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THE IRIS GENERAL PLANT ARRANGEMENT

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ABSTRACT

IRIS (International Reactor Innovative and Secure) is a light water cooled, 335 MWe power reactor which is being designed by an international consortium as part of the US DOE NERI Program. IRIS features an integral reactor vessel that contains all the major reactor coolant system components including the reactor core, the coolant pumps, the steam generators and the pressurizer. This integral design approach eliminates the large coolant loop piping, and thus eliminates large loss-of-coolant accidents (LOCAs) as well as the individual component pressure vessels and supports. In addition, IRIS is being designed with a long life core and enhanced safety to address the requirements defined by the US DOE for Generation IV reactors. Bechtel, with Westinghouse consultation, has performed a layout study of the IRIS plant and this paper will discuss the results of this design effort.

INTRODUCTION

A study on the general arrangement of a complete IRIS electrical power plant was performed in response to a request by Dominion Resources to provide IRIS input to a generic early site permit siting evaluation they began conducting in the summer of 2001 under a DOE RFI. The IRIS plant site plot plans and the preliminary general arrangement drawings developed in this study were largely based on the assumption that the IRIS control room, emergency power supply batteries, reactor control and protection cabinets and switchgear areas would be similar in size to the corresponding areas provided in the AP600 plant design. As such, it is expected that more detailed layout development effort will result in a significant reduction in the IRIS building volumes and the overall plant footprint. This layout does however provide a starting point for future optimization and illustrates the integration of the small, spherical IRIS containment with the fuel handling area and innovative safety systems into an overall plant arrangement. Two plant arrangements were considered in this initial IRIS site layout study; three independent single unit plants, and a twin-unit arrangement with two independent plants. The three single unit plants provide a net electrical output of 1005 MW and the two twin-units provide a net electrical output of 1370 MW, in order to meet the request for 1000 MWe minimum output.

SITE PLAN

Single unit and twin unit arrangements were investigated. The plot plan for these options show three independent single units (Figure 1) and two independent twin unit (Figure 2) arrangement options. The preliminary arrangement of the IRIS

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units features auxiliary building (Item 1) on a seismic basemat at –13 meters (-42'-8"). The auxiliary building contains the containment/shield area (Item 2) and the fuel handling area (Item 3), and also contains the control room and all safety related equipment. The plant grade level is at 0 meters. The fuel handling area occupies the southern portion of the auxiliary building and extends over the containment such that the containment and RV closure heads can be lifted vertically and stored in the fuel building during refueling operations.

Independent Multiple Single Unit Arrangement

The three single unit arrangement (Figure 1) shows three independent IRIS units each providing 335 MWe capacity. This arrangement is based on the assumption that the units would be constructed in series in a "slide-along" manner. The units would be started up in sequence as construction, pre-operation testing, fuel load, and startup testing are all completed for a unit. The completed unit could be operated while construction of the subsequent units was still in progress by establishing a temporary exclusion zone between the operating unit(s), and the unit(s) under construction. This arrangement and construction sequencing is aimed at minimizing the construction time of a unit and at providing the utility with generating capability as soon as possible. Other advantages of this slide-along construction method are envisioned to be shorter construction time for the second and third units, by taking advantage of the experience of the work force. In order to accomplish this series construction, the units are spaced sufficiently apart so that the exclusion zone associated with the operating unit(s) can be established.

However, it is not at all certain whether the above advantages are actually preferable to lower capital costs and more compact site obtainable through sharing of auxiliary systems among the three units. This is not a specific IRIS issue, but it is common to all modular plants.

The overall nuclear related exclusion area as currently shown has a north–south dimension of 332 meters (1090'), with the switchyard located north of the exclusion fencing. The site east-west dimension is 489 meters (1605').

Each IRIS single unit arrangement includes the following major building structures (refer to Figure 1):

Auxiliary Building, Item 1

The IRIS auxiliary building encompasses the containment and shield as well as the fuel handling facilities and equipment and is founded on a common basemat with the containment/shield. It also contains the typical auxiliary building features including the main control room, steam and feed water piping and isolation valve room, safe shutdown panel, and all safety related equipment including the safety related instrumentation and control system, and batteries for safety grade electrical power. The dimensions of the auxiliary building are 50 x 4' meters (164' x 134.5') and the building extends from the basemat (-13 meters) to a roof elevation of +20 meters. The fuel handling area (Item 2) of the auxiliary building extends a portion of the south side an additional 8 meters and has a roof elevation at +42 meters.

Containment and Shield Area, Item 2

The IRIS spherical steel containment is 25 meters (82') in diameter and is surrounded by a cylindrical concrete shield structure. This cylindrical shield has an OD of 30 meters (98'-5") and extends from the basemat at elevation –13 meters to +13 meters. This +13 meters elevation is the elevation of the bottom of the refueling cavity.

Fuel Handling Area, Item 3

The fuel handling area is that portion of the auxiliary building that contains the spent fuel pool, new fuel storage area, the refueling cavity above the containment and reactor vessel closure heads, the spent fuel cask loading and washdown pits, the refueling machine, the heavy lift crane for removing and installing the closure heads and reactor internals, and a rail-car bay. This fuel handling operating floor is located at elevation +20.5 meters, and the roof elevation is at +42 meters. The fuel handling area footprint is 38 x 25 meters (125' x 82').

Turbine Building, Item 4

The IRIS turbine building contains equipment associated with the power plant steam and feed water systems and power generation equipment. It is a non-seismic building and contains no safety related equipment. The turbine and generator have been sized based on the 1000 MWt (335 MWe) reactor power. The building dimensions are 80 X 36 meters (260' X 118').

Annex Building, Item 5

The IRIS annex building is a non-seismic, non-safety related structure that houses access control, health physics, technical support center, and non-safety related equipment. This building is constructed at grade and its dimensions are 84 x 15 meters (275' X 50').

Multiple Twin-Unit Arrangement

The two twin-unit arrangement (Figure 2) shows two independent, twin unit reactors. This arrangement is aimed at maximizing shared components between the two units comprising one twin-unit, yet maintaining the ability to initiate operation of a completed twin-unit while construction of subsequent twins proceeds in a "slide-along" manner. Each twin-unit is independent of the subsequent twin(s). Within a twin-unit most systems, functions, and physical facilities are shared including: (back to back) control rooms, fuel handling area with refueling machine and spent fuel pit and cask loading facility, radwaste treatment, and support systems. Within the twin-unit, separate safety grade power supplies and protection cabinets and switchgear, and systems are maintained for each reactor. A common turbine building is provided with two T/G sets positioned with the generators at the facing ends.

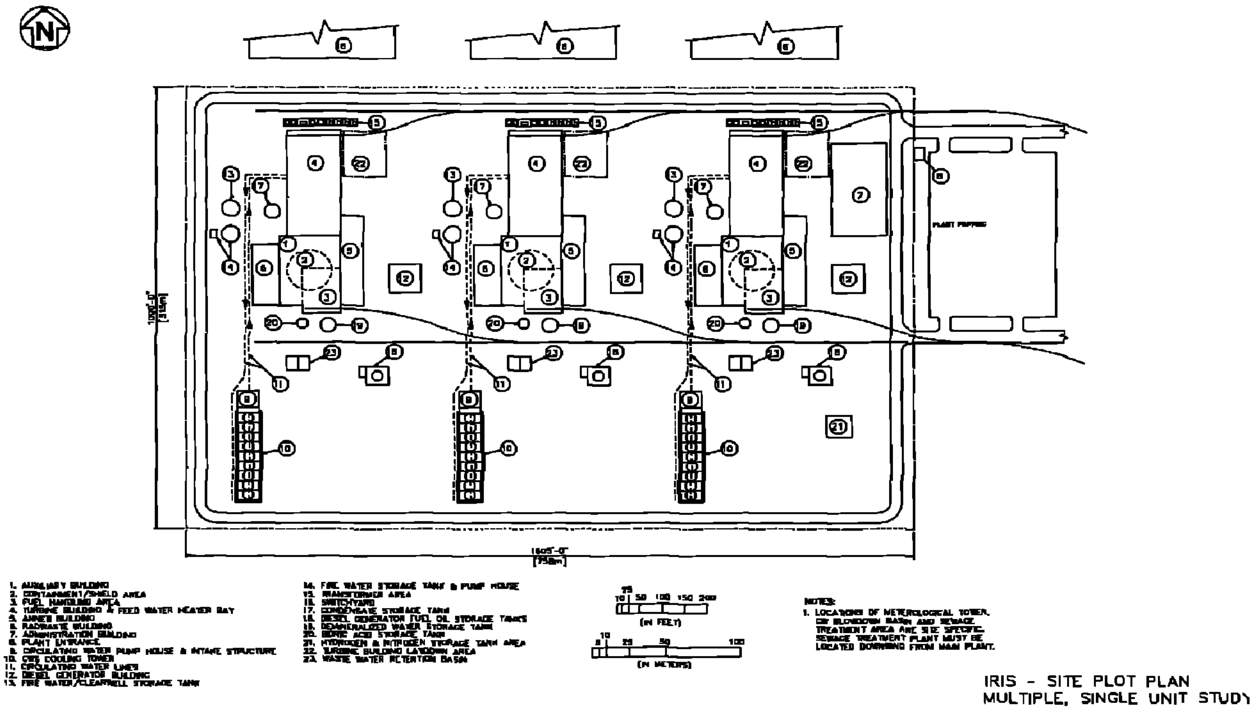

Figure 1 IRIS – Multiple, Single Unit Site Plot Plan

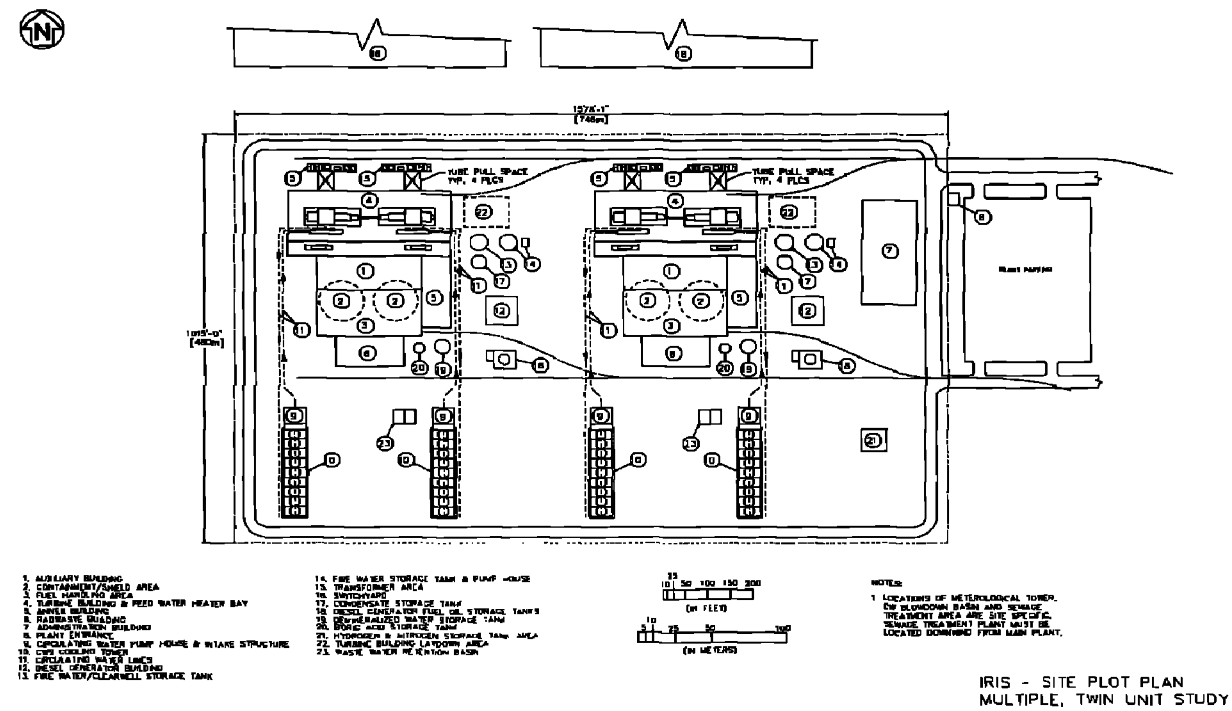

Figure 2 IRIS Multiple, Twin Unit Site Plot Plan

The overall site nuclear related exclusion area with two twin-units as currently shown has a north–south dimension of 309 meters (1015'), with the switch yard located north of the exclusion fencing. The site east-west dimension is 481 meters (1578').

Note that this arrangement study will be the basis for continued optimization of the IRIS plant aimed at reducing the plant building volumes and the overall plant foot-print. Potential optimizations will include evaluations on increasing the amount of shared equipment between units with the goal of establishing a single, centralized, control and protection building for all the units on a given site.

The IRIS twin unit arrangement includes the following major building structures (refer to Figure 2):

Auxiliary Building, Item 1

The IRIS twin-unit auxiliary building encompasses the two containment and shield structures as well as the shared fuel handling facilities and equipment, all of which are on a common basemat. It also contains the typical auxiliary building features including the shared back-to-back main control room, a steam and feed water piping and isolation valve room for each reactor, safe shutdown panels, and all safety related equipment including batteries for electrical power. Separation between the safety related equipment for the two reactors is maintained throughout the building with the only access to both units via the main control room area. The dimensions of the twin-unit auxiliary building are 60 X 70 meters (200 X 250') and the building extends from the basemat (- 13 meters) to a roof elevation of 42 meters.

Containment and Shield Area, Item 2

This plant arrangement places two containments and their surrounding shields on a common basemat. Each of these containments and the surrounding cylindrical concrete shield are identical to a single unit. The shield structures surrounding the containment are spaced sufficiently apart in order to provide space for containment penetrations and access between the north and south sides of the auxiliary building.

Fuel Handling Area, Item 3

The twin-unit IRIS arrangement incorporates a single fuel handling area that is shared between the two reactors. This area utilizes a single refueling machine that can traverse over either units' refueling cavity. Also shared is a centrally located spent fuel storage pool, spent full pit cask loading and wash-down pit, and a single heavy lift overhead crane. Sufficient laydown area is provided for both unit's containment and reactor vessel closure heads.

Turbine Building, Item 4

The IRIS twin-unit turbine building contains equipment associated with the power plant steam and feed water systems and power generation equipment. It is a non-seismic building and contains no safety related equipment. It contains two turbine and generators that have been sized based on the 2000 MWt (670 MWe) output of both the reactors. The two T/G's are positioned end to end with the generators at facing ends. The building dimensions are 111 x 48 meters (364' x 157').

Annex Building, Item 5

The twin-unit IRIS annex building is a non-seismic, non-safety related structure that houses access control for both the auxiliary building and turbine building, health physics, technical support center, and non-safety related equipment. This building is constructed at grade and its dimensions are 55 x 20 meters (180' x 66') with an extension to the turbine building.

GENERAL ARRANGEMENT

A preliminary general arrangement of the single unit IRIS auxiliary building was performed to establish a base-line design for equipment arrangement, separation criteria, fuel building arrangement, refueling scheme, spent fuel pool and spent fuel and cask handling equipment, control room layout, location of the emergency heat removal system and its integration with the main steam and feedwater lines, etc. Below is provided a brief description of the layout features of the IRIS auxiliary building.

Auxiliary Building Elevation View (Refer to Figure 3)

This figure is an elevation view of the IRIS auxiliary building, which illustrates several key features of the IRIS design, including the spherical containment building which has a closure head directly in the top, and the fuel handling area located directly above the containment. With this arrangement, all refueling activities are conducted in the fuel handling area at elevation +20.5 meters and no refueling equipment is located inside the containment. Refueling is accomplished by removing the containment closure head and the reactor vessel closure head, installation of a flange seal between the RV flange and the containment flange, followed by floodup of the refueling cavity (note that a flange seal between the containment vessel flange and the refueling cavity is in place). A single refueling machine located in the fuel building at elevation + 20.5 meters is used to remove fuel from the reactor vessel, to move the fuel to the spent fuel storage pit, and to bring fresh fuel from the storage pit and place it in the reactor vessel. The large gantry crane in the fuel handling area is used for the movement of the containment closure head and reactor vessel closure head to their laydown areas. This crane is also used to remove the reactor vessel upper internals prior to refueling, removal of the lower internals as needed, and to remove the reactor coolant pumps and steam generator modules if required. The overhead crane would also be employed to lower a shielded maintenance/inspection basket into the top of the reactor vessel for the placement of the reactor vessel flange seal rings, or other normal vessel/component maintenance.

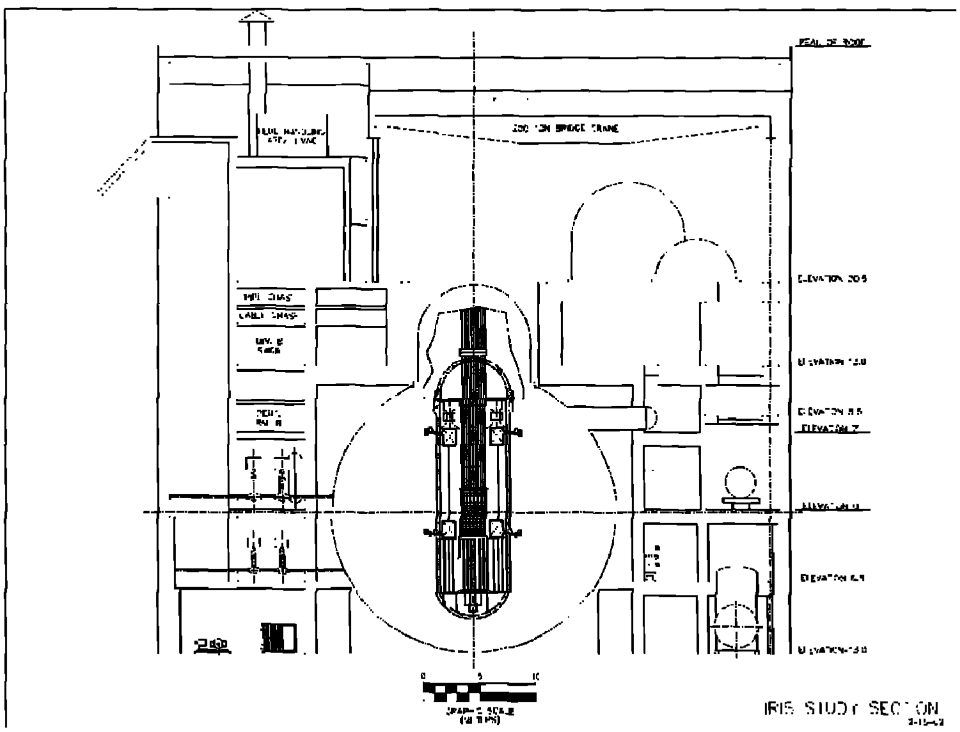

Figure 3 IRIS – Auxiliary Building Elevation View

The refueling cavity above the reactor vessel is flooded using water stored in a refueling water storage tank (RWST) that is located within the auxiliary building at elevation + 20.5 meters, outside the containment vessel. This RWST is shown on the left side of the auxiliary building, just to the right of the steam and feed line penetration room vent. The main steam lines and feedwater lines are shown at elevations 0 meters (grade) and at elevation – 6.5 meters, respectively.

Elevation -13 meters (Refer to Figure 4)

This elevation clearly illustrates that the northern (top of page) half of the auxiliary building contains non-radioactive (clean) electrical equipment, while the southern portion contains radioactive mechanical equipment. This separation between non-radioactive and radioactive equipment is maintained throughout the building's higher elevations. The north half of the –13 meter elevation is devoted to the batteries and their support equipment that provide the safety-grade electrical power for monitoring the plant parameters, actuating safety related equipment, and powering the main control room. This portion of the building contains two of four battery power divisions, and the next higher elevation contains the remaining two divisions. Separate access paths to the two separate divisions are provided. A normally closed, emergency egress path is provided between the two separated divisions, that is only used in the event the normal access/egress is not usable.

The south half of the building contains normally used mechanical equipment including the normal residual heat removal pumps and heat exchangers, the reactor makeup pumps, and liquid radwaste treatment and storage tanks. Two access/egress paths are provided to this portion of the building.

Elevation +20.5 meters (Refer to Figure 5)

This elevation is the operating floor elevation for the fuel handling and refueling activities. At the west wall, over the containment are the rails for the refueling machine which can traverse over the refueling cavity above the containment and reactor vessel closure heads and the spent fuel pit and spent fuel cask loading area. The east side of the building provides large laydown areas for storing the containment closure head, and the reactor vessel upper head package. The building area over the containment closure heads and including the laydown areas is traversed by a large 200 ton capacity, over-head crane that is used to lift these large components. Also the handling of heavy loads by the over-head crane is restricted such that these loads cannot travel over the stored spent fuel or the new fuel storage area. Hatches are provided in the floor of this elevation to provide access to the rail car bay both for new fuel delivered to the site, and for the removal of loaded spent fuel casks. The rail car bay is at the southern end of the fuel handling area at the grade elevation (0 meters).

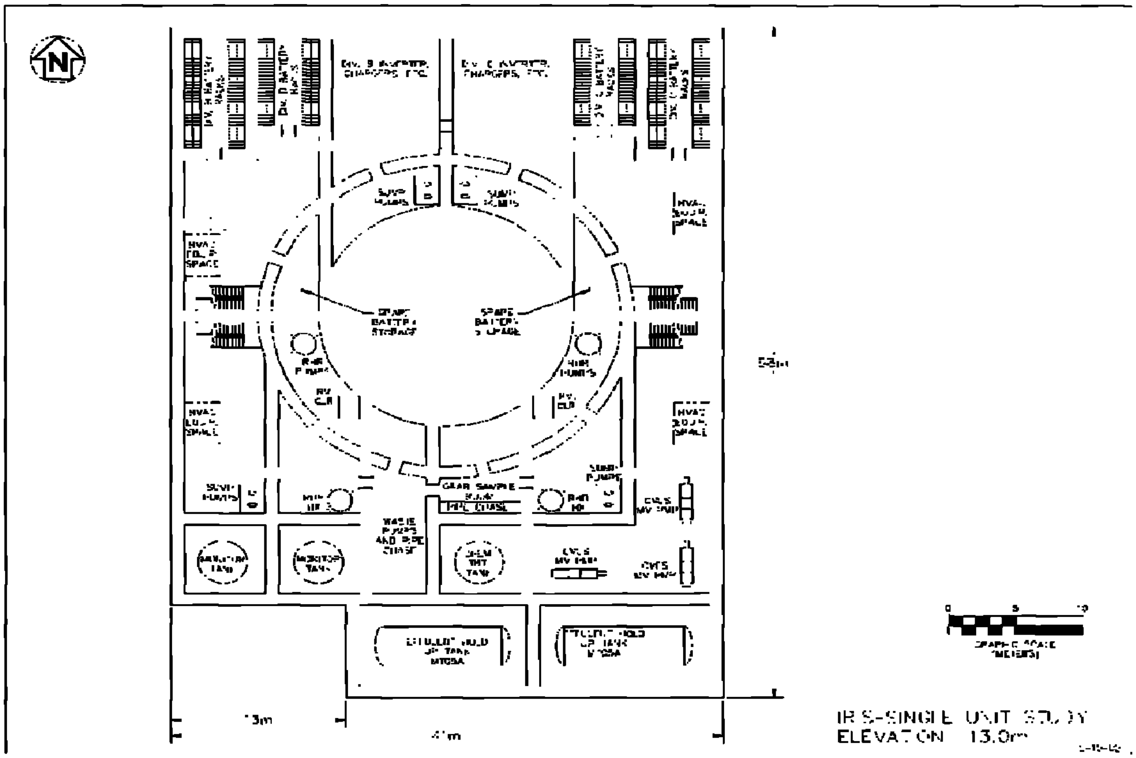

Figure 4 IRIS – Single Unit Plan View at Elevation −13 Meters (Basemat)

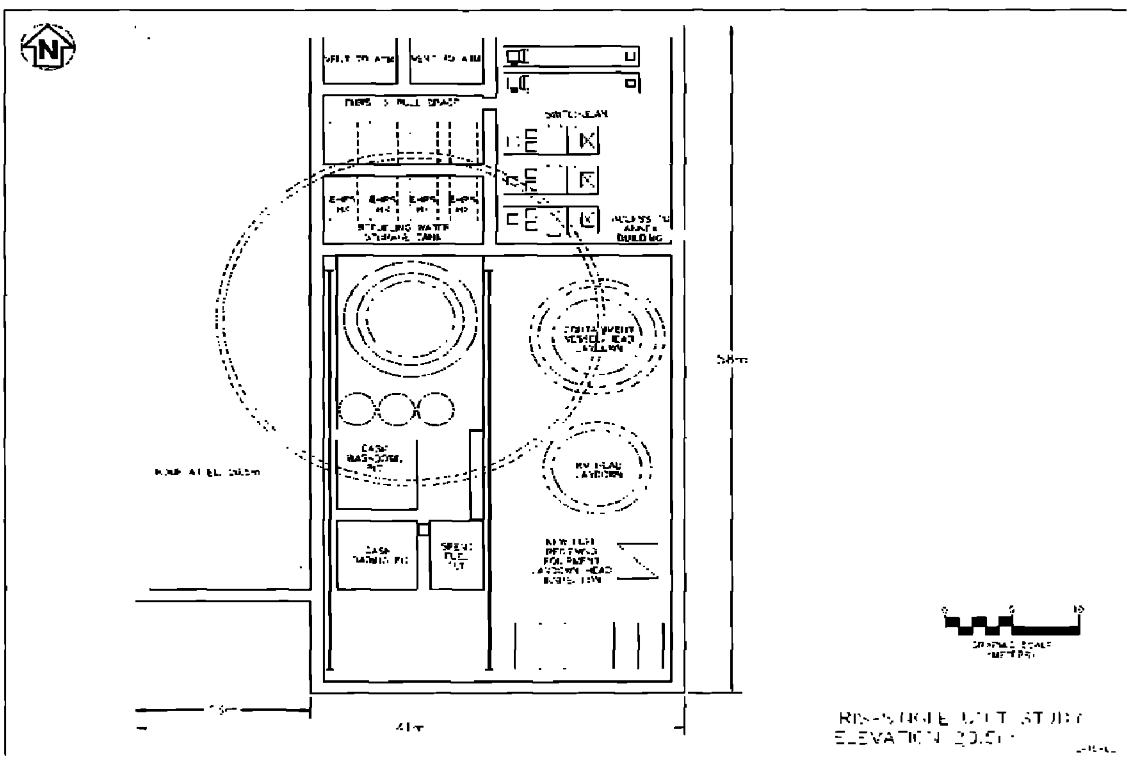

Figure 5 IRIS – Single Unit Plan View at Elevation +20.5 Meters (SFP Operating Floor)

The arrangement of having the over-head crane in the fuel handling area, which also serves as the access to the reactor vessel, allows this crane to be used for the installation and removal of the in-vessel components. This includes the reactor coolant pumps and steam generators in addition to the reactor vessel internals. The large laydown area can be used to do equipment inspection and repairs out of the vessel. Also, equipment can be moved to and from this operating deck level to the rail car or to the grade elevation.

The north side of the building houses the refueling water storage tanks which contains the water needed to fill the refueling cavity above the reactor after the containment closure head and reactor vessel head have been removed. This tank also contains the passive Emergency Heat Removal System (EHRS) heat exchangers that provide the safety grade means of removing heat from the reactor vessel via the in-vessel steam generators. Thus, this water serves also the function of being the safety grade heat sink and therefore the tank is vented to the atmosphere to allow it to steam to the environment in the event that extended heat removal from the reactor vessel is required. This elevation also shows the continuation of the steam and feed water penetration area vents which continue up to elevation +35 meters where they vent to the environment. This portion of the building also contains the normal and emergency HVAC equipment for the main control room located directly below at elevation +13 meters.

CONCLUSION

A preliminary site plot plan and auxiliary building general arrangement has been completed for both a multiple single unit and twin-unit IRIS reactor installation. These preliminary layout studies will be used as the starting point for future optimization studies aimed at reducing the overall IRIS building volumes and costs.

REFERENCES

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