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ADVANCED LIGHT WATER REACTOR PROGRAM AT ABB-COMBUSTION ENGINEERING NUCLEAR POWER

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To meet the needs of Electric Utilities ordering nuclear power plants in the 1990s, ABB-Combustion Engineering is developing two designs which will meet EPRI consensus requirements and new licensing issues. The System 80 Plus design is an evolutionary pressurized water reactor plant modelled after the successful System 80 design in operation in Palo Verde and under construction in Korea. System 80 Plus is currently under review by the US Nuclear Regulatory Commission with final design approval expected in 1991 and design certification in 1992. The Safe Integral Reactor (SIR) plant is a smaller facility with passive safety features and modular construction intended for design certification in the late 1990s.

INTRODUCTION

The advanced light water reactor program in the United States is based on the premise that nuclear power plants ordered in the 1990s and beyond must address new licensing issues and meet the needs of Utilities for increased public safety, investment protection, operational flexibility, reduced cost and ease of maintenance. These needs of the Utilities were formulated in detail in a program started in 1982 by the Electric Power Research Institute (EPRI) culminating in an EPRI requirements document which spelled out in detail the consensus of requirements to meet the needs. Licensing issues are addressed by the Design Certification Policy formulated by the US Nuclear Regulatory Commission (NRC) in mid-1989 whereby the entire nuclear power plant would be certified for operation in one step at any site. Review of a specific power plant application would then concentrate only on site-related issues. In addition, licensing would require compliance with the NRC's Severe Accident Policy formulated in 1985. Besides compliance with other current NRC regulations, the policy provides for resolution in the design of the NRC's Unresolved Safety Issues and Generic Issues, evaluation of the design by Probabilistic Risk Assessment methodology and consideration of degraded core issues. All of these requirements have been factored into the EPRI requirements document.

Another factor which will influence nuclear power in the 1990s is the issue of public acceptance. Numerous polls in the US have revealed that a majority of the public will still accept construction of nuclear power plants but there are calls for improved safety. The "public" are not specific on the nature of the increased safety, be it active or passive systems, but merely want assurance that safety is the predominant concern of the designer.At ABB-Combustion Engineering, our assessment of the best way to meet the needs of the 1990s is with nuclear power plants which are not major departures from the light water reactor plants presently operating. We see the evolutionary light water reactor with its proven base of technology and economy of scale as the design most acceptable to Utilities. Operators of nuclear power plants are sufficiently absorbed in understanding and implementing the technology now proven and are more anxious to test the institutional process of licensing in an environment of familiar technology. We do not see Utilities ordering plants which require prototypes or lead units necessary to prove principles of operation.

Accordingly, we have developed the System 80 Plus nuclear power plant design, which is a modification of the standard System 80 design which has been proven in operation at the three-unit Palo Verde site in Arizona starting in 1986. Modifications were made to this design to meet conditions of the EPRI requirements document and the further licensing requirements.

For the longer term, we have heeded the call for smaller nuclear power plants with lower total capital costs and improved modular construction and incorporating so-called "passive" safety systems which would result in a perception of increased safety. The result has been the Safe Integral Reactor (SIR) which, by housing the entire primary coolant system within the reactor vessel, eliminates the large break loss of coolant accident, allows pressure suppression containment and passive means of decay heat removal.

SYSTEM 80 PLUS

The System 80 Plus design has been developed by ABB-Combustion Engineering together with Duke Power Company with support from the US Department of Energy at the US licensed power level limit of 3800MWt for a station output in the vicinity of 1300 MWe. The Safety Analysis Report is being submitted to the NRC for final design approval in 1991 and design certification in 1992. A 1000MWe version of System 80 Plus is being developed in conjunction with the Korea Atomic Energy Research Institute as a follow on to the System 80 units at this power level under construction at the Yonggwang station in Korea.

The System 80 Plus station layout shown in Figure 1 is a departure from the System 80 layout of Palo Verde but only in directions of proven technology. The major design changes from the System 80 standard are summarized in Table 1. These subtle, but significant, changes have been made in the System 80 design which will result in a more forgiving plant that (1) can accommodate a wider range of plant transients, without tripping the reactor or activating safety systems, (2) provides more time for operator actions, (3) has increased margins to technical specification limits that could shut down the plant, (4) is simple to operate, and (5) is easier to maintain.

One of the most fundamental ways to increase safety is to create redundancy: multiple sets of systems that back up each other. The System 80 Plus standard design does just that with an array of features that improve not only safety, but reliability. Now there are four trains, or sources, of emergency feedwater to cool the reactor and protect it from overheating after being shut down. To prevent any possibility of this feedwater being cut off, two sources are driven by electric motor, two by steam turbine. In still another effort to assure uninterrupted service, pumps in the shutdown cooling system are idential to those in the containment spray system, and are interchangeable. As a result, complete water flow can be maintained in either system if a pump is not available. To guard against the loss of outside power to any part of the plant, another diverse power supply is being added to the already existing diesel and battery back-up systems. In this way, the loss of any critical function is extremely unlikely. And finally to minimize damage in the event of fire or sabotage, safety systems are contained in separate quadrants of the plant. An event that damages one train of a safety system cannot reach the others. With design redundancy in key plant areas, Utilities are sure to find an extra margin of safety and reliability never before possible.

The Three Mile Island (TMI) accident heightened the nuclear industry's awareness of the critical importance of regard for the human operator, and the man-machine interface, to producing safe, economical power. As a result, the most dramatic advances in the System 80 Plus design are being made where man ultimately faces machine--in our totally redesigned Nuplex 80 Plus advanced control complex. What has happened in the last ten years might best be described as a revolution in the computer and electronics industry itself. Computers, mini-computers, programmable logic controllers and a host of other advances have all helped ABB-CE to dramatically improve the design of the control room and the way information is presented to the operator. For the System 80 Plus control room, it represents a total revamp of the way information is collected, transmitted and processed for use by the operator--processed information that is directly usable by the operator for monitoring and control of the plant. The result is information that is easier to comprehend; simpler, but more complete. It is simpler because computers will reduce the amount of information continuously presented to the operator. Yet it is more complete because it will allow access to all plant data at the touch of a finger.

The Nuplex 80 Plus control complex also allows shorter construction schedules, reduced maintenance workloads, and lower material costs due to the displacement of large quantities of cable, a major reduction in the number of alarms and indicators, and the application of off-the-shelf components. The control consoles are physically smaller than those in currently operating plants, and minimized cabling require- ments reduce congestion during construction. The control room is designed for command by a single operator from startup through full power operation, but can accomodate more operators and supervisory staff both on a regular basis and during emergency conditions.

SAFE INTEGRAL REACTOR (SIR)

The Safe Integral Reactor is being designed by ABB-Combustion Engineering, Rolls-Royce & Associates, the UK Atomic Energy Authority and Stone & Webster Inc. The design is for application in the US and the UK and will produce a power level of 1000MWt for a net electrical output of 320MWe. The eventual application in the UK is as a replacement for current gas-cooled reactors where the site cooling capabilities limit the amount of power which can be produced. The first application of SIR is expected to be the Winfrith site in the UK. Design certification of the SIR in the US would be expected in the late 1990s as would licensing in the UK. It is intended for the SIR design to be implemented in modules of 320MWe. Multiple module layouts have been developed for power levels up to 1280MWe.

The SIR design is based on the inclusion of the entire primary coolant loops within the reactor vessel itself thereby eliminating large piping penetrations of the reactor vessel which, upon failure, could produce a large break loss-of-coolant accident. Twelve steam generators are located in the annulus between the core and the reactor vessel (see Figure 2). Six primary coolant pumps are attached directly to the vessel to pump the primary coolant down through the steam generators, to the bottom of the vessel and up through the reactor core. Reactor pressure is maintained by the pressurizer section in the reactor vessel head.

In this concept, we have eliminated all large pipe penetrations of the reactor vessel. The largest pipe connected to the steam area of the reactor is 7cm in diameter while the largest penetration to the liquid region is 2.5cm. With the large reservoir of coolant within the reactor vessel, a rupture of either of these penetrations would allow more than four hours for remedial action to take place before the core would become uncovered.

The containment boundary of the SIR is designed to eliminate the large dry containment building and to provide for modular construction of components. The containment consists of the reactor vessel compartment and a series of eight pressure suppression tanks and connecting piping (see Figure 3) to relieve pressure in the reactor compartment and to condense steam formed as a result of any pipe break. Natural convection cooling by air on the outside of the suppression tanks provides the ultimate heat sink.

Inherent passive safety features of the reactor design include the abundance of water above the reactor core with only small penetrations to the reactor vessel and the potential for natural circulation cooling of the reactor core within the vessel. In addition, the SIR is designed for operation without dissolved boron in the moderator which results in a substantially negative moderator temperature coefficient. Sufficient control rod worth is provided to allow shutdown to ambient temperature conditions.

A number of decay heat removal systems are provided which are both redundant and passive (see Figure 4). Normal decay heat removal when AC power is available would be accomplished by the power generation system with steam dump to the condenser. At lower temperatures, the steam generator recirculation system, again with AC power, would reject heat to the component cooling water system.

In the event of a loss of coolant accident, the passive safety injection system would draw water from the pressure suppression tanks with steam injected from the pressurizer to provide the energy to inject the water into the reactor vessel. A second passive system is the Secondary Condensing System which, by natural circulation, draws steam from four steam generators through a condensing pool with condensate returned to the steam generators. For rapid cooling and depressurization of the reactor vessel, a safety depressurization system is available, discharging steam from the pressurizer directly to the suppression tanks. Upon depressurization this system would then allow gravity drainage of water from the suppression tanks back to the reactor vessel. For all of these passive systems, battery operation of valves is the only feature requiring electric power.

While the SIR design does represent a novel approach including many passive operating and safety features, it should be recognized that all of the components of the design have been proven in operation on existing light water reactors. The elimination of primary coolant loops and the use of pressure suppression containment tanks reduce the amount of field construction required and should reduce construction time. The compact construction coupled with the simplicity of adding extra units for higher capacity requirements should make SIR eminently suitable for smaller Utilities.

TABLE 1
MAJOR SYSTEM 80 PLUS DESIGN CHANGES

I. REACTOR

1. Increased Overpower Margin
2. Control of Load Changes without Change in Dissolved Boron
3. Ring-forged Reactor Vessel
4. Reduced Hot Leg Temperature
5. Advanced Burnable Poison
6. Control Rods with Longer Design Life

II. REACTOR COOLANT SYSTEM

1. Larger Pressurizer
2. Increased Steam Generator (SG) Tube Plugging Margin
3. Increased Secondary Inventory in SG
4. Improved Access for SG Maintenance
5. Improved SG Tube Material

III. SAFEGUARDS SYSTEMS

1. Four Train Safety Injection
2. Direct Vessel Injection with Single Pump per Train
3. In-containment Refueling Water Storage Tank
4. Four Train Emergency Feedwater System
5. Safety Depressurization System
6. Higher Pressure Shutdown Cooling System
7. Alternate A/C Power Supply

IV. INSTRUMENTATION AND CONTROL SYSTEMS

1. Advanced Control Center (Nuplex 80 Plus)
2. Digital Protection System
3. Improved Data Communication (multiplexing)
4. Microprocessor-based Component Control
5. Alarm and Indication Prioritization, Validation, and Reduction

V. CONTAINMENT BUILDING

1. Large Steel Spherical Containment
2. Concrete Shield Building (Dual Containment)
3. Safety Systems in Separate Quadrants of Sub-Sphere Zone
4. Provisions for Degraded Core Cooling

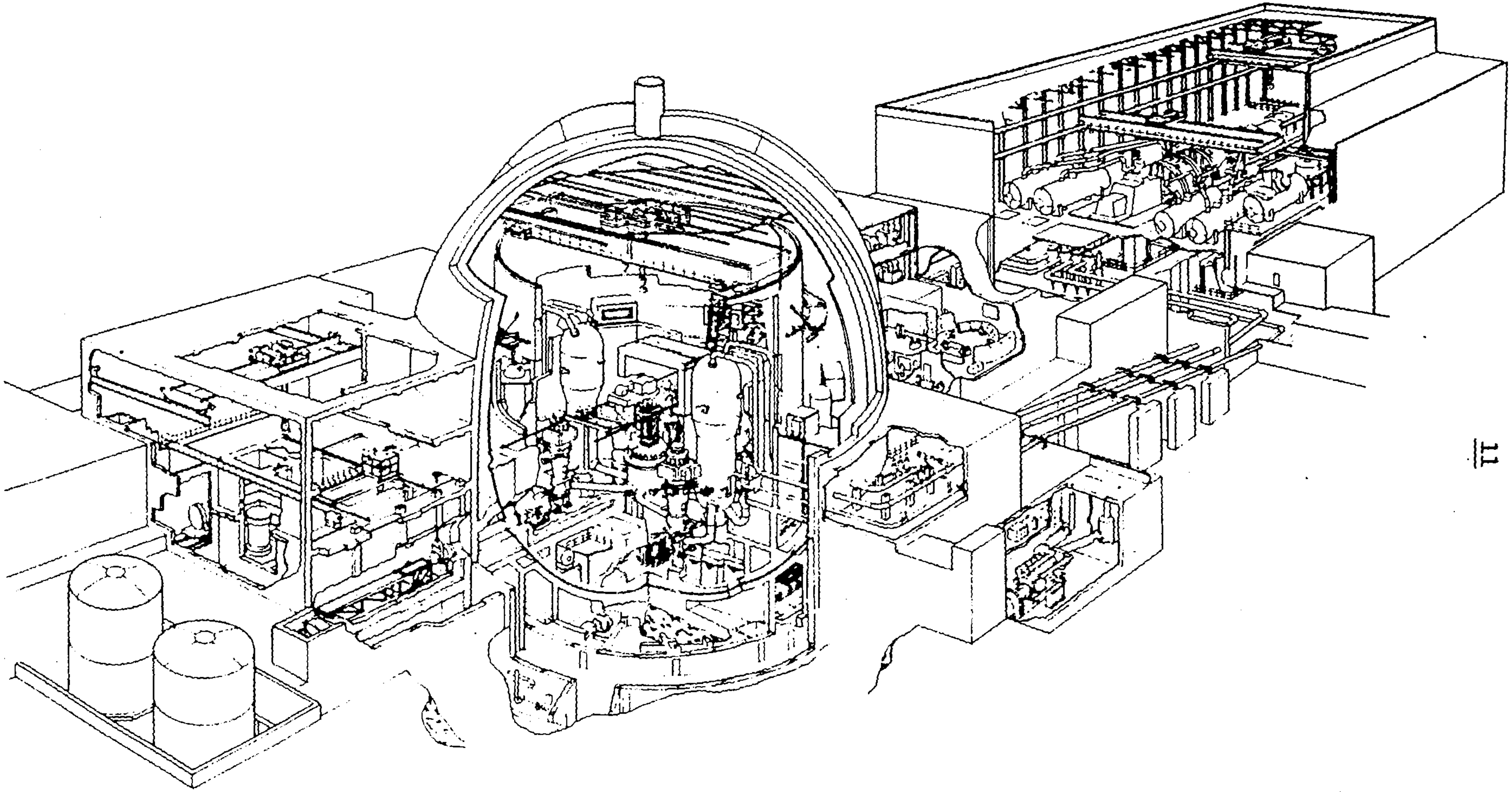
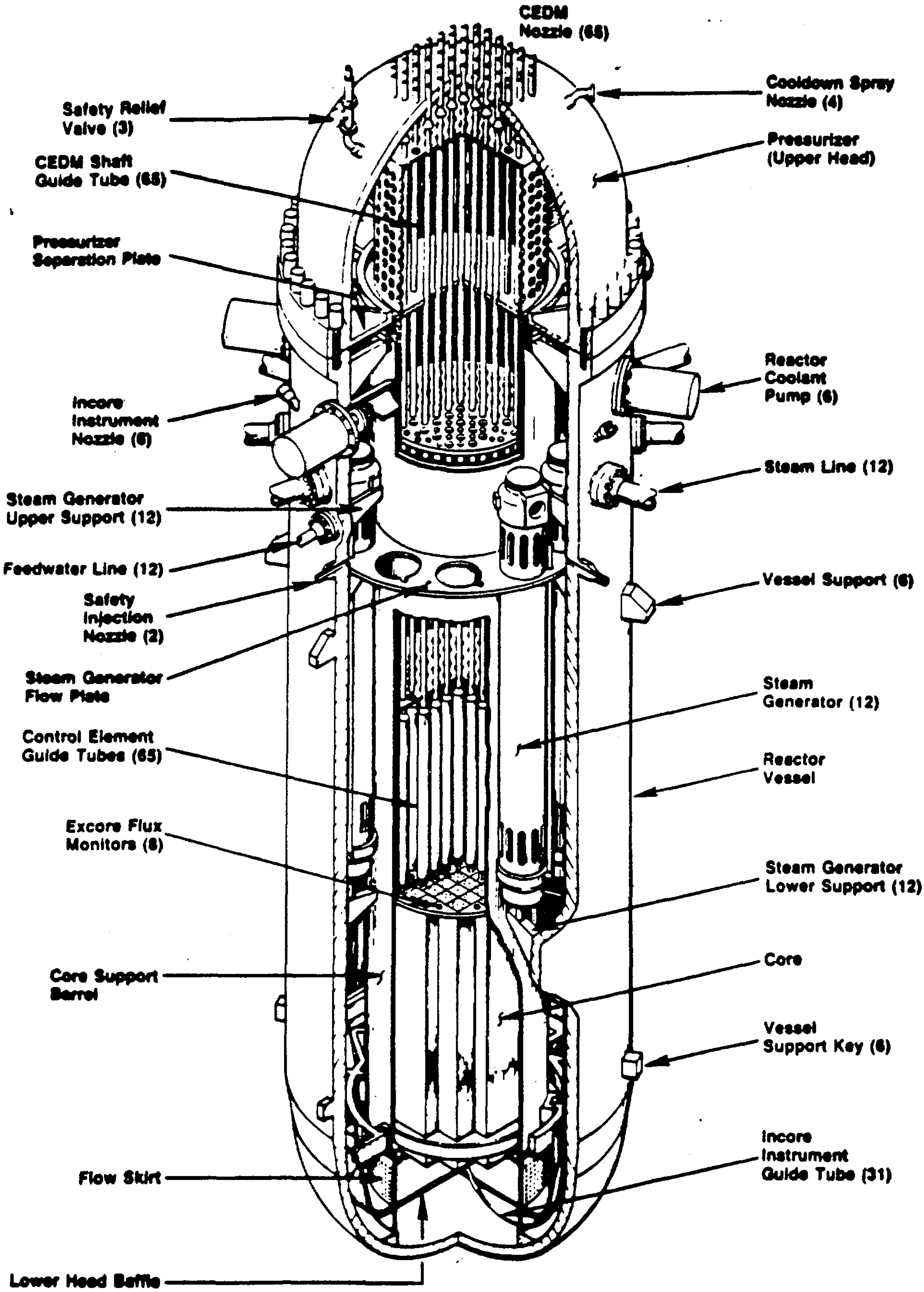


FIGURE 1

SYSTEM 80 PLUS NUCLEAR POWER PLANT

FIGURE 2

SAFE INTEGRAL REACTOR



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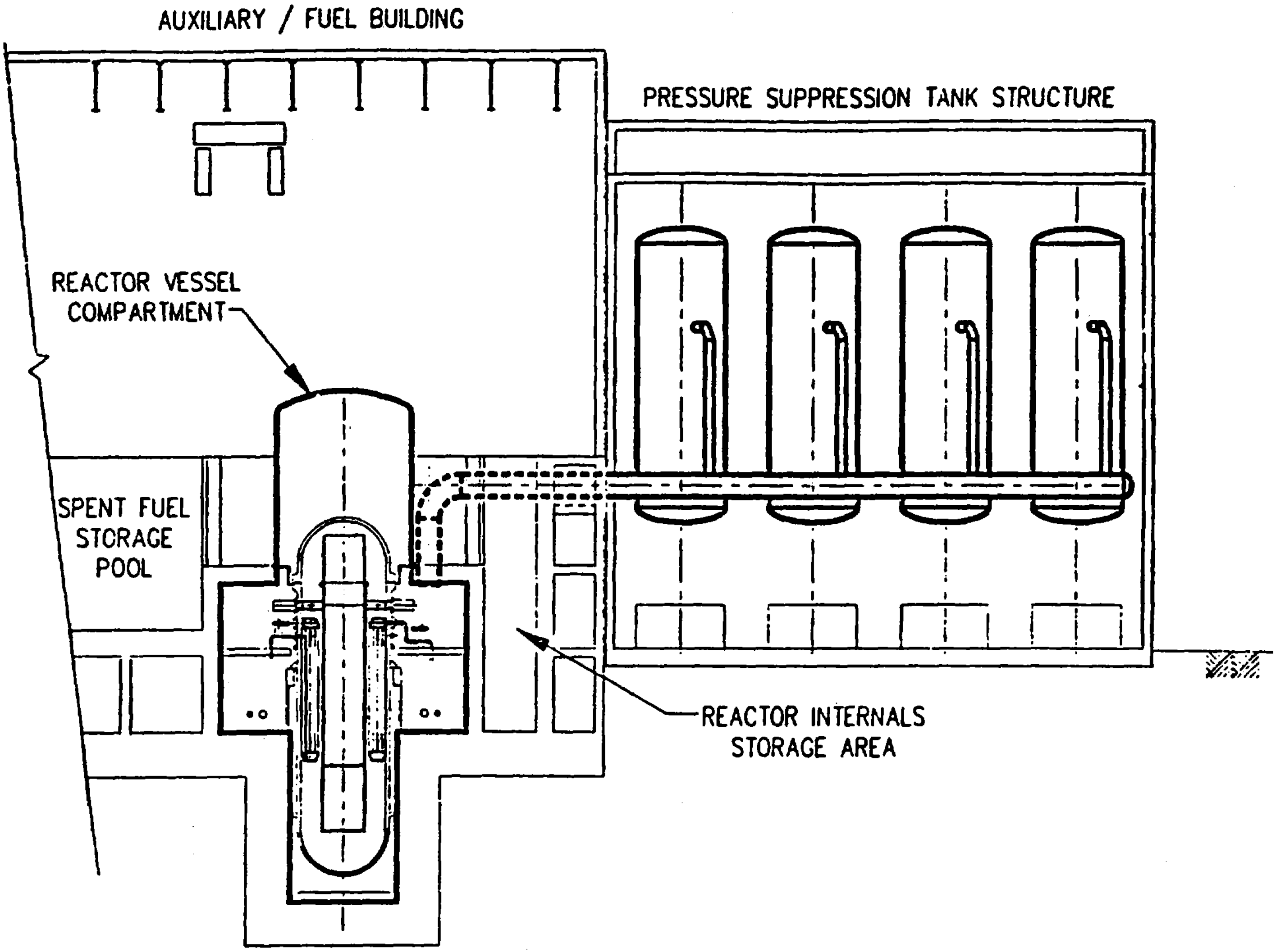

FIGURE 3
REACTOR CONTAINMENT BOUNDARY

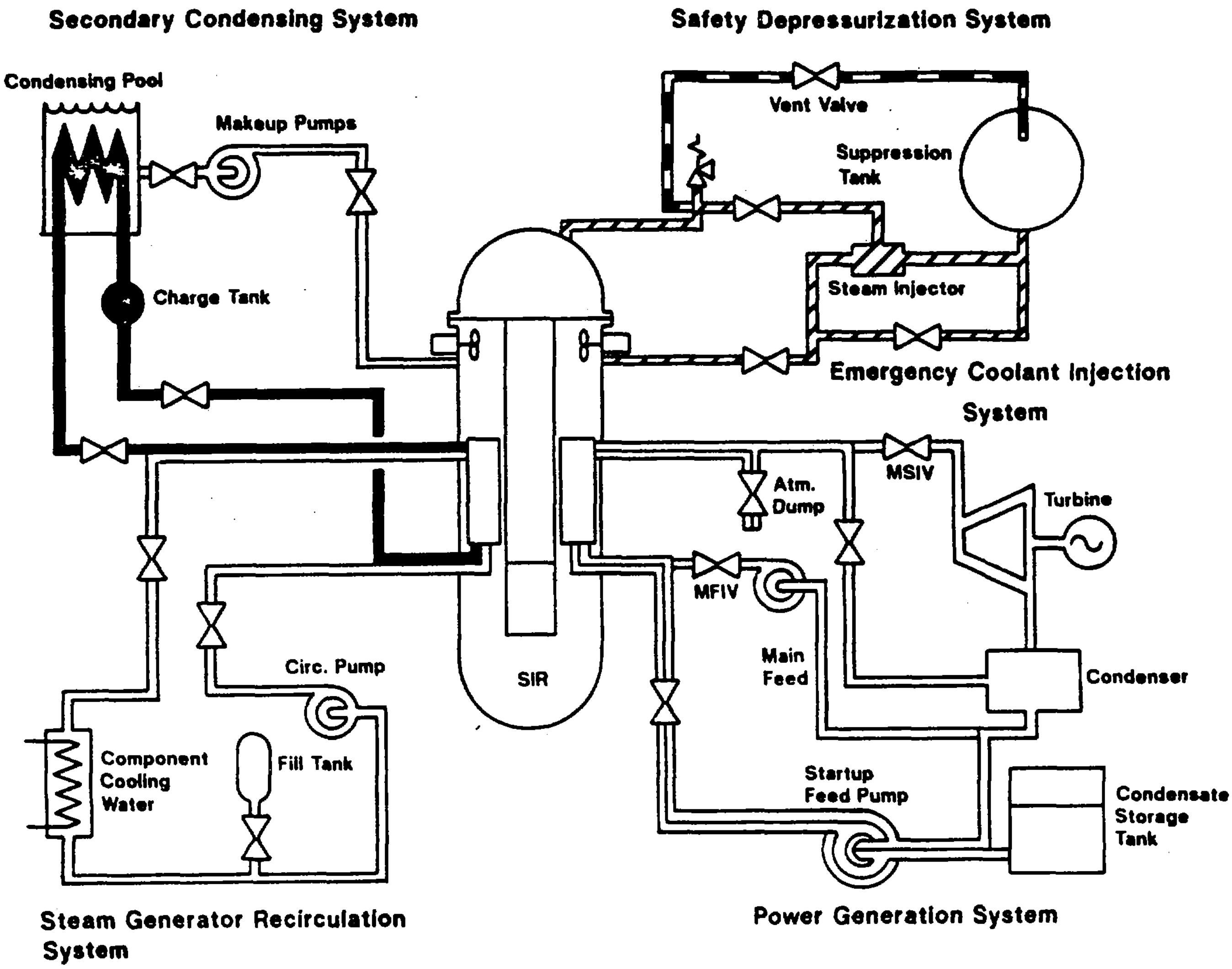

FIGURE 4
SIR HEAT REMOVAL SYSTEM