BROWNS FERRY FIRE

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INTRODUCTION

The Browns Ferry Nuclear Power Plant is a three-unit Boiling Water Reactor, BWR power generating station located near Athens, Alabama on the banks of the Tennessee River. It was commissioned in the summer of 1966 and fully constructed by 1974. The plant became the Tennessee Valley Authority's; a USA government entity, first nuclear generation station. All three units were online by 1977.

Figure 1. Browns Ferry, Tennessee Valley Authority BWR 3-unit plant. Source: TVA.

TENNESSEE VALEY AUTHORITY, TVA PLANTS

TVA's nuclear power plants contribute about 6,600 MWe of electricity to the power grid, making the Nuclear Power Group an integral part of a seven-state power system.

TVA began building nuclear power plants in the 1960s, responding to the growing prosperity of the Tennessee Valley and the rising demand for power in the Department of Energy, DOE nuclear development complex around the Oak Ridge National Laboratory, ORNL.

Its three nuclear plants: Browns Ferry, Sequoyah, and Watts Bar, provide about 30 percent of TVA's power supply.

The six operating reactors provide more than 6,900 megawatts of electricity serving more than three and a half million homes in the Tennessee Valley.

About 30 percent of TVA's power supply comes from its three nuclear plants: Browns Ferry, near Athens, Alabama; Sequoyah, in Soddy-Daisy, Tennessee, and Watts Bar, near Spring City, Tennessee.

WATTS BAR NUCLEAR PLANT

Watts Bar, a two-unit Pressurized Water Reactor nuclear plant, is located on the Chickamauga Reservoir in Spring City, Tennessee. Unit 1 at Watts Bar began operating in 1996, the last commercial nuclear unit in the USA to come online in the 20th century.

In August 2007, following detailed studies of energy needs, schedule, costs, environmental impacts, and financial risks, the TVA Board decided to complete construction of Watts Bar Unit 2 to help meet the Tennessee Valley's growing demand for power.

Initial construction on Unit 2 stopped in 1985. Completion will put an existing asset to work for TVA customers and is estimated to take five years and cost $2.49 billion. When completed by 2013, Watts Bar Unit 2 will add 1,180 megawatts to the TVA power system.

TVA holds a construction permit for Watts Bar Unit 2 and will apply for an operating license from the NRC under the licensing process used for permitting the existing nuclear plants.

SEQUOYAH NUCLEAR PLANT

Sequoyah is a two-unit Pressurized Water Reactor nuclear plant located on Chickamauga Reservoir near Chattanooga, Tennessee. Unit 1 began commercial operation in 1981 and Unit 2 in 1982.

BELLEFONTE NUCLEAR SITE

Bellefonte is the site of an unfinished nuclear plant near Scottsboro, Alabama. Itwas selected in 2005 by NuStart Energy for the development of the reference combined license application for the Westinghouse Advanced Passive 1,000 MWe (AP1000) nuclear reactor design.

Though no decision to build new units at Bellefonte has been made, TVA, as the utility owner of the site, will be the applicant and will receive the combined license if approved and issued by the NRC.

BROWNS FERRY PLANT

TVA's first nuclear plant, Browns Ferry is located on 840 acres beside Wheeler Reservoir on the Tennessee River, near Athens, Alabama. The plant is named after a ferry that operated at the site until the middle of the 20th century.

Browns Ferry's three Boiling Water Reactors, BWRs were the first in the world capable of powering generators that could produce more than 1,000 MWe of electricity each, making it the largest nuclear power plant in the world at that time. The plant's maximum capacity of 3,440 MWe is about 10 percent of TVA's total generation capacity and enough electricity to meet the needs of about 2 million homes.

TVA plans to increase the generating capacity of each unit to about 1,280 megawatts, following approval from the Nuclear Regulatory Commission (NRC) and installation and implementation of modifications.

TVA employs about 1,000 people to maintain and operate Browns Ferry with an annual payroll of about $107 million.

BROWNS FERRY UNIT ONE

TVA restarted Browns Ferry Units 2 and 3 in the 1990s. As part of a long-range integrated resource planning process, TVA deferred the decision in 1995 to recover Unit 1.

In 2002, TVA completed a number of detailed studies and determined that restarting the long idled reactor was the best business decision to help meet growing demand for electricity in its service area.

In 2002, when the TVA Board decided to authorize the restart project, TVA estimated Unit 1 would have to operate between seven and eight years in order to pay back the cost of recovery.

When the $1.9 billion project to restart Unit 1 completed in 2007 as scheduled, the payback period had dropped to about two and a half years of operation due to the rising costs of power across the nation. After one year of operation, it has saved its customers nearly $800 million in avoided power purchases.

The American Nuclear Society, ANS presented TVA with the 2007 Utility Achievement Award for Outstanding Improvement in Performance "in recognition of the most extensive restart effort in the nuclear industry, culminating in the successful return to service of Unit 1 as the first nuclear generating plant to come online in more than a decade."

Figure 2. Browns Ferry BWR plant's turbine hall. Source: TVA.

FIRE AT BROWNS FERRY UNIT 1

FIRE INITIATION

The Browns Ferry Unit 1 BWR, 1,065 MWe reactor began operating at the very end of 1973 and was licensed to operate for the next 60 years. This operational plan, however, was cut drastically short when a fire in 1975 damaged the unit and caused the reactor to remain out of service for one year.

The accident was the result of a combination of both human error and, from a safety perspective, insufficiently designed Engineering Safety Features.

On March 22, 1975 a fire started in the Brown's Ferry Unit One nuclear reactor. The accident resulted largely in part to human error. It was near the plant's control room that two electricians were trying to find air leaks in a wall. The hole in the wall was necessary to allow cables through from the control room to the reactor vessels and was sealed with foamed plastic.

The electricians were searching for air leaks and plugging the subsequent holes with a foam rubber material. However, the air leaks were not being detected with a scientific device but rather with a simple candle. The electricians used the movement of a candle flame in order to locate the escaping air indicative of a leak.

The accident began when one of the electricians brought the flame too close to the highly combustible material. Although the permanent seal material was coated with a flame retardant paint, the fire quickly spread from the temporary foam rubber to the entire cable seal. As a result, there was significant damage to the control cables which compromised many engineered safety features (ESFs).

FIRE PROGRESS

Before one can investigate the subsequent deficiences that became evident as a result of this fire, it is necessary to examine the flaws that lead to the fire itself. The most obvious culprit was human error. The electricians were using an open flame to search for air leaks near highly sensitive equipment.

Clearly a fire that caused damaged to the critical control cables would be devastating. Furthermore, from a safety standpoint, there were flaws in using highly combustible material in a nuclear power plant. The material, a polyurethane foam, amplified the effects of the fire. Once the foam started burning, it would splatter causing the fire to grow even larger. Attempts at extinguishing the flames with a carbon dioxide extinguisher proved uselesss. Two attempts were made by the electricians to extinguish the flames. The first fire extinguisher blew the lit material through the other side of the wall into the reactor building where it continued to burn rapidly. The second fire extinguisher discharge was sucked through the wall due to the airflow caused by fire and only caused the flammable material to spread even more.

FIRE EXTINGUISHMENT

The initiation of the fire was not the only event triggered by human error. After efforts made by the electricians to put out the fire with extinguishers had failed, one engineer attemped to activate an emergency system that would purge the room of oxygen by releasing a large amount of carbon dioxide.

There were a chain of events, however, that caused these attempts to fail as well. The first attempt to activate the system was hindered when it was discovered that the electricians had disabled the system that was used to release the carbon dioxide. The manual turn-on could not easily be activated either as a result of a construction plate that was hard to remove.

Once the system was finally activated, the hole in the wall, from the now burning cable seal, allowed the carbon dioxide to enter the control room. This caused a great deal of problems for the operators who began choking and putting on breathing apparatuses.

Despite the suggestion made by the local fire chief to use water to extinguish the fire, the plant operators, under the direction of their superintendent, continued to combat the fire with carbon dioxide. This method, however, was not suitable for extinguishing the flames. The electrical wires, which had been heated by the fire, needed to be cooled with water in order to prevent the foam from re-igniting. After finally heeding the superintendent's advice, water was used and the fire was quickly extinguished.

DAMAGE TO CONTROL SYSTEM

Soon after the fire had started, the reactor operators noticed that the Unit One reactor was beginning to operate erratically. It was evident that there had been at least some damage to the Emergency Core Cooling System (ECCS) once smoke began to come from the panel that controlled this ESF.

The combination of warning sounds and signals as well as smoke and strange reactor behavior finally alerted the operators that there was a serious problem which needed a quick response.

One the Unit One cooling pumps suddenly stopped working, the reactor operator inserted the control rods in order to shut down the reactor. Only a few minutes after the shutdown, all power and control of the ECCS was lost. In addition, many other ESFs became disabled including the low-pressure ECCS, the core isolation cooling, and the core spray system. The fire destroyed much of the control cabling and as a result the operators lost critical instrumentation that describes the state of the reactor. The loss of such important safety features and control devices demonstrated the vulnerability of the plant design to single event failures. In other words, the single fire that began in the control room cabling caused a sequence of events that could lead to catastrophic results.

DECAY HEAT COOLING

Despite the fact that the reactor had been shutdown, the risk of a core meltdown was still present. After the operator had inserted the control rods, it was still necessary to maintain the flow of coolant to the reactor core. The presence of radioactive decay heat meant that the core needed to be covered with water at all times. The damaged caused by the fire had rendered the majority of the cooling systems useless. Only one high-pressure pump was being used to inject water into the core and reactor operators realized that this alone would not be able to maintain the proper water level.

Despite having lost the majority of his instrumentation, the unit one operator still had control of four pressure relief valves. It was decided that these valves would be used to depressurize the reactor in order to allow a low pressure pump to force water into the core. Since most of the pumps had been rendered inoperable, a condensate booster pump was temporarily arranged to deliver the necessary core cooling, and for the time being, a core meltdown was avoided.

Roughly six hours after the initial fire had disabled many of the safety systems, however, all control of the four previously working relief valves was lost. As the pressure inside the reactor began to rise, the low pressure condensate booster pump would not be able to to deliver the cooling water needed to keep the core covered. This left the single high pressure pump as the only source capable of injecting cooling water and this single pump would be insufficient at keeping the core covered. A little more than three hours later, control of the relief valves was regained and the pressure was lowered enough to allow the condensate booster pump to continue working. By early morning the next day, the danger of a boiloff and subsequent meltdown was gone and the reactor was sufficiently "shutdown."

SAFETY ISSUES

The accident at Brown's Ferry highlighted a number of significant risks, flaws, and safety issues that one must be aware of when dealing with engineering systems. The most obvious risk illustrated by this incident was the risk of human error. Clearly, using a candle to check for air leaks near combustible materials was a less than wise choice. One electrician who started the fire even admitted that he thought "everyone" knew that the material for sealing air leaks would burn and that he, despite being weary of it, continued to use the candle method which had been the norm for a number of years.

Adding to the list of human errors, the plant operators battled the fire with carbon dioxide for hours before finally taking the advice of the fire chief to extinquish the flames with water.

Nevertheless, quick thinking by the reactor operators triumphed over many of the engineered safety features which had been compromised by the fire. The damaged cables presented a single point of failure for a majority of the control and safety system in place at the power plant.

Despite redundancies in many of the ESFs, the single cable tray entering the control room was highly critical to the safe operation of the plant. The use of flammable material near such a sensitive piece of plant infrastructure represented a flaw in the engineering behind the plant design. As is the case in many industrial accidents, a combination of human error, design flaws, and equipment failures led to the severity of the Browns Ferry Unit 1 fire.

OPERATIONAL HISTORY

Major construction on Browns Ferry began in1967.
Unit 1 began commercial operation on August 1, 1974.
Unit 2 began commercial operation on March 1, 1975.
On March 22, 1975 a fire started in the Brown's Ferry Unit One nuclear reactor and stopped its operation for one year.
Unit 3 began commercial operation on March 1, 1977.
TVA shut down Browns Ferry and the rest of its nuclear fleet in 1985.
TVA restarted units 2 and 3 in 1991 and 1995 respectively.
TVA Board approved the restart of Unit 1 in May 2002.
After an extensive recovery effort, Unit 1 became the nation's first nuclear unit to come online in the 21st century when it was restarted on time in May 2007.

PRESENT AND FUTURE OPERATION

Browns Ferry Unit 1 and the rest of the TVA nuclear fleet were shut down in 1985. Units 2 and 3 were restarted in the 1990s. Unit 1 was restarted in May 2002 after a detailed schedule and cost study. After an extensive recovery effort, Unit 1 became the nation's first nuclear unit to come online in the 21st century when it was restarted in May 2007.

Unit 1 was returned to service within a projected five-year schedule and at a cost of about $1.9 billion. TVA spent more than four million work-hours preparing the engineering and design specifications and more than 15 million work-hours modifying, replacing, and refurbishing systems and components to ensure Browns Ferry Unit 1 was ready for restart.

Unit 1 provides 1,155 megawatts of power. TVA plans to eventually increase capacity of all three boiling water reactor units to 1,280 megawatts following approval from the Nuclear Regulatory Commission (NRC) and installation and implementation of modifications.

Operating licenses for Browns Ferry Units 1, 2, and 3 were renewed in May 2006, which will allow continued operation of the units until 2033, 2034, and 2036.

REFERENCES

1. David C. Comey, “The Fire at the Bown's Ferry Nuclear Power Station,” The Canadian Coalition for Nuclear Responsibility, March 27, 1996. http://www.ccnr.org/browns_ferry.html

2. Nuclear Regulatory Commission, NRC, “Fire Barrier Penetration Seals in Nuclear Power Plants,” NUREG-1552, Supplement 1, http://www.nrc.gov.edgesuite.net/reading-rm/doc-collections/nuregs/staff/sr1552/s1/

3. “Safety Deficiencies at the Brown's Ferry Nuclear Power Complex,” Nuclear Information and Resource Center, December 2010. http://www.nirs.org/factsheets/brownsferryfactsheet.pdf

4. Tennessee Valley Authority, TVA, “Browns Ferry Nuclear Plant, December 2010. http://www.tva.gov/sites/brownsferry.htm