Systems to Measure Airborne Radioactive Substances in the Reactor Containment in Event of a Severe Accident

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Abstract

In the event of a major release of radioactive substances into the containment atmosphere, the presence of aerosols and iodine may pose a larger threat than the noble gases. They tend to deposit in sampling lines to a varying degree. This makes precise measurement difficult, particularly if small volumes have to be handled, because of high activity . Most systems on the market do not solve these problems. Four different systems have been evaluated and optimized with respect to this task. They allow sufficiently accurate measurement of these substances in the containment atmosphere over a wide range of conditions and temperatures (dry atmosphere up to 100% steam

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In the event of a major release of radioactive substances into the atmosphere of a reactor containment, countermeasures inside and outside the plant can only be optimized if the actual potential radiological hazard can be determined.

Substances which accumulate in the human body and are deposited in the biosphere represent a higher potential hazard than gases with low or no reaction with other substances. It is therefore important to know the actual concentration particularly of these substances. Even if they are absent or at low levels it is important to be aware of that fact. Countermeasures usually pose other hazards and therefore they have to be optimized, which is only possible if the actual threat is known.

In contrast to noble gases, the concentrations of aerosols and airborne iodine not only depend upon the degree of core degradation but also on a number of other parameters which are unlikely to be known in the actual case. "Conservative assumptions" which are meaningful for the **design** of protective devices may lead to wrong decisions in an actual case as has been demonstrated in the assumed radiolysis during the accident at TMI.

It is therefore important that a wide range of concentrations of these substances can be measured even in the presence of a high background of radioactive noble gases. This background of noble gases can easily be estimated at an early stage from a dose rate measurement inside or close to the containment. Only within the first hours of an extreme event may aerosols contribute significantly to that dose rate. Fig.1 shows the dose rate which would result from the various substances at a distance of 50 cm from just 1 ml containment atmosphere. Their relative contribution to the radiation from the entire containment is approximately the same. In addition this figure shows how large a volume could be handled safely in such an extreme situation.

The measurement of aerosols and airborne iodine may be distorted by their tendency to deposit on surfaces in sampling lines. The degree of such deposition is highly dependent on the velocity, particle size distribution, temperature and material. Because some of these parameters are not known in the actual case correction factors may be highly inaccurate. Fig.2 gives an example of these effects. The losses of aerosols (diameter 5 µ) and elemental iodine have been calculated as a function of the velocity for a specific configuration of a slightly heated sampling line to avoid condensation.

The losses in the sampling line are tolerable at a specific velocity only.

Losses in unheated sampling lines could become extremely high if steam is present in the containment atmosphere: If the sampling line passes through cooler areas the inner surfaces may become wet. This would effectively filter out these substances. Depending upon the actual conditions varying with time and location, this liquid may reach the sampling station hours later. It could then show a concentration in the containment which may not exist any more at that time due to deposition and washout effects.

It has been decided by those German utilities operating nuclear power stations that they want to obtain more accurate measurement results for these most important substances and that it should be made possible to perform the analyses in the radiochemical laboratory using routine methods. In a high-stress situation such routine methods are less prone to operator error.

Existing systems were first analyzed and found not to meet these requirements. Then four different systems were selected for more detailed investigation and development according to the given specification. All of them now meet the requirements.

In system 1 the sampling lines are heated to prevent condensation. The flow is regulated independently of the pressure within the containment. Directly outside the containment noble gases are separated from the other substances by a washer (Fig.3). A small sample of the gas and the water phase will be taken remotely without further losses by deposition in sampling lines. This fraction will then be further diluted for analysis in the laboratory.

In system 2 a small sample is taken by means of a container which is transported by a shuttle system to a location inside the containment (Fig.4).

The essential part of system 3 is a remotely operated snapper inside the containment which also takes only a small sample (Fig.5). In contrast to system 2, it operates with a liquid transport medium. Substances which are airborne in the containment are transported as a gas bubble or dissolved or suspended in the liquid. Temporarily deposited substances would immediately be resuspended or dissolved by the circulating fluid. This fluid simultaneously dilutes the high concentrations.

In system 4 the gases and other substances are separated by a gas washer within the containment (Fig.6). This washer operates without condensation because it is at the same temperature as its environment. Gases which pass the washer together with steam and/or air are analyzed first. The other substances will remain in the washing liquid. At the end of a short sampling period part of the liquid will be taken to the outside and the concentrations will be determined. Because the volume of the liquid and the containment volume which has passed the washer are known, the concentrations in the containment atmosphere can be evaluated.

Each of these systems tolerates extreme concentrations of radioactivity as well as a large variety of conditions with respect to temperature, pressure and composition (from 100% air to 100% steam). Which system is the optimum depends on the specific circumstances of the plant, e.g. the number of required measuring points in the containment, the distance to the nearest location accessible after a major release of radioactive substances within the containment and the availability and cost of isolation/transfer valves through the containment.

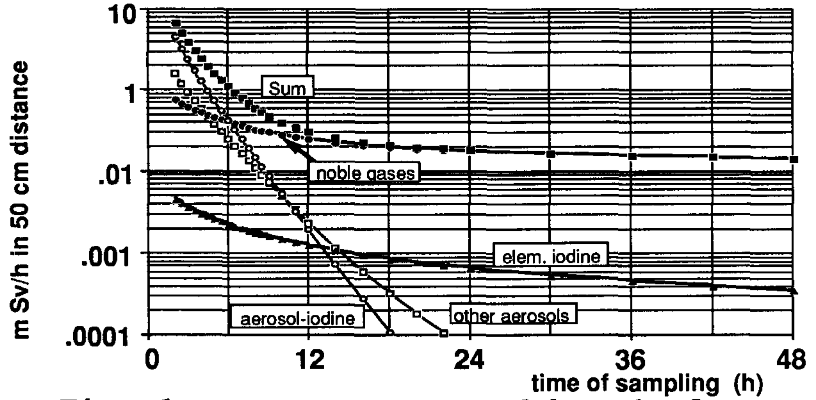

Fig. 1 Dose rate caused by 1 ml BWR containment atmosphere after a severe core melt accident

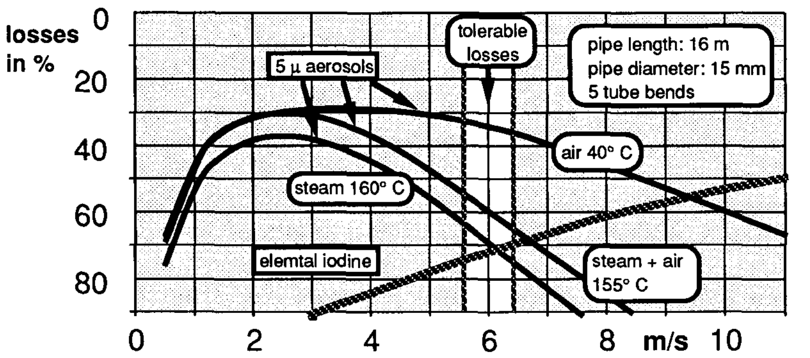

Fig.2 Losses in a sampling line as a function of sampling velocity (m/s)

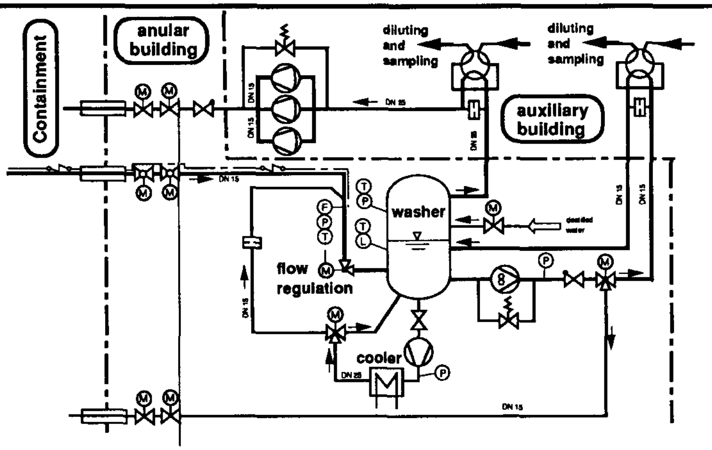

Fig.3 Sampling System for the Containment Atmosphere (System 1)

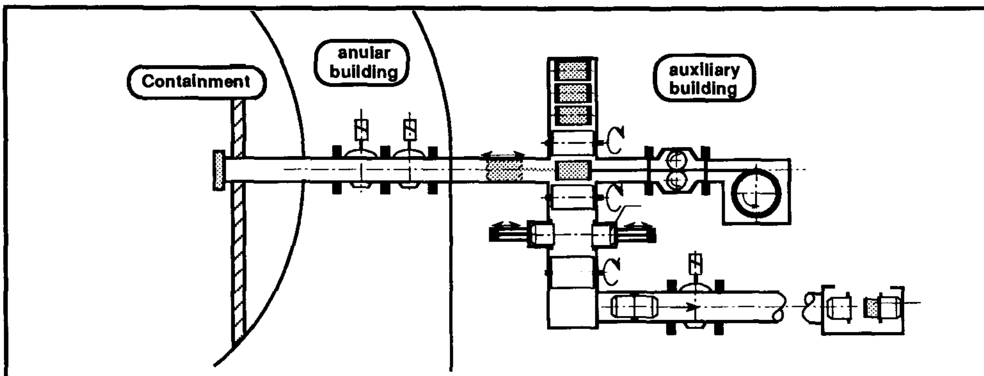

Fig.4 Sampling System for the Containment Atmosphere (System 2)

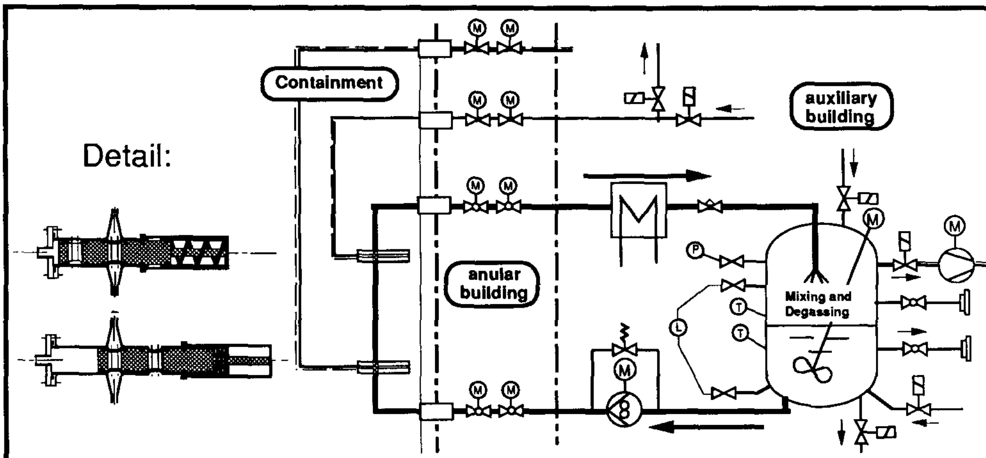

Fig.5 Sampling System for the Containment Atmosphere (System 3)

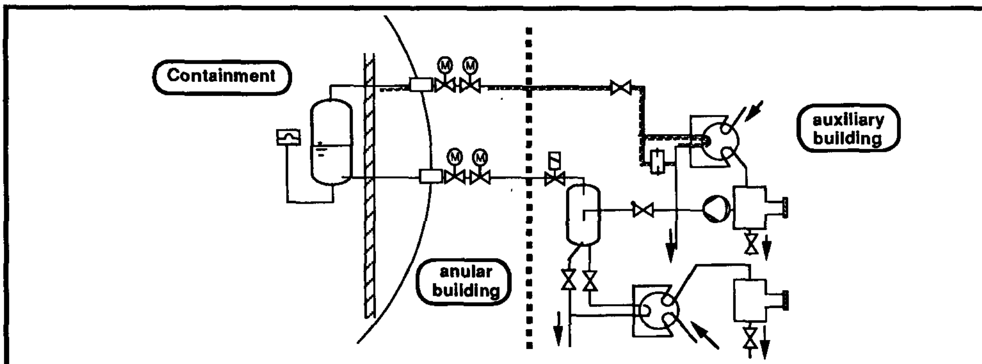

Fig.6 Sampling System for the Containment Atmosphere (System 4)