DCD Section 6.3 Clarification Call (June 7, 2016) NPSH Audit Notes and Questions

1. Page 24 of Technical Report APR1400-E-N-NR-14001-P, Rev. 0, indicates a value of 2.95 ft. for the $NPSH_m$. Table 3.6-2 indicates a value of 1.73 ft. for $NPSH_m$. Please explain the discrepancies.

Response:

The minimum NPSH margins for the SIPs and CSPs on page 24 of the TeR will be revised to 1.73 ft. and 3.0 ft., respectively, as shown in Attachment 1. They are consistent with those of Table 3.6-2.

The difference between the calculation sheet and Table 3.6-2 of TeR APR1400-E-N-NR-14001-P is listed below.

Pump	Head	Calc. Sheet (ft.)	Table 3.6-2(ft.)	Remark
SIP	Static head	30	30	Strainer head loss in calculation sheet will be changed to 2.0 ft.
	IRWST strainer head loss	1.5	2.0	
	Total head loss	5.78 (5.775)	6.28	
	NPSHA	24.23	23.73	
	NPSHR	22	22	
	NPSH margin	2.23	1.73	
CSP	Static head	30	30.16	Strainer head loss and NPSHR in calculation sheet will be changed to 2.0 ft. and 17.5 ft., respectively.
	IRWST strainer head loss	1.5	2.0	
	Total head loss	9.17 (9.165)	9.67	
	NPSHA	20.83	20.5	
	NPSHR	19	17.5	
	NPSH margin	1.83	3.0	

2. Please provide the calculation file detailing the calculation of H_{loss} for the SIPs and CSPs.

Response:

Excerpts from the NPSH calculation sheet for the SIPs and CSPs can be reviewed in the ERR.

3. Figure 3.9-3 of APR1400-E-N-NR-14001-P – clarify the values used to calculate 262,388 gallons.

Response

During normal operation, the IRWST water level is maintained at 93.0 ft. (elevation, EL) (77.04%, 649,000 gal). The IRWST is designed to minimize water evaporation, however, if the IRWST water level is less than 92.6 ft. (EL) (74.43%, 627,000 gal, the water level is recovered by a makeup operation from the boric acid storage tank via the boric acid makeup pump. Therefore, the water level of 92.6 ft. (EL) is the minimum IRWST water level during normal operation and becomes the initial water level for postulated accidents.

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The calculated IRWST water level for ESF operation during a LOCA is calculated by subtracting the holdup volume and inactive pool volume from the initial water volume at 92.6 ft. (EL) followed by adding the volume of three SITs, as follows:

$$V_{ESF,\ calculated} = V_{Initial} - V_{Holdup} - V_{Inactive} + V_{SIT} = 280{,}056\ gallon$$

Where,

- $V_{ESF,\ calculated}$ = calculated IRWST water volume for ESF operation
- $V_{Initial}$ = Initial water volume, 627,000 gallon
- V_{Holdup} = Holdup volume on the way to the IRWST, 162,829 gallon
- $V_{Inactive}$ = Inactive pool volume, 224,282 gallon
- V_{SIT} = Volume of three SITs, 40,167 gallon

The equivalent height for the minimum IRWST water volume for ESF operation becomes:

$$H_{cal} = \frac{V_{ESF}}{\pi \left(R_{outer}{}^2 - R_{inner}{}^2\right)} = 5.07\ ft$$

Where,

- H_{cal} = Calculated equivalent IRWST water height for ESF operation
- R_{outer} = IRWST outer radius, 71.83 ft.
- R_{inner} = IRWST inner radius, 53 ft.

Since the instrument lower tap height of 0.25 ft. is considered above the IRWST floor of 81 ft. (EL), the actual IRWST water level for ESF operation from the IRWST floor becomes 86.32 ft. (EL) (81 + 5.07 + 0.25 ft.).

The design basis of the minimum IRWST water level for ESF operation is set at 5 ft. above the IRWST floor, or 86 ft. (EL), with a margin of 0.32 ft.

Therefore, the water volume at 86 ft. (EL) of the IRWST water level becomes the minimum water volume for ESF pumps operation. The V_{ESF} volume of 262,388 gal is calculated as follows.

$$V_{ESF} = \pi\ (IRWST\ outer\ radius^2 - IRWST\ inner\ radius^2) \times (Minimum\ water\ level\ for\ ESF\ operation - IRWST\ lower\ tap\ level)$$

$$= \pi\ (71.83ft^2 - 53ft^2) \times (86ft - 81.25ft) = 262{,}388\ gal$$

In order to clarify these points, DCD, Subsections 6.2.1.1.2.2 and 6.8.4.5.8, and TeR, Subsections 3.6.2, 3.9.1, 3.9.2, and Figure 3.9.3 will be revised as shown in Attachment 2 and 3.

4. How is H_{static} calculated? What elevation is the SIP centerline?

Response

$$H_{static} = IRWST\ minimum\ water\ level\ for\ ESF\ operation - SIP\ elevation$$
$$= 86\ ft - 56\ ft = 30\ ft$$

The top elevation of suction nozzle of SIP is 56 ft. based on the reference plants.

5. Maximum NPSH required = 6.1m (20.0ft), Minimum NPSH available = 6.7m (22.0ft). Where does the value of 6.1m come from? APR1400-E-N-NR-14001 indicates the required NPSH is 22.0ft and the minimum available is NPSH is 23.73ft. This is inconsistent with DCD Tier 2, Table 6.3.2-1.
   a. Markups from a previous phone call report a NPSH requirement of 6.1m (20.0ft).

Response

The maximum NPSH required, including an uncertainty of 21%, is 22.0 ft., and the minimum NPSH available is 23.73 ft., as indicated in APR1400-E-N-NR-14001.

DCD Tier 2, Subsection 6.3.2.2.3 and Tables 6.2.2-1 and 6.3.2-1 will be revised as shown in Attachment 4.

Regarding the markup from the previous teleconference, the response to RAI 158-7997 Question 06.03-4 will be revised.

term phase, as shown in Figure 3.6-3. The $NPSH_m$ for the SIPs for the range of post-LOCA coolant temperatures is included as Table 3.6-2, and the $NPSH_m$ for the CSPs is included as Table 3.6-3.

The time-dependent NPSH curves shown in Figures 3.6-4 and 3.6-5 are based on Figure 3.6-3. These figures represent the most limiting pumps (CSP PP01B and SIP PP02D) and demonstrate positive NPSH margin for all ESF pumps over a full range of IRWST temperatures.

As illustrated in Figures 3.6-4 and 3.6-5, the $NPSH_a$ exceeds the $NPSH_r$ for all expected sump temperatures (and therefore, at all times throughout the LOCA transient). The minimum $NPSH_m$ calculated with this methodology is approximately ~~0.90 m (2.95 ft)~~ 0.53 m (1.73 ft) for the SIP and ~~0.65 m (2.14 ft)~~ 0.91 m (3.0 ft) for the CSP. Therefore, the IRWST sump strainer of the APR1400 provides sufficient $NPSH_a$ to ensure reliable operation of the ECCS pumps and CSPs.

3.6.3 Cavitation Erosion

Subsection 6.3 of Enclosure 1 of SECY-11-0014 (Reference [3-10]) describes the erosion effects of pump operation due to insufficient NPSH margin. Pump tests indicate that the zone of maximum erosion rate lies between $NPSH_m$ ratios ($NPSH_a$/$NPSH_r$) of 1.2 to 1.6, and guidance is provided to limit the time of operation in this zone to 100 hours. For the SIPs with an $NPSH_r$ of 6.71 m (22.0 ft), the range of $NPSH_a$ values that correspond to the maximum erosion zone is 8.05 to 10.73 m (26.4 to 35.2 ft). From Table 3.6-2, these pumps experience maximum erosion when the fluid temperature is between about 87.8 °C (190 °F) and 98.9 °C (210 °F). Similarly, the maximum erosion $NPSH_a$ range for the CSPs with an $NPSH_r$ of 5.33 m (17.5 ft) is 6.40 to 8.53 m (21.0 to 28.0 ft). From Table 3.6-3, these $NPSH_a$ values occur when the fluid temperature is between approximately 93.3 °C (200 °F) and 100 °C (212 °F). A review of the temperature data in Figure 3.6-3 indicates that the total duration, when the IRWST fluid temperature is between 90.6 °C (190 °F) and 100 °C (212 °F), is approximately 90,000 seconds (approximately 25 hours), which is within the 100 hour limit recommended in Subsection 6.3.3 of SECY-11-0014 (Reference [3-10]).

Located at the bottom of the containment, at El. 81 ft., the IRWST is a reinforced concrete structure with a stainless steel inside liner. The IRWST provides continuous subcooled water for the SI and CS to cool the containment in the event of abnormal events such as a LOCA or secondary system piping rupture. Section 6.8 describes the in-containment water storage system (IWSS).

6.2.1.1.2.1 Protection against External Pressure Loads

Inadvertent operation of the CS system, containment purge, and containment fan cooler systems could potentially result in a significant containment external pressure loading. The APR1400 containment is designed to withstand an external pressure loading of 0.28 kg/cm2G (4.0 psig) relative to ambient pressure. An evaluation and associated analyses demonstrate that the containment structure integrity is maintained under maximum external pressure-loading conditions; see Subsection 6.2.1.1.3.5.

6.2.1.1.2.2 Potential Water Traps Inside Containment

for ESF operation

The evaluation of the IRWST upstream effect is a review of the flow paths leading to the IRWST to identify flow paths that could result in blocking the return water that could challenge the IRWST minimum water level. The evaluation also includes identifying holdup volumes, such as recessed areas and enclosed rooms where trapped water volumes do not return to the IRWST. All of the hold-up volumes were taken into account in the minimum water level evaluation of the IRWST.

for ESF operation

Holdup volumes are divided into two groups: Hold-up water on the way to the IRWST and the inactive pool volume. Detail holdup volume capacities are listed in Table 6.8-2 and the schematic of potential water traps in containment is shown in Figure 6.2.1-20. The groups are defined as follows:

a. Hold-up volume on the way to the IRWST

In a LOCA, the IRWST water returns from the containment spray nozzles and broken pipe. The water on the way to the IRWST decreases the initial IRWST water level. The following are the source of hold-up water on the way to the IRWST:

blockage. Smaller debris would just pass straight through. Debris would also need to be planar to adequately seal the opening. A crumpled piece of RMI would not seal the opening.

The IRWST is designed to provide adequate water level to SI and CS/SC pumps. In addition, in consideration of the static head and suction line pressure drop, the evaluation of the available NPSH assumes that the vapor pressure of the liquid in the IRWST is equal to the containment ambient pressure. This assumption provides reasonable assurance that the actual available NPSH is always greater than the calculated NPSH. The minimum water level of the IRWST provides the basis for estimating static head in the NPSH evaluation as described in Section 6.3 and Subsection 6.5.2.

for ESF operation

The minimum water level of the IRWST during a LOCA is calculated by subtracting the hold-up volume from the initial water volume in the IRWST and adding the water volume of three SI tanks. The minimum water level was determined to be 1.52 m (5 ft) above the IRWST bottom (at El. 81 ft) and this value is used in the NPSH evaluation.

for ESF operation

6.2.1.1.3 Design Evaluation

A containment response analysis is performed to demonstrate the containment's integrity to postulated accident conditions. The APR1400 uses a simplified and distinct containment model using the Generation of Thermal-Hydraulic Information for Containment (GOTHIC) computer code (Reference 2) to calculate the containment pressure and temperature response following the M&E release from primary and secondary system pipe ruptures. This section presents a description of the analysis methodology and containment response calculations following a postulated LOCA and secondary system pipe rupture.

6.2.1.1.3.1 Description of Containment Analysis Methodology

The GOTHIC computer code (version 8.0) is selected to develop the APR1400 containment model since it is widely used to perform containment pressure and temperature (P/T) response analyses in the nuclear industry. The code is suitable to predict the containment pressure and temperature response to the M&E release following high-energy line breaks such as reactor coolant, main steam, and main feedwater piping. Besides the containment response analysis, GOTHIC is used to calculate the M&E release during the decay heat

Surrogate suspensions of chemical precipitates representing this chemical debris can be included as an additional debris source to the strainer testing program to qualify the strainer for “chemical effects”. The quantities of chemical precipitates are based on reactive material surface areas and quantities, temperature, water level, pH and other parameters related to the plant specific environment and postaccident evolution. The calculated result based on the WCAP-16530-NP (Reference 9) methodology referenced in RG 1.82 (Reference 3) is provided in Table 6.8-3.

6.8.4.5.8 Upstream Effects

for ESF operation

The evaluation of upstream effect is a review of the flow paths leading to the IRWST, identifying those flow paths which could result in blocking the return water that could challenge the IRWST minimum water level evaluation. The evaluation also includes identifying the hold-up volumes, such as recessed areas and enclosed rooms, for which trapped water will not return to the IRWST. All of the hold-up volumes were taken account of in the minimum water level calculation. Detail holdup volume is provided in Table 6.8-2.

for ESF operation

Figure 6.2.1-20 show a schematic of containment spray and blowdown return pathways, and the schematic of potential water traps in containment. During long-term cooling subsequent to a RCS pipe break, borated water is drawn from the IRWST by the SIPs and injected into the RV for core cooling. This water is ejected to the bottom floor of the containment within the secondary shield wall through the horizontal platforms which are constructed of open grating within the SG compartments. The CSPs also draw water from the IRWST sumps to cool the containment building. This water rains down on all containment surfaces, and then drains to the bottom floor of containment within secondary shield wall and annulus via the stairway and a ring of deck grating around much of the circumference of the building.

Water spilled from RCS break and the uniformly distributed containment spray water drain back to the HVT, and then drains to the IRWST via spillways. Since there are four pathways on the bottom floor of the containment, the debris will not clog these pathways. As a result of evaluation, no choke points that may block the flow paths of return water are identified. Therefore, only the hold-up volumes may challenge the minimum water level of the IRWST.

for ESF operation

phase (containment atmosphere) and to the IRWST (liquid phase) inside the containment volume. Steam released from the primary system postulated break maintains the containment atmosphere at saturated conditions during almost all of the LOCA transients. Moreover, fluid condensed by passive heat sinks (such as the containment shell liner, supporting structures and concrete) and the CS is added to the IRWST. The condensed water entering the IRWST is at the steam partial pressure in the containment atmosphere. After the long-term operation, the IRWST liquid temperature is strongly affected by the liquid water condensed from the atmosphere during the CS operation. The condensed water is also saturated at the steam partial pressure.

Therefore, a higher containment pressure provides condensed water at a higher temperature and higher IRWST liquid temperatures. Similarly, a lower containment pressure provides condensed water at lower temperature and a lower IRWST liquid temperature. For the purposes of the $NPSH_a$ determinations for ECCS pumps, the APR1400 does not consider the IRWST vapor saturation pressure (based on IRWST liquid temperature) to exceed the containment pressure for any postulated DBA.

Figure 3.6-3 (Figure 6.2.1-4 of Reference [3-1]) shows the containment pressure and IRWST water temperature response during a LOCA and MSLB accident. The IRWST temperatures are calculated conservatively by mixing the condensed liquid in the containment with the IRWST water. The limiting case is the double-ended discharge leg slot break with minimum SI flow from Reference [3-7]. The IRWST maximum water temperature is 119.15 °C (246.47 °F) at 16,007 seconds. Containment pressure at the maximum IRWST water temperature is 1.07 kg/cm^2 (15.21 psia) higher than saturation pressure, which provides reasonable assurance that water temperature does not exceed the saturation temperature in the range of containment pressures analyzed. Therefore, the assumption that containment pressure and IRWST vapor pressure are equal when evaluating $NPSH_a$ is appropriate and conservative for the ECCS and CSS.

(c) Water level

The contribution of the volume of water spillage from the RCS is conservatively neglected, and the volume of water spillage from SITs is available in three of four SITs in accordance with EPRI, Chapter 5, "Engineered Safety System," in Vol. II, "ALWR Evolutionary Plant," of Advanced Light Water Reactor Utility Requirements Document (Reference [3-8]).

With the CSS actuated, the reactor cavity and in-core instrumentation (ICI) cavity are assumed to be flooded to a level that can overflow onto the floor at El. 100 ft through the openings of HL and CL pipes at El. 114.29 ft. The HVT is also just below the level at which water begins to return to the IRWST through the spillways.

Spray water is held up on surfaces throughout the containment. The accumulation of water inside the containment includes water held up on horizontal surfaces, clogged floor drains, water held up in containment spray pipes, water in the containment atmosphere, water film on vertical surfaces, puddles trapped on equipment, water soaked into insulation, and the containment free volume filled with steam.

Based on the above assumption, the IRWST water level for the $NPSH_a$ calculation is determined to be 1.52 m (5 ft) above the IRWST bottom (El. 81 ft). The details of the minimum water level are described in Subsection 3.9.2.

for ESF operation

(d) Head loss

Head loss calculations for the $NPSH_a$ are based on hydraulic models of the system aligned to take suction from the IRWST. The system configurations of SIP suction and CSP/SCP

3.9 Upstream Effect

3.9.1 Holdup Volumes

The evaluation of the upstream effect is a review of the flow paths leading to the IRWST, identifying the flow paths that could result in blocking the return water that challenges the IRWST minimum water level evaluation. The evaluation also includes identifying the holdup volumes, such as recessed areas and enclosed rooms, for which trapped water does not return to the IRWST. All of the holdup volumes are taken account of in the minimum water level calculation.

for ESF operation

Figures 3.9-1 and 3.9-2 show a schematic of CS and blowdown return pathways, and the schematic of potential water traps in containment. During long-term cooling subsequent to an RCS pipe break, borated water is drawn from the IRWST by the SIPs and injected into the RV for core cooling.

The water is ejected to the bottom floor of the containment within the secondary shield wall through the horizontal platforms which are constructed of open grating within the SG compartments.

The CSPs also draw water from the IRWST sumps to cool the containment building. This water rains down on all containment surfaces, and then drains to the bottom floor of containment within the secondary shield wall and annulus via the stairway and a ring of deck grating around much of the circumference of the building.

There are two 10 inch drain pipes in the refueling cavity that are connected to the bottom portion of the containment. The refueling cavity surrounds the upper part of the reactor and extends from the operating floor at El. 156 ft down to the reactor head flange at El. 130 ft. The west part of the cavity encompasses the upper guide structure (UGS) laydown area which extends down to El. 106 ft 6-3/8 in. The east part of the refueling cavity encompasses the fuel transfer system upender and core support barrel (CSB) laydown area. The fuel transfer system upender and the CSB laydown area extends down to El. 114 ft 6 in.

The cavity can collect approximately 9% of the containment main spray flow and fill up except for the two floor drains. Both drains are 10 inch diameter drain pipes in the floor of the refueling cavity liner. One combined drain is the CSB laydown area and the fuel transfer system upender area, and the other is the UGS laydown area. Both drain to El. 100 ft area.

A concern with the refueling cavity is the potential for pieces of debris (e.g., a 25. 4 cm x 25.4 cm (10 inch x 10 inch) piece of RMI) to migrate to one or both drains and greatly restrict the flow so that the refueling cavity may fill. The water sprayed on the refueling cavity area is finally gathered to the lowest parts of the refueling cavity, UGS laydown area, and CSB laydown area, which hypothetically could hold thousands of cubic feet of water if their drains are blocked. However, this scenario is deemed not credible. No high-energy pipes are near the 10 inch openings that drain the refueling cavity. The 10 inch drains are open with no covers, grates, or screens, so the minimum flow restriction in the cavity drain line flow path is the inner diameter of the 10 inch drain line. Debris needs to be at least 10 inches wide to bridge the opening and cause blockage. Smaller debris passes straight through. Debris also needs to be planar in order to adequately seal the opening. A crumpled piece of RMI would not seal the opening.

Water spilled from RCS break and the uniformly distributed CS water drains back to the HVT, and then drains to the IRWST via spillways. Since there are four pathways on the bottom floor of the containment (two 0.91 m (3 ft) wide pathways are personnel entrances leading into secondary shield wall from annulus and two 2.92 m (9 ft 7 inch) wide pathways are located at the front of the HVT trash racks in the secondary shield wall), the debris would not clog these pathways. As a result, no choke points that could block the flow paths of return water are identified. Therefore, only the holdup volumes may challenge the minimum water level of the IRWST.

for ESF operation

The following assumptions are made in the calculation for holdup volume conservatism:

1) The LBLOCA is assumed so that the coolant completely fills the reactor cavity and ICI cavity.

2) The water transfer from the HVT into the IRWST is assumed to spill over into the IRWST through one spillway to maximize water volume to be held up in the HVT.

3) A portion of the CS is delayed in the containment building. The maximum CS flow rate for a two-train operation is assumed to conservatively maximize the CS hold up.

4) The amount of water needed to fill the SIS and CSS is the volume of SIS and CSS piping above ~~the minimum Technical Specification level~~. the minimum water level during normal operation.

5) The maximum containment atmospheric conditions at CSAS are assumed for each scenario to maximize water that would be held up in the atmosphere. CS water may be held up in the containment atmosphere, in the containment spray droplets, and in the condensation on containment building and equipment surfaces. A fraction of the total water delivered to containment evaporates in the containment atmosphere. The evaporation quantity is calculated based on the steam mass and pressure conditions at CSAS as determined in the associated analyses. CS volume holdup is determined by calculating the fall time at terminal velocity for water droplets from the main spray median header height and the average drop diameter, and the fall time at terminal velocity for droplets from the auxiliary spray median header height and average drop diameter. The delayed volume is thus the product of the fall time and the maximum spray flow rate for each system.

6) Condensation holdup on horizontal and vertical surfaces for containment walls, structures, and equipment is determined by calculating a total surface area and then applying a uniform water film thickness. This value is considered conservative because no distinction is made for surface area orientation; the water film is assumed to be uniform over all horizontal and vertical surfaces.

7) The minimum IRWST and SIT volumes are assumed to minimize water transferred to the containment floor during injection.

The holdup volumes are categorized into two groups: Holdup volume on the ways to the IRWST and inactive pool volume. Two groups are defined as follows:

1) Holdup volume on the ways to the IRWST

   In a LOCA, the IRWST water returns from the CS nozzle and broken pipe. The held-up water on the way to the IRWST decreases the initial IRWST water level. The following are the source of held-up water on the way to the IRWST.

   (a) CS suspended water in the containment atmosphere
   (b) CS steam water
   (c) Initial filling water for the SIS and CSS pipe

(d) Condensate water on various surfaces
(e) Water stream on the floor at El. 100 ft
(f) Water steam on the refueling cavity floor

2) Inactive pools volume

An inactive pool volume is defined as a holdup volume that entraps return that will not contribute to recovering the IRWST water level. The following are considered as the ineffective pools:

(a) HVT water volume to fill up to level that can flow back into the IRWST through the spillways
(b) Reactor cavity and ICI cavity volume
(c) Containment drain sump volume
(d) ICI cavity sump volume

The calculated holdup volumes are provided in Table 3.9-1.

3.9.2 Minimum Water Level

for ESF operation

The following assumptions are made for water sources to minimum water level determination:

1) Water sources available to provide flood water volume are the IRWST volume.

2) RCS spillage from a break point is not credited.

3) Three SITs volumes are added to the IRWST inventory to establish the total volume of water available for flooding.

4) The minimum IRWST and SIT volumes are assumed to minimize water transferred to the containment floor during injection.

for ESF operation

The minimum water level of IRWST provides the basis for estimating static head in the NPSH evaluation, as described in Section 3.6. It is conservatively calculated as follows:

During normal operation, the IRWST is not less than 2,373.5 m^3 (627,000 gallons, 74.43% water levels of the IRWST) to ensure an adequate supply of borated water to the SIS and CSS. The IRWST is designed to minimize water evaporation, however, if the water reaches a level of less than 74.43%. The makeup operation from the boric acid storage tank via the boric acid makeup pump is activated and continued until 74.43% water level is recovered. This level is defined as “below normal water level” of the IRWST and is used as the initial water level for postulated accidents. In case of an LBLOCA, the water mass in the SIT can contribute to recovering the IRWST, and water in three of the four SITs is considered in the calculation in accordance with Reference [3-8].

for ESF operation

The minimum water level of the IRWST during a LOCA is calculated by subtracting the holdup volume from the initial water volume in the IRWST and by adding the volume in three SITs. The minimum water level used in the NPSH evaluation is calculated as 1.52 m (5 ft) above the IRWST bottom (El. 81 ft) and is shown in Figure 3.9-3.

for ESF operation

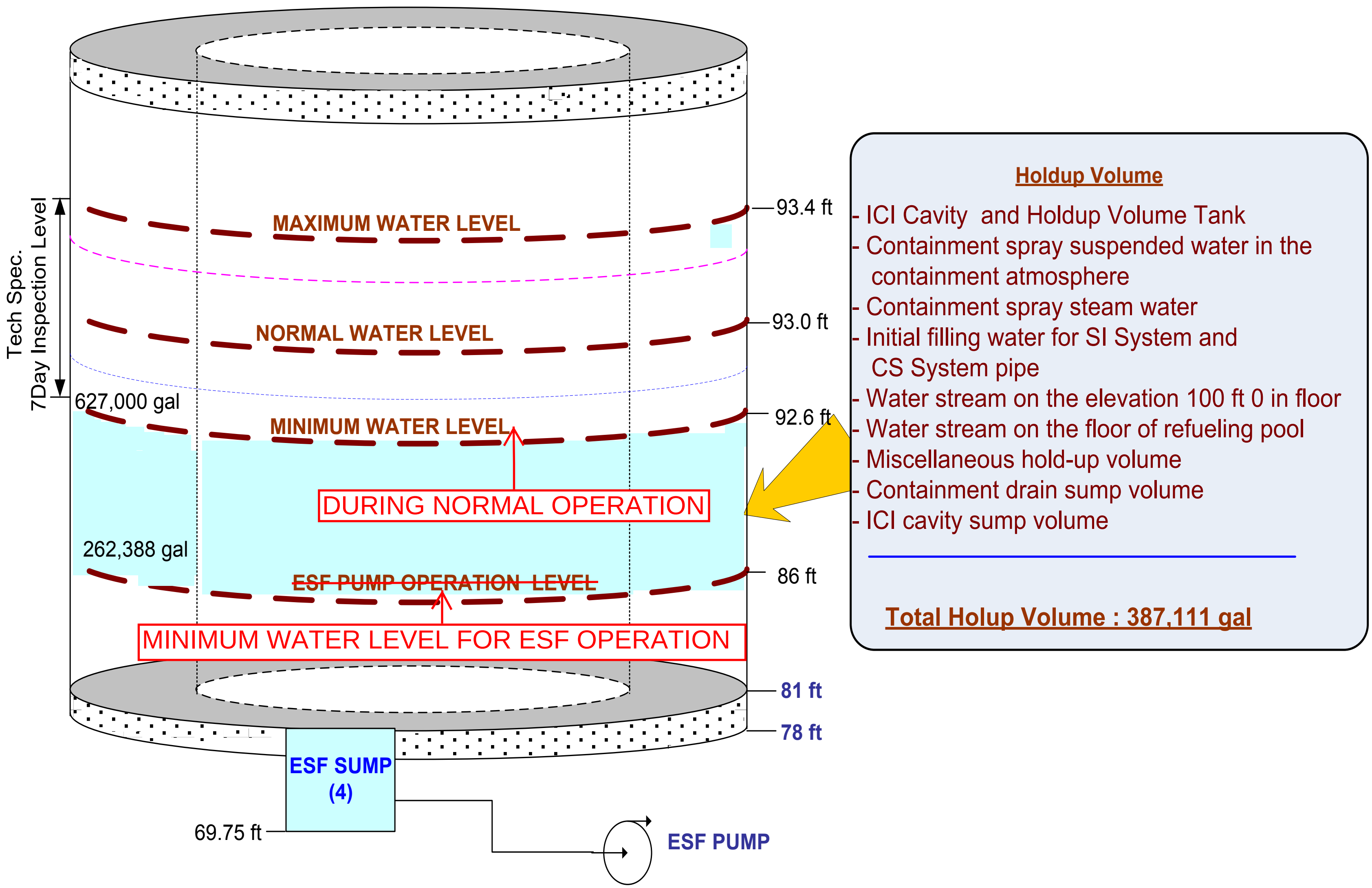

Figure 3.9-3 Schematic Diagram for IRWST Water Volume

Table 6.2.2-1

Input Values Used in CSS Evaluation Calculations

CSP NPSH Evaluation	
$h_{static\ head}$	9.19 m (30.16 ft)
$h_{line\ loss}$	2.34 m (7.67 ft)
$h_{IRWST\ sump\ strainer}$	≤ 0.61 m (2.00 ft) (1)
$NPSH_{available}$	6.25 m (20.50 ft)
~~$NPSH_{required}$~~ → $NPSH_{required,\ effective}$ (2)	5.33 m (17.50 ft)
$NPSH_{margin}$	0.91 (3.00 ft)
SI Pump NPSH Evaluation	
$h_{static\ head}$	9.14 m (30.0 ft)
$h_{line\ loss}$	1.30 m (4.28 ft)
$h_{IRWST\ sump\ strainer}$	≤ 0.61 m (2.00 ft)(1)
$NPSH_{available}$	7.23 m (23.73 ft)
~~$NPSH_{required}$~~ → $NPSH_{required,\ effective}$ (2)	6.71 m (22.00 ft)
$NPSH_{margin}$	0.53 m (1.73 ft)

(1) Contains head loss due to debris clogging and chemical effect.

(2) Contains uncertainty of 21%.

Mechanical shaft seals are used and provided with leakoff that collect any leakage past the seals. The seals are designed for operation with a pumped fluid temperature of 176.7 °C (350 °F).

The SI pump motors are specified to have the capability of starting and accelerating the driven equipment, under load, to a design point running speed within 5 seconds. This is based on an initial voltage of 75 percent of rated voltage at the motor terminals, increasing linearly with time to 90 percent voltage in the first 3 seconds and to 100 percent voltage in the next 2 seconds.

The SI pumps are provided with drain and flushing connections to permit a reduction of radioactive contamination before maintenance. The pressure-containing parts of the pump are stainless steel with internals selected for compatibility with boric acid solutions. The materials selected are analyzed to provide reasonable assurance that differential expansion during design transients can be accommodated.

The design temperature of the SI pumps is based on the saturation temperature of the reactor coolant at the containment design pressure plus a design tolerance. The design pressure for the SI pumps is based on the shutoff head plus maximum containment pressure plus a design tolerance. The pump data are provided in Table 6.3.2-1.

available NPSH effective evaluations below the availalbe NPSH.

The SI pumps are specified to limit the ~~maximum~~ effective required NPSH ~~to 6.1 m (20 ft) at pump runout flow~~ below the availalbe NPSH. The SI pump NPSH ~~requirements~~ evaluations are described in Table ~~6.3.2-1~~ 6.2.2-1. Pump vendor tests are conducted to provide reasonable assurance that the ~~actual~~ effective required NPSH does not exceed the ~~specified limit~~ available NPSH. Available NPSH is calculated in accordance with NRC RG 1.1 (Reference 4). ~~The difference between required NPSH and available NPSH provides reasonable assurance that NPSH requirements are satisfied.~~

6.2.2-1 effective

The strainer is designed to protect the pump inlet and prevent ingestion of debris that can cause a loss of NPSH, in accordance with NRC RG 1.82 (Reference 5), for long-term recirculation cooling following a LOCA.

Table 6.3.2-1 (1 of 3)

SIS Component Parameters

Safety Injection Pumps

Quantity	4
Type	Multistage, horizontal, centrifugal
Safety classification	2
Seismic Category	I
Code	ASME Section III, Class 2
Design pressure	144.1 kg/cm^2G (2,050 psig)
Maximum operating suction pressure	7.0 kg/cm^2G (100 psig)
Design temperature	176.7 °C (350 °F)
Design flow rate	3,085 L/min (815 gpm)(1)
Design head	868.7 m (2,850 ft)
Materials	Stainless steel, type 304, 316 or approved alternate
Shaft seal	Mechanical
Brake horsepower	746 kW (1,000 hp)

Safety Injection Pump NPSH

	~~Flow/Pump L/min (gpm)~~	~~Maximum NPSH required m (ft)~~	~~Minimum NPSH available m (ft)~~
~~Long-Term Cooling Mode~~	~~4,675(1,235)~~ (2)	~~6.1 (20)~~ (3)	~~6.7 (22)~~ (3)

~~(1) Does not include minimum bypass flow.~~

~~(2) Including minimum bypass flow.~~

~~(3) Calculation is based on the NRC RGs 1.1 and 1.82. SI pumps take suction from the IRWST at runout flows.~~

See Table 6.2.2-1.