CHARACTERISTICS AND PERFORMANCE
OF THE HEATER FACILITY
FOR LONG EBR-II COMPONENTS

by

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EBR-II Project
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ABSTRACT

A heater facility for long EBR-II components has been fabricated and tested, and will be installed in one of the existing 38-ft-deep storage holes in the EBR-II reactor building. The facility will be used for pre- and postirradiation heating of In-core Instrumented Test Facility components, instrumented subassemblies, and other EBR-II components. The heater assembly is approximately 33 ft long and 1 ft in diameter. The lower 20 ft is divided into three independent heating zones. Various temperature profiles can be obtained by controlling power to selected zones. A maximum heating rate of 20°F/min can be attained with a heater load of 2.4 lb/ft of stainless steel within the heater. The maximum operating temperature is 900°F.

I. INTRODUCTION

The desirability of having a heater facility that could accommodate long, slender components in the reactor building of EBR-II became evident with the development and utilization of irradiation facilities such as the In-core Instrument Test Facility (INCOT)¹ and the Instrumented-Subassembly System (INSAT).² Both of these facilities contain components ranging from 27 to 36 ft long, and these components usually must be preheated before they are installed in the primary tank. In addition, postirradiation heating of INCOT

components would be a valuable asset to the INCOT program because it would minimize reactor downtime during change-out operations and would allow additional information to be obtained from experiments.

A heater facility capable of both pre- and postirradiation heating of long components within the reactor building has been built and tested. This report describes the facility, its characteristics, and its performance.

II. SUMMARY DESCRIPTION OF FACILITY

The heater facility, capable of accommodating long components as well as handling tools, will be installed in one of the existing 38-ft-deep storage holes in the reactor building. Because the storage holes provide adequate biological shielding, postirradiation heating of components such as INCOT sensor bundles and sensor assemblies will be possible.

The heater assembly is approximately 33 ft long; the heated section has a 3.4-in. ID, is 20 ft long, and is positioned at the lower end of the assembly (see Fig. 3 in Appendix). The top of the assembly contains a 15-in.-thick steel shield plug, a holding chuck, and a shielded adapter plate for a handling container. With the shield plug and chuck in place, components as large as 3 in. in diameter can be inserted into the heater. The components will be loaded into the heater at the reactor-operating-floor elevation, through the shielded handling-container adapter plate. Irradiated components may be unloaded directly from shielded casks such as the INCOT handling container. The chuck at the top of the heater assembly may be used to hold components at various elevations within the heater.

The heated section of the facility is divided vertically into three independently controlled zones. The lowest zone (No. 1) can supply 2.3 kW, and the two higher zones (Nos. 2 and 3) 1.9 kW each. Three electric resistance heaters (Calrod type) supply heat to each zone. The heater circuits are designed to operate the heaters at half their rated voltage and at a maximum power density of 10 W/in.². A redundant set of three heaters installed at each zone provides backup in case of heater failure or is used to obtain special heating rates.

The heater facility is designed to operate continuously at 900°F. It is estimated that 1 hr will be required to raise the temperature of a stainless steel heating load of 4 lb/ft from room temperature to 900°F. When the facility is operating at 900°F, the total conductive heat losses are estimated to be 0.5 kW. This heat is removed by circulating building air over the outside of the heater with a positive-displacement blower. The differential pressure of the blower system is expected to be about 1 psi. The blower can be operated at two speeds and thus provide about 50 or 100 cfm. It is expected that 50 cfm will be sufficient to cool the heater assembly under normal operating conditions.

Sixteen Type K grounded-junction thermocouples are attached to the outside of the heater tube. Six of these are used for power control, and the rest are spares. All thermocouples terminate at the control console and can be monitored (using additional instrumentation) if a temperature profile of the heater is required. Two additional Type K thermocouples monitor the difference between the temperatures of the input and exhaust cooling air.

The control of the heater may be accomplished either automatically or manually; however, the facility is intended for use in the automatic control mode. Automatic control is provided by three 3-mode controllers that provide proportional, differential, and integral control action for each heater zone. Each zone may be energized and controlled independently. Redundant upper-temperature-limit alarms and interlocks for each zone prevent the temperature from exceeding predetermined safe limits by deenergizing the heaters automatically. Additionally, all energized zones will be deenergized if either the cooling-air differential pressure drops below approximately 1/2 psi or the inlet-outlet differential temperature exceeds a predetermined safe limit. Any or all zones may be deenergized manually by actuating either the "zone off" or "heater power off" switches. In an emergency situation, tripping the "master stop" switch will deenergize all the heaters and the blower motor.

A complete description of the facility is in the System Design Description, which appears in the Appendix of this report.

III. FUNCTION AND UTILIZATION

Currently, the heater facility is capable of (but not limited to) performing the following functions.

A. Preheating of INCOT and INSAT Components

Preheating of INCOT and INSAT components before they are installed in the primary tank is usually required for either of the following reasons:

(1) The experiment may be of such a nature that the thermal shock associated with immersion into the hot sodium might cause damage. This was the case with the INCOT YY01 experiment, which required preheating the sensors just above the bulk-sodium level before immersion. (2) The experiment contains sodium-bonded fuel elements or capsules. Here, the sodium bond must be melted from the top downward to avoid the pressure buildup that occurs when the bottom is melted first.³

Preheating of sodium-containing capsules (or elements) in INSAT and INCOT experiments is currently being accomplished with an 8-ft-long preheating furnace that uses a power gradient to obtain higher temperatures at its top end.⁴ This operation is usually time consuming and requires exclusive use of the reactor-building crane.

With the new heater facility, sodium-filled capsules can be preheated in the region between heating zones No. 1 and 2 or No. 2 and 3 by actuating only the heaters of the upper zone of two adjacent zones. During preheating, the component can be held in the chuck at the top of the heater facility and hence free the crane for other uses. Heatup times can also be substantially reduced when using the new facility, because it has a higher output than the older furnace (approximately 2 kW/zone as compared with 0.5 kW total).

B. Postirradiation Heating of INCOT Components and Experiments

Irradiated INCOT sensor bundles and sensor assemblies can be heated in the new facility because it is housed within a shielded storage hole. The irradiated components will be transferred from the reactor in a suitable shielded cask, such as the INCOT handling container, and unloaded from the bottom of the cask into the heater facility through its top.

1. Separation of a Sensor Bundle from an INCOT Model 3 Sensor Assembly

After irradiation of an INCOT Model 3 sensor assembly,¹ two components usually must be removed from the reactor: the sensor bundle and the sensor assembly. In the past (for the YY01 experiment), these had to be removed separately from the primary tank. If the sensor bundle and sensor assembly were removed together, the residual sodium between them would freeze and make separation of the two very difficult if not impossible.

With the heater facility, the sensor bundle and sensor assembly can be removed together in one operation. The combined assembly can be transferred into the heater facility, where the residual sodium can be melted to allow removal of the sensor bundle from the sensor assembly. This handling method keeps reactor downtime to a minimum and simplifies INCOT removal operations.

2. Heating of Irradiated Experiments and Components

The heater facility will enable postirradiation heating of INCOT experimental sensors. Since, in most cases sensor outputs can still be monitored during postirradiation testing, results from postirradiation heating tests would yield data uninfluenced by the reactor environmental conditions.

C. Comparison of Pre- and Postirradiation Electrical Characteristics of INCOT Sensors in a Heated Environment

The effects of prolonged irradiation and temperature-dependent aging and drift could cause differences in either output or response, or both, of the sensors during their irradiation period in the INCOT facility. In the heater facility, measurements obtained before and after irradiation can be compared. To accomplish this, special reference instrumentation can be inserted into the facility through a removable insert (see Fig. 1A). The

Fig. 1. Heater Facility with (A) Removable Instrumentation Insert Installed and (B) Borescope Installed

removable insert with reference instrumentation is replaceable and can be suited to specific requirements.

D. Postirradiation Visual Inspection

A borescope with photographic capability can readily be installed into the upper end of the heater facility (see Fig. 1B). The borescope will enable viewing and photographing of irradiated components such as INCOT sensor bundles and reactor assemblies, thimbles, control-rod drive shafts, etc.

The borescope system consists of a 12-ft-long borescope (four 3-ft-long sections) with self-contained light source, a camera adapter with automatic exposure control, and a Polaroid-film back. The borescope optics are fabricated from radiation-hardened glass. A borescope adapter -- consisting of a borescope guide tube, a stiff post to which the guide tube is attached, and a double rack and pinion for changing borescope elevation -- is fastened to the top of the heater. The guide tube and post maintain the radial position of the borescope and protect it during its vertical travel. The rack-and-pinion support allows for 12 in. of vertical travel of the borescope; thus, objects between 9 and 10 ft within the facility can be viewed.

IV. OPERATING CHARACTERISTICS AND PERFORMANCE

A. Temperature Profiles

Figures 2, 3, and 4 show the temperature profiles along the length of the heater for various modes of operation. The measurements were obtained after thermal equilibrium was established. The controlling thermocouples for all runs were Nos. 4, 10, and 15 for zones 1, 2, and 3, respectively. A thermal load representative of INCOT with a typical experiment was fully inserted into the heater. The load consisted of a 2-in.-OD by 0.120-in.-wall tube (2.4 lb/ft of stainless steel). A thermocouple probe was made to traverse the center of the tube and measure the gas temperature within. To minimize gas circulation, the probe was actuated through a gland at the top of the tube.

Fig. 2. Temperature Profiles: All Heater Zones Operating at Same Temperature

Fig. 3. Temperature Profiles: Heater Zones Operating Individually at 400°F

Fig. 4. Temperature Profiles: Heater Zones Operating Individually at 650°F

B. Preheating

Preheating of sodium-filled capsules will require use of the heaters of either zone No. 2 or zone No. 3. If the heaters of zone No. 2 are used, the axial center of the sodium length in the capsule should be positioned at the 100-in. reference elevation. If the heaters of zone No. 3 are used, the axial center of the sodium length should be positioned at the 175-in. reference elevation. In both cases, a sodium length of 30 in. or less will be preheated so that the sodium melts from the top downward. Once the initial sodium melting has been completed (normally, thermocouples within the sodium capsule are monitored during preheating), the capsule may be raised to allow for a more uniform heating of the entire length.

In the past, preheating temperatures have generally been limited to 650°F. When the heater facility is used for preheating, the components should be placed into a "cold" heater and then brought up to temperature using the heater control system. The total time required to preheat to 650°F will be less than 1 hr if the system is allowed an uninterrupted ascent to temperature.

C. Uniform Heating

Regions of uniform temperature (bands within 10°F) appear to center about reference elevation 48 in. for zone No. 1, 124 in. for zone No. 2, and 187 in. for zone No. 3. The lengths of the regions above and below those elevations are about ± 20 in., ± 18 in., and ± 15 in. for zones No. 1, 2, and 3, respectively. (Note: These data are with regard to all zones controlling at 400°F.)

D. Thermal Cycling

Thermal cycling or shocking of a component (probably a post-irradiation activity) could yield valuable information about its ability to withstand the temperature perturbation experienced in a reactor. Short-period thermal cycling using the heater facility can be accomplished by moving the

component in and out of different temperature regions. As an example (see Fig.2), with zones No. 1 and 2 operating at 650°F, a component can be raised from the 50-in. elevation, where the temperature is 650°F, to the 90-in. elevation, where the temperature is 500°F, in a rather short period of time. For more severe cycling, a component can be moved from a powered zone to a non-powered zone to subject it to a temperature differential of several hundred degrees.

E. External Controlling Sensors

Because the controlling thermocouples of the heater facility are mounted on the outside of the main heater tube, a temperature lag will exist between the controllers and the component being heated. Should more precise temperature control be required, the thermocouple within the heated experiment can be used to control the temperature of a particular zone. The only requirements for operating in this mode are that the thermocouple be Type K (Chromel/Alumel) and that the maximum temperature of the heater facility remain within the heater design limit of 900°F.

APPENDIX

System Design Description

This appendix is a direct reproduction of the current (as of May 1, 1973) System Design Description for the heater facility. The four figures are at the end of the appendix.

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FOR
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COMPONENTS

Date

September 8, 1972

Responsible Engineer

Group Leader

Section Manager

PQE

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* The document number as it appears on this page only shall be used to identify this document. The last two digits denote the revision number of this document (see Revision Authorization block below).

This document is fully representative of the Document No. only when the revision number on its pages correspond with those in the index below.

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SUMMARY

The heater facility for long EBR-II components will be installed in one of the existing storage holes in the reactor building. This facility consisting of a lower subassembly, a blower, and a control console. It will be independent of reactor operations and will provide preheating of INCOT and INSAT experiments, preheating of handling tools and post-irradiation heating of INCOT sensors. A control console, located adjacent to the storage hole, will provide necessary control functions and instrumentation for the heater facility operation. Cal-rod heaters mounted in the lower subassembly will provide a total heating capacity of approximately 6.0 KW. Temperature controllers will regulate the flow of power to the heaters, and a blower mounted on the reactor building operating floor, adjacent to the storage hole, will furnish air circulation in the annulus formed by the storage hole and the lower subassembly to dissipate heat losses. An additional temperature indicator will monitor the inlet and exhaust cooling air temperatures. Power is fed (via the control console) to the heater circuits from the Fuel Element Rupture Detector Panel (FERD) and to the blower from the Radioactive Sodium Chemistry Loop power panel (RSCL).

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SECTION 1

FUNCTIONS AND DESIGN REQUIREMENTS

1.1 FUNCTIONS

The heater facility shall be capable of:

- . Preheating INCOT and INSAT experiments
- . Preheating handling tools
- . Post-irradiation heating of components such as INCOT sensor bundles and sensor assemblies
- . Future use as a pre- and post-irradiation INCOT instrument calibration facility.

1.2 DESIGN REQUIREMENTS

The heater facility shall include the requirements cited in paragraphs 1.2.1 through 1.2.9.

1.2.1 OPERATIONAL REQUIREMENTS

The heater facility shall incorporate the operational requirements shown in Table 1.

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Table 1

Design Operating Temperature:	Continuous.....900°F Short duration...1000°F
Time Required to Raise Temperature from Ambient (70°F) to 900°F:	1 hour
Total Conductive Heat Loss at 900°F:	1
Heating Method:	Three independently-controlled zones with three cal-rod heaters per zone (plus a spare set of three heaters per zone)
Total Heater Capacity per Zone:	Zone 1 (lowest zone).....2.3 KW Zone 2 (mid-zone).....1.9 KW Zone 3 (highest zone).....1.9 KW
Heater Limits:	Designed to operate heaters at one-half rated voltage and a maximum watt density of 10 watts/in. ² .
Cooling Medium for Transferring Conductive Heat Losses:	Two-speed positive displacement blower (50 cfm and 100 cfm)
Blower System Pressure Differential:	1.0 psi
Thermocouples:	Type K, grounded junction, 6 used for heater power control, 2 used for monitoring inlet and exhaust air temperature, 10 installed as spare

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Table 1 (Contd.)

Power Source:

SCR power controller and heater
circuits....120/208 Vac, 3-phase
60 HZ, 20 amp circuit at 3-pole
circuit breaker in FERD panel.

Blower motor....480 Vac, 3-phase,
60 HZ from 20 amp circuit at 3-
pole circuit breaker in RSCL
power panel.

1.2.2

STRUCTURAL REQUIREMENTS

The requirements shown in Table 2 shall be observed.

Table 2

Sizes:

Overall heater assembly...33 ft long by
12 in. diameter (approx.)

Heated Section....20 ft long by 4 in.
diameter (approx.)

Control Console...85-1/2 in. high, 19
in. wide, 26 in. deep

Insulation:

Pabco-Super Caltemp pipe and block in-
sulation, 1-1/2 to 2 in. thick

Blower:

Belt-driven, Rotary type, Series 17,
North American Rockwell, Pneumatics
Div., Model 3204

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Table 2 (Contd.)

Blower Motor:

7-1/2 HP, fan cooled, 3-phase, 230/460
Vac, 60 HZ, 1800 rpm totally enclosed
Reliance Electric Co., Model P21G311

1.2.3 SYSTEM CONFIGURATION AND ESSENTIAL FEATURES

The heater assembly shall fit into one of the existing 38 foot deep storage holes in the reactor building. The blower assembly shall be mounted adjacent to the heater assembly and a flexible hose shall be connected from the blower outlet to the heater assembly inlet. The control console shall be located at any convenient position near the storage hole selected to permit connection of incoming power cables, connection of the blower cable and instrument and heater cables.

1.2.4 MAINTENANCE

The control console shall be provided with an access door to permit hands-on maintenance and servicing of all racks, components and wiring. The console shall be mounted on casters to permit movement of the console for full access to all sides of the console. The blower and motor shall be mounted on the reactor building floor to facilitate hands-on maintenance. The heater assembly shall be provided with a lifting fixture to permit its complete removal from the storage hole by the small overhead building crane.

1.2.5 SURVEILLANCE AND IN-SERVICE INSPECTION

The calrod heaters and thermocouples are the only components within the heater assembly subject to malfunction. Should failure of these components occur, spare heaters and

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thermocouples are installed in place within the heater assembly. Should it become necessary to physically remove the heater assembly from the storage hole, a lifting fixture is provided for use with the small building crane. All controls are contained within the console which is positioned on the reactor building operating floor and is fully accessible.

1.2.6 INSTRUMENTATION AND CONTROL

The following requirements for system operation and control apply:

- . A spare set of three heaters shall be provided for each zone.
- . Ten thermocouples shall be installed as spares.
- . All facility controls shall be located in the console.
- . All heater zones shall be automatically deenergized if zone temperature or cooling air temperature rise above their alarm set points.
- . All heaters shall automatically deenergize if the cooling air inlet and/or outlet temperatures exceed a specified temperature.
- . All heaters shall automatically deenergize if the cooling air pressure drops below 1/2 psig.
- . All zone heaters shall be capable of being deenergized manually either individually or simultaneously.
- . Two separate high temperature alarm set points shall be provided for each heater zone. One alarm in each zone temperature controller shall have an internal adjustment to permit changes up to 10% above the control set point; the other alarm shall have a "Tamper-proof" Factory-Mutual approved set point screwdriver adjustment.

SCR ac power controllers shall have zero-crossover firing to suppress the generation of electrical noise.

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- . A "master-stop" button shall be provided to simultaneously deenergize all heaters and stop blower motor operation.
- . Manually operated disconnect switches shall be provided to interrupt AC power to the console to preclude shock hazard to servicing personnel.
- . All cable connectors in the power and control circuits shall be keyed, or otherwise marked by identifying colors and alphanumeric symbols, to prevent improper connections.

1.2.7

INTERFACING SYSTEMS

Not applicable.

1.2.8

QUALITY ASSURANCE

The heater facility design shall be reviewed in accordance with the EBR-II Policy and Procedures Manual. It shall be assembled and checked in accordance with an approved Assembly and Test Procedure; installed at the site in accordance with an approved Installation Procedure, checked out in accordance with an approved Preoperational Checkout Procedure, and operated in accordance with an approved Operating Procedure. Safety Procedure No. SA-3-69, EBR-II Electrical System, "General Safety Requirements for Maintenance or Installation", shall be followed during the performance of all electrical work.

1.2.9

CODES AND STANDARDS

The following standards shall be used:

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Electrical Standards for
General Purpose Machine
Tools

JIC Standard EGP-1-1967

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SECTION 2

DESIGN DESCRIPTION

2.1

SUMMARY

The heater facility, positioned in the reactor building, (see Figure 1), consists of the following major components:

- . Blower assembly
- . Lower subassembly
- . Shield plug
- . Holding chuck
- . Lifting fixture
- . Top shield
- . Control panel

These components function as follows:

Blower assembly: Provides circulation of cooling air through the annulus formed by the walls of the storage hole and the lower subassembly to dissipate heat losses which occur through the insulation of the lower subassembly.

Lower subassembly: Mounts in the storage hole and provides accommodations for preheating or postirradiation heating of long EBR-II components. It is of nested-tube configuration, is approximately 33 ft long and contains heaters, thermocouples, cooling air tubes, insulation, and an argon line.

Shield Plug: Mounts in the top of the lower subassembly. Incorporates tapped holes to secure the

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Shield Plug:

contd.

lifting fixture and a viewing port to permit boroscope examination of an experiment within the lower subassembly.

Holding Chuck:

Bolted to the top of the lower subassembly. Holds an INCOT or INSAT experiment (or a handling tool) at any elevation within the lower subassembly.

Lifting Fixture:

Used only for installation or removal of the lower subassembly from the storage hole. Is removed to permit installation of the holding chuck.

Top Shield:

Is a top closure for the lower subassembly and the storage hole. Has provisions for installation of various additional containment enclosures which would extend vertically above the reactor building floor. Is provided with a capped entry port for securing or tightening the holding chuck and incorporates a viewing port to permit boroscope examination of an experiment within the lower subassembly.

Control Panel:

Contained in a caster-mounted cabinet positioned adjacent to the storage hole in which the heater facility is located. Contains all controls and equipment required for the facility.

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2.2

DETAILED SYSTEM DESCRIPTION

The system flow path is shown in Figure 2. Cooling air from the blower at 50 or 100 cfm is ducted through a 48 in. long 1-1/2 in. diameter flexible hose to the heater assembly inlet pipe. The cooling air circulates through the annulus formed by the walls of the storage hole and the suspended lower subassembly and is exhausted back to the reactor building through four one-inch OD air tubes positioned 90° apart in the annulus. The exhaust air inlets are located slightly below the bottom of the lower subassembly. One thermocouple each monitors the cooling air inlet and outlet temperature.

Should the inlet or exhaust differential air temperature exceed the set point, the thermocouples, through a temperature-indicating limit and alarm controller on the panel, will automatically deenergize the heater. Should the cooling air differential pressure (a nominal 1.0 psi) fall below 1/2 psig, an air pressure tube positioned in the inlet cooling air duct and connected to an air pressure switch on the control panel will sense the pressure change and automatically deenergize the heaters.

The heated section of the lower subassembly in which INCOT, INSAT, or handling tools are placed, is 20 ft long and 3.4 in. ID. It is divided into three independently-controlled zones with three energized and three spare calrod heaters positioned in each zone. Thermocouples attached to the outside of the heated tube control power to the heaters through a temperature controller and an SCR power controller for each zone. Should the zone temperature rise above the alarm set points, the temperature controller will automatically deenergize the heaters.

A "master-stop" button located on the console permits all heaters to be simultaneously deenergized and blower operation to stop.

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2.3 SYSTEM PERFORMANCE CHARACTERISTICS

Not applicable.

2.4 SYSTEM ARRANGEMENT

The heater facility is arranged as shown in Figure 1. The heater assembly is positioned in the storage hole as shown in Figure 3.

Access for boroscope inspection of an experiment positioned in the heater facility is provided by a viewing port through the shield plug and through the top shield. One hex head retaining bolt is removed from the holding chuck to provide thru access.

2.5 COMPONENT DESIGN DESCRIPTIONS

2.5.1 BLOWER ASSEMBLY (See Figure 4)

The blower assembly, mounted on a steel base, and protected by a steel shroud, occupies a 20-in. by 30-in. space on the reactor building floor. It consists of a belt-driven rotary blower and a motor. The blower is commercially available from North American Rockwell, Pneumatics Div., Series No. 17, Model 3204. The motor is a Reliance Electric Co. 7-1/2 h.p. fan-cooled, 3-phase, 230/460 Vac., totally enclosed, 60 HZ, 1800 rpm unit.

A 49 in. circular "V" belt, Gates Rubber Co. "Truflex" No. 3490; and a 1-3/8 in. bore sheave, Gates Rubber Co. "Vulco-mount" No. 3-B-5.6 in. VT, are used to produce 50 cfm air flow. Should greater blower rpm and 100 cfm air flow be required, an alternate belt and sheave, also available from Gates Rubber Co., is used. The belt is 58 in., their No. 3580 and the sheave is their No. 3-B-11.0 in. VT.

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2.5.2

LOWER SUBASSEMBLY (See Figure 3)

The lower subassembly is made up of three basic weldments:

- . Center tube
- . Internal tube and flange
- . External tube and flange.

The center tube, into which the experiments to be heated are placed, is approximately 20-1/2 ft long. It consists of a 3 in. diameter Schedule 5, Type 304 stainless steel pipe, a 45° tapered section guide which is welded to the top end of the center tube, and a 1/4 in. diameter Schedule 40 pipe welded to the center tube 12-1/2 in. from the bottom of the tube. The small diameter pipe provides for entry of argon for purging. Sixteen thermocouples (refer to Table 3) are secured to the outer wall of the center tube with bands which are spot welded to the center tube. The lowest zone (Zone 1) is 80-1/2 in. long, measured from the bottom of the subassembly and incorporates 6 thermocouples (2 used, 4 spares), Zone 2 is 72 in. long and incorporates 5 thermocouples (2 used, 3 spares), Zone 3 (the highest zone) is 73-1/2 in. long and incorporates 5 thermocouples (2 used, 3 spares).

Eighteen cal-rod heaters (refer to Tables 4 and 5) are also secured to the outer wall of the center tube with retainer strips which are tackwelded to the wall of the center tube. Six heaters are installed per zone (3 used, 3 spares).

The center tube is insulated with a double layer of insulation; the first layer is 1-1/2 in. thick, the second layer is 2 in. thick. Slits are cut in the insulation to clear the heater terminals and thermocouple leads.

The internal tube and flange fits over the top end of the center tube. It is a weldment consisting of a flange and tube, 9.0 in. diameter and approximately 13 ft long. The external tube and flange which forms the outer wall of the subassembly fits over the center tube. The external tube is 11-1/2 in. OD and is approx. 33 ft long. Four in. OD

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air tubes and one 1/4 in. dia. argon tube are positioned between the external tube and the internal tube and are secured at the top by the flange of the external tube and at the bottom by the bottom plate. The bottom plate acts as the bottom closure for the lower subassembly and is provided with holes to permit entry of the four air tubes and the center tube. The air tubes project through the bottom plate and are welded to the bottom plate; the center tube is welded flush with the bottom plate, and the bottom plate is also welded to the external tube.

An 8 in. long Schedule 40 stainless steel 4 in. half nipple is welded to the bottom plate and is threaded to accommodate a pipe cap. A centering plug fits inside the half-nipple flush against the bottom face of the bottom flange and extends into the center tube. The bottom end of the centering plug is provided with a 3/8-16 UNC-2B tapped hole. This permits the use of a gear puller to disengage the center plug in the event that sodium from one of the experiments should seize the center plug to the center tube.

Insulation is installed inside of the half nipple and a pipe cap is threaded over the nipple. Four inch-thick insulation, with cutouts to accommodate the air tubes, is also installed against the outside face of the bottom plate.

Table 3. Thermocouple Data

Manufacturer:	Conax, Model No. K-SSb-G-T4-CL-52-12
Sheathing:	Type 304 stainless steel
Lead Lengths:	Thermocouple No. 1 thru 6 --- 45 ft Thermocouple No. 7 thru 12 -- 40 ft Thermocouple No. 13 thru 16 - 36 ft

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Table 4. Calrod Tubular Heater Data (Zone 1)

Manufacturer:	G.E. (Catalog No. 5D7962)
Sheath Diameter:	0.315 in.
Max. Output per Heater:	3000 watts
Effective Heating Length:	76 in.
Quantity Used per Zone:	3 (plus 3 additional for spares)

Table 5. Calrod Tubular Heater Data (Zones 2 and 3)

Manufacturer:	G.E. (Catalog No. 5D7862)
Sheath Diameter:	0.315 in.
Max. Output per Heater:	2500 watts
Effective Heating Length	63 in.
Quantity Used per Zone:	3 (plus 3 additional per zone for spares)

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2.5.3 SHIELD PLUG

The shield plug, a Type 304 stainless steel weldment is approximately 21 in. long, fits inside of the internal tube and flange and is secured to the flange of the internal tube with six screws and lockwashers. Its 3 in. diameter center opening coincides with the center tube. A 1/2 in. diameter hole thru the length of the plug provides entry for boroscope viewing. This hole, plus 2 additional holes, are tapped for the first 1.0 inch to provide points of attachment for the chuck or the lifting fixture.

2.5.4 HOLDING CHUCK

The holding chuck is self-centering, is 10 in. diameter, and is provided with a straight recess with tongue and groove jaws. It is commercially available (Cushman No. 10-104-10-000B) and is secured to the shield plug with three 1/2-13 x 1-1/2 in. bolts.

2.5.5 LIFTING FIXTURE

This fixture is a 6 in. diameter, 3/4 in. thick steel plate provided with 3 tapped holes to accommodate 1/2-13 x 1-1/2 in. bolts which secure the fixture to the shield plug. The lifting fixture is removed when the heater assembly is installed in the storage hole and is replaced by the holding chuck. A tapped hole in the center of the fixture accommodates a 3/4-10 in. eye bolt for use with the small building crane.

2.5.6 TOP SHIELD

The top shield, machined from mild steel, has an OD of 18 in. and is 8-1/2 in. thick. It is drilled to provide an entrance hole for loosening or tightening the chuck. A pipe plug closes off this entry hole. A 3-1/2 in. diameter hole bored through the top of the shield accepts an INCOT Thimble Handling Container. The top shield fits over the chuck and rests on the flanges of the shield plug and the external tube.

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A hole for boroscope viewing lines up with a corresponding hole in the shield plug. Should viewing be necessary, one screw which retains the chuck is removed to provide access into the lower subassembly. Six tapped holes are also provided on the top of the top shield to be used as points to secure other enclosures, not a part of the heater facility, which would extend above the top shield and be used in conjunction with an INCOT or INSAT experiment.

2.5.7

CONTROL CONSOLE

The control console is 85-1/2 in. high, 19 in. wide and 26 in. deep overall. It is caster-mounted and of conventional construction.

The following heater facility instruments and controls are mounted on the face of the cabinet:

Heater temperature indicating controllers (one for each heater zone): 3

Air temperature indicating controller: 1

Three-mode (proportional, differential (rate) and integral (reset) temperature controller (one for each heater zone): 3

On-Off Heater Pushbuttons (one set of pushbuttons per zone): 3

Cooling air pressure switch: 1

Heater power switch (on-off): 1

Master stop switch: 1

Blower motor start switch: 1

Miscellaneous pilot lights to indicate on or off condition: 10

Control voltage meters: 3

Heater current meters: 3

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Mounted within the cabinet are the following components:

AC power controllers (SCR's):	3
480V, 3 phase combination starter and circuit breaker (for blower motor power) from RSCL panel:	1
30 amp. nonfusible disconnect switch for incoming 208/120 V power from FERD panel:	1

Tables 6 and 7 provide additional data on the proportional temperature controller and the AC power controllers.

Table 6. 3-Mode Proportional Temperature Controller

Manufacturer:	Research Inc., Model 640-B-MA-AM
Temperature Range:	0-1000°F
Set Point Accuracy:	±0.5% of input span (±5°F)
Input Impedance:	4K Ohms minimum
Input Thermocouple:	Chromel - alumel
Output:	0 to 5 V
Deviation Indicator:	±100°F, approximately
Indication Accuracy:	±0.5% of span at null; ±1.0% of span away from null
Repeatability:	0.1% of span
Step Response Time:	100 msec maximum to 90% of steady state value

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Table 6 (Contd.)

Common Mode Rejection:	120 dB minimum at 60 Hz
Normal Mode Rejection:	40 dB minimum at 60 Hz
Proportional Band:	Continuously variable
Maximum lower limit:	1% of span
Minimum upper limit:	50% of span
Automatic Reset Rate:	Continuously variable
Maximum lower limit:	0.1 repeats per minute
Minimum upper limit:	1.0 repeats per minute
Rate:	Continuously variable
Maximum lower limit:	0.1 minutes
Minimum upper limit:	5.0 minutes
Operating Voltage:	120 Vac, 60 Hz, 1 $\emptyset$
Operating Voltage Range:	-15% to +10%
Dead Band:	0.01%
Alarm Trip:	Adjustable, control setpoint $\pm 10\%$ of span
Alarm Contact Rating:	2 A at 120 Vac resistive
Operating Modes:	Automatic, manual, remotely programmable
Point Drift:	± 30 V/week maximum (referred to the input)
Temperature Effect:	3μ V/ $^{\circ}$ F maximum (referred to the input) for temperatures of 80° - 40° F
Line Voltage Effect:	1% maximum change in control point for voltage of 120V ac $\pm 10\%$

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Table 6 (Contd.)

Power Consumption:	20 W maximum
Thermocouple Break: Protection:	Output to be zero with open circuited thermocouple

Table 7. AC Power Controller (SCR)

Manufacturer:	Research Inc., Model 632-252C
Control Input:	0-5V dc
Supply Voltage:	120V ac, 60 Hz, 1 ϕ
Input Impedance:	5K Ohms minimum
Output Voltage:	Controllable from 0 to within 1.5 V ac of the full ac line voltage
Output Current:	25 A maximum
Protective Devices	I ² t fusing. Transient voltage and current protection
Operating Ambient Temperature:	122°F maximum
Control Modes:	Local Manual, Remote
Enclosure:	Nema 1

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2.6

INSTRUMENTATION AND CONTROL

(Refer to paragraphs 1.2.6, 2.2 and 2.5 for description of system instrumentation, controls, and interlocks. Refer to Section 4 for system operation and set points.)

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SECTION 3

SYSTEM LIMITATIONS, SET POINTS AND PRECAUTIONS

3.1

SET-POINTS

Zone Heater 3-Mode Temperature Controllers:

Set-point dial pointer on each of the three zone controllers is manually set to the desired temperature range required for each zone (from 0 to 1000°F). Internal adjustment for mode, automatic reset range, automatic rate range, proportional bandwidth, adjustments and alarm set point are given in para 4.2.7.

Heater Temperature-Indicating, limit and alarm, Controllers:

Screwdriver set-point adjustment on front of each indicator permits individual setting for each of the three zones. (The set-point for alarm to be specified by the responsible engineer).*

Differential air temperature-indicating, limit and alarm, controller:

Screwdriver set-point on front of unit set to alarm at 67°F air differential temperature (unless otherwise specified by responsible engineer).*

*Depress set point knob to reset the limiting function after an alarm.

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Cooling Air Pressure Switch: Low-limit set point adjustment screw is set at 1/2 psig.

3.2 INTERNAL ADJUSTMENTS TO HEATER TEMPERATURE CONTROLLERS

The following procedures are to be followed if it is necessary to adjust each of the three proportional heater controllers to settings other than those recommended in paragraph 4.2.7.

3.2.1 ADJUSTING THE PROPORTIONAL BAND CONTROL

The PROPORTIONAL BAND setting establishes the amount of proportional output signal for a given difference between the Setpoint command and the feedback signal. Clockwise rotation (increasing gain) of this control increases instrument output for a given difference in the signals, thus narrowing the band of proportional control, which provides tighter control of controller output.

The PROPORTIONAL BAND control should be increased to a point where system oscillations occur in response to small shifts in command level; the control must then be rotated counter-clockwise until oscillations stop. The RESET switch must be in the OFF position when adjusting the PROPORTIONAL BAND control.

3.2.2 SETTING THE RESET SWITCH

A control system employing proportional control only, will always show some discrete error between command level and actual process level. This effect is termed 'proportional droop and is due to the difference signal required to maintain a control signal to the process. Errors of this type are eliminated with reset action.

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Reset action is introduced by moving the RESET switch clockwise from the OFF position, after a control point has been established. The command level should now be shifted and any overshoot noted. The RESET switch should be moved in clockwise steps until a small amount of overshoot occurs with repeated changes in command level. The RESET switch must be moved counterclockwise if excessive overshoot or instability occur with changes in command level.

3.2.3 ADJUSTING THE RATE CONTROL

Rate action aids system stability by sensing the rate-of-change of the difference between the command and feedback levels. This action minimizes overshoot and "hunting" type oscillations. Rate action is measured in seconds of anticipation or seconds of system lag time and is set to correspond to the response time of the overall control system.

Rate should only be added after initial Proportional Band and Reset adjustments have been made.

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SECTION 4

OPERATION

4.1 PREOPERATIONAL CHECKOUT PROCEDURES

4.1.1 GENERAL

Since the heater facility is independent of reactor operations, the preoperational checkout may be conducted at any time. Part numbers noted in the following checkout procedures are shown in drawing numbers E0397-0031-DE, E0397-0030-DE and E0397-0028-DD.

Cables 1c thru 8c shall be connected to the control console and the following measurements made. The circuit breaker in the RSCL and FERD panels should be open when making the measurements described in paragraphs 4.1.2 thru 4.1.6.

4.1.2 HEATER RESISTANCE

With the console deenergized, i.e., with 2CB and the 30A NFSS disconnect open, measure the resistance of each wired heater circuit at terminal boards 1, 2 and 3TB using a volt-ohmmeter calibrated in accordance with Procedure MCP No. 19, Maintenance and Calibration of Instrumentation Equipment for Quality Assurance, Revision 1, November 18, 1971. The measured resistance of each heater shall be between 18 and 24 ohms.

4.1.3 HEATER INSULATION RESISTANCE

The resistance from each wired heater circuit to facility ground shall be measured using an ohmmeter at a test potential of approximately 250V dc. The measured resistance of each circuit shall be at least 25,000 ohms.

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4.1.4 BLOWER MOTOR INSULATION RESISTANCE

The insulation resistance from each phase of the blower motor windings to facility ground shall be measured as described in paragraph 4.1.3.

4.1.5 THERMOCOUPLE RESISTANCE

The resistance of the thermocouple circuits shall be measured at terminal boards 4, 5, 6 and 7TB using a volt-ohmmeter. The measured resistance of each circuit shall be between 55 and 72 ohms.

4.1.6 GROUND CIRCUIT CONTINUITY

The continuity of the ground circuit, between the console and the facility ground, shall be measured using a volt-ohmmeter. The measured resistance shall be less than 0.5 ohms.

4.1.7 480 Vac CIRCUITS

The circuit breakers in the RSCL panel and in the 480V, 3 phase combination starter, part No. 3, shall be closed. The quiescent status lights will go on if the console is energized. If lights do not go on check the main circuit breaker.

NOTE: Do not attempt to start the blower until proper motor rotation is determined. To determine rotation, remove the "V" belts and then start the motor by pushing the "Blower-Motor Start" button (2PB). If the phase sequence is incorrect and reverse rotation of the motor occurs, stop the motor by pushing the "Master Stop" button (1PB) and interchange any two line connections to the motor. Reconnect the "V" belts.

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4.1.8 TEMPERATURE CONTROLLERS

When the 480 Vac circuits are energized in step 4.1.5, the power "on" lights in 1, 2 and 3TCA, 1, 2 and 3TIA, and dTIA should go on.

4.1.9 120 Vac CIRCUITS

The circuit breaker in the FERD panel and the disconnect switch (part No. 21) shall be closed and the voltages to the master contactor (4CON) measured between wires 36 and 39, 37 and 39, and 38 and 39.

NOTE: The console is now energized and the precautions specified in paragraph 6.1 shall be followed.

Voltages measured shall be nominally 120 Vac. If no voltage is measured, check the main circuit breaker.

At the termination of the above checkout procedure, the 480V circuit breaker, part No. 3, and the 120V disconnect switch, part No. 21, shall be returned to the power "OFF" position.

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4.2 OPERATING PROCEDURES

4.2.1 GENERAL

Upon completion of the preoperational checkout procedures, covered in paragraph 4.1 the following operating procedures shall be followed. Since the heater facility is independent of the reactor operation, the reactor may be operating or shut down.

Part numbers cited in the following paragraphs are shown in drawing no. E0397-0031-DE.

4.2.2 ENERGIZING 120 Vac and 480 Vac CIRCUITS

Throw the disconnect switches, part Nos. 3 and 21, to the "On" position. The green "Off" blower motor status light and heater zone status lights should go on. The red cooling air "off" status light should also go on.

4.2.3 TEMPERATURE CONTROLLER SET-POINT ADJUSTMENT

Using the set-point dial on the front of the zone heater three-mode temperature controllers (part No. 30), adjust the set point to the desired temperature for each of the three zones. If a particular zone is to remain de-energized no initial adjustment is necessary.

4.2.4 TEMPERATURE ALARM SET-POINT ADJUSTMENT

4.2.4.1 0-1000°F Zone Temperature Indicator and Alarm

Using the screw driver set-point adjustment on the front of the zone heater temperature indicator and alarm (part No. 27) set the pointer to the alarm set-point specified by the responsible engineer, or his representative.

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4.2.4.2 0-300°F Cooling Air Differential Temperature Indicator and Alarm

Using the screwdriver set-point adjustment on the front of the cooling air differential temperature indicator and alarm (Part No. 28) set the pointer to the alarm setpoint of 67°F, unless otherwise specified by the responsible engineer or his representative.

4.2.5 COOLING AIR, LOW PRESSURE SWITCH SET-POINT ADJUSTMENT

Push the "Blower-motor Start" button. The blower motor status light should change from green "Off" to amber "Run".

Set the set-point adjustment screw of the differential pressure switch, accessible through the 1/4 in. hole directly above the "Blower-motor start" pushbutton, to the minimum differential pressure (maximum counterclockwise) position. The cooling air status light should change from red "off" to white "Flowing".

4.2.6 INTERNAL ADJUSTMENTS

Unlock the temperature controllers (part No. 30), associated with the energized zones, from their manifolds by turning the "lock" screw on the front of the controller. Draw the controllers forward until the mode switch, automatic reset range, automatic rate range and proportional bandwidth adjustments, and alarm set-point (mounted on the circuit board) are accessible.

4.2.6.1 Mode Selection

Switch the mode switch to the "Auto" position. The controller will normally operate in the automatic mode. The manual mode of operation, that is available by placing the mode switch in "Man" position, will not be used in normal operation.

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4.2.6.2 Reset, Derivative, and Proportional Bandwidth Adjustment

The adjustment of the reset time (R) the derivative time (D) and the proportional bandwidth (P) will be predetermined by an individual designated by the responsible engineer. The procedure used in determining these values will be as described in paragraph 3.2. The responsible engineer or his representative shall be contacted by the operator to determine what values of D, R, and P are to be used. The recommended settings (as determined with a 2.4 lbs/ft thermal load) are as shown below:

4.2.6.3 Temperature Alarm Adjustment

The upper temperature alarm set point adjustment of Part Nos. 27 and 28 shall be set as specified by the responsible engineer or his representative. If the alarm lights are on the set point knob shall be depressed and the lights will go off.

After the adjustments have been made, push the controllers back into their manifolds and lock in place. The temperature controller is now ready to control the subassembly temperature automatically.

4.2.7 ZONE HEATER STATUS

Push the heater power "On" pushbutton. This will close the master heater contractor (part No. 1). The status lights remain unchanged.

Zone heaters may be energized, as required, by pushing their "On" pushbuttons. The zone status lights associated with the energized zones will change from green "Off" to red "On".

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The "power on" status light contained in the three-mode controllers will go on. If the set point is above ambient temperature the control voltage meters (part No. 72) and the heater current meters (part No. 73) should indicate.

4.2.8 HEATER POWER OFF AND MASTER STOP

The heater power to all three heater zones may be turned off simultaneously by pushing the heater power "Off" button. All three green "Off" zone status lights will light. Any one of the three zones can be turned off independently by pushing its zone "Off" button. In that case only the green "Off" zone status light associated with the deenergized zone will light. In either case the blower motor will continue to run after the heater power is removed.

If an emergency stop is desired, the "Master-Stop" button should be pushed, this will deenergize both the heaters and the blower motor simultaneously. All status lights will revert to their "Off", or deenergized conditions.

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SECTION 5

CASUALTY EVENTS AND RECOVERY PROCEDURES

Not applicable

SECTION 6

MAINTENANCE

6.1 MAINTENANCE APPROACH

Maintenance to the heater facility can be accomplished at any time since it is independent of reactor operation. Repair or replacement of components within the lower subassembly can be accomplished after removal of the lower subassembly from the storage pit using the small overhead reactor building crane. Immediate access is possible to components installed in the console or in the blower assembly since this equipment is positioned in the reactor building.

The voltages within the control console are considered to be dangerous. Procedure SA3-69, EBR-II Electronic System, General Safety Requirements for Maintenance or Installation dated July 23, 1969, shall apply whenever it is necessary to open the rear door of the control console.

6.2 CORRECTIVE MAINTENANCE

(To be provided at completion of the modification)

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6.3 PREVENTIVE MAINTENANCE

(To be provided at completion of the modification)

6.4 IN-SERVICE MAINTENANCE

(To be provided at completion of the modification)

6.5 SURVEILLANCE

Not applicable.

FIG. 1. HEATER FACILITY LOCATION

FIG. 2. HEATER FACILITY FLOW AND BLOCK DIAGRAM

FIG. 3. HEATER FACILITY LOWER SUBASSEMBLY

FIG. 4. BLOWER ASSEMBLY

REFERENCES

1. E. Hutter and O. S. Seim, Preliminary Design Description of the EBR-II In-core Instrument Test Facility, ANL/EBR-023 (June 1970).
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3. Reactor Development Program Progress Report: April-May 1969, ANL-7577, p. 82.
4. Reactor Development Program Progress Report: August 1969, ANL-7606, p. 42.