SAND79-2240
Unlimited Release
Printed July 1980

Distribution
Category UC-20e

Master

SANDIA IRRADIATOR FOR DRIED SEWAGE SOLIDS FINAL SAFETY ANALYSIS REPORT

Marvin E. Morris
Applied Biology & Isotope Utilization Division 4535
Sandia National Laboratories
Albuquerque, New Mexico 87185

ABSTRACT

Analyses of the hazards associated with the operation of the Sandia Irradiator for Dried Sewage Solids, as well as methods and design considerations to minimize these hazards, are presented in this report in accordance with DOE directives.

3-4

CONTENTS

		Page
I.	Introduction	9
	A. Overall Description	9
	B. Facility Rationale	9
II.	Summary	10
	A. Most Hazardous Accidents	10
	B. Safety Features	10
	C. Radiation Data	10
III.	Site Considerations	11
	A. Site Description	11
	B. Meteorological, Geological, Hydrological, and Population Data	11
	C. Security	14
	D. Environmental Impact	14
	1. Modification to the Site	14
	2. Air Release Potential	14
	3. Water Release Potential	14
	4. Personnel Exposure	15
	E. References	15
IV.	Description of Facility	16
	A. General Description	16
	B. Component Descriptions	18
	1. Design Constraints	18
	2. Shielding	18
	3. Conveyor	18
	4. Source Plaque	19
	5. Lead Shutter	20
	6. Gamma-Source Pins	20
	C. Interlock and Control Systems	23
	1. Interlock Design Philosophy	23
	2. Radiation Monitoring	23
	3. Electrical Interlocks	25
	4. Mechanical Interlocks	26
	5. Electrical Control	27
	D. Ventilation and Cooling System	28
	E. Fire Control System	28
	F. Miscellaneous Equipment	31

CONTENTS (Cont)

			Page
V.	Description of Operations		32
	A.	Introduction	32
	B.	Pin Loading Procedures (LOAD-UNLOAD Mode)	32
	C.	Normal Operations (NORMAL Mode)	34
		1. Definition	34
		2. Radiation Sensor Checkout	34
		3. Lead Shutter Opening and Closing	34
		4. Source Plaque Extension and Retraction	34
		5. Conveyor Loading and Unloading Operations	35
	D.	Maintenance (ACCESS Mode)	35
	E.	Standby (OFF Mode)	37
	F.	Pin Unloading Procedures (LOAD-UNLOAD Mode)	37
VI.	Accident Categories		38
	A.	Introduction	38
	B.	Loading and Unloading Gamma-Source Pins	38
		1. Introduction	38
		2. Pool Cover Dropped	38
		3. Transportation Cask Dropped	39
		4. Shielding Water Release	40
		5. Pool Cover Removed Without Water in Pool	40
	C.	Maintenance	41
		1. Introduction	41
		2. Shutter Opens in ACCESS Mode	41
		3. Shutter Jammed Open	41
		4. Shutter Closes on Source Plaque	42
		5. Mechanical Dangers	42
		6. Person Locked In	43
	D.	Normal Operation	43
		1. Introduction	43
		2. Source Pin Leak	43
		3. Fire	44
		4. Explosion	45
		5. Conveyor Jams Against Source Plaque	45
		6. Mechanical Dangers	45
		7. Source Plaque Jammed on Conveyor Side or in Cavity	46
	E.	Natural Events	46
		1. Floods	46
		2. Earthquakes	46
		3. Tornadoes	47

CONTENTS (Cont)

		Page
	F. References	47
VII.	Facility Expansion	48
VIII.	Environmental Monitoring Program	49
	A. Preoperational Sampling	49
	B. Operational Sampling	49
	C. References	49
IX.	Waste Handling	50
	A. Introduction	50
	B. Solid Wastes	50
	C. Liquid Wastes	50
X.	Quality Assurance and Acceptance Procedures	51
	A. Introduction	51
	B. Facilities	51
	C. Operations	51
XI.	SIDSS Decontamination	52
XII.	Summary of Emergency Plans	53
	A. Immediate Response	53
	B. Secondary Actions	53
	C. Call Lists and Checklists	54
XIII.	Summary of Employee Training	55
	A. Training Requirements	55
	B. Training Program Contents	55
XIV.	Safety Management System	60
XV.	Summary of Operating Procedures	61
XVI.	Operational Safety Requirements	62
XVII.	Conclusion	64
APPENDIX A --	Cesium-137 Waste Encapsulation and Storage Facility (WESF) Capsule Description	65
APPENDIX B --	Shielding and Scatter Calculations for the Sandia Irradiator for Dried Sewage Solids	71
APPENDIX C --	Electrical Control System for the Sandia Irradiator for Dried Sewage Solids	85
APPENDIX D --	CsCl Cylinder Heat Transfer Studies	95
APPENDIX E --	Detailed Operating Procedures	115
APPENDIX F --	Safe Operating Procedures	127

SANDIA IRRADIATOR FOR DRIED SEWAGE SOLIDS
FINAL SAFETY ANALYSIS REPORT

I. Introduction

A. Overall Description

This Safety Analysis Report describes the Sandia Irradiator for Dried Sewage Solids (SIDSS) designed by Sandia Laboratories and assesses the hazards associated with its operation. The SIDSS consists of a conveyor system, a source plaque and associated shielding, and a gamma-source pin loading/unloading pool. The facility was installed next to Building 6720 in Technical Area III (TA-III) in April 1979. This facility provides Sandia Laboratories with the capability of exposing up to 8 tons per day of sewage solids to 1 Mrad absorbed dose.

B. Facility Rationale

The basic purposes for constructing the SIDSS are fourfold:

1. to provide a high-dose rate research facility to examine further the effects of radiation on sewage sludge,
2. to function as a testbed for the mechanical and electrical components to be used in larger facilities,
3. to fulfill the formal requirements of a pilot plant so that the Environmental Protection Agency (EPA) can fund the construction of a larger plant as a demonstration facility using a proven technology, and
4. to provide accurate data, based on operating experience, for the Environmental Impact Assessment (EIA) and the Safety Analysis Report (SAR) for a much larger facility that is to be constructed by the EPA.

Dried digested and dried raw sludge from New Mexico State University are being processed for various purposes in the SIDSS. Other cities and agencies probably will want to conduct tests with the SIDSS as well.

II. Summary

A. Most Hazardous Accidents

The two types of accidents that are regarded as most hazardous are ones which result in radiation exposure to personnel higher than the prescribed limits and ones which result in leakage of radioactive material from the gamma-source pins.

The accidents that could result in excessive radiation exposure to personnel are removing the pool cover without shielding water, removing the conveyor access area access cover with the lead shutter open, and opening the lead shutter while personnel are in the conveyor access area. These accidents, along with consequences and preventive measures, are discussed in Chapter VI. The components of the system, such as the conveyor and lead shutter, are described in Chapter IV.

The actions that could result in leakage of radioactive material from the gamma-source pins are corrosion from within or outside the capsule or mechanical fracture of the pins. The integrity testing of the pins is described in Appendix A, and the consequences of a mechanical fracture, and the design and procedural provisions incorporated to prevent such a fracture, are presented in Chapter VI.

B. Safety Features

The safety features are described in detail in Chapter IV and Chapter VI and include independent mechanical and electrical interlock systems, and sensitive radiation monitoring equipment to measure radiation exposure to personnel and to prevent discharge of radioactive material to the environment. A 1000-gallon holding tank is provided for water discharged from the facility so that the water can be thoroughly checked for contaminants before discharge to the environment. The High Efficiency Particulate Air (HEPA) filters placed in series are provided to clean thoroughly any air discharged from the facility.

C. Radiation Data

The detailed analyses presented in Appendix B indicated that the highest expected dose rate inside the conveyor area was 1 mrem/hr with the lead shutter closed. The maximum measured dose rate there was 0.3 mrem/hr; this could be reduced even further by stacking lead bricks in the aperture of the cavity leading from the pool area to the conveyor area. The highest dose rate outside the facility from the cesium-137 within was expected to be less than 0.035 mrem/hr; the measured dose rate outside the facility was less than 0.035 mrem/hr everywhere except at a small crevice between the first and second pool lids where the dose rate was 0.8 mrem/hr and at a small 6 by 6-inch patch next to where the conveyor exits the structure where the dose rate was 0.2 mrem/hr. The crevice is being grouted, and a small patch of lead is being added next to the conveyor exit in order to reduce even these low dose rates to background level. The 0.035 mrem/hr value is at or below background radiation level in the area. In order to obtain this low level, some patch shielding has been provided to prevent radiation scatter back through the conveyor path and access area.

III. Site Considerations

A. Site Description

The Sandia Irradiator for Dried Sewage Solids (SIDSS) is located within Sandia Technical Area (TA) III at the northwest corner of Building 6720, as shown in Figures III-1 and III-2. TA-III is located well within the boundaries of the Kirtland Air Force Base East area, which is a major portion of the Kirtland Air Force Base. TA-III is physically located about 6 km south of Sandia TA-I, which contains the largest concentration of Sandia Laboratories personnel and equipment. The Exclusion Area for the SIDSS is defined as that region bounded by a circle of 1 km radius centered at Building 6720. This definition places all of the Exclusion Area within the direct control of Kirtland Air Force Base (i.e., either military or Sandia Laboratories).

B. Meteorological, Geological, Hydrological, and Population Data

The SIDSS facility is located approximately 1.5 km west of Sandia TA-V. There are no major distinguishing characteristics between the two sites. The above data have been very thoroughly tabulated, analyzed, and summarized for TA-V in Chapter III of the Hot Cell Facility (HCF) Safety Analysis Report.[1]

To summarize the description of the site features, the SIDSS is located in a relatively low population density area. The closest distance of any location with personnel maintaining normal working hours is approximately 0.25 km away at Building 6721. All facilities are sufficiently remote from the SIDSS that it is very unlikely that operation at the other facilities would affect the SIDSS. The location and populations of the other facilities are tabulated in Reference 1.

The generally dry weather patterns around Albuquerque keep the annual rainfall down to an average of just over 20.3 cm. Sheet flooding occurs occasionally and has been provided for in the design of the SIDSS. Tornadoes are quite infrequent, with a probability of 0.1 per year or less. Most of the SIDSS (including the radioactive material) is below ground level and therefore not vulnerable to tornado wind loadings. A pressure differential of over 6.5 psi between the inside and the outside would be required to lift the pool cover. A pressure differential of over 2.5 psi would be required to lift the concrete cover atop the conveyor access area. Tornadoes which occur in New Mexico do not generate pressure differentials this large.

The water table is approximately 150 m below the surface in TA-III. The high ion-exchange capacity of the surface and subsurface soil would bind the cesium ions and would prevent rapid migration of the radioactive material were contaminated solids or water to be accidently discharged to the environment. Adequate time would be available to clear the area of contaminated soil before the ground water table became endangered.

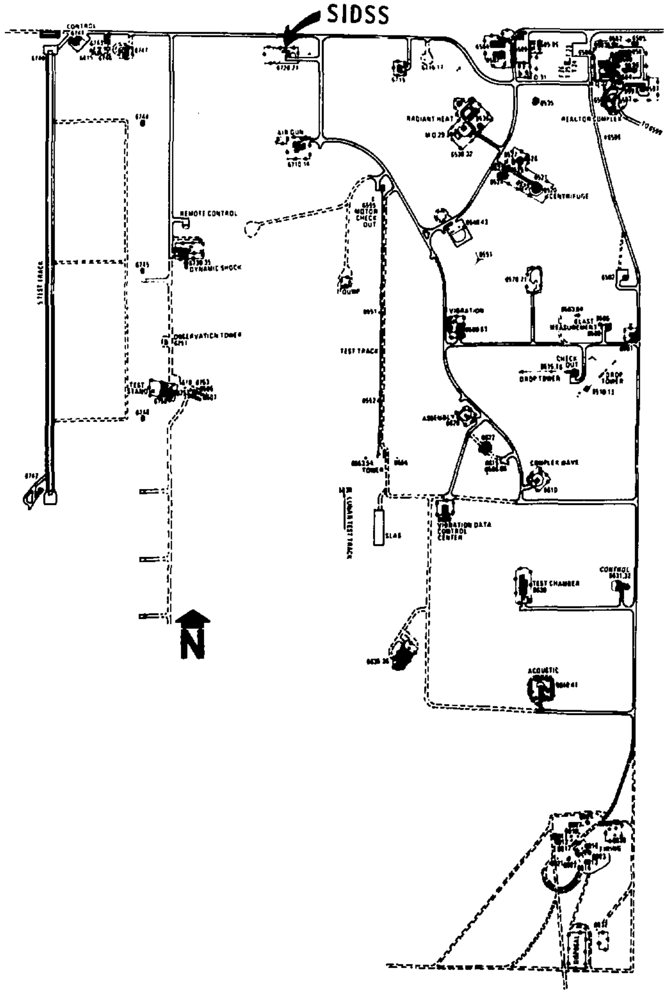


Figure III-1. Area III Map

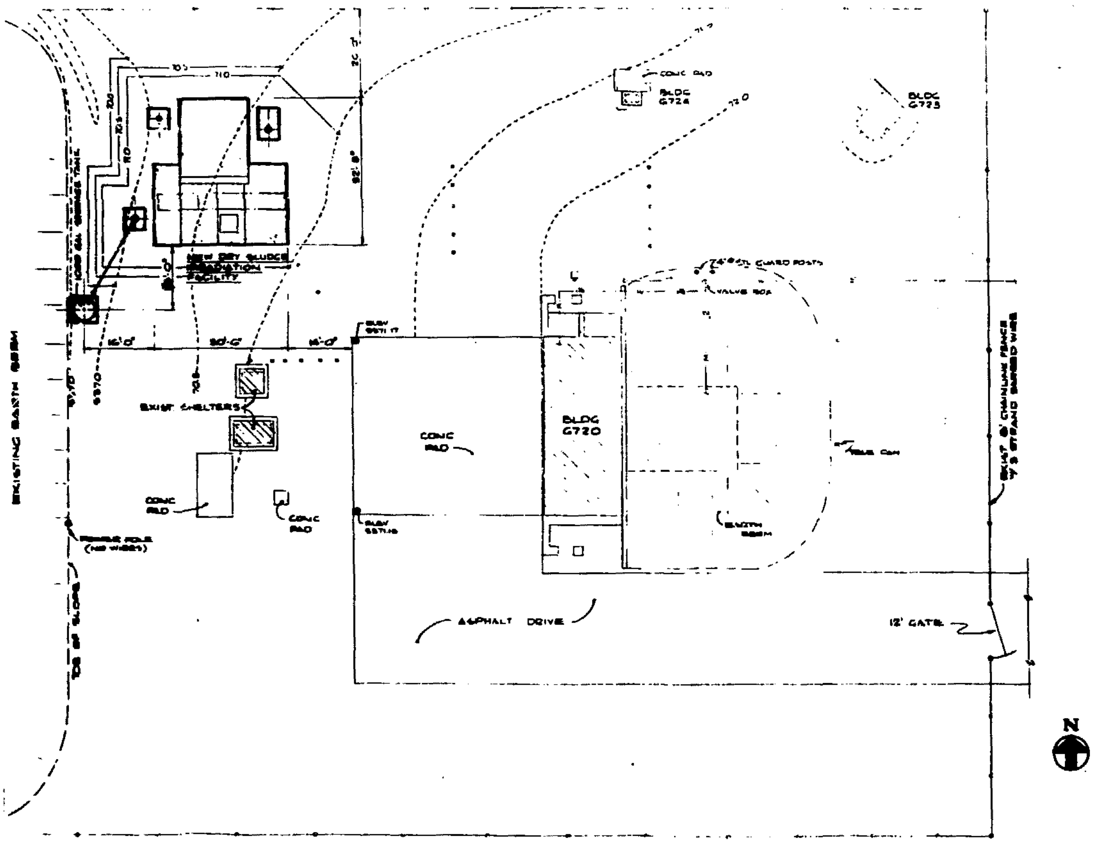


Figure III-2. SIDSS Plot Plan

C. Security

The SIDSS is within TA-III, which is a controlled access area with a security fence on the north boundary and with guards on duty 24 hours per day. A security badge is required in order to gain entrance to the area. TA-III is within Kirtland Air Force Base, which is a controlled access base. An automobile decal is normally required for entrance to the base, and, in addition, a personal identification card is required during off-hours.

In addition to the above security features, a 10-foot high security fence is installed around the SIDSS and Building 6720. The gate to the enclosed area is opened only when operations are to be carried on at the SIDSS. The SIDSS control panel is inside the normally locked Building 6720. Building 6720 is unlocked only when operations are to be carried on at the SIDSS.

In addition to these features, special keys are required to operate the SIDSS control panel in any of the four operational modes (described in Chapter IV).

Personnel entering the security fence around the SIDSS are required to wear personnel dosimeters and to carry a radiation survey meter.

D. Environmental Impact

1. Modification to the Site

The construction site inside the security fence surrounding Building 6720 was cleared of vegetation in conjunction with tests carried out more than 5 years earlier. The necessary excavation, backfill, and construction operations are not expected to change the character of the site significantly.

2. Air Release Potential

The normal operation of the SIDSS will not generate any airborne particulate materials. Airborne pollutants would be limited to small quantities of radioactive products which might be released if the integrity of a gamma-source pin were compromised from corrosion or mechanical fracture. In the event that this small amount of radioactive material were to become airborne, it would be filtered by the two High Efficiency Particulate Air (HEPA) filters that are installed in series in the cooling air outlet of the facility. This event is discussed in Chapter VI.

3. Water Release Potential

After the initial charging of the SIDSS with cesium, which took place underwater, no water is used in the facility. The normal groundwater level is approximately 150 m below the surface, so the only water that might leak into the facility would be from thunderstorms. Care has been taken to slope the approaches to the facility, to slope the covers, and to waterseal the joints of the facility. In the event water did enter the facility, the sump pump would attempt to discharge the water before it reached the height of the pins. An undetected leak in a source pin would have to be present and the radiation sensor checking any water discharged by the sump pump would have to malfunction for any contaminated water to be pumped into the holding tank. Consequently, the probability of a water release of radioactive material is extremely small during normal operation.

Administrative procedures require that the water samples from the holding tank be analyzed for cesium to ensure that concentrations are well below the levels specified by the DOE of 2×10^{-5} μCi of cesium-137 per milliliter of water before it can be discharged to the environment.[2]

If water with minute amounts of cesium-137 were accidentally discharged to the environment, the high ion-exchange capacity of the soil would bind the cesium until the area were decontaminated.

4. Personnel Exposure

The shielding of the facility, as shown in Appendix B, is adequate to reduce the radiation exposure levels to near background levels. No dose of over 0.035 mrem/hr is expected in any normal work areas outside the facility. The dose rate inside the conveyor access area of the facility with the load shutter closed is only 0.3 mrem/hr. This dose rate can be reduced even further if extended repair times are required in the conveyor access area.

E. References

1. Bernard, E. A., H. D. Burress, and R. J. Dye, Hot Cell Facility (HCF) Safety Analysis Report, Sandia Laboratories, Albuquerque, NM, to be published.

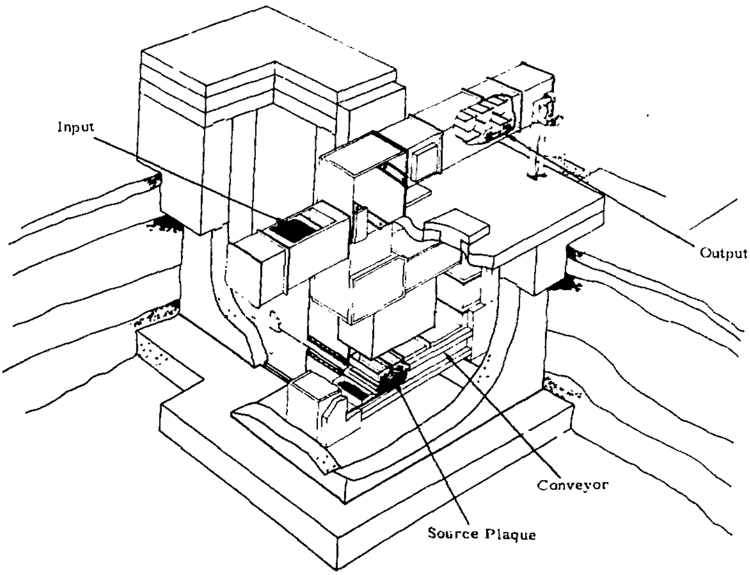
2. ERDA Appendix 0524 Annex A, April 8, 1975.

IV. Description of Facility

A. General Description

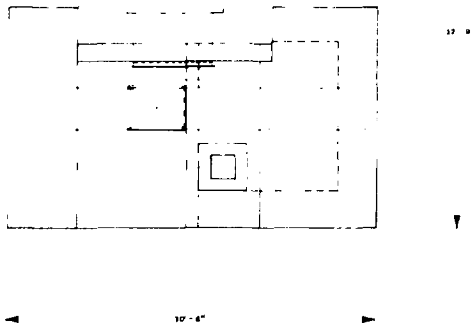
A cutaway, an elevation, and a plan view of the Sandia Irradiator for Dried Sewage Solids (SIDSS) are illustrated in Figure IV-1. The facility is designed to irradiate up to 8 tons/day of sewage solids to a radiation dose of 1 Mrad. Larger quantities of solids can be processed at a lower total dose by adjusting conveyor speed. Both bulk and bagged dried materials can be irradiated.

Major components of the system are shown in Figure IV-1. A temporarily water-filled pool lined with stainless steel is required to load or unload gamma-source pins from the shipping cask used to transport them. When installed in the facility, the gamma-source pins was secured in a 2- x 6-ft source plaque. When the plaque is in the pool area, a lead shutter can be closed to prevent radiation from streaming into the conveyor area. After the pool cover was secured and the water pumped from the pool, a water seal was manually removed in the conveyor area. Once the facility was properly secured, the lead shutter was opened to allow the source plaque to be driven on tracks to the conveyor side of the facility. With the source plaque in place, the conveyor can be operated to transport material past the gamma-source pins.

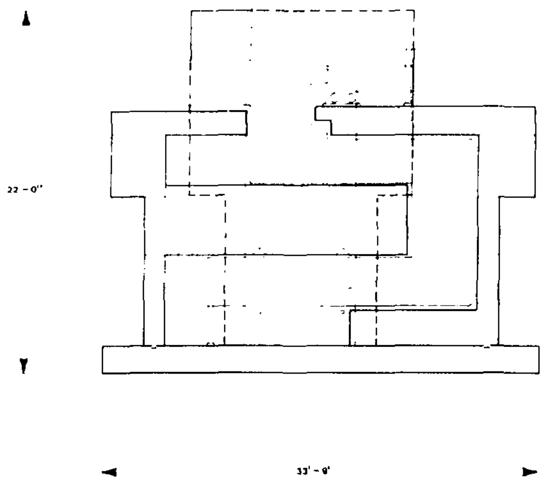


a.

Figure IV-1. Cutaway of Sandia Irradiator for Dried Sewage Solids



b.



c.

Figure IV-1 (Cont)

In the next section, pertinent technical details of the above components are described.

B. Component Descriptions

1. Design Constraints

The components of the irradiator are designed to limit the radiation exposure dose rate to 1 rem/yr for workers using the facility, and to 170 mrem/yr above natural background for personnel not directly connected with the use of the irradiator, such as janitors, maintenance personnel, or material handlers.

2. Shielding

As illustrated in Figure IV-1, shielding requirements for a 1-MCi cesium-137 gamma source are considerable. The upper portions of the pool walls are 4 ft thick and the cover is 3 ft thick in three separate layers. This thickness, as shown in Appendix B, is adequate to reduce dose-rate levels in working areas outside the building to less than 0.035 mrem/hr over background when the source plaque is on the pool side. On the conveyor side of the facility, a section of concrete 5 ft thick separates the source from the upper part of the system. This thickness, as illustrated in Appendix B, is adequate to reduce dose-rate levels in the upper part of the conveyor compartment to less than 0.035 mrem/hr over background when the source plaque is on the pool side. The 5-ft thick wall between the pool and the conveyor area is thick enough to provide protection from the radiation to the side of the lead shutter that the lead shutter does not absorb. A cross-sectional drawing of the lead shutter is shown in Appendix B.

3. Conveyor

The conveyor system shown in Figure IV-2 transports dried sewage solids past the radiation source. The conveyor system has unusual features and is well suited to its task. The buckets are supported by a heavy link chain that is extended to allow the buckets to go around corner sprockets without contact, but in the radiation field or in the fill section, the chain sections collapse to allow the buckets to come together. In the radiation zone, this feature permits very efficient use of the gamma-source. In the fill section, bulk material will fill the buckets without falling between them. Either bulk material 8 in. deep or two 40-lb bags will fill a bucket.

The sprockets allow very sharp turns to be made by the chain-bucket assembly. The buckets are irradiated from both above and below for a more uniform dose distribution. Normal operating speed for a 1-Mrad dose is approximately 4 in./min. The upper limit of the recommended design speed for this type of conveyor is 30 ft/min. Automatically operated air jets clean and lubricate the chain continuously.

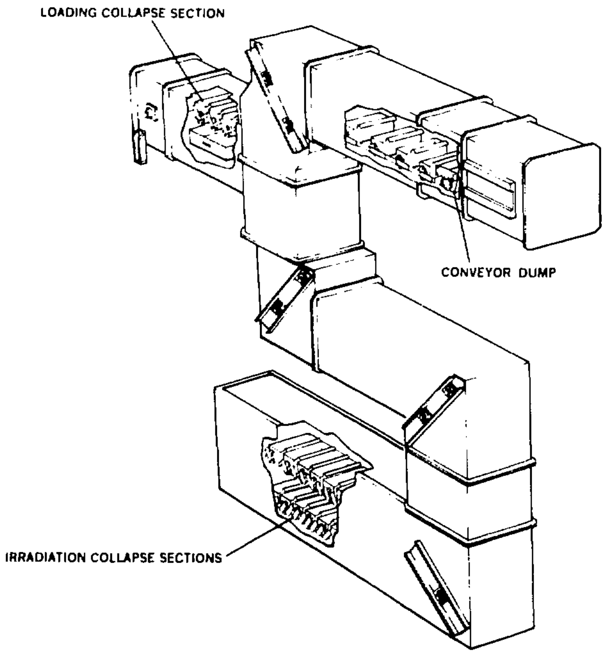


Figure IV-2. Gough Max-Econ Conveyor System

The conveyor is called Max-Econ and is manufactured by Gough-Econ, Inc., of Staffordshire, England.

4. Source Plaque

The function of the source plaque is to provide a secure assembly for the cesium-137-filled gamma-source capsules. The plaque shown in Figure IV-3 holds 15 of these gamma-source capsules for a total of 975 kCi of cesium-137. The four wheels attached to each of two sides of the plaque roll on a track. The track allows movement of the plaque between the pool and conveyor areas. The tracks are designed so that any inadvertent granular material buildup will be pushed off by the wheels. Arms attach to the plaque to drive it with a cable assembly from outside the facility. The plaque is open to enhance heat dissipation by convection.

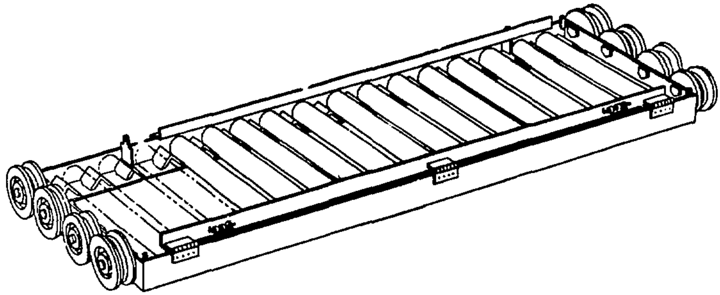


Figure IV-3. Gamma Source Plaque

5. Lead Shutter

The lead shutter shown in Figure IV-4 shields the conveyor access area when the shutter is in the closed position and the gamma-source plaque is retracted into the pool area. The 9-in.-thick stainless-steel-lined lead shutter is supported and aligned by rollers below and above. In the closed position, the shutter compresses a bellows that provides fluid pressure to release the access cover lock if the system is in the access mode. Magnetically actuated reed switches also indicate when the shutter is in the closed position. Magnetically actuated reed switches at both ends of the travel of the shutter limit the motion by turning off the drive motor. With the source plaque in the pool and the lead shutter closed, the radiation field is less than 1 mrem/hr at the location of the water seal in the conveyor area (see Appendix B for computational details and diagrams).

6. Gamma-Source Pins

The gamma-source pins that contain cesium-137 in the form of cesium chloride are shown held in the source plaque in Figure IV-3. Each capsule contains 65 kCi of cesium-137, double-encapsulated in 316L stainless steel. The overall length of the outer capsule is 20.775 in., and it is 2.625 in. in diameter. The other dimensions of the capsule components are tabulated in Figure IV-5, as are the pertinent physical characteristics of the capsule.

The capsules are fabricated by Rockwell International at the Waste Encapsulation and Storage Facility (WESF) at Richland, WA. The welds made on the capsule are ultrasonically tested. The fabrication and quality assurance steps taken during manufacturing are described in the Appendix A.

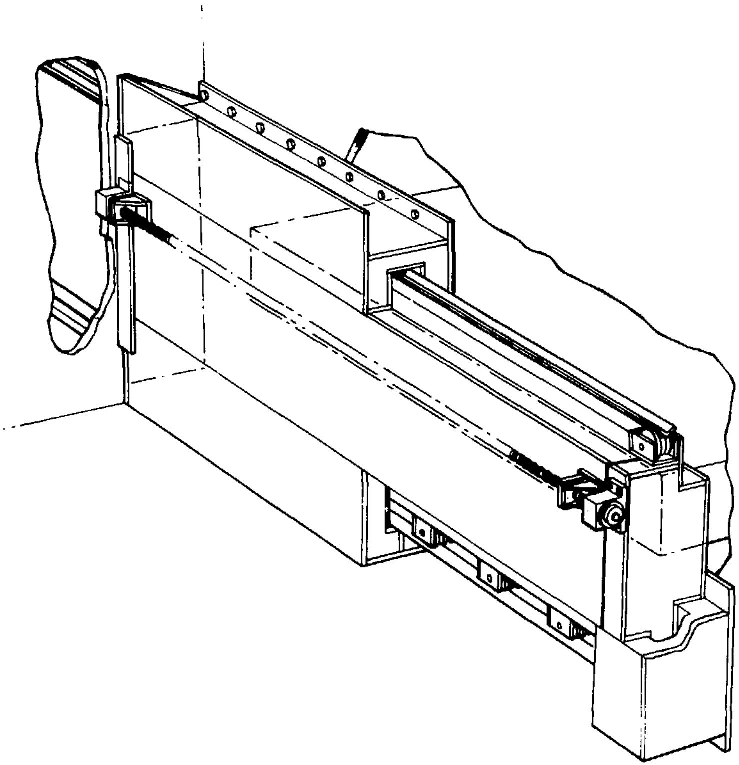
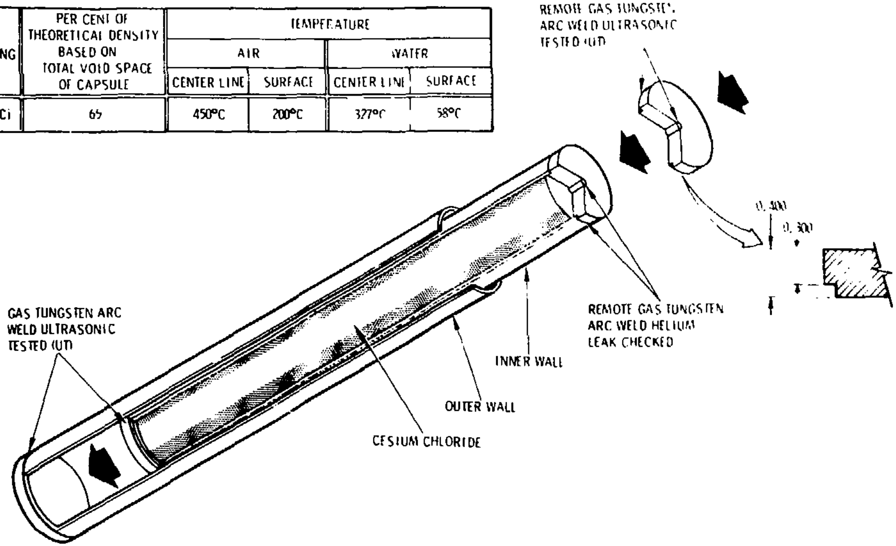


Figure IV-4. Lead Shutter

	FORM	LOADING	PER CENT OF THEORETICAL DENSITY BASED ON TOTAL VOID SPACE OF CAPSULE	TEMPERATURE			
				AIR		WATER	
				CENTER LINE	SURFACE	CENTER LINE	SURFACE
CESIUM CHLORIDE	MELT-CAST	70 KCi	65	450°C	200°C	327°C	58°C



	CAPSULE									
	INNER					OUTER				
	MATERIAL	WALL THICKNESS	OUTSIDE DIAMETER	TOTAL LENGTH	TOTAL CAP THICKNESS	MATERIAL	WALL THICKNESS	OUTSIDE DIAMETER	TOTAL LENGTH	TOTAL CAP THICKNESS
CESIUM CHLORIDE	316L STAINLESS STEEL (UT)	0.095 (UT)	2.250	19.725	0.400	316L STAINLESS STEEL (UT)	0.109 (UT)	2.625	20.775	

NOTE: ALL DIMENSIONS ARE IN INCHES — NOVEMBER 1972

Figure IV-5. Hanford Waste Encapsulation and Storage Facility Capsules

C. Interlock and Control Systems

1. Interlock Design Philosophy

Several criteria were paramount in designing the interlock and control systems:

a. Failure of any single interlock component cannot result in radiation exposure to operating personnel.

b. Failure of any single interlock system cannot result in radiation exposure to operating personnel.

c. To prevent radiation exposure to operating personnel, no administrative control is required during any operation except for loading or unloading radiation-source capsules.

During all operations that could result in personnel exposures following a failure of both the electrical and mechanical interlock systems, Safe Operating Procedures (SOPs) (properly followed) provide operating personnel with a third level of safety from exposure. These SOPs prescribe radiation surveys by qualified health physicists before workers can enter the conveyor access area. The procedures will also prescribe the use of "chirpers" and personnel dosimeters by personnel at all times when they are within the security fence surrounding the facility.

Because the two independent interlock systems (one electrical and one mechanical) are separate from each other physically and functionally, the possibility of common-mode failures is minimized.

Additionally, at least two steps of holding, with radiation monitoring before or after the steps, are provided to prevent release of radioactive material to the environment either through air or water discharges. These systems are described in detail later.

2. Radiation Monitoring

Outputs from radiation sensors play a key role in controlling the electrical interlock system. Sensor positions are shown in Figure IV-6, and the sensitivity of the detector in each position is given in Table IV-I.

TABLE IV-I

Sensitivities of Radiation Monitors

Sensor	Sensitivity
1	0.1 - 1000 mR/hr
2	0.1 - 1000 mR/hr
3	0.05 - 50 mR/hr
4	0.05 - 50 mR/hr
5	500 - 50,000 counts/min
6	500 - 50,000 counts/min
7	0.05 - 50 mR/hr

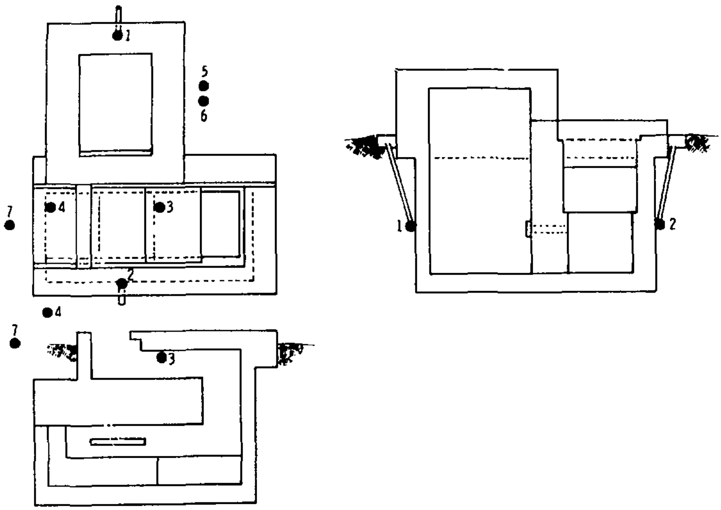


Figure IV-6. Radiation Sensor Locations

The sensors and the associated circuitry have self-consistency checks that will be performed each time the system is used. The sensors are in use throughout Sandia and will be recalibrated annually by qualified health physicists, following maintenance, or after malfunction. Sensors 1 and 2 monitor whether the source plaque is on the pool side or the conveyor side of the system, and whether the lead shutter between the pool and conveyor areas is open or closed. Sensor 3 is located inside the conveyor system before the final right-angle bend of the system, so that if any radioactive material is brought up by the conveyor, the system shuts down before the material can reach a position to expose operating personnel to radiation. Sensor 4 warns the operator whether any radioactive material is being loaded inadvertently into the conveyor, and also whether a radiation field exists in the dry solids loading zone. Because the sensitivity of the sensor is 0.05 mR/hr, serious exposure to the operators would be prevented. Sensor 5 is a β-γ air monitor that senses whether radioactive material is in the air stream supplied to the HEPA filters. Sensor 6 is a β-γ air monitor that samples the air stream after the High Efficiency Particulate Air (HEPA) filters. The air passing through the air monitor is passed through an air filter on a continuous basis for a permanent record of any radioactive release. If any air release of radioactive material through the HEPA filters should occur, the sensor will detect any leak and alarms will be activated. The blowers will be switched off in the event of a release combined with a HEPA filter failure so there will be little or no release to the environment. An air sampling port is provided just before as well as after the HEPA filters so that samples can be taken by Millipore filters for more sensitive measurements. If the HEPA filters are not compromised, the ventilation system will be kept operating to prevent radioactive particles from settling and contaminating the entire facility. Sensor 7 monitors the output of the sump pump. If water were to enter the conveyor side of the system, the sensor would prevent the sump pump from pumping high concentrations of radioactive contaminated water to a holding tank. This measurement is not particularly sensitive and must be supplemented by taking a sample from the holding tank and analyzing it in a counting chamber before the water can be released to the environment.

3. Electrical Interlocks

The electrical control system is designed to operate in four separate modes depending on the operation being carried on at the facility. The four modes (Figure IV-7) are as follows

a. The OFF mode conditions the alarm system to allow the facility to be unattended for long periods of time. If the radiation or fire sensors are triggered, the local audible and visible alarms (with emergency power backups) operate until the problem is corrected.

b. The ACCESS mode is used whenever it becomes necessary for someone to enter the conveyor access area. The main interlock feature of this mode is that the access cover lock, which prevents removal of the access cover leading to the conveyor side of the facility, is released only when the radiation sensors register within preset limits. This interlock system prevents the access cover leading to the conveyor from being removed unless the lead shutter is closed; this prevents radiation exposure of personnel entering the cavity alongside the conveyor. When the access cover is lifted, a switch on the cover provides the signal to lock the shutter drive mechanism, and power to the shutter drive motor is automatically turned off. If radiation levels exceed preset alarm limits or if high temperatures activate the fire sensors, the system, except for ventilation, is shut down, and audible and visible alarms (with emergency power backup) operate until the problem is corrected.

c. The NORMAL operating mode is used whenever the only operation to be carried out is irradiation of dried sewage solids in the conveyor system. In this mode, if the radiation or fire alarms go into an improper state, the conveyor system is shut down, and audible and visible alarms (with emergency power backup) operate until the problem is corrected.

d. The LOAD-UNLOAD mode is used when it is necessary to transfer gamma-source pins to or from a shipping cask. The principal feature of this mode is that the pool cover cannot be removed unless the pool is full of water, as indicated by a float switch. When the pool cover is removed, a switch turns off the pool water discharge pump.

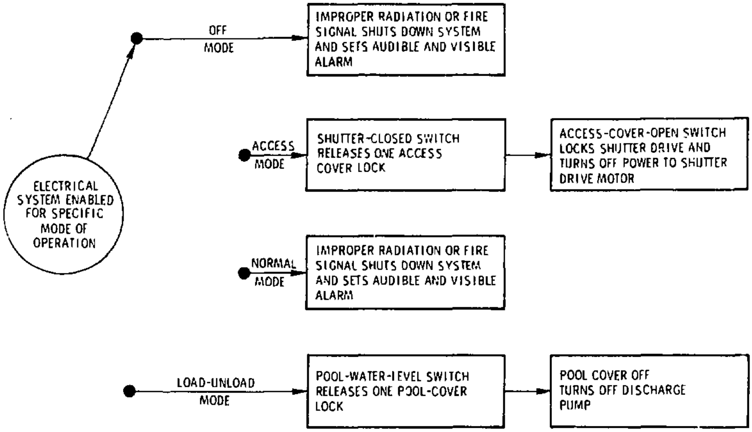


Figure IV-7. Electrical Interlock System

The above paragraphs describe only the basic operation of the electrical interlock system. The less important features are described logically and schematically in Appendix C.

4. Mechanical Interlocks

As a result of the design philosophy used for the interlock system, parallel backup mechanically operated interlock systems were designed for the critical operations (those operations that could result in direct exposure to operating personnel if the electrical system failed).

The critical events were identified as follows:

a. the conveyor access cover could be removed with the lead shutter open,
b. while a person was in the conveyor access area, the lead shutter could open, and
c. the pool cover could be removed with the gamma-source plaque at the bottom of the pool, but with no water in the pool.

To prevent these events from occurring, even in the event of an electrical system malfunction, a mechanically actuated hydraulic system was designed. The hydraulic pumping action of the system is provided by bellows. The bellows are either compressed by mechanical action to provide fluid pressure or are expanded by hydraulic action to provide mechanical motion.

The actions of the basic systems are described in Figure IV-8. In the first system, the final quarter-inch closure of the lead shutter pumps a bellows that provides mechanical action to unlock the access cover. When the access cover is removed, a bellows action provides motion to lock the shutter drive in the closed position. The second system uses water pressure from filling the pool to unlock the pool cover. Stainless-steel hydraulic lines and Inconel bellows have been selected for the system.

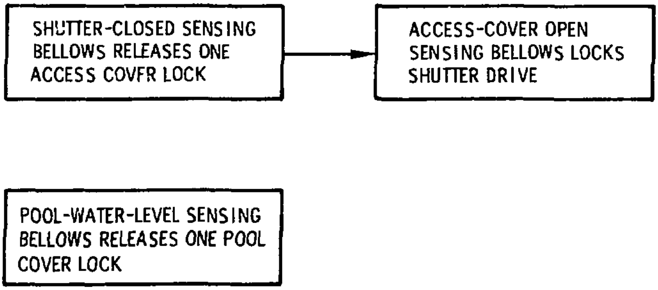


Figure IV-8. Mechanical Interlock System

In the design of the system, several problems have arisen and been resolved. A hydraulic operating fluid had to be selected that would not freeze at temperatures down to -30°C but could stand the high radiation field without deterioration of physical or chemical properties. No such fluid was found, but as a solution a transfer bellows was placed in the hydraulic line immediately after the line left the radiation zone. Water is used in the portion of line inside the pool, and ethylene glycol is used in all other hydraulic lines. Problems occur even with water because the radiation field very slowly converts water to H_2, O_2, and H_2O_2. The hydrogen peroxide is slightly corrosive but decomposes rapidly and is no problem. However, pressure from the hydrogen and oxygen gases will build steadily. To correct this problem, palladium, which catalyzes H_2 and O_2 to H_2O at room temperature, is vacuum deposited onto the inside of the bellows from the water-filled section of hydraulic line to prevent pressure from gas buildup.

5. Electrical Control

Several features of the system are controlled electrically. The source plaque and the lead shutter are motor-driven and are turned off by magnetically actuated reed limit switches in the radiation zone. Manually operated switches that can turn off the sump pump, ventilation system, conveyor, feed hopper, and electrical outlets are provided on the control panel. Indicator lights are provided on the control panel for all electrically actuated equipment.

D. Ventilation and Cooling System

The system for transporting air through the facility serves two functions: first, clean air flowing over the capsules in the source plaque tends to cool them; and, second, the small pressure differential between the air outside the facility and the air inside helps confine any radioactive aerosols that might be generated by a leak in the capsules or an accident inside the facility.

Air-flow in the ventilation system is shown in Figure IV-9. Air that enters the conveyor system is contained by the metal on the sides of the conveyor frame. The conveyor air system, aside from small leaks, is separate from the main air system for the rest of the facility. Air that flows past the gamma-source pins enters through a prefilter beside the hole through which the conveyor system enters the concrete structure. The air flows down beside the conveyor to the location of the gamma-source plaque, which is contained in a stainless-steel-lined cavity between the upper and lower collapse sections of buckets. The air flows axially along the cylinders through a section of the stainless-steel-lined cavity to the pool area and out through a 4-in. stainless-steel pipe to a vertical 12-in. polyvinyl chloride plastic-lined air shaft to ground level. A fan pulls the air through a double HEPA filter to contain any potential radioactive release. This filter never comes in contact with combustible materials. If radioactivity is detected after the HEPA filters by the permanently mounted β-γ radiation sensor, audible and visible alarms are triggered. The air stream from the β-γ monitor is continuously passed through an air filter for a permanent record of any radioactive release.

The geometry of the gamma-source pins and the airflow past them is shown in Figure IV-10. The thermal properties of the pins and plaque have been examined. In the case of no airflow, the centerline temperature of the capsules would be expected to reach 450°C. With the design airflow, the centerline temperature of the capsules is reduced slightly. A β-transition accompanied by a volume change of approximately 17 percent occurs if the temperature of 451°C is exceeded by the cesium chloride. The capsules were filled with molten cesium chloride at greater than 648°C and allowed to cool, so the volume expansion that accompanies the phase transition could cause no problems. Because of convective heat transfer to the steel liner and concrete and subsequent conductive heat transfer to the earth, no excessive temperature could occur even if the airflow were stopped.

E. Fire Control System

Basic elements of the fire control system are shown in Figure IV-11. Heat detectors are placed in the conveyor at the locations shown because the dried sewage solids are the only materials that could possibly burn in the facility. If a temperature of 57°C is reached in the upper section of the conveyor access area, the heat detector senses it and an audible and visible alarm activates, causing a solenoid actuated valve to open and the conveyor system to be flooded with carbon dioxide. The CO_2, being heavier than air, fills the conveyor. An override valve is provided to switch off pressure to the valves so that personnel would not suffocate if the valve opened while they were working in the conveyor access area.

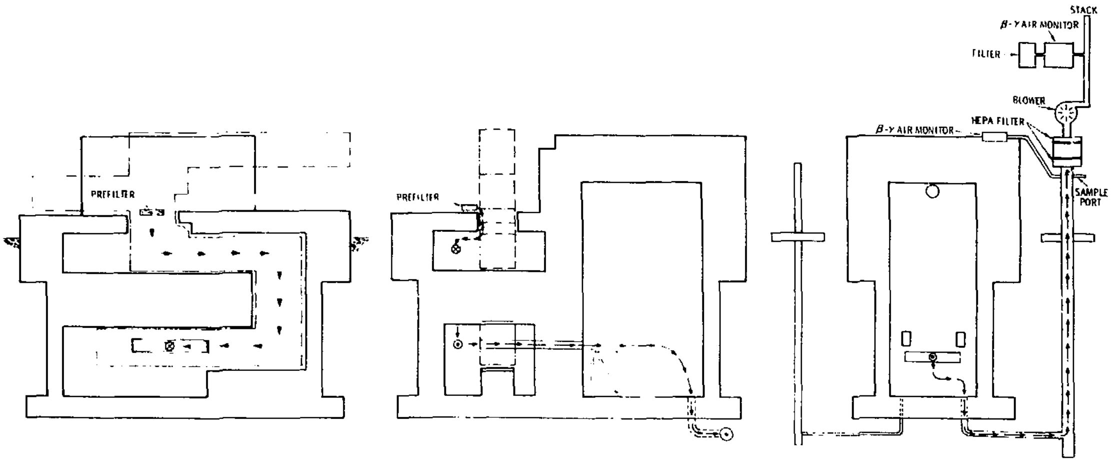


Figure IV-9. Air Flow Paths

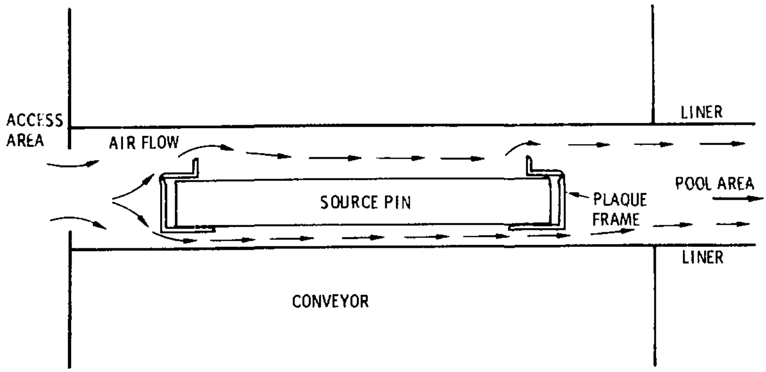


Figure IV-10. Source Pin Cooling

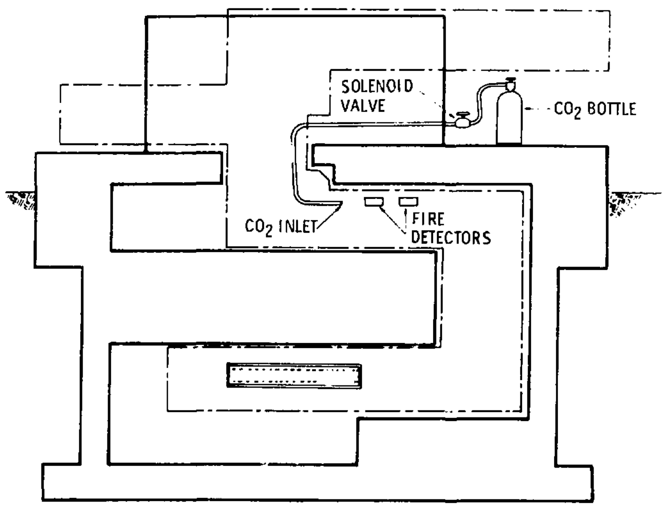


Figure IV-11. Fire Control System

F. Miscellaneous Equipment

Miscellaneous equipment such as a sump pump, interior lighting, and [illegible] system is provided in the facility. In addition, pool-fill and pool-empty pumps, as well as water level controls, are temporarily installed during pin loading and unloading operations.

V. Description of Operations

A. Introduction

The operations carried out at the irradiation facility can be divided into five separate categories. The first category is the gamma-source pin loading operation. This operation is performed when the facility is initially charged with radioactive material, or when the gamma-source is recharged. The second category of operations is labeled "normal" operations. These operations would be regarded as the normal function of the facility: source plaque extension and retraction, lead shutter closing and opening, bulk and bagged material loading and unloading, and routine radiation sensor checkout. The third category of operation includes all procedures where the conveyor access cover must be removed. These procedures are conveyor repair, swipe tests to check for leaks, and water seal installation and removal. The fourth category of operation is performed when the facility is placed in STANDBY or OFF mode and is to be left unattended for any length of time. The final category of operation is the pin removal procedures for decommissioning the facility. Safe Operating Procedures (SOP) are being written for all these operations. These operations will now be described in detail.

B. Pin Loading Procedures (LOAD-UNLOAD Mode)

When the Sandia Irradiator for Dried Sewage Solids (SIDSS) is initially charged or recharged with Waste Encapsulation and Storage Facility at Richland, WA (WESF) capsules, special precautions must be taken. The presence of a professional health physicist is required during all the steps in these procedures to prevent exposure to personnel. In preparation for the loading, the facility must be keyed in the ACCESS mode and must be prepared for the water seal installation procedures described in Paragraph D of Section V. After the source plaque bridge assembly has been removed, the water seal has been installed in the conveyor side of the facility, and the access cover replaced, the pin loading can commence.

The control panel for the facility is keyed into the LOAD-UNLOAD mode. The lead shutter is then opened. The source plaque is moved into a position inside the cavity between the conveyor area and the pool area. In the event a pool cover broke and/or was dropped, the plaque would be protected. After the High Energy Particulate Air (HEPA) filters and the blower are removed, the pool is filled with deionized water through the air outlet port. When the pool is filled, two independent mechanical and electrical interlocks disable the lock that prevents the pool cover from being removed. With a health physicist present with a radiation survey meter, the three concrete pool cover slabs are removed individually with a crane. As each slab is removed, the shielding is reduced. If the electrical and mechanical interlock systems and visual inspection of the water level fail, radiation would still be detected while at a level low enough to cause no danger. When the pool covers are removed, a water level controller is installed. The source plaque is pulled into the pool area, the arms attached to the source plaque are removed and the source plaque is pushed back inside the cavity between the pool and the conveyor areas. The lead shutter is closed to give additional structural protection in case the transport cask should be dropped. If necessary, the cables are loosened and allowed to drop to the side so that the transport cask has adequate clearance to be lowered to the pool bottom. Several stainless-steel I-beams are placed on the bottom of the pool to distribute the weight of the cask and to prevent tearing of the stainless-steel pool liner.

The cask is readied for lowering into the pool area by removing most of the bolts holding the cover in place. A crane is used to lift the cask, and slings attached to eye-bolts are used to support the cask. A secondary set of slings is attached to the cover so that after the cask is lowered into the pool and the remaining cover bolts removed, the cask cover can be pulled out of the pool. A release of accumulated ozone usually accompanies the removal of the cover, and personnel must clear the area for several minutes to allow the ozone to dissipate. A trial evacuation will be conducted before the actual event.

The lead shutter is retracted and the source plaque is moved into the pool area again. The source plaque cover is unlocked and flipped open. The WESF capsules are moved from the cask to the plaque with tools specially designed by Rockwell International at Richland, WA. The first pin to be transferred is a dummy source pin to be used in a dry run. After the pins are placed in the plaque, they are secured in place by a locking cover. The plaque is moved into the cavity and the lead shutter closed again. The crane is then used to remove the cask from the pool. The cask cover is placed on the cask, the cover bolts are tightened in place, and the cask is shipped out.

The lead shutter is opened and the source plaque is moved back into the pool area with handling tools. The cables are reassembled and the drive arms are attached to the source plaque. The source plaque is again moved into the cavity. The pool covers are replaced, and the pool cover locks are enabled. The pool water is pumped into a 1000-gallon holding tank, and samples of the water are checked before the contents are discharged to the environment. The ventilation system is then reinstalled. The source plaque is moved to the pool, and the lead shutter is closed once again.

The control panel is keyed into the ACCESS mode, and the access cover is removed. After health physics personnel survey the area with radiation survey meters, the water seal is removed and the source plaque bridge assembly is replaced. Personnel must wear "chirpers" at all times while in the conveyor access area. After careful inspection, the personnel leave the conveyor access area, the access port cover is replaced, and the interlocks are enabled.

The facility can now be switched to either the STANDBY mode or the NORMAL operation mode.

C. Normal Operations (NORMAL Mode)

1. Definition

Normal operations are those that can be performed by workers using the facility without danger of radiation exposure. In these operations, access to the conveyor access area or the pool area is not required. The operations are conducted from the control panel in Building 6720 or at the conveyor loading and unloading stations. The operations that fit within this category are radiation sensor checkout, source plaque extension and retraction, conveyor loading and unloading, and lead shutter closing and opening.

2. Radiation Sensor Checkout

Before the facility can be used for any purpose whatever, several routine precautionary steps must be taken. First, before entering the security fence, all personnel must attach radiation badges to their clothing. At Building 6720, radiation survey meters and "chirpers" will be stored for use by personnel within the security fence. These survey meters are routinely checked and calibrated by Sandia Division 3312. Personnel planning to use the facility must first enter Building 6720 to perform a radiation sensor check. The radiation alarm systems have self-consistency check switches for each of the six radiation alarms. These switches must be turned to the proper position to assure that the sensors are working properly. After the sensors are checked, a person wearing a TLD badge (personnel monitoring device) and with a "chirper" in his possession must make a radiation survey of the entire facility before any further operations can be carried out.

3. Lead Shutter Opening and Closing

When the facility is left unattended (OFF mode), the source plaque is stored in the pool area and the lead shutter is kept in the closed position. After the radiation sensors and the electrical interlock system are checked, the lead shutter is opened by pushing the "shutter opening" switch until the "shutter opened" light comes on. When the shutter is completely open, position switches in the pool disable the shutter drive motor and the operator can release the button. The opening requires approximately 6 min. All personnel should remain in Building 6720 during this operation. The shutter can be closed by pushing the "shutter closing" switch until the "shutter closed" light comes on. When the shutter is completely closed, position switches in the pool disable the shutter drive motor and the switch can be released. The closing operation requires approximately 6 min. Electronic logic does not allow the shutter drive motor to close the shutter unless the source plaque is fully retracted into the pool area. A torque-limiting clutch on the shutter drive motor prevents damage to the source plaque and shutter if the electronic logic or the position indicators fail. After the shutter has been opened the source plaque can be extended into the conveyor side of the facility.

4. Source Plaque Extension and Retraction

The source plaque is extended by pushing the "source plaque extending" switch until the "source plaque extended" light comes on. When the source plaque is fully extended, a position switch in the pool disables the source plaque drive motor and the switch can be released. The [illegible] takes approximately 1 min 45 sec. Electronic logic prevents the source plaque drive motor from extending the source plaque unless the shutter is fully open. A torque-limiting clutch on the source plaque drive motor prevents damage to the source plaque and the shutter in the event the electronic logic or the position indicators fail. Source plaque extension takes approximately . After the source plaque extension has been performed, a radiation survey must be performed by the operator with a survey meter before the remaining personnel leave Building 6720. The operator must wear a personnel monitoring device and have a "chirper" in his possession while conducting the survey. The source plaque can be retracted by pressing the "source retracting" switch until the "source retracted" light comes on. When the light comes on, a position indicator in the pool disables the source plaque drive motor. The retraction takes approximately 1 min [illegible] sec.

C. Conveyor Loading and Unloading Operations

After the source plaque has been extended and a radiation survey conducted, the conveyor can be operated by pushing the "conveyor on" switch. The personnel can then leave Building 6720 to perform the conveyor loading and unloading operations.

The conveyor can be loaded with either bagged or bulk dried sewage sludge. A vibratory feed hopper is provided to load bulk material. The capacity of the hopper is about 0.5 yd^3, and the hopper must be kept loaded with bulk material. Because of the slow motion of the conveyor (4 in./min), the hopper can be kept loaded by hand. The height of the sludge in the bucket is automatically controlled by adjusting the feed rate of the hopper. Any sludge that could fall from the buckets in the loading operation is caught in a tray below the buckets. The tray must be cleaned periodically. Two 40-lb bags of sewage sludge are of the proper dimensions to fit into one conveyor bucket. The depth of the sludge in this case is 8 to 10 in. Since a bucket must be loaded only every 3 to 5 min in operation, the buckets will be manually loaded with bags. The conveyor moves so slowly that mechanical danger from moving parts is very remote. The conveyor chain is automatically cleaned and lubricated with molybdenum disulfide during operation.

The bulk material is automatically dumped from the conveyor buckets into a container on the west side of the facility. Bagged sludge is automatically dumped from the buckets onto a pallet.

D. Maintenance (ACCESS Mode)

All the operations that require personnel to enter the conveyor access area have been lumped together under the title "Maintenance Operations." These operations include conveyor inspection and repairs, conducting swipe tests and water seal installation and removal.

The procedure required to gain access to the conveyor access area is common to all three operations. With the facility in the NORMAL operation mode, the source plaque must be fully retracted and the lead shutter fully closed. The facility can then be switched into the ACCESS mode. With the lead shutter properly closed both the electrical and mechanical interlocks allow the access cover lock to be unlocked manually. With a health physics representative present with a survey meter, a small crane must be used to remove the access cover. When the access cover is removed both the electrical and mechanical interlock systems lock the lead shutter closed. The health physicist with survey meter, personnel monitoring device, and "chirper" must survey the conveyor access area before other personnel enter the area. The dose rate should be less than 1 mrem/hr in the bottom of the area and much less elsewhere in the access area. All personnel entering the conveyor access area must wear personnel monitoring devices and have "chirpers."

The conveyor is very simple and is operated at a small fraction of its rated speed. For these reasons, very few repairs are anticipated. Periodic inspections of the drive chain and the collapse sections will be made. Repairs to the conveyor can be made by removing the side panels to the conveyor housing.

Swipe tests will be performed at least once annually on the cesium-137 gamma-source capsules. The swipe tests are conducted by placing a swipe test fixture into the source plaque bridge track housing. The fixture is so constructed that it presses cloth swipes, or glass fiber swipes if the temperature is high, against the top and bottom of the capsules over almost the entire length of the capsules when the source plaque moves over the fixture. The swipe test is conducted by going through the above procedures to obtain access to the conveyor access area. The swipe test fixture is inserted. Personnel leave the conveyor access area and replace the access cover. The interlock systems are enabled, the facility is switched back into NORMAL operations mode, and the lead shutter is opened. The source plaque is extended, and in the process of extension a swipe sample contacts both top and bottom of the capsules over almost the entire length of each capsule. The source plaque is then retracted and the lead shutter closed. The facility is switched into ACCESS mode, and the conveyor access area entry procedures described above are followed to gain access to the conveyor access area. The swipe test fixture is removed from the conveyor access area. The access cover is replaced, the interlock systems are enabled, and the facility is switched back into either the NORMAL operations mode or the OFF mode. The 30 swipe samples (2 per capsule) are analyzed for cesium-137. Detection of greater than 0.05 μCi of cesium-137 (1.1×10^5 dpm) indicates a probable leaking source.

In the event of a leak, only two possibilities exist. Because no provision is designed into the facility for dry loading, the normal underwater pin unloading procedures can be carried out, while tolerating the slow leakage of cesium chloride into the water; or if the leak is very large, the facility can be decommissioned with the source in place.

In order to remove or install the water seal over the plaque pass-through cavity opening, access must be gained to the conveyor access area by following the above procedures. To install the water seal, the source plaque bridge assembly must first be removed. An undamaged rubber seal is installed over the studs around the cavity opening. The cover is lifted from below the conveyor and pushed over the studs. By installing nuts on the studs and tightening the nuts to compress the rubber seal, water is prevented from passing from the pool side to the conveyor side. Removal of the water seal is the reverse of these procedures. Obviously, the pool must be emptied of water before the water seal is removed. At no time during the removal procedure should the swinging arm installed over the cavity opening be secured to prevent it from hanging straight down. The function of the arm is to prevent the source plaque from being pushed onto the floor of the conveyor area if someone inadvertently forgets to install or reinstall the source plaque bridge track assembly. After installation or removal is complete, personnel leave the conveyor access area and the access cover is replaced. The interlocks are enabled, and the facility is switched into whichever of the other three modes that is needed.

E. Standby (OFF Mode)

When the facility is switched to the OFF mode, it can be left unattended for extended periods of time. The radiation alarms, the interlock system, and the ventilation systems are operational in this mode. The alarm system has battery-supplied emergency backup standby power. Prior to switching the facility to the OFF mode, the source plaque should be moved to the pool side of the facility.

F. Pin Unloading Procedures (LOAD-UNLOAD Mode)

The same procedures are followed to prepare the facility for pin unloading as were followed in the pin loading procedures. If no radioactive material is contained in the shipping cask, the cask cover can be removed before the cask is lowered into the pin transfer pool. Removal of the cask cover must be performed in the presence of a qualified health physicist with survey meter and "chirper". After the cask cover is lowered into the pin transfer pool, the lead shutter is opened and the source plaque is moved out of the cavity between the pool area and the conveyor area into the pool area. The top of the source plaque is released by turning the cover securing bolts 1/4 turn with specially prepared 20-ft.-long tools. Some or all of the pins can be transferred to the cask from the source plaque. The cask cover is lowered into place through the water, and several bolts are screwed on to secure the cask cover to the cask. The cask is lifted out of the pool with a crane, and the other bolts are screwed on to secure finally the cover for shipment. The remaining steps to secure the facility are described in the pin-loading procedures section.

VI. Accident Categories

A. Introduction

In this chapter, low probability events whose occurrence could damage the facility or injure workers or the public are analyzed. These events are called accidents and are separated into four major categories:

a. accidents that could occur when source pins are being loaded into or unloaded from the facility,

b. accidents that could occur when maintenance operations that require access to the conveyor access area are carried out,

c. accidents that could occur when normal operations (irradiating sewage sludge) are carried out at the facility, and

d. accidents that could be caused by natural disasters.

Each of these categories has specific accidents that are conceivable. Each accident is described along with the measures taken to prevent its occurrence. The consequences, if any, of each accident are discussed.

B. Loading and Unloading Gamma-Source Pins

1. Introduction

During the operation of preparing the facility for the loading or unloading of the source capsules, various accidents could occur, including dropping the pool cover, dropping the transportation cask, releasing shielding water from the pool, and removing the pool cover without water in the pool. Each of these accidents are discussed in detail below.

2. Pool Cover Dropped

The pool cover consists of three separate, thoroughly reinforced concrete slabs placed on top of each other over the pool cavity. The covers have a combined thickness of 4 ft and a total weight of approximately 80 tons.

The covers are removed individually with a crane and cable sling which attaches at four lifting points built into each cover. Failure of the crane or cable assembly or a fracture of the lid during movement would cause all or part of the cover to drop either onto other covers, onto the pool edge, onto the ground, or into the pool. Possible damage to the facility is minimized by restricting the lift height of the upper three covers to 3 in. maximum above the cover below. The final cover must be lifted 12 in. to clear the radiation shielding step in the pool edge. Additionally, all lifting equipment has been designed with safety factors of 400 percent or greater.

The lifting points on the covers will be inspected regularly and the cranes used in this operation are regularly proof- and load-tested.

In preparation for removing the pool cover, the source plaque is extended into the cavity between the pool area and the conveyor area to provide further protection. The pool must be full of water before the pool cover can be removed; the water provides additional cushioning for any objects falling into the pool. Therefore, any objects falling into the pool would be slowed by the water and could damage only the cable assembly and drive arms, but not the source plaque.

This class of accidents could not result in a fracture of the gamma-source pins, and therefore no radioactive material would be released. As long as the accident results in no objects falling into the pool, the damage would be relatively minor, and appropriate concrete patching should repair the facility for operation. Water could be kept in the pool until the repairs were effected. If objects fall into the pool area, damage to the drive arms and the cable assembly might result. If this damage were simple, it could be repaired with tools from above. In some cases, with water in the pool the arms can be removed from the source plaque and the source plaque can be pushed into the area between the pool and the conveyor. With the lead shutter closed, the pool can be emptied to allow direct access to the drive assemblies. For any but the simplest repairs, the radioactive material must be removed from the facility to allow access.

3. Transportation Cask Dropped

The gamma-source pins are transported in Department of Transportation approved casks. The cask consists of a base which holds the pins and a cover that is bolted in place. A double cable sling arrangement is used to lift the cask and lower it into the water-filled pool. After the pins have been removed from or installed in the cask, the cask is lifted out of the pool.

During these operations, it is possible that crane operator misjudgement or mechanical failure of the crane, sling, or cask could result in the cask being dropped. If the cask were dropped outside the facility no damage would occur because the cask is adequately designed to sustain drops of 30 ft onto an unyielding surface. If the cask were dropped while over the pool area, the water would cushion the fall of the cask somewhat. The stainless-steel pool liner might be damaged slightly, but the 24-in.-thick concrete base of the facility could sustain the impact without major structural damage. In order to minimize any possibility of damage to the source plaque during the cask-lifting operations, the arms are disconnected from the source plaque, the source plaque is pushed into the cavity between the conveyor and pool areas, and the lead shutter is closed before the cask is lifted. The lead shutter and the concrete above the cavity provide substantial protection to the source plaque.

This class of accident would not result in any release of radioactive material. At most, the facility base might be damaged and the pool liner slightly damaged. Physical injuries to employees would be prevented by strict adherence to administrative safety procedures.

4. Shielding Water Release

The pool must be filled with water for gamma-ray shielding during gamma-source pin loading or unloading or during repair operations on mechanical equipment installed in the pool area. During any operation that involves removal of the concrete pool covers, automatic water level controllers and water level alarms are temporarily installed. Accidental release of this shielding water could result in radiation exposure of personnel working in the area. Release of the pool water could be caused by inadvertent operation of the pool-emptying sump pump, a leak in the water seal installed in the conveyor area, or a massive fracture of the pool sides.

Accidental release of the shielding water could occur by sump pump actuation. The facility does not have a gravity or natural drain from the pool storage area. All water must be pumped out. The sump pump is a low-volume pump capable of 10 gal/min. At that rate, the pump would require 23.9 hrs of unnoticed operation to drain the pool.

The load or unload cycle takes significantly less time. The accidental use of the sump pump is prevented by the interlock system while the alarm systems are on.

The other possibility of water leakage is through the water seal between the conveyor area and pool area. This normally would amount to a small volume of water leakage. The control system prevents the removal of the pool covers without there being an adequate water level in the pool. If no water were added, the water in the pool side would leak into the conveyor side and eventually stabilize at a depth of 7 ft 7 in. above the pool floor. Additional water would, however, automatically be added to provide adequate protection from the source plaque.

In the event of a massive fracture to one of the pool sides, the automatic water-fill system could probably keep the pool full until emergency action could be taken because of the low porosity of the soil that is densely packed around the facility. If the fill apparatus could not keep up with the leakage, a high-rate fill hose from an available 3/4 in. water pipe or a water tank truck would be used to keep the pool full until the covers could be refitted or the source material removed.

In all the above situations, the automatic water level controller would compensate for minor leaks (less than 1 gal/min) and the alarms would sound if the water level changes more than 2 in. below the required level.

In general, water release does not represent a very significant hazard because the release would occur at a very slow rate compared to the pool capacity. This slow leakage rate allows adequate time for corrective action to be taken.

5. Pool Cover Removed Without Water in Pool

The pool cover is removed when charging or recharging the facility. Pool cover removal without shielding water being present would represent a radiation exposure hazard to personnel.

During the procedures to be followed for pool cover removal, Health Physics personnel will be present with monitoring equipment. Since the pool cover consists of three separate covers, readings can be made to assure that the radiation levels stay within predetermined levels as each cover is removed.

The facility safety design uses both a mechanical and an electrical interlock system to prevent cover removal. There are two pool cover locks; one is released if the float switch senses the proper water level, and the second is released if a mechanical bellows senses the proper water pressure. Furthermore, the removal of the pool cover can occur only if the key-controlled function switch is in the LOAD-UNLOAD mode of operation.

If all systems failed, there would not be any damage to the facility, but a potential would exist for a low-level radiation exposure of personnel while the first cover was removed.

C. Maintenance

1. Introduction

A number of accidents are possible that affect maintenance operations performed with the facility in the ACCESS mode: the shutter opening while in the ACCESS mode, the shutter jammed open, the shutter closing on the source plaque, general mechanical damages, and a person accidently being locked in the facility. These accidents are described in detail below.

2. Shutter Opens in ACCESS Mode

The lead shutter provides the necessary shielding from the retracted source plaque to allow access into the conveyor area. Without the shutter in place, personnel entering the conveyor area would be exposed to harmful levels of radiation, but the event would cause no damage to the facility.

The entrance to the conveyor area is made through the access cover which has two locks. One lock is released by a mechanical bellows and indicates that the shutter is closed. The second lock is released when a magnetic reed switch senses that the shutter is closed. When the access cover is removed, the mechanical interlock system and the electrical interlock system separately lock the shutter drive. In addition, the power to the drive motor is shut off.

As a result, entrance can be made only when both interlock systems provide a positive indication that the shutter is closed. Once access is gained, the shutter cannot be operated. Once the access cover has been removed (with a crane), a qualified health physicist will survey the access area with a radiation survey meter before other personnel are allowed to enter.

3. Shutter Jammed Open

The lead shutter used for shielding is moved between an open and closed position depending on the operation to be performed. The shutter is moved by a motor-driven cable arrangement to drive a lead screw. Since this electrical-mechanical system has a number of components that may fail, the various situations that might occur to leave the shutter in the open position are described.

With the shutter in the open position, the water seal cannot be installed due to radiation exposure that would be encountered. As a result, any repair of the drive system elements located within the facility, such as chain arrangement or the lead screw would require filling the facility with water. Since the water seal is not in place, water would fill both the pool area and the conveyor area, but this represents no serious damage to the facility. If extensive repairs to the shutter are needed, the source material might have to be unloaded from the facility and the pool drained.

More serious mechanical deformation of the shutter and its drive system is minimized by a torque-limiting clutch on the drive motor.

4. Shutter Closes on Source Plaque

There is a remote possibility of the lead shutter closing on the source plaque while the source plaque is not completely retracted. This event is mentioned since the two devices travel paths that cross each other at right angles. The result of this type of accident could be damage to either the shutter or the source plaque or both. Any damage, however, would be minimal because of torque-limiting clutches on both drives. Repairing damage from this type of accident would require filling the facility with water and performing repairs as needed. Depending on the severity of the repairs needed, the radioactive material may have to be removed by normal unloading procedures.

The prevention of this type of accident is covered by a number of features included in the design of the facility. The source plaque has both electrical and mechanical sensing devices that indicate when the shutter is totally retracted. Without both types of sensing switches indicating retraction, the shutter cannot be operated. The converse also holds; that is, the source plaque drive system cannot be operated until both sensing systems on the lead shutter indicate the shutter is open. In addition, radiation sensors are an integral part of the control system that determines the location of the source plaque and the shutter. Control panel logic prevents movement of either device unless the other device is determined to be in the proper position.

Assuming both control panel logic failure and the failure of the dual-sensing indicators, the final safety measure includes the torque-limiting clutches of each of the drive motors. These devices would minimize damage if the two devices were driven simultaneously.

This type of accident would represent no serious damage to the facility or harm to personnel.

5. Mechanical Dangers

Under this heading is a collection of items related to general mechanical dangers encountered during the initial setup and normal operation of the facility.

The drive systems for the source plaque and shutter are internal to the facility during normal operations. During initial checkout, personnel may be required to verify operation of these drive systems. The conveyor drive system is partially exposed--mainly for process material to enter and exit the conveyor. With any moving system, there is a possibility of injury to personnel. The movement of the pool covers and the access cover can also be viewed as potentially injurious operations.

Safeguards for all of the above types of danger will consist mainly of adhering to sound safety practices during all phases of operation.

6. Person Locked In

Entrance to the conveyor area can be accomplished only in the ACCESS mode of operation. Removal of the access cover can be effected only when there are no exposure hazards to personnel. A crane is required to remove the cover. Also, entrance to the conveyor area requires that a qualified health physicist be present with monitoring equipment. An intercom system is used to maintain contact with personnel in this area. Visual checking is performed before sealing the area.

This event is prevented by strict adherence to administrative procedures.

D. Normal Operation

1. Introduction

During the normal operation of the facility, several accidents are possible: a source pin could develop a leak, the sewage sludge could catch fire, organic dust from the sludge could cause an explosion, the conveyor could jam against the source plaque, the conveyor operation could injure someone, and the source plaque could get jammed on the conveyor side or in the cavity between the pool and the conveyor area. Each of these accidents and their consequences are discussed in detail below.

2. Source Pin Leak

During normal operation, the source pins are extended into the conveyor area. If a pin were to develop a leak, radioactive material could be discharged and either settle in the facility or be carried by the cooling air system up to the double High Efficiency Particulate Air (HEPA) filter discharge-air filtering system.

The only ways for a pin to develop a leak that can be envisioned are defective capsule welds, corrosion from within or outside the capsule, and mechanical fracture from malfunction of the conveyor, source plaque drive, or lead shutter.

The welds on the outer capsule are leak-checked by filling the void between the capsules with helium before welding. After the weld is made, the capsule is leak-checked with a residual gas analyzer.

Materials compatibility studies of the cesium chloride and the stainless-steel liner have been performed and are described in detail in Appendix A. Capsules stored in water and for up to 2 months in air have shown no degradation of the inner stainless-steel liner upon sectioning.

Substantial mechanical protection is provided for the source pins in the source plaque frame and in the housing that surrounds the source plaque while it is in the extended position. Torque-limiting clutches are provided for all mechanical equipment that could exert force on the source plaque during a malfunction.

Were a leak to develop in a source pin from any of the causes discussed, the minute traces of radioactive material discharged would most likely remain on the surface of the capsule where it would be detected by swipe tests. If enough material were to leak so that it fell from the capsule, the material would become airborne and either be filtered by the HEPA filters or settle on the open surfaces in the facility. If any material settled onto the buckets, which is extremely improbable, a radiation sensor would turn off the conveyor before the material reached the outside. If water dissolved some of the cesium chloride, a radiation sensor would prevent the sump pump from pumping it to the water holding tank.

If the β-γ air monitor, which is located after the second filter surface, detected radioactive material, the air entering the filter would be sampled about 1 ft ahead of the filters through an air-sampling port. If the air samples corroborated the presence of radioactive material, the source plaque would be retracted into the pool area and the lead shutter closed. Sampling filters placed in-line after the β-γ air monitor take a cumulative recording of any radioactive releases from the facility. The HEPA filters will be checked before and after installation with the homogeneous dioctylphthalate (DOP) method by health physics representatives. If swipe tests did not detect which capsule was leaking, the pins would have to be loaded for transportation back to Richland, WA. The shielding water would probably become slightly contaminated during this loading procedure. The facility would have to be thoroughly decontaminated after the accident. The water would also have to be decontaminated before discharge.

3. Fire

The facility structure and internal components of the facility are classed as non-combustible material. Fire concern is limited to the sewage solids passing through the conveyor.

Heat detectors in the conveyor area are used to detect a fire and initiate an extinguishing system. If the heat detectors sense an abnormal condition, the audible and visible alarm systems are activated and the hopper feed system shuts down. Another preventive measure controlled by a heat detector is the actuation of a solenoid valve that releases carbon dioxide into the conveyor area.

The above represent adequate measures for the detection and prevention of fire, which in any case would be limited to the sewage solids.

4. Explosion

The only material within the facility considered explosive is the organic dust from the waste material to be processed. The facility is designed to process either dried bulk material or bagged material. The bagged material is not considered explosive since the material is contained.

The dried bulk waste material generates a small amount of dust that possibly could be considered explosive when exposed to open flames. No burning occurs as part of the facility operation, thereby reducing this possibility. If any buildup of the dust occurs, the conveyor system will be vacuumed on a regular basis to alleviate the condition.

If this event did occur, the explosion would occur within the conveyor system which is constructed of 1/8-in. steel panels.

The conveyor is also open to the atmosphere at the load and unload points which provide a vent path that prevents a pressure buildup within the conveyor.

An explosion of the organic dust would be considered an unlikely incident.

5. Conveyor Jams Against Source Plaque

With the facility in a normal operating mode, the source plaque is extended to lie within the conveyor drive system. Consideration is given to the possibility of damage that might occur if the moving conveyor system jams against the extended source plaque.

To prevent this event, the conveyor has been modified to include a sturdy metal box which accepts the extended-source plaque. As a result, the conveyor drive system cannot damage the source plaque without first damaging the metal box. The conveyor, operating at a very slow speed (4 in./min), also has a torque-limiting clutch to prevent serious damage to the metal box.

The design of the box and the low speed of the conveyor represent appropriate safeguards against the occurrence of this event.

6. Mechanical Dangers

In normal operations, mechanical dangers are limited to only two moving systems, which are the conveyor-drive and the hopper-feed systems.

The conveyor system and feed system operate at very slow speeds, thus reducing the possibility of physical harm to operators. The conveyor system is covered so that none of the system is exposed except for the small openings for the entrance and exit of the material to be processed.

Normal administrative safety practices will be followed to prevent harm to operators.

7. Source Plaque Jammed on Conveyor Side or in Cavity

The source plaque is moved from the retracted to the extended position at the start of the NORMAL mode of operation. The process is reversed at the end of the NORMAL mode.

Consideration is given to the failure of the plaque to move in the proper direction because of jamming. The plaque being jammed in the extended position has been discussed in VI. D. 5. The plaque cannot be jammed in the retracted position since there are no other devices that could cause jamming.

This event reduces to failure of the plaque-drive system. Repair would be performed by filling the facility with shielding water and correcting the problem. If the drive motor failed, the shielding water fill would not be required.

The jamming or failure of the drive system represents no harm to personnel or damage to the facility.

E. Natural Events

Several natural events are considered that could result in damage to the facility: floods, earthquakes, and tornadoes.

1. Floods

Of the three types of events to be described, flooding is the most probable. Flooding at the site from the overflow of the Rio Grande River is unlikely because the site elevation is approximately 160 m above the river channel. Localized sheet flooding due to thunderstorm activity does occur occasionally, but because the site is situated on a slight ridge, all drainage would be away from the site and any flooding that occurred would be minor. A slight grade is provided up to the facility to prevent this minor flooding from affecting the facility. If flood water were to enter the facility, the damage to the facility would be minor and the sump pump would clear it out.

2. Earthquakes

Seismic activity for the Albuquerque-Belen Basin, which contains Technical Area (TA) III, has a relatively high occurrence rate, but the magnitudes are low on the order of Richter magnitude 3.5 or less. Earthquakes of higher magnitude have occurred; however, geological evidence indicates that significant earth movement has not occurred for several hundred years, and historical evidence indicates that the largest earthquake expected within a 100-year period is Richter magnitude 6.0 (Ref. 1). The low intensity of the earthquakes coupled with the substantial structure (mostly underground) of the facility (4-ft-thick reinforced-concrete walls and 4-ft-thick reinforced-concrete covers) will provide adequate protection.

3. Tornadoes

Albuquerque is classified as a region of low occurrence of tornadoes, with an annual frequency of 0.1 or less. Because of the low frequency of tornadoes and the fact that most of the structure of the facility is underground tornadoes are not a significant design consideration. If a tornado were to pass directly over the facility the most severe damage expected would be destruction of the part of the conveyor that extends above the facility.

F. References

1. Sanford, A. R., et al., "Seismicity of the Rio Grande Rift in New Mexico," New Mexico State Bureau of Mines and Mineral Resources, Circular 120, 1972.

VII. Facility Expansion

Because of the very specific goals established for the Sandia Irradiator for Dried Sewage Solids (SIDSS), it is anticipated that the facility will be in use in the Beneficial Uses Program only about 5 years. During that time period, the cesium-137 will have decayed only 12.2%. This small amount of decay can easily be compensated for by adjusting the speed of the conveyor. During this time period, it is not anticipated that the facility will be upgraded with replacement gamma-source pins of cesium-137 or cobalt-60.

VIII. Environmental Monitoring Program

A. Preoperational Sampling

An environmental monitoring program has been conducted at Sandia Laboratories Albuquerque (SLA) since 1959. Over the years soil, vegetation, surface water, and deep well water have been analyzed for uranium, plutonium, gross beta, cesium-137, and strontium-90 at intervals ranging from quarterly to annually. The materials analyzed, analyses performed and frequencies have varied considerably depending on the operations being conducted by SLA at each sampling occasion (References 1, 2, 3, 4, 5). Because of the observed variations in background levels, additional soil, water, and vegetation samples will be taken at a minimum of ten selected sampling sites just prior to Sandia Irradiator for Dried Sewage Solids (SIDSS) start-up.

The soil and dried vegetation samples will be split; one half of each sample will be stored for possible future analysis; the other half will be gamma-scanned for cesium-137. These samples would provide background data in case an accident involving a radioactive release were ever to occur.

B. Operational Sampling

No release of cesium-137 is anticipated; if any particulate cesium-137 were released, most of it (greater than 99.95%) would be captured on the series of High Energy Particulate Air (HEPA) filters in the cooling air discharge line. The first surface of the first HEPA filter will be swipe tested initially and at least once monthly for the first [illegible] months of operation. The sampling frequency will decrease to once every 3 months thereafter. If [illegible] discharge to the filters were ever to occur, the filter in-line after the β-γ air monitor would be analyzed for cesium-137 to place an upper bound on the source term for air dispersion of cesium-137.

C. References

1. W. D. Burnett, et al, Radioactive Environmental Survey at Sandia Corporation, SC-4628(M), Sandia Laboratories, Albuquerque, NM, May 1961.
2. L. W. Brewer, Environmental Monitoring Report for Sandia Laboratories from 1964 through 1972, SLA-73-0339, Sandia Laboratories, Albuquerque NM, March 1973.
3. L. W. Brewer, Environmental Monitoring Report for Sandia Laboratories for 1973, SLA-74-0167, Sandia Laboratories, Albuquerque, NM, April 1974.
4. W. L. Holley, Environmental Monitoring Report, Sandia Laboratories 1974, SAND75-0257, Sandia Laboratories, Albuquerque, NM, May 1975.
5. W. L. Holley and T. N. Simmons, Environmental Monitoring Report, Sandia Laboratories 1975, SAND76-0209, Sandia Laboratories, Albuquerque, NM, April 1976.

IX. Waste Handling

A. Introduction

As stated earlier, except in the case of serious accidents, no solid or liquid radioactive waste should result from the use of the Sandia Irradiator for Dried Sewage Solids (SIDSS). The waste-handling procedures for the accident cases described in Chapter VI are described below.

B. Solid Wastes

Radioactive solid waste could result only from liquid radioactive waste-cleaning procedures, from manual decontamination procedures undertaken in the event of a gamma-source capsule leak, from contaminated sludge, or from contaminated High Efficiency Particulate Air (HEPA) filters. An approved burial ground will be used for disposal of any solid radioactive waste from the SIDSS.

C. Liquid Wastes

Radioactive liquid waste could result only from water coming in contact with a leaking gamma-source capsule during charging or decommissioning of the facility or in the event of a serious flood. Should one of these events occur, the water in the facility will be decontaminated as thoroughly as possible with ion-exchange resins before being pumped to the 1000-gallon water-holding tank. In the instance of a low-level leak that would pass the sump pump radiation sensor without triggering it to turn the sump pump off, the waste might be transferred to the holding tank. The water in the holding tank will be sampled and evaluated for cesium-137 in all cases before discharge. If the level is low enough, the liquid will be discharged to the environment. If the radiation level is higher than allowed for discharge, the water will be passed through additional ion-exchange resins until the level is low enough for discharge. The ion-exchange resin beds will be handled as solid radioactive waste. The disposal of the beds is described in the previous section.

X. Quality Assurance and Acceptance Procedures

A. Introduction

A quality assurance program has been applied to the design and will be applied to the construction and testing of the Sandia Irradiator for Dried Sewage Solids (SIDSS).

B. Facilities

The design and construction of the SIDSS are basically conventional, and as such the level of the quality assurance program applied in these areas is considered to be Level C. This level of quality assurance is described in the document "Quality Assurance Programs for Sandia Laboratories" which addresses construction programs of the Laboratories.

Several critical components have been identified and will have tests associated with their acceptance. The stainless-steel pool liner, piping, and cavity liner will be dye-tested for leaks. The lead shutter will be x-rayed for voids in the lead, and the control console will be electrically tested in the presence of Sandia personnel.

After the conveyor, source plaque, and shutter are installed by Sandia personnel, the contractor will return to perform the final wiring. The facility, including all components and interlock systems, will have to pass a thorough checkout before it will be accepted by Sandia.

After acceptance from the contractor, the critical components of the system will be cycled a number of times over a 3-week period for reliability checks before the facility is charged with radioactive material.

Before the gamma-source pins are transferred to the SIDSS, the outside container will be swipe-tested

C. Operations

The quality assurance program will be supplemented by establishing a continuing test program that will assure that the system and components of the SIDSS continue to operate properly and by maintaining accurate records concerning the facility. These records will include operating logs, inspection and test results, results of safety reviews, repair actions, operating procedures, radiation surveys, swipe-tests results, equipment records, up-to-date copies of blueprints of the facility and its components, and qualifications of operating personnel. All these actions will be coordinated under a continuing and comprehensive quality assurance program that is now being developed.

XI. SIDSS Decontamination

The Sandia Irradiator for Dried Sewage Solids (SIDSS) is expected to be used by the Beneficial Uses Program until about 1984. At that time demonstration plants of a similar design will be on line. The operation of the SIDSS may become unnecessary, and, if so, the facility will be decommissioned.

If the SIDSS operates as anticipated, no decontamination of the facility will be necessary. The gamma-source pins will be unloaded as per the procedures in Chapter V. Swipe tests will be conducted in the pool and conveyor areas to verify that no residual cesium-137 is left, and the facility will be decommissioned.

If an accident occurs that produces a leak in one or more capsules, various components of the SIDSS may become contaminated. In case of such an event, the Sandia Health Physics Division is responsible for directing the SIDSS decontamination operations. As a safeguard against such an event, all surfaces which one might expect to become contaminated are lined with either stainless steel or plastic.

Portions of the facility that might need decontamination include the pool area, the cavity between the pool and conveyor areas, High Energy Particulate Air (HEPA) filter holders, and various components in the air path of the cooling air for the source pins.

Any residual cesium-137 on the interior of the stainless-steel liner will be removed by washing. The wash water will be decontaminated with ion-exchange beds. It is improbable that the interior of the facility would become so contaminated that washing operations would be inadequate.

XII. Summary of Emergency Plans

A. Immediate Response

The proper response to any system alarm condition or radiation anomaly as indicated by a personnel alarming dosimeter or survey meter is immediate evacuation of the irradiator site to a distance of 500 feet or more. The responsible health physicist and operating organization representative should be contacted. The area should be reentered only by the health physicist and an operating organization representative with a survey meter and alarming dosimeters.

B. Secondary Actions

The irradiator should be reentered only as far as the control panel by these two people. The outputs of the gamma sensors and the β-γ air monitors should be examined for an alarmed state.

If the gamma sensor outputs and the β-γ air monitors are not alarmed, the reason for the system alarm should be ascertained and corrected. If the cause is a conveyor jam, the source plaque should be retracted, the shutter closed, and the conveyor repaired. If the cause is a power failure, logic error, ground fault trip, or other minor reason, the problem should be corrected and the alarm system reactivated.

If the conveyor exit alarm, conveyor entrance alarm, sump pump alarm, or β-γ air monitor alarms are activated, the sensors should be checked from the console. If a release to the atmosphere has been detected by the second β-γ air monitor, the area should be evacuated immediately and reentered only by a team of experienced decontamination specialists. They must ascertain the extent of the release and take appropriate action. If the sensors check out correctly, a radiation survey should be made cautiously of the entire area and particularly of the activated sensor. In the case of the gamma sensors, the survey meter readings should corroborate or disprove the readings. If the readings are corroborated, the extent and quantity of the leak must be determined by survey and sampling.

If the first β-γ air monitor is alarmed, the extent of the leak should be ascertained by analysis of the filter paper contained in the instrument.

If a swipe test determines that the leaks are slight, the source plaque should be retracted, the lead shutter closed, the bridge assembly removed, and the water seal installed if possible. If this is not possible, the entire facility can be filled with water, the lids removed, and the pins transferred to a shipping cask for return to the hot cell facilities at Richland, WA. The water must be cleaned up with ion-exchange resin beds and disposed of properly.

If the source plaque is jammed or if the lead shutter is jammed open, the entire facility must be flooded with water, the lids removed, and the appropriate steps taken to extract the plaque and remove the pins.

C. Call Lists and Checklists

Emergency call lists with the telephone numbers of the facility operators and the responsible health physicists will be provided at the gate at the entrance to the area surrounding Building 6720 and at the operation console. An emergency inspection checklist will also be provided at each of these locations.

XIII. Summary of Employee Training

A. Training Requirements

Personnel associated with the irradiator can be separated into two categories--irradiator operators and sludge loading and unloading personnel.

Sludge loading and unloading personnel need only minimal training concerning radiation. They will not be exposed to dose rates above background levels in their normal work environment. They must understand the need to wear personnel dosimetry badges and the need to carry personnel alarming dosimeters. They must be trained to leave the area immediately if the alarm system is triggered or if the personnel alarming dosimeters indicate any anomalous situation.

The irradiator operator is responsible for normal operations and for conducting swipe tests on the source under the direction of a qualified health physicist. Consequently, the training necessary for an operator is both extensive and intensive; it lasts approximately two weeks.

An operator should have a high school level or higher education. He should be capable of understanding the concept of a graph and be capable of understanding very simple algebraic equations. If the operator does not have these capabilities, he must intensively study the first several modules in the training program to be described.

The operator should complete the described training before operating the irradiator. He should receive the training at Sandia Laboratories, Albuquerque, NM from Division 4535 and Division 3312 personnel or from a Sandia designated subcontractor.

B. Training Program Contents

The training program is divided into two parts: a general nuclear training program and a training segment concerning the irradiator explicitly.

A video tape training program prepared by NUS Corporation is suitable for the general nuclear training programs. An outline of the required sections for this training program is shown in Table XIII-1.

The second part of the training program concerns the operation of the irradiator. An outline of the training topics is shown in Table XIII-2.

The described training, complete with hands-on operation of a similarly designed irradiator, is adequate for a person who will operate the irradiator. After successful completion of the training program, the operator will be certified by the training organization.

TABLE XIII-1

Necessary Elements of the NUS Nuclear Training Program

Module 2 - Basic Nuclear Concepts (BNC)
(Prerequisites - Power Principles Basics Topics 2, 3, or 4, or equivalent)

Unit	Title
1	Mathematical Manipulations Mathematical Notation Scientific Notation Dimensional Analysis Ratio and Proportion Problem-Solving Techniques
2	Exponents and Logarithms Rules of Exponents Common Logarithms Operations with Logarithms and Exponents Natural Logarithms Exponential Equations
3	Graphic Presentations Rectangular Coordinate Plots Slope of a Line Area Under a Line Curves: Slope and Area Plotting and Reading Semi-Logarithmic and Logarithmic Graphs
4	Presentation of Mathematical Data Meters and Charts Nomographs and Tables Interpolation and Extrapolation Statistics Probability
5	The Atom Atomic Structure Electrons Protons and Neutrons Chart of the Nuclides Properties of Nuclear Forces Nuclear Models
6	Equivalence of Mass and Energy Conservation and Conversion of Mass and Energy Mass Defect Binding Energy Binding Energy per Nucleon The Payoff: Energy from Fission and Fusion
7	Radiation - What Is It and Where Does It Come From Radioactivity and the Chart of the Nuclides Alpha Radiation Beta Radiation Gamma and Neutron Radiation Decay Chains

TABLE XIII-1 (Cont)

Module 2 (Continued)

Unit	Title
8	*Interaction of Radiation with Matter*
	Alpha and Beta Interactions
	Photon Interactions
	Neutron Interactions
	Range of Radiation in Matter
	Basic Shielding
9	Number of Atoms
	Abundance and Enrichment
	Mass Density
	Parts per Million
	Number of Atoms: Part 1
	Number of Atoms: Part 2
	Number of Molecules
	Atom Density
10	Radioactive Decay
	Activity
	Specific Activity
	Decay Equation
	Half-Life
	Graphing Radioactive Decay
11	*Induced Nuclear Reactions*
	The Induced Nuclear Reaction Mechanism
	Types of Induced Nuclear Reactions
	Neutron Production
	Radiation Detection
	Radioactive Material Production
12	Nuclear Fission
	The Fission Process
	Fissionable Nuclides
	Products of Fission
	Fission Energy Release and Distribution
	Decay Law and Reactors

Module 5 - Radiation Protection (RP)
(Prerequisites NET Module 2 or equivalent)

Unit	Title
1	Biological Effects of Radiation
	Protection From Radiation
	Cellular Damage
	Acute Whole Body Dose
	Chronic Whole Body Dose
	The Effects of Contamination
2	*Units, Guides and Limits*
	Radiation Protection Units
	Radiation Limits and Guides
	Radiation Areas
	Contamination Limits
	Maximum Permissible Concentration: Part 1
	Maximum Permissible Concentration: Part 2

TABLE XIII-1 (Cont)

Module 5 (Continued)

Unit	Title
3	Protection Techniques Against Radiation Protection Technique: Time Protection Technique: Distance Protection Technique: Shielding Radiation Work Permit
4	Protection Against Contamination Plant Controls for Protection Against Contamination Common Sense Rules Respiratory Protection - Part 1 Respiratory Protection - Part 2 Dressing in Protective Clothing Removing Protective Clothing
5	Radiation Detection Basic Circuit Recombination and Ionization Region Proportional and Limited Proportional Region Geiger Muller Region Continuous Discharge Region and Detector Characteristics
6	Detection and Personnel Monitoring Scintillation Detectors Semiconductor Detection System Neutron Detection Film Badges and Direct Reading Dosimeters Thermoluminescent Dosimeters Physical and Electronic Discrimination
7	Survey Techniques What A Survey Is Radiation Instrumentation The Radiation Survey Contamination Surveys Airborne Contamination Surveys
8	In-Plant Monitors Introduction to In-Plant Monitors Area Radiation Monitors Continuous Air Monitors
9	Radioactive Material Control Decontamination Radwaste Disposal Release of Radioactive Material to the Environment Atmospheric Dispersion of Radioactive Material Atmospheric Dispersion Calculations
10	Environmental Considerations and Emergency Planning Siting Criteria Environmental Surveillance Emergency Planning - Part 1 Emergency Planning - Part 2 Protective Action Guides

TABLE XIII-2

Irradiator Operation Training Program

I. Review of the Final Safety Analysis Report

II. Description and Demonstration, Including Maintenance, of the Interlock System
   A. Electrical Interlocks
   B. Mechanical Interlocks

III. Description and Demonstration, Including Maintenance, of Radiation Monitoring Equipment
   A. Gamma Sensors
   B. Air Monitors
   C. Survey Meters
   D. Personnel Dosimetry Badges
   E. Personnel Alarming Dosimeters

IV. Description and Demonstration, Including Maintenance and Swipe Testing, of Major Mechanical Components of the Irradiator
   A. Lead Shutter
   B. Source Plaque
   C. Conveyor
   D. Air Handling System
   E. Water Handling System

V. Review and Demonstration of Irradiation Operating Procedures
   A. Load/Unloading Operation
   B. Access Operation (Swipe Test)
   C. Off-Mode
   D. Normal Operations (Product Irradiation)

VI. Description and Demonstration of Emergency Procedures

XIV. Safety Management System

It is the responsibility of Organization 4535 to generate and to update periodically the operating procedures for the facility. The responsibility for review and approval rests with four different organizations: the line organization (4535), the Radiation Safety Committee, Health Physics (3312), and the Operational Safety Division of DOE/ALO. The chain of authority within each organization is shown in Figure XIV-1. The necessary level of approval required is shown with an asterisk.

The operating procedures will be reviewed at least once annually by the line organization and Health Physics (3312) for accuracy and applicability. If the review procedure reveals that the procedures are inadequate, they will be updated, and then reviewed and approved by the appropriate organization. If changes in operation necessitate operating procedures changes before the review, they will be made as necessary and appropriately reviewed and approved.

Line Organization	Radiation Safety Committee	Health Physics	DOE/ALO Operational Safety Division (OSD)	
*4535, J. S. Sivinski	*Chairman, T. R. Schmidt, 4451	*3312, G. E. Tucker, Jr.	Facility Design & Safety Analysis, Br. Chief	W. B. Sayer
4530, R. W. Lynch		3310, W. D. Burnett		
4500, E. H. Beckner		3300, P. B. Mossman, MD	*Director	J. R. Roeder
4000, A. Narath		3000, R. B. Powell	Office of Operations	J. F. Burke
1, M. Sparks		1, M. Sparks		
			Office of the Manager	H. E. Roser
			DOE/SAO Manager	G. E. Cordova

Figure XIV-1. Organization Chart for Generation, Updating, Review, and Approval of Operating Procedures for the SIDSS

XV. Summary of Operating Procedures

The operations carried out at the irradiation facility can be divided into five separate categories. The first category is the gamma-source pin loading operation; this operation is performed when the facility is initially charged with radioactive material, or when the gamma source is recharged. The second category of operations is labeled "normal" operations; these operations would be regarded as the normal function of the facility: source plaque extension and retraction, lead shutter closing and opening, bulk and bagged material loading and unloading, and routine radiation sensor checkout. The third category of operation includes all procedures where the conveyor access cover must be removed; these procedures are conveyor maintenance and repair, swipe tests to check for radiation leaks, and water seal installation and removal. The fourth category of operation is performed when the facility is placed in STANDBY or OFF mode and is to be left unattended for any length of time. The final category of operation is the pin removal procedures for decommissioning the facility. Step-by-step detailed procedures for each of the operations described above are presented in Appendix E.

XVI. Operational Safety Requirements

A list of operational safety responsibilities is presented below:

A. Operation of the facility shall be the responsibility of Division 4535.

B. All operators shall be familiar with the guidelines of these procedures and a copy will be posted or filed as follows:

1. SIDSS control panel
2. Division 3312 (file)
3. Division 4535 (file)

C. Operators and health physics personnel shall be responsible for:

1. Keeping occupational exposure to radiation as low as possible.
2. Ensuring that personnel radiation dosimeters (PDB badges) and personnel alarming dosimeters (chirpies) are worn by all personnel in the SIDSS area.
3. Following radiation safety rules and regulations in the prescribed manner.
4. Keeping accurate log book of the use, functioning, and testing of the facility.
5. Reporting radiation accidents, incidents, and unsafe working conditions.
6. Ensuring that the required periodic swipe testing is performed.

D. No one should load or unload material from the irradiator without Division 4535 personnel being present to operate the irradiator.

E. The conveyor access area is to be treated as a radiation area and the time necessary for conveyor lubrication, swipe testing, etc., should be kept to a minimum. The conveyor access area should not be entered without Health Physics (3312) personnel present. Access to Building 6720 is restricted by a locked gate.

F. Normal operation of the SIDSS will be conducted only by 4535 personnel. Night work, weekend work, or off-hour work at the SIDSS will be allowed only when coordinated through Health Physics (3312).

G. If a radiation area monitor alarms, all personnel will evacuate the area by the west gate of the fence surrounding the area.

H. SIDSS operating personnel and product loading personnel will wear personnel alarming dosimeters (chirpies) and PDB badges.

I. SIDSS keys (gate, building, and control panel) will be kept under the control of 4535 personnel. For normal operations, 4535 personnel will use the keys and be responsible for switching the control panel to the off mode and locking the control panel, Building 6720, and the area gate.

J. Source pin loading and unloading operations will be conducted under the supervision of Health Physics (3312). Initial entry to the conveyor access area will be made only with Health Physics (3312) personnel present.

K. No electrical or mechanical interlocks will be bypassed except with the written consent of Health Physics (3312) and the Division 4535 supervisor.

L. All interlock systems (mechanical and electrical) will be checked each month and the results of this check will be entered in the SIDSS operation log book. The check will be made by Division 4535 personnel.

M. No modifications or changes to the SIDSS will be made without prior approval of the Division 4535 supervisor and Health Physics (3312).

N. The SIDSS area gate, Building 6720, and the SIDSS control panel will be locked except when in use.

The brief Safe Operating Procedures (SOP's), posted on the SIDSS console, are shown in Appendix F. These SOP's have been approved by 4535, Health Physics (3312) and DOE/ALO Operational Safety Division.

XVII. Conclusion

Based on the analysis of the Sandia Irradiator for Dried Sewage Solids (SIDSS) site characteristics (Chapter III) and the proposed operations in the SIDSS (Chapter IV), it is concluded that the SIDSS (Chapter II) as designed will adequately protect the health and safety of the public. Likewise, the level of protection afforded operating personnel precludes operating exposures above the acceptable limits prescribed in Chapter 0524.

A spectrum of accidents in the SIDSS has been analyzed (Chapter V), and it is concluded that sufficient safety features have been incorporated into the SIDSS design to reduce the consequences of these accidents to acceptable levels. As a backup for the more severe and less probable accidents within the SIDSS, evacuation procedures will be developed to avoid unacceptable exposures.

Other factors taken into consideration--Facility Expansion (Chapter VII), Environmental Monitoring Program (Chapter VIII), Waste Handling, Storage, and Disposal (Chapter IX), Quality Assurance and Acceptance Procedures (Chapter X), and Facility Decontamination (Chapter XI)--show that the SIDSS is of such a nature that all these areas pose no problem in its design, operation, and decommissioning.

The overall conclusion is that the SIDSS can be operated safely taking into account all aspects of its design, control, and projected operations.

APPENDIX A

Cesium-137 Waste Encapsulation and Storage Facility (WESF) Capsule Description

Rockwell International currently encapsulates cesium-137 at the Waste Encapsulation and Storage Facility (WESF) at Richland, WA. The cesium-137 is in the form of cesium chloride when it is encapsulated. The radioactive cesium chloride is double encapsulated in welded 316L stainless-steel tubing. A cross-sectional drawing of the capsule is shown in Figure IV-5.

The inner and outer capsules arrive at the WESF each with one end cap welded on. The inner capsule, which is 2.250 in. in diameter and 19.975 in. long with a 0.103-in.-thick wall, is placed in a special fixture inside a hot cell and then is poured nearly full of molten (temperature greater than 645°C) cesium chloride. Upon cooling the cesium chloride passes through a β-transition at 451°C and undergoes approximately a 17% volume reduction. A 0.400-in.-thick stainless-steel cap is then welded onto the open end of the inner capsule. The inner capsule is then cleaned and transferred into the outer capsule, which is 2.625 in. in diameter and 20.775 in. long and has a wall thickness of 0.100 in. A 0.400-in.-thick stainless-steel end cap is then welded onto the outer capsule. The capsules are then cleaned. The welds are ultrasonically tested, and the pins are moved to a water-filled pool for storage.

Prior to starting operations in the WESF, several nonradioactive cesium-chloride-filled capsules were fabricated using the WESF production equipment and procedures to be used in production. One inner capsule and one completed capsule were subjected to an extensive battery of tests including free drop, percussion, heating, and immersion. These tests were intended to qualify the complete capsules as a "special form material" suitable for shipping in a cask (NRBK-43) with no need for additional protective packaging. The test results proved that the inner capsules are capable of withstanding tests more severe than those specified in Annex 4 of ERDA Appendix 0529. When provided with the additional protection of the outer capsule, the assembly far exceeds the requirements to qualify as a "special form material."

Although the welds and thick double walls of these pins provide substantial structural strength, there are several disadvantages to this capsule design.

One disadvantage is that cesium chloride is the source material. This material is highly soluble in water (162.22 gm/100 cc of H_2O at 0.7°C and 259.56 gm/100 cc of H_2O at 89.5°C) and could present cleanup problems if large amounts were exposed to water. Because no dry loading capabilities are provided in the facility, water would have to be used for pin transfer to or from a shipping cask. If major cracks or holes were made in both capsule walls (which is very improbable), some radioactive cesium chloride would be dissolved in the shielding water used to transfer the pins to a shipping cask. In tests at Oak Ridge National Laboratories, holes have been drilled into cesium-chloride-filled capsules and the capsules immersed in water. The tests showed that even with holes as large as 1/8 in. in diameter, the rate of dissolution of the cesium-chloride salt was so small that pin transfer procedures could be carried out with only very small material releases into the shielding water.[1] The shielding water could then be cleaned up with ion-exchange columns which could be disposed of in approved solid radioactive waste disposal sites.

Another disadvantage of this design is that the air gap between the inner and outer capsule wall presents a significant thermal resistance to heat released in the cesium chloride from radioactive decay. Consequently, although the temperature is reasonably uniform throughout the volume, the temperature is very close to, if not above, the β-transition point of 451°C during normal use. The salt may very well cycle above and below the β-transition point, depending on external conditions, during normal operations. As stated earlier, a temperature rise above the β-transition point is accompanied by a 17% volume increase in the cesium chloride. Because the molten salt is well above the β-transition point when poured into capsules, adequate free volume is left for the expansion. Although this expansion should cause no problems, ideally, one would prefer no mechanical motion of the salt.

Another disadvantage of this capsule is that the cesium-137 isotope is diluted with other cesium isotopes.[2] An analysis of the capsule's contents indicated the following:

Mass (no.)	Atom (%)
133	50
135	14
137	36

Of more concern is the fact that after neutralization of the contents of the capsule with 0.32 mole OH^- per kg of solid, an insoluble fraction slightly greater than 3% of the total weight of the sample was left. These solids contained a complicated spectrum of elements, with iron, sodium, nickel, and lead being prevalent. No quantitative analysis was done. The capsule contents, after removal of the residue, had a specific activity of 24.4 ± 0.8 Ci/gm. The soluble portion of the sample was analyzed by emission spectrograph, mass spectrograph, and flame photometer; the analyses yielded the following results:

Element	Weight % of Product
Barium	0.57
Chromium	0.06
Sodium	0.10
Potassium	0.07
Rubidium	0.06

1. J. H. Gillette, Review of the Radioisotope Program, ORNL 4155, Oak Ridge National Laboratory, Oak Ridge TN, 1966.

2. Intra-Laboratory Correspondence, Oak Ridge National Laboratory, to E. Lamb, Subject: First Shipment of WESF $^{137}CsCl$ to ORNL, May 27, 1976.

The difficulty with the impurities, was that if the temperature of the cesium chloride became high enough to melt the salt, the cesium chloride and the impurities might become corrosive enough to damage the 316L stainless-steel capsule liners. The original materials compatibility tests were performed with pure salts. A very carefully prepared series of thermal calculations* showed that under no operating conditions expected in the facility would the temperature of the cesium chloride become high enough to melt the salt. Temperatures typically stayed at least 150°C below this point.

The final disadvantage of the capsule is that the design parameters were optimized for pool storage. The capsules are so large in diameter and have such thick stainless-steel walls that the self-absorption of the γ-radiation is high. Calculations have shown that if the pin diameter were reduced to 1 in. with 0.100 in. total stainless-steel wall thickness, the γ-source efficiency would increase from 60 to 77%.

In order to detect any leaks in the capsules after installation in the facility, a number of tests will be performed. In the first test, the γ-source plaque will be withdrawn into the pool area and the lead shutter closed. With the γ-source isolated, thermoluminescent dosimeters (TLD's) will be sent down to the plaque area with the conveyor system. After the TLD's have been analyzed, any increase in dose rate would indicate a leak. This test is very insensitive but should be performed at least once monthly. The second test is described in detail in Section V.D. A swipe test of the upper and lower portion of each capsule will be performed. The swipe samples would be analyzed for any leakage. This test must be simple enough that it can be performed at least once every 6 months. The final test is to withdraw the source plaque into the pool area and to install the water seal. The pool is then flooded to a level slightly above the source plaque. After a certain period, the water is analyzed for radioactivity. The pool is then drained. This test is extremely sensitive and should be performed no more often than once yearly.

---

*See Appendix D.

APPENDIX B

Shielding and Scatter Calculations for the Sandia Irradiator for Dried Sewage Solids

APPENDIX B

Shielding and Scatter Calculations for the Sandia Irradiator for Dried Sewage Solids

The calculations in this appendix are divided into two categories. These two categories are direct shielding and indirect scattering of gamma rays.

The γ-source is 15 pins containing cesium-137 in the form of cesium chloride. The cesium-137 is double encapsulated in 316L stainless steel. A drawing of an individual pin, complete with dimensions, is shown in Figure IV-5. Fifteen of these pins are placed in a source plaque as shown in Figure IV-3. The source plaque can be positioned either in the conveyor area, the pool area, or in the cavity between the pool and conveyor areas, as shown in Figures IV-1 and IV-2. A number of conservative, idealized calculations have been performed to demonstrate the adequacy of design of the facility with respect to radiation exposure levels.

The design dose commitments that must be kept in mind for the evaluation of these calculations are maximums of 1 rem/yr for workers and 170 mrem/yr over background for the public and workers not directly associated with operation of the facility (janitors, maintenance personnel, material handlers, etc.).

I. Direct Shielding Calculations

The direct-shielding calculations are divided into those that apply when the source plaque is positioned on the pool side of the facility and those that apply when the source plaque is positioned on the conveyor side of the facility. All calculations were made by the author and checked by G. E. Kaye (3312 Health Physics Division).

A. Calculations for Source Plaque on Pool Side of Facility

The calculations performed in this category must document the adequacy of the shielding water depth during pin loading or unloading operations, the adequacy of the shielding provided by the concrete pool cover after the pool water has been removed, and the adequacy of the shielding provided by the lead shutter when workers are in the conveyor access area.

1. Pool Water Shielding

The geometry of the pool and water is shown in Figure B-1. The γ-source is idealized as a point source 15 ft 6 in. below the surface of the water. The energy fluence from uncollided photons is given by

$$F_0 = \frac{CE\,(3.7 \times 10^{10})}{4\pi r^2}\, e^{-\mu r}\,(3600) ,$$

where

F_0 - energy fluence

C - source strength in Curies

E - photon energy in MeV

μ - linear attenuation coefficient

r - distance from the source.

$$F_0 = \frac{(1.05 \times 10^6)(0.66)(3.7 \times 10^{10})}{4\pi r^2} e^{-40.68} (3600)$$

$$F_0 = 7.08 \times 10^{-5} \text{ MeV/cm}^2 - \text{hr}$$

The buildup factor to compensate for scattered photons is given by

$$B = 1 + a\mu r e^{b\mu r} ,$$

where

B - buildup factor

μ - linear attenuation coefficient

a, b - constants determined from Monte-Carlo calculations

$$B = 1.39 \times 10^4 .$$

The dose rate is then

$$D_0 = 1.602 \times 10^{-8} \, \overline{\mu}_a \, B \, F_0 ,$$

where

D_0 - dose rate

$\overline{\mu}_a$ - mass absorption coefficient of gamma rays in air

B - buildup factor

F_0 - energy fluence.

$$D_0 = (1.602 \times 10^{-8})(2.95 \times 10^{-2})(1.39 \times 10^4)(7.08 \times 10^{-5})$$

$$D_0 = 4.66 \times 10^{-7} \text{ mR/hr} .$$

This dose rate is five orders of magnitude below background levels in this location.

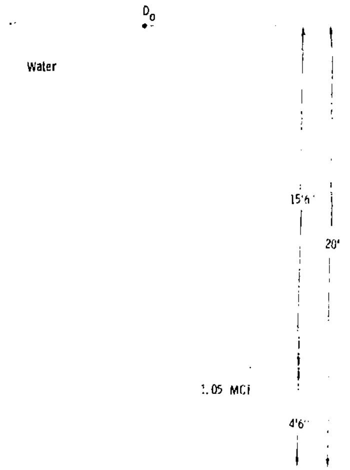


Figure B-1. Pool with Water

2. Pool Cover Shielding

After the pool cover is placed atop the pool and the water is removed, the pool cover must provide adequate shielding to prevent radiation exposure to workers on top of the pool cover. The geometry of the situation is shown in Figure B-2. Because the distance from the γ-source to the pool cover is so large, the photons reaching the cover can be approximated as a broad parallel beam, with unattenuated and uncollided energy fluence G_0 given by

$$G_0 = 3.29 \times 10^{13} \text{ MeV/cm}^2 - \text{hr} \ .$$

The energy fluence from the uncollided photons is given by

$$F_0 = G_0 e^{-\mu x} \ ,$$

where

x = attenuation distance,

$$F_0 = 1.09 \times 10^{4} \text{ MeV/cm}^2 - \text{hr}.$$

The buildup in this case is approximately 20. Using these facts, the dose rate is given by

$$D_0 = (1.602 \times 10^{-8})(2.95 \times 10^{-2})(1.09 \times 10^{4})\,20$$

$$D_0 = 0.103 \text{ mR/hr} \ .$$

This dose is approximately four times the background levels in this area. The cover to the pool is 10 ft above ground level, and no workers will be on top except during γ-source pin loading and unloading operations. The pool will be full of water then, and the dose rate will be lower. The high-dose-rate area will be marked, and access will be limited. Sandia Health Physics personnel will be present at all times anyone is on top of the cover.

Above ground, the walls adjacent to the pool are 4 ft thick. The gamma rays from the source arrive at the wall at such an oblique angle that they must traverse 5 or more feet of concrete before they are released to the atmosphere. The calculations in this appendix demonstrate that this thickness of concrete is adequate to reduce the dose to less than 0.035 mrem/hr.

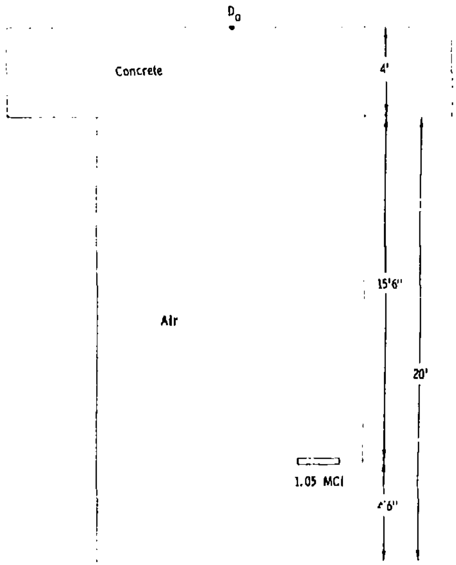


Figure B-2. Pool Cover

3. Lead Shutter Shielding

The geometry of the lead shutter and the relative position of the source plaque is shown in Figure B-3. For calculations, the source pins can be idealized as finite-length line sources and the lead shutter idealized as a finite thickness plate of infinite extent. First, the effective line source strength of a single capsule will be determined from calculations that have been correlated with experimental data. In air, the dose rate 20 cm from the end of a single capsule is 8.33 rads/s. The photon flux at a distance h from the end a line source of length ℓ is given by

$$\phi = \frac{S_L \ell}{4\pi} \frac{1}{h(\ell+h)} ,$$

where

ϕ - photon flux

S_L - specific strength of line source

ℓ - length of line source

h - distance from end of line source .

The relation between dose, D, and photon flux is given [illegible]

$$D = \frac{\phi E \bar{\mu} \; 1.6 \times 10^{-6}}{100} .$$

Using these two formulas,

S_L = 9.27×10^{12} photons/s - cm,

or

$S_{L,c}$ = 2.50×10^{2} Ci/cm

as the effective line source strength off the end of the capsule. The [illegible] $1.[illegible] \times 10^{3}$ Ci/cm. The effective line strength is approximately [illegible]. Self-absorption accounts for the difference. The energy fluence from [illegible] by

$$F_0 = 2.96 \times 10^{9} S_L E \left\{ \frac{1}{h} - \frac{1}{\ell + h} \right\} e^{-\mu t} ,$$

where

h - distance from end of line source

ℓ - length of line source

for the geometry shown in Figure B-4,

$$F_0 = 8.12 \times 10^{4} \text{ MeV/cm}^2 - \text{hr} .$$

Using a buildup factor of four and assuming a 1.15 pins to be superimposed (a worst-case [illegible]tion), the dose rate is given by

$$D_0 = 1.14 \text{ mR/hr} .$$

Because the access area will be used very infrequently, this low-dose rate is acceptable.

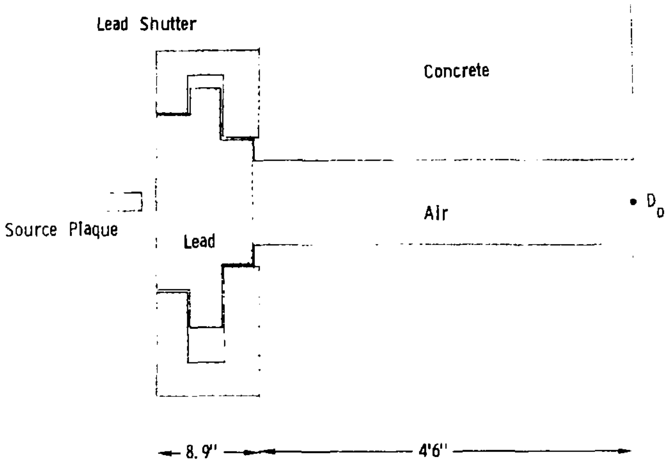


Figure B-3. Lead Shutter

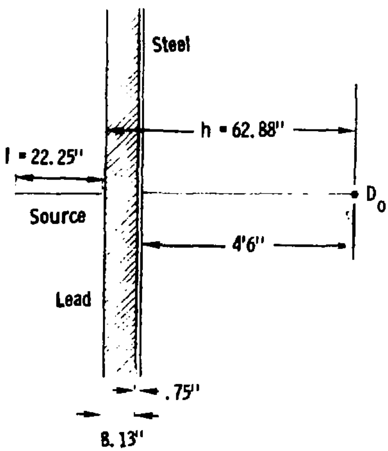


Figure B-4. Idealized Line Source and Shutter

B. Calculation for Source Plaque on Conveyor Side of Facility

These calculations must prove the adequacy of the shielding while the source plaque is on the conveyor side of the facility. When the source plaque is on the pool side, the dose rate above the slab is substantially reduced. The specific calculation made will be for the slab directly above the source plaque on the conveyor side.

1. Calculations for Shielding Above the Source Plaque

The concrete above the source is 4 ft 11 in. thick, as shown in Figure B-5. If the source is idealized as an infinite plane source and the 4-ft 11-in.-thick slab of concrete is idealized as an infinite slab in two dimensions, as shown in Figure B-6, the theoretical calculations are very conservative. The uncollided energy fluence is given by

$$F_0 = 1/2\, N E\, E_1(\mu x) \ ,$$

where

N - number of gamma rays emitted from each square centimeter of source/hr

E_1 - exponential integral; $E_1(v) = \int_v^\infty dt\, \frac{e^{-t}}{t}$

x - attenuation distance into slab

$$F_0 = 3.44 \times 10^2 \text{ MeV/cm}^2 - \text{hr.}$$

The buildup is

$$B = 215.3 \ ,$$

and the dose rate is given by

$$D_0 = (1.602 \times 10^{-8})\, \bar{\mu}_a\, B F_0$$

$$D_0 = 0.035 \text{ mR/hr} \ .$$

This exposure level is near background levels in that area.

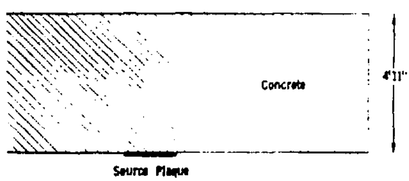


Figure B-5. Shielding Above the Source Plaque

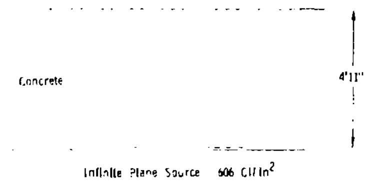


Figure B-6. Idealized Shielding Above the Source Plaque

II. Multiple-Scatter Calculations

Gamma-rays from the source plaque must be reflected at least three times off concrete, steel, or lead walls or objects before they can be reflected out the hole in the top cover that the conveyor penetrates. Accurate gamma backscatter calculations are difficult to perform for geometries as complex as the concrete conveyor cavity. The procedure used incorporated the Klien-Nishina differential albedo backscattering formula and a semi-empirical Chilton-Huddleston formula to estimate the dose from scattered photons.

These calculations were very conservative because the low energy of the emitted photons implies that after two interactions, the energy is so low that it is close to the K shell energy of lead. For this situation, photoelectric absorption, for which there is very little back-scatter, would dominate, tending to reduce the dose rates substantially below the estimates. The geometry for these calculations is shown in Figure B-7. The procedures that were carried out for each photon interaction area are enumerated below.

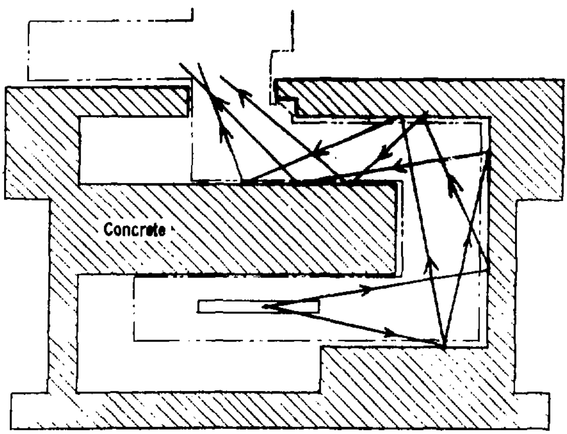


Figure B-7
Photon Backscattering Geometry

1. Determine the average angle of incidence and the average angle of reflection, the target area, as well as the average distances between targets.

2. Determine the incident exposure D_{inc}

$$D_{inc} = \frac{\Phi E_{inc} \bar{\mu}_a \, 1.6 \times 10^{6}}{100} \text{ rads/hr}$$

Φ photon flux

E_{inc} - energy of incident photon in MeV

$\bar{\mu}_a$ - mass absorption coefficient of gamma-rays in air.

3. Determine the energy of the scattered photon

$$E_{scatt} = E_{inc} \left[\frac{1}{1 + \frac{E_{inc}}{0.511} \left(1 - \cos \theta_s\right)} \right]$$

E_{scatt} - energy of scattered photon

E_{inc} - energy of incident photon

θ_s total scattering angle .

4. Use the Klein-Nishina differential scattering formula,

$$K(\theta) = \frac{E_{scatt}}{E_{inc}} \, \frac{1}{2} r_e^2 \left[\frac{1}{\left\{1 + k(1 - \cos \theta_s)\right\}^2} \right] \left[1 + \cos^2 \theta_s \frac{k^2 (1 - \cos \theta_s)^2}{1 + k(1 - \cos \theta_s)} \right] ,$$

where

$$k = \frac{E_{inc}}{0.511}$$

$$r_e = 2.82 \times 10^{-13} \text{ cm} .$$

5. Use the semi-empirical Chilton-Huddleston formula for

$$A_{JX} = \frac{C K(\theta_s) \times 10^{26} + C'}{1 + \cos \theta_0 \sec \theta} ,$$

where C and C' are constants determined from Monte-Carlo calculations for various materials and

θ_0 - angle of incidence of the photon, and

θ - angle of reflection of the photons .

6. The dose rate at the desired location is given by

$$D_f = \frac{D_{inc} \cos \theta_0 \, A_{JX} \, S}{r^2}$$

D_{inc} - incident dose in rads/hr

S - area of scatter

r - distance from the scattering surface to the point where the dose is required.

7. Use the calculated dose as the incident dose for the next scattering surface calculations; repeat the above steps until the location of the required dose is reached.

The shielding has been arranged so that a minimum of three scatters is required for a photon to exit the structure. The largest portion of the energy at the exit is caused by the three scatter paths. The appropriate physical data for the three primary three-scatter paths have been tabulated and used for the calculations described above. The dose calculated at the center of the exit aperture for each of the primary paths is given below:

	Dose
path #1	0.19 R/hr
path #2	0.03 R/hr
path #3	0.06 R/hr
Total	

Even though conservatively calculated, the dose is still much too high to permit routine work in the vicinity of the conveyor exit aperture. In anticipation of this problem, a number of design features were incorporated:

1. Provisions were made to install a lead barrier at the end of the source plaque.
2. A center divider adequate to support 1/2-in.-thick lead sheet was installed in the conveyor to make the scattering path narrower.
3. Adequate clearances around the conveyor were provided to insert 1/4-in.-thick lead sheet. Lead sheet has a much lower albedo than concrete or steel for photons of this energy.
4. Clearances were provided within the conveyor to position lead shielding at critical locations.

The shielding that we propose to add is shown in Figure B-8. The thicknesses proposed will reduce the dose at the aperture to 0.02 mR/hr. Because at least one additional foot of concrete is above the slab that is over the source plaque, the 0.02 mR/hr will be the total dose except possibly at a small aperture around the conveyer exit. No more than 0.055 mR/hr would be expected in this aperture. We anticipate that some minor patch shielding will be added to the final structure.

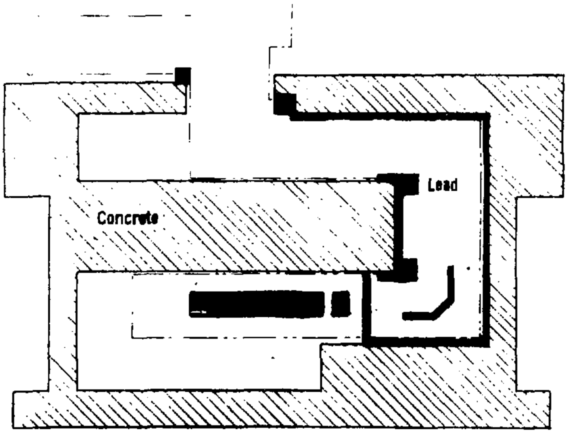


Figure B-8. Additional Shielding

APPENDIX C

Electrical Control System for the Sandia Irradiator for Dried Sewage Solids

Copy Copy

Sandia Laboratories

Albuquerque, New Mexico
Livermore, California

August 31, 1977

H. D. Sivinski - 5445

M. E. Morris - 5445

Electrical Control System for the Sandia Irradiator for Dried Sewage Solids

This document defines the electrical control system necessary to operate the proposed Sandia Irradiator for Dried Sewage Solids (SIDSS).

The electrical and mechanical operation of an irradiator is generally a moderately complex task because of the interlocks required for safety. First, the inputs to the radiation alarms, from the various limit switches, and from various inductors will be described. Second, the equipment to be controlled by the system will be described. Third, the operating modes and states are defined. Fourth, and finally, the electrical system necessary to effect these modes and states is provided.

Table 1 shows the inputs to the electrical control system and describes the switch position. Each input provides the equivalent of a single pole, single throw (SPST) switch, a momentary single pole, double throw (SPDT) switch, or a fusible link.

TABLE 1

Inputs to the Electrical Control System

		Switch Position
i.)	radiation sensors	
	a.) pool side	(normally open)
	b.) conveyor side	(normally open)
	c.) conveyor exit	(normally open)
	d.) conveyor entrance	(normally open)
	e.) HEPA filter surface	(normally open)
	f.) sump pump	(normally open)
ii.)	lead shutter switches	
	a.) shutter open switch	(closes when shutter opened)
	b.) shutter closed switch	(closes when shutter closed)

Copy Copy

TABLE 1 (cont'd)

		Switch Position
iii.)	gama-source plaque position switches	
	a.) source plaque retracted switch	(closes when plaque retracted)
	b.) source plaque extended switch	(closes when plaque extended)
iv.)	access cover switch	(closes when cover open)
v.)	torque limit switch for conveyor	(closes for torque overload)
vi.)	float water level switch	
vii.)	shutter switch position indicator	
	a.) opening	
	b.) closing	
viii.)	source plaque switch position indicator	
	a.) extending	
	b.) retracting	
ix.)	fusible link fire indicator	

The location of the radiation sensors is indicated by the dots in Figure 1. The design of the sensors and alarm control system is briefly described in the attached Nuclear Measurements Corporation literature.

Table 2 shows the items that are to be controlled by the system. Some of these items are also to have local control switches at the instrument control panel; and some of these switches are keyed

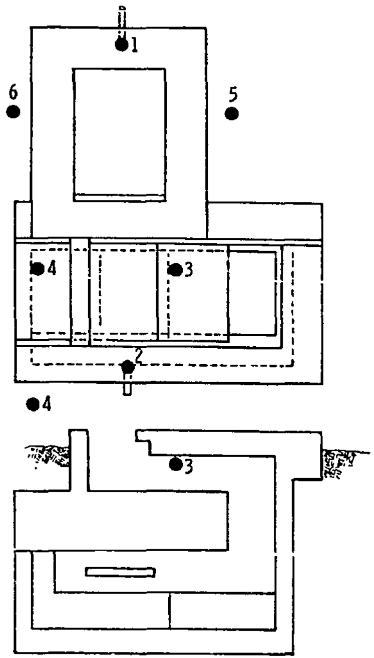
TABLE 2

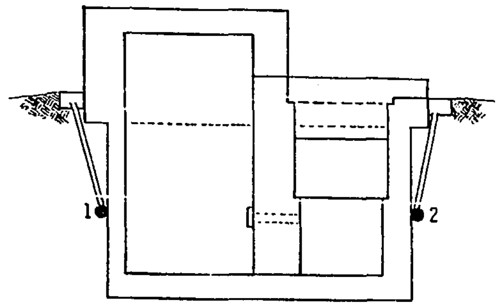
Outputs of the Electrical Control System

		Control Box Control Switch	
a.)	alarm system and sensors	ON OFF	(keyed)
aa.)	audible alarm and visible light	ON OFF	(Keyed)
b.)	ventilation system and discharge pump	ON OFF	(keyed)
c.)	sump pump	ON OFF	
d.)	shutter control	OPEN CLOSE	(keyed)

Copy

Copy





RADIATION SENSOR LOCATIONS

Copy Copy

TABLE 2 (cont'd)

		Control Box Control Switch	
e.)	plaque position control	EXTENDED RETRACTED	(keyed)
f.)	conveyor system and compressor	ON OFF	
g.)	access cover interlock solenoid (locks with power off - 115 v)		
h.)	pool cover interlock (locks with power off - 115 v)		
i.)	inside lighting	ON OFF	
j.)	outside outlets	ON OFF	
k.)	inside outlets	ON OFF	
l.)	feed hopper motor	ON OFF	
m.)	fire control system	ON OFF	(keyed)
n.)	shutter switch power and plaque switch power	ON OFF	(keyed)
o.)	shutter lock switch (locked when off)		
p.)	flashing red light		

The inputs to and the outputs from the electrical control system for the sludge irradiator are now defined. The question now is, for each different operating mode (4 modes) what are the output states for a given set of input states.

The four operating modes are:

1.) off mode;
2.) normal operating mode;
3.) access mode (conveyor maintenance, or swipe test, or water seal, installation or removal); and
4.) source load - unload mode.

For each operating mode, the output states of each device can be defined as:

1.) unconditionally on;
2.) unconditionally off;
3.) conditionally on; and
4.) conditionally off.

These states feed into the local control s[illegible] as defined in Table 2. The desired states of the output devices in [illegible]ms of the input devices are defined in Table 3 for each of the four operating modes.

Copy Copy

TABLE 3

Defined Output States of the Electrical Control System for Each Operating Mode

1. Off Mode
   - I.) unconditionally on
     a.), i.), j.), k.), m.), n.)
   - II.) unconditionally off
     d.), e.), f.), g.), h.), l.), o.) p.)
   - III.) conditionally on
     aa.) if [ib.) or ic.) or id.) or ie.) or if.) or (not ix.)]
   - IV.) conditionally off
     b.) if [ic.) or id.) or ie.) or if.) or (not ix.)]
     c.) if [ic.) or id.) or ie.) . if.) or (not ix.)]

2. Normal Operating Mode
   - I.) unconditionally on
     a.), i.), j.), k.), m.), n.), o.), p.)
   - II.) unconditionally off
     g.), h.)
   - III.) conditionally on
     aa.) if [ic.) or id.) or ie.) or if.) or iv or v or (not ix.)]
     d.) if {[ia.) and (not ib.))] and [iiia.) and (not iiib.))]
     e.) if {[iia.) and (not iib.))] and [not iv] and not [ic.) or id.) or ie.) or if.) or (not ix)]
   - IV. conditionally off
     b.) if [ic.) or id.) or ie.) or if.) or (not ix)]
     c.) if [ic.) or id.) or ie.) or if.) or (not ix)]
     f.) if [ic.) or id.) or ie.) or if.) or v or (not ix)]
     l.) if [ic.) or id.) or ie.) or if.) or v or (not ix)]

3. Access Mode
   - I.) unconditionally on
     a.), i.), j.), k.), m.), p.)
   - II.) unconditionally off
     d.), e.), l.), m.), o.)
   - III.) conditionally on
     aa.) if [ic.) or id.) or ie.) or if.) or (not ix)]
     g.) if {[ia.) and (not ib.))] and not [ic.) or id.) or ie.) or if.) or (not ix)] and [iib.) and (not iia.)] and [iiia.) and (not iiib.)]

TABLE 3 (cont'd)

IV.) conditionally off
- b.) if [ic.) or id.) or ie.) or if.) or (not ix)]
- c.) if [ic.) or id.) or ie.) or if.) or (not ix)]
- f.) if [ic.) or id.) or ie.) or if.) or v or (not ix)]
- l.) if [ic.) or id.) or ie.) or if.) or v or (not ix)]

4. Source Load-Unload Mode

I.) unconditionally on
- a.), i.), j.), k.), m.), n.), o.), p.)

II.) unconditionally off
- e.), f.), g.), l.)

III.) conditionally on
- aa.) if [ic.) or id.) or ie.) or if.) or (not ix)]
- h.) if [(not ia.)) and (not ib))] and vi]

IV. conditionally off
- b.) if [ic.) or id.) or ie.) or if.) or (not ix)]
- c.) if [ic.) or id.) or ie.) or if.) or (not ix)]
- d.) if [iv]

These control states are defined in the electrical logic diagram in Figure 2. The four position switch in the upper left-hand corner selects the operating mode, and the proper circuitry is enabled to allow the prescribed output states for the given inputs.

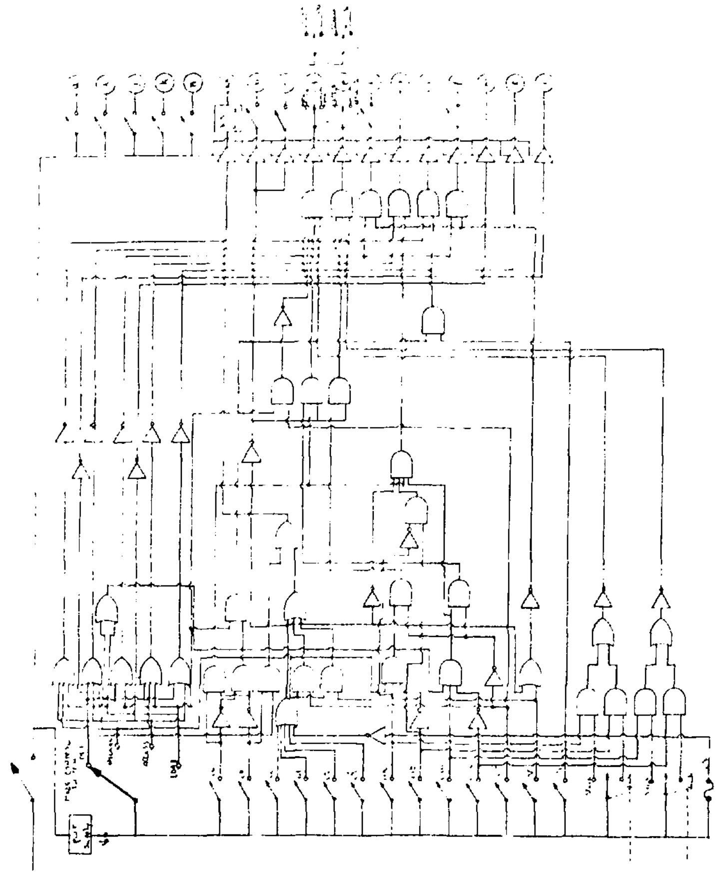
In the control box, at least the following control indicators will be needed:

Table 4

Control Indicators

- a.) ventilation or discharge pump operating
- b.) conveyor operating
- c.) sump pump operating
- d.) shutter open
- e.) shutter closed
- f.) source plaque retracted
- g.) source plaque extended
- h.) access cover off
- i.) conveyor jammed

Copy Copy



In [illegible] control [illegible], a number of signal lights will [illegible] necessary. These are shown in Table 5.

TABLE 5

Signal Lights

	Light	Color
	Power	Red
aa.	Alarm	Red - Green
b.	Ventilation System	Red - Green
c.	Sump Pump	Red - Green
d.	Shutter Control	Purple - Green
e.	Plaque Control	Purple - Green
f.	Conveyor	Amber
v.	Torque Limit Switch	Red - Green
g.	Access Cover Interlock	Red - Green
h.	Pool Cover Interlock	Red - Green
l.	Feed Hopper Motor	Amber
m.	Fire Control	Red - Green
n.	Shutter and Plaque Switch Power	Amber
o.	Shutter Lock Switch	Red - Green
p.	Flashing Operating Light	Red
vi.	Float Switch	Red - Green
iv.	Access Cover Switch	Red - Green
	OFF Mode	Green
	Normal Operating Mode	Red
	Access Mode	Red
	Source Load-Unload Mode	Red

This information, along with the attached radiation alarm documentation, should provide the electrical designer with enough criteria to design the electrical control system.

MEM:5145:s)

Copy to:
5440 P. W. Lynch

Copy Copy

Sandia Laboratories

[illegible]

[illegible]

Arthur C. Ratzel III

[illegible]

[illegible] Heat Transfer [illegible]

[illegible]

[illegible] and [illegible] Jaeger, [illegible], Oxford, Clarendon Press, [illegible]

[illegible] and W. [illegible], "Heat Transfer [illegible] Air [illegible]," [illegible], February, [illegible]

"[illegible]," [illegible], March [illegible], 197[illegible].

[illegible] and J. R. Howell, Thermal Radiation Heat Transfer, New York, McGraw-Hill, [illegible]

Thermophysical Properties of High Temperature Solid Materials, Y. S. Touloukian, ed., New York, The Macmillan Limited, 19[illegible].

Heat transfer studies for a CsCl cylinder for the [illegible] treatment facility have been completed. A cross-sectional view of the geometry considered is provided in the appendix [illegible] with material property data. For simplicity of analysis, steady-state conditions were incorporated in the work.

Equilibrium temperatures were obtained using energy balances created for each of the cylindrical surfaces. Temperature variations were assumed to occur only in the radial direction (axial effects for the CsCl have also been modelled and will be discussed). Question areas which were specifically addressed include the following:

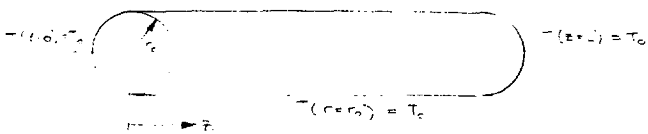
(1) Effects of axial conduction within the CsCl cylinder
(2) Effects of adjacent CsCl cylinders on the radiation heat transfer
(3) Effects of natural and forced convection from the outer stainless steel sheath.

Each of the aforementioned [illegible] will be [illegible] in separate sections. Results from [illegible] are [illegible] in figure form in the Appendix.

[illegible]

[illegible] Effect of Axial Conduction [illegible] Canister

Calculations made assuming the [illegible] boundary conditions and configuration.



yielded the following solution

$$\theta = T - T_o = \sum_{n=1}^{\infty} \sum_{j=1}^{\infty} \frac{Q \sin(\alpha_n z)\, J_0(\beta_j r)}{\alpha_n \beta_j (\alpha_n^2 + \beta_j^2)\, J_1(\beta_j r_o)} \qquad (1)$$

$$\alpha_n = \frac{(2n-1)\pi}{L}$$

$$\beta_j = \frac{z_j}{r_o} \qquad J_0(z_j) = 0$$

$$Q = \frac{8 q'''}{K r_o L}$$

Results obtained using Equation (1) are shown below. They indicate that the effect of axial conduction is negligible compared to radial conduction. The data tabulated is for the case of Q = 0.39W/cm^3 (37900 Btu/hr-ft^3). R and Z are measured in feet and the numbers tabulated are $\theta = T(r,z) - T_o$ and are in degrees Rankine

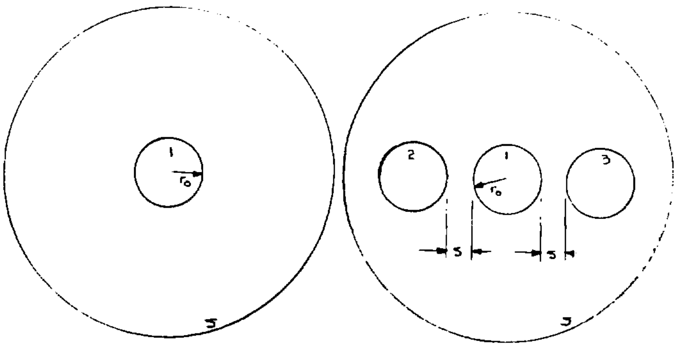
FINAL RESULTS

Z=	R=0.0000	R= .0085	R= .0170	R= .0256	R= .0341	R= .0426	R= .0511	R= .0596	R= .0682	R= .0767	R= .0852
0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
.0433	32.89	32.62	31.74	30.37	28.36	25.70	22.15	18.22	13.22	7.21	-.00
.0865	42.48	42.27	40.84	38.74	35.88	32.17	27.49	21.97	15.55	8.33	-.00
.1299	45.18	45.93	44.57	42.79	39.04	34.35	29.90	23.89	16.37	8.37	-.00
.1731	46.79	46.33	44.98	42.58	39.30	35.33	29.95	23.83	16.82	8.46	-.00
.2164	47.50	47.04	45.62	43.25	39.94	35.68	30.47	24.31	17.18	9.04	-.00
.2596	47.23	46.76	45.34	42.97	39.59	35.33	30.19	24.14	16.95	8.91	-.00
.3029	47.56	47.09	45.67	43.30	39.98	35.71	30.49	24.31	17.17	9.02	-.00
.3462	47.29	46.82	45.40	43.01	39.71	35.45	30.24	24.09	16.98	8.95	-.00
.3895	47.54	47.09	45.65	43.28	39.96	35.69	30.45	24.29	17.15	9.04	-.00
.4327	47.12	46.85	45.41	43.06	39.74	35.47	30.26	24.10	17.03	8.95	-.00
.4760	47.53	47.06	45.64	43.26	39.94	35.67	30.45	24.27	17.14	9.05	-.00
.5193	47.35	46.96	45.44	43.07	39.75	35.48	30.27	24.11	17.01	8.97	-.00
.5626	47.52	47.05	45.63	43.25	39.93	35.66	30.44	24.26	17.14	9.05	-.00
.6059	47.24	46.57	45.45	43.09	39.75	35.47	30.28	24.12	17.01	8.97	-.00
.6491	47.51	47.04	45.62	43.25	39.92	35.65	30.43	24.25	17.13	9.04	-.00
.6924	47.15	46.89	45.45	43.08	39.76	35.50	30.28	24.12	17.02	8.97	-.00
.7357	47.41	47.04	45.61	43.24	39.92	35.65	30.43	24.26	17.13	9.04	-.00
.7789	47.35	46.88	45.46	43.09	39.77	35.50	30.29	24.12	17.02	8.97	-.00
.8222	47.50	47.04	45.61	43.24	39.92	35.65	30.43	24.25	17.13	9.04	-.00
.8655	47.35	46.89	45.46	43.09	39.77	35.50	30.29	24.13	17.07	8.97	-.00

Copy Copy

Effect of Adjacent CsCl Canisters in Radiation Calculations.

Data taken from the TPRC references indicate that the thermal emittance of stainless steel is 0.30. Assuming that the surroundings can be treated as a blackbody surface, two possible cases can be considered and are shown below.



Case A Case B

For Case A, the surrounding temperature (T_s) is assumed constant, as is the outer surface temperature of T_1. Therefore, the radiative energy exchange becomes

$$Q_{RAD} = A_1 \epsilon_1 \sigma (T_1^4 - T_s^4) \quad (2)$$

For Case B, it is again assumed that T_s is a constant. In addition, it is assumed that $T_1 = T_2 = T_3$ and that each cylinder has the same thermal emittance and area. The radiative energy exchange becomes

$$Q_{RAD} = A_1 \epsilon_1 \sigma \mathcal{F} (T_1^4 - T_s^4) \quad (3)$$

$$\mathcal{F} = \frac{(1 - 2F_{1-2}) + 2F_{1-2}(1-\epsilon_1)(1 - F_{1-2})}{1 - 2(F_{1-2}(1-\epsilon_1))} \quad (4)$$

Copy   Copy

and
$$F_{1-2} = \frac{1}{\pi}\left[\sqrt{X^2 - 1} + \sin^{-1}\frac{1}{X} - X\right] \qquad (5)$$

with $X = 1 + \frac{S}{2r_o}$

For the particular spacing between cylinders and also for the given cylinder radii

$$\varepsilon = 0.92$$

with
$$F_{1-2} = 0.[illegible]3$$
$$\varepsilon = 0.30$$

Calculations comparing the effect of radiation to adjacent cylinders with those neglecting radiation to adjacent cylinders indicates that the additional radiation exchange is fairly negligible. This can be noted in the attached figures on temperature versus volumetric heat flux (the plotted curves are drawn between two data points corresponding to (1) the temperature neglecting radiation between adjacent cylinders, and (2) temperature including the effects of adjacent cylinders).

(3) <u>Modelling of Convection Heat Transfer Along the Cylinder</u>

Two cases are considered for the convective energy transfer for the CsCl canister to its surroundings.

(A) Natural Convection – Classical results for natural (free) convection are provided in the literature. The convection coefficient utilized for analysis is shown below, with results for centerline temperature and temperature of the inner radius of the first stainless steel sheath provided versus the volumetric heat generation of CsCl in Figures 1A and 1B.

$$\bar{h} = 0.27\left[\frac{T - T_S}{2r_o}\right]^{.25} \qquad (6)$$

Two cases are shown in each figure, corresponding to T_S = 66°C (150°F) and 24°C (75°F). The range of the volumetric heat generation (0.38W/cm^3 to 0.543W/cm^3) corresponds to the minimum and maximum data located within work documented by Battelle Northwest. Using natural convection cooling, it appears that temperatures in excess of 400°C (750°F) may be reached within the CsCl for heat generation fluxes above 0.4W/cm^3.

(B) Forced Convection Along the Cylinder – The majority of correlations for forced convection along a cylinder allow for calculations using flat plate correlations and then adjusting them incorporating curvature effects. Problems arise in trying to use flat plate approximations, however, because the leading edge of the cylinder is blunt. Work done by M. Jakob and W. M. Dow indicated that the leading edge conditions can render a normally laminar flow problem turbulent.

Copy Copy

Further questions relating to the flow conditions at the trailing edge of the cylinder may render the flat plate approximations invalid at that location also. Therefore, rather than attempting to calculate the temperature distributions as a function of length down the cylinder, only average temperatures based on average convection coefficients are provided. Both laminar and turbulent correlations were considered, since leading edge effects were undefined.

The governing equations for the convection heat transfer have been taken from Heat Transfer, by A. Chapman and from work done by M. Jakob and W. M. Dow and are provided as shown

Laminar Flow

$$\overline{Nu}_{F.P.} = 0.664\, R_e^{.5}\, P_r^{.333} \qquad (7)$$

$$\overline{Nu}_{CYL} = \overline{Nu}_{F.P.}\left(1 + 0.088\left[\delta_T / r_o\right]\right) \qquad (8)$$

where $\delta_T = 5.83L / R_e^{.5}$

Turbulent Flow

$$\overline{Nu}_{F.P.} = 0.036\, R_e^{.8}\, P_r^{.333} \qquad (9)$$

$$\overline{Nu}_{CYL} = \overline{Nu}_{F.P.}\left(1 + 0.3\left[\delta_T / r_o\right]\right) \qquad (10)$$

where $\delta_T = 0.366L / R_e^{.2}$

and

$$\overline{Nu} = \frac{\bar{h}L}{k}$$

$$R_e = \frac{uL}{\nu}$$

$$P_r = \frac{\nu}{\alpha}$$

As can be seen from the above expressions, the variation between flat plate and cylinder average Nusselt numbers results from a ratio of boundary layer thickness (δt) and curvature (denoted through r_0). As the cylinder diameter increases, it would be expected that the flat plate model would be valid, and infact this can be seen by comparing Figures 2A and 2B with 3A and 3B and 4A and 4B with 5A and 5B. Figures with the 'A' designation provide centerline temperature data while figures with the 'B' designation yield data on the temperature of the inner surface of the CsCl containment cylinder.

Figures 2 through 5 provide data showing the effects of wind. Comparisons of the 5mph wind cases with the natural convection plots for T_{amb} = 24°C (75°F) indicate that there is no significant cooling obtained by the addition of air flow. For air velocities above 10mph, however CsCl material temperatures may be reduced significantly (30-40°C less than those expected for the natural convection case). .

Three other noteworthy points should also be made. First, comparisons of the temperature plots for the flat plate and cylinder indicate that using a flat plate approximation does not critically affect the results. Comparisons of Figures 2A and 3A (laminar flow case) indicate that less than 10°C difference results. Although the differences may be slightly greater for turbulent flow, the flat plate approximation for convection heat transfer is still acceptable. Second, significant temperature differences result from choosing a turbulent or laminar convection model, particularly if the higher air velocity conditions are considered. Nearly 50°C temperature differences between the laminar and turbulent flow models occur, for example, for air velocities above 10mph. Typical transitions Reynolds numbers range from 100,000 to 500,000 for flow over a flat plate, and therefore, the convection problem would normally be considered laminar. (Re_{max} is estimated to be 120,000 for an air velocity of 20mph along the cylinder). Leading edge effects (blunt front surface) will, however, at least enhance the heat transfer along the first part of the cylinder and may even result in such instablities in the momentum boundary layer that turbulent heat transfer occurs. For conservative estimates on the CsCl material temperature, however, laminar convection models should be used. Finally, it should be noted that the temperature data provided in Figures 2 through 5 result from average convection coefficients. For flow along a flat plate, the heat transfer decreases as the thermal boundary layer increases in thickness. Therefore, higher surface temperatures than estimated using an average Nusselt number correlation will occur near the trailing edge of the cylinder. Such increases, however, may be offset by conduction losses at the end.

Conclusions

The following statements summarize the results obtained through the work undertaken.

Copy Copy

(1) Axial conduction within the CsCl material as expected is negligible compared to radial conduction.

(2) Radiation effects from adjacent CsCl cylinders are negligible.

(3) CsCl centerline temperatures in excess of 350°C should result from natural and forced laminar convection and may be as high as nearly 500°C depending upon location on the cylinder and whether or not air is moving over the cylinder.

(4) The blunt leading edge of the CsCl cylinder may result in turbulent heat transfer, which would reduce expected maximum centerline temperatures below 400°C for air velocities above 10mph.

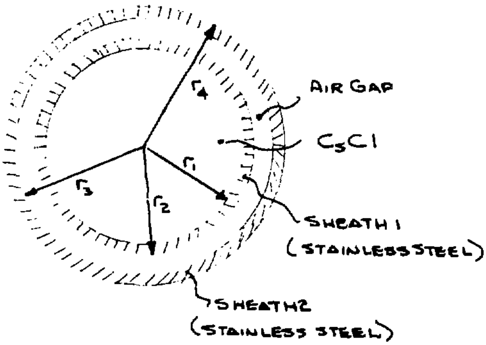
(5) The best way to lower the CsCl temperature, it appears, would be to eliminate the radition shield effect which occurs between the two stainless steel sheaths. The low thermal emittance of stainless steel results in temperature increases of over 100°C across the annular space.

ACR:1262:jp

Copy to:
1260 K. J. Touryan
1262 H. C. Hardee

APPENDIX

GEOMETRY ANALYZED



DIMENSIONAL DATA

$r_1 = 1.02''$
$r_2 = 1.125''$
$r_3 = 1.194''$
$r_4 = 1.312''$
$L = 20.77''$

ADDITIONAL DATA USED IN ANALYSIS

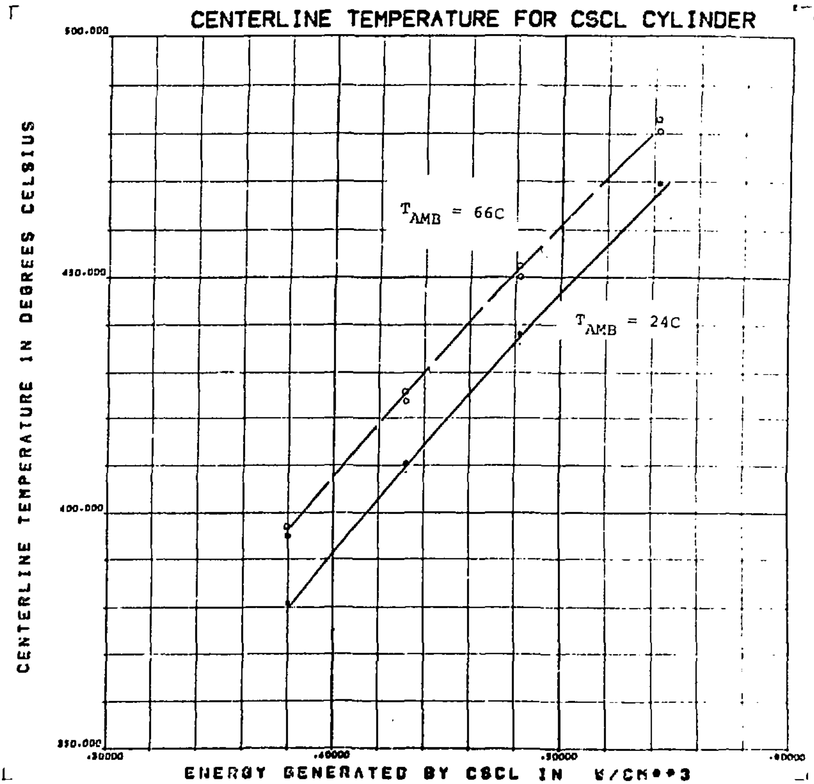
ϵ (STAINLESS STEEL) = 0.30
K (STAINLESS STEEL) = 0.0091T + 7.69 (T IN °F) $\frac{BTU}{HR \cdot FT \cdot F}$
K (CsCl) = K(NaCl) = 1.45 BTU/HR-FT-F

STAINLESS STEEL TUBES ASSUMED TO BE CONCENTRIC
STEADY STATE CONDITIONS ASSUMED
UNIFORM HEAT GENERATION ASSUMED
AMBIENT TEMPERATURE ASSUMED TO BE 24°c (75°c)
UNLESS OTHERWISE SPECIFIED.

Copy Copy

Figure 1-A

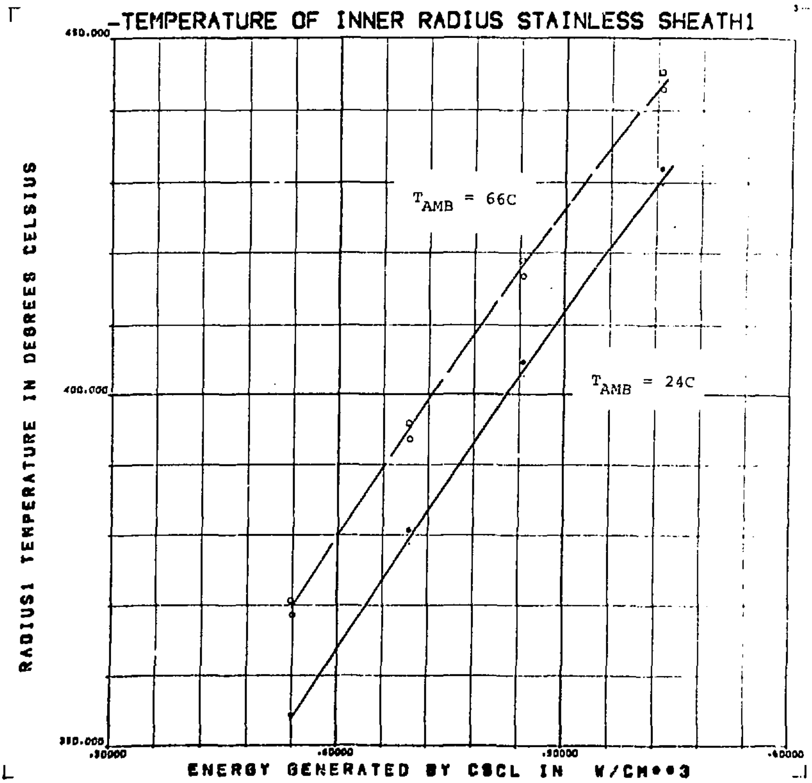
Natural Convection Heat Transfer Along A Cylinder



Copy Copy

Figure 1-B

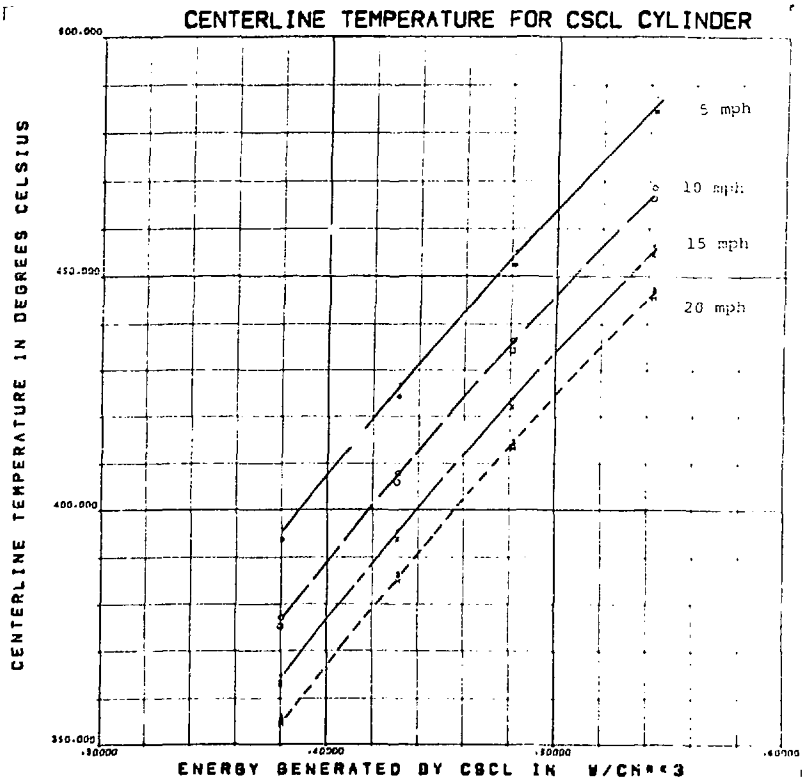
Natural Convection Heat Transfer Along A Cylinder



Copy Copy

Figure 2-A

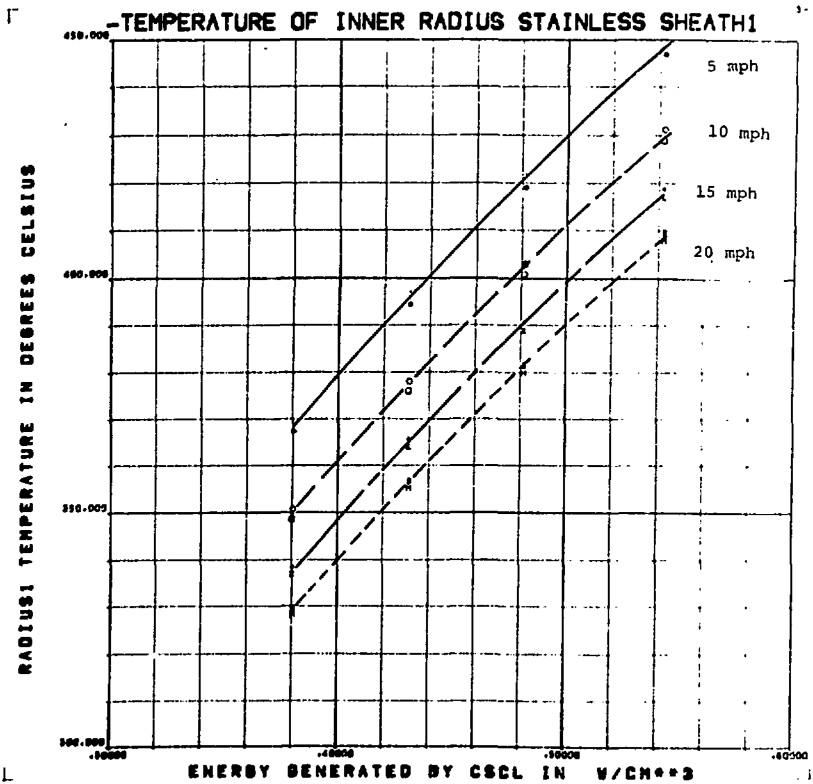
Laminar Flow Heat Transfer Along A Flat Plate



Copy Copy

Figure 2-B

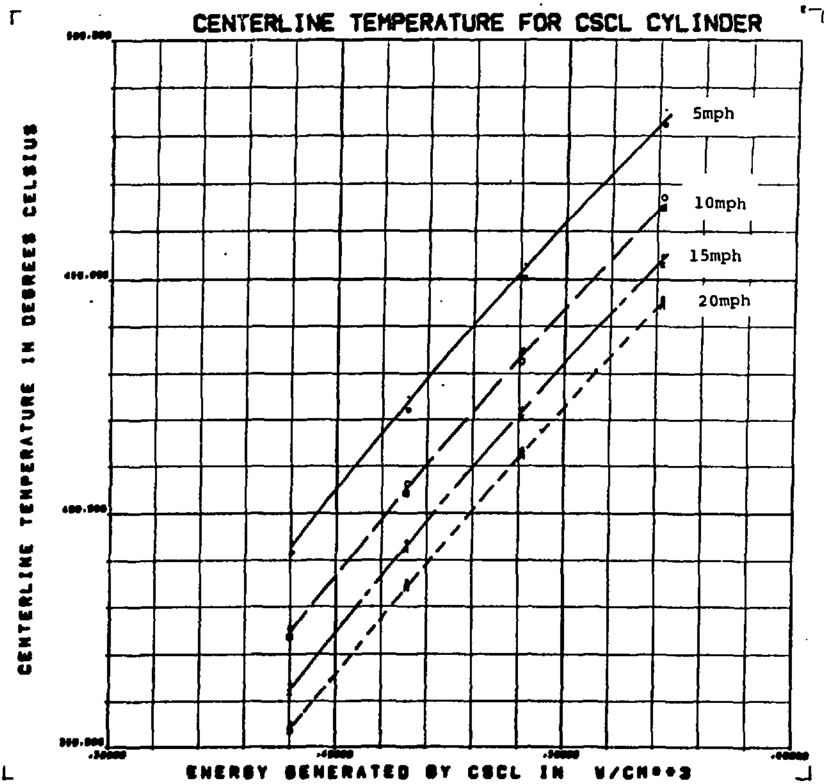
Laminar Flow Heat Transfer Along A Flat Plate



Copy Copy

Figure 3-A

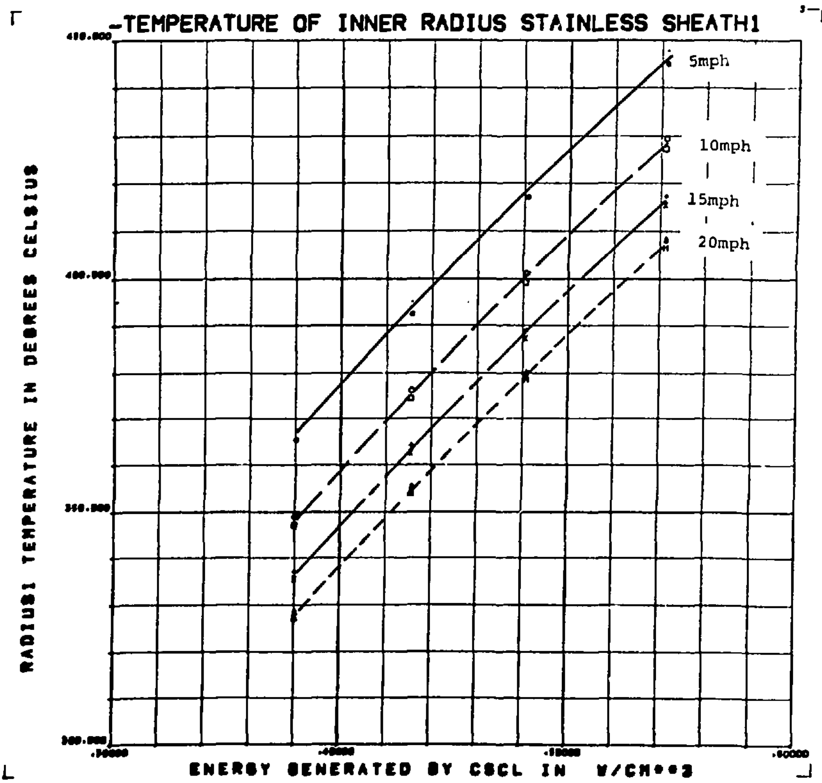
Laminar Flow Heat Transfer Along A Cylinder



Copy Copy

Figure 3-B

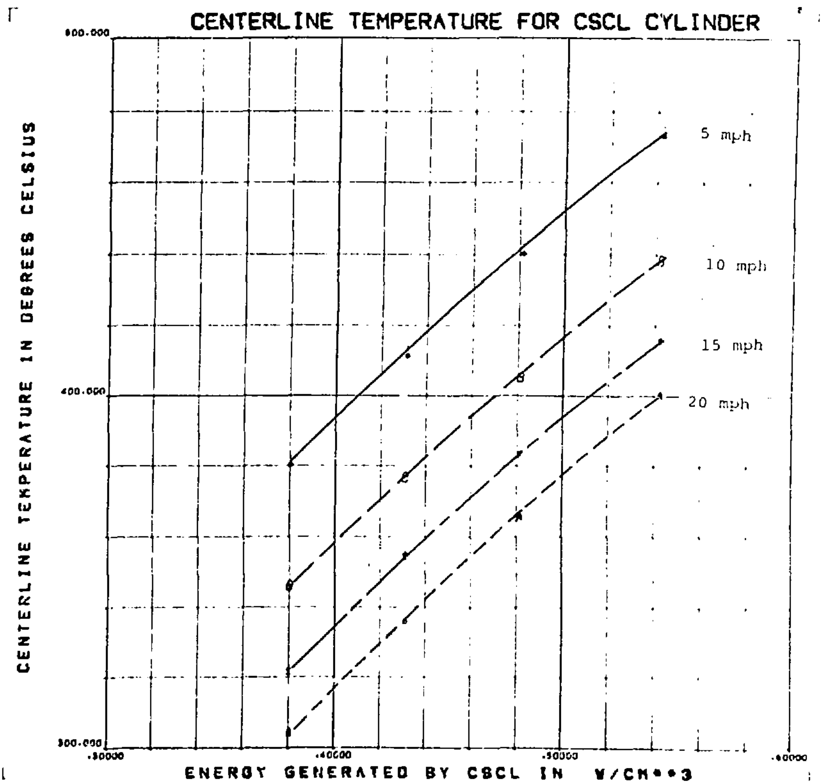
Laminar Flow Heat Transfer Along A Cylinder



Copy Copy

Figure 4-A

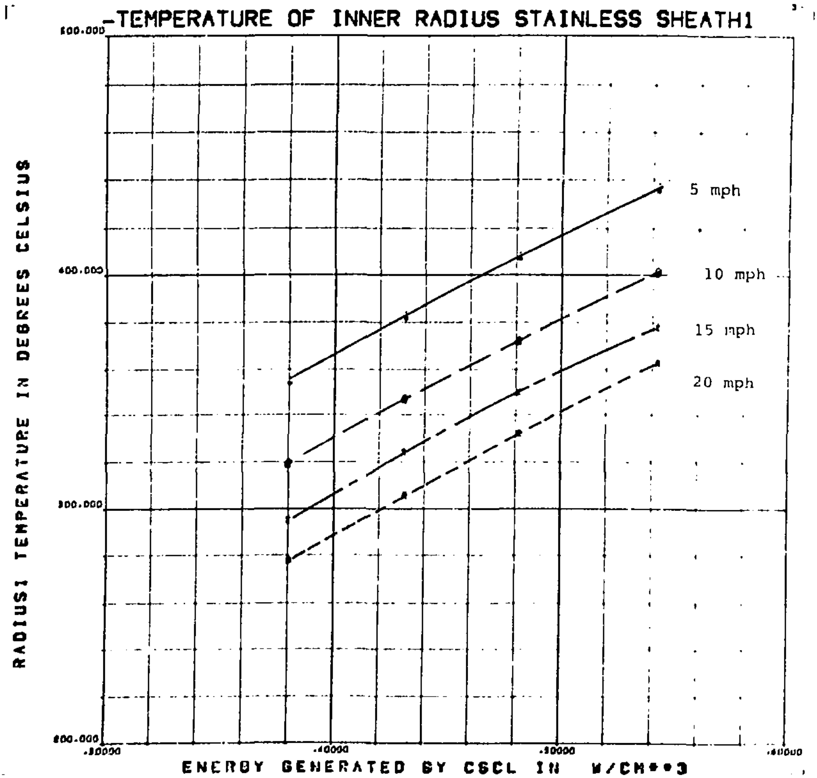
Turbulent Flow Heat Transfer Along A Flat Plate



Copy Copy

Figure 4-B

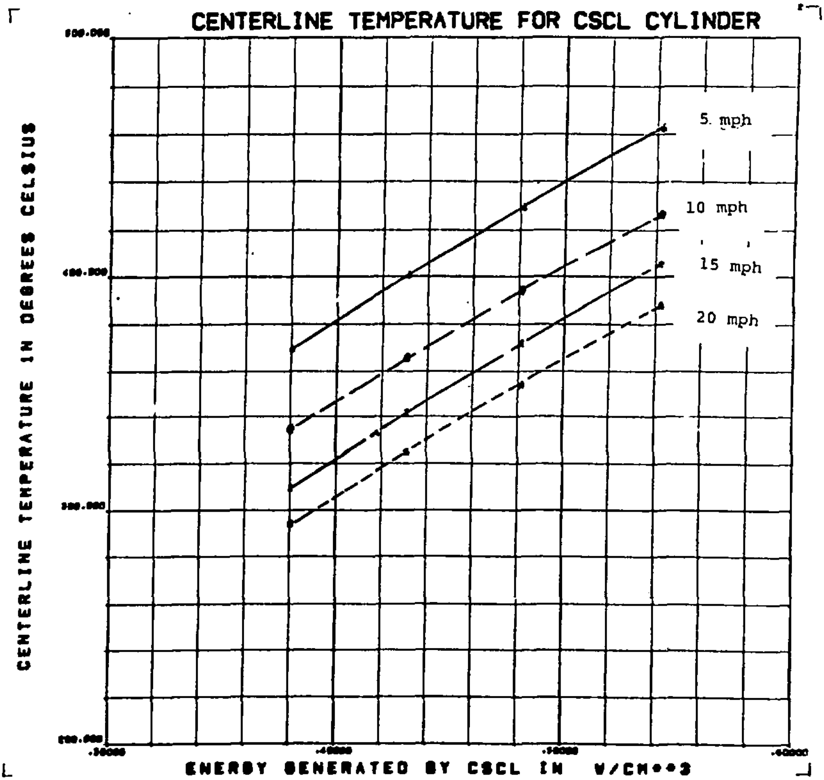
Turbulent Flow Heat Transfer Along A Flat Plate



Copy Copy

Figure 5-A

Turbulent Flow Heat Transfer Along A Cylinder

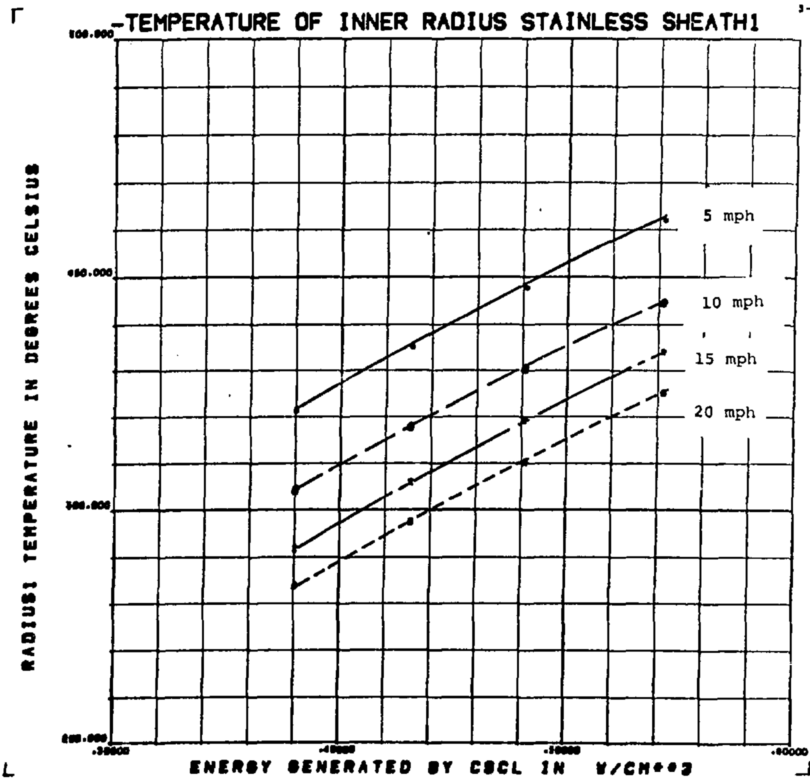


Copy

Copy

Figure 5-B

Turbulent Flow Heat Transfer Along A Cylinder



APPENDIX E

Detailed Operating Procedures

A. Introduction

The operations carried out at the irradiation facility can be divided into five separate categories. The first category is the gamma-source pin loading operation; this operation is performed when the facility is initially charged with radioactive material, or when the gamma-source is recharged. The second category of operations is labeled "normal" operations; these operations would be regarded as the normal function of the facility: source plaque extension and retraction, lead shutter closing and opening, bulk and bagged material loading and unloading, and routine radiation sensor checkout. The third category of operation includes all procedures where the conveyor access cover must be removed: conveyor maintenance and repair, swipe tests to check for radiation leaks, and water seal installation and removal. The fourth category of operation is performed when the facility is placed in STANDBY or OFF mode and is to be left unattended for any length of time. The final category of operation is the pin removal procedures for decommissioning the facility. A preventative maintenance section is provided in the step-by-step procedures.

B. Pin Loading Procedures (LOAD-UNLOAD Mode)

When the Sandia Irradiator for Dried Sewage Solids (SIDSS) is initially charged or recharged with Waste Encapsulation and Storage Facility (WESF) at Richland, WA capsules, special precautions must be taken. The presence of a professional health physicist is required during all the steps in these procedures to prevent exposure to personnel. In preparation for the loading, the facility must be keyed in the ACCESS mode and must be prepared with the water seal installation procedures described in paragraph D of Section II. After the source plaque bridge assembly has been removed, the water seal has been installed in the conveyor side of the facility, and the access cover replaced, the pin loading can commence.

The control panel for the facility is keyed into the LOAD-UNLOAD mode. The lead shutter is then opened. The source plaque is positioned in the pool area. After the High Energy Particulate Air (HEPA) filters and the blower are removed, the pool is filled with deionized water through the air outlet port. When the pool is filled, two independent mechanical and electrical interlocks disable the lock that prevents the pool cover from being removed. With a health physicist present with a radiation survey meter, the three concrete pool cover slabs are removed individually with a crane. As each slab is removed, the shielding is reduced. If the electrical and mechanical interlock systems and visual inspection of the water level fail, radiation would still be detected while at a level low enough to cause no danger. When the pool covers are removed, a water level controller is installed.

After the cask containing the cesium-137 arrives, the cask is readied for lowering into the pool area by removing most of the bolts holding the cover in place. A crane lifts the cask, and slings attached to eyebolts support it. A secondary set of slings is attached to the cover so that after the cask is lowered into the pool and the remaining cover bolts removed, the cask cover can be pulled out of the pool. A release of accumulated ozone usually accompanies the removal of the cover, and personnel must clear the area for several minutes to allow the ozone to dissipate. A trial evacuation will be conducted before the actual event.

The source plaque cover is unlocked and flipped open. Th WESF capsules are moved from the cask to the plaque with tools specially designed at Sandia. The first pin to be transferred is a dummy source pin to be used in a dry run. The crane is then used to remove the cask from the pool. The cask cover is placed on the cask, the cover bolts are tightened in place, and the cask is shipped out. The cask unloading procedure must be repeated until the source plaque is filled. After the plaque is filled, the pins are secured in place by a locking cover.

The source plaque is now moved into the cavity. The pool covers are replaced, and the pool cover locks are enabled. The pool water is pumped into a 1000-gallon holding tank, and samples of the water are checked before the contents are discharged to the environment. The ventilation system is then reinstalled. The source plaque is moved to the pool, and the lead shutter is closed.

The control panel is keyed into the ACCESS mode, and the access cover is removed. After health physics personnel survey the area with radiation survey meters, the water seal is removed and the source plaque bridge assembly is replaced. Personnel must wear "chirpers" at all times while in the conveyor access area, as well as other places around the facility. After careful inspection, the personnel leave the conveyor access area, the access port cover is replaced, and the interlocks are enabled.

The facility can now be switched to either the STANDBY mode or the NORMAL operation mode.

C. Normal Operations (NORMAL Mode)

1. Definition

Normal operations are those that can be performed by workers using the facility without danger of radiation exposure. In these operations, access to the conveyor access area or the pool area is not required. The operations are conducted from the control panel in Building 6720 or at the conveyor loading and unloading stations. The operations that fit within this category are radiation sensor checkout, source plaque extension and retraction, conveyor loading and unloading, and lead shutter closing and opening.

2. Radiation Sensor Checkout

Before the facility can be used for any purpose whatever, several routine precautionary steps must be taken. First, before entering the security fence, all personnel must attach radiation badges to their clothing. At Building 6720, radiation survey meters and "chirpers" will be stored for use by personnel within the security fence. These survey meters are routinely checked and calibrated by Sandia Division 3312. Personnel planning to use the facility must first enter Building 6720 to perform a radiation sensor check. The radiation alarm systems have self-consistency check switches for each of the six radiation alarms. These switches must be turned to the proper position to assure that the sensors are working properly. After the sensors are checked, a person wearing a PDB badge (personnel monitoring device) and with a "chirper" in his possession must make a radiation survey of the entire facility before any further operations can be carried out.

3. Lead Shutter Opening and Closing

When the facility is left unattended (OFF mode), the source plaque is stored in the pool area and the lead shutter is kept in the open position. After the radiation sensors and the electrical interlock system are checked, the shutter can be closed by turning the "shutter closing" switch until the "shutter closed" light comes on. When the shutter is completely closed, position switches in the pool disable the shutter drive motor, and the switch can be released. The closing operation requires approximately 6 min. Electronic logic does not allow the shutter drive motor to close the shutter unless the source plaque is fully retracted into the pool area. A torque-limiting clutch on the shutter drive motor prevents damage to the source plaque and shutter if the electronic logic or the position indicators fail. The lead shutter is opened by turning the "shutter opening" switch until the "shutter opened" light comes on. When the shutter is completely open, position switches in the pool disable the shutter drive motor and the operator can release the button. The opening requires approximately 2 min. All personnel should remain in Building 6720 during this operation. After the shutter has been opened the source plaque can be extended into the conveyor side of the facility.

4. Source Plaque Extension and Retraction

The source plaque is extended by turning the "source plaque extending" switch until the "source plaque extended" light comes on. When the source plaque is fully extended, a position switch in the pool disables the source plaque drive motor and the switch can be released. The extension takes approximately 1 min 45 sec. Electronic logic prevents the source plaque drive motor from extending the source plaque unless the shutter is fully open. A torque-limiting clutch on the source plaque drive motor prevents damage to the source plaque and the shutter in the event the electronic logic or the position indicators fail. Source plaque extension takes approximately 2 min. After the source plaque extension has been performed, a radiation survey must be performed by the operator with a survey meter before the remaining personnel leave Building 6720. The operator must wear a PDB badge and have a "chirper" in his possession while conducting the survey. The source plaque can be retracted by pushing the "source retracting" switch until the "source retracted" light comes on. When the light comes on, a position indicator in the pool disables the source plaque drive motor. The retraction takes approximately 2 min.

5. Conveyor Loading and Unloading Operations

After the source plaque has been extended and a radiation survey conducted, the conveyor can be operated by pushing the "conveyor on" switch. The personnel can then leave Building 6720 to perform the conveyor loading and unloading operations.

The conveyor can be loaded with either bagged or bulk dried sewage sludge. A vibratory feed hopper is provided to load bulk material. The capacity of the hopper is about 0.5 yd^3, and the hopper must be kept loaded with bulk material. Because of the slow motion of the conveyor (4 in./min), the hopper can be kept loaded by hand. The height of the sludge in the bucket is automatically controlled by adjusting the feed rate of the hopper. Any sludge that could fall from the buckets in the loading operation is caught in a tray below the buckets. The tray must be cleaned periodically. Two 40-lb bags of sewage sludge are of the proper dimensions to fit into one conveyor bucket. The depth of the sludge in this case is 8 to 10 in. Since a bucket must be loaded only every 3 to 5 min in operation, the buckets will be manually loaded with bags. The conveyor moves so slowly that mechanical danger from moving parts is very slight. The conveyor chain is automatically cleaned and lubricated with molybdenum disulfide during operation.

The bulk material is automatically dumped from the conveyor buckets into a container on the west side of the facility. Bagged sludge is automatically dumped from the buckets onto a dumping conveyor.

D. Maintenance (ACCESS Mode)

All the operations that require personnel to enter the conveyor access area have been placed together under the title "Maintenance Operations." These operations include conveyor inspection and repairs, conducting swipe tests, and water seal installation and removal.

The procedure required to gain access to the conveyor access area is common to all three operations. With the facility in the NORMAL operation mode, the source plaque must be fully retracted and the lead shutter fully closed. The facility can then be switched into the ACCESS mode. With the lead shutter properly closed, both the electrical and mechanical interlocks allow the access cover lock to be unlocked manually. With a health physics representative present with a survey meter, a forklift is used to remove the access cover. When the access cover is removed, both the electrical and mechanical interlock systems lock the lead shutter closed. The health physicist with survey meter, PDB badge, and "chirper" must survey the conveyor access area before other personnel enter the area. The dose rate should be less than 0.5 mrem/hr in the bottom of the area and much less elsewhere in the access area. All personnel entering the conveyor access area must wear PDB badges and have "chirpers."

The conveyor is very simple and is operated at a small fraction of its rated speed. For these reasons, very few repairs are anticipated. Periodic inspections of the drive chain and the collapse sections will be made. Repairs to the conveyor can be made by removing the side panels to the conveyor housing.

Swipe tests will be performed at least once annually on the cesium-137 gamma-source capsules. The swipe tests are conducted by placing a swipe test fixture into the source plaque bridge track housing. The fixture is so constructed that it presses asbestos swipes against the top and bottom of the capsules over almost the entire length of the capsules when the source plaque moves over the fixture. The swipe test is conducted by going through the above procedures to obtain access to the conveyor access area. The swipe test fixture is inserted. Personnel leave the conveyor access area and replace the access cover. The interlock systems are enabled, the facility is switched back into NORMAL operations mode, and the lead shutter is opened. The source plaque is extended, and in the process of extension a swipe sample contacts both top and bottom of the capsules over almost the entire length of each capsule. The source plaque is then retracted and the lead shutter closed. The facility is switched into the ACCESS mode, and the conveyor access area entry procedures described above are followed to gain access to the conveyor access area. The swipe test fixture is removed from the conveyor access area. The access cover is replaced, the interlock systems are enabled, and the facility is switched back into either the NORMAL operations mode or the OFF mode. The 30 swipe samples (2 per capsule) are analyzed for cesium-137. Detection of greater than 0.05 μCi of cesium-137 (1.1×10^5 dpm) indicates a probable leaking source.

In the event of a leak, only two possibilities exist. Because no provision is designed into the facility for dry loading, the normal underwater pin unloading procedures can be carried out while tolerating the slow leakage of cesium chloride into the water; if the leak is very large, the facility can be decommissioned with the source in place.

In order to remove or install the water seal over the plaque pass-through cavity opening, access must be gained to the conveyor access area by following the above procedures. To install the water seal, the source plaque bridge assembly must first be removed. An undamaged rubber seal is installed over the studs around the cavity opening. The cover is lifted from below the conveyor and pushed over the studs. By installing nuts on the studs and tightening the nuts to compress the rubber seal, water is prevented from passing from the pool side to the conveyor side. Removal of the water seal is the reverse of these procedures. Obviously, the pool must be emptied of water before the water seal is removed. After installation or removal is complete, personnel leave the conveyor access area and the access cover is replaced. The interlocks are enabled, and the facility is switched into whichever of the other three modes is needed.

E. Standby (OFF Mode)

When the facility is switched to the OFF mode, it can be left unattended for extended periods of time. The radiation alarms, the interlock system, and the ventilation systems are operational in this mode. The alarm system has battery-supplied emergency backup standby power. Prior to switching the facility to the OFF mode, the source plaque should be moved to the pool side of the facility.

F. Pin Unloading Procedures (LOAD-UNLOAD Mode)

The same procedures are followed to prepare the facility for pin unloading as were followed in the pin loading procedures. If no radioactive material is contained in the shipping cask, the cask cover can be removed before the cask is lowered into the pin transfer pool. The cask cover must be removed in the presence of a qualified health physicist with survey meter and "chirper." After the cask cover is lowered into the pin transfer pool, the lead shutter is opened and the source plaque is moved out of the cavity between the pool area and the conveyor area into the pool area. The top of the source plaque is released by turning the cover-securing bolts 1/4 turn with specially prepared 20-ft-long tools. Some of the pins can be transferred to the cask from the source plaque. The cask cover is lowered into place through the water, and several bolts are screwed on to secure the cask cover to the cask. The cask is lifted out of the pool with a crane, and the other bolts are screwed on to secure the cover for shipment. The remaining steps to secure the facility are described in the pin-loading procedures section. Asterisks are marked beside the steps which the Health Physics Division would include on a minimum checklist for supervision of operations at the SIDSS. All these procedures will be incorporated into official standard operating procedures which will be regularly updated and reviewed and which will be controlled.

G. Step-by-Step Procedures

1. Pin Loading Procedure

*a. Health Physics personnel should be present through entire procedure.
b. Turn on main power.
c. Turn function switch to source LOAD/UNLOAD mode.
d. Check alarm system and sensors--all should be on.
*e. Water tight seal and gasket should already be installed in the conveyor area--this should have been done in the ACCESS mode.
f. Turn off ventilation system and remove fan and filter assembly.
g. Fill pool with clean, clear water and activate water makeup system and emergency fill system.
h. Install float switch.
*i. Remove pool cover locking mechanism--everything should now be unlocked--if not, find out why!
*j. Move crane into place.
*k. Remove pool cover.
l. Unlock hinged assemblies and open them with handling tools to allow pin loading.
*m. Move truck with cask into place.
*n. Sling the cask and hook onto the crane.
*o. Pick up cask and lower into the pool until the lid is a few inches above the surface of the water.
*p. Sling the lid of the cask and tie a rope to this sling and also to slings for the cask.
*q. Remove the nuts to the cask lid. Lower the cask to the bottom of the pool.
*r. Unhook from the cask sling and hook up to the lid sling.

s. Lift the cask lid a few inches and evacuate the area for a few minutes to allow the ozone to dissipate.

t. Remove the cask lid from the pool.

u. Using a handling tool, remove each pin from the cask and load it into the source plaque until the cask is empty.

v. Remove the cask from the pool.

w. Load the cask onto the truck and replace the lid and crash shield.

x. Repeat the operation with more casks until the source plaque is filled.

y. Close hinged angle assemblies and lock to confine pins.

z. Remove float switch.

aa. Replace pool lid.

ab. Replace pool lid lock mechanism.

ac. Activate interlocks and check them for proper operation.

ad. Deactivate water makeup and emergency water fill system.

ae. Install discharge pump.

af. Drain pool.

ag. Install the fan and filter assembly and activate.

ah. The watertight seal and door must be removed, but this is done in the ACCESS mode.

*ai. Connect the bridge assembly and attach the dust cover, but this, too, is done in the ACCESS mode.

2. NORMAL Operating Mode

a. Main power should be on.

b. Health Physics may need to be present initially.

c. Turn function switch to Normal Operating Mode.

d. Check alarm system and sensors--all should be on.

*e. Watertight seal should already be removed--this should have been done in the ACCESS mode.

f. The bridge assembly and dust cover should be installed--this also should have been done in the ACCESS mode.

g. The ventilation system should be on.

h. The sump pump should be on.

i. The pool cover should be on and locked.

j. The access cover should be on and locked.

k. All interlocks should be activated.

l. Fire protection system should be on.

m. Shutter switch power and plaque switch power should be on.

n. Open shutter if it is not already open and wait for the "shutter open" signal.

o. Extend source plaque and wait for the "extend" signal to come on.

p. Lubricate all parts that need to be lubricated.

q. Turn on lubrication and cleaning system for the conveyor and be sure of proper operation.

r. Turn on conveyor system and adjust speed for proper dose.

s. If hopper feed system is to be used, turn on hopper feed system and adjust flow rate for proper bucket filling.

t. Keep feed hopper full for proper operation.

u. If bags are to be loaded manually, load them.

v. Monitor all systems for proper operation and cor 'ir e ⁿⁿ.

w. When ready to shut down, shut off feed hopper and allow the material in the conveyor to travel through the radiation zone before shutting down the conveyor.

x. When the last of the material has passed thr ugh the radiation zone, the source plaque can be retracted -wait for the "retracted" signal to come on.

y. Leave the load shutter open to increase airflow and reduce wheel bearing wear.

z. When the last of the material has exited the conveyor, shut off lubrication and cleaning system.

aa. Turn off conveyor.

ab. Clean up.

ac. Turn function switch to OFF mode.

ad. Follow check list for OFF mode.

3. ACCESS Mode

a. Health Physics personnel should be present for initial access.

b. Turn on main power.

c. Turn function switch to ACCESS mode.

d. Check alarm system and sensors--all should be on.

e. Ventilation system should be on.

f. Source plaque should be retracted and locked--check mechanical and electrical signals.

g. Lead shutter should be closed and locked--check mechanical and electrical signals--this is the most critical procedure.

h. Sump pump should be on.

*i. Fire control system should be off--disable CO_2 bottles before access by disconnecting the copper tubing from the CO_2 bottles.

j. Access cover interlock should be on--this energizes solenoid to unlock access cover--mechanical interlock should be off.

*k. Unlock access cover by turning crank handle and removing the securing screws.

*l. Remove access cover with a large forklift.

*m. Set up fan and hose for ventilation in access area.

*n. Take light and radiation monitor and enter access area with health physics personnel.

o. Survey access area--especially in radiation zone. The dose should be lower than 0.5 mr/hr in all areas.

p. Intercom should now be connected in radiation zone.

*q. Area is now ready for whatever work is needed.

(1) If a swipe test is to be conducted, remove the cover from the top of the bridge assembly.

(2) After installing new asbestos cloth in the swipe test assembly, bolt the upper and lower sections of the swipe test assembly to the bridge assembly.

(3) Evacuate the conveyor access area and replace the concrete access plug and locking mechanism.

(4) Switch the facility into the NORMAL mode and cycle the source plaque to the extended position and then to the retracted position. Do not stop source plaque motion until it is completed automatically in either direction.

(5) Close the shutter and perform steps a. through o. of the ACCESS mode procedures.

(6) Remove the swipe assembly and replace and caulk the bridge assembly cover.

(7) Send the asbestos cloth swipe test samples to the Health Physics Division for analysis.

r. After work is completed, remove intercom and light.

s. Evacuate area.

t. Remove portable ventilation system.

u. Recheck to be sure all personnel are out of access area.

v. Replace access cover.

w. Lock access cover.

x. Turn fire control system on and reconnect CO_2 bottles.

y. Turn function switch to desired position.

4. OFF Mode

a. Main power should be on.

b. Turn function switch to OFF mode.

c. Alarm system and sensors should all be on--check for proper operation.

d. Ventilation system should be on.

e. Source plaque should be retracted.

f. Shutter should normally be left open.

g. All interlocks should be activated.

h. Conveyor and feed hopper should be off.

i. Access cover should be on and locked.

j. Pool cover should be on and locked.

k. Fire control system should be activated.

l. Secure area by locking control panel, Building 6720, and the east access gate when leaving.

5. Pin Unloading Procedure

*a-x. Steps are the same as steps a-x of the pin loading procedure.

*y. Using a handling tool, remove each pin from the source plaque until the cask is full.

*z. Lower lid and gasket into place on the cask.

*aa. Raise cask to surface--check for radiation carefully during this procedure.

*ab. When the cask lid is a few inches above the water, replace the nuts to the cask lid.

*ac. Do Steps z.-al. of Pin Loading Procedure.

6. Preventative Maintenance

a. The conveyor lubrication reservoir level should be checked once every [illegible], and the conveyor should be operated at high speed with air pressure to the reservoir until the conveyor chain is clean and lubricated.

b. The mechanical interlock should be visually checked once monthly for proper operation.

c. The electrical interlock should be checked visually once monthly for proper operation.

d. Swipe tests should be conducted at least once annually.

e. The bearings in the lower section of the conveyor and the lower [illegible] chain [illegible] be lubricated when the swipe tests are conducted.

f. The shutter lubrication reservoir should be filled [illegible] the load station [illegible].

g. The radiation sensors must be calibrated once yearly by Health Physics [illegible].

Copy Copy

Sandia Laboratories

July 19, 1979

Distribution

Health Physics - 3312

Safe Operating Procedures for the Sandia Irradiator for Dried Sewage Solids (SIDSS), Bldg. 6720 and 6725

The enclosed instructions outline the necessary procedures for operating the Sandia Irradiator for Dried Sewage Solids (SIDSS) in the NORMAL operations mode.

1. These procedures supersede all previous oral and/or written procedures.

2. The operating organization has the responsibility of notifying the Health Physics Division, 3312, before the SIDSS is operated in any other mode, if the machine is modified in any way, if any anomalies exist in the radiation readings observed on fixed instrumentation or during radiation surveys, or if any additions are made to the list of authorized operators.

3. Post these procedures in a conspicuous place in the work area.

GET:3312:mr

Distribution:
3312 C. B. Berglund (Original + 1)
4535 J. S. Sivinski
4535 M. E. Morris
4535 J. D. Pierce

Copy Copy

SAFE OPERATING PROCEDURES

FOR

The Sandia Irradiator for Dried Sewage Solids (SIDSS)

DO NOT ATTEMPT TO OPERATE THIS FACILITY UNLESS YOU ARE AN AUTHORIZED OPERATOR.

READ THESE PROCEDURES COMPLETELY BEFORE OPERATING THE FACILITY IN ANY MODE.

IF, AT ANY TIME, UNUSUAL RADIATION FIELDS ARE NOTED, EVACUATE ALL PERSONNEL THROUGH THE EAST GATE OF THE FENCED AREA.

AFTER USE, THE FACILITY MUST BE RETURNED TO THE "OFF" MODE AND THE CONTROL PANEL, BUILDING 6720, AND THE AREA GATE MUST BE LOCKED. (KEYS WILL BE UNDER THE CONTROL OF 4535 PERSONNEL AND ISSUED, BY LOG, ONLY TO AUTHORIZED OPERATORS).

SPECIFIC ACTIONS BY THE OPERATOR(S)

1. All SIDSS operating and product loading personnel must wear personnel radiation dosimeter badges and "chirpers" while in the SIDSS area.

2. The radiation alarms must be checked immediately upon entering the SIDSS area and a radiation survey completed before proceeding with any operations.

ACTIVITIES THAT MUST BE COORDINATED WITH HEALTH PHYSICS

1. Bypassing any facility interlocks.

2. Modification of equipment or shielding.

3. Operation of the facility in any mode other than the "Normal" or "Off" mode.

AUTHORIZED OPERATORS

Signatures below indicate that the signer has read and is familiar with these procedures and the standard operating procedures in the FSAR.

Authorized Operator	Supervisory Approval	Date
[signature]	[signature]	7/30/79
[signature]	[signature]	7/30/79

Approved: [signature]
J. S. Divinski - 4535

Approved: [signature]
G. E. Tucker, Jr. - 3312