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SAFETY ANALYSIS REPORT - BIOLOGY LABORATORIES
PLUTONIUM - 238 EXPERIMENTS

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PLUTONIUM-238 EXPERIMENTS

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Summary

Fifty-watt, triply encapsulated radiation sources, supplied by the Division of Isotopes Development, AEC, and consisting of about 125 g of $^{238}\text{PuO}_2$ (87.8 g of ^{238}Pu in 110.2 g of Pu mixture, total activity 1500 Ci), are to be used in studies of the biologic effects of heat and radiation in support of the artificial heart program, under sponsorship of the Division of Biology and Medicine, AEC. A review of the circumstances which could lead to a loss of control of this material while in the Biology Laboratories (331 Building, 300 Area) has been made and steps taken to minimize the likelihood of such an occurrence. Significant external dose and criticality accidents are not judged to be credible. Credibility of an internal exposure accident is marginal to insignificant. An internal exposure accident is postulated; however, it is concluded that loss of control is unlikely and the studies would not result in significant risk to the public.

Source and Facility Description

The material to be handled consists of six encapsulated sources of plutonium oxide of the following approximate mixture

<u>Isotope</u>	<u>Abundance %</u>	<u>-Ci in Mixture (60-50-100)</u>
^{238}Pu	79.7	1500
^{239}Pu	17.0	1.1
^{240}Pu	2.9	0.72
^{241}Pu	0.3	34.3
^{242}Pu	0.1	0.00042
^{236}Pu	1.2×10^{-4}	0.070

Some of the sources may contain about 90% by weight of ^{238}Pu in which case the abundance of the other isotopes would be altered from the values in the preceding table.

A representative source consists of plutonium oxide in the shape of a right circular cylinder 1.0 in. diameter by 1.0 in. long which has been encapsulated in a right circular inner cylinder of tantalum metal (20-mil wall, 30-mil endcaps) surrounded by a Ta-10W pressure vessel (60-mil wall, 90-mil endcaps) and a Pt-20 Rh container (25-mil wall, 30-mil endcaps). A void in the inner container initially contains helium and argon in an 8:1 ratio. Absolutely no work will require removal of any of these encapsulating containers. The total weight of a representative 50W source is about 435 g. The sources are expected to be used in these facilities for a period of up to five years.

Prior to bench studies on heat transfer and dosimetry and before implantation in an experimental animal, the source will be placed in a specially designed heat exchanger where it shall remain, sealed in position, throughout the experimental period. The heat exchanger, diagrammed in the following figure, is in the approximate

shape of a right semiprolate cylindroid approximately 3 in. long and 4 in. wide at its greatest chord. The bulk of the exchanger is graphite, surrounded in turn by layers of high-temperature insulating material and medical grade silicone rubber. Although dictated primarily by thermodynamic and surgical considerations, it will be noted that this hermetic containment provides additional protection against material release and personnel exposure in the unlikely event that all three source capsules should fail. In total, six layers of encapsulating materials actually enclose the oxide itself when the source is in actual use.

The facilities in which the sources are to be used are those of Rooms 122, 126, 129, 175, 186 and 190 of the 331 Building, 300 Area. The work consists of implanting heat exchangers (described above) containing the sources in the chest and abdominal cavities of miniature swine for long-term in vivo studies of the biologic effects of heat and radiation, in which flowing blood serves as the source coolant. Past experience with electrical heat exchangers has verified that sources of 60 watts or more are tolerated in such animal preparations for periods of years. These animals shall be kept for the most part in Room 126 of the 331 Building, except for relatively brief periods as indicated in the following table. A floor plan of the first floor, 331 Building, showing the location of these rooms, is in Appendix I.

<u>Room No.</u>	<u>Primary Function of Room</u>	<u>Anticipated Duration of Source Presence in Room</u>
122	Postoperative recovery	Less than 2 weeks*
126	Large animal housing bay	Up to 5 years*
129	Large animal necropsy	Less than 1 day**
175	Isotope handling & storage	Up to 3 months***
186	X-ray	Less than 1 day*
188	Surgery	Less than 1 day**
190	Exam & surgical prep	Less than 1 day**
121	<i>Small animal studies</i>	<i>Less than 1 week***</i>
* Implanted in miniature swine.		
** Implanted in or retrieved from animal.		
*** Out of animal - stored in 175 when not in actual use.		

The outside (north) doors of Room 126 shall be locked to prevent accidental escape of the animals to the exterior of the building should they somehow free themselves from their (locked) pens. The other possible exit from Room 126 involves passing through a minimum of two (locked) doors, gaining access thereby to the hallway from which building escape requires their passage through main building access doors, all of which are kept closed at all times. Although escape of the animals is not deemed a credible occurrence, animals carrying the exchanger-enclosed encapsulated sources shall be uniquely and clearly labelled by tattoo, ear crop or other easily identifiable means for identification purposes.

As in the case of death of any experimental animal in the Department, the principal investigator or, in his absence, responsible colleagues shall be notified immediately of the death of any miniature swine on this program. Postmortem examinations shall be conducted promptly and in the presence of radiation monitoring personnel; full protective measures shall be employed until such time as it is determined by those personnel that the heat exchanger implant is intact and no radioisotope leakage has occurred.

The surface and midline temperatures of the encapsulated source within a heat exchanger contained in a dead miniature swine (no coolant flow) is expected to be in the neighborhood of 900-1,000°F at equilibrium. Appropriate handling techniques shall be employed in removing encapsulated sources from the heat exchangers in view of the high surface temperatures involved, and radiation monitoring personnel shall examine the sources prior to insertion in and immediately on removal from the exchangers to certify encapsulation integrity. Each source shall be stored in an appropriate heat-sink container placed within a lead container in Room 175 when not in use.

Criticality

The 331 Building may not procedurally contain more than 95% of a minimum critical mass of fissionable material. Biology Department Nuclear Safety Procedures are specific in this requirement and administrative controls will be exercised to assure that the limit is not exceeded. This control is the responsibility of the Building Manager who maintains a log of all current holdings and must approve all additions before the material is accepted. Each of ^{the 50-unit} ~~these~~ sources represents about 3.0% of the minimum critical mass for ^{238}Pu (3.0 Kg) and also contains about 3.7% of a minimum critical mass of ^{239}Pu (510 g) for a total of about 6.7%. Due to source geometry, the 6.7% potential critical mass is a very conservative estimate.

External Exposures

The dose rate on contact with the capsule has been estimated to be ^{about 1 rem/hr} (combined neutron-gamma). The dose rate in

tissue at 10 cm from the source center is expected to be about 16 mrem/hr. Contact measurements have not been made, however; measurements reported by MSL for similar source configurations are 0.16 mr/hr-g Pu from gamma radiation and 0.28 mrem/hr-g Pu from neutrons at 10 cm in air. The interposed tissue would reduce the value for neutrons by a factor of about 2. While the external dose rate from the power source if in contact with the body for as much as a day may be excessive when compared to a criterion of 25 rem (total body for penetrating radiations), the temperature of the source is sufficiently high to preclude such an inadvertent exposure. Situations whereby significant risk could occur from external radiation are not considered credible.

Internal Exposures

In its encapsulated form the Pu source presents no credible internal hazard. If the source container should be violated such that the plutonium escapes to the air, a hazard from inhalation of plutonium oxide may result. The combination of events necessary to bring about such a situation is not credible; however, we may postulate various events and analyze the consequences.

Suppose that the Pu source is outside its storage container and in a miniature swine, and the 331 Building catches fire and burns. There is pressure on the walls of the container due to expansion of helium generated by the alpha decay of plutonium and by the gas mixture contained in the void. The source design and attention to quality control procedures in source fabrication and testing, assures containment of fuel under all credible operational and