Dismantling and Disposal Plan
California Polytechnic State University
AGN-201 Reactor

License No.: R-121

Docket No.: 50-394

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DISMANTLING AND DISPOSAL PLAN

I. INTRODUCTION

California Polytechnic State University (CPSU) possesses an AGN-201 nuclear training reactor under USNRC License no. R-121 (Docket No. 50-394). It is proposed that this facility be defueled and dismantled in preparation for transfer of the reactor to: (a) another NRC-licensed facility; or (b) a DOE facility for ultimate disposal. The fuel will be retained at CPSU pending approval to transfer it to one of the above mentioned facilities. To permit the transfer of the AGN reactor, this document provides the CPSU plan for dismantling of the reactor's component parts. interim storage of the fuel at CPSU, and subsequent shipment of the fuel from the campus. 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 and the start-up source have been removed, and then to remove the thermal column, the intact core can, and the separate sections of the reflector and shield assembly. The Ra-Be sources will remain locked in the shielded storage container adjacent to the west wall of the N.P.F. The control rod thimbles will remain stored in a locked cabinet in the separated adjacent Radioisotope Laboratory room. After having ascertained that the preceding items are properly stored, the general procedure for disassembly will be to remove the top cover, thermal column, the intact core can, then the separate sections of the reflector and shield assembly.

Next, the individual fuel discs will be removed from the core can, wipe tested, and checked off by number for inventory and stored in two separate locked vaults, one-half in each.

After all the fuel has been removed to storage, 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 appropriate approvals) are received by CPSU, the fuel will be shipped to the approved facility in accordance with all applicable Federal and State regulations. CPSU'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 Safety Officer, 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 have been previously removed and stored in the separate radioisotope 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 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.

In addition to a portable gamma monitoring meter, a portable neutron survey meter will be in continuous operation during the removal of the core can as one indicator of neutron multiplication. Two of the existing three thermal neutron instrumentation channels of the reactor will also be operational during dissassembly.

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 the area where the fuel will be removed and stored. See Section II-C, Specific Procedures.

2. Radiation Safety

Radiation exposure could arise from three sources: the reactor core, activiation 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 Safety Officer.

The Ra-Be start-up sources were removed from the reactor last year. The sources were leak-tested by wiping after removal and remain stored in a shielded container in the N.R.F. source storage vault.

Personnel monitoring devices will be worn by individuals entering the AGN reactor area during disassembly.

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 Radiation Safety Officer 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. If all monitoring equipment responds properly, the operation will proceed.
2. The Senior Reactor Operator 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. Drain the thermal column.
7. Unbolt and remove the thermal column.
8. Ascertain that neutron sources have been removed from the graphite

reflector and placed in the storage container.

9. Conduct an initial core survey, including a direct radiation survey and smear survey of the core tank top.
10. Remove the cadmium from the glory hole.
11. Remove the glory hole tube.
12. Lift the intact core can from the reactor.
13. Replace the cadmium in glory hole.
14. Conduct radiation survey to determine direct radiation levels from the core can and removable surface contamination on the exterior surface of the can.
15. Transfer the core can to the room adjacent to the reactor for disassembly and storage of the fuel.
16. The fuel will be removed from the core can sequentially with the top half of the fuel plates transferred to fuel safe number one and the bottom half to fuel safe number two.
17. The Radiation Safety Officer will perform a radiation survey of accessible internal surfaces to ascertain direct (induced) radiation levels and removable contamination levels.

<u>NOTE</u>: 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 Radiation Safety Officer.

17. Remove the four access port tubes.
18. Remove the outer graphite shield.
19. Remove the four lead shield rings.

20. Remove the core support plate.
21. Remove the lead base plate shield.
22. Drain the shield water tank.
23. 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-amp (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 CPSU/SLO

A. Storage Location and Configuration

As indicated before, the individual core fuel disks and the fueled control and safety rods will be stored separately, well apart from each other. The rod fuel thimbles are stored in a locked cabinet located in the radioisotope room. These items will remain under physical security in separate locations in the N.R.F. until shipment from CPSU/SLO.

B. Criticality Considerations

With the fueled control rods and the reactor core divided into two physically well-separated locations, inadvertant criticality is impossible. 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 adjacent room, which is a vital area as defined in the N.R.F. Security Plan. Thus these AGN components will be protected and covered by the active Security Plan, which provides excellent coverage for these components.

IV. TRANSPORTATION PLAN

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

A. Confirm that the recipient is properly licensed or otherwise authorized to receive the radioactive material.

B. Utilize an NRC approved (licensed) DOT Type B shipping container(s) for the special nuclear material contained in the core and control rods.

C. CPSU will obtain approval to use the NRC approved DOT Type B shipping containers in accordance with 10 CFR 71.12.

D. CPSU will obtain approval for a transportation physical security plan which meets the required level of security for the SNM at the time of shipment.

E. Shipment will be by a means authorized by the NRC, DOT and State of California.

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.

No significant exposure to personnel or generation of any waste will occur during the disassembly process and all components are at very low level of radioactivity and in solid form. These low levels result from the operating history of the reactor (less than 3,000 watt-minutes of energy release throughout the reactor lifetime) and inoperative period (about two and a half years). The small volume of low level waste (paper towels, gloves, wipes, etc) used during disassembly will be disposed of in accordance with appropriate State and Federal regulations.

The AGN-201 has not operated in the past two and a half years, and there are no present or future plans to operate or use this reactor at CPSU. The space it occupies is urgently needed by the University for Mechanical Engineering laboratories. 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 estimated cost of these changes is about $5,000. No other changes to the building, electrical lines. water lines. or sewerlines 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 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 containers. 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_1 embedded in stabilized polyethylene, the same composition as in the reactor core. This active fuel material is enclosd 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 compressions and shear 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 uneffected 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 the their outermost positions.

The safety system is a "fail safe" design in that the scram signal opens the holding magents 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 post 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 switched at the control console. The maximum speed of travel of the rods is .465 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.

APPENDIX B

Operating History of the California Polytechnic State University AGN-201 Reactor

The original AGN-201 Reactor (Serial No. 100) was operated first by the U.S. Naval Postgraduate School in Monterey, California and initially went critical on April 30, 1957. It was operated intermittently at the one-tenth watt power level as originally designed for instructional purposes until about 1963. The reactor was then modified for higher power operation, the license amended, and then relicensed for operation at the 10 watt level until 1971. A total integrated power of 908,625 watt-min (631 watt-day) was logged during the above period of operation at the USN Post Graduate School.

It was then disassembled and reconstructed in the Mechanical Engineering Laboratory on the CPSU campus, relicensed for the original 0.1 w level and went critical in its new location on October 7, 1975. Operated occasionally during the intervening period it was then shut down on May 30, 1978 and placed in stand-by condition (inoperative) by removing all four control rods to storage.

CPSU was in possession of the reactor for a total of 5 years. Actual operating time amounted to 17.8 hours with a total energy release of only 61.2 watt-min (0.043 watt-day) since beginning operation in its present location.

APPENDIX C

Fission Product Radioactivity of Fuel

The expected radioactivity of the CPSU AGN-201 reactor core is computed from the operating history of the reactor since it was constructed (Appendix B).

To determine the maximum present fission product due to operation at the USN PGS, we assume that the 908,625 watt-min of operation occurred at the 10 watt level during a period immediately preceding shutdown. Thus the operation is assumed to occur during the 90,865 minutes or 63.1 days prior to shutdown after last major operation on November 30, 1969.

Following reconstruction and relicensing at 0.1 watt power of the reactor on the CPSU campus, total energy release was 61.2 watt-min over a four year period (1975-1978). Again, for a conservative calculation, operation was assumed at maximum licensed power (0.1 w) continuously for the 612 min or 0.43 days, ending on May 30, 1978, so that the total energy release is 61.2 watt-min. A shutdown time of 31 months (May 1978 through December 1980) is assumed after last operation.

For both locations, the following equation was used to calculate fission product 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 calculations are:

	LOCATIONS	
	USNPGS	CPSU
P (MW)	1.00×10^{-5}	1.00×10^{-7}
T (days)	63.1	0.43
t (days)	4046	942
A (Ci)	8.2×10^{-3}	3.1×10^{-6}
A (μCi)	8.2×10^{3}	3.1

It is relevant to compare the fission product activity of the core as calculated above to the natural activity of the core due to the uranium present. Natural core activity = (specific activity of U-235)(amount of U-235) 1 (specific activity of U-238)(amount of U-238) = (2.16 μCi/gm)(655 gm) + (0.33 μCi/gm)(2647 gm) = 2288 μCi

Thus, the ratio of natural core activity (2288 μCi) to fission product activity are 0.28 and 738 for the USNPGS and CPSU operations, respectively.

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, S, is then:

$$S = (3.1\,\mu\text{Ci})\ [3.7 \times 10^{4}\ \text{dis/sec}\ \mu\text{Ci}]\ [1\gamma/\text{dis}]$$

$= 0.115 \times 10^6\ \gamma/\text{sec}$

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

$= S/4\pi r^2 = (0.115 \times 10^6)/4\pi(30.48)^2 = 9.83\ \gamma/\text{cm}^2\text{sec}$

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

$H = 0.0567\ \phi\ E\ [\mu_a/\rho]$ tissue [mrem/hr]

$= (0.0567)(9.83)(1)(0.0300)$

$= 0.017$ mrem/hr

Thus the maximum possible amount of activity from the fission products is equivalent to about 3.5 times the natural uranium activity.

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

Actual measurements of the radioactive levels at the surface of individual fuel plates only one year after the shutdown at USN PGS showed a maximum value of 2 mrem/hr. Wipe tests performed on the plates at the same time disclosed negligible amounts of removable contamination. Confirmation of these measurements were made on the fuel prior to reassembly at the CPSU campus.

Any additional radiation due to the operation at CPSU is calculated to be less than 0.02 mrem/hr; the combined activity will accordingly produce about 2 mrem/hr at the surface of the fuel plates.

When the fuel is divided into two equal amounts for storage and shipment, each contained in one-inch thick steel wall safes, the maximum radiation level at the safe surface is calculated to be no more than 3 mrem/hr.

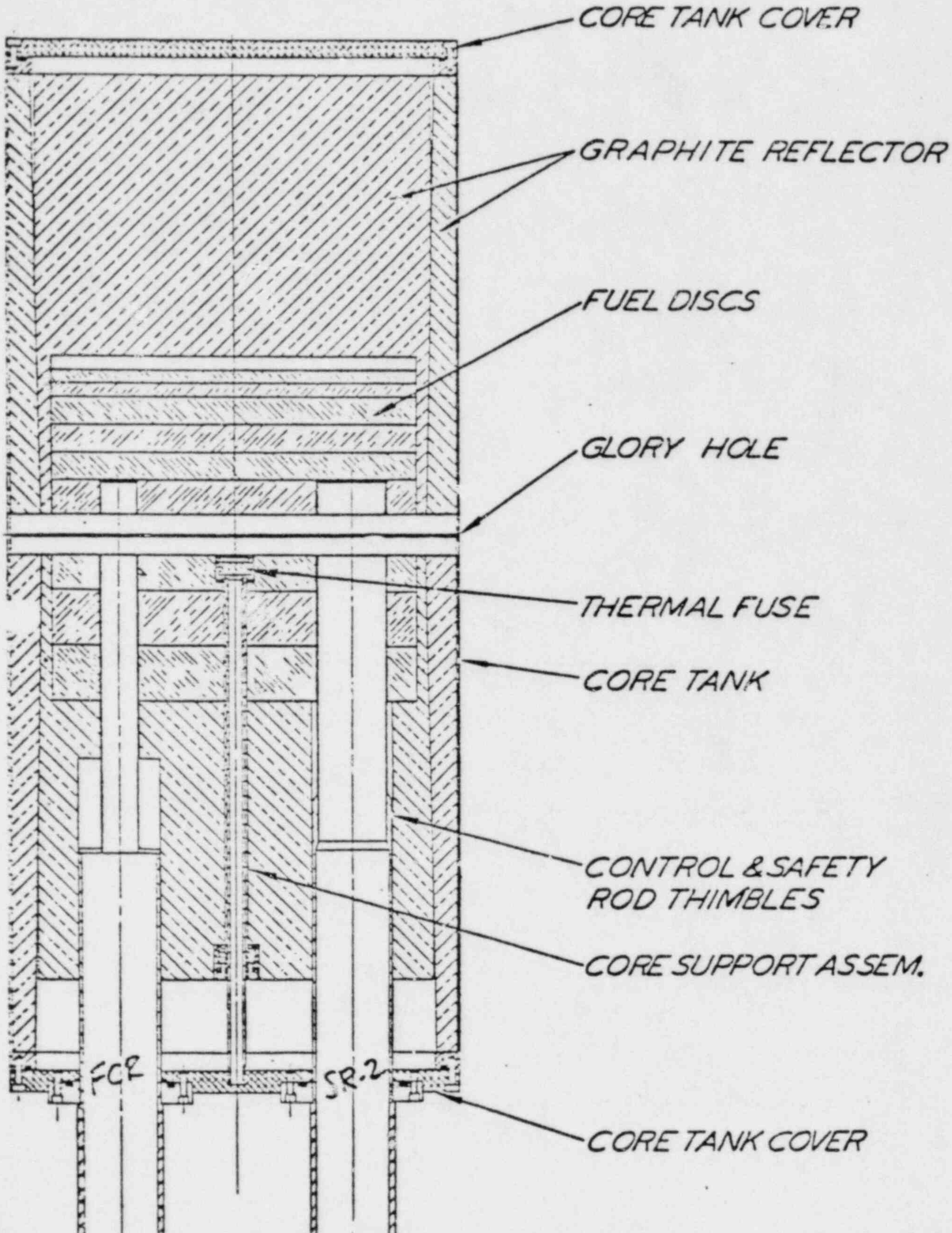

Figure A-1 Core Cross Sectional Drawing

201 REACTOR GAS TIGHT SEAL DIAGRAM

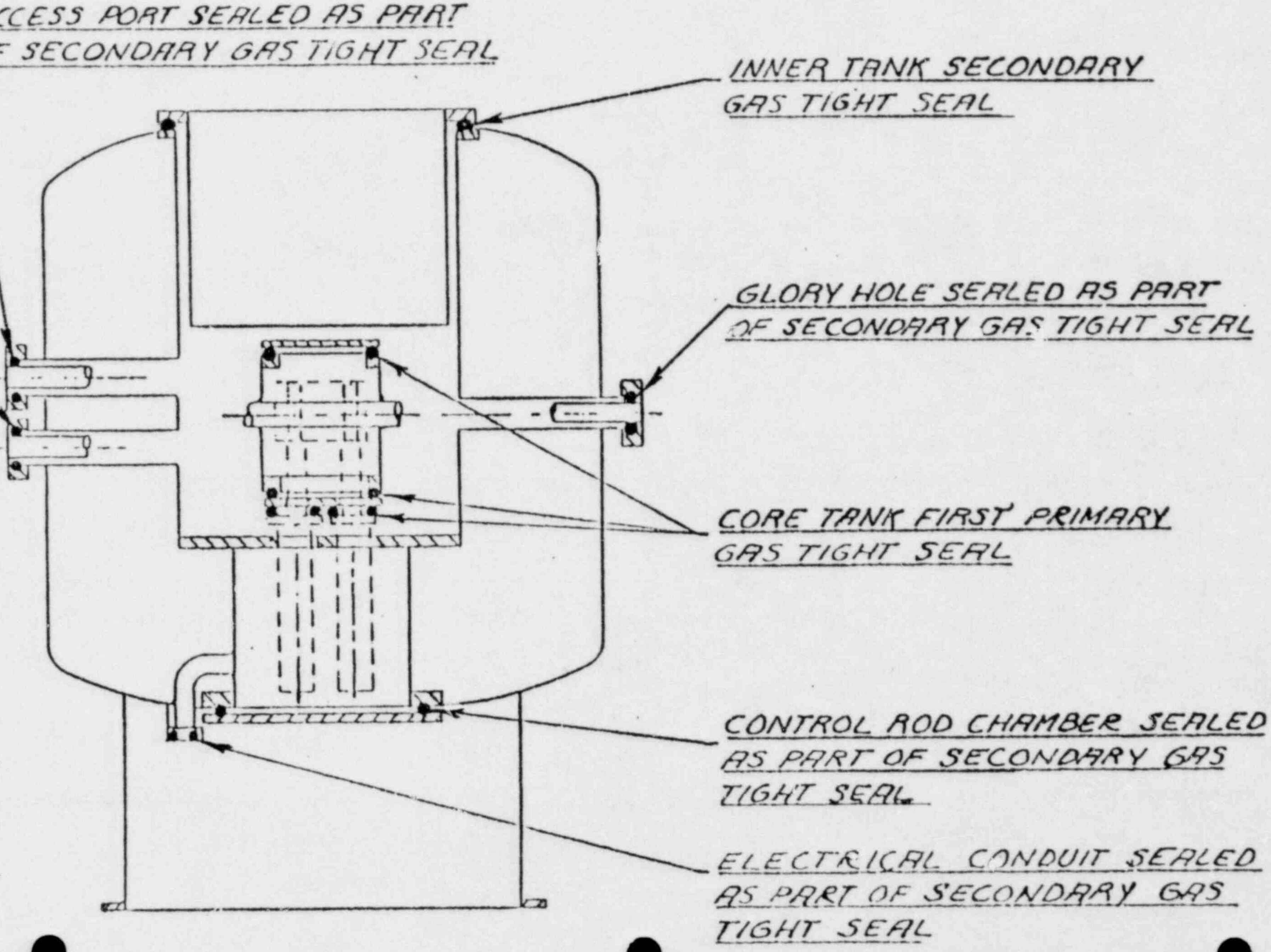

Figure A-2

Cross Sectional Drawing of AGN-201 Nuclear Reactor