Technical Meeting No. 1/3

The Reference Plant Design
an Optimized PWR Plant Layout

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RESUME.

Se basant sur une expérience importante accumulée dans le domaine de la production d'énergie par centrale nucléaire, la Westinghouse a entrepris l'étude d'unités complètes, optimisées et standardisées tant au point de vue équipements et circuits qu'au point de vue structures.

La conception d'ensemble de ces centrales est décrite, montrant leur intérêt aux points de vue construction, exploitation, économie et entretien.

SUMMARY.

Having gained valuable experience in the whole field of nuclear power generation, Westinghouse has undertaken the design of complete nuclear plants with particular attention given to the optimization and standardization of equipment, systems, structures and layout.

The general layout of these optimized units is described, as are the benefits of this concept with regard to construction, operation, economy and maintenance.

ZUSAMMENFASSUNG.


Die Gesamtauslegung dieser optimierten Anlage wird beschrieben; ebenso wird eingegangen auf die Vorteile dieses Konzepts bezüglich Bauablauf, Betrieb, Wirtschaftlichkeit und Unterhaltung.
1. INTRODUCTION.

There are, today, more than 60 Westinghouse Pressurized Water Reactor power plants in operation or in various stages of design or construction. Comparison of different plants equipped with Westinghouse Reactors shows that, although the NSSS components have been similar, the resultant overall designs have been completely different in respect of balance of plant designs, construction, licensing problems, and overall schedules.

The essential part of a PWR plant consists of 4 functional buildings; the reactor or containment building, the reactor auxiliary building, the fuel handling building, and the turbine building. In addition, each plant has an administrative building, a maintenance building, and an intake structure. Connection to the electrical grid is made through a switchyard.

The four main buildings perform the same essential functions on every site, yet a significant portion of the capital expenditure for nuclear power plant is spent in developing new designs, new arrangements, as well as the necessary new license and safety evaluations, new construction procedures and new operating procedures. The result is that the benefits of standardization are missed in important areas of the nuclear plant.
To remedy the situation, Westinghouse has undertaken the design of an optimized total reference plant which, when combined with our mature NSSS, provides enhanced assurance of predictable construction schedules at the lowest possible cost. The reference plant incorporates our past experience, with particular emphasis on that gained through our turnkey efforts, into an optimized cost-evaluated design consistent with current technology.

Specific emphasis has been placed on solving certain problems that may arise during construction, startup and operation of large PWR plants now on line. The major goals in mind have been:

- to ease the construction schedule.
- to reduce known operating problems.
- to assure optimum control of radiation and contamination levels.
- to improve the degree of separation of both mechanical and electrical safety features.
- to achieve optimum ease of operation.

2. GENERAL LAYOUT OF THE PLANT - THE PLOT PLAN.

An extremely significant feature in the successful design of any plant is the arrangement of the buildings that make up the total plant. They should comprise an efficient work place, combined with ease of maintenance, minimum construction problems, and they should, of course, provide the best possible plant for the least total cost.
In order to study this problem, we have defined the various functions of the plant into building segments or categories. These functions or categories have been rated according to:

1. Function.
2. Safety.
3. Radiation and contamination control.
4. Plant maintenance.
5. Plant operation.
6. Future expansion of individual buildings.
7. Future expansion of the plant and
8. Future expansion of the total site to include additional plants.

It is important to note that no single one of the above criteria is permitted to dictate the design, as would be the case where a plant site has been preselected.

The plant arrangement (Fig.1) presented here offers the possibility of building two plants which are identical, with a common service building serving both plants. It should be noted that the plants can be built individually, rather than combined, if the twin plant arrangement is not acceptable to a particular utility. This plot plan provides for maximum construction accessibility to all areas of the plant, even when constructing the second unit. Thus, movement of heavy equipment, building material, and construction manpower is not restricted by the existence of Unit №1 during the construction of Unit №2 main equipment.
A significant feature in the flexibility of the arrangement of the two plants is the inclusion of a service building with a pipe tunnel running directly beneath it, connecting the auxiliary building of Unit N°1 to the auxiliary building of Unit N°2. The pipe tunnel permits the connection of identical systems in the two plants, so as to increase service flexibility in either plant. This is particularly valuable at times when one plant is experiencing difficulty due either to malfunction or to peak loading of auxiliary equipment. This tunnel also serves to combine functions from the turbine building of one plant to the other.

The location of the turbine building has been studied with respect to condenser circulating water, main power transmission, and personnel access to the building. The following conclusions have been reached:

- the main transmission lines are routed directly from the transformers to the switchyard and no unusual problems are encountered with this layout.
- the circulating water intake and discharge for the turbine buildings are compatible for intake and discharge channel structures.
- the distance separating the turbine buildings is a minimum of 57 meters, which is consistent with easy communication, and access, from one turbine building to the other by plant operators.

The economy of design effort, and the savings of pipe, volume of concrete, excavation, and power and control cables, are distinct advantages of the plant layout proposed here.
3. MAIN BUILDINGS.

3.1. Reactor Building.

The major structure of a nuclear power plant is the reactor building. It must be designed to protect the environment against irradiation and contamination under all circumstances, and to assure a stable support structure for the primary components.

The internal diameter of the contained structure has been sized on a detailed analysis of areas required to permit adequacy in placing of the reactor coolant system, structural support and shielding. It also provides sufficient dismantling and laydown space for refueling, maintenance, and in-service inspection operations for component parts and tools.

The minimum height of the contained structure, once the internal diameter is established, is considered to provide sufficient free volume to limit design pressure within the shell to an acceptable value, and to provide adequate height for the hook of the polar crane to erect the steam generators at the time of construction.

The arrangement shown in fig.2 and 3 has been selected:
- to provide a compact layout of the primary system and shielding. This minimizes pipe loads and improves the stability of the reactor coolant system.
- to assure adequate strength of the structures, equipment supports and pipe restraints. The failure of any pipe or equipment must not propagate to other systems.
to protect the containment lining against any possible missiles or pipe whipping.
- to permit safe, accurate and fast fuel handling and refueling operations.

Moreover, erection of all the containment components has been analyzed in the light of past experience, with particular attention given to locating the construction opening and various hatches, to sizing the polar crane bridge and to planning the sequence of operation to allow the erection of any component and interior concrete. This is, of course, of major importance in keeping a project on schedule, despite unavoidable delays in the delivery of one component.

3.2. Fuel Building.

The main function of the fuel building is to facilitate receiving, inspecting, and storing the fuel elements before their loading into the core, and during the decay period which precedes their shipment to the reprocessing plant.
The fuel building must, therefore, be designed to provide:
- a safe storage of the elements, with adequate cooling under all circumstances.
- easy and safe handling of fuel within the buildings, and between storage racks and the reactor.
- easy and safe receipt, and shipment, of fuel.

The fuel storage area is completely isolated from the rest of the plant and from the outside environment, and its ventilation system is independant.
The transfer of the fuel elements between the containment and the fuel building is accomplished under water through a tube which acts as a lock and assures complete separation between the two buildings. The receiving and shipping area, annexed to the fuel building, can be tailored to fit the site access layout and specific requirements of the plant owner. The new fuel elements are transferred into the fuel building through an air-tight door. Special attention has been given to the spent-fuel cask handling. The movement of the heavy cask is restricted to areas free of equipment, and the loading cell is designed to avoid complete immersion of the cask. Such design reduces almost to zero cask cleaning and decontamination. The layout of the fuel building is shown on Fig. 3 to 6.

3.3. Reactor Auxiliary Building.

The auxiliary building is a concrete structure consisting of two main floor levels which house the mechanical and electrical equipment required:

- to control the chemistry of the primary water.
- to provide safe shutdown and cooling of the reactor under all circumstances.
- to process the radioactive waste produced by the plant operation.

The design of the reactor auxiliary building has been established with the following guidelines:

- to locate safeguard and vital systems as close as possible to the containment and, on the lower floors, to assure good protection against external missiles, and to minimize the spread of potential contamination.
- to arrange the equipment by functional groups, minimizing the connection length for pipes and wires.
- to provide complete separation between the redundant circuits in order to avoid any failure propagation. Special attention has been given to flooding hazards resulting from a pipe rupture, and to fire hazards.
- to provide easy access to all equipment, with minimum radiation hazards for the personnel.
- to facilitate maintenance, with the maximum of safety for personnel.
- to segregate, when feasible, potentially radioactive, or contaminated, equipment from the non-radioactive equipment.

The arrangement of equipment and structures inside the Reactor Auxiliary Building is shown on Fig.4 to 6.

Floors are of the slab design, a proven inexpensive and simple construction method. Levels are evenly spaced, permitting maximum use of the floor-to-ceiling area. Equipment shield walls, required to reduce personnel radiation exposure, are shared, thus reducing the total number of walls required. These walls vary in thickness, depending on the radiation level emitted by the equipment. Second floor walls are placed directly over first floor walls, utilizing their support value, thus eliminating the need for a highly reinforced second floor slab which would otherwise be required to support these walls.
Pipe chases criss-cross the building between floor levels, allowing pipes carrying radioactive materials from both elevations to be run in shielded areas. These chases extend to the circular penetration chase around the containment and serve to reduce the overall building radiation level significantly. Penetrations into the containment are spread over a two-level, 105 degree arc eliminating a congested penetration area. This technique of using pipe chases accomplishes two major objectives:

1) It keeps the pipe out of the ceiling, where it could become a radiation problem, in addition to interfering with the routing of electrical cable and heating and ventilation ductwork.

2) Valves are made accessible, but are shielded from the pipe to as large an extent as possible while keeping them close to the pipe, thus minimizing undesirable "dead legs".

The layout of the equipment is system-oriented, which reduces pipe-run lengths and allows system maintenance to be performed more expeditiously.

Filters and demineralizers are aligned in banks to facilitate maintenance operations. Filters are aligned and served by a single monorail. They can be removed and replaced and the contaminated cartridge sent directly to the drumming station with minimum contamination and irradiation hazard.
Demineralizers are positioned such that, if their removal is required, the cavity can be shielded by flooding with water, the connecting pipes cut, and the demineralizer removed by access through the roof. Normally clean equipment that could become contaminated by various radioactivity sources is segregated from such sources. Examples of this segregation are the inclusion of all control and electrical equipment including the control room, switchyard and relaying in an area sealed from the mechanical area by controlled access and seal walls.

In addition, the mechanical portions of this building are separated into clean and potentially contaminated areas. Examples of this are:

Separation of the auxiliary feedwater pumps, air compressors, and complete raw water or service water system, from the contaminated area of the building. There is also complete separation of the raw water piping to prevent a potential pipe-break in this system from feeding raw water into the auxiliary building. A seal wall separates the raw-water pipes from the main auxiliary building so that any raw-water pipe-break drains back into the intake, instead of into the building.

Separation of safeguard trains is, in general, maintained by keeping a concrete floor or wall between the two parallel safeguard trains, or by enclosing the cables in enclosed conduits or trays.
This separation is accomplished by routing one train on one floor of the auxiliary building and its redundant train on the other floor. This is done to minimize safely-related cable trains from interfering with each other on one floor. This layout assures effective physical train separation, and provides an added level of quality assurance that the constructor can use in controlling cable installation.

3.4. Service Building.

The various rooms needed for the operating and maintenance crew, visitors, offices, laboratories, health physics rooms, control access gate as well as laundry, store rooms, cafeteria and lockers are arranged on the third floor. Here also, the separation of clean-controlled areas is maintained, the control gate being located in the vicinity of the containment main personnel air-lock. When two units are built, the run ways are arranged so that these service rooms are common to the two plants. This area has been sized large enough to permit the customer to arrange the area to meet his individual needs. A typical arrangement is indicated on Fig.7

3.5. Secondary Building.

The secondary building, which houses the turbine-generator group and the steam systems, is functionally connected to the nuclear steam supply system through an intermediate structure.
The arrangement of the building selected in the Reference Plant minimizes interactions between primary and secondary structures. This gives the architect-engineer freedom to tailor the secondary systems to the particular equipment selected in the design of the system and to the local requirements of the plant.

4. CONCLUSION.

The standardization of not only the equipment but also the layout of the systems and the plant main structures is a major advance in the development of the use of nuclear energy.

This program, which is based on more than 14 years of experience of the Westinghouse Nuclear Energy Systems Divisions, will provide a complete defined plant at the beginning of the entire project schedule, including a total plant equipment schedule and bill of material. The design is standardized for minimum cost and scheduled with maximum operation benefits.

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The following 5 x 5 cm slides will be used in the presentation of this paper:

2. Twin Units Plot Plan.
3. Piping Interface.
4. Electrical Interface.
5. Reference Plant Containment.
6. Reference Plant 1st floor.
7. Reference Plant 2nd floor.
8. Reference Plant - Service Building.
FIG. 1 PLAN GENERAL ARRANGEMENT

KEY

1 Containment
2 Fuel Building
3 Auxiliary Building Mechanical
4 Auxiliary Building Electrical
5 Diesel Building
6 Turbine Building

FIG. 2 REACTOR BUILDING
Fig. 3 Reactor Building

Fig. 4 Plan View - 1st. Floor