PROPOSAL FOR AMENDMENT TO
SPECIAL NUCLEAR MATERIAL LICENSE SNM-639

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It is requested that the quantity of special nuclear material Uranium-235 be amended from our present possession limit of 250 grams as per License SNM-639, to 650 grams of Uranium-235. The proposed quantity limitation of 650 grams of ^{235}U is based upon data given in report ANSI-N16.1-1969 by the American National Standard for Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors and our requirements in conducting nuclear experimental programs. A copy of this standard is attached in Appendix II.

a. Limitations

Operations with fissile materials may be performed safely by complying with any one of the subcritical limits specified in ANSI-N16.1-1969. The subcritical, single-parameter limit for mass of fissile nuclide ^{235}U in a nonuniform slurry is 700 grams. We propose that the total on site mass of fissile nuclides pertaining to SNM-639 shall not exceed 650 grams.

b. Process Analysis

Procedures have been written for all aspects of our experiments involving uranium enriched in the isotope ^{235}U, and everyone participating in these experiments has familiarized themselves with them. Every experiment irradiated in the Union Carbide reactor is evaluated comprehensively by the Nuclear Safeguards Committee to insure that all potential hazards are identified and that the experiments adhere to the required specific technical limitations.

c. Material Control

To insure that inaccuracies will not result in exceeding our proposed 650 gram limit for a running total mass on site, the movement of fissionable materials shall be controlled at all times. The list of controlling parameters is as follows:

1. Not more than 300 grams of special nuclear material shall be ordered at any one time. All incoming orders will be approved by the Health Physics Supervisor.
2. A special nuclear materials control sheet shall be maintained at all times by the Health Physics Supervisor. Accountability of SNM authorized herein shall be maintained in accordance with procedures set forth by the Health Physics Supervisor. A copy of the ^{235}U Master Log sheet is included as Appendix III.
3. Irradiation targets containing ^{235}U shall be numbered and used in an approximate chronological order.
4. When not in use, all unirradiated special nuclear material will be kept in a locked steel cabinet.

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5. Not more than 350 grams of special nuclear material ^{235}U shall be stored in the locked steel cabinet at any one time. The locked cabinet shall be stored in a restricted area of the Hot Laboratory (Appendix IV). This area is patrolled on a 2-hour interval during non-operating periods. Keys to the cabinet shall be kept by the Health Physics Supervisor and an alternate authorized individual designated by the Health Physics Supervisor.

6. Not more than 200 grams of unirradiated ^{235}U shall be in solution at any one time.

7. Not more than a total of 300 grams of ^{235}U will be present at any one time in encapsulated targets intended for irradiation.

8. Irradiation targets shall be stored in a locked storage compartment within a restricted Hot Laboratory area (Appendix V). This area is segregated from the locked steel cabinet containing the bulk ^{235}U.

9. Not more than 500 grams of irradiated ^{235}U will be permitted in the Hot Cells at any one time.

10. No other fissionable material, viz., spent fuel elements and/or source material, shall be permitted in the hot cells with unencapsulated ^{235}U.

11. Reflecting materials such as beryllium and deuterium shall not be permitted in the Hot Cells with unencapsulated ^{235}U.

12. An inventory of ^{235}U in the Hot Cells shall be maintained and incorporated in the operating procedures.

13. Dissolution materials shall be stored in the Hot Lab cells in an array such that the batch solutions containing irradiated ^{235}U can be ascertained. A schematic of our proposed in-cell storage area for spent ^{235}U solutions is attached in Appendix VI.

14. Concentrations of alpha radioactivity in the air effluent from the Hot Laboratory facility shall be determined whenever operations are performed with unencapsulated ^{235}U.

15. Air samples and smear surveys shall be conducted during work with any unencapsulated ^{235}U. Removable alpha contaminants from 100 cm^2 of floor area in excess of 100 dpm shall require immediate clean-up.

16. Spent solutions containing irradiated ^{235}U shall be solidified, placed in approved type containers, and shipped as solid waste to approved burial sites.

17. Disposal of spent solutions containing ^{235}U shall be under the supervision of the Superintendent of Nuclear Operations and the Health Physics Supervisor.

18. Regulations of Department of Transportation and Atomic Energy Commission pertaining to disposal of enriched Uranium and mixed fission products shall be strictly adhered to.

d. Accountability Errors

To insure that the single-parameter limit of 700 grams will not be reached, the following margins of error have been calculated based upon our assay techniques:

Operation	% Error
Weighing of uranium oxide	$\pm$ 0.1%
Assay of encapsulated UO_2	$\pm$ 3.0%
Assay of Uranium in solution	$\pm$ 1.5%
Amount of Uranium in Hot Cell	$\pm$ 3.0%

Assuming that all assay errors during the various stages of the process are in the same direction, then the total error in the inventory records could be 27.3 grams of UO_2.

(300 grams of UO_2 in storage)	(0.001)	= 0.3 grams
(300 grams of UO_2 in irradiation targets)	(6.03)	= 9.0 grams
(200 grams of UO_2 in solution)	(0.015)	= 3.0 grams
(500 grams of UO_2 in the Hot Cell)	(0.03)	=15.0 grams
TOTAL		- 27.3 grams

With the proposed limit of mass and the calculated margin of assay error, it can be seen that the greatest error is approximately two (2) times the margin (50 grams) we have allowed between the quantity of ^{235}U we are requesting, and the 700 gram mass limitation specified in ANSI-N16.1-1969. The errors cannot be compounded since a new assay of UO_2 is performed each time a portion of the UO_2 is transferred.

e. Operational Control and Reviews

Process conditions for experimental work with source and/or special nuclear material are initially approved by the Nuclear Safeguards Committee prior to use. The Nuclear Safeguards Committee continually reviews the conditions of the experiments to ascertain that procedures are being properly followed and that operational conditions have not been so altered as to effect the overall nuclear criticality safety parameters as indicated in the proposal.

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STERLING FOREST
RESEARCH CENTER

APPENDIX F

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April 28, 1969

Mr. D. A. Nussbaumer
Source and Special Nuclear Materials Branch
Division of Materials Licensing
U. S. Atomic Energy Commission
Washington, D.C. 20545

Dear Mr. Nussbaumer:

Union Carbide Corporation hereby requests the renewal of our Special Nuclear Material License No. SNM-639. This license is required in conjunction with our New York State Radioactive Materials License No. 729-0322 and our A.E.C. Reactor Operating License No. R-81 to cover a broad program of research and development. This license does not authorize the insertion or removal of special nuclear materials into or from our nuclear reactor. It does cover work with special nuclear material in our Hot Laboratory which is connected to our reactor building (see attached floor plan).

The special nuclear materials covered by this license are:

Materials	Quantity Limit
A. U-233	A. 10 grams
B. U-235	B. 250 grams
C. Pu-238	C. 2 milligrams
D. Pu-239	D. 10 grams
E. Pu-241	E. 2 milligrams
F. Pu encapsulated as Pu-Be neutron sources	F. 160 grams
G. The special nuclear material contained in four (4) spent fuel elements from U.C.C. research reactor.	

When not being used, all unirradiated special nuclear material will be kept in a locked steel cabinet under the control of the Health Physics Department. Work with more than 0.1 gms of Plutonium or 10 millicuries of any other special nuclear material, in unencapsulated form, shall be performed in a glove box or hot cell with separate alpha containment. The concentrations of alpha radioactivity in the air affluent from the Hot Lab facility shall be determined whenever operations are performed with unencapsulated special nuclear materials.

A maximum of four spent fuel elements from our research reactor will be utilized in the hot cells at one time as a source of gamma photons. No other fissionable material will be permitted in the cell with the four fuel elements. Four spent elements will contain approximately 640 grams of Uranium-235 (four new elements would contain approximately 784 grams of Uranium-235). No cutting or dissolution of these elements will be done.

Mr. D. A. Nussbaumer
U.S. Atomic Energy Commission: April 28, 1969

During work with any unencapsulated special nuclear material, room air samples and floor wipes shall be counted for alpha radioactivity. Removable alpha radioactivity from 100 cm^2 of floor area in excess of 100 dpm shall require immediate clean-up.

Because of the research nature of our activities we are not able to provide exact details on equipment and procedures. All equipment and procedures involving the use of licensed materials are required to be reviewed and approved by our Nuclear Safeguards Committee.

The Committee is charged with the responsibility for insuring that the administrative controls, operating procedures and experimental programs of the reactor and hot laboratory are reviewed and approved to minimize the hazards to the facility, the staff, and the general public. The Committee is to insure that all operations and experiments are conducted in accordance with existing State and Federal regulations, and that the procedures and experiments not approved in the facility operating license or in applicable amendments are not conducted until approval is received from the Atomic Energy Commission. In general, the Committee shall

A. Review and evaluate scheduled experiments, and make recommendations for the safe conduct of experiments in the facility.

B. Review and evaluate the qualifications of the individuals desiring to use radioactive materials at the facility.

C. Review and evaluate operating procedures, and recommend safe limits of operation.

D. Review and evaluate proposed changes to the control system of the reactor or of related equipment that affect the safety of the facility.

E. Recommend procedures for the safe handling of materials and equipment used in applications that may involve radiation hazards. These procedures shall conform to all existing local and federal regulations.

F. Review and evaluate proposals for the purchase of radioactive materials.

G. Review and evaluate health physics procedures and to recommend procedures for the facility that conform to all existing local and federal regulations. The Committee shall evaluate emergency disaster and evacuation procedures.

H. The Committee shall review reports describing the causes and results of all incidents which might have or did lead to radiation hazards and recommended remedial action and changes to existing methods of operation. Such reviews shall be made a part of the Committee's record and used as a guide in future evaluations.

Mr. D. A. Nussbaumer
U.S. Atomic Energy Commission: April 28, 1969

The Committee is composed of the following persons:

1. Chairman, a senior technically qualified person not in the line of organization of the Operations or Research Groups.

2. A senior technically qualified person responsible for the operation of the laboratory.

3. An engineer directly responsible for the operation of the Hot Lab.

4. A responsible health physicist.

5. A consultant in the field of reactor technology.

6. A consultant in the field of hot laboratory operations.

The consultants shall visit the laboratory at least once each twelve months to review the operating procedures and to assist the Committee in the review of the experimental program.

The special nuclear materials covered by this license are used in our Radioactive Materials Laboratory (Hot Lab) in a broad program of research and development.

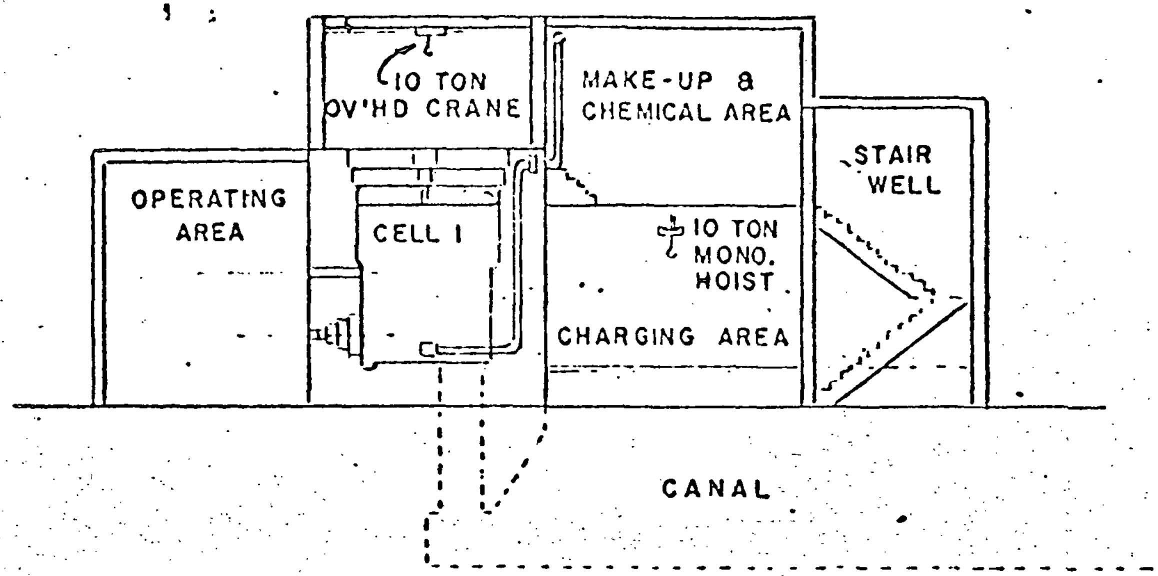
The Hot Laboratory is a concrete structure 139 feet long by 57 feet wide by 37 feet high. There are five hot cells, each having 4 foot thick walls of high density concrete (240 lbs/ft^3). The cells are separated from each other by 4 foot thick, high density concrete walls. An elevation and section drawing for the Hot Lab is shown in Fig. 2. Fig. 3 shows the second floor working area for the Hot Lab, and Fig. 4 shows the second floor office area.

1. Hot Cells

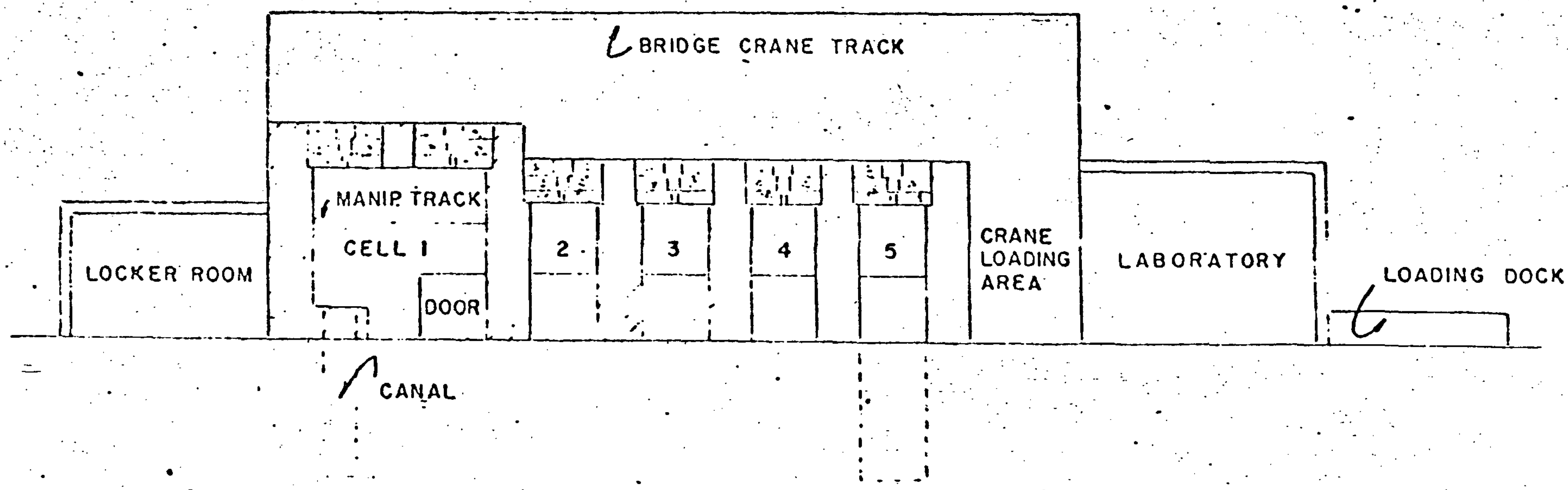
The cells are general purpose units designed to accommodate a variety of operations including chemical experiments, radiochemical separations of isotopes, physical testing for evaluation of irradiated material, solid state investigations and metallurgical work. A general description of the cells is presented below.

Cell 1 is 16 feet wide by 10 feet long by 15 feet in height. This cell is equipped with a General Mills Remote Handling Arm (750 lb. capacity), one pair of Heavy Duty Model 8 manipulators and one pair of Standard Duty Model 8 manipulators. Two Corning 4 foot thick glass shielding windows are located in the front shielding wall of Cell 1. These viewing windows consist of Corning's "Radiation Shield Standard Assembly 1480", which is their standard unit for 4 foot shielding walls. The windows are constructed from five sections of 3.3 density lead glass each 9-1/2 inches thick.

A Kollmorgan periscope, currently in use in Cell 1, can be relocated to any of the other cells. With auxiliary attachments on the periscope it is possible to do in-cell microscopy and to take photographs of specimens in the cell.



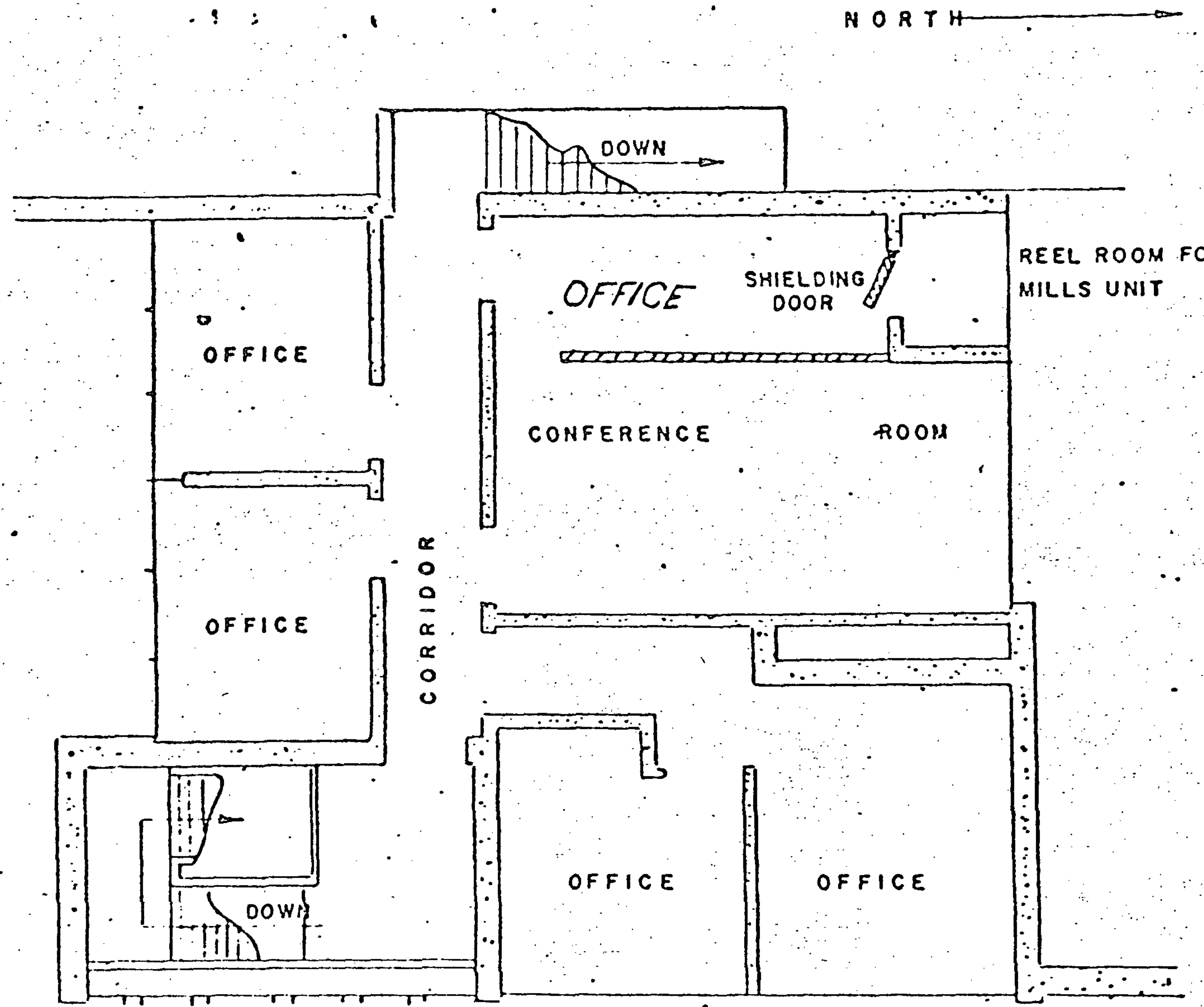
SOUTH ELEVATION THRU CELL I



WEST ELEVATION THRU CELL BLOCK

HOT LABORATORY : ELEVATION & SECTION

FIGURE 2.



HOT LABORATORY · OFFICE AREA · UPPER LEVEL

FIGURE 4.

Mr. D. A. Nussbaumer
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Cells 2, 3 and 4 are 6 feet wide by 10 feet long by 12.5 feet in height, while Cell 5 is 6 feet wide by 10 feet long by 25 feet in height. Cells 2, 3, 4 and 5 are each equipped with a Corning 4 foot thick glass shielding window and all cells are equipped with one pair of Model 8 Master Slave Manipulators.

Major access to all the cells is possible through the rear doors (7 feet wide by 6 feet high by 4 feet thick) which can be withdrawn utilizing electrical drives. The electrical connection and power supply to drive these doors are kept locked to prevent unauthorized entrance. An alarm sounds when any of these rear access doors are opened. The access doors for the cells are motor driven through a 1200:1 reduction worm gear and move on steel rails located in the floor of the charging area.

Access to all cells also is possible via top roof openings containing removable plugs. The roof and roof plugs of all cells are 3-1/4 foot thick magnetite concrete with a density of 240 lbs/ft^3. The roof plug is made up of three 14 inch thick concrete slabs which must be removed individually with a 10 ton capacity overhead crane. A 6 inch diameter charging sleeve located in the center of the roof plug is fitted with an 8 inch long lead filled steel plug. Two 4 inch diameter charging sleeves also are provided through the roof. They have magnetite plugs 6 inches in diameter at the exterior surface and are stepped to 4 inches in diameter 18 inches from the interior surface. There are laboratories and a solution make-up room above the charging area but no occupied areas directly above the cells.

A canal containing water 12 feet deep connects Cell 1 with the reactor pool. Radioactive samples, specimens, isotopes, etc., are transferred through this canal and brought into Cell 1 via an automatic elevator mechanism.

2. Operating Area

The area on the front side of the cells is the operating zone and is maintained as a clean area. The viewing windows, manipulator controls, intercell conveyor controls, in-cell service controls (air, water, vacuum, gas) and periscope are located in this area. The operating control panels for the ventilation system and the Radioactive Waste Water Treatment System are located at the north end of this area.

Fifteen radiation monitrons serving the Hot Lab and cells are linked to a master panel which is located in the operating area. Both audio and visual alarms are activated at this master panel. Ten monitrons, located outside of the cell, are normally set to alarm at 5.0 mr/hr. Five in-cell monitrons are used to indicate the radiation level within the cells. These can be set to alarm at any level from 1 to 10,000 mr/hr.

In the front shielding wall of each cell there are twelve removable 2 inch diameter stepped pipe sleeves, one 8-1/2 inch diameter sleeve (to accommodate the periscope) and two 10 inch diameter sleeves (to accommodate the Model 8 manipulators). When the sleeves are not in use magnetite shielding plugs are placed in the sleeves. Special services not available within the cell (such as inert gas, high pressure air, natural gas) can be led into the cells through special plugs which can be inserted in place of the standard 2 inch diameter stepped pipe sleeves. Locking bars are used to prevent accidental removal of any of these plugs.

3. Charging Area

The charging area is located to the rear of the cells. Controls for the rear access doors to the cells are located here. Access to the decontamination room, exhaust fan room, waste treatment facility and conveyor loading station are from the charging area (see Fig. 1).

The north loading dock is separated from the charging area by swinging doors. At the south end of the charging area swinging and sliding doors separate this area from the canal and the south loading dock.

In the rear shielding wall of each cell there are five 2 inch diameter stepped pipe sleeves. Each rear cell door also contains one 8 inch diameter stepped sleeve. These sleeves provide additional access ports from the charging area to the cells. They contain magnetite shielding plugs when not in use.

4. Radiochemical Laboratory

Low level radioactive specimens or samples will be handled in the Radiochemical Laboratory. Equipment available in the laboratory includes standard laboratory benches with stainless steel tops, glove boxes and hoods.

Operations in this laboratory involving higher level radioactive gases will be conducted within special hoods. There are three hoods; two regular and one walk-in unit. These hoods, with all interior surfaces of stainless steel, are 6 feet wide and are designed for work with radioactive materials. All flow from these hoods pass through roughing filters, and absolute filters (these are standard units) prior to passage to an exhaust fan and monitoring system. The exhaust air flows to a 50 foot stack which also receives exhaust air from the Reactor area.

Supporting non-radioactive analytical work also is done in this laboratory.

5. Second Floor Work Area

a. Laboratories

Two laboratories are located in this area. They will be used for work similar to that described for the Radiochemical Lab. All operations involving radioactive materials will be carried out in hoods of the type used in the Radiochemical Lab.

b. Solution Make-up Area

The solution make-up area is a room 20 feet by 11 feet located on the second floor of the Hot Lab. A 100 gallon stainless steel vessel and a centrifugal pump are available in this room. Chemical addition to the tanks and vessels in the Radioactive Waste Water Treatment System can be accomplished by preparing the desired solution in the 100 gallon vessel and pumping to any desired tank. A section of this room is used as a general purpose laboratory. It contains two hoods of the same type used in the Radiochemical Lab.

c. Work Area

An area, 38 feet by 20 feet, on the north end of the second level is utilized for major repair of Model 8 manipulators and for mock-up experiments of planned in-cell work. A unit for producing distilled water and a transmitter rack for instrumentation are located in this general area.

6. Maintenance Shop

A shop 29 feet by 25 feet is available in the Hot Lab. This shop contains a drill press, lathe, milling machine, band saw, electric and gas welding equipment, and a variety of hand tools.

7. Personnel Facilities

Six offices, a conference room, a change room (17 feet by 9 feet), a locker room (30 lockers), and rest rooms are in the Hot Lab.

AUXILIARY SYSTEMS

1. Ventilation System

The Hot Laboratory ventilation system is pressure regulated to insure a continuous, positive flow of air from non-radioactive areas to contaminated or radiation areas. There are two major supply fans. One fan supplies 21,000 cu.ft/min of air to the first floor offices, loading dock, second floor offices, operating area, and the Radiochemical Lab. A second fan supplies 9,000 cu.ft/min of air (total) to three laboratories on the second floor.

The cells are maintained at a negative pressure with respect to the operating area and the charging area. The system is designed to provide 20 air changes per hour in all cells. In any cell where fission products or other radioactive particulate matter may be handled the inlet is equipped with an Aerosolve 95 filter. Such filters have an efficiency of 90-95% for removal of atmospheric dust. These filters will limit "blowback" to the operating area during a sudden pressurization within the cell.

All exhaust air from the Hot Lab passes through roughing filters and absolute filters prior to discharge, via an exhaust fan, to the stack. The 50 horsepower exhaust fan, operating on normal power, has a capacity of 30,000 cu.ft/min against a head of 7.5" of water. In the event of a power failure the fan is automatically switched onto an emergency power station (gasoline driven generator) and operates at 1/2 speed on this emergency power supply.

An emergency fan (5 horsepower) with a capacity of 8,000 cu.ft/min against a head of 3.0" of water is provided as backup for the 50 horsepower fan. This fan can be operated on either normal or emergency power.

If a rear door of any cell or the door to the decontamination room is opened the flow of air is inward from the charging area to the cell. Approximately 100 ft/min of air flows past any rear cell door opening or decontamination door opening. For an open rear cell door this corresponds to a flow volume of approximately 4,000 cu.ft/min. This volume of air comes from the charging area. Air from the charging area normally discharges to the second floor.

Exhaust air from the Hot Lab is added to the exhaust air from the Reactor area and the combined flow discharges into a 4 foot diameter vent header which leads to a stack. Its base is located on a ridge at an elevation of 945 feet. The stack is 50 feet high and the top is at an elevation of 995 feet, about 187 feet above the main floor of the Hot Lab. All exhaust air entering the stack is continuously monitored for gaseous and particulate radioactivity.

2. Radioactive Waste Water Treatment System

The Radioactive Waste Water Treatment System is utilized to treat wastes containing isotopes higher than the levels prescribed by Sec. 20.106 10 CFR Part 20. The bulk of the waste water, after treatment, is suitable for discharge from the site. The handling and treatment facilities combine storage, evaporation, ion exchange, and recycle if it is required, to accomplish this objective.

All radioactive waste water resulting from Reactor or Hot Laboratory operations are collected in a 7200 gallon stainless steel tank located in a separate cell under the main floor of the Hot Laboratory. All hot drains in the Hot Lab and drains from vent and off-gas headers also tie into this tank. There is access to this cell via a shielded 3 foot square by 3 foot thick plug in the charging area. The following units are located in a separate area adjacent to the 7200 storage tank:

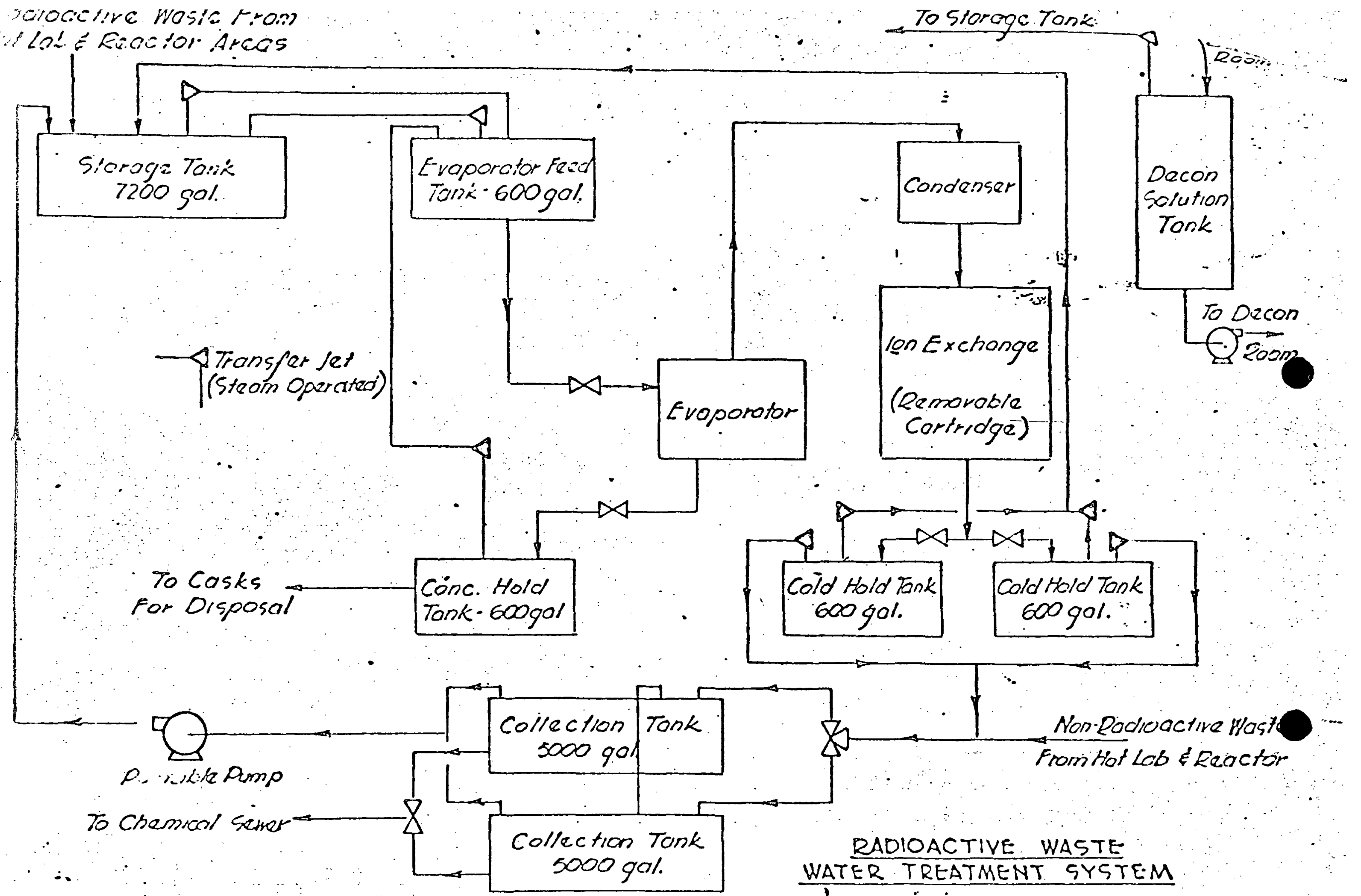
Evaporator Feed Tank	-	600 gallon capacity
Evaporator	-	1500 gal/day capacity, heat source - steam in external jacket.

Ion Exchange Columns	-	Two, containing cation and anion resin, each column 4" diameter by 2 feet long.
Cold Hold Tanks	-	Two, each 600-gal. capacity, for receiving decontaminated water following ion exchange.
Concentrate Hold Tank	-	600 gal. capacity for receiving concentrated radioactive waste water from evaporator.
Sampling System	-	Recirculating hypodermic needle type similar to system used at ORNL Thorex pilot plant.
Instrumentation	-	All tanks equipped with liquid level and density indicators with audio and visual alarms.

The radioactive waste water system is designed for batch or continuous type operation. Samples of the contents of the storage tank are taken via a sampling system and the activity of the waste determined. The volume and the activity of the wastes to be treated determine the method of evaporator operation. For example, high level, low volume wastes are evaporated at a very low rate (5 GPH) to obtain the highest decontamination factor possible for the evaporation cycle and the ion exchange cycle. Low level, large volume wastes are evaporated at increased rates (60 GPH). The decontaminated wastes are collected in either of two clean hold-up tanks. When one tank is full, flow from the ion exchange columns is directed to the other tank. Samples are taken of the contents of these hold-up tanks. If the activity level is satisfactory for discharge, the tank contents are jetted to a waste header leading to two 5000 gallon hold tanks. If the activity level is too high for discharge, the liquid is recycled through the evaporator-ion exchange circuit.

The ion exchange columns, 4" diameter by 2 feet long, are continuously monitored. They are connected into the system by snap-tite quick disconnect units and they are replaced prior to exhaustion and before they become too radioactive to handle with 2-foot tongs. A radiation monitron is located adjacent to the columns. The radiation level detected by this unit can be read on the radiation monitron control panel in the operating area. The spent columns (with resin) will be placed in a suitable container for shipment to an approved burial ground.

The concentrated, low volume radioactive waste water is converted into a solid form by using such wastes to prepare concrete or plaster of paris. This solid material is placed in containers which conform to DOT regulations governing the packaging and shielding of radioactive materials for shipment. The containers are monitored for both contamination and external radiation before they are shipped. After packaging, these containers are shipped to an approved burial site.



RADIOACTIVE WASTE
WATER TREATMENT SYSTEM

Figure 8

High level radioactive waste liquids produced as a result of research and development with nuclear fuel elements or other operations will be processed to a solid and packaged within a hot cell. An example of this would be fission product wastes resulting from fuel reprocessing studies. Such wastes would be shipped, in approved containers, to the burial ground.

3. <u>Non-Radioactive Waste Water</u>

All other waste water from the Reactor and Hot Lab, with the exception of sanitary wastes and storm water, are collected in two 5000 gallon hold-tanks. These two 5000 gallon tanks were incorporated in the waste system to prevent the accidental discharge of contaminated water from the site. For example, water flowing through cooling coils in some of the radioactive waste water treatment vessels discharges into a header which leads to the 5000 gallon tanks. If any of these coils ruptured, radioactivity could contaminate the cooling water. Without the two hold-up tanks this contaminated water would be discharged from the site.

The waste water collected in these tanks is sampled and checked for activity. If the activity is lower (considering dilution with other non-radioactive waste water from the site) than values specified in Sec. 20.106 of 10 CFR 20, the waste water is discharged. If the contents of either of the 5000 gallon vessels require treatment to remove radioactivity the water is pumped to the 7200 gallon storage tank in the Radioactive Waste Water Treatment System.

A record is kept of the amount and concentration of waste water leaving the site. If both 5000 gallon vessels are full, Hot Lab operations which generate non-radioactive waste water will be restricted. The inlet valves to these tanks will be closed. There is approximately 2000 gallons of capacity available in the process header (and manhole) leading from the Hot Lab to the 5000 gallon hold tanks. Under our usual operating conditions this is sufficient for at least 10 hours. In this time the 5000 gallon vessels can be sampled and the samples counted to determine activity. The tank contents can be either discharged from the site or if the waste water contains radioactivity above allowable limits it will be pumped back to the main storage vessel in the Radioactive Waste Water Treatment System.

4. <u>Intercell Conveyor</u>

An intercell conveyor permits transfer of samples or equipment between cells or from an external loading station to any cell.

The intercell partitions have 12 inch by 14 inch openings in them to allow for passage of the intercell conveyor.

HOT LAB OPERATIONS

1. Rules of Practice

A Nuclear Safeguards Committee is responsible for insuring that the administrative controls, operating procedures and experimental programs of the Reactor and Hot Laboratory are reviewed and approved to minimize the hazards to the facility, the staff, and the general public. The committee will insure (1) that all operations and experiments are conducted in accordance with existing State and Federal regulations and (2) experiments not approved in the facility operating license or in applicable amendments are not conducted until approval is received from the Atomic Energy Commission.

2. Responsibility for Operations

Operations in the Hot Lab are the direct responsibility of the Supervisor - Nuclear Operations, who reports to the Director-Nuclear Operations of the Research Center. It is the responsibility of the supervisor to direct operations, assign and schedule all work in the Hot Lab and see that this work is carried out safely.

3. Level of Activity

There is sufficient shielding to permit the safe handling of 1 million curies of Cobalt-60 or equivalent radiation in any of the 5 cells with the resulting dose rate at the external wall of the shield being no more than 2 mr/hr in areas normally occupied by personnel.

4. Alpha Work

These hot cells are not specifically designed for handling alpha emitters such as plutonium 239. Separate alpha containment will be provided for work in the cells involving more than one gram (.63 mc) of plutonium 239 or equivalent of a plutonium compound. All work in the Radiochemical Laboratory or other laboratory areas involving plutonium will be done in special equipment designed for alpha work.

HEALTH PHYSICS AND GENERAL SAFETY

A senior Health Physicist is responsible for all phases of Health Physics as well as the general safety procedures for the Reactor and Hot Lab areas. He supervises the activities of Health Physics technicians.

1. Health Physics Training

All personnel working with radioactive material in the Hot Lab receive basic radiation safety training. This initial radiation safety instruction is supplemented by on-the-job training during each new operation.

d. Stack monitor

The exhaust air from both the Reactor and Hot Laboratory are continuously monitored for radioactive particulate matter and for gaseous activity. This monitor is equipped with a recorder and alarm circuits to indicate high activity or equipment failure. It is checked on a routine basis at least once a day. Any unexpected increase in stack activity is investigated to determine the cause and the corrective action necessary to eliminate it.

e. Hot Lab evacuation system

An intercom system is in operation with units located in every major area of the Hot Lab. Auxiliary amplifiers have been provided and tests have proved that an evacuation alarm announced over this system from the front office on the first floor can be clearly heard in any area. This is utilized as the evacuation alarm system and all personnel have been instructed in the use of the system.

f. Wipe tests

Wipe tests are made of the floors daily. All equipment and materials require Health Physics approval before being removed from a controlled area. All materials packaged for off-site shipment are checked to insure that all appropriate shipping regulations have been followed.

4. General Safety

a. Fire and explosion potential

Fire extinguishers (dry chemical and CO_2) are available. They are located in the cell if flammable materials are being handled. The fire extinguisher itself is located in-cell with the operating mechanism for discharging the unit located in the operating area.

Flammable solvents will not be heated or steam jetted. Any explosion as a result of burning such solvents would be a low grade type and the force would be contained by the foot foot thick cell walls. No more than 2 liters of flammable solvent will be contained in any cell at one time with a maximum of 5 liters in the entire cell block at the same time. If 2 liters of an organic solvent (such as kerosene) exploded the volume formed, at the atmospheric pressure would cause a pressure rise of only 0.2 inches of water. Inasmuch as the pressure within the cells is maintained at 0.5 inches below that in the operating area the pressure rise due to 2 liters of solvent exploding would not result in the pressure in the cell exceeding that in the operating area.

Other explosive materials (such as NaK, hydrazine) are not stored in the cells.

2. Personnel Monitoring

All personnel working in the Hot Lab wear a film badge and two pocket ionization chambers. The pocket chambers are read daily and the film badges are evaluated biweekly by an approved commercial laboratory.

3. Instruments and Equipment

All radiation detection and monitoring equipment are set and kept in proper operating condition by the Health Physicist.

a. Radiation detection and monitoring

Radiation detection instruments available for monitoring include at least (5) Ion Chamber Meters with range up to 50,000 mr/hr, (2) Geiger Detectors with range up to 20 mr/hr, (1) Alpha Scintillation Counter, (1) Atomic Model 1095 Scaler and End Window G.M. Counter, (1) Gas-Flow Proportional Counter with Tracerlab Ampliscaler, and (1) Pulse Height Analyzer.

Portable radiation detection equipment such as cutie-pies and G-M survey meters are located at various points in the area and a Hand and Foot Counter is near the main exit from the Hot Lab. It is used by visitors and personnel before going to lunch or leaving the building.

b. Area monitrons

Area radiation monitrons are located in 15 different positions throughout the Hot Lab. Five are located in-cell (one in each cell), three in the charging area, two in the second level area above the cells, and one each at 1) south loading dock, 2) canal gamma facility, 3) ion exchange columns in Radioactive Waste Water Treatment System, 4) exhaust air filter room, and 5) operating area. These monitors have audio and visual alarms at the local point and at the main monitron control panel in the operating area of the Hot Lab.

These area monitrons, excluding the in-cell units, are normally set to alarm at 5.0 mr/hr.

c. Air Monitors

Two continuously-operated air monitors are located in the Hot Lab. These units include an audible alarm system and a recorder. In addition, there are approximately ten two-inch-diameter air sampling units operating continuously, connected to the building vacuum system. They contain both a particulate filter and activated carbon. These samples are evaluated at least once during each working day.

b. Other safeguards

All two inch diameter cell access plugs in the operating area shielding wall are bolted to the concrete on the outside of the cell to prevent blowing out in the case of an explosion.

All spare lines terminating in-cell are capped.

Chemicals or solvents are not stored in the cells. Small quantities (up to 5 liters) are kept in the Radiochemical Lab. Larger quantities are not stored in the Hot Lab but are procured as needed from a central solvent storage area.

In this application, requesting renewal of our Special Nuclear Material License No. SNM-639, we have attempted to provide sufficient information to enable you to grant a renewal of our license. If you find that you need additional information, please let me know.

Very truly yours,

C. J. Konnerth

C. J. Konnerth
Health Physics Supervisor

CJK:AB

ANSI
N16.1-1969
Revision of
N6.1-1964

American National Standard For Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors

Sponsor

American Nuclear Society

Approved August 1, 1969

American National Standards Institute

Foreword

(This Foreword is not a part of American National Standard for Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors, N16.1-1969.)

This Standard provides guidance for the prevention of criticality accidents in the handling, storing, processing, and transporting of fissionable materials. It was first drafted in 1958 by a subcommittee of both the Standards Committee of the American Nuclear Society and Sectional Committee N6 of the American Standards Association and was designated American Standard N6.1-1964. (In 1966, the USA Standards Institute was constituted as successor to the ASA; in 1969 the name of the Institute was changed to American National Standards Institute.) Increased basic knowledge and operating experience have made desirable this revision which extends American Standard N6.1-1964 and includes the specification of limits applicable to process variables for the prevention of criticality accidents. The revision was inaugurated by the Sponsor in 1963 and was approved finally by the formulating group in 1968. An American Standards Committee processed and approved the proposal in 1969.

The Standards Committee, N16, on Nuclear Criticality Safety, which processed and approved this Standard, had the following personnel:

Dixon Callihan, *Chairman* E. B. Johnson, *Secretary*

Organization Represented	*Name of Representative*
American Institute of Chemical Engineers	Alex Perge
American Nuclear Society	Dixon Callihan
American Society for Testing and Materials	A. N. Tschaeche J. A. Dwyer *(Alt)*
Atomic Industrial Forum, Inc.	D. F. Cronin
Health Physics Society	Fred Sanders
Institute of Nuclear Materials Management	C. Leslie Brown George Wuller *(Alt)*
U. S. Atomic Energy Commission	Wade C. McCluggage Robert L. Stevenson
U. S. Public Health Service	Robert Jacobs Frank R. Grossman *(Alt)*
Individual Members	E. B. Johnson H. C. Paxton

This revision was prepared by Subcommittee 8 of the Standards Committee of the American Nuclear Society which had the following personnel at the time of approval:

J. D. McLendon, *Chairman, Union Carbide Corporation, Nuclear Division, Y-12 Plant*
H. K. Clark, *E. I. Du Pont de Nemours and Company, Savannah River Laboratory*
E. D. Clayton, *Battelle Memorial Institute, Pacific Northwest Laboratory*
D. M. Dawson, *General Electric Company, Nuclear Fuels Department*
E. B. Johnson, *Union Carbide Corporation, Nuclear Division, Y-12 Plant*
W. A. Johnson, *U. S. Atomic Energy Commission, Oak Ridge Operations Office*
Norman Ketzlach, *Atomics International*
W. B. Lewis, *Phillips Petroleum Company, National Reactor Testing Station*
J. D. McGaugh, *Westinghouse Electric Corporation, Atomic Power Division*
Karl H. Puechl, *Nuclear Materials and Equipment Corporation*
C. L. Schuske, *Dow Chemical Company, Rocky Flats Plant*
A. J. Smith, *Lawrence Radiation Laboratory, Livermore*
David R. Smith, *Los Alamos Scientific Laboratory*
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The revision was drafted by a Work Group of the Subcommittee comprised of H. K. Clark, R. J. French, Norman Ketzlach, J. D. McLendon, and K. H. Puechl.

CONTENTS

American National Standard For Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors

Revised Standard

1. Introduction

Operations with fissionable materials introduce risks of a criticality accident resulting in the release of radiation that may be lethal to nearby personnel. Experience has shown, however, that extensive operations can be performed safely and economically when proper precautions are exercised. The few criticality accidents that have occurred show frequency and severity rates far below those typical of nonnuclear accidents. This favorable record can be maintained only by continued adherence to good operating practices. In seeking a balance between operating cost and nuclear criticality safety, the protection of operating personnel and the public must be the dominant consideration; however, it is not possible to establish safe processes in an absolute sense by this or any standard.

2. Scope

This Standard is applicable to operations with ^{235}U, ^{233}U, ^{239}Pu, and other fissionable materials outside of nuclear reactors, except the assembly of these materials under controlled conditions, such as in critical experiments. Generalized basic criteria are presented and limits are specified for some simple single fissionable units but not for multiunit arrays. This Standard does not include the details of administrative controls, the design of processes or equipment, the description of instrumentation for process control, or detailed criteria to be met in transporting fissionable materials.

3. Definitions

3.1 Limitations. The definitions given below are of a restricted nature for the purposes of this Standard. Other specialized terms are defined in American National Standard Glossary of Terms in Nuclear Science and Technology, N1.1-1967.

3.2 Glossary of Terms

3.2.1 *Shall, Should, and May.* The word "shall" is used to denote a requirement, the word "should" to denote a recommendation, and the word "may" to denote permission, neither a requirement nor a recommendation. In order to conform with this Standard, all operations shall be performed in accordance with its requirements but not necessarily with its recommendations.

3.2.2 *Nuclear Criticality Safety.* The prevention or termination of inadvertent nuclear chain reactions in nonreactor environments.

3.2.3 *Criticality Accident.* The release of energy as a result of accidentally producing a self-sustaining or divergent neutron chain reaction.

3.2.4 *Subcritical Limit (Limit).* A limit to a specified variable for the optimum values of all unspecified variables that keeps the system subcritical by a margin of reactivity sufficient to compensate for inexactness in experimental data and calculations, but that contains no allowance for operating contingencies (e.g., double batching) or for inaccuracies in the values of process variables (e.g., mass or concentration).

3.2.5 *Areal Density.* The product of the thickness of an infinite, uniform slab and the concentration of fissionable material within the slab; hence, the mass of fissionable material per unit area projected onto a plane parallel to the slab surfaces.

3.2.6 *Slurry.* A mixture or suspension of water and insoluble particulate fissionable material such as metal shavings, oxide particles, salts, or precipitates.

4. Nuclear Criticality Safety Practices

4.1 Administrative Practices

4.1.1 *Responsibilities.* Management shall clearly establish responsibility for nuclear criticality safety. Supervision should be made as responsible for nuclear criticality safety as for production, development, research, or other functions. Nuclear criticality safety differs in no intrinsic way from industrial safety, and good managerial practices apply to both.

Management shall provide personnel skilled in the interpretation of data pertinent to nuclear criticality safety and familiar with operations to serve as advisors to supervision. These specialists should be, to the extent practicable, administratively independent of process supervision.

Management shall establish the criteria to be satisfied by nuclear criticality safety controls. Distinction may be made between shielded and unshielded facilities, and the criteria may be less stringent when adequate shielding assures the protection of personnel.

4.1.2 *Process Analysis.* Before a new operation with fissionable materials is begun or before an existing operation is changed, it shall be determined that the entire process will be subcritical under both normal and credible abnormal conditions.

4.1.3 *Written Procedures.* Operations to which nuclear criticality safety is pertinent shall be governed by written procedures. All persons participating in these operations shall be familiar with the procedures.

4.1.4 *Materials Control.* The movement of fissionable materials shall be controlled. Appropriate materials labeling and area posting shall be maintained specifying material identification and all limits on parameters that are subjected to procedural control.

4.1.5 *Operational Control.* Deviations from procedures and unforeseen alterations in process conditions that affect nuclear criticality safety shall be investigated promptly and action shall be taken to prevent a recurrence.

4.1.6 *Operational Reviews.* Operations shall be reviewed frequently to ascertain that procedures are being properly followed and that process conditions have not been altered so as to affect the nuclear criticality safety evaluation. These reviews shall be conducted, in consultation with operating personnel, by individuals who shall be knowledgeable in nuclear criticality safety and who, to the extent practicable, should not be immediately responsible for the operation.

4.1.7 *Emergency Procedures.* Emergency procedures shall be prepared and approved by management. Organizations, local and offsite, that are expected to respond to emergencies shall be made aware of conditions that might be encountered, and they should be assisted in preparing suitable emergency procedures.

4.2 Technical Practices

4.2.1 *Controlling Factors.* Nuclear criticality safety is achieved by exercising control over:

(1) The mass and distribution of all fissionable materials, and

(2) The mass, distribution, and nuclear properties of all other materials with which the fissionable materials are associated.

4.2.2 *Double Contingency Principle.* Process designs should, in general, incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible.

4.2.3 *Geometry Control.* Where practicable, reliance should be placed on equipment design in which dimensions are limited, rather than on administrative controls. Full advantage may be taken of any nuclear characteristics of the process materials and equipment. Control shall be exercised to maintain all dimensions and nuclear properties on which reliance is placed.

4.2.4 *Neutron Absorbers.* Reliance may be placed on neutron-absorbing materials, such as cadmium and boron, that are incorporated in process materials or equipment or both, provided their effectiveness is confirmed by available data. Control shall be exercised to maintain their continued presence with the intended distributions and concentrations. Care should be taken with solutions of absorbers because of the difficulty of exercising such control.

4.2.5 *Subcritical Limits.* Where applicable data are available, subcritical limits shall be established on bases derived from experiments, with adequate allowance for uncertainties in the data. In the absence of directly applicable experimental measurements, the limits may be derived from calculations made by a method shown to be valid by comparison with experimental data, provided sufficient allowances are made for uncertainties in the data and in the calculations.

5. Single-Parameter Limits for Fissile Nuclides

Operations with fissile materials may be performed safely by complying with any one of the subcritical limits given in 5.1, 5.2, and 5.3 provided the conditions under which it applies are maintained. A limit shall be applied only when the effects of neutron reflectors and of other nearby fissionable materials are no greater than reflection by an unlimited thickness of water. The limits shall not be applied to mixtures of ^{235}U, and ^{233}U, and ^{239}Pu.

> ***Process specifications shall incorporate margins to protect against uncertainties in process variables and against a limit being accidentally exceeded.***

5.1 Uniform Aqueous Solutions. Any one of the limits of Table 1 is applicable provided a uniform aqueous solution is maintained and provided, for ^{239}Pu, at least four nitrate ions are present for each plutonium ion. The ^{239}Pu limits apply to mixtures of plutonium isotopes provided the concentration of ^{240}Pu exceeds that of ^{241}Pu and provided ^{241}Pu is considered to be ^{239}Pu in computing mass or concentration.

Table 1
Single-Parameter Limits for Uniform Aqueous Solutions Containing Fissile Nuclides

Parameter	Subcritical Limit for ^{235}U	^{233}U	^{239}Pu Provided N:Pu$\geq$4
Mass of fissile nuclide, kg	0.76[a]	0.55[a]	0.51[b]
Solution cylinder diameter, cm	13.9[a]	11.5[a]	15.7[b]
Solution slab thickness, cm	4.6[a]	3.0[a]	5.8[b]
Solution volume, liters	5.8[a]	3.5[a]	7.7[b]
Concentration of fissile nuclide, g/liter	11.5[a]	10.8[a]	7.3[c]
Areal density of fissile nuclide, g/cm^2	0.40[a]	0.35[a]	0.25[d]
Uranium enrichment, wt % ^{235}U	1.00[e]	—	—
Uranium enrichment in presence of two nitrate ions per uranium atom, wt % ^{235}U	2.07[f]	—	—

[a] Data from Ref. 1 (The references are listed in Section 7.)
[b] Data from Ref. 2
[c] Data from Ref. 3
[d] Data from Ref. 4
[e] Data from Ref. 5
[f] Data from Ref. 6

5.2 Slurries

5.2.1 *Uniform Slurries.* The limits of 5.1 may be used for macroscopically uniform slurries, provided:

(1) There are at least four nitrate ions intimately associated with each plutonium atom, and

(2) For the dimensional and volume limits, the ratio of hydrogen-to-fissionable material does not exceed that in an aqueous solution having the same concentration of fissionable material.

The limit on the enrichment of uranium in 5.1 is valid [7] only for slurries in which the ratio of surface-to-volume of the particles is at least 80 cm^{-1}.

5.2.2 *Nonuniform Slurries.* The limits on cylinder diameter and slab thickness in Table 1 may be used for nonuniform slurries provided [4]:

(1) Four nitrate ions are intimately associated with each plutonium atom,

(2) The restriction on the ratio of hydrogen-to-fissionable atoms, specified in Condition 2 of 5.2.1, is met everywhere throughout the system,

(3) For cylinders, the concentration gradient is only along the length, and,

(4) For slabs, the concentration gradient is only parallel to the faces.

For ^{239}Pu in the absence of nitrate ions, but with the proviso that no localized regions of density greater than 0.25 g of $^{239}Pu/cm^3$ are permitted, limits of 15.1 and 5.4 cm on cylinder diameter and slab thickness, respectively, are applicable [2] under Conditions 2, 3, and 4 above (this section).

The areal densities given in 5.1 are valid for nonuniform slurries provided these densities are uniform.

The subcritical mass limits for ^{235}U, ^{233}U, and ^{239}Pu in nonuniform slurries are 0.70, 0.52, and 0.45 kg, respectively [2, 4]. Nitrate ions need not be present.

5.3 Metallic Units. The enrichment limit for uranium and the mass limits given in Table 2 apply to a single piece having no concave surfaces. They may be extended to an assembly of smaller units provided there is no inter-unit moderation.

The ^{235}U and ^{233}U limits apply to mixtures of either isotope with ^{234}U, ^{236}U, or ^{238}U provided all isotopes except ^{238}U are considered to be ^{235}U or ^{233}U, respectively, in computing mass. The ^{239}Pu limits apply to isotopic mixtures of plutonium provided the concentration of ^{240}Pu exceeds that of ^{241}Pu, all plutonium isotopes are considered to be ^{239}Pu in computing mass, and no more than 1% ^{238}Pu is present.

Table 2
Single-Parameter Limits for Metal Units

Parameter	Subcritical Limit[a] for		
	^{235}U	^{233}U	^{239}Pu
Mass of fissile nuclide, kg	20.1	6.7	4.9
Cylinder diameter, cm	7.3	4.6	4.4
Slab thickness, cm	1.3	0,54	0.65
Uranium enrichment, wt % ^{235}U	5.0	—	—

[a] Data from Ref. 8.

6. Multiparameter Control

Although the single-parameter limits are adequate for many purposes, they are inconveniently and uneconomically small for many others. In many cases, simultaneous limitation of two or more parameters may allow more flexible operational control. General guidance for multiparameter control and for the extension of certain single parameter limits may be found in the technical literature [9-12].

6.1 Uranium Enriched to No More Than 5% ^{235}U. An application of multiparameter control is control of both the enrichment of uranium and one of the parameters of 5. Subcritical limits [13, 14] applicable to aqueous systems containing uranium metal or uranium oxide (UO_2), regardless of the degree of heterogeneity of the system, are specified as functions of enrichment in Figs. 1 through 5 which give, respectively, the mass of ^{235}U, the cylinder diameter, the slab thickness, the volume, and the areal density. These limits shall be applied only when the effects of neutron reflectors and other nearby fissionable materials are no greater than reflection by an unlimited thickness of water.

Process specifications shall incorporate margins to protect against uncertainties in process variables and against a limit being accidentally exceeded.

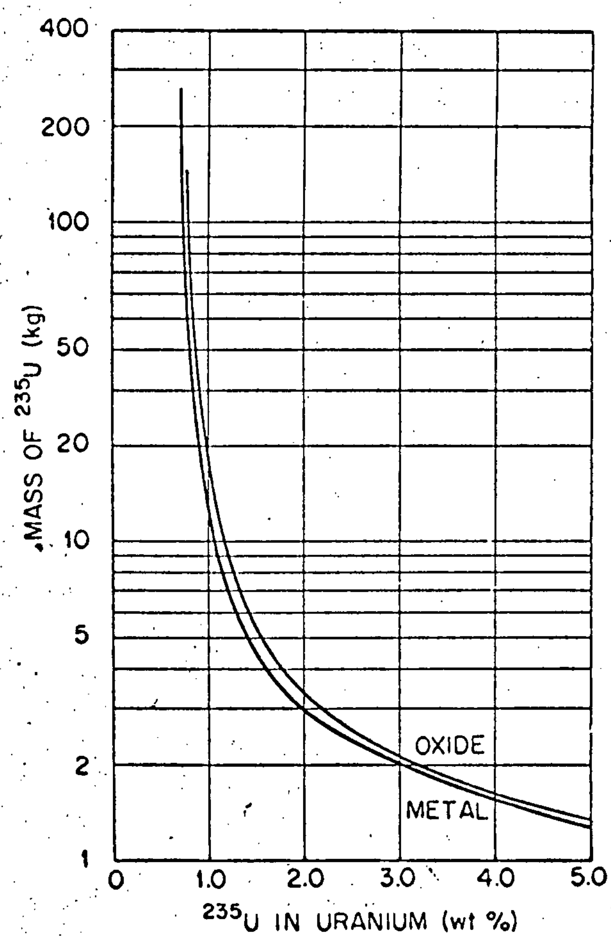

Fig. 1 Mass limit for uranium-water lattices.

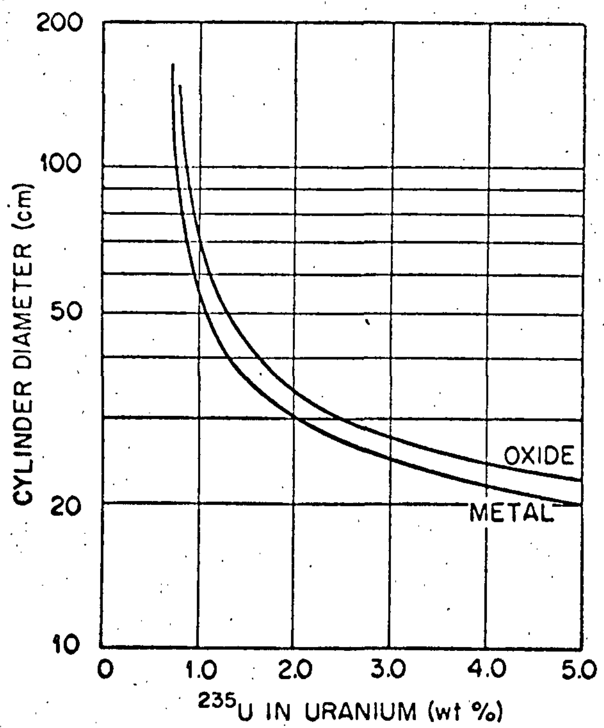

Fig. 2 Cylinder diameter limit for uranium-water lattices.

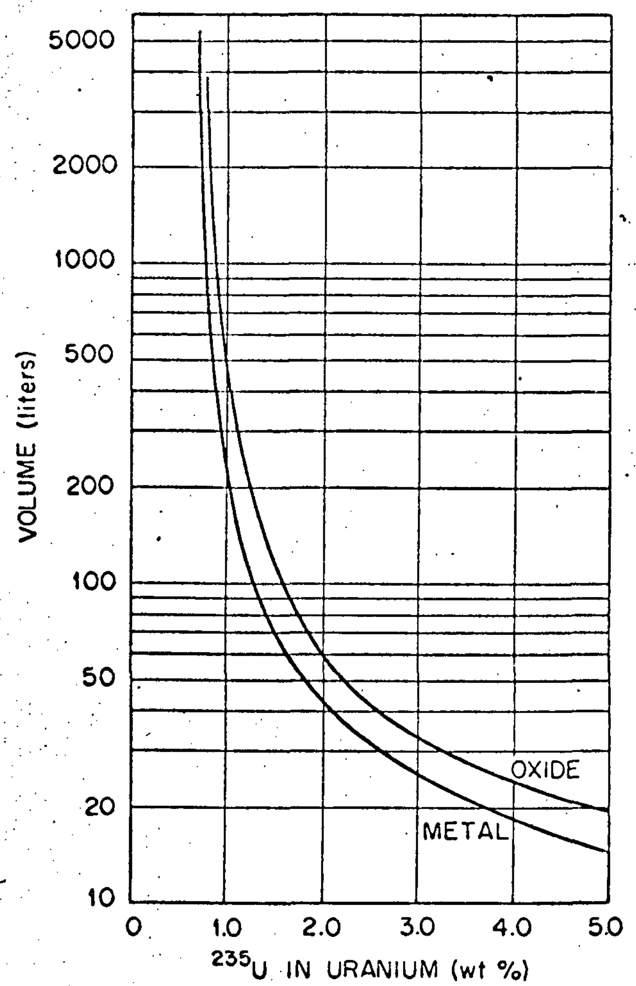

Fig. 4 Volume limit for uranium-water lattices.

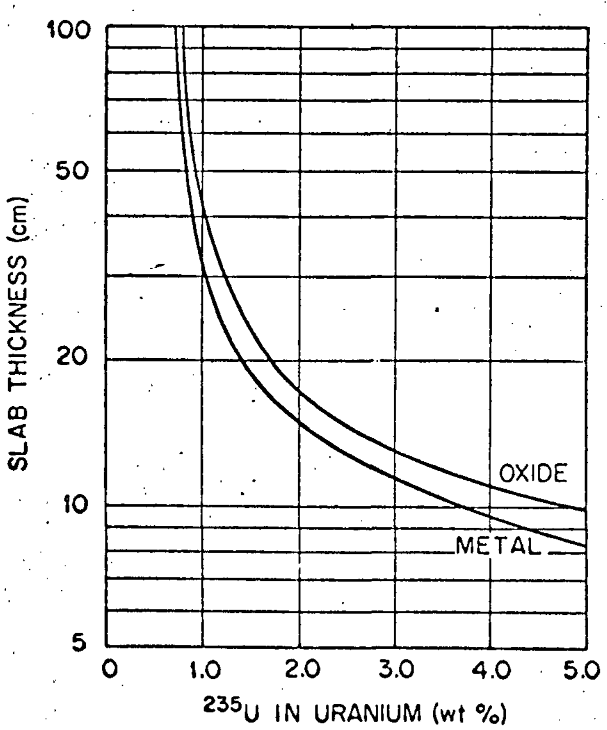

Fig. 3 Slab thickness limit for uranium-water lattices.

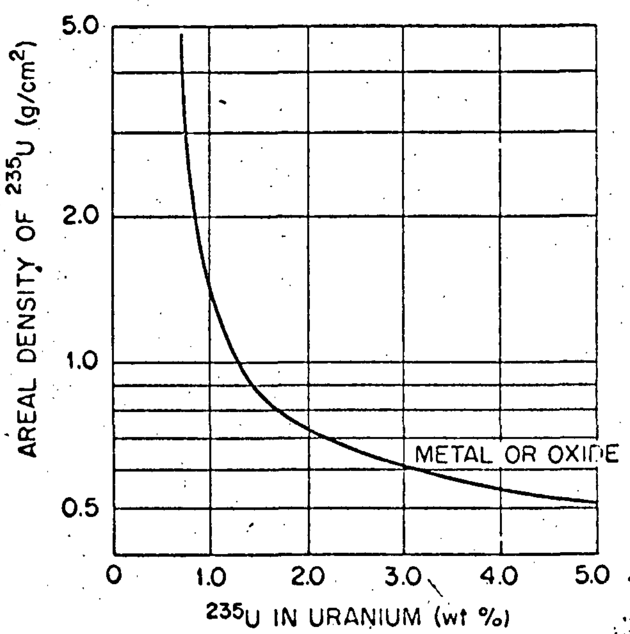

Fig. 5 Areal density limit for uranium-water lattices.

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Appendix

(This Appendix is not a part of American National Standard N16.1-1969 but is included for information purposes only.)

The determination that a process will be subcritical under credible abnormal conditions requires careful study. The following are typical examples of changes in process conditions that should be considered:

(1) A change in intended shape or dimensions resulting from bulging, corrosion, or bursting of a container, or failure to meet specifications in fabrication.

(2) An increase in the intended mass of fissionable material as the result of operational error.

(3) A change in the intended ratio of moderator to fissionable material resulting from:

- (a) Inaccuracies in instruments or chemical analyses.
- (b) Flooding, spraying, or otherwise supplying units or groups of units with water, oil, snow (i.e., low-density water), cardboard, wood, or other moderating material.
- (c) Evaporating or displacing moderator.
- (d) Precipitating fissionable material from solutions.
- (e) Diluting concentrated solutions with additional moderator.

(4) A change in the effectiveness of an absorber resulting from:

- (a) Loss of solid absorber by corrosion.
- (b) Loss of moderator.
- (c) Redistribution of absorber and fissionable material by precipitation of one but not the other from a solution.
- (d) Redistribution of solid absorber within a matrix of moderator or solution by clumping.
- (e) Failure to add the intended amount of absorber to a solution or failure to add it with the intended distribution.

(5) A change in the effectiveness of a reflector resulting from:

- (a) An increase in reflector thickness by adding additional material (e.g., water or personnel).
- (b) A change in reflector composition such as loss of absorber (e.g., by corrosion of an outer casing of absorber).

(6) A change in the interaction between units and reflectors resulting from:

- (a) The introduction of additional units or reflectors (e.g., personnel).
- (b) Improper placing of units.
- (c) Loss of moderator and absorber between units.
- (d) Collapse of a framework used to space units.

(7) An increase in the intended density of fissionable material.

(8) The substitution of units containing more fissionable material than intended as a result of operational error or improper labeling.

Appendix III

^{235}U MASTER LOG

Date	Description of Transaction	Quantity in Ready Storage			Quantity in Process			Quantity in Waste Storage			Balance on Hand			Custodian	H.P. Supvr.
		Element	Enr.	Isotope	Element	Enr.	Isotope	Element	Enr.	Isotope	Element	Enr.	Isotope		

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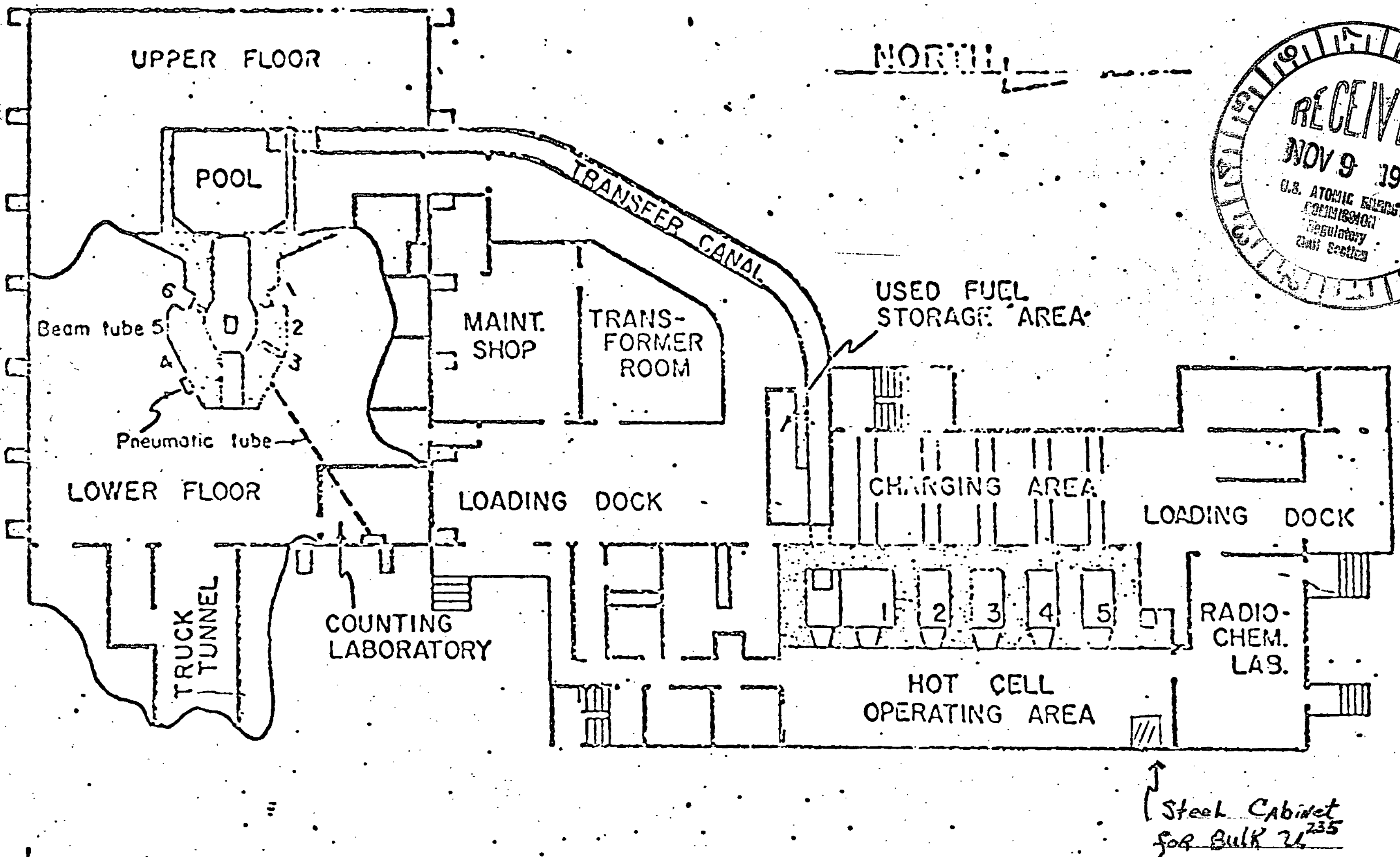

PLAN OF REACTOR AND HOT LABORATORY

FIGURE I

APPENDIX IV

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APPENDIX V

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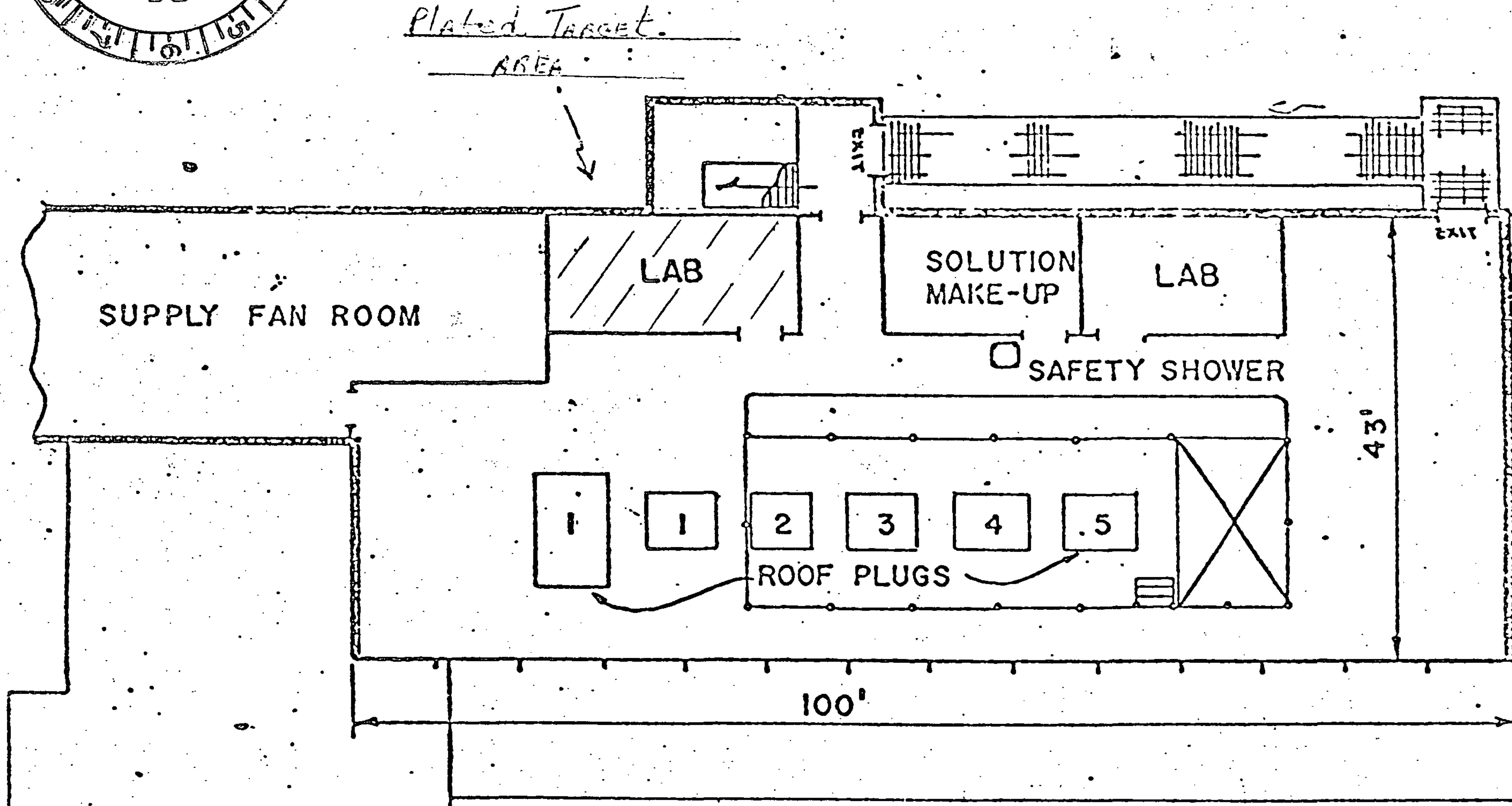
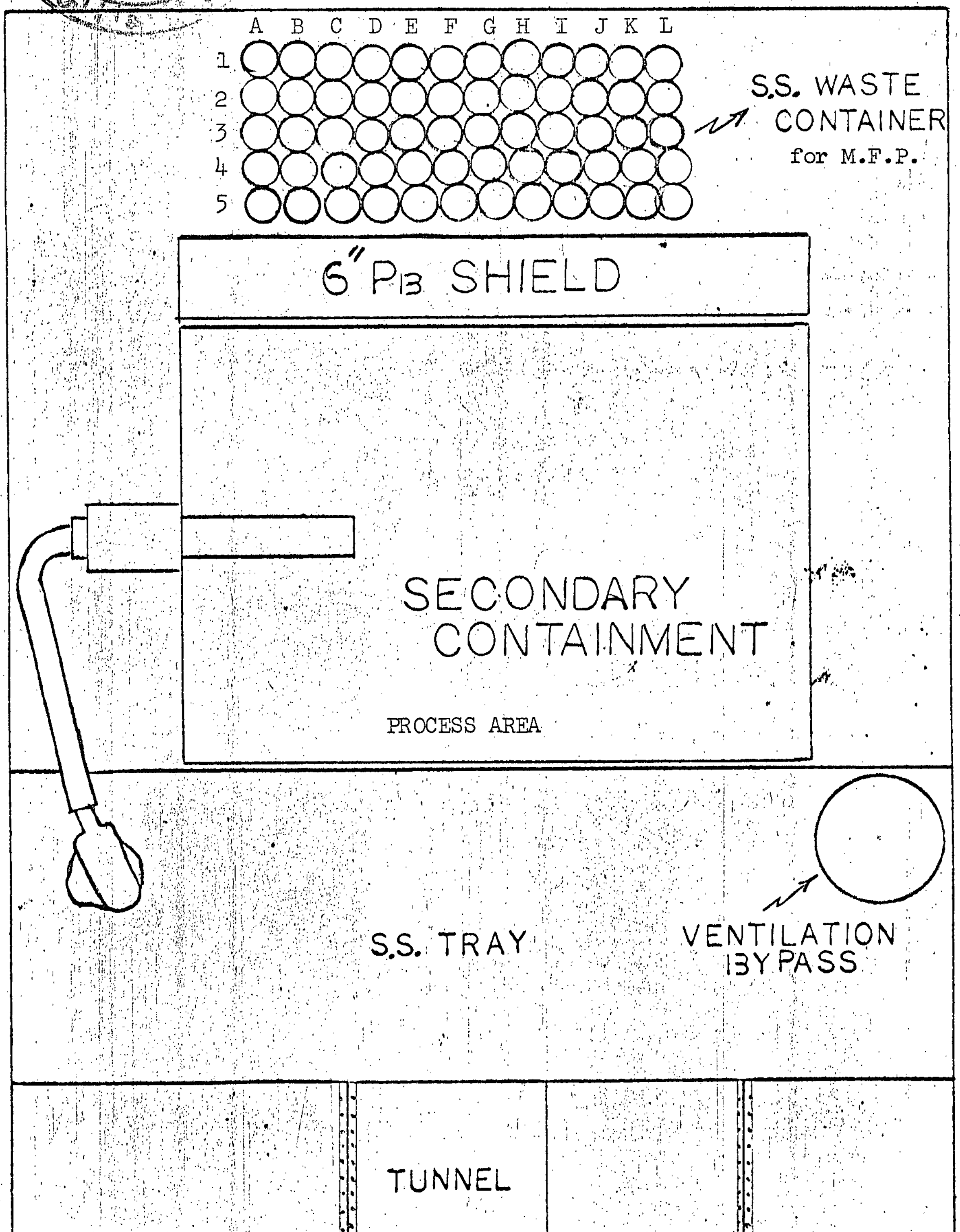


HOT LABORATORY · FLOOR PLAN · UPPER LEVEL

FIGURE 3.

APPENDIX VI



CELL TABLE

CELL No. 5