required for identification was considered unwarranted because of the radiation hazard. In retrospect, more sections should have been obtained in order to investigate their state of post-mortem preservation. The section of testis (Fig. 6) showed preserved mitotic figures, spireme in the spermatocytes, and, in general, normal cytology of all cells except the spermatogonia, which were almost all densely pyknotic. The cells of Leydig were all autolyzed and not recognizable.

3.4 Causes of Death

The deaths of the 3 men were individually quite different, even though they were in a small area which was subjected to a severe blast for a short time. RA-1 died as the result of hemorrhage from the avulsion of his left hand and the right side of his face, along with the intracranial subdural hemorrhage that followed a lacerating blow to the top of his head. He lived a short time (about 2 hours) unconscious and in deep shock after the explosion. RA-2 died the instant he struck a flat surface that fractured his chest and drove a rib through his heart. External hemorrhage from his blast wounds was post mortem. RA-3 died instantaneously from the destruction of his viscera by rapidly expanding gases that penetrated his abdominal cavity along with a heavy missile.

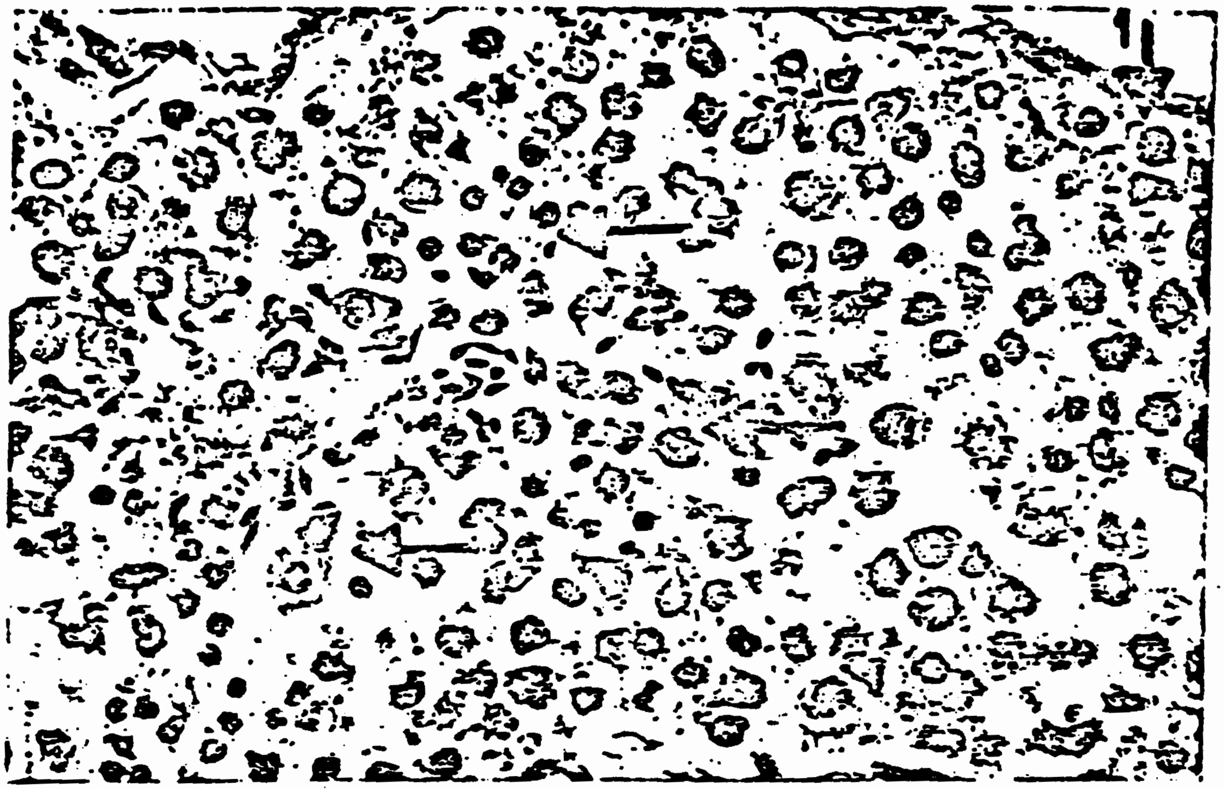

Fig. 6. Photomicrograph (X 700) of a testicular tubule from RA-3, formalin-fixed 9 days after death. Post-mortem autolysis is minimal. Arrows point to (1) pyknotic spermatogonia; (2) normal appearing spermatids and sperm; (3) normal spireme in a spermatocyte; and (4) a recently completed but pyknotic mitosis.

3.5 Biochemical Findings

Samples were obtained for chemical estimation of fast neutron dose from the hair removed from the head and pubis of these men. Previous studies (3) had shown that quantitative isolation of radiophosphorus from hair exposed to fast neutrons afforded an excellent means of estimating total neutron doses of known energy distribution. In the present investigation, heavy contamination of the samples by fission products imposed the problem of separating P^{32} activity from large amounts of other beta and gamma radioactivity. The samples were handled preliminarily in a hot cell, where they were washed successively with detergents, water, and organic solvents. Residual radioactivity was then 30 r/hr. They were then decontaminated further chemically (4) and the phosphorus ultimately isolated after a series of repetitive precipitations as magnesium ammonium phosphate hexahydrate, which was then radioassayed.

The assumption was made that all P^{32} activity in the samples was the result of fast neutron activation. The results of this investigation, which are summarized in Table 3, showed that a critical excursion of the order of 3×10^{18} total fissions had occurred at the time of these fatalities. These data suggest that all 3 men received large neutron doses to the head. The amount each man appeared to have

TABLE 3. NEUTRON DOSIMETRY BASED UPON RADIOCHEMICAL PHOSPHORUS^{32} ANALYSES OF HAIR SAMPLES

Sample No.	Source	Flux Detected by Sulfur (n/cm^2)	Dose > 2.5 Mev (rads)	Deduced Position
RA-1	Head	2.04×10^{12}	7.81×10^{3}	Partially shielded
	Pubis	8.27×10^{9}	3.17×10^{1}	Shielded
RA-2	Head	2.84×10^{13}	1.08×10^{5}	Exposed
	Pubis	4.85×10^{11}	1.86×10^{3}	Partially shielded
RA-3	Head	9.26×10^{12}	3.54×10^{4}	Exposed

*3×10^{18} total fissions, based on the average flux detected by all samples except the pubis from RA-1, and assuming an energy distribution comparable to the Los Alamos Omega West Reactor.

received corresponded well with the reconstruction of the scene of the accident based upon the blast injuries. Since an indeterminate amount of the isolated P^{32} activity could have resulted from contamination by phosphates in reactor water previously activated during operation of the reactor, these neutron dosage estimates may be fallacious. However, they are certainly useful in positioning the men in relation to the source of radioactivity and its explosion.

3.6 Reconstruction of Positions of the Men at Time of the Accident

Study of the nature, distribution, and severity of the blast wounds of these men enabled a reconstruction of their most likely positions and relationships to one another and to the blast at the time the accident occurred (Figs. 7, 8, and 9). RA-1 was obviously the most distant because he received the fewest and least severe blast injuries and was the only one wounded by flying missiles from the reactor shield. He was most likely standing with his left leg and hand nearest the reactor, facing the other 2 men. His right hand and arm were away from the blast, either behind him or behind an object he was carrying into the area (Figs. 8 and 9). RA-2 and RA-3 were both blasted severely and must, therefore, have been upon the reactor top. The

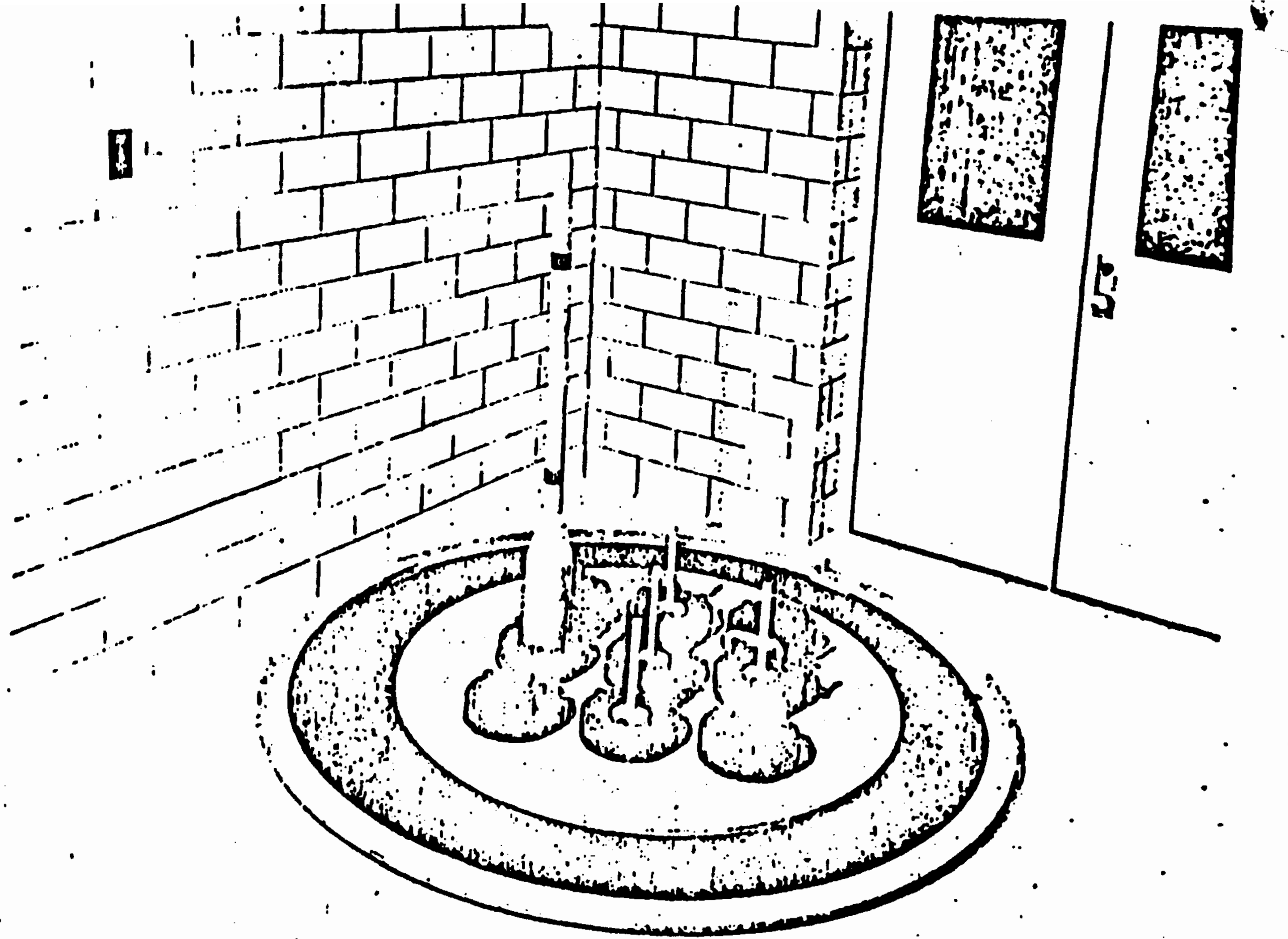

Fig. 7. Mock-up of SL-1 reactor top used to position subjects in order to reconstruct the scene at the time of the accident. The C-clamp identifies port No. 1; the bell housing covers port No. 5.

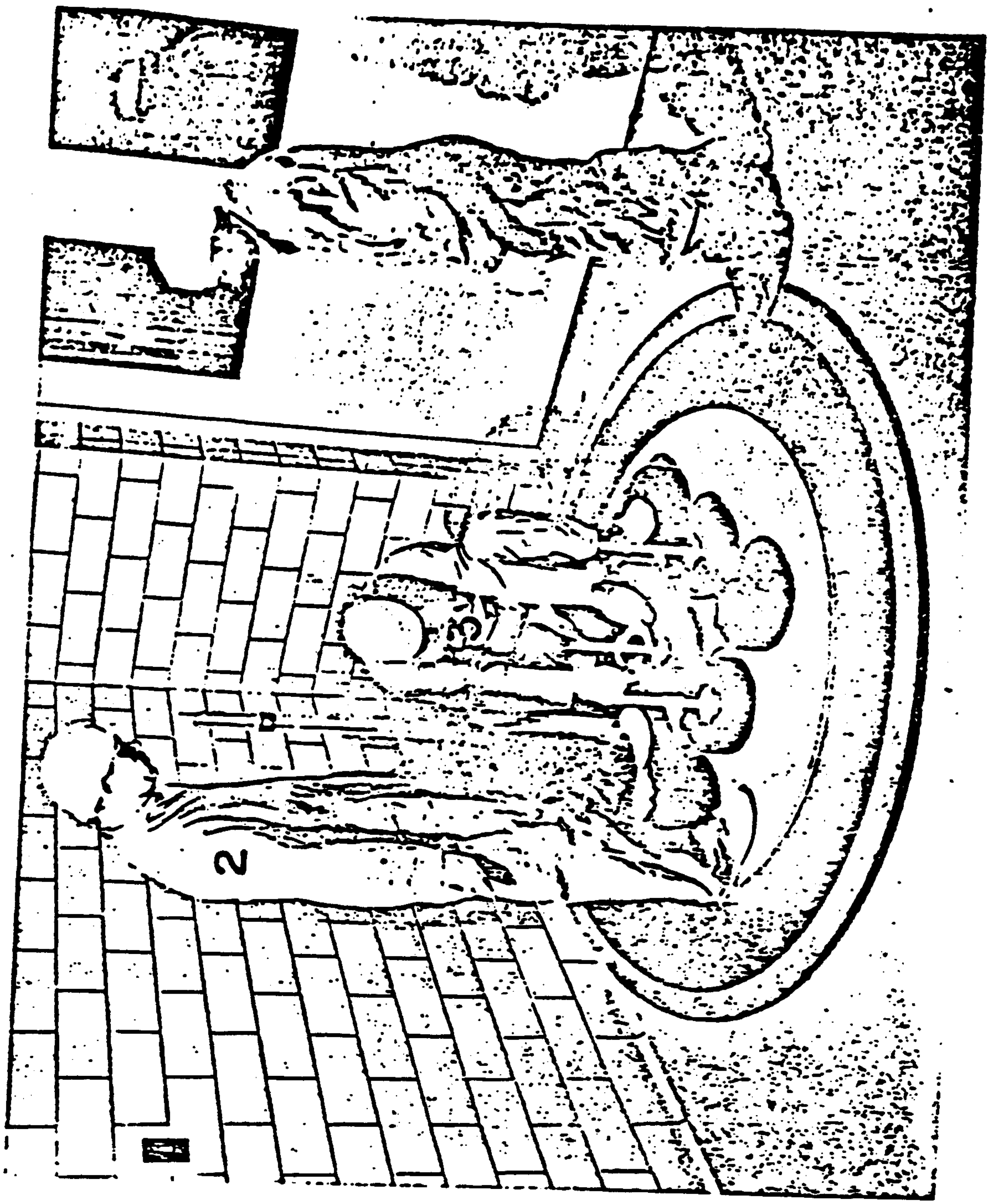

Fig. 8. Simplest positions for all 3 men that seem to satisfy the requirements for causing their blast wounds. The numbers identify them as RA-1, RA-2, and RA-3.

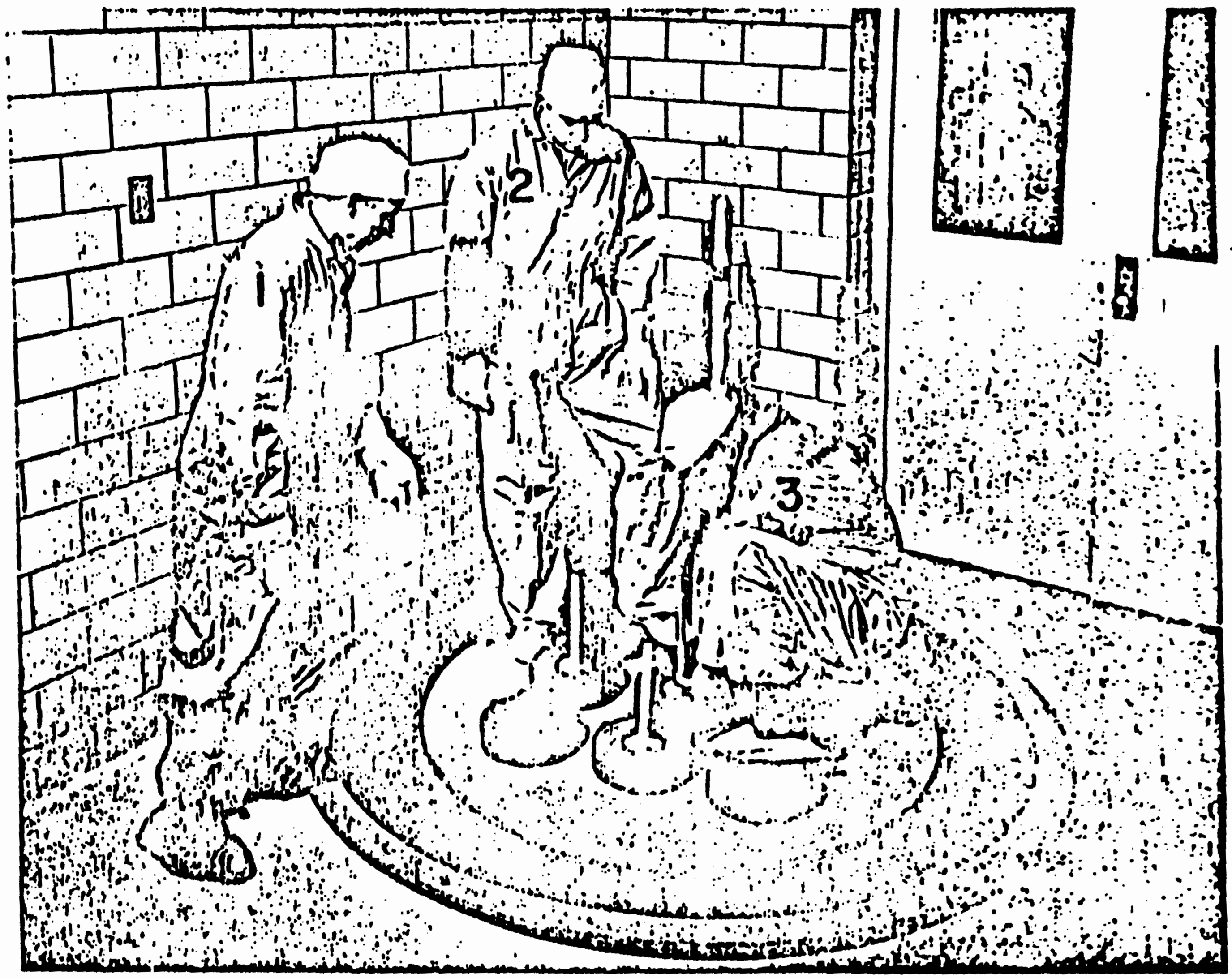

Fig. 9. Simplest positions for all 3 men that seem to satisfy the requirements for causing their blast wounds at 90° counterclockwise from positions given in Fig. 8.

fact that the right foot of RA-2 was not injured, while his lower left leg and foot were demolished, seemed to indicate that his right leg was to the outside or adjacent to a reactor port that did not explode, while his left leg was in the midst of the blast. He was in a standing position facing slightly outward, since he was struck chiefly from below and behind so that his buttocks, left hip and upper leg, and back of right knee were destroyed (Fig. 9). The dilemma of blast injury to his face (on the side of his body uninjured by blast) can be resolved by turning his head to look back over his shoulder under an outstretched arm or between his legs. His uninjured hands must have been up and out of the vortex of the blast or protected by his body.

The multiple severe blast wounds of RA-3 indicated that he was the closest in and right over the principal upward force. His wounded ankles, thighs, hands, face, and head appeared at first glance to be randomly distributed and widely separated from one another by large comparatively unharmed areas. That they all could have occurred simultaneously in a small confined area of rapidly expanding forces is seen when a man is placed in a squatting position with his head bent down as he watches what he is doing with his hands inside his ankles (Figs. 8 and 9). This position appears to satisy not only the requirements of his external injuries but shows how the blast could also have penetrated his abdomen and simultaneously destroyed his viscera. While this reconstructed scene probably is not exactly correct, it appears to be sufficiently well fixed by the nature of the wounds to warrant the important conclusion that these men were carrying out their assigned task in accordance with the standard operating procedures in which they had been trained.

CHAPTER 4

SUMMARY

A 9 man team, comprised of 1 pathologist, 2 physicians, 1 radiobiologist, and 5 health physicists, decontaminated and autopsied 3 men heavily contaminated with radioactive materials. Although surface level exposure rates were in excess of 500 r at the beginning of the operation, final radiation levels (with 1/8 to 3/4 in. lead) were below 650 mr/hr. None of the personnel involved received in excess of 4 r. The autopsies showed that 2 of the men died immediately and 1 within 2 hours from the primary and secondary wounds they received. The distribution and nature of these wounds, along with chemical dosimetric studies of hair samples, enabled a logical reconstruction of the scene at the time of the explosion, which led to the conclusion that the explosion occurred while standard operating procedures were being followed.

This investigation showed that complete autopsies can be done safely upon men emitting large amounts of gamma activity and that the autopsy procedures themselves can be a material aid in physical decontamination of such bodies and in preparation for their burial. In addition, the following recommendations were derived from this experience for the design of a room for decontamination of radioactive dead bodies:

1. Sinks large enough to hold a human body are absolutely necessary; this room should be equipped with remotely operated water and drains which cannot be plugged by bodies or debris.

2. A portable lead shield with a lead-glass viewing area should be provided, and arm ports should be available for positioning in front of the sink.

3. Vertical pits in the floor of the room (6 feet deep and 3 feet wide) could be used to shield bodies not being decontaminated and to hold heavily contaminated materials for future disposal.

4. A remotely controlled overhead crane should be available for lifting and moving bodies, which should be brought to the facility with a rope sling under the arms and about the chest. These slings should have quick connect-disconnects.

5. If contamination by plutonium is conceivable, the

room should have airlock entrances and exits.

6. The room should be uncluttered and easily cleanable. Large trucks should be able to enter it.

7. Lead casks should be designed no deeper than necessary to hold and shield human bodies to expedite immediate transportation. This cask should have drains operable from the outside.

8. Shielded deep-freeze units should be available and large enough to store whole bodies and biologic samples.

9. Studies of decontamination of experimental animals should be made of various decontamination agents, collodion and strippable agents, and perhaps ultrasonic cleansing procedures.

The following recommendations concerning chemical dosimetry were made:

1. Samples should be taken under conditions as close to those extant at time of the incident as possible and before decontamination procedures are instituted. If a living patient is involved, the sampling would have to be done immediately, since it would not justify a delay in decontamination, and appropriate personnel (i.e., first-aid and rescue people) should be aware of sampling techniques, if dose information from conventional dosimetry systems is not available.

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