PRELIMINARY SYSTEM DESIGN DESCRIPTION
OF THE EBR-II
IN-CORE INSTRUMENT TEST FACILITY

by

E. Hutter and O. Seim

Major Contributors

R. C. Brubaker	J. A. Pardini
R. J. Dickman	T. E. Sullivan
H. H. Hooker	W. M. Thompson
R. H. Olp	

EBR-II Project
Argonne National Laboratory
Argonne, Illinois -- Idaho Falls, Idaho

June 1970

Work performed under the auspices of the U.S. Atomic Energy Commission

LEGAL NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

DISTRIBUTION OF THIS DOCUMENT IS UNL

TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	9
1.0 INTRODUCTION	10
1.1 System Function	10
1.2 Summary Description of the System	10
1.2.1 Description of EBR-II.	10
1.2.2 Description of INCOT	16
1.3 System Design Requirements.	18
2.0 DETAILED DESCRIPTION OF SYSTEM	19
2.1 Components.	19
2.1.1 Thimble Assembly	21
2.1.2 Sensor Assembly.	32
2.1.3 Terminal-box Assembly.	33
2.1.4 Sensor-data Transmission System.	35
2.1.5 Elevating System	36
2.1.6 Handling System.	40
2.1.6.1 Straight Type of Sensor Handling Container	41
2.1.6.2 Offset Type of Sensor Handling Container	45
2.1.6.3 Thimble-assembly Handling Container . .	47
2.2 Instruments, Controls, Alarms, and Protective Devices .	49
2.2.1 Elevating System	49
2.2.1.1 Controls.	49
2.2.1.2 Interlocks.	50
2.2.1.3 Protective Devices.	51
2.2.1.3.1 Force Limits of Elevator Drive Mechanism.	51
2.2.1.3.2 Limit Switches	53
2.2.1.4 Alarms.	53
2.2.1.5 Indicating Instruments.	53
2.2.1.6 Design Criteria	53
3.0 PRINCIPLES OF OPERATION.	54
3.1 Startup	55
3.2 Operation	55
3.3 Shutdown.	55
4.0 SAFETY PRECAUTIONS	56
4.1 Portions Outside the Primary Tank	56
4.2 Portions Inside the Primary Tank.	58

LIST OF FIGURES

<u>No.</u>	<u>Title</u>	<u>Page</u>
1.	EBR-II Reactor Plant.	11
2.	EBR-II Reactor Assembly	13
3.	EBR-II Control-rod Drive.	15
4.	Plan View of Small Rotating Shield Plug of EBR-II, Showing INCOT Location.	17
5.	INCOT Thimble Assembly.	22
6.	Upper Portion of Thimble Assembly Containing Sensor Assembly Model 1	23
7.	Middle Portion of Thimble Assembly Containing Sensor Assembly Model 1	24
8.	Lower Portion of Thimble Assembly Containing Sensor Assembly Model 1	25
9.	Upper Portion of Thimble Assembly Containing Sensor Assembly Model 2	26
10.	Middle Portion of Thimble Assembly Containing Sensor Assembly Model 2	27
11.	Lower Portion of Thimble Assembly Containing Sensor Assembly Model 2	28
12.	Upper Portion of Thimble Assembly Containing Sensor Assembly Model 3	29
13.	Middle Portion of Thimble Assembly Containing Sensor Assembly Model 3	30
14.	Lower Portion of Thimble Assembly Containing Sensor Assembly Model 3	31
15.	INCOT Elevating System.	37
16.	INCOT Elevator Assembly Attached to Guidance- and-support Assembly.	38
17.	Straight Type of Sensor Handling Container (shown in sensor-removal position).	42
18.	Offset Type of Sensor Handling Container (shown in sensor-removal position).	46
19.	Thimble-assembly Handling Container (shown with terminal box removed)	48

LIST OF TABLES

<u>No.</u>	<u>Title</u>	<u>Page</u>
I.	INCOT Components.	20
II.	Interlocks of INCOT Elevating System.	52

PRELIMINARY SYSTEM DESIGN DESCRIPTION
OF THE EBR-II
IN-CORE INSTRUMENT TEST FACILITY

by

E. Hutter and O. Seim

Major Contributors

R. C. Brubaker	J. A. Pardini
R. J. Dickman	T. E. Sullivan
H. H. Hooker	W. M. Thompson
R. H. Olp	

ABSTRACT

The EBR-II In-core Instrument Test Facility (INCOT) provides the means of inserting instrument sensors into the EBR-II core, exposing them to a fast-neutron flux of 2×10^{15} nv, and monitoring their performance during their experimental life. The facility includes a thimble assembly that serves as a container for one of three basic types of sensor assemblies, which hold the test sensors during irradiation. The thimble assembly extends from the core, up through the reactor-vessel cover, into the primary-tank sodium, and from there through the small rotating shield plug and onto the operating floor. There it is connected, through a terminal box, to the elevating system that provides the necessary motions to make the facility compatible with reactor fuel-handling operations. Shielded handling containers make it possible to remove individual tests or experiments from the facility and to remove parts of the facility itself. A system for transmitting sensor data carries the sensor signals to the instrument readout and data-logging equipment.

This Preliminary System Design Description (PSDD) describes the facility, discusses the principles of operation, and presents pertinent safety precautions.

1.0 INTRODUCTION

The Conceptual System Design Description (CSDD) of the EBR-II In-core Instrument Test Facility (INCOT)* described various concepts of the facility, evaluated their merits, and recommended the one most favorable of the concepts. That concept is described in this report, which presents information pertinent to the preliminary design stage.

1.1 System Function

The function of INCOT is to provide data pertaining to the performance of instrument sensors, instrument-sensor cabling, and of other materials in the EBR-II core, under typical LMFBR operating surroundings. The facility enables an experimenter to insert test sensors into the reactor core, monitor their responses during irradiation, and extract them into a handling container for transfer to a postirradiation-examination station. Because of the various test requirements (depending on the type, number, and size of the sensors), three different basic sensor arrangements (or models) are planned. The facility must be fully compatible with the existing fuel-handling components and must fit into the limited space that is available.

1.2 Summary Description of the System

Because INCOT will be an integral part of the EBR-II facility, that facility is briefly described first, under Section 1.2.1. The summary description of INCOT follows, in Section 1.2.2.

1.2.1 Description of EBR-II

The EBR-II reactor and the entire primary system are contained in the primary tank, as shown in Fig. 1, and operate completely submerged in the sodium coolant. The primary-sodium coolant is pumped

*O. Seim, et al., Conceptual System Design Description of the EBR-II In-core Instrument Test Facility, ANL/EBR-004 (June 1969).

Fig. 1. EBR-II Reactor Plant

directly from the primary tank into the reactor vessel and up through the reactor core. The effluent coolant flows from the reactor vessel, through the shell side of a heat exchanger, and back to the primary tank. Sodium in the secondary system flows through the tube side of the heat exchanger. This sodium transfers the heat it picks up to a steam generator, which supplies the steam for a turbine-generator.

The basic components of the reactor assembly (Fig. 2) are the reactor vessel, the grid-plenum assembly, and the reactor-vessel cover. The assembly is surrounded by the neutron shield and is submerged under approximately 10 ft of sodium.

The grid-plenum assembly supports and locates the sub-assemblies and incorporates the coolant inlet plena. The assembly accommodates 637 hexagonal subassemblies spaced on a triangular pitch of 2.320 in. The present nominal core loading consists of 78 (total) enriched-uranium driver and experimental-irradiation subassemblies, 2 safety subassemblies (or safety rods), and 11 control-rod subassemblies (or control rods). The inner blanket contains 36 (total) natural-uranium and experimental-irradiation subassemblies, and the outer blanket contains 510 natural-uranium subassemblies.

The external dimensions of the fuel and irradiation subassemblies are the same, and the reactor has a closely packed geometry. Each subassembly tube is hexagonal, measures 2.290 in. across external flats, and has a 0.040-in.-thick wall. A nominal clearance of 0.030 in. between subassemblies facilitates their removal from the reactor. The same top end fixture is used on all types of subassemblies so that they can be accommodated by the same handling and transfer mechanisms. The lower adapters are of different sizes to distinguish between the three regions of subassemblies, and are of different configurations to accommodate the two coolant inlet plena.

The reactor-vessel cover, which serves as a neutron shield as well as a closure, is clamped to the vessel flange by three holddown clamps. When the cover is lowered, it forms the reactor upper plenum from which the coolant flows to the heat exchanger.

Fig. 2. EBR-II Reactor Assembly

The control-rod drive shafts operate through seals and guide bearings in the reactor-vessel cover. Each control rod is operated independently by an electromechanical drive mounted on top of the rotating shield plug (Fig. 3). In the event of a reactor scram, the control rods operate simultaneously.

The two safety rods, which are a separate part of the system, do not provide operational control. Their main purpose is to provide their available negative reactivity to the core during reactor shutdown.

The primary tank contains: the reactor vessel; two primary-sodium pumps; the heat exchanger; a storage basket for sub-assemblies; various instruments, mechanisms, and auxiliary systems; and 80,000 gal of sodium. The tank is of double-wall construction to provide maximum reliability of sodium containment. The inner tank is 26 ft in diameter; its side walls are constructed of 0.5-in.-thick plates, and its bottom is constructed of 1-in.-thick plates. The bottom-plate structure of the inner tank supports the reactor-vessel assembly, the neutron shield, some of the primary-sodium piping, and the sodium. This load is transferred by the tank wall to the top cover, which supports the tank. The structure of the outer tank is designed to carry the sodium load in case a leak develops in the inner tank. The cover of the primary tank is 39 in. thick and contains shielding material and thermal insulation. The region above the bulk sodium is filled with inert argon cover gas.

The primary tank has no side or bottom openings, but allows access to its interior through 67 nozzles in the cover and one large circular opening in the center of the cover. Each nozzle accommodates one primary-system component, which is removable in most cases, and the central opening accommodates the rotating shield plugs.

The primary tank, its contents, and the components that are connected to the primary-tank cover are supported by six hangers, which in turn transfer these loads to the top-structure beams. Each hanger is supported by a roller so that differential radial expansion between the top structure and the primary-tank cover will not produce additional stresses in the system.

Fig. 3. EBR-II Control-rod Drive

An EBR-II modification is being planned in which the existing control rods will be replaced with the minimum number of higher-worth control rods that proves to be adequate. This arrangement will make available a maximum number of control-rod locations for components such as oscillator rods, instrumented subassemblies, and INCOT. A study of space requirements for the supporting facilities of the proposed INCOT led to the selection of the No. 2 control-rod position as the location for the facility. Figure 4 shows this position in relation to other existing control-rod positions.

1.2.2 Description of INCOT

In INCOT, a thimble assembly situated in the No. 2 control-rod position serves as a container for the experiments and test specimens to be irradiated. The thimble assembly extends from the core, up through the reactor-vessel cover, into the bulk sodium, and from there through the small rotating shield plug and onto the operating floor. There it is connected, through a terminal box, to the elevating system that provides the necessary motions to make the facility compatible with the fuel-handling operations. Shielded handling containers make it possible to remove individual tests or experiments from the facility as well as parts of the facility itself. (An existing calibration station inside the reactor containment building is available for visual inspection and limited calibrations.) A system for transmitting sensor data carries the signals from the sensors to those portions of the EBR-II instrument readout and data-logging equipment that will be available at the time of the experiment or to equipment that will be supplied by the experimenter.

A sensor assembly, which fits into the thimble assembly, holds the test sensors (or other items to be irradiated and tested) in the proper position within the reactor. To meet the various needs of the experimenters and the different characteristics of the irradiation tests, three basic types of sensor assemblies are planned. (These three types -- Models 1, 2, and 3 -- are described in Section 2.1.2.)

Fig. 4. Plan View of Small Rotating Shield Plug of EBR-II, Showing INCOT Location

The facility is designed to exert a minimum effect on the other systems already installed in the reactor. It fits into the limited space of a control rod and drive, which it replaces. It is fully compatible with the EBR-II fuel-handling systems and is interlocked with the fuel-handling control console. None of the facility components, including the test sensors, can be moved while the reactor is operating. During installation and removal of the thimble assembly, the sensor assembly, and the rigid sensor leads, several brackets and the motor of the drive that lifts the reactor-vessel cover must be removed. Sensors with slightly flexible extension leads, however, can be inserted or removed without removing that motor. During reactor operation, all sensors can be monitored, and the valve controlling the flow of coolant through the thimble assembly can be adjusted.

1.3 System Design Requirements

In addition to meeting the requirements for personnel and reactor safety and the need to be fully compatible with the reactor operations and components, the facility fulfills the following experiment-oriented requirements:

Temperature of Sensors and Sensor Environments:

	<u>Environment</u>	
	<u>Gas</u>	<u>Sodium</u>
Minimum Sensor Temperature, °F	750	700
Maximum Sensor Temperature (Surface), °F	1400	1200
Maximum Environment Temperature, °F	1200	1200

Temperature of Sensor Leads: The portion of the sensor leads in the zone of high neutron flux is at approximately the same temperature as the sensor.

Neutron-flux Environment: The peak fast-neutron flux is approximately 2×10^{15} nv where the sensor thimble is located in the reactor.

Fluid Environment: Depending on the model of the sensor assembly, the sensor environment is either gas (helium or argon) or sodium.

Temperature Control: Sensor temperatures can be controlled (within certain limits) during reactor operation by actuating the coolant-flow control valve near where the coolant enters the thimble and sensor assemblies.

Cooling Medium: Primary-tank sodium provides the necessary cooling of the facility.

Heating Medium: Gamma radiation in the reactor core is the primary energy source for heating the sensors above the environmental sodium temperature.

Sensor Position during Test: In Models 1 and 2 of the sensor assembly, the elevation of individual sensors may be varied (while the reactor is temporarily shut down) during the life of the irradiation test. In all models, the elevation of the entire group of sensors may be varied by raising or lowering the thimble assembly.

Removal and Insertion of Sensors: With Models 1 and 2 of the sensor assembly, individual sensors may be removed from the facility and replaced with new ones (while the reactor is temporarily shut down) during the life of the irradiation test.

2.0 DETAILED DESCRIPTION OF SYSTEM

2.1 Components

The principal components of INCOT are:

- Thimble Assembly
- Sensor Assembly
- Terminal-box Assembly
- Elevating System
- Sensor-data Transmission System
- Handling System

These are further subdivided as shown in Table I:

TABLE I. INCOT Components

<u>Thimble Assembly</u>	<u>Sensor Assembly</u>	<u>Terminal-box Assembly</u>	<u>Sensor-data Transmission System</u>	<u>Elevating System</u>	<u>Handling System</u>
Support Tube	Alternative Models: 1	Terminal Box		Elevator Assembly	Sensor Handling Container (Straight)
Insulating- gas Tubes	2	Flow-control- valve Drive Mechanism		Guidance- and- support Assembly	Sensor Handling Container (Offset)
Lower Adapter	3			Elevator Drive Assembly	Thimble- assembly Handling Container
Thimble Guide Tube				Support Assembly	
				Blanket- gas Bellows Seal Assembly	

2.1.1 Thimble Assembly

The thimble assembly is a container that extends downward from the top of the small rotating shield plug, into the primary-tank sodium, through the reactor-vessel cover, and into the core of the reactor. The thimble assembly surrounds, locates, and supports the sensor assembly. The coolant sodium enters the thimble at its base; it leaves the thimble and joins the primary-tank sodium above the reactor-vessel cover. The major parts of the thimble assembly (Fig. 5) are the support tube, the insulating-gas tubes, the lower adapter, and the thimble guide tube.

The support tube (Tube No. 1 on Figs. 6, 9, and 12) is connected to the bottom of the terminal-box assembly, extends downward through the blanket-gas bellows seal assembly, continues downward through the region of the primary-tank cover, and passes through the primary-tank sodium. It continues as the reactor-vessel guide and seal tube (Tube No. 2 on Figs. 7, 10, and 13) through the reactor-vessel cover. The clearance between this tube and the opening in the reactor-vessel cover is about the same as that between the present control drives and the openings in the cover. This configuration avoids uncertainties that would be caused by changing present clearances and keeps the leakage of reactor coolant sodium between the reactor-vessel cover and the support tube the same as that for a control-drive position. The support tube terminates in the upper plenum of the reactor.

The insulating-gas tubes (Tubes No. 6 and 7 on Figs. 7, 10, and 13) provide a thermal barrier between adjacent subassemblies and the sensor assembly so that the temperature of the coolant can be adjusted to the desired value. Each insulating-gas tube comprises two concentric tubes with inert gas in the annulus between them. The annulus is sealed by an expansion bellows near the lower adapter. The insulating-gas tubes permit the temperature of the sodium at the sensor to increase by gamma heating to a maximum of 1200°F (unless the sensor mass is very small or the coolant flow rate very high). Sensors placed in the ambient gas may reach much higher temperatures than the thimble

Fig. 5. INCOT Thimble Assembly

Fig. 6. Upper Portion of Thimble Assembly Containing Sensor Assembly Model 1

Fig. 7. Middle Portion of Thimble Assembly Containing Sensor Assembly Model 1

SECTION AA

SECTION BB

SECTION CC

Fig. 8. Lower Portion of Thimble Assembly Containing Sensor Assembly Model 1

Fig. 9. Upper Portion of Thimble Assembly Containing Sensor Assembly Model 2

Fig. 10. Middle Portion of Thimble Assembly Containing Sensor Assembly Model 2

Fig. 11. Lower Portion of Thimble Assembly Containing Sensor Assembly Model 2

Fig. 12. Upper Portion of Thimble Assembly Containing Sensor Assembly Model 3

Fig. 13. Middle Portion of Thimble Assembly Containing Sensor Assembly Model 3

Fig. 14. Lower Portion of Thimble Assembly Containing Sensor Assembly Model 3

coolant sodium. The insulating-gas tubes extend up into the reactor-vessel cover, where they become thermal barriers (Tubes No. 3, 4, and 5 on Figs. 7, 10, and 13). This design feature reduces stresses that would result from large radial thermal gradients through these tubes. Before the coolant sodium exits to the sodium in the primary tank, heat transfer during vertical transit will have reduced its temperature to within 100°F of that of the bulk sodium.

The lower adapter, at the base of the insulating-gas tubes (Figs. 8, 11, and 14), contains the lower orifice plate of the coolant-flow control valve. (The upper orifice plate of that valve is part of the sensor assembly.) Flow is controlled by rotating the sensor assembly within the thimble assembly. The drive for this rotation is part of the terminal-box assembly.

The thimble guide tube (Figs. 8, 11, and 14) is anchored in the reactor grid-plenum assembly and provides a cylindrical, guiding channel of precise dimensions for the lower end of the thimble assembly. (The outside of the guide tube is hexagonal.) A labyrinth seal and bearing on the lower adapter of the thimble assembly bears on the inside cylindrical surface of the guide tube to seal off the high-pressure coolant. The internal cylindrical surface of the guide tube is long enough so that the thimble assembly can be positioned at more than one elevation (up to 39 in. above its basic position).

2.1.2 Sensor Assembly

The sensor assembly fits into the thimble assembly and holds the test sensors (or other items to be irradiated and tested) in the proper position.

Depending on the needs of the experimenters and the characteristics of the test, different sensor assemblies may be used. At present, three types (designated Models 1, 2, and 3) are planned, each providing a different test arrangement. Details of these models will be established as experimenters make known their detailed requirements for specific experiments.

In Model 1, the sensors are in a gas environment in individual sensor thimbles (Figs. 6, 7, and 8) within the sensor container tube (Tube No. 8). Each sensor and its lead extend from the terminal-box assembly, and from there through a sensor guide tube and into an individual sensor thimble. The sensor thimble is a small-diameter tube, closed at the bottom, and extends upward from the core to the sodium exit of the sensor assembly. The sodium coolant flows around each individual sensor thimble. Indentations in each sensor thimble center the sensor with a small radial clearance (about 1/64 in.) to prevent the sensor from contacting the wall of the sensor thimble.

In Model 2, the sensors are all in one gas-filled, 1.4-in.-dia. sensor container tube (Tube No. 8) outside of which the sodium coolant flows (Figs. 9, 10, and 11). The sensors can be spaced within the sensor container tube by individual guide tubes to ensure that the desired positioning is achieved, or they can be preassembled into a cluster that is handled as a unit.

In Model 3, the sensors are in the EBR-II primary-sodium coolant (Figs. 12, 13, and 14). The sensors are arranged as in Model 2, within an open-ended sensor container tube. With this model, the temperature of the sensors will be more uniform than in Model 2, but the maximum temperatures of the sensors will be lower because there is no inert-gas environment surrounding the sensor.

2.1.3 Terminal-box Assembly

The terminal-box assembly is on top of the thimble and sensor assemblies (Figs. 6, 9, and 12). It provides connections between the sensors and the sensor-data transmission system, contains components of the flow-control-valve drive mechanism, forms a secondary closure for the radioactive primary sodium, contains the inert gas at or above the sensors, and serves as a connecting link between the thimble assembly and the handling container.

The terminal box encloses the top ends of the sensor leads. The top ends of these leads are fitted with individual connectors to facilitate transfer of the sensors into and out of the handling

container. Flexible extension leads connect the sensor leads to one or more gas-sealing, multi-pin connectors on the front cover of the terminal box. The terminal box is 27 in. long so as to allow positioning of individual sensors at a variety of elevations (within a range of about 18 in.) The width of the terminal box is limited by the locations of adjacent control drives. The pressure of the inert gas (argon) in the terminal-box assembly is slightly above atmospheric. The sensors are at this pressure in Models 1 and 2. In Model 3, the sensors are at the pressure of the primary sodium coolant, which is higher than the pressure in the terminal box. A seal in the top of the thimble assembly for Model 3 prevents gas flow between the primary tank and the terminal-box assembly during reactor operation. The terminal-box assembly has connections for inert-gas supply, purge, pressure indication, and pressure relief.

A probe for detecting sodium leaks may be inserted inside the sensor assembly or, alternatively, inside the terminal-box assembly. In the remote event that the level of the sodium rises higher than predicted for the particular experiment, visual and audible alarms will be actuated.

The flow control valve is actuated by a 60 to 90° rotational motion at a speed of 0.6°/sec. This motion slides two orifice plates over each other to achieve a wide variation in flow opening. The orifice plates are above the lower adapter in the bottom of the sensor assembly. The upper orifice plate is attached to the bottom of the sensor assembly and, therefore, rotates with that assembly. The lower plate is stationary. A miter gear attached to the upper end of the sensor assembly is driven by a pinion attached to the extension shaft of the drive mechanism of the valve. This shaft extends through the lower part of the front cover of the terminal box. A rubber O-ring provides a seal between the extension shaft and the cover. A 1/15-hp reversible electric motor drives an adjustable torque limiter which, in turn, drives the extension shaft. Mechanical limit stops are provided for the full-open and closed positions of the flow control valve. Cams fastened to the extension shaft actuate two electrical switches for remote indication of the full-open and closed positions of the valve. A potentiometer geared to the extension shaft

provides a signal for remote readout of the flow setting of the valve. Also, a dial indicator coupled to the extension shaft provides visual display of valve position at the drive.

Two pressure-limit switches ensure that the pressure of the argon gas in the terminal box is held between 2 and 6 psig. A pressure-relief valve, set at 7 psig to protect against over pressure, and a pressure gauge are also attached to the terminal box. All these instruments are assembled to a manifold block, which is attached to the support bracket for the drive of the flow control valve. Two valves are used for the purging system; one is attached to the inlet of the manifold block, and the other is positioned between the manifold block and the connection to the terminal box.

2.1.4 Sensor-data Transmission System

The sensor-data transmission system carries sensor signals from the terminal-box assembly to data-logging and readout equipment. It consists of cables running from connectors in the terminal-box assembly, under the operating-floor deckplates, through conduits in the biological shield (or, alternatively, in cable trays), to the test instrument room on the mezzanine of the reactor building. Other routings may be accommodated as required.

Within the reactor plant, the cables may be shielded twisted pairs or other electronic cable, coaxial cables, electric power cable, or whatever serves a particular experimenter best. Cables, pipelines, or interconnections that could cause operational problems (such as NaK-filled lines, inflexible conduits or piping, electrical connections that must be maintained during rotation of the rotating shield plugs, or lines that could under some possible circumstance contain radioactive material) will be permitted only as regulations and careful safety judgment allow.

Standard commercial electrical cable and pneumatic lines will be provided as required; other interconnections will be supplied by experimenters.

When available, EBR-II analog and digital equipment for data readout and logging can be used for INCOT experiments. Experimenters will also be able to use data-logging or readout equipment that they may themselves supply.

2.1.5 Elevating System

The elevating system raises the thimble assembly (including the sensor assembly and terminal-box assembly) 80 in. so as to allow rotation of the shield plugs during fuel-handling operations.

The elevating system (Fig. 15) is above the rotating shield plugs. It operates in the limited space between the center support column for the control drives and the adjacent control drives. The major parts of the elevating system are the elevator assembly, guidance-and-support assembly, elevator drive assembly, support assembly, and blanket-gas bellows seal assembly.

The elevator assembly raises and supports the thimble assembly in its travel. It is attached to the terminal-box assembly through a connection between the top of the terminal box and the elevator arm in the elevator assembly. This connection is comprised of a spring-supported connecting rod that is fastened to a load transducer on the top of the terminal-box assembly (Fig. 16). The connecting rod is held by a bearing in the center of the elevator arm. The connecting rod and this bearing provide the necessary support and guidance to the thimble assembly during the raising operation. A load-sensing apparatus on the elevator arm senses any relative axial motion between the elevator arm and the spring-supported thimble assembly. In the event of a significant load change, the length of the support spring changes, thereby actuating switching circuits that stop the vertical movement. A load transducer also monitors electrically the lifting forces experienced during vertical movement of the thimble assembly and activates an alarm if the load limit settings are exceeded. The elevator arm is attached at its back face to the guidance-and-support assembly. The arm can be detached as a unit from that assembly to provide the space required for the sensor handling container.

Fig. 15. INCOT Elevating System

Fig. 16. INCOT Elevator Assembly Attached to Guidance-and-support Assembly

The guidance-and-support assembly provides the precise alignment necessary to keep the elevator assembly properly located over the centerline of the control-rod opening in the rotating shield plug during the entire 80 in. of elevator travel. The guidance-and-support assembly consists of: a linear-bearing housing; a pair of ball-bearing lead nuts and lead screws; and a guide track on which the linear-bearing housing travels. The linear-bearing housing is the lifting component. It is locked to the V-shaped guide track by self-contained roller bearings and also holds captive the two ball-bearing lead nuts. These lead nuts are moved vertically by two lead screws along which they travel. The lead screws, each 112 in. long, are placed one on each side of the guide track and operate in the open space between the center column and the terminal-box assembly. The lead screws are supported at their upper ends by the elevator drive assembly on top of the center support column for the control drives.

The elevator drive assembly operates the lead screws that provide the lift to the elevator assembly. The elevator drive is an electromechanical system similar to that used on the EBR-II instrumented subassembly. The drive components are arranged to form a compact mechanism, which is attached to the top of the extension of the center support column of the control drives (Fig. 15). The main parts of the drive are a drive motor, a torque-limiting and backstopping assembly of clutch and gearbox for driving the lead screws, and related interlocking safety devices. The drive motor is a reversing, gear type with built-in automatic braking system. The output shaft of the motor drives the torque-limiting and backstopping assembly that automatically locks the drive train when the drive motor is stopped. The output shaft of the clutch drives a right-angle gear set, which, in turn, drives a speed-reducing gear set. A rate of travel of about 16 in./min is used for raising or lowering the elevator assembly. The drive motor can be stopped and restarted at any intermediate elevation of the elevator assembly between the full-up and the full-down positions. Positional interlocks are incorporated into the drive system as dictated by safety considerations. A sliding yoke, part of the drive system, engages the connecting rod when the elevator assembly reaches the upper limit of its travel. This

arrangement locks the thimble assembly at its highest point of travel and prevents the inadvertent lowering of the assembly during fuel handling.

The support assembly (Fig. 15) provides a precise elevation at which the thimble assembly is maintained during reactor operation. It consists of a holddown plate that is attached to a support structure on the top of the small rotating shield plug. The support structure is attached to the reactor-vessel-cover-lifting structure and to the platform support column. The support assembly also supports the biological shielding located below the terminal-box assembly and in front of the blanket-gas bellows seal assembly. A set of electromechanical switches and interlocks is attached to the holddown plate.

The blanket-gas bellows seal assembly provides a gas-tight seal between the thimble assembly and the top of the small rotating shield plug to prevent leakage of blanket cover gas. This seal is accomplished by a bellows assembly attached to the top of the existing guide-bearing tube in the rotating shield plug and to the flange of the thimble assembly. The bellows thus surrounds the upper end of the support tube of the thimble assembly, thereby sealing it to the small rotating shield plug and expanding when the thimble assembly is raised.

2.1.6 Handling System

The handling system provides the means of removing individual sensors, the sensor assembly, and the entire thimble assembly from the reactor. This system is also used to reinsert test sensors or sensor assemblies that have been removed previously for interim inspection. Three types of handling containers are required: a straight type of sensor handling container; an offset type of sensor handling container; and a thimble-assembly handling container. The first two of these handling containers are designed to accommodate all the various types of test sensors proposed for INCOT, with or without their sensor assemblies. The thimble-assembly handling container is designed to handle removal of the entire thimble assembly from the reactor.

2.1.6.1 Straight Type of Sensor Handling Container

The straight type of sensor handling container (Fig. 17) is a 36-ft-long vertical assembly that will be suspended from the reactor-building overhead crane. It is designed to accommodate all test sensors and their sensor assemblies that have rigid leads. The container consists of: a shielded coffin section; an extension control arm; an exchangeable pipe section; a pulling-pipe section; and a sensor-lifting drive.

The lower portion of the handling container consists of the 4-ft-long shielded coffin section attached to the exchangeable pipe section. The exchangeable pipe section is in turn connected to the upper permanent portion of the handling container (the pulling-pipe section). Each of these sections contains a 2.65-in.-ID axial opening to allow passage of the sensors with their leads.

The shielding of the coffin section provides biological protection against the radioactive sensor and lead while they are being moved to and from the reactor. The sensors and attached leads become radioactive within a short time in the core during reactor operation and are expected to reach gamma-activity levels of 10^3 to 10^4 R/hr (activation equilibrium). Shielding-design calculations indicate that a 6-in. thickness of lead will reduce these expected radiation levels to less than 100 mR at the front surface of the coffin section.

The sensors and about the lower 4 ft of their leads operate in or close to the reactor core and hence receive the strongest irradiation. Consequently, it is desirable, for reasons of instrument integrity, to prevent bending or flexing of the sensors or the lower portions of their leads during handling, insertion, and removal, even if the leads are of the flexible type. Therefore, the lower part of the sensor lead and the sensor are kept straight (unflexed) within the shielded coffin section.

The shielded coffin section progressively narrows toward its rear face so as to fit in the confines of the space vacated by the control-drive mechanism. Because of this special configuration, a shadow-shielding (partial-shielding) approach is used in which the thickest shielding is at the front of the coffin section. Hence, orientation of the shielded coffin section is required during transfer of radioactive sensors.

Fig. 17. Straight Type of Sensor Handling Container (shown in sensor-removal position)

The handling container (and thus the coffin section) is oriented manually, from a location off the rotating plug, with an extension control arm attached to the upper section of the container. The arm extends over and around the components of the fuel-handling mechanism and their supporting structures.

The shielded coffin section consists of: a lead-filled container weighing approximately 450 lb; a coffin shutter; a top flange for attaching the coffin to the exchangeable pipe section; and an internal, removable shield sleeve. The internal shield sleeve is removed from the central opening in the coffin when handling a cluster of sensors or a sensor assembly and is replaced when a single small-diameter sensor is withdrawn into the coffin. The sleeve serves as a guide for the cable connector (which connects the sensor-lifting cable to the sensor lead) as the connector travels through the coffin opening. The bottom surface of the coffin shutter is designed to be located on the top of the terminal-box assembly preparatory to sensor removal.

The coffin shutter can be adjusted by inserting special adapters either for extracting any one sensor from a number of sensors in the sensor assembly or for extracting the entire sensor assembly. The coffin shutter provides 6 in. of lead shielding (which is equivalent to the main body of the coffin section) during lifting and transfer of the handling container.

The exchangeable pipe section, which comprises the central portion of the straight handling container, is a 10-ft-long straight section of Schedule 80 steel pipe. At the bottom flange, it is attached to and supports the coffin section. At its top flange, it is attached to the permanent part of the handling container (the pulling-pipe section) to provide an enclosed path of travel between the coffin and the pulling pipe. The exchangeable pipe section may be disconnected and replaced by a curved section of pipe (the offset pipe section described in Section 2.1.6.2) to convert the straight type of sensor handling container into the offset type of sensor handling container.

The pulling-pipe section of the handling container is permanently attached to the circular plate supporting the sensor-lifting drive; together, these parts form the upper end of the handling container. As stated above, the pulling-pipe section is attached at its lower end to the exchangeable pipe section.

The sensor-lifting drive consists of a sensor-lifting cable, a cable-drive mechanism, a 1/6-hp reversible-gearmotor drive, a synchro transmitter for indicating cable elevation, and appropriate cable end connectors. The sensor-lifting cable and cable drive comprise a Teleflex drive system using a flexible 40-ft-long x 1/4-in.-dia steel cable rated at 1800 lb static load capacity (weight of the sensor and sensor container tube is approximately 325 lb). The sensor-lifting cable operates inside the pulling pipe and is connected to the sensor lead in the terminal box when lifting the sensor lead from the sensor assembly into the handling container.

The lower end of the sensor-lifting cable is fitted with a threaded adapter to which a variety of sensor connectors may be attached. In addition, the cable can be attached to the complete sensor assembly. The connectors and adapters are designed to be manually connected or disconnected inside the terminal box through its front opening.

The cable-drive mechanism is powered by a mechanical-clutch-and-gearmotor arrangement supplying up to 650 in.-lb of torque. The synchro transmitter is connected to one end of the Teleflex drive shaft by a sprocket and chain. The readout indicator of the transmitter is in a remote motor-control box attached to the end of a 50-ft-long electrical cable.

The circular plate supporting the sensor-lifting drive is attached to the overhead crane hook by a flexible cable harness. A support arm on the underside of the plate allows the suspension system to be adjusted for changes in the center of gravity of the overall mass of the handling container when changing from one type of handling container to another. (The same upper section is used for both the straight and the offset types of handling container.)

The motor and motor-support frame of the reactor-vessel-cover-lifting drive must be removed from the reactor-vessel-cover-lifting support structure to provide access for the straight handling container when it is suspended from the overhead crane. The handling container is too long (36 ft) to be lifted above this support structure; it must follow a side-access route between the upright structures and the control drives. The handling container is maneuvered along this route and to a location over the terminal box by the container's extension control arm. The use of this extension not only provides orientation of the front shield portion of the coffin section but also provides a 6-ft distance between the operator and the coffin section. After the handling container has been positioned over the terminal-box assembly, the coffin shutter is opened, and the sensor-lifting drive is operated to lower the drive cable through the pulling pipe, the exchangeable pipe, and the coffin sections to a point in the terminal-box assembly just above the sensors. After the flexible extension leads have been disconnected from the sensor leads, the sensor-lifting cable is attached to the sensor (or to the sensor assembly) by a cable connector. The sensor is then pulled up into the coffin section of the handling container by the sensor-lifting drive, after which the coffin shutter is closed in preparation for transferring the handling container by overhead crane to an off-plug location.

2.1.6.2 Offset Type of Sensor Handling Container

The offset type of handling container (Fig. 18) is provided as an alternative handling arrangement for individual sensors with leads that are flexible enough to tolerate a 30° bend on a 2-ft radius. This type of container can be installed on top of the small rotating shield plug much easier than can the straight type. Because of its off-set, this container can be installed without removing the components and structures of the reactor fuel-handling mechanism. It is similar to the straight type of sensor handling container in that it uses the same coffin section, pulling pipe, and sensor-lifting drive. Only the removable pipe section differs. The 10-ft-long straight pipe section is replaced by a curved pipe section to provide a 20-in. center-line offset.

Fig. 18. Offset Type of Sensor Handling Container (shown in sensor-removal position)

As in the case of the straight type of handling container, the coffin section must be oriented for transfer. This orientation is provided by a 6-ft extension arm attached to a connector on the front of the coffin section.

Use of the offset handling container requires a minor modification of a brace support on the overhead structure of the rotating shield plug. A slot will be made in this support to provide a 6-in.-long path for the offset section of the container. Additional, compensating support will be provided to retain the integrity of this structure.

2.1.6.3 Thimble-assembly Handling Container

The thimble-assembly handling container (Fig. 19) is used to remove the irradiated thimble assembly from the primary tank. It is similar to the straight type of sensor handling container in that it uses the same arrangement of components. The major differences are in the size and shape of the coffin section, the diameter of the pulling pipe, and the type of lifting drive.

The coffin section is 7 ft long (the thimble assembly extends further into the reactor core than do the sensors or their assemblies) and has tapered end sections to reduce shielding weight. The opening in the coffin section is 3 in. ID to accommodate the passage of the thimble-assembly support tube. Because of space limitations, 6 in. of lead shielding are positioned only around the front portion of the central coffin section. For this reason, orientation of the coffin section and handling container is maintained during transfer, using the same extension control arm used for the straight type of sensor handling container.

Since the estimated weight of the entire thimble assembly is approximately twice that of a sensor assembly, a chain-drive system is used to lift the thimble assembly. The drive is powered by a reversible-gearmotor-and-clutch arrangement and is controlled from a control station at operating-floor level.

Fig. 19. Thimble-assembly Handling Container
(shown with terminal box removed)

The thimble-assembly handling container is suspended from the reactor-building overhead crane in the same manner as the other handling containers and uses similar transfer procedures. The thimble-assembly handling container may also be used for reinserting an irradiated thimble assembly.

2.2 Instruments, Controls, Alarms, and Protective Devices

The discussion under this heading is limited to the elevating system. Instruments, controls, alarms, and protective devices for the terminal-box assembly depend on the model of the sensor assembly used, which, in turn, depends on the experiment.

2.2.1 Elevating System

2.2.1.1 Controls

The drive of the elevating system is controlled at the vertical control panel of the EBR-II fuel-handling console. Assemblies combining pushbuttons and indicating lights are provided for the up and down motions. The appropriate UP or DOWN pushbutton is depressed momentarily to initiate the motion, which continues automatically. While the elevator drive is moving, a red running light is displayed in the pushbutton assembly. When the end of travel is reached, a limit switch on the elevator drive assembly is actuated, thereby causing the drive to stop and a green completion light to replace the red. A stop button is also provided for manually stopping the motion. A similar arrangement of pushbutton control is provided for the upper locking yoke. Since the lower yoke is manually operated, only indicating lights are provided for it.

Operation of the elevator drive assembly in the proper sequence with respect to the other fuel-handling operations is controlled by the interlocks described in Section 2.2.1.2. In general, the thimble assembly is raised to completely clear the sub-assemblies in the reactor core before unrestricted fuel handling can take place. In the "unrestricted fuel handling" condition, reactor

subassemblies can be removed and replaced within the reactor as required. This procedure necessitates movement of the large and small rotating shield plugs with respect to the reactor vessel. Since the facility is located on the small rotating shield plug, it must be completely disengaged from any stationary parts of the reactor structure during plug rotation.

2.2.1.2 Interlocks

Although the operating pushbuttons described above can be depressed at any time, they are not functional unless the appropriate interlock conditions are satisfied. For example, the up or down motion cannot occur unless both locking yokes are withdrawn and the instrumentation cables are disconnected.

In addition, other associated fuel-handling mechanisms must be appropriately interlocked to ensure proper sequencing and safe operation. The control-drive-lifting platform, for example, cannot be lowered to release the control rods unless the thimble assembly has been raised and locked in its "up" position by the upper yoke. Conversely, once the platform has been moved from its "reactor operate" elevation, the thimble assembly cannot be moved up or down. At the completion of fuel handling, the thimble assembly cannot be lowered until both the reactor-vessel cover and the platform have been returned to their "reactor operate" positions.

During fuel handling, the elevator drive is electrically disconnected so that electrical operation is impossible. However, as a further precaution against the remote possibility of manual movement, the drive for rotating the shield plugs is interlocked with the elevator drive so that the plugs cannot rotate unless the thimble assembly is up and locked. This up-and-locked condition is determined by a circuit connected through one of the festoon cables, which remain connected during plug rotation.

After fuel handling has been completed, another interlock in the reactor-startup chain requires that the thimble assembly be both down and locked.

All the interlocks, including those for force limits (described in Section 2.2.1.3.1) are summarized in Table II.

2.2.1.3 Protective Devices

2.2.1.3.1 Force Limits of Elevator Drive Mechanism

Since there is relative motion between the thimble assembly and other elements inside the reactor (e.g., the reactor-vessel cover, adjacent subassemblies), any excessive binding between the thimble assembly and these elements must be detected. Any binding occurring when the elevator drive is producing the motion or when either the platform or reactor-vessel cover is producing the motion is detected by monitoring three ways:

(1) A prescribed deflection of the upper support spring (which carries the weight of the thimble assembly and the bellows) in either direction deactuates one of two force-limit switches: one for push force, one for pull. The limit-switch circuits prevent further motion of the elevator drive motor in the direction that increases the deflection from normal. Reverse motion (to relieve the binding) is permitted. (These circuit functions also apply to the motors driving the control-drive-lifting platform and the reactor-vessel-cover-lifting mechanism.) The switches are normally actuated; therefore, a loose or removed switch also causes the elevator drive motor to stop.

(2) The spring deflection is also monitored by an indicating meter connected to a linear resistance potentiometer. The meter will be adjusted so that the weight of the thimble assembly is balanced out to read zero. It indicates forces in either direction and has adjustable limits connected in the motor-control circuits as above.

TABLE II. Interlocks of INCOT Elevating System

Necessary Interlock Condition	The Interlock Conditions Indicated by X Must Be Satisfied for the Listed Actions to Start or Continue							
	Elevator Drive		Reactor-vessel-cover Drive		Platform Drive		Plug Rotation	Reactor Startup
	Up	Down	Up	Down	Up	Down		
Unrestricted-fuel-handling Keyswitch KS-2 On (administrative control)	X	X	X	X	X	X	X	
Elevator Up			X	X	X	X	X	
Upper Yoke Retracted	X	X	X	X	X	X		
Upper Yoke Engaged							X	
Connector Cover Plate in Place	X	X						
Drive -- Push Force within Set Limit		X	X		X			
Drive -- Pull Force within Set Limit	X			X		X		
Rotating Plugs (and Other Fuel-handling Mechanisms) at "Operate" Position	X	X						X
Elevator Down								X
Lower Yoke Engaged								X
Lower Yoke Retracted	X	X						

(3) The weight of the thimble assembly is directly monitored by the load transducer, independently of the spring support. A meter displays the resultant load due to the weight of the thimble assembly, the weight of the bellows, and buoyancy. A set of high and low limits is provided at the meter.

2.2.1.3.2 Limit Switches

Limit switches provide the signals for stopping the drive at discrete positions or in response to excessive forces. In all cases, however, the limit switches are backed up by mechanical stops, slip clutches, etc. so that ultimate safety does not depend only on switch action. The final positioning of any switch whose malfunction would cause considerable operating inconvenience or mechanical damage to a part is set by dowel pins, locking screws, etc.

2.2.1.4 Alarms

Separate alarm lights are provided for indicating excessive push or pull forces as detected by each of the three monitoring systems described in Section 2.2.1.3.1.

2.2.1.5 Indicating Instruments

One meter will display the differential push or pull force detected by the linear potentiometer on the support spring as described in Section 2.2.1.3.1.

Another meter will display the total weight on the elevating drive, as measured by the load transducer also described in Section 2.2.1.3.1.

2.2.1.6 Design Criteria

All control and interlocking circuits are designed to be consistent with other EBR-II mechanisms, with respect to safety and other general requirements. The following criteria have been used for these circuits and their components:

(1) All circuits are "fail safe." For example, a control relay causes a positive action (e.g., running a motor) only when energized. Therefore, stopping the motor of the example requires only interrupting the power to the relay.

(2) Wherever possible, limit switches with self-monitoring circuits are used to provide reliability.

(3) Wherever appropriate, as in the case of the force limits, limit switches are used in their actuated condition, so that removal or a loose mounting results in an alarm.

(4) Control circuits are protected with fast-blowing, properly sized fuses to prevent welding of the contacts of the limit switches and relays in case of accidental short circuits.

(5) In important cases, redundancy is employed. For example, the interlock for plug rotation requires both that the thimble assembly be "up" and that the upper yoke be engaged, although the latter condition is sufficient by itself. Similarly, the interlock for reactor operation requires both that the assembly be down and that the lower yoke be engaged.

3.0 PRINCIPLES OF OPERATION

INCOT is fully compatible with existing reactor operations. The sensors being tested within the facility are not connected to reactor control or scram circuitry. The readings are to be evaluated and taken into consideration by the reactor operators.

Operations of INCOT are interlocked with the EBR-II fuel-handling control console. Thus, no reactor-operations steps can be performed out of sequence, and fuel handling cannot proceed unless INCOT is in an appropriate operational phase.

The experimenters using INCOT have a number of choices pertaining to sensor tests. These choices will, in part, determine the model of the sensor assembly to be used. It must be understood that the facility is not limited to the three models of sensor assemblies described in this report; future models will serve as sensor vehicles to accommodate different sensor sizes, test conditions, and sensor operations.

3.1 Startup

Before the start of an experiment, the user can choose (within limits) the ranges of temperature, flow, and elevation of the sensor. These requirements determine the design of the sensor assembly.

3.2 Operation

During the life of the experiment, the user may want to change certain test conditions. (All such changes must be approved by the EBR-II Project.) The facility has the following provisions for changes:

(a) While the reactor is operating, the INCOT coolant-flow control valve may be adjusted to regulate (within certain limits) the rate and temperature of the sodium flow through the facility.

(b) While the reactor is temporarily shut down, the sensor assembly can be raised (or lowered) over a 34-in. distance.

(c) While the reactor is temporarily shut down, individual sensors in sensor assembly Models 1 or 2 can be raised (or lowered) approximately 18 in.

(d) While the reactor is temporarily shut down, one sensor in sensor assembly Models 1 or 2 can be raised substantially more than 18 in.

3.3 Shutdown

At the end of an irradiation experiment or an irradiation phase of the experiment, the user has the following options:

(a) Removal and/or replacement of the complete sensor assembly containing all the sensors.

(b) Removal of individual sensors from sensor assembly Models 1 or 2, and their replacement by new sensors while the other sensors remain in the facility to accumulate higher fluences.

4.0 SAFETY PRECAUTIONS

INCOT will be operated in EBR-II in such a manner as to not compromise the safety and operating characteristics of the reactor system. The facility can be divided into two basic areas of safety interest: portions outside the primary tank of the reactor, and portions inside the primary tank.

4.1 Portions Outside the Primary Tank

Portions of INCOT outside the primary tank are the terminal-box assembly, the sensor-data transmission system, the elevating system, and the handling system.

The terminal-box assembly is a gastight structure and provides an additional seal for the internals of the thimble assembly.

The elevating system embodies a number of important safety considerations relating to safe operation of the reactor, because it controls the in-core position of the thimble assembly. The elevator drive is an electrically operated arrangement of gears, clutches, torque limiters, helical drive screws, and ball-nut travelers that provides controlled vertical movement for lifting the thimble assembly during reactor fuel handling. The elevator assembly contains a spring arrangement that supports the weight of the thimble assembly. Appropriate mechanical and electrical interlocks for controlling the position of the thimble assembly in the reactor are incorporated in the design of the elevating system. The elevator drive cannot be operated to raise the thimble assembly unless the thimble operating-position interlock, which mechanically holds the thimble assembly, has been retracted.

The fuel-handling operation, including the rotation of the plugs, cannot begin unless the elevator assembly is in its fully up position and locked at this elevation by the sliding yoke on the top of the center support column.

The elevator drive cannot be operated to lower the elevator assembly and the thimble assembly unless the rotating shield plugs are in their "reactor operating" position, at which point the proper electrical interlock circuits are made. These interlock circuits control the power supply to the motor of the elevator drive.

Appropriate mechanical and electrical interlocks are incorporated into the fuel-handling controls to prevent overloading of the components of the thimble assembly and the reactor vessel during fuel-handling operations.

Forces on the elevator assembly that are significantly greater than the weight of the thimble assembly produce a change in spring deflection. The deflection is electrically monitored. Any change beyond a preset amount during vertical travel of the assembly or contiguous mechanisms will stop the motion and produce an alarm. For additional protection, a separate electrical load transducer also monitors the same forces.

Any excessive forces experienced by the thimble assembly while it is in the reactor core will be reflected by the vertical motion of the spring package in the mechanical-load-sensing apparatus and will also be sensed by the electrical load transducer. Electrical limits on these two systems then will actuate an alarm. Depending on the mode of operation at the time, this actuation also will either (a) prevent actuation of, or stop, the reactor-vessel-cover-lifting drive and the control-rod-lifting platform during reactor fuel-handling operations, or (b) stop the motor of the elevator drive.

Most of the required safety devices discussed in this report are electromechanical or electrical controls and interlocking circuits. They are designed to meet safety criteria similar to those used in designing existing mechanisms in the EBR-II reactor system.

The safety considerations for the handling system are concerned primarily with the biological shielding. Because of the lack of space on top of the rotating shield plug, partial (shadow) shielding is employed on the shielded coffin section. While being transferred, this section is held by special tools in such a position that the shield is always between the operators and the irradiation source.

4.2 Portions Inside the Primary Tank

Portions of INCOT inside the primary tank are the thimble assembly and the sensor assembly. An important safety consideration involved in operating the thimble assembly in the reactor vessel is the proper dimensional design and structural integrity of the thimble support tube. This tube is the main structural member in the thimble assembly. It passes through the opening in the reactor-vessel cover and into the thimble guide tube in the reactor core. The outside dimensions of the thimble support tube are such that the tube can pass through these openings with proper clearances to prevent interference in the core, reactor-vessel cover, and primary-tank nozzle. The materials and assembly techniques for the tube and the thimble assembly conform with proved design criteria for the nuclear, thermal, and chemical environments of the EBR-II reactor.

Leak prevention is another important safety consideration applied to the thimble and sensor assemblies. The provisions differ slightly, depending on which model of the sensor assembly is being used. With each model, however, leakage of sodium from the primary tank to the operating floor is prevented by at least two seals. All provisions include prevention of leaks that might originate from a faulty or damaged sensor or sensor lead. Metal bellows are used to seal the argon blanket gas of the primary tank.

The coolant-flow control valve is designed so that the coolant cannot be shut off completely. Since the thimble and sensor assemblies use only a small portion of the primary sodium flow through the reactor, a reliable and adequate source of coolant supply is assured. Since none of the INCOT coolant leaves the primary tank, no shielding against radioactive coolant is needed.