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A NEW COMBINED IODINE AND PARTICULATE EFFLUENT MONITORING SYSTEM AT THE RISØ HOT CELL PLANT

by

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ABSTRACT

A new effluent monitoring system has been installed at the Hot Cell facility at Risø National Laboratory. In this connection the monitoring philosophy has been changed; new type of equipment has been chosen, and higher sensitivity, accuracy, and reliability has been obtained.

1. INTRODUCTION

This paper describes a newly installed system for monitoring effluent radioactivity in the air from the ventilation outlet at Risø National Laboratory's Hot Cell facility. The new system replaces an older one that was in operation for approximately 25 years. A reevaluation of the monitoring and detection methods resulted in the following differences between the old and new systems:

Old equipment	New equipment
- Two 2-of-3 systems	- One 2-of-3 system + 4 single systems
- Changes in ventilation mode based on release of particles	- Changes in ventilation mode based on release of ^{131}I
- Sampling by electrical pumps (contains moving parts)	- Sampling by air ejectors (pressurised air, no moving parts)
- Low sensitivity	- High sensitivity
	- Improved accuracy

More than 20 years experience and a comprehensive analysis have shown that the possibility for a release of particles is very low compared to the risk for a release of ^{131}I. A potential risk of release of ^{131}I is present each time a fuel rod, newly received from a reactor, is handled, whereas such a risk does not exist in practice concerning particles, because the ventilation air passes through two HEPA-filters (99.97% efficiency for particles with a diameter larger than 0.7 μm). The new system therefore changes the ventilation mode (or stops the ventilation and seals the building) on the bases of an ^{131}I-release rather than a release of particles.

The air sampling in the new system is performed by air ejectors driven by pressurised air instead of electrically driven pumps. In this way moving parts have been avoided, which is an advantage regarding maintenance and stability compared to the old system.

The new system contains one 2-of-3 system, which in two steps changes the mode of ventilation: First, the ventilation is reduced, and then the building is sealed. The 2-of-3 system is supplemented by four single monitors to indicate from which system of cells a radioactive release originates. At the same time up-to-date monitors, electronics, and recorders have been chosen so that the sensitivity, accuracy, and reliability have been optimised.

2. THE VENTILATION SYSTEM

A detailed description of the ventilation system is not relevant here.

In the old system, two sets of 2-of-3 monitors were independently operated. If a certain level of radioactivity from the ventilation stack was detected at at least 2 of the 3 monitors, the flushing of the cells was changed to recirculation and the ventilation from the cells was reduced. If the second set of monitors detected a further release, the limit of which is specified by regulations for the plant, then the concrete cells were completely sealed to avoid any further release of radioactivity to the environment.

In the new system, a new set of cells has been included. Only one set of 2-of-3 monitors is installed to regulate the ventilation system as follows

a) reduce the ventilation of the building and shift the ventilation of the cells from flushing to recirculation, and

b) if further release is monitored, seal the cells and stop the ventilation completely.

The 2-of-3 system is located just before the ventilation air is released from the ventilation stack, which means that the air from the cells has passed at least 2 HEPA filters. This also means that the monitoring system is placed at a location where a complete mixing of all ventilation air in the building has taken place.

In Fig. 2.1 is shown how the air from the different single ventilation channels is mixed before it is monitored.

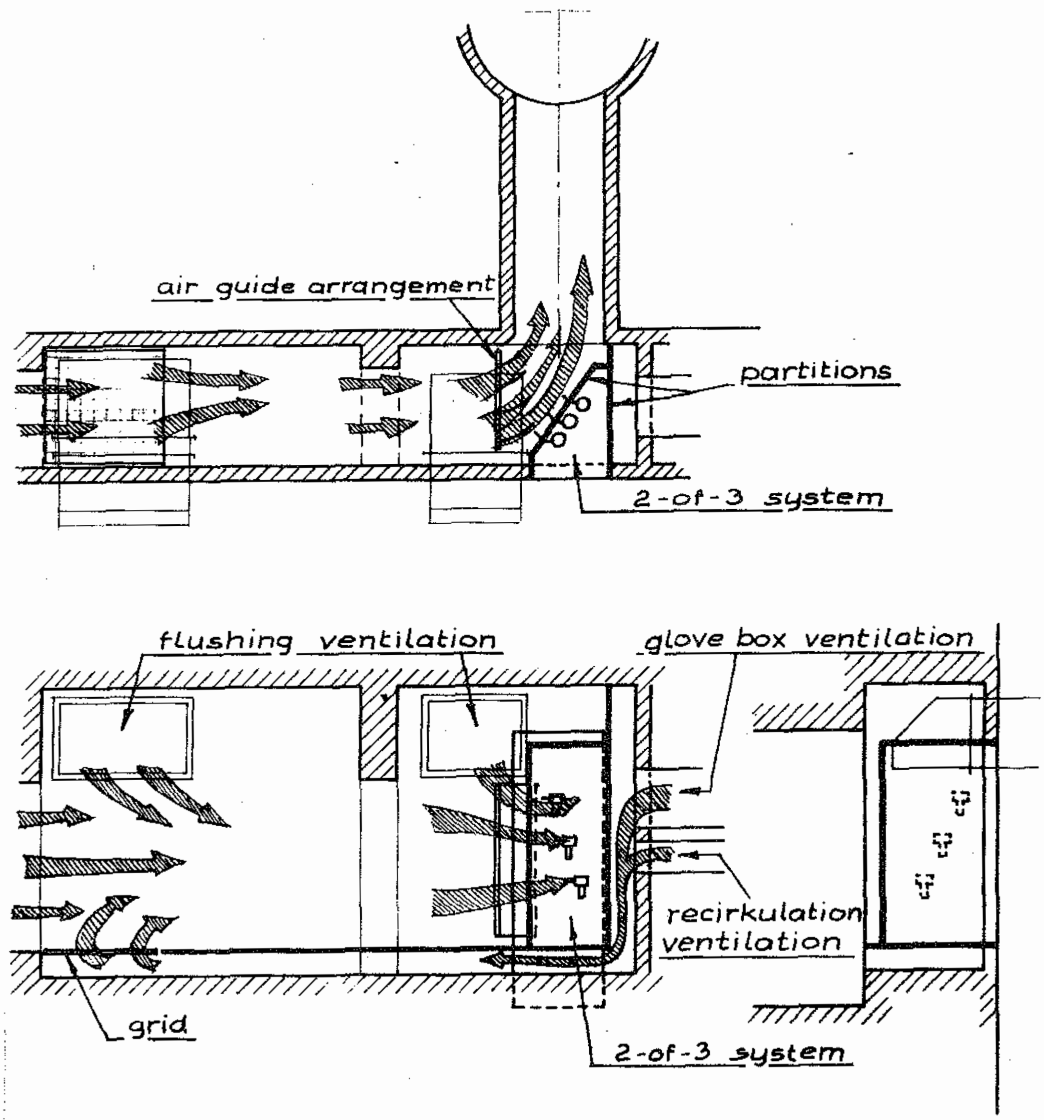

Fig. 2.1. The ventilation outlet with the 2-of-3 system.

3. THE MONITORING SYSTEM

The release monitoring system includes a GM-system for detection of external γ-radiation from noble gas releases and a particulate/iodine monitoring system that has a regulating function to the ventilation system.

The safety philosophy behind the system is based on the following: Only radioiodine and particular activity of radionuclides such as strontium, cerium, tellurium etc. - all being present in irradiated fuel in the cells - can cause significant inhalation doses to the surrounding population after a release through the ventilation stack.

The maximum amount of noble gas activity that will be present in the cells is approximately 500 Ci ^{133}Xe, 100 Ci ^{135}Xe, and 4000 Ci ^{85}Kr. A whole-body dose of 1 mrem at the Risø-fence line from extermal gamma radiation will result from a short-time release of 200 Ci ^{135}Xe, 10000 Ci ^{133}Xe or 200000 Ci ^{85}Kr through the ventilation stack under neutral stability conditions. Therefore, the noble gas activity in the cells could never be of any risk for the surrounding population.

The radionuclide ^{131}I can be present in hundreds of curies in the cells, and can, if released to the surroundings, result in inhalation doses to the thyroids of the exposed population of several rems. Also a release of the radionuclides ^{90}Sr, ^{144}Ce, and ^{132}Te can result in significant inhalation doses to the bones and lungs of the exposed population.

The iodine/particular monitoring system should therefore include the following characteristics

- integrating β-counting system that allows detection of low release rates of iodine or particulate activity
- fail safe system (2-of-3 system)
- relatively low sensitivity for external γ-radiation
- large dynamic response-range

The above mentioned criterias can be fullfilled using a γ-shielded flow house through which a continous air flow from the ventilation channel is sucked through a coal filter paper and a glass filter paper. The iodine will then be trapped on the coal filter paper and the glass filter paper will trap the particular activity. An thin plastic scintillator detects the beta radiation from the activity that has been accumulated on the filter papers.

On the basis of many years experience with air suction devices driven by compressed air, an air ejector system was chosen rather than electrically driven pumps. Air ejectors are commercially avialable in many sizes and the quality and stability of these devices are excellent, especially with respect to maintenance. The air flow through the filter papers in the flow house is 10 liters per minute. The air sampling probes were made of teflon tube to obtain the lowest possible plate out of iodine. All three probes are sampling from a common point inside the channel, a point that was found to be representative by experiments where smoke and experiments where iodine was dispersed in the ventilation channel.

A control board that contains signal rate meters, recorders, signal lamps, and activation switches is placed in a rack system in the Hot Cell control room. Fail indication is given for wrong airflow and missing filter papers.

The following figures show the different parts of the monitoring system.

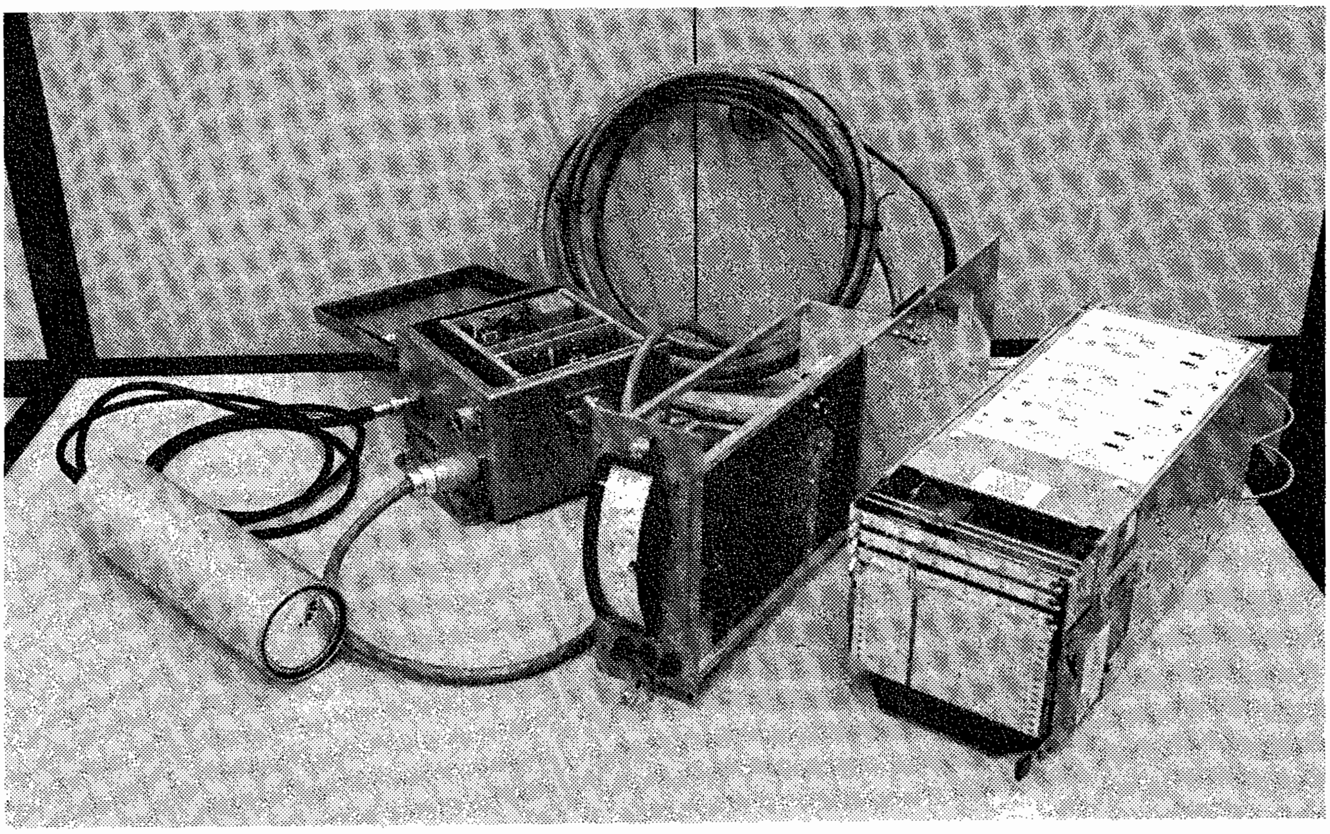

Fig. 3.1. Beta detector, interface/power supply, rate meter and recorder.

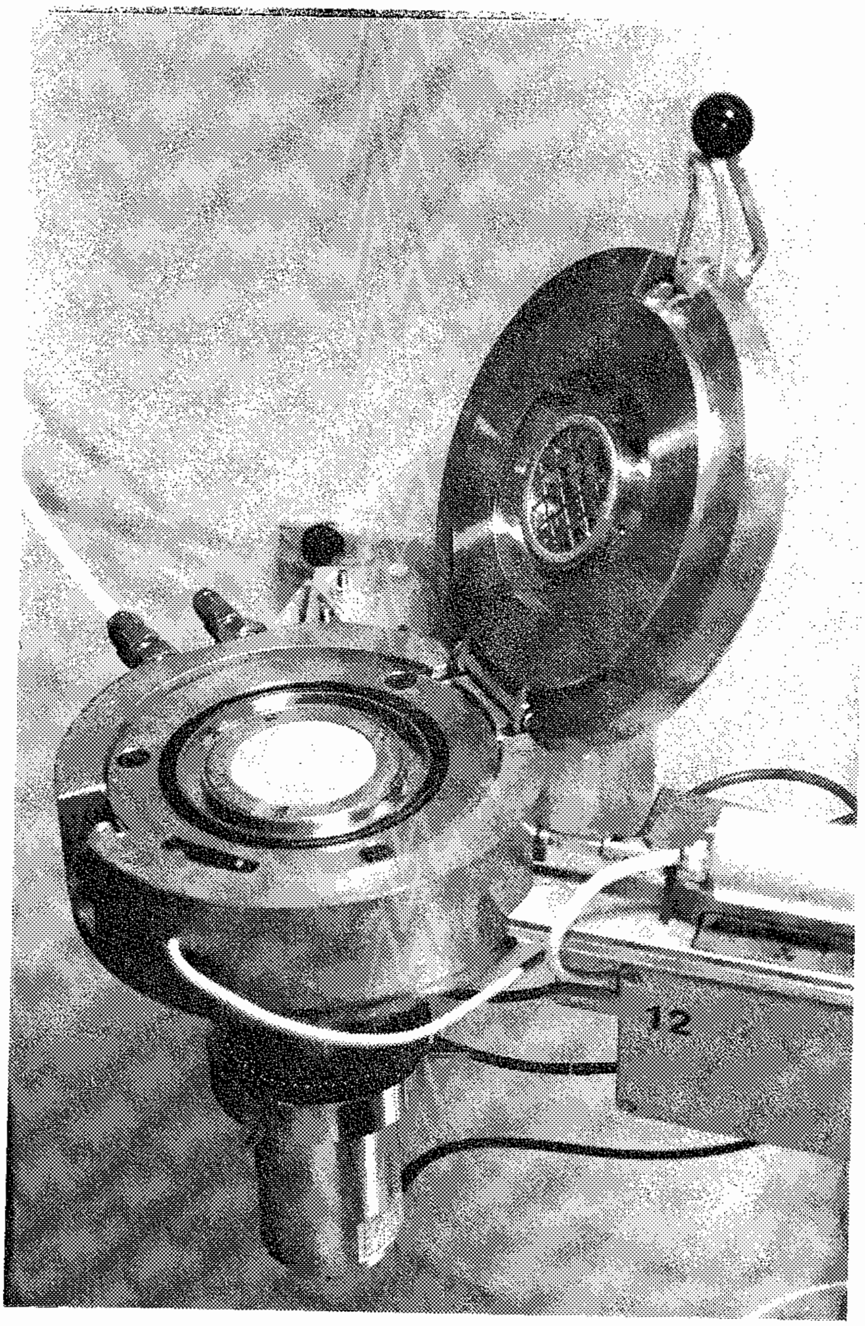

Fig. 3.2. Air flow house with detector, filter papers, and check source facility.

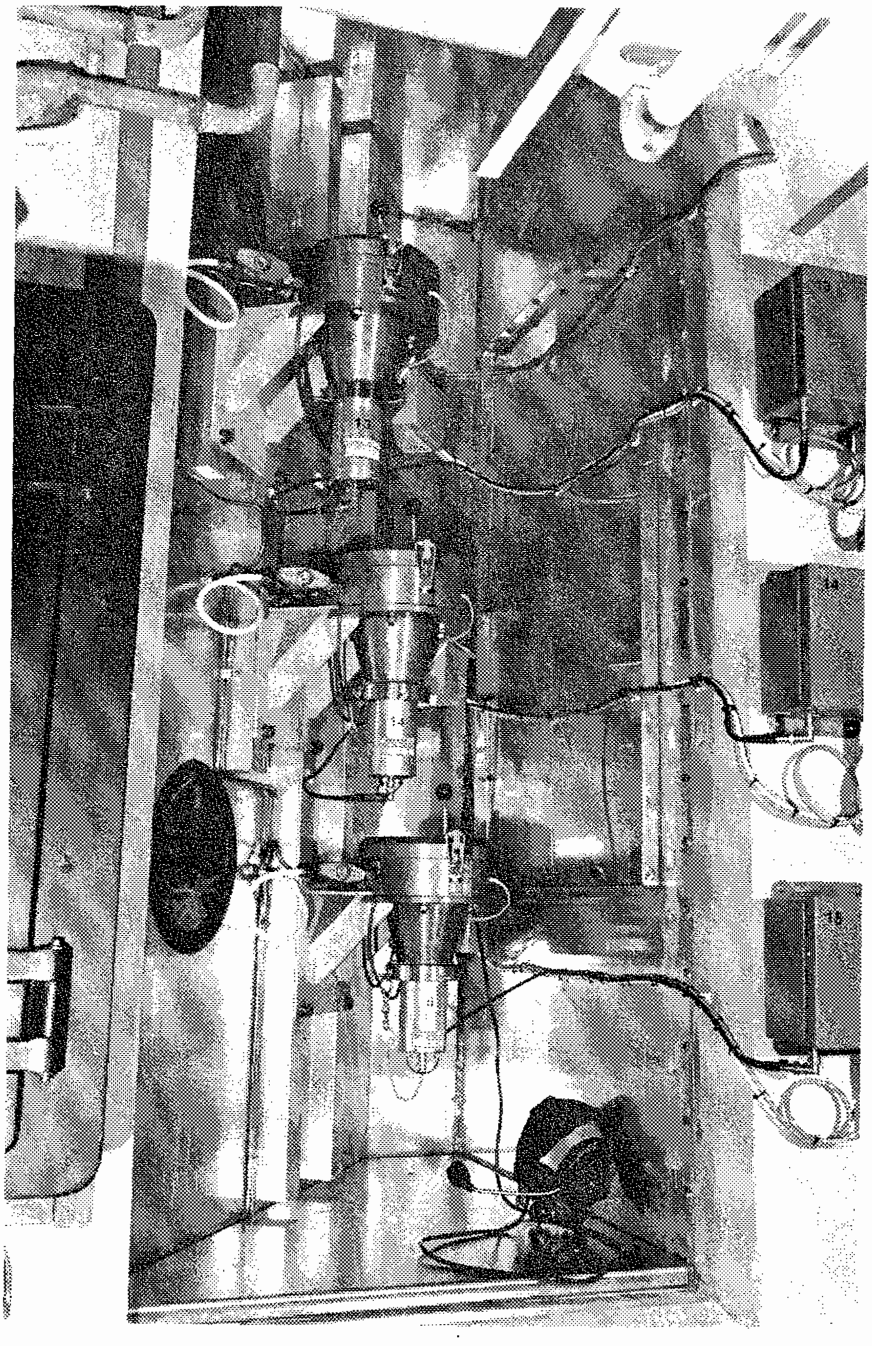

Fig. 3.3. Arrangement of the 2-of-3 system in the ventilation channel.

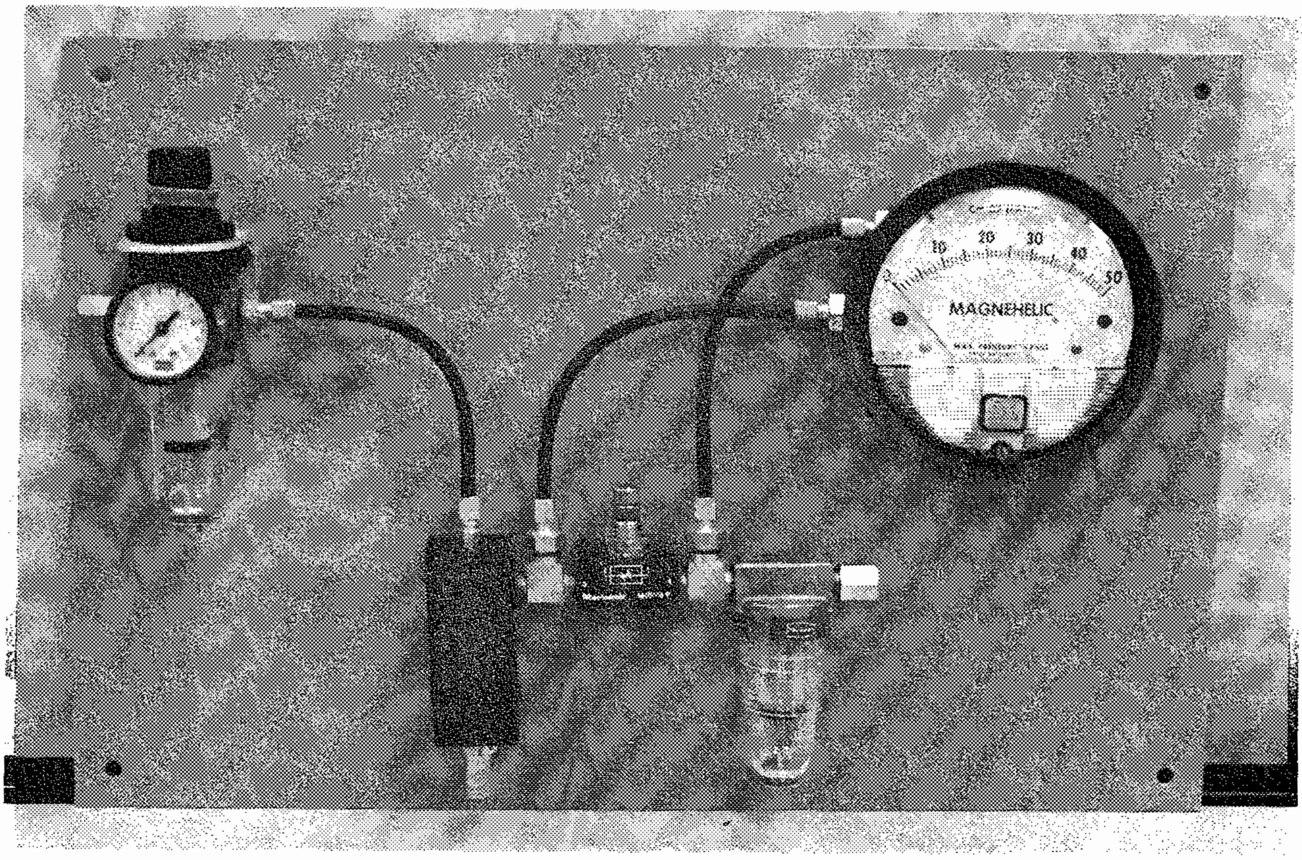

Fig. 3.4. Air ejector arrangement with air flow controllers.

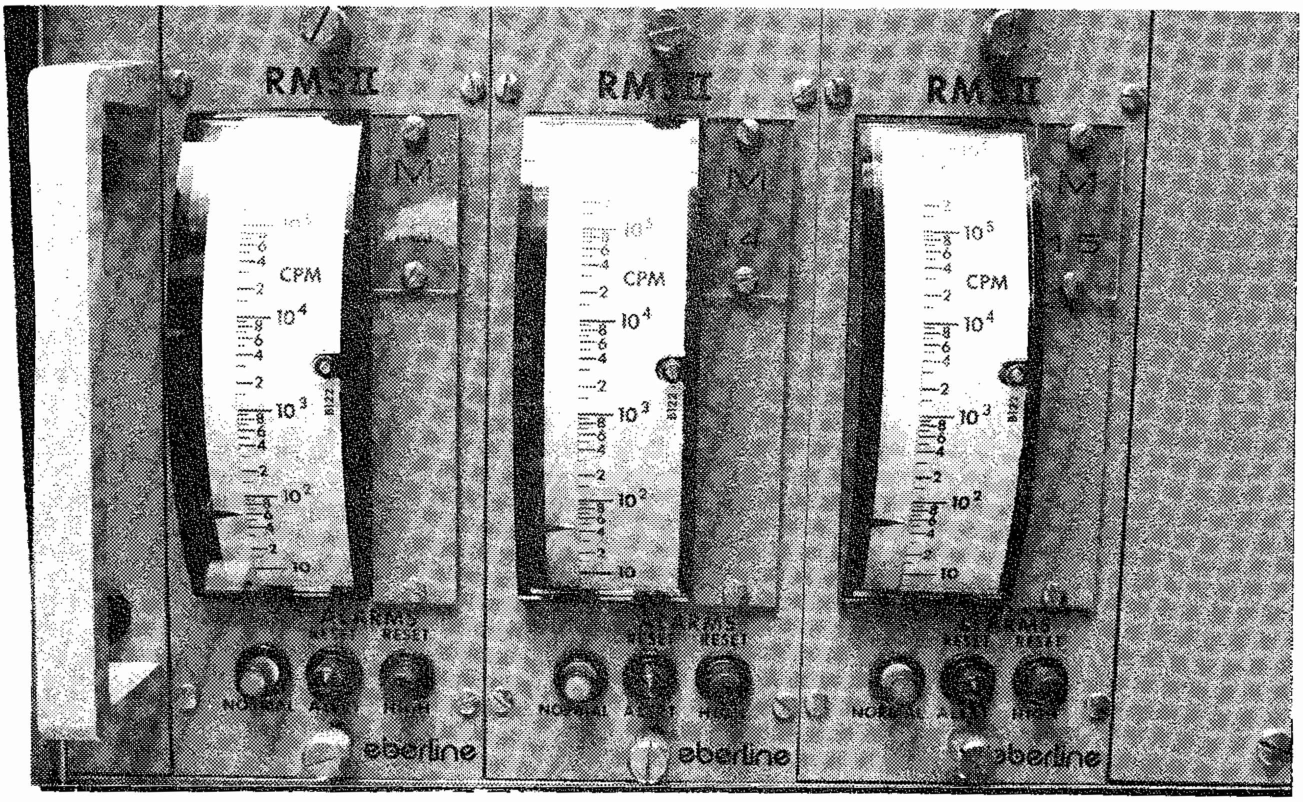

Fig. 3.5. Five decade rate meters of the 2-of-3 system.

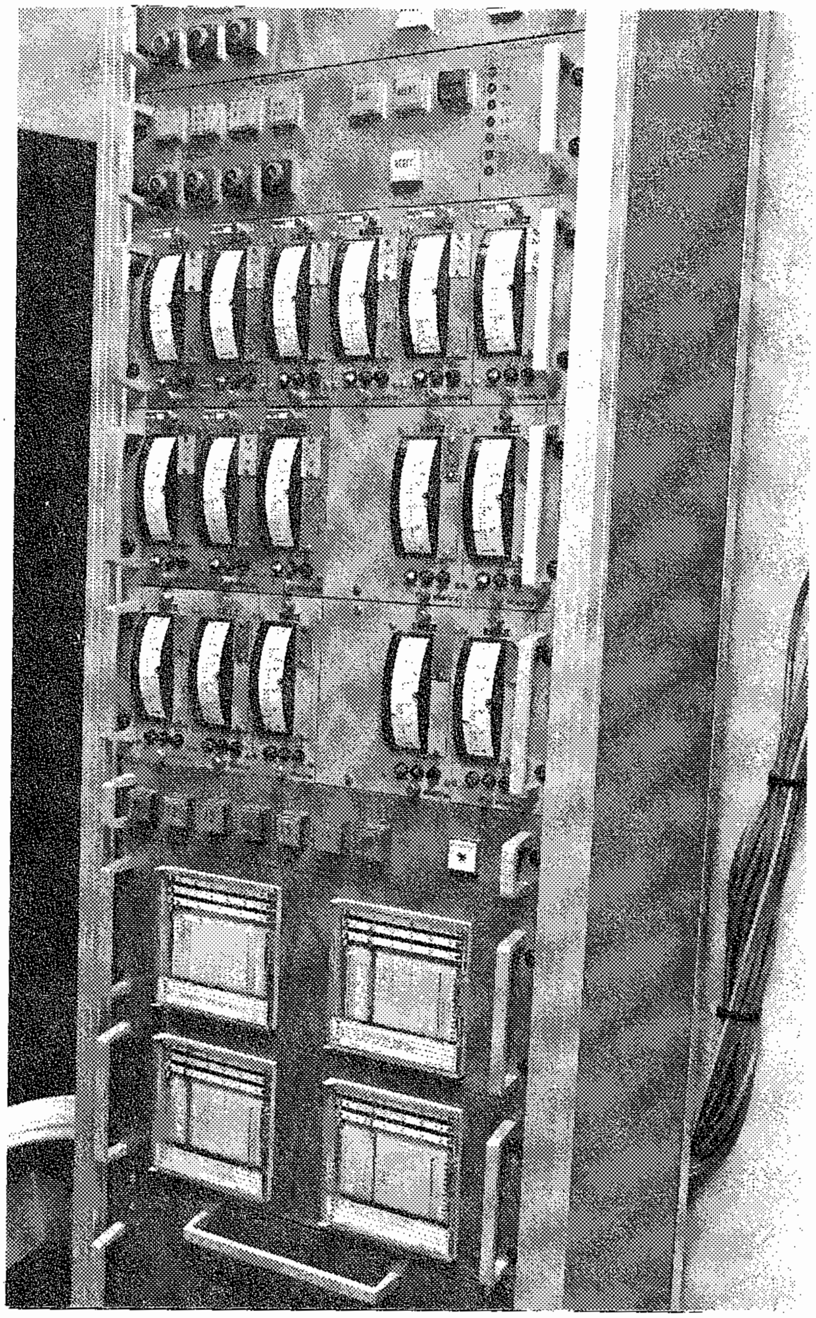

Fig. 3.6. Control board rack with rate meters, recorders, signal lamps and activation switches.

4. CALIBRATION

4.1. Iodine response of the 2-of-3 system.

The flow in the ventilation channel is 60000 m^3/h under normal conditions cf. Sect. 2. If this flow is called F_1 and the sampling flow through the flow house is called F_2 then - after a release of Q curies of iodine through the ventilation channel - the following activity will have been collected on the coal filter paper:

$$q = \varepsilon \cdot \frac{F_2}{F_1} \cdot Q \tag{4.1}$$

where ε is the collection efficiency of the sampling probe and flow house, i.e. the fraction of the activity entering the sampling probe that is trapped on the coal filter inside the flow house.

Experiments with the nuclide ^{131}I were made to determine this collection efficiency. Elementary iodine (I_2) was released into the ventilation channel at a location sufficiently upstream. At the end of one of the three sampling tubes inside the channel, see Fig. 3.4, a coal filter paper was tightly mounted so that the sampling conditions for this filter paper were exactly equal to that of the filters inside the remaining two flow houses.

After a certain time, the accumulated activity on the coal filter papers were measured with a γ-spectrometer. The collection efficiency ε was then determined as the ratio between the activity on the filter paper inside one of the flow houses and that collected on the filter paper inside the channel. The experiments resulted in an ε-value of 84%, meaning that 16% of the iodine that enters the probe will plate out inside the sampling tube and flow house.

For a release of 1 mCi ^{131}I the monitoring system will have collected the following activity at the coal filter papers:

$$q = 0.84 \cdot \frac{0.6}{60000} \cdot 1.0 \cdot 10_3 = \underline{0.0084\ \mu Ci\ ^{131}I}$$

The count rate per unit ^{131}I-activity on the coal filter paper has been measured to be $6 \cdot 10^4$ cpm/μCi which gives the following count rates for the 2-of-3 system for the 1mCi release:

$$n = 0.0084 \cdot 6 \cdot 10^4 = \underline{5 \cdot 10^2\ cpm}$$

4.2. Noble gas response of the 2-of-3 system.

If noble gases are released in the concrete cells, the iodine/particulate monitors will respond due to two radiation sources. The first one is the large volume source of noble gas that the detectors will "see" in the ventilation channels. The second one is the gas that is contained in the cavity of the flow house due to the sampling flow through the house. The size of the cavity is approximately 60 cm^3, and here it is the β-radiation from the cavity gas that will contribute to the response.

Several experiments were made with the radioactive noble gas ^{41}Ar that emits both β- and γ-radiation to determine the importance of these two sources. A noble gas response is highly unwanted - especially if the triggering levels n_{recirc} and n_{seal} could be reached by a fairly harmless noble gas release to the surroundings.

In each experiment 1-2 Ci of ^{41}Ar was released instantaneously in one of the concrete cells. The reason for using this method was that the resulting "impulse-response" function measured by the detector system also can be used to determine the detector response for a constant release rate.

Fig. 4.1 shows the resulting response functions for the 2-of-3 system (N), the GM-system ($\dot{X}$) and a gas monitor (K), that measured the Ar-concentration inside the ventilation channel. The marks on the figure were read from the recorder paper and the curves are fits to these points. The ventilation system was operated in the flushing-mode.

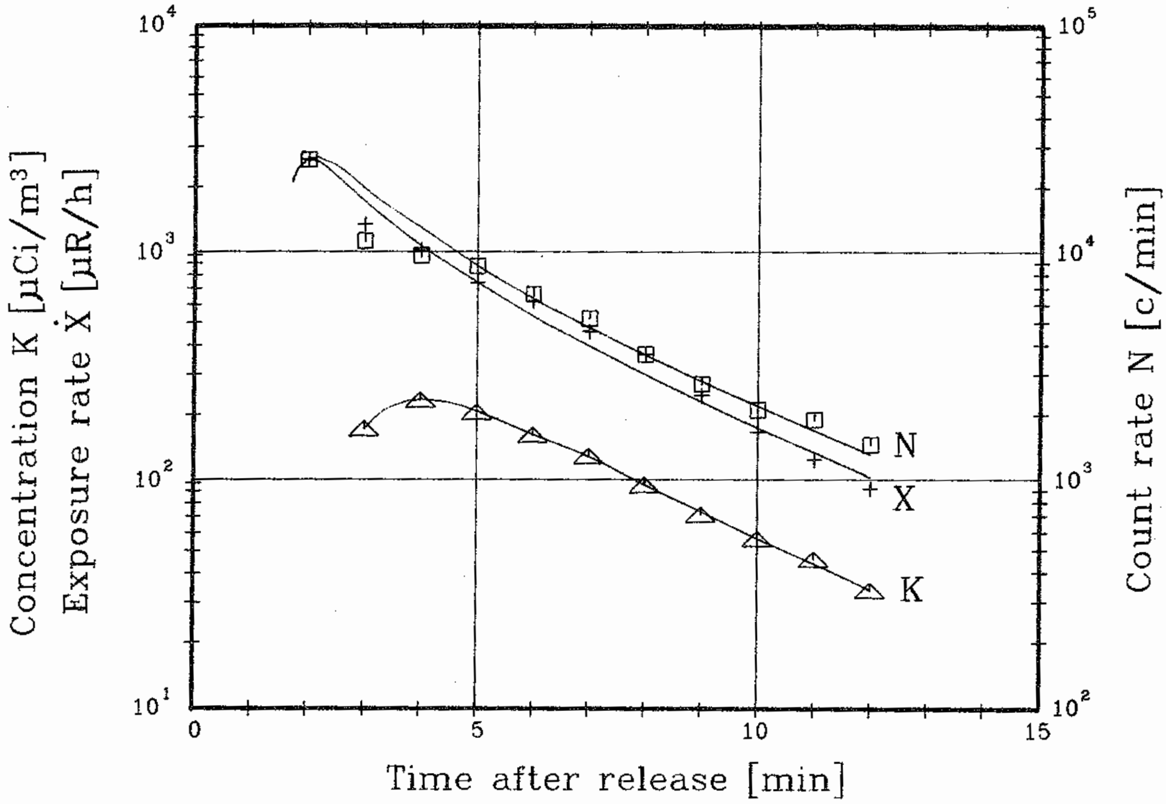

Fig. 4.1. Measured count rate (N) from the iodine/particular monitors, exposure rate ($\dot{X}$) from the GM-system and concentration (K) in the ventilation channel after a momentary release of 1.5 Ci ^{41}Ar. Unshielded 2-of-3 monitors.

The count rate N is composed of the two above mentioned components and can therefore be expressed by:

$$N(E_\beta, E_\gamma) = N_V(E_\beta) \cdot K + N_\gamma(E_\gamma) \cdot \dot{X} \tag{4.2}$$

where $N_V(E_\beta)$ is the count rate per unit concentration of gas in the cavity with β-energy E_β and $N_\gamma(E_\gamma)$ is the count rate per unit exposure rate from a γ-radiation field of energy E_γ and a source geometry like that of the ventilation channel.

For the source geometry that exists when the ventilation is operated in flushing-mode, $N_\gamma(E_\gamma)$ has been determined experimentally for an unshielded 2-of-3 system and for different photon energies E_γ between 80 kev and 1300 keV to be approximately 2000 cpm/mRh^{-1}.

From Fig. 4.1 $N_V(E_\beta)$ can be determined from the corresponding values of K, N and $\dot{X}$ (at t = 7 min) to be 32 cpm/μCi·m^{-3}. This figure was confirmed by other experiments that gave values of 26 - 28 cpm/μCi·m^{-3}.

To reduce the sensitivity of the 2-of-3 system to external γ-radiation from the ventilation channel, in particular when the ventilation system is operated in the recirculating mode, a lead shield of 2 cm was placed around the flowhouse. This reduced the value of $N_\gamma(E_\gamma)$ to 800 cpm/mRh^{-1} for γ-radiation from ^{41}Ar for the flushing geometry. For the recirculating geometry the corresponding value of $N_\gamma(E_\gamma)$ was found by another experiment to be 442 cpm/mRh^{-1} for γ-radiation from ^{41}Ar. Fig. 4.2 shows the response functions from this experiment.

The concentration was measured in the ventilation channel for recirculation and the concentration in the main ventilation channel was assumed to be 1/60 of this, because the flow here is 60 times higher than in the recirculation channel.

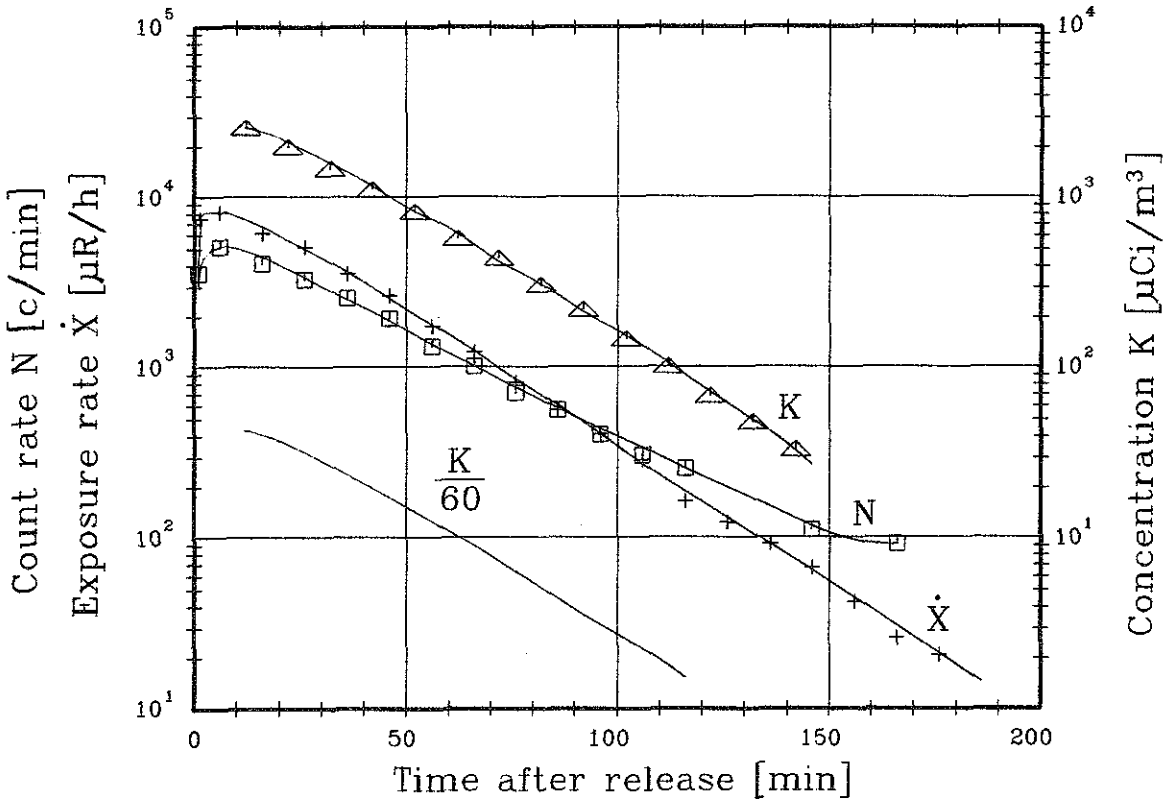

Fig. 4.2. Measured count rate (N) from the iodine/particular monitors, exposure rate (Ẋ) from the GM-system, and concentration (K) in the ventilation channel for recirculation and concentration K/60 in the ventilation channel after a momentary release of 1.5 Ci ^{41}Ar. Lead shield of 2 cm around the flow house.

The total response can be calculated from Eq. 4.1 and the integrated response functions at Figs. 4.1 and 4.2. Assuming a release rate of 1 $mCi.min^{-1}$ the steadystate response will be:

Flushing mode	Recirculating mode
^{85}Kr : N_∞ = 58 cpm	^{85}Kr : N_∞ = 43 cpm
^{133}Xe : N_∞ = 13 cpm	^{133}Xe : N_∞ = 10 cpm
^{135}Xe : N_∞ = 65 cpm	^{135}Xe : N_∞ = 49 cpm

A corresponding release rate of ^{131}I of 1 $mCi.min^{-1}$ will result in an accummulation rate on the coal filter paper of approx. 0.01 $\mu Ci.min^{-1}$, giving a count rate increase of 600 cpm/min. Therefore, the noble gases will be of no importance for the total response if the gases are released with the same rate as for ^{131}I. Building-seal will automatically be established at a count rate of 4.10^5 cpm. This could in fact be caused by a release rate of 7-10 Ci/min of ^{85}Kr, 30-40 Ci/min of ^{133}Xe, or 6-8 Ci/min of ^{135}Xe. However, release rates of this magnitude are considered highly improbable.

4.3. Response of the 2-of-3 system for particulate activity.

If particulate activity is released through the ventilation channel, then after a release of Q curies the following activity will have been collected on the glass filter paper:

$$q = \frac{F_2}{F_1} \cdot Q$$

where F_1 and F_2 are the flow in the ventilation channel and the flow house, respectively. It is here assumed that the collection efficiency ε is 100%. Knowing the β-energy dependence for the plastic scintillator, the following count rate can be calculated for a release of 1 mCi for each of the given nuclides:

$^{90}Sr/^{90}Y$: N = 2000 cpm
$^{144}Ce/^{144}Pr$: N = 2300 cpm
$^{132}Te/^{132}I$: N = 1300 cpm

5. CONCLUSION

A new effluent monitoring system has been designed and installed at the Hot Cell plant. The 2-of-3 system is extremely sensitive for iodine and particulate releases. Activity effluents as low as 50 µCi are easily detected. The location of the monitoring system ensure that any release of activity is monitored, and the mode of ventilation changed accordingly. The GM-tube easily detects noble gas releases of a few millicuries per second.