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DESIGN OF A FILTER SYSTEM FOR PWR CONTAINMENT VENTING

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ABSTRACT

The physical background, parametric test data and the construction of the aerosol filter stage of a venting system for severe accidents are given.

KEYWORDS

Venting system; severe accidents.

Particle filters used during depressurization have to meet considerable requirements with respect to temperature, moisture, radiation and loading.

The filter layout calculations were permormed with the aerosol behaviour code NAUA and are based on the low-pressure scenario (LP path) as in this scenario the highest aerosol concentration may be expected /3/. In addition to former calculations not only the releases during the melt down phase of the core (3000 kg) and of the high temperature phase of the core concrete interaction (500 kg in 10 min. directly after the failure of the reactor pressure vessel) were considered, but also the aerosol release during the long term core-concrete interaction. This additional long time source consists mainly of silicates and contains only little radioactivity but causes the main filter load and is therefore of great importance for these filter layout calculations. According to the results of the BETA experiments /4/ the source rate could be estimated to 0,1 g/s and the particle size distribution could be described by a geometric diameter d_g = 0,85 µm and a geometric standard deviation σ_g = 2. These are typical values for a recondensation aerosol Fig.1. The thermodynamic data calculated by KWU with the code COCMEL /5,6/ show that a pressure of 6 bar will be reached 122 h after start of the accident. The containment will be depressurized after this time by an opening of 80 cm^2 leading to the venting filter system. The total filter load could be calculated in this basis to 60 kg with an mean mass-related particle diameter of 0,5 µm for the particles which have to be filtered. The gas composition is variable. The initial steam/air ratio is approximately 2.7:1. CO_2 and H_2 constituents can also be found in the gas. During venting, the temperature amounts to 160 °C. After venting, a further increase in the temperature may occur due to the decay heat of the fission products separated on the filter.

Paper filters, which have usually been applied up to now, do not meet the above requirement. For this reason, a new filter with a removal efficiency [illegible] that of a HEPA filter has been developed by KfK on the basis of **stainless steel** fibers of variable diameters. This new "SSF" is entirely made of stainless steel, no organic casting and sealing materials are used. The development of this filter has already been reported about in several publications /3 through 6/.

In German PWRs, the SSF is used together with the iodine filter described in /3/. Two designs of dry filtering during venting have to be distinguished:

In some plants, the SSF and iodine filter are located downstream of the expansion valve. Here, the SSF with a surface

area of about 20 m^2 may consist of two stages. In this case, the sorption part has about the same surface area (Fig. 2).

In other plants, the SSF and iodine filter sections are separated. The SSF is operated under pressure in the containment (Fig. 3). This allows the design of the filter modules to be very compact and the solid fission products remain in the containment. During operation under pressure, the filter surface may be kept smaller due to the reduced volume. To attain the load required, the SSF module consists of three stages. This design was also subjected to all kinds of functional tests. The constructional dimensions are obvious at Fig. 4 and 5.

Removal efficiency was investigated mainly using uranin, as this test aerosol is to be found in the penetration maximum of the SSF. The particle diameter of uranin is about 0.15 µm.

The following parameters of the SSF were investigated: Removal efficiency as a function of the face flow velocity, system pressure, system temperature, gas composition and loading /6/.

Droplet retention was studied. Additional loading and separation experiments were carried out using $BaSO_4$, a condensation aerosol, titanium dioxide and CsOH. Other tests were performed with a view to examine the corrosion behavior of the fibers with and without the addition of a simulant fission product in air and air/steam mixtures over periods of several months /5/.

It was demonstrated that heat removal takes place even without a venting gas flow. It is evident from the experiments that the filter is not adversely affected by reverse flows /7/.

Usually, a separation efficiency of > 99.99% is attained for uranin on the finished SSF module. Each filter module is tested separately prior to delivery /4/.

When using other test aerosols with increased size distributions, higher values were determinded accordingly. For example, values of 99.998% were measured for DOP and 99.9999% MnO or CsOH, respectiveley in the ACE reference test /3/.

In the loading tests with a linear steam velocity of 30 cm/s, loads of up to about 20 kg/m^2 were attained for $BaSO_4$ depending on the design of the filters: The MMD of the particles was assumed to be about 0.8 µm /3/.

It must be noticed that the filter design may be changed in structure depending on the respective requirement to be complied with. As a result, variable performance data can be obtained, especially as far as the removal efficiency, loading and the permissible differential pressure are concerned.

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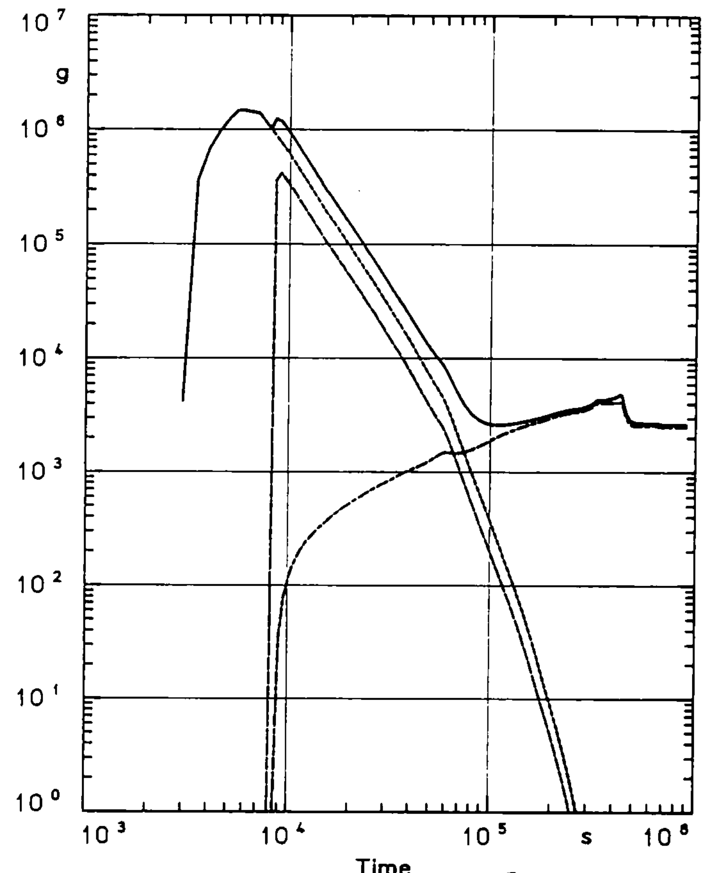

FIG. I Airborne Mass
Total, Component 1,
Component 2, Component 3

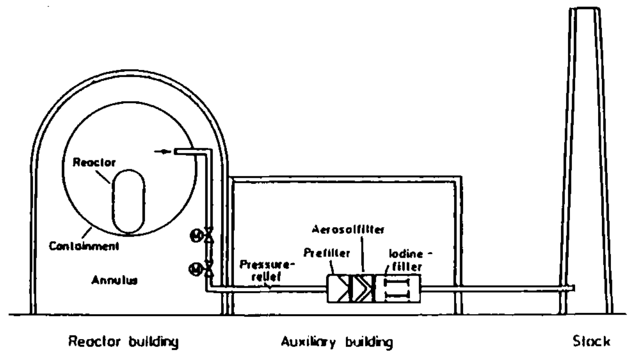

Fig. 2

Containment venting

Metal fiber filter for particulates and iodine filter outside of the containment

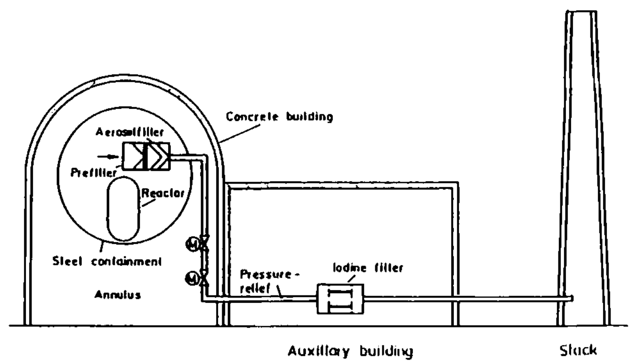

Fig. 3

Containment venting

Metal fiber filter for particulates inside, iodine filter outside of the containment

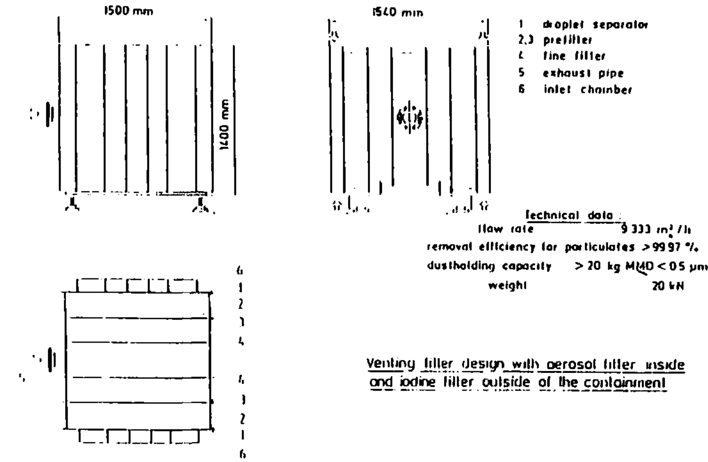

FIG. 4 Metal Fiber Filter Modul

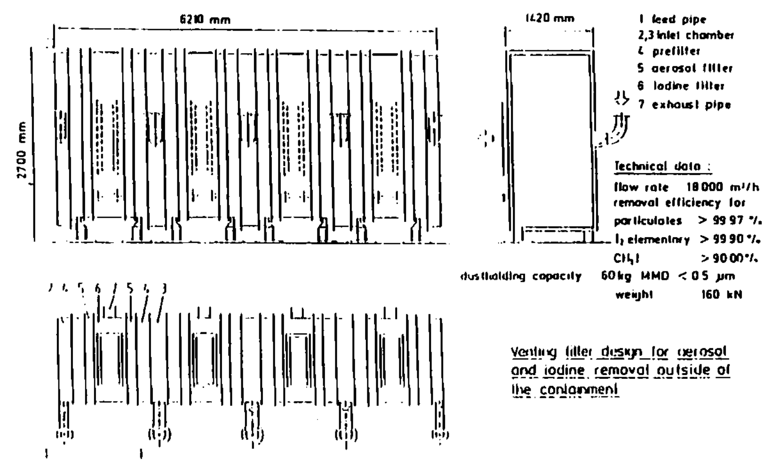

Fig. 5
Combined Metal Fiber and Zeolite Iodine Filter Modul