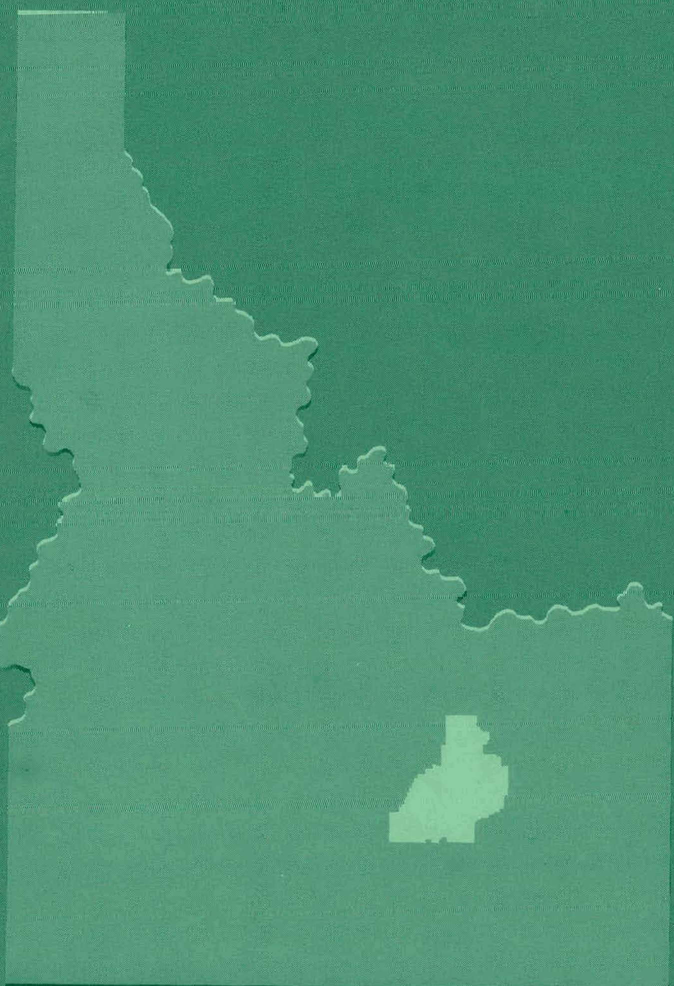
IDO-16689

SPERT IV HAZARDS SUMMARY REPORT

F. L. Bentzen
J. G. Crocker

July 7, 1961



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NATIONAL REACTOR TESTING STATION
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SPECIAL POWER EXCURSION REACTOR TESTS

SPERT IV HAZARDS SUMMARY REPORT

F. L. Bentzen
J. G. Crocker

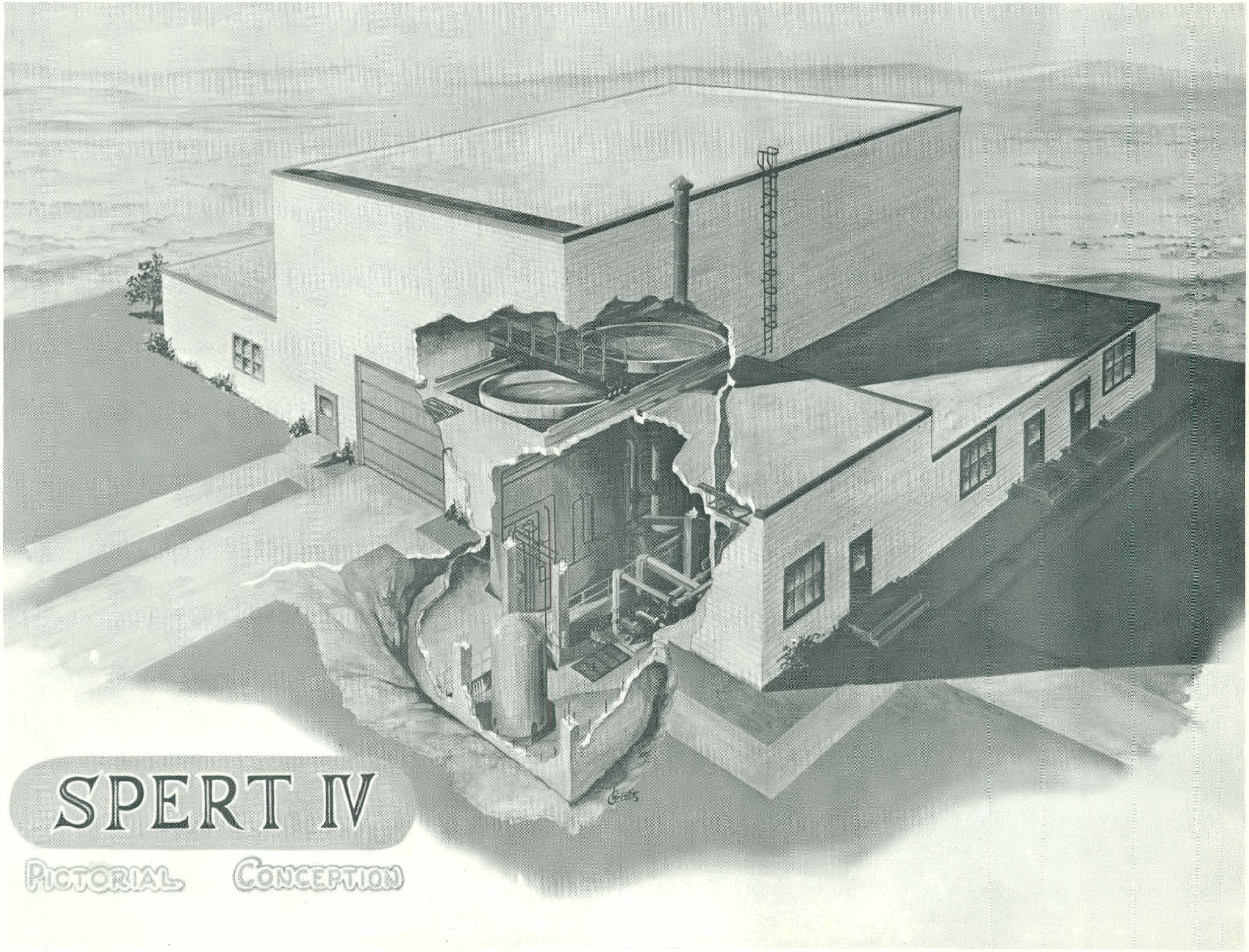
PHILLIPS
PETROLEUM
COMPANY

Atomic Energy Division
Contract AT(10-1)-205
Idaho Operations Office
U. S. ATOMIC ENERGY COMMISSION

Addendum to IDO-16689

NOTE:

A description of SPERT IV is now available in IDO-16745, "SPERT IV Facility" by R. E. Heffner et al, February 22, 1962.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SPERT IV HAZARDS SUMMARY REPORT

by

F. L. Bentzen and J. G. Crocker

A B S T R A C T

Spert IV is a large pool-type experimental facility which will be utilized for the performance of reactor kinetic studies as a part of the U. S. Atomic Energy Commission's Reactor Safety Program. These studies will include power excursion and instability tests for a variety of reactor designs. Since the Spert IV experimental program requires the performance of tests which will approach, and may exceed the threshold of reactor destruction, the probability of occurrence of the maximum possible accident is not negligible compared with that of other possible accidents. This accident, then, is considered as the maximum credible accident in this report.

The maximum possible accident for this facility is considered to be a severe nuclear excursion which results in the destruction of the reactor building and the release of 100% of the accumulated fission product inventory to the atmosphere in a steam cloud. The fission product source assumed in the analysis of this accident is an upper limit in view of the nature of the tests to be performed and the heat removal capacity of the system. This postulated accident is independent of the details of core and control system design and is valid for all cores anticipated for use in the experimental program.

This report discusses the major hazards present in the operation of this facility, the precautions to be taken to reduce the probability of an accident, and the consequences of the maximum possible accident. It is concluded that the proposed method of operation will minimize the hazard to operating personnel, and that the site location will make possible the operation of the Spert IV facility without hazard to the general public.

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SPERT IV HAZARDS SUMMARY REPORT

I. INTRODUCTION

The Spert Project is operated by Phillips Petroleum Company at the National Reactor Testing Station as a part of the U. S. Atomic Energy Commission's Reactor Safety Program. Spert IV will be the fourth Spert reactor facility to be placed in operation for the investigation of the kinetic behavior of various reactor types. The Spert IV experimental program will include reactivity coefficient measurements, core parameter studies, power excursions, and instability tests. The initial objective in this program is to determine the conditions that lead to reactor instabilities in heterogeneous, light-water-cooled and -moderated systems. The experiments will be performed under various conditions of reactor power level, water temperature, top reflector height, and core geometry.

The purpose of this report is to present a summary of the hazards involved in operating the Spert IV facility, the precautions to be taken to reduce the probability of an accident, and the possible consequences of such an accident.

II. DESCRIPTION OF SITE

The Spert IV facility is located within the Spert area at the National Reactor Testing Station in Idaho. The Spert area site is shown in relation to other installations at the NRTS in Figure 1. The closest population center in the general down-wind direction is the Mud Lake-Terreton area 30 miles to the northeast. The site boundary in that direction is about 20 miles distant. Other nearby points of importance are: MTR-ETR about 5 miles northwest; CPP about $3\frac{1}{2}$ miles west-northwest; Central Facilities about 4 miles west-southwest; OMRE about 3 miles south-southwest; GCRE and ML-1 about $2\frac{1}{2}$ miles southeast; Atomic City about $7\frac{1}{2}$ miles southeast; nearest point of U. S. Highway 20, about 3 miles south; and the nearest site boundary $6\frac{1}{2}$ miles south.

Figure 2 shows the general site plan for Spert, and the location of the four Spert reactors. Each reactor area is approximately $\frac{1}{2}$ mile from the adjacent reactor sites and $\frac{1}{2}$ mile from the Control Center. The entire Spert area is surrounded by a barbed wire obstruction fence which is a nominal distance of 1/3 mile from any reactor building.

Figure 3 is a plan view of the Spert IV area showing the locations of the reactor building, contaminated waste hold-up tank, leaching pond, and electrical sub-station.

Waste water from the reactor pools is normally pumped to a leaching pond located about 270 ft south of the reactor building. A contaminated waste hold-up tank is located approximately 170 ft south of the reactor building. A barbed wire exclusion fence surrounds the leaching pond and contaminated waste tank area. Uncontaminated waste water will be pumped to "Spert IV Lake", which has a storage capacity of six million gallons. Should this Lake become full an overflow weir will perimt the excess water to flow into the desert.

Meteorological, hydrological, and seismological data for the NRTS have been described in previous reports (1)(2) and will not be presented in detail in this report.

Figure 4 shows the seasonal wind roses for the 250 foot level for both inversion and lapse conditions. This figure indicates that there is approximately an equal probability for lapse or inversion conditions, but lapse conditions with the prevailing southwesterly winds, are more prevalent during normal working hours when reactor tests are usually performed.

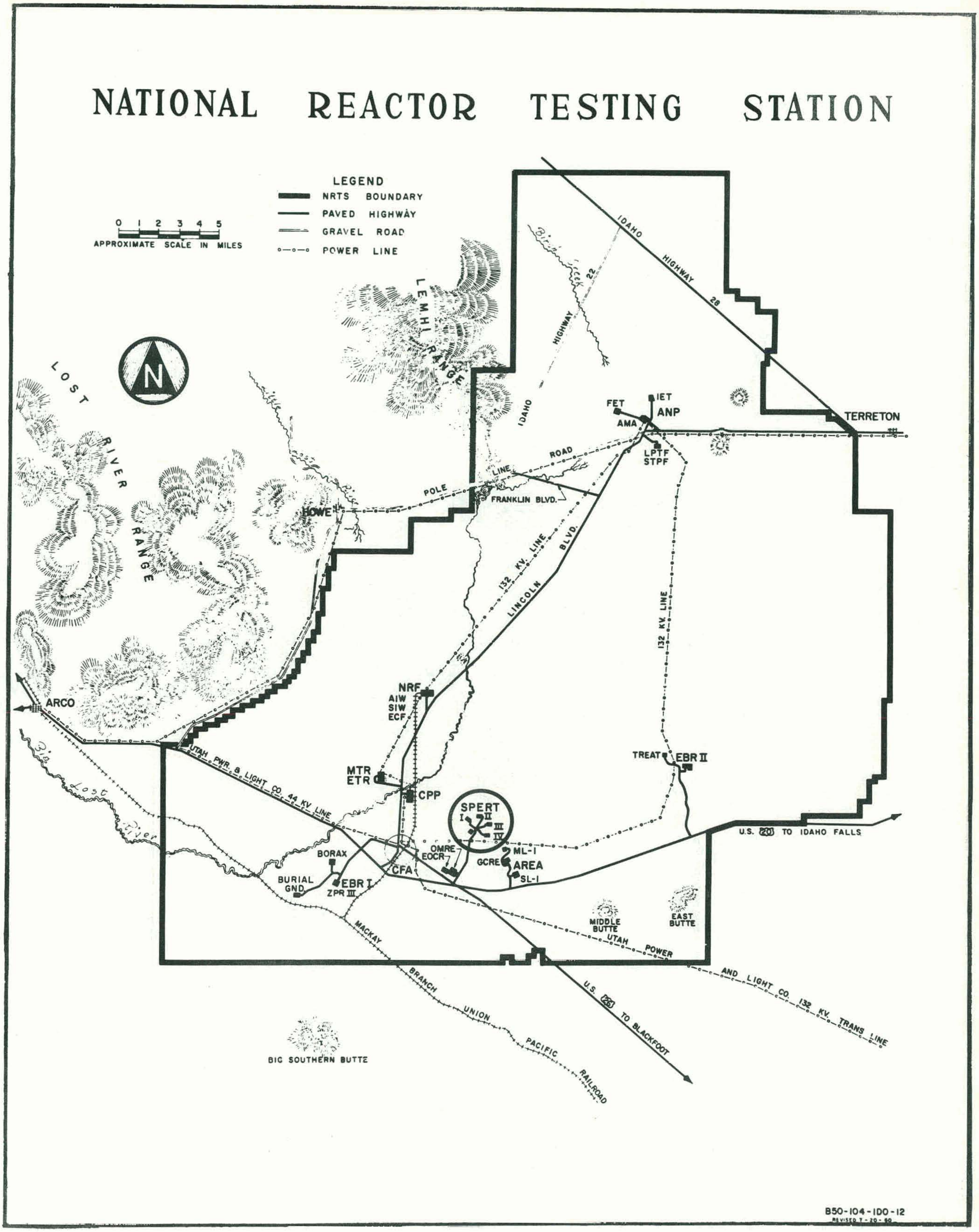

Figure 1 - National Reactor Testing Station

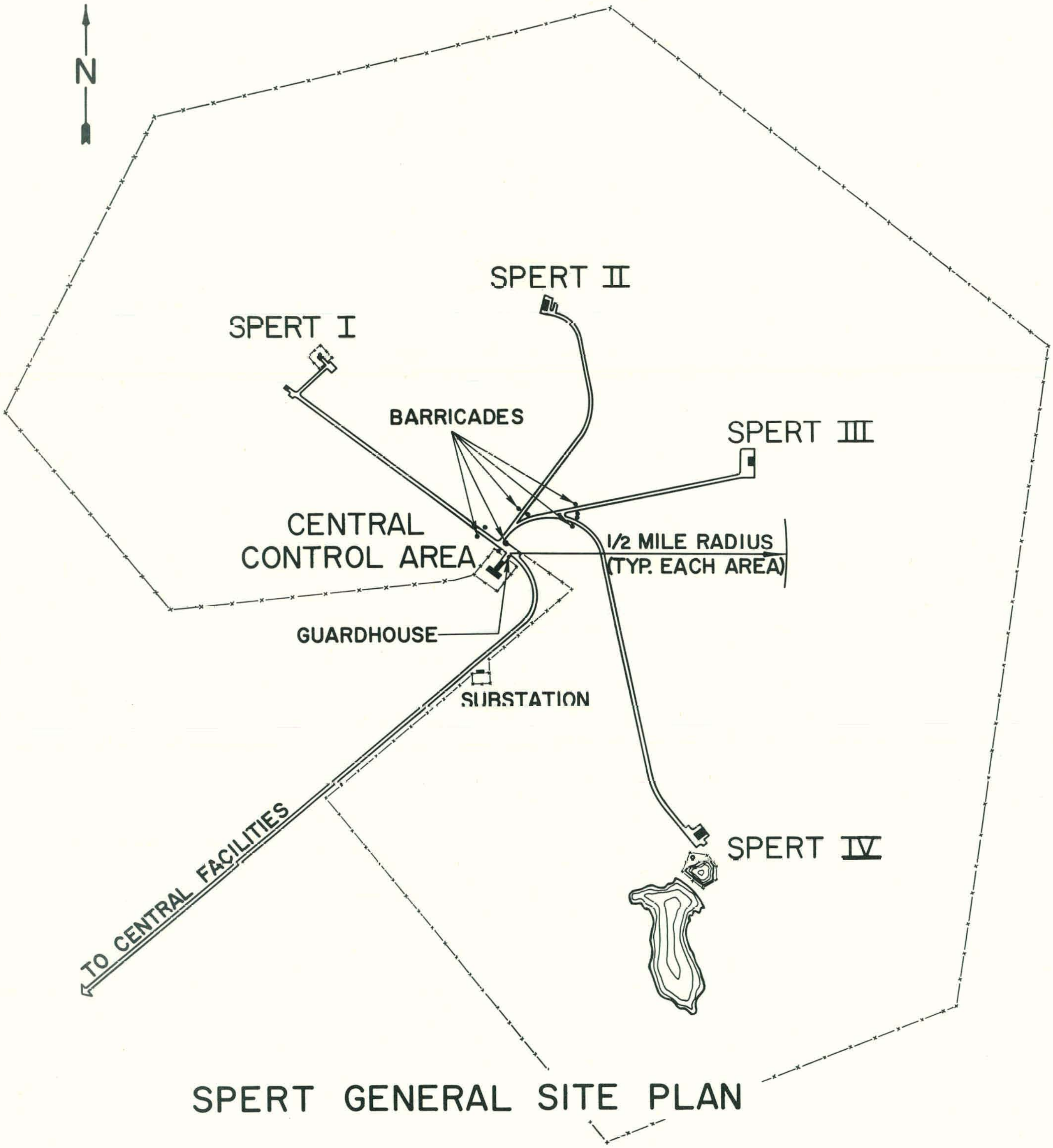

Figure 2 - Spert Site Plan

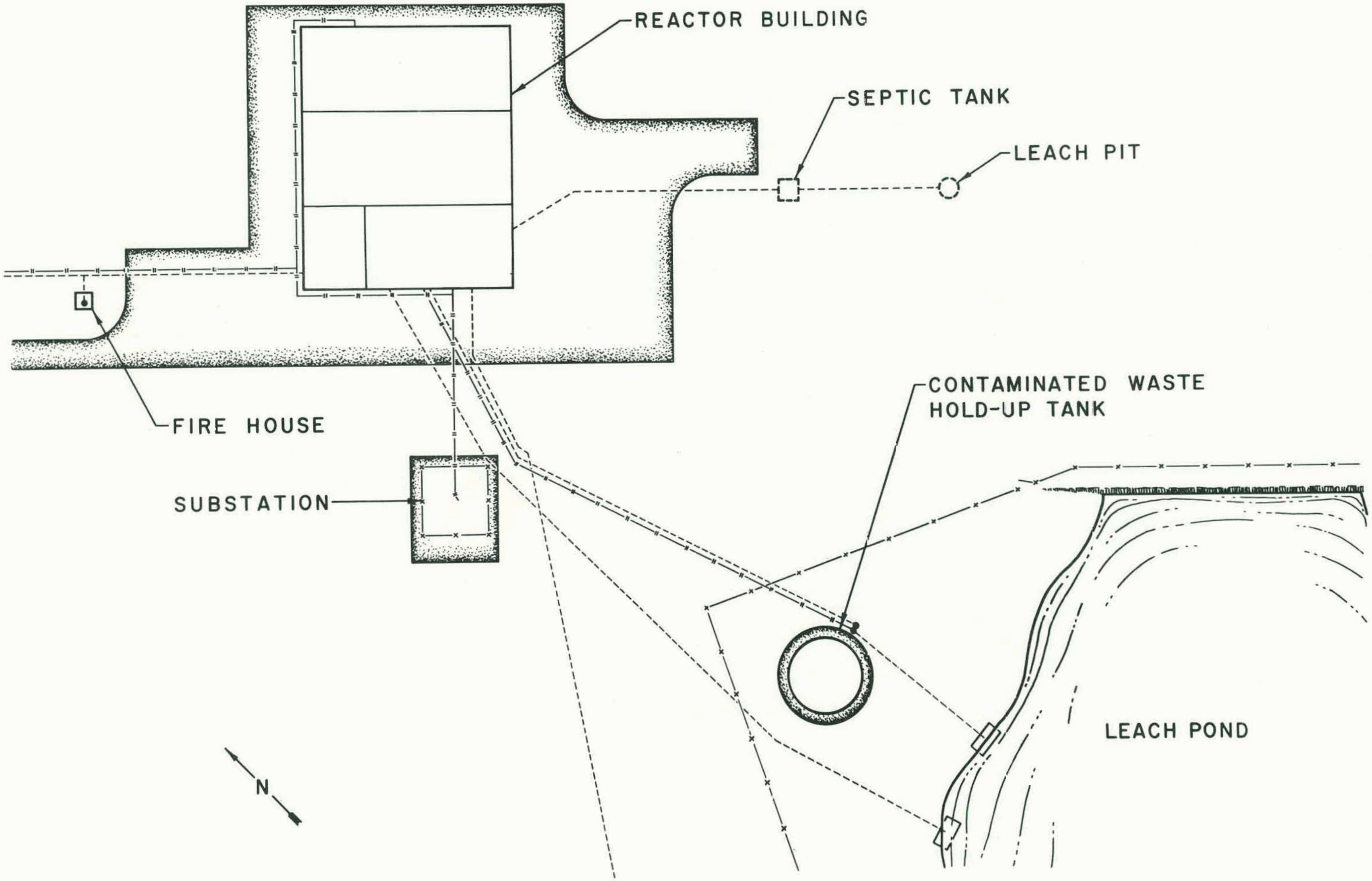

Figure 3 - Spert IV Site Plan

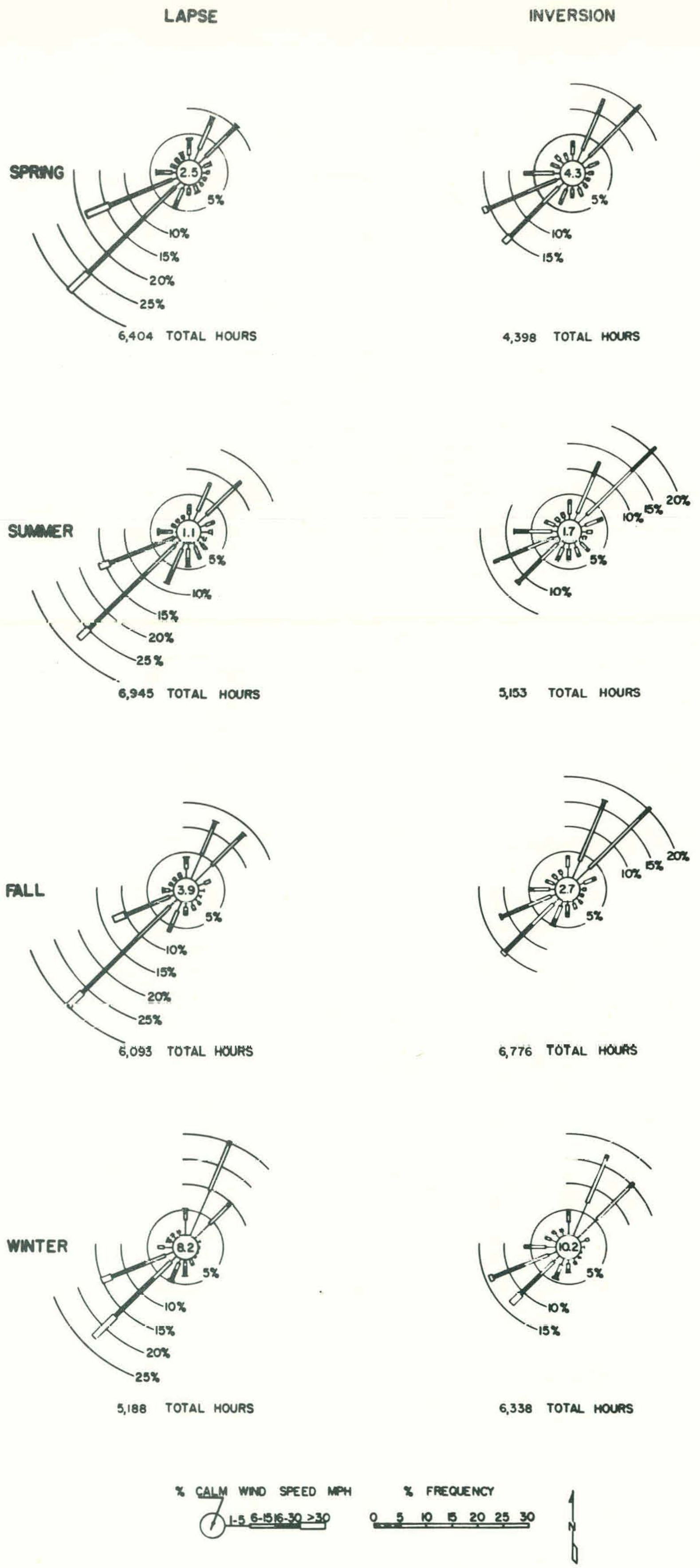

Figure 4 - WBO 250 Foot Level Wind Roses
1952 Through 1956

III. DESCRIPTION OF THE SPERT IV FACILITY

A. General

Spert IV was designed as an experimental facility in which to conduct safety and kinetic studies with various reactor types. These studies will include measurements of core parameters, and the performance of power excursion and instability tests. Because of the nature of some of the tests to be performed, the reactors will be operated from the control center approximately $\frac{1}{2}$ mile from the reactor building and access to the reactor area will not be allowed during nuclear operation.

The facility provides two large pools in which reactors may be assembled for testing. The necessary auxiliary equipment is included to provide a maximum forced coolant circulation of 5000 gpm, and a maximum steady state heat removal of 1 Mw. Indication and control of flow and other plant variables may be implemented at either the reactor area or the control area.

The principal features of the Spert IV design are presented in this section of this report. Additional details are given in the Design Data Summary, Appendix C.

B. Reactor Building

The reactor building consists of a high-bay main portion housing the reactor proper and process equipment, and two low-bay wings housing an office, instrumentation rooms, a utility room, a mechanical work area, and a change room. A reactor building plan and section are shown in Figures 5 and 6. The main portion of the reactor building is a 73 ft long, 48 ft wide, and 44-$\frac{1}{2}$ ft high, steel-girdered, pumice block structure with a 27 ft deep full basement. A 12-ton overhead traveling crane spans the length and width of this portion of the building.

Hatches are provided in the main floor for access to the principal equipment in the basement. This equipment includes the deionized water storage tank, the two coolant pumps and associated piping, the heat exchanger, the sump pump, and the air compressor with an associated air receiver.

The allowable floor loading in the basement is 2500 lb/ft^2. Allowable loading for the main floor is 750 lb/ft^2, except for the floor area south of the pools which has an allowable loading of 2500 lb/ft^2. Both of the building wings have an allowable floor loading of 250 lb/ft^2.

The east wing portion of the building is 22 ft 8 in. wide, by 73 ft 4 in. long, by 13 ft high, and has space for an office, a mechanical work area, an electronics work area, and an instrumentation room. The instrumentation room is air-conditioned to reduce instrument drift due to changes in temperature.

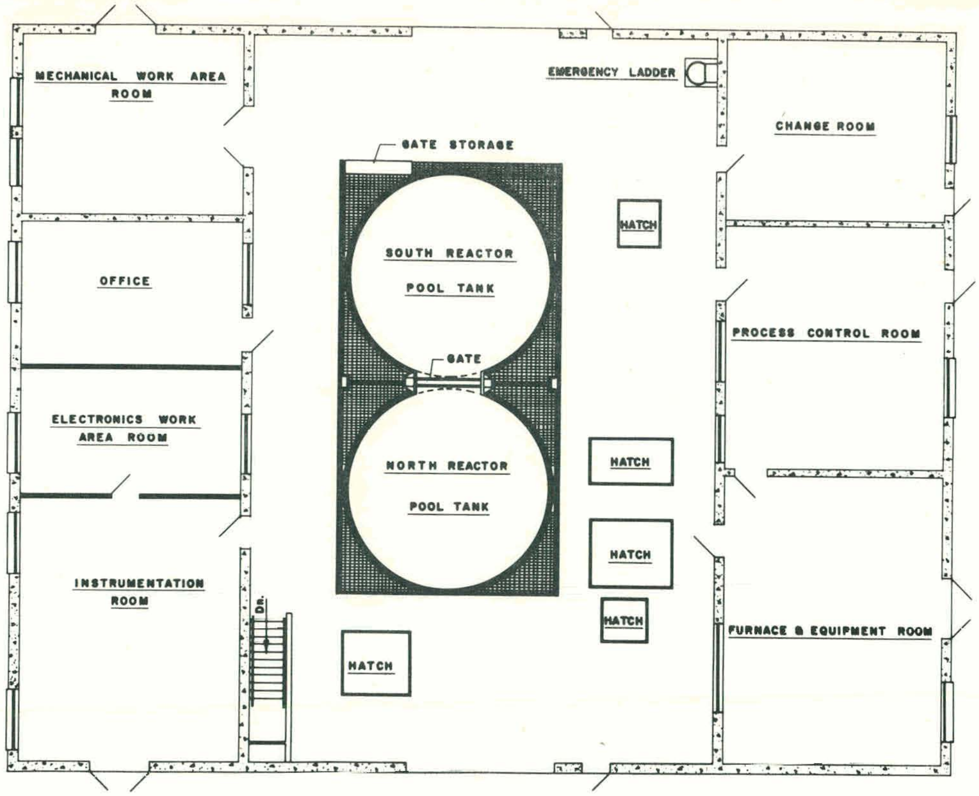

Figure 5 - Spert IV Reactor Building Plan

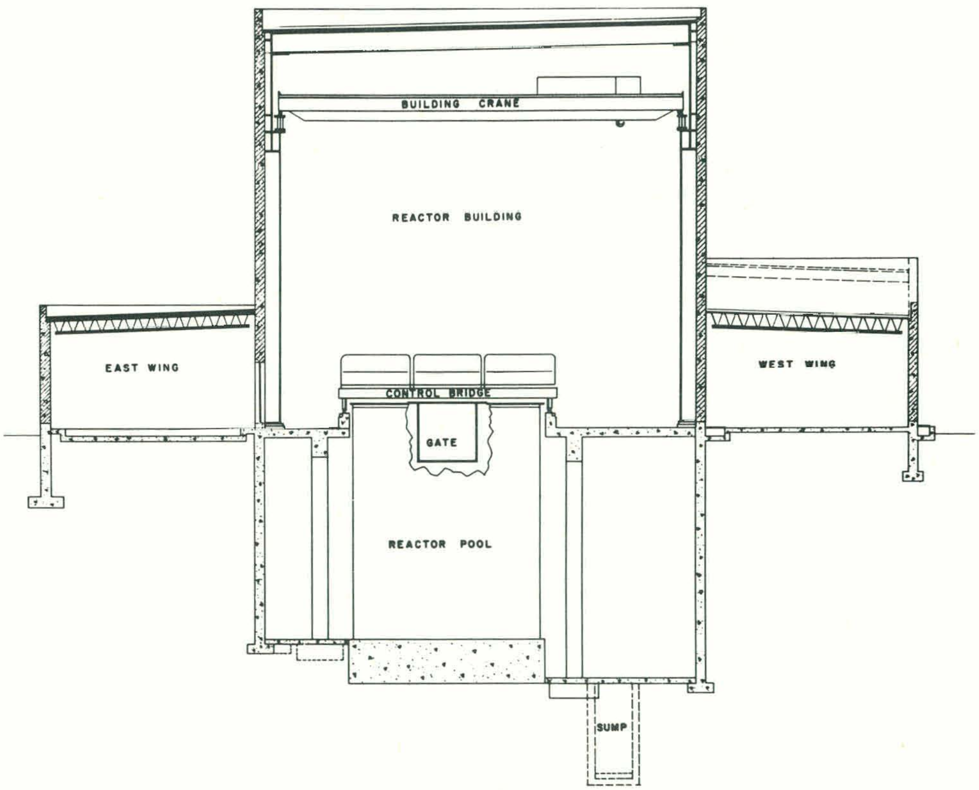

Figure 6 - Spert IV Reactor Building Section

The west wing is the same size as the east wing, except for the area over the utility room where a 17 ft roof height has been provided for clearance of the water demineralizing equipment. This wing houses the process control room, locker and washroom facilities, and the furnace and utility room containing heating and ventilating equipment, water softener, demineralizers, and the steam boiler for space heating.

C. Reactor Pools

The pool portion of the facility is made up of two 50,000 gal capacity tanks. The pools are fabricated from 5/16 in. thick stainless steel and are designed for 25 ft of hydrostatic load plus a 50 psi overpressure. Although either pool may be used for nuclear testing, simultaneous operation of more than one core is not possible in the present design. Initially, the north pool will be used for the installation and testing of reactor cores, and the south pool will be used for fuel storage. The two pools are connected at the top by a 6 ft by 6 ft removable gate which permits underwater transfer of radioactive objects from one tank to the other. Each pool has four scupper drains one foot from the top, thus limiting the effective water height to 24 ft. The pools extend 2 ft 4 in. above the main floor of the reactor building.

Each pool has two 12 in. nozzles in the pool wall for connections to the coolant pumps. These nozzles are located approximately 5-1/2 ft and 20 ft from the bottom of the pools. The north pool also has a 16 in. flanged nozzle centrally located in the bottom of the tank. This nozzle connects to the coolant system and may be used for forced circulation through reactor cores, or for flanging to future reactor pressure vessels. The north pool is also provided with three 16 in. diameter windows located 5, 7, and 10 ft from the bottom of the pool. The windows, which are covered with slide gates operated from the main floor, may be used for television observation or photography of the core region.

D. Control Bridge

The control bridge will be used for suspension of the reactor core and support of the control rod drive units. This bridge is constructed of two, 22-ft long, wide-flange beams which are covered with aluminum floor plate. This assembly is mounted on trucks which can travel on rails for the full length of the pools. By use of positioning pins on the rails and jack shafts on the bridge, the bridge alignment and position can be accurately reproduced. The vertical adjustment range of the bridge is five inches. Design live loading of the bridge is 2500 lb on each flange beam with a maximum deflection of 0.010 in. Instrument and control cables are placed in cable raceways on the outside of the wide-flange beams.

E. Reactor Coolant System

The reactor pools are normally filled directly from the deionizer effluent, with rates up to 100 gpm attainable when both deionizers are in operation. At this flow rate, approximately 16 hours are required to fill one pool. This time includes one regeneration of the deionizers, each of which has a 15,000 gal capacity. A 50 gpm fill pump is normally used to supply small amounts of demineralized water to the pools and to demineralized water service outlets. The reactor coolant flow diagram is shown in Figure 7. The water may be circulated through either or both of the two 2500 gpm pumps, through the heat exchanger, and back into the pools.

In order to conserve demineralized water, a 50 gpm cleanup pump returns a side stream of the pool water to the deionizer to provide continuous cleanup and to maintain the water purity. Water that is contaminated with fission products will not be returned for cleanup. If necessary, the reactor pools may be filled with raw water through a 3-in. line.

When the heat exchanger is in use, demineralized reactor pool water flows through stainless-steel tubes, and raw cooling water flows through the shell side of the exchanger. The raw cooling water effluent is dumped into Spert IV Lake. The actual heat transfer rate will vary considerably, inasmuch as the main uses of the heat exchanger are to stabilize the reactor pool temperature at any desired temperature up to 130°F during power operation and to cool the reactor pools following high temperature (130°F maximum) tests.

F. Auxiliary Equipment

1. Air Compressor

A 64 cfm, 125 psi air compressor serves the utility air and instrument air demands. All air is dried to -30°F dewpoint by an automatic regeneration-type air dryer.

2. Mixed-Bed Demineralizing System

Two mixed-bed demineralizers are employed to furnish 50 gpm each of 500,000 ohm-cm or better resistivity water. Capacity between regenerations is 15,000 gal of water for each bed.

3. Water Softener

A 10,000 gal capacity zeolite water softener is employed to provide soft water for deionizer feed-water, a boiler, showers in the locker room, and deionizer regeneration. Four regenerations of the water softener will be required to initially fill one pool.

4. Heating and Ventilating Equipment

A 50 boiler-horsepower, 15 psig boiler provides steam for the heating and ventilating system. Ventilating and heating of the building is accomplished by a forced air system with steam heating. The capacity

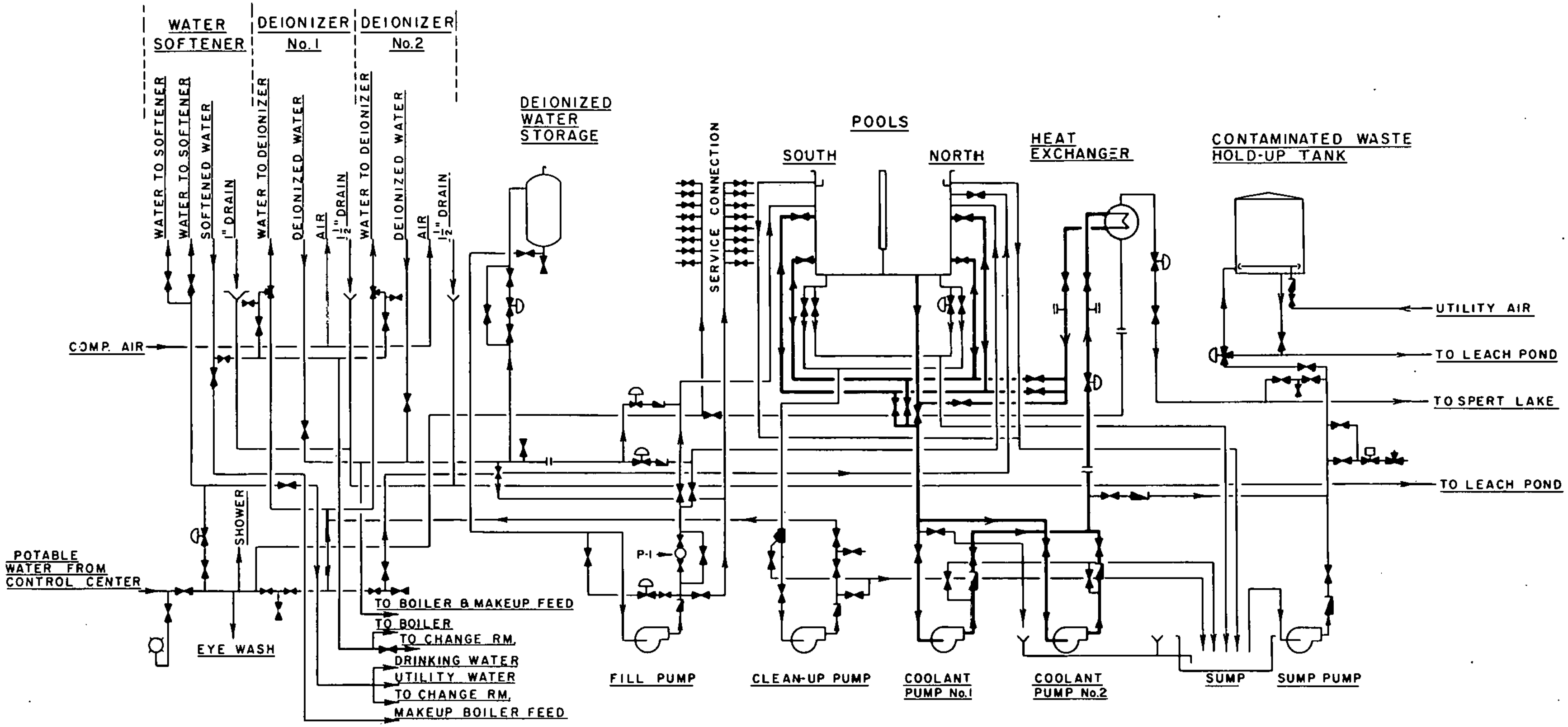

Figure 7 - Spert IV Process Flow Diagram

of the ventilating system is 22,350 cfm with the steam coils capable of heating the full flow capacity from -20°F to 60°F using 10 psig steam.

Under normal ventilating conditions, a portion of the building air is recirculated through the system to maintain comfortable temperatures. If the building air should become contaminated, the system will automatically prevent the exhaust of the contaminants to the atmosphere. A system condition which will supply 100% filtered outside air in a pattern designed to flush the contaminated air from the building may be implemented by use of a manually operated switch at the control center.

The instrumentation room air-conditioner provides for manual tempering of the recirculated room air with outside fresh air. This air conditioning will be turned off automatically should the ventilating system be required to expel contaminated air from the building.

G. Instrumentation

The experimental instrumentation for the Spert IV facility is divided into three categorics: the process instrumentation, the reactor control instrumentation, and the transient instrumentation.

1. Process Instrumentation

The process instrumentation consists of the sensing devices, instruments and controllers necessary to maintain the coolant system at the desired conditions of temperature and flow rate. A block diagram is shown in Figure 8 which indicates the process variables to be measured or controlled. The system can be operated from either the control center or the reactor building. During reactor operation the system must be controlled from the control center. Because of the 1/2-mile distance separating the reactor and the control center, electronic transmission is required for all signals transmitted to the control center. The signals terminating at the control center will be transmitted via multi-conductor or coaxial cables which are laid on the surface of the ground and protected by a gravel covering. Cables transmitting control power are separated by a distance of 15 ft from cables transmitting instrument signals to insure minimum of interference with the instrument signals.

2. Reactor Control Instrumentation

The reactor control instrumentation includes those components necessary to observe and control the reactor power under nontransient conditions. This description will deal primarily with the observation of the reactor power. Appendix A contains a more complete description of the control system design.

For low level neutron observation at least two boron-lined neutron pulse chambers or fission counters will be used with their outputs displayed on scalers mounted in the reactor console. For monitoring powers above a few watts, two boron-lined ionization chambers will be used with

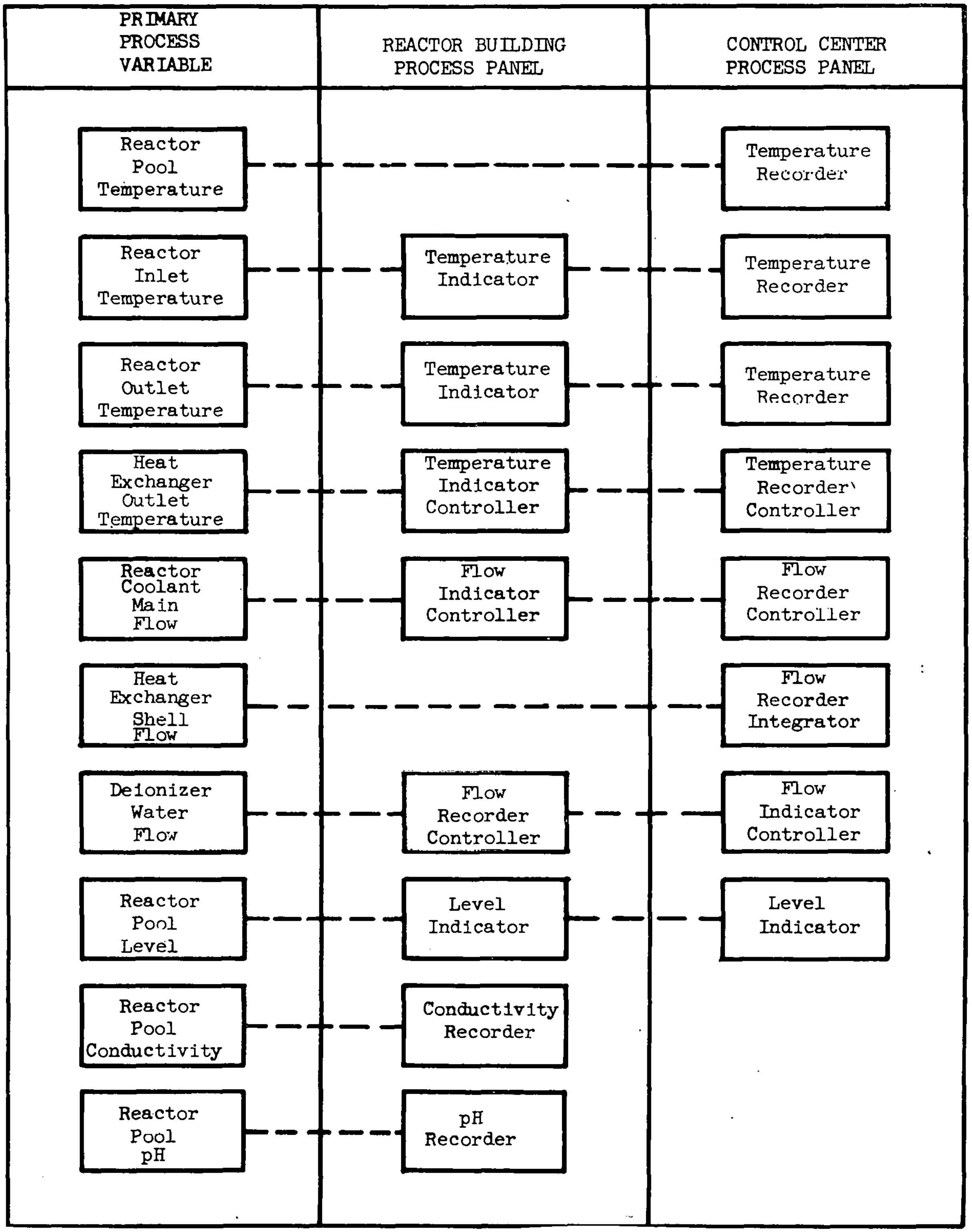

Figure 8 - Spert IV Simplified Process Instrumentation Block Diagram

their outputs displayed on two operational power recorders mounted on the console. One of these recorders will display linear power, and the other will show log power. These recorders will be on during all reactor operation.

Automatic sequence control of test events is possible by use of two timers covering time intervals of 30 sec and 5 min. These timers may be used to initiate tests, control auxiliary equipment, and to terminate tests by scramming the control rods. A closed-circuit TV system will permit the operator to survey the reactor and process area of the reactor building.

3. Transient Instrumentation

The transient instrumentation is a data-gathering system, designed solely to record the behavior of rapidly varying parameters during reactor tests. This instrumentation will not affect the control or safety of the reactor, and therefore, will not be considered in detail in this report.

The information to be recorded in a test will typically be reactor power, fuel plate surface temperatures, transient pressure moderator flow, and time sequence indications of such occurrences as transient rod drop and control rod scram. An instrumentation channel for one of these parameters will normally consist of a sensing device, a pre-amplifier, a driver-amplifier, 3000 ft of cable, and the recorder. The information will be recorded on two 36-channel recording oscillographs with a 14-channel magnetic tape system supplementing this system during selected tests.

H. Radioactive Materials Handling

Several types of operations requiring the handling of radioactive materials will be performed at Spert IV. Most of these operations will involve the handling of radioactive fuel assemblies or primary system water. Highly radioactive fuel can be unloaded from the reactor core and transferred to the storage pool through the removable gate. Thus, the transfer can be completed with the operator shielded from the assemblies by several feet of water.

Two cadmium-lined storage racks, each having 88 storage positions, will be located in the storage pool. Although these racks were specifically designed for fuel assembly storage, they may also be used for storage of other radioactive materials. Should the necessity arise for complete removal of the core or other highly radioactive materials from the pools, transfer coffins will be used. A "hot" work table in the storage pool will allow mechanical operations to be performed on selected fuel assemblies under various water depths.

When the primary coolant water must be drained, it is dumped into the building sump. From the sump, a 300 gpm pump transfers the waste to Spert IV Lake, the leaching pond, or the contaminated waste holdup tank. This pump is automatically controlled by the sump liquid level and has provisions for manual operation from the control center.

Normally the pool water will be uncontaminated and will be pumped into Spert IV Lake. However, since the Spert IV reactor is an experimental facility, rupture or melting of the fuel plates may occur during experiments, thereby releasing substantial quantities of fission products into the primary coolant water. Contaminated water may be discharged directly to the leaching pond or, in the event that the radiation levels are too high for discharge to the leaching pond, the water will be pumped to the contaminated waste holdup tank. Water that has been pumped to the holdup tank will be subsequently discharged to the leaching pond when the activity has decayed to permissible limits.

IV. HAZARDS DISCUSSION

A. General

The nature of the Spert IV experimental program requires that many tests be performed which involve the addition of large amounts of excess reactivity. In order for the program to yield maximum information, tests will be included which closely approach those circumstances leading to the maximum possible accident with the facility. For this reason, although the probability of occurrence is low, the maximum possible accident will be treated for the purposes of this report as the maximum credible accident.

B. Accident Initiation

The kinetic studies to be performed in Spert IV will include power excursion and instability tests. The instability studies will consist of tests which range from the determination of the onset of small power fluctuations to tests in which violent, divergent power oscillations are observed. The power excursion tests will involve a study of the response of the system to large, sudden reactivity insertions. Normally, a discussion of the possible means of reactivity insertion would be appropriate in a report of this type. However, the Spert IV facility was designed for studies of the system response to large reactivity insertions, and since the postulated maximum accident is independent of the means of insertion, such a discussion is not pertinent in this case. Many of the safety circuits, which normally would be of value, cannot be used during the tests because of the nature of the program. These automatic safety circuits are omitted and reliance on administrative procedures is used to minimize the possibility of the occurrence of accidents.

The Spert IV experimental program includes tests which simulate possible reactor accidents. In fact, the results of some tests would ordinarily be considered the consequences of an accident. However, the results of these tests are not and will not be considered to be accidents. For the purposes of this discussion accidents are defined in the normal sense as unforeseen or unexpected events. Classification of accidents is made according to the circumstances of the initiation as the results of planned or unplanned nuclear excursions.

(1) Accidents Resulting from Planned Nuclear Excursions.

An accident of this type would occur as a result of the unexpected behavior of the reactor during a planned test. This accident could result from inaccurate predictions, failure of reactor components, or operator error. Careful analysis of previous test results, frequent inspection of system components, and the use of trained personnel and carefully planned test procedures are the only effective means for preventing such accidents. This type of accident is defined to occur during a planned test, and the exclusion radius would provide protection to personnel from the effects of an explosion. The maximum consequences, therefore, would be reactor destruction and radiation hazards from scattered core debris.

(2) Accidents Resulting from Unplanned Nuclear Excursions.

This type of accident could be initiated by a premature nuclear excursion or the accidental assembly of a supercritical core caused by equipment malfunction or operator error. Proper design of the reactor system and the use of carefully prepared operating rules and procedures are the most effective means to reduce the probability of this type of accident. This type of accident could result not only in reactor destruction and radiation hazards, but also in serious injury to operating personnel.

To reduce the probability of occurrence of accidents, the following general procedures will be applied to the operation of Spert IV.

(1) All reactor operation will be conducted from the control center, approximately 1/2 mile from the reactor building with no personnel within the exclusion area.

(2) The experimental program will be subjected to critical review by a staff composed of the Spert senior supervisors prior to approval by the branch manager.

(3) Experiments for which the results cannot be reasonably predicted by extrapolation or interpolation of previous test results, or for which there exists a moderate or high probability of core destruction will be performed only under favorable meteorological conditions.

The detailed adminstrative procedures which supplement these general statements are presented in Appendix D and constitute the means by which the probability of initiation of accidents will be reduced in the operation of Spert IV.

C. The Maximum Possible Accident

Because the nature of the experimental program requires that the reactor be subjected to conditions that may exceed the threshold of reactor destruction, the probability of occurrence of the maximum possible accident is not negligible. In evaluating the hazards to other NRTS installations and to off-site areas, this will be the only accident considered.

The maximum possible accident with the Spert IV facility is considered to be a severe nuclear excursion terminating in a steam explosion which demolishes the reactor and reactor building and releases the entire accumulated fission product inventory in the core to the atmosphere. This postulated accident is independent of the details of the core and control system design and is valid for all cores anticipated for the use in the experimental program.

In evaluating the local hazards due to the maximum possible accident, it is assumed that serious radiation hazards would exist in the entire Spert area. If the accident occurred during a planned test, personnel would not be affected by the blast. If, however, the accident was the result of an unplanned nuclear excursion, then personnel in the immediate vicinity of the reactor building could be killed or seriously injured.

To evaluate the hazards to other NRTS and off-site areas, estimates have been made of the hazards due to the release of fission products for the following postulated conditions.

1. The reactor and reactor building are destroyed with 100% of the accumulated fission product inventory of the core being released to the atmosphere in a steam cloud.

2. This cloud is of negligible radius and is released at ground level. (These assumptions will cause over-estimates of the doses at points close to the incident.)

3. The estimates are made for average meteorological conditions, inversion conditions, and strong wind conditions. The meteorological constants used for these cases were taken from Table 8.2 of Reference 3 and are shown in Table 1.

TABLE 1

SUTTON'S METEOROLOGICAL CONSTANTS[3]

	Average Meteorological Conditions	Inversion Conditions	Strong Wind Conditions
Stability Index, n	0.25	0.50	0.25
Diffusion Parameter, C	0.20(meters$^{1/8}$)	0.05(meters$^{1/4}$)	0.20(meters$^{1/8}$)
Wind Velocity	3 meters/sec	1 meter/sec	15 meters/sec

The fission product inventory in the core is assumed to consist of a long-lived group resulting from a maximum continuous operation of eight megawatt hours per day, and a short-lived group resulting from operating at a power of 30 megawatts for 30 minutes. The accident is assumed to have occurred immediately following this 30 megawatt operation with the integrated power resulting in an equivalent instantaneous source for the short-lived group of 5×10^4 Mw-sec. The nature of the experimental program, and the limited heat removal capacity of the system makes these assumptions upper limits to the fission product source which would be achievable in the planned operation of this reactor. Results from the Borax destructive test(4) and Spert power excursions(5) indicate that the energy released in a destructive excursion would not likely exceed 10^3 Mw-sec which is negligible compared with the energy release already assumed for the short-lived fission product source.

Estimates have been made of the total integrated external gamma dosages which would be received by an individual standing directly in the path of the radioactive cloud as it passes overhead. The long-lived source is assumed to decay as $t^{-0.21}$, and the short-lived source as $t^{-1.21}$. The nomograms due to Holland(6), which assume no fallout or rainout, have been used in making these estimates. The results are shown in Table 2 for four distances from the incident. Even under the worst weather conditions these dosages would not constitute serious hazards to areas other than the immediate vicinity of the Spert site. The nearest population center (Mud Lake-Terreton) is about 30 miles from the Spert site in the prevailing down-wind direction. No other NRTS installations are located in this direction.

In order to estimate the internal doses from inhalation, it is assumed that the radioactive cloud falls immediately to the ground and thereafter moves along the ground at constant velocity in a hemispherical shape.

The approximate dosages to the bone and to the thyroid have been estimated for infinite time after inhalation. The constants and equations used in these calculations are given in Appendix E. Except for an inversion condition, the dosages for distances greater than 15 miles are substantially less than the maximum "once in a lifetime" exposure (assumed to be 25 rad). Large inhaled dosages which could result during inversion conditions indicate the necessity for favorable weather conditions during tests where there is a reasonable chance for occurrence of fission product release. In particular, such experiments will not be performed under inversion conditions or wind conditions such that other installations are in the down-wind direction.

The operating procedures outlined in Appendix D should prevent the occurrence of the accident that is postulated here, and the nature of the test program should keep the fission product source considerably below the levels used in these calculations. The probability of such an accident is not negligible, however, and in the event of such an occurrence, the normal NRTS disaster plan would be placed in effect and the AEC Idaho Operations Office would be alerted in order to direct the precautionary efforts. It should be stressed that every attempt has

TABLE 2

APPROXIMATE DOSES FROM RADIOACTIVE CLOUD FOR MAXIMUM POSSIBLE ACCIDENT

Distance from Origin of Incident (miles)	Average Conditions Long-Lived	Average Conditions Short-Lived	Inversion Conditions Long-Lived	Inversion Conditions Short-Lived	Strong Wind Conditions Long-Lived	Strong Wind Conditions Short-Lived
			External Gamma Dose (roentgens)			
0.5	1.9	3.0×10^{2}	4.0×10^{1}	2.5×10^{3}	5.4×10^{-1}	4.0×10^{2}
5	5.4×10^{-2}	1.0	5.4	2.5×10^{1}	1.1×10^{-2}	1.5
15	2.7×10^{-3}	1.0×10^{-1}	1.4	3.0	------	1.5×10^{-1}
30	------	------	5.4×10^{-1}	5.0×10^{-1}	------	------
			Internal Dose to Thyroid from Inhalation (rads)			
0.5	6.8×10^{1}	1.2×10^{2}	1.7×10^{4}	3.0×10^{4}	1.4×10^{1}	2.5×10^{1}
5	1.2	1.9	5.4×10^{2}	5.0×10^{2}	2.4×10^{-1}	4.5×10^{-1}
15	1.6×10^{-1}	2.0×10^{-1}	8.1×10^{1}	1.0×10^{2}	2.7×10^{-2}	5.0×10^{-2}
30	5.4×10^{-2}	5.0×10^{-2}	2.7×10^{1}	1.8×10^{1}	1.1×10^{-2}	1.5×10^{-2}
			Internal Dose to Bone from Inhalation (rads)			
0.5	1.9×10^{3}	3.8	4.9×10^{5}	1.0×10^{3}	3.8×10^{2}	7.5×10^{-1}
5	3.5×10^{1}	7.0×10^{-2}	1.6×10^{4}	3.1×10^{1}	7.0	1.4×10^{-2}
15	5.1	1.0×10^{-2}	3.0×10^{3}	6.0	1.0	2.0×10^{-3}
30	1.5	3.0×10^{-3}	1.1×10^{3}	2.1	3.0×10^{-1}	6.0×10^{-4}

been made in these considerations to postulate the worst possible conditions.

D. Criticality Hazards

The accidental assembly of a critical configuration of fuel elements is an accident that could conceivably occur at Spert IV. The probability of such an accident is nonzero because of the numerous changes in reactor core components and configuration that must be accomplished to meet the demands of the experimental program. The procedures outlined in Appendix D will be followed to minimize the possibility of the occurrence of this type of accident. These procedures provide that any operation involving the change or addition of any core component or in-pile instrumentation must be approved in advance by the Nuclear Test Group Leader and will be monitored from the nuclear console. A physicist from the Nuclear Test Section must be present during the operation to observe and evaluate the operation from a nuclear safety standpoint.

E. Non-Explosive Release of Fission Products

Partial fuel melting or failure of the fuel cladding with the resultant release of fission products to the tank and primary coolant system is a situation which could occur during routine dynamic testing in Spert IV. Since the reactor is in an open pool, the reactor building air as well as the pool and primary coolant system could become contaminated. The reactor building is not a containment vessel, therefore it must be assumed that a portion of the fission products would be released to the atmosphere outside the building. The hazards from this release would be orders of magnitude less than the hazards from the maximum possible accident described above and would be minor for all locations other than the immediate reactor building area.

Re-entry to the reactor building following reactor operation is routinely accomplished under health physics surveillance to protect operating personnel from unknowingly entering high radiation fields. A constant air monitoring system is in continuous operation to indicate the presence of airborne contamination.

The contaminated water in the reactor pool would be transferred to the contaminated waste hold-up tank, if the radiation level was too high for discharge directly to the leaching pond.

F. Conclusions

In the study of reactor safety, tests are frequently performed which involve the addition of large excess reactivities. These tests, in many cases, closely approach the threshold of core damage and may, indeed, include the planned destruction of the reactor. The nature of this program leads to the conclusion that the maximum possible accident should be considered in discussing the possible hazards from the operation of the Spert IV reactor. Since this postulated accident is essentially unrelated to the details of core and control system design, the discussion is valid for all core types to be investigated in the program.

For reference purposes Appendix B describes the design of the initial core to be used in Spert IV.

The philosophy used to reduce the hazards involved in the operation of this reactor is one of isolation and administrative control. The remote location of the Spert site provides protection to other NRTS installations and off-site areas. To protect Spert personnel, the reactor is located 1/2 mile from the nearest other Spert facility, and a 1/3-mile exclusion radius will be maintained during reactor operation.

Table 2 presents the estimates of the external gamma dosage and dosages to bone and thyroid from inhalation which would be received by a person in the direct line of the cloud from the maximum possible accident. These estimates have been made for various weather conditions and distances from the site of the accident. Every attempt has been made to postulate the worst possible conditions in the dosage calculations. Under favorable meteorological conditions radioactive hazards arising from the maximum possible accident will be serious only in the immediate reactor area with minor hazards to downwind areas. Because of the serious radiation hazards which could exist during unfavorable weather conditions, all reactor experiments which have a reasonable probability of leading to large scale release of fission products will be subjected to meteorological control. Specifically, reactor experiments for which a "moderate" or "high" probability for destruction or serious damage to the facility exists, as defined in Appendix D, or for which a large fission product inventory is present in the core, will not be performed under inversion conditions or when nearby populated areas are in the downwind direction.

The operation of this reactor will be subjected to a strictly enforced set of operating rules and procedures as outlined in Appendix D. It is concluded that the site location, control design and proposed operating rules will permit operation of the Spert IV facility without hazard to the general public.

G. Acknowledgment

The authors wish to express their thanks to the following persons for help in the preparation of this report; R. E. Heffner for providing information for the facility description and D. T. Jones for the control system design.

V. REFERENCES

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6. Figures 8.1 and 8.3 of reference 3.

APPENDIX A

CONTROL SYSTEM DESIGN

I. INTRODUCTION

The Spert IV control system is composed of those components necessary for the safe and positive control of the reactor power through control and transient rod motion. The transient rod is a specialized control element which is not used for routine control of the reactor, but may be rapidly ejected from the core to initiate reactor power excursions.

The system contains no automatic safety circuits which act independently of the reactor operator, but does include electrical and mechanical interlocks to prevent the initiation of certain undesirable actions.

In general, control of the reactor is achieved by varying the vertical position of four control rod assemblies and a transient rod assembly. These rods are connected to the rod drives by electromagnet assemblies which are equipped with accelerating springs for rapid control rod insertion. The control rod speed is variable from 0 to 12 in./min. A digital indicator on the reactor console indicates the control rod drive position to 0.01 inches.

II. DESCRIPTION OF CONTROL SYSTEM

The rod drives are equipped with individual non-overhauling screws for the transient rod and each of the four control rods. Each screw is driven by a worm gear. The control rod worm shafts are coupled together in pairs by shaft couplings and the two pairs then driven by a roller chain from a sprocket on the output shaft of a variable speed transmission. Power is supplied to the transmission by a one-horsepower reversible induction motor. The transient rod is driven independently by a similar motor and transmission system. Each motor and the output shaft of each transmission is furnished with a spring-set, magnetically-released brake to eliminate overtravel after the motor power has been switched off. Individual switches are provided for each rod drive magnet so that one or more rods may remain seated as the magnet assemblies are raised. Release of the control rods is accomplished by de-energizing the electromagnets. High initial acceleration is obtained through the use of adjustable springs. The transient rod drive has a solenoid-operated mechanical latch for positive coupling of the transient rod to the rod drive. This latch prevents the unintentional dropping of the transient rod which would otherwise occur if the transient rod electromagnet current were accidentally turned off.

Step-wise additions of reactivity resulting in transient power excursions are approximated by the rapid insertion of the transient rod into the reactor core. Tests in which reactivity is added approximately linearly with time are initiated by steady withdrawal of the control rods, or insertion of the transient rod, with the rod drives. Either type of reactivity addition may be programmed by use of a sequence timer.

Two sequence timers having ranges of 0 to 30 seconds and 0 to 300 seconds are included in the system for precise programming of experiments. Each timer has seven available circuits. The timer program is started by operation of a spring-return key-switch, and may be stopped by use of a push button switch on the console. If the transient rod has been dropped out of the core to initiate a power excursion, the timers may not be stopped but must complete the sequence to include the programmed "scram".

Limit switches are provided which stop the drive motors when the drives are inserted or withdrawn to predetermined lower limit or upper limit positions. The lower limit is close to the mechanical bottom of the drive travel. The upper limit switches are positioned to stop withdrawal at the height at which the poison sections of the control rods, or the non-poison section of the transient rod, are completely out of the core.

To allow operation of the drive system for maintenance purposes, or perhaps in circumstances of emergency nature, two key-operated switches are provided to remove certain electrical restraints from the control circuitry. These switches are mounted on the console and are designated as "upper limit bypass" and "connector continuity bypass". The function of the upper limit bypass switch is to shunt the upper limit switch, thereby allowing withdrawal of the rod drives above the reactor core upper limit position. Another set of limit switches referred to as "top limits" prevents the drives from reaching the mechanical upper limit of travel. Use of the connector continuity bypass allows control system power to be turned on despite the presence of the following conditions: low voltage, reversed phase sequence, broken cable or connector, or control system relay rack doors open.

Annunciator alarms are provided for the following conditions which should be brought to the attention of the reactor operator.

(1) Improper line voltage or phase sequence.

(2) Disengagement of any control cable connector.

(3) A lapse of more than three seconds time between the release and seating in the core of any rod.

(4) Control or transient rod motor overheat. The motor starter circuitry is such that overheating does not interrupt motor power, but a thermal overcurrent relay causes the annunciator to alarm.

(5) Scram.

(6) Opening of control system relay rack doors with control power on.

(7) Operation of either the upper limit bypass switch or the connector continuity bypass switch. This alarm is primarily to insure that these bypass switches are not unintentionally left on for operation subsequent to a bypass operation.

In normal operation a faint glow is emitted by each annunciator light to assure that it is not burned out. An alarm condition causes a buzzer to sound and the appropriate red light to come on. The buzzer can be silenced by use of a console push button switch, but the red light remains until the alarm condition is cleared. The annunciators operate on control center power through a separate circuit of the power control switch.

III. OUTLINE OF CONTROL SYSTEM OPERATIONAL REQUIREMENTS

A. <u>Required Conditions for Obtaining Control Power</u>

1. Operation of main power key switch.

2. Commercial power of rated voltage and correct phase sequence.

3. Electrical cable connectors in control system correctly engaged.

4. Reactor building control system relay rack doors closed.

(Conditions two, three, and four are necessary only for obtaining, not for maintaining, control power.)

B. <u>Requirements for "Scram Reset"</u> (This circuit must be energized in order to obtain magnet current after a scram.)

1. No scram signal.

2. Transient rod in contact with electromagnet.

3. Operation of scram reset button.

C. <u>Requirements for Control Rod Withdrawal</u>

1. All rods to be withdrawn must be in contact with energized magnet.

2. All rods to be left in the core must be seated.

3. Transient rod latch control not energized. (When energized, the latch control unlocks the mechanical safety latch that

prevents inadvertent transient rod drop).

4. No condition calling for insertion of rods.

5. Control rod drive below "upper limit" (top of core).

6. Operation of spring-return control rod withdrawal switch or energizing of control rod ramp transient circuit by sequence timer.

D. Requirements for Manual Control Rod Insertion

1. Operation of maintained contact control rod insert switch.

2. Control rod drive not at lower limit.

E. Requirements for Automatic Control Rod Rundown (Automatic insertion of control rod drive)

1. Control rod drive not at lower limit.

2. Non-programmed scram, or programmed rundown called for by sequence timer.

F. Requirements for Control Rod "Scram"

1. A series of normally closed push button switches are located at the console and various places in the reactor building for de-energizing the scram circuit, which in turn de-energizes the control rod electromagnets.

2. The sequence timer is permanently wired into the scram circuit for use when a programmed scram is desired.

3. A power failure will scram the reactor by de-energizing the control rod electromagnets and the scram relays.

G. Requirements for Transient Rod Withdrawal

1. Transient rod electromagnet in contact with armature.

2. Transient rod electromagnet energized.

3. Transient rod latch control not energized.

4. Transient rod latch registering "locked".

5. Transient rod latch not registering "unlocked".

6. Transient rod drive below "upper limit" (top of the core).

7. Transient rod insert contactor not energized.

8. Operation of spring-return transient rod withdrawal switch on console.

H. Requirements for Transient Rod Insertion

1. Transient rod withdraw contactor not energized.

2. Transient rod drive not at lower limit.

3. Operation of spring-return transient rod insert switch on console, or energizing of transient rod ramp circuit by sequence timer.

I. Requirements to Energize Transient Rod Electromagnet

1. Transient rod electromagnet in contact with armature.

2. Any one of the following conditions met:

   a. Transient rod FIRE relay not energized;

   b. Transient rod latch control not energized;

   c. Transient rod locked switch actuated;

   d. Transient rod unlocked switch not actuated.

3. Operation of transient rod electromagnet push button.

J. Requirements to Unlock Transient Rod Latch

1. No insertion or withdrawal of transient rod or control rod drives. Energizing latch control inhibits withdrawal of either drive but does not inhibit insertion. Insertion of either drive will instantly de-energize latch control.

2. Transient rod electromagnet energized or transient rod registering seated.

3. Operation of spring-return transient rod latch key switch.

K. Requirements to De-energize Transient Rod Electromagnet

1. Latch control energized.

2. Latch unlocked switch actuated.

3. Latch locked switch not actuated.

4. Operation of FIRE circuit by sequence timer.

APPENDIX B

INITIAL CORE DESIGN

I. GENERAL

The initial core to be used in the Spert IV facility will be a highly enriched uranium-aluminum, plate-type core. Control of the reactor will be accomplished by the use of four control rod assemblies each of which contains two neutron absorbing blades. A similar assembly called the "transient rod" will be used for step insertions of reactivity. The support structure will include an 81 position bottom core grid, a flow skirt to direct flow through the core, and fuel assembly hold-down bars.

II. REACTOR COMPONENTS

A. Fuel

The fuel assembly to be used in the core is the Spert "D" type assembly (Fig. 9) which consists of a 3 in. square by 27-5/8 in. long, aluminum retaining can, a 2.7 in. square lower end box, two grooved side plates, a lifting bail and 12 removable fuel plates. The lifting bail and the lower end box perform the secondary function of holding the plates in the assembly. Disassembly of the fuel assembly is accomplished by the removal of twelve machine screws which fasten the lifting bail and end box to the retaining can.

The fuel is contained in plates, each consisting of 14 grams of U-235 alloyed with aluminum melting stock to produce a "meat section" 0.020 in. thick, 2.45 in. wide, and 24 in. long. This fuel section is clad with 6061 aluminum to produce a plate with overall dimensions of 2.704 in. wide, 25-1/8 in. long, and 0.060 in. thick. A fuel assembly when fully loaded with 12 of these plates will contain 168 grams of U-235. The water channel spacing is nominally 0.165 in., but can be varied by the use of different side plates or the removal of some of the fuel plates.

Hydraulic flow data on the type "D" assembly have shown that a relatively flat velocity profile exists in the assemblies at all velocities up to 60 ft per second, which was the maximum velocity available for the test. At all velocities used for this test no structural weakness appeared which would limit the use of this fuel assembly at high flow rates.

B. Control Rods

The control rods for the "D" core are 5/16 in. thick by 2-1/2 in. wide blades and are made of Binal* containing 7% natural boron. There

- - - - - - - - - - - - - - - - -

*Trade name for the Sintercast Corporation aluminum-boron processed material.

are four control rod assemblies, each having two blades which fit in guide slots in the standard fuel assemblies. Each control rod blade replaces two fuel plates in an assembly. An aluminum follower blade acts both as a guide and a flux peak suppressor when the control rod blade is withdrawn.

C. Transient Rod

The transient rod for initiating step reactivity injections is identical to the control rods except that the upper portion of the blade is aluminum and the follower blade is Binal. This rod is raised to decrease reactivity and dropped to increase the reactivity of the core.

D. Core Structure

The Spert IV core structure, shown in Figure 10, is a nine by nine square aluminum lattice of 3 in. by 3 in. cells supported from the reactor control bridge. The grid is attached to a mounting plate, which also serves as the mounting surface for a core flow adapter which connects through an expansion joint to the 16 inch coolant nozzle in the bottom of the vessel.

The square flow skirt provides lateral support for the assemblies, and serves as the hold-down bar mount as well as providing an enclosure for directing the flow through the core. This flow skirt may be filled with water without filling the reactor pool, thus providing a small tank in which to perform such experiments as calorimetric power calibrations and temperature coefficient measurements.

A sway brace, which is fastened to the pool floor, is provided to prevent lateral movement of the core structure. This sway brace is not mechanically connected to the grid structure, and allows vertical movement of the grid and support structures.

E. Control Rod Drive Units

The control rod drive units for the Spert IV "D" core were designed for open pool operation with cores up to 36 inches long. Basically, the control rod drive units consist of four inverted hollow shaft screw jacks mechanically connected and driven by a variable speed transmission. The control rod speed is variable from 0 to 12 in./min. A synchro transmitter connected to the transmission output drives a digital indicator on the control console which indicates the control rod drive position to 0.01 inches.

Control rod pickup is accomplished by means of an electromagnet suitable for underwater service (Fig. 11). An adjustable spring is provided for initial acceleration when the control rods are dropped. The transient rod magnet, also shown in Figure 11, is equipped with a mechanical latch to prevent an inadvertent drop, since dropping this rod increases the reactivity of the core.

Shock absorbers are integral with the drive units and are suitable for operation either above or below the water level.

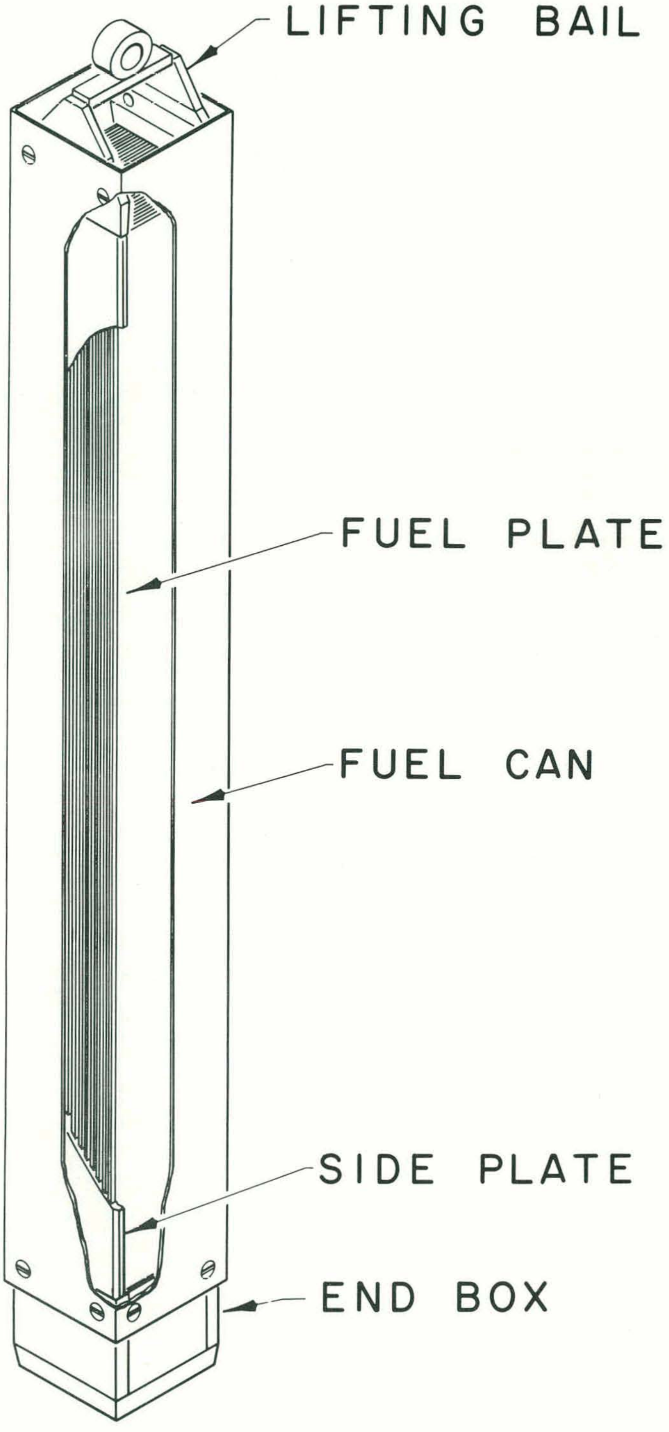

Figure 9 - Spert "D" Assembly

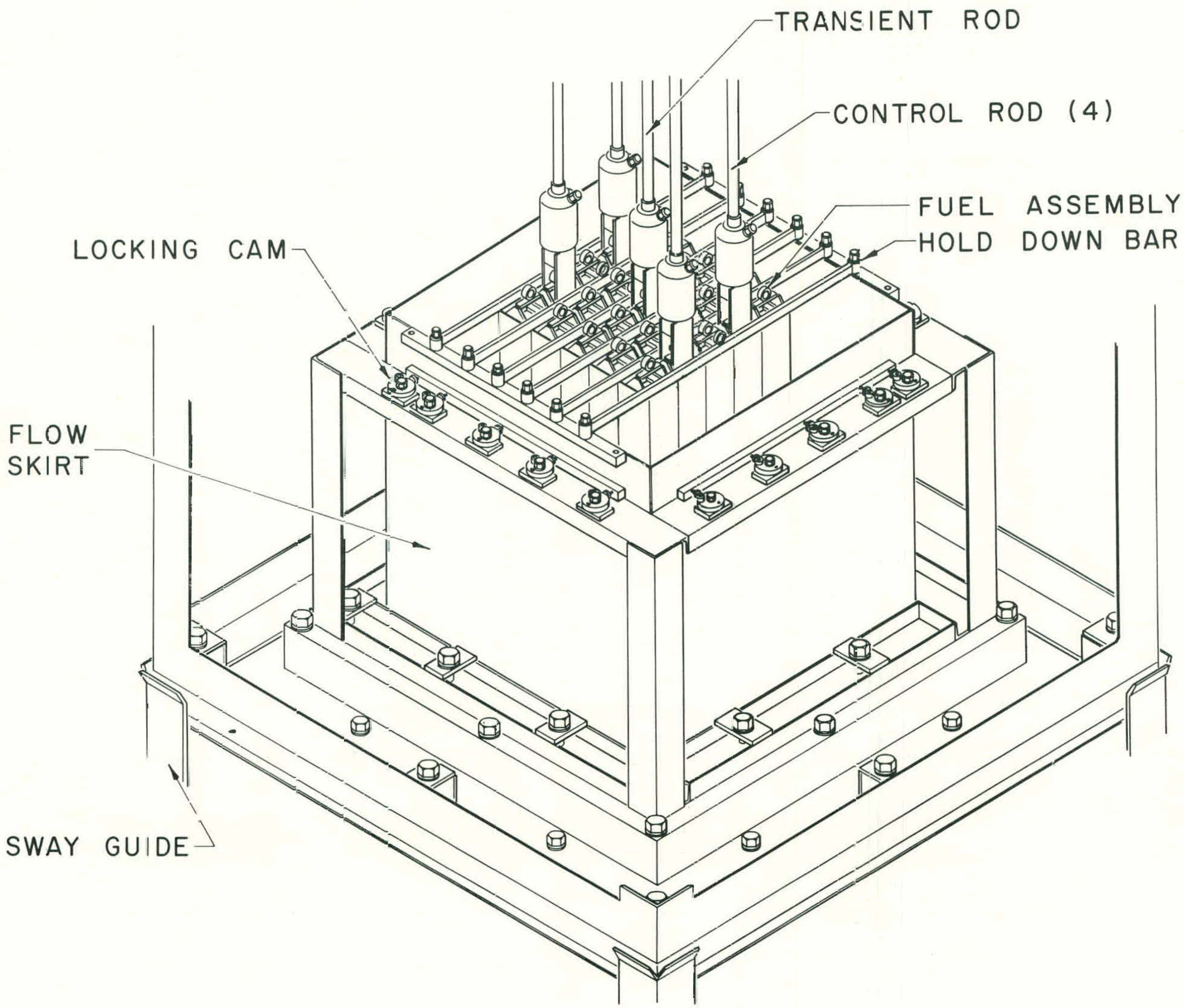

Figure 1C - Spert IV Core Assembly

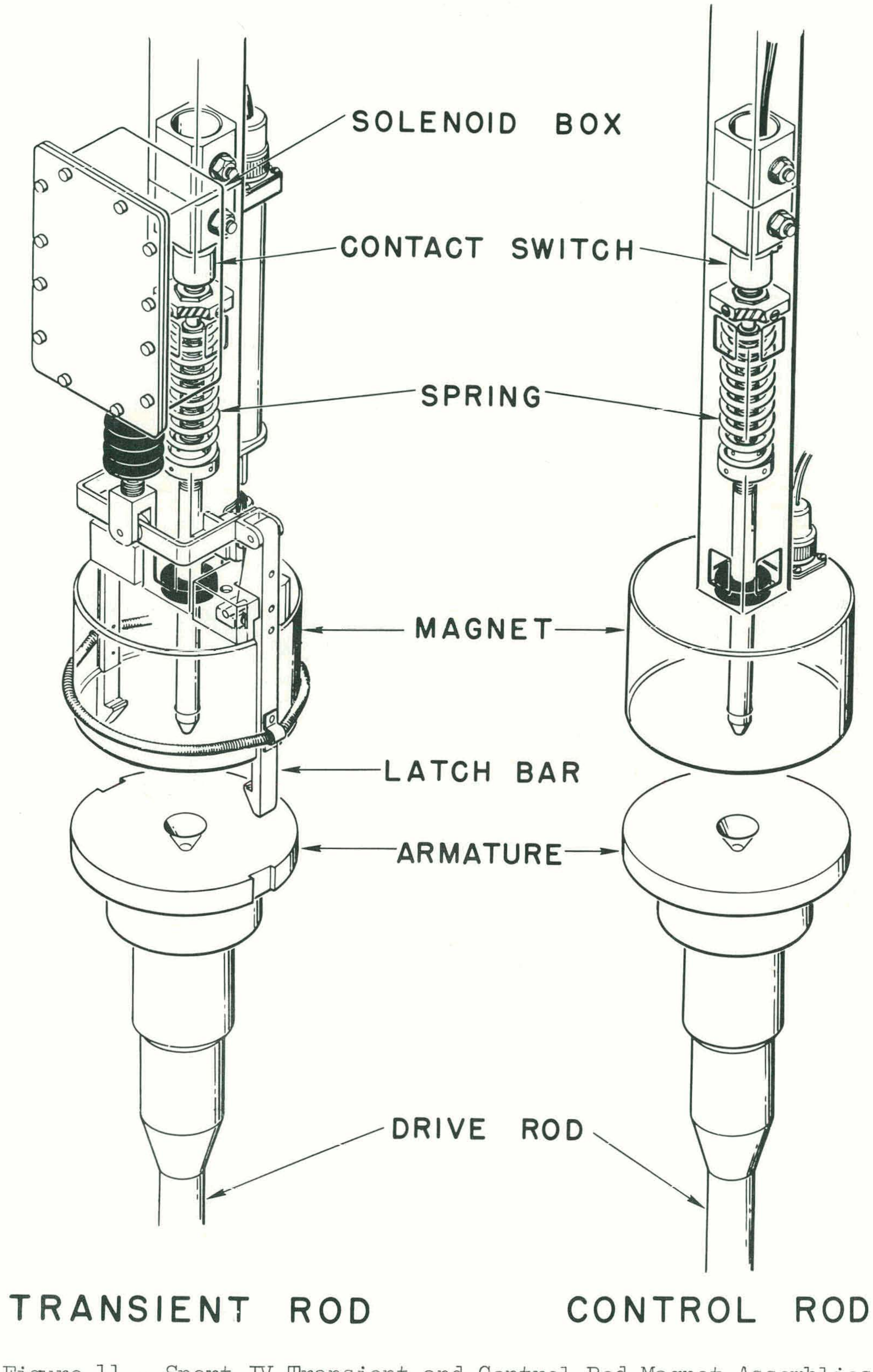

Figure 11 - Spert IV Transient and Control Rod Magnet Assemblies

APPENDIX C

DESIGN DATA SUMMARY

I. PURPOSE

The intent of this appendix is to provide a concise listing of the pertinent specifications for the major equipment, other than instrumentation and core components, necessary for the operation of the Spert IV facility. The equipment is listed in outline form giving sizes, capacities, materials, etc. where applicable.

II. EQUIPMENT DATA SUMMARY

A. Pools

1. Size - 20 ft diameter x 25 ft high
2. Number - 2
3. Heat capacity (each pool) - 2.55×10^7 Btu with $60^\circ F$ ΔT
(1.02×10^6 Btu/ft water in pool)
4. Drain time (minimum each pool) - 2 hours, 46 min
5. Fill time (minimum each pool) - 16 hours
6. Gallons/foot water (each pool) - approximately 2000 gal
7. Circulation rate - up to 5000 gpm
8. Temperature of fill water - $60^\circ F$

B. Reactor Control Bridge

1. Capacity of bridge - 2500 lb/beam w/0.010 in. deflection
2. Services available at bridge
   a. Demineralized water
   b. 110 v instrument power
   c. 110 v service power
   d. Reactor scram station
3. Vertical adjustment of bridge - 5 in.
4. Horizontal adjustment of bridge - full length of both pools

C. <u>Working Bridge</u>

1. Capacity of bridge - 50 lb/ft^2 live load

2. Facilities on bridge - none

D. <u>Circulating Pumps</u>

1. Capacity - 2500 gpm @ 170 ft discharge head and 130°F

2. Number - 2

3. Material of construction

   a. Casing - cast iron

   b. Impeller wear rings - 17 chrome steel

   c. Case wear rings - 12 chrome steel

   d. Shaft - SAE 4140 steel

   e. Shaft sleeves and impeller - series 300 stainless steel

E. <u>Fill Pump</u>

1. Capacity - 50 gpm @ 50 ft discharge head

2. Number - 1

3. Material of construction - all wetted surfaces of the pump are of 300 series stainless steel

F. <u>Clean-Up Pump</u>

1. Capacity - 50 gpm @ 140 ft discharge head

2. Number - 1

3. Material of construction - all wetted surfaces of the pump are 300 series stainless steel

G. <u>Sump Pump</u>

1. Capacity - 300 gpm @ 70 ft discharge head and 130°F

2. Number - 1

3. Material of construction

   a. Pump equipped with fully enclosed impellers

   b. Pump bearings - water lubricated

   c. Pump case - cast iron

H. Demineralizer

1. Type - mixed bed demineralizer
2. Flow capacity
   a. Units used singly - 50 gpm
   b. Units used in parallel - 100 gpm
3. Gallons between regeneration - 15,000 gal (each bed)
4. Water resistivity - 500,000 ohm-cm (minimum)
5. pH - 6.0 to 7.0

I. Water Softener

1. Capacity - 10,000 gal of water free of specific hardness
2. Flow rate - periodic peak loading at approximately 22 gpm

J. Heat Exchanger

1. Type - vertical shell and tube type w/fixed tube sheets
2. Materials - carbon steel, except stainless steel surfaces where wetted with demineralized water
3. Cooling water (shell side)
   a. Flow - 252 gpm
   b. Temperature in - 58°F
   c. Temperature out - 90°F
   d. Inlet pressure - 40 psig
   e. Coolant - raw water
4. Tube side
   a. Flow - 5000 gpm
   b. Temperature in - 100°F
   c. Temperature out - 98.4°F
   d. Inlet pressure - 90 psi (maximum)
   e. Fluid - demineralized water

5. Heat exchanged per hour - 4.05×10^6 Btu/hr continuous duty

6. Transfer rate (service) - 250 Btu/ft^2 x hr x F^o

K. Air Compressor

1. Capacity - 64 cfm @ suction (100^{o}F, 12.2 psia)(3.76 lb/min)

2. Pressure - 125 psig

3. Type - single stage, water cooled

4. Compression rings - segmented carbon (oil free, non-lubricated)

5. Controls-electro-pneumatic automatic stop-start with unloader

L. Air Drier

1. Type - fully automatic dual column

2. Capacity - 30 scfm per tower

3. Outlet dew point; -30^{o}F

4. Maximum inlet conditions; 85^{o}F, 100% relative humidity

5. After filter

    a. Type - dry

    b. Capacity air - 60 cfm @ 30 psig

    c. Particulate removal - 3 to 4 micron

M. Boiler

1. Type - horizontal four pass fire tube

2. Ratings

    a. Boiler horsepower - 50

    b. Gross Btu output - 1670 MBH

    c. Heating surface - 266 ft^2 (water side)

    d. Oil consumption (#2 oil) - 15 gal/hr

    e. Steam pressure - 15 psig

3. Feedwater - soft water or demineralized water plus condensate return

N. <u>Transient Instrumentation Room Air Conditioner</u>

1. ARI capacity - 54,000 Btu/hr
2. Air supply - manual dampered for 0 to 100% recirculated air
3. Cooling - air cooled refrigeration unit

O. <u>Overhead Traveling Crane</u>

1. Description - The crane is an overhead, electrically operated, traveling 3 motor, 12 ton capacity, double-girder-type with a single trolley and two 6 ton hooks connected by a 12 ton load bar with a single 12 ton hook. The crane is operated from the floor and a remote station by push-button-pendant-type controllers.
2. Operating conditions
   a. Capacity - 12 tons
   b. Span - 42 ft 8 in. center to center of runway rails
   c. Hook-lift - 58 ft
   d. Maximum hook height - 6 in. below top of crane runway rails for both 6 ton hooks, 10 in. below top of crane runway for 12 ton hook
   e. Length of crane runway - 69 ft $2\frac{1}{2}$ in.
   f. Duty - occasional (indoors)
   g. Speeds - two speeds at full load capacity as follows:
      1. Hoist - 5 ft/min and 15 ft/min each direction
      2. Bridge - 15 ft/min and 50 ft/min each direction
      3. Trolley - 15 ft/min and 50 ft/min each direction

P. <u>Deep Well Pump</u> (Location: No. 2 well pump house)

1. Temperature of water pumped - $56^{\circ}F$
2. Inside diameter of well casing - 12 inches
3. Elevation of area - 5050 ft
4. Depth to water (estimated) - 470 ft
5. Draw down (estimated) - 20 ft

6. Pump speed - 1760 rpm

7. Pump setting (length of column pipe) - 520 ft

8. Total dynamic head above ground - 55 ft

9. Total pump head - 545 ft

10. Capacity of pump @ 545 TDH - 550 gpm

11. Electric power - 3-phase, 60-cycle, 480-volt

III. TANKS AND VESSELS

A. <u>Contaminated Waste Hold-Up Tank</u>

1. Size - 26 ft ID x 16 ft high (61,000 gal)
2. Snow load - 30 lb/ft^2
3. Wind load - 30 lb/ft^2
4. Foundation - Maximum soil bearing pressure is 3500 lb/ft^2. Exposed portions of foundation are stabilized with asphalt.
5. Controls
   a. High-level alarm
   b. Low-level alarm
   c. Level indicator
   d. Temperature controller

B. <u>Water Storage Tank (Spert Control Center)</u>

1. Size - 26 ft ID x 16 ft 8 in. high (61,000 gal)
2. Foundation - Maximum soil bearing pressure is 3500 lb/ft^2. Exposed portions of foundation stabilized with asphalt.
3. Controls
   a. Level controller
   b. Level indicator
   c. Low-level alarm

Air Receiver Tank

1. Size - 3 ft 6 in. OD x 10 ft high

2. Maximum pressure - 125 psig

3. Maximum temperature - 150°F

D. Demineralized Water Storage Tank

1. Size - 7 ft 6 in. OD x 18 ft high (5700 gal)

2. Lining - 3/32 in. minimum thickness of sheet polyvinyl chloride plastic

3. Pressure - atmospheric

E. Fuel Oil Tank

1. Capacity - 3000 gal

2. Pressure - not to exceed 10 psig

APPENDIX D

OPERATING RULES AND PROCEDURES

I. INTRODUCTION

The operating rules and procedures given in this appendix have been extracted from the Spert Operating Instruction Bulletins which apply to all reactors in the Spert project. These instructions set forth the minimum requirements for the safe and efficient operation of the Spert reactors and will be strictly enforced in the operation of the Spert IV facility.

II. GENERAL AND ADMINISTRATIVE

The Spert Operating Instruction Bulletins are intended to provide in a single written reference, those minimum rules and instructions which must be followed by all Spert personnel in the performance of their duties in order to promote the safe and efficient operation of the Spert facilities, and to provide the high degree of administrative control and cognizance which this requires. In recognition of the fact that such a set of rules will frequently need additions or modifications, the Operating Instruction Bulletins are organized as a set of separate bulletins which can be individually written, revised and approved as the need develops. It is also recognized that, occasionally, a minor deviation from the written rules may be required in order to achieve specific experimental objectives. The recognition of the necessity for such a deviation and the responsibility for determining that such action constitutes a minor deviation, and a safe act, resides with the appropriate Spert Section Chief. It is required that he indicate his approval in the appropriate operating log book prior to the action and that, at the earliest practical time, he inform the Spert Project Manager in writing of such approval and the nature of the deviation.

Preparation of additional bulletins and revision of existing bulletins will be the responsibility of the Nuclear Test Section Chief or the Spert Engineering Section Chief. Such bulletins will not be placed in effect, or distributed, until the proper approvals have been obtained as indicated below. Those portions which have been changed in a revised bulletin will be indicated by marginal asterisks.

Following a review of each new or amended Operating Instruction Bulletin by the Spert Senior Staff, the Spert Project Manager and the Reactor Projects Branch Manager will indicate their approval by dated signature on the first page of the individual bulletin. The procedures contained in the bulletin will then be placed in effect.

It will be the responsibility of each supervisor to insure that all personnel under his supervision are cognizant of the contents of the Spert OIB.

In recognition of the continuing need for review of the operating rules, the Spert Project Manager will periodically call for a formal review of the Operating Instruction Bulletins by the Spert Senior Staff.

A written summary of this review will be prepared by the Spert Project Manager for distribution to all recipients of the Operating Instruction Bulletins. Such formal reviews will be held at intervals not to exceed nine months in duration.

III. REACTOR OPERATING PROCEDURES

A. Philosophy of Operation of the Spert Reactors

1. Statement of Operating Philosophy

The operation of the Spert reactors is to be carried out in a manner consistent with the overall objectives of the experimental program which requires tests closely approaching and possibly attaining the maximum possible accident with any facility. Since these objectives require the performance of tests under conditions which would normally be considered unsafe for most reactor facilities, administrative control must be relied upon to minimize the possibility of nuclear incidents, to insure the safety of Spert personnel and the NRTS, and to eliminate hazard to the general public.

The type of information the experimental program is designed to provide dictates that the reactor control system not be provided with automatic safety circuits. The control systems of the various Spert reactors do, however, contain numerous interlocks, both electrical and mechanical, to reduce the probability of unplanned reactor excursions and to prevent procedures from being followed which could lead to unanticipated situations or unsafe operating conditions.

No reactor operation is permitted with any person within one-half mile of the reactor.

The application of safe operating practices and the recognition and prevention of potentially unsafe acts and situations is the individual responsibility of every member of the Spert Organization.

2. Definition of Reactor Operation

Any set of conditions in a facility which constitutes use of the reactor as a nuclear device shall be considered reactor operation. This shall specifically include all critical measurements, all excursion measurements and all nuclear power operation but is not limited and is not intended to be limited to these three categories.

The instructions governing activities which do not constitute reactor operation but are normally considered to be nuclear operations, such as the transfer and assembly of fuel, are specified in the section on fuel handling.

3. Spert Organization - Functions and Definitions

The general structure of the Spert organization provides a type of parallel assignment of both engineering- and physics-oriented personnel for each of the reactor facilities. In general, the responsibility for each facility resides in the physics-oriented structure for all reactor operation and in the engineering structure for all plant operation; the latter includes the coordination and direction of non-Spert personnel assigned to maintenance activities on and around the Spert reactors.

Both aspects of facility operation demand the participation and concurrence of both areas of interest and of the other areas of the Spert organization through the functions of the Spert Senior Staff as shown below.

a. The Spert Senior Staff consists of the following personnel:

Manager, Reactor Projects Branch
Manager, Spert Project
Spert I Reactor Experiments Section Chief
Spert II Reactor Experiments Section Chief
Spert III Reactor Experiments Section Chief
Spert IV Reactor Experiments Section Chief
Spert Nuclear Test Section Chief
Spert Engineering Section Chief
Spert Data Reduction and Analysis Section Chief

The function of the Spert Senior Staff is to formulate the experimental program, review proposals for tests within the project and, in general, act as an advisory group to the project managers concerning the operation of the Spert facilities.

b. Nuclear Test Section Chief is defined as the supervisor designated by the Manager, Spert Project, to be responsible for the operation of all of the Spert reactors in all their aspects, and for the execution of experiments performed therewith. The Nuclear Test Section Chief reports to the Manager, Spert Project.

c. Nuclear Test Group Leader is defined as the designated supervisor of the Nuclear Test Group of a given facility. The Nuclear Test Group Leaders report to the Nuclear Test Section Chief.

d. Engineer-in-Charge is defined as the designated engineer responsible for plant operation of a given reactor facility. The Engineer-in-Charge reports to the Engineering Section Chief.

e. Responsible Supervisor in Control Room is defined as the Nuclear Test Section Chief or Group Leader having the assigned responsibility for all activities in the control room during reactor operation of a given facility.

f. Reactor Operator is defined as the qualified technical person assigned to operate the reactor console during reactor operation. The reactor operators report to their respective Responsible Supervisors in the Control Room. A person trained in the operation of the reactor, particularly in the performance of and the hazards attendant to kinetic tests, can be designated a qualified reactor operator by the Nuclear Test Section Chief with the approval of the Manager, Spert Project.

4. Other Considerations Reflected in Operating Philosophy

The attitudes reflected in the operating philosophy are based on the physical principles of nuclear chain reacting systems and fissionable materials, the standard procedures employed in similar non-nuclear industrial applications and acceptable practices for remote testing.

B. Pre-Operational Planning and Approvals

1. Purpose and Scope

This bulletin sets forth certain minimum actions which must be taken as part of the pre-operational planning of reactor experiments in order to insure the proper administrative review and approval, and in order to promote the necessary flow of information between various parts of the Spert organization. The steps are described which must be completed prior to the performance of each series of related tests involving reactor operation at any of the Spert facilities.

2. Preparation of Test Series Proposal

The Reactor Experiments Section Chief is responsible for the preparation of a written "Test Series Proposal" for each series of related reactor operations. This proposal will include: a statement of the objectives of the test series; the relation of these objectives to the overall experimental program for the reactor; the expected results; any unusual procedures to be used, or hazards to be expected; and the approximate schedule for the tests. As a part of the proposal, the Section Chief will also state, for the entire series or each test, whether the probability of destruction or serious damage to the facility is "slight", "moderate" or "high". These terms are, of necessity, loosely defined, but the following definitions will be used as guides

a. "Slight" probability is used to describe tests for which sufficient previous data and experience exist to permit confident predictions of the results of the tests.

b. "Moderate" probability is used to describe tests for which the results cannot be reasonably predicted by extrapolation or interpolation of previous test results. Once such tests have been safely performed, repeated tests of the same type may be classed in the "slight" category. The "moderate" category should be selected by the Section Chief for any tests which, in his opinion, involve unusual risks to the reactor or potentially large hazards to the surrounding area. For example, whenever the reactor fuel contains an unusually high concentration of fission products, tests which would otherwise be classed as "slight" will be considered as having "moderate" probability.

c. "High" probability will be used to describe tests which constitute a planned approach to destruction of the reactor.

Copies of the "Test Series Proposal" will be distributed to each member of the Spert Senior Staff, for review.

3. Approvals

Following a review of the "Test Series Proposal" by the Spert Senior Staff, the Spert Project Manager and the Reactor Projects Branch Manager will note their approval of the test series on a copy of the proposal to be retained in the Nuclear Test Section File. Whenever the test series, or parts thereof, are classed in the "moderate" or "high" categories, it will be the responsibility of the Nuclear Test Section Chief to request and obtain higher management approval for performance of the tests. The Nuclear Test Section Chief must also coordinate the performance of the tests with the activities of the AEC-IDO Site Survey Branch from whom meteorological information will be obtained. In the case of "high" category tests, at least six weeks notice will be given to IDO Site Survey and Health and Safety Branches in order to permit adequate preparations to be made for area monitoring.

4. Planning Meeting

Following approval of the "Test Series Proposal", the Reactor Experiments Section Chief will call a "Planning Meeting". Attendees at this meeting shall include the Reactor Experiments Group Leader, the Nuclear Test Group Leader, the Engineer-in-Charge, an instrumentation representative designated by the Nuclear Test Section Chief, and such other persons as the Reactor Experiments Section Chief shall designate. At this meeting, the "Test Series Proposal" will be reviewed and detailed plans will be made for the performance of the test series.

5. Briefing Meeting

Shortly before the initiation of each test series, the Nuclear Test Section Chief will call a meeting of all personnel who will be involved in the performance of the tests. The purpose of this meeting will be to acquaint all operating personnel with the objectives of the tests, the detailed procedures to be followed, the expected results and the possible alternatives which may arise as a result of unforeseen events. Each person will be made aware of his individual responsibility and his working assignment for the test series.

C. <u>Operating Rules in the Control Room</u>

1. During all reactor operations, the Nuclear Test Section Chief or Group Leader is in command of all reactor and plant operations and is the responsible supervisor in the control room.

2. During reactor operation, conversations in the control room must be limited to those pertinent to the experiment. The responsible supervisor may, at any time, request that the room be cleared of nonessential personnel.

3. A minimum of two persons qualified as reactor operators, as assigned by the Section Chief or Group Leader, shall be present in the control room during nuclear operation.

4. Nonessential personnel shall request permission of the responsible supervisor upon entering the control room.

5. The console power or upper limit by-pass switch will not be turned on without permission of the responsible supervisor.

6. The console power key and upper limit by-pass key will be kept in a locked key repository when not in use. Access to the repository will be restricted to the appropriate Group Leader and Section Chief and to the Spert Manager.

7. Any person in the control room has the permission and responsibility to scram the reactor if he thinks an unusual or dangerous situation is present.

D. <u>Record Keeping</u>

1. Purpose and Scope

The purpose of this section is to specify the information required to be recorded in the console log and on recorder charts for maintaining a proper account of all reactor operations. It shall be the responsibility of the reactor operator to see that all relevant information describing the reactor operations and conditions of the system be appropriately recorded in the console log, on the operational linear and log recorder charts, and on process recorder charts. The Nuclear Test Section Chief will inspect the console log books daily.

2. Console Log

a. The console log shall be a bound book having numbered pages.

b. All entries will be written in ink with no erasures permitted.

c. Entries will be made on the right-hand page only, leaving the left-hand page for later annotations (which must be dated and initialled) and for subsidiary information.

d. The date and initials of the writer shall be entered on the top of each new page and for each continuous series of entries.

e. Entries for a new day shall start on a new page.

f. The time of each entry shall be recorded

g. An entry will be made for each working shift, indicating the condition of the reactor and any major operations under way.

h. All fuel transfers (including fuel assembly numbers) to and from the reactor shall be recorded. A summary of the core loading shall be entered periodically.

i. All changes to the reactor control system shall be recorded.

j. Any deviation from standard procedure shall be recorded with the reason for the deviation. Notation of prior approval for the deviation must be initialled by the Nuclear Test Section Chief.

k. Items of procedure followed during reactor operation, e.g., the scram tests made, warning, shutdown of the reactor, etc., shall be recorded.

l. The following information shall be recorded for all experiments performed:

   (1) Title of the test

   (2) Purpose of the experiment

   (3) Experimental conditions

   (4) Rod positions

   (5) Approximate power level

   (6) Reactor temperature

   (7) Period measurements

   (8) Pertinent oscillograph record numbers

   (9) Location of further related information on the test

   (10) Diagrams wherever appropriate

m. Any significant radiation levels: (a) in the reactor building following reactor operations, and (b) of any reactor components or equipment transferred within the facility, shall be recorded.

n. Any unusual, unexpected, anomalous, or unexplained occurrences of the plant, reactor, control system or instruments shall be recorded.

o. Any occurrence which might, by any stretch of the imagination, be considered an accident, incident or near-miss incident shall be recorded. Such entries must be called to the immediate attention of the Nuclear Test Section Chief and initialled by him prior to further operation.

3. Operational Linear Recorder

The following items shall be entered on the operational linear power recorder chart:

a. Date and time of run

b. Run number

c. Type of test

d. Chart speed

e. Critical Rod Positions

f. Rod positions during period measurements

g. Range setting

4. Process Recorders and Operational Log Recorder

The following items shall be entered on all process and operational log recorder charts:

a. Date and time of run

b. Run number

c. Time at appropriate intervals

E. <u>Preparations for Reactor Operation</u>

1. Purpose

To establish the rules, minimum instrumentation and preparations required for reactor operation and the mechanisms for assuring continuous administrative control during the transition from Engineering Section Control to Nuclear Test Section Control.

2. Minimum Neutron Instrumentation

Prior to evacuation of the reactor building, the Nuclear Test Section shall be responsible for assuring the operability of the following as a minimum:

a. Low-Level Instrumentation. At least two neutron pulse-counting channels shall be on and operating prior to startup. Evidence of proper operation from background or artificial source will be verified by the reactor operator.

For startup experiments requiring discrete counting intervals on several channels, at least one pulse channel shall be relegated to remain in continuous operation.

Under all startup conditions where the neutron level is below 1/2 full scale on the most sensitive range of the operational linear power recorder, at least one pulse-counting channel shall be audible in the control room.

b. Power Recorders. One operational linear and one operational log power recorder shall have been checked for (a) proper operating performance; (b) an adequate amount of chart paper; and (c) writing ink. The linear recorder shall be on the most sensitive range and without "damping" prior to startup.

3. Check Lists

Check lists will be made by the Nuclear Test Section to verify that all instrumentation and/or experimental equipment pertinent to the planned operation are in the proper operating condition. The reactor operator will verify the completion of the check list.

The Engineer-in-Charge will prepare a check list and verify that all plant equipment is in the proper condition required for the reactor operation.

4. Transfer of Control and Responsibility

At such time as the reactor operator has completed all items on the check list and has verified completion of all Nuclear Test Section responsibility for the preparations for the nuclear run, he will so notify the Engineer-in-Charge and the Nuclear Test Group Leader.

After the Engineer-in-Charge has verified that all plant preparations are complete, has received notice that the Nuclear Test Section is ready, and has verified that no non-Spert personnel are in the building or reactor area, he shall verbally transfer the control and responsibility of the reactor and reactor plant to the Nuclear Test Section by notifying and obtaining concurrence of both the Test Section Chief, or his designated representative, and the reactor operator. The concurrence and acceptance of control and responsibility shall be noted in the console log.

The reactor operator may then initiate routine evacuation of the reactor building.

F. Routine Evacuation

The following steps must be performed in the sequence shown to effect routine evacuation:

1. When the Nuclear Test Section has assumed administrative control and responsibility for the reactor and plant, the reactor operator will instruct the assigned health physicist (HP) to proceed with routine evacuation.

2. The HP will notify the security guard that the reactor area is being evacuated and that no non-Spert personnel may be admitted until further notice.

3. The HP will then announce the order to evacuate over the intercom system and the reactor operator will sound the warning horn three times.

4. The Engineer-in-Charge or his delegated representative will obtain the plant operations log book and remove it from the reactor area during the reactor operation.

5. The HP will inspect the reactor area, including both the inside and outside of all buildings in the area to insure that all personnel have left the reactor area.

6. The HP will then set up the road block and signal the reactor operator (1 buzz) to turn on the exclusion light. When the light comes on the HP will acknowledge (2 buzzes).

7. The HP will then report to the security guard that the reactor area is closed to all personnel.

8. The HP will report to the control room that the area is clear.

9. The Engineer-in-Charge will report to the control room.

G. Reactor Operation

The purpose of this bulletin is to set forth the general operating rules to be followed during reactor operation. These rules are intended to promote a safe and unified operational procedure for all Spert reactors.

1. The evacuation of the reactor area is not considered completed until the assigned health physicist and Engineer-in-Charge have reported in person to the Reactor Operator.

2. The Nuclear Test Section Chief, or the Group Leader designated by him, is in charge of all reactor and plant operation during reactor operation, and is the responsible supervisor in the control room. In the event of a plant emergency, command reverts to the Engineer-in-Charge after the reactor has been safely shut down.

3. The Reactor Operator will announce over the intercom system his intent to start nuclear operation and will listen for possible response from the reactor area before proceeding with any reactivity addition.

4. The reactor annunciator panel must not indicate any faults.

5. Before any rod motion is attempted or other operations that might change the reactivity are initiated, at least two neutron pulse counters will be indicating the neutron background level and the operational log and linear power recorders will be on and the chart paper will be in motion. One neutron pulse counter must always be operating continuously, providing an audible count rate indication to the operator, until reliable indication of power is observed on the linear power recorder.

6. Permission to turn on the console power switch will be obtained from the responsible supervisor.

7. When the required instrumentation is in operation, the reactor scram system will be checked and the performance of the check noted in the console log. In no case will the reactor be made critical during the performance of these scram checks.

8. Timer Check

   When the test is to be programmed by the sequence timer, a dry run will be made to check the operation of the timer prior to rod withdrawal.

9. Shutdown

   After the reactor is safely shut down, the console keys will be returned to the locked repository and notation of their return made in the console log. The Reactor Operator will remain on duty at the console until building re-entry has been made.

H. Safe Shutdown of Reactor and Transfer of Control

The section defines the minimum conditions which must exist before the reactor is safely shut down and the reactor console secured, and establishes continuous administrative control during the transition between Nuclear Test Section responsibility and control, and Engineering Section responsibility and control of the reactor plant.

1. Conditions for Safe Shutdown

These minimum conditions must exist before the reactor can be said to be safely shut down:

a. All control rods and transient rod seated.

b. All control rod and transient rod drives at lower limit.

c. Instrumentation must indicate a shutdown reactor.

d. In the best judgement of the Responsible Supervisor in the control room, the reactor is subcritical and no foreseeable events will lead to criticality.

e. The evaluation of any reactor annunciator signal or other abnormal condition existing at the time of shutdown shall be completed prior to securing the console.

f. The console power must be turned off.

g. The reactor operator must remain at the console until re-entry of the reactor building is established and the time of re-entry and radiation levels have been noted in the console log.

2. Transfer of Reactor and Reactor Plant Control and Responsibility

After a test or series of tests occurring in any one day, when it has been determined by the Responsible Supervisor in the control room that the reactor has been safely shut down, the Responsible Supervisor in the control room will immediately notify the Engineer-in-Charge that the reactor has been shut down and will at this time transmit any other information pertinent to the plant or reactor conditions to the Engineer-in-Charge. The Responsible Supervisor in the control room will then request the Engineer-in-Charge to assume control and responsibility for the reactor. With concurrence of the Engineer-in-Charge, control and responsibility for the reactor and reactor plant then passes to the Engineering Section.

I. <u>Routine Re-Entry into the Reactor Area</u>

1. If routine re-entry into the reactor area is desired, the Responsible Supervisor in the control room (when responsibility and control reside with the Nuclear Test Section) or the Engineer-in-Charge (when responsibility and control reside with the Engineering Section) will so inform the assigned Health Physicist and, if plant process equipment is operating, the Engineer-in-Charge will station a technician at the process panel in the control room until re-entry is established. The reactor operator will remain at the console until re-entry is established and the time of re-entry and radiation levels have been noted in the console log.

2. The Health Physicist will inform the security guard that re-entry is being made, but that the area is still closed to non-Spert personnel.

3. The Health Physicist will be accompanied by the Engineer-in-Charge or a member of the Nuclear Test Section.

4. The Health Physicist will remove the road block, signal for the exclusion light to be turned off (1 buzz) and will acknowledge (2 buzzes) when the light has been turned off.

5. The Health Physicist will determine the radiation levels in the area and building and will inform the Engineer-in-Charge or the member of the Nuclear Test Section of the level of radiation and of the special precautions or restrictions, if any, that must be made upon re-entry.

6. The Health Physicist will inform the guard when the area is open to non-Spert personnel.

J. Meaning of Reactor Warning Lights and Horns and Radiation Alarms

This bulletin describes the meaning of the reactor warning horn, "Reactor On" lights and the radiation alarm bells in the reactor areas and sets forth the action to be taken by personnel in the reactor area upon recognition of these signals.

1. The reactor warning horn will be sounded three times immediately following the evacuation announcement over the reactor area intercom as a signal to evacuate the area. Any other sounding of this horn indicates that control rods are being withdrawn in the reactor and that the reactor is in operation.

2. The red flashing lights on and within the reactor buildings indicate that control rods have been withdrawn in the reactor and that the reactor is in operation.

3. Any personnel inside the reactor building at any time the warning horn blows and the "Reactor On" warning lights come on will immediately evacuate the building and the area (run) and report to the reactor control room. If such persons pass a scram button on their fastest exit path from the building, they will push the button during evacuation. Since microphones at several building locations are normally live, an attempt should be made to establish voice contact with the control room (shout), but such attempts should in no way delay rapid exit from the building. Any personnel outside the reactor building, but within 1/2 mile of the building at any time the warning horn blows or the "Reactor On" warning lights come on, will immediately leave the area and report to the reactor control room.

4. Radiation alarms have been provided in the reactor buildings to warn of high radiation fields or air contamination. Each of the alarm circuits causes a bell to ring in the reactor building. When these bells sound anywhere in the building, personnel must leave the area immediately and report the situation to the Health Physicist. Re-entry to the area will not be made until the radiation level has been determined by the Health Physicist.

IV. GENERAL HEALTH PHYSICS RULES.

A. General Rules

1. Never enter a ribboned-off area without shoe covers when the radiation tag states that it is a shoe cover area or Anti-C clothing area.

2. Never enter a ribboned-off area without first reading the radiation tag attached to it. Consult Health Physics if the information on the tag is not completely understood.

3. When entering or leaving a shoe cover area, never place an uncovered shoe inside the ribbon, or a possibly contaminated shoe cover outside the ribbon.

4. Do not stand against a radiation ribbon when it is around a shoe cover area. This may result in a person's feet being on the opposite side of the ribbon.

5. Never remove a radiation ribbon without first consulting Health Physics.

6. Never touch doorknobs or other "clean" surfaces with hands or gloves that may be contaminated.

7. If there is a slightest possibility that personal clothing has become contaminated, request a Health Physics survey before leaving the contaminated area. The frisker or hand and foot counter will not indicate such contamination unless the clothing is highly contaminated.

8. Upon reaching the control center, hands and feet should be checked on the hand and foot counter if there is a possibility of them having become contaminated. Hands and feet should always be checked immediately after leaving a contaminated area.

9. If the hand and foot counter indicates shoe contamination, do not move from the counter before putting on shoe covers.

10. Do not handle articles that may be contaminated without wearing appropriate gloves. (For example, wear rubber gloves while handling wet articles.)

11. If a person suspects that he has contaminated an area, he should not leave the area, but should get someone to contact Health Physics for a check of the area. He should also assume responsibility for preventing the spread of the contamination by stopping traffic in or out of the area.

12. Never alter or adjust Health Physics monitoring instruments in any way without first consulting Health Physics. This includes

unplugging, moving the instrument, and turning off the alarm. A violation of these rules may result in the instrument being inoperative when it is most needed.

13. All personnel decontamination should be done under Health Physics supervision.

14. A quintector is installed at the entrance to the Spert control center. This will provide a method of monitoring for beta and gamma radiation. It is set to alarm at slightly above background and serve as a warning that person(s) passing through the doorway might be carrying radioactive materials. The person(s) involved should proceed directly to the HP office for a more complete check in order to locate and measure the intensity and nature of the radiation.

15. Never open a cask that is used for radioactive shipments without a Health Physicist in attendance. Do not look in before it is monitored.

16. No movement of radioactive materials from one area to another should be made without consulting Health Physics.

17. No source should be exposed or handled without a Health Physicist in attendance.

18. Do not put known "cold" waste in "hot" waste containers. The disposal of "hot" waste is expensive. Also, do not put what may be "hot" waste in "cold" waste containers. This may result in a hazard to someone or a considerable amount of work in removing it later from the dumpsters.

19. All fuel and equipment pulled from the reactor vessel, canal, hot storage holes, etc., must be monitored as it is pulled. HP personnel should be present whenever possible. If there is a possibility of a radiation field existing and HP personnel are not present, the field should be monitored by operating personnel using appropriate instrumentation.

B. Exposure and Dosimetry Rules

1. Do not work in a radiation field unnecessarily. The allowable radiation exposure when necessary is 60 mrem/day. This amount can be authorized by Health Physics for a particular job or time interval in one day. If it is necessary that a larger exposure be received in one day (up to 300 mrem), this can be authorized by the immediate supervisor once a week. For visitors this authorization must come from the Project Manager. An exposure greater than 300 mrem/day, once per week, must be authorized by the Branch Head. For visitors, this authorization must come from their home office.

2. Under no circumstances should personnel enter any of the reactor areas without a film badge. If a badge is lost or missing,

pick up one of the temporary badges that are available at the guard gate.

3. Dosimeters have been assigned to personnel having occasion to work in reactor areas. Personnel who do not have a regularly assigned dosimeter will continue to secure them at the HP office. Regularly assigned dosimeters are to be picked up each morning, worn on person during day, and placed back in the rack at the end of shift.

V. GENERAL INSTRUCTIONS REGARDING THE HANDLING OF FUEL, REACTOR COMPONENTS, EXPERIMENTAL EQUIPMENT, ETC., WITHIN REACTOR VESSELS AND FUEL STORAGE AREAS

A. Purpose and Scope

The purpose of this bulletin is to set forth general instructions governing the transfer into, from or within the confines of reactor vessels and storage areas of any fuel, reactor component, experimental equipment, or any other object which can possibly affect the reactivity of the system. These instructions specify the requisite approvals and responsibilities attendant to all such transfer operations, and are intended to eliminate any possibility of a nuclear incident. These instructions apply to all personnel and all facilities in the Spert area.

B. General Instructions

1. Approval of Transfer Operation

Approval for all transfer of fuel, reactor components experimental equipment, or of any object which significantly affects the reactivity of the system, into, from or within the confines of the reactor vessel or fuel storage area must be given by the Nuclear Test Section Group Leader in the form of a request for such transfer. These requests will be directed to the appropriate Engineer-in-Charge and will include all necessary detailed instructions for carrying out the transfer operation and will indicate a designated Surveillant Physicist from the Nuclear Test Section for monitoring the operation.

2. Responsibilities

a. Engineer-in-Charge. After obtaining the required approval and instructions, the Engineer-in-Charge shall notify the Nuclear Test Section Group Leader immediately prior to the time operations in the reactor vessel or fuel storage area are to be performed and must ensure that a Surveillant Physicist be present during the operation.

The Engineer-in-Charge is responsible for all manipulations performed, and he must personally supervise such manipulations. He has the responsibility and authority to clear the building of all nonessential personnel if, in his judgment, the nature of the operation warrants it.

The Engineer-in-Charge shall be responsible for maintaining fuel transfer and inventory records at the reactor building.

The Engineer-in-Charge must ensure that an HP be present whenever fuel or equipment is pulled from the reactor vessel or storage area and that it be monitored by Health Physics personnel as it is pulled. In no case shall the HP doing the monitoring assist in the actual operation.

b. Nuclear Test Section Group Leader. The Nuclear Test Section Group Leader shall initiate the request for the transfer operation and shall provide the Engineer-in-Charge with both the detailed procedures and information on the nature of the monitoring instrumentation which are required for carrying out the operation.

The Nuclear Test Section Group Leader will name and make available for the operation a Nuclear Test Section Surveillant Physicist, who is cognizant of the detailed operation to be performed and of the nuclear safety inplications involved in the operation.

c. Surveillant Physicist. The Surveillant Physicist has the responsibility to ensure (with information on the date and nature of the last instrumentation checks) that the required monitoring instrumentation is available and in operation, with signals audible or visible to him at his station prior to start of the work. He must serve no other function during the operation than to observe, in detail, all movements or manipulations occurring and to evaluate these movements or manipulations with regard to nuclear safety. It is his duty to be aware at all times of the neutron pulse register sound or signal as an aid to his evaluation. If at any time he feels that a hazardous condition may occur, he must stop all operations until the situation has been cleared. He may request of the Engineer-in-Charge that the building be cleared of nonessential personnel if, in his judgment, the nature of the operation warrants it.

The Surveillant Physicist shall be responsible for ensuring that someone is available in the control room for recording in the console log all information on fuel transfers, control rod removal and source transfers, as they occur. Wherever applicable, a record shall be maintained by the Nuclear Test Section of the location of each numbered fuel plate. The console log record of fuel transfers will document assembly transfers by assembly number only, and will refer to the appropriate record location for the individual plate locations and/or contents of individual assemblies. The console log will contain a record of transfers of fuel plates to or from assemblies only to the extent of documenting that changes were made in a particular assembly and of referencing the record location of the details of the changes made.

VI. GENERAL INSTRUCTIONS FOR MISCELLANEOUS OPERATIONS WHICH MAY AFFECT NUCLEAR SAFETY

A. Purpose

This bulletin provides a general set of instructions for performing miscellaneous plant or reactor operations which may affect nuclear safety. It is intended that these instructions eliminate the possibility of a nuclear incident.

B. Scope

This bulletin covers all operations which may affect the nuclear safety and which are not specifically covered elsewhere in the Operating Instruction Bulletin. Some, but not necessarily all, of the operations are:

(1) Changes in reactor water level

(2) Operation of the primary system pumps

(3) Changes in the coolant temperature, pressure or flow

(4) Changes in the reactor control system including the control rod drive mechanisms.

C. General Instructions

Prior to the onset of any operation which may affect the nuclear safety of the reactor, the Engineer-in-Charge must obtain approval for the operation from the Nuclear Test Section Group Leader. (Operations of the primary system which do not affect water level or temperature of the reactor do not require approval.) This approval must indicate the required surveillance and instrumentation required, permissible rates of system changes, and the degree of latitude permitted the Engineer-in-Charge for the operation.

Flow must not be started unless the control rod assembly is in contact with the control rod drive assembly.

Prior to flow, the Engineer-in-Charge must request the Nuclear Test Section Group Leader to verify that installed instrumentation is compatible with the flow rates expected.

At the completion of the operation, the Engineer-in-Charge must notify the Nuclear Test Section Group Leader that the approved operation has been completed.

APPENDIX E

INHALED DOSE CALCULATIONS

In order to calculate the inhaled dosages quoted in Table 2 of this report, the following procedure has been followed. The radioactive cloud volume as a function of distance from the origin is assumed to be

$$V = \left[\pi^{1/2}\ CX^{\frac{2-n}{2}}\right]^3 , \qquad (1)$$

where

V = cloud volume (m^3),

X = distance from origin (m),

n = Sutton's stability parameter (dimensionless),

C = Sutton's diffusion coefficient ($m^{n/2}$).

The concentration of activity in the cloud is assumed to follow the following relation:

$$C_{(r)} = \frac{A}{V}\ e^{-\left(\frac{r}{r_o}\right)^2} , \qquad (2)$$

where

$C_{(r)}$ = radioactive cloud concentration $\left(\frac{\text{curies}}{m^3}\right)$,

r = distance from center of cloud (m),

r_o = cloud radius (m) = $CX^{\frac{2-n}{2}}$,

A = total curies in cloud.

The activity of a specific isotope inhaled by a person standing directly in the path of the cloud during its total passage is given by

$$\begin{aligned} I &= \int_0^{\infty} J\ C_{(r)}\ dt \\ &= \int_{-\infty}^{\infty} J\ \frac{A}{V}\ e^{-\left(\frac{r}{r_o}\right)^2}\ \frac{dr}{v} \qquad (3) \\ &= \frac{JA}{vV}\ r_o\ \pi^{1/2} = \frac{JA}{vV^{2/3}} \end{aligned}$$

where

I = inhaled activity (millicuries),

v = cloud velocity (m/sec),

J = inhalation rate (liters/sec).

Assuming

$$J = (17 \text{ liters/min}) \cdot (1.67 \times 10^{-2} \text{ min/sec}),$$

then

$$I = 2.84 \times 10^{-1} \frac{A}{vV^{2/3}} \text{ millicuries.} \qquad (4)$$

For a specific isotope the cloud activity is calculated by

$$A = (8.4 \times 10^{5}) \, P \, y \, (1 - e^{-\lambda t_o}) \, e^{-\lambda\left(\frac{X}{v}\right)} \text{ curies,} \qquad (5)$$

where

P = reactor power (Mw),

y = fractional fission yield,

λ = radioactive decay constant for isotope (sec^{-1}),

t_o = operating time prior to release of fission products (sec),

X = distance from release (m),

v = cloud velocity (m/sec).

The internal dose rate at a time t following inhalation is given by

$$\frac{dD}{dt} = \frac{f_a \, I \, E}{f_c \, g} \, \frac{(3.7 \times 10^{7})(1.6 \times 10^{-6})}{10^{2}} \, e^{-\lambda_e t} \text{ rads/sec,} \qquad (6)$$

where

f_a = fraction of inhaled activity deposited in critical organ,

f_c = fraction of organ available (= 0.2 for bone, = 1 for thyroid),

g = mass of critical organ (grams),

E = effective energy of radiation (Mev/disintegration),

λ_e = effective decay constant (sec^{-1}) = $\lambda + \lambda_b$,

λ_b = bilogical elimination constant (sec^{-1}),

t = time after inhalation (sec),

I = inhaled activity (millicuries).

Therefore, the total dosage for an infinite time thereafter is

$$D = \int_0^\infty \frac{dD}{dt}\, dt = \frac{f_a\, I\, E}{f_c\, g\, \lambda_e}\,(5.91 \times 10^{-1}) \text{ rads,} \qquad (7)$$

and using equations (4) and (5) above

$$D = (1.41 \times 10^5)\ \frac{P}{vV^{2/3}} \left\{ \frac{f_a\, E\, y}{f_c\, \lambda_e\, g}\,(1 - e^{-\lambda t_o})\ e^{-\lambda\left(\frac{X}{v}\right)} \right\} \text{rads} \qquad (8)$$

for a specific isotope.

The constants used to obtain the results given in Table 2 of this report are shown in Table 3. The meteorological constants used are shown in Table 1, page 18.

TABLE 3

ISOTOPIC DATA FOR INHALED DOSE CALCULATIONS (SEE TEXT FOR DEFINITIONS OF SYMBOLS)

Isotope	Critical Organ	g (grams)	f_c	f_a	E(Mev)	y	$\lambda(sec^{-1})$	$e(sec^{-1})$
I^{131}	Thyroid	20	1	0.15	0.22	0.031	$9.86x10^{-7}$	$1.03x10^{-6}$
I^{132}	Thyroid	20	1	0.15	0.50	0.045	$8.02x10^{-5}$	$8.02x10^{-5}$
I^{133}	Thyroid	20	1	0.15	0.40	0.051	$9.44x10^{-6}$	$9.44x10^{-6}$
I^{134}	Thyroid	20	1	0.15	0.65	0.063	$2.88x10^{-5}$	$2.88x10^{-5}$
I^{135}	Thyroid	20	1	0.15	0.31	0.062	$2.20x10^{-4}$	$2.20x10^{-4}$
I^{136}	Thyroid	20	1	0.15	2.2	0.034	$8.06x10^{-3}$	$8.06x10^{-3}$
Sr^{89}	Bone	$7x10^3$	0.2	0.22	0.55	0.047	$1.52x10^{-7}$	$1.54x10^{-7}$
Sr^{90}-Y^{90}	Bone	$7x10^3$	0.2	0.22	1.00	0.052	$8.80x10^{-10}$	$2.97x10^{-9}$
Y^{91}	Bone	$7x10^3$	0.2	0.14	0.57	0.056	$1.41x10^{-7}$	$1.57x10^{-7}$
Zr^{95}-Nb^{95}	Bone	$7x10^3$	0.2	0.12	0.2	0.067	$1.24x10^{-7}$	$1.70x10^{-7}$
Ba^{140}-La^{140}	Bone	$7x10^3$	0.2	0.20	1.06	0.066	$6.26x10^{-7}$	$6.69x10^{-7}$
Ce^{141}	Bone	$7x10^3$	0.2	0.10	0.16	0.059	$2.43x10^{-7}$	$2.58x10^{-7}$
Pr^{143}	Bone	$7x10^3$	0.2	0.063	0.31	0.061	$5.81x10^{-7}$	$7.30x10^{-7}$
Ce^{144}-Pr^{144}	Bone	$7x10^3$	0.2	0.10	1.29	0.059	$2.92x10^{-8}$	$4.46x10^{-8}$
Eu^{154}	Bone	$7x10^3$	0.2	0.09	0.37	0.0085	$4.07x10^{-9}$	$9.80x10^{-9}$

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