Frequency of Frazil Ice and Algae Threats to Ultimate Heat Sink for Hanhikivi-1 NPP

Ilkka Männistö[1]

[1] *Fennovoima Oyj, Salmisaarenaukio 1, 00180 Helsinki, Finland, Ilkka.mannisto@fennovoima.fi*

Hanhikivi-1 NPP is going to be built in Northern Finland in a greendfield site. Design phase PRA requires frequency estimates for external threats. The objective of this paper is to assess the initiating event frequencies for two phenomena that can affect the seawater intake: frazil ice and algae. Analysis of these initiating event frequencies is a part of the PRA performed for construction license application. To assess the frequencies of external threats a combination of analytical and empirical studies were performed. The analytical studies were concerned on frazil ice, as the phenomenon is still not completely understood. Empirical statistical method was used to assess the final frequencies for both phenomena, by using observations from other plant sites and production facilities that have seawater intakes, have similar climate and similar geographical qualities. Information was gathered by interviews and questionnaires with personnel of the power plants or production facilities.

I. INTRODUCTION

Hanhikivi-1 NPP is a 1200 MW VVER type plant that is going to be built in Northern Finland. The project is currently in licensing stage with civil and earthworks already in progress at the site. At the licensing stage a full scope level 1 and 2 PRA (probabilistic risk assessment) is required. External initiating events related to the plant site have to be assessed for magnitude and frequency for this purpose. The plant design used seawater as the ultimate heatsink, which means that any threats that could block the seawater channel have to be assessed as well. In this paper the method and results of frequency assessment for two threats against the ultimate heatsink: frazil ice and algae. Both of these phenomena could block the seawater channel intake grating.

Additionally analyses were performed on packed ice, natural growths and biological hazards (such as fauna, clams, seaweed), foreign objects, trash, humus and oil and other chemical spills. These phenomena are not considered in this report.

I.A. Site description

Hanhikivi-1 NPP will be built on the coast of Gulf of Bothnia in Northern Finland. Site selection was started in 2007, and a site on Hanhikivi headland (64°31'N 24°15'E) in Pyhäjoki county was chosen in 2011. The Hanhikivi headland is located in low-lying land-uplifting coastal area. The coastline around the Hanhikivi headland is very open, and water level fluctuates efficiently in the area. The depth of the water around the Hanhikivi headland increases very slowly seawards. The sea water quality at the Hanhikivi headland corresponds to the general state of the Bay of Bothnia. The average salinity of the sea water close to Hanhikivi is 3 ‰.

Weather in Finland is typical of mid-latitudes with disturbances carried in the prevailing westerly winds between the polar and tropical air masses.The duration of seasons in Finland varies greatly, with four distinct seasons nevertheless present. Winter is characterized by temperatures below freezing, snowfall and higher than average winds, as well as potential cyclonic storms with strong winds.

Fig. 1. Location of the Hanhikivi-1 plant site in Finland, Northern Europe.

II. PHENOMENA AND STUDY METHOD

II.A. Background information on frazil ice

Frazil ice is a type of frozen water that has been observed to form in subcooled moving water and can form very quickly (Ref 1.). It has has blocked seawater intakes previously in cold climates (Ref 2. and 3.). Olkiluoto NPP site has experienced 3 frazil ice related incidents since its commission 1979 (Ref. 4). Frazil ice is a natural phenomenon that has proven difficult to analyze exactly. Frazil ice that forms directly on a surface instead of moving water is called anchor ice. It is noted in literature (Ref 3.) that frazil ice usually forms when the water is open (from ice), air temperature is below -8 C and wind speed is at least 5-10 m/s. In these conditions it is possible that seawater will cool below the freezing point, and in the moving undercooled water frazil ice can form. However, while these seem to be necessary conditions, frazil ice does not always form in these conditions. The analytical studies commissioned by Fennovoima were not able to establish sufficient conditions for occurrence of frazil ice (Ref 1.). Figures 2 and 3, below, show frazil ice.

Fig. 2 and 3. Frazil ice in an experimental test rig (left) and frazil ice in seawater intake mesh grid (Ref 1.)

II.B. Background information on flora and algae

Plant site flora has been investigated already for the environmental impact assessments. The studies (Ref 5.)(Ref 6.) cover the types of seawater plants that are commonly encountered in the area, and the state of the vegetation. However, this study is not practical for assessing probability of threats to seawater intake. Finnish experiences at the existing NPP sites confirm that large amounts of algae can potentially cause a seawater blockage (Ref 4.).

II.C. Empirical data gathering

Preceding work on the climatological conditions of the site, combined with use experiences in Finland, established that frazil ice is a potential threat to seawater intake and that it does occur at Hanhikivi site. Similarly algae and other growths had been identified as possible threats to seawater intake. Because there is no existing empirical data on frequencies of these phenomena at Hanhikivi, a project was started to gather use experience from similar sites in the Gulf of Bothnia. Power plants with similar characteristics (geography, climate) as Hanhikivi were identified for this purpose. The conventional power plants chosen also use seawater for cooling or other process needs, and thus might have experience database on the frequency of seawater intake clogging.

The methodology was to send a questionnaire to the selected facilities, and follow up with phone interview. Most of the facilities did not have a systematic use experience process (as is common in NPPs), but depended on personnel experiences.

The following facilities were contacted, and all provided responses:

- Wisapower power plant (Finland)
- Toppila power plants (Finland)
- Alholmens Kraft (Finland)
- Tornio power plant (Finland)
- Kokkola power plants (Finland)
- Ruukki power plant (Finland)

The following information was collected from each facility:

- location
- general plant information
- problems in the cooling water system
- consequences and repair actions

The methodology and results were compiled into a report (Ref 7.) This data was used to establish the frequencies for occurrence of frazil ice and algae.

III. RESULTS

The questionnaire and interview method II.C was used to gather the known frazil ice and algae induced seawater blockages in conventional power plants in the Gulf of Bothnia area. Table I, below, lists the major events from different power plants:

TABLE I. Seawater blockage incidents from conventional power plants in Gulf of Bothnia area

	Years observed	Frazil ice	Algae
Toppila 2 (algae)	19	0	5
Toppila 2 (frazil ice)	10	1	0
Alholmens Kraft	12	1	1
Tornio power plant	7	0	0
Kokkolan voima	13	0	0
Ruukki power plant	6	0	0

TABLE II. Frazil ice frequency estimate

	Total years	Events	Yearly probability
Frazil ice	48	2	4,17E-02

TABLE III. Algae frequency estimate

	Total years	Events	Yearly probability
Algae	57	6	1,05E-01

IV. CONCLUSIONS

This empirical study has two main limitations: not many large facilities that use large amounts of seawater exist in the Gulf of Bothnia, and many do not keep data logs of events in a way that is consistent with the nuclear industry. However, the study did yield quantitative information on both algae and frazil ice caused incidents. However, uncertainty analysis has to be completed before inclusion in to the plant PRA model.

The results for frazil ice are similar to the values assessed in other Finnish NPP sites. Loviisa has analyzed the frequency as 2.2E-2 and Olkiluoto site as 1.1E-2 (both Ref 1.). Due to different site characteristics the values are not 100% comparable. Additionally, since both existing sites have instituted countermeasures against frazil ice, no additional empirical observations have been made.

ACKNOWLEDGMENTS

Author would like to acknowledge Henni Simpanen’s (Fennovoima) effort in gathering the empirical data used in this study.

REFERENCES

1. L. MAKKONEN, Supon aiheuttaman vedenottamon tukkeutumisen estäminen, VTT (2013)
2. S. F. DALY and R. ETTEMA, Frazil ice blockage in the Great Lakes, Journal of Hydraulic Engineering (2006)

3. M. RICHARD and B. MORSE, Multiple frazil ice blockages at a water intake in the St. Lawrence River, Cold Regions Science and Technology (2008)
4. T. ROUTAMO (ed), European Stress Test for Nuclear Power Plants – National Report, Finland, STUK (2011)
5. K. ILMARINEN, J. LEINIKKI, P. OULASVIRTA, Vedenalaisen luonnon nykytilan kuvaus Alleco Oy (2009)
6. J. LEINIKKI, J. SYVÄRANTA, Pohjaeläinselvitys rakennusaikaista seurantaa varten Hanhikiven merialueella. Alleco Oy (2012).
7. H. SIMPANEN, Study of power plant cooling incidents in the Bothnian Bay area, Pöyry Oy (2014)