THE CANDU 9

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ABSTRACT

The CANDU 9 nuclear power plants, with electrical outputs ranging from 900 MW to 1300 MW, can meet the current and future requirements of utilities with relatively large electrical grids.

The CANDU 9 plants are single unit versions of the very successful four unit Bruce B design, incorporating relevant technical advances made in the CANDU 6 and the newer Darlington and CANDU 3 designs. The CANDU 9 plant described in this paper is the CANDU 9 480/SEU with a net electrical output in of about 1050 MW. In this designation 480 refers to the number of fuel channels, and SEU refers to slightly enriched uranium.

Emphasis is placed on evolutionary design and the use of well-proven design features to ensure minimum financial risk to utilities choosing a CANDU 9 plant by assuring regulatory licensability and reliable operation. Specific attention is given to enhancing safety through the simplification and improvement of key systems and components. In addition, the CANDU 9 power plants reflect the important lessons learned by utilities in the construction and operation of CANDU units and, the relevant experience gained by the world nuclear community in its operation of over 400 reactors of a variety of types. As a result, the CANDU 9 plants offer a high level of investment security to the owner, together with relatively low energy costs. The latter results from reduced specific capital cost, reduced operation and maintenance cost, and reduced radiation exposure to plant staff.

A high level of standardization has always been a feature of CANDU reactors. This theme is emphasized in the CANDU 9 plants; all key components (steam generators, heat transport pumps, pressure tubes, fuelling machines, etc.) are of the same design as those proven in-service on operating CANDU power stations.

This paper also briefly reviews CANDU fuel cycle flexibility; the advanced fuel cycles noted are readily accommodated by CANDU 9.

The CANDU 9

1. DESIGN BASIS

The CANDU 9 design follows the same evolutionary path as the CANDU 6, which is a single-unit design evolved from the Pickering multi-unit design. The direct antecedent of the CANDU 9 plants is the multi-unit Bruce B station operated by Ontario Hydro. CANDU 9 also incorporates advanced features which were developed for the newer Darlington and CANDU 3 design.

Large nuclear units (i.e. units with greater electrical output) offer a number of advantages to utilities with compatible grid capacity. These include economy of scale in capital cost, economy of scale in operating cost, and more effective land utilization. The CANDU 9 plants exploit the CANDU experience base by utilizing the proven systems, components and technologies of the very successful Bruce B and CANDU 6 plants, updated by relevant technical advances made in Darlington and CANDU 3, to provide a modern, economical and safe large CANDU plant. The design is also consistent with the Electrical Power Research Institute (EPRI) top tier requirements for Advanced Water Cooled Reactors and the established requirements of CANDU utilities.

Modern design methods and features provide further economies in both capital cost and operation costs through the use of advanced technologies; this is particularly true for construction methods (heavy lift cranes, modularization, etc.) and control and information systems, where technology has advanced at a very rapid rate. Gains have also been made by utilizing the experience base developed by operating plants.

All of the basic and well-proven features which are the hallmarks of CANDU are retained. These include:

- heavy water (D_2O) moderation and cooling
- horizontal pressure tubes in a low pressure, low temperature moderator tank called the calandria
- standard CANDU 37-element natural uranium or Slightly Enriched Uranium (SEU) fuel
- on-power refuelling which avoids refuelling outages.
- two diverse, fast-acting and fully capable safety shutdown systems which are independent of each other and of the reactor regulating system.

The CANDU 9 is intended for utilities having a grid capacity suitable for 900 MWe to 1300MWe class units. The electrical output of CANDU 9 is determined by the number of fuel channels and the fissile content of the fuel which are selected. All CANDU 9 models are accommodated within the same basic design. The CANDU 9 480 SEU is the focus of this paper; in this designation, 480 refers to the number of fuel channels, and SEU to the use of slightly enriched uranium fuel.

The use of slightly enriched uranium fuel (0.9% U_{235}) in CANDU 9 480/SEU, in place of the natural uranium fuel (0.7% U_{235}) utilized in the operating 480 fuel channel Bruce and Darlington plants facilitates an increase in net electrical output to the range of 1050 MW(e). This results from two factors:

- The use of SEU fuel increases the reactivity differential between new fuel and depleted fuel. This allows higher reactivity fuel to be maintained in the outer fuel channels, thereby increasing their power output to levels approaching that of the inner channels.

- The use of a 2 bundle shift refuelling scheme, facilitated by the use of SEU, instead of the 4 bundle shift refuelling scheme used with the NU fuelled reactors, reduces the increase in channel power on refuelling (known as the refuelling ripple), thereby increasing the time averaged channel powers without increasing the peak fuel bundle or channel power.

Hence, the fuel and fuel channels of CANDU 9 480/SEU perform within the same operating limits as CANDU plants now in service, including the maximum fuel burn-up in the high burnup fuel pencils. In addition, all of the principal characteristics of natural uranium fuel that influence the handling and storage requirements of new and irradiated fuel are retained in the SEU fuel (for example, no potential for criticality in light water).

The emphasis placed on evolutionary design and the use of well-proven design features is intended to ensure minimum financial risk to utilities choosing a CANDU 9 plant by assuring regulatory licensability and reliable operation. In addition to this emphasis, the CANDU 9 reflects the important lessons learned by utilities in the construction and operation of CANDU units and, indeed, relevant experience gained by the world nuclear community in its operation of over 400 reactors of a variety of types.

The CANDU 9 plant designers have paid particular attention to the protection of the owner's investment and to minimizing energy costs. This includes the minimization of capital cost, the provision of a short and secure construction schedule, the assurance of a high capacity factor through the use of highly reliable and easily maintainable systems and components, the maximization of component life, and the provision for the fast and easy replacement of components at the end of their life. Operations, maintenance and Administration (OM&A) costs are further reduced by the automation of many operations activities (for example, plant surveillance and operation work control), and by reduced radiation exposure to plant operating staff.

The CANDU 9 power plants are readily adaptable to the individual requirements of different utilities, and are suitable for a range of site conditions. For example, the space provisions within the reactor building and the equipment and piping layout can accommodate different component sizes associated with different cooling water temperatures and changes in the output range.

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2. PLANT DESCRIPTION

2.1 PLANT LAYOUT

CANDU 9 plants are designed as self-contained single-unit power plants (Figure 2.1). Multiple-unit CANDU 9 stations are achieved using single-units as building blocks (Figure 2.2). The layout provides for a short construction schedule by simplifying, minimizing and localizing interfaces; by reducing construction congestion through the provision of construction access to all areas; by providing flexible equipment installation sequences; and by reducing material handling requirements. The relatively small and narrow "footprint" of the CANDU 9 plant provides flexibility in the arrangement and construction sequence of multiple-unit CANDU 9 stations, resulting in very effective land utilization. The relatively small exclusion radius required for CANDU 9 plants (700m) further enhances land utilization.

The layout is strongly influenced by the *Two-Group Separation Philosophy.* This safety-related design approach requires that all plant systems be assigned to one of two groups (Group 1 or Group 2). Each group can, by itself, shut down the plant, assure removal of decay heat from the fuel, and provide plant monitoring. Generally, Group 1 systems sustain normal plant operation and power production and support plant safety, whereas Group 2 systems are dedicated to plant safety. The two groups are separated in the layout, so that a local hazard such as a fire cannot disable more than one group. For widespread external events, such as an earthquake, at least one group is capable of mitigating the effects. The layout also benefits from the application of modern human factors design practices, including a plant wide "Link Analysis"; this serves to improve operations and maintenance efficiency, and to minimize the frequency of human error.

A single unit CANDU 9 station layout is shown in Figure 2.1. The principal buildings comprising the CANDU 9 plant are:

The reactor building, a steel-lined, reinforced concrete structure, contains the reactor, the main reactor cooling system (the heat transport system), the moderator system, and other support equipment. The reactor building assures containment of radioactivity in case of an accident. The design improvements relative to the CANDU 6 reactor building, including increased design pressure and the use of a steel liner, eliminate the need for the complex and costly dousing system, eliminate the cost and inspection burden of post-tensioning cables, and substantially reduce building leakage. A section view through the reactor building is shown in Figure 2.3.

The reactor auxiliary building surrounds the reactor building, and contains the main control room, the fuel handling and irradiated storage facilities, and the piping and cabling which run between the main buildings. The reactor auxiliary building is protected against internal and external flooding and is qualified to earthquake and tornado standards according to specific site requirements.

The Group 2 service building contains essential Group 2 safety services including the secondary control area, Group 2 diesel-generators, emergency water supplies, and safety shutdown systems. The Group 2 service building and its contents are seismically qualified and protected against design basis external hazards such as tornadoes according to specific site requirements. This safety philosophy places essential Group 2 safety equipment in one area where it can be protected against external and internal hazards, and where it is isolated from the effects of accidents affecting Group 1 systems.

The Group 1 service building contains the Group 1 diesel-generators and the Group 1, Class IV and Class III electrical power distribution systems.

The turbine building houses the turbine generator and support equipment. The turbine generator axis lies along the reactor building radius, both to protect nuclear steam plant equipment from missiles due to a postulated turbine breakup, and to minimize station land requirements.

The maintenance building provides the facilities for the day-to-day maintenance of the plant including shops, stores and change rooms. It is located between the turbine building and the reactor auxiliary building, with direct access to both. On multiple-unit stations, the maintenance building crane halls are connected, and extend the width of the station.

The station services building accommodates certain services for the station such as heavy water management, liquid waste management, overhaul facilities, and change rooms for contract staff. Only one station service building is needed for a multiple-unit CANDU 9 station; it can be located at either end of the station or between units.

2.2 NUCLEAR STEAM PLANT

This section gives a brief description of the main parts of the Nuclear Steam Plant, comprising systems and equipment within the reactor building, the reactor auxiliary building, and the Group 2 service building.

2.2.1 FUEL

The fuel for CANDU 9 plants is the standard CANDU 37-element bundle (Figure 2.4). CANDU 9 480/SEU utilizes uranium dioxide enriched to 0.9% U_{235}. This level of enrichment is consistent with that available in Recovered Uranium, a product of spent LWR fuel reprocessing. CANDU 9 plants can take advantage of the CANFLEX fuel bundle when it is available.

2.2.2 FUEL CHANNELS

The CANDU 9 plants use the proven CANDU 6 fuel channel (Figure 2.5). Each fuel channel consists of a zirconium-niobium alloy pressure tube, centred in a Zircaloy calandria tube by annular spacers, and expanded into stainless steel end fittings at both ends. Each channel contains twelve fuel bundles. Modest improvements have been incorporated in the CANDU 6 fuel channel, including thickening the end sections of the calandria tubes (to reduce sag), addition of a second set of pressure tube rolled joint grooves in one end fitting (to reduce pressure tube replacement time), and more stringent metallurgical specifications for pressure tube material that reduce initial hydrogen concentrations and increase resistance to toughness reduction (in order to ensure a 35-year life).

Pressure tube replacement is not required for 35 or more years; however the design of the fuel channels and the layout within the reactor building facilitate fuel channel replacement, required to achieve the 60 year plant design life.

2.2.3 CALANDRIA AND SHIELD TANK

The reactor core consists of 480 fuel channels held in a square lattice array by circular end-shields, and contained within a cylindrical low-pressure tank called the calandria (Figure 2.6). The calandria contains the heavy water moderator at near-atmospheric pressure. The CANDU 9 plants utilize the proven Bruce B/Darlington (480 fuel channel) calandria. Some limited improvements have been made; the most significant is the relocation of the moderator system inlet and outlet nozzles to enhance moderator circulation in the calandria, thereby providing improved cooling during potential severe accident conditions.

The CANDU 9 plants adopt the basic Bruce/Darlington arrangement of a water filled steel shield tank surrounding the calandria. Improvements to the shield tank include a cylindrical shape (rather than the octagonal shape of Bruce and Darlington) to enhance seismic capability and supporting the shield tank by embedding the end structure into the reactor vault end walls (similar to CANDU 6), rather than by supporting it from the floor as in Bruce B/Darlington; this stiffens the structure, and further improves seismic capability. The CANDU 9 shield tank design combines the advantages of the Bruce/Darlington shield tank, including reduced construction time and access to the reactor vault during reactor shutdown, with the structural and seismic advantages of the CANDU 6 design.

2.2.4 HEAT TRANSPORT SYSTEM

CANDU 9 plants utilize the basic single-loop Bruce B heat transport system arrangement, with two inlet headers and one outlet header at each end of the reactor, and two single discharge, single suction, heat transport pumps serving the inlet headers at each end of the reactor (Figure 2.7).

At each end of the reactor, each inlet header provides coolant flow to alternate fuel channel inlet feeders. For large reactors, this arrangement (derived from the Bruce B design) reduces the rate of reactivity insertion in the event of a large Loss of Coolant Accident (LOCA), thereby increasing safety margins relative to arrangements in which all inlet feeders at one end of the reactor are supplied by a single inlet header. For smaller reactors (such as CANDU 6) a similar benefit is obtained by dividing the heat transport system into two independent circuits or loops.

2.2.5 MODERATOR SYSTEM

Heat is deposited in the heavy water moderator during normal operation, from direct gamma and neutron interaction and through thermal conduction from the fuel channels. This heat is removed by the moderator cooling system, which circulates and cools the heavy water in an external circuit connected to the calandria.

2.2.6 REACTOR CONTROL

Reactor control is provided by reactivity control mechanisms consisting of light-water zone compartments, absorber rods, and adjuster rods; all are located between fuel channels within the low pressure heavy water moderator. The overall reactor control system is described in Section 2.2.10.

2.2.7 FUEL HANDLING

The CANDU 9 plants utilize the CANDU 6 double-ended on-power refuelling system (see Figure 2.8). On-power refuelling is performed by two fuelling machines, located at opposite ends of the reactor. These machines transport new fuel bundles to the fuel channel to be refuelled, and load them into the fuel channel while the reactor is operating. Simultaneously used fuel bundles are removed from the fuel channel. The fuelling machines subsequently transport the used fuel to the irradiated fuel storage bays. The refuelling operation is fully automatic. In the event that a defect occurs in a fuel bundle during reactor operation, the fuelling machines can be used to remove the defective fuel, thereby limiting the release of fission products to the heat transport system coolant. Systems are provided for the detection and location of defective fuel.

Fuel handling system improvements relative to CANDU 6 include:

- Location of new fuel loading outside of the reactor building as in Bruce B/Darlington, to minimize radiation exposure of staff loading new fuel.
- Moving the fuelling machines on transfer carriages that travel between the reactor face and the reactor building wall (as in CANDU 3); this improves seismic capability and simplifies the fuel transfer system.

CANDU 9 plants utilize the CANDU 6 fuelling machine design, with a number of enhancements, adopted from the proven Bruce B/Darlington fuelling machines. These include:

- A forged body housing with an end flange, thereby eliminating the costs and complexity of the large Graylok connection.
- Electric drives to replace the D_2O hydraulic drives, thereby improving reliability and reducing maintenance.

2.2.8 SAFETY SYSTEMS

The four Group 2 safety systems comprise the two diverse, passive, dedicated reactor shutdown systems; the emergency core cooling system; and the containment system. Each is separated from and is independent of the Group 1 systems, and of all the other safety systems.

Shutdown System No. 1 utilizes spring-assisted, gravity-drop neutron absorbing rods, which drop into the moderator, between the fuel channels.

Shutdown System No. 2 utilizes horizontal perforated tubes through which a liquid neutron absorber is injected into the moderator.

The Emergency Core Cooling System (ECCS) uses high pressure gas to inject ordinary water into the fuel channels, followed by pumped recirculation and cooling of water within the reactor building. The emergency core cooling system is essentially the same as for Bruce B, but is replicated for each CANDU 9 unit, whereas a single system serves the four Bruce B units. Improvements incorporated are discussed in Section 4.3.

The *containment system* is a conventional dry single-unit structure, consisting of a reinforced-concrete building with a steel inner liner which encloses the reactor and other nuclear steam supply system components. Each CANDU 9 unit has its own independent containment system. Note that the containment type is independent of the reactor type. CANDU does not require a specific form of containment system and can readily adopt other containment system arrangements to suit specific utility requirements.

2.2.9 INFORMATION AND CONTROL SYSTEM

Plant instrumentation, computer control systems, control room man/machine interface and the plant information system are provided by the ICS-90+ Systems (Information and Control Systems-90+).

ICS-90+ evolved from the highly automated CANDU control systems developed for the CANDU 6 stations and Darlington, and takes advantage of the dramatic developments in digital systems and communications systems that have occurred in recent years. The result is substantial improvements in safety and reduced operating cost.

The CANDU 9 main control room is illustrated in Figure 2.9. The control room retains the basic arrangement of the CANDU 6 control room, while incorporating major technical advances; these include the addition of large displays, control consoles from which the plant is operated via keyboards and CRTs, and reduced main panel complexity.

3. OM & A COST REDUCTION

A cost reduction in the range of 25% of the OM & A costs from operating CANDU-6 plants on a per megawatt basis will be realized. Some of the factors contributing to this improvement, principally through staff reduction, are the following:

- The use of proven components and system designs, improved based on operating experience, to reduce maintenance and inspection requirements.
- The use of a detailed three dimensional (3-D) electronic plant model permits the designers to better provide for maintenance procedures and staff requirements. Hence, access routes, shielding, cranage, etc. to facilitate maintenance and inspection are provided as part of the basic CANDU 9 design.
- Improved operational state monitoring and detailed plant configuration control and work management is provided by the ICS-90+ operations information system.
- Specific design changes focused on eliminating personnel operations inside containment, reducing the number of components, reducing complexity and increasing automation in labour intensive areas such as safety system availability testing and plant surveillance activity.
- The automotion of activities such as plant surveillance and operations work control.
- Faster fault correction resulting from improved on-line equipment diagnostics.
- Immediate availability of real-time operational information to utility management and operational support personnel.
- Reduced maintenance resulting from a significantly reduced number of components including cables, cable trays, wiring and terminations.
- Less labour intensive plant configuration control.
- Less Manual control of plant operation – for example, warm-up from zero power cold.

4. SAFETY ENHANCEMENTS

4.1 GENERAL

A large number of system and component improvements have been incorporated in the CANDU 9 to enhance safety. Many of these improvements, including the improved Grouping and Separation philosophy (Section 2.1), the dry steel lined reactor building (Section 2.1), and the full pressure Group 2 feedwater system were developed for and implemented on CANDU 3. The following subsections give further information on CANDU 9 safety enhancements. Many of these have been incorporated in the CANDU 3.

4.2 RESERVE WATER SYSTEM

The reserve water system illustrated in Figure 3.1, which is an extension of the coolant recovery system of the CANDU 6, includes a large high-level reserve water tank, located in the reactor building. The reserve water tank, conceptually similar to the CANDU 6 dousing tank, serves as a head tank for the shield cooling system; and provides passive cooling of the shield tank and end shields in the case of a loss of normal cooling capability. The tank also provides makeup water via gravity to the steam generators if required, provides makeup water to the moderator and heat transport systems if required, and supplies water to the ECC system sump in the event of a LOCA to ensure ECC pump net positive suction head.

In addition to the passive functions noted above, the reserve water system includes recovery pumps that can return leakage from either the heat transport system or the moderator system to the appropriate system.

4.3 EMERGENCY CORE COOLING SYSTEM

The CANDU 9 Emergency Core Cooling System (Figure 3.2), although conceptually the same as the system utilized at Bruce B, incorporates a number of enhancements. These include:

- Placement of all ECCS equipment, except the gas tanks, within the Reactor Building, eliminates the need for a number of isolation valves, and precludes the possibility of active leakage outside of containment during ECC operation.
- The use of one-way rupture discs to separate the heat transport system from the emergency core cooling system, thereby greatly simplifying the emergency core cooling system.

Although significantly reducing both the capital cost and maintenance cost of the Emergency Core Cooling System, the principal safety benefit is a substantial increase in reliability.

4.4 MAN MACHINE INTERFACE

Advanced human factors principles have been applied throughout the CANDU 9. This is particularly the control centre and operator interface. Information is presented to the operators in a clear and concise manner through the extensive use of graphic displays. This, in combination with electronic procedures and symptom based diagnostic tools provide assurance of appropriate operator actions under accident conditions, and reduce the likelihood of operator error throughout the plant operating life.

4.5 OPERATIONAL SAFETY

Operational safety is assured by the application of human factors principles to all aspects of plant operation and maintenance. This assures adequate access, and the provision of appropriate facilities for all maintenance and inspection operations. This significantly reduces the radiation exposure to operating staff, and reduces operation and maintenance costs.

4.6 SEVERE ACCIDENT PREVENTION / MITIGATION

As in operating CANDU plants, there is a defence in depth approach to the prevention of severe accidents. This includes the two independent, passive shutdown systems that greatly reduce the probability of a transient without shutdown (scram) occurring, and the moderator system which can remove decay heat from the fuel even if no coolant is present in the fuel channels (LOCA plus loss of ECC).

Should the moderator heat sink also fail, the light water shield tank surrounding the calandria can retain the debris from the overheated fuel channels. In CANDU 9 this capability is enhanced by connecting the shield cooling system to the reserve water tank; shield cooling is hence available by passive convection (thermosyphoning).

5. FUEL AND FUEL CYCLE FLEXIBILITY

High neutron economy is the feature of the CANDU reactor that makes it possible to operate with a variety of low-grade fuels. These include natural uranium (NU cycle) and slightly enriched uranium (SEU cycle). Also, this feature of CANDU provides a unique synergy between CANDU and LWRs as there is sufficient fissile content in spent PWR fuel to burn in CANDU (Tandem cycle) as mixed uranium and plutonium oxide (MOX) fuel. Alternately, the recovered uranium from the PWR spent fuel can be burned without the plutonium (RU cycle) to operate in synergy with PWRs that recycle the plutonium.

In addition to burning the products of conventional reprocessing, the CANDU reactor can operate on PWR spent fuel (DUPIC cycle), the latter being a dry process that is easier to safeguard against diversion of fissile material.

An overview of the fuel cycle options is given in Table 1. CANDU capability to detoxify actinides is discussed in another paper being presented at this conference. [1]

6. SUMMARY

The CANDU 9 plants are an evolutionary single unit development of the successful four unit Bruce B design, utilizing proven systems, component designs, and concepts. The CANDU 9 incorporates a number of safety enhancements derived from the ongoing research and development activities within AECL. CANDU 9 makes large modern CANDU plants available to both Canadian and foreign utilities with compatible grid size and electricity requirements.

7. REFERENCES

[1] Actinide Annihilation in CANDU, A. Dastur/ N. Gagnon AECL CANDU presented at CNS 94, Montreal Québec, Canada.

TABLE 1

Summary of Fuel Cycle Options

Fuel Cycle Option	Fuel Cost	Security of Supply	Quantity Spent Fuel
1) Natural uranium (NU) fuel	About 50% of PWR fuel cost.	Uranium utilization approximately 30% higher than PWR's. No dependence on enrichment.	4700 CANDU fuel bundles (about 110 tonnes spent fuel) per year from CANDU-6 plant, based on 80% capacity.
2) Slightly enriched (SEU) fuel	About 40% of PWR fuel cost for 1.2% SEU.	Enrichment readily available. Uranium utilization 100% higher than PWR.	As low as 1/3 spent fuel volume of NU cycle.
3) Recovered Uranium (RU) fuel	As low as 33% of PWR fuel, cost varying with RU price.	Existing and planned reprocessing facilities have capacity for RU to supply 60 CANDU plants.	About 1/2 spent fuel volume of NU cycle.
4) DUPIC cycle	Fuel cost impact will depend on final development of DUPIC process. Note: Cost improvement increases for "scarce" fuel resource scenario.	Existing stock of PWR spent fuel is a resource for CANDU. Overall Uranium utilization up to 40% lower than PWR alone.	As low as 1/2 spent fuel volume in CANDU compared to NU. PWR spent fuel volume drastically reduced by recycling.
5) Thorium/U_{235} cycle without reprocessing	Similar to natural uranium fuel cost.	Major resource for countries with thorium.	Marginal reduction from natural uranium.
6) Thorium/U_{235} cycle without reprocessing	Depends on reprocessing costs.	Major resource for countries with thorium.	Depends on frequency of reprocessing.
7) Transuranic mix	Depends on reprocessig costs.	Secure for countries with PWRs.	Negligible.

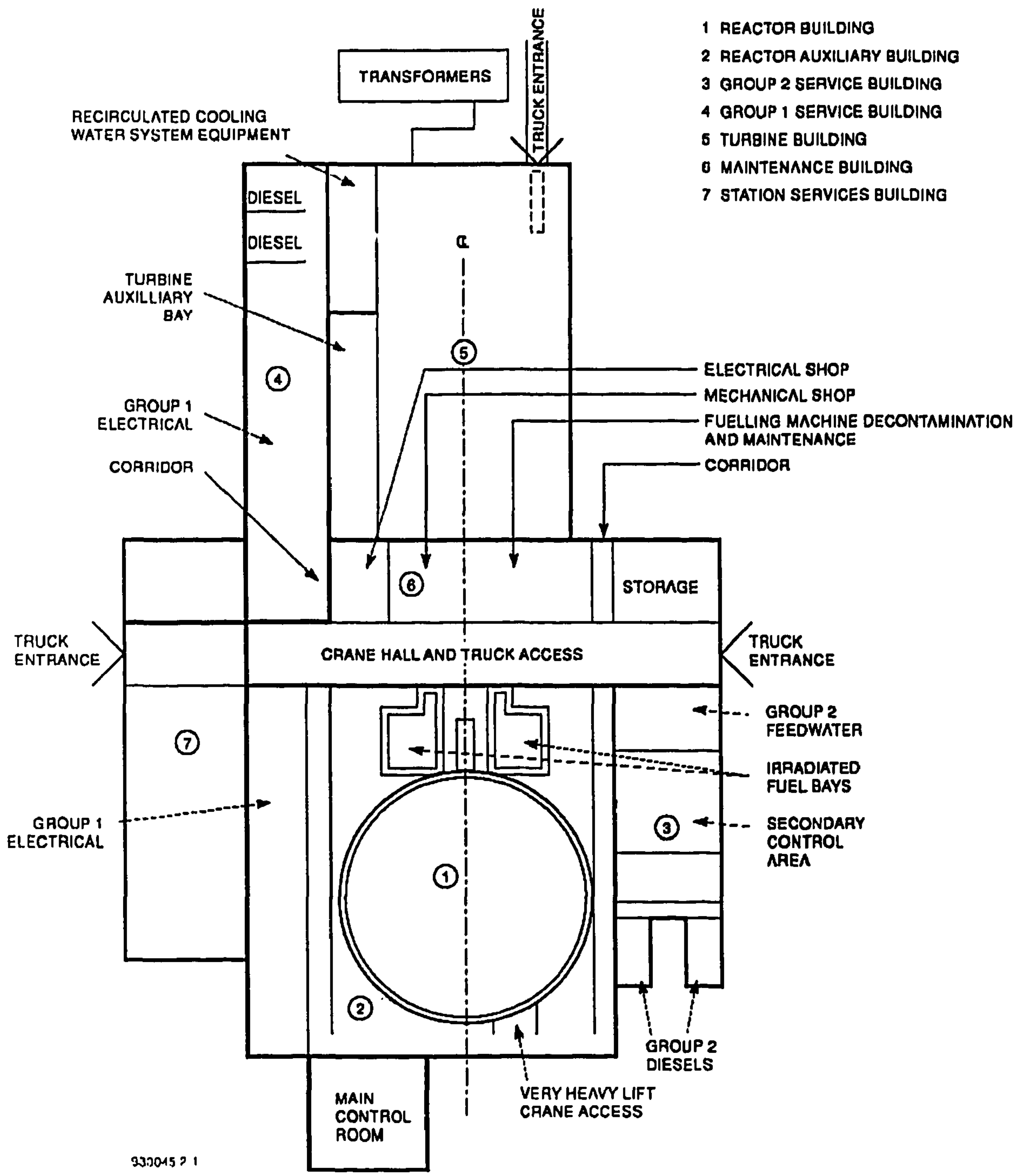

Figure 2.1
Single Unit Station Layout

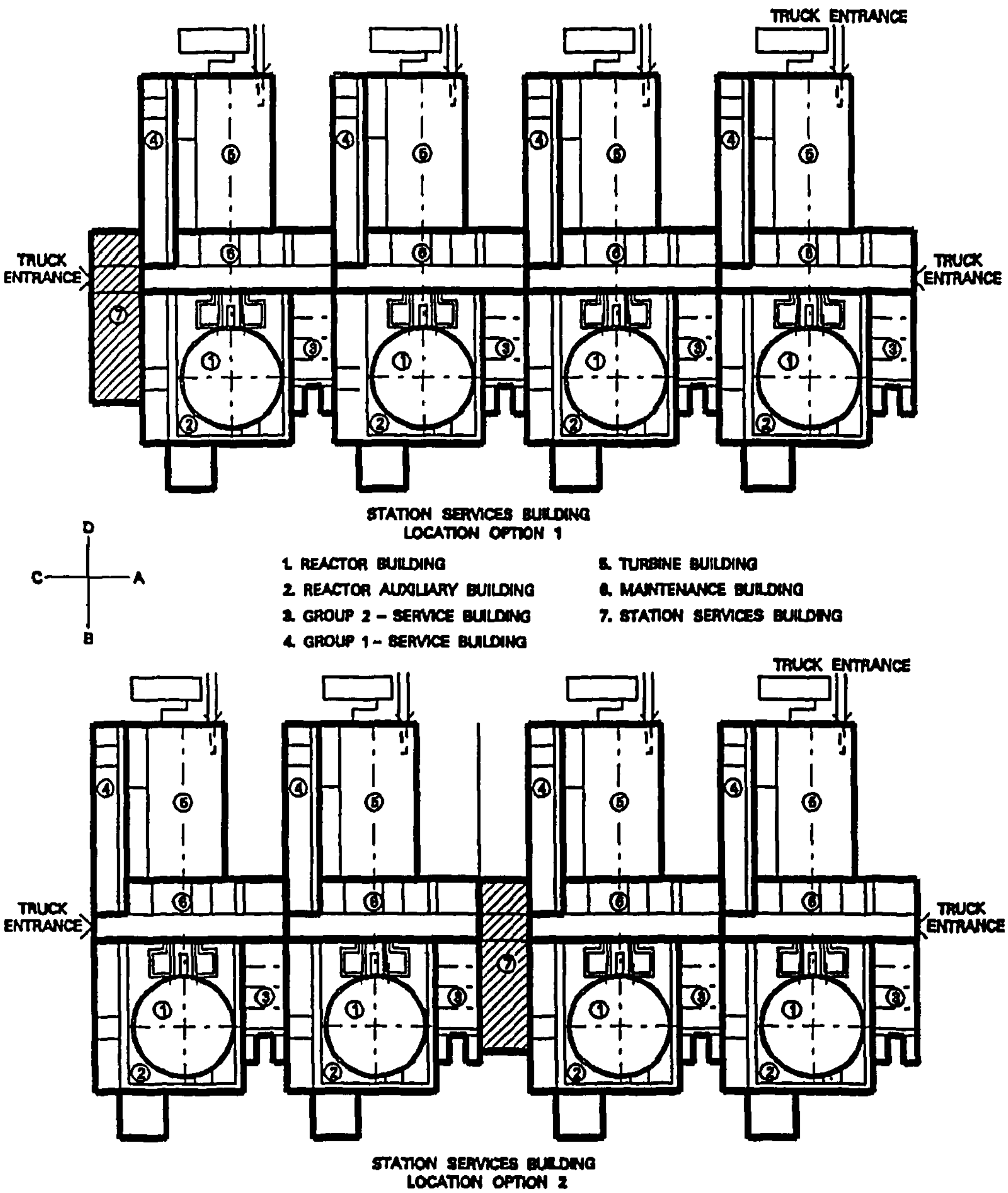

Figure 2.2
Multiple Unit Layout Options

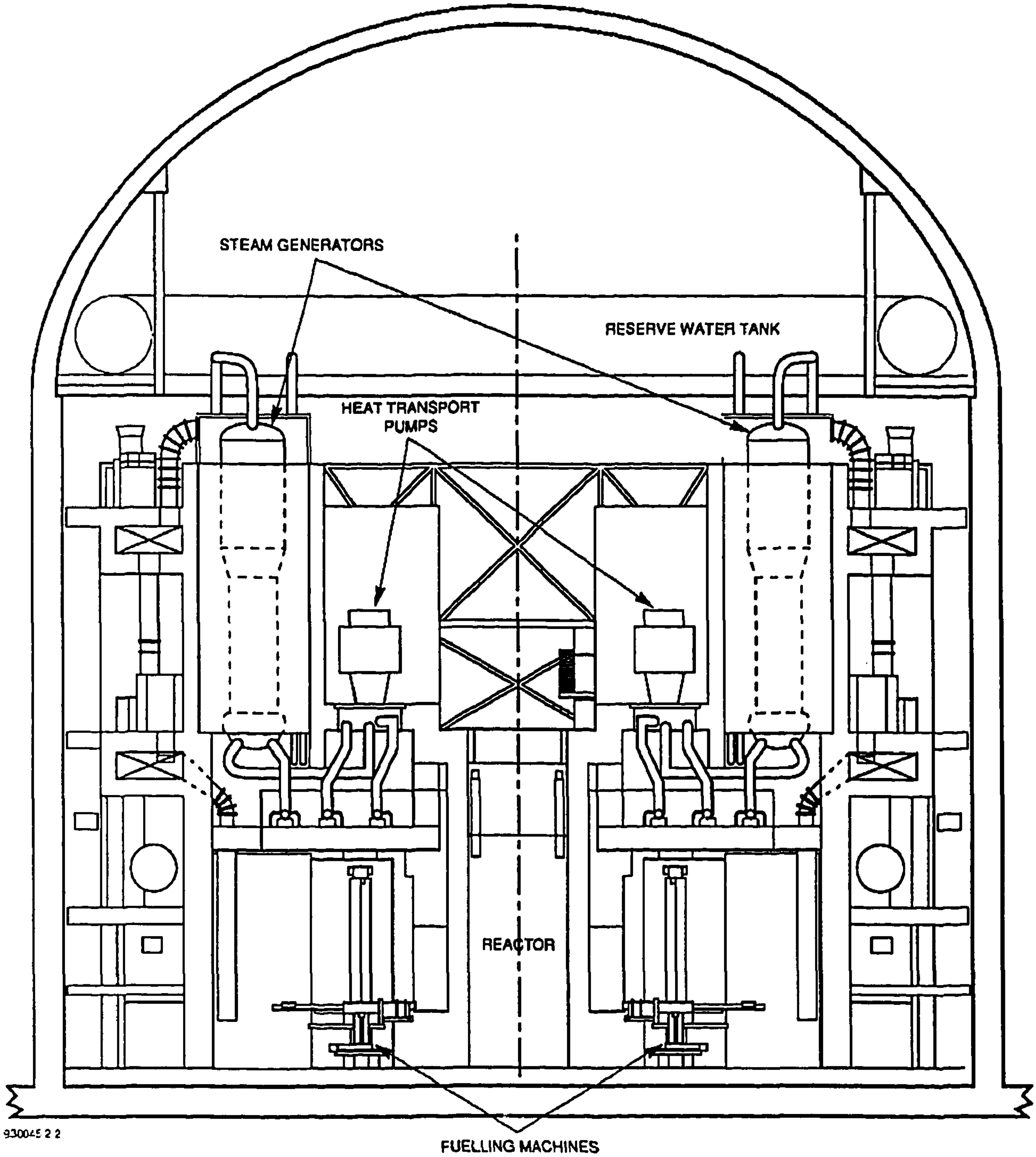

Figure 2.3
Reactor Building Section

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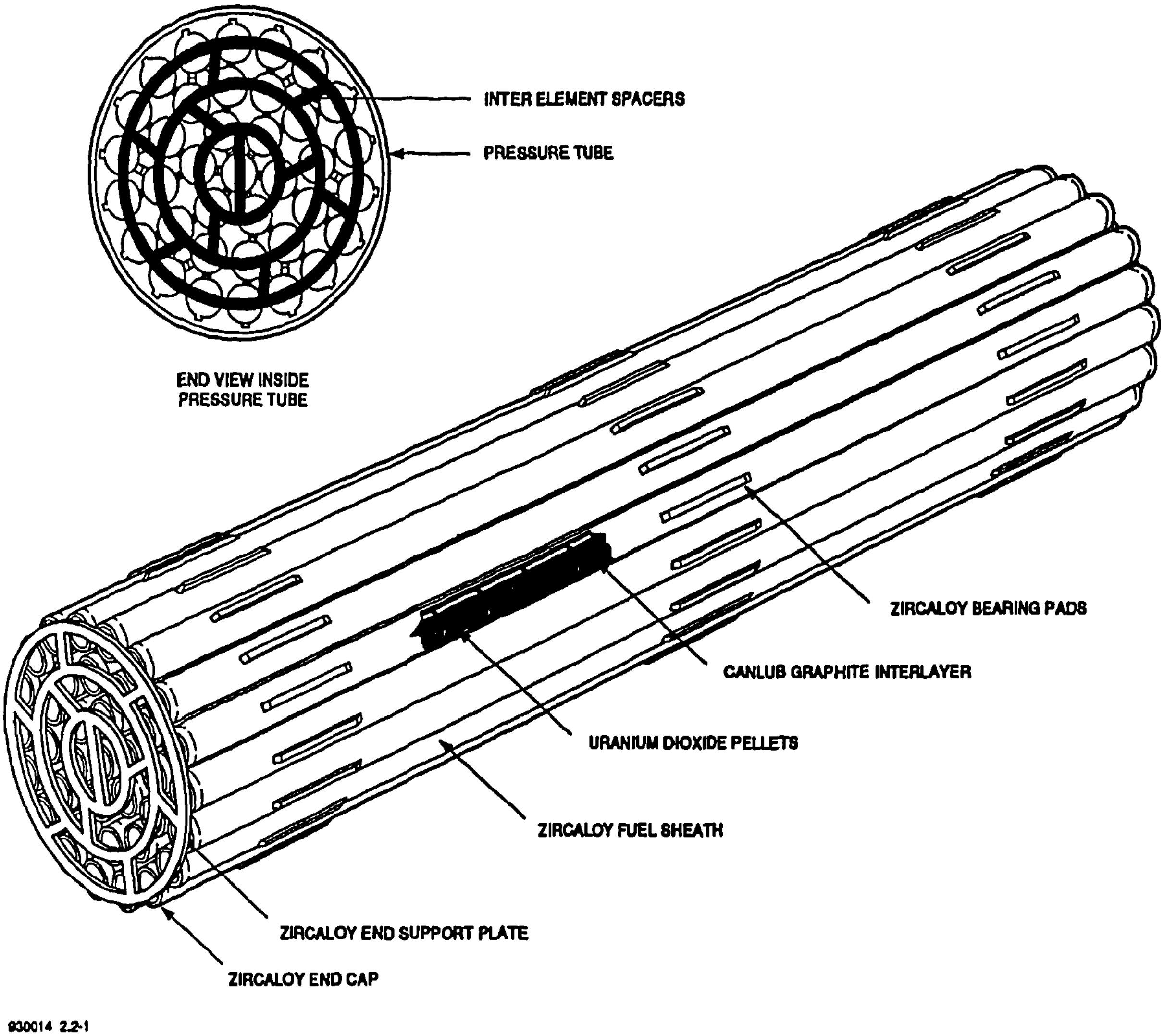

Figure 2.4
37-Element Fuel Bundle

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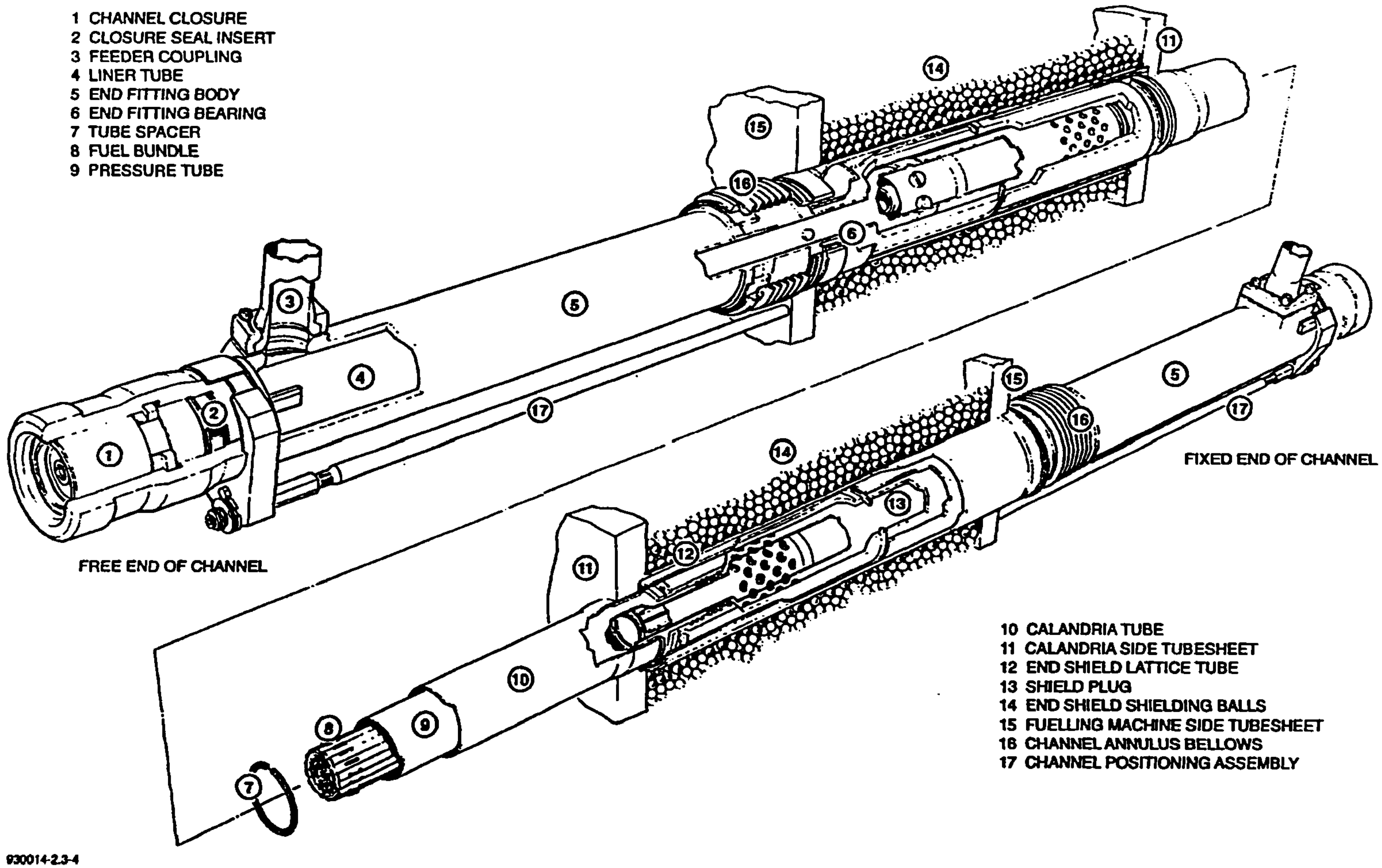

Figure 2.5
Fuel Channel Assembly

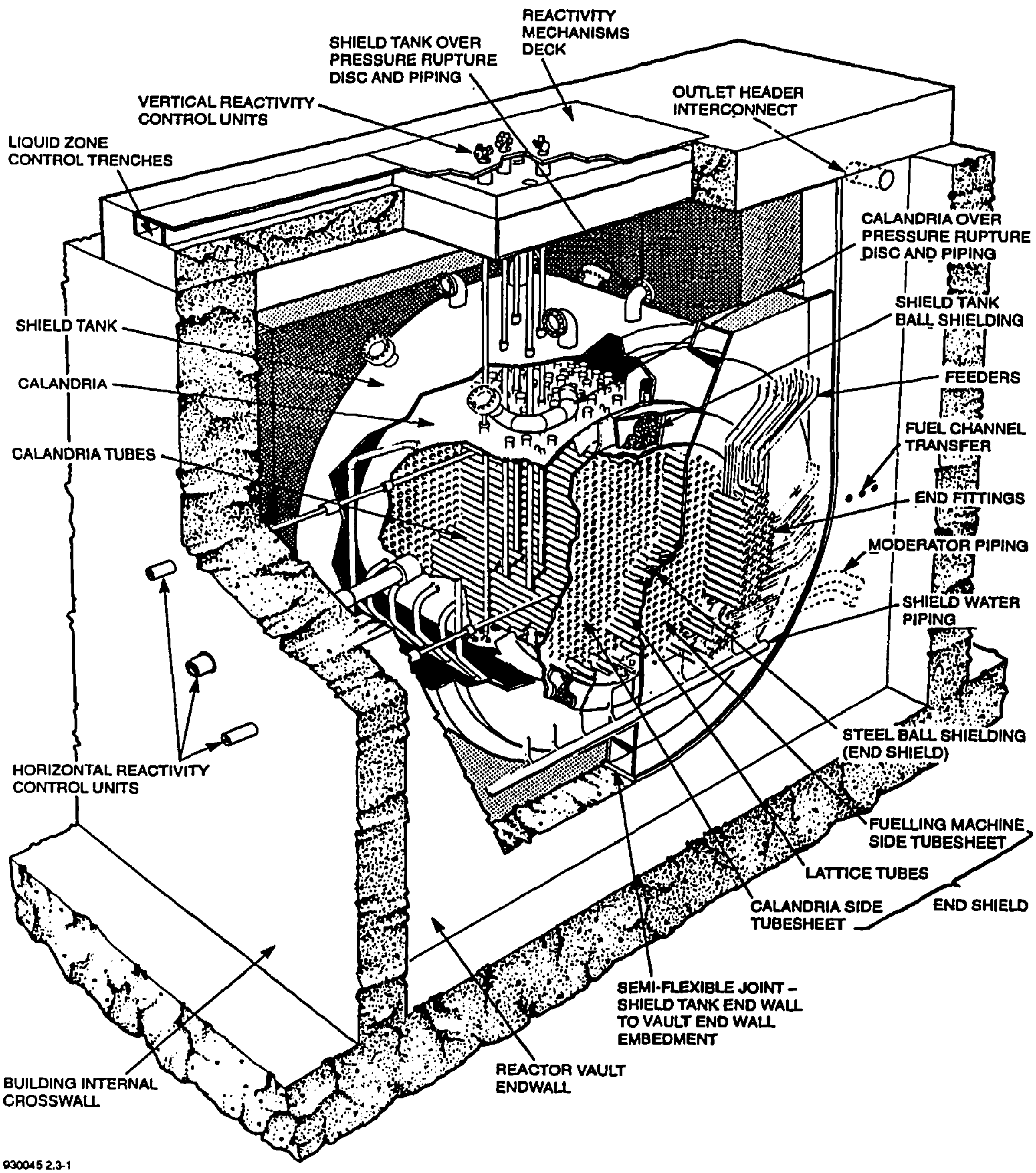

Figure 2.6
Reactor Assembly

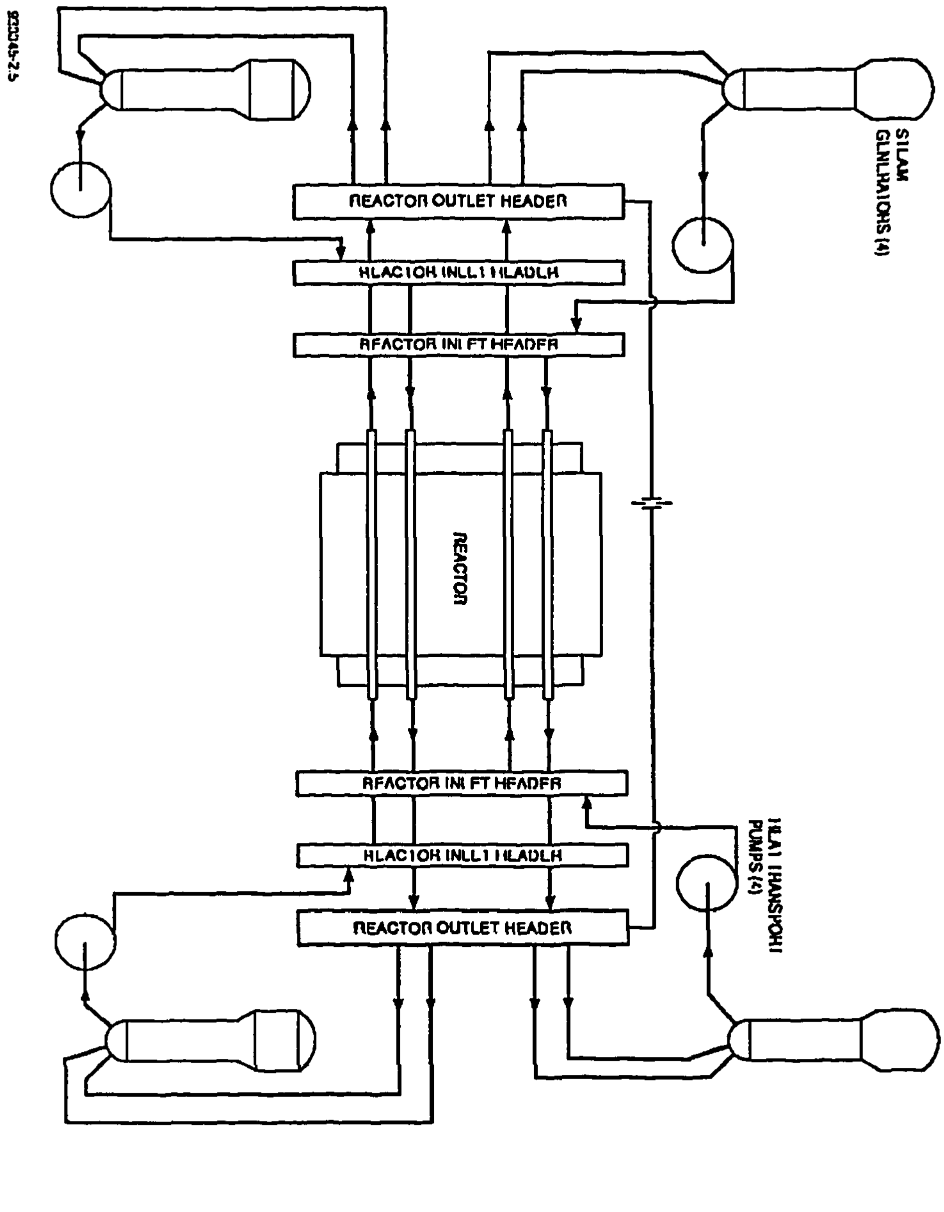

Figure 2.7
Heat Transport System Simplified Composite Flow Diagram

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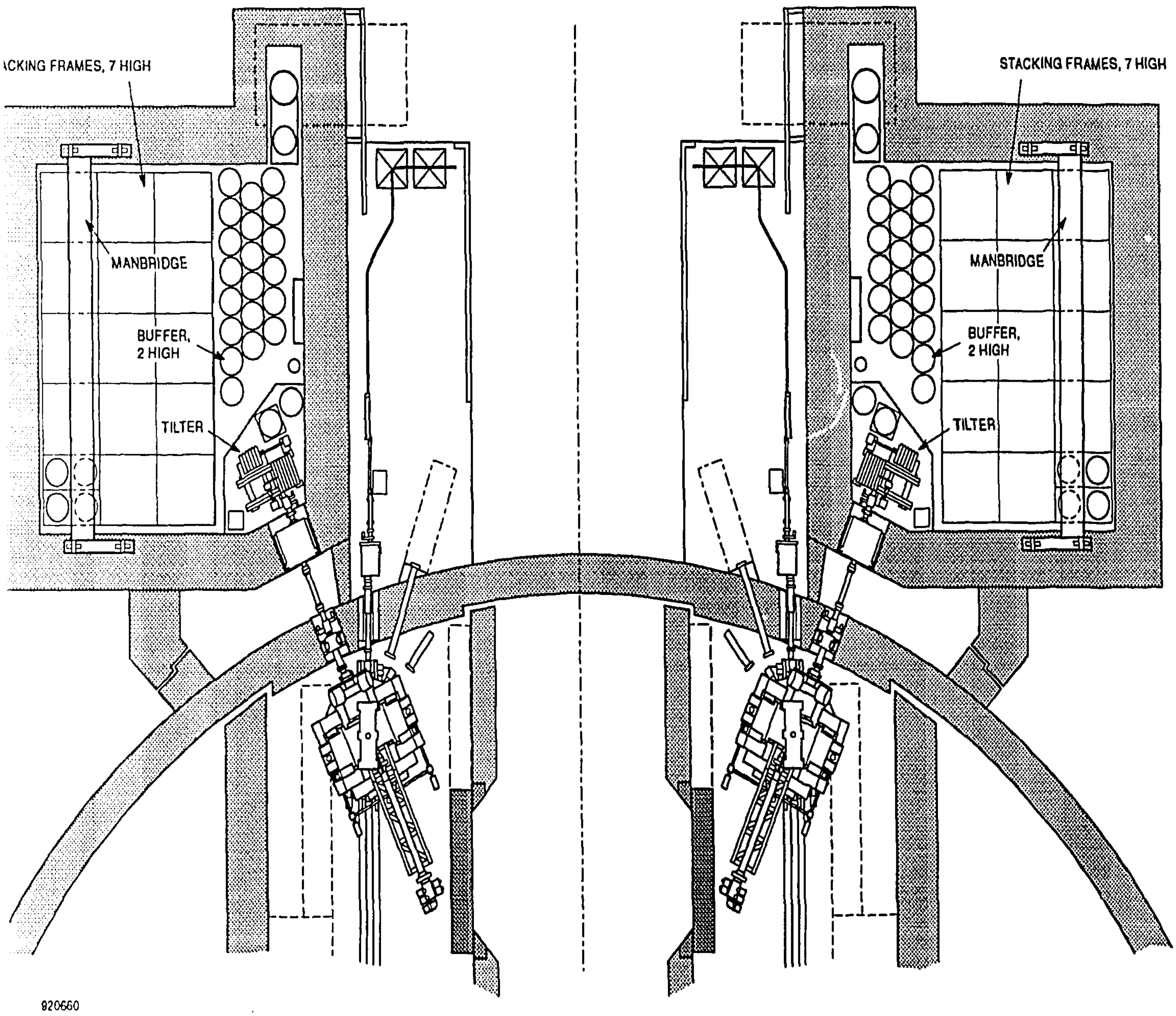

Figure 2.8
Fuel Transfer System

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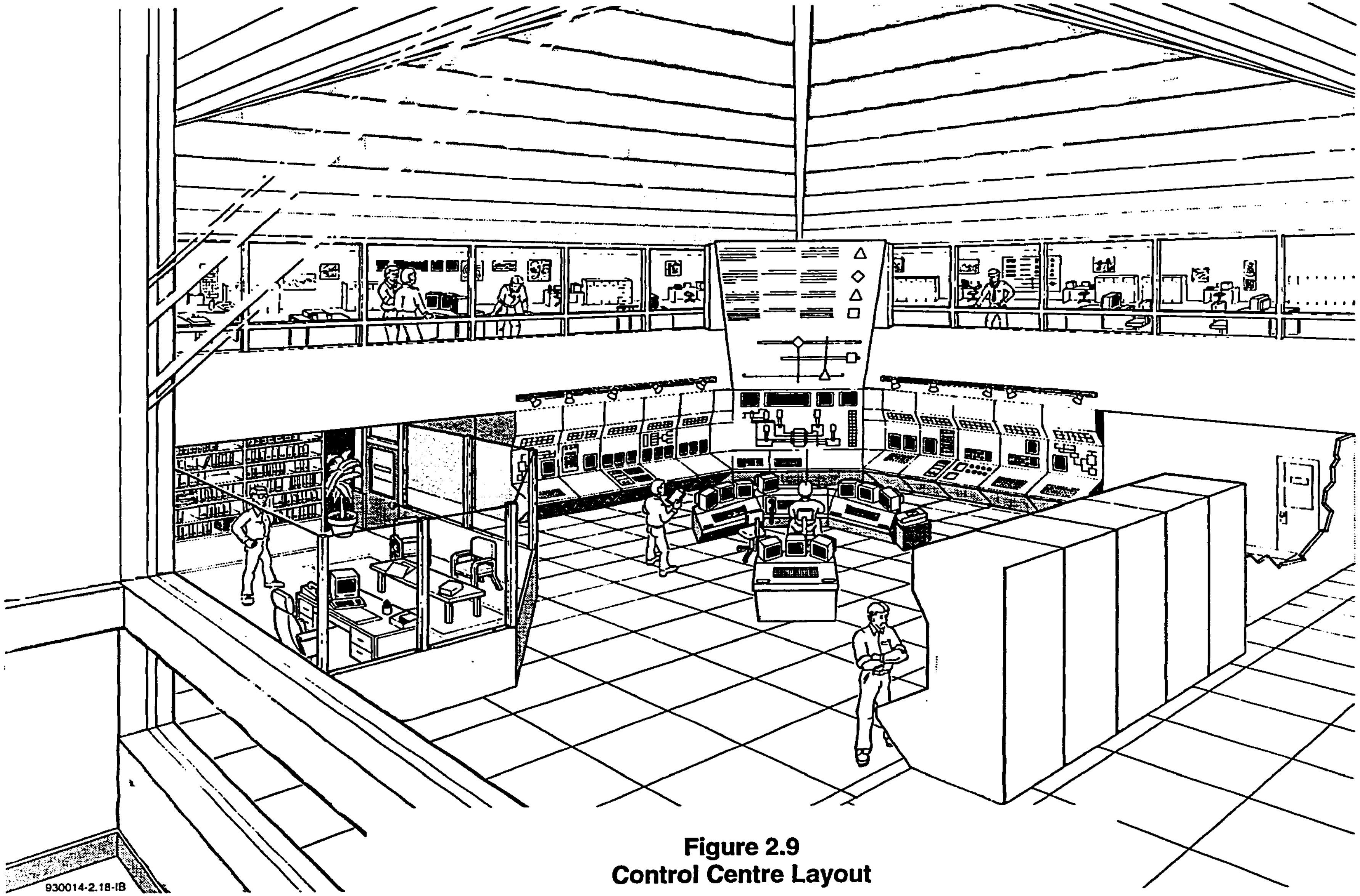

Figure 2.9
Control Centre Layout

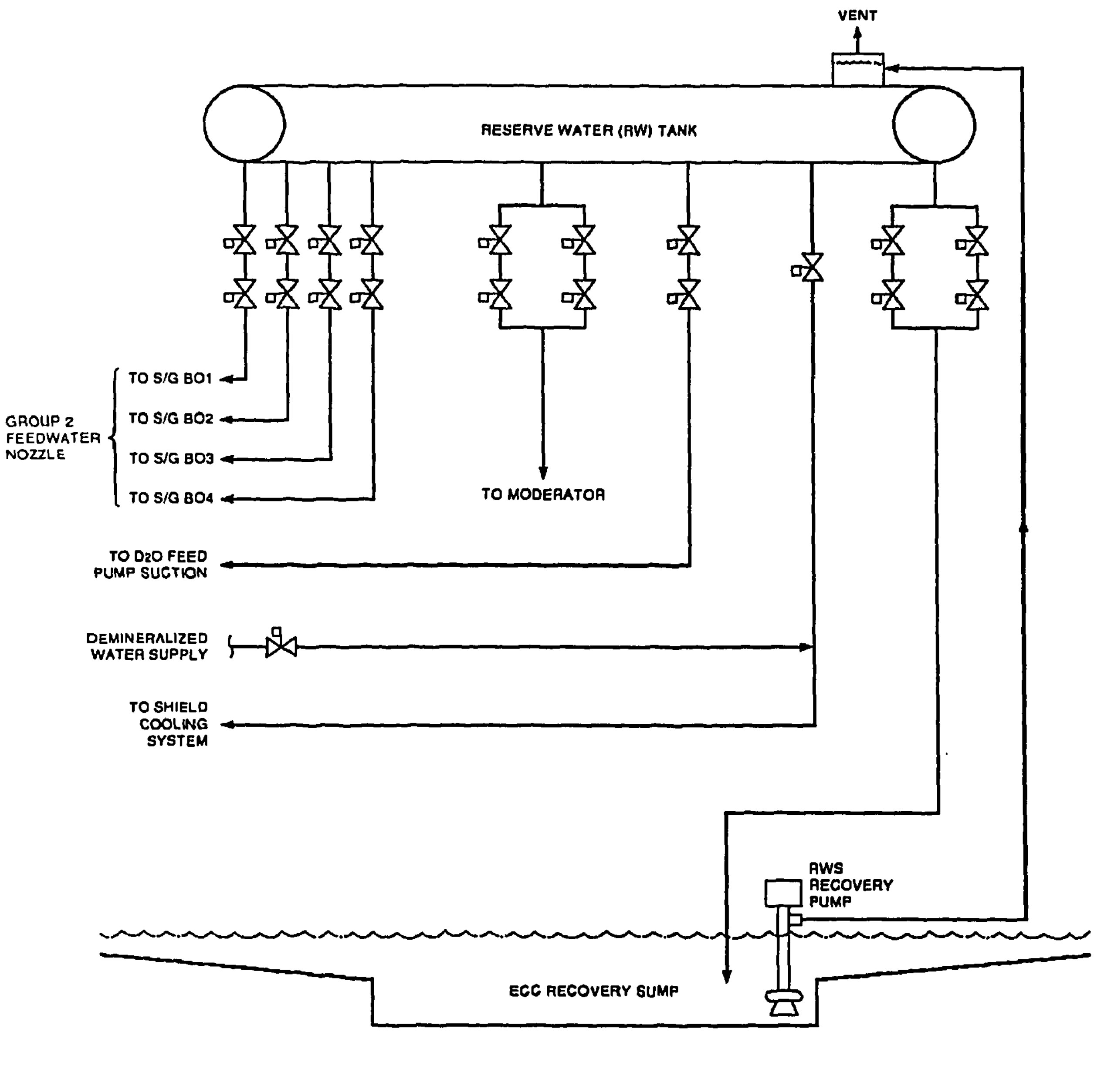

Figure 3.1
Reserve Water System

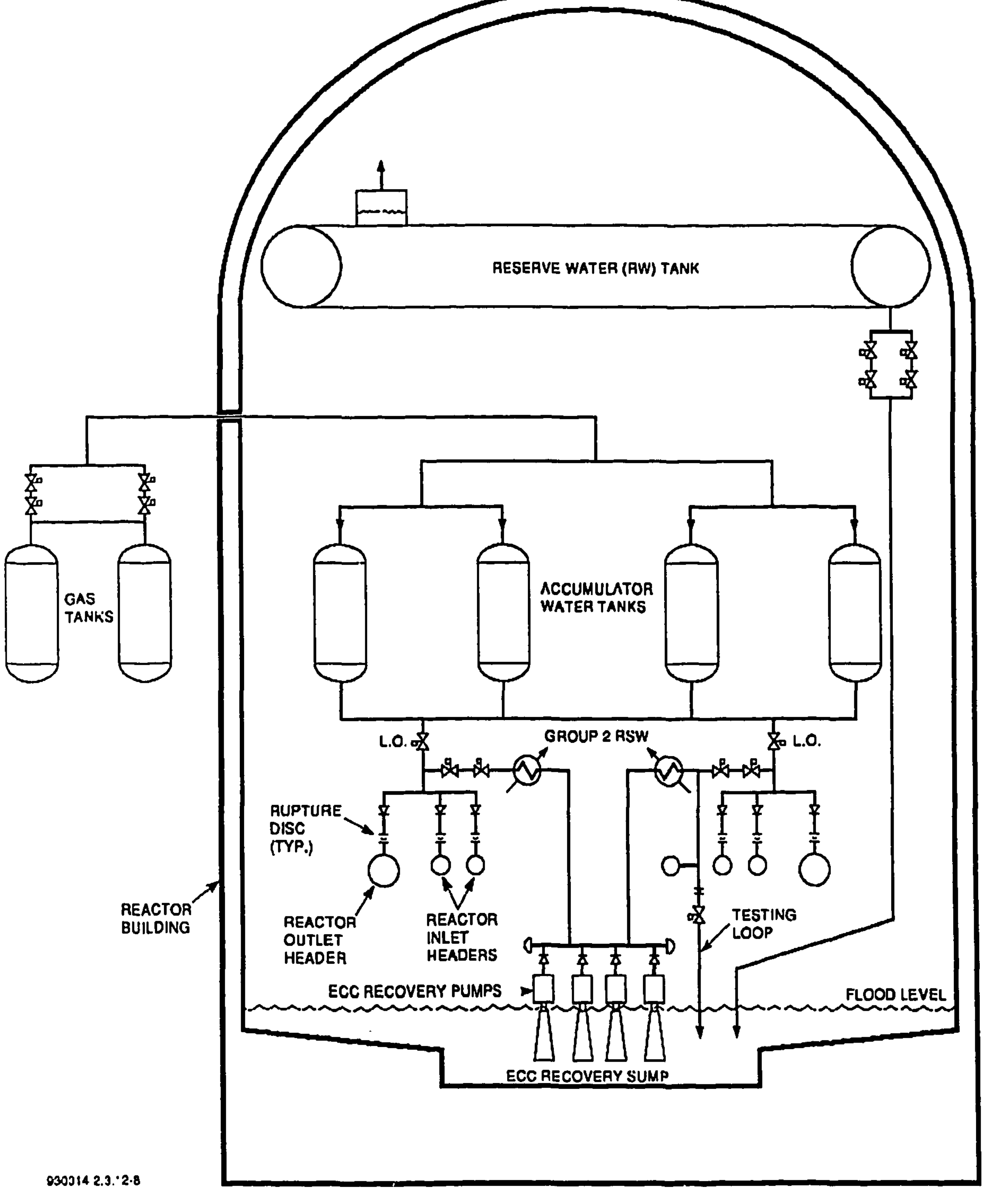

Figure 3.2
Emergency Core Cooling System

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