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FILTERED CONTAINMENT VENTING SYSTEMS

Note on the Outcome of the May 1988 Specialists' Meeting on Filtered Containment Venting Systems

COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS
OECD NUCLEAR ENERGY AGENCY

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CSNI Specialist Meeting on
Filtered Containment Venting Systems

Prepared by the
Senior Group of Experts on Severe Accidents

November 1988

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FOREWORD

At its November 1987 meeting the OECD (NEA) Committee on the Safety of Nuclear Installations (CSNI) had agreed that the time was ripe for an international exchange of information on technical aspects of Filtered Containment Venting Systems (FCVS). In addition to exchanging information on various FCVS concepts, associated R&D, and their analysis, the specialists had been asked to discuss the objectives of the systems (including the nature of the risks and the challenges, in particular in relation to accident management aspects) and the utilization procedures.

The Specialist Meeting on Filtered Containment Venting Systems was organised by a Programme Committee composed of Members of CSNI's Senior Group of Experts on Severe Accidents: Mr. J. Pelcé (Chairman of the Programme Committee and of the Specialist Meeting), Mr. P. Bystedt, Prof. Dr. E.F. Hicken, Dr. T.P. Speis, and Dr. J. Royen (Secretary of the Senior Group).

At the invitation of Electricité de France it was preceded by a visit to the Nogent-sur-Seine 1300 MWe PWR (unit 2) where a sand-bed filter has been installed.

The following note, prepared by the Senior Group of Experts on Severe Accidents, supplements the Proceedings of the Specialist Meeting [published as CSNI Report 148] and its summary record [SEN/SIN(88)16 Revision 1].

FILTERED CONTAINMENT VENTING SYSTEMS

A seminar was held in Paris on 17th and 18th May 1988 under the aegis of the OECD for the purpose of evaluating in detail the potential advantages of installing Filtered Containment Venting Systems (FCVS) at existing PWRs and BWRs in the different Member countries of the OECD.

The three countries which are most committed to this system have decided to install FCVS at all their light water reactors. The Federal Republic of Germany, France and Sweden gave in-depth presentations of their motivations and the technical solutions adopted.

The Senior Group of Experts on Severe Accidents was entrusted with the task of summarizing the information brought to light during the Seminar, whether from the communications of the three countries mentioned above and other contributions or from the ensuing discussions.

1. Motivations and Objectives

The overall approaches of the three countries (Federal Republic of Germany, France and Sweden) are very similar, starting with the motivations which can be summed up as follows:

- to provide the operator with the best means for controlling the situation, and in particular the most effective means now available for maintaining the containment function, both above and below ground, until the end of the accident, no matter how severe;

- to limit the level of releases into the environment via the atmosphere: this is an explicit objective for some, but not for others, depending on the implementation of emergency plans at the time of the accident and on the long-term ground contamination.

Although the technical solutions adopted show quite significant differences, like the basic motivations described above, they have nonetheless all been designed to meet the same requirements:

- nothing must detract from observance of the design rules throughout the installation, and implementation of these systems must not worsen the accident; consequently, if fission products have been released to the containment, venting is only to be considered as a last resort;

- the systems are designed on a realistic or reasonably conservative basis, with certain margins - more or less significant depending on the countries - to broaden the scope for use (margins relating to the efficacy of the filter or to the capacity of use as regards a wide spectrum of accidents but excluding extreme accidents which could lead to premature rupture of the containment);

- correlatively, the problems concerning safety aspects which are directly related to the use of the system are clearly identified: specific solutions must then be found to these problems for each

system: constraints due to the design of the system, without for all that applying the strict design rules (except however for the control of opening and closing of the isolation valves of the containment), constraints arising from the presence of trapped radioactive products after use of the filter (radiation, thermal energy, risk of migration into the filtering media), possible difficulties due to the (momentary) presence of condensed water, loads resulting from a hydrogen burn, surveillance and maintenance throughout the reactor lifetime;

-- the technical options are selected on the basis of knowledge which is already acquired or easily accessible; filter capability is the only area requiring a little direct R & D support for the design and operation of the systems, and in fact, most of the work on essential systems is almost completed;

-- the cost of the solutions adopted by each of the three countries is very modest, and all criteria of the cost/benefit type are therefore irrelevant: the cost lies between $1 and 5 million per reactor, depending on the country (except for the unique FILTRA system installed at Barsebäck).

Special considerations

In addition to these general observations, specific concerns were expressed about certain aspects although they were not necessarily perceived by all to the same extent; answers have to be found during the design of the system; the following, listed in the form of questions, are given as examples:

-- what is the significance of the possible presence of molecular or organic iodine, or of the size of aerosols in suspension in the atmosphere of the containment, even if the margins adopted make this consideration less important?

-- what is to be understood by qualification of the system to verify its capacities and the associated procedures of use?

-- what is suggested by passivity (degree and duration) of all parts involved in the use of the FCVS?

-- what instrumentation should be available, in particular for measuring radioactive releases (measurements inside the containment and/or at the outlet of the system, overall or confined to a particular important radionuclide)?

-- what are the criteria for determining the maximum venting pressure?

-- what relative importance should be given to automatic control as opposed to operator control, the existence of the latter appearing nevertheless to be necessary, while also bearing in mind the problem of choosing a remote control system (energy source problem) and deciding whether to have local manual actuation (access problem)?

-- what is the expected state of the installation after the use of the FCVS?

It should be pointed out that no contradictory requirements were present in the motivations and objectives leading to the solutions implemented in the three countries.

Source term considerations of deliberate venting through filters

The following considerations are intended to show certain intrinsic advantages provided by the possibility of deliberate venting through filters.

Deliberate filtered venting has to be compared with the base case: i.e., a containment failure several hours or even days after the start of the accident, a release of fission products from the containment atmosphere, due to releases from fuel, to resuspension from the primary circuit, from walls and a water pool, and from a melt/concrete interaction without or with water, through an opening at a mostly undefined location and with a mostly undefined leakage rate.

Deliberate venting prevents containment failure due to slow overpressurisation, allows a controlled release of containment atmosphere and can even stop a release, if required.

The limited and delayed release of fission products allows for further decay and different kinds of deposition process within the containment.

Deliberate venting can be used to mitigate the effect of released fission products in case of unforeseen leakages or a basemat melt-through. Moreover, it prevents any consequences of the pressure rise in the containment resulting from the cooling of the corium by the water.

Existing designs cannot retain noble gases. Aerosols are initially kept within the filter with a retention factor greater than 10, or 100 or more, depending on the design of the filter and the sequences.

Some filter designs can also retain elemental iodine, thereby further decreasing short-term contamination of the immediate environment.

Deliberate filtered venting capability also allows optimised release strategies.

Suitable instrumentation should be used to measure the released fission products taking into account the low probability of these events: examples are simple instrumentation to monitor the release continuously and an appropriate sampling technique.

2. SYSTEMS DESCRIPTION

2.1 Federal Republic of Germany, France and Sweden

All the systems selected for implementation were fully described in papers presented at the Seminar. A few brief indications are given below.

Federal Republic of Germany

In Germany, LWRs have to fitted with filter systems for containment venting. Four PWRs have been supplemented with a modular two stage deep-bed metal fibre filter. Two BWRs are already equipped with filter systems, including a Venturi scrubber and a two stage deep-bed metal fibre filter. The removal efficiency of the metal fibre filters is as high as that of HEPA filters.

The fully stainless steel filters consist, in principle, of two separate stages of fleeces: in the first stage the fibre diameter decreasing gradually from 30 µm to 8 µm, whereas in the second there are only stainless steel fibres of 2 µm diameter. The decontamination factors reached range between 1×10^4 and 2×10^4. By a modular design of the whole filter system, vent-gas can be cleaned with volumetric flow rates of the order of tens of thousands of m^3/h.

Filter systems accommodating a flow rate of 30 000 m^3/h at a pressure close to 1 bar, corresponding to 4.5 kg/s, have already been built. If the filter systems are designed to work at containment pressure, they can be considerably reduced in size.

In German PWRs some of the design requirements are as follows:

-- the system opens at the containment test pressure;

-- the isolating valve must be capable of being opened, closed or adjusted in stages under all accident conditions;

-- the cross-section of the opening is to be dimensioned so that test pressure is halved within two days with water injection, or remains limited to the test pressure without water injection;

-- the double shut-off valves remain closed during normal operation and are designed in accordance with safety criteria of the containment up to the outer isolating valve. The connecting filter system will be constructed according to conventional rules, whereby piping and valves are designed for double the normal operating pressure;

-- the system design must take account of a build-up of condensate and must provide suitable drainage for the filter;

-- in addition to the present measuring station on the containment, a further high dose measuring device is planned for the venting line;

-- the venting mass flow will be determined via a pressure measurement coupled with the characteristic curve of the relieving device.

France

An ultimate procedure, called U_5, has been implemented to limit the containment pressure increase and to reduce the associated radioactive release by means of a filter (sand bed filter), to a level leading to radiological

consequences compatible with the implementation of the "PPI" (local emergency plan).

Some of the sizing requirements are as follows:

- minimum filter efficiency: 10, related to aerosols;
- time allowed before starting the procedure: at least 24 hours after the beginning of the accident;
- maximum flowrate: 3.5 kg/s;
- temperature: 140°C;
- upstream expansion: 5 bar abs.

The containment depressurization and filtration system mainly includes: a containment penetration with double isolation by means of two valves, an orifice plate, a sand bed filter, connecting pipes, a continuous conditioning device, a radiation monitor device, a release duct (located inside the gaseous release plant stack).

The filter is a cylindrical tank, made of stainless steel, with a diameter of 7.30 m and a height of about 3.50 m. The filtering medium is made of 80 cm of sand (average diameter: 0.6 mm). The average gas speed in the filter is about 10 cm/s; the pressure drop in operating condition is about 0.1 bar.

The FCVS is installed at all PWRs in France; the latest units in operation will be fitted by mid 1989.

Sweden

The severe accident mitigation programme was started in 1980 with the FILTRA-Barsebäck project and will be completed by the installment of mitigation systems in the other plants. By the end of 1988, all Swedish plants will therefore satisfy the requirement that in an accident the release of radioactive material causing land contamination shall be limited to 0.1 per cent of the core content in a reactor of Barsebäck size.

The basic requirements regarding environmental consequences are the same for all plants, and the mitigation strategies include a FCVS for prevention of gross rupture of the reactor containment. The strategies and the hardware systems implemented in the Forsmark, Oskarshamn and Ringhals plants are somewhat different from the FILTRA concept implemented in Barsebäck. In addition to the FCVS an independent water supply system for the containment spray, and some plant specific modifications are included in the installations. Also the large capacity vent. installed for containment protection in case of LOCA and degraded PS-capacity, is unfiltered in the later BWRs. This reflects the development of licensing requirements and greater knowledge about severe accidents acquired since the FILTRA concept was established. One important development is that the requirement of 24 hours passive function given for FILTRA has been lifted for the other plants and a more active accident management approach is being taken. To some extent specific plant considerations have also influenced the solutions adopted.

For the nuclear units at Ringhals, Oskarshamn and Forsmark (7 BWRs and 3 PWRs) a wet scrubber system has been selected for containment venting. This filter system, which is called FILTRA-MVSS (Multi Venturi Scrubber System), is capable of covering a wide range of hypothetical design basis events for BWRs and PWRs.

The FILTRA-MVSS, which can accommodate flow rates in the range of 0.1 to 12 kg/s based on an automatic passive technique, consists of a set of venturi nozzles submerged in a pool of water. High retention factors for both aerosols and iodine are obtainable.

The venturi system comprises a pressure relief system, a venturi scrubber system with a pool for collecting iodine and particulate matter, a moisture separation system and a service system.

2.2 Other countries

In other countries the situation is generally less clear as decisions still remain to be taken. However the following points can be mentioned briefly.

Belgium

No position on filtered containment venting had been defined yet. However, some possible techniques are under investigation.

Finland

Some equipment is likely to be installed at the Olkiluoto BWRs by the end of 1988 namely a large capacity safety valve to prevent gross containment rupture.

A system for controlled containment venting is to be installed by the end of 1989; a decision regarding the choice of an external filter is imminent.

Italy

Several issues are being studied further; they include the possibility of installing a filtered containment venting system.

A paper entitled "Outlines of possible strategy for containment venting" was presented concerning the Caorso and Alto Lazio plants where existing facilities are used, such as the off-gas and ventilation (purge and emergency) systems.

Japan

At the moment, there is no decision regarding FCV.

The Netherlands

No official position.

A study of existing power stations includes recommendations for extending the capacities of safety systems, including FCVS.

Spain

The regulatory authorities and the utilities are all concerned by the FCV problem. Spanish authorities are studying the technical basis and the reasons which have induced several European countries to install FCVS, and at the same time the USNRC requirements and studies on this topic. So far, the regulatory authorities have not imposed any explicit requirement.

The CSN required a specific FCV study from BWR and PWR owners' groups. According to the technical conclusions of the BWR owners' group study, the possibility of installing a venting system from 1990, and filters from 1991 exists. The PWR study will be presented in July 1989.

Switzerland

The Swiss Nuclear Inspectorate required at the end of 1986 that all BWR and PWR containment be equipped with filtered venting, although it did not specify the type of filter.

A final decision regarding the design requirements for Swiss FCVS was about to be made. The installation of the systems is expected to be completed by the end of 1990 or the beginning of 1991.

United Kingdom

The evaluation of FCVS is at an early stage in the UK.

However, provisions have been made at Sizewell B to install a FCVS if needed.

United States of America

The capability to vent with or without attenuation of fission products exists at some US facilities. In addition, two utilities have proposed enhanced capabilities, and generic enhancements are being considered under a regulatory evaluation of severe accident vulnerabilities at all US commercial reactors.

Emergency Procedure Guidelines (EPGs) have been developed by industry and approved by the NRC staff for use at US BWRs.

Primary containment venting is called for by the EPGs for two situations. The first is for hydrogen control (except Mark III). The second situation is for venting to prevent overpressurization and to maintain primary containment integrity. For the latter the operator is instructed to vent the primary containment to reduce and maintain the pressure below the primary containment pressure limit (PCPL). The PCPL is defined to be the lesser of either (1) the pressure capability of the containment, (2) the maximum containment pressure at which vent valves can be opened and closed to reject decay heat from the containment, (3) the maximum containment pressure at which safety relief valves (SRVs) can be opened, or (4) the maximum containment

pressure at which vent valves can be opened and closed to vent the reactor presssure vessel.

Venting procedures as used within the EPGs are intended as a "last resort" operator action. Uncontrolled increases in containment temperature or pressure will result in containment failure with unknown results. Therefore, it is felt that a controlled action with defined consequences is preferable to no operator action.

PWRs also contain systems that could be used for venting to prevent containment overpressurization. The feasibility of utilizing them for that purpose, however, has not been extensively explored. Certain engineered systems such as fan coolers and containment sprays could also enhance the trapping and retention of fission products over and above the effects of natural deposition processes.

3. RESEARCH AND DEVELOPMENT FOR FILTERED CONTAINMENT VENTING SYSTEMS

The presentations given during the Specialist Meeting covered to some extent R & D in the severe accident field. In line with the meeting's objective, efforts directly related to the specification, design, verification and use of filtered containment venting systems were in focus.

Generally, rather similar types of activities have been and are being performed. Venting systems do not require much specific R & D. Their specifications, design basis and strategy for use can be derived from the current analysis of severe accidents. However, a plant-specific severe accident analysis is required if an appropriate choice of systems is to be made. Moreover, the performance targets of the systems in terms of filter retention capacities, for instance, may depend on emergency planning considerations specific to each site and country.

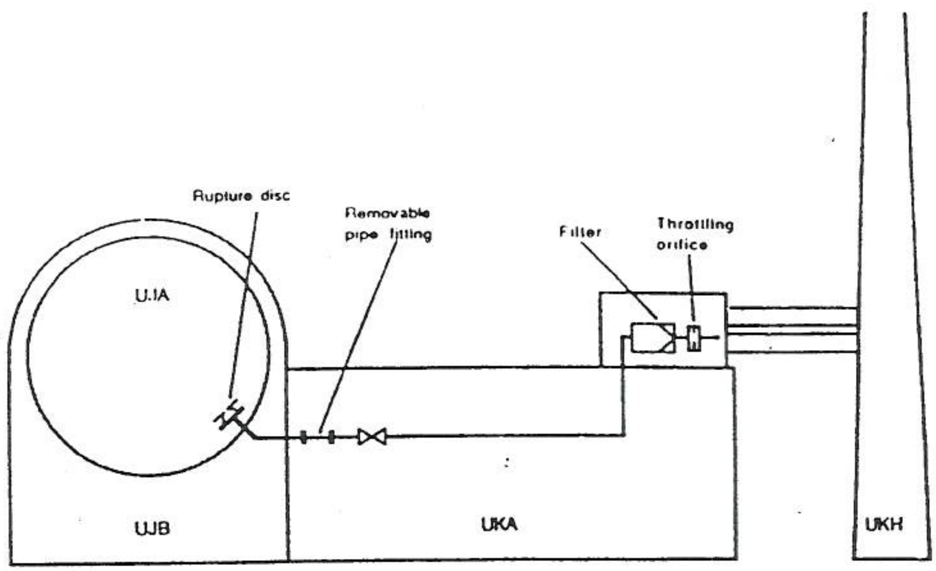
The specific R&D required for such systems includes the optimization and verification of the capacity and performance of the filter and the study of certain special aspects. As to filter verification a number of relatively straightforward measurements on retention capacities and performance have been carried out on the types of filters that are in use. Thus, gravel beds, sand beds, steel wire mesh and submerged venturi nozzles have been tested. Test results show retention factors for aerosol greater than 10, or 100 or more. A wide range of retention factors (10 to 100) for iodine exists for these filters. The test scale varies and also test parameters such as gas composition and test aerosols. This relates to differences in prerequisites for different concepts in terms of other support for the verification of experiments on other applications and support with code calculations. An appropriate basis for verification seems to be possible with the use of such approaches.

Some calculations have been also performed on special aspects of venting e.g. subpressure in the containment and hydrogen burn in the ventpipe or filter. Such analysis can be performed with existing engineering tools. Also, reliability analysis to the extent necessary for such systems, for use e.g. for design and test and maintenance intervals, can be performed with available tools.

R&D activities aimed at developing strategies and procedures for the use of filtered venting have been carried out, and further work is in progress. This covers the instrumentation necessary for the operation of venting systems and the prediction and monitoring of radioactivity release. These studies can be seen as part of the considerable research on accident management that is being conducted in most countries. Such procedures are crucial for the protection of the containment and the reduction of source term by use of filtered venting.

In summary, the Specialist Meeting showed that an adequate basis for the introduction of filtered venting systems can be established from the information (much of which is accessible) gained from past and ongoing R&D, supplemented by further relatively straightforward work with existing engineering tools on specific areas, depending on the concept chosen.

SIEMENS



UJA : Primary containment
UJB : Annulus
UKA : Reactor auxiliary building
UKH : Vent stack

CONTAINMENT

Design pressure : 5.3 bar
Test pressure : ca. 6.74 bar
Free volume : ca 70 000 m^3

PWR 1300 MW CONTAINMENT VENTING
FLOW DIAGRAM AND ARRANGEMENT : SLIDING PRESSURE FILTER OUTSIDE CONTAINMENT

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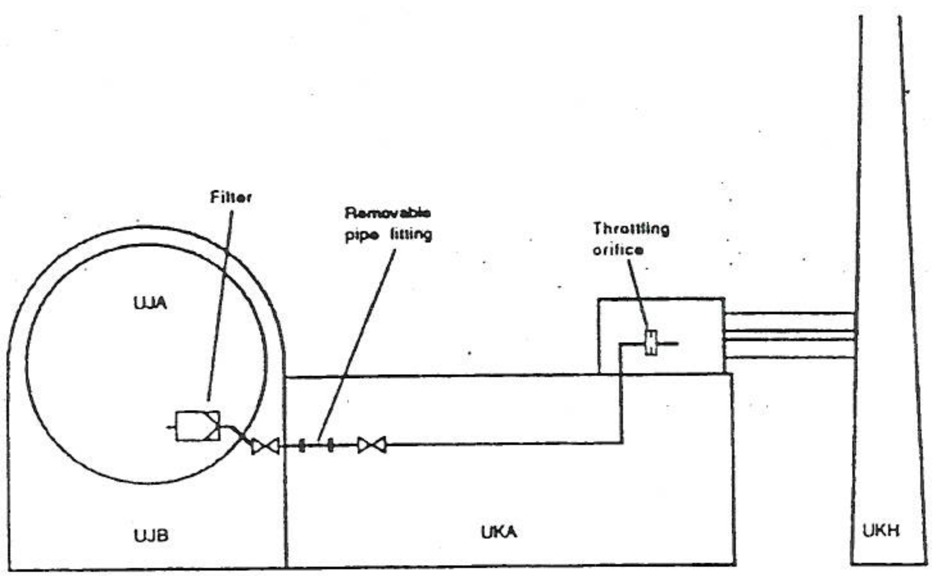
SIEMENS



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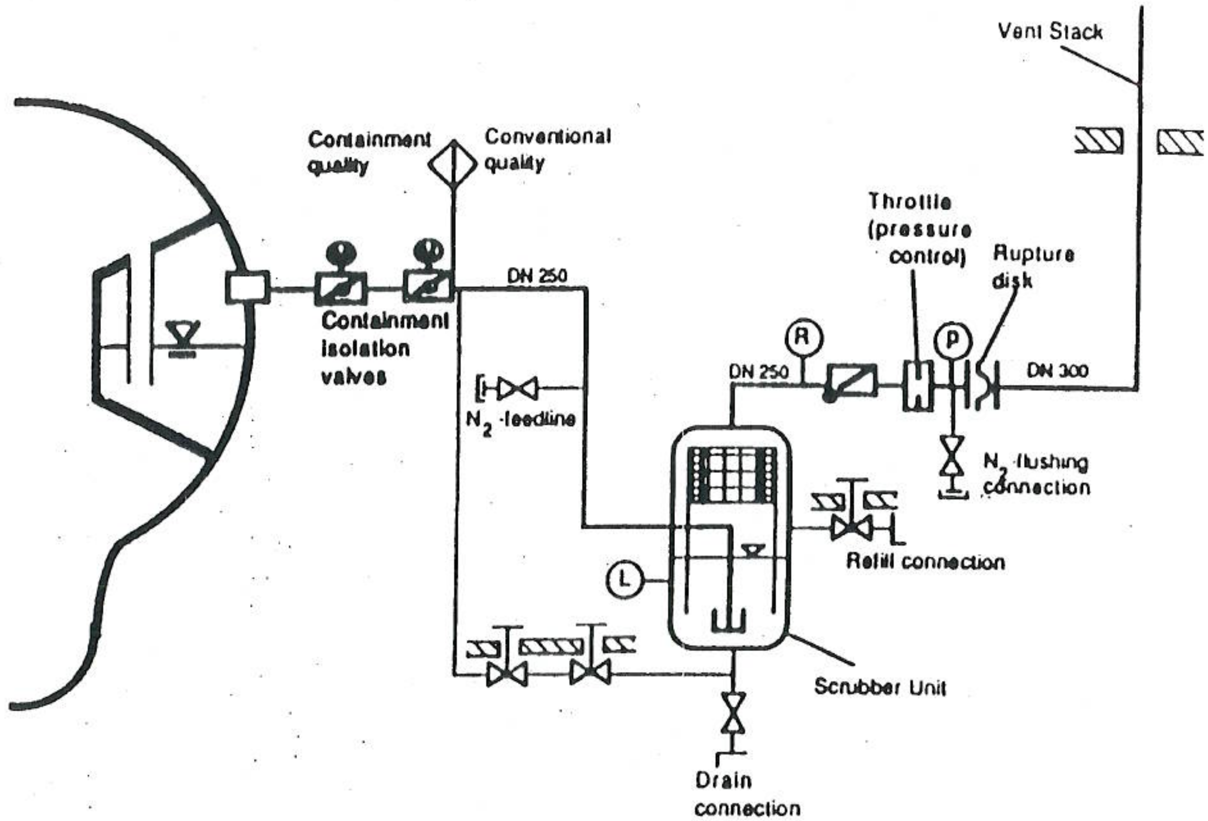
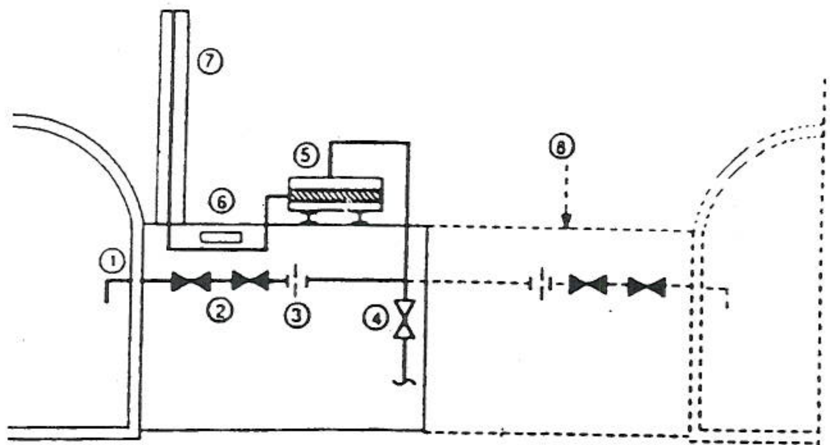


HEW 1988	BWR FILTERED CONTAINMENT VENTING SYSTEM	
Sketch of Flow Diagram		Original: KWU

DEPRESSURIZATION - FILTRATION SYSTEM OF THE CONTAINMENT OF FRENCH PWRs

SCHEMATIC DIAGRAM

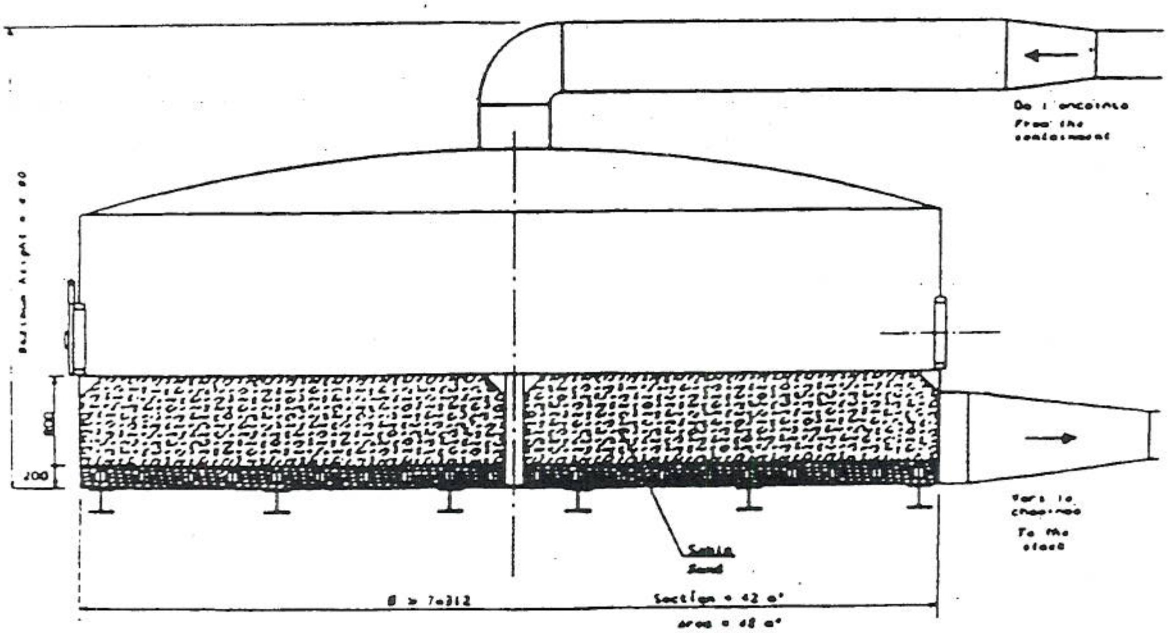


Legend

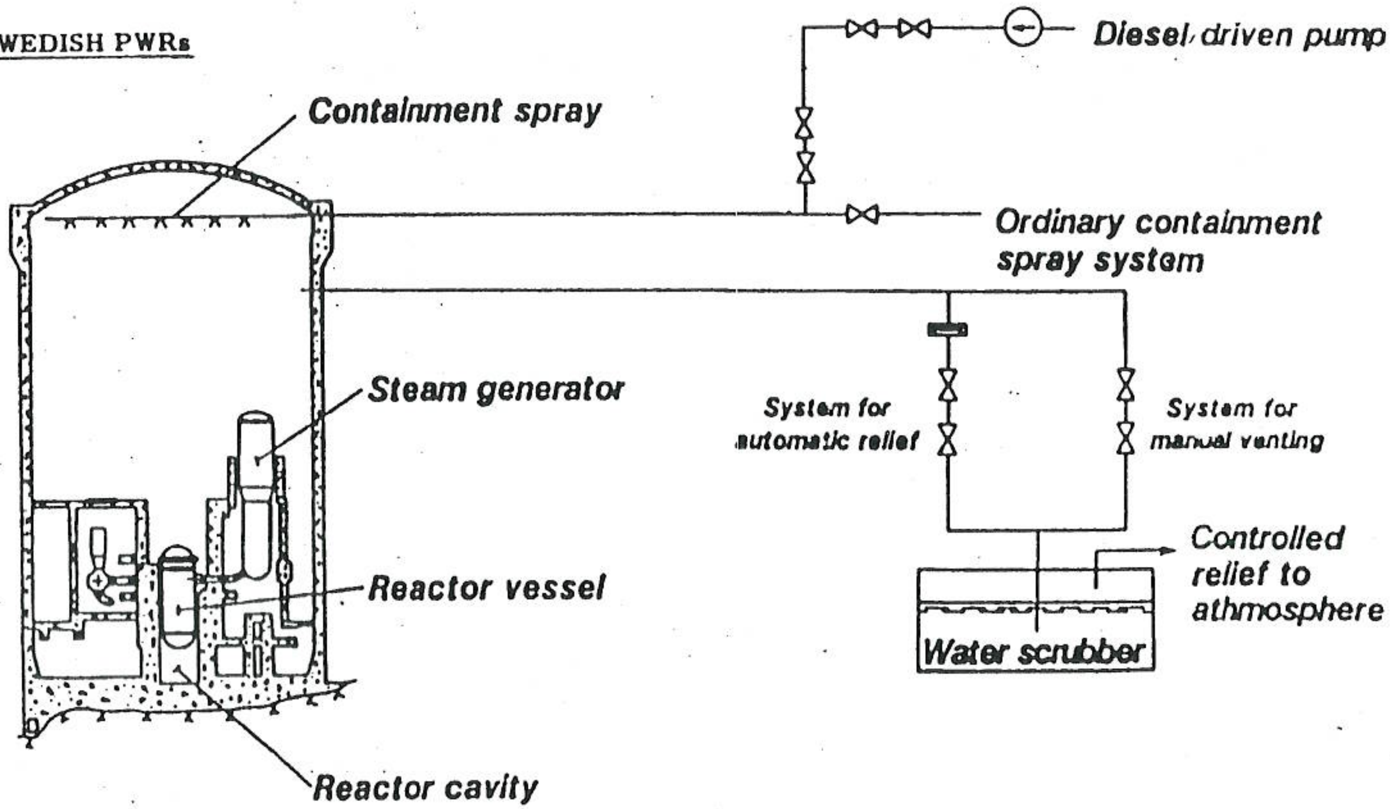
1. Existing penetration, 300 mm diameter for 1300 MWe plants, 250 mm diameter for 900 MWe plants.
2. Manual valves, operated by reach rods from behind shielding.
3. Pressure letdown orifice.
4. Filtered dry air supply during normal operation.
5. Sand filter.
6. Radiation monitor.
7. Plant stack, with small vent stack.
8. Arrangement for twin units.

U5 - FILTRE A SABLE

U5 SAND BED FILTER

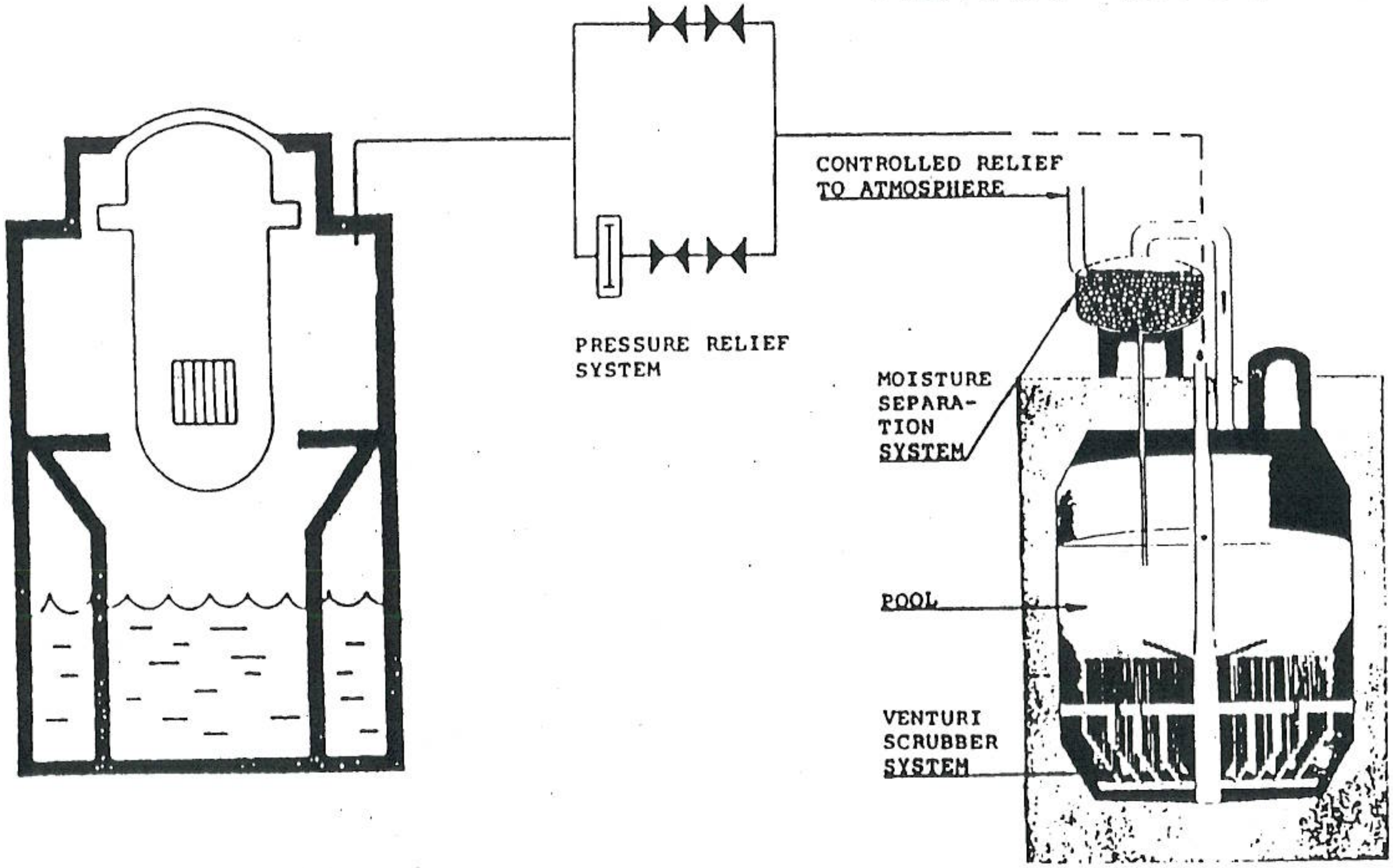


SWEDISH PWRs

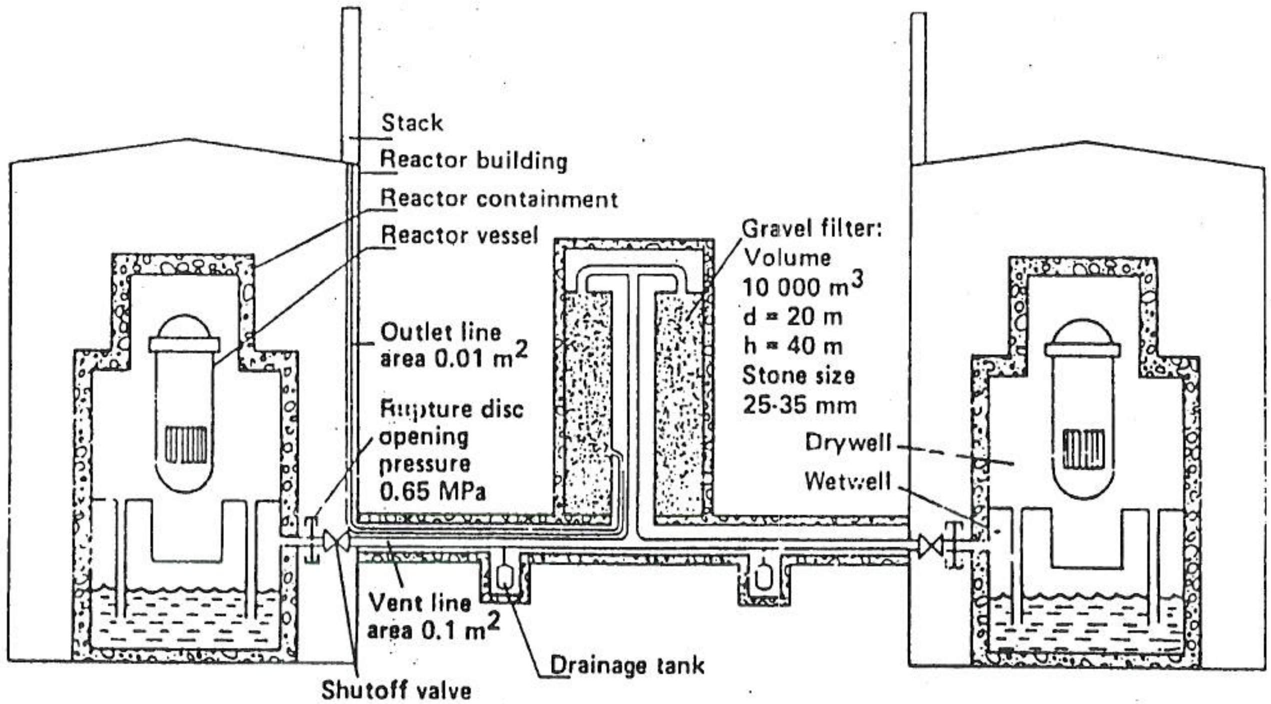


System for Redundant Spray and Filtered Vent.

FILTRA - MVSS



System for filtered containment venting with a FILTRA-MVSS unit



Schematic drawing – FILTRA-Barsebäck.