Annals of Nuclear Energy 93 (2016) 58–64

Contents lists available at ScienceDirect

Annals of Nuclear Energy

journal homepage: www.elsevier.com/locate/anucene

Methodology developed for the definition of the design parameters and associated safety criteria of the Filtered Containment Venting Systems for Belgian NPPs

Ph. Dejardin *, T. Helman *, J. Bulle, J. Dienstbier, L. Oury, L. Sallus

Tractebel Engineering S.A. (ENGIE), Brussels (BE), Belgium

ARTICLE INFO

Article history:
Received 22 July 2015
Received in revised form 3 December 2015
Accepted 10 December 2015
Available online 21 January 2016

Keywords:
Severe accident
Filtered Containment Venting System
Design parameters

ABSTRACT

Following the post-Fukushima stress tests performed in Belgium, Filtered Containment Venting Systems (FCVS) are foreseen to be installed on Belgian Nuclear Power Plants (NPPs) as ultimate means to cope with slow pressurizations of the containments that could occur during potential Severe Accidents (SA).

The present paper discusses the methodology supporting the definition of the FCVS main design parameters and associated safety criteria.

This methodology, developed by Tractebel Engineering and accepted by the Belgian nuclear Safety Authorities, followed a series of subsequent steps starting with the definition of the safety referential applicable to the FCVS and leading to the identification of a reference sequence, namely the Complete Station BlackOut (CSBO).

Then, key parameters for the FCVS design were defined (e.g. pressure range, venting flow, stored decay heat, stored mass, Decontamination Factors (DF)) along with the associated safety criteria. Several of them were assessed through a well-defined set of supporting calculations. This set included both best estimate representative cases as well as conservative bounding cases performed with state-of-the-art SA codes.

The SA codes used were first of all the MELCOR 1.8.6 code and, subsequently, the ASTEC V2.0 code (CPA/IODE modules), considering a chaining methodology. The aim of this approach was to take advantage of the iodine chemistry models features in the CPA/IODE modules of ASTEC to calculate the iodine speciation in the containment and in the FCVS, without having to run a full scope ASTEC calculation.

In conclusion, appropriate values for the safety criteria of each design parameters were assessed. In particular, the ones related to the minimum DF relied on a marginal gain approach to cope with the large uncertainties existing when performing dedicated radiological evaluations.

Finally, the next steps of this continuous safety assessment of the FCVS that are foreseen to be installed on Belgian NPPs are highlighted at the end of this paper.

1. Introduction

1.1. Belgian context

The article 21.4 of the Belgian Royal Decree published on November 30th, 2011 (Belgian Royal Decree, 2011), requires that the containment shall be protected from overpressure in a severe accident. This requirement is highlighted in the Western European Nuclear Regulators Association (WENRA) reference level F.4.5 (WENRA Reactor Safety Reference Levels, 2008). There is however no further national requirement or specific guidance related to the implementation of Filtered Containment Venting Systems (FCVS).

The current situation in Belgium is that there is no FCVS installed but that studies are ongoing to install such systems beyond 2015 for 5 of the 7 Belgian Nuclear Power Plants (NPPs) shown in Table 1.

Indeed, following the safety assessment performed in the framework of the Stress Tests of the Belgian Nuclear Power Plants, the Belgian Federal Agency for Nuclear Control (FANC – i.e. Belgian Safety Authorities) and Electrabel – GDF SUEZ (i.e. Belgian Nuclear Utility) agreed on an action plan to further enhance the safety of the Belgian NPPs against Fukushima-type events (Stress Tests – National action plan, 2012). One of the main actions required

* Corresponding authors.
E-mail addresses: philippe.dejardin@tractebel.engie.com (Ph. Dejardin), thibaut.helman@tractebel.engie.com (T. Helman).

http://dx.doi.org/10.1016/j.anucene.2015.12.024
0306-4549/

Table 1
Belgian units concerned by FCVS studies.

Unit	Commercial year	Supplier	Power	RCS	Containment
Tihange 1	1975	Framatome	~1000 MWe	PWR 3 loops	Double containment with inner metallic liner and annular space in under pressure
Tihange 2	1982	Framatome			
Tihange 3	1985	Westinghouse			
Doel 3	1982	Framatome			
Doel 4	1985	Westinghouse			

was to perform a feasibility study for the implementation of FCVS on Belgian units.

1.2. Objectives of the FCVS

The main objective of the FCVS is to preserve the containment integrity to avoid any uncontrolled radioactive release towards the environment due to a potential SA provoking a slow pressurization of the containment above or close to its design pressure.

Additionally, as containment venting is inherently associated with radioactive releases, a second objective is to limit the latter ones as far as reasonably achievable by filtering the fission products passing through the venting system during SA conditions.

The FCVS is however seen as an ultimate mitigation mean and should only be relied upon as the last resort in the frame of a global SA mitigation strategy, in accordance with the emergency plan of the Belgian NPPs.

2. Methodology for establishment of FCVS design parameters and associated safety criteria

The first step taken in this methodology was to categorize the design parameters in two groups, namely either requiring specific supporting calculations or not.

The latter group concerned on one hand general specifications, for instance related to the global design, the Emergency Planning of the Belgian NPPs or the foreseen SA mitigation strategy, as presented in Section 2.1. On the other hand, this group also comprised the design parameters related to the opening and the closing pressure of the FCVS, assessed based on the available fragility curves of the containment buildings, as discussed in Section 2.2.

The present paper focusses on the former group, i.e. on design parameters requiring specific supporting calculations and for which specific methodologies had to be developed, as detailed in Sections 2.3 and 2.4. As shown in Table 2, two assessment methods were defined for these parameters, one relying solely on MELCOR calculations and one relying on both MELCOR and ASTEC-CPA/IODE calculations. The second method was of particular importance to more properly evaluate the impact of the iodine chemistry than solely relying on the MELCOR code, historically used in Tractebel Engineering and for which full input decks of Belgian NPPs have been developed.

Table 2
Design parameters requiring supporting calculation and assessment methods.

Nb	Design parameter	Assessment method
1	Venting mass flow rate	From MELCOR 1.8.6 calculations
2	Mixture temperature and composition	
3	Decay heat retained in FCVS	From MELCOR 1.8.6 and ASTEC V2.0 (CPA/IODE) calculations
4	Mass retained in FCVS	
5	Decontamination Factors (DF)	

2.1. General specifications

The considered FCVS is a wet-type filter with the following general specifications:

1. The actuation of the vent shall require manual handling operation, based on a specific criteria associated to the measurement of the containment pressure.
2. The opening of the venting valve shall be possible from the control room as well as locally, via a manual handling actuation.
3. The access to the rooms and systems needed for the correct operation of the FCVS should be guaranteed.
4. The shielding should be sufficient to limit the dose to a maximum of 50 mSv per operator and per intervention that is estimated to last for around 1h30.
5. The FCVS only operates during beyond design basis events. Therefore, the single failure criterion does not apply. System redundancy is thus not foreseen except for the containment isolation function.
6. The FCVS must be available during all plant operating states except during the periods when maintenance activities have to be performed on the FCVS.
7. After the first opening of the containment isolation valves, the FCVS is designed to operate without assistance during at least 24 h.
8. The permanently installed reserves of water and chemical additives on site shall allow for a FCVS autonomy of at least 72 h after the accident initiating event.
9. After a period of maximum 10 days from the accident initiating event, it is assumed that the conventional safety systems (for example cooled recirculation) would have been recovered ensuring a long term controlled stable state of the NPP.
10. Provisions against explosion of combustible gases in the FCVS should be foreseen.
11. The FCVS is actuated when the "venting opening pressure" is reached, and stopped when the pressure decreases below the "venting closing pressure". These plant-specific thresholds are determined based on containment design pressure and fragility curves. Multiple venting phases are thus considered if the containment cooling system is not recovered.
12. The FCVS has to withstand the following external hazards: earthquake, flooding and extreme weather conditions (extreme winds, lightning, rainfall, temperature range, snowfall).

2.2. Criteria assessed based on fragility curves

The safety criteria related to the opening pressure was assessed based on the fragility curves of Belgian units with the objectives to limit the containment failure probability to maximum 5%, in accordance with the Westinghouse Owner Group (WOG) Severe Accident Management Guidances (SAMG).