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HAZARDS ANALYSIS BY THE DIVISION OF LICENSING AND REGULATION IN THE MATTER OF CURTISS-WRIGHT CORPORATION - DOCKET NO. 50-39

Introduction

The Curtiss-Wright Corporation submitted on October 29, 1956 an application for a license to construct and operate a 1000 kilowatt pool-type nuclear reactor. A construction permit was issued by the Atomic Energy Commission on June 20, 1957.

Location and Description

The reactor is located at the Curtiss-Wright Research and Development Center at Quehanna, Pennsylvania. This center is located on an 80 square mile tract of land, surrounded by a low population density area, in the north central portion of the State. Of the 51,175 total acres controlled by Curtiss-Wright, 8,579 are owned outright and 42,596 are leased from the State of Pennsylvania for 99 years. The reactor itself will be located a minimum of 3 miles from the present boundary of the property. The closest towns of any appreciable size are about 10 miles distant from the reactor. The area within a 25 mile radius of the reactor has an average population density of approximately 28 people per square mile.

The reactor is of the light water moderated and cooled, solid fuel type, often referred to as a swimming pool reactor. The aluminum-uranium alloy fuel plates are similar in construction to those used in the Bulk Shielding Reactor at Oak Ridge,Battelle Memorial Institute and the Materials Testing Reactor at Arco, Idaho. Cooling water is circulated through the core by natural convection at power levels up to 100 kilowatts; cooling is to be by forced circulation of water above 100 kilowatts. The core is immersed in a 20 feet wide by 40 feet long by 26 feet deep pool, with a minimum of 19½ feet of water covering the core. The reinforced concrete pool is separated into two sections, one being a three-sided end section penetrated by three beam tubes for experimentation purposes, the other a 20 feet by 24 feet section used for bulk shielding studies. The larger pool volume is about 93,600 gallons, while the smaller contains 53,800 gallons. The reinforced concrete pool walls are 18 inches thick, except at the beam hole end where the thickness is increased to 5½ feet. The outer four feet contain a high density ferrophosphorus aggregate which extends to 9½ feet above the floor level in the beam room.

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The reactor core will be made up of eighteen or more Curtiss-Wright-designed, MTR-type fuel elements. The standard elements will contain ten fuel bearing plates. Each fuel plate contains a uranium-aluminum alloy "meat" 0.020 inch thick surrounded by 0.020 inch thick aluminum cladding. The uranium in the meat is enriched to greater than 90 per cent in U-235. The dimensions of the finished plate are approximately 3 inches wide, 24 inches long and 0.060 inch thick. Ten fuel plates are fitted into an aluminum box (3 inches by 3 inches) to make up a standard fuel element. At one end of the element, a male guide piece of circular cross-section is attached, bringing the over-all length of an element to about 3 feet. This guide piece is inserted into a hole in the grid plate which supports the entire fuel element array. Both ends of the elements are open so that cooling water may flow between the fuel plates. The outer surfaces of the elements are cooled by water which passes through a funnel formed at the intersection of four elements and through auxiliary coolant holes in the grid plate. Partial fuel elements identical in size to the standard element are available in which solid aluminum plates have replaced some of the fuel bearing plates. Thirty graphite reflector elements and eight beryllium oxide reflector elements also will be available for use in the reactor. These will be canned in aluminum and tested with helium to insure leak-tightness. Reflector elements will be clearly distinguishable from the fuel elements under the full depth of water in the pool. Moreover, each reflector element will have a large identification number engraved on two sides in order to positively distinguish these elements from the fuel elements. Both the fuel and reflector elements will be supported in a grid plate which has 54 holes, in a 9 by 6 array. The grid plate is positioned so that the fuel is at least 4 feet above the pool floor.

When the reactor is operating at powers in excess of 100 kilowatts, convective cooling will not be relied upon. Instead, water will be pumped downward through the core. This will not only cool the fuel plates, but will reduce the quantity of radioactive N^{16} rising to the pool surface.

The reactor pool is housed in a large bay 48 feet wide, 120 feet long and extending 40 feet above the general floor level and, yielding a free volume of about 230,000 cubic feet. At the beam hole end, the floor is dropped 20 feet to provide access to the beam tubes as they emerge from the pool wall. The walls of the bay area are constructed of corrugated aluminum pannels fastened to the structural steel framework and insulated by a 1 inch layer of Fiberglass. The roof consists of a metal deck, 3/4 inch Fiberglass insulation, and four ply roofing. There are no windows in the bay and only two doors opening directly to the outside. The estimated leakage rate with doors closed and

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ventilation off is one air-change per 32 hours under normal atmospheric pressure and temperature conditions.

The pool water supply is softened and deionized prior to being supplied to the pool. There is also a continuous pool water repurification system which makes use of additional ion-exchange columns. Special lead shielded containers are available in case the resin should become contaminated.

A pneumatic rabbit is provided for short term irradiations and, three beam tubes are provided primarily to obtain collimated beams of neutrons for experimental purposes, and they are also used to provide dry irradiation chambers. Each beam tube contains a boral 8 inch internal diameter section which extends from the beam hole room through the concrete shield and then tapers to a 6.06 inch internal diameter aluminum beam tube extender section (four feet long) which reaches to the face of the core and is sealed at their reactor ends. Concrete shielding plugs are available for each hole when not in use. The plugs are contained in a 1/4 inch thick aluminum outer casing. There are 1 inch drains leading from the beam hole liner to the contaminated waste system. These beam hole drains will carry away any water which might leak into the beam tubes.

Heat and ventilation for the reactor bay are supplied by a single overhead space heater. This oil fired unit provides a minimum of 20 per cent outside air and at least 6 air changes per hour. The supply fan is suspended from the ceiling of the reactor bay and draws its air from above roof level. Associated with the supply fan is an oil fired space heater which is actuated by a thermostat in the reactor bay. There are two exhaust vents located at the opposite end of the roof from the supply unit. A system of recirculation is normally used whereby a portion of the exhaust air is recirculated to the intake of the supply fan. An air sampler located in the reactor bay will provide a continuous record of the amount of radioactive air contamination. In the event of high activity in the bay air, the ventilation fan can be stopped manually and all dampers closed, thus confining the contaminated air to the stated normal leakage rate.

Three safety-shim rods and one regulating rod are used in controlling the reactor. Each of the three safety rods, made of boron carbide and cadmium, provides a delta k/k of 2.7 per cent for a light water reflector, and a delta k/k of 4.0 per cent for a graphite reflector. There are insufficient BeO reflector elements to completely surround the core, although a calculation by the applicant indicated that a 3 inch layer of BeO backed by water would provide about the same reflector savings as would a 3 inch graphite layer backed by water. Therefore, the applicant considers that each of the shim safety rods would be worth about 4.0 per cent for a BeO partial reflector. The safety rods are magnetically coupled to

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their respective drive mechanisms, and during a scram, the rods fall freely under gravity. The maximum rate of withdrawal of the safety rods is 6¼ inches per minute. At their most effective position, about 50 per cent withdrawn, this speed corresponds to a rate of change of reactivity for any one rod of about 0.021 per cent per second for a water reflector, and 0.031 per cent per second for a graphite reflector. The safety rods may be withdrawn individually, or any combination of the three rods may be withdrawn simultaneously as desired. Since the migration length for light water is so small, there will be little "rod shadowing" and hence the maximum rate of reactivity insertion corresponding to the simultaneous withdrawal of all three rods would be 0.063 per cent per second for a water reflector and 0.093 per cent per second for a graphite reflector.

One stainless steel regulating rod is used in the control system. This rod provides a delta k/k of 0.7 per cent for a light water reflector and delta k/k of 1.2 per cent for a graphite reflector. The maximum withdrawal rate for this rod is 25 inches per minute. In its most effective position, the maximum rate of change of reactivity of the regulating rod is 0.018 per cent per second for a water reflector and 0.029 per cent per second for a graphite reflector. An interlock requires 2 counts per second signal before rod withdrawal is permitted.

The position of all control rods is continuously indicated to within ± 0.05 inches at the reactor control console. A servo amplifier system is used to automatically control the power level at the desired operating level. This system is interlocked so that it cannot be energized unless the actual power level is greater than 90 per cent of the desired operating value. Four gamma compensated ionization chambers and a fission chamber serve as the flux level detecting devices. One of the ion chambers is connected to the Log N period amplifier system which furnishes a period signal to the safety amplifiers.

There are three types of automatic shutdown which provide protection against nuclear excursions. They are:

1. Slow shutdown
2. Slow scram
3. Fast scram

The slow shutdown is initiated by a microswitch in the Log N recorder whenever the flux level exceeds 120 per cent of the desired operating level or the period is less than 20 seconds. This action drives all control rods to their lower limit at full speed. The slow shutdown feature is designed to be the first line of defense against any incipiently dangerous condition such as a relatively slow rate of increase in flux level above the desired operating value.

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The slow scram action is initiated by a disruption of power to the safety amplifiers, which results in a somewhat longer rod release time (about 50 milliseconds) than would result from a fast scram brought on by a current interruption to the safety rod coupling magnets. Both scram actions result in all rods falling under the force of gravity. The slow scram is brought on by movement of the reactor bridge during reactor operation or by manually pushing the scram button. The fast scram is brought on when the neutron flux increases to 140 per cent of the desired operating level or when the reactor period is 5 seconds or less.

Gamma radiation detectors are located in the beam room and on the reactor bridge. The bridge monitor is interlocked with the reactor safety system to cause an automatic slow shutdown in the event that radiation levels become greater than during normal operation. A coolant activity monitor which detects delayed neutrons will cause an automatic slow shutdown upon the release of fresh fission products.

Hazards Analysis

There is an extensive body of relevent knowledge and successful operating experience for swimming pool type reactors. Further the BORAX and SPERT experiments have provided information relating to reactivity restrictions necessary in this type reactor.

The applicant has reviewed the available BORAX and SPERT data and coupled with the results of calculations has concluded that the Curtiss-Wright reactor can withstand a step function increase in reactivity of as much as 1.5 per cent and a ramp addition of about 2.5 per cent at a rate of 0.09 per cent per second without mechanically damaging the fuel elements or approaching the melting point of the fuel elements. This appears to be a reasonable conclusion.

Based on these observations, the applicant has designed the control and regulating rod drives to prevent withdrawal of the rods at a rate which would be dangerous. Also, based on the above conclusions, they have limited the total reactivity worth of small experiments of the type which could conceivably be rapidly removed to 0.2 per cent. Further, under no circumstances will an experiment be installed which has a reactivity worth greater than 1.5 per cent. This type of experiment would be designed to prevent its removal except while the reactor is shut down. In addition, the total worth of all "fixed-type" experiments will be restricted to a reactivity worth of 3 per cent.

Two desirable characteristics in any reactor are a negative temperature and a negative void coefficient of reactivity. Curtiss-Wright has stated that they expect their reactor to have a temperature coefficient

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of - 1.5 x 10^{-5} delta k/k per °F. at about 100°F. and an average void coefficient of approximately - 5 x 10^{-6} delta k/k per cubic centimeter. Battelle Memorial Institute has conducted a number of experiments to determine the void and temperature coefficients in a reactor employing fuel elements of the same plate spacing and thickness as Curtiss-Wright. The results indicate that the values quoted by Curtiss-Wright are of the magnitude to be expected. We feel there is reasonable assurance that this facility will have both a negative void and temperature coefficient; however, Curtiss-Wright will measure these coefficients during critical experiments prior to full power operation.

The applicant has considered a number of mechanisms which would unintentionally introduce excess reactivity into the core. None of these accidents would result in the release of fission products. In view of the aforementioned reactivity limitations placed on the control rods and experiments and the expected negative temperature and void coefficients, we concur on this conclusion.

Although there does not appear to be a credible accident which would release fission products, the applicant has calculated the doses which would result should such a release occur. The dose at the site boundary following the release of 10 per cent of the fission products in the reactor would be less than 1 rad from internal or external radiation. Such a low dose is due primarily to the large area controlled by the applicant. The nearest site boundary is three miles.

Conclusion

Due to uncertainties in the magnitude and sign of the temperature and void coefficients of reactivity, it is recommended that initial experiments on the Curtiss-Wright Research Reactor should verify these coefficients prior to full-power operation. However, due to the remoteness of this reactor site, the relatively low dosages which would result in public areas even from the release of fission products by some accident which does not appear credible and the existance of fully developed emergency procedures, there appears to be sufficient assurance that this facility can be operated at the proposed location and at power levels up to 1000 kilowatts without undue hazard to the health and safety of the public.

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STANDARD FORM NO. 64

Project # 28

Office Memorandum • UNITED STATES GOVERNMENT

TO : Lyall Johnson, Chief
Licensing Branch

DATE:

FROM : Clifford K. Beck, Chief
Hazards Evaluation Branch

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