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SUMMARY OF REVISIONS

Revision 0: Initial Issue.

1.0 INTRODUCTION

1.1 This report documents the evaluation of possible internal and external hazards at the KRSKO nuclear station. The KRSKO technical specification SP-ES5104, R4, [3.1] requires that Holtec's dry storage system for spent nuclear fuel is safe against external hazards. Possible sources of external hazards at the KRSKO nuclear station are earthquakes, strong wind, rain, snow / ice, thunder / lighting, river (flood) and temperature [3.3].

2.0 DEFINITIONS

2.1 MPC-37: Holtec International Multi-Purpose Canister, a stainless steel cylindrical pressure vessel used to store 37 PWR fuel assemblies.

2.2 HI-STORM FW Overpack: Holtec International heavy container, into which an MPC is placed for storage. The Cask provides radiation shielding and protects the MPC from harm. The HI-STORM FW overpack is stored in the Dry Storage Building.

2.3 HI-TRAC VW: Intermediate transport container that provides temporary storage and transport capabilities for the MPC during loading and transfer at the site.

3.0 REFERENCES

3.1 Technical Specification Spent Fuel Dry Storage Construction Campaign I and II, SP-ES5104, Rev 4

3.2 Final Safety Analysis Report, HI-2177798, latest revision

3.3 WENRA Report - Guidance Document Issue T: Natural Hazards Head Document, 18 February 2015

3.4 IAEA Safety Standards, External Event Including Earthquake in the Design of Nuclear Power Plants, NS-G-1, Rev 0

3.5 IAEA Safety Standards, Safety of Nuclear Fuel Cycle Facilities, NS-R-5, Rev 1

3.6 SKI Report 02:27 - Guidance for external events analysis

3.7 Holtec Drawing 10992, Dry Storage Building Design and Details, latest revision

3.8 Evaluation of Plant Hazards at KRSKO Nuclear Power Plant, HI-2177799, latest revision

3.9 KRSKO Nuclear Power Plant Updated Safety Analysis Report, Revision 23

3.10 Plant Modification No. 1101-SF-L, Rev 0

3.11 Screening of Internal Hazards, Report Number: NEK ESD-TR-07/17, Rev. 0

3.12 Screening of External Hazards, Report Number: NEK ESD-TR-18/16, Rev.1

3.13 NEK Safety Upgrade Project Design Inputs and Interfaces, DCM-D1-001, Rev. 8

3.14 Procedures for the External Event Core Damage Frequency Analyses for NUREG-1150, NUREG/CR-4840

4.0 DISCUSSION

The Final Safety Analysis Report (FSAR) [3.2] analyzes the different external hazards that the HI-STORM FW system may experience at the KRSKO nuclear station. The HI-STORM FW containing the MPC loaded with spent nuclear fuel and the ISFSI pad will be able to withstand possible hazards caused by the occurrence of natural phenomena. In fact, the 'FW' in HI-STORM FW system stands for Flood and Wind, indicating that the HI-STORM FW system is specifically designed to consider the adverse effects of "Floods and Wind".

The effects of external hazards on the HI-STORM FW system can result from individual external hazards or the combination of multiple external hazards. NEK may be exposed to internal hazards as covered in Section 4.2. Both individual and combined effects of hazards are covered below in Sections 4.1 and 4.3, respectively.

4.1 INDIVIDUAL EXTERNAL HAZARDS:

Individual external hazards considered in this report are mainly due to natural phenomena. The KRSKO Nuclear Power Plant (NEK) evaluated plant conditions and upgraded safety measures to prevent accidents per DCM-D1-001, Rev 8 [3.13]. The various hazards that NEK may experience, and the findings of the evaluations are documented in NEK ESD-TR-18/16, Rev 1 [3.12]. The fundamental reason to evaluate the external as well as internal hazards is to determine whether they will possibly increase the Core Damage Frequency (CDF) or Large Early Release Frequency (LERF) of NEK. The risk associated with individual hazards is analyzed in report [3.12] per the qualitative and quantitative screening criterion, and then appropriately implemented in the NEK Probabilistic Risk Assessment (PRA) model for further evaluations.

Table 2 of NEK ESD-TR-18/16, Rev. 1 [3.12] lists different external hazards. Each of these external hazards are evaluated based on 7 qualitative and quantitative screening criterion. Only external hazards which are considered realistic to NEK are considered in this report.

The following sections cover the various individual external hazards and their effect on the HI-STORM FW system and ISFSI at the KRSKO nuclear station.

a. EARTHQUAKE: The effect of an earthquake on the HI-STORM FW system and ISFSI are analyzed in the FSAR [3.2]. The seismic analysis using the applicable seismic response information at KRSKO nuclear station was carried out. It is shown that the design of the HI-STORM FW system and ISFSI will not be damaged in the event of an earthquake [3.9].

b. WIND: The HI-STORM FW system is designed to withstand the wind load present at the KRSKO nuclear station, as well as the effects of tornados and missiles generated by tornados, as supported by the evaluation performed in [3.8]. In addition, the HI-STORM FW is stored inside the Dry Storage Building which lends further protection of the stored fuel.

c. RAIN: The HI-STORM FW consists of a cylindrical vessel and lid, with the outer shell and lid constructed from carbon steel. The carbon steel plates of the HI-STORM FW's outer shell are coated to prevent corrosion. Since the weight of the HI-STORM FW, with MPC, is substantial, and it is securely fastened to the ISFSI pad, it cannot be swept away from heavy rain. Furthermore, the ISFSI pad is located inside the Dry Storage Building, a high strength concrete structure, and is protected from any rainfall.

d. FLOOD: Flood conditions will not have adverse effects on the HI-STORM FW. The large horizontal ISFSI pad is concrete and is at an elevation higher than the surrounding area. The HI-STORM FW system will not sustain any damage from floods since it is constructed from metallic components and installed inside the Dry Storage Building. The inlet vents are designed to resist “smart” flood situations, and even in extreme situations, a flood will not be able to block the inlet vent of HI-STORM FW for a considerable duration.

The Dry Storage Building is designed against possible flooding from the Sava River [3.9]. The KRSKO nuclear power plant has a canal and proper drainage system to mitigate flood conditions resulting from high precipitation in the area and is further protected from floods by a dike along the left bank of the Sava River. The HI-STORM FW is designed for submergence under 125 feet of water per HI-STORM FW FSAR [3.2]. Additionally, the Dry Storage Building has 21 feet high concrete walls, with metallic walls extending beyond the concrete walls. The door of Dry Storage Building is also specially designed with seals to make it leak proof.

e. SNOW: The HI-STORM FW system is constructed from metallic components of mainly carbon steel, and the outer shell of the HI-STORM FW is coated to prevent corrosion. The HI-STORM FW and ISFSI pad are enclosed inside the Dry Storage Building, which is constructed from concrete and metallic walls and a metallic roof. Any snow deposited on the roof of the Dry Storage Building will eventually melt down. The hazards due to snow on HI-STORM FW will be very insignificant.

f. LIGHTNING AND THUNDER: The HI-STORM FW is installed on the ISFSI pad and constructed from metallic components that are good electrical conductors. The Dry Storage Building also encloses the HI-STORM FW, so when lightning strikes, the metallic roof and concrete wall will transfer the electricity to the ground via the ISFSI concrete pad. A lightning strike will therefore not have considerable effect on the metallic HI-STORM FW system and MPC inside.

g. TEMPERATURE: The HI-STORM FW is designed for a normal ambient temperature of 80°F, as well as extreme temperatures in the range of -40°F to 125°F. The MPC is designed to maintain the peak cladding temperature (PCT) of the spent nuclear fuel, which generates residual heat. This residual heat will be dissipated by conduction and convection through the MPC and HI-STORM FW by means of the high thermal conductive metallic components and inlet and outlet vents of HI-STORM FW. The MPC and HI-STORM FW are designed to maintain the temperature of the spent nuclear fuel and HI-STORM FW system below the PCT of the spent nuclear fuel stored inside the MPC.

h. BIOLOGICAL HAZARDS: Biological growth normally occurs in confined, moist regions, and generally results from stagnant water or a restricted configuration. In the case of the HI-STORM FW system and ISFSI pad, there is no stagnant water that will cause an increase in humidity in confined regions. Because the ISFSI pad is a flat horizontal concrete surface and the HI-STORM FW is cylindrical covered vessel, it is very unlikely water will collect and cause biological growth. Normal growth of plants and weeds in the soil adjacent to the ISFSI pad will have to be cut and cleaned to reduce the possibility of overall biological growth in the vicinity of the ISFSI pad at the KRSKO nuclear station.

i. METEORITE: The HI-STORM FW is constructed from a thick carbon steel lid bolted on the top and outer shell that is filled with a large amount of dense concrete for shielding. Because the HI-STORM FW is firmly bolted to the ISFSI pad and has significant mass, it is very stable. A meteorite falling through the atmosphere could be massive, but since it is falling under the force of gravity, its velocity will not be very high. Its momentum will therefore not be significant enough to cause appreciable damage to the HI-STORM FW. Additionally, the meteorite will strike the Dry Storage Building first where its velocity and momentum will be greatly reduced. The chance of a meteorite impacting the HI-STORM FW at the KRSKO nuclear station is very unlikely.

j. SUN: The sun will mostly affect the HI-STORM FW and ISFSI pad due to its temperature, however since the HI-STORM FW is enclosed in the Dry Storage Building, the effect of the sun will be quite low. Also, since the HI-STORM FW and MPC have mainly metallic components and the ISFSI pad is concrete, they are further resistant to the temperature effects of the sun. Section 4.1g above covers in detail the effect of temperature on the HI-STORM FW, as well as ISFSI pad.

k. RIVER: Because the KRSKO nuclear station is located next to the Sava River, the possibility of flooding exists. However, since the ISFSI pad is a huge, flat concrete structure with an elevation higher than adjacent soil and is located inside the Dry Storage Building which is covered with concrete and metallic walls on four sides and roof on the top, the likelihood is minimal. Additionally, the HI-STORM FW's mass is significant, and is firmly fastened to the ISFSI pad, preventing flood water, even in extreme circumstances, from causing the HI-STORM FW to drift or move slightly. Section 4.1d above provides more information on the effects of flooding on the HI-STORM FW and ISFSI pad.

l. EXPLOSION: There is a possibility of explosion at the Dry Storage Building. This has been analyzed in the NEK safety report, DCM-D1-001, Rev 8 [3.13], as an aircraft accident at NEK. The Dry Storage Building is built conservatively with thick concrete and metallic enclosures on all sides that would considerably reduce the kinetic energy of an aircraft. Furthermore, the large metal / concrete mass of the HI-STORM FW protects the MPC and enclosed SFAs against the final impact and possible explosion. Any damage to the MPC and SFAs is highly unlikely and insignificant.

Some NEK PRA (Probabilistic Risk Assessment) models of specific external hazards are modified and refined depending on the level of risk associated with them. The risk associated with the flooding of the Sava River is one of the major concerns. The effect of the external flooding causing an increase in Core Damage Frequency (CDF) is $2x10^{-7}$

/yr [3.13]. This value is only applicable to the reactor core inside the reactor building of NEK and is not applicable to the SFAs stored in the MPC. Additionally, since the SFAs are further stored inside the HI-STORM FW, which is firmly fastened to ISFSI pad inside the Dry Storage Building, external flooding cannot initiate any nuclear release, increase CDF, or cause alteration in the frequency of Large Early Release Frequency (LERF) at NEK.

The residual risk from the various external hazards is evaluated [3.13] to be less than $1x10^{-7}$ /yr, and the cumulative effect of LERF less than $1x10^{-8}$ /yr.

4.2 SCREENING OF INTERNAL HAZARDS

The NEK could be exposed to various internal hazards initiated inside the Radiologically Controlled Area (RCA) of NEK. The effects of these internal hazards on NEK are evaluated in NEK ESD-TR-07/17, Rev 0 [3.11]. Table 2 of the report [3.11] analyzes the possible hazards on seven qualitative and quantitative screening criterion. The three most likely internal hazards that may cause risk to the SFAs in the DSB are fire, flooding, and external missiles. The other internal hazards, i.e. steam release, gas release, pipe whip, vibration etc., are listed in Table 2 of the report [3.11], and are not applicable to the Dry Storage Building (DSB) or ISFSI pad.

The risk associated with the internal hazards is analyzed in the report [3.11] per the qualitative and quantitative screening criterion, and then appropriately implemented in the NEK Probabilistic Risk Assessment (PRA) models for further evaluations. The CDF due to fire is evaluated as $1.26x10^{-5}$ /yr [3.11]. The DSB does not have a reactor core with nuclear fuels. It is very unlikely that the fire will damage SFAs sealed in MPC which is further confined in the HI-STORM FW inside the DSB. Because the DSB has concrete and metallic walls and 2 m tall barriers in front of the doors, it is very difficult for flood water to enter the DSB and cause damage to fuel cladding or SFAs. The CDF due to flooding is evaluated as $1.14x10^{-6}$ /yr [3.11]. This value is mainly applicable to the reactor core, however since the DSB neither has a reactor core nor active (unused) nuclear fuels, this value is not applicable to the DSB and SFAs stored inside. The impact of external missiles (i.e. aircraft impact) on the DSB and subsequent damage to the SFAs is very unlikely. External missiles must pierce through the multiple boundaries of the DSB, HI-STORM FW and finally MPC to finally hit and cause damages to SFAs and claddings. The internal hazards report [3.11] evaluates CDF due to external missiles/aircraft as $2x10^{-7}$ /yr. The possible exposure of internal hazards at the DSB does not require modification of existing PRA models for NEK.

4.3 COMBINED EXTERNAL HAZARDS: The KRSKO nuclear station is analyzed for potential effects of combined external hazards that mainly result from natural phenomena or possible explosion. There are many possible combinations of external hazards, however, the four most severe combinations of the external hazards and their effects on the HI-STORM FW system and ISFSI at KRSKO nuclear station are outlined below:

a. SNOWFALL AND STRONG WIND: The HI-STORM FW system and ISFSI are conservatively designed with a high factor of safety. The HI-STORM FW is firmly fastened to concrete ISFSI structure, so winds are not able to move the HI-STORM FW from the ISFSI pad. The HI-STORM FW is stored inside the Dry Storage Building, which is constructed from concrete, metallic walls on four sides and a metallic roof. The Dry Storage Building is also designed with several cross-trusses and strong columns and will be able to withstand the combination of strong wind and snow deposits on the roof. The HI-STORM FW's external shell and lid are further coated to protect against the combined effects of snow and strong winds.

b. EARTHQUAKE AND FLOOD: The HI-STORM FW system and ISFSI are seismically designed with the applicable floor response information of the KRSKO nuclear station. The HI-STORM FW and the ISFSI concrete structure is covered on four sides by the concrete and metallic walls of the Dry Storage Building (metallic walls extended from the top of the concrete walls). The concrete walls are 6.40 m (21 feet) high and 0.8 m (2.62 feet) thick [3.7], and the doors of KRSKO Dry Storage Building are specially designed with a 2 m barrier outside the door, preventing flood water from entering through the door into the Dry Storage Building. The FSAR of HI-STORM FW, HI-2177798 [3.2], analyzes flood levels at the ISFSI pad. If the inlet opening of the HI-STORM FW is blocked due to flood water, the heat removal capacity from MPC will remain unaffected. This is very unlikely, though, since it is difficult for flood water to enter inside the DSB because of the very conservative design of the DSB and its doors. The HI-STORM FW is strictly designed against 'Flood and Wind' as denoted by the name "FW".

   Section 3 of the NEK safety report, DCM-D1-001, Rev 8 [3.13], analyzes loss of the secondary heat sink due to the combined external hazard of earthquake and flooding. The residual heat in the SFAs is significantly lower than the heat in the reactor core, and temperature inside the DSB is maintained by a ventilation system. Additionally, the HI-STORM FW has inlet and outlet vents for air to circulate and ensure the residual heat of the SFAs is properly dissipated. The availability of a system similar to the RHR system for the reactor core is not mandatory. The SFAs are confined in sealed MPCs and it is very unlikely that flood water in the occurrence of earthquake can even pierce through the multiple boundary layers of the DSB, HI-STORM FW and MPC, in order to damage the cladding of the SFAs.

   The Design Basis Flood Elevation is 155.35 m, the DEC Flood elevation 157.33 m, the plant elevation 155.2 m [3.10], and the floor elevation of Dry Storage Building 155.75 m. The floor elevation of the DSB is higher than the plant elevation and the design of the DSB with concrete / metal walls are very conservatively designed from flood consideration. In the case of a flood, it is very difficult for flood water to enter inside the Dry Storage Building due to the 6.40 m (21 feet) high concrete walls and further extension of metallic walls on all four sides of the Dry Storage Building. The height of concrete wall of DSB (6.40 m) well exceeds the DEC Flood elevation difference of 1.58 m. Additionally, the doors of the Dry Storage Building are specifically designed against floods, with a barrier in front of the door to prevent flood water from entering through the door.

Since the HI-STORM FW is seismically stable and stored inside the Dry Storage Building, the combined effects of earthquake and flood will not cause damage to the HI-STORM FW system and ISFSI at the KRSKO nuclear station.

c. FIRE AND EXPLOSION: The HI-STORM FW outer shell and lid are constructed from thick carbon steel, with a thick concrete deposit inside the outer shell for shielding. The ISFSI pad concrete, and the Dry Storage Building at the KRSKO nuclear station is comprised of non-flammable, 21 feet tall concrete and metallic walls [3.7]. The fire will not cause damage to the Dry Storage Building as well as HI-STORM FW, constructed from non-flammable material. In the case of an explosion, it is difficult to penetrate the 6.40 m (21 feet) tall and 0.8 m (2.6 feet) [3.7] thick concrete walls on all four sides of the Dry Storage Building. Section 3 of the NEK safety report, DCM-D1-001, Rev 8 [3.13], evaluates the possibility of an aircraft accident on NEK. The aircraft impact and possible fire in the DSB will not have a significant effect because of the thick walls of the DSB, as well as the sturdy construction of the HI-STORM FW (thick carbon steel shell and lid with concrete). It is very difficult for the aircraft to penetrate and cause damage to fuel cladding stored inside huge mass of the HI-STORM FW and MPC. Since the MPC and HI-STORM FW are constructed from non-inflammable materials, the probability of fire is very unlikely and the availability of a system for heat removal (i.e. similar to a RHR system) is not required. The HI-STORM FW system and ISFSI at KRSKO nuclear station will therefore not be damaged by the combined effects of fire and explosion.

d. FIRE AND EARTHQUAKE: The HI-STORM FW system and ISFSI are seismically designed and qualified as described in paragraph b. above. The HI-STORM FW and the ISFSI concrete structure is enclosed by the walls (metallic walls extended from the top of the concrete walls) and metallic roof of the Dry Storage Building. These materials are not combustible. The HI-STORM FW is fundamentally a thick concrete and metallic structure which are also not combustible. Because there is no increase in combustible material around the HI-STORM FW as a result of a seismic event, the existing fire analysis conducted is bounding. The HI-STORM FW system and ISFSI at KRSKO nuclear station will therefore not be damaged by the combined events of fire and earthquake. Additionally, it will have no effect on Core Damage Frequency (CDF) of KRSKO nuclear station.

5.0 CONCLUSION

5.1 The information above clearly shows that the individual external hazards will not impact the HI-STORM FW and ISFSI pad at the KRSKO nuclear station. The evaluation of plant hazards contained in [3.8] analyzes and documents the effects of various possible hazards at KRSKO nuclear station.

5.2 The HI-STORM FW system and ISFSI may experience different combined external hazards [3.6], with the four most probable combinations of external hazards covered in Section 4.3 above. The most severe combined external hazard is that of a simultaneously occurring earthquake and flood; and is covered in Section 4.3b. The HI-STORM FW is specifically designed against the adverse conditions of “Flood and Wind” (denoted by “FW”). The Dry Storage Building of the KRSKO nuclear station is specifically designed against floods with tall concrete and metallic walls on all four sides. Additionally, the probability of more than one external hazards occurring at the same time on the HI-STORM FW system at KRSKO nuclear station and duration of such an event is extremely low. Therefore, effects of combined external hazards at the Dry Storage Building of KRSKO nuclear station, with HI-STORM FW stored inside, is negligible.

5.3 The NEK safety report, DCM-D1-001, Rev 8 [3.13], screening of internal hazards report, NEK ESD-TR-07/17, Rev. 0 [3.11], and screening of external hazards report, NEK ESD-TR-18/16, Rev.1 [3.12], analyze and evaluate the plant conditions based on various possible hazards that may impact the NEK's Core Damage Frequency (CDF) and Large Early Release Frequency (LERF) and its ability to dissipate residual heat from the reactor core. The probability of the scenarios covered in these reports are mainly applicable to the reactor core, i.e. Reactor Pressure Vessel (RPV), and are not applicable to the SFAs because the SFAs are stored inside the MPC/HI-STORM FWs in the DSB and have an energy level (both radiation and heat) significantly lower than the actual nuclear fuels in the reactor core. Additionally, the HI-STORM FW system and ISFSI pads are very conservatively designed and constructed. NUREG/CR-4840 provides information on the strategy and steps to be used in analyzing external events when determining CDF (for NUREG-1150) [3.14]. In the case of SFAs in the DSB, the information regarding external events and possible damage to SFAs is relatively low due to the lower energy level in the SFAs as well as absence of the reactor core (RPV). The extent of risks associated with SFAs and the HI-STORM FW are therefore significantly lower than the risk involved with actual fuels in the reactor core. The PRA models of NEK are more relevant to actual plant conditions such as the fuel in the reactor core. The CDF and LERF will not be impacted by the HI-STORM FW and ISFSI designs. Hence, the existing NEK PRA models will not require modification or even refinement because of the very conservative design of the HI-STORM FW system and ISFSI pad.

5.4 The dry storage HI-STORM FW system at KRSKO nuclear station is safe against effects of various external hazards.