BALTIMORE 3, MARYLAND

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

MASTER

50-181
JES-0200

RADIOACTIVE MATERIALS LABORATORY
SAFETY REPORT
MARTIN NUCLEAR FACILITY
QUEHANNA SITE
MND-2410

September 1960

641 007

FOREWORD

This Safety Report has been prepared by the Nuclear Division of The Martin Company in support of their application for a license to operate the Nuclear Facility at Quehanna, Pennsylvania.

641 003

page blank

CONTENTS

	Page
Foreword	iii
Contents	v
I. Introduction	I-1
II. Quehanna Site.	II-1
A. Site Location	II-1
1. Regional	II-1
2. Exclusion Area.	II-1
B. Geography	II-6
1. Topography.	II-6
2. Land Usage.	II-6
C. Population Density and Distribution	II-6
D. Meteorology (Ref. 2).	II-6
1. Data Available	II-6
2. Wind Flow	II-8
3. Precipitation	II-8
4. Atmospheric Stability	II-8
5. Temperature	II-8
6. Summary	II-8
E. Geology.	II-13
1. Stratigraphy	II-13
2. Structure	II-14
F. Hydrology.	II-14
1. Subsurface Hydrology	II-14
2. Surface Hydrology	II-14
G. Seismology	II-16
III. Radioactive Materials Laboratory	III-1
A. Hot Cells	III-3

CONTENTS (continued)

	Page
B. Storage Facilities	III-11
1. Solid Source Storage Assembly	III-11
2. Storage Pool	III-11
3. Cask Storage	III-12
C. Decontamination Room	III-12
D. Radiochemistry Laboratory.	III-13
1. Fume Hoods	III-13
2. Lead Caves	III-13
E. Building Services	III-14
1. Electrical Power	III-14
2. Piping and Plumbing Services	III-14
F. Emergency Facilities	III-19
1. Emergency Power.	III-19
2. Fire Equipment	III-21
IV. Safety Features and Procedures	IV-1
A. Philosophy of Containment	IV-1
B. Health Physics Program	IV-2
1. Instrumentation	IV-2
2. Personnel Monitoring and Protection.	IV-6
3. Facility Monitoring	IV-9
4. Environmental Monitoring	IV-11
5. Source Supervision	IV-12
C. Shielding.	IV-14
1. Radioactive Materials to be Processed.	IV-14
2. Results of Shielding Analysis	IV-14
D. Air Handling Systems	IV-19
1. General Description of Ventilation Systems	IV-19

CONTENTS (continued)

	Page
2. System No. 3	IV-19
3. System No. 4	IV-21
4. System No. 5	IV-21
5. System No. 7	IV-21
6. Hot Cell Exhaust System	IV-21
7. System No. 9--Cell Dry Box Air Supply and Exhaust	IV-21
8. Control Systems Cell Exhaust	IV-22
9. Emergency System Control	IV-23
10. Ventilation Air Monitoring Systems and Controls	IV-23
11. Balancing and Testing of Air Systems	IV-24
E. Emergency Control	IV-25
1. Organization	IV-25
2. Equipment	IV-25
3. Emergency Plans	IV-25
4. Power Failures	IV-29
5. Storms	IV-30
6. Contamination in Building	IV-30
7. Contamination Air Release	IV-30
8. High Radiation	IV-31
F. Preparation Checks	IV-32
1. Ventilating Systems	IV-33
2. Filter Efficiency	IV-34
3. Fan Operating Sequences	IV-34
4. Radiation Detection Systems	IV-34
5. Dry Box Fire Protection System	IV-35
6. Piping	IV-35
7. Protective Coatings	IV-35
8. Regulated Area Control	IV-35
9. Dry Runs	IV-35
10. Liquid Waste Treatment Runs	IV-35
11. Emergency Power Plant	IV-36
V. Radioactive Materials and Their Properties	V-1
A. Strontium-90	V-1
1. Nuclear Properties	V-1

CONTENTS (continued)

	Page
2. Chemical Properties	V-4
3. Radiobiological Properties.	V-6
B. Curium-242.	V-6
1. Nuclear Properties.	V-6
2. Chemical Properties.	V-7
3. Radiobiological Properties.	V-9
VI. Process Flow.	VI-1
A. Strontium-90	VI-1
B. Curium-242	VI-5
C. Strontium Procedures	VI-7
1. Processing of Strontium Fuel in Hot Cells	VI-7
D. Curium Procedures.	VI-12
1. Processing of Curium Fuel in Hot Cells . . .	VI-12
VII. Operating Procedures, Credible Problems, and Remedial Steps	VII-1
A. Procedures for Fuel Preparation and Handling	VII-1
B. Curium Purification	VII-6
C. Strontium-90	VII-17
VIII. Maximum Credible Incidents	VIII-1
A. Postulation of Incidents.	VIII-1
B. Assumptions	VIII-1
C. Analysis	VIII-2
1. Radiostrontium Incident	VIII-2

641 007

CONTENTS (continued)

	Page
2. Curium Incident	VIII-4
3. Contamination	VIII-5
D. Evaluation	VIII-7
1. Radiation Doses	VIII-7
2. Contamination	VIII-7
3. Consequences Relative to Site	VIII-8
IX. References	IX-1
Appendix A--Radioisotope Committee	A-1
Appendix B--Alternate Process Flow for SrCO_3 Conversion to SrTiO_3	B-1

I. INTRODUCTION

This summary report has been prepared by the Nuclear Division of The Martin Company to provide a general evaluation of the potential hazards associated with the Pennsylvania State University Hot Cell Facility located at Quehanna, Pennsylvania. It describes the safety features incorporated in the existing laboratory and the major alterations to be performed prior to occupancy. Certain alterations noted in Chapters III and IV are necessary in view of the fact that the laboratory, as presently constructed, was designed to process reactor elements rather than the particular alpha and beta emitters proposed. This evaluation is forwarded to the USAEC in support of the application The Martin Company has for a license to process multikilocurie quantities of Sr-90 and Cm-242.

The facility is a portion of the Reactor Facility located at Quehanna, Pennsylvania. The facility, as described in Chapter II, contains a four-megawatt swimming pool reactor, in addition to five high level gamma cells and various supporting facilities. It was constructed by Curtiss-Wright in 1957 and presented to the Pennsylvania State University in September 1960. Contingent on the receipt of a license to operate, The Martin Company will lease the entire hot cell portion of this facility together with other related ancillary supporting areas within the Reactor Facility from Pennsylvania State University.

The physical relationship of the swimming pool reactor and the hot cells has been examined to determine the effect of simultaneous operation on the Martin safety analysis. Reactor accidents postulated by Curtiss-Wright in their Evaluation Report (Ref. 1) would not, in our opinion, interfere with either the operation or the safety of the hot cell portion of this facility.

The objective of the fabrication work in the Martin Nuclear Laboratory is to produce safe sources of isotopic power. One of the foremost criteria for the use of such power sources is safety under diversified and extreme conditions. Detailed hazards evaluation and actual physical tests have played an important part in establishing the safe performance of these sources.

These tests have included both low and high velocity impact tests. The contained radioisotope heat source was impacted against targets such as granite, concrete and packed earth, at velocities varying from terminal velocity to three times terminal velocity. All specimens were heated to temperatures equivalent to those at impact and fired from rocket sleds. All specimens that were fired at speeds equivalent to terminal velocities remained intact, although extensive deformation was encountered when they impacted with granite.

641 009

These same radioisotope heat sources have been subjected to missile failure tests such as exploding mixtures of liquid oxygen and kerosene. Though the specimens were subjected to very high transient temperatures and pressures from the detonation of this mixture, they maintained their integrity in all tests. Even when fuel blocks were heated to more than 2000° F and plunged directly into liquid oxygen (at almost 297° F below zero), the test specimens failed to support combustion and survived intact.

The concern of The Martin Company with the safe production of isotopic power sources parallels the concern for their safe use. In addition to a strong capability in safety evaluation and testing, The Martin Company Health Physics Section is fully qualified to oversee the radioisotope processing proposed for this facility and is cognizant of the need to achieve rigorous containment of alpha emitters such as Cm-242 and to adhere to the monitoring procedures more fully discussed in Chapter IV.

It is recognized that the role of Health Physics in an industrial program of this magnitude must be one of constant surveillance using personnel of commensurate background and experience. All operations and proposed new operations will be thoroughly studied from a technical standpoint and approved by a Technical Committee of which the resident Health Physicist is a member. These proposed operations will then be reviewed by the established Administrative Isotope Committee of which the Health Physicist is Chairman.

The design of the Nuclear Laboratory provides flexibility for processing of these radioisotope and the fabrication of isotopic power sources. The projected physical flow of materials for production of Sr-90 and Cm-242 power sources is schematically outlined in Chapter V.

While a total of 400 kilocuries of Sr-90 may be at the facility at any time, it may be stipulated that no more than 25 kilocuries will be undergoing chemical processing at one time. The remainder will be either in the form of a maximum of 300 kilocuries of SrTiO_3 pellets awaiting encapsulation and assembly into a generator or as 100 kilocuries of SrCO_3 or SrCl_2 residing in a storage cask or tank.

Similarly, while a total of 10 to 12 kilocuries of Cm-242 may be at this facility at one time, it may be stipulated that no more than eight kilocuries of Cm-242 will be undergoing chemical processing at any one time, the remainder being in the form of the final fuel pellets awaiting encapsulation.

Chapter VII contains a more detailed description of the process steps involved in the production of these isotopic power sources. Accompanying this is an evaluation of the operational hazards, malfunctions, etc., and the remedial health physics procedures involved. Maximum credible accidents are considered separately in Chapter VIII.

The backgrounds and experience of personnel who will be associated with the Nuclear Laboratory are described in Appendix A. In addition, an alternate process for Sr-90 is described in Appendix B.

641 011

II. QUEHANNA SITE

The site of the Martin Nuclear Laboratory is the former Curtiss-Wright Quehanna Research Facility located 37 miles northwest of State College in north-central Pennsylvania and includes parts of Elk, Cameron and Clearfield Counties. Figure II-1 shows the site location relative to the State of Pennsylvania. The site is perhaps the most remote one for a nuclear facility in the Eastern United States, since it is in a sparsely populated region and has a controlled exclusion area of approximately 80 square miles. The nearest population centers, Sinemahoning (Population 450) and Frenchville (Population 558), are nine miles from the site. The site is ideally located for the proposed hot cell operations with respect to its population, meteorologic and hydrologic characteristics, and its general features are representative of those of the Appalachian Plateau physiographic province. The Commission has previously reviewed the Quehanna site for purposes of licensing former nuclear facilities and operations there. (Ref. 1)

A. SITE LOCATION

1. Regional

Figure II-2 shows the site location relative to the surrounding region with circles of 5.1, 10.4, and 25-mile radii superimposed. The highway network circles the site region and serves the closest population centers. This is well beyond the exclusion area of the site. The intervening land between the surrounding road network and the exclusion perimeter is principally State Forest land.

2. Exclusion Area

The exclusion area is shown in Fig. II-3. Access is from Karthaus on a hard surface road running northerly to Quehanna at the edge of the exclusion perimeter where entry is controlled by a manned gate. Other roads and trails into the exclusion area are closed. This area consists of a polygonal block of land which is roughly a circle 10 miles in diameter encompassing approximately 80 square miles. The site per se, consisting of the Laboratory, attendant structures and a fenced security area, consists of several acres located in the southwest quadrant of the exclusion area. Figure II-4 shows the site.

Fig. II-1. Site Location in Pennsylvania (relief map)

MND 2410

641 013

© General Drafting Co., Inc.

Fig. II-2. Regional Site Location (road map)

Fig. II-3. The Quehanna Site (N41°--W78°)

641 0.5

MND 2410

Fig. II-4. Site Layout

B. GEOGRAPHY

1. Topography

The topography of site is typical of the Appalachian Plateau and is a relatively flat area at an average elevation of 2000 feet above mean sea level. The edge of the exclusion perimeter is incised by several gorges up to one-half mile in width and 1000 feet in depth which radiate from their origin near the center of the site.

2. Land Usage

The land bordering the site exclusion perimeter consists of State Forest land with a secondary growth of trees. In this area, there is seasonal recreational activity. Beyond the State Forest land, near the outlying townships, there is small scale agricultural activity. Land usage is, therefore, quite limited.

C. POPULATION DENSITY AND DISTRIBUTION

The sparse population in the site environs is perhaps the most favorable site feature. The surrounding State Forest beyond the site exclusion area has a negligible permanent population density. Within a 25-mile radius of the site the population density is 30 individuals per square mile with a total population within this zone of about 60,000.

The population distribution within a 25-mile radius of the site is allotted into about 40 small villages having populations of less than 1000 individuals (average 500), six small towns averaging 6000 individuals and a minimal number of outlying individual habitations. Table II-1 gives the population distribution within a 25-mile radius of the site.

The predominant wind directions at the site are from west-north-west and south-southeast. From a population distribution standpoint these are favorable, since they are not directed at the major population centers of the region nor into areas of above average population density.

D. METEOROLOGY (Ref. 2)

1. Data Available

No meteorological data exist for the site and extrapolation must be made from records taken at the Philipsburg Airport, 27 miles south-east of the site. This extrapolation is valid in all respects since the topography of the Philipsburg Airport (elevation 1963 feet) is very

641 017

TABLE II-1
Towns Nearest Reactor Site*

<u>Population</u>		<u>Population</u>	
Bald Hill	250	Lecontes Mills	600
Benezette	200	Morrisdale	655
Bloomington	200	Moshannon	500
Blue Ball	900	Munson	450
Brockport	415	Oak Grove	300
Byrnedale	500	Oshanter	300
Caledonia	300	Orviston	400
Chester Hill	954	Penfield	600
Clarence	530	Philipsburg	3988
Clearfield	9357	Quail	600
Crenshaw	550	Renovo	3751
Curwensville	3332	Rockton	250
Driftwood	289	Saint Marys	7846
Drury Run	300	Sinnemahoning	450
Emporium	3646	Snow Shoe	670
Force	506	South Renovo	862
Frenchville	558	Sterling Run	225
Glen Richey	425	Tyler	300
Hawk Run	651	Wallaceton	440
Hyde	750	Weedville	600
Karthus	575	Westport	201
Keewaydin	200	Woodland	650
Kylertown	500	Winburne	700
Lanse	350	Pine Glen	182

*From Rand McNally Commercial Atlas and Marketing Guide, Eighty-sixth Edition, 1955. Includes towns within 25-mile radius of site.

similar to the site, and the same general meteorological conditions prevail at each location.

2. Wind Flow

Hourly wind observations for an eight-year period (1948 to 1955) were studied in detail. Table II-2 presents the annual frequency at various times and weather conditions. Figure II-5 shows the annual frequency of wind direction. There is little variation in wind direction frequency due to time of day, weather condition and season of the year. Winds from the west-southwest through west-northwest occur 30 to 40% of the time with 20% of the remaining winds from east-southeast to south. The dominant winds are from west-northwest and south-southeast.

Wind speeds during the daylight hours vary from a maximum average of 12.4 mph (spring) to 8.2 mph (summer). Nighttime speeds are somewhat lower with the highest average speed of 10.1 mph (winter) and the lowest speed of 4.2 mph (summer). The maximum number of calms occur during the summer (night) when 39% of the time the wind is less than 1 mph. Maximum wind speeds are generally from the west with a maximum speed of 50 mph and a peak instantaneous gust of 60 mph recorded. Unrecorded gusts may attain 80 to 90 mph. Table II-3 presents the annual frequency of wind speeds. It is noted that the most frequent winds are between 4 and 12 mph (50%) with the second frequency preference in the 13 to 24 mph category.

Five tornadoes have been reported in the site region (the surrounding five counties) in a 35-year period.

The winds aloft have the same general pattern as the surface winds, except that they will increase in velocity with altitude.

3. Precipitation

The average annual precipitation at the site is estimated to be between 40 to 50 inches per year. Maximum precipitation occurs in May through July, and minimum precipitation occurs in November and December. The range of average precipitation is from 2-1/2 to 4-1/2 inches per month. Table II-4 shows the average number of days of precipitation. Precipitation is quite variable due to the frequency of storms.

Storms occur throughout the year with heavy rainfall from thunderstorms during the spring and summer months. Maximum precipitation varies from 1.38 inches registered over a one-hour period to 4.68 inches recorded in a 48-hour period. An unusual storm in July 1942 produced a maximum average rainfall depth of 35.5 inches over a 24 hour period.

Day	3 mph and calm	10.1%
	Average speed	10.4 mph
Night	3 mph and calm	30%
	Average speed	7.3 mph

Fig. II-5. Annual Wind Direction

TABLE II-2

Annual Frequency of Wind Directions (%) and Average Speed (mph)

Direction (Wingspeed 4 mph)	Daylight (07-1700 EST)	Night (18-0600 EST)	During Precipitation	During Low Visibility
N	1.7	0.9	0.8	0.8
NNE	2.1	1.4	1.4	1.3
NE	1.2	2.1	1.1	1.5
ENE	1.6	2.3	2.0	2.4
E	1.7	2.0	2.3	2.5
ESE	4.9	4.9	7.1	7.1
SE	5.5	5.1	6.8	7.3
SSE	11.1	8.6	11.7	12.2
S	5.1	3.8	4.2	5.0
SSW	4.1	3.1	5.5	4.3
SW	3.5	3.8	2.4	3.2
WSW	10.1	7.0	9.2	8.0
W	10.6	8.3	10.2	8.6
WNW	18.8	14.3	21.9	13.1
NW	5.7	6.1	5.2	3.4
NNW	5.4	3.4	3.2	2.4
3 mph and calm	10.1	30.9	8.5	23.8
Average speed, mph	10.4	7.3	11.8	8.3

TABLE II-3
Annual Frequency of Wind Speeds (%)

Mph	Calm	1 to 3	4 to 12	13 to 24	25 to 31	32 to 46	> 47
Daylight	6.8	3.4	59.8	27.3	2.2	0.4	< 0.1
Night	23.0	7.9	51.2	16.3	1.3	0.3	< 0.1
During precipitation	5.1	3.4	52.4	34.4	3.8	0.9	< 0.1
Visibility ≤ 6 miles	16.9	6.9	55.1	19.1	1.7	0.4	< 0.1

TABLE II-4

Average Number of Days of Precipitation

Inches	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
≥ 0.10	8	10	9	9	10	8	7	6	6	6	8	6	89
≥ 0.50	1	2	3	3	3	2	2	2	2	3	2	2	27
≥ 1.00	*	*	1	1	1	1	1	1	1	1	1	1	9

Range of Precipitation Occurrences

≥ 0.10	from 72/year to 113/year
≥ 0.50	24/year to 38/year
≥ 1.00	3/year to 15/year

*Less than 1/2

Snowfall is estimated to be an average total of 40 inches per year. Heavy snowfalls are not uncommon (10 inches in a single storm). The maximum snowfall recorded was 12.6 inches over a 24-hour period.

4. Atmospheric Stability

The vertical temperature distribution at or near the site has not been measured. Extrapolation has been made between other locations having similar weather conditions. A measure and direct correlation between low visibility and low wind velocity conditions indicates that one-third of the time inversion conditions exist, chiefly at night. Variations are expected in the duration of inversions due to the site topography where inversions in the air drainage of the radial gorges will be more prolonged than those on the plateau above. However, good dispersion is expected during the daylight hours, and inversions would be of short duration.

5. Temperature

The average monthly temperature will range from 65°F in July to 22°F in January with an annual temperature of 44°F. Below freezing temperatures occur many days per year.

6. Summary

While meteorological data is not directly available on the site, qualitative estimates of the meteorological pattern can be made from the Philipsburg Airport and from regional characteristics which are relatively uniform. Anomalous micrometeorological phenomena, i.e., diffusion, can be induced by the local topography and subsequent air drainage into the surrounding gorges.

E. GEOLOGY

1. Stratigraphy

Table II-5 shows the stratigraphic section in the site area. Outcrops in the area are meager; and incomplete logs of drill holes must serve as the basis for evaluation. However, due to the lack of tectonic disturbances in the area, lateral correlation from existing data is possible. The lower portion of the Pottsville formation caps the area. It consists of sandstones with the lowest sandstone unit as the predominant aquifer. This is underlaid by the Mauch Chunk shale which is an impervious layer about 50 feet thick. Beneath this is the Pocono formation of interbedded sandstones and shales which forms the steep slopes of the gorges.

2. Structure

In the site area the beds are generally horizontal and demonstrate the lack of structural disturbance of the area. In the northern portion of the site area, there is field evidence of gentle folding. Faults, joint and fractures are probably not abundant at the site and the area is considered to be stable.

F. HYDROLOGY

1. Subsurface Hydrology

As stated previously, the predominant aquifer in the area is contained at the base of the Pottsville, though it is not very productive. Since the Pottsville forms the surface exposure, it collects water and transmits it downward to a saturated sandstone member 40 feet thick near the interformational contact with the impervious Mauch Chunk shale. Secondary recharge is provided by streams cutting the Pottsville and discharge occurs as springs at the interformational contact. The top of the Mauch Chunk is at less than 1900 feet elevation and is presumed to be less than 100 feet vertically from the Laboratory.

Of five wells drilled on the site only three were moderately productive. The single well in the laboratory area has a rated capacity of 120 gpm. This well is 400 feet deep and bottoms far into Knapp Formation.

Downward transmission of contaminants released to the Pottsville formation is prevented by the underlying impervious Mauch Chunk shale. Lateral transmission within the Pottsville aquifer would be of a somewhat limited nature and would not pose a significant subsurface contamination problem in the light of the large exclusion area surrounding the Laboratory. *

2. Surface Hydrology

Surface drainage from the site exclusion area is from four major radial stream systems: Mix Run (north), Wykoff Run (northeast), Upper Three Run (southeast), and Mosquito Creek (south). The former two streams drain into Sinnemahoning Creek which flows into the west branch of the Susquehanna River; the latter drain directly into the river.

* The movement of soluble contaminants within the Pottsville would be measured in the terms of feet per year.

TABLE II-5

Generalized Section of Geology at Quehanna, Karthaus, Pennsylvania

Age	Formation	Thickness (ft)	Description	Water-Bearing Properties
Pennsylvanian	Pottsville	200+ —	Consists of massive coarse-grained gray-to-white sandstones with pebbles as large as hazelnuts. Caps hilltops. Probably represents the Olean member of formation.	Sandstones productive where found below drainage level, generally yield small to moderate supplies elsewhere.
Mississippian	Mauch Chunk shale	50+ —	Red and green argillaceous shale with some sandstone. Not generally exposed, indicated by terrace developed between Pottsville conglomeratic cliffs above and steep Knapp slopes below.	Not a water-bearing horizon, probably forms impervious strata retarding downward percolation of water.
Mississippian or Devonian	Knapp (Pocono)	600+ —	Succession of alternating olive-gray, gritty, micaceous sandstones and gray-green argillaceous shales. Some red beds occur near bottom of formation.	Productive consolidated rock where encountered below drainage level.

MINND 2410

647 000

Of prime interest is Mosquito Creek which drains the laboratory area as shown in Fig. II-6. Surface water in this area flows successively into Reactor Run, Meeker Run, Mosquito Creek and ultimately the west branch of the Susquehanna. The latter has a rather large average flow rate at Karthaus (maximum 50,900 cfs, average 2463 cfs and minimum 109 cfs). This branch of the Susquehanna is not used for public water supply because of its acidity (pH~3).

There are two reservoirs within the exclusion area, both of which are far removed from the laboratory by several miles, away from the runoff of Meeker Run.

G. SEISMOLOGY

A total of six earthquakes has been recorded, having their epicenter in Pennsylvania with some of the Canadian and New York State earthquakes being felt there. Of the epicenters cited, none were in the site region, and all were in Eastern Pennsylvania involving low intensity shock (maximum 6-7 Rossi-Forel Scale). It is concluded that, due to their low frequency and intensity, the foundation material of the facility and its massive structure, earthquakes do not present a significant problem. (Ref. 3)

Fig. II-6. Site Drainage

641 028

III. RADIOACTIVE MATERIALS LABORATORY

The Ralph M. Parsons Company of Los Angeles was retained to prepare the preliminary facility and the detailed architectural plans, drawings and specifications suitable for lump sum bidding by the building contractors. The reactor and some installed equipment such as viewing windows, beam tubes and certain experimental equipment were handled under separate contract or arrangement by Curtiss-Wright.

A view of the exterior of the building is shown in the frontispiece. The exterior, of simplified contemporary design, consists largely of insulated aluminum curtain walls applied to the steel frame. The two large bays housing the reactor and the hot cell service area are evident. The reactor area is isolated from the cell service area except for a large truck door and a pedestrian door, both of which will normally be closed and locked.

The general layout of the site, Fig. II-4, shows the relative position of the main laboratory, radioactive waste treatment plant and underground holdup and storage tanks.

The 24,700-square foot reactor and hot lab building is basically a one-story structure. Figure III-1 shows the main floor plan. It has been designed to provide as positive separation as possible between contaminated and radioactively clean areas. Those areas which will remain free of contamination include offices, dark room, staff laboratory, cell operating area and the reactor area. As reference to Fig. III-1 will reveal, the only normal access between clean and contaminated areas is via the change area. The large access door between the operating and service areas will normally be closed and locked. Care will be exercised in passing large objects through this door. Because of the relative isolation of the contaminated areas, an intercommunication system to connect all parts of the building has been installed.

A more detailed description of that portion of the building with which this report is concerned, the Radioactive Materials Laboratory, is covered in the following pages.

Figure III-1 will show that portion of the building known as the Radioactive Materials Laboratory, which includes the Change Room, Operation Area, hot cells, isolation rooms, Service Area, Radioactive Materials Storage, Radiochemistry Laboratory and cask storage. To provide for expansion of the Laboratory in the future, the building was laid out with the entire east wall unobstructed. Additions can be made relatively simple by building additional laboratory space or hot cells in line and extending the Operation and Service Areas.

Fig. III-1. Main Floor Plan

MND 2410

641 000

The Operation Area is the area from which remote operations in the hot cells are controlled. The front walls of the hot cells containing the viewing windows and through which the remote manipulators pass, face this area.

The Service Area at the back of the cells is bounded on one side by the hot cell isolation rooms and on the opposite side by supporting laboratories and storage areas.

A. HOT CELLS

This facility consists of five cells with the physical configurations as indicated in Table III-1.

TABLE III-1

<u>Cell No.</u>	<u>Floor Size (ft)</u>	<u>Ceiling Height (ft)</u>	<u>Wall Thickness (ft)</u>
1	6 x 7	12	3
2	6 x 12	15	3
3	6 x 7	12	3
4	8 x 12	12	2
5	8 x 8	12	2

Each of these cells is provided with manipulator ports for the use of Argonne Model 8 manipulators. Cells 2 and 4 have two pairs of manipulator port openings so the entire area of the cell can be covered. There is also a General Mills Manipulator, Model 300 in Cell 2. The configuration of the cell with the General Mills Manipulator is shown in Fig. III-3. A detailed plan view of the cell block is shown in Fig. III-4.

The shielding walls of the cells which reach to a height of 9-1/2 feet above the floors are constructed of ferrophosphorous concrete with a minimum weight of 280 pounds per cubic foot. The concrete above 9-1/2 feet is ordinary concrete having a minimum density of approximately 150 pounds per cubic foot.

All of the dense concrete was poured with 1/4-inch steel plate forms which remained in place. The steel plates simplify decontamination of the cells, afford a good base for attaching fixtures to the interior or exterior and prevent chipping of the concrete around plugs, drawers and access ports.

641 032

MND 2410

Fig. III-2. Basement Floor Plan

Fig. III-3. Cell Detail

Fig. III-4. Detailed Cell Layout

The radiation shielding windows are of 3.6 density glass and were received as packaged, oil-filled units ready for insertion into previously installed steel frames. Each window is roughly the same thickness as the 4.5 density wall in which it is installed so that they are undershielded as compared with the wall. This undershielding can be made up by using an additional four-inch thick slab of 6.2 density glass. There is one four-inch thick 6.2 density glass block for supplementing the window shielding that can be used any time additional shielding is required. There are a total of seven windows, two in each of the larger cells and one in each of the remaining three cells. The windows are 36 by 48 inches on the hot face, giving a view of all of the cells.

Access to the cells is through doors at the rear which open into the isolation rooms. As reference to Fig. III-4 will reveal, the openings have been placed and are of such size that modular equipment tables covering one-half, or in the case of the large cells, one-third, of the floor area, can easily be removed or reshuffled within the cell. Considerable thought was given to the method of operating the doors. Details of the door arrangement may be seen in Fig. III-5. Equipment which is too large to pass through the doors may be placed in the cell by removing one or more of the two-foot thick slabs which form the cell roof. By using the 15-ton bridge crane to remove these slabs, the entire cell area may be uncovered if necessary.

Monochromatic lighting is provided in Cell 1 only. However, provision has been made to install sodium vapor lamps in the other cells if this proves desirable. In the meantime, illumination is supplied by incandescent lamps. Standby or emergency lighting is supplied in all cells so that lamp failures will not cause shutdown. A propane-fueled motor-generator set supplies sufficient power to continue operation of the cell ventilating and lighting systems in case of an electrical failure.

Transfer of samples between cells is accomplished by using transfer drawers which can accommodate samples up to 12 inches on a side. Details of a typical transfer drawer may be seen in Fig. III-6. These drawers are accessible to and may be operated by the manipulators. A pass-through drawer also penetrates the front face of Cell 1 so that small objects can be placed into the cell by the operator.

The operating face of the cells is liberally supplied with access ports. All standard services are available in a trench immediately in front of the cell face so that they may be extended through the wall as needed. Channels through plugs carrying services into the cells are bent so that there is no direct path for radiation from the cell to the operating area. Only a few 110-volt electrical lines are permanently installed within the cells. The arrangement of ports is shown in Fig. III-7. Many of them have been placed in rectangular drawers or inserts which can be removed and replaced with drawers having plugs designed for a specific application. Individual intercommunication connect the operating face and interior of each cell.

Fig. III-5. Cell Door Detail

Fig. III-6. Sample Transfer Drawer

Fig III-7 Front View of Cells

B. STORAGE FACILITIES

1. Solid Source Storage Assembly

Located in the service area, as shown in Fig. III-1, is a solid source storage assembly. This consists of a total of 24 storage pipes, 4 by 6 by 8 inches, which are installed in a closely nested vertical group. The pipes are made of galvanized steel and are eight feet long and closed at their lower ends. They are encased in concrete for shielding and the concrete and tops of the pipes extend six inches above the level of the service room floor. Steel-encased concrete shielding plugs are available for the top of each hole.

2. Storage Pool

Figure III-1 also shows the location of the storage pool in the service area. Radioactive samples, the radiation from which is too intense for storage in the sample tubes described, or which might require cooling, are stored in the storage pool. The pool is 8 feet wide, 10 feet long and 16 feet deep. The reinforced concrete pool walls extend three feet above the service area floor. The pool is spanned by a bridge which runs on tracks mounted lengthwise atop each 10-foot wall. The bridge is positioned by hand and is used as a platform when samples are moved underwater by the use of long handling tools. Samples to be introduced into the pool are generally sufficiently radioactive to warrant the use of a shielded transfer cask. This is handled by the service area crane and lowered into the pool where the sample is removed for storage. The cask is then lifted above water level, drained, decontaminated if necessary and removed for further use.

The storage pool is filled from the pool water supply system as described in Chapter III-E. An overflow pipe, which terminates one foot below the top of the pool, leads to the contaminated drains. Chapter III-F describes the contaminated waste system.

Water in the pool is continuously circulated through a purification system. Water is circulated at a normal flow rate of 5 gpm from a sump sunk below the pool floor level, through a single pump and one of a pair of deionizer tanks, and then back to the pool where it is released at a depth of about five feet from the top of the pool. An emergency flow rate of about 30 gpm is possible if the pool water becomes seriously contaminated.

Each of the deionizer tanks contains a removable cartridge containing mixed anion and cation resins. No attempt is made to regenerate the resins. Once they become exhausted, the spent cartridge is removed for disposition and replaced with a fresh one. The effluent of the deionizer

units contains not more than 0.004 ppm total solids. A conductivity meter in the effluent line from the deionizers and sample cocks, before and after the deionizers, make it possible to determine when the resins are exhausted.

The pump and deionizer units are located in the mechanical equipment room. It is not expected that the deionizers will become sufficiently radioactive to require shielding. However, under emergency conditions, it is possible that they could become highly radioactive. If such an eventuality arises, provisions have been made to erect a concrete wall about the equipment and a shielding cask would be required for removal of the resin cartridges.

3. Cask Storage

Location of the cask storage room is shown in Fig. III-1. The walls of this room are of concrete block construction eight inches thick, approximately eight feet high and open at the top. This allows the shielding casks, containing radioactive specimens, to be placed in the room by means of the service area crane. Radioactive dry waste, properly sealed in containers, may also be stored here prior to disposal.

C. DECONTAMINATION ROOM

The Decontamination Room is used mainly for decontaminating portable equipment and materials. Such items are adequately wrapped or boxed to retain any loose contamination within the wrapping or box and thus prevent its spread throughout the area.

The room contains two fume hoods. One is of standard construction except that all interior surfaces and exterior working surfaces are lead-lined. It contains a 12-inch by 18-inch by 12-inch deep lead-lined sink, and a 12-inch diameter by 12-inch deep removable crock for acid storage. This hood is used mainly for the decontamination of items which are small enough to fit into the sink.

The second fume hood is of original design and is used for the decontamination of relatively large equipment such as transfer casks, machinery and modular tables used in the hot cells. The horizontal dimensions of the hood are approximately 8 feet by 8 feet. Essentially, it is a concrete cubicle with a face opening approximately 7 feet high by 8 feet wide. The floor of the hood is depressed six inches below the room floor and contains a floor drain leading to the contaminated drain system. The hood is supplied with services such as water, steam, compressed air, and electrical outlets.

D. RADIOCHEMISTRY LABORATORY

A laboratory, equipped to handle curie-level quantities of isotopes, opens off the service area as shown in Fig. III-1. The following equipment is provided in this laboratory.

1. Fume Hoods

There are three standard isotope hoods grouped along one wall of the room together with a stainless steel laboratory sink and stainless steel topped work bench. Dimensions of the hoods are 6 feet wide by 3 feet deep by 4 feet high. The interior of the hoods are fabricated of stainless steel and all working surfaces are ground and polished for easy decontamination. The exterior of the hoods is of mild steel with a baked enamel finish. Services for air, gas, vacuum and water are provided and are remotely controlled from the exterior of the hoods.

The hoods are of the "airflow" type and contain double wall end panels to achieve streamlined entrance shapes. A single removable baffle is provided at the rear of the fume hoods with fixed openings at top and bottom for exhausting air from within the interior of the hoods. There is an automatic air by-pass at the top of the sash opening which limits the maximum air velocity through the face of the hoods. It also provides for removing a constant volume of air through the hood when the exhaust fans are in operation.

The fume hoods are designed for safe, efficient operation at an average air velocity of 50 lfpm through a 24-inch sash opening under normal operating conditions. The maximum velocity obtained through the hood opening with the sash lowered is 225 lfpm. Exhaust of the fume hoods is described in Chapter IV-D.

2. Lead Caves

On the opposite side of the laboratory are four lead and concrete caves, each 6 feet wide, 3 feet deep and 4 feet high. The lead brick forming the front and sides may be arranged at will, giving considerable flexibility as to the size of apparatus that can be accommodated and the position of manipulators and windows.

Fundamentally, the lead caves consist of a stainless steel topped bench 24 feet long by 3 feet deep by 3 feet high, placed along the east concrete wall of the radiochemistry laboratory. Suspended from the wall and the ceiling, directly over the bench, is an air exhaust hood of such dimensions that there is a four-foot gap between the bench and the bottom of the hood. It is in this space that lead bricks may be arranged on the bench so as to form the four caves mentioned.

Air exhaust of the caves is in parallel with the three standard hoods on the opposite side of the lab and is described in Chapter IV-D.

E. BUILDING SERVICES

1. Electrical Power

Electrical power is supplied the Quehanna Facility by a 13,200-volt power line leading to a substation consisting of two 500 kva, 13,200-volt, 200/240-volt transformers. One of these transformers supplies the general building equipment through a motor control center. The second transformer supplies a bus duct that runs through the reactor pool area. There are switchover provisions so that the second transformer can be used in case the first fails. This provision ensures the availability of a substation in case the first fails and assurance of power to operate the essential ventilating equipment in the hot cell area. This 440-volt power is reduced to 208/120-volt service as required for lighting and other services throughout the Radioactive Materials Laboratory.

2. Piping and Plumbing Services

The following general services are available throughout the area:

- (1) Hot and cold water.
- (2) Propane gas.
- (3) 100 psig air.
- (4) Steam.
- (5) Sanitary drain and hot drains in the potentially contaminated areas.

The potentially contaminated drains and monitoring and disposal are contained in a subsequent section.

In addition to these standard services, deionized water is available for filling the source storage pool as well as for any other chemical uses that may be required. As this deionizing system was installed primarily for the purpose of providing water for the reactor pool, it is available in quite large quantities and should ensure sufficient water for maintaining the water level in the storage pool even though a leak should develop. The rating capacity of this system is approximately 140,000 gallons per day. Figure III-8 is a block diagram of the system.

Fig. III-8. Pool Water Supply System

F. LIQUID WASTE TREATMENT PLANT

A plant for the treatment of liquid contaminated waste is housed in a separate building about 50 feet from the main building. The capacity of this plant was based on an estimated flow of 300 gallons per day, of which about 10% might actually require treatment.

Figure III-9 shows that the flow of wastes to the treatment plant is via one of two collection systems. A low level waste system originates in areas of potential radioactive liquid wastes and contamination such as floor drains in the hot cells, radiochemistry laboratory drains and decontamination effluents from the fume hoods in the decontamination room. Drains from areas of unlikely but possible radioactive contamination lead to a "suspect" waste system and originate from such places as the service area, change room showers, reactor area and the personnel decontamination sink in the Change Room. Each system may be terminated in either of two 3000-gallon underground tanks. When one tank in one system is full, the other tank in the same system may receive drainage while the contents of the full one are being drained or circulated for treatment.

There are two pumps for each system: one in each system will operate when required, with the second used as a standby. When a tank is full, the contents will be mixed by circulation through the pump and back to the tank. A sample will then be taken from the sampling cock on the pressure side of the pump and an analysis for radioactive content made. If the sample is below the maximum permissible level for release, the contents of the tank will be pumped out for disposal (described later) via the gravity head tank. If the sample is above the permissible level, the contents of the tank will be pumped to the evaporator.

Following evaporation, the sludge will be drained to drums which will be shipped off-site for ultimate disposal. The water vapor from the evaporator passes through a heat exchanger-type condenser, and the condensate flows into the vacuum receiver tank where it is sampled and then discharged via the gravity head tank to the stream system or again put through the evaporation process.

The vacuum receiver tank is kept at a vacuum of about 15 inches of Hg by means of a jet ejector operated by compressed air. This causes the liquid in the evaporator to boil at a relatively low temperature (approximately 80° C). The jet ejector ejects its air through an absolute filter to the atmosphere above roof level.

A radiation monitor, with an alarm arrangement, is situated on the drain line from the gravity heat tank. If, through some set of unforeseen circumstances, a slug of active liquid is being drained to the

641 044

Fig. III-9. Waste Treatment Plant

Fig. III-10. Waste Treatment Runoff

641 046

streams, the monitor will alarm and cause a valve in the drain line to close. The liquid in the gravity head tank can then be routed back to the storage tank for reprocessing.

A station has been provided for the addition of caustic to any storage tank for acid neutralization. This station may also be used for the transfer of radioactive waste solutions from other laboratories to one of the storage tanks.

Each group of two storage tanks are vented above roof level through absolute filters.

The system has been designed to be flexible. The following operations are possible:

- (1) The contents of any storage tank can be pumped to the evaporator.
- (2) The contents of any storage tank can be pumped to the gravity head tank.
- (3) The contents of any storage tank can be pumped to any other storage tank.
- (4) The contents of the gravity head tank can be routed to any storage tank.

Also included in the building housing the liquid waste treatment plant is a complete laundry facility for laundering potentially contaminated clothing. The effluent from the laundry facility is monitored in the liquid waste treatment plant.

F. EMERGENCY FACILITIES

1. Emergency Power

In any radioactive materials laboratory, it is necessary that electrical power be supplied to certain sections at all times. This necessitates an auxiliary generator, engine drive, which will automatically supply the required power whenever there is a failure of the normal supply.

In the Quehanna installation, the main emergency power system consists of a generator rated at 43.75 kva, 35 kw, 0.8 pf, 227/480 volt, 3 phase, 4 wire, 60 cycle. The generator is driven by a propane gas-fueled engine delivering a rated output of 81.5 horsepower at a speed of 1800 rpm. The propane fuel is obtained from the building gas system.

An automatic transfer panel transfers the load from the normal source to the emergency source when the normal line voltage falls below 85% and returns the load to normal when all normal line voltages have been restored to 95% or more. Time delay relays are incorporated in the transfer switch which permit the emergency unit to reach rated voltage and speed before the transfer is effected. This takes approximately 10 seconds.

When normal power is again available, the normal power is on the normal bus for 15 minutes before the critical load is automatically transferred from emergency to normal power. The automatic transfer switch is electrically and mechanically interlocked so that there is no feedback from the normal bus to the emergency generator or vice versa. Full relay protection guards against phase failure. A built-in test switch to simulate power failure is provided for maintenance checks and testing. An on-off switch on the generator set permits the engine to operate without interrupting the normal source of supply. A four-position control switch on the control panel permits selection of four operating positions marked "stop," "handcrank," "test," or "automatic."

During a normal power failure, it is necessary to provide emergency lighting, instrumentation, heating and ventilation for the hot cells. Emergency lighting is supplied in most rooms in the building and mainly consists of one electric bulb per room. This does not apply to the hot cells where 50% emergency lighting is provided so that an experiment, which is at a critical stage when the normal power fails, may continue.

It is necessary to keep the hot cells at a negative air pressure with respect to the surrounding areas at all times to prevent leakage of contaminated air into these areas. The following equipment is therefore connected to the emergency power supply:

- (1) Exhaust fans E-4 to E-10 and E-13 and E-14.
- (2) Differential pressure switches across the exhaust fans.
- (3) The pneumatic electric switches which cause E-4 to operate in case of an exhaust fan failure.
- (4) Air monitor.
- (5) Radiation monitor.
- (6) Model 8 Manipulator.
- (7) Emergency lighting.

This ventilation equipment is described in Chapter IV-D and illustrated in Fig. IV-6.

It may be seen that failure of both the normal and emergency power supplies, while most improbable, could cause a potential hazard throughout the building, and emergency exit lights are, therefore, automatically fed by independent battery units. When the normal power is restored, the emergency exit lights are automatically returned to the normal power circuits. Trickle chargers ensure that all batteries are fully charged when not in use.

2. Fire Equipment

Fire equipment is installed in and about the building in accordance with the requirements of the National Board of Fire Underwriters. Most sections of the building in which radioactive work is not carried on are protected by an automatic sprinkler system. When any part of this sprinkler system is actuated, an alarm will sound throughout the building. It is also arranged that an alarm will sound if the water pressure in the sprinkler system drops below a preset level.

It is not practical to use sprinkler systems in most areas where chemical and radioactive work take place because the reagent which should be used to put out the fire depends largely on the material in the laboratory and what is burning. In such areas, therefore, automatic fire detectors have been installed. If the temperature in one of these areas rises above a preset limit, it will result in the continuous ringing of all fire alarm bells throughout the building. Automatic detectors are located in the reactor bay, remote control room, reactor pump room, mezzanine fan rooms, Operation Area, above the isolation rooms, the Services Area, decontamination room and the Radio-chemistry Laboratory.

The entire fire alarm system will operate from the normal power bus. In case of a power failure, the system will automatically switch over to a 24-volt d-c supply obtained from storage batteries kept charged by means of a trickle charger. Provision is made for the system to be connected to a future central fire station.

In the areas in which only fire detectors are installed, it will be necessary to combat fires with locally available fire extinguishing apparatus. This mainly includes water, foam, carbon dioxide and powdered sodium chloride. The reagent to be used depends upon the type of fire.

There is no provision for fixed sprinkler or automatic fire detector equipment in the hot cells. Each experimental installation is evaluated individually for an associated fire hazard, and appropriate alarm and

fire extinguishing apparatus is installed with the experimental equipment as required.

Around the outside of the building there are three fire hydrants. The first is located approximately 60 feet from the northeast corner of the building, the second about 100 feet from the northwest corner, and the third, a pumper hydrant, on the south side of the building. Each unit is enclosed in a hydrant and hose-reel house which contains 200 feet of 2-1/2 inch hose and 300 feet of 1-1/2 inch hose which is sufficiently long to reach any section of the building.

An electrically driven pressure pump on the fire protection pumping system starts at 95 psig and stops at 100 psig and will supply 500 gpm at 100 psi. A booster pump cuts in if the pressure in the fire lines drops to 85 psig and cuts out again when the pressure reaches 110 psig. In case of an electrical power failure, a propane-fueled, engine-driven pump will cut in automatically when the water pressure drops to 75 psig but must be stopped manually.

Reference to Fig. III-11 shows how water is obtained from a surface storage reservoir which is covered by an aluminum structure and which holds not less than 135,000 gallons usable water volume when the surface is not frozen. The domestic water suction line removes water from a higher elevation in the reservoir than the fire protection suction line so that, in case of a water drawdown, there will always be 50,000 gallons of water available for fire protection.

Fig. III-11. Water Reservoir

IV. SAFETY FEATURES AND PROCEDURES

A. PHILOSOPHY OF CONTAINMENT

The Nuclear Facility as modified (refer to Chapter III) will safely contain and handle kilocurie amounts of most nonvolatile radioisotopes. The concept of isotope handling adopted by The Martin Company is the same as that reflected by the University of California Radiation Laboratory in Berkeley, California and numerous AEC Laboratories. This technique consists of confining the radioisotopes under process to an enclosure designed as a disposable unit. This technique has demonstrated that it is possible to confine multicurie amounts of activity within these enclosures without releasing activity to the external environment.

The Nuclear Facility is divided into two parts, the administrative and the hot working areas. The operating area is readily maintained in an uncontaminated condition. It is accessible only through the Change Room. The flow of air is progressively from uncontaminated areas to those of increasing likelihood of contamination.

Contaminated air generated within the hot cell containment box passes through a prefilter and an absolute filter before leaving the box, two absolute filters as it leaves the cell, a prefilter, and two more absolute filters before being released to the stack (see Chapter IV-D).

Standard operating procedures are established to minimize the spread of contamination wherever it may occur. Health Physics procedures are more fully discussed in the following section.

The Martin Company philosophy of multiple containment is evident at the start of the process. Three distinct containment barriers exist in the processing area:

- (1) Process equipment itself.
- (2) Steel containment box.
- (3) Hot cell system.

All transfer lines from the shipping casks to the storage vessel and from the storage vessels to the process equipment will be through tubes encased by an auxiliary tube. In those instances where a transfer is required from a cold area to a hot area, the equipment will be elevated to ensure that any leakage of material into the outer tube will flow directly into the receiving dry box.

The first containment barrier will be the process equipment itself located within the steel containment boxes inside the hot cells. As far as possible, the process equipment will contain any large particulate matter, i.e., dust. It will be vented directly to the exhaust system of the containment box so that both contamination and corrosion to the box will be reduced. The second, and most positive, containment barrier is the containment box. The boxes will be designed to have the lowest air pressure in the system and will be protected by both absolute inlet and outlet air filters. In addition, they will be designed to have as small an air flow as possible consistent with a safe operating pressure drop from the cell environment. The third containment barrier will be the hot cell which also has absolute filters on both inlet and outlet air streams. The operating air pressure in the cells will be higher than the dry box but lower than the operating area. To accomplish this and to ensure the containment of all radioactive material, utmost care will be taken to seal all ports, access holes and entrance ways. If additional equipment is needed in the box or sources removed, air locks will be provided for this purpose. The transfer of material from one dry box to another will be accomplished by placing the material in a clean container before transferring it through the air lock. In addition, ultrasonic cleaning devices will be available within the box to decontaminate fuel sources prior to loading them into a generator.

There is confidence that the Nuclear Facility has been designed to safely contain radioactive materials in the operating areas.

B. HEALTH PHYSICS PROGRAM

This section contains a general outline of the Health Physics procedures and controls necessary to assure maximum safety in handling large amounts of radioactive material. These procedures have been reviewed and approved by the Radioisotopes Committee of The Martin Company. It will be the function of the Health Physicist assigned to the facility to carry out these procedures with the cooperation of the operating personnel. He will be responsible for a radiation safety education program for all the employees at the facility.

The operating personnel must have a thorough understanding of the basic safety rules governing handling of radioactive materials. They must be fully familiar with the following information and willing to cooperate with the Health Physicist in maintaining a rigorous safety program. They will receive all revisions and special instructions as they are issued.

1. Instrumentation

An adequate supply of instruments, capable of detecting and measuring ionizing radiation throughout the facility, will be maintained as Health Physics equipment.

Monitoring systems.

a. Area monitoring systems. An area monitoring system, consisting, of gamma and high energy beta detectors with a range from 1 mr/hr to 10,000 r/hr, is installed with the control panel in the operating area. The alarm circuit can be set to activate the building evacuation alarm system.

b. Air monitoring system (see Fig. IV-6)*. Equipment is provided for monitoring levels of radioactive particulate contamination in the laboratory atmosphere and in the air handling system. The specific equipment chosen has been demonstrated to be appropriate for Sr-90 and Cm-242, the nuclides to be processed.

(1) Duct monitoring system

(a) Filter paper samplers

A central vacuum system will be provided for filter paper samplers at various locations in the air handling system chosen to enable evaluation of the performance of the filters. The sample filters will be changed and counted daily and results will be recorded. This will make possible the detection of filter deterioration so that corrective action may be taken before a serious problem develops.

(b) Continuously monitored filter paper samplers

A filter paper sample with a gas flow proportional counter and dual channel rate meter will be provided for the dry box exhaust and the cell exhaust ducts. These instruments will measure the alpha and the beta activity of the sample and will alarm upon a change in the ratio between the alpha and the alpha plus beta countrate. Both monitors will be interlocked with the air handling system to provide automatic corrective action.

(2) Room monitoring system

Continuously monitored filter paper samplers will be provided in three locations to monitor the room air.

(a) Operating area and machine shop

The monitor sampling the exhaust air from the operating area and machine shop will detect alpha and beta activity and will alarm upon a change in the ratio. An interlock with the

*For details of emergency corrective action, see Part D, Paragraph 10, Ventilation Air Monitoring Systems and Controls.

ventilating system will cause automatic corrective action.

(b) Service area

This monitor will sample the air from the service area as it enters the recirculation system. It will detect alpha and beta activity and automatically initiate corrective action as indicated in Item (a).

(c) Radiochemical laboratory and the decontamination room

This monitor will sample the air exhausted from the Radiochemical Laboratory and Decontamination Room and measure the alpha and beta activity of the sample. An increase in countrate will activate an alarm and automatically shut down the fan supplying air to these rooms.

(3) Dry box contamination samplers

A flexible tube will be provided within each dry box to facilitate the sampling of radioactive particulates within the box. The sample will be drawn out of the cell onto a filter paper sampler. Adequate precautions will be taken to prevent contamination from entering the room air due to the use of this sampler.

(4) Portable air samplers

Portable air samplers will be provided to monitor the radioactive particulates in the vicinity of hazardous operations such as decontamination and repair of contaminated equipment. They may also be used to supplement information provided by the installed systems.

c. Contamination checking stations. An alpha scintillation probe-countrate meter and a geiger tube-countrate meter will be provided at each of several locations within the facility to aid in contamination control:

- (1) Outside the Radiochemical Laboratory and Decontamination Room.
- (2) At each entrance to the controlled side of the Change Room.
- (3) At the entrance to the Operating Area.

- (4) At the main entrance to the building to supplement the existing beta-gamma hand and foot counter.

Counting equipment. A supply of scalers and detectors capable of detecting, measuring and differentiating between alpha, beta and gamma activity on smears, air samples, water samples, etc., will be maintained and operated by Health Physics. The counting equipment will employ scintillation, gas flow proportional and geiger tube detectors, and Health Physics will endeavor to maintain in operating condition at least:

- (1) Two each geiger tube scalers.
- (2) Two each alpha scintillation scalers.
- (3) One each gas flow proportional scaler.

Portable radiation detectors.

a. Beta-Gamma Detectors

- (1) Ionization chamber instruments with overall range from 1 mr/hr to 10,000 r/hr.
- (2) Geiger tube survey meters with range from 0 to 2000 mr/hr.

b. Alpha Detectors

- (1) Portable gas proportional alpha counters with scales ranging from 0 to 10,000 counts per minute.
- (2) Portable alpha scintillation counters with ranges from 0 to 200,000 counts per minute.

c. Neutron Detectors

- (1) Portable fast neutron scintillation-type counters with a range from 0 to 5000 neutrons/cm²/sec.
- (2) Portable thermal neutron boron trifluoride counter.

Instrument maintenance and calibration.

a. Maintenance

Routine maintenance will be accomplished at the facility under the direction of Health Physics. Instruments requiring major repairs will be returned to Baltimore.

b. Calibration

- (1) General. The calibration procedures for the various portable, permanently installed and counting room equipments are varied and sometimes complicated. To ensure adequate calibration of each instrument, a loose-leaf manual will be prepared entitled, "Calibration and Maintenance of Health Physics Instrumentation and Equipment." A card file will be maintained showing the date of each calibration and maintenance procedure for each instrument. A reminder sheet and tags on each instrument will ensure that calibration is performed on schedule.
- (2) Calibration specifications. In general, instruments will be calibrated to within 20% of the true dose rate. For greater deviations, the instrument will be marked or a calibration curve will be attached to the instrument. A card showing calibration and limits of accuracy will be attached to all air monitors and Counting Room equipment.

2. Personnel Monitoring and Protection

All persons entering the facility will be monitored for radiation exposures in accordance with current applicable regulations and standards for personnel protection.

Personal detection devices.

a. Film badges

All persons entering controlled areas will be required to wear a film badge. The film badge will contain two film packs, the first containing two films sensitive to beta-gamma radiation and the second containing a nuclear track emulsion film sensitive to fast neutron radiation. Films will be changed weekly, biweekly or quarterly (if regulations permit) depending upon the exposure of the individuals. Special film changes will be made as necessary. The upper limits of film response are as follows:

Gamma	-	1000 r
Beta	-	500 r
Neutrons	-	100 rem

b. Self-reading dosimeters and pocket chambers

All persons entering controlled areas will be required to wear

641 057

a dosimeter or a pair of pocket chambers. Dosimeters will be collected daily, read, recharged and recorded by Health Physics. The upper limit of response for pocket dosimeters is 200 mr gamma.

Permanent records will be maintained of all exposures.

Medical examination. All employees will receive a medical examination prior to any radiation work. Routine examinations will be conducted annually. In the case of unusual incidents, special examinations will be required.

Internal exposure evaluation.

a. Whole body count. Arrangements will be made for a whole body count of all operating personnel before starting work and periodically thereafter. In the case of suspected ingestion, special counts will be performed and recorded.

b. Bioassay. All facility personnel are required to submit bioassay samples prior to the start of operation and routinely thereafter. In case of suspected body intake of radioactive materials, i.e., intakes by ingestion, inhalation or penetration through the skin, special samples are collected from personnel involved. All bioassay results and other information on intake of radioactive materials are filed as permanent records.

Protective clothing and equipment

- (1) Protective clothing, specifically marked for radiation areas, will be available to all facility personnel. All personnel entering the operating and service areas will be required to wear laboratory coats. A more complete set of protective clothing consisting of coveralls, gloves, shoe covers, etc., will be required while working in contaminated areas. Such requirements are prescribed by Health Physics as conditions change.
- (2) All personnel will receive instructions on the proper use of respiratory protective equipment. Such aspects as proper fitting of filter elements, damage to filter elements, proper fit of the mask to the face, etc., will be emphasized. Personnel will be instructed to wear filter-type respiratory equipment whenever appreciable airborne contamination is present and will be instructed to use supplied air-type full face respirators when the concentration is highly variable or unknown.
- (3) The efficiency of the respirator filter units is checked by the manufacturer before shipment. All respiratory equipment will be inspected by Health Physics prior to use, for mechanical

integrity. It is felt that careful inspection is adequate to guarantee the effectiveness of the filter-type respirators since they will not be used where concentrations could result in serious overexposure to the wearer. The supplied-air respiratory equipment is more positive in its protection since it provides a positive pressure on the mask at all times during the breathing cycle. This equipment will be inspected by Health Physics before use.

- (4) Personnel leaving the regulated area will discard protective clothing in containers located in the change room. These containers will be periodically collected and transferred to the decontamination room where the clothing will be sorted and monitored by Health Physics. It is planned to hire a properly licensed decontamination laundry service to launder contaminated, protective clothing. If this plan is not carried out, the protective clothing will be laundered at the laundry facility in the Waste Handling Building. Waste from the laundry process will be treated as liquid or solid waste and disposed of accordingly.

Contamination monitoring.

a. Count rate meters. Both stationary and portable count rate meters will be situated within the operating service and change rooms. These instruments will be equipped with alpha and beta-gamma probes and are to be used by personnel for monitoring their clothing and persons prior to leaving the area. Health Physics will assure proper operation of these instruments and instruct personnel in their use.

b. Final checkout. A beta-gamma hand and foot counter will be available at the main entrance for checkout of hands and feet prior to leaving the facility. This instrument will be supplemented by an alpha probe count rate meter to detect alpha contamination on hands and feet.

c. Personal decontamination. Personnel detecting contamination on any part of their body or clothing will call Health Physics for decontamination before leaving the facility. Decontamination will be accomplished under the supervision of Health Physics in the Change Room where the proper decontamination supplies and equipment will be maintained. A record of all personal contamination will be entered in the employee's exposure file.

Regulated areas. Prior to and during operation of the facility, Health Physics will designate certain areas according to the degree of contamination and/or radiation levels, as regulated areas.

641 059

a. Entry and exit. Doors to all regulated areas will be controlled by a restrictive key system to prevent unauthorized entry. Personnel requiring entry to areas where the radiation levels exceed 100 mr/hr will be monitored continuously by Health Physics while they are in the area. Doors to these areas can be opened only with a master key controlled by Health Physics.

All personnel exiting regulated areas must complete checkouts of their clothes and person as detailed in "Contamination Monitoring."

b. Work permits. Health Physics will be notified, prior to the start of any new work, i.e., work in the cells, maintenance work, loading or unloading of sources, etc., and will conduct radiation surveys. Work in any area where the radiation level exceeds 6 mr/hr will be approved by the issuance of a "work permit." The work permit form will contain instructions as to the controls required. (See Fig. IV-1). The work permit will be kept at the job site during work and all personnel associated with the job for which it was issued will sign their name and clock number at the bottom of the sheet. When work is completed, a contamination check will be made by Health Physics and the permit will be collected and filed as a permanent record.

3. Facility Monitoring

The Health Physics Section will monitor all work involving radioactive materials at the facility to assure adequate personnel protection and compliance with current standards and federal regulations. Where operationally convenient, internal working limits lower than those specified in 10 CFR 20 will be enforced. These limits will be set by Health Physics in consultation with the facility supervisor.

Radiation surveys. Health Physics will conduct daily radiation surveys throughout the facility. Any unusual levels will be reported to supervision and proper precautions will be taken to reduce personnel exposures. Special radiation surveys will be performed as required.

Contamination surveys.

a. Surface contamination. Daily smear surveys will be conducted throughout the facility. Routines will be arranged to include a very detailed survey of a selected portion of the regulated area each day. The supervisor will be advised of loose contamination and will initiate decontamination procedures. Areas found contaminated will be marked by Health Physics until decontamination is completed.

b. Air contamination.

RADIATION AREA WORK PERMIT			
LOCATION _____		Incl Dates: _____	
JOB: _____			
HEALTH PHYSICS INSTRUCTIONS: Equipment and tool check required upon work completion. Have waste properly packaged.			
Radiation Level	Location	Time Limit	Health Physics
A			
B			
C			
PROTECTIVE EQUIPMENT		WORK PERFORMED BY:	
		Name & Badge No.	Dept
Cap or Hood			
Labcoat			
Coveralls			
Rubbers			
Shoecovers			
Rubber, gloves, cotton			
Respirator		APPROVALS:	
Breathing Air		Health Physics: _____	
Film Badge		Area Supervisor: _____	
Pocket Chambers			
Others			

Fig. IV-1. Work Permit

641 061

- (1) Fixed filter air samples from locations in the duct and room air monitoring systems will be changed and counted each shift. Air samples of the atmosphere of the dry boxes will be collected and counted during various phases of the process.
- (2) Continuously monitored filter samplers will be serviced during each shift and the filter paper changed and counted.
- (3) Small air pumps and high volume samplers will enable quick sampling of remote locations.

c. Water samples. Daily samples will be taken from the water system and analyzed for gross alpha and beta. Samples of the storage pool will be collected daily when radioactive material is stored there. Otherwise, samples will be taken when necessary.

d. Materials removed from controlled areas. All equipment will be monitored by Health Physics prior to removal from the facility. If no radiation or contamination is detected, a green tag is attached to the equipment and it may be taken into clean areas. If radiation or contamination is detected, the proper contamination and/or radiation tag is attached to the equipment until decontamination is effected or proper shielding is supplied at which time the equipment will again be monitored by Health Physics and retagged.

4. Environmental Monitoring

The environmental sampling program conducted by Curtiss-Wright will be adapted to the requirements of The Martin Company and continued.

Air samples. Air particulate samples will be taken at various locations. The filter media will be chosen for high filter efficiency and slow loading so that these samples can be allowed to run one week. Using Hollingsworth and Vose HV70 9-mil thick paper at 1 cfm flow, average concentrations as low as 10^{-13} $\mu\text{c} / \text{ml}$ can be measured.

Water. One-liter water samples will be collected weekly from several locations and analyzed. A proportion of the samples collected will be analyzed specifically for the isotopes used. Sampling locations will include Reactor Run, at least three from Meeker Run, one at Mosquito Creek and one from Wykoff Run.

Soil and vegetation samples. These will be collected before operation begins and then at six-month intervals, thereafter. The sampling locations and methods of Curtiss-Wright will be repeated. Specific analyses will be performed in addition to the gross alpha and beta.

Gamma background measuring. A gamma survey will be conducted in the area to establish background levels before operation and periodically thereafter.

In addition to this schedule, emergency samples will be taken in the event of an incident which might have released contamination to the atmosphere.

5. Source Supervision

Records. A monthly inventory will be kept for each source. It will contain such information as present source strength, source location, user, license number and other comments.

Leak tests of sealed sources. All sealed sources will be leak tested at not greater than six-month intervals by Health Physics. Where possible, the source itself is smeared making use of remote handling tools. If this is not possible, leak tests will be conducted by sampling storage pool water or surfaces of storage casks. Records of leak tests will be maintained according to the latest Federal Regulations.

Transportation.

a. Receiving. All incoming shipments of radioactive material will be monitored by Health Physics as they are opened. Smears will be taken of each layer as the container is opened, and portable survey meters will be used to monitor for external radiation.

The Health Physics representative will ensure that the source is transferred to its proper storage location, and is properly marked.

b. Radioactive material shipment. All shipments will be monitored by Health Physics to ensure compliance with applicable regulations. Bureau of Explosives permits will be obtained for special shipments.

6. Waste Disposal

The disposal of radioactive wastes will be in full compliance with Title 10, Part 20 of The Code of Federal Regulations.

Solid waste. Solid waste collected by operating personnel will be monitored by Health Physics and tagged with a radioactive material label and stored in the waste storage area.

Health Physics will monitor all waste cleanup in the cells and tag waste containers accordingly. The drums must be free of surface contamination and sealed in a manner suitable for burial. Periodically, the drums will be shipped to the waste disposal site. Interstate Commerce Shipping Regulations apply to all these shipments. High level waste might

be sealed in concrete "coffins" prior to shipment from the facility if necessary.

Liquid waste. Disposal of liquid waste will be conducted in full compliance with all provisions of Title 10, Part 20, of the Code of Federal Regulations. All liquid waste will be monitored by Health Physics prior to disposal to determine if the radioactive concentrations are within permissible limits. Any waste containing concentrations of radioactive materials above the permissible limits listed in 10 CFR 20 will be recycled through the waste cleanup system and resampled until it is within effluent limits. Liquid waste that cannot be "cleaned" within effluent limits for disposal will be mixed in concrete. Permanent waste disposal records are maintained by Health Physics.

C. SHIELDING

In the Quehanna installation there are five cells, side by side, with common adjoining walls. Figures III-1, 3, 4, and 5 show the general details of the cells and Table 6 gives the general cell dimensions. Chapter III-A gives a detail description of the cells.

1. Radioactive Materials To Be Processed

At the present time, the materials expected to be processed in the hot cells are Sr-90 and Cm-242.

Impure Sr-90 will be received in a solid form and converted to a liquid containing 100,000 curies in 10 liters of liquid. This will be concentrated and made into Strontium Titanate pellets. It is anticipated that the pellets will contain a total of almost 300,000 curies. Shielding will have to be provided by the bremsstrahlung generated by the 2.26 Mev beta particle from the Y-90 as well as by the 0.545 Mev beta from Sr-90. Varying amounts of Sr-89 will be present depending upon the age of the waste being processed. An analysis of the effect of Sr-89 present in wastes of various ages shows that it is never present in quantities large enough to affect the shielding for the Sr-90. Strontium-89 does, however, affect the heat output considerably.

Curium-242 will be obtained from irradiated Americium-241. The Am-241 is combined with aluminum to form a fuel slug approximately one inch in diameter by five inches long. After irradiation, the slugs will be very radioactive. The radiations present are gamma rays and neutrons. The gamma rays are due primarily to the fission products that were produced when the Am-241 and Cm-242 were irradiated in the reactor. Most of the neutrons result from spontaneous fissioning of Cm-242 and (alpha, neutron) reactions with aluminum*. The irradiated slugs will contain between 1.4 and 1.5 grams of curium. Thirty days after removal from the reactor, the unshielded dose rates at one meter for each slug will be 1.75×10^5 mrem/hr from gamma rays and 1.4×10^2 mrem/hr from neutrons.

2. Results of Shielding Analysis

Strontium-90 Analysis. Present plans call for the chemical processing of Sr-90 in 100,000-curie batches in Cell 2. Pelletizing and fuel loading of the generator will be performed in Cell 1. It is planned that the total amount of Sr-90 in this cell will be no more than 300,000 curies. The three-foot thick walls of these cells are more than adequate to contain the contemplated amount of curies. As a matter of interest, cells with two-foot thick walls would be adequate. Dose rates for these cells, calculated for the geometry shown in Fig. IV-2B are as follows.

*J. H. Roberts, Neutron Yields of Several High Elements with Polonium Particles MDDC-731.

Fig. IV-2. Geometry for Calculations

Fig. IV-3. Geometry for Calculations

Fig. IV-4. Geometry for Calculations

Sr-90	(mrem/hr)
100,000 curies in liquid form	
Dose rate through walls	4.5×10^{-5}
Dose rate through windows	6.6×10^{-2}
300,000 curies in pellet form	
Dose rate through walls	3.5×10^{-4}
Dose rate through windows	0.51

The dose rates for two-foot thick walls, calculated for geometry shown in Fig. IV-2A, are as follows:

Sr-90	(mrem/hr)
300,000 curies in pellet form	
Dose rate through walls	0.71
Dose rate through walls (3.6 density glass only)	100
Dose rate through window and 4 inches of 6.4 density glass	3.5

Curium-242 analysis. The irradiated Am-241 slugs will be processed in Cell 3. In this cell, the aluminum, plutonium and fission product will be separated from the curium. Cells 4 and 5 will be used to process further the curium and to form the final pellet. Shielding analysis results for Cell 3 are given in Table IV-1. As mentioned previously, the radiation emitted will be primarily the gamma rays from fission products, neutrons from spontaneous fissioning and neutrons from (α , n) reactions in the aluminum matrix. Examination of the results shows the cell to be adequate for processing two slugs simultaneously.

After the fission products are removed, the gamma dose rate becomes negligible when attenuated by the hot cell walls or window. Consequently, shielding of Cells 4 and 5 was calculated for neutron dose rates only. Neutron production will vary with the element with which curium is combined (Ref. 5). Dose rates for curium combined with nitrogen, oxygen, fluorine, carbon and chlorine are given in Table IV-2. Examination of the results shows that of these, fluorine compounds cause the greatest dose rates. Also shown in Table IV-2 are the inches of thickness of polyethylene which must be added to reduce the dose rate to 2.5 mrem/hr.

Shielding Analysis of Irradiated Am-241 Slug Processing in Cell 3

			Dose Rates (mrem/hr) 30 Days After Removal From Reactor		
			1 Slug 1.54 gmCm 5.1×10^3 Curies	2 Slugs 3.08 gmCm 10.2×10^3 Curies	
Bare Slug Dose Rate at 4 Feet			Gammas	1.75×10^5	3.50×10^5
			Neutrons	1.37×10^2	2.74×10^2
Operating Face of Cell	36-in. Ferrophosphorous Concrete	Gammas	3.7×10^{-4}	7.4×10^{-4}	
		Neutrons	3.2×10^{-3}	6.4×10^{-3}	
	36-in. Lead Glass Window	Gammas	6.71×10^{-2}	1.34×10^{-1}	
		Neutrons	.212	.424	
	Totals	Walls	3.6×10^{-3}	7.2×10^{-3}	
		Windows	.279	.558	
Back of Cell Outside of Retention Room	From Neutrons	Without Door	5.6	11.2	
		With 15 in. CI Door	9.3×10^{-3}	1.86×10^{-2}	
	From Gammas	Without Door	5.03×10^3	1.01×10^4	
		With 15 in. CI Door	7.6×10^{-3}	1.52×10^{-2}	
	Totals	Without Door	5.03×10^3	1.01×10^4	
		With Door	1.9×10^{-2}	3.38×10^{-2}	
		From Gammas	17.7	35.4	
		From Neutrons	7.3×10^{-2}	0.146	

641 088

TABLE IV-2

Shielding Analysis for Cells 4 and 5

			mrem/hr Per Gram of Curium	Grams Req'd To Make 2.5 mrem/hr at Dose Point	50 Grams (1.66 x 10 ⁵ Curies)		2 Grams (6.7 x 10 ³ Curies)		3.03 Grams 10 ⁴ Curies	
					Dose Rate	*	Dose Rate	*	Dose Rate	*
Operational Face of Cell (Fig. IV-2a)	Window	Nitrogen	0.274	9.12	13.7	6	0.55	-	0.83	-
		Oxygen	0.417	6.00	20.8	7.4	0.83	-	1.26	-
		Fluorine	28.9	0.0865	1445	22.4	57.8	11.0	87.6	12.5
		**	0.516	4.84	25.8	8.2	1.0	-	1.56	-
	Wall	Nitrogen	0.0165	151	0.82	-	0.033	-	0.050	-
		Oxygen	0.0251	99.6	1.26	-	0.050	-	0.076	-
		Fluorine	1.74	1.44	87.0	12.5	3.48	1.2	5.27	2.6
		**	0.0311	80.4	1.55	-	0.062	-	0.094	-
Back of Cell (Fig. IV-3)		Nitrogen	2.89 x 10 ⁻³	865	0.144	-	0.006	-	0.0087	-
		Oxygen	4.41 x 10 ⁻³	567	0.220	-	0.009	-	0.0134	-
		Fluorine	0.306	8.17	15.3	6.4	0.61	-	0.93	-
		**	5.46 x 10 ⁻³	458	0.273	-	0.011	-	0.016	-
Top of Cell Fig. IV-4a		Nitrogen	0.0115	217	0.575	-	0.023	-	0.035	-
		Oxygen	0.0175	143	0.873	-	0.035	-	0.053	-
		Fluorine	1.22	2.05	61.0	11.2	2.44	-	3.69	1.4
		**	0.0217	115	1.08	-	0.043	-	0.066	-

* Inches of Polyethelene to reduce Dose Rate to 2.5 mrem/hr at Dose Point

** Applies to both Carbon and Chlorine
Dose Rates are all based upon Weight of Curium - Not the compound.
Dose Rates are in mrem/hr

D. AIR HANDLING SYSTEMS

1. General Description of Ventilation Systems

Figure IV-5 indicates the areas described herein. The areas outlined on the drawing including Rooms 102, 103, 105, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118 and 119. All are considered to be in the contained area. All admission to this area is through air locks from outside the building or from adjoining areas.

The contained area is divided into four subareas of controlled ventilation served by Supply Air Systems 3, 4, 5 and 7. The areas outside the contained area are served by other separate supply and exhaust systems.

The air flow pattern within the contained facility is from the Machine Shop to Operation Area, Operation Area to Service Area, Service Area to Isolation Area, Isolation Area to Cells, and Cells to Dry Boxes.

All air supplied to the Service Area is exhausted through the cells and dry boxes through at least three absolute filters in series and then to the outside through the main stack.

During normal operation, the Operation and Service Areas will be at atmospheric pressure with increasingly more negative pressures in the Isolation Room, cell and cell dry box, in that order.

In addition to the shielding door, each cell has a sealed door to minimize leakage, with an absolute filter to allow air flow into the cell.

An emergency system with manual controls located in the Service Area, Operations Area and outside the building will provide emergency conditions as described under Control Systems. Another emergency system, actuated by a constant exhaust air monitor, will provide emergency conditions as described under Ventilation Air Monitoring Systems.

A description of the systems which follow are found on Fig. IV-6, p IV-37.

2. System No. 3

A supply fan, SH-2, supplies 100% outside air to the Service Area.

A static pressure regulator located in the duct to the area modulates Damper D-2 to keep constant supply air volume to the area. All air supplied to the Service Area will eventually be exhausted through the cells. (See description System No. 4.)

Fig. IV-5. Layout of Air Conditioned Rooms

3. System No. 4

Fan UC-1 takes air from the Service Area, prefilters, cools and discharges it to a booster fan, S-1. Booster Fan S-1 discharges the air through absolute filters, then to the isolation rooms adjoining each cell to maintain the proper working temperature in the cells.

A static pressure regulator, located in the discharge duct from booster Fan S-1, modulates the inlet vane control on Fan S-1 to maintain a constant air flow to the isolation areas.

4. System No. 5

Supply Fan UC-2 supplies a mixture of outside and return air to the Machine Shop and Operation Area. A static pressure regulator on the discharge side of the fan modulates Damper D-3 to maintain a constant air supply to the area. Another static pressure regulator in the exhaust duct maintains the Operation Area at atmospheric pressure by modulating a variable inlet vane damper at Exhaust Fan E-11.

5. System No. 7

Supply Fan UV-2 supplies 100% outside air to Rooms 102 and 103 through a roughing filter. All air from these areas is exhausted to the outside through roughing and absolute filters.

A backflow damper is provided in the main exhaust duct to prevent air from being drawn into the room from the hoods under emergency conditions.

6. Hot Cell Exhaust System

The normal exhaust system from each cell takes air from the Isolation Area, through an absolute filter, into the cells. The air leaving the cell passes through a roughing filter (changed from inside the cell), two absolute filters in series and an exhaust fan. The exhaust fan from each cell exhausts to a common stack.

The high volume exhaust system exhausts from any one cell at one time through roughing filters (changed from inside the cell), two absolute filters in series, an exhaust fan and duct connected to the stack. (See Control Systems for description of operation).

7. System No. 9 -- Cell Dry Box Air Supply and Exhaust

The theory of operation for the Nuclear Facility is to perform all of the work which constitutes a source of radioactive contamination within a dry box which, in turn, is wholly contained within the cell.

The cell dry box ventilation system, in keeping with the facilities overall design concept that the most highly contaminated area will have the greatest negative pressure, has been designed accordingly.

A system of noncombustible filters on both influent and effluent air lines is provided to assure that the introduction of foreign matter in the cell dry box will be minimized, and that no particulate matter of any kind will leave the cell dry box.

The cell dry box ventilation equipment will be wholly contained within the cell utilizing that particular dry box.

The air supply to the box will be taken from the cell and will flow into the box due to the negative pressure in the box. A static pressure regulator sensing differential pressure between the box and the cell will maintain the box at a negative pressure of 0.25 inch WG (water gauge) with respect to the cell. The supply air prior to entering the box will pass through a noncombustible absolute filter. The dry box will have dual exhaust ducts installed in parallel. Each exhaust duct will have noncombustible prefilters and absolute filters within the dry box enclosure. The purpose of the second set of filters is to function as an installed spare unit and will be utilized when the accumulation of contamination becomes excessive on the filters in use.

The exhaust air, after leaving the box, passes through two additional absolute noncombustible filters which are located within the cell. The cell dry box exhaust air then enters the facility dry box exhaust duct system, passes through two absolute noncombustible filters, is monitored and then vented to the atmosphere through the stack.

The dry box exhaust system has two exhaust fans. One fan is a normal fan and the other is a spare. The spare fan will start automatically on failure of the normal fan. The fans are high suction-type to ensure a box pressure that is always negative with respect to the cell.

8. Control Systems Cell Exhaust

Each cell exhaust fan has a differential pressure switch across it. On loss of differential pressure due to fan failure, the pressure switch will cause Damper D-5 to close, D-4 to open on that particular cell and Emergency Fan E-4 to start.

A static pressure regulator connected between each hot cell and the outside atmosphere will maintain a minimum negative pressure of -0.25 inch WG by modulating the variable inlet vanes at the fan. If

the fan is unable to maintain this negative pressure due to a door being open, a dirty filter or some other reason, a pneumatic electric switch will start Fan E-4 and open Damper D-4 on that particular cell to increase the cell exhaust volumes.

The cell exhaust system is started by one control pushbutton. This start button starts Fans E-5 through E-10 with a time delay before Fans UC-1, and SH-2 start. This ensures that the hot cells are never positive in pressure with respect to the Service Area. A time delay on the differential pressure switch on Fans E-5 through E-10 prevents operation of the emergency exhaust fan before the system stabilizes.

9. Emergency System Control

Manually operated pushbutton stations one located in the Service Area, one in the Operation Area and one on the outside of the building will operate as follows.

Activation of any of these buttons will stop Fans UV-2, UC-1, S-1, SH-2, UC-2 and E-11. This will ensure that during emergency conditions all air flow will be into the contained area through leakage, and from this area to the cells and dry boxes and then to the stack after filtering.

A weighted louver in the wall between the Operations and Service Areas will permit air to flow from the Operations Area to the Service Area during emergency conditions to purge the Operations Area. Under normal conditions there will be no flow through this louver.

10. Ventilation Air Monitoring Systems and Controls

Five constant air monitors will control stopping of the air handling systems to prevent the spread of contamination in the areas or its discharge to the outside. The procedure follows:

- (1) Monitor 2, located in the cell exhaust duct, will monitor exhaust air from the cells in the combined exhaust duct. If a high level is indicated, this instrument will start the cell emergency Exhaust Fan E-4 and open its associated cell exhaust dampers, stop all normal cell exhaust fans and associated cell exhaust dampers, and stop Fans UC-1, S-1, SH-2, UC-2 and E-11. An automatic, tight closing damper in the supply duct from Fan S-1 will close so all air entering the isolation rooms and cells will be through inleakage to ensure a negative pressure in the cells.
- (2) Monitor 1 in the combined discharge duct from the dry box exhaust fans will, on indication, start the dry box exhaust system spare fan and stop the normal fan, thus closing its dampers. An alarm will sound.

641 074

- (3) Monitor 4, located in the recirculating duct from Operations Room 118, will on indication stop Fans UC-1, S-1, SH-2, UC-2, E-11, UV-2 and E-12 and sound an alarm.
- (4) Monitor 3 will monitor the Air entering System 4 from Service Area Room 107. On indication, this monitor will stop Fans UC-1, S-1, SH-2, UC-2, UV-2 and E-12 and sound an alarm.
- (5) Monitor 5 will monitor exhaust air from Rooms 102 and 103. On indication, this instrument will stop the Supply Fan UV-2 and sound an alarm.

11. Balancing and Testing of Air Systems

After completion of all construction work in the facility, an extensive balancing and testing program will be carried out to ensure the proper operation of all systems and the proper flow of air.

All emergency conditions provided for in the design will be simulated to see that the requirements of the systems are satisfied.

E. EMERGENCY CONTROL

A great deal of planning and equipment will have been incorporated into the facility before work with radioisotopes begins. Nevertheless, it is recognized that it is possible for accidents to happen. This section presents a summary of the available means for dealing with emergencies. While it is not possible to predict all the accidents that might happen, it is felt that the equipment provided, combined with intelligent understanding of the facility and careful preplanning, will make it possible to deal with any emergency that could arise.

1. Organization

The Facility Manager will supervise the emergency control procedures. He will also issue any alternative procedures which he may feel to be necessary to cope with a particular situation. It will also be his responsibility to report an emergency incident to responsible authorities of The Martin Company and to the facility owner, Penn State University. In the absence of the Facility Manager, an Emergency Supervisor will be designated.

Health Physics. The Facility Health Physicist will determine the hazards in the situation and report these to the Manager. He, along with the Engineering Representative, will also offer advice on how best to alleviate the emergency and oversee the ensuing decontamination.

Off-Hour Coverage. At least one person will be in attendance at all times. In case of emergency, they will notify the Facility Manager and the Chief Health Physicist and carry out any orders issued.

2. Equipment

In addition to the support equipment previously mentioned, and the ventilation Air Monitoring Systems and Controls, Health Physics will maintain and operate an emergency vehicle outfitted with equipment capable of detecting and measuring air contamination and radiation levels on the site environs. The vehicle will include protective clothing and equipment, decontamination supplies and other items necessary to cope with emergency situations.

3. Emergency Plans

In case of a radiation or air particulate alarm, all personnel will evacuate the facility and congregate in the parking lot until the Health Physicist and Facility Manager can determine the cause of the alarm and plan immediate action.

Dosimetry and Follow-up Procedures. Dosimetry and follow-up

procedures will be conducted on all personnel who may have become contaminated or exposed.

a. External Exposure

- (1) Survey personnel monitoring equipment for contamination.
- (2) Remove, decontaminate and identify film from grossly contaminated badges.
- (3) Read dosimeters immediately and record exposures.
- (4) Arrange for film processing.
- (5) Report individual exposures to supervisor.
- (6) Excessive exposures will be handled according to 10 CFR 20.

b. Internal Exposures

- (1) Obtain nasal smears from all personnel.
 - (a) Count and record activity of nasal smears.
 - (b) Perform nasal irrigation if necessary. (Smears count greater than 50 dpm alpha or 500 dpm beta.)
 - (c) Issue urinalysis sample kit.
 - (d) Report individual exposures to supervisor.
 - (e) Excessive exposures will be handled according to 10 CFR 20.

Fires and/or Explosion

a. Fire or Explosion in Cell Dry Box

(1) Detection

A temperature indicator near the exhaust of each dry box will be connected to a dry box temperature alarm in the Operation Area. This may, in turn, be connected to the building fire alarm system. An explosion would actuate the pressure sensing switch.

641

(2) Control Equipment

Dry boxes used for handling readily oxidizable materials will be operated under an inert gas atmosphere. It is not economically feasible to perform all the work contemplated in a suitable inert atmosphere due to the high cost of the gas involved. Provisions will be made for automatically purging the dry box in the event of a fire. To ensure protection when the cell is unattended, the argon purge will be released by a heat activated device.

(3) Standard Procedure

The Cell Operator will be responsible for the following:

- (1) Don respiratory protective device.
- (2) Sound alarm (if not already done).
- (3) Start inert gas purge (if not done automatically).
- (4) Use extinguishing chemicals if possible, and/or smother with local inert gas supply.
- (5) Leave area if radiation alarm or evacuation alarm sounds.

The Emergency Supervisor will be required to:

- (1) Check performance of cell operator and assist if necessary.
- (2) Direct others in assisting if necessary.
- (3) Inform his superiors.

In case of a fire or explosion, the Health Physicist is responsible for:

- (1) Verifying correct operation of monitoring equipment.
- (2) Checking function of ventilating equipment.
- (3) Advising Emergency Supervisor as required.
- (4) Preparing for environmental monitoring.

(5) Checking all personnel for possible exposure.

(6) Making thorough post emergency evaluation.

All the other personnel in the area would report to the Assembly Area near the main entrance and await instructions.

b. Fires in Low Hazard Area

(1) Detection

Nonradiation areas are protected by sprinklers. The radiation areas with the exception of the cells are protected by heat detector alarms. Manual fire alarm stations are provided in each area.

(2) Control Equipment

Locations of sprinklers, fire extinguishers and other fire control equipment is described in Chapter III.

(3) Standard Procedure

The Cell Operator will:

(1) Sound alarm if not already done. Bring work in dry box to a point where it is safe to leave if necessary.

(2) Extinguish fire if nearby.

(3) Check operation of ventilation system.

(4) Remain in operation area, alert for problems, until instructed otherwise.

The Emergency Supervisor is responsible to:

(1) Determine location of alarm.

(2) Don respiratory protection.

(3) Proceed to extinguish fire or assist others.

(4) Instruct others to assist if necessary.

(5) Check with Health Physics.

641 655

The Health Physics representative will:

- (1) Don respiratory equipment.
- (2) Proceed to fire location.
- (3) Evaluate radioactive hazard.
- (4) Help extinguish fire.

Others persons, if in vicinity of fire, will sound the alarm, don respiratory protection and extinguish fire. If in another location, they should report to the Assembly Area to be available to assist.

c. Forest Fires

Around the outside of the building there are three fire hydrants. The first is located approximately 60 feet from the northeast corner of the building, the second about 100 feet from the northwest corner and the third is a pumper hydrant and hose-reel house which contains 200 feet of 2-1/2-inch hose and 300 feet of 1-1/2-inch hose. This is sufficient to reach any section of the building.

The building is surrounded by a cleared area several hundred feet wide which serves as a fire break. Because water is available to hose down the building and the exterior construction is fire resistant, it is felt that a severe fire in the surrounding woods would do essentially no damage to the facility.

4. Power Failures

Frequency. Power failures in the past have occurred on an average of about twice a year.

Measures. Should the power fail, an emergency power system will be automatically operated. Transfer from the main source of power to the emergency power system will take place through time delay relays which will permit the emergency unit to reach rated speed and voltage. This takes approximately 10 seconds.

The emergency system will supply power to the following:

- (1) Dry box exhaust.
- (2) Normal and high volume cell exhaust.

- (3) Manipulators.
- (4) Duct monitoring system.
- (5) Area radiation monitors.
- (6) Emergency lighting in rooms and hot cells.

5. Storms

Wind damage. Under normal conditions, the average wind speed in the area will not affect the building ventilation system. However, if wind speeds should increase to such a degree that they cause an unbalance of the system by varying the static pressure of the building, corrective action will be taken where necessary, i.e., supply air will be reduced to increase negative pressure in the cells and dry boxes, open or close doors and/or dampers to rebalance air systems in the operating and service areas. Questionable air flow and pressure will be measured with smoke tubes and velometers.

Flooding. The Facility is located on a plateau approximately 1900 feet above sea level. As drainage flows away from the site to lower altitudes, the possibility of flood damage within the facility is quite remote.

6. Contamination in Building

If a case of major contamination within some part of the building, due to a spill or other accident, occurs, the area will be marked by Health Physics and decontamination procedures will be initiated. Full protective clothing will be worn during this time.

7. Contamination Air Release

Contamination in the building. The room air radiation monitor systems will be connected to the alarm system. In case of an air monitor alarm, all operating personnel will immediately leave the Facility and congregate in a prearranged area. The Facility Manager and the Senior Health Physicist will don respirator protection and evaluate the radiation hazards. Ventilation and decontamination procedures will be carried out in full protective clothing including respirators or self-contained breathing apparatus, if necessary.

Contamination release to environs.

a. Air

If contaminated air should be released to the environment, a survey

641 081

will be conducted to determine the extent. A high volume air sampler mounted on the Health Physics emergency vehicle will be used for sample collection.

Simultaneously, general gamma readings will be taken with a scintillation detector.

b. Water

Contamination of the environmental water system might result from the following:

- (1) Release of high level liquid waste from the waste treatment plant.
- (2) Air contamination which might have been released from the Facility.

In either event, Health Physics will be aware of the situation via alarm systems. Samples of Meeker Run water, Mosquito Creek and Wykoff Run water will be collected. After a period of time following an incident, silt samples from these creeks will be collected.

Following this, the proper agencies will be notified.

8. High Radiation

Source storage pool leaks. Sources will be stored in the pool within a closed source storage bucket equipped with an upright bail to facilitate remote handling with the Service Area crane. If a leak should develop in the source storage pool, radiation levels will increase with reduction of the water level.

a. Detection

The area radiation monitor situated above the pool area will alarm automatically, setting off the building evacuation system.

b. Action will be taken as follows:

- (1) All personnel will leave the facility and gather at designated assembly area.
- (2) Health Physics will enter the building and survey the area to determine radiation levels.
- (3) The pool water supply will be increased to reduce the rate of shielding loss.

- (4) A concrete cask of sufficient thickness and density to reduce radiation to a tolerable level will be moved into position beside the storage pool from its location outside the Service Area.
- (5) The Service Area crane will be used to lift the source bucket from the pool into the cask, taking precautions to properly shield the crane operator and reduce his exposure.
- (6) The lid will be placed on the concrete cask and the area monitored by Health Physics. Radiation safety barriers will be erected around the cask, if necessary.
- (7) The cause of the leak will be determined by Health Physics and the Facility Manager and repairs and preventive remedies initiated.

Source dropped from transfer cask during transfer from storage pool to hot cell.

a. Detection

The area radiation monitor will alarm and set off the evacuation system.

b. Action will be as follows:

- (1) Leave the Facility and congregate at assembly area.
- (2) Health Physics will survey the area to determine radiation levels.
- (3) Remote or extended handling tools will be used to replace the source in the cask or storage pool, taking precautions to minimize all personnel exposures.

F. PREOPERATIONAL CHECKS

Inasmuch as The Martin Company is leasing a facility that is already constructed, the preoperational checks will accomplish two important purposes. The first will be to familiarize the personnel with the various services, capacities and general operational techniques; the other to establish the adequacy of radiation safety which was originally built into the facility as well as to verify the performance of those equipment and operational modifications made by The Martin Company and discussed in Chapter III. Based upon the results of these preoperational checks, a Master Checklist will be prepared which will establish the appropriate future frequency of these specified tests.

641 C82

A Standard Operating Procedure will detail the execution and criteria for evaluation of each such test.

The first order of business will be to examine closely all the pre-operational checks conducted by the Curtiss-Wright Corporation. Particular attention will be paid to the Co-60 analysis of the hot cells and the testing procedures for the ventilation, fire, heating and air conditioning systems. Any deficiencies observed will be corrected prior to actual startup.

The following are some of the specific tests that will be done before processing of any isotopes will be approved by the Martin Isotope Committee.

1. Ventilating Systems

The ventilating system modifications made to satisfy more rigid requirements in the handling of high energy alpha and beta contamination are defined in Chapter IV-D. Fan speeds, dampers, deflectors and air outlets will all be adjusted so that the air quantities are as called for. Readings will be made with a velometer or an equally accurate instrument. After all adjustments have been made, adjusting levers will be locked in position.

The entire ventilating system will be tested for a period of not less than two days of 7-1/2 hours each to demonstrate that each unit has the specified capacity required and that the system operates satisfactorily.

Exhaust ductwork shall be leak tested as follows:

- (1) Blank off all duct work openings at inlet and fan connections.
- (2) Pressure will be applied at one inch SPWG to ductwork.
- (3) Visual smoke tests will be conducted by discharging smoke into ducts.

Any leaks detected in these tests shall be repaired and the test repeated.

A preoperational check of the heating, ventilating and air conditioning systems interlock and damper control mechanisms will be performed. These tests will include adjustments to limit switches, pilot positioners, inlet vanes and outlet control dampers. Tests shall be performed to ascertain that control response time is in accordance with the specification or as indicated on the design drawings.

After all tests have been completed, typed results of the reports shall be prepared for permanent filing.

2. Filter Efficiency

Tests will be conducted, in situ, using finely divided material, such as copper powder, as a radioisotope tracer, on all filters after they are installed to ensure that they have not been damaged in handling and that they are properly set in their mounting. Guidance in the performance of these tests will be requested from the filter manufacturer to ascertain that the filters as installed are performing to design specifications.

3. Fan Operating Sequences

The fan startup sequencing will be checked to ensure that fans will actually start in the order specified. During the startup procedure, pressure gradients between adjacent areas will be measured to ensure that actual air flow is from the less hazardous to the more hazardous areas.

After startup sequencing is verified, fan failures will be simulated and the shutdown of other desired fans will be measured to verify transient flow under conditions of fan failure.

Also, a power failure will be induced and the proper startup of the emergency generator verified. The automatic startup of exhaust fans in proper sequence will be observed and pressure gradients measured.

Any changes indicated by these tests will be made and the tests re-run until the desired results are obtained to ensure proper air flow in any anticipated emergency.

4. Radiation Detection Systems

During the period immediately after portions of the building have been reconstructed, a considerable amount of monitoring equipment must be installed, checked out, calibrated and, in some cases, interconnected with previously installed systems. Radiation levels in the vicinity of this equipment will be carefully measured and steps will be taken to ensure that this protective equipment will function properly under all conditions of cell loading. Radiation monitoring equipment is calibrated by the manufacturer before shipment and will be recalibrated on at least three points after installation. Air sampling equipment will be calibrated before installation for each radionuclide in use in the laboratory and will be rechecked subsequent to installation. Reliability of all monitoring equipment will be tested under various abnormal operating conditions, including power failure and

641 085

ventilation system shutdown.

5. Dry Box Fire Protection System

The automatic argon purge system for control of fire within the dry boxes will be checked to ensure that the heat-activated devices release the argon in the quantities specified when the temperature within the dry box reaches a preset level. Also, the ventilation system will be checked to ensure that no unbalance occurs during this operation.

6. Piping

All water pipes, air lines, sewer lines, air sampling conduits, etc., will be carefully traced by The Martin Company after occupancy of the building to ensure proper connections.

7. Protective Coatings

All protective coatings in the potentially contaminated area will be carefully inspected visually to ensure adequate coverage. Any defects will be corrected to prevent future spread of contamination to porous materials. This inspection will be facilitated by the use of different colored coatings for each layer.

8. Regulated Area Control

The special, restricted key way, interchangeable core, lock system will be installed by the person responsible for its maintenance and carefully checked to be sure that it provides the necessary restrictions for entry to hazardous areas. It is planned to have the combination for this key system in the possession of one responsible person (Health Physicist or Facility Manager) so there will be no chance of inadvertent entry to a hazardous area.

9. Dry Runs

Dry runs will be performed on all operations until the Facility Manager and Health Physicist are assured that all possible operating difficulties have been overcome before actual radioactive operations begin.

10. Liquid Waste Treatment Plant

Dry runs will be conducted to familiarize operating personnel with this facility. Automatic controllers will be recalibrated, and piping, valves and tanks will be checked for leaks.

641 000

11. Emergency Power Plant

Simulated failures will be done to check the emergency power plant under full load conditions. The time required to re-establish operating conditions, efficiency of system pertaining to ability to operate all needed operating equipment will be observed.

641 037

V. RADIOACTIVE MATERIALS AND THEIR PROPERTIES

It is proposed that several types of radioisotopes will be processed in the Nuclear Facility. The two nuclides of immediate concern are an alpha emitter, Cm-242, and a beta emitter, Sr-90. They have been selected primarily for their capability of being used safely as fuel for thermoelectric generators. The final chemical form of Cm-242 may be either the oxide, carbide, or metallic mixtures or alloys, and for Sr-90 the final form will be the titanate. Other intermediate compounds will be prepared and handled, however.

The nuclear, chemical, physical and radiobiological properties of each isotope and its chemical form have been investigated. These data are presented in a condensed form in Tables V-1 and V-2.

A. STRONTIUM-90

1. Nuclear Properties

Strontium-90 is produced primarily from the decay of Kr-90 with a minor amount also produced from the direct yield in the fission process. It has a half life of 27.7 years and decays with a 0.545 Mev beta to Y-90. Shielding will have to be provided for the bremsstrahlung generated by the 2.26 Mev beta from Y-90 as well as the 0.545 Mev beta from Sr-90.

The daughter, Y-90, has a half life of 64.2 hours and decays to Zr-90. The decay beta of yttrium is 2.26 Mev and is accompanied by a 1.73 Mev gamma in 0.02% of disintegrations. The beta contributes bremsstrahlung X-radiation. There is a 6×10^{-8} second excited level of Zr-90, but the Zr-90 ground state is stable.

Genetic relationships. Strontium-90 has the following genetic relationship:

TABLE V-1
Physical Properties of Radioisotopes

	<u>Strontium- Yttrium-90</u>	<u>SrTiO₃</u>	<u>SrO</u>	<u>Curium-242</u>	<u>Cm₂C₃</u>	<u>Cm₂O₃</u>
Mev emission	(0.61β, 2.18B + bremsstrahlung)			S. F. neutrons α, γ		
Molecular weight	90	186	106	242	520	532
Melting point (°C)	800	2000	2430	950	2000	
Specific power, (watts/gm) (isotopically pure)	0.921	0.456	0.39	120	114.3	109.2
Half life	27.7Y			162.5 d		
Grams/K curie	(9.5) 4.99			0.3018	0.317	
Density (gm/cc)	2.66	5.11(4.6) ⁽¹⁾		13.5	10	11.75 ⁽²⁾

(1) Compacted and sintered

(2) Extrapolated values

MIND 2410

641

For maximum permissible amounts of radiation in human body refer to ICRP Committee II on Permissible Dosage for Internal Radiation (1959).

2. Chemical Properties

Strontium belongs to Family A of the Group II elements. These elements are the alkaline-earth metals with similar chemical properties. They resemble the alkali metals and their oxides resemble the "earths" (such oxides as those of iron and aluminum). The oxide of strontium may be prepared by heating the carbonate. Strontium exhibits only a divalent state.

Yttrium belongs to Family A of the Group III elements. These elements have two electrons in the outermost shell, and a third one which may be removed from the next inner shell. Yttrium is a member of the transition elements and has a trivalent state.

Strontium is a silver-white metal, soft as lead, malleable, ductile, oxidizes rapidly on exposure to air, and burns when heated in air, emitting a brilliant light and forming the oxide and nitride. The melting point of the metal is 800°C and the boiling point is 1150° C.

Strontium oxide is prepared by heating the carbonate and is a white solid which melts at about 2400° C. It is reactive with water to form strontium hydroxide.

Strontium titanate may be prepared by the calcination of strontium titanyl oxalate, $\text{SrTiO}(\text{C}_2\text{O}_4)_2 \cdot 4\text{H}_2\text{O}$. This compound is prepared by the addition of SrCl_2 to cold TiCl_4 , with the further addition of ammonium oxalate $(\text{NH}_4)_2\text{C}_2\text{O}_4$. The precipitate is placed in a furnace at 1100° C for three hours to achieve conversion to the titanate.

The strontium titanate, the final fuel form for Sr-90 isotopic power applications, exhibits different physical characteristics than the metal or oxide. The titanate is a brittle ceramic-type material which has a melting point of 2000° C and acts as an insulator rather than a conductor of electricity. The density is also greater, 5.11 grams per cubic centimeter, and the molecular weight is 199.5. The compound form is insoluble in water, hydrochloric acid or ammonium chloride. The solubilities of strontium titanate that have been determined to date are given in Table V-3.

Strontium compounds such as the carbonate, nitrate, and oxide are soluble in common laboratory reagents. The carbonate and nitrate are relatively insoluble in water, whereas the oxide decomposes to $\text{Sr}(\text{OH})_2$ in cold water which will subsequently dissolve when heated to 100° C. At 18° C, SrCO_3 is soluble in water to the extent of 10^{-2} grams per 1000 grams of solution.

641 092

TABLE V-3

Solubility of Strontium Titanate in Acids and Bases at 20° C

<u>Concentration</u>	<u>Exposure (hr)</u>	<u>HNO₃ (ppm)</u>	<u>HCl (ppm)</u>	<u>H₂SO₄ (ppm)</u>	<u>NH₄OH (ppm)</u>	<u>NaOH (ppm)</u>
0.1 N	336	2	2	4	1	3
6.0 N	336	50	625	0	0	245
0.1 N	750	2	2	5	2	4
6.0 N	750	85	660	0	5	150

Solubility of Strontium Titanate in Aqueous Solution at 60° C

<u>Demineralized Water</u>	<u>Tap Water</u>	<u>Natural Sea Water</u>
6ppb/100 days	Less than 1 ppb/100 days	20 ppb/100 days

3. Radiobiological Properties

The ecological path of Sr-90 is very similar to calcium. It, therefore, will be deposited mostly in the bone by replacing calcium and will act as an internal source of radiation to the blood forming organs. Strontium-90 is combined with Y-90 to obtain the radiobiological permissible concentrations. The maximum permissible body burden of Sr-90-Y-90 is two microcuries. For occupational areas, the maximum permissible concentrations in air and water of Sr-90-Y-90 are 3×10^{-10} and 4×10^{-6} microcuries per cubic centimeter, respectively.

B. CURIUM-242

1. Nuclear Properties

Curium-242 is artificially produced by neutron irradiation of Americium-241. Curium-242 has a half life of 163 days and decays via alpha emission to Plutonium-238 which has a half life of 86 years. The reactions involved are as follows:

Table V-4 shows the number of gammas of the various energies per alpha disintegration in Cm-242, and the gamma dose rate in rem that is present one yard from a pure, unshielded Cm-242 source of 100 thermal watts of power (2734 curies). Gamma radiation below 0.210 Mev is considered to be self-absorbed in the fuel itself, one proposed form being a platinum-curium oxide cermet.

TABLE V-4

<u>Gamma Energy (Mev)</u>	<u>Disintegration (gamma/alpha)</u>	<u>Rem/hr at 1 yd/100 (thermal watts)</u>
0.044	3.9×10^{-4}	Source absorbed
0.100	3.6×10^{-5}	Source absorbed
0.157	2.3×10^{-5}	Source absorbed

TABLE V-4 (continued)

<u>Gamma Energy (Mev)</u>	<u>Disintegration (gamma/alpha)</u>	<u>Rem/hr at 1 yd/100 (thermal watts)</u>
0.210	2×10^{-7}	5.7×10^{-5}
0.562	1.8×10^{-6}	1.4×10^{-3}
0.605	1.4×10^{-6}	1.16×10^{-3}
0.890	9×10^{-8}	1.1×10^{-4}
1.01	1×10^{-8}	1.36×10^{-4}
Spontaneous Fission Gammas	4.7×10^{-7}	2.54×10^{-3}
Total - Gamma/rem/hr at 1 yd =	0.0043	

Two different processes are responsible for fast neutron emissions from Cm-242 oxide. Spontaneous fission is responsible for 60% of the neutrons, while the remainder are the result of alpha particles impinging on the oxygen in the curium oxide. This same α, n reaction will also occur with many other light elements. The neutron flux is dependent upon the energy threshold for this reaction which varies greatly from isotope to isotope. Oxygen 16, for example has too high a threshold to exhibit this reaction with Cm-242. The neutrons from a Cm-242 source amount to 3.4×10^4 neutrons/sec 4π steradian. This amounts to 2.72×10^7 total spontaneous fission neutrons per 100 watts of Cm-242.

2. Chemical Properties

The chemical properties of Cm 242 are well known. It is the seventh member of the second rare-earth series, the actinide series. In this transition series, the inner electron orbits of the 5f shell are being filled. Curium, being the seventh member of this series, is the element analogous to gadolinium in the lanthanum series that has these inner orbital shells half-filled.

To date, all attempts to oxidize or reduce curium from its tripositive state in aqueous medium have failed. From the attempts to oxidize Cm-242 and Cm-244, both in macro amounts and tracer scale, it may

be concluded that the potential is more negative than minus two volts, or that the rates are too slow for concentrations of curium that will allow an oxidation medium to exist.

Attempts to reduce curium to the dispositive state have been made. Barium metal in hydrochloric acid was used as the reducing agent. No positive evidence for any reduction has been observed.

Curium metal has been prepared on the microgram scale by the reduction of curium trifluoride with barium metal vapor at 1275° C, using a vacuum furnace and a double crucible system similar to that described by Fried and Davidson. Data on the reduction of curium to metal indicate that the melting point of curium metal is between 1250 to 1275° C.

From mass and volume measurements, the density of the metal was computed to be approximately 13.5 grams per cubic centimeter. This number is a refined measurement which proved that early curium metal measured had void spaces within the metal.

Curium tetrafluoride and curium dioxide have been prepared in an anhydrous form from Cm-244 (an alpha emitter with a half life of 17.9 years), but these higher oxidation states have not been possible to date from Cm-242.

Curium carbide, Cm_2C_3 , a potential fuel form, may be prepared by reacting curium oxide with excess carbon at elevated temperatures.

Curium tetrafluoride was formed by fluorinating curium trifluoride at 400° C for one hour. The curium tetrafluoride formed appeared as light greenish-tan aggregates with a monoclinic crystal structure.

The calcination of curium oxalate at 500° C yields the sesquioxide, Cm_2O_3 .

Curium dioxide can be produced from curium sesquioxide by heating Cm_2O_3 in one atmosphere of oxygen at 650° C then cooling the compound slowly. Curium dioxide is a black powder while curium sesquioxide is a white or faint tan color.

Americium and curium are separated from plutonium when the latter is precipitated as the peroxide out of HNO_3 solution. After subsequent isolation of americium and curium as the solid oxalates, they may be further purified by ion exchange techniques.

The actinide elements are absorbed on Dowex-1 resin from highly concentrated chloride solutions such as saturated LiCl and may, in

this way, be separated from the lanthanide elements which pass through the column.

A chemical separation of americium and curium has been developed (Ref. 3) based upon the selective precipitation of the +6 state of americium as KAmO_2CO_3 . A slurry of americium and curium hydroxide in approximately 0.03 Molar NaHCO_3 is treated with ozone and the americium under these conditions is oxidized to the Am(VI) state whereupon it precipitates. The curium remains soluble in this carbonate solution.

A list of solubilities of curium salts may be seen in Table V-5. It can be seen that these solubilities are typical of other rare earths.

TABLE V-5
Solubility of Curium Salts

<u>Compound</u>	<u>Formula</u>	<u>Solubility</u>
Curium carbonate	$\text{Cm}_2(\text{CO}_3)_3$	Insoluble in water Soluble in excess $(\text{NH}_4)_2\text{CO}_3$
Curium hydroxide	$\text{Cm}(\text{OH})_3$	1 milligram/liter H_2O
Curium trifluoride	CmF_3	1 milligram/liter H_2O
Curium nitrates	$\text{Cm}(\text{NO}_3)_3$	Soluble in H_2O
Curium oxalate	$\text{Cm}_2(\text{C}_2\text{O}_4)_3$	Very insoluble in H_2O
Curium oxide	Cm_2O_3	Fairly soluble in H_2O

3. Radiobiological Properties

Curium-242 is characterized by high energy alpha emission and low energy gamma emission. With soluble compounds, the critical organs are the gastrointestinal tract and the liver; with insoluble forms, the gastrointestinal tract and lungs. While the only two humans who have been contaminated with Cm-242, under controlled conditions, excreted much of the curium with a biological half life of 25 days, the biological half life of the remaining or "fixed" curium is undoubtedly much longer. The maximum permissible body burden of Cm-242 is $0.05 \mu\text{c}^*$; other radiobiological properties are noted in Table V-2.

* based upon the liver as the critical organ.

VI. PROCESS FLOW

The five hot cells utilized in the processing of Sr-90 and Cm-242 and their conversion to suitable heat sources are depicted in Fig. III-1. Figure VI-1 schematically represents these cells and tabulates these process operations that are to be carried out within each cell.

A. STRONTIUM-90

Strontium-90 is received from the AEC as a separated fission product in the form of approximately 100 kilocuries of SrCO_3 residing on a metal filtering medium within a shielded shipping cask.

Dissolution of the carbonate with hydrochloric acid takes place within the shipping cask introduced into the doorway of hot Cell 2. The solution is subsequently drawn into a storage tank located in Cell 2.

Remote chemical processing within this cell takes place inside of a steel containment or dry box through the use of remote manipulators. These boxes are protected by absolute air filters and possess necessary services such as refrigerant cooling, vacuum, etc., as described in Chapter IV-D. A block diagram of the equipment in this cell appears as Fig. VI-3.

In batches of from 10 to 25 kilocuries, of strontium chloride is drawn from its storage tank in the containment box to a process point where it is precipitated as strontium-titanyl-oxalate. Filtration and drying of this precipitate is followed by furnace calcination to form strontium titanate. This product is then passed through a small ball mill to reduce it to an optimum size for compacting. The powder is introduced into a pellet press and is compressed into a pellet of SrTiO_3 which is then sintered at high temperature to yield the final fuel form.

When the requisite number of fuel pellets have been assembled in the metal fuel capsule, the exterior capsule surface is cleaned and the capsule is transferred from Cell 2 to Cell 1. In Cell 1 (see Fig. VI-2) it enters another metal containment box where it is remotely encapsulated, welded in an inert atmosphere and is subsequently ultrasonically cleaned to remove any traces of surface contamination.

Fig. VI-1. Process Flow

Fig. VI-2. Block Diagram Sr-90

Cell 2

12 ft

6 ft

Fig. VI-3. Block Diagram Sr-90

After removal from the welding containment box, the fuel capsule is loaded into a generator which has been introduced into Cell 1 for this purpose. The Sr-90 source size may be as large as 300 kilocuries. The adequacy of Cells 1 and 2 shielding (three feet of ferrophosphorus concrete) may be verified in Chapter IV-C.

B. CURIUM-242

Curium-242 is produced by irradiating Am-241 in a high flux reactor. Three aluminum slugs with a one-inch outside diameter and five inches in length, each containing four grams of AmO_2 dispersed in aluminum, will be irradiated for about 90 days and returned to The Martin Company in a suitably shielded cask. Each capsule should contain approximately four kilocuries of Cm-242 plus well over a kilocurie of mixed fission products.

The cask will be unloaded under water (in the storage pool) and either one or two capsules transported via a shielded cask to Hot Cell 3.

Once inside of this hot cell, the curium-containing capsule is transferred from its cask into the steel containment box whose processing equipment is shown in block diagram form in Fig. VI-4.

Chlorine volatilization of the aluminum contained in this irradiated capsule is the first step of this process. The excess chlorine ultimately passes into an alkaline scrubbing system within this hot cell. The americium-curium residue, containing both plutonium and non-volatile fission products, is dissolved in acid after which plutonium is precipitated as the peroxide.

The americium and curium in the filtrate are transferred to Cell 4 and into Containment Box 4A where they are precipitated as the oxalate. This oxalate solid is subsequently destroyed in nitric acid, after which Am-Cm are precipitated as hydroxides before being put into HCl solution.

After concentrated lithium chloride is added, the americium and curium are passed through an anion exchange system to separate them from rare earth fission products. Liquid waste fractions are held in this Containment Box for further treatment prior to discarding.

After elution from the column, curium undergoes further purification by passage through a second cation exchange column when low chloride concentrations prevail. After evaporation of the purified solution to near dryness, the separation of americium from curium

Fig. VI-4. Block Diagram Cm Cell 3

may be achieved (if desired) by adding potassium bicarbonate solution followed by oxidation of americium to the +5 state which promptly precipitates as the carbonate (KAmO_2CO_3). After filtration, curium in the filtrate is again precipitated as the oxalate.

The curium oxalate is ignited to curium oxide which may be an acceptable fuel form in itself when used as a cermet with Mo or Pt.

This final cermet may be prepared by transferring the oxide to Box 4B where it is blended with the matrix alloy or metal, and is pelletized and sintered to the desired density.

Alternative fuel forms are the curium carbide and a curium-metal mixture.

The preparation of the carbide is accomplished by transferring the oxide to Containment Box 4B, where it is blended with excess carbon, compacted and reacted at furnace temperatures. Subsequent grinding, pelletizing and sintering at high temperature yields the desired carbide fuel pellet.

The preparation of curium metal may also be carried out in Containment Box 4B. Curium oxide is first chlorinated* to provide the chloride salt. Formation of the curium mixture with another metal is achieved by co-reduction of their respective chlorides by calcium or magnesium metal reductant.

The fuel capsule, containing pellets of final curium fuel (cermet, carbide or metal mixture), is transferred to Cell 5 and introduced into Containment Box 5 where it is remotely encapsulated, welded in an inert atmosphere and is then ultrasonically cleaned to remove surface contamination prior to testing.

C. STRONTIUM PROCEDURES

1. Processing of Strontium Fuel in Hot Cells

The following list of processing steps defines the operations, conditions and equipment employed in Hot Cells 1 and 2. Refer to Figs. VI-2 and VI-5.

*Production of curium metal via the fluoride route is to be avoided, if possible, due to the prominent α, n reaction on fluorine and the need for added neutron shielding.

Hot Cell No. 2Dry Box 2EquipmentPrecipitation of Strontium-Titanyl Oxalate

1. Add stepwise a total of 10 liters of HCl to the container that is in the shipping cask positioned in the doorway of Cell 2 to dissolve the SrCO_3 off of the metal filter.
2. After dissolution, transfer SrCl_2 to a metal, cooled storage vessel in Cell 2 by applying vacuum to storage vessel. Note the volume by reading liquid level meter. Maximum volume is dictated by approximately 10 liters of solution used. Cooled, agitated storage tank
3. At the reaction tube, see Fig. VI-5, open door and place metal or glass vessel in position on rack. Move laterally to first process position. The motor-driven chill block is raised to contain the beaker in the rack support. Add TiCl_4 and chill to 5°C . (TiCl_4 is added by gravity from a calibrated storage vessel.) 1.5 liter metal or glass vessel for precipitation
4. Apply air pressure and transfer 10 kc SrCl_2 (~ 1 liter) to beaker in reaction tube. Watch liquid level indicator to ensure proper quantity. Metal process enclosure with glass face and lateral transfer tong, chill block, vacuum filter stick and furnace
5. By gravity flow, slowly add the necessary $(\text{NH}_4)_2 \text{C}_2\text{O}_4$ to beaker for precipitation.
6. By use of manipulator, lower the metal filter stick and rinse ring into beaker*.

*The filter and rinse tubes are supported by a block that is fitted by O rings, thereby obtaining an air-tight seal above the vent. At no time will this block be lowered below the side vent tube.

Dry Box 2Equipment

7. Turn on vacuum in scavenger vessel and transfer filtrate from reaction tube beaker. Add washings in same manner.
8. To scavenger vessel, add CaCl_2 to precipitate $\text{Ca}(\text{C}_2\text{O}_4)_2$, thus, "carrying" any SrCl_2 remaining in filtrate.
9. Allow $\text{SrTiO}(\text{C}_2\text{O}_4)_2$ to self dry by lowering chill block. Calcining dish, supported by rack, remains in place beneath filter.
10. Remove filter after separation of dried precipitate. Note if any precipitate remains. If so, gently tap filter stick to shake precipitate off into dish.
11. Move dish into furnace and calcine at 1100°C for 3 hours. Dish will remain on support rack during calcining. A slot will be provided in the furnace door to allow door to be closed.
12. Remove calcined product and place dish under overhead door in reaction tube.
13. Using a manipulator, pick up dish and transfer to ball mill. Close and fasten ball mill door securely. Ball mill will be pivoted and be in a vertical position at this time. After material has been transferred, lower ball mill and start rotation.

Waste filtrate vessel and vacuum filter stick for scavenger ppt*

Ball mill

*The scavenger vessel will be contained within a cast lead container. The vessel will be fitted with removable ball joint fittings in order for the manipulator to remove all lines from the vessel and replace with ball joint caps. Prior to removal, it will be fitted with a lead cap. It is possible that the container will be contaminated. It will be rolled into a detachable air lock. Both the door on the dry box and the air lock will be closed. The air lock will then be removed from the cell and packaged for disposal.

The filtrate from the scavenger will be evaporated. All condensate will be collected and sampled prior to withdrawing it to the plant waste disposal system. If the activity is such as to prevent such action, it will be packaged in concrete and disposed of by burial. The condensate in the evaporator will also be disposed of by packaging in concrete.

<u>Dry Box 2</u>	<u>Equipment</u>
14. Replace dish in reaction tube. Close tube door.	
15. Crush precipitate. Incline ball mill to emptying position and vibrate ball mill to transfer material to press through the pellet press feed tube. Lower ball mill, rotate and repeat operation to ensure removal of all material. The mouth of the ball mill will fit snugly onto the pellet transfer tube to prevent the escape of radioactive dust. The screen at the tapered end will prevent the balls from entering the pellet transfer tube.	Pellet press and pellet chill block
16. Press at 5 tsi. Place pellet in chill block by use of transfer plate and manipulator. Do not grasp pellet with manipulator since pellet is fragile at this time.	Pellet press and pellet chill block
17. Pick up green pellet in its chill block and transfer to calcination dish in reactor tube.	
18. Move to furnace and sinter for 3 to 5 hours at 1350° C.	Sintering furnace
19. Remove sintered pellet and place in chilled fuel capsule for storage.	Chill block for fuel capsule
20. After all pellets are made, transfer fuel capsule to cleaner. Cap top opening and decontaminate exterior surfaces below this cap.	Chemical or ultrasonic cleaner for exterior of fuel capsule
21. Transfer fuel capsule in chill block to Cell 1 for welding.	
22. Remove cover from welder, load capsule into special welding jig holder.	Remote welding equipment
23. Close weld chamber and evacuate; backfill with inert gas.	
24. Weld capsule.	
25. Ultrasonically clean exterior of fuel capsule prior to loading into generator.	Ultrasonic cleaner
26. Load into generator for testing.	

D. CURIUM PROCEDURES

1. Processing of Curium Fuel in Hot Cells

The following list of processing steps defines the operations, conditions and equipment employed in hot Cells 3 and 4. Refer to Figs. VI-6, VI-7 and VI-8.

Hot Cell No. 3

<u>Dry Box 3A</u>	<u>Equipment</u>
<u>Chlorine Volatilization of Curium-Aluminum Capsule</u>	<u>Transfer Cask and Dolly</u>
Capsule Size = 1.7 grams curium oxide	
1. Loading of cask with 1 irradiated americium capsule, in pool.	Remote operation manipulators
2. Transport cask to Cell 3 on dolly.	
3. Remove cover of cask with hoist inside hot cell.	
4. Chill cask and then with manipulator, remove capsule with chill block.	Copper chill block
5. Insert chill block and capsule in dry Box 3A.	Reaction furnace and condenser
6. Remove fuel capsule from chill block, and rapidly insert in reaction zone in furnace.	
7. Seal volatilization furnace and pass helium gas through for cooling and purging of oxygen and moisture.	
8. Slow down helium flow rate and decrease external cooling to permit an increase in temperature to reaction level.	Alkaline scrubber columns
9. Introduce chlorine gas and continue helium flow.	
10. Maintain capsule temperature below 1200° F by:	
(a) Reduction in chlorine flow; increasing helium flow.

Fig. VI-6. Curium Purification Cell 3

Fig. VI-7. Curium Purification Cell 4

MND 2410

641 113

Fig. VI-8. Curium Purification Cell 5

VI-15

Dry Box 3AEquipment

- (b) Increasing water jacket cooling of reaction zone.
11. After all aluminum has been sublimed (10 to 12 hours), stop chlorine flow, purge excess or unacted chlorine into alkaline scrubber.
 12. Continue helium purge (removal of all chlorine from system).
 13. Cool apparatus to permit isolation of volatilizer and connection of dissolver and condensers.

Dissolver and
reflux con-
densers

Low Temperature Sublimation from Condenser

1. Revolatilize AlCl_3 sublimate trapped in first condenser; condenser retaining semivolatile isotope compounds at low temperature (300°C).
2. Discard of resublimed AlCl_3 (in second condenser). Take sample to check radioactivity content of sublimate during operation.
3. Isolate curium oxide or chloride plus non-volatile rare earth products from boat in reaction zone and the product from first sublimation condenser after resublimation at low temperature.

Waste disposal
equipment

Curium Purification Processing--Dissolving of Curium

1. Volatilization Residue (curium, americium and fission product). Connect volatilizer to the aqueous dissolver system and reflux condenser.
2. Final dissolution of curium oxide with HCl or HNO_3 acid to solubilize any curium oxide. Evaporate to approximately 40 millimeters of solution with about 2M-HNO_3 or 2M HCl present in solution.

Dissolver and
reflux con-
denser

Dry Box 3A

3. Reprecipitate plutonium in the presence of alkaline carbonate (or peroxide). (To be tested by both methods for maximum yield evaluation.) Allow slurry to stand for 4 hours at 5° C in filtration (or precipitating) flask.
4. Filter of supernatant liquid leaving the plutonium isotopes, 238, 241, 244, as a cake on filter. Wash cake.
5. Redissolve plutonium to transfer to storage flask for recovery.
6. Take filtrate from Step 4 and transfer solution to hot Cell 4.

Equipment

Precipitating
flask
chill block

Plutonium
storage flask

Curium Purification--Ion Exchange and Fuel Form

1. Add saturated oxalic solution to precipitate americium-curium as oxalates, in precipitator flask.
2. Filter precipitate through platinum filter. Transfer filtrate to storage for further processing.
3. Dissolve oxalate precipitate in minimum volume of 6M-HNO₃ and boil to destroy oxalate; reprecipitate with ammonium hydroxide and filter. Redissolve cake in 1.0 M hydrochloric acid solution, then dilute with 11.5 M lithium chloride.
4. Solution added to Dowex 1 x 8 anion resin column.
5. Wash column with 10 column volumes of 10.5 M lithium chloride and 0.1 M HCl solution (2.2 liters = 1 column volume). Rare earths pass through column first and iron remains on column.
6. Elute americium and curium from resin by washing column with 3 column volumes of 6 M HCl.

Waste storage
flask

Dowex 1 ion
exchange col-
umn 2-1/2 inch
diameter by 36
inches long

<u>Dry Box 3A</u>	<u>Equipment</u>
7. Evaporate elutriant to near dryness and add water to produce an acid solution concentration of 0.5 to 1.0 M HCl.	
8. Pass solution through Dowex 50 x 8 cation column.	Dowex 50 Ion Exchange Column 1
9. Wash column with 3 column volumes 0.5 M NH_4Cl . Elute americium and curium ahead of the lanthanides with 10 column volumes of 2.5 M lactic acid at pH 4.5, heat to 70° C (2.2 liter = 1 column volume).	
10. Pass lactic acid elutriant for americium and curium (adjusted to pH 1) through Dowex 50 x 4 cation column. Column is washed with 2 column volumes of 0.5 nitric acid.	Dowex 50 Ion Exchange Column 2 2-1/2 inch by 36-inch column
11. Elute americium-curium with 3 column volumes of 8 M nitric acid.	
12. Evaporate solution to near dryness and diluted to an acid concentration of about 0.5 molar HNO_3 . Add saturated oxalic acid to solution. Americium-curium precipitated and filtered with platinum filter.	Oxalic acid precipitator flask
13. Dry precipitate and ignite to curium oxide at 500° C for 4 hours.	
14. Cermet Preparation for Fuel Form	Blender, press, chill block, sintering furnace
(a) Transfer oxide from Box 4A to 4B	
(b) Blend with matrix alloy or metal (i.e., Mo or Pt).	
(c) Press into pellets; each pellet 6000 curies.	
(d) Sinter pellet by placing into furnace at 1300° C for several hours.	

Fuel Compound Preparation--Curium Carbide

Alternate 1

Hot Cell No. 4Dry Box 4BEquipment

1. Transfer curium oxide to blender and add excess carbon. Argon furnace
 2. Compact carbon-curium oxide mix into pellet. Maximum pellet 6000 curies of curium.
 3. Insert pellet in tube furnace and heat to 1550° C or higher (in experimental stage) 2 hours. Pellet press
 4. After cooling, remove pellet and place in motor. Grind and repelletize. Grinder (mortar and pestle)
 5. Resinter at 1800° C. Cool and take sample for analysis.
 6. Analyze for curium conversion content.
 7. If satisfactory, transfer to container for encapsulation (in chill block).
 8. Carbide preparation for fuel form.
- Since the pure curium carbide is too hot for most applications, a diluted fuel is required.
- (a) Blend curium carbide with carbon* to desired concentration (i.e., 1/20 or more). Blender, press

*Alternate method may substitute silicon carbide for the carbon diluent.

<u>Dry Box 4B</u>	<u>Equipment</u>
(b) Compact pellets.	
(c) Load capsule with pellets taking care not to contaminate welding zone.	
(d) Decontaminate outer surface of capsule by removal of plastic coating in solution.	

Alternate 2

Curium Fuel Alloy or Metal Mixture

Note: For a thermoelectric fuel capsule, a metal mixture may be the most suitable fuel. Co-reduction of both metals is accomplished.

1. Transfer curium oxide to reaction vessel for fluorination in dry Box 4B (6000 curies).	Chlorination reactor
2. Purge system with argon.	
3. Place unit in induction furnace with 1/2 gram of curium present. Heat to 500° F and add HCl gas plus dry oxygen in the ratio of 3:1 for 4 hours.	Oxo drier for argon
4. Cool and discharge furnace to storage container and chill block.	Dry Box 4B (inert atmosphere)
5. Blend co-reductant (i.e., Pt or Mo) with curium chloride and compact into disc.	
6. Place the disc material in reaction vessel.	
7. Preload isolated chamber with calcium (or magnesium) shot.	Induction heating unit
8. Initiate reaction by allowing shot to fill spaces between discs and induction heat to 750° C	Plastic hood for crucibles
9. Cool chamber and remove liner and reactants to plastic hood with chisel holder.	Hammer and chisel
10. Chip off button and clean surface of metal button.	

Dry Box 4BEquipment

Optional Procedure

Separation of Americium and Curium

1. The solution from Step 12 of Section D upon evaporation to near dryness, treat with potassium bicarbonate until 0.03 molal.	Ozone generator
2. Heat solution to 92° C and bubble freshly prepared ozone through solution to precipitate the americium.	Precipitator flask
3. Filter off americium precipitate.	
4. Wash precipitate with K_2CO_3 (dilute) and then redissolve cake in concentrated hydrochloric acid and discharged to storage.	
5. Add oxalic acid to filtrate from Step 3 to precipitate curium.	
6. Filter precipitate on platinum filter and dry cake.	
7. Ignite oxalate to curium oxide at 500° C for 4 hours.	Furnace
8. Transfer precipitate in flask to dry Box 4B for fuel form preparation.	

Disposal of Reduction Slag

The excess calcium and entrained curium in slag must be treated for disposal.

Dry Box 4AEquipment

1. Check for radioactivity level. Take sample and dissolve in H_2O . Take aliquot and check α content.	
2. Destroy the excess Ca or Mg by the slow addition of alcohol (propyl or butyl alcohol).	Waste reaction vessel
3. After completion of reaction, add water and cool. Using a carrier precipitant (i.e., lanthanum), or curium as well as any Pu formed or remaining.	

Dry Box 4AEquipment

4. Redissolve precipitate and pass through ion exchange columns to collect any Am or Cm present. Use column for several batches until saturated or capacity point is reached.
5. Elute column and precipitate Am-Cm mixture with concentrated oxalic acid solution.

Dry Box 5AEquipmentCurium Processing

Fuel Container Loading and Welding

1. Transfer loaded and capped capsule in a finned-type chill block from Cell 4B to Cell 5. Dry Box 5A.	Remote welder
2. Load capsule into special welding jig-holder.	Chill blocks
3. Close weld chamber and purge by evaluation. Back fill with argon or helium (dry). Repeat operation.	
4. Weld capsule shut.	
5. Remove from weld jig and reload into chill block.	Ultrasonic cleaner
6. Decontaminate capsule with ultrasonic cleaner in dry Box 5A.	
7. Transfer capsule to dry Box 5B and load into ultrasonic cleaner. Clean capsule.	Ultrasonic cleaner
8. Transfer to external-type cask.	

VII. OPERATING PROCEDURES, CREDIBLE PROBLEMS AND REMEDIAL STEPS

A. PROCEDURES FOR FUEL PREPARATION AND HANDLING

Chapter VI has presented a general picture of the equipment, procedures and process chemistry employed for converting SrCO_3 to an encapsulated heat source of SrTiO_3 and, similarly, for the conversion of an irradiated capsule of Al-AmO_2 containing Cm_2O_3 to an encapsulated heat source of either Cm_2C_3 , a cermet or a metal mixture.

This section presents these processing steps in somewhat more detail and includes an evaluation of credible problems and their solution. More detailed sketches of the hot cell equipment are included (Figs. VII-1, VII-2, VII-3 and VII-4) and are referenced in the text.

The problem of waste disposal is mentioned in these procedures but is not discussed in detail. Liquid wastes generated within the hot cells and specifically within the process containment boxes will be scavenged with a "carrier" precipitate to concentrate the bulk of the radioactivity into a small volume for disposal or will be reduced in volume by evaporation. The scavenging technique is normally preferred although in some instances both methods may be employed.

As an example of the scavenging technique, the precipitation of as little as one gram of ferric hydroxide per liter will remove $\sim 100\%$ of the Am or Cm from solution. The precipitation of $\text{Bi}_2(\text{C}_2\text{O}_4)_3$ from acid solution will also achieve this decontamination. Similar exchange and coprecipitation is known to scavenge Sr-90 and diverse fission products from solution.

Concentrated fractions of, or from, liquid wastes will be removed from the containment boxes in sealed containers to be subsequently immersed in concrete* for shipment to an AEC disposal site. Solid wastes will be similarly packaged for disposal.

The following table endeavors to show the operations carried out together with an evaluation of the credible problems encountered, the remedies required by such problems and the Health Physics assistance which would be applied to individual situations. Health Physics services and procedures controls are discussed in greater detail in Chapter IV-B.

It is assumed, for purposes of this condensed presentation, that the appropriate instrumentation, monitors and alarms are in use as defined in Chapter IV-B. Similarly, the case of fire within these operating boxes has been adequately covered in Chapter IV-E.

*Or as otherwise specified by the AEC site.

Fig. VII-1. Curium Purification--Cell 3, Box 3a

Fig. VII-2. Curium Purification--Cell 4, Box 4a

Fig. VII-3. Curium Purification--Cell 5

MND 2410

641 124

Fig. VII-4. Processing of Curium Fuel Curium Purification Flow Diagram

B. CURIUM PURIFICATION

Bx Cont Smpl - Box Contaminated Samples
 Cell Rd Prb - Cell Radiation Probe
 Port Rd Mon - Portable Radiation Monitor
 Mbl Air Mon - Mobile Air Monitor
 Sm Svy - Smear Survey
 Bx Spl Cnp - Box Spill Cleanup
 Man Decon - Manual Decontamination

	<u>Process Flow</u>	<u>Health Physics</u>	<u>Credible Problems</u>	<u>Remedies or Controls</u>
1.	Loading of Irradiated Aluminum Capsule into Cell 3	Equipment	(1) Shielded Transfer Cask (2) 15-Ton Hoist (3) Dolly and Lift Fork Truck	(4) Dry Box 3A in Cell 3 (5) Chill Block (Copper)
	(a) Cask into pool 28,000 curies per shipment	H ₂ O smpl Sm Svy	Leak in capsule contaminates shipping cask	Sample of cask solution Seal cask up Remove from pool and decontaminate surface of cask (and pool, if required)
	(b) Remove all 7 capsules from cask. Transfer 6 capsules to storage chamber in pool	Port Rd Mon	Leak in capsule contaminates storage unit	Sample storage chamber solution. Decontaminate same as (a)
	(c) At bottom of pool, place 1 capsule in transfer cask. Transfer to Cell 3 through 3-1/6 in. door	Port Rd Mon	Dropping of transfer cask with damage of capsule-- release of rare earth Sr-90, Cerium-144, etc. to transfer cask	Sealed container checked for contamination, e.f. extreme surface contaminated (see Emergency Procedures)
	(d) Remove capsule from cask. Place in chill block (copper) in Dry Box 3A	Bx Cont Smpl Cell Rd Prb		Careful handling of cask

MND 2410

CHI
100

	<u>Process Flow</u>	<u>Health Physics</u>	<u>Credible Problems</u>	<u>Remedies or Controls</u>
2.	Chlorination of Capsule Cell 3--Container 3A	Equipment	(1) Dry Box 3A (2) Copper Chill Block (3) Flow Meters (4) Volatilization (5) Remote Manipulators	(6) Chlorine Scrubbers (7) Waste Containers
	(a) Take capsule from chill block. Place in reactor (volatilizer). Pass helium gas to keep solid Al cool	Bx Cont Smpl	Clogged gas line Breakage of quartz tube Radioisotope still contained by secondary barrier (of metal tube)	Increase water cooling Turn off chlorine Increase by-pass He gas Replace clogged section Seal end of quartz with plastic during change Remedy: Check for system pressure leak.
	(b) Adjust He and chlorine flow	Bx Spl Cnp Bx Cont Smpl	Leakage of scrubbers	Shut off gases. Seal off scrubber and cut in new bank. Control: Careful inspection of equipment.
	(c) Allow reaction to proceed below 1200° F	Cell Rd Prb (neutrons)		
	(d) After reaction in quartz, reaction vessel is disconnected and connected to dissolver	Bx Cont Smpl Bx Spl Cnp	Reaction of Cl ₂ with moisture getting into volatilization system with rupture of quartz tube	Procedure (same as (a), if it occurs) Remedy: Maintain slightly positive pressure on volatilization system. Auxiliary helium pressure regulator in system.
	(e) Excess gas flow goes to external scrubber		Loss of solution in scrubber	Initiation of coolant flow alarm. Light flashes, open valve to refill scrubber.
	(f) Sample for analysis of exhaust air	Bx Cont Smpl		Dry box exhaust air sample taken.

	Process Flow	Health Physics	Credible Problems	Remedies or Controls
3.	Disposal of Aluminum Chloride Sublimate Dry Box 3A, Hot Cell 3	Equipment	(1) Tube Heater Furnace with Vycor Tube and Protective Jacket	(2) Controller (3) Condenser and Traps
	(a) Waste disposal alternatives proposed:	Bx Cont Smpl		
	(1) Continually running water or sodium hydroxide solution through columns and feed powdered $AlCl_3$ continuously as formed to keep quantity small. Scavenge with insol hydroxide in waste storage chamber, if necessary, to recover.	Bx Spl Cnp	Adding solid too rapidly causes gas evolution over pressure in system Clogging of discharge valve Excessive addition of solid. Too much heat generation sufficient to boil over into vent system	Increase water flow for cooling. Decrease reaction rate Shut down and disconnect valve. Replace valve Temperature indicator or dissolver. Increase condenser water flow. If still boils, stop addition. Remove contaminated section and replace vent line
	(2) Collect solid condenser product and slowly add water; again scavenge, if necessary. Then filter off precipitate and rework material.			
4.	Dissolution of Curium Following Chlorination--Box 3A	Equipment	(1) Dry Box (2) Glass Dissolver	(3) Cooler (Glass) (4) Volatilization Apparatus
	(a) Curium oxide (Cm_2O_3) or chloride ($CmCl_3$) plus fission products (now volatile) in quartz. Tube connected to dissolver and cooler	Cell Rd Prb	Leakage on connection to apparatus or at valves	Shut down apparatus and remove section that leaks and replace. Decontaminate in dry box using an absorbent ash. Absorbent to recover material

MIND 2410

641

100

MND 2410

641
129

	<u>Process Flow</u>	<u>Health Physics</u>	<u>Credible Problems</u>	<u>Remedies or Controls</u>
	(b) Reflux column to prevent loss of vapor		None	
	(c) Add HNO_3 and water to dissolver	Bx Cont Smpl	None	
	(d) After removal of curium from volatilizer, open stop cock to first AlCl_3 trap and reflux solution		Loss of coolant on charcoal. Absorber with increased release of gases	Remedy: Immediately recool with liquid air. Emergency "light" alarm in Hot Cell panel for increase in temperature
	(e) Purge volatilizer and AlCl_3 trap		None	
	(f) Add dilute H_2O_2 to solution or neutralize and add carbonate. Allow to stand 4 hours at 5°C	Bx Cont Smpl	None	
	(g) Filter plutonium through platinum filter		None	
	(h) Redissolve Pu in HNO_3 and transfer to Pu recovery storage tank		Leak in plastic transfer line but not in secondary barrier	Cap off line and remove section. Decontaminate pipe and replace with new section
5.	Transfer of Solution	Equipment	(1) Double Barrier Feed Pipe	
	(a) Solution transferred in dry box in irradiated polyethylene tubing (inside secondary plastic tube barrier)	Bx Cont Smpl Cell Rd Prb	Break tubing	Immediately stop flow. Shut down and remove tubing. Replace. Decontaminate dry box with absorbent, if required

	<u>Process Flow</u>	<u>Health Physics</u>	<u>Credible Problems</u>	<u>Remedies or Controls</u>
	(b) Solution will be transferred from Cell 3, Dry Box 3A to Cell 4, Dry Box 4A	Bx Spl Cnp	Break in tubing but not secondary barrier	Box decontamination required in hot cell. Vermiculite absorbent. Clean-up with manipulator
6.	Curium Purification--Ion Exchange, Cell 4, Dry Box 4A,	Equipment	(1) Ion Exchange Columns--3 (2) Storage Chambers--3	(3) Precipitator (4) Storage Chambers
	(a) Transfer solution to Curium-Americium precipitator and add saturated oxalic solution plus HCl solution	Bx Cont Smpl Bx Spl Cnp	Breakage of chamber	Secondary-catch basin provided. Suck back into storage and decontaminate basin. Replace chamber
	(b) Transfer to Dowex columns and wash. Total volume--22 liters		Breakage of chamber	Same as above
	(c) Collect in storage chambers 22 liters		Same as above	Same as above
	(d) Evaporate solutions to near dryness	Bx Con Smpl Bx Spl Cnp	Overheat evaporator and melt through chamber	Remedy: Temperature indicator with TC on wall of vessel. If rupture, remove chamber and decontaminate. Provide catch basin in bowl of heater
Optional Procedure:				
Do not adjust acidity. Follow procedure in Section 7; omit Steps e, f, g, h of 6				
	(e) Add HNO ₃ to make 0.5 Molar and transfer to second curium precipitator		None	

MND 2410

641

100

	<u>Process Flow</u>	<u>Health Physics</u>	<u>Credible Problems</u>	<u>Remedies or Controls</u>
	(f) Add concentrated oxalic acid to precipitate Am-Cm and filter	Bx Cont Smpl Bx Spl Cnp	Breakage of chamber	Same as above
	(g) Ignite oxalate to curium oxide at 500° C for 4 hours		Breakage of evaporate chamber	Recover powder and decontaminate box
	(h) Transfer unit from Box 4A to 4B			
7.	Fuel Form Preparation--Hot Cell 4--Dry Box 4B	Equipment	(1) Induction Furnace 1 (2) Sintering Furnace	(3) Blender (4) Press
	(a) Transfer of oxide from Box 4A	Bx Cont Smpl Cell Rd Prb	Spill of powder	Wipe up powder and ash to recover. Decontaminate dry box
	(b) Compacting with matrix alloy and sintering (Mo or Pt) for thermionic capsules (Ta liner with steel or nickel) for thermoelectric	Bx Cont Smpl Bx Spl Cnp		
	(c) Carbide fuel form--Curium carbide from Step 9. Blended with matrix--compacted into pellets	Cell Rd Prb	Fuel subject to oxidation in air or moisture	Inert atmosphere Dry helium or argon
	(d) Alloy of curium shaped or formed in crucible during co-reduction	Bx Cont Smpl	Subject to oxidation	Inert atmosphere Dry helium or argon
	(e) Cermet made by mixing carbide or oxide with matrix metal and compacting in press	Bx Cont Smpl	Loss of powder during loading into die block	Container under press die block to collect particles

<u>Process Flow</u>	<u>Health Physics</u>	<u>Credible Problems</u>	<u>Remedies or Controls</u>
8. Loading of Pellets into Fuel Capsule Container--Hot Cell 4--Box 4B	Equipment	(1) Capsule Container Loading Jig (2) Funnel for Pellet Loading	(3) End Plug and Seater
(a) Place container into holder and seal top rim to funnel	Bx Cont Smpl	Dusting	Wire surfaces and ash wipes to recover material
(b) Load pellets (maximum 12,000 curies)	Cell Rd Prb		
(c) Decontaminate rim with absorbent			
(d) Add end-plug and press end-plug to seal capsule and then decontaminate capsule surfaces where possible	Cell Rd Prb Bx Spl Cnp		
(e) Load capsule into transfer chamber and transfer to Box 5A			
9. Fuel Compound Preparation Hot Cell 4--Dry Box 4B Alternate 1	Equipment	(1) Induction Furnace 1 (2) Induction Furnace 2 (3) Sintering Furnace	(4) Weighing and Blending (5) Oxo-Dryer
(a) Conversion of oxide to carbide		Dry atmosphere required to prevent slow reaction of carbide with air or moisture	Inert atmosphere Oxo-Dryer. Dry Box 50 ppm moisture
(1) Transfer solid curium oxide from Dry Box 4A to Cell 4, Dry Box 4B, for use in induction Furnace 1	Bx Cont Smpl Bx Spl Cnp		

MIND 2410

641 102

	<u>Process Flow</u>	<u>Health Physics</u>	<u>Credible Problems</u>	<u>Remedies or Controls</u>
	(2) Mix carbon with curium oxide		Dust in blender	Use rotary valve
	(3) Compact in press; 12,000 curies per batch or capsule (6000 curies per pellet)	Cell Rd Prb	Contamination in press	Pan under dieblock
	(4) Conversion by sintering in induction furnace		Ignition of pellet	Air moisture and oxygen Control with alarm
	(5) Crush and repress pellets	Bx Cont Smpl	Dusting	Controlled with absolute filter
10.	Curium Mixed Metal Fuel Alternate 2			
	(a) Transfer oxide to reaction vessel	Bx Cont Smpl	Excessive heat	Ash filter to recover
	(b) Add HCl and O ₂	Cell Rd Prb (neutrons)	High neutron flux	Adjust batch size and shield for neutron flux Follow reaction with neutron flux
	(c) Co-reduce curium chloride and other metal chloride with calcium or magnesium in reaction vessel with ceramic liner	Bx Cont Smpl Cell Rd Prb	Non-reaction of curium and Ca with the subsequent reaction while container is open. Release of Cm metal	Continue gas flow of He or Argon. Close container and decontaminate dry box
	(d) Removal of liner from vessel. Chipping off of cake (slag) and removal of mixed metal button	Bx Spl Cnp	Oxidation of fuel	Release of activity in dry box. Decontaminate

	<u>Process Flow</u>	<u>Health Physics</u>	<u>Credible Problems</u>	<u>Remedies or Controls</u>
11.	Separation of Americium from Curium--Hot Cell 4--Dry Box 4A Operational Procedure	Equipment	(1) Ozonizer--Arc Type and Power Pack (2) Reaction Vessel	(3) Filter (4) Storage Chamber
	(a) Take solution after evaporation and add KHCO_3 to make 0.03 Molal	Bx Cont Smpl Bx Spl Cnp	Reaction of ozone with an organic compound to cause ignition or over pressure	Do not use grease or any solvents in system. Dilute exhaust with argon during operation. Following reaction, use an argon purge to get rid of excess ozone
	(b) Heat solution to 92° C and bubble ozone through the solution			
	(c) Filter off americium precipitate			
	(d) Wash--dilute K_2CO_3			
	(e) Precipitate curium as the oxalate recycle filtrate			
	(f) Dry the curium oxalate solid and ignite to curium oxide at 500° C	Bx Cont Smpl Bx Spl Cnp		
	(g) Filtrate from (c) is recovered for americium purification at Martin, Baltimore		Overheat flask (i.e., evaporate to dryness. Melt through container)	Oven temperature controller on container. Thermocouple to shut off heat. Increase flow of water on jacket cooler
12.	Disposal of Reduction Slag			
	Disposal of slag and recovery of the radioisotopes. Argon Dry Box 4A	Bx Cont Smpl	Neutralization of slag Release of excessive heat. Over pressure of system and subsequent fire	Release of Ca to atmosphere. Put out fire with K_2CO_3 crystals or dry chemical. Exclude air with an argon purge

MND 2410

641
134

	<u>Process Flow</u>	<u>Health Physics</u>	<u>Credible Problems</u>	<u>Remedies or Controls</u>
	(a) Redissolve excess calcium or magnesium			
	(b) Ion exchange absorption of americium-curium after initial precipitation with oxalate	Bx Spl Cnp		
13.	Transfer to Welding Box Hot Cell 5--Box 5A	Equipment	(1) Remote Welder (2) Welding Chamber (3) Welding Jig (4) Refrigeration System	(5) Leak Test Equipment (6) Ultrasonic Cleaner (7) Sandblaster
	(a) Load fueled capsule container into remote welder chamber	Cell Rd Prb	Contamination on outside of capsule	Ultrasonic cleaning and sandblasting, if required
	(b) Set capsule in jig and clamp		Poor weld due to contamination material in weld	Inspection plus ultrasonic inspection and reweld
	(c) Close chamber and evacuate. Back fill with helium		Porous capsule void in weld	Ultrasonic clean and pressure test for He leak. Add filter metal and recheck weld
	(d) (Repeat) Operation (c) until no oxygen is present		Contaminated material on jig and torch	
	(e) Fusion weld capsule rim and then seal vent hole	Bx Cont Smpl		
	(f) Release vacuum and remove capsule			
	(g) Ultrasonically clean capsule	Sm Svy		
	(h) Transfer to either shipping cask or to test chamber	Port Rd Mon Sm Svy		

641
135

The following table endeavors to show the operations carried out together with an evaluation of the credible problems encountered, the remedies required by such problems and the Health Physics services and procedures controls are discussed in greater detail in Chapter IV-B.

It is assumed, for purposes of this condensed presentation, that the appropriate instrumentation, monitors and alarms are in use as defined in Chapter IV-B. Similarly, the case of fire within these operating boxes has been adequately covered in Chapter IV-D.

641 106

C. STRONTIUM-90

Cell 1 6 by 7 foot floor area

Cell 2 6 by 12 foot floor area

<u>Process Flow</u>	<u>Health Physics</u>	<u>Credible Problems</u>	<u>Remedies or Controls</u>
A. Box 2 Preparation of Strontium Titanate		Equipment: Storage Tank, Closed Reactor Process Tube, Precipitation and Filter System, Transfer Tongs, Calcining Furnace, Copper Chill Blocks	
1. Introduce Sr-90 Shipping Cask into doorway of Cell 2 (100 kilocuries per shipment)	Port Rad Mon Sm Svy		
2. Dissolve SrCO_3 contained in cask using successive portions of HCl totalling 10 liters	Cell Rd Prb Mbl Air Mon		
3. Transfer SrCl_2 solution by vacuum (via polyethylene tubing within a larger tube) to storage tank within containment Box 2. System and transfer tubing will be rinsed	Box Spl Cleanup Mbl Air Mon	(1) A clog in line (2) Leak in transfer line (3) Broken transfer line	(1) Solution passes through SS filter in shipping cask (2) The line is encased in an outer polyethylene tubing. Cask is elevated to ensure flow of solution plus any leakage into box
4. Aliquot 1 liter containing 10 kc of Sr-90 into precipitation vessel in enclosed process line; cool	Cell Rd Prb Box Spl Clean Up	(1) A clog in transfer line (2) Broken transfer line connection	(1) Tubing will be connected with plastic compression fittings removable with manipulators
5. Chill to 5° C, add cold solution of TiCl_4	Bx Spl Cleanup	Inoperative chill block	Turn off cooling system, check, replace lines using compression fittings

MND 2410

641
137

VII-17

<u>Process Flow</u>	<u>Health Physics</u>	<u>Credible Problems</u>	<u>Remedies or Controls</u>
6. Precipitate strontium titanyl oxalate by addition of ammonium oxalate	Cell Rd Prb		
7. Filter through pt filter and wash with $(\text{NH}_4)_2\text{C}_2\text{O}_4$. (Apply vacuum to scavenger vessel to transfer filtrate)	Cell Rd Prb Bx Spl Cleanup	(1) Blocked filter (2) Broken connection in transfer line	(1) Replace entire filter unit. Dissolve adhering ppt and re-process (2) Replace entire transfer line
8. Filtered solid, dried by self-generated heat, transferred along process tube with tongs into calcining furnace	Bx Spl Cnp Bx Cont Smpl	Spill of $\text{SrTiO}(\text{C}_2\text{O}_4)_2$ powder in process tube	Process tube designed to be readily cleaned. "Vacuum" powder into aspirator bottle, swab surface clean. Reprocess if warranted
9. Calcine in furnace for 3 hours at 1100°C		Burned out furnace element	Replace furnace elements or, if necessary, entire furnace with spare on hand. Old furnace decontaminated prior to removal from containment box
10. Remove from process tube, transfer calcined product to ball mill for crushing. Replace calcining vessel in process tube	Bx Spl Cnp Bx Cont Smpl	Spill of powder during transfer	(1) Handle as in 8
B. Box 2--Ball Milling Pelletizing and Sintering of Strontium Titanate		Equipment: Small Ball Mill, Pellet Press, Copper Chill Blocks and Sintering Furnace	
11. Incline and rotate ball mill to transfer crushed SrTiO_3 into feed tube of pellet press. Vibrate to aid transfer	Bx Cont Smpl Bx Spl Cleanup	Dusting of ball mill discharge port	Employ rotary valve and use funnel-shaped feed tube opening

MND 2410

SH 100

<u>Process Flow</u>	<u>Health Physics</u>	<u>Credible Problems</u>	<u>Remedies or Controls</u>
12. Pelletize at 5 tsi to yield "green" pellets of 2-inch diameter, 1-inch height	Bx Cont Smpl	Contamination in and around press	Employ retention pan under die block
13. Transfer pellet to sintering furnace in reactor process tube. Sinter at 1350° F for 3 to 5 hours	Cell Rd Prb		
14. Place sintered pellet in fuel capsule in chill block	Cell Rd Prb		
15. Cap fuel capsule and decontaminate exterior by cleaning			
16. Transfer capsule in chill block out of Cell 2 into Cell 1 and into welding jig holder	Cell Rd Prb		
C. Box 1--Welding Fuel Capsule and Loading Fuel Equipment: Chill Block, Ultrasonic Cleaner, Welder Generator			
17. Weld and then ultrasonically clean exterior	Cell Rd Prb Sm Svy		

VIII. MAXIMUM CREDIBLE INCIDENTS

The purpose of the postulation, analysis and evaluation of the following maximum credible incidents is to demonstrate the radiological consequences of incredible hypothetical accidents. It is based upon the most pessimistic (conservative) assumptions, in order to define an upper limit of potential radiobiological hazards in terms of the Quehanna Laboratory and site.

A. POSTULATION OF INCIDENTS

It is postulated that two radioisotopes (Cm-242, Sr-90) are released in separate events from Cell 5 of the Laboratory in an instantaneous manner, and that a portion of each is expelled through the air handling system and stack directly into the atmosphere according to the following chronology of events:

- (1) Fire and/or explosion in Cell 5.
- (2) Rupture of the welding enclosure.
- (3) Release of the radioisotopes as soluble aerosols, uniformly within the cell.
- (4) Failure of the cell filter of the air handling system.
- (5) Failure of the dual filters preceding the stack.
- (6) Failure to shut down air handling system and a release of radioisotopes through the stack.

Therefore, there are six simultaneous events required to produce the maximum credible incidents that follow.

B. ASSUMPTIONS

The magnitude of the consequences of these incidents is dependent upon the quantity of radioisotopes released, the heat content of the cloud, the particle size of effluents, meteorological conditions, terrain and the location of off-site population centers. The following simplifying assumptions are made:

- (1) The incident originates from Cell 5 where 100,000 curies of Sr-90 or 10,000 curies of Cm-242 are involved. Approximately 10% of this material (10,000 curies of Sr-90, 1000 curies of Cm-242) is instantaneously released from the stack of the Laboratory as soluble aerosols.

- (2) The volume of the cloud at its origin is 15 cubic meters, equivalent to the volume of Cell 5.
- (3) The heat content of the cloud is negligible, and the cloud moves horizontally along the ground.
- (4) The terrain downwind is flat.
- (5) Average meteorological conditions prevail which are representative of daytime. The following meteorological parameters apply:
 - (a) Wind speed ($\bar{U}$) = 5 meters per second.
 - (b) Diffusion coefficient (C) = $0.40 \text{ meters}^{n/2}$.
 - (c) Stability parameter (n) = 0.25.
 - (d) Isotropic turbulence is assumed.
- (6) The breathing rate for exposed individuals in the fallout field is 500 cubic centimeters per second.

C. ANALYSIS

The dose rates, for both internal and external radiation from the incident cloud to individuals in the fallout field, were calculated by using modifications to Sutton's Diffusion Equations. Doses were computed at radii of 500, 1000, 3000, 5000, 8000*, and 16,000* meters from the Laboratory site. The fate of contaminants is also presented. Table VIII-1 presents a summary of the radiological consequences of the incidents.

1. Radiostrontium Incident

The incident is based upon a release of soluble Sr-90, since it is the most pessimistic case. Though this factor would not affect external doses, the use of insoluble material would lower the internal doses by a factor of 5. The exclusion perimeter has a radius of about 5 miles (8000 meters), and the average distance to the nearest population center is about 10 miles (16,000 meters).

*5 miles and 10 miles, respectively.

TABLE VIII-1
Summary of Radiological Consequences Postulated Accident During A
Lapse (Average Daytime) Meteorological Conditions

1	2	3	4	5		6	7		8		9	10		11		12		13		14	
Distance from Release (d) (meter)	Cloud Radius (r) (meter)	Cloud Volume (V) (meters ³)	Time for Cloud to Reach (d) (seconds)	Maximum Dry Deposition Rate (curies/meter ²)		Effected Ground Area (A) (meter ²)	Total Activity in Cloud (curies)		Concentration in Cloud (microcuries/cc)		Cloud Exposure Submersion Time (t) (seconds)	Total External Dose from Airborne Cloud (rem)		External Dose Due To Ground Deposition T, I, D-2 Days (rem)		Internal Dose to Critical Organ Due to Inhalation (rem)		Activity Fixed in Critical Organ Due to Inhalation (microcuries)		Ratio of Incident Activity to MPB in Critical Organ, Due to Inhalation (MPB = 2μc) (MPB = 0.05μc)	
0	15	15	0	--	--	7	10 ⁴	10 ³	6.7 x 10 ⁻²	67	0.3	--	--	--	--	--	--	--	--	--	--
500	92.7	4.8 x 10 ⁶	100	5.6 x 10 ⁻³	5.6 x 10 ⁻⁴	4.2 x 10 ⁴	9.8 x 10 ³	9.8 x 10 ²	2 x 10 ⁻³	2 x 10 ⁻⁴	37	2.2 x 10 ⁻²	1.1 x 10 ⁻³	3.2	3.3 x 10 ⁻²	1.3 x 10 ³	1.9 x 10 ²	8.1	3.7 x 10 ⁻¹	4.05	7.4
1,000	169.4	2.5 x 10 ⁷	200	1.6 x 10 ⁻³	1.6 x 10 ⁻⁴	1.4 x 10 ⁵	9.60 x 10 ³	9.60 x 10 ²	3.84 x 10 ⁻⁴	3.84 x 10 ⁻⁵	68	7.8 x 10 ⁻³	3.9 x 10 ⁻⁴	8.8 x 10 ⁻¹	9 x 10 ⁻³	4.54 x 10 ²	6.5 x 10	2.9	1.3 x 10 ⁻¹	1.45	2.6
3,000	441.7	3.6 x 10 ⁸	600	1.9 x 10 ⁻⁴	1.9 x 10 ⁻⁵	7.79 x 10 ⁵	9.50 x 10 ²	9.50 x 10 ²	2.7 x 10 ⁻⁵	2.7 x 10 ⁻⁶	177	1.3 x 10 ⁻³	7.1 x 10 ⁻⁵	1.08 x 10 ⁻¹	1.09 x 10 ⁻³	83	12	5.3 x 10 ⁻¹	2.39 x 10 ⁻²	0.265	0.478
5,000	690.2	1.7 x 10 ⁹	1000	7.4 x 10 ⁻⁵	7.4 x 10 ⁻⁶	2.7 x 10 ⁶	9.4 x 10 ³	9.4 x 10 ²	5.4 x 10 ⁻⁶	5.4 x 10 ⁻⁷	276	4.4 x 10 ⁻⁴	2.2 x 10 ⁻⁵	4.4 x 10 ⁻²	4.4 x 10 ⁻⁴	26	3.7	1.6 x 10 ⁻¹	7.45 x 10 ⁻³	0.08	0.149
8,000	1041	5 x 10 ⁹	1600	3 x 10 ⁻⁵	3 x 10 ⁻⁶	6.88 x 10 ⁶	9.2 x 10 ³	9.2 x 10 ²	1.84 x 10 ⁻⁶	1.84 x 10 ⁻⁷	416	2.2 x 10 ⁻⁴	1.1 x 10 ⁻⁵	1.1 x 10 ⁻²	1.7 x 10 ⁻⁴	13	1.9	8.4 x 10 ⁻²	3.8 x 10 ⁻³	0.042	0.076
16,000	1909	3 x 10 ¹⁰	3200	8.4 x 10 ⁻⁶	8.4 x 10 ⁻⁷	2.2 x 10 ⁷	9.1 x 10 ³	9.1 x 10 ²	3 x 10 ⁻⁷	3 x 10 ⁻⁸	764	6.67 x 10 ⁻⁵	3.3 x 10 ⁻⁶	4.8 x 10 ⁻³	4.8 x 10 ⁻⁵	4	5.7 x 10 ⁻¹	2.5 x 10 ⁻²	1.15 x 10 ⁻³	0.0125	0.023

Method of Calculations and Notes

1 Distances represent pertinent points downwind

2 Column 2 was calculated from:
$$r = C(d_v + d)^{(2-n)/2}$$
where d_v = distance from virtual origin to origin of accident = 4.5 meters

3 Column 3 was calculated from:
$$V = \pi^{3/2} c^3 d^{\frac{3(2-n)}{2}}$$

4 Column 5 was calculated from:

$$W_{dry-max} = \frac{nQ}{2e\pi^{1/2}cd^{2-n/2}}$$

5 Column 6 was obtained by:
$$A = 2c \int_0^d (dv + d)^{\frac{(2-n)}{2}} + \frac{\pi}{2} r^2$$

6 Column 7 was obtained by:
Total Activity = $Q_{org} - Q_{fallout}$

7 Column 10 was calculated from:

$$Z = 2.6 \times 10^{-7} E_s \bar{Q} t$$
where E_s = effective energy (Mev/dis)
 $\bar{Q}$ = average concentration in cloud (μc/m³)
 t = submersion time (Column 9)
8 Column 11 was obtained from $D = 3 \times 10^{-3} X_o \frac{T}{0.693} (1 - e^{-\frac{0.693t_i}{T}})$
where X_o = deposition factor
 T = half life of isotope
 t_i = time of dose integration (2 days)

9. Column 12 was obtained by:

$$D = \frac{73.8faB\bar{Q}tE_i(RBE)NT_e}{M}$$
where fa = inhalation factor
 B = breathing rate
 E_i (RBE) N = effective energy
 T_e = effective biological half life
 M = mass of critical organ

External doses. The external dose from the incident cloud at the exclusion perimeter is 0.22 millirem integrated to infinity. The comparable dose is 0.066 millirem 10 miles from the Laboratory.

The external doses due to fallout are 11 and 4.8 millirem, respectively, for the site perimeter and nearest population center*. The doses were integrated over a two-day period. The corresponding ground concentrations from dry deposition were 30 microcuries per square meter (site perimeter) and 8.4 microcuries per square meter (nearest population center).

Internal doses. The organ of reference for soluble strontium is the bone, with the internal dose from inhalation of the incident cloud integrated to infinity. The dose from Sr-90 is 34.8 rem per microcurie inhaled. The internal dose at the site perimeter is 13 rem and 4 rem at the nearest population center. This assumes direct exposure to the incident cloud. The fixed Sr-90 in the bone corresponding to exposure at the exclusion perimeter and nearest population center is 0.084 and 0.025 microcurie, respectively.

2. Curium Incident

The incident is based upon a release of soluble Cm-242.

External doses. The external doses are integrated to infinity and include only the gamma component from Cm-242, since the alpha component has a very short path in air and can be eliminated for all practical purposes.

The total integrated dose from the incident cloud is 11 microrem at the exclusion area perimeter and 3.3 microrem 10 miles from the site.

The total external dose received in the fallout field during two days of exposure is 0.17 millirem at five miles and 0.048 millirem at 10 miles.

Internal doses. The critical organ for soluble curium is the liver, and the internal dose from the incident cloud is integrated to infinity. The internal dose is 1.9 rem at the site perimeter and 0.57 rem 10 miles downwind. The fixed Cm-242 in the liver, corresponding to exposure at the exclusion perimeter and nearest population center, is 0.0038 and 0.00115 microcurie, respectively.

*5 miles and 10 miles, respectively.

641 143

3. Contamination

Assuming that the incident cloud moves from west-northwest to east-southeast, as shown in Fig. VIII-1, it will create a fallout field of 6.9×10^6 square meters within the five-mile perimeter. Since the fallout field is heavily forested, it is estimated that only 10% of the radioactive material deposited will enter the drainage pattern and ultimately enter Mosquito Creek. The drainage from the fallout field into Mosquito Creek is through its tributaries, Panther Run, Twelvemile Run and Dry Draft. The indicated flow rate of Mosquito Creek is in excess of 4000 gpm (1.6×10^7 cc/min). Mosquito Creek drains into the West Branch of the Susquehanna near Karthaus, where the flow rate of the Susquehanna is about 2500 cfs (4.2×10^9 cc/min). The isotopes released are considered to be soluble.

Strontium incident. The fallout field up to the five-mile perimeter contains 800 curies of Sr-90, yielding an average ground concentration of 116 microcuries per square meter. It is assumed that 10% of this amount (80 curies) enters Mosquito Creek gradually and uniformly over a two-month period (8.6×10^4 minutes). Consequently, the average activity of Mosquito Creek as it enters the West Branch of the Susquehanna River is:

$$\frac{80 \times 10^6 \text{ microcuries}}{(1.6 \times 10^7 \text{ cc/min}) (8.6 \times 10^4 \text{ min})} = 5.8 \times 10^{-5} \mu\text{c Sr-90/cc}$$

As Mosquito Creek enters the Susquehanna, this activity will be diluted in the ratio of the stream flow rates. The activity in the West Branch of the Susquehanna will then be:

$$(5.8 \times 10^{-5}) \frac{(1.6 \times 10^7)}{(4.2 \times 10^9)} = 2.2 \times 10^{-7} \mu\text{c Sr-90/cc}$$

Since the maximum permissible concentration in water for Sr-90 is $10^{-7} \mu\text{c/cc}$, the activity in the River will be slightly in excess of the MPC.

Curium incident. A parallel computation can be made for the curium incident. The fallout field up to the five-mile perimeter contains 8 curies of Cm-242, yielding a ground concentration of 11 microcuries per square meter. If 10% of the fallout (8 curies) enters Mosquito Creek uniformly

Fig. VIII-1. Fallout Cloud, Regional Site

641 145

over a two-month period, the average activity in the Creek as it enters the Susquehanna is:

$$\frac{8 \times 10^6 \text{ microcuries}}{(1.6 \times 10^7 \text{ cc/min}) (8.6 \times 10^4 \text{ min})} = 6 \times 10^{-6} \mu\text{c Cm-242/cc}^*$$

Since the maximum permissible concentration of soluble Cm-242 in water is $2 \times 10^{-5} \mu\text{c/cc}$, the activity in Mosquito Creek as it enters the River is well below tolerance.

D. EVALUATION

1. Radiation Doses

The external radiation doses from immersion in the cloud calculated at the five-mile perimeter are 0.22 millirem for the Sr-90 incident and 11 microrem for the Cm-242 incident. These are well below the annual allowable dose of 5 rem.

The external doses from two days of residence in the fallout field calculated at the five-mile perimeter are 11 millirem for Sr-90 and 0.17 millirem for Cm-242. This is also below the annual allowable dose.

The internal exposures at the same point are 13 rem (Sr-90) and 1.9 rem (Cm-242). The corresponding amounts of material fixed in the body are 0.084 microcurie (Sr-90, bone) and 0.0038 microcurie (Cm-242, liver). These compare favorably with the maximum permissible body burden for Sr-90 of 2 microcuries and the maximum permissible body burden of Cm-242 of 0.05 microcurie, with the bone and liver as the organs of reference respectively.

2. Contamination

Though Mosquito Creek will be contaminated somewhat above the maximum permissible concentration as a consequence of the strontium incident, the Sr-90 will be diluted to a point only slightly above MPC at the confluence of Mosquito Creek and the West Branch of the Susquehanna.

*Decay was neglected.

The results of the curium incident show that Mosquito Creek will not be contaminated above MPC.

3. Consequences Relative to Site

Figure VIII-1 shows the projection of the incident cloud relative to the site environs. This projection utilizes the west-northwest wind direction which is predominant at the site. The downwind zone is clear of population centers for a distance of 10 miles, where one small settlement is located. Beyond this, the zone is clear of population centers for an additional 10 miles.

In view of the large site exclusion area and the distance to surrounding population centers, the site is ideally located. Doses to exposed individuals are within permissible levels for the incidents postulated.

IX. REFERENCES

1. "Hazards Evaluation Report, Curtiss-Wright Research Reactor, 4 Megawatt Operation," CWR-4062, April 1959.
2. Pack, D.H., "Meteorological Appraisal of the Quehanna, Pa. Site of CW," May 1956.
3. Heck, N.H., "Earthquake History of US, Part I," USCGS 609, 1947.
4. "Description of the Curtiss-Wright Research Reactor and Radio-active Materials Laboratory," CWR 474.
5. "SNAP Program, Quarterly Progress Report No. 3," MND-P-3011, April 1960.

APPENDIX A

RADIOISOTOPE COMMITTEE

A Radioisotope Committee has been instituted to govern the use and/or possession of radioisotopes within the Martin Nuclear Division. The organization is as follows:

Purpose: To assign responsibility for adequately controlling the handling, processing, shipping, and containment of radioisotopes while such materials are in the possession of or assigned to the jurisdiction of The Martin Nuclear Division.

Responsibility: The responsibility for maintaining control over radioisotopes is delegated to a Radioisotope Committee consisting of individuals who are familiar with the hazards and properties of radioisotopes and who can independently direct and control the methods of handling, processing, shipping, and containment of radioisotopes.

Organization: The Radioisotope Committee consists of the following members:

Chairman: Health Physics

Members: Isotopic Power Department
Operations Department
Engineering Department
Licensing Officer

Function: The Committee will be convened by the chairman to review any use of radioactive material which involves greater than normal hazards to persons, property or the public. In addition to the normal reviews conducted by the Radioisotope Committee, the Committee will, at the request of a Department

Manager, meet to review conditions deemed unsafe or potentially unsafe within the Division. It is the responsibility of the Chairman of the Committee to secure from the organization proposing the use, a written description of the proposed use sufficiently detailed to enable review by the Committee. Copies of this written description will be circulated to members of the Committee and a meeting will be held to discuss pertinent features. A presentation by the group proposing the use will be requested if necessary. If the Radioisotope Committee is unable to reach a unanimous decision on the safety of the proposed use, outside technical help will be secured in order to resolve the problem.

641 150

Fig. A-1. Organization Chart

NAME: MORSE, Jerome G.

POSITION: Manager, Isotopic Power Department

EDUCATION: B.S., College of City of New York
M.S., University of Pennsylvania
PhD, Illinois Institute of Technology
Graduate, Oak Ridge Institute of Nuclear Studies

EXPERIENCE: 1955 to present -- The Martin Company, Isotopic Power Department Manager since its inception in 1958. Technical and administrative responsibility for all radioisotope program activity. Formerly Nuclear Requirements Department Manager (one year). Formerly Radiation Effects Unit Supervisor. Technical responsibility for design and installation of Gamma Radiation Facility, and supervision of radiation programs including moderators, fuel elements, plastics, etc.

1952 to 1955 -- University of Miami, Coral Gables. Assistant Professor, Chemistry Department and Director, Radioisotope Laboratory. Laboratory with staff of six, operated under industrial and government contract research.

1951 to 1952 -- General Electric Company. Research Chemist. Mass spectrometric studies of vapor phase distribution of isotopes.

PUBLICATIONS: Co-editor "Effects of Radiation on Materials," Rheinhold Publishing Company.

AFFILIATIONS: Presently Consultant to Oak Ridge Institute of Nuclear Studies.

641 152

NAME: CROMPTON, Charles E.

POSITION: Director, Advanced Development Section, Isotopic Power Department

EDUCATION: B.S., Physical Chemistry, University of California, Berkeley, 1943
Graduate work, Radio Chemistry, Washington University, St. Louis, 1946-47
PhD, Physical Chemistry-Physics, University of Tennessee, 1949

EXPERIENCE: 1960 to present -- The Martin Company. Director of Advanced Development Section of Isotopic Power Department.

1956 to 1960 -- Associate Technical Director, National Lead Company of Ohio. Directing research and development on chemical and metallurgical aspects of uranium refining, metal production and fuel element fabrication. Chemistry of uranium, thorium, radium and the lanthanides was of particular importance. Chairman of Criticality Committee for enriched uranium processing and member of Plantwide Engineering Committee. Private consulting on radiation shielding. Served as Acting Director, Winchester Development Laboratory, Mass., for a 10-month period directing work on radium chemistry.

1952 to 1956
1949 to 1951 -- Deputy Director, AEC Isotopes Division, Oak Ridge, Tennessee. Administering the licensing and radiological safety inspection program of the Commission's Isotopes Distribution Program. Coordination of radioisotope production and pricing; formulation of regulatory policies.

1951 to 1952 -- Head, Radioactivity Division, U. S. Testing Company. Doing industrial consulting and pursuing a radiological warfare study.

641 153

1943 to 1946 -- Manhattan Project work as a research chemist at University of California and subsequently at Oak Ridge, Tennessee. Involved in the chemistry of uranium, neptunium, plutonium, thorium and the major fission products.

641 154

NAME: STRINGHAM, W. S.

POSITION: Supervisor, Nuclear Facility

EDUCATION: A.B., Chemistry, KSTC, Pittsburg, Kansas, 1939
Graduate courses in chemistry at Ohio State
University and Ohio University

EXPERIENCE: 1960 -- The Martin Company, Nuclear Division.
Design of equipment for remote control operation.

1953 to 1960 -- Supervisor, Works Laboratory,
Goodyear Atomic Corporation. Responsible to
staff laboratory. Designing and building equipment
to sample uranium hexafluoride. Supervisor,
Technical Presentations Department.

1946 to 1953 -- Research chemist on polonium,
radium, actinium. Design work in two laboratories
in addition to the design, installation and operations
of hot cell.

NAME: BOUTELLE, Richard H.

POSITION: Chief, Health Physics

EDUCATION: A. B., Physics, Bates College, 1953

EXPERIENCE: 1959 to present -- The Martin Company. Responsible for the evaluation of all radiation safety problems in The Martin Company. Work involves critical testing, fuel element production, radioisotopes studies, radiography, material testing, waste disposal, facility design and use of X-ray equipment. Represents the Company in all radiation safety problems in contacts with federal, state and local agencies. Establishes procedures to prevent overexposure to ionizing radiation. Reviews all proposals, projects, facility sites, etc., to determine compliance with current radiological safety practices.

1953 to 1959 -- Brookhaven National Laboratory, Upton, Long Island, New York. Started employment as Junior Health Physicist. Became Associated Health Physicist, Supervisor of Health Physics at the Research Reactor in 1955. Supervised all phases of radiation and general safety for the Research Reactor and the Critical Experiment Facility. Initiated plans for coping with a major nuclear emergency which might occur at Brookhaven or one in which they might be called on by others to assist. Conducted and supervised research studies on radiation measurement, instrumentation, air cleaning and sampling, etc. Lectured visiting groups on various aspects of Health Physics.

AFFILIATIONS: Chief of Radiological Service for Suffolk County, 1954-59

Health Physics Society

NAME: TOENNIES, John Michael

POSITION: Health Physicist

EDUCATION: B.S., Chemistry, Davis and Elkins College, 1956

EXPERIENCE: 1959 to present -- The Martin Company. Health Physicist assisting Chief Health Physicist in radiation problems in The Martin Company. Work involves critical testing, fuel element production, radiography, materials testing, waste disposal, facility design and use of X-ray equipment.

1956 to 1959 -- Savannah River Project, E. I. DuPont deNemours, Aiken, South Carolina. Health Physics Engineer.

Shift engineer in Area Survey Group controlling radiation and determining hazards during production reactor operations. Work also included personnel and work site monitoring for reactor maintenance and repairs during the reactor outages.

Special Problems Engineer in Regional Survey Group collecting information and reporting on special problems concerning site survey, especially radioactivity released to the surrounding environs through plant operations. Also involved in experimental work in uptake of various isotopes by soil and vegetation.

Shift engineer in Area Survey Group controlling radiation and determining hazards during U-Pu separations process.

AFFILIATIONS: National Health Physics Society

Baltimore-Washington Health Physics Society

641 157

NAME: NEAL, Jackson S.

POSITION: Chief, Nuclear Factory, Manufacturing Department

EDUCATION: University of Maryland

EXPERIENCE: 1933 to present -- The Martin Company. Has worked in Materials Testing and Chemical Laboratory, Experimental Detail and Assembly Section, Hydraulic and Electromechanical, Precision Detail and Assembly including Wind Tunnel Models. In Nuclear Manufacturing, work has been with radioactive materials, fabrication of fuel elements by powdered metallurgy techniques, fabrication of all types of reactor hardware such as control rods and mechanisms, pressure vessels, cores, grids, etc.

NAME: JONES, James B.

POSITION: Chief, Nuclear Plant Engineering

EDUCATION: Georgia Institute of Technology, 1938
B.S.C.E., Alabama Polytechnic Institute, 1944

EXPERIENCE: 1956 to present -- The Martin Company. Responsible for design, construction, maintenance of Nuclear Division facilities and equipment for product manufacture.

1951 to 1956 -- General Electric Company. Was General Foreman responsible for processing and assembly of hardware and porcelain for shipment. Was supervisor responsible for new packaging design and material handling. Was Methods Engineer on development of new methods of porcelain manufacturing. Was Supervisor for design criteria and construction of General Electric Aircraft Nuclear Propulsion.

1946 to 1951 -- Southern Railroad Company. Was Assistant Engineer on design, construction of railway yards and preliminary investigation for location of industries.

641

NAME: BOWES, William M.

POSITION: Assistant Project Engineer, Advanced Development
Section, Isotopic Power Department

EDUCATION: B.S., Chemistry, Massachusetts Institute of
Technology, 1941
M.S., Chemical Engineering, Polytechnic Institute
of Brooklyn, 1947
Westinghouse (Bettis) Reactor Engineering School

EXPERIENCE: 1959 to present -- The Martin Company, Nuclear
Division. Responsible for the technical direction
of Fuel Technology Development Program (Task 6)
including both materials for radioisotope fuels and
container design of prototype processes for curium
and plutonium.

1956 to 1959 -- Westinghouse Electric Corporation,
Bettis Atomic Power Division, Advanced Develop-
ment Department. Technical Assistant to Manager.
Work on the development of fuel fabrication tech-
niques for low cost reactor fuels used in the
pressurized water reactors. Responsible for all
Bettis test planning on thermal and hydraulics work
to be conducted at the National Reactor Testing
Station at Idaho Falls, Idaho.

1950 to 1956 -- American Cyanamid Company,
Stanford Research Laboratories, Assistant Plant
Manager of the Operation Department. Responsible
for all services for the laboratory including pilot
plant operations, safety, medical, purchasing plant
maintenance and construction, etc.

641 100

NAME: KEENAN, James

POSITION: Assistant Project Engineer, Strontium-90 Project

EDUCATION: B.S., Chemical Engineering, Massachusetts Institute of Technology, 1948
M.S., Chemical Engineering, University of Maryland, 1960

EXPERIENCE: 1956 to present -- The Martin Company. Senior Engineer. Worked in the Systems Analysis Group which prepared cycle analyses and evaluated various nuclear power plants. Assistant Project Engineer on The Martin Power Reactor Project and the SNAP Project. Presently Assistant Project Engineer on the Strontium-90 Project.

1955 to 1956 -- Machine and Tool Design Company, Baltimore, Maryland. Chemical Engineer. Worked as a chemical engineer in chemical process flow design. Position involved preparing process flow sheets, heat and material balances, selection of equipment, sizing of pipes, valves, etc.

1948 to 1955 -- U. S. Government, Army Chemical Center, Maryland. Was Ordnance Design Engineer. Worked as project engineer and assistant section chief on several research and development programs concerning chemical aerial munitions.

PATENTS: U. S. No. 579122 Co-inventor of Explosive Gas Bomb for the Department of the Army.

NAME: SAMOS, George

POSITION: Nuclear Engineer, Reactor Test Unit

EDUCATION: B.S., Chemistry, Fordham University, 1943
M.S., Chemistry, Brooklyn Polytechnic Institute, 1954

EXPERIENCE: 1957 to present -- The Martin Company. Presently in the Reactor Test Unit of the Nuclear Division. Responsible for the design, operation and testing of critical assemblies and zero power reactors.

1951 to 1957 -- Group leader of analytical department under Dr. H. L. Finston. Work involved analysis of samples for fission products, uranium, iodine, tilburin, etc., by chemical and instrumental methods. Developed method for analysis of radioactive Xe from metals and gases.

1947 to 1949 -- Brookhaven National Laboratory, Chemistry Department. Assisted various group leaders with research problems while learning techniques for handling and using radioisotopes. Did basic research on exchange of CO₂ between BaCO₃ and CO₂ gas.

641 182

NAME: DIX, George P.

POSITION: Supervisor, Nuclear Safety Analysis Unit, Nuclear Engineering Department

EDUCATION: A. B., Geology, Johns Hopkins University, 1952

EXPERIENCE: 1956 to present-- The Martin Company. Analysis of nuclear hazards of stationary, portable, and airborne reactors; isotope-fueled thermoelectric generators for marine, terrestrial and space applications; and facilities such as critical and zero power reactor test facilities and isotope handling facilities. Specific studies include the PM-1, LFBR, and APPR reactors; the SNAP programs; and the Martin-sponsored nuclear rocket study. Analysis of sites for nuclear facilities and missile sites for nuclear payloads including hydrological, meteorological, geological, seismological and population factors.

Basic studies of waste disposal, containment, missile and satellite applications of nuclear components and fallout.

1955 to 1956 -- Hunt Oil Company, in charge of sub-surface, ground and airborne exploration using radiation detection techniques. Applications of gamma ray detection of anomalous natural radioactivity.

1954 to 1955 -- Consultant nuclear geologist, self-employed.

1953 to 1954 -- Utex Exploration Company, Field geologist in charge of exploration and development of Mi Vida uranium deposit, Grand County, Utah.

1952 to 1953 -- U. S. Atomic Energy Commission, Division of Raw Materials, field geologist.

PUBLICATIONS: "Uranium Geology," USAEC-TIS Publications RME-4022, RME-10, RME-4038, RME-25 and RME-34. U. S. Bureau of Mines Information Circular on Uranium, 1952, 1953.

"Origin and Disposal of Power Reactor Wastes," MND-1235, USAEC-TIS, 1958.

"Preliminary Operational Hazards Summary Report for the Task 2 Thermoelectric Generator," MND-P-2184, 1959

PATENTS: Patent applied for Subsurface Containment, USPO No. 754,324, 1958.

641 164

NAME: HENRY, Joseph G.

POSITION: Supervisor, Instrumentation Laboratory

EXPERIENCE: 1956 to present -- The Martin Company. Presently assigned to general instrument maintenance, fabrication and modification of all MPR and ERDL critical facility equipment and maintenance of Health Physics equipment.

1955 to 1956 -- J. G. Henry Company. Owner, distributor for Crawford Company, Hoke Valve Company, and U. S. Gauge Company.

1952 to 1955 -- Goodyear Atomic Corporation. General Foreman, supervisor in charge of instrument development, in charge of all field maintenance -- 144 mechanics. Supervision of engineers engaged in instrument development.

1944 to 1952 -- Goodyear Synthetic Rubber Corporation. Instrument Engineer, Master Mechanic, in charge of development, design, and maintenance of all instrumentation. In charge of all maintenance.

1941 to 1944 -- Bristol Instrument Company. Field Service Engineer on call for maintenance field service.

AFFILIATIONS: Instrument Society of America

NAME: VOGT, Joseph H.

POSITION: Technical Group Leader, General Engineering Laboratory

EDUCATION: B.S.E.E., The Rice Institute, 1949

EXPERIENCE: 1958 to present -- The Martin Company. Responsible for the General Engineering Laboratory technical direction of developmental and evaluation effort on isotopic power programs. Also responsible for the technical supervision of the gamma pool facility used for gamma irradiating of materials to determine the effects of gamma irradiation on material properties.

1949 to 1958 -- Development Engineer, Experimental Reactors and Equipment Unit, Knolls Atomic Power Laboratory. Position involved the direction of equipment development programs in support of the design of Test and Research Reactor Systems.

641 166

NAME: KANE, John C.

POSITION: Ceramic Engineer

EDUCATION: B.S., Ceramic Engineering, Alfred University, 1949
M.S., Ceramic Engineering, Alfred University,
1950

EXPERIENCE: 1958 to present -- The Martin Company. Develop-
mental work on ceramic materials for nuclear
applications.

1952 to 1958 -- Cincinnati Milling Machine Company.
Senior Ceramic Engineer doing development and
research work on regular and special **grinding**
wheel systems. In charge of petrographic and
photographic work.

1950 to 1952 -- Erie Resistor Corporation. Con-
cerned primarily with production problems and
development of new processes. Also did develop-
ment work on titanate compositions for capacitors.

AFFILIATIONS: American Ceramic Society

NAME: CORCORAN, Robert E.

POSITION: Radiochemist

EDUCATION: B.S., Chemistry, University of Denver, Colorado, 1948
University of Tennessee Evening School, Oak Ridge, Tennessee, Math. Analysis, 1958, 1959

EXPERIENCE: 1960 to present -- The Martin Company. Radio-chemist in radioisotope laboratory. Spent two months at the Lawrence Radiation Laboratory, Livermore, California, learning radiochemical techniques as applied to the processing of americium and curium.

1954 to 1960 -- Oak Ridge National Laboratory. Analytical Chemist. Development and application of methods of chemical analysis of homogeneous reactor fuel solutions. Due to the high level gamma radiation involved, much of the work was done in hot cells using master slave manipulators.

641 168

NAME: FOWLER, Edward E.

POSITION: Radiochemist

EDUCATION: University of Pittsburgh, 3 years
Electronics School, 2 years

EXPERIENCE: 1960 to present -- The Martin Company

1956 to 1960 -- Westinghouse A.P.D. Hot Laboratory working with high level amounts of gamma and alpha emitting materials.

Two years' experience in radiochemistry and maintenance of radiation detection apparatus.

NAME: PEASE, Emerson P.

POSITION: Engineer, General Metallurgy Unit

EXPERIENCE: 1939 to present -- The Martin Company. Senior Radiography Specialist in the Structures Department. Designed and supervised construction of special tooling and fixtures required for radiographic examination of heavy forgings and similar items. Planned and performed radiography of parts, evaluated results. Operated X-ray and gamma ray sources.

In the Nuclear Division, worked on design and construction of large pool-type gamma facility. Operated facility, assisted in design of apparatus used in extensive radiation-chemistry studies including polyester curing, radiation grafting of co-polymers, synthesis of metallo-organic polymers, etc. Worked on development of soluble inhibitors to prevent "browning" of zinc-bromide hot cell windows. By a loan-training arrangement, was Test Engineer with the CTA Hot Laboratories of the Westinghouse Bettis Plant. Responsibilities now include planning of hot cell work on the Project Engineer level, and supervision of technicians engaged in post-irradiation testing of fuel elements and other reactor components.

PUBLICATIONS
AND PATENTS:

Co-inventor of process for curing liquid polyesters by means of gamma radiation (patent applied for).

641 1.0

APPENDIX B

ALTERNATE PROCESS FLOW FOR SrCO_3 CONVERSION TO SrTiO_3

An alternate process to that described in the text is outlined here (see Fig. B-1).

1. The carbonate will be removed as a slurry by back flushing with water into the storage tank in Cell 1.
2. An aliquot, representing approximately 10 curies of Sr-90, will be transferred through a filter. It is allowed to self dry, is weighed and transferred to a mixing device.
3. The stoichiometric amount of TiO_2 is then added. The mixture is blended as a wet slurry.
4. After allowing to self dry, the mixture is transferred to a furnace and calcined at 1100°C for 3 hours.
5. After removal from the furnace, the compound, SrTiO_3 , will be crushed in a ball mill and pelletized at 5 tsi.
6. The fragile pellet is sintered at 1350°C for 3 hours.
7. The pellet is placed in a fuel fixture, cleaned and welded.

Fig. B-1. Alternate Sr 90 Process

641 172

MEMORANDUM BY THE DIVISION OF
LICENSING AND REGULATION IN THE
MATTER OF THE MARTIN COMPANY

DOCKET NO. 50-181

I - INTRODUCTION AND GENERAL DESCRIPTION

In accordance with the provisions of the Commission's regulations 10 CFR 50, 10 CFR 70 and 10 CFR 30, the Martin Company, Baltimore, Maryland, has filed an application for a license to construct and operate a Production Facility as defined in section 104 c. of the Atomic Energy Act of 1954, as amended, and to possess and use up to 400 kilocuries of Strontium 90, 12 kilocuries of Curium 242, 2 kilocuries of fission products, 12 grams of plutonium and 14 grams of Americium 241. The facility will be used for chemical processing of irradiated Americium 241 to separate Curium 242, plutonium and fission products and to process Strontium 90 and Curium 242 into forms suitable for heat sources. The facility is to be located at Quehanna, Pennsylvania. The initial application for a byproduct material license dated September 22, 1960, has been amended by letters dated November 8, December 12, December 22, 1960 and January 20, 1961. An application for a Part 50 and Part 70 license was filed on January 25, 1961.

General Nature of Work - In the radioactive decay of an atom, energy is released. This energy, although only a small fraction of that released in the fission of a uranium atom, is much greater than the energy associated with a chemical reaction involving a single atom. This decay energy first appears as the energy of motion of the emitted radiation. As this radiation collides with surrounding material, its motion stops, the radiation is absorbed, and its energy is changed to heat. By use of thermocouples, this heat energy can be converted to electrical energy by contacting the hot radioactive material with the hot junction of the thermocouple. A device designed to change the radioactive decay energy into electrical energy is called an "isotopic power source". Under ideal conditions, an isotopic power source containing only a few grams of radioisotope, may dependably deliver several hundred watts of electrical energy. Such a device may find application where conditions of use require a relatively light weight, dependable, long-life electrical power source.

Under the proposed license, the Martin Company will develop and produce isotopic power sources. These activities are to be performed under AEC Contract AT (30-3)-217.

Strontium 90 will be received from the AEC as a separated fission product in the form of approximately 100 kilocuries of SrCO_3 (499 grams of Sr-90), residing on a metal filtering medium within a shielded shipping cask.

The shipping cask is to be inspected for contamination upon arriving at the Martin Laboratory. Then it is transferred to an isolated hot cell area before operations are begun. Dissolution of the carbonate with hydrochloric acid takes place within the shipping cask after it has been placed in the hot cell, and the solution is subsequently drawn into a storage tank within a hot cell. In batches of from 10 to 25 kilocuries, strontium chloride is drawn from its storage tank to a process point where it is precipitated as strontium-titanyl-oxalate. Filtration and drying of this precipitate is followed by furnace calcination to form strontium titanate. This product is then passed through a small ball mill to reduce it to an optimum size for compacting. The powder is introduced into a pellet press and is compressed into a pellet of SrTiO_3 , which is then sintered at high temperatures to yield the final fuel form. When the required number of fuel pellets have been assembled in the metal fuel capsule, the exterior capsule surface is cleaned and the capsule is transferred to a second hot cell. In the second cell, it is placed into a metal capsule, which is closed by welding in an inert atmosphere. The closed capsule is then ultrasonically cleaned to remove any traces of surface contamination. The fuel capsule is then loaded into a generator.

Curium 242 will be produced by irradiating Am-241 in a Commission high-flux reactor. Each slug will be one inch in outside diameter, five inches long, and will contain four grams of AmO_2 in an aluminum capsule. Three capsules will be irradiated for about 90 days and then shipped to the Martin Company in a suitably shielded cask. Each capsule should contain approximately four kilocuries of Cm-242 (1.5 grams), 12 curies americium (1.3 grams), 0.8 grams of plutonium, and a kilocurie of fission products. The cask will be unloaded under water and either one or two capsules will be transported via a shielded cask to a hot cell for processing. Chlorine volatilization of the aluminum contained in this irradiated capsule is the first step of this process. The excess chlorine ultimately passes into an alkaline scrubbing system within this hot cell. The americium-curium residue, containing both plutonium and non-volatile fission products, is dissolved in acid after which plutonium is precipitated as the peroxide. The americium and curium in the filtrate are transferred to a second cell where they are precipitated as the oxalate. This oxalate solid is subsequently destroyed in nitric acid, after which Am-Cm are precipitated as hydroxides before being put into HCL solution. After concentrated lithium chloride is added, the americium and curium are passed through an anion exchange system to separate them from rare earth fission products. Liquid waste fractions are held for further treatment and disposal in a safe manner. After elution from the column, curium undergoes further purification by passage through a second cation exchange column when low chloride concentrations prevail. After evaporation of the purified solution to near dryness, the separation of americium from curium may be achieved (if desired) by adding potassium bicarbonate solution followed by oxidation of americium to the plus-five state, which precipitates as the carbonate. After filtration, curium in the filtrate is again precipitated as the oxalate. The curium oxalate

is ignited to curium oxide, which may be an acceptable fuel form in itself when used as a cermet with Mo or Pt. This final cermet may be prepared by blending with the matrix alloy or metal, pelletizing and sintering to the desired density. Alternate fuel forms are the curium carbide and a curium-metal mixture. The carbide is prepared by blending with excess carbon, compacting and reacting at furnace temperatures. Subsequent grinding, pelletizing and sintering at high temperature yields the desired carbide fuel pellet. To prepare curium metal the curium oxide is first chlorinated to provide the chloride salt. Formation of the curium mixture with another metal is achieved by co-reduction of their respective chlorides by calcium or magnesium metal reductant.

The fuel capsule, containing pellets of final curium fuel (cermet, carbide or metal mixture), is remotely encapsulated, welded in an inert atmosphere, and then ultrasonically cleaned to remove surface contamination. The capsule is then loaded into an isotopic power generator.

Radiation Safety Problems - Strontium 90, Curium 242, americium and plutonium are very toxic radioactive materials when taken into the body. Thus the radioactive materials must always be contained so that they cannot escape to areas occupied by plant personnel or by the public. Sufficient shielding material must also surround these radioactive sources to absorb the beta, gamma, and neutron radiations that are emitted to prevent exposure of personnel to external radiation. The quantity of plutonium present in the process, or allowed to accumulate, is much less than the quantity required to form a critical mass and there is therefore no hazard from criticality.

The following sections contain a description and an analysis of the equipment, facilities, and procedures to be used to assure that the proposed operations will be carried out in a safe manner.

II. SITE EVALUATION

The site of the Martin Nuclear Laboratory is the Curtiss-Wright Nuclear Research Laboratory of the Pennsylvania State University located at Quehanna, Pennsylvania. The site is remotely located. The nearest towns, Sinnemahoning (Population 450) and Frenchville (Population 558) are nine miles from the laboratory. Within a 25-mile radius of the site the population density is 30 individuals per square mile with a total population within this zone of about 60,000. There is an area of approximately 80 square miles surrounding the laboratory which is accessible by vehicle only through a single manned gate.

The site, consisting of the laboratory, attendant structures and a fenced security area, consists of several acres. An exclusion area of 0.5 mile radius has been established. The rugged terrain, wooded areas, absence of access roads and towns provides an isolated area on the order of nine miles in diameter.

The topography of site is typical of the Appalachian Plateau and is a relatively flat area at an average elevation of 2000 feet above mean sea level.

The land bordering the site exclusion perimeter consists of State Forest land with a secondary growth of trees. Beyond the State Forest land, at a distance greater than 5 miles from the laboratory, there is small scale agricultural activity. Land usage is quite limited.

Extrapolation of meteorological data taken at the Philipsburg Airport, 27 miles southeast of the site, indicates an average annual precipitation of 40 to 50 inches per year. The elevated laboratory location precludes flood damage. It is indicated that one-third of the time inversion conditions exist, chiefly at night. Good dispersion is expected during the daylight hours and inversions would be of short duration.

A stratigraphic section in the site area indicates a Pottsville formation about 200 feet in thickness. It consists of massive coarse-grained gray-to-white sandstones with pebbles as large as hazelnuts. The lowest portions of the sandstone unit are water productive where found below drainage level and generally yield small to moderate supplies elsewhere.

Of five wells drilled on the site, only three were moderately productive. The single well in the laboratory area has a rated capacity of 120 gpm. This well is 400 feet deep.

Surface drainage from the laboratory area is via Mosquito Creek. Surface water flows successively into Reactor Run, Meeker Creek, Mosquito Creek and ultimately the west branch of the Susquehanna. The latter has a rather large average flow rate at Karthaus (maximum 50,900 cfs, average 2463 cfs and minimum 109 cfs). This branch of the Susquehanna is not used for public water supply because of its acidity.

A total of six earthquakes has been recorded, all involved only low intensity shock. It is concluded that, due to their low frequency and intensity, the foundation material of the facility and its massive structure, earthquakes do not present a significant problem.

Based upon an evaluation of the described features, particularly the remote location with a low population density, non-agricultural use of land close to laboratory, and favorable hydrological characteristics, it is concluded that the site is suitable for the proposed operations.

III. DESCRIPTION OF FACILITIES & EQUIPMENT

Building Layout - The Martin Radioactive Materials Laboratory (RML) will be housed in a one-story, 24,700 square foot building consisting of insulated aluminum curtain walls applied to a steel frame. The building houses a research reactor (not presently in operation) in addition to the Radioactive Materials Laboratory (RML). However, the reactor will be isolated from the

RML by closing and locking all access doors between the RML and reactor bay area and the safety of activities in the two facilities are not interrelated.

The building layout provides separation between potentially contaminated and clean areas. Those areas that will remain free of contamination include offices, dark room, staff laboratory, cell operating area, and the reactor area. The large access door between the clean operating area and the potentially-contaminated service areas will be closed and locked except when large objects are being passed through. Personnel may move between the clean areas and contaminated areas only by passing through a system of air locks and dressing areas. All chemical procedures with miltikilocurie quantities of material will be performed inside stainless steel dryboxes that are contained within the five hot cells. Adjacent to and behind each hot cell is a room called an "isolation area", which can be closed off and made contiguous with the cell atmosphere. The door between an isolation area and the service area is closed when extra room is needed for transferring radioactive materials from shipping containers into the cells, or when decontamination operations require more space.

Thus, even if safeguards and planned chemical procedures failed, radioactive material in process could not spread to areas occupied by plant personnel without escaping first from the processing vessel to the drybox, then from the drybox to the hot cell, then from the hot cell to the isolation area, then from the isolation area to the service area. The ports in the front faces of the hot cells will all be filled with manipulator arms or cables, or will be sealed. It is highly unlikely that any of the chemical processes could release enough energy under a credible accident to produce blast pressures that would breach the cell faces or the multiple filters in the cell ventilation system.

Airlock arrangements on doors to the outside guard further against the spread of radioactivity outside the building.

The facility also includes a decontamination room on the opposite side of the service area from the hot cells, an intermediate level chemistry laboratory (for performing analyses and various experiments on minor quantities of radioactive material), a solid-source storage area containing 24 concrete-encased storage pipes, a storagepool, and supporting offices and laboratories. Mechanical and electrical support equipment is located in separate, isolated rooms. A standby electric generator and a standby battery supply for emergency lighting are included in these rooms. A 300-gallon-per-day plant for the treatment of liquid contaminated waste is located in a separate building about 50 feet from the main building.

Cell Construction and Shielding - There are five adjacent hot cells of inside dimensions 6 feet by 7 feet by 12 feet high, 6 feet by 12 feet by 15 feet high, 6 feet by 7 feet by 12 feet high, 8 feet by 12 feet by 12 feet high, and 8 feet by 8 feet by 12 feet high, respectively. The first three cells have front walls 3 feet thick of high density (280 pounds per cubic foot) concrete up to 9-1/2 feet high, with the remaining height to the ceiling constructed of ordinary concrete (150 pounds per cubic foot minimum density). Cells Number 4 and 5 have similarly-constructed concrete front walls that are 2 feet thick. The larger cells have two windows each and the smaller cells have one each. The windows are made of 3.6 density glass and are oil filled to provide radiation shielding. An additional 4-inch thick 6.2 density glass block is available for supplemental shielding when necessary.

Functions within the cell area are segregated to prevent any contamination from operations in one cell from spreading to other cells. Thick concrete-and-lead shielded walls, with pass-through, air-lock ports separate one cell from another. The doorways in the rear of each cell are closed by heavy, 15-inch-thick cast-iron doors, which are suspended by trolleys that roll on the flange of a steel I-beam. The ceilings of the cells are removable plugs of 2-feet-thick concrete, which are adequate to prevent radiation scattering back down on the operators from the roof of the building. The cell ceilings can be lifted during the preparation of processes if it is necessary to lower large equipment into the cells.

When radioactive materials are in process, the cell doors will be closed and all cell ventilation air will be exhausted through an absolute filter system. The chemical and mechanical operations within the cells will be manipulated by persons in the "operating area" by use of remote mechanical manipulators.

Drybox and Containment Systems Within the Hot Cells

The containment systems to be used by the Martin Company are similar to those that have been developed at the University of California Radiation Laboratory in Berkeley, California, and in AEC laboratories.

All radioactive material received by the laboratory will be transferred from the shipping casks only in a hot cell or isolation area. All transfer lines from the shipping casks to storage facilities, or from storage facilities to process equipment, will be contained in auxiliary concentric tubes that surround the main transfer tubes. This transfer procedure will insure that the radioactive materials have the same degree of multiple containment during transfer that they have during chemical processing.

During processing, the first containment barrier will be the processing equipment. It is located within steel dryboxes, which are inside the hot cells. The process equipment generally will contain any large radioactive particulate material. The process equipment will be vented directly to the exhaust system of the drybox so that both contamination and corrosion to the box will be reduced. The second and most positive containment barrier is the drybox, which is designed to have the lowest air pressure in the system. Both incoming air to the box and exhaust air will be filtered by absolute filters. The boxes will have as small an air flow rate as possible in order to avoid stirring up radioactive dust. The third containment barrier will be the hot cell, which has absolute filters in the incoming and outgoing air streams. The operating air pressure in the cells will be higher than in the drybox but lower than in the operating area. To accomplish this and insure containment, all ports, access holes and entrance ways will be sealed. The transfer of material from one drybox to another will be accomplished by placing the material in a clean container before transferring it through the airlock. Ultrasonic cleaning devices will be available at the boxes to decontaminate finished fuel capsules prior to loading them in isotopic power generators.

Ventilation and Filtration Systems

The ventilation system for the Radioactive Materials Laboratory is safeguarded by multiple filter systems, spare exhaust systems, backflow dampers, pressure and flow regulators, and constant air monitors. These devices are arranged to automatically prevent release of radioactive materials to occupied areas, or to the outside of the building, under normal or accidental conditions.

The contained area is divided into four subareas of controlled ventilation. The areas outside of the contained area have separate supply and exhaust systems. The air within the main protective systems of the contained area flows from the service area to the isolation areas and from the isolation areas to the hot cells. Some of the air in the hot cells flows into the dryboxes and then into the drybox exhaust system. The drybox exhausts pass from the drybox atmospheres to the stack through separate duct systems, each system containing a total of 2 pre-filters and 5 absolute filters in series.

The intake air for the hot cells is supplied first through a noncombustible absolute filter to the isolation rooms. Then, the incoming air passes through another absolute filter in the (sealed) door of each cell. Thus, not only is the air entering the cells kept clean, but any releases of radioactive material within the hot cells would be prevented from escaping upstream through the ventilation network. After entering the hot cells, most of the air (that which does not enter the dryboxes) is exhausted from each hot cell through a roughing filter (changed from inside the cell), two absolute filters in series, and an exhaust fan, to a common stack. An auxiliary high-volume exhaust and filter system is also connected to each cell. The auxiliary system is automatically activated by pressure sensing devices or radioactivity monitors in the exhaust stream, whenever the air pressure within the cells rises above 0.25 inches water gauge negative pressure with respect to the outside, or whenever radioactivity leakage through the normal filter system is detected by the cell exhaust monitor.

About 1/6 to 1/12 of the air flowing into each hot cell is drawn into the dryboxes within the cell for drybox ventilation. The air is drawn into the dryboxes by a separate high-suction exhaust fan that maintains the dryboxes at 0.25 inches water-gauge negative pressure with respect to the cells (0.50 inches negative with respect to outdoors). Air enters a drybox through an automatic damper and an absolute filter that removes any dust that may have been entrained within the cell. Air leaves a drybox through a pre-filter and an absolute filter that are contained within the drybox. A spare set of filters is maintained in parallel within the drybox for use in case the other set fails or when the other set is removed for disposal. As the exhaust air passes out of a drybox, it is filtered further by two additional absolute filters in series, located within the cell. Then the drybox exhaust air leaves the cell and enters the drybox exhaust duct system (which is separate from the cell exhaust system). In the drybox exhaust system, the drybox effluent air passes through another pre-filter, two more fire-resistant absolute filters, a damper, and the final exhaust fan that feeds through a backflow damper to the stack. A spare set of filters and dampers and a spare exhaust fan are maintained in parallel with the regular drybox exhaust system. The spare fan and filters would be activated automatically, and the other set would be shut down, if the air monitor in the drybox exhaust should detect radioactivity. Thus, the atmosphere in any drybox is separated from the building effluent air by two pre-filters and 5 absolute filters in series, in addition to ductwork, dampers and fans. Such a system would reduce radioactivity concentrations by a factor of at least 10^{-15} by the time the airstream reaches the exhaust stack. Such a dilution factor and protective network would be adequate to reduce airborne radioactive particulates, from either normal or accidental conditions within the drybox, to negligible concentrations in the stack effluent. Even if an unexpected explosion or fire should result in the dispersal of some radioactive material directly from a drybox to a hot cell, a reduction factor of at least 10^{-6} in the concentrations of airborne particulates reaching the stack would be effected by the cell exhaust filtration system.

A separate outside air intake and exhaust system (System No. 7) supplies the decontamination room and intermediate radiochemical laboratory. The exhaust from this system is filtered with one pre-filter and one absolute filter. Accidental releases from these areas are prevented by an exhaust monitor that automatically shuts off the intake fan N-2 and sounds an alarm if excess radioactivity is detected in the exhaust stream. Reverse air flow out of the hoods in the radiochemical laboratory is prevented by a backflow damper in the exhaust airstream from this system.

A separate intake and exhaust fan system also ventilates the Operation Area and the Machine Shop. The major part of the Operation Area air is exhausted directly to the outside, since this is normally a clean area, well separated from sources of contamination. However, a constant air monitor will automatically shut down this system and sound an alarm if radioactivity is detected in the airstream.

Additional safeguards in the ventilation system include: automatically controlled startup sequences for the fans; manual pushbuttons in the Service Area, Operations Area and outside the building for emergency shutdown of hot cell supply fans; a monitor with an alarm and appropriate automatic fan shutdown servomechanisms in the supply airstream entering the isolation area; an alarm as well as the appropriate servomechanisms attached to the drybox exhaust air monitor; static pressure regulators and automatic dampers to maintain pressure balances; backflow damper in each cell and drybox exhaust stream and elsewhere, to prevent reverse air flow even if all other safeguards fail; air sampling stations between each pair of absolute filters, to allow inspection for radioactivity at any point in the system; temperature and explosion indicators and alarms for each drybox; inert gas purge systems for extinguishing accidental fires within dryboxes; and an emergency generator that will supply enough electricity to provide drybox and hot cell ventilation if commercial power fails. All air exhausts are to be monitored continuously and records of air concentrations will be kept.

Radiation Monitoring and Alarm Equipment

Radiation monitoring and alarm equipment of various types will be provided to enable a continuous check of radiation and contamination levels.

Portable survey instruments for measuring alpha, beta, gamma and neutron radiation will be maintained and calibrated by the Martin Company health physics staff at Quehanna.

An area monitoring system consisting of gamma detectors with a range from 1 mr per hour to 10,000 r per hour will be installed in the facility. The area monitor will also respond to high energy beta radiation. The system will be connected to audible and visual alarms at a central control panel in the operating area.

Area monitoring equipment will be provided for measuring concentrations of levels of radioactive material in the laboratory atmosphere and in the ventilation duct work. Equipment for monitoring room air includes the continuous monitors for measuring the alpha and beta activity in the exhaust air from the operating area and the machine shop; a continuous monitor for sampling the air from the service area as it enters the recirculating system; and a continuous monitor that will sample the air exhausted from the radiochemical laboratory and decontamination room. Each of these room air samplers will measure both alpha and beta activity and will be connected to appropriate alarm and interlock systems.

Drybox atmosphere will be sampled at different stages of processing by means of a flexible tube through which the sample will be drawn out of the cell onto a filter paper sampler. Special precautions will be taken to prevent contamination of room air during the use of this sampler.

Duct monitors include, between each pair of absolute filters, filter paper samplers that will be changed and counted daily in order to detect filter deterioration before serious leaks develop. Continuously monitored filter paper samples, with appropriate alarms and automatic control connections, are provided in the drybox exhaust duct and in the cell exhaust duct.

Portable air samplers will also be provided to monitor radioactive materials in the vicinity of operations where some release of airborne radioactive materials may be expected.

Other equipment includes: alpha scintillation probe count rate meters and geiger count rate meters outside the Radiochemical Laboratory and Decontamination Room, at each entrance to the control side of the change room, and at the entrance to the Operating Area; pocket ionization chambers and film badges to be used by each person working in the radioactive materials laboratory for measuring beta, gamma and neutron radiation; a supply of laboratory scalars and detectors for measuring alpha, beta, and gamma activity on smears, air samples, water samples, and air filter samples; a beta-gamma hand and foot counter at the main entrance for checking hands and feet before leaving the facility, with an alpha probe count rate meter to detect alpha contamination on hands and feet; a radiation monitor, with an alarm arrangement, situated on the drain line from the gravity head tank which will cause a valve in the drain line to close automatically if, through some unforeseen circumstances, radioactive liquid is detected in the drain line.

Fire Protection Equipment

Fire equipment is installed in and around the building in accordance with requirements of the National Board of Fire Underwriters. Most sections of the building where no radioactive work is carried out are protected by automatic sprinklers that sound an alarm when they are actuated by fire or when the system water pressure drops below a pre-set level. Sprinklers are not used where chemical and radioactive work take place because the fire extinguishing reagent depends largely on the chemical nature of the burning material. Therefore, automatic fire detectors have been installed in the operation area, above the isolation rooms, in the service area, in the decontamination room, in the radiochemistry laboratory, in the pump room, and in the mezzanine fan rooms. The entire fire alarm system will automatically operate from the normal power busses, but in case of power failure will automatically switch over to a 24-volt storage battery supply. In areas in which only fire detectors are installed, fires will be fought with locally available fire extinguishing apparatus supplying water, foam, carbon dioxide, or powdered sodium chloride.

Within the hot cells, each experimental installation will be evaluated for possible fire hazards, and appropriate alarm and fire extinguishing equipment will be installed. Also, an automatic argon purge system will be available for purging dryboxes either automatically or manually to smother any fires that accidentally arise. An electric-driven pressure pump, plus a booster pump when needed, will supply about 500 gallons of water per minute at 100 psi from fire hydrants outside the building. If electric power fails, a propane fuel pump will cut in automatically when the water pressure drops to 7 psi. A water storage reservoir is maintained that holds 135,000 gallons or more of usable water, with a minimum of 50,000 gallons maintained available at all times for fire protection.

Waste Disposal Facilities

A separate plant for the treatment of liquid contaminated waste is located in a separate building about 50' from the main building. Drainage from either the low-level waste system of the laboratory, or the non-radioactive but "suspect" waste system from such places as the service area or change room showers, is terminated in either of two 3,000 gallon underground tanks. Two tanks serve each system. When one tank of a system is full, the other tank in the same system may receive drainage while the contents of the full one are being drained or circulated for treatment.

Two pumps serve each system, with one used as a standby. When a tank is full the contents are mixed and sampled for radioactive content. If the sample is below the permissible level for release the contents of the tank will be pumped out for disposal via the gravity head tank.

If the sample is above the permissible level the contents of the tank will be pumped to the evaporator. Sludge from the evaporator will be drained into drums for shipping offsite. A vacuum receiver tank collects the condensate at a pressure of 15" Hg by means of a jet ejector operated by compressed air. The jet ejects its air through an absolute filter to the atmosphere above roof level. Each group of two storage tanks is vented above roof level through absolute filters also. A station has been provided for the addition of neutralizing agents to the storage tanks, or for transfer of radioactive waste solutions to the tanks from other laboratories. Also included in the building is a laundry facility for laundering potentially contaminated clothing. The effluent from the laundry facility is monitored in the liquid waste treatment plant.

There is adequate separation between waste treatment systems and potable water supplies. As a final precaution the drain line from the gravity head tank, which normally should contain only liquids that have been previously sampled and analyzed, is monitored with a radiation detection device that will alarm and automatically cause a valve in the drain line to close if radioactivity is detected.

Conclusion

It is concluded that the equipment and facilities proposed by the applicant are adequate to protect public health and safety in the proposed operations.

IV - OPERATING PROCEDURES

Administrative Control

The applicant has established internal administrative control, organization, and procedures to assure that proper consideration is given to controlling radiation hazards during planning, operational, and post-operational activities in the Quehanna laboratory. The nature of the operations to be carried out are such that the applicant must have some flexibility in adapting processes in accordance with the operational experience. The applicant has delineated the types of decisions regarding safety of operation which have been delegated to the operating staff at the Quehanna laboratory and the types of changes and decisions which must be referred to higher management located at the Martin Company headquarters in Baltimore. The proposed license will contain a condition which will limit the changes the licensee will be authorized to make in the equipment, facilities, and chemical processes as specified in the application without prior Commission approval.

Standard Operating Procedures

The applicant has submitted detailed operating procedures relating to rules on radiation safety which must be adhered to by all laboratory personnel. The procedures deal with pre-operational review and approval of hot cell operations, instruction of personnel, use of personnel monitoring equipment, medical examinations and bio-assay procedures, use of respiratory equipment and protective clothing, contamination control, waste disposal, and recordkeeping. Each step in the hot cell operations has been analyzed for potential problems that could create a hazard and remedial action has been delineated. Strict housekeeping is to be observed to assure that flammable materials are not taken into the hot cell areas.

Environmental Surveys

The environmental sampling program conducted by Curtiss-Wright, described in Report CWR-400-34, will be used as a basis for the environmental sampling program to be conducted by the Martin Company. The Curtiss-Wright sampling program was begun in October 1956 prior to operation of the Curtiss-Wright Research Reactor and Radioactive Materials Laboratory. The program includes collection and analysis of surface and ground water samples, silt and water vegetation samples, soil samples, vegetation samples and atmospheric fallout samples. The sample locations (extending out to 20 miles from the Laboratory) and sample preparation techniques contained in CWR-400-34 will be duplicated in the Martin survey in order that the existent collected information can be used.

Continuation of an existent environmental survey program facilitates determination of the effects, if any, which the Martin Company's operations may have on the neighboring areas.

Emergency Procedures

In the application (Section IV E, MND-2410), the Martin Company has described its plans for emergency control. The plans reflect an awareness of the necessity for alertness in the event that accidents do occur. To assure that appropriate action is taken in a timely manner, responsibilities have been delegated, equipment provided, and general plans of approach have been formulated.

In case of air contamination in the building, the alarm system will sound, the facility personnel will be evacuated, and the situation will be evaluated by the Facility Manager and Health Physicist after donning protective respiratory equipment. If contamination is released to the environment, proper agencies will be notified and action will be initiated to determine the magnitude and effect of the release with respect to public health and safety.

Conclusion

It is concluded that the Administrative Control, Standard Operating Procedures, Environmental Surveys, and Emergency Procedures established by the applicant are adequate to provide a high degree of safety in the proposed operation and to protect the public health and safety in the event of an accident.

V - PRE-OPERATIONAL CHECKS AND DRY-RUNS

The proposed operating license will not be issued to the Martin Company until a pre-operational check of all equipment and facilities in the laboratory related to radiation safety has been made, dry-runs to familiarize operating personnel with the equipment and procedures have been carried out, and a report on these activities has been submitted to the Commission for approval. This will give the Commission an opportunity to insure that the proposed safeguards will function as planned and will allow the Commission to impose any additional safety provisions that may be indicated by the results of the checks and dry-runs. Checks and dry-runs to be carried out by the Martin Company are given in the application. Some of the checks and dry-runs are summarized below.

Tests on the ventilating system will include the adjustment of fan speeds, dampers, deflectors, and air outlets and measurement of air velocities. After all adjustments have been made, adjusting levers will be locked in position. The entire ventilating system will be tested as it is designed to function under normal conditions for a period of not less than two days of 7 1/2 hours each. Also, a specific check will be made on all exhaust duct work by applying 1" of air pressure (water gauge) to the duct work with openings blocked off, and by discharging smoke into the ducts and testing for leakage. Heating, ventilating, and air conditioning interlocks and damper control mechanisms will be tested to ascertain that control response time is in accordance with design specifications. The fan start-up sequences will be checked to insure that fans actually start in the order specified. Pressure gradients between adjacent areas will be measured during start-up procedure to insure that air flow is always toward the most contaminated areas. After the start-up sequence is verified, fan failures will be simulated to insure the shut-down of other parts of the ventilation system as planned and to insure that transient conditions of air flow during fan shut-down will be safe. Further, a power failure will be induced to ascertain that the emergency generators start properly and that emergency operation of the ventilation system meets specifications.

All absolute filters will be tested using finely divided material with a radioactive tracer to insure that they have been properly placed and have not been damaged during installation.

A considerable amount of monitoring equipment must be installed, checked out, calibrated, and in some cases connected to previously installed systems. The locations of these monitoring devices will be checked to insure that extraneous background radiation levels during operation will not prevent their measuring radiation intensities or concentrations as intended. Air sampling equipment will be calibrated before installation for each radionuclide to be used in the laboratory and will be rechecked following installation. The reliability of all monitoring equipment will be tested under various abnormal operating conditions including power failure and ventilation system shut-down.

Other pre-operational checks will be made on the drybox fire protection system; all water pipes, air lines, sewer lines and air sampling conduits; all protective paint coatings in potentially contaminated areas; specially constructed key-ways to control entry to hazardous areas; and the emergency power plant. Dry-runs will be performed on all operations to assure that all possible operating defects have been overcome before actual radioactive operations begin.

VI - ANALYSIS OF CREDIBLE ACCIDENTS

The Martin application includes an analysis of the potential radiation hazards to the public under a postulated serious accident. Under a set of assumed "maximum credible accident" conditions, the Martin Company staff has calculated that a release of 10,000 curies of Strontium 90 (10 per cent of the maximum accumulation of unencapsulated strontium) in the form of a cloud of soluble aerosol at ground level would deliver a total bone dose, due to inhalation, of 4 rem to an individual at 10 miles distance present at the center of cloud during its entire passage. The nearest population center in the most probable wind direction is 10 miles downwind. The maximum internal inhalation dose (to the liver) at 10 miles resulting from a similar release of 1,000 curies of Curium-242 (10 per cent of the maximum amount in process) is 0.57 rem. Corresponding external doses at 10 miles were found to be negligible.

Some of the reasons for concluding that the Martin analysis presents an upper limit to the public hazard are:

1. The postulated accidents would require the simultaneous failure of at least 6 plant safeguards, including the rupture of 3 absolute cell filters in series in any cell exhaust system.

2. The amounts of chemical energy from the maximum heats of reaction of the quantities of process chemicals present are highly unlikely to rupture the drybox enclosure, the filter at the cell exhaust, and the dual filters preceding the stack, all at once.

3. The radioactive materials are not in a chemical form likely to result in the production of soluble aerosols when they are processed in the amounts postulated.

4. Even if all of the barriers could fail at once as postulated, it is unlikely that as much as 10 per cent of the strontium or curium compounds would escape the facility before impinging or condensing on the maze of wall and equipment surfaces with which it would come in contact.

VII - CONCLUSIONS

From the considerations summarized in this memorandum, the AEC staff has concluded that the proposed site, facilities and equipment, and procedures are adequate for the proposed operations at the Martin Company's Quehanna facility. Based on these considerations and an analysis of the postulated maximum credible accident, it is concluded that these operations can be carried out without undue risk to the health and safety of the public.

Lester R. Rogers
Assistant Director for Nuclear
Materials Safety
Division of Licensing and Regulation

Date: MAR 1 1961