

FEB 7 1969

J. R. Rosder, Chief, Materials Inspection
& Enforcement Branch, Division of Compliance

NUCLEAR MATERIALS AND EQUIPMENT CORPORATION
609 NORTH WARREN AVENUE
APOLLO, PENNSYLVANIA 15613
PLACE OF USE: QUEHANNA, PENNSYLVANIA
LICENSE NO. 37-04456-08

Transmitted herewith is the subject investigation report involving non-compliance, for appropriate enforcement action.

The investigation, although establishing that the inadvertent opening of a hot cell containing 50,000 Ci of Co-60 did not result in personnel radiation exposure, it did reveal serious deficiencies in adherence to procedures and maintenance of controls governing hot cell use.

The corrective action taken by the licensee to correct the specific defects noted appears adequate and it is believed that the operations at Quehanna are currently being conducted safely. CO:1 is concerned, however, that the primary cause of the incident namely a breakdown in management control, was discovered by the licensee only as the result of a near serious incident. It is therefore suggested that the licensee be asked as to why the administrative checks made by the Corporate Hazards Review Committee during its periodic surveillance of Quehanna operations failed to reveal the unsafe situation. Furthermore, it is suggested that the licensee be requested to submit a description of the corrective measures being taken to ensure adequate management control.

Please note that the NUMEC manual dated August 1967, and included in Condition 15 of the license appears to be applicable only for those radioisotopes described in subitems A and B of the license. Inasmuch as the manual covers many facets of the Quehanna facility operation such as administrative control, organization, operational responsibilities, personnel qualifications, waste disposal, and radiation safety, all of the radioisotopes authorized by the license should be subject to the provisions of this manual. Since the licensee reportedly is revising the manual and will be submitting it for licensing approval, it is recommended that at that time this needed change be incorporated.

OFFICE ▶	COMPLIANCE:					
SURNAME ▶	<i>Nelson</i> Epstein:dmm	<i>Nelson</i> Nelson	Kirkman			
DATE ▶	2/7/79					

Information from AEC-315 (Rev. 1-68) deleted
in accordance with the Freedom of Information
Act, exemptions 6
EOIA- 2004-171

B-2

It should also be noted that license authorization to irradiate material in hot cells is rather ambiguous. Authorization as set forth in 9A of the license appears to exclude such use, however, Chapter I - Introduction of the manual, included in Condition 15, sets forth the use as "to encapsulate irradiation sources, load irradiation equipment, and perform gamma irradiation". It is suggested that authorization of such use be clarified when the licensee submits the revised manual for licensing approval.

CO:1 plans to reinspect the licensed activities immediately following completion of enforcement action. Particular inspection emphasis will be directed at management control and follow-up.

CO:1:EE

Paul E. Nelson
Senior Radiation Specialist

Enclosure:
Original and 3 cys of report.

COMPLIANCE INVESTIGATION REPORT

DIVISION OF COMPLIANCE

Region I

Subject: NUCLEAR MATERIALS & EQUIPMENT CORPORATION
609 NORTH WARREN AVENUE
APOLLO, PENNSYLVANIA 15613
PLACE OF USE AND OCCURRENCE: QUERHANA, PENNSYLVANIA
LICENSE NO. 37-04456-08

Type of Case: Miscellaneous - Hazardous situation caused by an
inadvertent opening of a hot cell containing
50,000 curies of cobalt-60.

Period of Investigation: January 6 - 7, 1969

Investigator:

Eugene Epstein, Radiation Spec.

FEB 7 1969

Date

Reviewer:

Paul R. Nelson, Sr. Radiation Spec.

FEB 7 1969

Date

REASON FOR INVESTIGATION

Based upon a DIX from the licensee, dated December 28, 1968, an investigation was conducted to determine the circumstances concerning the inadvertent opening of a door to a hot cell containing 50,000 curies of cobalt-60, and the possible exposure to the employee involved.

SUMMARY

A health physics technician, at 4:00 pm on Friday, December 27, 1968, was directed by the resident RSO to make air surveys in Hot Cell #2 in preparation for a cell entry. Earlier in the day 50,000 Ci of Co-60 had been placed in the cell by a hot cell trainee for irradiation effect studies on methyl methacrylate monomer. The licensee was conducting this hot cell work using only a hot cell trainee without benefit of a supervisor or the guidance of a hot cell operator. Further more this work was being performed without the issuance of a required radiation work permit. The HP technician inquired of the hot cell operator trainee whether it was safe to enter Cell #2 and was told that it was safe. Given permission to enter the cell, the HP technician obtained the operations key to the cell and began to open the heavy cell door, standing behind the door as he operated the differential chain drive. When the door had moved approximately 1" to 3" an area alarm sounded and he observed that his survey meter, positioned at the crack, was off-scale. Without moving from behind the door he immediately closed the door and left the area. The resident RSO calculated that the maximum radiation exposure which the HP technician could have received, if he had been directly in the beam, as 18 rem. Reenactment of the incident indicated that no overexposure occurred as the technicians whole body and extremities were shielded by the hot cell door which was constructed of high density concrete 15 inches thick. This was substantiated by his film badge which, although including the previous 26 days, showed only a dose of 200 mrem.

The incident resulted primarily from a breakdown in administrative control which permitted a trainee to conduct hot cell operations, acting as both the hot cell operator and the supervisor.

Licensee management reportedly has reemphasized current operating procedures, with respect to hot cell door opening, and now has a qualified operations supervisor to ensure all applicable procedures are being followed.

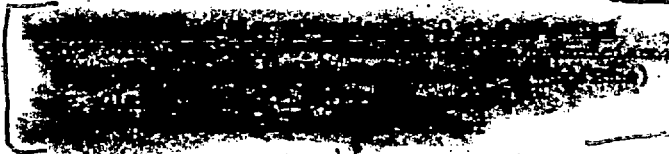
Items of Noncompliance which Contributed to the Incident

- a. Hot Cell operations on December 27, 1968 were being conducted not by a hot cell operator but rather by a trainee who was not under the supervision of a shift supervisor or cell operator as set forth in chapters 4.2.1 and 4.2.2 of the application dated August 16, 1967, included as part of License Condition No. 15. See paragraphs 4, 6, 7, 8, 12, 13, 21, 22, of the Details.
- b. [REDACTED] a hot cell operator and acting shift supervisor does not have the qualifications for these positions. [REDACTED] a hot cell operator trainee who acted as both hot cell operator and supervisor on December 27, 1968 does not have the qualifications for these positions. The minimum qualifications are set forth in chapters 4.4.1.1.2, 4.4.1.1.3 and 4.4.1.2. of the application of August 16, 1967 included as part of License Condition No. 15. See paragraphs 4, 6, 7, 8, 12, 13, 20, 21, 22, of the Details.
- c. A key to Hot Cell #2 was not under the control of the shift supervisor on December 27, 1968 as specified in chapter 10 (10.4.4.3.3) of an application dated August 16, 1967 and included as part of License Condition No. 14. See paragraphs 6, 7, 8, 13, of the Details.
- d. A radiation work permit was not initiated or issued for the irradiation polymerization studies being performed in Hot Cell #2 contrary to chapter 10.4.5 of the application of August 16, 1967 included as part of License Condition No. 15. See paragraphs 23 and 24 of the Details.

Other items of Noncompliance Related to the Incident

3. The health physics technician was not wearing a self-reading dosimeter pen at 4:00 pm on December 27, 1968 when he was opening the doors to the hot cell containing 30,000 Ci Co-60 as required by procedures set forth in chapter 10.5.2.1, 2.1 of the application dated August 16, 1967 included as part of License Condition No. 15. See paragraph 9 of the Details.

Persons Interviewed:



Persons Accompanying Inspector:

Mr. Joel Lubanau and Mr. Sheldon Levin, both from the Pennsylvania Division of Radiological & Occupational Health

Exhibits:

- A - Drawing of Hot Cell #2, isolation room and location of area monitors.
- B - Calculations

DETAILS

1. A TWX transmitted Saturday, December 28, 1968, at 11:45 am by the licensee was telephoned to this office from NYOO on December 30, 1968. The licensee failed to reach COI on December 28, 1968, because of mistakenly telephoning COI at Newark rather than NYOO. The TWX informed us that on December 27, 1968 at approximately 4:30 pm, a health physics technician partially opened a concrete door of a hot cell in which 50,000 Ci of Co-60 was exposed.
2. Although it was believed a significant radiation exposure had not occurred, an investigation was initiated because of the potential for injury associated with this incident and the indication that administrative control had broken down.

Background Information

3. The last previous inspection was performed October 28 - 31, 1968 and the results reported using Form AEC-392. Four items of noncompliance were noted not relating to the current incident. The inspector, however, in his evaluation of the licensee's program stated that the hot cell operations staff was over burdened by mass resignations in August 1968; therefore, one person was doing all cell entries, decontamination, encapsulation, etc., and that such a heavy workload on one person increased the likelihood of an accident.

Statement

4. [redacted] stated that on Friday morning, December 27, 1968, he, together with [redacted] and [redacted] entered Cell #2, to position within the cell a wooden rack containing 50 vials filled with methyl methacrylate monomer. He added that prior to this entry an air survey was conducted. He stated that he was aware that Owens was going to place two stainless steel plaques inside Cell #2 and that each plaque contained 25,000 Ci of Co-60 in the form of 12" long pencils for the purpose of irradiating the methyl methacrylate. [redacted] at that time indicated he wanted the samples withdrawn at 4:00 pm.
5. [redacted] stated he forgot about the 4:00 pm withdrawal request because he had a doctor's appointment at that time and had changed into his street clothes at 3:30 pm, when he was informed by [redacted] that the samples would have to be withdrawn and that an air sample would have to be taken prior to [redacted] entry into Cell #2.
6. [redacted] stated that [redacted] was not in the hot cell operations area at 3:30 pm and he located him at the large pool where [redacted] was engaged in transferring 80,000 Ci of Co-60 from the small irradiation pool to a plaque at the bottom of the large irradiation pool. He stated he asked [redacted] if it was alright to enter Cell #2 and that [redacted] replied "O.K.". He stated that he then entered the operations area and removed the operations hot cell key from a desk drawer and using this key and the health physics key proceeded to open the two padlocks attached to the 3-1/4" thick wooden entrance door of the isolation room immediately in the rear of Cell #2.
7. [redacted] was asked by the inspector if he knew that this was a violation of authorized procedures described in chapter 10 of supplementary information to an application dated August 16, 1967, included as part of License Condition No. 14. [redacted] stated he knew he should not have used the operations Staff hot cell key, but that [redacted] hot cell operator and acting shift supervisor, was on vacation since December 24, 1968, and [redacted] the only other hot cell operator, was engaged in transferring sources so he felt he could use both keys and not disturb [redacted].
8. Chapter 10, 4.4.3.3, of the above described application states, "Areas where radiation levels are greater than 25 r/hr, these areas are locked with two separate locks, one of which is controlled by the shift supervisor and one by the Health Physics representative on duty. Both locks must be unlocked to gain access". [redacted] agreed with the inspector that the operations key was not under the control of the shift supervisor. He also stated that there is no actual shift supervisor and that [redacted] who acts as shift supervisor as well as hot cell operator was on vacation.

9. [redacted] stated that he took a Jordan "Rad-Gun" survey meter with him and that he put a laboratory coat and plastic shoe covers over his street clothes. A film badge was attached to his left breast pocket. He stated that he forgot to wear a self-reading dosimeter pen because of the change to street clothes. He stated he knew that this was an item of non-compliance since chapter 10.5.2.1.2.1 Personnel Monitoring of the August 1967 application, states, "all persons entering the hot cell area must wear a personal gamma dosimeter, such as a film badge, TLD dosimeter gamma pencil or self-reading dosimeter. In addition, personnel assigned to work in the hot cell area must wear a dosimeter which may be evaluated quickly, such as self-reading or TLD dosimeters". [redacted] stated he is one of two persons assigned to work in the hot cell area and is required to wear a dosimeter pen.

10. [redacted] stated that he entered the isolation room in the rear of Cell #2 and approached the 15" thick high density concrete shielding doors of the hot cell and noted surface radiation readings at the center joint where the shielding doors interlocked of 30mr/hr and 4-6 mr/hr at 15" distance. He stated he thought that these radiation levels were unusual but attributed them to scatter radiation because of 80,000 Ci Co-60 stored in Cell #1 and 600 Ci fission products stored in Cell #3.

11. [redacted] stated he remained behind the 3' wide and 15" thick left concrete door and started with his left hand to pull the differential chain drive to open the doors and that as he was pulling the chain he heard an audible alarm sound. He stated he looked at his Jordan Rad-Gun which was in his right hand with the end immediately in front of the 3" wide crack in the 15" thick shielding doors and noted that the indicator had pegged at a maximum reading of 10 r/hr on the IX scale. He stated that remaining where he was, he immediately closed the shielding doors of the hot cell using the differential chain and retreated rapidly out of the isolation room. He estimated that he was at the shielding door for no longer than 10 seconds and that at all times his body and hands were shielded by 15" of high density concrete. He stated that he and [redacted] who had responded upon hearing the audible alarm, went into the operations area and visually noted via the call viewing glass that two plaques containing a total of 50,000 Ci Co-60 were in Cell #2 approximately 9' from the inner surface of the 15" thick rear shielding doors.

Statement of [redacted]

12. [redacted] stated that he had been working at Qushanna since April 22, 1968, and started as a hot cell operator trainee on 9/3/68. He stated he is a high school graduate and had no prior nuclear experience.

13. [redacted] stated that on Friday, December 27, 1968, at 8:00 am, he was requested by [redacted] to place 50,000 Ci of Co-60 in Cell #2 because he had samples which he wished irradiated. [redacted] stated he did so after [redacted] had placed the specimens to be irradiated in the cell. He stated that both he and [redacted] were present for the cell door opening when [redacted] entered. He stated [redacted] told him he wanted the samples out at 4:00 pm. [redacted] stated that for the remainder of the day he was in the irradiation pool area transferring Co-60 sources from the small pool to the large pool and that [redacted] approached him about 4:00 pm and asked if it was alright to enter Cell #2. He stated he replied "O.K.". He stated he forgot that the sources were still in Cell #2. [redacted] stated he knew it was a violation of procedures to allow [redacted] to open the door of the isolation room to Cell #2 alone, but that he was occupied at the time and couldn't drop what he was doing. He stated this had not happened before because [redacted] the acting supervisor, was usually present and some one was available to follow the proper cell door opening procedures. He stated that [redacted] on January 7, 1969, was still on vacation and he, although a trainee, was still working alone.

14. [redacted] stated he attended a lecture in radiation safety given in November by [redacted] and was trained in hot cell SOP by [redacted] but that due to the pressure in building up the large pool to 375,000 Ci Co-60 for irradiation of wood products he forgot what he was doing.

Statement of [redacted]

15. [redacted] stated that at about 3:30 pm, December 27, 1968, he told [redacted] to make required surveys in Cell #2 because [redacted] wished to enter to retrieve the methyl methacrylate. [redacted] described the 50,000 Ci in Cell #2 as contained in two stainless steel plaques 12" high, 10" wide and 2" thick, and that each plaque contained 30-40 pencils 12" high for a total of 25,000 Ci per plaque. He stated that at about 4:00 pm he heard an audible alarm sound and he rushed into the operations area and noted that an audible and visible alarm on the Jordan area monitor in the service area above the entrance to the decontamination room had energized at an alarm level of 20 mR/hr and that a Jordan area monitor which has no visible alarm and which was located in the service area about 20 ft distance from the decontamination area monitor had alarmed at a pre set limit of 30 mR/hr. He stated he depressed the acknowledgment button on the alarm readout control located in the hot cell operations area. This halted the audible alarm. He stated that he ran to the service area behind the hot cells and saw [redacted] who told him what happened.
16. [redacted] stated he removed [redacted] film badge and sent it to Eberline for immediate processing. He stated [redacted] had worn the film badge since December 1, 1968. He stated he received notification from Eberline on December 30, 1968 that the film badge had an exposure of 200 mrem gamma. [redacted] radiation exposure during this period as shown by weekly dosimeter readings, totaled 240 mR. He stated he made a calculation assuming that all the Co-60 was contained as a point source and that a major portion of [redacted] body was in the beam at a distance of 9 ft for 10 seconds. He explained that such assumptions gave a maximum whole body exposure of 18 mR. He pointed out that such a dose did not occur as no portion of [redacted] body had been in the beam path having been entirely shielded by 15" of high density concrete.
17. [redacted] stated that a meeting of the Plant Safety Committee was held on December 31, 1968, at his request. He stated those attending in addition to himself were:

[redacted]
Lewis Boaco, Chemist
Theodore Tripp, Chemical Engineer

18. He stated that during the meeting discussion of this incident covered the need for specific operating procedures, the need for having trained personnel on hot cell operations, and the corrective action necessary to prevent the recurrence of such an incident. [redacted] stated that it was believed that the hot cell door opening procedure should be improved as follows: each cell would have a different key for the operations staff to open the rear doors to the isolation rooms of cells. These keys would be in locked boxes located in front of each cell. Only the hot cell supervisor would have the key to these locked boxes and no person other than he would use or issue the key. In addition, a switch would be located at the front of the hot cell which when "on", would energize flashing red lights to be located at the cell entrance. The switch would be placed "on" when radioactive material is present in the hot cell. He stated this new procedure would require license amendment, but that in the meantime they would emphasize to all personnel that they correctly follow the present SOP.

Personnel Monitoring

19. The calendar quarter film badge reports supplied by Eberline on a monthly basis were examined and it was noted that including the 200 mrem exposure in December, 1968, [redacted] received a total of 340 mrem whole body gamma exposure during the fourth calendar quarter, 1968. Your AEC-4 is maintained for [redacted]

Additional Information

20. Chapter 4.2.1 Hot Cell Operator, of the application dated August 1967, "The hot cell operator is responsible for carrying out actual operations. The operations to be conducted during each shift are reviewed with the operator by the shift supervisor? ... Apprentice operators will work along with Experienced Operators ..."

21. As noted in paragraphs 4, 6 and 7 of the Details [redacted] since December 24, 1968, and at least up to January 7, 1969, he has worked alone in cell operations not in the presence of an experienced operator.
21. Also as noted in paragraph 7 and 8 of the Details there is no shift supervisor. [redacted] a hot cell operator, has been acting as both shift supervisor and hot cell operator. This information was supplied by [redacted] Chapter 4.4.1.1.3 of the August 1967 application states operator A (Journeyman) should have 36 months experience in handling radioactive materials. Chapter 4.4.1.1.2 stated that an operator B (Intermediates) should have 18 months experience. [redacted] only has 12 months experience having started December 1967 according to employment records. [redacted] stated that [redacted] does not have the required experience and certainly not the experience required for a supervisor as set forth in chapter 4.4.1.2 which requires 5 years in the nuclear field and 2 years as an operator.
23. The licensee by License Condition No. 15 is required to follow the procedures set forth in an application dated August 16, 1967. Chapter 10. 4. 5, "Radiation Work Permit", of that application states "All activities in Radiation or High Radiation Areas" are performed in accordance with standard operating procedures. Work performed in these areas require special authorization in the form of a Radiation Work Permit (RWP).
24. [redacted] stated no RWP had ever been initiated or issued for using a hot cell to irradiate plastic monomer. [redacted] who has been performing irradiation polymerization studies, stated he had been doing the studies in hot cell #2 about 3 days weekly for the past two months and no RWP was ever given him. The hot cell according to [redacted] is a High Radiation Area during these irradiations and usually contains from 25,000 - 50,000 Ci of Co-60.

Reenactment of Incident

25. [redacted] reenacted the incident for the benefit of the inspector. TLD dosimeters supplied by HASL, NYO, were placed on a tree where [redacted] indicated he stood, and on the Decontamination Room Area Alarm which alarmed during the incident. [redacted] opened the doors of the Hot Cell #2, to a point where there was an opening to the cell 3-3/4" wide. This was estimated to be the width of the opening at the time of the incident. The area was evacuated and 50,000 Ci of Co-60 was placed in the hot cell in the same form (two identical plaques) and in the same position as during the incident. The decontamination room monitor alarmed both visually and audibly at a pre set limit of 20 mR/hr. The service area alarm some 20 ft away from the decontamination room monitor also alarmed at a pre set limit of 50 mR/hr. The TLD dosimeters were read by HASL on January 8, 1969, and gave the following exposures.

- | | |
|-----------------------------------|-----------|
| a. On tree where [redacted] stood | 11.5 mrem |
| b. At decontamination alarm | 415 mrem |

(See Exhibit A for diagram of hot cell, isolation room and location of area alarms).

26. The above exposures were due to 25,000 Ci being present in the hot cell for 11 minutes and 15 seconds and 50,000 Ci for 1 minute and 15 seconds. This gave a dose rate due to 50,000 Ci of Co-60 in the hot cell of 3.63 r/hr at the decontamination room alarm and 100 mR/hr behind the door where [redacted] stood. See Exhibit "B" for calculations.

Local Management Interview

27. A conference was held with [redacted] Plant Manager at Quakana, on January 7, 1969, after the investigation of the incident. Attending the conference besides Witt and the inspector were Mr. Joel Lubanau and Sheldon Levin, Pennsylvania Office of Radiation Control, and [redacted].
28. The items of noncompliance were discussed with Witt, who stated that the items of noncompliance indicated there was a breakdown in administrative control and that he would take steps to ensure that proper controls would be instituted and that all personnel would be thoroughly indoctrinated in the procedures set forth in the application of August 1967. He stated no person would be permitted to work in hot cells without proper review of their proposals and issuance of a Radiation Work Permit.

29. He stated he could not do anything about cell operators to ensure that properly qualified persons as defined in the license perform hot cell operations because they have been unable to hire qualified personnel to work in a remote area such as Quahanna. It was pointed out that during the incident on December 27, 1968 and on January 7, 1969 when 200,000 Ci of Co-60 arrived and was placed in a hot cell he had only a hot cell operator trainee in charge. He stated this was a bad situation, but there was backup in engineers and other technical help who had prior radiation training before coming to Quahanna.

30. Witt stated they intended to apply for an amendment to revise the key call door opening procedures to provide locked boxes in the service area where keys for each cell would be located. Only the shift supervisor would have a key to the locked box, thus making these keys unavailable to other personnel. Witt also stated they would install flashing red lights to be located at the entrance to each hot cell. The hot cell operator would actuate these lights upon placing radionuclides in the hot cell.

31. On January 21, 1969, a conference regarding the items of noncompliance was held at the licensee's corporate headquarters at Apollo, Pennsylvania. Attending the conference were:

- Dr. E. Shapiro, President, Humsac Corp.
- Mr. S. H. Bailey, Manager, Research & Development Humsac.
- Mr. S. Weber, Manager of Operations, Humsac
- ~~Mr. J. J. [redacted]~~
- Mr. E. Caldwell, Manager, Health & Safety Humsac
- ~~Mr. [redacted]~~
- Mr. E. Epstein, Radiation Specialist CO:1
- Mr. P. Malson, Jr, Radiation Specialist CO:1

32. Licensee representatives agreed that all items of noncompliance were valid, and occurred because of a breakdown in administrative control. In order to establish proper control of operations it was reported that a person with many years of nuclear experience has already been placed in direct control of operations and has been designated as shift supervisor. Shapiro, Weber and Bailey stated that in order to prevent a similar incident they were going to install a radiation actuated alarm to indicate the presence of materials in hot cells as well as improving the key procedures described in paragraph #31. Dr. Witt stated all personnel at Quahanna have since been instructed in the proper administrative and health and safety procedures.

LOT Cell # 2 Area
NUMEC QUEHANNA Pa.

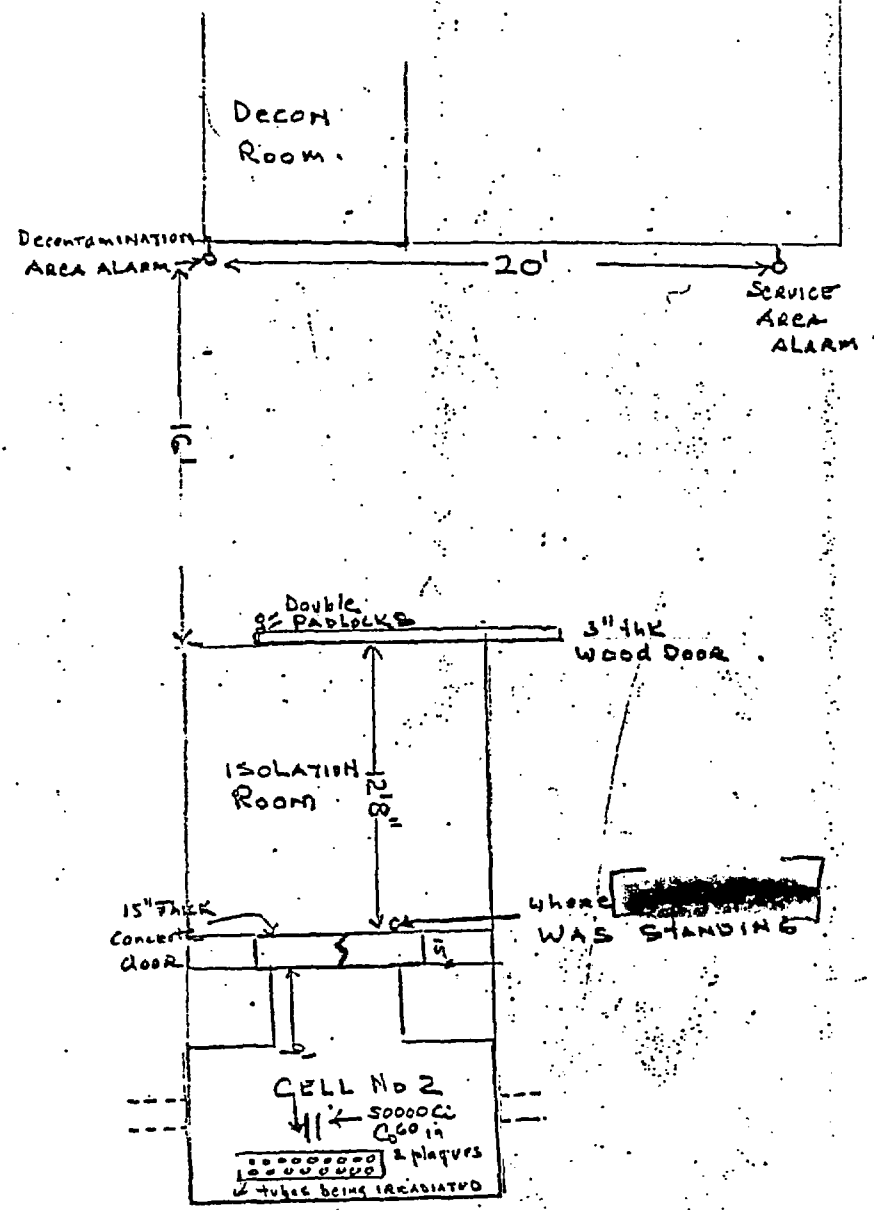


Exhibit A.

CALCULATIONS

1. During the simulated exposure 415 mrem was measured on a dosimeter (TLD) located at the decontamination room monitor during the exposure of 50,000 Ci Co-60 for 1 minute and 15 seconds, and 25,000 Ci Co-60 for 11 minutes and 15 seconds.

The dose from a point source of 50,000 Ci Co-60 at one foot for 1 minute and 15 seconds =

$$50,000 \text{ Ci} \times 14 \text{ R/hr/Ci} \times \frac{75 \text{ sec}}{3600 \text{ sec/hr}} = 14,600 \text{ R}$$

The dose from a point source of 25,000 Ci Co-60 at one foot for 11 minutes 15 seconds = $25,000 \text{ Ci} \times 14 \text{ R/hr/Ci} \times \frac{675}{3600 \text{ sec/hr}} = 65,800 \text{ R}$

$$\text{Percent of dose from the 50,000 Ci of Co-60} = \frac{14,600}{14,600 + 65,800} = 18.2\%$$

$$415 \text{ mrem} \times .182 = 75.6 \text{ mrem.}$$

During the simulated exposure 75.6 mrem was received at the decontamination area alarm due to exposure to 50,000 Ci Co-60 for 75 seconds. During one hour or 3600 seconds the dose rate would be 3.63 R/hr at the radiation alarm located approximately 39' -5" from the center of two plaques containing 50,000 Ci Co-60.

2. During the simulated exposure, 11.5 mrem was measured on a dosimeter (TLD) located behind Cell #2 door during the exposure of 50,000 Ci Co-60 for 1 minute and 15 seconds, and during the exposure of 25,000 Ci Co-60 for 11 minutes and 15 seconds. 18.2% of this dose resulted from exposure to 50,000 Ci of Co-60.

$$11.5 \text{ mrem} \times .182 = 2.09 \text{ mrem.}$$

2.09 mrem received in 75 seconds, therefore the dose in one hour or 3600

$$\text{seconds would be: } \frac{(2.09)(3600)}{75} = 100.3 \text{ mrem.}$$

EXHIBIT "B"