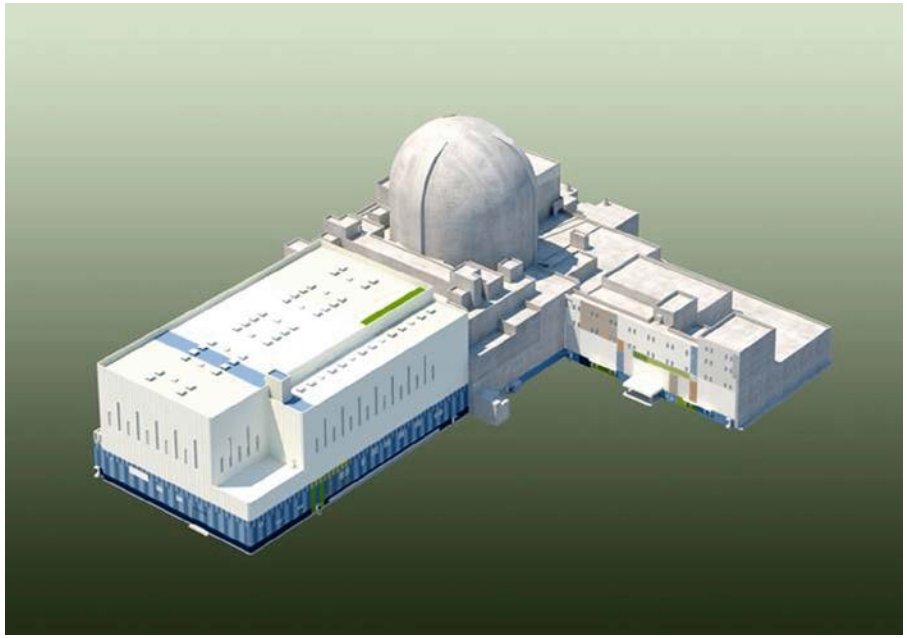
APR1400 NSSS Design



KEPCO/KHNP

April 20~21, 2016

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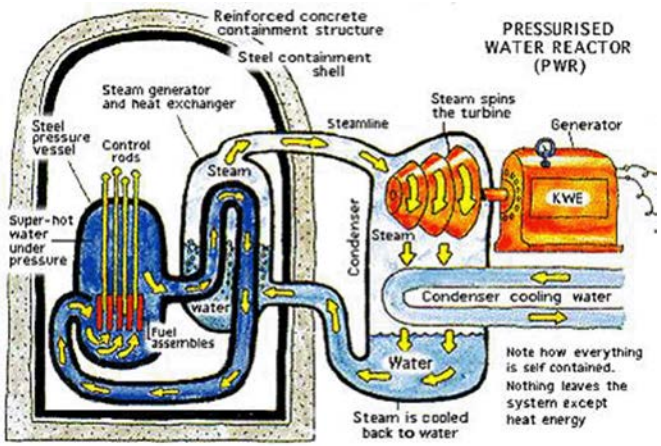
NSSS Design Overview



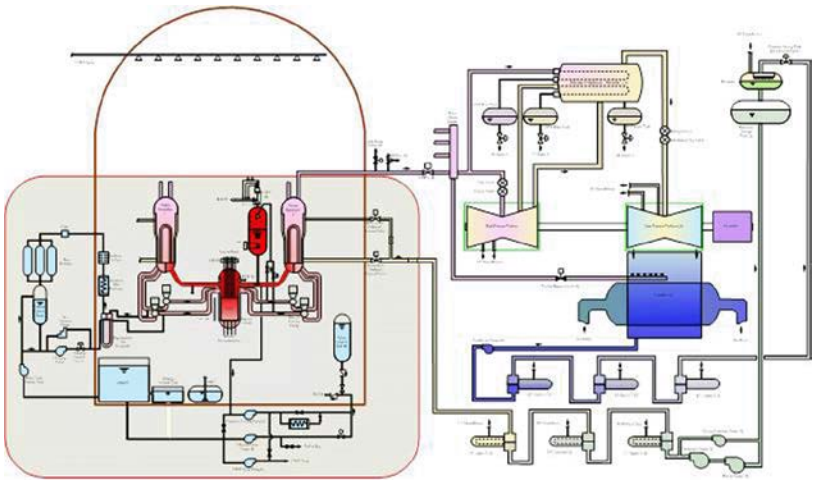
NSSS Design Overview

- **NSSS Design of APR1400**
  - **is identical to that of Shin-Kori Unit 3 in the Republic of Korea, recently under the power ascension tests**
  - **is similar to the System 80+ Certified Design except for unique design features**
  - **is consistent with the regulations of the United States of America**
  - **adopts the industry codes and standards applicable in the United States of America**

NSSS Design Overview

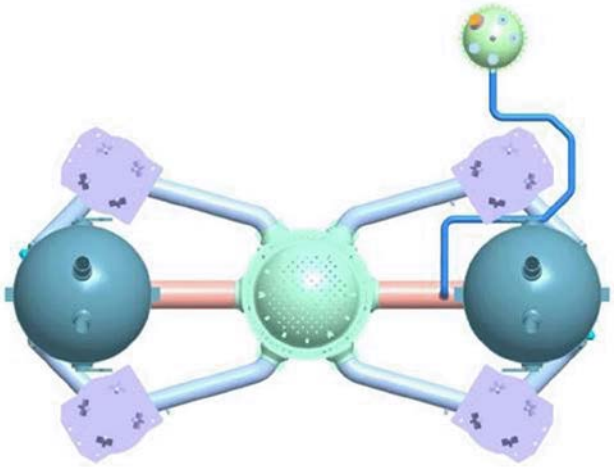
- **Regulatory Bases of APR1400**
  - **Compliance with US NRC regulation documents**
    - **Code of Federal Regulations**
    - **Regulatory Guides**
    - **Standard Review Plan, NUREG-0800**
    - **Generic Letters and Bulletins**
  - **Compliance with the rules and regulations in effect as of September 2014 of the United States of America**

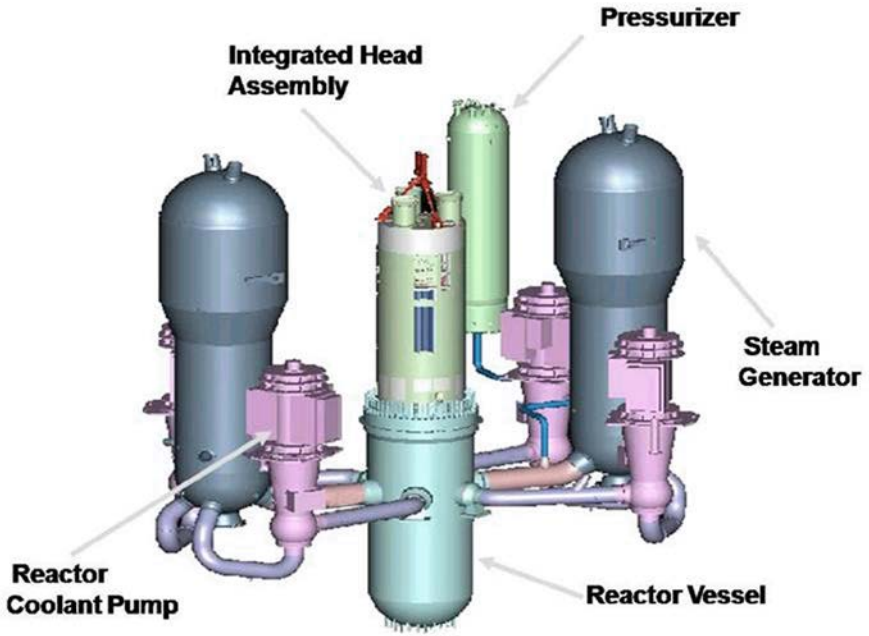
Major NSSS Systems



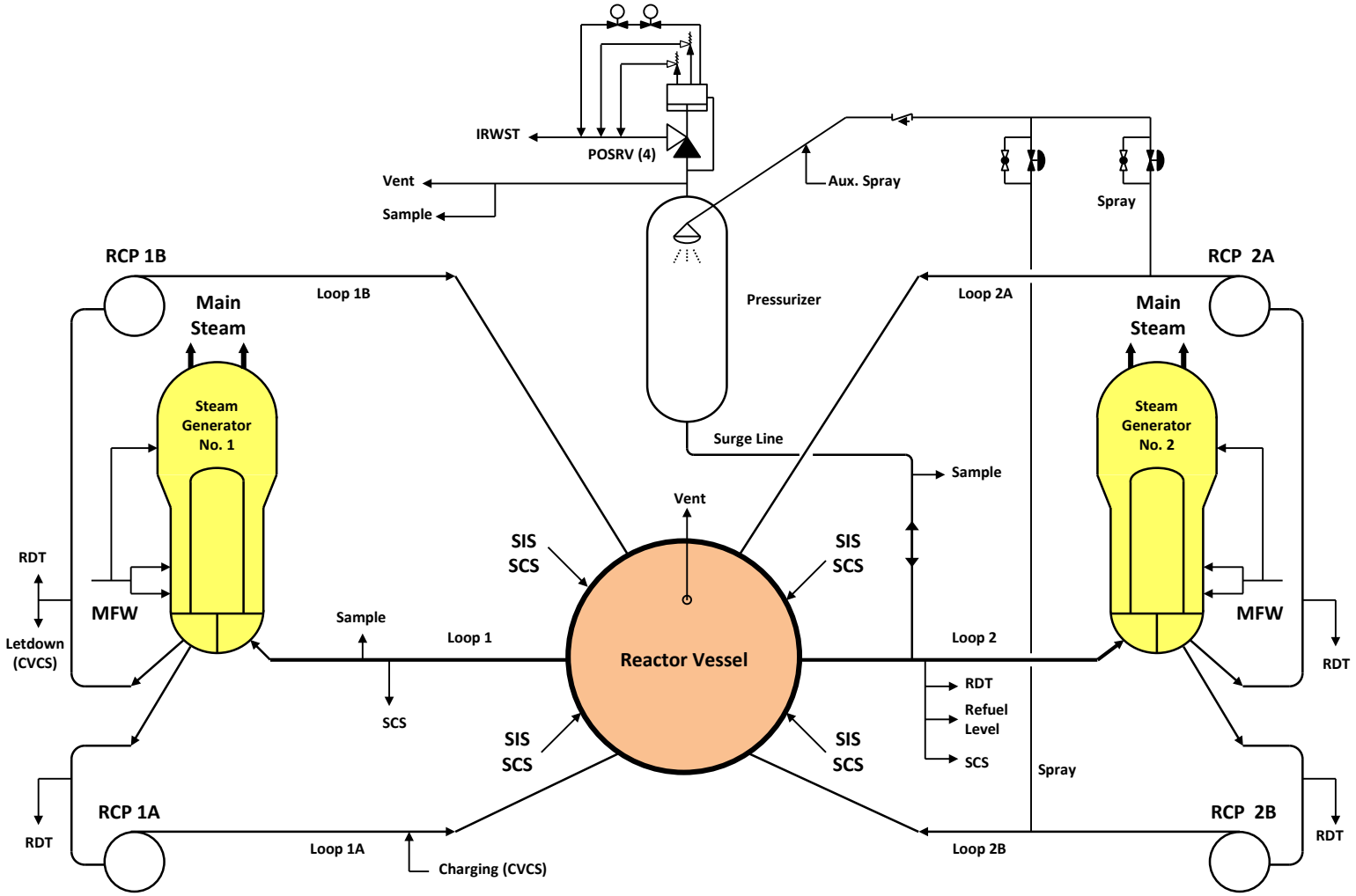
Reactor Coolant System (RCS)

- **RCS Configuration**
  - 2-loop
  - Reactor Vessel
    - Integrated Head Assembly
  - Steam Generators : 2
  - Reactor Coolant Pumps : 4
  - Pressurizer
    - POSRVs : 4
  - Main piping
    - Hot leg pipes : 2
    - Cold leg pipes : 4
    - Suction pipes : 4
    - Surge line : 1



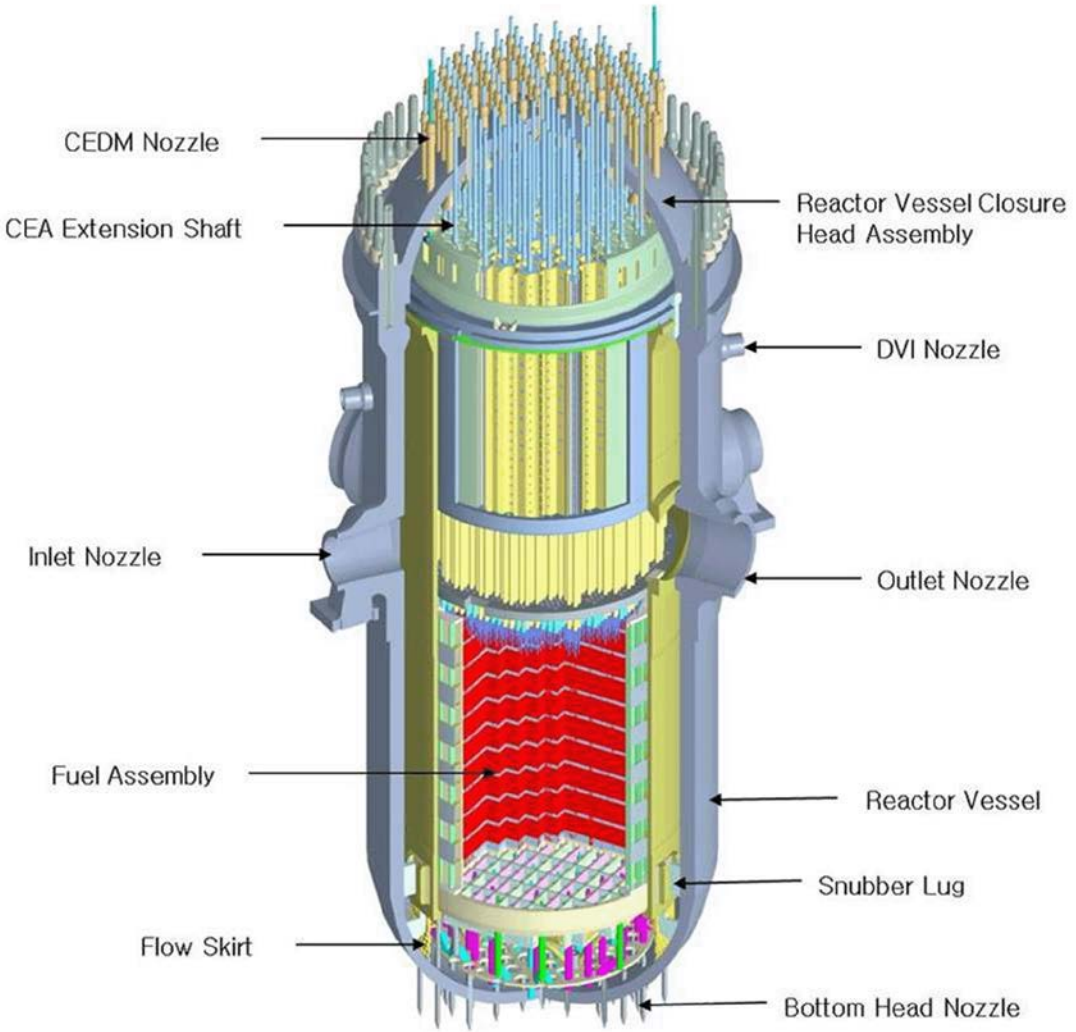


RCS Schematic Diagram



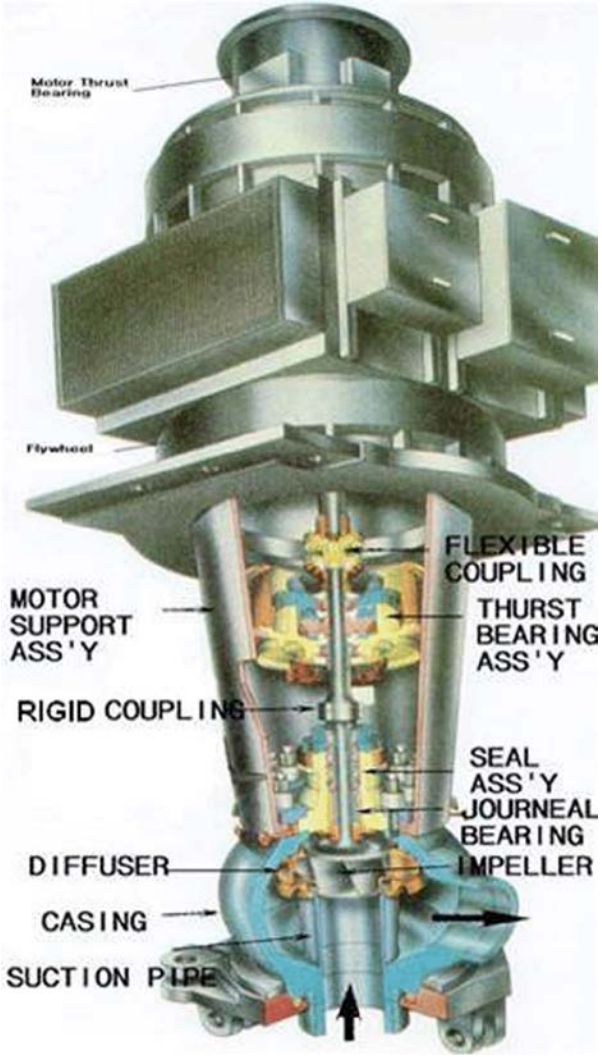
Reactor

- **Reactor Vessel**
- **Reactor Internals**
  - **Upper Guide Structure Assembly**
  - **Core Support Barrel Assembly**
- **Reactor Core**
  - **Fuel Assembly**
  - **Control Element Assembly**



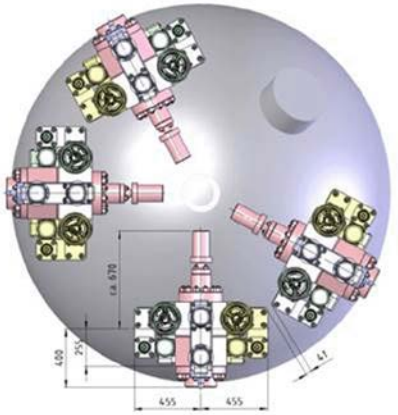
Reactor Coolant Pump

- **Motor driven, Single-stage Centrifugal Pump**
  - **Bottom suction and radial discharge**
- **Flexible Coupling of Shaft to the Motor**
  - **Low vibration and noise**
- **Pump Flywheel**
  - **Sufficient coastdown flow following loss of power to the pumps**
- **RCP Shaft Seal System**
  - **Three stage mechanical seals**
  - **Cooled by seal injection water and high pressure water cooler**



Pressurizer

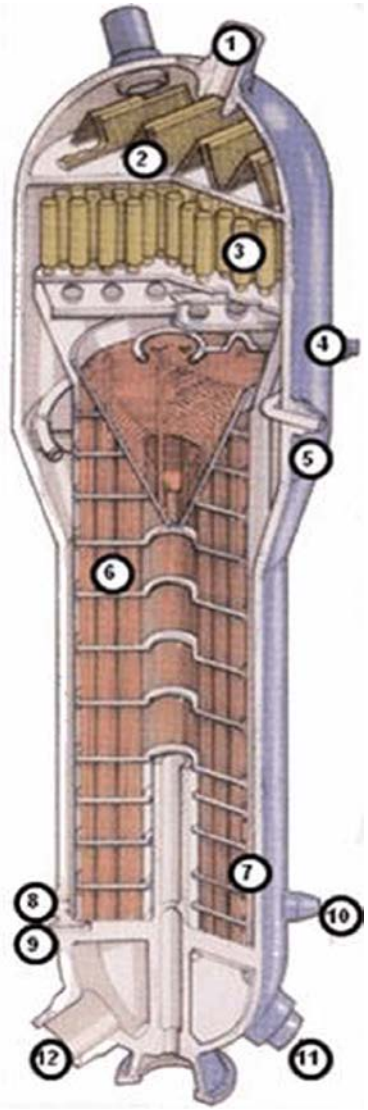
- **RCS Pressure and Volume Control**
  - **Sufficient capacity to accommodate pressure and volume changes due to operational transients without opening the safety valves**
- **Four Pilot Operated Safety Relief Valves (POSRVs)**
  - **Overpressure protection of RCS**
  - **Manual rapid depressurization of RCS to initiate Feed-and-Bleed operation in a total loss of feedwater event**



<Top view>

Steam Generator

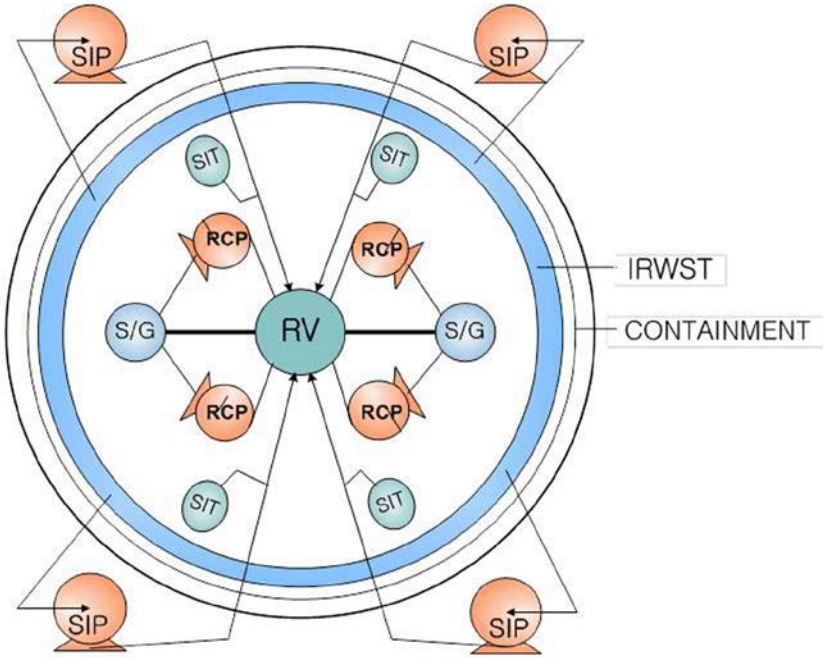
- **Vertical, U-tube, Recirculation type**
- **Alloy 690 U-tubes**
  - **Resistant to primary water stress corrosion cracking**
- **Integral Economizer**
  - **Enhance thermal effectiveness**
- **Flow Restrictor**
  - **Limit steam flow in the unlikely event of a main steam line break**



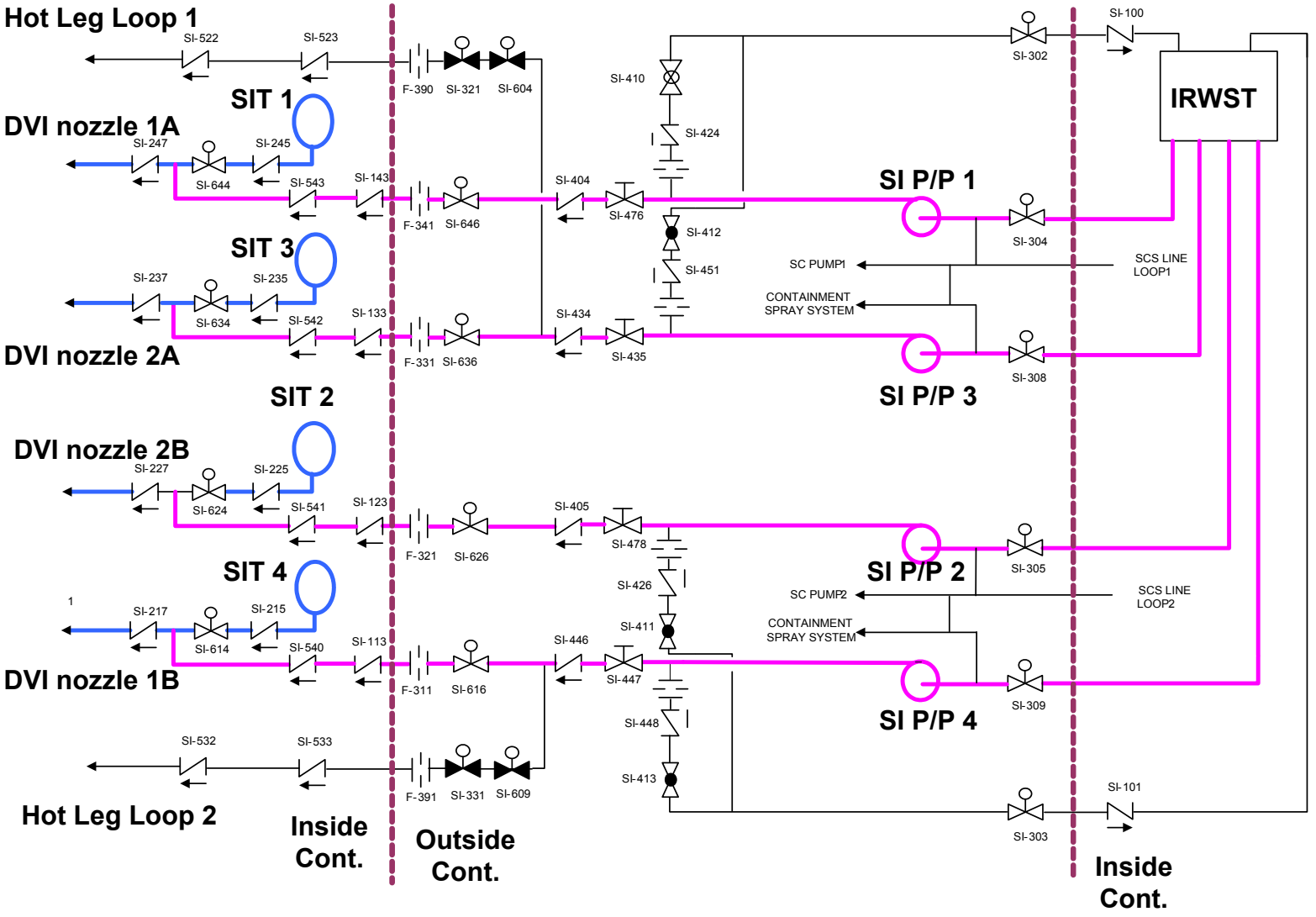
1. Steam Nozzles
2. Steam Dryers
3. Steam Separators
4. Recirculation Nozzle
5. Downcomer Feedwater Nozzle
6. Heat Transfer Tubes
7. Economizer
8. Lancing Hole
9. Blowdown Nozzles
10. Economizer Feedwater Nozzles
11. Primary Outlet Nozzles
12. Primary Inlet Nozzle

Safety Injection System

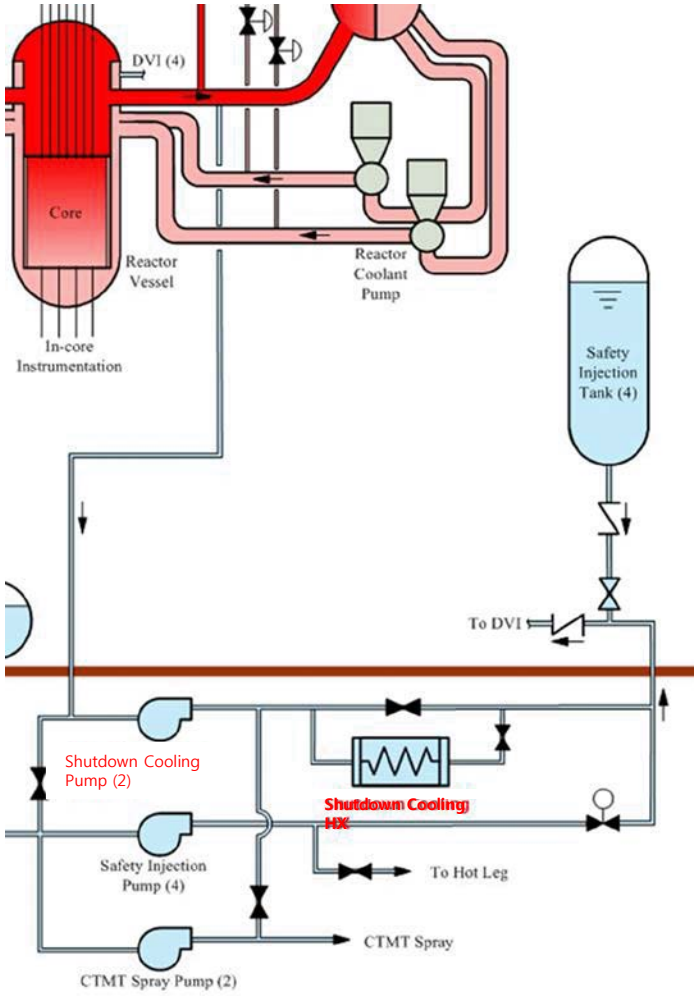
- **System Function**
  - Emergency Core Cooling
  - Reactivity and Inventory Control
  - Feed-and-Bleed Operation
- **SIS Design**
  - SIS consists of four mechanically and electrically separated trains.
  - Borated water is injected directly to the reactor vessel.
  - Borated water source is taken from In-containment Refueling Water Storage Tank (IRWST).



SIS Flow Diagram

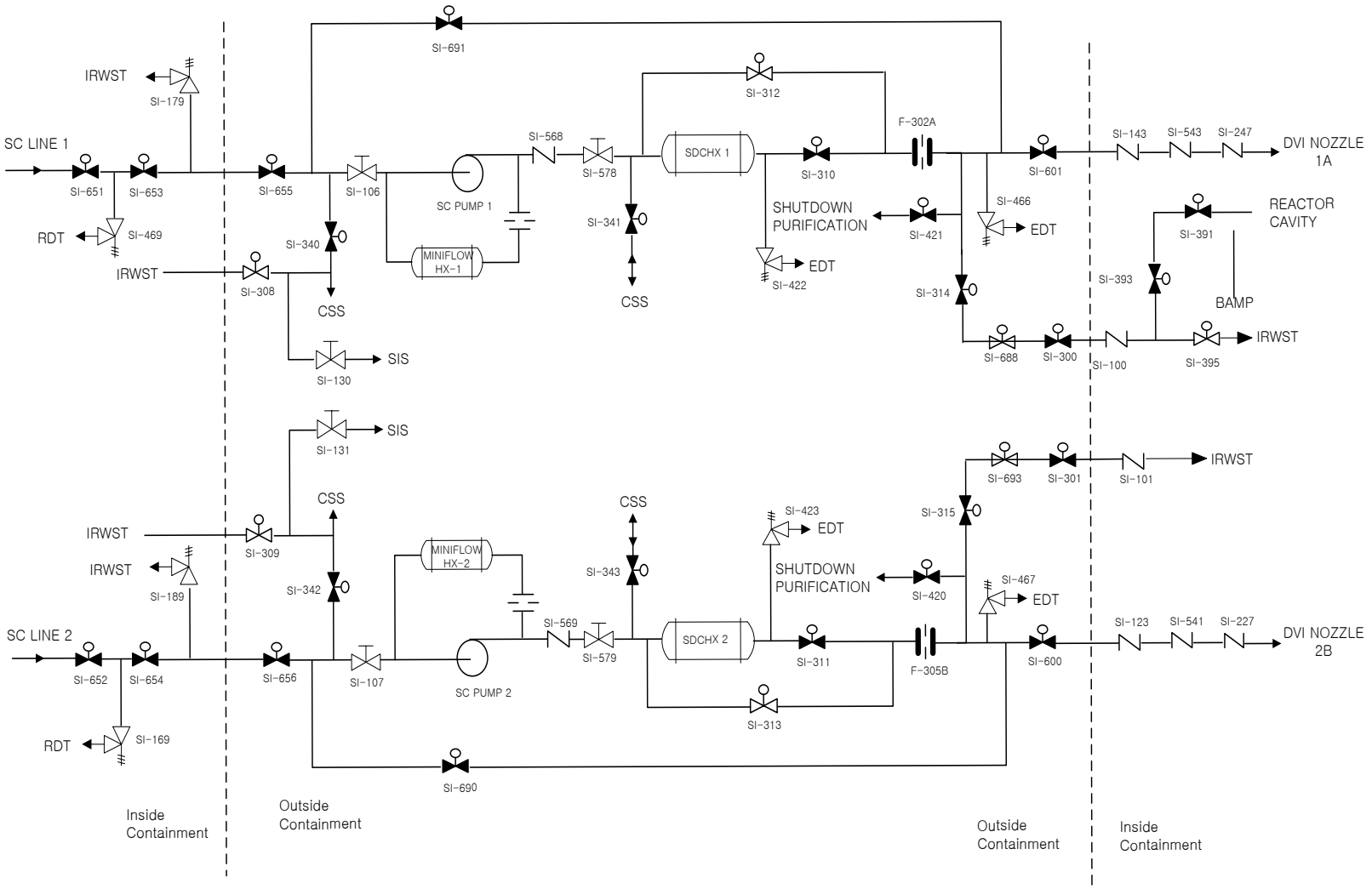


Shutdown Cooling System (SCS)

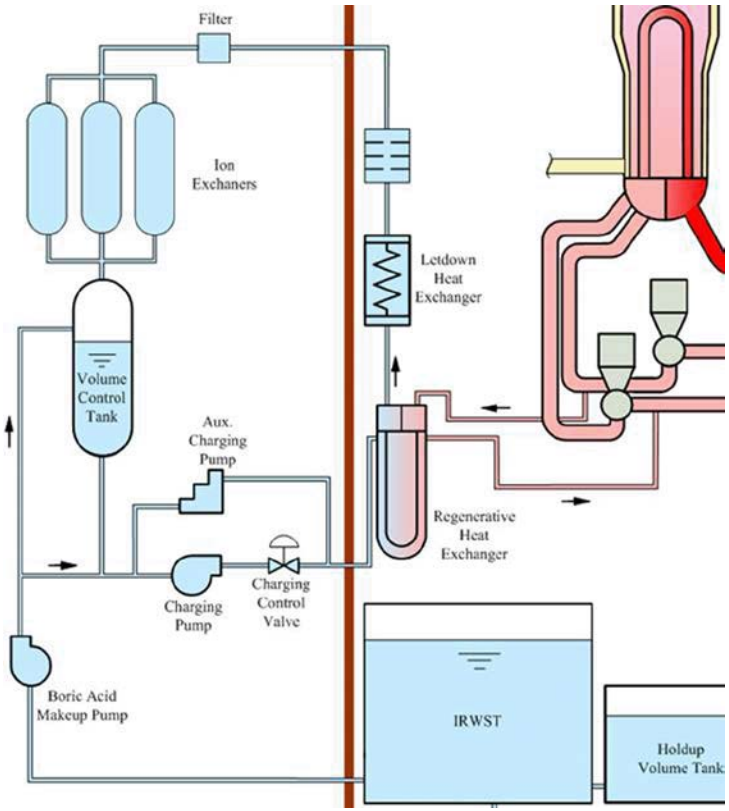


- **System Function**
  - **Decay Heat Removal**
- **SCS Design**
  - **SCS consists of two mechanically and electrically separated trains.**
  - **Shutdown Cooling Pump is interchangeable with Containment Spray Pump.**
  - **SCS suction line relief valves provide RCS low temperature overpressure protection.**

SCS Flow Diagram

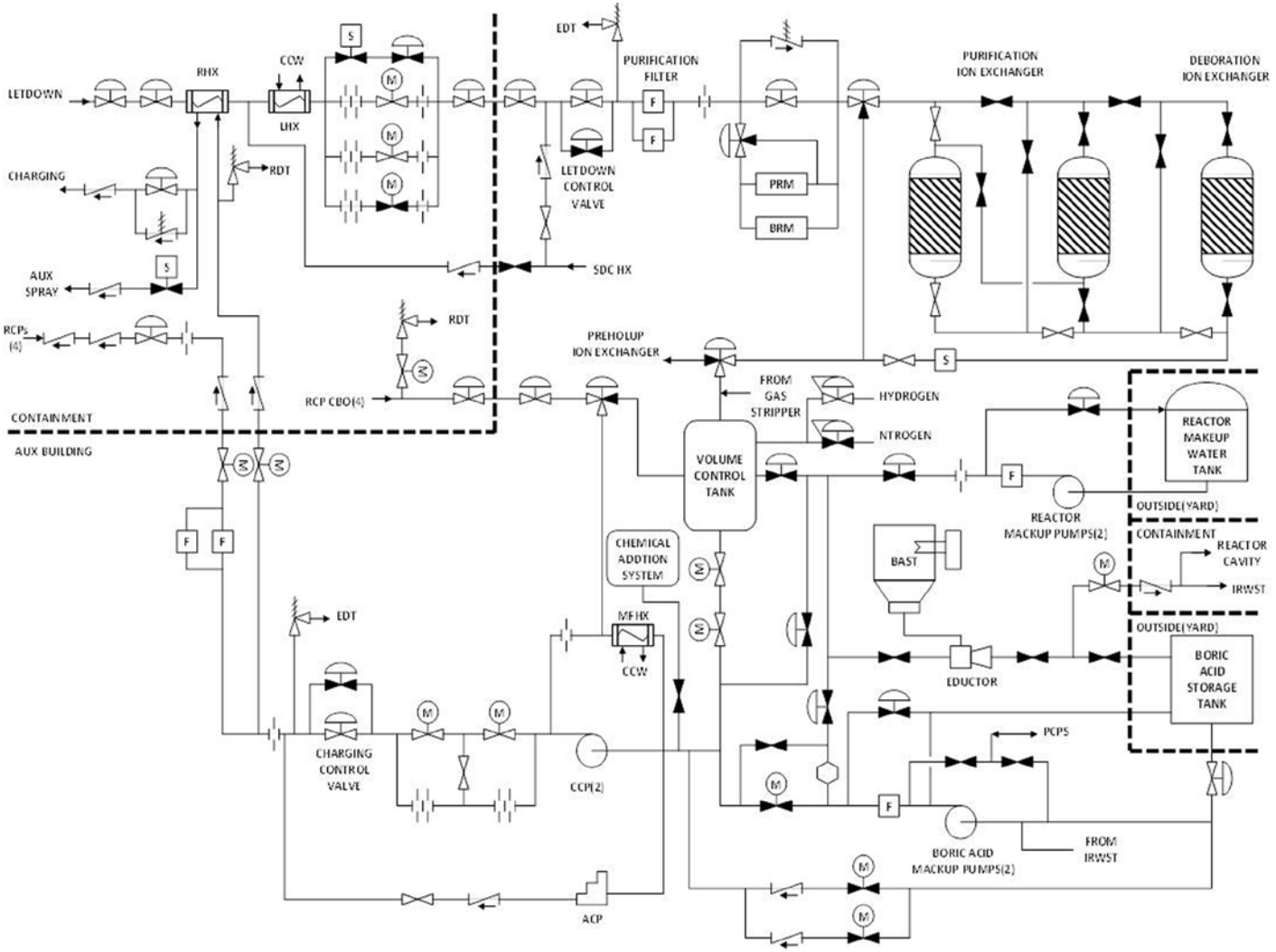


Chemical & Volume Control System (CVCS)



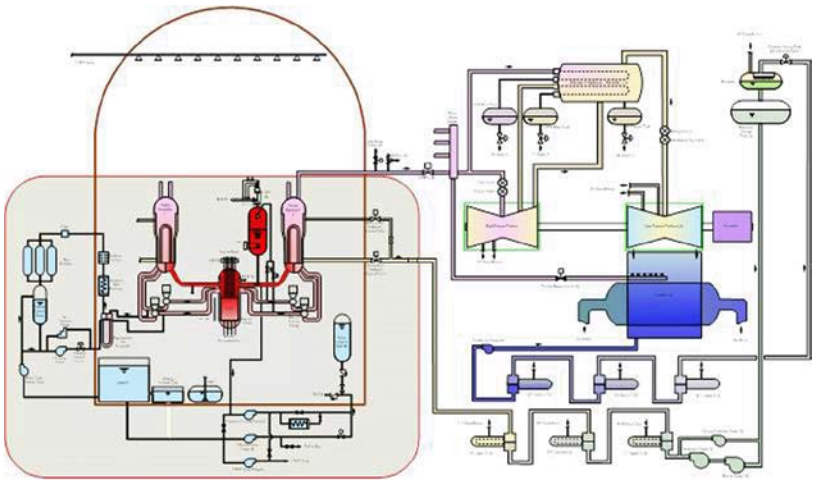
- **System Function**
  - RCS Inventory (Volume) Control
  - RCS Chemistry Control
  - Reactivity Control
  - Other Functions
    - Auxiliary spray to the pressurizer
    - Seal injection to the RCPs
- **CVCS Design**
  - CVCS consists of charging pumps, auxiliary charging pump, regenerative heat exchanger (HX), letdown HX, filters, ion exchangers, volume control tank, valves, etc.

CVCS Flow Diagram



Unique Design Features

- **Safety Injection Tank with Fluidic Device**
- **Pressurizer Pilot Operated Safety Relief Valve**

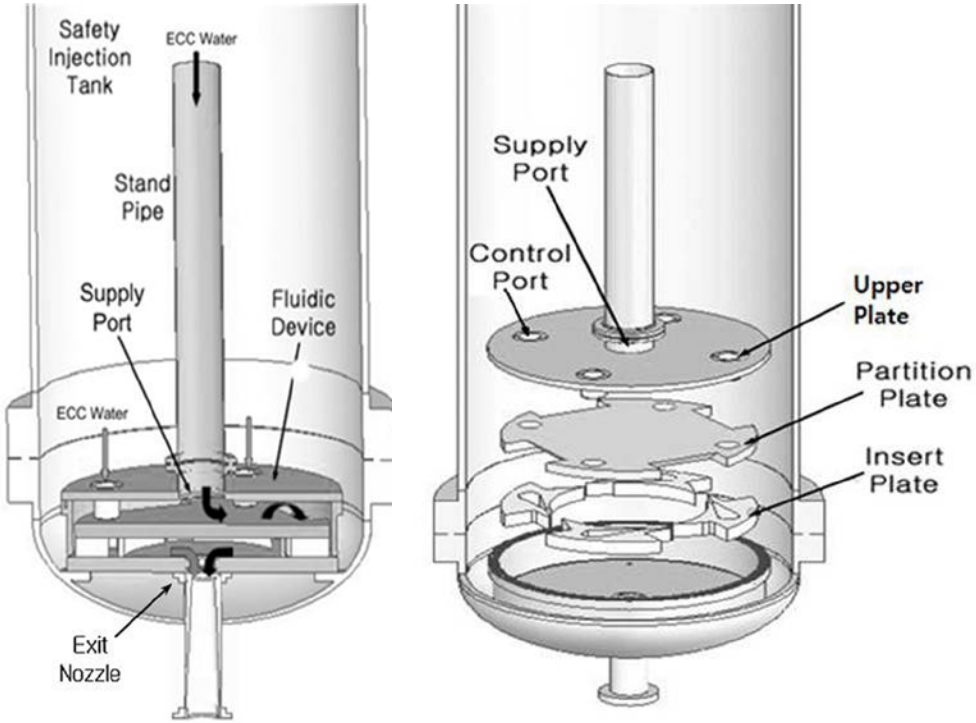


Safety Injection Tank with Fluidic Device

- **Safety Injection Tank (SIT) with Fluidic Device**
  - **is an accumulation tank partially filled with borated water and pressurized with nitrogen**
  - **provides inherent reliability to achieve a desired injection flow scheme without the need for any active components**
  - **controls injection flow rates during refill and reflood phases**
  - **ensures effective use of SIT water**

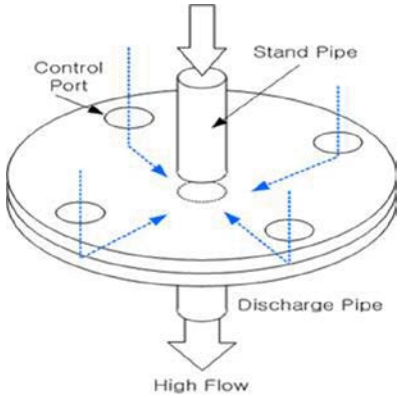
Working Principles of Fluidic Device

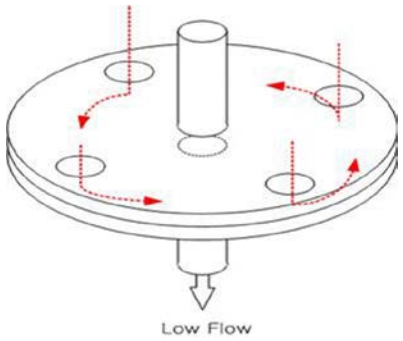
- **Structures of SIT with Fluidic Device**
  - **Fluidic Device is installed at the bottom part of the SIT.**
  - **Fluidic Device has a supply port at the center and four control ports around the supply port.**
  - **Supply port is connected to a stand pipe.**

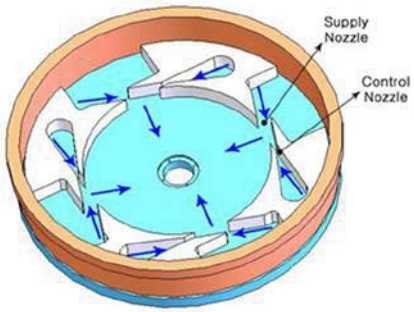


Working Principles of Fluidic Device

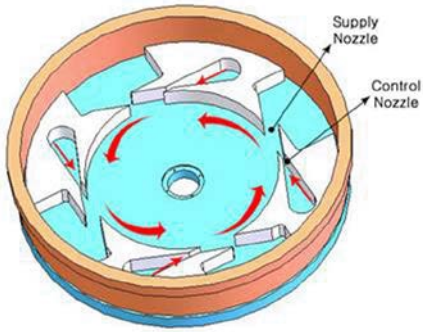
- **Typical Flow Pattern inside the Vortex Chamber**
  - **SIT water entered through the supply port flows into the vortex chamber through four supply nozzles.**
  - **SIT water entered through the four control ports flows directly into the vortex chamber through four control nozzles.**
  - **When SIT water is only injected through the control nozzles, SIT water is injected tangentially into the vortex chamber, establishing a strong swirling flow.**
  - **When SIT water is delivered through both the supply and control nozzles, the flows through each supply nozzle and a neighboring control nozzle collide each other, resulting in no swirling flow.**







Large Flow Rate



Small Flow Rate

Performance Test of Fluidic Device

- **Full scale test by Korea Atomic Energy Research Institute in Korea**

Summary of Performance Test

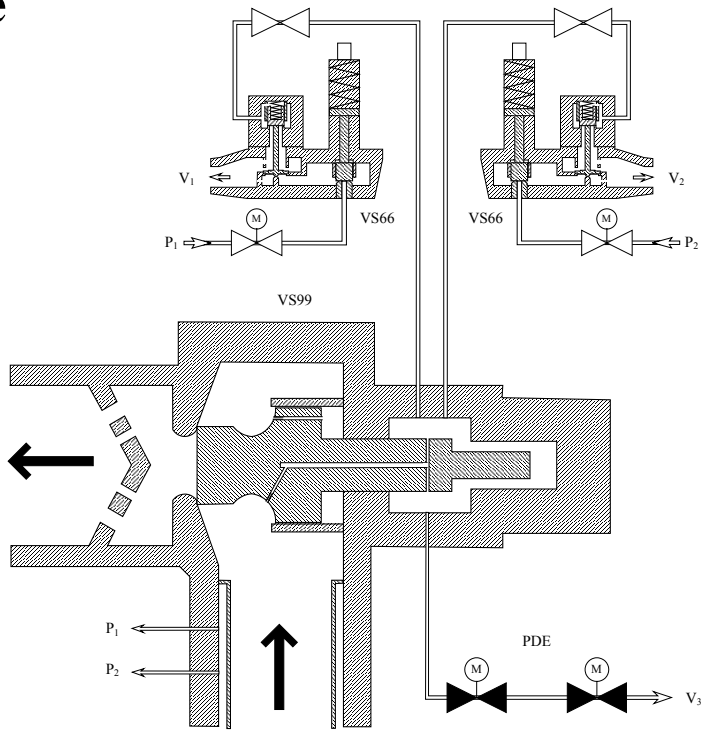
- A series of tests were performed to evaluate and verify the performance of SIT with Fluidic Device of APR1400.
  - Repeatability with regard to the performance was confirmed.
  - Pressure loss coefficient is not materially affected by initial pressure and manufacturing tolerances.
  - Design requirements including the pressure loss coefficient are met for both large and small flow injections.
- Topical Report for Fluidic Device Design for the APR1400 (APR1400-Z-M-TR-12003-NP) has been submitted on January 2013. Advanced TR Safety Evaluation is issued on April 2016.

Design Features of POSRV

- **Design Characteristics of Pilot Operated Safety Relief Valve (POSRV)**
  - **High seat tightness**
  - **Low possibility of chattering**
  - **Reliable for steam, water and two-phase discharge**
  - **Complicated installation and maintenance**
- **POSRV Function**
  - **Overpressure protection by automatic actuation of spring loaded pilot valves**
  - **Rapid depressurization by manual actuation of motor operated pilot valves**

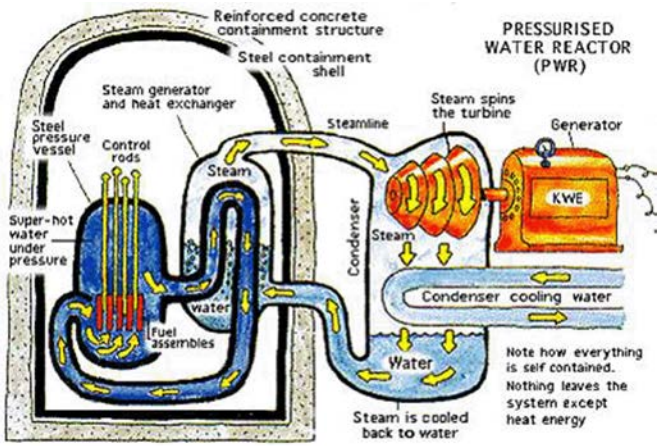
POSRV Assembly

- Main Valve (1)
- Spring Loaded Pilot Valve (SLPV) (2)
  - Automatic actuation for overpressure protection
  - Motor operated isolation valve
    - Normally open
    - Power removed
    - Closed in case of SLPV stuck open
  - Manual isolation valve
    - Isolation for SLPV test and maintenance
    - Locked open
- Motor Operated Pilot Valve (2)
  - Manual actuation for rapid depressurization
  - Two valves installed in series
    - Normally closed
    - Power removed



VS99 : Main Valve
VS66 : Spring Loaded Pilot Valve
PDE : Motor Operated Pilot Valves
M : Motor Operated Valve
V_1 : Pilot Discharge
P_1 : Impulse Line

Summary


Reinforced concrete containment structure
Steel containment shell
PRESSURISED WATER REACTOR (PWR)
Steam generator and heat exchanger
Steam spins the turbine
Steamline
Generator
Steel pressure vessel
Control rods
Steam
KWE
Super-hot water under pressure
Condenser
Steam
Condenser cooling water
water
Fuel assemblies
Water
Note how everything is self contained. Nothing leaves the system except heat energy
Steam is cooled back to water

Summary

- APR1400 NSSS design complies with US NRC regulatory requirements.
- APR1400 SIT with Fluidic Device is an innovative design which ensures effective use of the SIT water. The SIT with Fluidic Device was verified in full scale test facility as well as in the pre-operational test of Shin-Kori Unit 3.
- The POSRV adopted in APR1400 provides dual functions of overpressure protection and rapid depressurization.

Thank you