1092 Willowcreek Dr.
Austin, Texas 78741
April 27, 19XX

Mr. David A. David McMurrey
Energy Research Consultants, Inc.
1307 Marshall Lane, Suite 3200
Austin, Texas 78712

Dear Mr. McMurrey:

In keeping with our January 22 agreement, I am submitting the accompanying technical background report entitled *Light Water Nuclear Reactors*.

The purpose of this report is to provide introductory information to city council members who are considering membership in a regional consortium. This report provides an explanation of how each type of light water reactor operates. In addition, the report discusses some of the basic safety mechanisms used in this type of reactor. The report concludes with a review of the economic aspects of nuclear power plants.

I hope this report will prove to be satisfactory.

Respectfully yours,

Jeffrey D. Lacruz

Encl. Technical background report on light water reactors

Report on

LIGHT WATER NUCLEAR REACTORS

submitted to

Mr. David A. McMurrey
Energy Research Consultants, Inc.
Austin, Texas

April 27, 19XX

by
Jeffrey D. Lacruz

This report examines light water reactors as a possible alternative source of energy for Luckenbach, Texas. Both types of light water reactors are described, and an explanation of how each reactor produces electricity is presented. Safety systems and economic aspects conclude the main discussion of the report.

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ABSTRACT

Light water reactors are a category of nuclear power reactor in which water is used as both a coolant and a moderator. There are two types of light water reactors: the pressurized water reactor and the boiling water reactor. In a pressurized water reactor, steam is produced in a secondary system. The main components of a pressurized water reactor are the core, control rods, reactor vessel, steam generators, and pressurizer. The core contains fuel assemblies that contain fuel rods filled with fuel pellets. The coolant flows through the core where it is heated at high pressure. Then coolant then flows to a series of steam generators where the collant flows through the heat exchangers and the steam drum. The pressure is lowered and ateam is allowed to form which then flows to a turbogenerator where electricity is produced. The control rods control the amount of nuclear fission reactions in the core while the pressurizer maintains the operating pressure in the reactor coolant system. The reactor vessel contains the fuel elements, the control elements, and the core monitoring instruments.

In a boiling water reactor, steam is allowed to form directly in the core. The main components of a boiling water reactor are the core control rods, the core shroud and reactor vessel, the recirculation system, the steam separators, and the steam dryers. The core of a boiling water reactor is slightly larger than that of a pressurized water reactor but contains the same elements. The coolant is circulated through the system by the recirculation system that consists of two loops containing pumps external to the reactor vessel and jet pumps inside the vessel. After steam in formed in the reactor vessel, it flows to a series of steam separators where it is separated from the coolant. The steam then flows through steam dryers where additional drying is done, and then it proceeds to turn a turbogenerator. The control rods and reactor vessel function in the same way as in the pressurized water reactor.

Safety system are designed to prevent meltdown in both types of light water reactors. The safety systems in a pressurized water reactor include the residual heat removal system, the emergency core colling systems, and the containment building. The residual heat removal system removes decay heat from the primary coolant system during plant shutdown. The emergency core cooling systems are designed to deal with loss-of-coolant accidents. The passive system consists of accumulators which inject coolant into the vessel when an accident occurs. The low pressure injection systems and the high pressure injection systems also provide make-up water. The safety systems of a boiling water reactor include the drywell and emergency core cooling systems. The reactor core isolation cooling system pumps water into the

reactor during a loss-of-coolant accident while the low and high pressure core spray systems provide make-up water. The drywell encloses the reactor vessel, and the containment vessel encloses all the components of the reactor. The Nuclear Regulatory Commission inspects all nuclear power plants to ensure than these safety systems are adequate.

The economics of a nuclear power plant are determined by the busbar cost and the operating capacity costs. The busbar cost is determined by the construction cost, the cost of operating and maintaining the plant, and the cost of the fuel. The operating capacity costs are determined by the availability of fuel and the capacity of the plant.

Report on

LIGHT WATER NUCLEAR REACTORS

I. INTRODUCTION

There are approximately five hundred nuclear power plants in operation or under construction worldwide. These plants can produce as much as 370,000 megawatts of electricity. These nuclear power plants can be categorized into four types: (1) light water reactors, (2) heavy water reactors, (2) gas-cooled reactors, and (4) breeder reactors. Basically, a nuclear power reactor operates by having a central unit, called the core, in which nuclear fission reactions take place and produce heat. A liquid, called the coolant, flows through the system and absorbs the heat produced in the core. The liquid is then converted into steam that drives a turbogenerator to produce electricity.

The purpose of this report is to present the basic design, operation, and safety measures of light water reactors to the city council. The city council is currently investigating the possibility of membership in a regional consortium as an alternative to increased coal-fired production of electricity. This report will explain how the two types of light water reactors, the design to be used by the consortium, operate and present the key safety and economic aspects of these reactors. Although the operations of nuclear power reactors does involve complex chemistry and physics, these aspects of the discussion have been avoided; only an introductory discussion of the mechanical operation of the reactor will be presented.

The four parts of this report discuss (1) the design and operation of pressurized water reactors, (2) the design and operation of boiling water reactors, (3) safety measures employed in these reactors, and (4) economic aspects of these reactors' operation. The sections on the two types of light water reactors will describe the components and explain their operation. The section on safety measures will discuss the causes of meltdown, safety systems used in both types of reactors, and the role of the Nuclear Regulatory Commission plays to ensure the safety of these reactors. The final section will review the various costs involved in the construction and operation of a nuclear power plant.

II. PRESSURIZED WATER REACTORS

This section of the report describes the key components of the pressurized light water reactor and explains their operation in the production of electricity.

Description of the Major Parts

In a pressurized water reactor (see Figure 1), the reactor cooling water entering the core is highly pressurized so that it remains below the boiling point. The water leaves the reactor to pass through steam generators where a secondary coolant is allowed to boil and produce steam to drive the turbine.

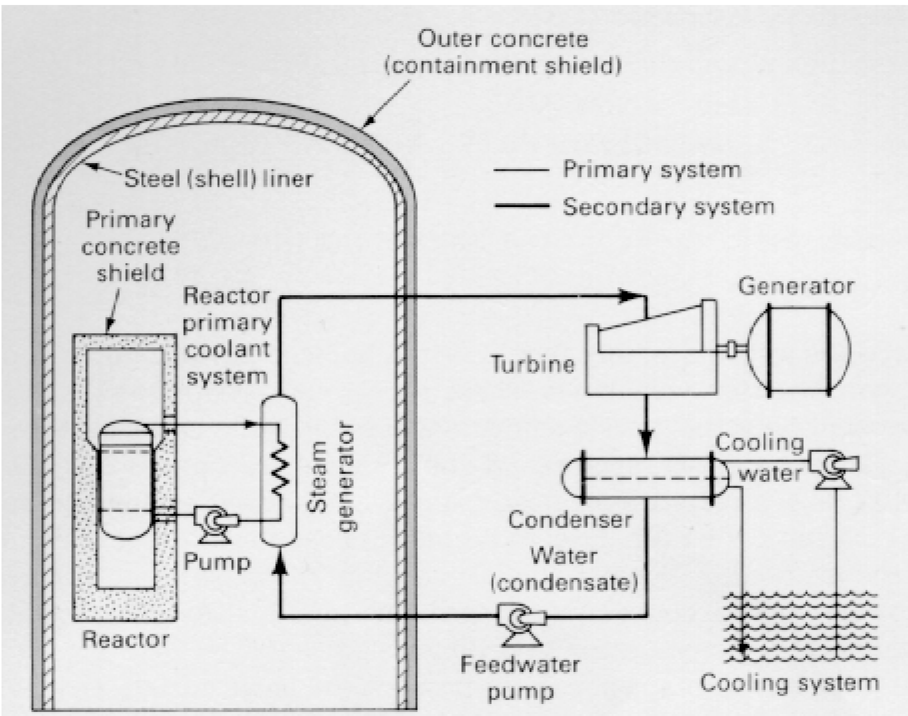

Figure 1. Schematic of a Pressurized Water Reactor. Source: Nero, Anthony V. *A Guidebook to Nuclear Reactors*, p. 78.

The key components in this process are the core, the control rods, the reactor vessel, the steam generators, and the pressurizer.

Core. The core is the active portion of the reactor providing heat to the system. The core contains fuel assemblies that contain fuel rods filled with fuel pellets.

Fuel. The fuel in the pressurized water reactor consists of cylindrical pellets of slightly enriched uranium dioxide with a diameter of 0.325 in by 0.39 in. The pellets are dished at the ends to allow for thermal expansion [12:2004].

Fuel Rod. A fuel rod consists of a cylindrical tube made of Zircalloy, a steel-gray alloy that highly resistant to corrosion. This tube is 13 ft long with an outer diameter of 0.39 in and a 0.025-in thich wall. The tube is filled with fuel pellets and is sealed [10:122].

Fuel Assembly. A fuel assembly is formed when about 230 of the fuel rods are grouped in a bundle. The fuel assembly is about 8 in on a side and 177 in long [10:122] . The reactor core is formed when about 240 of these assemblies are arranged in a cylindrical array. These assemblies are supported between upper and lower grid plates and are surrounded by a stainless steel shroud. The grid plates consist of an assembly of spring clips interlocked to form an egg-crate arrangement providing rigid support and spacing of the fuel rods [3:259].

Control Rods. Control rods provide a means of changing the amount of heat produced in the core . . .[text deleted]

V. ECONOMIC ASPECTS

This section presents some of the key costs that determine the economics of a nuclear power plant. These costs will be compared to those associated with other energy-producing systems, primarily those involving coal. Costs are determined by the busbar cost and the operating capacity costs.

Busbar Cost

The busbar cost is the total cost of electricity leaving the power station. The busbar cost consists of several factors: (1) construction cost, (2) operation and maintenance costs, and (3) cost of the fuel. The per-kilowatt cost of electricity estimated by the Energy Research and Development Administration, generated from 1000-megawatt nuclear, coal, and oil plants beginning operation in 1980 is as follows:

Table 1. Busbar Costs
Electricity costs (in mills* Costs per kilowatt hour)

Category	Nuclear	Coal	Oil
Capital costs	18.7	15.2	10.5
Fuel cost	5.8	13.7	25.7
Operation & maintenance costs	2.8	3.3	2.2
TOTAL	27.3	32.2	38.4

* A mill is 1/10 of a cent ($0.001).

Construction Cost. The construction costs include the hardware, labor, original capital borrowed, interest generated on that capital, and inflation of capital costs. The construction costs for a nuclear power plant are 18.7 mills per kilowatt hour, while those of coal are 15.2 mills per kilowatt hour [8:20] . However, there is evidence to show that complete or nearly complete nuclear power plants cost about twice as much in real dollars than they do at the time they are ordered [1:1] . This inflation is the result of additional quality assurance, inspection, and documentation requirements. The rise in costs can also be attributed to increases in the cost of engineering manpower and of materials such as concrete, steel, and wire [11:113] . However, the actual cost of nuclear steam supply system and the turbine generator together amount to only 15% of the total cost [11:117] . Most of the cost of a nuclear plant can be attributed to interest on capital during construction. Industry experts hope that reducing the time between initial plans for and operation of nuclear power plants will cut these costs [8:23] .

Operation and Maintenance Costs. The operation and maintenance costs for a nuclear power plant are 2.8 mills per kilowatt hour compared to 3.3 mills per kilowatt hour for a coal power plant. The difference can be attributed to recent requirements for installation of environmental protection scrubbing equipment in coal plants. Another factor . . .[text deleted]

APPENDIX

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