CRAFT – CONTROL ROOM ACCIDENT FILTRATION

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Abstract

In the very unlikely case of severe accidents, radioactive noble gases will be released from nuclear power plant into the plant environment. Noble gases are a large part of the radioactivity released into the environment during containment venting activities or via potential containment bypass scenarios. To ensure that the workforce's exposure to radiation doses does not exceed specified limits (according to OECD recommendation, doses within the control room should be kept below 100 mSv over a 7-day period), special measures need to be taken both during and after a severe accident to prevent activity from entering the control rooms.

One of AREVA´s new innovative products is called CRAFT (Control Room Accident Filtration System), which is a control room noble gas retention unit. It ensures safe working conditions in habitable rooms during severe accidents through the reduction of dose exposure due to noble gas release.

The CRAFT module can be used to protect:

- control rooms,
- emergency response centers
- or other rooms designated for prolonged use during accidents

CRAFT retains noble gases by means of dynamic adsorption from the incoming fresh air. If not already implemented in existing air conditioning systems, the noble gas retention unit can be enhanced by an aerosol and iodine filtration unit.

CRAFT's operation time is unlimited. It is designed to operate through a complete accident progression and is suitable even in the case of multiple venting scenarios. Moreover, CRAFT covers scenarios on NPP sites with more than one unit.

CRAFT can be used for all types of rooms requiring protection, independent of the type of NPP. The number of people inside the room is the main factor for the dimensioning of CRAFT. The system can be installed inside or outside existing buildings. It can also be provided as a mobile solution. Another important characteristic of CRAFT is its low maintenance.

1. Introduction

One of AREVA´s new innovative products is called CRAFT, which is a control room noble gas retention unit. It ensures safe working conditions in habitable rooms during severe accidents through the reduction of dose exposure due to noble gas release.

The retention of radioactive noble gases from the control room and other habitable rooms during severe accidents will be discussed in the following report.

Severe accidents might cause the release of radioactive substances into the environment of a Nuclear Power Plant for example by leakages from the containment or an intentional containment venting via a filtered containment venting system (FCVS). Although a FCVS has retention capability for iodine and aerosols, there is no significant retention of noble gases. Noble gases are gaseous fission products (mainly Krypton Kr-85, Xenon Xe-133) that dominate the radiologic release of a core melt accident with Xe-133 as the dominating noble gas (97 %). Noble gases do not form fallouts and they do not accumulate in the food chain. However, noble gas release leads to significant dose exposure for the emergency response team, hindering the execution of Severe Accident countermeasure actions.

OECD recommends to take measures to prevent activity (including noble gases activity) from entering inhabited rooms and areas in order to reduce the exposure and protect the Emergency Response Team (see report NEA/CNRA/R(2014)2 from 13-Feb-2014 “Accident management insights after the Fukushima Daiichi NPP accident”). The key point is to ensure safe working conditions for as long as possible in order to avoid the scenario where severe accident mitigation measures have to be halted due to unacceptable activity level in control rooms.

In the meantime, some safety authorities have requested protection of the plant staff in response centers and defined the highest possible activity impact on staff (e.g. 100 mSv/7 days) in case the of a severe accident.

In the Fukushima Daiichi nuclear accident, the workers receiving the highest dose rates worked in the control rooms. Thereby the external dose can be primarily attributed to radioactive noble gases in the air of the main control rooms while the internal dose is dominated by the indigestion of radioactive iodine.

These occurrences in Fukushima Daiichi emphasized, that for the protection of the recovery workers on the plant side, and especially the crew in the control rooms, the ventilation of these rooms must be filtered to remove aerosols, especially iodine compounds, and the ingression of noble gases should be avoided. Therefore, in the following report, a filter unit for noble gases is discussed, which preserves the habitability of the control room during a severe accident even under the most unfavorable conditions.

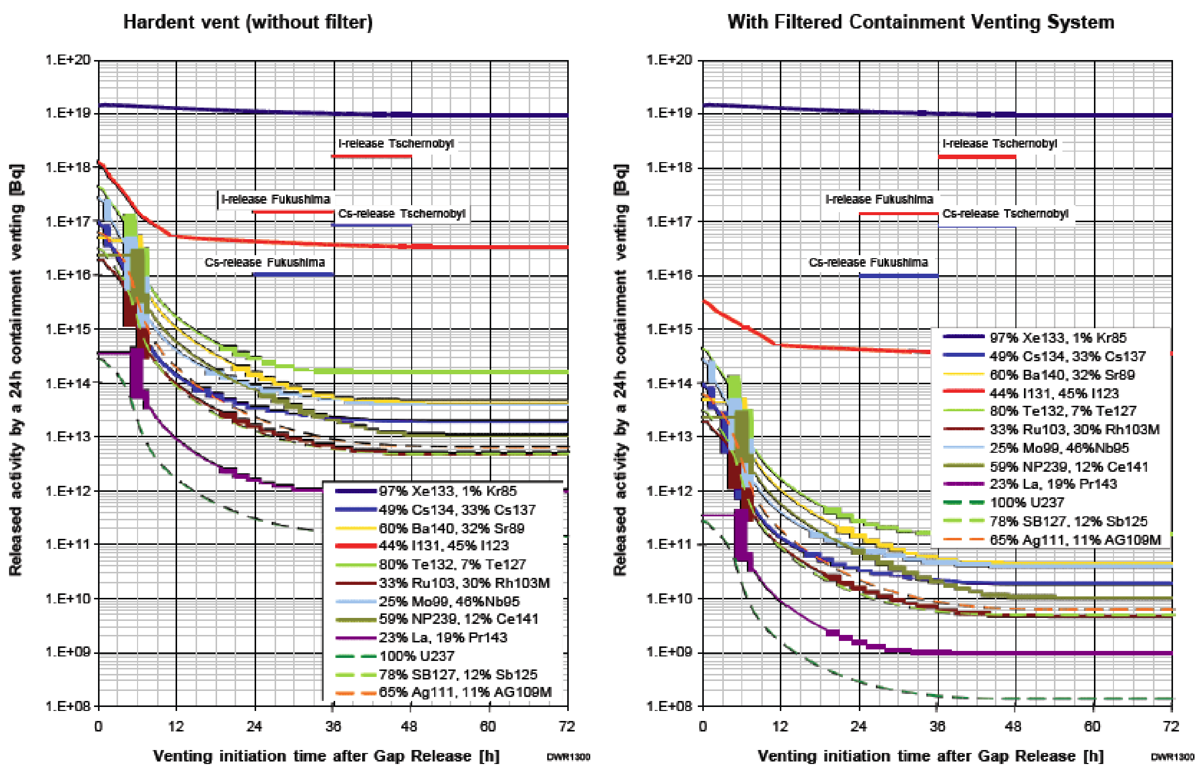

Figure 1 Fission Product Release into Environment by Containment Venting.

2. AREVA's CRAFT

AREVA has developed a Control Room Accident Filtration System (CRAFT) which is a control room noble gas retention unit. It ensures safe working conditions in habitable rooms during severe accidents through the reduction of dose exposure due to noble gas release.
The CRAFT module can be used to protect:

- control rooms,
- emergency response centers
- or other rooms designated for prolonged use during accidents

CRAFT retains noble gases by means of dynamic adsorption from the incoming fresh air. If not already implemented in existing air conditioning systems the noble gas retention unit can be enhanced by an aerosol and iodine filtration unit.
CRAFT is based on proven technology for treatment of active gases, which has been used by AREVA since the 1970s.
The CRAFT system is designed for accident conditions with increased activity concentration in the plant environment e.g. during complex accident scenarios in combination with containment bypasses, leakages and/or during Containment Filtered Venting operation. It is usually in standby and planned to be put into operation during accident conditions.

3. CRAFT technical description

3.1 System Concept

Figure 2 shows a schematic sketch of the CRAFT system. On the left hand side, the control room is shown while the contaminated air supply is on the right hand side. After passing an aerosols and iodine filter that is not considered in scope of this study, the airflow is guided via pipes and pneumatic valves to a vessel that is filled with a delay bed based on activated carbon.

In general, a multiple of a double unit of delay beds needs to be installed. This means that at least two delay beds (one double unit) are necessary. While the fresh air is pumped into the control room via the first column which is loaded with noble gas, the second column is desorbed with the consumed air leaving the control room.

The retention effect is based on the fact that the velocity of gas components inside the activated carbon depends strongly on its individual mass. Hence, nitrogen, oxygen, and carbon dioxide are not affected significantly, but heavy nuclides like heavy noble gases such as Kr and Xe are affected. These components are delayed compared to light components due to physical temporary adsorption. From this it follows that no radioactive noble gases will pass the delay bed within a certain time window that in turn depends on several aspects like the dimensioning of the delay bed, pressure, temperature, humidity, etc.

Since these time windows are well studied by AREVA GmbH, the use of the first delay bed is limited to a time within the discussed time window before the noble gases are able to break through. Now, the delay beds have to be switched and the fresh air is guided through the second delay bed while the consumed air from the control room is guided to the first delay bed containing the retained radioactive noble gases. With the consumed air stemming from the control room, the noble gases inside the first delay bed are desorbed and flushed back. Since both delay beds are of the same dimensions, the time for the back flushing process is identical to the previous flushing process.

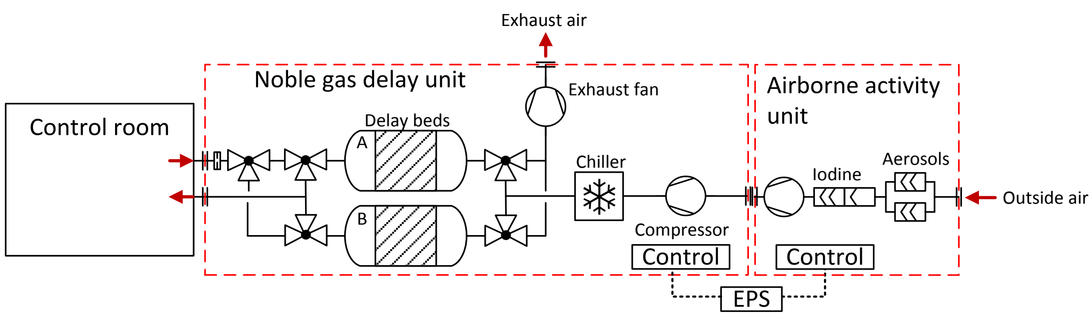

Figure 2 Schematic overview of the CRAFT system.

Improved solution with 3 columns

As an improved solution, the implementation of a third column to the system is possible.

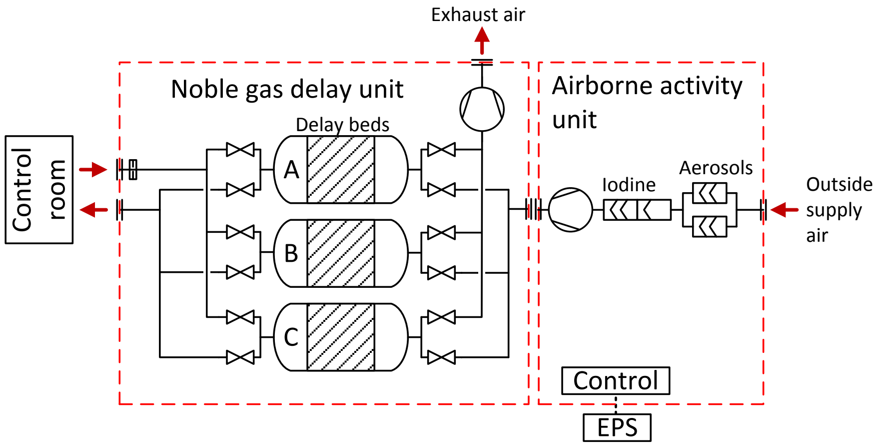

Figure 3: Schematic overview of an improved CRAFT version with three columns

Using three columns instead of two allows a permanent air injection to the control room. The interruption of air supply during the pressurization and depressurization phase as seen in the standard two column solution can be avoided.

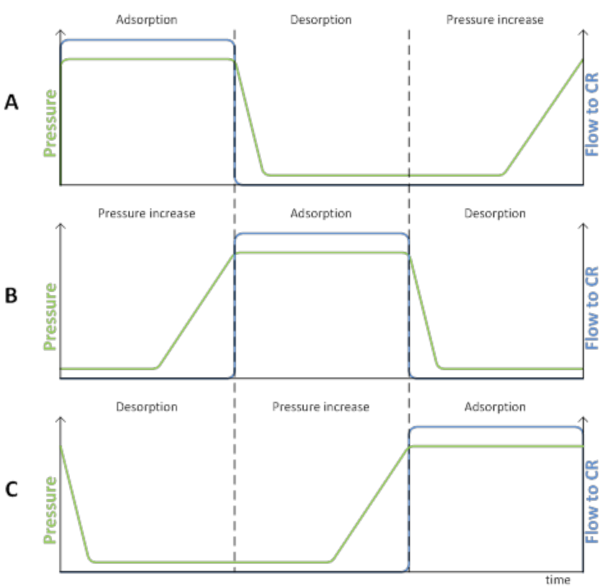

Figure 4: Principle of permanent air injection to the control room by using three columns

3.2 Requirements O_2 and CO_2: air quality

Instead of focusing on a fixed air exchange rate per person inside the MCR, requirements on the air quality are provided. The air exchange rate needs to be calculated based on a model that takes the requirements and all other input parameters as well as assumptions of the human breathing cycle into account. Two main aspects need to be fulfilled at any time: concentration of CO_2 may not exceed a limit and concentration of O_2 should be sufficiently high.

Various publications and regulations deal with the air quality for different scenarios. Regarding the influence of the CO2 concentration on the human physiology, many studies have been performed in the last decades. As a result, typical long-term exposures are limited to a CO2 concentration of 0.7 to 1.3 Vol.-%. As discussed in table 2 of [13] no significant effects on the human body for a long-term exposure of 1.0 Vol.-% CO2 are given. Therefore, a CO2 concentration of ≤ 1.0 Vol.-% is assumed as requirement for the CRAFT system. The limit of the CO2 concentration within the MCR shall not exceed this value even though an unlimited operation time of CRAFT is assumed.

The following values were proposed based on information from respective regulations and publications.

- $C(CO_2) < 1.0$ Vol.-%
- $C(O_2) > 18.0$ Vol.-%

These values can be adapted to customer requirements if needed.

3.3 Mission Time

As already mentioned, severe accidents and their consequences as well as their duration and impact on the direct environment are difficult to predict due to their complexity. In any case, an MCR or ERC needs to be operational for severe accident management measures and the staff needs to be protected. Hence, a system for fresh air supply shall be operational.

3.4 Tests

Even well-known technologies have been used for the design of CRAFT; a prototype of the system has been built for testing at AREVA Site in Karlstein, Germany. This prototype has been tested under different relevant conditions and scenarios.

4. Standard sizing of CRAFT

Dimension and capacity of the CRAFT module will be designed with consideration to relevant customer requirements.

Table 1 shows three typical sizes in accordance to different applications.

Craft module size	S	M	L
Capacity	50 – 70 m3/h	350 – 450 m3/h	1’000 – 2’500 m3/h
Number of persons	5 – 15	70 – 120	>200
Length	2,5 m	6,5 m	11 m
Width	1,3 m	3,0 m	8 m
Height	2,5 m	3,8 m	4 m
Footprint	~3,3 m2	~20 m2	~90 m2
Electrical power consumption (total)	20 kW	70 kW	400 kW
Weight	2,5 t	14 t	40 t

Table 1: Typical sizes of CRAFT module

5. Conclusion

CRAFT is a new development using proven technology which allows the protection of operation staff during severe accidents from airborne activity and the minimization of staff exposure to non-filterable noble gas activity. The combination of this technical solution with other filters is possible.

The CRAFT system has been designed as a modular system which can be either installed permanently at the plant or also transported by conventional truck or aircraft and connected at fixed interface points to the existing air conditioning system. CRAFT can be connected to existing HVAC or can use its own air supply line.

CRAFT provides considerable dose reduction of the MCR/ ERC crew.

The consequences on the staff on shift inside the MCR or ERC show clearly the effect of using the CRAFT system. The exposure dose requirements are fulfilled for the applied severe accident scenarios if the CRAFT system is installed. Furthermore, the functionality of the system has been proven during several tests at the radiochemical laboratory.

The long-term use of the CRAFT system is an important issue since the duration of a severe accident, the venting or, in general, the presence of a contaminated environment is difficult to predict. Furthermore, several units of the power plant might be affected by the same initiating event causing a severe accident. Thus several venting procedures might be necessary within several days. Therefore, the long-term operability of the CRAFT system is crucial. The CRAFT system has shown that it has no time limitations and is therefore well suited for the present application.