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ORNL Fast Burst Reactor and Facilities

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ABSTRACT

The conceptual design of a Fast Burst Reactor and its Controls has been completed. The reactor is capable of achieving bursts of 1×10^{17} fissions, with a half width of $\sim$ 38 μsec. Design information on the reactor, its associated laboratories and facilities, and the analyses of effects of several categories of possible accidents are summarized here.

Preliminary design studies of a reactor for producing fast neutrons, in bursts and at a constant flux, for use in support of the radiation dosimetry and radiobiomedical research programs at ORNL, have been completed.[1,2,3]

An overall isometric view of the reactor, its core, control rods, rod drivers, and supporting structure is shown in Fig. 1.

The reactor core is essentially a cylinder 7 $\frac{7}{8}$ in. in diameter and 7 $\frac{1}{16}$ in. in length. A removable 2 $\frac{3}{4}$ in. diameter safety section (safety block) with a central plug of stainless steel, two $\frac{3}{4}$ in. diameter mass adjustment (control) rods, and one $\frac{3}{4}$ in. diameter burst rod, are provided. Except for the central plug of stainless steel, the reactor is composed of highly enriched U-10 w/o Mo alloy. The reactor is designed for operation while suspended from a reactor positioning device at an elevation up to 30 feet above floor level.

The mechanical design parameters are summarized in Table I.

Table I

Summary of Reactor Design and Performance Characteristics

<u>Mechanical Design</u>	
Reactor diameter, in.	7 $^7/_8$
Reactor height, in.	7 $^1/_{16}$
Fuel material	U-10 w/o Mo
Enrichment, % U-235	93.5
Total mass, kg U-Mo alloy	80
Void volume, % of total	3
Mass adjustment (control) rods	
Material	U-Mo
Number	2
Worth per rod, $	1.04
Drive	Electric motor
Positioning accuracy, in.	0.001
Burst rod	
Material	U-Mo
Worth, $	1.04
Drive	Pneumatic cylinder
Safety block	
Material	U-Mo
Worth, $	17.5
Drive	Electric motor

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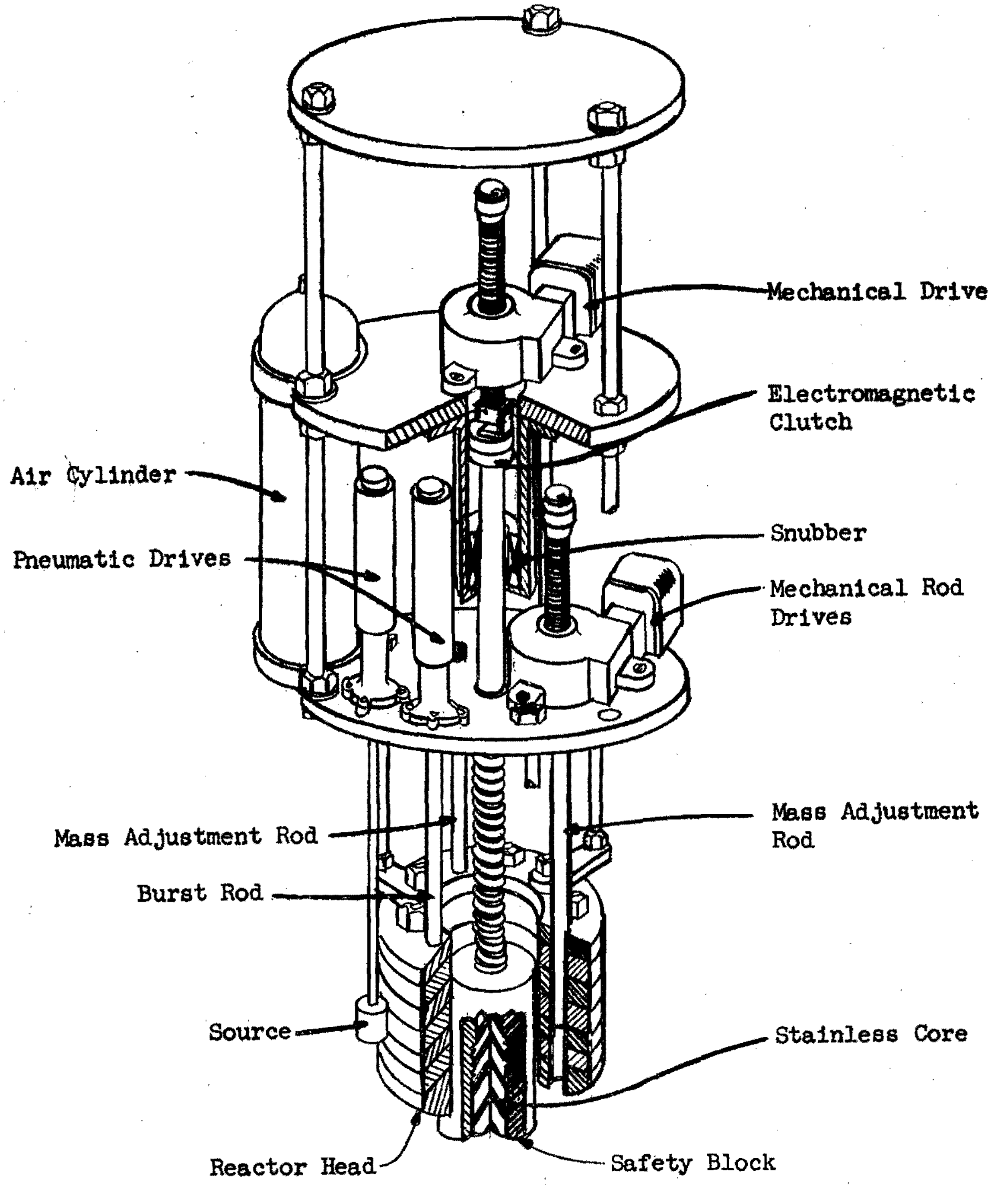

Fig. 1. ORNL FAST BURST REACTOR
(Downward Scram)

It should be noted that the design of this reactor is very similar to that of the Los Alamos Godiva II, which served as a basis for the design. The Godiva II has been in operation for many years and has undergone over 1000 bursts without serious incident. Improvements have been made over the Godiva II design to increase the performance of the reactor. These improvements include a core consisting of a layered structure, a safety section containing a stainless steel plug and the use of uranium-10 w/o molybdenum as the fuel alloy.

The addition of molybdenum to uranium improves the high temperature strength of the fuel material, provides increased dimensional stability under thermal cycling and reduces the thermal expansion stresses. The "hollow" central cylindrical section of the reactor (safety block) flattens the flux distribution and permits larger and narrower bursts than are possible with Godiva II.

A summary of the comparative performance characteristics of Godiva II and of the ORNL Fast Burst Reactor is shown in Table II.

Table II

	Godiva II	ORNL — FBR
Burst yield: fissions/pulse	1.0×10^{16}	1.0×10^{17}
Leakage: neutrons/pulse	1.4×10^{16}	1.3×10^{17}
Pulse width: μ/sec	80	38
Maximum temperature rise °F	180	740
Total energy release (Mw-sec)	0.32	3.22
Peak power (Mw)	-	63,000

The burst performance characteristics at various yields from 3×10^{16} to 1×10^{17} fissions are tabulated in Table III. It should be noted that the maximum temperature rise has been limited to 740°F.

Under constant flux conditions the reactor can achieve continuous steady state power levels up to 1 Kw, utilizing natural convection cooling. With forced convection cooling, such as may be achieved with a blast of air, it is estimated that a power level of ~ 10 Kw can be maintained for ~ 10 minutes.

After each pulse the reactor may be removed quickly by remote control to a shielded underground pit. Since it is not expected that there will be appreciable residual radioactivity in the testing area, immediate entry can be made for examination of test specimens and to set up for succeeding experiments.

Table III

Burst Performance Characteristics

Burst yield, fissions	3×10^{16}	5×10^{16}	1×10^{17}
Pulse repetition rate	~ 1 per hr		
Total temperature coefficient, ¢/°F	-0.11	-0.11	-0.11
Initial reactivity insertion above prompt critical, ¢	4.4	5.7	7.6
Integrated neutron current 1 in. from the reactor surface, n/cm^2	6×10^{12}	1×10^{13}	2×10^{13}
Total leakage neutrons	4×10^{16}	7×10^{16}	1.3×10^{17}
Peak power, MW	12,000	25,000	63,000
Initial reactor period, μsec	23	18	13
Burst half-width, μsec	65	50	38
Maximum temperature rise, °F	220	370	740
Average temperature rise, °F	108	180	360

Typical proposed experimental programs are based on operation of the reactor in several modes as follows:

1. Low power runs for in-laboratory dosimetry research: new detectors and spectrometers are placed at 1 to 3 meters from the reactor for exposure of up to 1 hour and at 1 to 100 watts.

2. High power runs for dosimetry research: new detectors, such as modified threshold detectors, are exposed at 1 to 20 meters to bursts of 10^{17} fissions or 1 Kw of power for 20 to 30 minutes.

3. Radiobiological research: the UT-AEC farm will want to expose burros at 3 meters or greater at power levels of up to 10 Kw for approximately 10 minutes or to bursts of 10^{17} fissions. Other groups will expose rats, mice, etc., at closer distances and less power.

4. Gaseous electronics, materials testing and radiochemistry research: small samples in chambers will be exposed to maximum fluxes at distances from a few inches to a few feet from the reactor.

The existing ORNL Reactor Review Committee will periodically review the reactor operating experience. An Operations Experiment Review Committee, composed of representatives of the groups that will operate and utilize the facility will be established. Based on an evaluation of the hazards involved and within the limits set by the Advisory Committee on Reactor Safeguards, the Operations Experiment Review Committee will perform a safety and feasibility review prior to running an experiment. The authority of the Operations Experiment Review Committee will be limited to the boundaries established by the Reactor Review Committee. This procedure is similar to that now followed for other similar experimental reactors in the ORNL area.

A system of warning horns, interlocks, and administrative control, utilizing a single key for access to the reactor area and for operation of the reactor is specified to insure removal of personnel prior to the start of operations. This type of operation has been proven successful at the Tower Shielding Facility at ORNL and for the Godiva Kiva at Los Alamos Scientific Laboratory.

The general procedure followed during operation of an approved experiment is first to transport and set up the equipment in the Reactor Building around a dummy reactor. The instruments are then checked out and the exclusion area is cleared. The reactor is then positioned in place of the dummy head and operated at the desired level.

After operation the reactor can be permitted to cool by natural convection or by forced air blast, either in position or after remote removal to one of the shielded pits in the floor, depending upon whether personnel access is desired to the experiment or whether further operation of the reactor is scheduled.

The reactor is designed for a burst yield of $\sim 1 \times 10^{17}$ fissions/pulse. The thermal expansion of the core (reactor head) provides a negative temperature coefficient of reactivity and results in a shutdown of the reactor with a burst half-width of $\sim$ 38 microseconds. The signal initiating removal of the burst rod and of the safety block is obtained during the burst. Thus the reactor is brought to a configuration below delayed critical within milli-seconds after a burst.

The reactor is also capable of continuous operation at steady state powers up to a maximum level of $\sim$ 1 Kw. Higher power levels for substantially reduced times are also possible, with a maximum capability of $\sim$ 10 Kw for $\sim$ 10 minutes.

The reactor and its associated laboratories and facilities will be located along Copper Ridge in the general area to the east of the Tower Shielding Facility, and south of the ORNL Main Laboratories, as shown in Fig. 2.

The reactor building will be located in a hollow, surrounded by an antipersonnel fence. The administration, laboratory and control building will be located outside this area, and will be further isolated from the ORNL area by a 1000 yard radius exclusion area marked by a barbed wire fence. Within this area there are hills of at least 50 ft height to provide natural shielding and to prevent "line of sight" at the reactor from all directions.

The proposed reactor operating area, as shown in Fig. 3, will be housed in a building provided with insulated aluminum siding giving weather protection for experiments and also providing a filtered and controlled circulation air exhaust system. The reactor can normally be operated from a special reactor handling device, inside or outside the building, up to a height of 30 feet.

The proposed administration, control and laboratory building is shown in Fig. 4.

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Fig. 2. ORNL Fast Burst Reactor - Site Location.

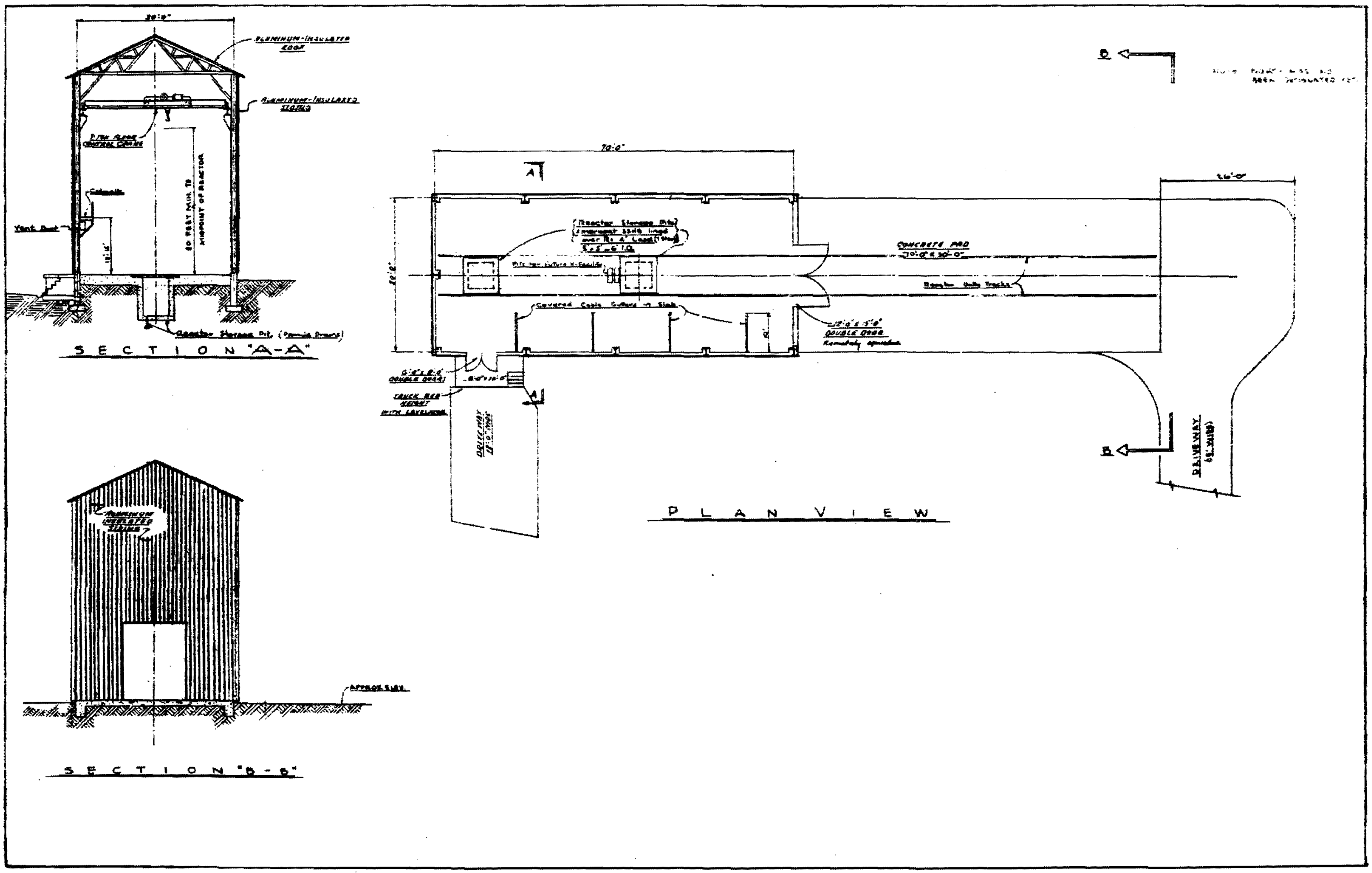

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Fig. 3. Reactor Building.

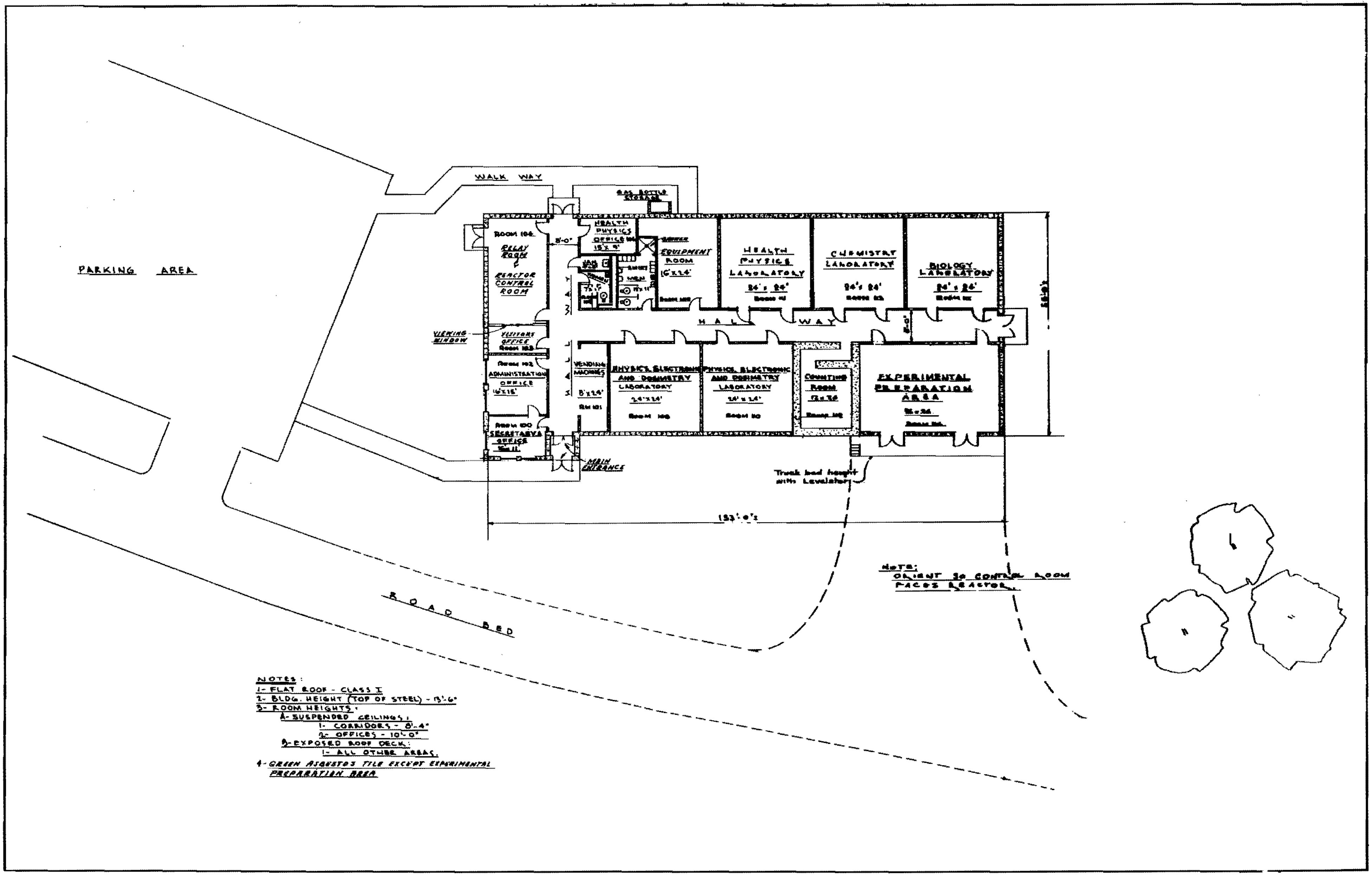

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Fig. 4. Administration, Laboratory and Control Building.

Hazard Analyses

An evaluation of the hazards associated with the operation of a fast burst reactor indicates that accidents of two major categories may occur. In the first type of accident, the failure of the safety mechanism to scram the burst rod and safety block can result in overheating and possible meltdown of the reactor core. In the second type, the addition of excess reactivity after calibration for presence of an experiment can result in excessive yields. If permitted to occur these high bursts would most probably result in meltdown or possible disruption of the reactor assembly.

1. Control Failures:

Failure of operation of the control mechanisms after conclusion of a burst would leave the reactor above delayed critical. After a burst of 1×10^{17} fissions, the reactor would attain an average temperature ~ 1080°C within ~ 13 seconds.(3) The temperature would then slowly decrease to an equilibrium temperature of ~ 544°C after a long period of time. Probably, local maximum temperatures in excess of the alloy melting point of ~ 1180°C could occur.

If such an accident would occur in the open after extensive operation,[1] the core could contain fission products equivalent up ~ 5.52 curies of Iodine-131.(4) In the postulated meltdown the fission products released would actually be a fraction of those present and volatile at the attained temperature.(5) An individual's internal exposure from inhalation of iodine isotopes accumulated during the period of extensive reactor operation has repeatedly been shown(6) to be more severe than his external exposure to the xenon and krypton or even to the total fission products if their release is assumed.

The total equivalent Iodine-131 present at meltdown (~ 5.52 curies) thus represents an excess of the maximum inventory available for release in a meltdown case. However, if this total were to be released, the estimated resultant intake by an individual at a distance of 1000 meters from the reactor would be, at 3.6×10^{-2} μc inhaled per curie released(7), 0.2 μc. The total resultant internal exposure to the individual's thyroid of 295 mrem is a pessimistic estimate and should be reduced both because the total melting of the reactor core is improbable and the total release of the iodine inventory cannot occur.

2. Excessive Yield:

The postulated maximum burst of 10^{19} fissions(3) is based on the unlikely event of the reactor falling to the ground with simultaneous insertion of the control rods, burst rod, and safety block. The yield in this case represents 312 Mw-seconds of energy which it is presumed would volatize at least part of the reactor core. The fission product inventory formed

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1 For this calculation it was assumed that the reactor operated at a level of 1 Kw for 2 hrs each day for an infinite number of days prior to the accident.

References

(1) NDA 2136-1, "Preliminary Design of the ORNL Fast Burst Reactor", Nuclear Development Corp. of America, July 30, 1960.

(2) NDA 2136-2, "Thermal Cycling Tests on U-10 w/o Mo for the ORNL Fast Burst Reactor", Nuclear Development Corp. of America, July 30, 1960.

(3) NDA 2136-3, "Operational Procedures and some Accident Analyses for the ORNL Fast Burst Reactor", Nuclear Development Corp. of America, July 30, 1960.

(4) T. H. J. Burnett, "FBR Hazards — Estimate of Fission Product Inventories and Exposures", July 18, 1960.

(5) G. E. Creek, W. J. Martin, G. W. Parker, "Experiments on the Release of Fission Products from Molten Reactor Fuels", ORNL-2616, Dec. 1958.

(6) T. H. J. Burnett, "Reactors, Hazard vs Power Level", Nucl. Sci. and Eng., Vol 2, No. 3, pp 382-393, May 1957.

(7) T. H. J. Burnett, "FBR Hazards: Dilution and Inhalation Intake Estimates", July 13, 1960.

(8) "Maximum Permissible Dietary Contamination after the Accidental Release of Radioactive Material from a Nuclear Reactor", Brit. Med. Jour., pp 967-969, April 1959.

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