Dismantling and Disposal Plan
Oregon State University
AGN-201 Reactor

License No.: R-51

Docket No.: 50-106

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DISMANTLING AND DISPOSAL PLAN

I. INTRODUCTION

Oregon State University (OSU) possesses an AGN-201 nuclear training reactor under USNRC License No. R-51 (Docket No. 50-106). It is proposed that this facility be defueled and dismantled in preparation for transfer of the reactor to: (a) Northwestern University in Evanston, Illinois; (b) another NRC-licensed facility; or (c) a DOE facility for ultimate disposal. The fuel will be retained at OSU pending approval to transfer it to one of the above mentioned facilities. To permit the transfer of the AGN reactor, this document provides the OSU plan for dismantling of the reactor's component parts, interim storage of the fuel at OSU, and subsequent shipment of the fuel from OSU. To the extent possible, provisions of NRC Regulatory Guide 1.86, "Termination of Operating Licenses of Nuclear Reactors" have been followed.

Appendix A to this plan gives a brief description of the reactor; Appendix B summarizes its operating history; and Appendix C discusses radiation levels anticipated.

The general procedure for disassembly and disposal will be to verify that the reactor control rods have been removed, and then to remove the thermal column, the Ra-Be start-up source, the intact core can, and the separate sections of the reflector and shield assembly. The Ra-Be source will be placed in a shielded storage container and stored in the Radiation Center source storage facility. The control rods will be stored in one of the locked fuel storage pits in the TRIGA reactor room and the core can will be stored separately in a locked enclosure in the TRIGA reactor room. This room is monitored by criticality and physical security devices. After all fuel and the neutron start-up source are removed, the electrical connections for the control rod drives and other instrumentation will be disconnected. All reactor components and areas will be checked for induced radioactivity and contamination, and decontaminated as required. Upon completion of this, all non-radioactive reactor components will be shipped to the scheduled recipient.

When all of the recipient's NRC license approvals (or other appropritate approvals) are received by OSU, the fuel will be shipped to the approved facility in accordance with all applicable Federal and State regulations. OSU's existing radiation protection program will be utilized to accomplish all necessary radiation monitoring, waste management, and other radiation safety related aspects of the operation. During the entire operation, care will be taken to protect both the operations personnel and the general public from exposure to ionizing radiation, and to keep necessary radiation exposure as low as reasonably achievable.

II. DISMANTLING PROCEDURE

A. General

During the dismantling operations, an NRC-licensed Senior Reactor Operator (SRO) for the AGN-201, will be present. The Radiation Center Health Physicist, or his representative, will be present as necessary to monitor the operations for radiological safety. Personnel involved in the dismantling operation will receive instructions on the procedures at a pre-dismantling meeting.

B. Safety Evaluation

1. Nuclear Criticality Safety

A nuclear excursion would be the most serious type of accident that could occur during the disassembly and removal of the reactor core. However, it is one of the least likely of all credible accidents. To obtain criticality, the complete core assembly, including all fuel discs, the two fueled safety rods, and the fueled coarse control rod, must be assembled with a reflector in an optimum geometry.

Nuclear safety will be maintained since the safety and control rods will have been previously removed and stored in a distant location in the TRIGA reactor room before any disassembly allowing removal of the core can is begun. The combined fuel content of the rods is approximately 45 grams of U-235 and the core itself contains approximately 620 grams of U-235. As an added but unnecessary precaution, cadmium will be inserted in the safety and control rod holes in the core can prior to any reactor disassembly.

As a further precaution, the temporary cadmium safety rod presently inserted into the glory hole will remain in place during disassembly of the reactor. This cadmium rod will have to be removed just prior to removing the core can since the glory hole liner tube must be removed before the core container can be lifted out of the reactor.

A portable neutron survey meter will be in continuous operation during the removal of the core can as one indicator of neutron multiplication. The existing three nuclear instrumentation channels of the reactor will also be operational during removal of the core can.

The removal of the reactor core can will be performed under the supervision of an NRC-licensed SRO. The Cd rod will be placed back into the glory hole immediately after the core can is removed from the reactor. The core can will not be left unattended. Upon removal, it will be transferred to its final storage container and storage destination. See Section II-C, Specific Procedures.

2. Radiation Safety

Radiation exposure could arise from three sources: the reactor core, activation products outside the core, and the Ra-Be start-up source. Thorough surveys of the reactor core and the other reactor components, and comprehensive monitoring of the area and personnel during disassembly will prevent accidental and/or excessive radiation exposures. Such monitoring will be supervised by the Radiation Center's Health Physicist.

The 10 mCi Ra-Be start-up source will be removed from the reactor after the removal of the thermal column. The source will be leak-tested by wiping after removal and stored in a shielded container in the Radiation Center source storage facility.

Personnel monitoring devices will be worn by individuals entering the AGN reactor area during disassembly. As necessary, these will include devices to measure extremity and/or whole body doses.

3. Mechanical Safety

The most probable type of accident is that which might be called mechanical and may result from either human error or mechanical failure. The probability of human error will be minimized by making adequate preparation for the work and by following a predetermined plan of action. The probability of mechanical failure will be minimized by thorough inspection of all equipment in advance.

C. Specific Procedures

1. The Health Physicist will make a special pre-disassembly radiological survey. He will also initiate special access procedures, personnel and equipment monitoring procedures, and other procedures needed to keep radiation exposure as low as reasonably achievable. An operational check will be made of radiation monitoring equipment present, including the AGN AREA/CRITICALITY monitor. If all monitoring equipment responds properly the operation will proceed.
2. The Reactor Supervisor will brief the disassembly group on each step prior to its accomplishment.

3. Insure that the temporary cadmium rod is in the glory hole.
4. Insure that the control and safety rods have been removed.
5. Remove the control rod drive mechanisms and dashpots.
6. Insert cadmium in the control and safety rod holes in the core can.
7. Drain the thermal column.
8. Unbolt and remove the thermal column.
9. Remove the Ra-Be neutron source from the graphite reflector. Leak-test the source and place it in the storage container.
10. Conduct a core survey. Since the core tank will not be opened at this time, an off gas sample will not be taken. A direct radiation survey and smear survey of the core tank top will be made.
11. Remove the cadmium from the glory hole.
12. Remove the glory hole tube.
13. Lift the intact core can from the reactor.
14. Replace the cadmium in glory hole.
15. Conduct radiation survey to determine direct radiation levels from the core can and removable surface contamination on the exterior surface of the can.
16. Transfer the core can to its storage container and remove it to its storage location.
17. Health physics will perform a radiation survey of accessible internal surfaces to acertain direct (induced) radiation levels and removable contamination levels.

Note: This concludes the nuclear portion of the disassembly process. The remaining disassembly will be conventional mechanical and electrical, with radiation surveys made as directed by the Health Physicist.

18. Remove the four access port tubes.
19. Remove the outer graphite shield.
20. Remove the four lead shield rings.
21. Remove the core support plate.
22. Remove the lead base plate shield.
23. Drain the shield water tank.
24. Reactor electrical and instrumentation disassembly -- the electrical and instrumentation cables will be disconnected in the following general sequence:
    a. Nuclear Channel #1:
        1) Detector chamber H.V. off.
        2) Ratemeter main power off.
        3) Remove detector dry well from reactor tank.
        4) Disconnect pre-am (2) and H.V. (1) cables.
    b. Nuclear Channels #2 and #3:
        1) Disconnect H.V. cables at battery supply pack.
        2) Remove detector dry wells from reactor tank.
        3) Disconnect signal and H.V. cables.
    c. Disconnect main distribution cable.
    d. Disconnect monitor cable.
    e. Disconnect main power cable.

III. STORAGE OF FUEL AT OSU

A. Storage Location and Configuration

As indicated before, the intact core can and the fueled control and safety rods will be stored separately, well apart from each other. The rods will be stored at the bottom of a locked 12-foot deep fuel storage pit located in the floor of the TRIGA reactor room. The intact core can, with cadmium inserted in the glory hole and control rod holes, will be stored in a locked enclosure also in the TRIGA reactor room. These items will remain in these locations until shipment from OSU.

B. Criticality Considerations

With the fueled control rods and the reactor core stored in physically well-separated locations, and with cadmium inserted in the glory hole and the control rod holes of the reactor core, inadvertent criticality is impossible. Nevertheless, criticality monitors and existing area radiation monitors will be used for surveillance of the core and the fueled rods while they are in storage.

C. Physical Security Considerations

The AGN core and fueled control rods will be stored in the TRIGA reactor room, which is a vital area as defined in the TRIGA Reactor Physical Security Plan. Thus these AGN components will be protected and covered by the active TRIGA Physical Security Plan, which provides excellent coverage for these components.

IV. TRANSPORTATION PLAN

OSU will ship the AGN core and start-up source in accordance with applicable NRC, DOT and State of Oregon regulations. As required, the following actions will be taken:

1. Confirm that the recipient is properly licensed or otherwise authorized to receive the radioactive material.
2. Utilize an NRC approved (licensed) DOT Type B shipping container(s) for the special nuclear material contained in the core and control rods, and a DOT Type A, Specification 7-A, shipping container for the RaBe start-up source.
3. OSU will obtain approval to use the NRC approved DOT Type B shipping containers in accordance with 10 CFR 71.12.
4. OSU will obtain approval for a transportation physical security plan which meets the required level of security for the SNM at the time of shipment.
5. Shipment will be by a means authorized by the NRC, DOT and State of Oregon.

V. ENVIRONMENTAL CONSIDERATIONS

As stated earlier, the fuel and radioactive sources will be removed from the reactor and stored in separate locations, pending shipment offsite. All remaining reactor components will be decontaminated such that surface contamination levels are below the levels listed in NRC Regulatory Guide 1.86 for release to unrestricted use. There should be no direct radiation emissions above natural background.

There should be no significant exposure to personnel or generation of wastes during the disassembly process because all components are at very low levels of radioactivity. These low levels result from the operating history of the reactor (1584 watt-minutes of energy release throughout the reactor lifetime) and the long shutdown time (about 4 years). A small volume of low level waste (paper towels, gloves, wipes, etc.) will be generated during the disassembly operation. This should be less than 10 cubic feet total, and will be disposed of in accordance with appropriate State and Federal regulations.

The reactor has not operated in the past four years, and there are no present or future plans to operate or use this reactor at OSU. The space the reactor occupies is needed by the university for laboratory purposes. The reactor has little or no resale value that we can determine. Its best use would be at another university (or other facility) which needed such a reactor and which would use it as it was originally intended to be used. As a last resort, the fuel could be sent to DOE for reprocessing and use in other reactors, and the other reactor components used as spare parts for other AGN facilities or reclaimed as scrap.

A physical security chain link fence around the reactor will have to be removed, and a portion of the outer brick wall of the reactor room must be removed to allow removal of the large reactor components. The brick wall will be rebuilt following reactor removal. The estimated cost of these changes is about $3,200. No other changes to the building, electrical lines, water lines, or sewer lines are required in the dismantling of the reactor.

APPENDIX A

DESCRIPTION OF AGN 201 TRAINING REACTOR

1. GENERAL DESCRIPTION

The AGN-201 consists of two basic units, the reactor unit and the control console. The reactor unit consists of the reactor core surrounded by a graphite reflector which in turn is enclosed by lead and water shielding. Control and safety rods are installed vertically in the bottom of the reactor unit and pass through the shields and graphite reflector into the uranium-polyethylene core. The control console consists of instruments and appropriate control mechanisms for measuring the power level of the core and for actuating the control and safety rods so as to provide safe and efficient operation of the nuclear reactor.

As an aid to a better understanding of some of the physical parts described herein, drawings (Fig. A-1 and Fig. A-2) are supplied.

2. THE REACTOR UNIT

2.1 Core

The AGN-201 reactor core is comprised of a series of discs formed from a mixture of polyethylene and UO_2 (the uranium content 20% enriched in the isotope U-235). Fig. A-1 shows the assembly arrangement of the core within the core tank and its respective position with the graphite and control rod components.

The estimated critical mass of the reactor is 600 ± 50 gm of U-235. The design volume of the core allowing for the void resulting from the glory hole and the fuse assembly is 12,000 cm^3. The core is loaded initially with a U-235 density of 54 milligrams cm^{-3} and will thus contain about 650 grams of U-235.

2.2 Core Tank Design

The core tank has been designed to contain any fission gases that might be given off by the polyethylene-uranium oxide core. Sixty five mil commercial (61 ST) aluminum is used throughout as the structural material. The core tank may be considered to be made of an upper and lower section, separated by an aluminum baffle passing through the core in the same plane as the glory hole. The aluminum serves to separate the core into two parts, and is part of the safety fuse system. Detachable top and bottom cover plates as well as control and safety rod thimbles form an integral part of the gas-tight core tank (Fig. A-2).

The lower section of the core tank contains 1/2 of the core material as well as a cylindrical section of graphite reflector. These pieces of core material and inner piece of graphite reflector are supported by an aluminum rod hanging from the fuse link which in turn is supported by a telescoping aluminum tube which is screwed into the bottom cover plate of the core tank. Ample space at the bottom of the cylinder, coupled with a tapered graphite-to-graphite joint is provided to insure free fall of the bottom half of the core plus reflector section when the fuse melts in the event of an accidental nuclear excursion.

The upper section of the core tank contains six of the core discs. A space for core expansion and gas accumulation is provided in the top section of the core tank.

2.3 Reflector and Lead Shield Design

The reflector consists of 20 cm of high density (1.7 gm cm^{-3}) graphite on all sides of the core. Appropriate holes are provided for the glory hole, the two safety, the two control rods, and the four access ports. All of the components of this section of the assembly are easily accessible from the top of the reactor. Ten cm of lead completely surrounds the core, reflector, and thermal neutron shield.

2.4 Reactor Tank

The lead shielding, reflector, and core are enclosed in and supported by a 5/16 inch wall steel tank (47.5 cm radius). A removable top cover is provided. This tank acts as a secondary container for the core tank assembly, and with the glory hole and access ports closed, is gas-tight.

The control rods and safety rods enter through the bottom of the reactor tank. The upper or "thermal column tank" serves as a shield tank (H_2O filled) or thermal column (graphite filled).

2.5 Water Tank

The water tank is the third and outermost of the fluid tight concentric container. This main structural member is 6-1/2 feet in diameter and constructed of steel. Access may be gained to the top of the tank even with water in the reactor tank by removing the top manhole cover plate. Another cover is provided at the bottom of the reactor tank over the control and safety rods, which serves to maintain the secondary gas-tight seal.

The fast neutron water shield is formed by filling the tank with 1,000 gallons of water.

2.6 Safety and Control Rods

The AGN-201 reactor has two safety rods and two control rods. Each rod operates in a manner such that reactivity is increased as the rod is inserted. Two of the rods are used as safety rods and the other two rods are used as fine and coarse control rods. The amount of reactivity each rod controls is nearly proportional to the amount of contained active material. With the same uranium concentration in the rods as is used in the core, each rod contains 14.2 grams of U-235 and controls about 1.6% reactivity.

The rods are lifted into the core by a pair of lead-screws. The screws are coupled to the coarse and safety rods through an electro-magnet. This allows decoupling when the scram signal is received. The fine rod is driven in a like manner but without the magnet coupling. It was felt that it controlled too little reactivity to be of practical value in a scram. The active length of each rod is 15 cm of UO_2 embedded in stabilized polyethylene, the same composition as in the reactor core. This active fuel material is enclosed in two aluminum containers, the outermost cover provides the gas seal from the core tank, and the innermost aluminum container seals the active fuel in the rod. By this design, a double gas-tight seal is maintained for the control and safety rods as well as for the core. The accompanying diagram indicates how the various gas-tight seals are accomplished.

For small adjustments of the U-235 in the reactor, the safety and control rods offer a convenient method of adding or removing fuel. For safety reasons, the safety rods will always contain at least 5 gm of U-235. When fuel discs are removed from the rods they are replaced by pure polyethylene discs.

2.7 Fusing System

The concept of the fuse in the 201 reactor is directly analogous to the electrical fuse used in every household. The AGN 201 reactor core fuse is made of polystyrene containing 108 milligrams of U-235 cm^{-3} that acts as the support for the bottom half of the reactor core and a section of the reflector. The load on this fuse is 15 kg. Most of the stress in the fuse is in compression and sheer so as to circumvent any possible creep problems of polystyrene in tension.

The higher loading density is used to generate heat at a higher rate in the fuse than in the core, such that the fuse rises in temperature about twice as fast as does the core proper. At about 100°C, the fuse melts and the core separates completely, thereby shutting down the reactor in the event of an accidental excursion. Polystyrene is used as the fuse material rather than polyethylene because of its resistance to changes in physical properties induced by radiation. Experiments indicate that the melting point of polystyrene is unaffected by radiation doses below 100 megarep. Thus, the properties of the fuse are not affected by several severe nuclear excursions, nor by normal operation for a score of years.

Care has been taken in the design of the reflector plug to insure that the plug actually drops after the fuse melts. Ample clearance and the tapered design have been provided to insure a free fall. The separation of the core reduces the reactivity by at least 5%, and more likely 10%.

2.8 Safety Rod Operation

The safety rods are in the safe or sub-critical position when they are in their outermost position. The total distance of travel is 25 cm. In the out position the active fuel in the rod is just inside the lead shield and partially in the graphite reflector. The rods are inserted one at a time by the drive mechanism. The maximum rate of travel inward is .46 cm $\sec^{-1}$. The magnet release mechanism is constructed in such a manner that if a scram signal is received during insertion, both rods are driven to their outermost positions.

The safety system is a "fail safe" design in that the scram signal opens the holding magnets allowing the rods to be accelerated outward by both gravity and spring loading. The spring constant is such that the rods are initially accelerated with a force of 5 g, requiring a total withdrawal time of 150 milliseconds. The reactivity change of both safety rods is minus 0.7% during the first 45 milliseconds. The rods are decelerated by an air dash pot in the last 12.5 cm of travel.

2.9 Control Rod Operation

Both the coarse and fine control rods are driven by reversible motors through lead screw assemblies which are controlled by switches at the control console. The maximum speed of travel of the rods is .46 cm $\sec^{-1}$, yielding a maximum reactivity change of 3×10^{-4} $\sec^{-1}$ for the coarse rod.

The positions of both control rods are indicated remotely at the control console. In the event of a scram, the coarse rod is automatically and instantaneously moved out to its safe position while the fine rod is automatically moved out by reversing the lead screws until it is in its outermost position. Interlocks prevent their movement unless the safety rods are "cocked." The safety rods cannot be cocked until the control rods have reached their safe or starting positions.

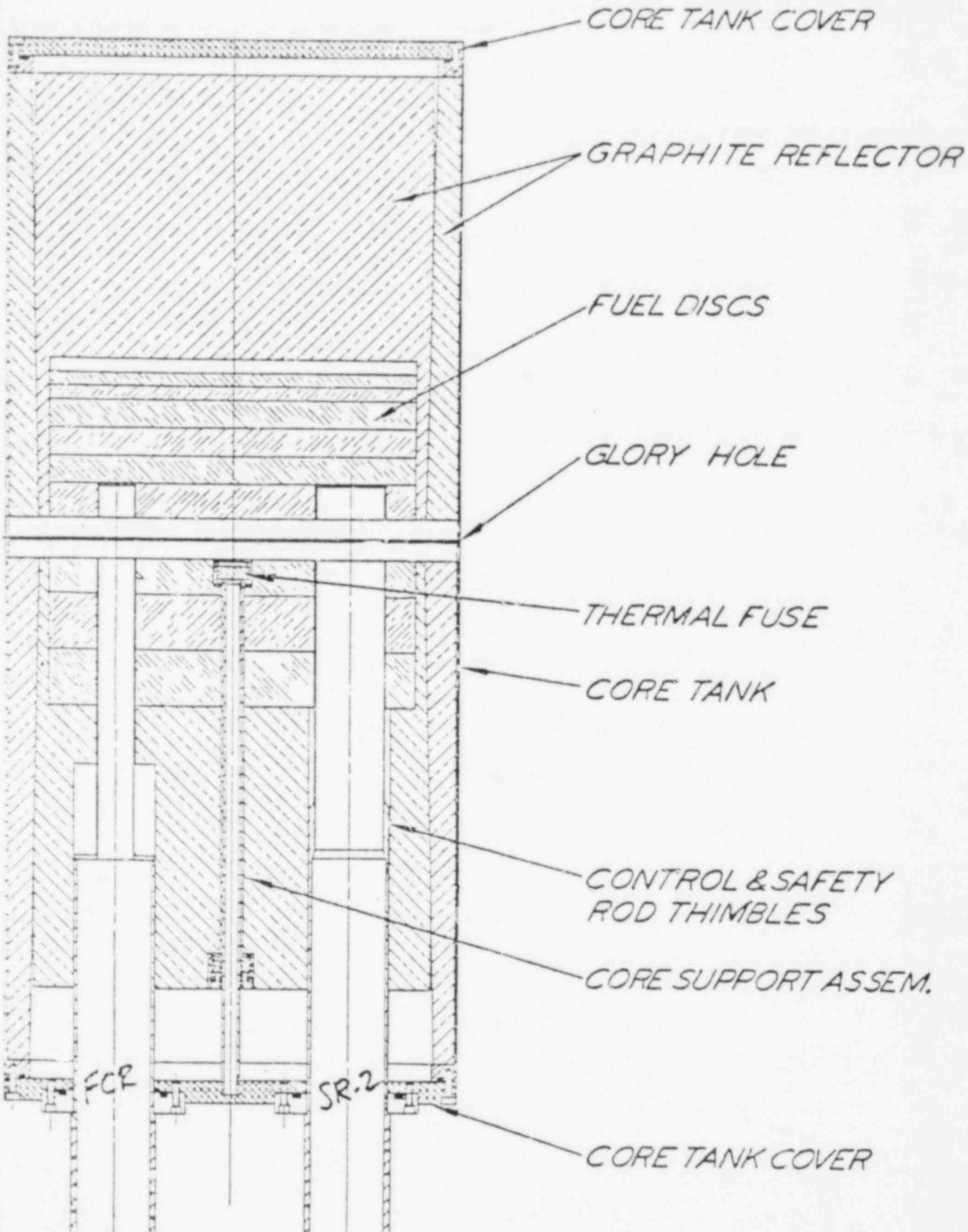
CORE TANK COVER
GRAPHITE REFLECTOR
FUEL DISCS
GLORY HOLE
THERMAL FUSE
CORE TANK
CONTROL & SAFETY ROD THIMBLES
CORE SUPPORT ASSEM.
CORE TANK COVER
FCR
SR-2

Fig. A-1

201 REACTOR GAS TIGHT SEAL DIAGRAM

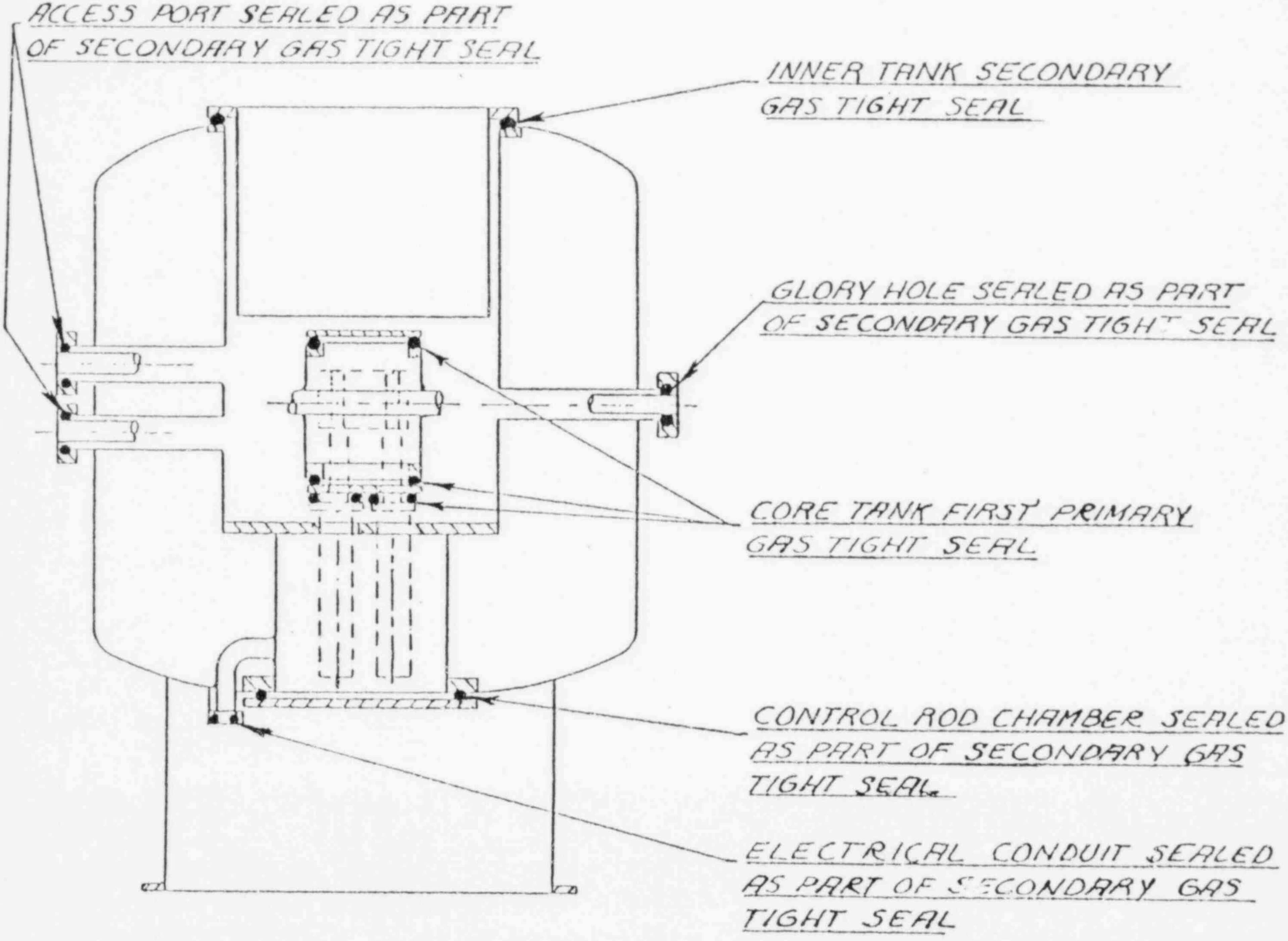

Fig. A-2

APPENDIX B

Operating History of the Oregon State AGN-201 Reactor

The AGN-201 Reactor (Serial #114) was operated by Oregon State University. The reactor first went critical on January 28, 1959. The reactor was used continuously by OSU until December of 1974 at which time it was shut down.

The reactor has been possessed for a total of 19 years by Oregon State University. Actual reactor operating time amounts to 408.6 hours with a total energy release of 1583.6 watt-min (1.1 watt day).

APPENDIX C

Fission Product Radioactivity of Fuel

The expected radioactivity of the OSU AGN-201 reactor core is computed from the operating history of the reactor (Appendix B).

The total energy release was 1583.6 watt-minutes, over a time period of 16 years (1959 to 1975). The actual operating time over this 16-year period was 408.6 hours. For the purposes of this calculation, two different operating scenarios were assumed:

1. Continuous operation over a 16-year period, at an average power level (1.882×10^{-4} w) determined by dividing the total energy release (1583.6 watt-min.) by the total time (16 years).
2. Operation at maximum licensed power (0.1 w) continuously for 15836 minutes, ending in December 1974, such that the total energy release is again 1583.6 watt-minutes.

For both scenarios, a shutdown time of four years (December 1974 to December 1978) is assumed after operation. For both scenarios, the following equation was used to calculate fission produce activity in the core:

$$A = (1.4 \times 10^{6}) P [t^{-0.2} - (t + T)^{-0.2}]$$

where A = total fission product activity (Ci)

P = operating power level (MW)

T = operating time (days)

t = shutdown time (days)

Results of the calculation are:

	Scenario #1	Scenario #2
P (MW)	1.882×10^{-10}	1.00×10^{-7}
T (days)	5844	11.0
t (days)	1460	1460
A (Ci)	1.69×10^{-5}	4.89×10^{-5}
A (μCi)	16.9	48.9

Scenario #2 should represent an upper limit, conservative estimate of the fission product activity. The actual fission product activity in the core should be somewhere between the values calculated by Scenarios #1 and #2; for future calculations in this section, however, the maximum, conservative value obtained from Scenario #2 will be assumed.

It is relevant to compare the fission product activity of the core to the natural activity of the core due to the uranium present.

$$\begin{aligned}\text{Natural core activity} &= (\text{specific activity of } {}^{235}\text{U})(\text{amount of } {}^{235}\text{U}) + \\ &\quad (\text{specific activity of } {}^{238}\text{U})(\text{amount of } {}^{238}\text{U}) \\ &= (2.16\ \frac{\mu\text{Ci}}{\text{gm}})(655\text{ gm}) + (0.33\ \frac{\mu\text{Ci}}{\text{gm}})(2647\text{ gm}) \\ &= 2288\ \mu\text{Ci}\end{aligned}$$

Thus, the ratio of natural core activity (2288 μCi) to fission product activity (48.9 μCi) is about 47.

The dose equivalent rate from the fission products in the core can also be estimated. Assume the core is unshielded in air, and it can be approximated by a point source, rather than the actual cylindrical volumetric source that it is. This should again be conservative, as no self-absorption in the source is assumed. Also assume that the fission products yield one gamma ray of 1 MeV per disintegration. The point source strength, S, is then:

$$S = (48.9\ \mu\text{Ci})\left(3.7 \times 10^4\ \frac{\text{dis}}{\text{sec}\ \mu\text{Ci}}\right)\left(\frac{1\gamma}{\text{dis}}\right) = 1.81 \times 10^6\ \gamma/\text{sec}$$

The point source flux, ϕ, at 1 foot is then:

$$\phi = \frac{S}{4\pi r^2} = \frac{(1.81 \times 10^6)}{4\pi(30.48)^2} = 155\ \gamma/\text{cm}^2\text{sec}$$

The dose equivalent rate, H, at 1 foot is:

$$H = 0.0576\ \phi\ E\left(\frac{\mu_a}{\rho}\right)^{\text{tissue}}\left(\frac{\text{mrem}}{\text{hr}}\right)$$

$$= (0.0576)(155)(1)(0.0300)$$

$$= 0.27\ \frac{\text{mrem}}{\text{hr}}$$

From the above, it is concluded that the fission-product radioactivity of the Oregon State University AGN-201 will present no significant hazard beyond that of the unirradiated reactor core when it was new.