12, 1959, was also a Ru^{106} accident, but in this case it was occasioned by the fallout of radioactive particulates from the Isotope Area stack following maintenance operations on the fan and ducts of the air cleaning system. On November 11 these particles were showered in the east parking lot, resulting in Health Physics recommending a free car wash for those employees who had cars parked there; and on the morning of November 12 the Isotope Area fan was run again, this time for about 30 minutes, resulting in contamination extending a short distance to the west of the stack. Figure 3 shows the distribution of the Ru^{106} in the laboratory area (the numbers on the curves correspond to the location numbers on the map at the top of the figure) and its disappearance since then due primarily to wash-off by rain. It is this wash-off that is competing with the seepage from the pits to bring about the sharp rise in the Ru^{106} concentration in the Clinch River. Although some persons have estimated this Ru^{106} fallout at no more than 0.3 curies, there is good reason to believe it was much greater for reasons as follow:

UNCLASSIFIED
ORNL-LR-DWG. 45058



Ru^{106} ACCIDENT OF NOV. 11, 1959

Fig. 3.

1. The calculations yielding the low fallout estimates were made assuming the contamination was contained on a plane surface, i.e., using a first order E function, and there was no correction made for soil attenuation. Burial of the Ru^{106} in the grass and soil and the washing of it into the storm sewers could make such estimates too low by an order of magnitude.

2. The level of Ru^{106} activity in the White Oak Creek draining the ORNL area rises considerably following each rain. Some of this rise seems to be due to rain run-off from the ORNL area.

In case of accident No. 2, once the Ru^{106} particle source, i.e., the fan, was cut off, the only effective Health Physics measures were as follows:

1. Restrict persons from entering the more contaminated areas.

2. Require protective clothing in certain areas.

3. Wash streets, walks, buildings, cars, etc., with copious quantities of water. In some cases a detergent (Tide) was used to free the contaminant from greasy surfaces.

4. Seal-off doorways and close ventilators in certain areas.

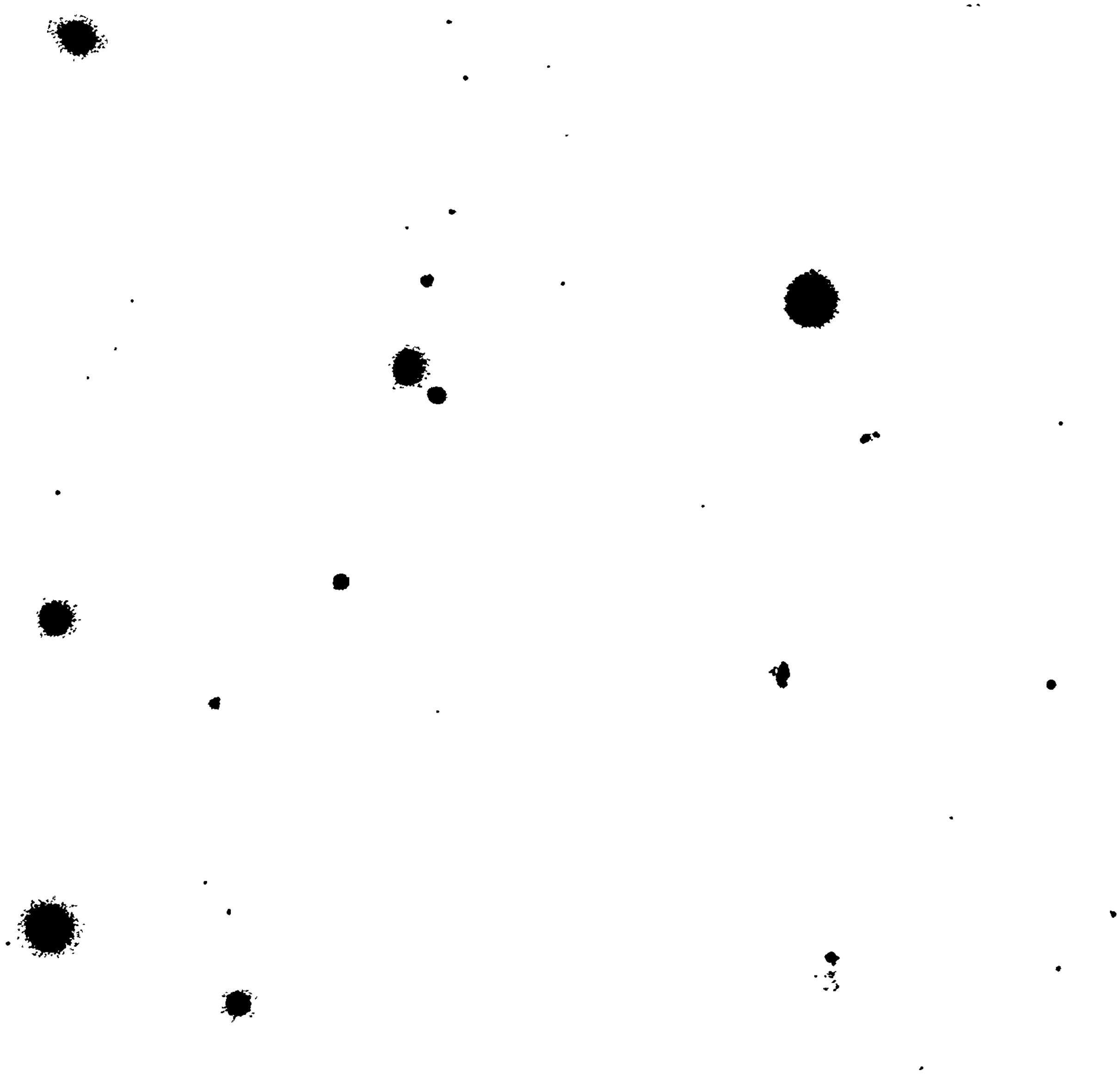
5. Place blotting paper on the floors of low background facilities.

6. Increase the number of urine and fecal analyses of samples furnished by the employees.

Although from the standpoint of low background counting accident No. 2 resulted in a serious contamination problem and presented a number of difficult public relations problems, it did not, according to present estimates, cause any serious radiation hazards to Laboratory personnel. This resulted from the following:

1. Most of the Ru^{106} was contained on large particles greater than 5 to 100 μ in diameter. This was evidenced from the fallout pattern which was localized close to the stack and from autoradiograms of gum paper collectors (Figure 4). Large particles such as those shown in Figure 4 cannot enter the lower respiratory tract where most of the damage ordinarily would be expected to result. If large particles should be inhaled, they would be held up in the upper respiratory tract and swallowed where the estimated hazard to the GI tract is less than 1/7 the hazard to the lung.

UNCLASSIFIED
PHOTO 48965



Ru PARTICLES COLLECTED ON GUMMED PAPER
(COLLECTION DATE 11/9 - 11/12)

Fig. 4.

2. The probability of inhaling these particles was very low as witnessed by the fact that during the entire period of the accident none of the very large and extremely radioactive particles happened to fall on any of our 74 fallout trays; yet a number of these particles were found with our survey meters on cars, on the roads, and in the grass, vis., our fallout trays presented a small cross-section for the collection of these large and widely scattered particles. Also, although the 10 constant air monitors we have in the area were run continuously, with few exceptions, they did not pick up particles containing sufficient Ru^{106} to produce large black film spots (such as shown in Figure 4) during a 24-hour exposure to a naked X-ray film. Figure 5 shows some of the many CAM autoradiographs. Particles containing as little as 3.5×10^{-6} μc of Ru^{106} can be detected by this 24-hour exposure technique.

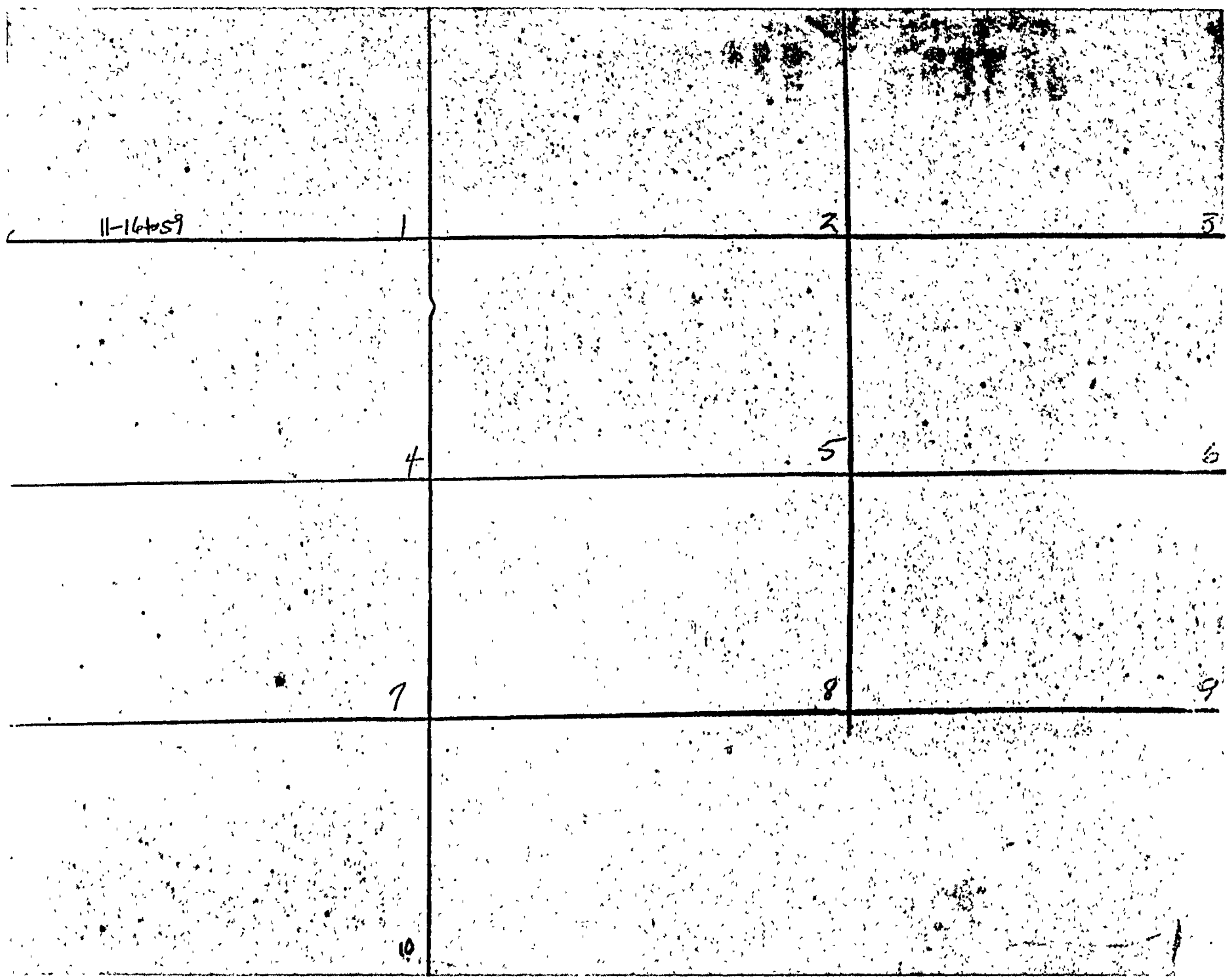
3. The Ru^{106} excreted in the feces and urine of the ORNL employees was relatively low. Figure 6 indicates the urinary excretion of Ru^{106} by the ORNL employees having the highest excretion rates, and with one exception these values are less than 1/2% of the maximum permissible excretion value for occupational workers subjected to chronic exposure to Ru^{106}.

   Figure 7 is a microphotograph of one of the Ru^{106} particles made by Ted Willmarth. Studies of some of the particles with polarized light and by X-ray diffraction made by R. L. Sherman indicated that they have a crystal structure and are composed of NH_4NO_3.

   Figure 8 is a plot of the background radiation level as measured in the control area by aerial surveys at about 400 feet elevation above the laboratory. The survey made November 11, 1959, was prior to the Ru^{106} accident No. 2 and may be compared with the more recent survey made January 15, 1960. From this it can be seen that the general level of background radiation in the Laboratory area has returned to a value not far from that prior to the accidents in 1959.

From the point of view of potential radiation hazards, I consider the accident on November 20, 1959, as the most serious we have had in the history of the Laboratory. At 10:58 p.m. on November 20, 1959, a small chemical explosion in cell 6 of the Thorex Plant in Building 3019 blew plutonium out into the street and into various buildings; especially into Buildings 3019 and 3001. A Health Physics surveyor was at the site of the explosion within minutes following the explosion. He made β and γ surveys and took smear samples, neither of which indicated a serious radiation hazard, e.g., the β + γ survey

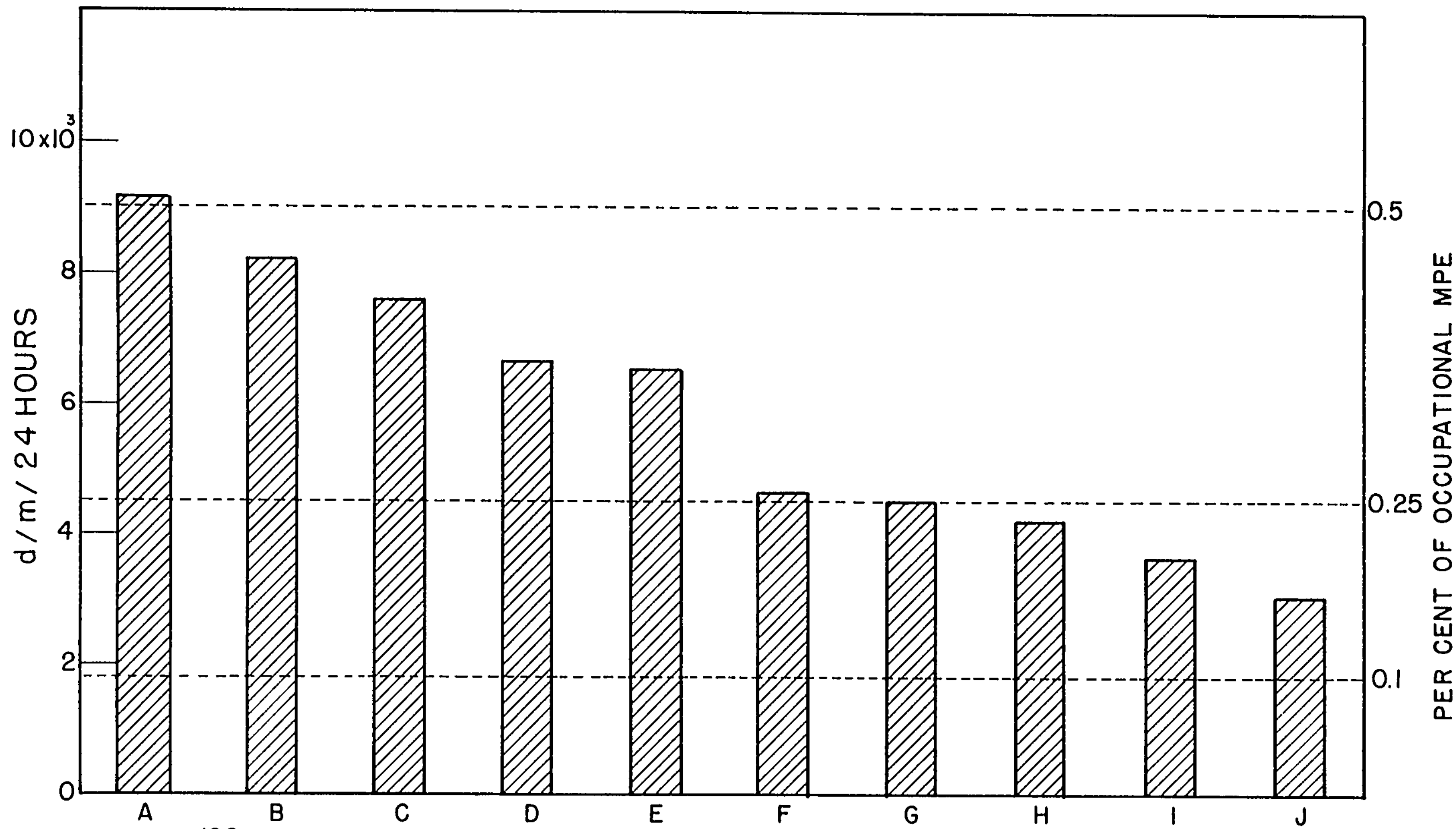
UNCLASSIFIED
PHOTO 48960



AUTORADIOGRAM OF TYPICAL CAM FILTERS IN SERVICE DURING Ru ACCIDENT

Fig. 5.

UNCLASSIFIED
ORNL-LR-DWG. 45060



Ru^{106} URINARY EXCRETION OF ORNL EMPLOYEES HAVING THE HIGHEST EXCRETION RATE

Fig. 6.

UNCLASSIFIED
PHOTO 48966

Ru FALL-OUT MATERIAL 200X BRIGHT FIELD ILLUMINATION

Fig. 7.

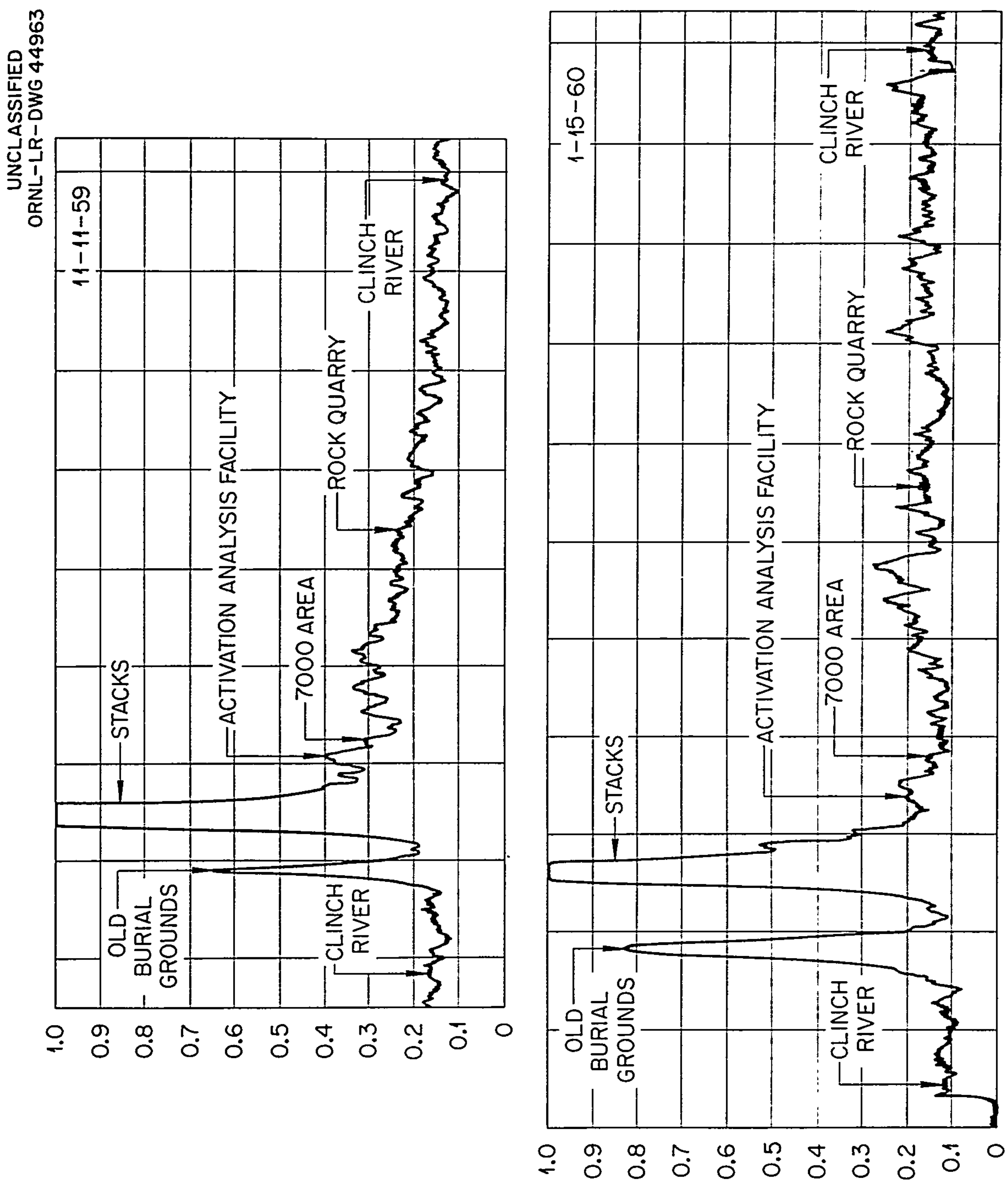

UNCLASSIFIED
ORNL-LR-DWG 44963
11-11-59
STACKS
ACTIVATION ANALYSIS FACILITY
7000 AREA
ROCK QUARRY
CLINCH RIVER
OLD BURIAL GROUNDS
CLINCH RIVER
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1-15-60
STACKS
ACTIVATION ANALYSIS FACILITY
7000 AREA
ROCK QUARRY
CLINCH RIVER
OLD BURIAL GROUNDS
CLINCH RIVER

Fig. 8.

reading in the middle of the road in front of cell 6 was only 15 mrad/hr. Unfortunately there was a lag of about 1-1/2 hours before it was discovered that there was α contamination associated with the accident. This delay was occasioned by the following:

1. Personnel who had been working with the operation in cell 6 of Building 3019 did not indicate the α contamination was present.

2. There were only two Health Physics surveyors on duty at that time of night, and following the accident they were unusually busy with many other assignments occasioned by the accident.

3. Health Physics surveyors do not ordinarily have α-survey meters with them when surveying in the general area of the Laboratory because

   (a) alpha-survey meters are not as fool-proof as $\beta + \gamma$ survey meters. This is especially true when it is very damp outside as on this night of accident No. 3, and

   (b) in most situations in the past α contamination has been associated with fission products so that its presence can be determined best by $\beta + \gamma$ surveys.

The first suggestion that there was an α problem came when one of the Health Physics surveyors was routinely checking his shoes with an α-survey meter and found them badly contaminated. Shortly afterwards filter paper from air monitors and from smear sampling indicated high levels of α contamination. Once it was recognized that α contamination had been involved in this explosion, Health Physics supervisors, surveyors, and others were telephoned and were soon on duty throughout the Laboratory area. At first it was feared there might have been a nuclear explosion. The only information that mitigated this fear was:

1. There was no evidence of the presence of large amounts of the short-lived fission products, e.g., Sr^{91}, Sr^{92}, Ce^{143}, Mo^{99}, I^{133}, Cb^{97}, Ba^{140}, La^{140}, etc.

2. There was the rise of radioactive contamination measured by the CAM located on the north side of Building 3025 and a short distance from cell 6, but this rise occurred some minutes after the explosion and was characteristic of airborne activity. There was no instantaneous rise indicated by the CAM's and various other recording meters operating in the area at the time of the explosion.

3. The NTA films worn by the employees in Building 3019 did not contain any proton tracks.

4. There was no activation of the In or Au in the badges of employees of Building 3019.

5. The threshold detector fission foils contained in a boron ball and the associated sulfur and gold samples which were 20 feet from cell 6 did not indicate any activation.

In spite of the above evidence strongly suggesting no criticality accident, it was not completely convincing since the explosion took place inside a cell that is shielded by 5 feet of concrete. The shielding provided by this concrete would greatly diminish the value of evicence of items 2, 3, 4, and 5 above. Also, the person in charge of the chemical operation pointed out the Health Physics several hours after the explosion that a rough and preliminary examination of the plutonium balance from past operations in cell 6 indicated that there might have been as much as 1200 g of Pu^{239} in the cell at the time of the explosion. (Note: It has since been established that 1100 g of Pu^{239} were in the cell at the time of the accident. See ORNL 2989 and CF 60-90-7.)

On the night of accident No. 3, many important measures were taken for personnel protection and to prevent the spread of radioactive contamination. Some of the measures taken by health physicists or at their request were as follows:

1. Blocked off entrance to the contaminated portion of Hillside Avenue (point 2 in figure 3).

2. Set up a clothing checking station on 3rd Avenue below the cafeteria.

3. Required all persons entering the contaminated area to be garbed completely in protective clothing.

4. Checked skin and clothing of everyone leaving the contaminated area.

5. Made numerous checks of many areas down wind from the Laboratory.

6. Obtained hundreds of smear samples, air samples, fallout samples, etc., for analysis by photographic and counting techniques.

7. Set up personnel monitoring stations at the east and west portals and at the cafeteria.

8. Notified all ORNL Laboratory Directors of the accident.

9. Checked cafeteria thoroughly several times before its use in the preparation of food.

10. Checked for radioactive contamination on cars and trucks leaving the Laboratory.

11. Maintained with the help of the Security Department a complete log on all persons entering and leaving the Laboratory during the night of the accident.

12. Placed paper in halls and doorways of all buildings in the Laboratory.

13. Obtained urine and fecal samples from exposed personnel and started the Health Physics urine analysis laboratory operating on a 24-hour basis.

14. Requested that tar and gravel be placed on Hillside Avenue (road surface was later removed to burial ground).

15. Requested that a heavy coat of paint be placed on sidewalks, grass, fence, cement blocks, etc., that were just outside cell 6 at time of accident. (These objects were later removed to burial ground.)

16. Requested a new tar and chip-roof coating be placed on Buildings 3025 and 3022. (Later a similar roof coating was placed on Building 3019) (Note: Building 3024 was taken down in sections in 1961 and removed to burial ground.)

17. Requested painting of north side of Buildings 3022 and 3025.

18. Required all persons entering Buildings 3022 and 3025 to wear shoe covers.

19. Closed a number of air vents to buildings near site of accident.

20. Requested that all roads and walks (except Hillside Avenue) be washed with copious quantities of water.

On the night of accident No. 3, Health Physics found some contamination tracked into the west side of the OR Reactor (Building 3042) and in the area of the LITR, but we had this contamination blocked off and cleaned up; then directed that entrance to these buildings be made only along uncontaminated pathways from the east side. This action made it possible to continue the unabated use of these facilities.

Unfortunately, on the night of the explosion large amounts of airborne Pu^{239} were blown into Buildings 3019 and 3001 necessitating the evacuation and shutdown of these facilities. Following this shutdown, entrance was permitted only by persons completely garbed in protective clothing and wearing full face masks. Monitoring and clothing checking stations were set up at entrances to these areas and since one of the greatest hazards in the handling of Pu^{239} is getting it into the body through wounds, no one was permitted to enter these areas if he had open wounds and a number of precautions were taken to avoid accidents that might lead to contaminated wounds.

As a consequence of accident No. 3 very little radioactive contamination was added to the Clinch River. By quick action on the part of members of the Operations Division, the water into Building 3019 was cut off and the liquid waste was impounded in the holding basin rather than let it enter White Oak Creek. Health Physics recommended that the waste water from the Laboratory be kept as low in volume as possible and that this waste should be pumped to the waste pits where we could expect 100% removal of the Pu^{239}. Our estimates indicated that there were about 44 mg of Pu^{239} impounded in the holding basin and it did not seem wise to send this through the process waste treatment plant where we could expect no more than 80 to 90% removal of the Pu^{239}.

In the clean-up operations in Building 3019 and 3001 two types of zones were established. Table 4 indicates the maximum and average levels used for the Technically Contaminated Zone. When the surfaces were cleaned down to or below these values, they were painted with several coats of paint. In the 3019 Building, the first coat was red, the second coat was white, and the outer coat was green. In the 3001 Building only the inner white coat and outer

UNCLASSIFIED
ORNL-LR-DWG. 45051

TABLE 4

TECHNICALLY CONTAMINATED ZONE

	DIRECT READING	TRANSFERABLE
MAXIMUM VALUE	3000 d/m/100 cm^2	300 d/m/100 cm^2
AVERAGE*	$\leq$300 d/m/100 cm^2	$\leq$30 d/m/100 cm^2

*THE NUMBER OF SAMPLES CONSIDERED IN DERIVING AN AVERAGE SHALL INCLUDE AT LEAST 10 SAMPLES AND THERE SHALL BE AT LEAST ONE SAMPLE FROM EACH SQUARE METER OF THE PROJECTED SURFACE AREA.

green coat of paint were used. Thus in the future when an inner coat (white and/or red) shows through the outer green coat of paint, we have warning that a new paint job is required to retain this plutonium that has a half life of 24,000 years. A Technically Contaminated Zone differs from an ordinary contaminated zone in that protective clothing is not required after the surfaces have been painted as indicated above. Most of the areas in Building 3019 are being cleaned down to the levels shown in Table 4 and this clean-up operation is still underway. (All areas except cell 6 have now - 1961 - been cleaned to the Laboratory levels.) After a month of hard work the contamination in Building 3001 was reduced to within the Clean Zone limits listed in Table 5 and the surfaces were painted with the two coats and colors of paint as specified above.

Table 6 indicates the results of the shoe checks for gross α contamination. Here it is observed that during the spot checks over the 3 day period 11 persons were found with α contamination on their shoes. This of course does not mean these were the only employees with α contamination on their shoes, for the efficiency of counting under these conditions, i.e., dirty shoes, rain, mud, etc., ranges between 0.1% to 5%. Only one person was found with extremely high α contamination from Pu^{239} and apparently he had violated the clearance procedure from Building 3019. There were four other persons with slight α contamination that was thought to be Pu^{239}. Two persons were found with Am^{241} contamination and three with uranium contamination. Thus these spot checks of shoes were useful not only in indicating the degree of compliance of Laboratory personnel with the zoning procedures established for the clean-up of Pu^{239} following accident No. 3 but also for indicating how well the zoning

UNCLASSIFIED
ORNL-LR-DWG. 45052

TABLE 5

CLEAN ZONE

	DIRECT READING	TRANSFERABLE
MAXIMUM VALUE	300 d/m/100 cm^2	30 d/m/100 cm^2
AVERAGE*	$\leq$ 30 d/m/100 cm^2	$\leq$ 3 d/m/100 cm^2

*THE NUMBER OF SAMPLES CONSIDERED IN DERIVING AN AVERAGE SHALL INCLUDE AT LEAST 10 SAMPLES AND THERE SHALL BE AT LEAST ONE SAMPLE FROM EACH SQUARE METER OF THE PROJECTED SURFACE AREA.

UNCLASSIFIED
ORNL-LR-DWG. 45053A

TABLE VII CONTAMINATED SHOE CHECK

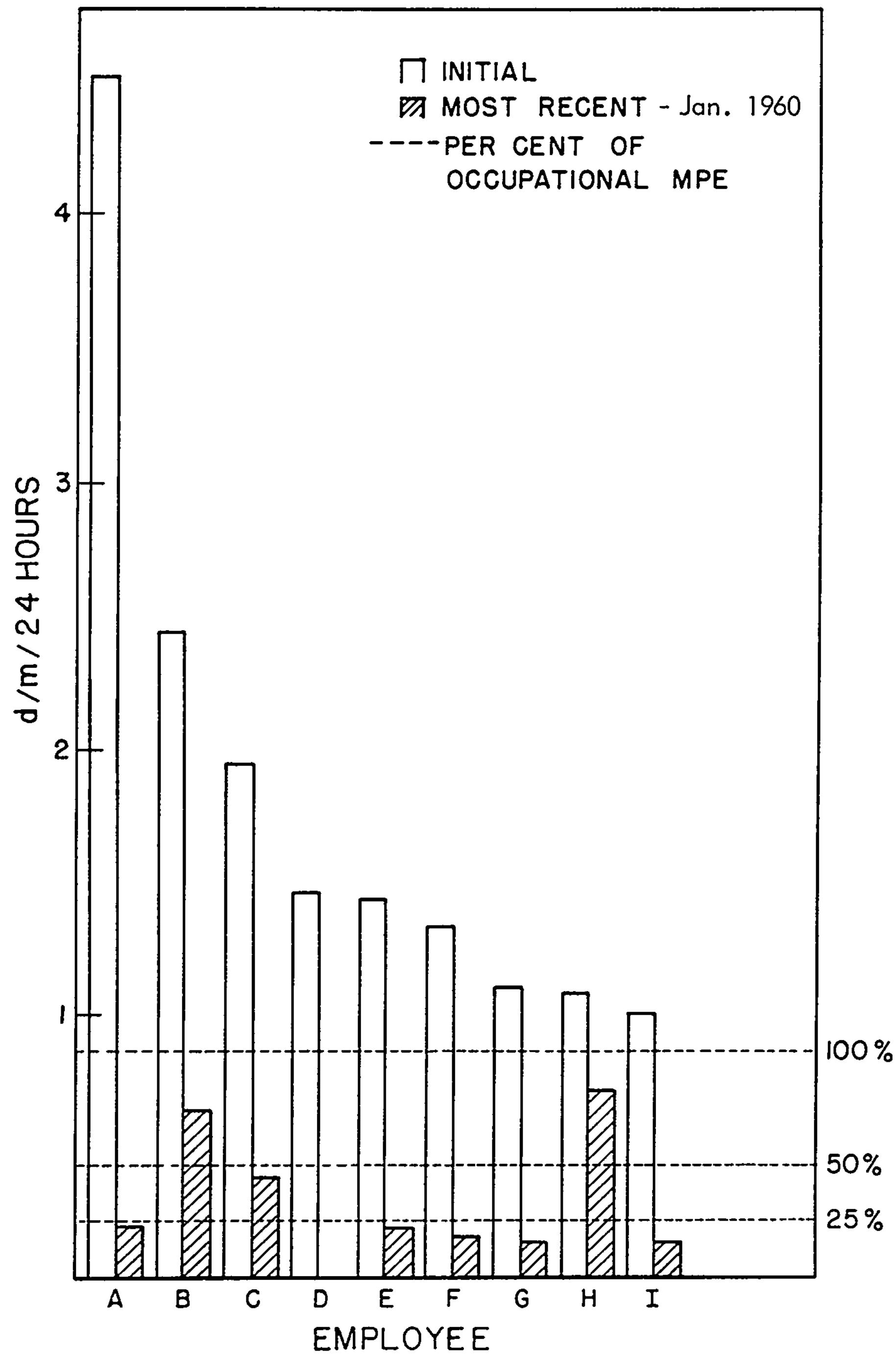
DATE	EMPLOYEE	CHECK POINT	APPROXIMATE CONTAMINATION LEVEL	REMARKS
NOV. 20	I	WEST PORTAL	OFF SCALE (>10,000 c/m)	VIOLATED CLEARANCE PROCEDURE AT BLDG. 3019
NOV. 23	II	CAFETERIA	100 d/m	ACTIVITY IDENTIFIED AS URANIUM
NOV. 23	III	CAFETERIA	80 d/m	NOT DETECTABLE ON RE-CHECK
NOV. 23	IV	EAST PORTAL	500 d/m	DECONTAMINATED AT PORTAL
NOV. 23	V	EAST PORTAL	3000 d/m	ACTIVITY IDENTIFIED AS AMERICIUM 241
NOV. 23	VI	BLDG. 3508	QUITE HIGH	ACTIVITY IDENTIFIED AS AMERICIUM 241
NOV. 24	VII	CAFETERIA	2000 d/m	ACTIVITY IDENTIFIED AS URANIUM
NOV. 24	VIII	EAST PORTAL	400 d/m	Y-12 EMPLOYEE WEARING FREE-ISSUE SHOES
NOV. 24	IX	EAST PORTAL	VERY SLIGHT	DECONTAMINATED AT PORTAL
NOV. 24	X	EAST PORTAL	VERY SLIGHT	DECONTAMINATED AT PORTAL
NOV. 24	XI	EAST PORTAL	VERY SLIGHT	DECONTAMINATED AT PORTAL
NOV. 25	XII	EAST PORTAL	$\sim 2 \times 10^5$ d/m	ACTIVITY IDENTIFIED AS URANIUM 233

procedures are followed in other areas. Perhaps spot checks of the radioactive contamination of clothing should be made periodically at the cafeteria and portals. However, any such measures can at best be only poor substitutes for an enlightened supervision that enforces the zoning regulations in each area of the Laboratory.

During the clean-up operations in Buildings 3019 and 3001 there have been many complaints regarding the difficulties of wearing full face masks, the discomfort of wearing shoe covers, the low levels (Tables 4 and 5) required before painting, the time consumed in changing clothing, the rules prohibiting eating and smoking in contaminated zones and the number of urine and fecal samples that must be submitted to Health Physics, etc. However, I believe in the long run these measures will pay big dividends and we will be happy these precautions were taken.

Regardless of the care with which the various Health Physics protective measures are carried out the proof of the success of the program is the lack of any resulting radiation damage. Since it may require 20 to 50 years for certain types of radiation damage to manifest themselves, the best immediate evidence of a successful Health Physics operation during the clean-up following accident No. 3 is the absence of any cases in which persons have large fecal and/or urinary excretion of Pu^{239}. Figure 9 gives the first (which is in each case also the highest) and the most recent Pu^{239} urinary excretion rates of the ORNL employees having the highest urinary excretion of Pu^{239}. All of these values initially exceeded the maximum permissible excretion rate (assuming the Pu^{239} is being eliminated primarily from the bone) but for the most recent urine analyses most of the values fell below 50% of this rate. (Note: In 1961 only 2 of these persons have 20 to 50% of the maximum permissible body burden.)

UNCLASSIFIED
ORNL-LR-DWG. 45061

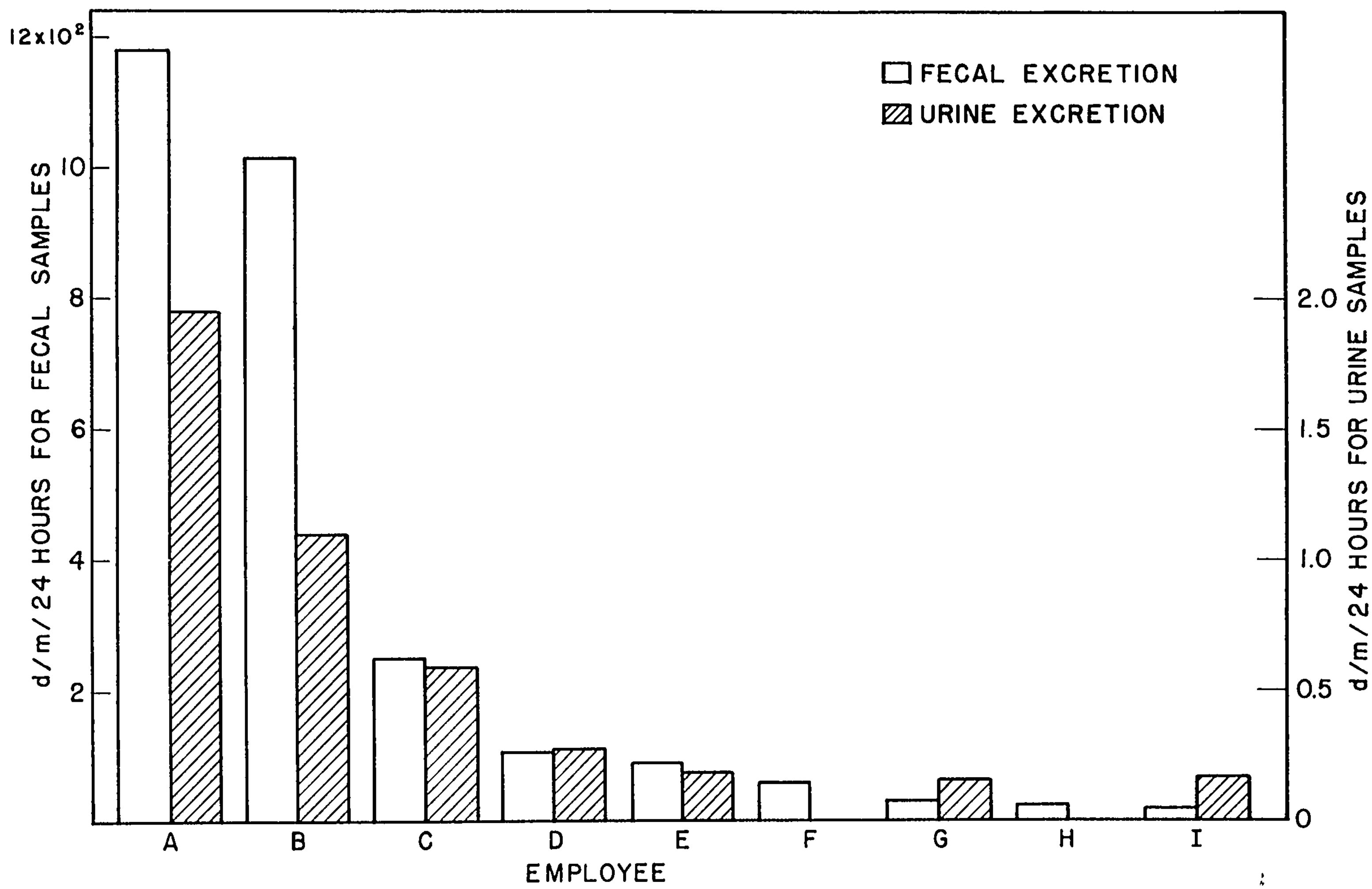


Pu^{239} URINARY EXCRETION OF ORNL EMPLOYEES HAVING THE HIGHEST EXCRETION RATE, SHOWING INITIAL AND MOST RECENT RESULTS.

Fig. 9.

Figure 10 is a plot showing the fecal excretion of Pu^{239} by ORNL employees having the highest fecal excretion of Pu^{239}. This figure shows also the urinary excretion of Pu^{239} by some of these same individuals. It is rather surprising that there is such close correlation in these data because fecal excretion of Pu^{239} indicates primarily that Pu^{239} has been taken into the body within 2 days prior to sampling and that some of the Pu^{239} entered the body in a relatively insoluble form - probably on large dust particles. In some cases the fecal excretion of Pu^{239} has given evidence that certain of the employees have not worn the masks properly or have otherwise been careless in the clean-up operation. The urinary excretion rate data indicate that some of the Pu^{239} has been incorporated into the body, perhaps as small particles deposited in the lower respiratory tract and in the pulmonary lymph nodes or it has been incorporated into the bone. The maximum permissible rate of excretion of Pu^{239} is not known. If the excretion comes primarily from the soluble fraction of Pu^{239} deposited in soft tissue, the rate should be about 7 d/m/24 hrs; it it comes from Pu^{239} incorporated in the bone, the rate should be about 0.8 d/m/24 hrs; and if it comes from insoluble Pu^{239} incorporated in the lymph nodes, the rate should be essentially zero. Figure 11 is typical of the 14 ORNL employees for whom the urinary excretion rate of Pu^{239} was originally in excess of the 0.8 d/m/24 hrs value. We have rather arbitrarily decided to follow the Pu^{239} urinary excretion rates of all ORNL employees for whom the urinary excretion rate has exceeded 0.2 d/m/24 hrs. Since accident No. 3 (until January 1960), 80 employees or about 30% of all those potentially exposed by accident No. 3 that submitted urine samples have exceeded this action level of 0.2 d/m/24 hrs. Figure 12 is typical of the urinary excretion of this group.

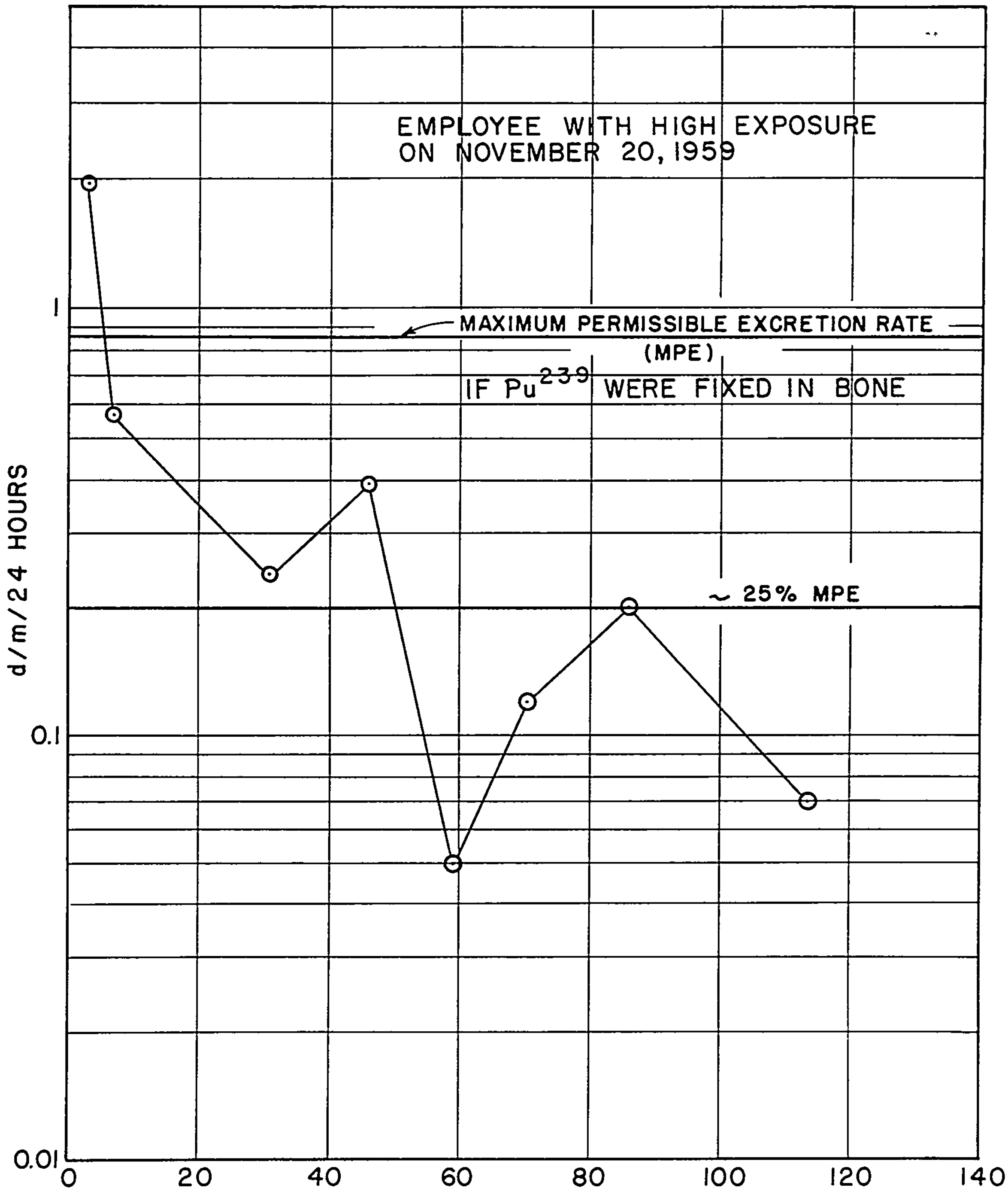
UNCLASSIFIED
ORNL-LR-DWG. 45057



Pu^{239} FECAL AND URINARY EXCRETION OF ORNL EMPLOYEES HAVING THE HIGHEST FECAL EXCRETION RATE.

Fig. 10.

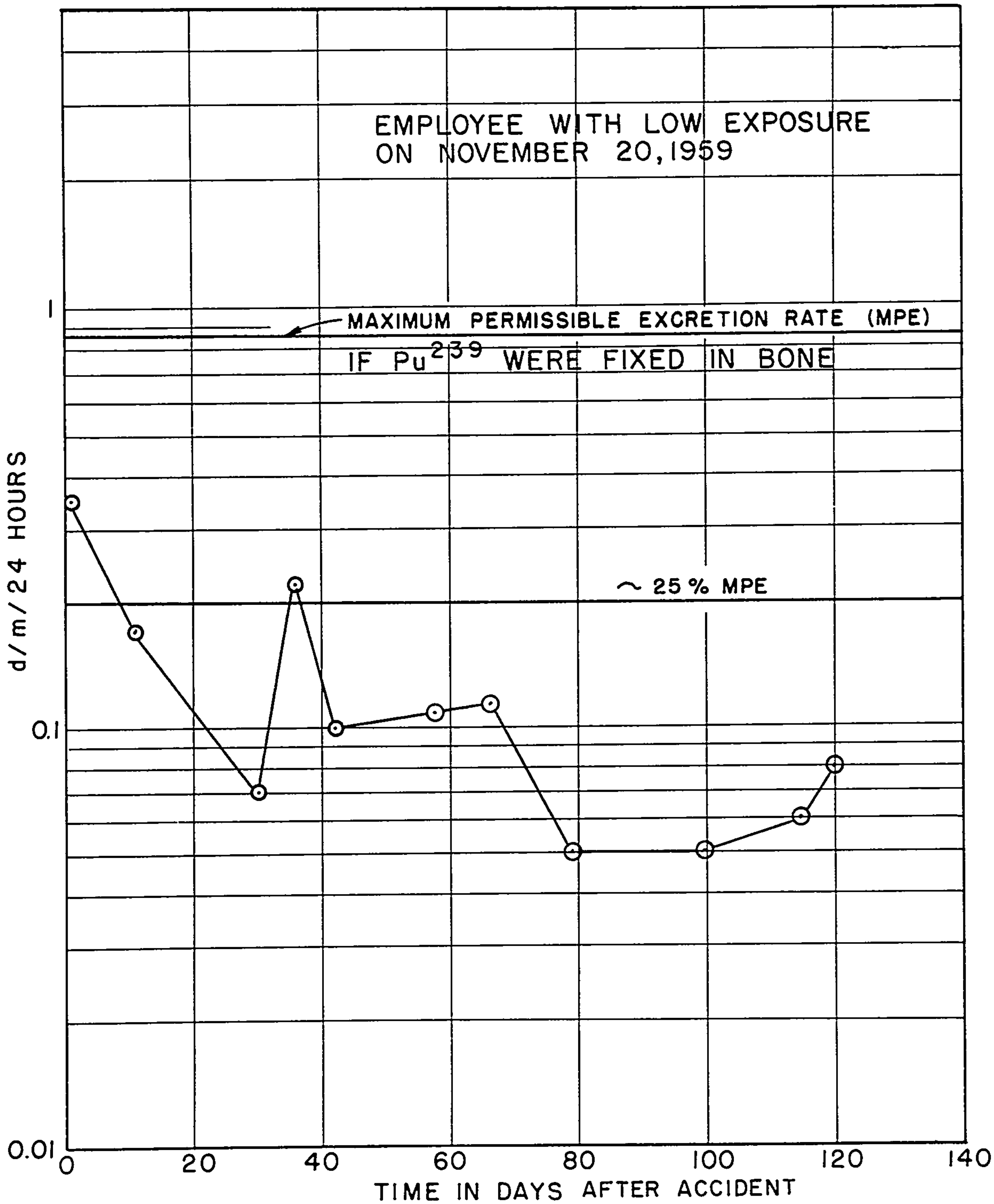
UNCLASSIFIED
ORNL-LR-DWG. 45054 R



INDIVIDUAL URINARY EXCRETION OF Pu^{239}-EMPLOYEE C

Figure 11

UNCLASSIFIED
ORNL-LR-DWG. 45062 R



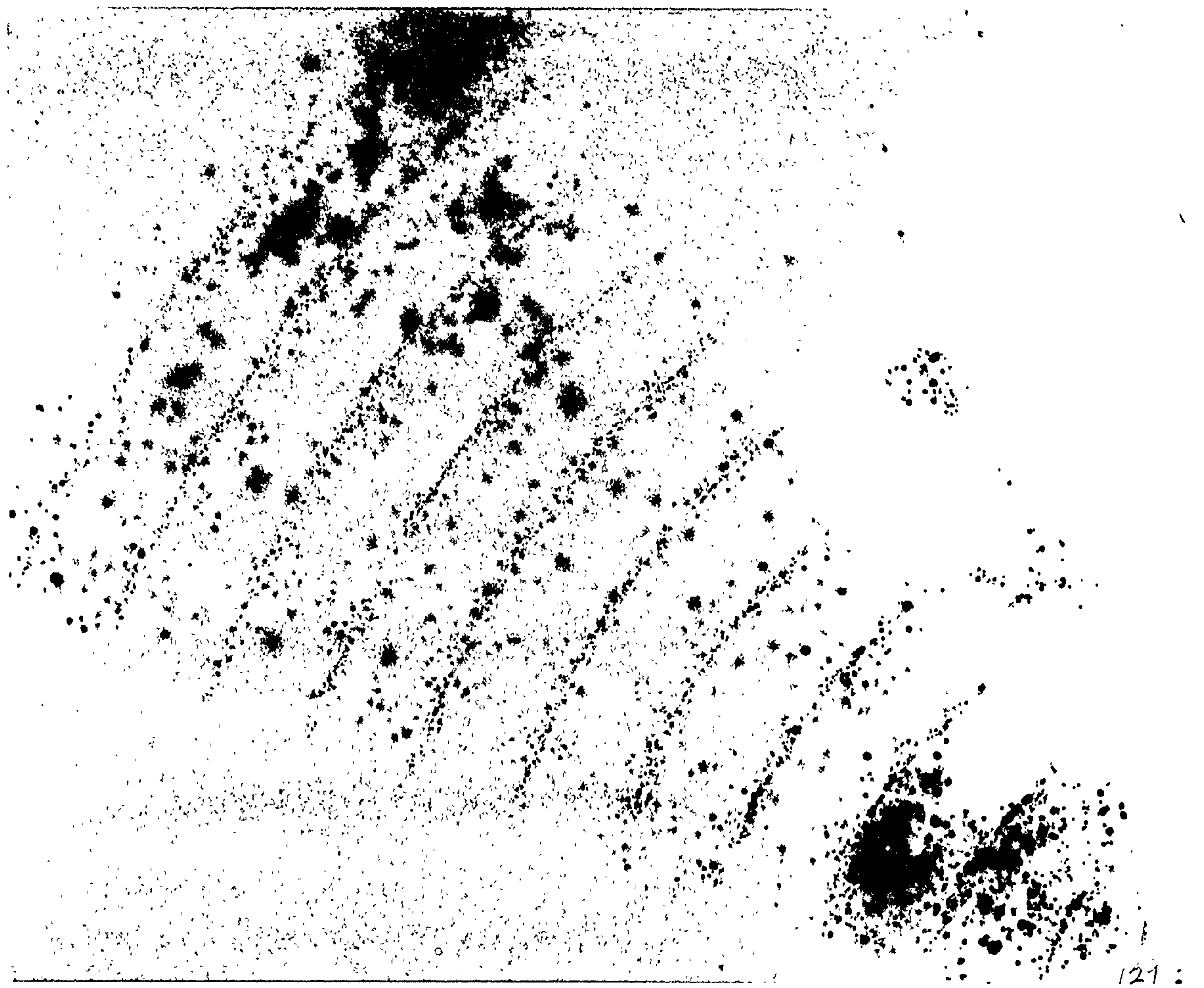
INDIVIDUAL URINARY EXCRETION OF Pu^{239}-EMPLOYEE B

Figure 12

Six persons who are considered to have been subjected to rather high Pu^{239} exposures as a result of accident No. 3 have been checked on the total body counter at Y-12. We are grateful to Y-12 and especially to C. M. West and R. E. Cofield for this assistance. Measurements on the six persons with the total body counter have indicated a detectable body burden of Pu^{239} in only one of these persons. In this case the intensity of the gamma spectrum of the Zr^{95} + Nb^{95} is so high that it is impossible to make direct measurements of the Pu^{239} from the weak, low energy gamma radiation it emits. However, assuming the same ratio of Zr^{95} + Nb^{95} to Pu^{239} in the man as in the smear samples collected from Building 3019, his body burden would be between 0.002 and 0.003 μc. Further measurements must be made to confirm these results. At present we cannot say whether this Pu^{239} is delivering an insignificant dose to the 7000 g of bone or a very large dose to a few grams of lymph nodes. If the Pu^{239} is fixed in the bone, it represents 5 to 8% of the maximum permissible body burden (0.04 μc) for the occupational worker. However, if it is fixed in only 10 g of lymph nodes it represents a much higher percent of the maximum permissible body burden. It is not surprising that the total body counter revealed traces of Pu^{239} in this one person for we found more α contamination on his skin ($\gtrsim 10^4$ d/m/100 cm^2 on his face) on the night of the accident than on anyone else who was surveyed for α contamination.

There is no question in our minds of the necessity for the wearing of complete face masks during the early clean-up operation following accident No. 3. Figure 13 is a radioautograph of one of the respirator filters worn by a person who was engaged in the early clean-up work in Building 3019. This X-ray film was exposed to the filter for 24 hours. Figure 14 is more typical

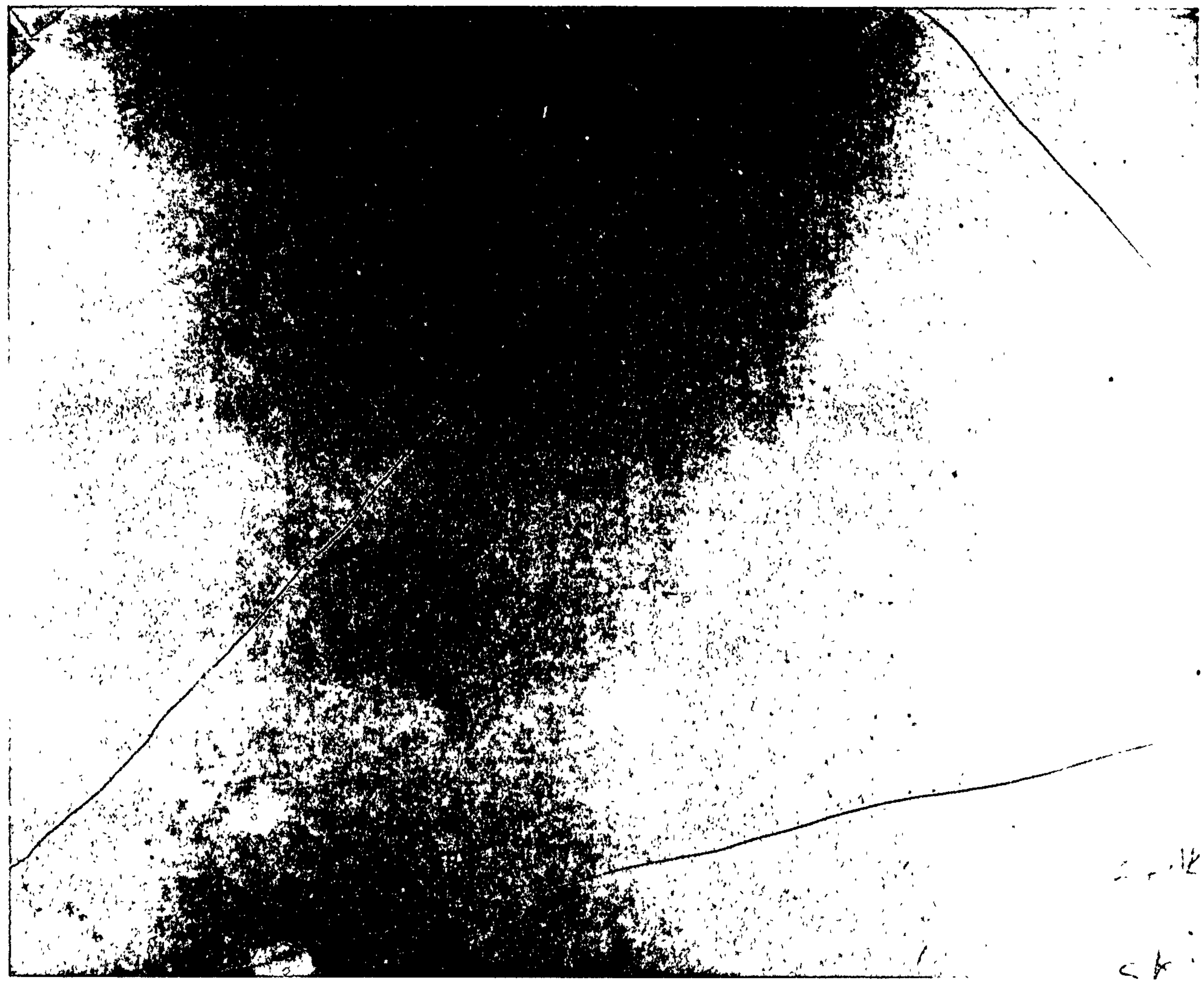
UNCLASSIFIED
PHOTO 48962



RESPIRATOR FILTER USED IN BLDG. 3019 CLEAN-UP OPERATIONS

Fig. 13.

UNCLASSIFIED
PHOTO 48961



RESPIRATOR FILTER USED IN BLDG. 3001 CLEAN-UP OPERATIONS
(24 HR AUTORADIOGRAM EXPOSURE)

Fig. 14.

of what we find on a respirator filter that has been worn after the initial clean-up. In most cases no Pu^{239} particles or only a few of them are found - as in this case - following a 24 hr exposure of a respirator filter to an X-ray film. The largest spot on this film (Figure 14) seems small and indeed it corresponds to a particle containing only 5×10^{-6} μc of Pu^{239}. However, in this case the average RBE dose within the range of the α particles is 2.4×10^5 rem/week. No one knows the significance of such exposure other than that body cells within the range of α radiation (45μ) from such a particle would be destroyed. This is just one more reason why Health Physics has been very insistent on the enforcement of rather rigid and restrictive regulations during this clean-up operation following accident No. 3.

Measurements made by B. R. Fish of the Health Physics Research group indicate that these Pu^{239} particles are very insoluble in water and in blood serum; therefore, it is not impossible that the urinary excretion of Pu^{239} by the 94 ORNL employees who have excreted at a rate in excess of 0.2 d/m/24 hrs reflects the very slow solution of "insoluble" particles in the lower respiratory tract and pulmonary lymph nodes.

I would like to say one final word about the maximum permissible occupationa exposure levels that are used by our Health Physics Division. These levels are established by the National Committee on Radiation Protection, NCRP, and the International Commission on Radiological Protection, ICRP, while the operating levels we set in the Laboratory are designed by us to make certain that the official levels are not exceeded. Table 7 summarizes the maximum permissible occupational exposure levels for the various body organs as specified by the NCRP and the ICRP. In the case of Pu^{239} and other bone-seeking radionuclides the RBE dose rate to the bone is 30/n rem/yr in which n, the radiation hazard factor, is equal to 5 for Pu^{239}. Thus the dose limit for Pu^{239} in the bone is about 6 rem/yr while for Ru^{106} in the gonads and total body it is 5 rem/yr. Some of you may believe, and in fact several of you have stated, that these levels are inordinately low. We can argue this issue but I doubt if at the present time I can convince you that you are wrong. As you well know there have been conducted many animal experiments at low dose rates of exposure to ionizing radiation, some of which seem to indicate damage at any dose rate (no matter how low) and others which might suggest a threshold dose or even a benefit from exposure at low dose rates.

The total body dose at the maximum permissible occupational dose rate for 50 years of occupational exposure would result in an accumulated dose of 250 rem. Although 250 rem is the maximum permissible dose for 50 years of occupational work such accumulated dose should be avoided, especially when a large number of employees is involved because it would most certainly produce some damage. The level of maximum permissible dose was established on the basis that any resulting damage would not be readily detectable in a single individual and the total expected damage would be no greater than that commonly accepted from other ordinary industrial hazards. I cannot be a Health Physicist and not recognize and point out to you the wisdom and prudence of avoiding all unnecessary exposure to ionizing radiation. The average accumulated RBE dose of all ORNL employees is 5.99% of the maximum permissible value or it is only 0.3 rem/yr/person, and we as health physicists intend to do all we can to maintain this good record. For comparison this average RBE dose rate of ORNL employees is only 2 to 3 times the natural background dose or 3/5 the value

Unclassified
ORNL-LR-DWG. 52781

TABLE 7

PRESENTLY RECOMMENDED PERMISSIBLE DOSE TO BODY ORGANS OF OCCUPATIONAL WORKERS EXPOSED TO IONIZING RADIATION

Body Organ	Maximum RBE Dose in any 13 weeks (rem/13 wk)	Average RBE Dose in one year (rem/yr)	Accumulated RBE Dose to age N ≥ 18 years (rem)
Blood forming organs	3 ICRP NCRP FRC	5 ICRP NCRP	5(N-18) ICRP NCRP FRC
Total body	3 ICRP NCRP FRC	5 ICRP NCRP	5(N-18) ICRP NCRP FRC
Head and truck	3 NCRP FRC	5 NCRP	5(N-18) NCRP FRC
Gonads	3 ICRP NCRP FRC	5 ICRP NCRP	5(N-18) ICRP NCRP FRC
Lenses of eyes	3 ICRP NCRP FRC	5 ICRP NCRP	5(N-18) ICRP NCRP FRC
Skin	8 ICRP 10 NCRP FRC	30 ICRP 30 NCRP FRC	30(N-18) ICRP 30(N-18) NCRP FRC
Thyroid	8 ICRP NCRP 10 FRC	30 ICRP NCRP FRC	30(N-18)) NCRP ICRP FRC
Feet, ankles, hands and forearms	20 ICRP 25 NCRP FRC	75 ICRP NCRP FRC	75(N-18) NCRP ICRP FRC
Bone	30/4n ICRP NCRP	30/n ICRP NCRP	30/n(N-18) NCRP ICRP
Other single organs	4 ICRP 5 FRC	15 ICRP NCRP FRC	15(N-18) NCRP ICRP FRC

suggested by the ICRP as a maximum permissible dose rate for members of the population-at-large. Figure 15 shows the accumulated dose of the 10 ORNL employees who have accumulated the highest doses. Only one of these has exceeded the age prorated dose given in the equation 5(N-18) in which N is the age of the employee. This good record can be maintained only with your full cooperation and active support.

UNCLASSIFIED
ORNL-LR-DWG 45075 A

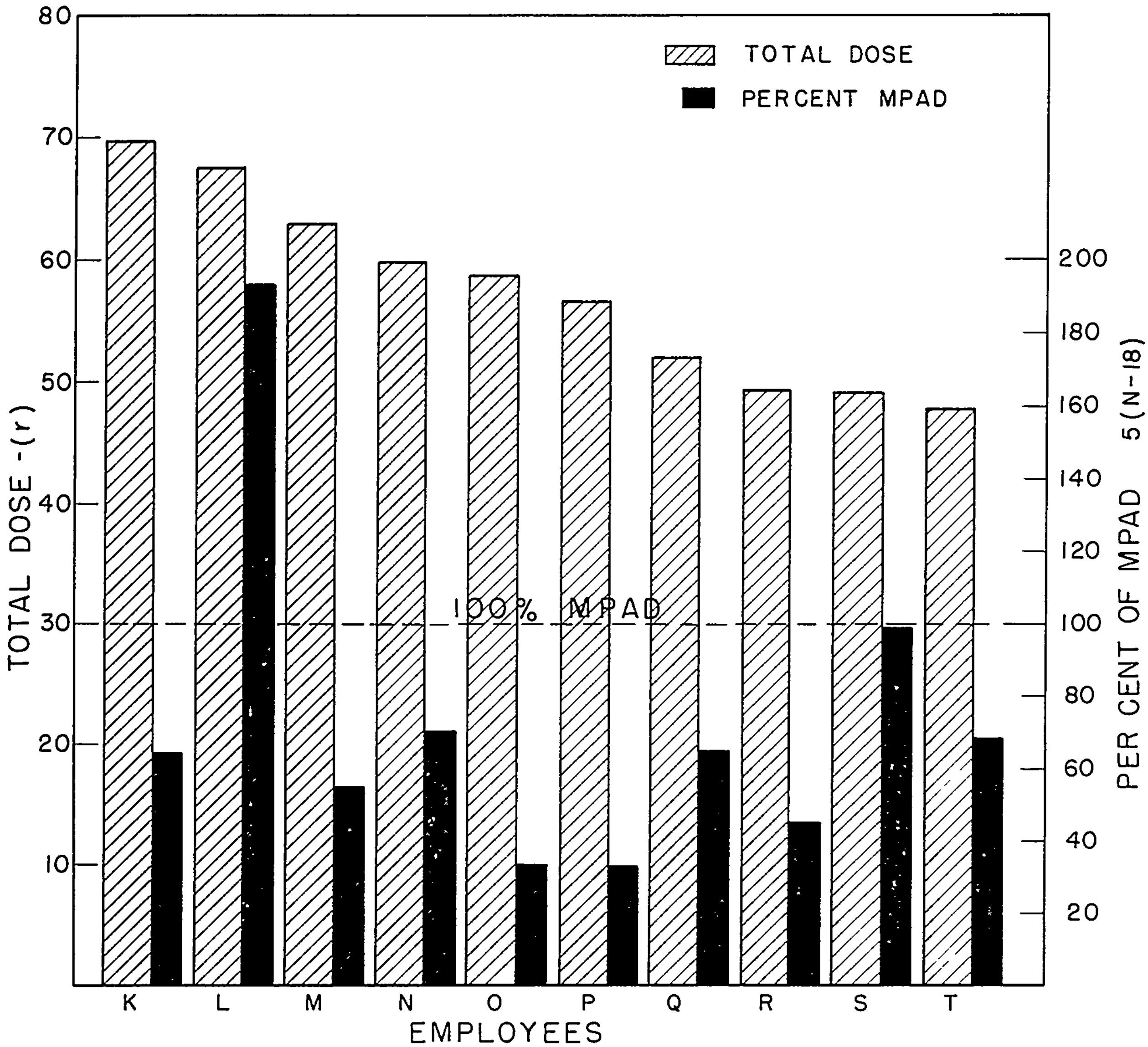


FIG. 15 10 HIGHEST RADIATION EXPOSURES THROUGH 1959

Distribution:

1. J. A. Swartout
2. C. E. Center
3. A. M. Weinberg
4. W. H. Jordan
5. F. R. Bruce
6-7. K. Z. Morgan
8. E. G. Struxness
9. W. S. Snyder
10. S. I. Auerbach
11. B. R. Fish
12. J. C. Hart
13. G. S. Hurst
14. D. M. Davis
15. A. D. Warden
16. M. F. Fair
17-27. Laboratory Records