



**NuScale Plant Design Overview**  
**NP-ER-0000-1198**

# **NuScale Plant Design Overview**

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**Note:** The design presented in this document reflects the stage of engineering design at the time of writing. As the engineering effort progresses, information presented is subject to change.

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## 1.0 Executive Summary

The purpose of this document is to provide an introduction to the NuScale plant.

The NuScale plant is an innovative design based on 50 years of practical application of light-water-cooled pressurized-water reactor (PWR) technology. The design incorporates several features that reduce complexity, improve safety, and enhance operability.

The NuScale Plant design philosophy includes:

- a design using proven standard technology.
- a modular nuclear steam supply system, the NSSS module, built with shippable components.
- a below grade containment submerged in a pool of water.
- passive safety systems.
- a two-year fuel cycle.

A 12-unit NuScale power plant takes advantage of the unique features of the NSSS module to provide plant owners with a highly reliable power plant capable of meeting customer energy demands.

Important features of a 12-unit plant

- scalable plant design allows for incremental plant capacity growth
- only eight (8) percent of a 12-unit plant is offline during a NSSS module refueling
- 60-year design plant life
- compact nuclear island
- no operator action required for 72 hours following a postulated accident
- after 72 hours, reactor pool evaporation, pool water boil-off and air cooling of containment provide long-term decay heat removal

NuScale's power plant design will allow plant owners to safely provide reliable electricity production to supply the needs of their customers.

## 2.0 Introduction

The NSSS module is a small, light-water-cooled, PWR. A NuScale power plant will provide customers with a scalable solution that allows a single facility to have up to 12 NSSS modules. The design takes advantage of existing design tools and available nuclear fuel options while leveraging the wealth of knowledge built through more than 50 years of practical application of light-water-cooled PWR technology.

The plant design provides a simple, highly reliable, and safe reactor that can be manufactured in the United States while maximizing the use of existing manufacturing capabilities and qualified "off-the-shelf" components.

The plant design meets these objectives by providing the following:

- reliable and passively safe systems that are simple in design and operation
- safety features that assure a core damage frequency significantly lower than the current light-water reactor fleet
- reactor building designed to prevent penetration of a large commercial aircraft into the building while maintaining spent fuel pool integrity and the containment remains intact, per 10 CFR 50.150
- 60-year design plant life
- significantly reduced construction schedule compared to nuclear plants of a comparable output
- modularization to enable in-shop fabrication of reactor and containment components
- use of readily available conventional nuclear fuel

## 2.1 Abbreviations and Definitions

Table 2-1. Abbreviations

Term	Definition
CVC	Chemical and volume control system
ECCS	Emergency core cooling system
HVAC	Heating ventilation and air conditioning
LOCA	Loss-of-coolant accident
NCIS	Non-safety control instrumentation system
NSSS	Nuclear steam supply system
PWR	Pressurized-water reactor
ROCA	Restricted owner controlled area
RRV	Reactor recirculation valves
RVV	Reactor vent valves
SAS	Shutdown accumulator system
SCIS	Safety control and instrumentation system

## 2.2 NSSS Module

The NSSS module is a nuclear steam supply system (NSSS) composed of a reactor core, a pressurizer, and two steam generators integrated within the reactor pressure vessel and housed in a compact steel containment vessel, as shown in Figure 2-1. The NSSS module's components are fabricated offsite and transported to the plant site.

The NSSS module is designed to operate efficiently at full power conditions using natural circulation as the means of providing core coolant flow, eliminating the need for reactor coolant

pumps. As shown in Figure 3-1, the reactor core is located inside a shroud connected to the hot leg riser. The reactor core heats reactor coolant causing the coolant to flow upward through the riser. When the heated reactor coolant exits the riser, it passes the tubes of the helical coil steam generator, which act as a heat sink. As the reactor coolant passes through the steam generator, it cools, increases in density, and naturally circulates down to the reactor core, where the cycle begins again.

NSSS modules are completely submerged in a reactor pool and protected by passive safety systems. Each NSSS module has a dedicated chemical and volume control system (CVC), emergency core cooling system (ECCS), and decay heat removal system (DHR).

Important features of the NSSS module include

- a small, modular design that allows for incremental refueling outages and system maintenance.
- an integral PWR NSSS that combines the reactor core, steam generator, and pressurizer within the reactor pressure vessel. Unlike a conventional PWR design, this design eliminates the external piping necessary to connect the steam generators and pressurizer to the reactor pressure vessel.
- buoyancy forces that drive natural circulation of the primary coolant, eliminating the need for reactor coolant pumps.
- a reactor pressure vessel housed in a steel containment submerged in water. The water provides an effective passive heat sink for long-term emergency cooling.
- the absence of reactor pressure vessel or containment penetrations below the top of the reactor core.
- a steel containment operated at a deep vacuum eliminating the need for insulation on the reactor pressure vessel.
- a modular design that can be built in a separate manufacturing facility, shipped to the site, and then installed, shortening the overall plant construction time resulting in significantly reduced costs for construction.

### **2.3 NSSS Module Construction**

The NSSS module components are fabricated at an offsite manufacturing facility. Offsite manufacturing allows for the standardization and streamlining of the manufacturing process resulting in higher quality and lower NSSS module cost. Costs are controlled by the efficiency of manufacturing and assembling components offsite.

### **2.4 Safety**

NuScale has achieved a substantial improvement in safety over existing plants through simplicity of design, reliance on passive safety systems, small fuel inventory, and use of additional fission product barriers. The integral design of the NSSS module eliminates external coolant loop piping, which eliminates large-break loss-of-coolant accident (LOCA) scenarios. The availability of passive safety systems for decay heat removal, emergency core cooling, containment heat removal, and control room habitability eliminates the need for external power under accident

conditions. With these passive safety systems, small-break LOCAs do not significantly challenge the safety of the plant. The result is a design with a core damage frequency significantly lower than the current light-water reactor fleet.

The reactor in a NSSS module has a small radioactive source term with less than 4 percent of the fuel inventory of a conventional 1000 MWe nuclear reactor. The amount of radioactive material available for release during a postulated accident is greatly reduced. NSSS modules are housed in a building designed to withstand a 0.5g ZPA earthquake, submerged in a reactor pool, and covered with a biological shield. Although not credited in design basis accident analysis, the reactor building, reactor pool and biological shield provide additional barriers to mitigate the release of radioactive material. The combined result of these features is a design that is extremely safe. See Table 2-2 for a listing of some of the features of a NSSS module.

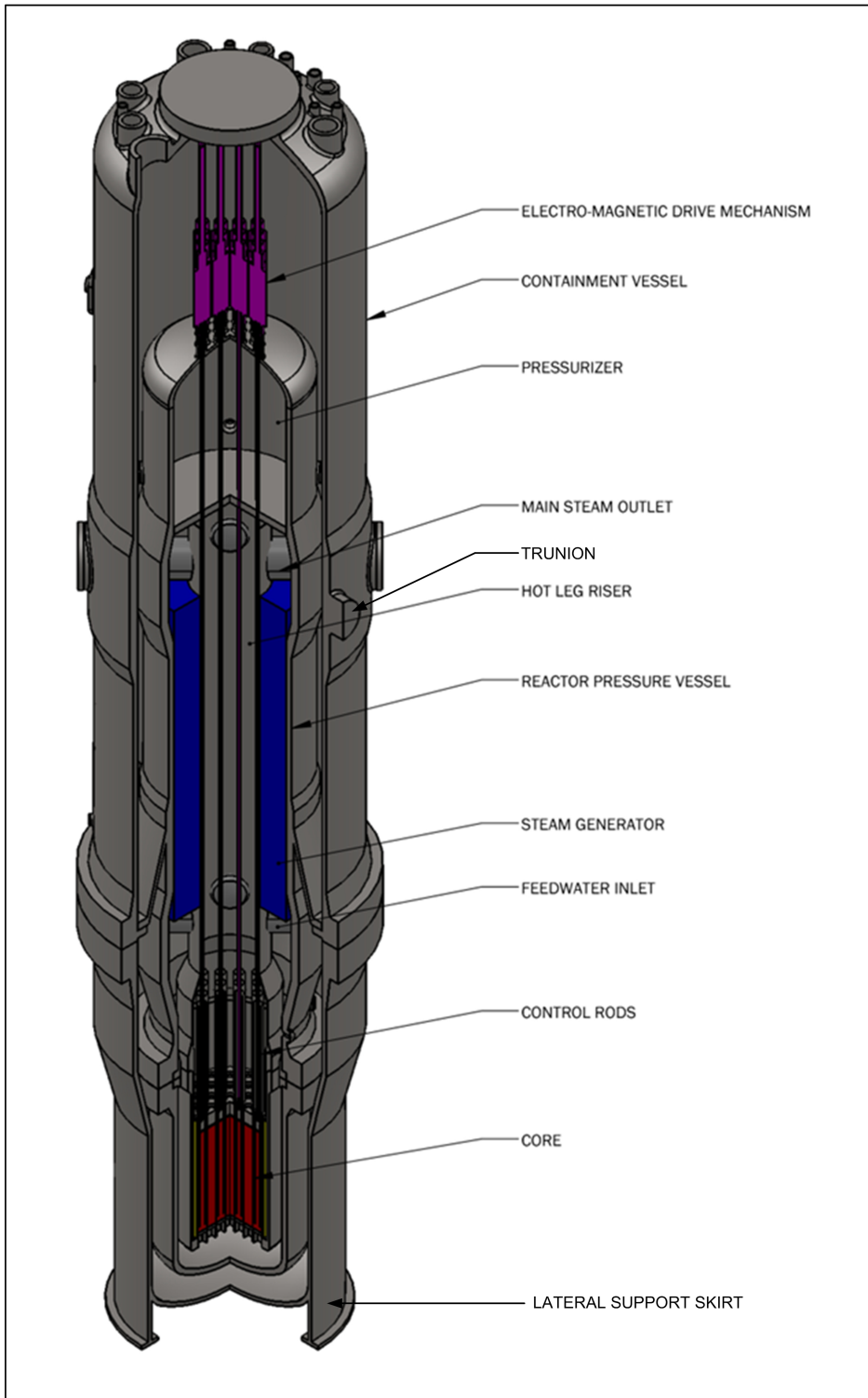


Figure 2-1. Cutaway view of the NSSS module

Table 2-2. Features of a NSSS module

NuScale Design Feature	Primary Impact	Safety
Reactor coolant system integral to the reactor pressure vessel	No large primary coolant piping	Eliminates postulated large-break LOCA spectrum of accidents
Natural convection-cooled core	No reactor coolant pumps	Eliminates reactor coolant pump accidents, shaft breaks, pump seizure, missile generation and pump leaks
Once-through integrated steam generator with feedwater and steam inside the tube.	Steam generator tubes are in compression	Improved steam generator tube integrity with steam generator tube rupture frequency reduced
High design pressure and evacuated containment	All water lost from reactor vessel stays within containment and is returned to reactor vessel by passive means	No postulated design basis small-break LOCA capable of uncovering nuclear fuel
	Containment equilibrium pressure for worst case design basis accident remains below containment design pressure	Containment integrity assured (due to the metallic containment vessel, molten core concrete interaction is not possible).
	Sub atmospheric pressure during normal operation	Increased steam condensation rates for containment heat removal during a postulated small-break LOCA. Any hydrogen postulated to be released is trapped in the containment vessel with little oxygen available to create a combustible mixture.
	No insulation on reactor vessel	Eliminates potential sump screen blockage and permits ex-vessel cooling
Low power core (160 MWt)	Reduces decay heat removal requirements	Enhances in-vessel retention; maintains low accident consequences; reduces fission product source term; simplifies emergency planning
Reactor pool with submerged NSSS and containment vessel	NSSS and containment vessel underwater	Provides passive long-term cooling and enhanced fission product retention
Passive safety systems	Safety systems cool and depressurize the containment vessel even in the event of loss of external power	Active safety systems are not required (low core damage frequency)

### **3.0 NuScale Power Plant General Description**

This section describes the nuclear NSSS module and associated power conversion system for a single unit and a 12-unit plant.

#### **3.1 Single-Unit Overview**

A unit consists of a simplified power conversion system using a skid-mounted turbine-generator set, a standard condenser and cooling tower arrangement, and feedwater system dedicated to a single NSSS module, as shown in Figure 3-1. Each unit produces approximately 45 MWe net output. The power conversion system is based on readily available, off-the-shelf components. Use of off-the-shelf components simplifies the design and helps reduce long-term maintenance costs.

The modular concept allows multiple NSSS modules to be placed at a single site. Individual NSSS modules can be placed into service incrementally to meet construction schedules and grid demand as permitted by the site license. NSSS modules also can be taken off-line individually for refueling outages and maintenance.

Feedwater from the condenser is pumped by condensate pumps to the condensate polishing equipment, where impurities are removed. Downstream of the polishing equipment, variable speed feedwater pumps supply flow to the feedwater heaters before feedwater regulating valves control feed to the steam generators.

In unit operation, preheated feedwater is pumped into the tube side of the steam generator where it boils. As the steam continues to flow upwards in the tubes, it continues to be heated to produce superheated steam before leaving the steam generator. The superheated steam is directed to a dedicated steam turbine. A generator, driven by the turbine, creates electric power that is delivered to the utility grid through a step-up transformer. A turbine steam bypass is provided that will allow the reactor to remain in operation in the event of a turbine trip.

Steam is extracted from turbine stages to preheat the feedwater and increase the efficiency of the power plant. Exhaust steam from the turbine is directed to the condenser, where a circulating water loop removes heat and condenses the steam. Heat from the circulating water loop is rejected to atmosphere by an evaporative mechanical-draft cooling tower.



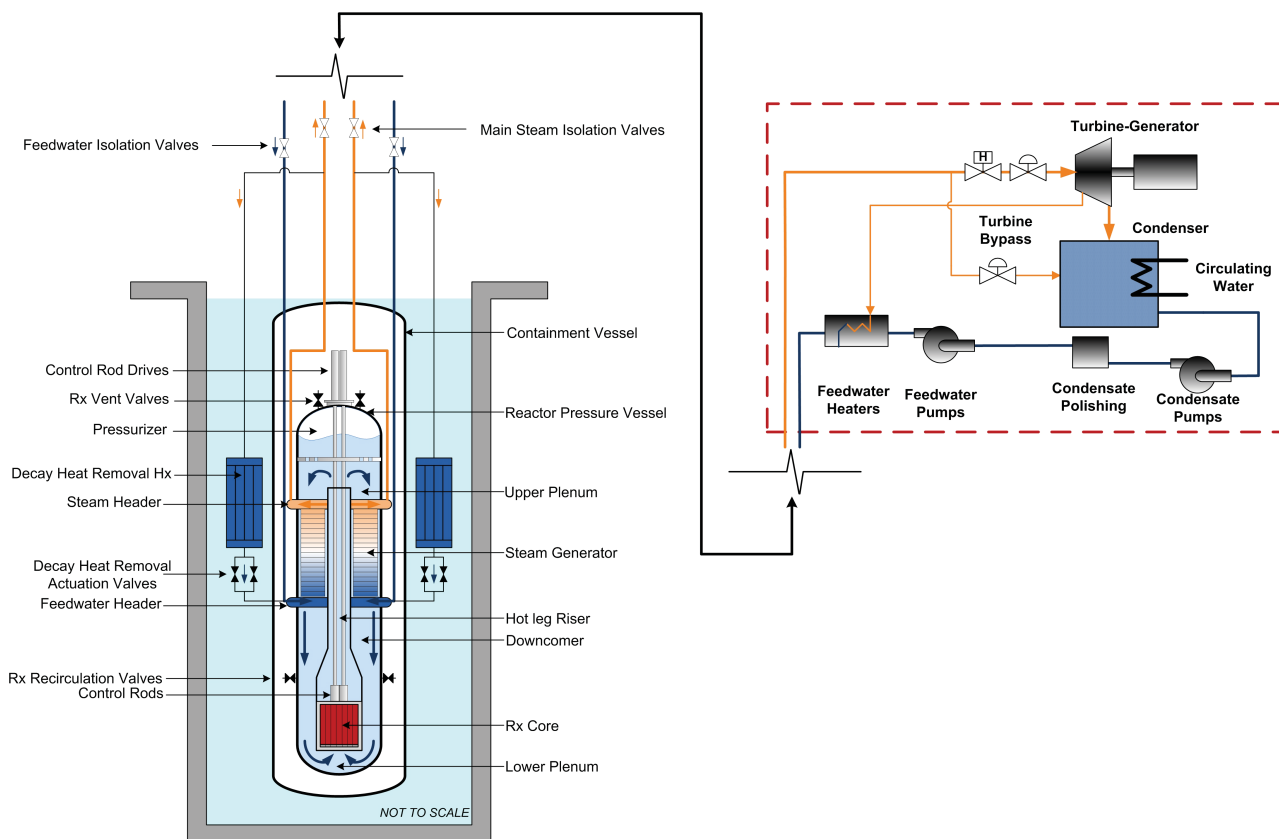


Figure 3-1. Two-dimensional schematic of a single NuScale unit

### 3.2 Plant Overview

Figure 3-2 presents the layout of a 12-unit plant. Each NSSS module is located underwater in its own bay of the common reactor pool. Each reactor bay is approximately 20 ft wide by 20 ft long and built into the nearly 75 ft deep pool. The entire pool is lined with stainless steel for leakage control. Each bay has a concrete cover that serves as a biological shield. The cover also serves to prevent deposition of foreign materials onto a NSSS module. The reactor pool is located in a Seismic Category I building designed to withstand postulated adverse natural conditions for the plant location.

The turbine-generator sets are skid-mounted and housed in the adjacent turbine buildings. Laydown area for turbine maintenance is provided in each of the turbine buildings.

NSSS modules in a multi-unit plant are refueled on a staggered 24-month cycle resulting in a high plant capacity factor.

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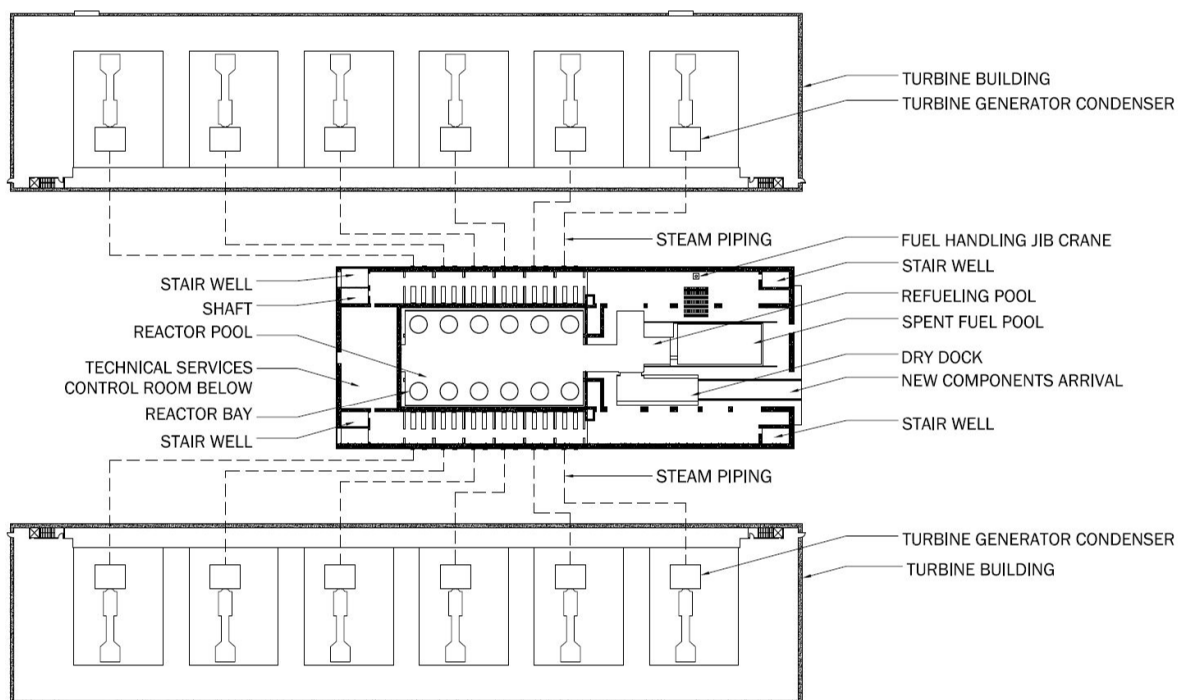


Figure 3-2. Layout of a 12-unit power plant

Table 3-1 presents the overall characteristics of the plant. The total generation of 540 MWe by a 12-unit plant is based on a single turbine-generator set per NSSS module with feedwater heating.

Table 3-1. Characteristics of a 12-unit power plant

Overall Plant	
Net nominal power rating	540 MWe
Net station efficiency	> 28%
Number of power units	12
Nominal plant capacity factor	92% - 95%
Power Unit	
Number of reactors	One
Net nominal power rating	45 MWe
Steam generator number	Two, independent tube bundles
Steam generator type	Vertical helical tube
Steam cycle	Rankine – subcritical regenerative with superheat
Turbine type	3600 rpm, condensing, with extraction
Thermal power rating	160 MWt
Operating pressure	1850 psig

Reactor Core	
Fuel	UO <sub>2</sub> (< 4.95% enrichment)
Refueling intervals	24 months

### 3.3 Nuclear Steam Supply System

The nuclear steam supply system (NSSS) consists of a reactor core, helical coil steam generators, and a pressurizer within a single pressure vessel. The NSSS is enclosed in a cylindrical containment vessel that sits in the reactor pool structure as shown in Figure 3-3. The reactor core is located below helical coil steam generator tube bundles inside the reactor pressure vessel. To effectively use natural circulation, the core is connected directly to the space above the steam generator via a large-diameter central riser. The primary liquid flow path is upward through the riser, and then downward around the steam generator tubes with return to the bottom of the core via an annular downcomer.

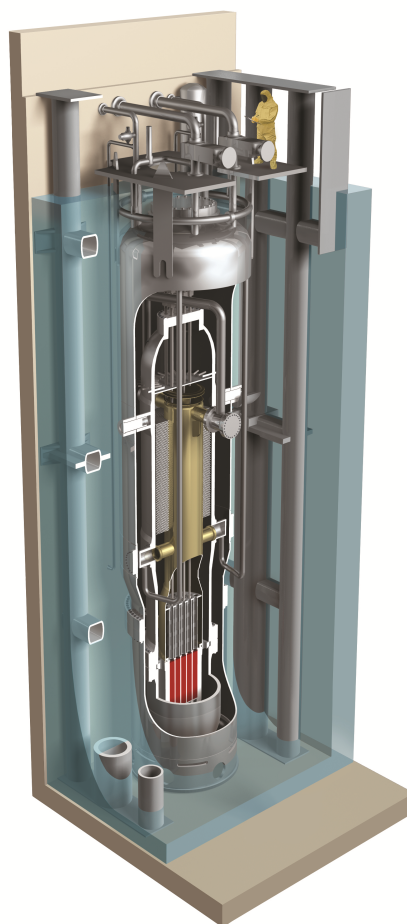


Figure 3-3. Three-dimensional rendering of a single NSSS module

### **3.3.1 Reactor Pressure Vessel**

The reactor pressure vessel consists of a steel cylinder with an inside diameter of approximately 9 ft and an overall height of approximately 45 ft and is designed for an operating pressure of approximately 1850 psig. To ensure safety and stability, ring forgings located at the steam and feed headers are thickened to provide reinforcement for the vessel nozzles. The upper and lower heads are elliptical, and the lower portion of the vessel has flanges to provide access for refueling.

The top of the upper head of the reactor pressure vessel provides support for the control rod drive mechanisms. Nozzles on the upper head provide connections for relief valves, reactor vent valves, and the pressurizer spray piping.

To provide a barrier between the saturated water in the pressurizer and the reactor coolant system fluid, a steel divider plate is located above the steam generator. The divider plate has orifices to limit the in and out surge of water in the pressurizer and to act as a thermal barrier.

### **3.3.2 Steam Generator**

Each NSSS module uses two once-through helical-coil steam generators for steam production. The steam generators are located in the annular space between the hot leg riser and the reactor vessel inside diameter wall. The steam generator consists of tubes connected to upper and lower plenums with tubesheets. Preheated feedwater enters the lower steam generator plenum through nozzles on the reactor pressure vessel (see Figure 3-4). As feedwater rises through the interior of the steam generator tubes, heat is added from the reactor coolant and the feedwater experiences a phase change and exits the steam generator as superheated steam.

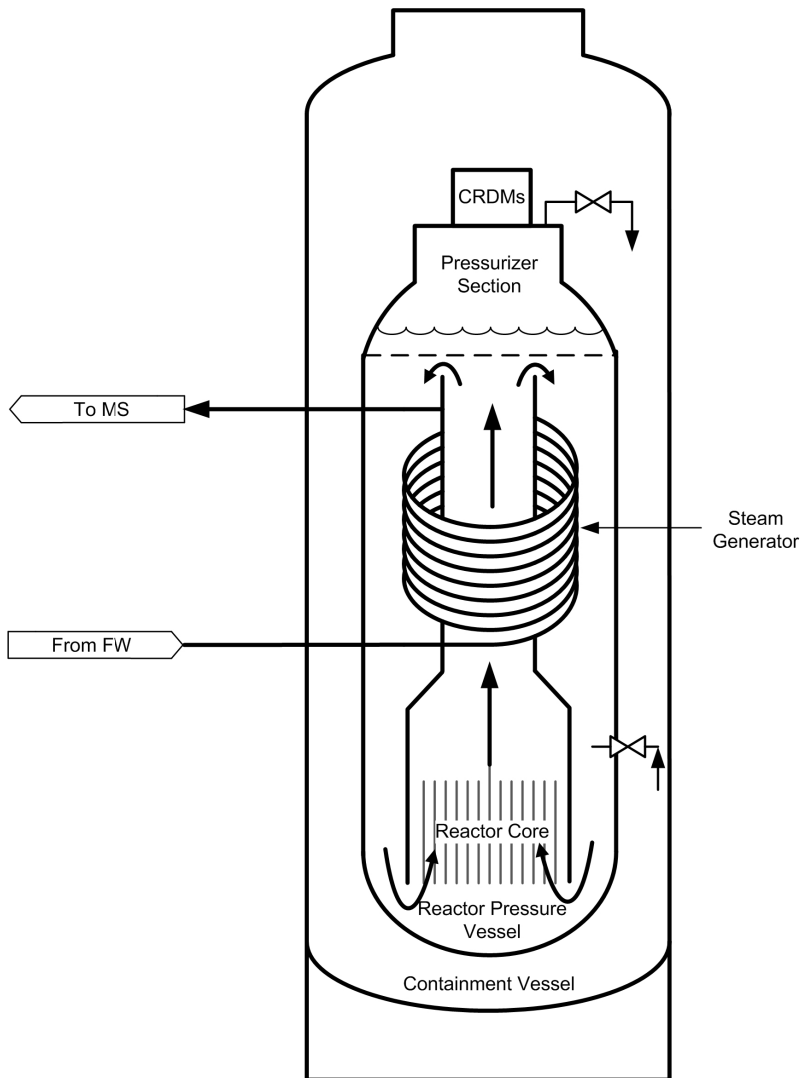


Figure 3-4. Steam generator and reactor flow

### 3.3.3 Pressurizer

The pressurizer provides the primary means for controlling reactor coolant system pressure. It is designed to maintain a constant pressure during operation. Reactor coolant pressure is increased by applying power to a system of heaters in the reactor pressure vessel head. The heater penetrations are installed above the pressurizer separator plate. Pressure in the reactor coolant system is reduced using spray provided by the CVC system.

### 3.3.4 Reactor Core

The core configuration for the NSSS module consists of 37 fuel assemblies and 16 control rod assemblies. The control rods are organized into two groups, a control group, and a shutdown group. The control group, consisting of four rods symmetrically located in the core, functions as a regulating group that is used during normal plant operation to flatten the overall neutron flux

pattern and control power. The shutdown group (12 rods) is used during NSSS module shutdown and scram events.

The fuel assembly design is modeled from a standard 17 x 17 PWR fuel assembly with 24 guide tube locations for control rod fingers and a central instrument tube. The assembly is nominally half the height of standard plant fuel and contains 5 spacer grids. The fuel is  $UO_2$  with  $Gd_2O_3$  as a burnable absorber homogeneously mixed within the fuel for select rod locations. The U-235 enrichment is below the current U.S. manufacturer limit of 4.95 percent enrichment. A list of baseline fuel design parameters is presented in Table 3-2.

Table 3-2. Reactor core and fuel parameters

Core Parameters	Dimensions
<b>Fuel Pins (Standard 17 x 17 PWR Enriched <math>UO_2</math> Fuel with Zircaloy Cladding)</b>	
Rod outside diameter	0.374 inches
Pellet outside diameter	0.322 inches
Clad thickness	0.0224 inches
Active height	1/2 standard height
<b>Fuel Assembly (17x 17 Square Array)</b>	
Assembly pitch	8.466 inches
Pin pitch	0.496 inches
<b>Control Rods (<math>B_4C</math> Absorber)</b>	
Absorber material diameter	0.339 inches
Control rod outside diameter	0.378 inches
Control rod length	1/2 standard height

### 3.3.5 Chemical and Volume Control System

The CVC system is simple in design and is not required to function during or after an accident. During normal operation, the CVC system recirculates a portion of the reactor coolant through demineralizers to maintain reactor coolant cleanliness and chemistry. Reactor coolant inventory is controlled by injection of additional water when reactor coolant levels are low or letdown of reactor coolant to the liquid radioactive waste system when coolant inventory is high. Additionally, during the power module startup process, the CVC will be used to add heat to the reactor coolant to establish uniform and stable natural circulation flow in the reactor coolant system. The CVC is not required to operate following an accident.

Boron concentration in the reactor coolant system is controlled by a feed and bleed process. Injection pumps provide borated water or clean demineralized water that is delivered into the reactor vessel with excess reactor coolant being letdown to the radioactive waste system.

## 4.0 Safety Features

Each NSSS module incorporates several simple, redundant, and independent safety features. These features are discussed in detail in the following sections.

### 4.1 Containment Vessel

The major safety functions of the containment vessel are to contain the release of radioactivity following postulated accidents, protect the reactor pressure vessel and its contents from external hazards and to provide an interfacing medium (reactor vessel to water, to containment vessel, to the pool) for decay heat removal following an accident or normal reactor shutdown.

Each containment vessel consists of a steel cylinder with an outside diameter of approximately 15 ft and an overall height of approximately 65 ft. The containment vessel houses the reactor pressure vessel, control rod drive mechanisms, and associated components.

Flanges are provided on the containment vessel to allow for disassembly and to allow access to the reactor pressure vessel during refueling operations and maintenance. Manways are located in the upper head and in the vessel circumference to allow access to the steam generator headers during refueling outages. Penetrations located on the vessel upper head provide access for process piping to the reactor pressure vessel and to the containment vessel interior. Additional penetrations are provided for electrical and instrumentation connections.

The vessel is vertically and laterally supported by connection to the reactor pool walls. A support skirt attached to the containment vessel lower head allows the vessel to be supported laterally. Internal to the containment, the reactor vessel is laterally and vertically supported by connections to the containment vessel wall.

The containment vessel is submerged in the reactor pool, which provides a passive heat sink for the containment heat removal under LOCA conditions. Although not credited, the reactor pool provides an additional means of fission product retention beyond that of the fuel, fuel cladding, reactor pressure vessel, and the containment for certain events. The containment vessel is designed to withstand the environment of the reactor pool as well as the high pressure and temperature of any design basis accident.

The containment vessel pressure is maintained at a deep vacuum under normal operating conditions. Maintaining a deep vacuum provides for reduced moisture that could contribute to component corrosion and impact the reliability of instrumentation and other systems within the containment vessel. The deep vacuum essentially eliminates convection heat transfer removing the need for "direct-contact" reactor pressure vessel insulation. Due to a lack of appreciable amounts of air, the deep vacuum also enhances steam condensation rates that would occur during an accident with ECCS actuation and would limit the formation of a combustible mixture of hydrogen and oxygen during a severe accident.

Following an actuation of the ECCS, heat removal through the containment vessel rapidly reduces the containment pressure and temperature and maintains them at less than design conditions for extended periods of time. Steam is condensed on the inside surface of the containment vessel, which is passively cooled by conduction and convection of heat to the

reactor pool water. Because the containment vessel is evacuated to a low absolute pressure during normal operation, few non-condensable gasses are present inside the containment vessel. This is beneficial, because the presence of non-condensable gasses has a tendency to reduce condensation heat transfer rates.

#### 4.2 Decay Heat Removal System

The decay heat removal system (DHR) provides secondary side reactor cooling for non-LOCA events when normal feedwater is not available. The system, as shown in Figure 4-1, is a closed-loop, two-phase natural circulation cooling system. Two trains of decay heat removal equipment are provided, one attached to each steam generator loop. Each train is capable of removing 100 percent of the decay heat load and cooling the reactor coolant system. Each train has a passive condenser submerged in the reactor pool. The condensers are maintained with sufficient water inventory for stable operation.

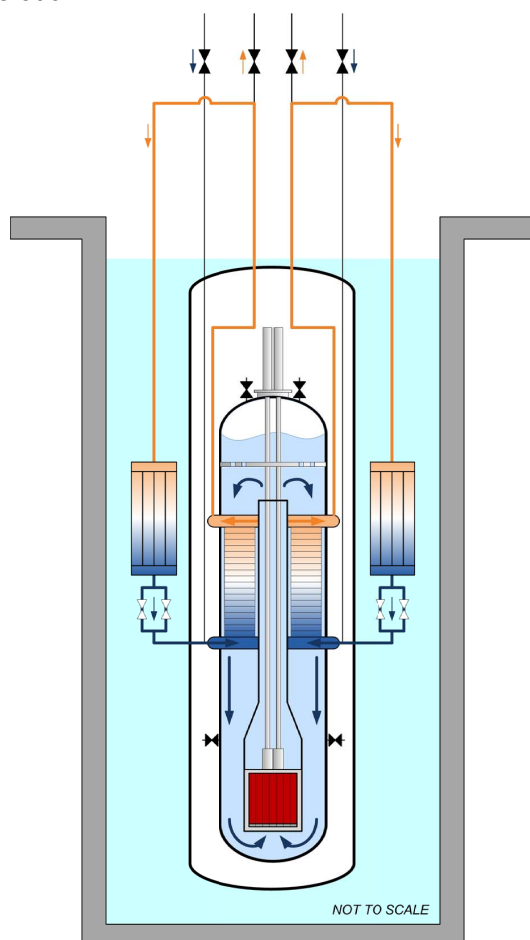


Figure 4-1. Decay heat removal system schematic

Upon receipt of an actuation signal, the DHR valves open. This allows water from the decay heat removal condensers to travel to the steam generators and cool the reactor coolant as it is turned to steam. The steam then travels through the steam generator back to the decay heat removal condenser where it is condensed by the reactor pool water, and the cycle is repeated. Heat is



removed via the steam generators, thus preserving natural circulation within the reactor coolant system.

### **4.3 Emergency Core Cooling System**

As shown in Figure 4-2, the emergency core cooling system (ECCS) consists of two independent reactor vent valves and two independent reactor recirculation valves. The ECCS provides a means of decay heat removal in the event of a loss of coolant accident or a loss of the main feedwater flow in conjunction with the loss of both trains of the DHR system.

The ECCS removes heat and limits containment pressure by steam condensation on, and convective heat transfer to, the inside surface of the containment vessel. It allows heat conduction through the containment vessel walls and heat conduction and convection to the water in the reactor pool. Long-term cooling is established via recirculation of reactor coolant to the reactor pressure vessel via the ECCS recirculation valves, which when opened provide a return flow of cooled water to the reactor.

The ECCS is initiated by opening the two (2) reactor vent valves in lines exiting the top of the reactor pressure vessel (the pressurizer region) and the two (2) reactor recirculation valves on lines entering the reactor pressure vessel in the downcomer region at a height above the core. Opening the valves allows a natural circulation path to be established. Water that is vaporized in the core leaves as steam through the reactor vent valves, is condensed and collected in the containment vessel, and is then returned to the downcomer region inside the reactor vessel through the reactor recirculation valves.

Following a LOCA or other condition resulting in an actuation of the ECCS, heat removal through the containment vessel rapidly reduces the containment pressure and temperature and maintains them at acceptably low levels for extended periods of time. Steam is condensed on the inside surface of the containment vessel, which is passively cooled by conduction and convection of heat to the reactor pool water. Since the containment vessel is evacuated to a low absolute pressure during normal operation, only a small amount of non-condensable gas will be present inside the containment vessel.

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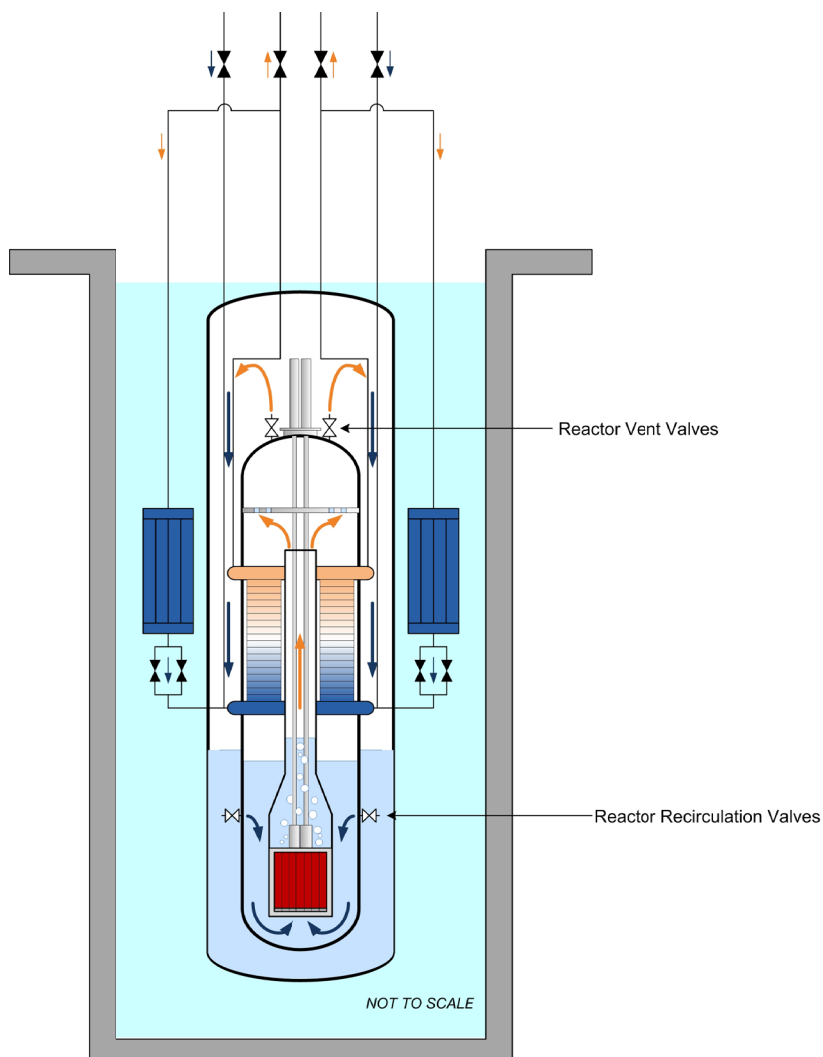


Figure 4-2. Emergency core cooling and containment heat removal system schematic

#### 4.4 Reactor Pool

The reactor pool consists of a large, below-grade concrete pool with a stainless steel liner that provides stable cooling for the containment vessel for a minimum of 72 hours following any LOCA. During normal plant operations, heat is removed from the pool through a closed loop cooling system and ultimately rejected into the atmosphere through a cooling tower or other external heat sink. In an accident where offsite power is lost, heat is removed from the reactors and containments by allowing the pool to heat up and boil. Water inventory in the reactor pool is large enough to cool the reactors for at least 72 hours without adding water. After 72 hours, reactor building pool water boil-off, and ultimately passive air cooling of the containments, provide adequate cooling for long-term decay heat removal.

#### 4.5 Shutdown Accumulator System

Currently, the shutdown accumulator system (SAS) is designed to provide boration to the reactor coolant system following an accident when reactivity suppression is necessary at low

temperature. The SAS consists of redundant pressurized accumulator tanks filled with borated water. The accumulators are connected to reactor coolant system injection lines, which are isolated during normal plant operation by use of check valves. Passive injection of the SAS contents is provided by gas pressure that forces the borated water into the reactor coolant system when reactor coolant pressure reduces to below accumulator pressure.

Design of this system is under review.

#### **4.6 Safety Control and Instrumentation System**

The NuScale plant design implements an integrated safety control and instrumentation system (SCIS). The SCIS protection functions are limited to automated safety responses to specific initiating events. The SCIS functional response to an initiating event is a reactor trip and a turbine trip followed by an integrated safety response from one or more of the passive safety systems; DHR system, containment heat removal system, ECCS, and SAS.

Transients requiring decay heat removal are addressed by the DHR system providing cooling through one or both of the steam generator tube bundles. For a steam generator tube rupture in a single tube bundle, the affected bundle is isolated and the DHR system provides cooling through the intact tube bundle. In the event of a steam generator tube rupture affecting both tube bundles, both tube bundles are isolated and the ECCS is activated. Transients requiring reactor coolant system inventory addition are first mitigated by the functioning of the CVC system. If the CVC system is inadequate to address the loss of reactor coolant, the ECCS is actuated and isolation of containment occurs. ECCS actuation provides a pathway to remove decay heat from the reactor core and prevent core melt by heat transfer through containment and into the reactor pool.

The physical design of the reactor vessel precludes large-break LOCAs. The DHR system can provide additional capacity for decay heat removal during the initial blowdown period of a LOCA, but it is not required nor credited for such events.

#### **4.7 Control Room Habitability System**

The control room habitability system ensures that plant operators are adequately protected against the effects of accidental releases of toxic and radioactive gases. The control room habitability system is a passive system that uses clean compressed breathable air. At least 72 hours of air is stored in a series of tanks providing the capacity to maintain the control room at positive pressure relative to adjacent areas.

#### **4.8 Safety Related Power**

See Section 5.9 for discussion of the safety DC electrical and essential AC distribution system.

## 5.0 Plant Arrangement and Operations

The 12-unit plant consists of a power generation complex and common facilities. The power generation complex for the baseline plant consists of 12 power generation units (12 NSSS modules and associated turbine generators), module assembly equipment, fuel handling, and turbine maintenance equipment. The plant net total output is approximately 540 MWe. Figure 5-1 presents a layout of the plant site.

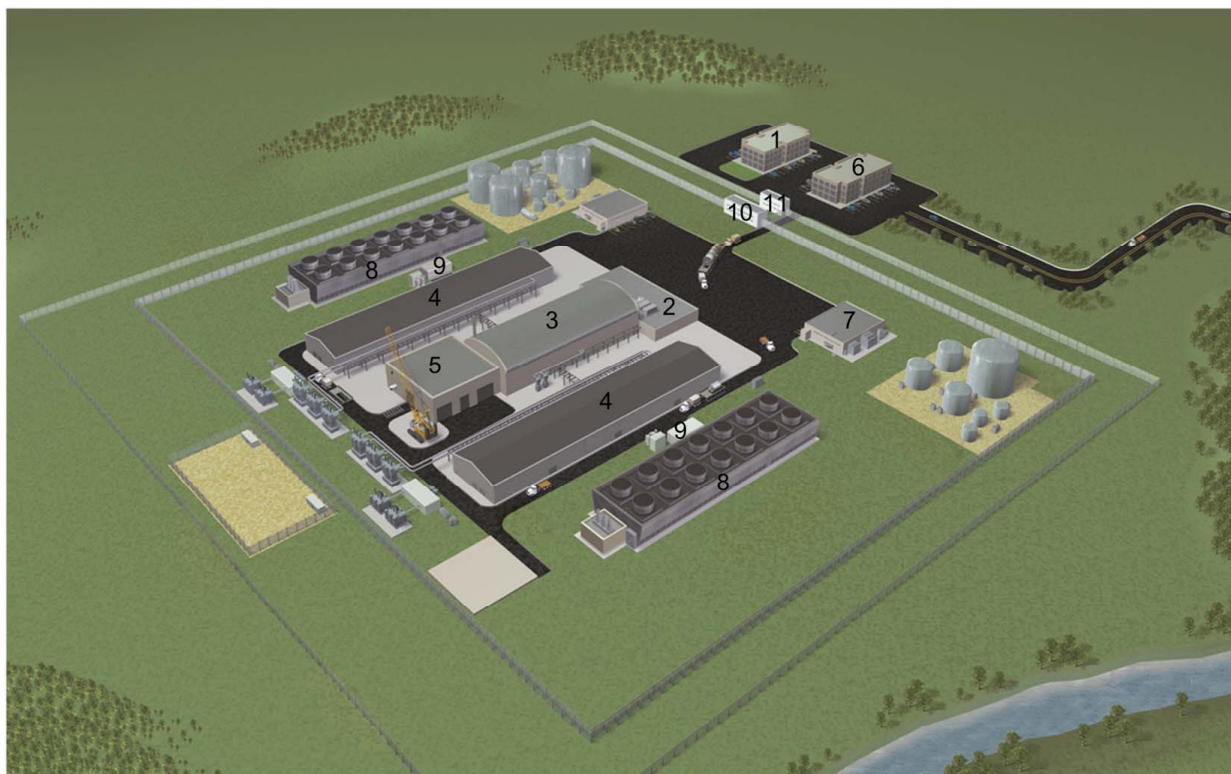


Figure 5-1. Conceptual plant site layout

The majority of the site buildings are located within the protected area and surrounded by a double fence and intrusion-detection equipment. The protected area and the switchgear area are located within the restricted owner controlled area (ROCA) surrounded by an additional single fence. Only the administration building and the warehouse are located outside of the ROCA.

### 5.1 Site Facilities

The site contains several facilities that are important to the operation and support of the plant. (Refer to Figure 5-1 for building number cross-references.) The following facilities are included in the plant design:

1. Administration Building – houses the administration services and the training center
2. Annex Building – provides space for the following facilities:
  - Personnel Services – houses various personnel support services such as locker rooms, showers, toilet facilities, lunch and conference rooms, and first aid.

- Access Control – controls access to both radiological-controlled and non-radiological-controlled areas of the reactor building
  - Health Physics – provides space for plant contamination evaluation and employee dosimeter processing
  - Security Services – a significant portion of the facilities that support plant security such as the secondary alarm station, security briefing room, armory, security manager's office, etc.
3. Reactor Building – located above and below grade, it provides space for all safety-related equipment and houses the following facilities (see Section 5.2):
    - Spent Fuel Pool – stores used fuel
    - Reactor Pool – location for the NSSS modules during operation
    - Fuel Handling Areas – (see Section 5.4)
    - Control Room – houses the plant's Main Control Room (see Section 5.3)
    - Technical Support Center – located below the Main Control Room, outside the radiological controlled area; provides space to support emergency operations and personnel
    - Remote Shut Down Station – provides space for the plant auxiliary shutdown system
    - Central Alarm Station – continuously manned primary location for monitoring the security system operation
    - Primary Systems
    - Safety Related DC Power Systems
  4. Turbine Building – houses the plant's turbine-generators (see Section 5.7.)
  5. Radioactive Waste Building – provides space for heating ventilating and air conditioning (HVAC) radiation filtering equipment, radioactive waste treatment equipment and for servicing all potentially radioactive and non-radioactive tooling, fixtures, and instrumentation (see Section 5.6).
  6. Warehouse Building – provides handling and hoisting equipment as well as space for controlled storage of spare NSSS modules, spare parts, and tools
  7. Water Treatment Building – houses common plant services such as demineralized water, potable water, fire protection water, and auxiliary steam. The building also houses the equipment and systems needed to treat all plant non-radioactive wastes before offsite disposal. The building is an above-grade, one-story structure with large storage tanks located outside.
  8. Cooling Towers – provides the water to air heat sink for the circulating water system
  9. Pump house – houses pumps for the circulating water system
  10. Security Building – provides controlled access into the secured areas of the plant
  11. Primary Access Control Building – provides for controlled access into the restricted, owner controlled area

## 5.2 Reactor Building

The reactor building, as depicted in Figure 5-2, houses the systems and components required for plant operation and shutdown. The reactor building is a Seismic Category I reinforced concrete structure designed to withstand the effects of aircraft impact, environmental conditions, natural phenomena, postulated design basis accidents, and design basis threats. The reactor building also provides radiation protection to plant operation and maintenance personnel.

Portions of the reactor building are located above and below grade. The NSSS modules, reactor pool, and the spent fuel pool are located at or below nominal plant grade level, while the hoisting and handling equipment is located above grade. Also located below grade are the safety-related batteries, main control room, most primary systems, and some radioactive waste equipment.

The surface of the reactor pool water is located at approximately ground level. The 12 NSSS modules are installed in a vertical position and are arranged into two rows of six NSSS modules along the external reactor pool walls. Concrete walls separate the NSSS modules in individual reactor bays. Additionally, an extra bay is located adjacent to the units for NSSS module maintenance or storage of a possible thirteenth NSSS module. A central canal is provided between the rows of NSSS modules to allow for moving of the NSSS modules between the reactor pool and the adjacent refueling pool.

Piping interfacing with the NSSS module (i.e., feedwater piping, steam piping, the chemical and volume control system, containment evacuation system, instrumentation, and power connections) is located partially above the water level. Pipe fittings are provided in this area to permit manual connection and disconnection during NSSS module installation, refueling outages, and during replacement or removal of NSSS modules.

To the maximum extent practical, equipment rooms or vaults within the reactor building are partitioned to provide separation between power generation units.

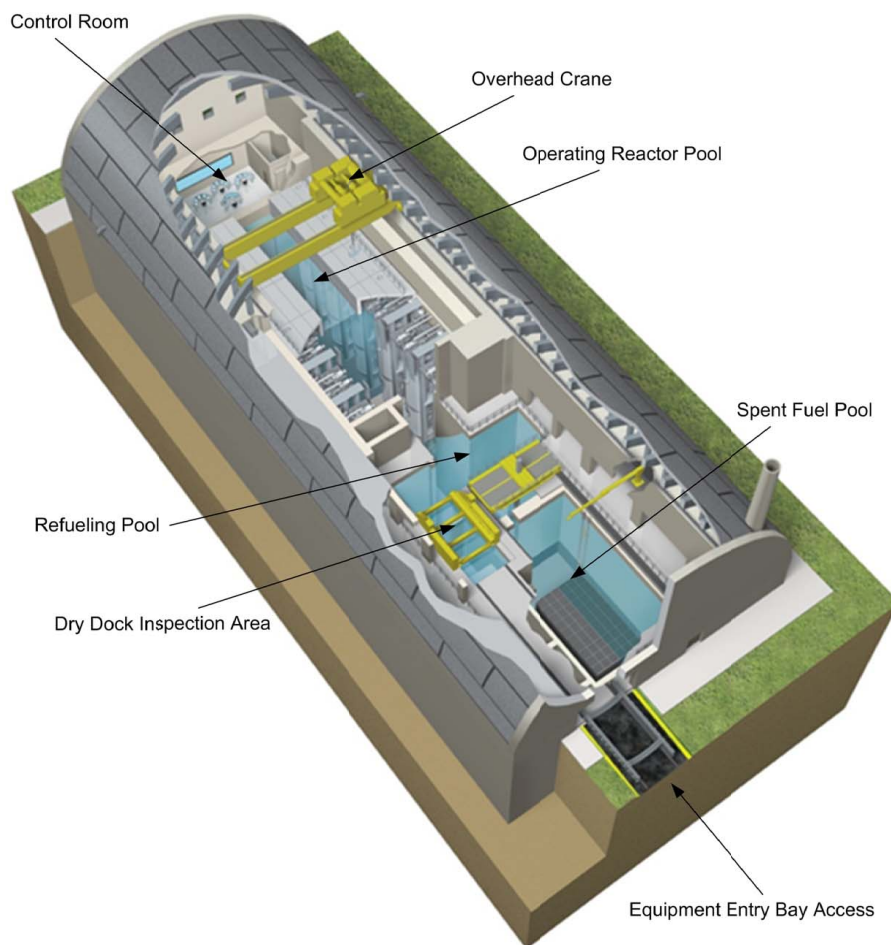


Figure 5-2. Reactor building view

### 5.3 Control Room

The main control room is housed below grade in the reactor building. The plant will have a control console in the main control room for all 12 units. Each reactor operator will monitor and control multiple units from the control room console.

A digital control system will be implemented in a manner that provides complete isolation between the SCIS and non-safety control instrumentation systems (NCIS). Each reactor control system display provides the monitoring for a specific reactor. Additional display stations, including a separate display for shared plant systems not associated with a single unit, provide control room operators with access to a wide range of plant information for trending and diagnostics.

The reactor operators monitor the automated control system for each reactor. Each reactor is outfitted with monitors provided with soft controls and some select manual push buttons for operator control. The supervisor station provides an overview of all reactors using multiple monitors. All monitor displays are designed using human factors analysis to promote simple

understanding of signals. The display layout and design uses graphical representations of plant systems and components.

The following monitoring and control activities are typical control room functions:

- initiate NSSS module startup
- initiate NSSS module shutdown
- set or correct set points that control the NSSS module or plant functions
- take corrective actions if any NSSS module or plant system does not operate as intended
- provide permission for the control systems to continue on past predefined “hold points” in major operations using automated control system functions

The plant’s main control room enhances supervisory control of the NSSS modules and plant systems by providing alarm annunciation on the plant group-view overview display monitor as part of the alarm management system. This system includes information from the individual NSSS modules via the SCIS system, the NCIS, and the shared instrumentation and control systems common to all the NSSS modules. In the unlikely event that the main control room becomes uninhabitable, a remote shutdown station provides a secondary location for shutdown of the reactors.

#### **5.4 Fuel Handling and Reactor Maintenance Areas**

The fuel handling and reactor maintenance areas include space for:

- new fuel storage
- spent fuel pool
- refueling pool
- dry dock

The fuel handling and maintenance areas are housed within the reactor building and consist of below-grade pools and dry, above-grade areas. The pools include the refueling pool, spent fuel pool, and dry dock. Above-grade areas provide space for the operation of handling equipment, access to the upper portion of NSSS modules while the reactor core is being refueled, and space for the storage of new fuel assemblies.

The refueling pool is connected directly to the reactor pool via a canal able to accommodate underwater transport of the NSSS module. A fuel canal between the refueling pool and spent fuel pool provides passage for fuel assemblies during the refueling process. The fuel handling and maintenance areas are designed to provide radiation protection for plant operation and maintenance personnel who are working in those areas.

The new fuel storage area contains a fuel receiving area, new fuel storage racks, and a jib crane for loading dry new fuel assemblies into the new fuel elevator. The area has forklift access for new fuel receiving as well as access for a cask transporter to support the preparation and movement of spent fuel to dry storage.



The spent fuel pool provides storage space for up to 15 years of accumulated spent fuel assemblies, temporary storage for new fuel assemblies. During refueling, new fuel assemblies are moved from dry storage and temporarily stored in racks in the spent fuel pool before being placed in the reactor core. After being removed from the reactor core, spent fuel assemblies are placed in spent fuel storage racks in the spent fuel pool. Within approximately 5 years, the thermal load of the spent fuel assemblies is reduced significantly, and the assemblies can be moved to a secure dry storage area. The plant site layout includes space allocation adequate for the dry storage of all of the spent fuel for the 60-year life of the plant.

The refueling area houses the equipment to disassemble and reassemble the NSSS module during refueling. The reactor core is stored in a specially designed fixture in the reactor pool while spent fuel is removed, fuel is shuffled, and new fuel is placed. A traveling bridge fuel handling machine moves new and used fuel through a submerged access path between the refueling pool and spent fuel pool.

The dry dock area is separated from the refueling pool by a gate. With the dry dock gate closed, pool water can be removed and maintenance activities can be completed in the dry dock. This area includes the necessary inspection and testing equipment needed for the NSSS module.

Introduction of new NSSS module into the reactor building pool system and NSSS module maintenance takes place in the dry dock. The dry dock provides maintenance access to the upper section of the containment vessel and reactor pressure vessel. The dry dock is also used for placing new NSSS module components into the reactor building pool system and preparing them for assembly. Additionally, it provides access for shipment of used NSSS modules offsite.

## **5.5 Refueling Operations**

In a 12-unit plant, an individual NSSS module is refueled while the remaining 11 NSSS modules remain online. During refueling, the NSSS module is moved from its operating bay in the reactor pool to the refueling pool. The reactor building crane is used to lift the NSSS module off its supports. The NSSS module is moved to the open area in the center of the reactor pool, which then serves as a pathway to transport a NSSS module to the refueling area.

In the refueling area, flange bolting tools are used to detach the lower portion of the containment structure and then the lower reactor vessel, including the core. The lower reactor vessel and core are staged in a refueling stand. After detaching the lower vessel sections, the reactor building crane transports the upper portion of the NSSS module to the dry dock area to carry out inspection, testing, and maintenance. The core is refueled using a dedicated fuel handling machine while the NSSS module is undergoing maintenance, inspection, and testing.

After inspection, maintenance, and testing are complete and the reactor core has been refueled, the upper portion of the NSSS module is moved from the dry dock to the refueling pool where the NSSS module is reassembled using the flange tools. Following reassembly, the NSSS module is moved into the reactor pool and returned to its operating bay. In the operating bay, startup tests are performed and the CVC heater is used to preheat the reactor coolant in preparation for restarting. Finally, after the NSSS module has passed all necessary tests and inspections and the reactor coolant is at startup conditions, the NSSS module is brought online, and steam and power production begins.

## 5.6 Radioactive Waste Building

The radioactive waste building houses equipment and systems for processing the plant's radioactive gaseous, liquid, and solid waste and for preparing the waste for shipment offsite. The building houses equipment to prepare low level radioactive waste for compaction to reduce volume and provides temporary storage for radioactive waste. HVAC equipment for providing radioactive waste building high-efficiency particulate air filtration is located in the building. The building is designed to maintain radiation exposures to operators and maintenance personnel at the lowest achievable levels.

## 5.7 Turbine Buildings

A 12-unit plant has two separate turbine buildings, each housing six turbine-generators. The turbine buildings are above-grade structures that house the main turbine-generators with their auxiliaries, the main condensers, condensate, and the feedwater systems. A turbine generator is shown in Figure 5-3. Each turbine-generator is associated with a single NSSS module and has dedicated condensate and feedwater pumps. Each turbine-generator is supported by an above-grade pedestal constructed of structural steel and reinforced concrete. Each condenser is located approximately at nominal plant grade level adjacent to the turbine-generator. An overhead traveling crane is provided for the installation and maintenance in each turbine building. The turbine buildings are steel-framed structures with insulated metal wall siding and roof decking.

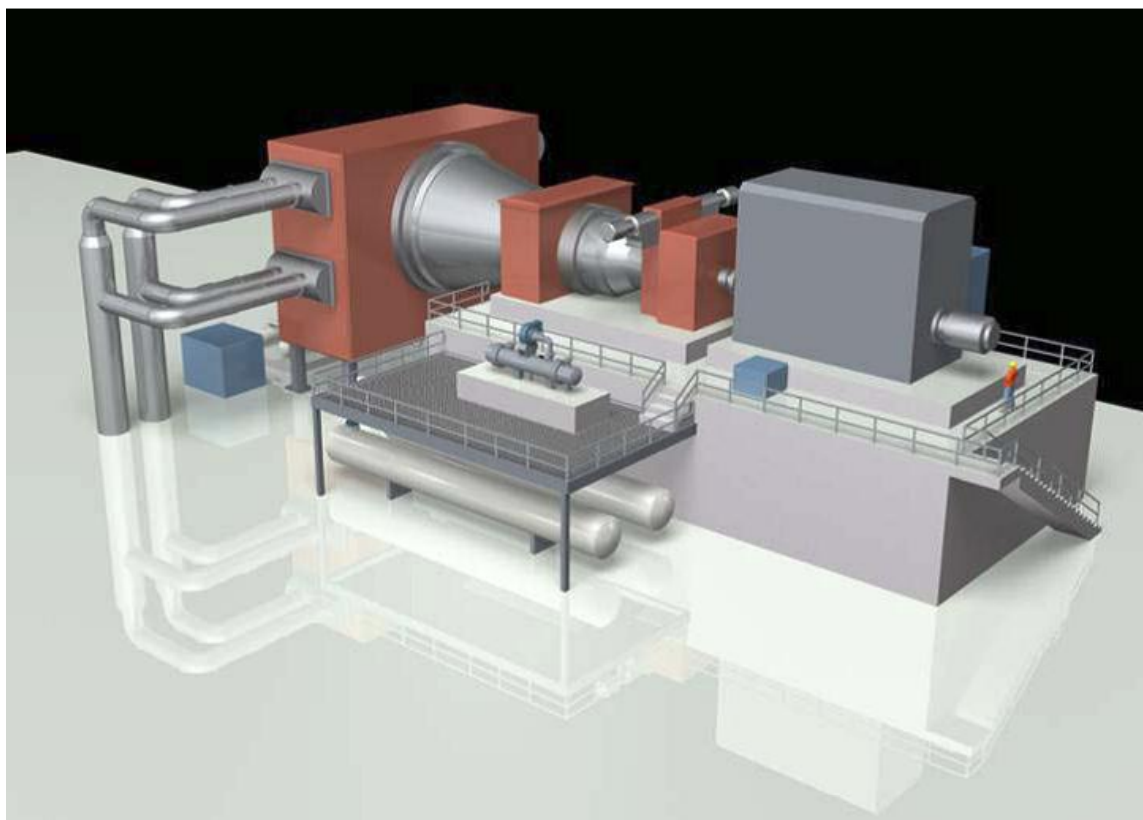


Figure 5-3. Turbine-generator set

## 5.8 Plant Cooling Systems

The plant cooling systems include several systems that are important to supporting plant operation. These systems include the following:

- The circulating water system provides a continuous supply of cooling water to the chilled water system, the balance of plant component cooling water system, and to the main condensers. Heat from the six condensers in one turbine building is returned to a set of mechanical draft cooling towers. The cooled circulating water collects in a common basin where it then feeds circulating water pumps that supply cooled water back to the chilled water system, balance of plant cooling water system, and the main condensers. The chilled water system provides cooling water to the reactor component cooling water system, the reactor pool cooling water system, spent fuel pool cooling water system, and the plant HVAC systems. The chilled water system transfers its heat to the circulating water system.
- The balance of plant component cooling water system provides cooling water to the turbine building loads.
- The reactor component cooling water system is a non-safety-related, closed-loop cooling system that transfers heat from various plant components to the chilled water system. The reactor component cooling water system provides cooling to the control rod drive mechanisms, the non-regenerative heat exchangers of the CVC systems, and the plant sample system coolers.
- The reactor pool cooling water system and the spent fuel cooling water system are closed-loop systems used to transfer heat from the pools to the chilled water system.

## 5.9 Electric Power Systems

The NuScale plant does not require offsite AC electrical power to cope with design basis events. Under normal operating conditions the AC electrical power distribution system supplies reliable and continuous power to equipment required for startup, normal operation, and shutdown of the plant. In the event of failure of the AC electrical power supply, the DC backup supply system provides the necessary AC power through inverters to ensure continuous operation of safety-related plant electronics.

The power systems within the plant are described below:

- Off-site electrical system - consists of the set of electrical circuits and associated equipment that are used to interconnect the off-site transmission system, the plant main generator, and the on-site electric power distribution systems. It includes the plant switchyard, the main step-up transformers, the unit auxiliary transformers, the high voltage tie lines, and their associated auxiliary systems, including protective relays and local instrumentation and controls.
- Medium voltage AC electrical distribution system - consists of the on-site electric power distribution circuits that operate at 4.16 KV and supply power to medium voltage loads.
- Low voltage AC electrical distribution system - consists of the on-site electric power distribution circuits that supply power to plant loads at 600 volts or less. The system does not include the low voltage vital AC power supply system or the normal and emergency lighting systems.

- Backup diesel generator system - consists of the on-site standby AC power sources (backup diesel generator) and associated power supply circuits up to the source breakers connecting to the on-site AC distribution systems. The system is designed to supply AC power to the plant permanent non-safety loads in the event of a main generator trip and loss of off-site power. Operation of the system is not required to ensure nuclear safety.
- Safety DC electrical and essential AC distribution system - the DC power supply system consists of the electric power supply and distribution equipment and circuits that provide DC power to the plant DC loads. The essential low voltage AC power supply system consists of the electric power supply and distribution equipment and circuits that provide low voltage AC power for continuous operation of safety instrument loads, and computer systems. The system is designed to provide continuous, reliable electric power for control and instrumentation loads such as the reactor protection and safety features actuation systems, and to other DC and important AC loads required for plant startup, normal operation, and normal or emergency shutdown.
- Non-safety DC electrical and AC distribution system - supplies low voltage DC and AC to all the non-safety control and instrumentation loads in the plant.