

MFC-768 Resource Record

Location

MFC-768 is the Power Plant located at the Materials and Fuels Complex (MFC). The building is four stories and was constructed in 1961 as the Power Plant for the Experimental Breeder Reactor II (EBR-II) Reactor Plant Building. The facility supports the turbine generator, EBR-II control room for the reactor and power system, the water treatment area, and personnel facilities. These mechanisms were intentionally placed away from the reactor to prevent any contact with radioactivity (Argonne National Laboratory [ANL] 1964; Koch et al. 1964).



Figure 1. Photo of MFC-768 (Wallace and Maxwell 2022).

EBR-II Heat Transfer System Overview

The Power Plant's turbine generator was one part of the EBR-II power cycle's heat transfer system. The heat transfer system consisted of three systems: the primary system, the secondary system, and the steam system. These systems worked together to remove heat from the reactor and its components and reutilize that heat to produce electricity (Figure 2) (Koch et. al. 1958:3-4).

The primary system was a tank in EBR-II that contained the reactor vessel and shield submerged in sodium. The sodium in this tank was used to remove heat from the reactor core. This heat was transferred to the secondary system which circulated in a closed loop separate from the EBR-II containment dome. The secondary system included a heat exchanger connected to the primary tank; a sodium to water-steam heat exchanger, also called the steam generator; an alternating current electromagnetic linear induction pump and surge tank located in a nearby Boiler House; and piping. Heat was transferred from the primary system to the secondary system through a shell-and-tube heat exchanger. This type of heat exchanger accomplishes cooling indirectly by "circulating a hot liquid around tubes which contain a cooler liquid" (Parisher and Rhea 2022:127). Figure 3 shows an example of a shell-and-tube heat exchanger. The tubes allow sodium from the

secondary system to indirectly pick up heat from the primary system sodium which resides in the shell (Koch et. al. 1958:3). This separation was important to eliminate contamination of systems external of the reactor. The heat was then transferred to the Boiler House where it passed through the superheater portion of the steam generator. Here, water supplied to the steam generator from the feedwater tanks at MFC-768 was transformed into superheated steam at 820 degrees F and 1250 pounds per square inch gauge, at a rate of up to 248,000 pounds per hour when the reactor operated at 62.5 megawatts thermal. This steam flowed to MFC-768 and powered the turbine generator, the final system in EBR-II's heat transfer system. The turbine generator was capable of producing a maximum of 20 megawatts electric (Klein and Hurst 1975:10). See figure 4 for a flowchart of operations.

The power supplied by EBR-II provided all of the power for Argonne National Laboratory-West, now referred to as MFC. Additional power was sold to the National Reactor Testing Station and to Idaho Power, ultimately saving the Atomic Energy Commission more than \$1 million each year and becoming the first co-generator in Idaho. From 1964 to 1994, the reactor generated over 2 billion kilowatt hours of electricity (Argonne National Laboratory 1964, 2020; Arrowrock Group, Inc. 1998; Department of Energy 1989; Koch et al. 1964; Pinkham 2020).

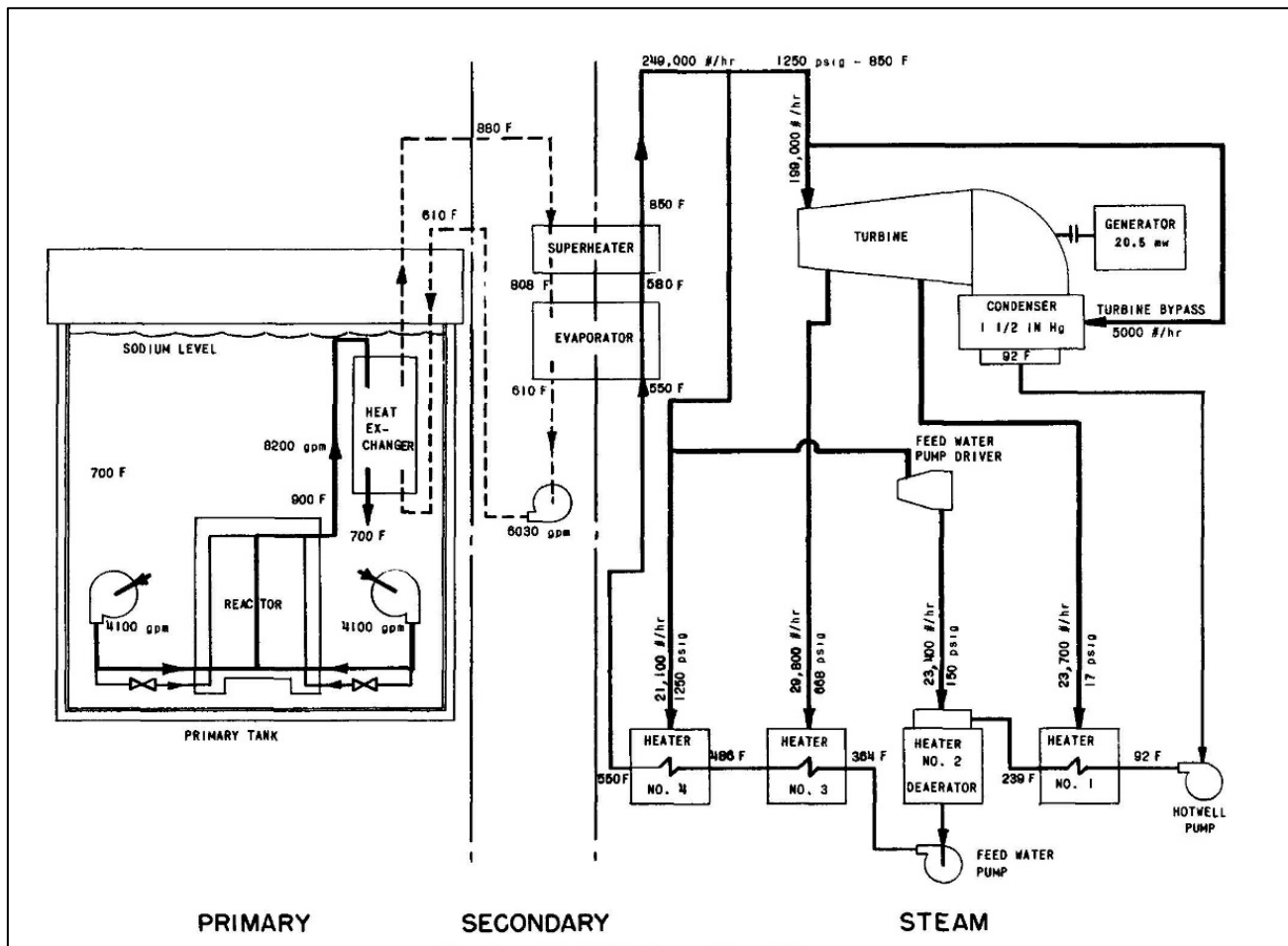


Figure 2. Diagram of heat transfer system (Koch et. al. 1958:4).

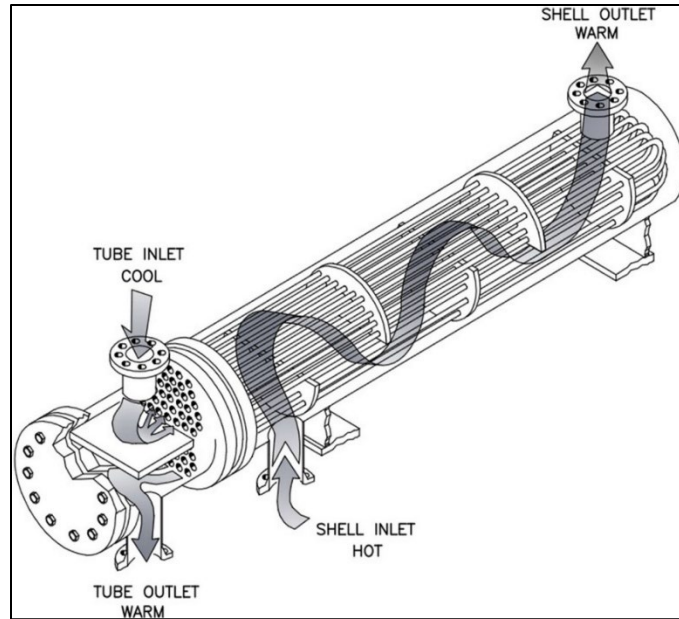


Figure 3. An example of a shell-and-tube heat exchanger (Parisher and Rhea 2022:128).

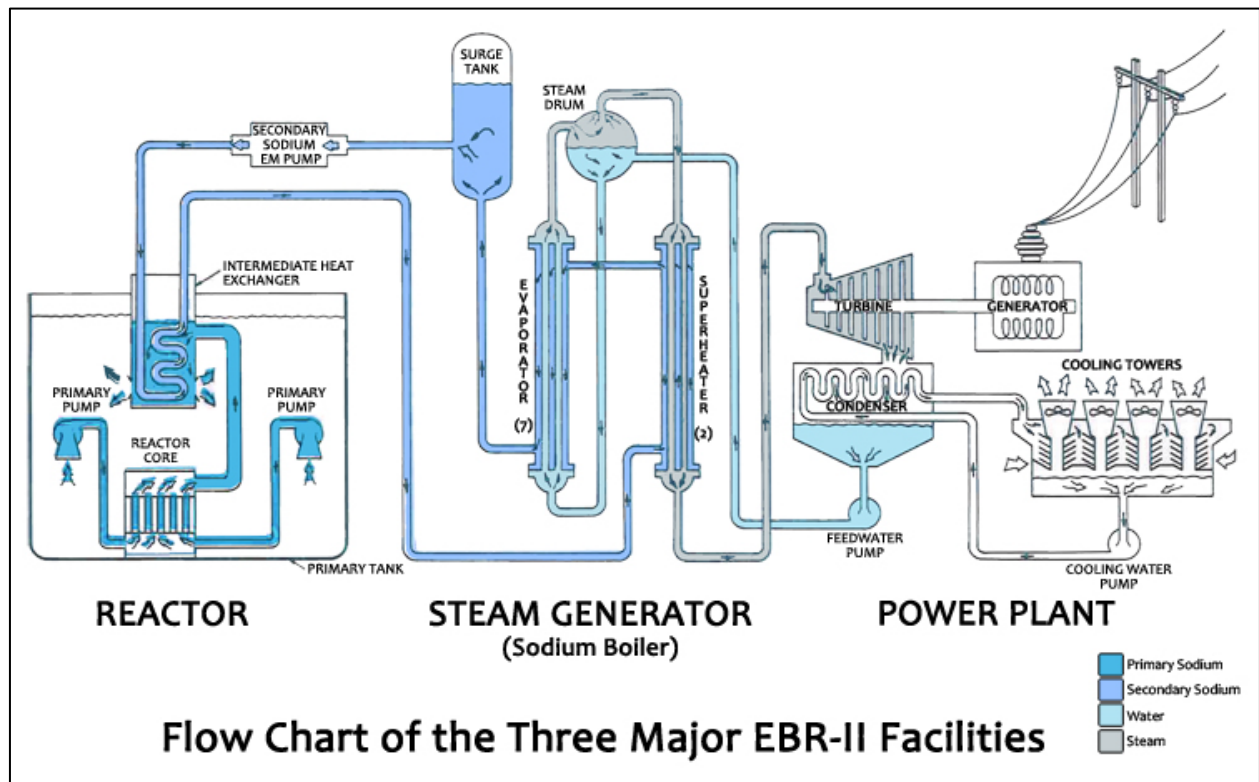


Figure 4. Flow chart of sodium, water, and steam in EBR-II's heat transfer system (Argonne National Lab 2020).

MFC-768 Steam System Operation

MFC-768 houses components to support the steam system (Figures 5 and 6). These components include a condensate system, blowdown system, makeup water system, feedwater system, and cooling water system that are located throughout the first and second floors (Klein and Hurst 1975) (INL 2023). Once steam was generated in the Boiler House, the steam flowed to MFC-768 where it powered the turbine generator and provided heat to the feedwater heaters. The turbine generator and its control panel are located on the third floor. The turbine generator is a standard commercial, horizontal General Electric system. There was an option to bypass the generator and direct the steam through a desuperheater and then to the main condenser. Steam system support components are described below in more detail.



Figure 5. Interior of MFC-768 showing piping for steam system (INL CRMO 2024).

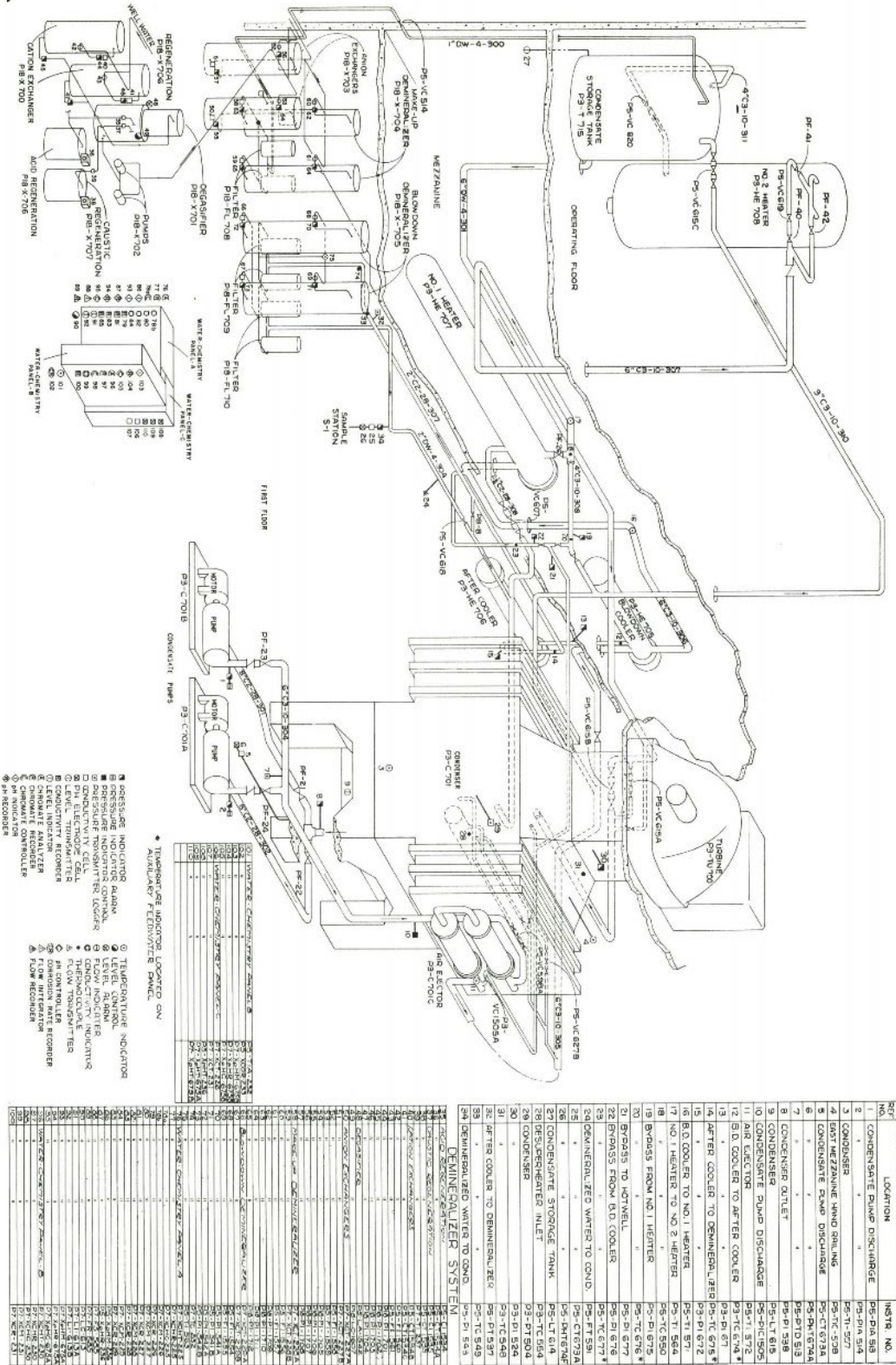


Figure 8.1-13 Makeup Water and Condensate Systems Sensor Locations

Figure 6. Steam system layout on MFC-768 on floors 1, 2, and 3 (Argonne National Laboratory 1972:8.1-18).

The condensate system includes a main surface condenser, an air ejector that removes air and other noncondensable gases from the condenser, a desuperheater that tempers bypass steam, condensate pumps, and a condensate storage tank. The main surface condenser is a tube-and-shell exchanger that connects to the exhaust outlet of the turbine generator. Cooling water flows in the tube side and condenses steam from the turbine exhaust and the bypass steam in the shell. The condensate collects in the condenser hotwell, and the water is recirculated through the feedwater system. The condensate storage tank receives demineralized water from the makeup water system and excess water from one of the feedwater heaters. When the water level in the condenser hotwell is low, the condensate storage tank provides water to the hotwell (Klein and Hurst 1975; ANL 1972). See Figure 7 for an overview of the main condenser.

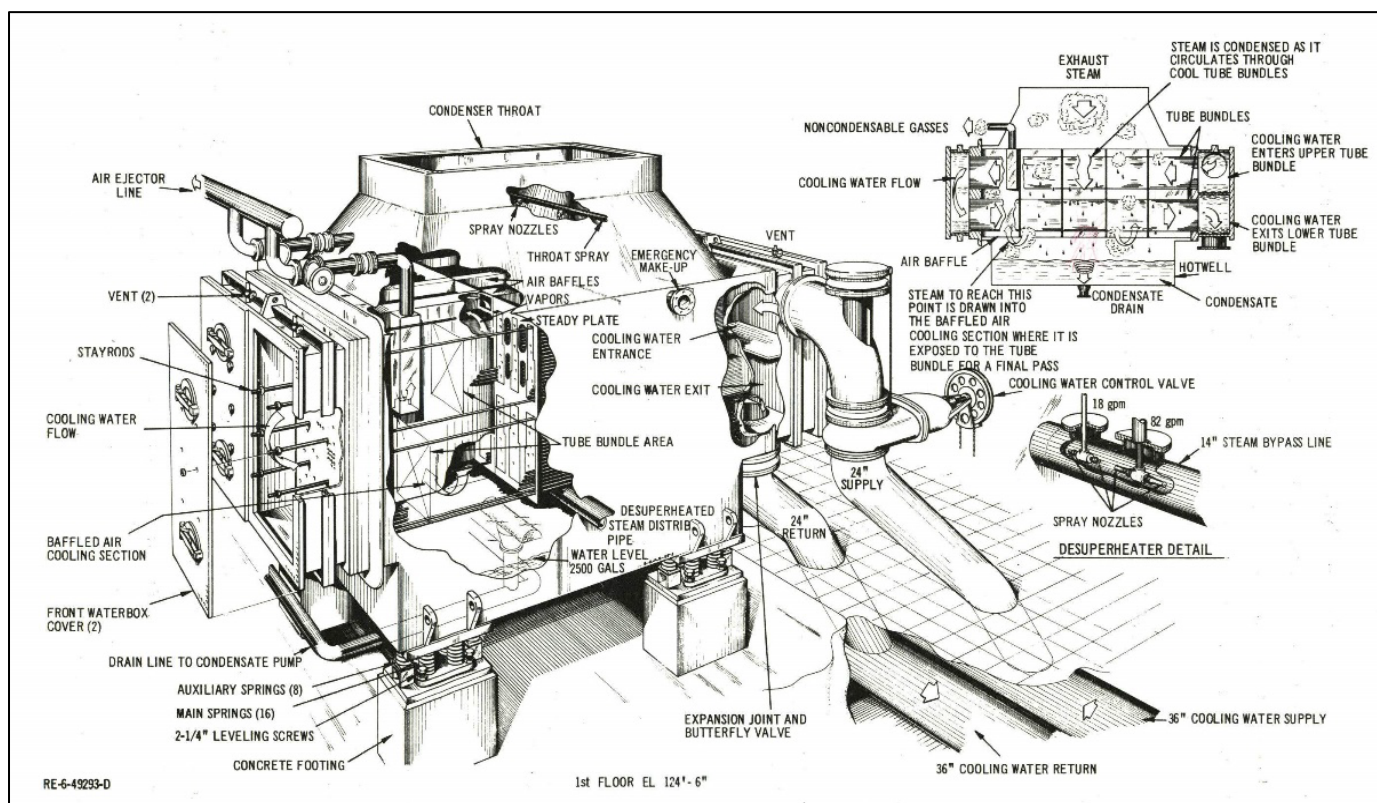


Figure 7. Main condenser on the first floor (Argonne National Laboratory 1972:3.2-3).

The blowdown system includes a demineralizer that continuously removes solids that build up in the steam drum to maintain high quality water in the steam system (Klein and Hurst 1975).

The makeup water system houses high purity and low purity demineralized water to replenish any water loss in the steam system. High purity water is provided to the condensate storage tank, and low purity water is provided to the auxiliary boiler and other EBR-II systems. Primary and secondary demineralizers treat the raw water that enters the system. The primary demineralizer removes most of the minerals from the raw water. The secondary demineralizer removes small amounts of ionic impurities that were unable to be filtered through the primary demineralizer, a process called “polish.” This process results in very high purity water (Klein and Hurst 1975; ANL 1972).

The feedwater system includes four feedwater heaters and three feedwater pumps. Feed water heaters incrementally heat condensate to be supplied to the steam generator. The feedwater pumps circulate water (Klein and Hurst 1975). Water in the system is already demineralized from passing through the blowdown and makeup water systems. However, it is necessary to manage the oxygen content and pH level of the water to minimize corrosion. The system utilized a “zero-solids” treatment. This treatment is named as such because chemical agents and reaction products used either are volatile or form water and do not contribute solids to the boiler water. In the case of MFC-768, hydrazine was used to remove dissolved oxygen; however, this formed ammonia which increased the pH level of the water. To address the pH level, morpholine was injected into the system (Klein and Hurst 1975:25-27; ANL 1972).

The cooling water system provides raw well water to the main condenser and other EBR-II systems for heat transfer (Klein and Hurst 1975). Cooling water is used to help keep systems cool and, as a result, condense steam, a process where steam is cooled and turned back to water.

While “the type of water treatment employed at EBR-II [was] not unusual nor [was] its use by the industry,” the system was important in that it was strategically situated within a separate building from the reactor, was used with a liquid-metal-cooled fast reactor, and ensured safe and reliable reactor operations (Klein and Hurst 1975:9-10).

The water treatment system was strategically designed to be separated from the reactor to “permit a maximum of experimental operational flexibility” (Koch et al. 1958:2). The design of the water treatment area helped to safely maintain water operations without possibility of contamination. Its separate location helped reactor operators easily monitor and tailor water needs to EBR-II projects.

Additionally, the choice to use water alongside liquid sodium made the system unique. Liquid sodium “reacts violently with water” (Westfall 2004:31). However, the benefits of water outweighed the risk. Water has “minimal interaction with neutrons,...high thermal conductivity, is noncorrosive with steel..., and has a high boiling point” (Westfall 2004:31).

Water was chosen as the vehicle to transfer heat and power the turbine generator, but this process required high purity water to prevent degradation of the materials with which it came into contact. Again, water and liquid sodium do not interact well, so it was crucial to maintain high purity water to prevent any leaks that could bring the two materials into contact. In addition, high purity water reduces accumulation of particulates that may decrease the ability of water to transfer heat. Therefore, the treatment system was an important part of EBR-II’s safety and heat transfer systems.

Two factors that characterize the quality of water and dictate the interaction between water and metals are water pH and conductivity (International Atomic Energy Agency [IAEA] 2011:4). In MFC-768, the pH level was managed by chemical injection, and conductivity was managed by demineralizers. Conductivity is a “measure of the ability of a medium to carry an electric current” (IAEA 2011:5). As conductivity increases, the potential for corrosion does so as well. In water, conductivity is achieved by the presence of cations and anions - dissolved ionic compounds. The principal cations found in water entering the EBR-II steam system were calcium, magnesium, sodium, and potassium. The principal anions were chloride, sulfate, nitrate, and carbonate. In

addition, silica was also present (Klein and Hurst 1975:19). All of these compounds needed to be filtered to maintain high purity water in the system, which is why half of MFC-768 was dedicated to water treatment.

As a result of meticulous design, the water treatment system maintained high purity water and kept steam components in safe and reliable operating conditions. Water was never leaked into the system's liquid sodium (NUMARK Associates, Inc. 2019).

EBR-II Control Room

The Control Room is on the third floor and was designed to operate the EBR-II reactor and its power systems (Verber and Schmidt 1966:12, 17). See Figures 8 through 11 for an overview of the third floor. The control room houses various components that monitor EBR-II operations such as a control panel, typewriter tables, a radiation monitoring section, an auxiliary section, a secondary section, primary section, nuclear section, graphic section, steam section, utilities section, data loggers, gauges, and a simplified flow diagram of the entire EBR-II plant (Koch et al. 1958:21; ANL 1972). Majority of operations in the control room were manual, except for a few important functions that are automatic. These important functions were considered, “those which might adversely affect facility safety if handled manually [such as] ...control of feedwater flow rate and steam pressure” (Koch et al. 1958:21). The control room originally had four windows that provided a view towards the turbine generator (Figure 10). However, the area immediately adjacent to the control room was infilled with concrete masonry units and converted to an office circa 1979 (ANL 1979). These offices still exist today.



Figure 8. Overview of control room (INL CRMO 2024).

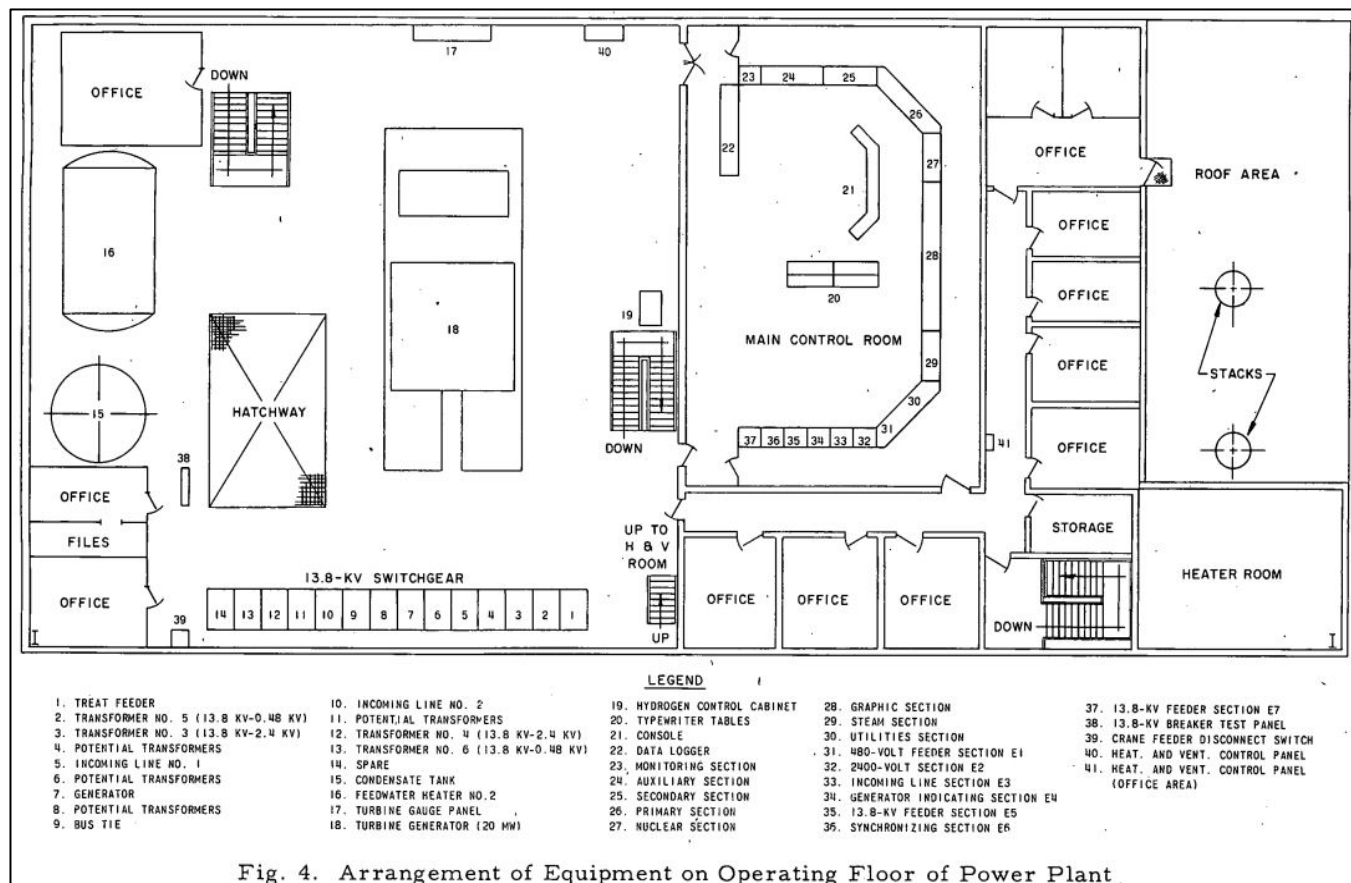


Fig. 4. Arrangement of Equipment on Operating Floor of Power Plant.

Figure 9. Arrangement of equipment on the third floor (Verber and Schmidt 1966:125).

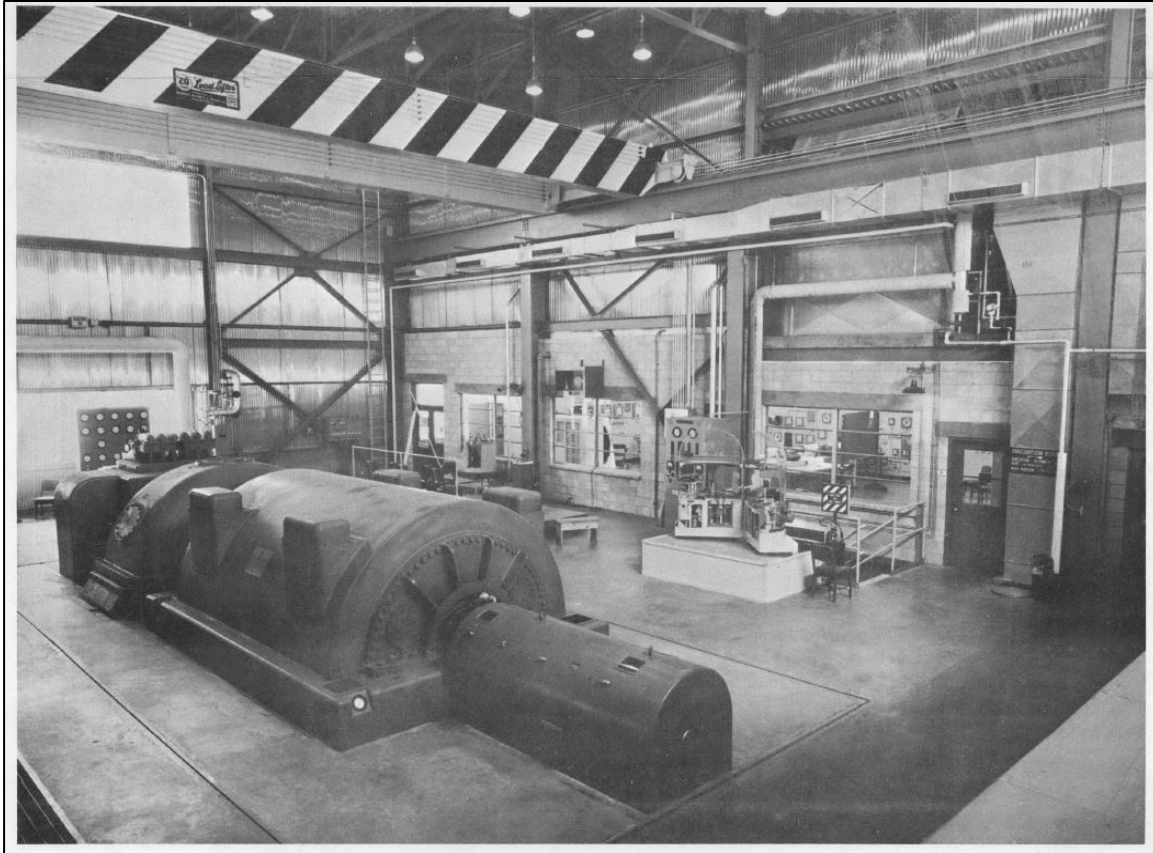


Figure 10. Photo of turbine generator and control room (Verber and Schmidt 1966:150).



Figure 11. Present overview of third floor (INL CRMO 2024).

Determination of Eligibility

MFC-768 is categorized as a Reactor Support Facility. Its period of significance is from its date of construction in 1961 until 1994 when EBR-II was shut down.

MFC-768 was constructed as the power plant of the EBR-II Reactor Plant Building and supports the turbine generator and EBR-II control room for the reactor and power system. The generator was one of the EBR-II power cycle's three transfer systems. After the first and secondary systems, heat was converted to steam and flowed to the turbine generator, which turned mechanical energy into electrical energy. The power supplied by the EBR-II provided all of the power for ANL-W with additional power sold to NRTS and to Idaho Power, making it the first co-generator in Idaho. As a result, MFC-768 meets the 50-year threshold for potentially historic properties. It retains a high level of integrity and is significant for its association with the EBR-II and its generation of electricity. Therefore, MFC-768 is recommended eligible for listing under Criterion A of the NRHP.

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