On-Site Test of Filters in Nuclear Facilities using Radioactive Sodium Chloride (24Na)-Aerosol and Methyl Iodine (131I)

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ON-SITE TEST OF FILTERS IN NUCLEAR FACILITIES USING RADIOACTIVE SODIUM CHLORIDE (^{24}Na)-AEROSOL AND METHYL IODIDE (^{131}I)

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Abstract. The nuclear facilities at Risø National Laboratory are equipped with high-efficiency filters to protect the environment from routine or accidental releases of radioactive material. The filter efficiency must be tested regularly and a method for on-site control is described. It is based on injection of a radioactive sample in the filter duct, followed by sampling before and after the filter. HEPA-filters are tested with a ^{24}NaCl-aerosol and charcoal filters with $^{131}ICH_3$. Normally samples of 1 mCi are used. Penetrations (1 - efficiency) can be determined with a relative uncertainty of 10-15%.

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PREFACE

In 1978 Risø National Laboratory asked the Air Pollution Laboratory in the Danish EPA to undertake the necessary control investigations of the Risø filter installations. Further, the Air Pollution Laboratory was asked to asssist in the choice of filter-material and filter types to be used in existing charcoal filter-installations.

The Air Pollution Laboratory surveyed all the installations (in all about 100) and classified them according to construction, accessibility and working conditions etc. It was suggested that all filters should be tested with radioactive isotopes, ^{24}Na for HEPA-filters (High Efficiency Particulate Filters) and ^{131}I for charcoal filters, and suggestions for measuring procedures were offered.

After an evaluation of the report from the Air Pollution Laboratory it was concluded by Risø that it would be necessary to test only 18 filters located at DR 1 (Danish Reactor 1), DR 3 and at the Hot Cell plant. The criteria for selecting these filters are presented in section 2.1. of the present report.

The administration of the filter tests will be carried out by the Risø Safety Department. It will comprise planning, control and reporting to the respective user departments. The user departments are responsible for reporting to public authorities, safety committees, etc.

The present report deals only with the technical aspects of the filter tests.

1. INTRODUCTION

At nuclear facilities high-efficiency filters are installed to protect the environment from routine- or accidental releases of radioactive material to the atmosphere. Although these filters are tested and certified by the manufacturer, an on-site control is necessary to ensure against filter damage or improper installation.

1.1. Statement of the problem

In principle the filter test is very simple (Figure 1). A test aerosol or gas is introduced in the duct well upstream from the filter. Test samples are extracted before and after the filter and the penetration is determined as the ratio of the test gas or aerosol concentration in the second to the first sample. The filter efficiency is one minus the penetration.

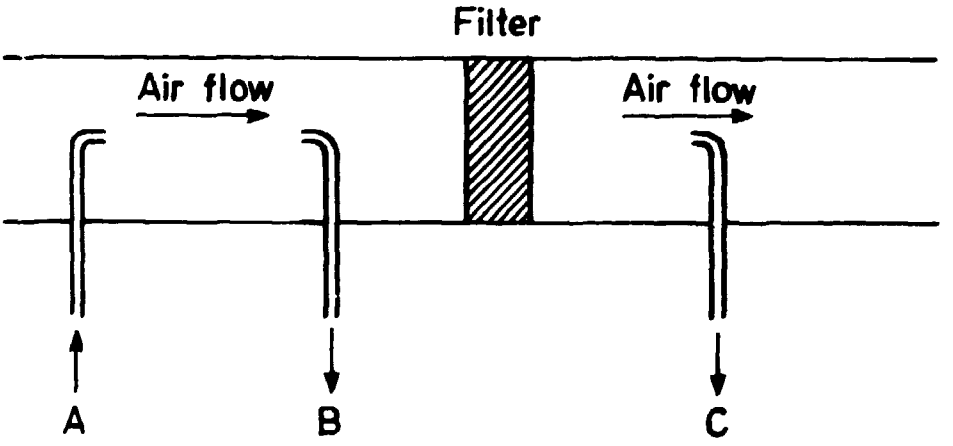

Figure 1. The principle of a filter test. A test aerosol or gas is introduced at A, and test samples are extracted at B and C.

In practice, the filter installations are often composed of several individual filters - either because capacity thereby is increased or because filtration of different pollutants is possible. In some cases these filters can be tested separately; in other cases only the entire installation can be tested. Error tracing in non-separable installations is often extremely difficult and may require extensive, special arrangements.

The tests are often encumbered with complications such as duct bends and varying duct widths. Further it may be difficult to gain access to the proper measuring points and it may be necessary to work simultaneously in separate rooms. Therefore, routine tests are greatly facilitated with compact and easily handled equipment.

1.2. The filters at Risø

Several of the laboratories at Risø are handling radionuclides in various fume cupboards, glove boxes and lead-shielded cells. All these facilities are supplied with a pre-filter and HEPA-filter through which the ventilation air is filtered before it is released to the atmosphere. The radionuclides handled in these laboratories are typically ^{3}H, ^{14}C, ^{22}Na, ^{32}P, ^{35}S, ^{36}Cl, ^{85}Sr, ^{134}Cs, ^{154}Eu, ^{238}Pu in kBq-quantities, ^{22}Na, ^{24}Na, ^{35}S, ^{42}K, ^{51}Cr, ^{57}Co, ^{59}Fe, ^{65}Zn, ^{82}Br, ^{110m}Ag, ^{131}I, ^{134}Cs, ^{137}Cs, ^{235}U, ^{238}U in MBq-quantities, and ^{32}P, ^{35}S, ^{60}Co, and ^{198}Au in GBq-quantities.

The two research reactors DR 1 and DR 3 and the Hot Cell plant each contains activity in much larger amounts. As a part of the safety systems to protect the environment from routine and accidental releases of radioactive material to the atmosphere, these facilities contain both HEPA-filters for filtration of airborne particulate activity in the exhaust air and impregnated charcoal filters for filtration of airborne radioiodine.

Access to the different filter systems varies considerably. The accessable part of the ventilation channels are often placed inside engineering corridors or in cellars where access is difficult and working conditions are very uncomfortable. Entry of operators and equipment is therefore in many circumstances difficult.

1.3. Review of techniques

Over the years several methods for in-situ testing of HEPA filters have been developed. They all rely on upstream and downstream measurements of a challenge aerosol (e.g. COMMISSION OF THE EUROPEAN COMMUNITIES, 1977). A range of aerosol types and associated methods of detection are available. Thus detection of methylene blue and DOP-aerosols depend on light scattering of single particles, whereas Na- and Li-aerosols are usually detected in bulk by flame-photometry (DORMAN, EDWARDS and POYNTING, 1976). Often NaCl-aerosols are preferred because they are easily produced by atomizing controlled solutions. Although flame-photometry is quite sensitive (detection limit 10^{-5}), the risk of Na-contamination of samples is large and the demands on sample handling are severe. To avoid these difficulties, on-site detection by a portable photometer has been attempted successfully in several cases, but this technique cannot be applied in cramped spaces. Application of a tagged NaCl-aerosol simplifies the problem, and samples can be transported without risk of contamination to a measurement laboratory, where counting takes place shortly after collection. In addition, calibration of counters is easier and more precise than calibration of photometers.

More advanced and more sensitive methods also exist. They rely on in-situ aerosol particle counting, usually with a laser spectrometer (SCHUSTER, KYLE and OSETEK, 1977; SCHUSTER and OSETEK, 1978). In some cases the laser excites fluorescence in the challenge aerosol thus removing the problem of a background (ELDER et al., 1980). These methods are well suited for large

installations (250 000 m^3/h), and penetrations around 10^{-8} have been detected. Penetrating particles can be sized and individual leaks located. These methods suffer from the drawback that costly and complicated equipment must be operated on site.

For the present purpose such sophisticated methods are unnecessary, the problem is simply whether the installation meets the penetration requirements or not. As indicated above a simple NaCl aerosol is sufficient. When radioactive labelling is used, the measurements are facilitated and the sensitivity can be increased by using sufficiently large activities. With a similar technique charcoal filters can be tested with radioactive methyl iodiode.

2. FILTERS TO BE TESTED

Risø National Laboratory is situated about 35 km west of Copenhagen, partly on a peninsula in Roskilde Fjord (Figure 2). The various laboratories and departments are housed in low, mostly one-story, buildings distributed on an area of about 1 square kilometer.

2.1. Criteria for selection of filters for testing.

The selection of filters that regularly should be efficiency tested depends on the risk that a release will occur, the amount of activity present in the given installation and the permissible dose to the population.

The reactor DR 3 and Hot Cell Plant have established release limits for annual releases of different groups of radionuclides, like for instance, fission gases and ^{131}I. For each group the annual release limit has been determined from an annual committed

effective dose-equivalent of 1 mrem to a fictive person standing outdoors at a fixed position by the fence line night and day. In other words, if a given nuclide group is released with a constant release rate during the year, corresponding to an annual release equal to the release limit, then the resulting dose to the fictive person would be 1 mrem. Both external and inhalation doses are considered.

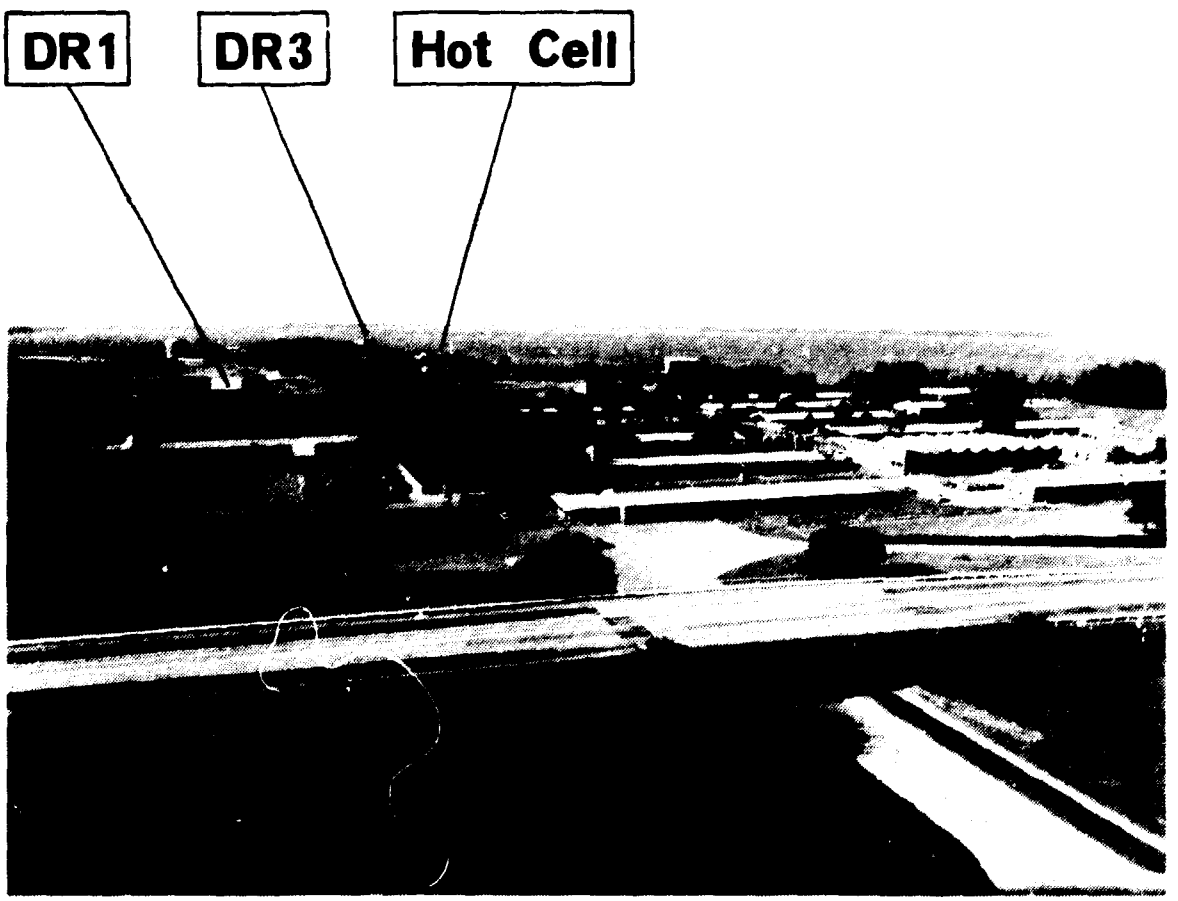

Figure 2. Risø National Laboratory is situated partly on a peninsula in Roskilde Fiord about 35 km west of Copenhagen.

The probability for a given release is very difficult to determine. It was therefore decided not to make a risk analysis for the different installations, but consider only the size of a potential release and the corresponding dose to the surrounding population. A general criterion for filter selection based on these considerations is consequently:

Filters in nuclear installations, laboratories etc. from which routine or accidental releases with no filtration can cause a committed effective dose-equivalent of 1 mrem to a person standing at the fence line should be tested regularly once a year.

An analysis of potential releases from all the nuclear plants and laboratories showed that only the Hot Cell Plant, DR 3 and DR 1 could cause doses to a person at the fence line in excess of 1 mrem.

2.2. Filters in the ventilation system in DR 3

The ventilation system in DR 3 is divided in three separate circuits as shown in figure 3.

Under normal conditions the containment is ventilated by the suction system through the HEPA-filter F2 (F3) and by the active ventilation system through the HEPA-/charcoal-filters F6/F8 (F7/F9). The flow in the suction system is 7600 m^3h^{-1} and in the active ventilation system up to 1800 m^3h^{-1}. These two systems join each other just before the air is released through a 23-m high ventilation stack. Under accident conditions where activity is released to the containment atmosphere the system can be operated in

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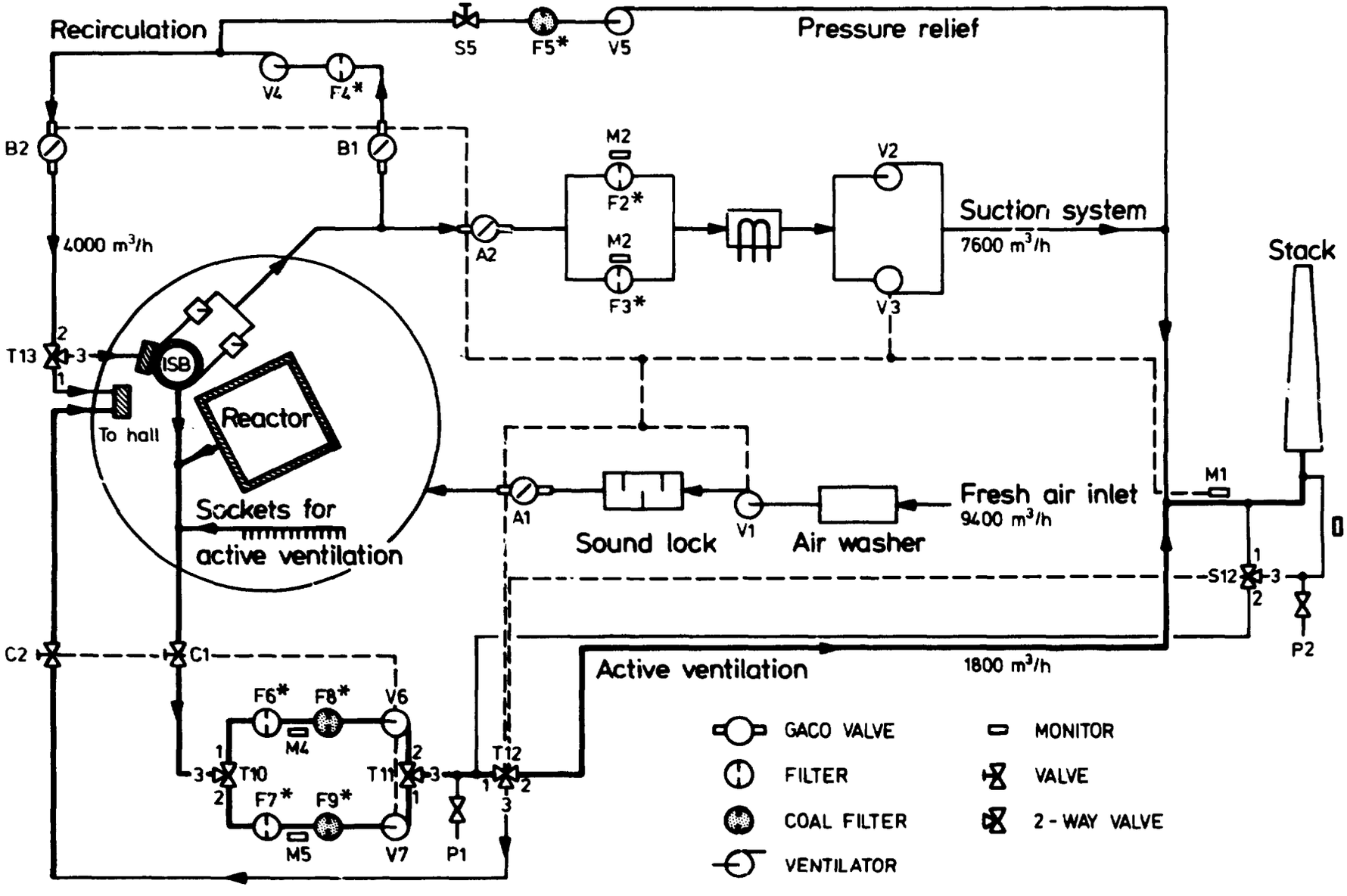
Figure 3. Flow diagram for the ventilation system at reactor DR 3. The filters to be tested are indicated with an asterisk on the filter numbers.


Recirculation
S5
F5*
V5
Pressure relief
V4
F4*
B2
B1
M2
F2*
M2
F3*
V2
V3
Suction system
7600 m³/h
4000 m³/h
A2
Stack
T13
ISB
Reactor
To hall
Sockets for
active ventilation
A1
Sound lock
V1
Air washer
Fresh air inlet
9400 m³/h
M1
S12
P2
C2
C1
Active ventilation
1800 m³/h
F6*
F8*
V6
M4
T10
T11
T12
F7*
F9*
M5
V7
P1
GACO VALVE
FILTER
COAL FILTER
VENTILATOR
MONITOR
VALVE
2 - WAY VALVE

different building seal modes where the containment air is recirculated through the filters F6/F8 (F7/F9) in the active ventilation system, thereby cleaning the air. The building seal condition is established automatically if either a 2-of-3-system of ionization chambers placed in the bottom of the stack or a 2-of-3-system at the reactor top exceeds preset values. During building seal conditions the containment is sealed from the surroundings.

If an over-pressure arises within the containment a controlled release of the containment atmosphere can be established manually through HEPA-filter F4 and charcoal filter F5 through the stack. The flow in this system is approximately 70 m^3h^{-1}.

If a larger part of the fission products in the reactor core is released unfiltered through the stack, an individual at the fence line could receive a dose that exceeds 1 mrem by several orders of magnitude. It is therefore important that the ventilation filters operate at high efficiency.

The following filters should therefore be tested:

- charcoal filters: F5, F8 and F9
- HEPA-filters: F2, F3, F4, F6 and F7

placed in the following three sub-systems:

- suction system: F2 and F3
- active ventilation system: F6, F7, F8 and F9
- pressure relief system: F4 and F5.

Figure 4 shows some of the filters at DR 3 and figure 5 shows the ventilation stack.

Figure 4. Filter installation at DR 3. In the foreground HEPA-filter F2 is seen; in the left-hand background HEPA/charcoal-filters F7/F9 are seen (cf. figure 3).

Figure 5. The building with the filters at DR 3. The filtered air is released through a 23-m high stack.

2.3. Filters in the ventilation system in DR 1

The ventilation system in DR 1 (Figure 6) is shown in Figure 7 and is very simple. The pressure in the cave inside the concrete shield of the reactor is kept lower than the pressure in the reactor room. A ventilation blower pumps air from the control rod room through the cave to a stack on the roof of the building. The exhaust is mixed with the exhaust air of the building.

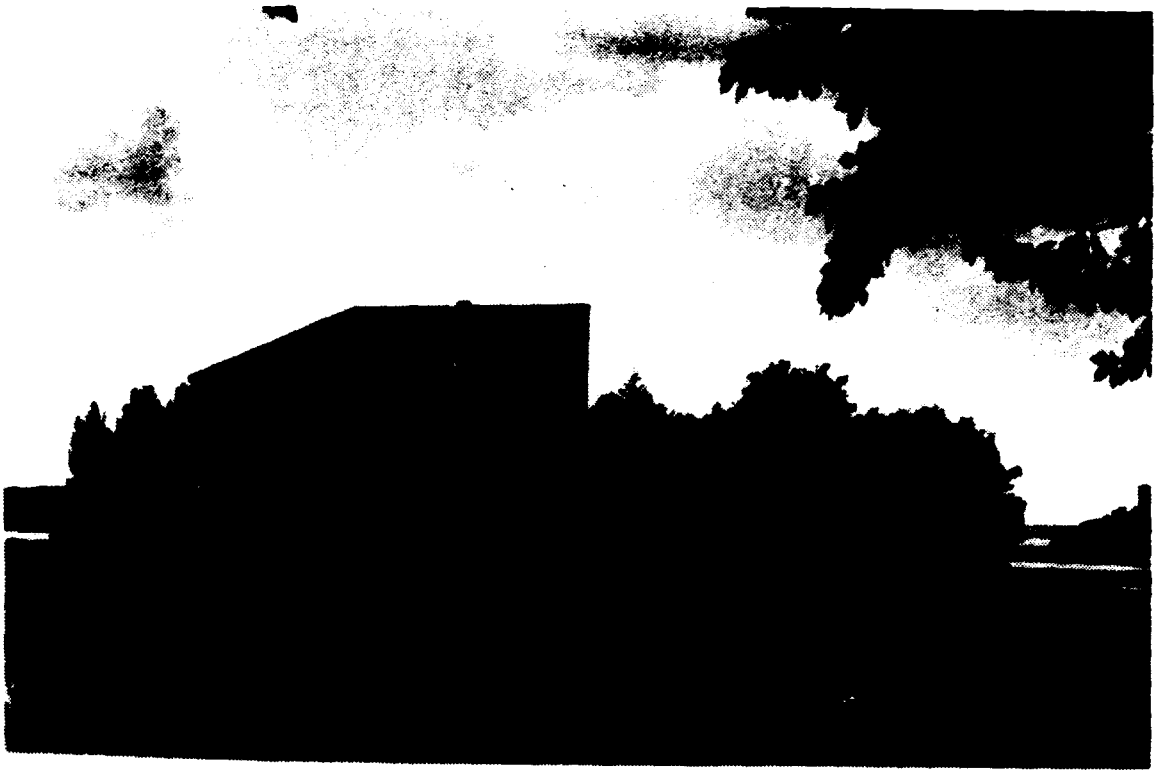


Figure 6. The DR 1-building

All the effluent air from the cave is passed through a Hepa-filter and charcoal filter before being released. The air which is pumped from the control rod room to the cave passes through absolute filters to prevent dust from entering the cave. The cave ventilation pump is used only during operation of the reactor.

If a leak occurs in the reactor tank, activity could reach the reactor hall without passing the Hepa- and charcoal filters. As the reactor hall is not an airtight containment, a release to the environment is possible even with high-efficiency HEPA- and charcoal filters.

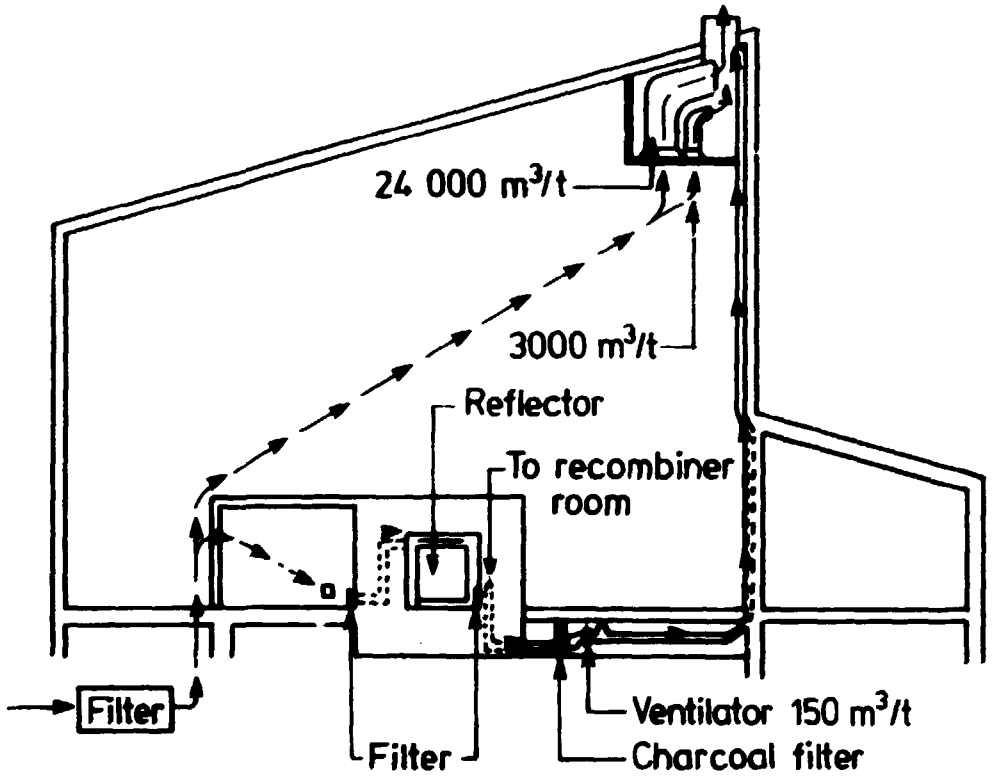


Figure 7. Vertical cut through the DR 1 building, showing the ventilation flow.

2.4. Filters in the ventilation system in the Hot Cell plant

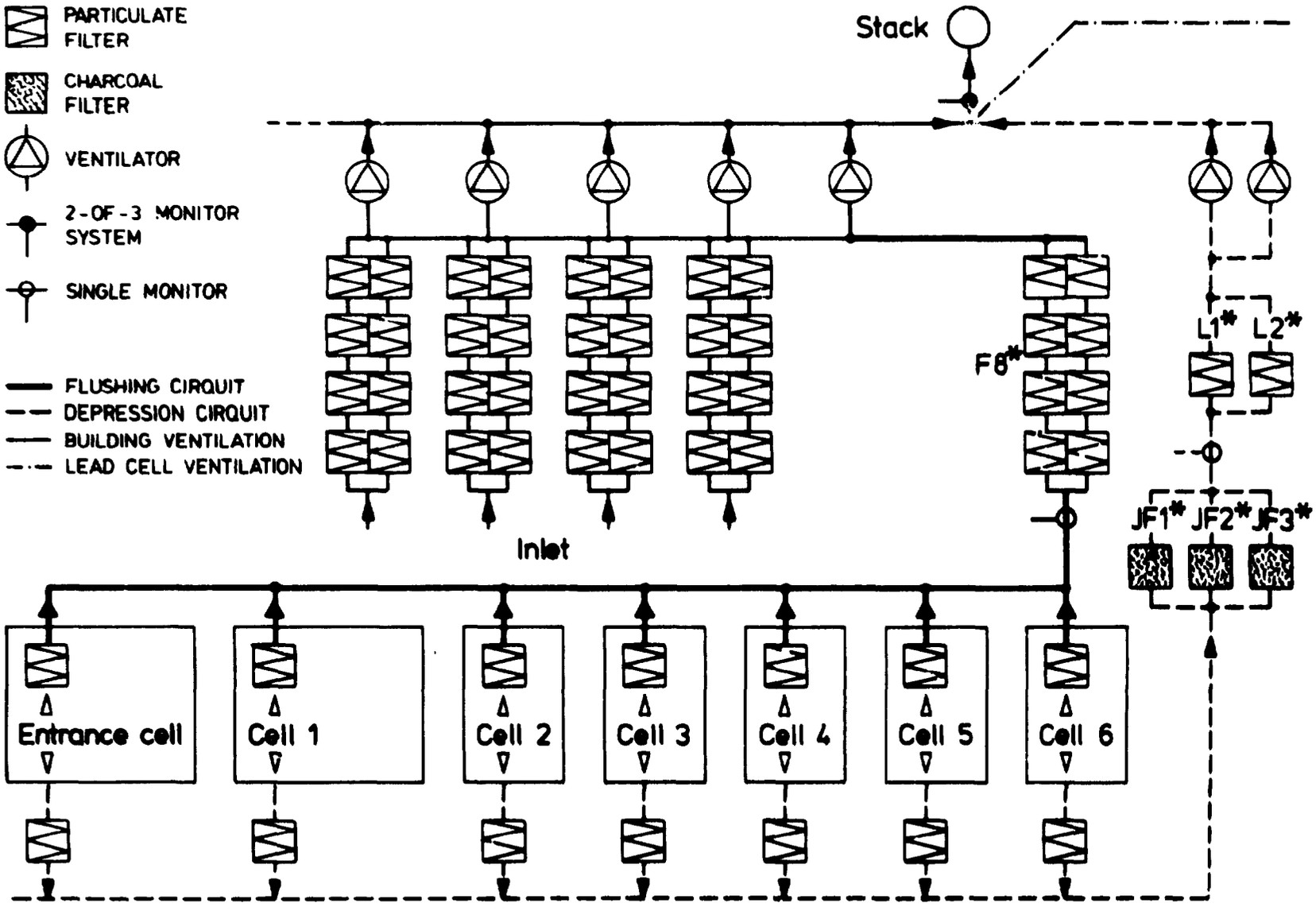
The ventilation system in the Hot Cell plant consists of three sub-systems:

- the flushing system for the concrete cells
- the depression system for the concrete cells
- ventilation system for lead shielded steel boxes and glove boxes.

The concrete cell ventilation system (Figure 8) is normally operated in the flushing mode with a flow through each cell of 1000-1800 m^3h^{-1}. The flushing ventilation air is filtered by a HEPA-filter bank consisting of a total of 8 single filters coupled in two parallel sections each with 4 filters in series before being released to the atmosphere through a 25-m high ventilation stack.

For each concrete cell the flushing operation can be changed to a depression mode where a low pressure of ca. 50 mm H_2O is maintained by a flow through the cell that, depending of the leakiness of the cell, will be 20-80 m^3h^{-1}. The depression air is filtered by HEPA- and charcoal filters before it is released to the atmosphere. In the depression mode it is obvious that the release to the atmosphere will be significantly lower than in the flushing mode.

Figure 8. Concrete cell ventilation with flushing and depression circuits at the Hot Cell Plant. The filters to be tested are marked with an asterisk on the filter numbers.


PARTICULATE FILTER
CHARCOAL FILTER
VENTILATOR
2-OF-3 MONITOR SYSTEM
SINGLE MONITOR
FLUSHING CIRQUIT
DEPRESSION CIRQUIT
BUILDING VENTILATION
LEAD CELL VENTILATION
Stack
F8*
L1*
L2*
JF1*
JF2*
JF3*
Inlet
Entrance cell
Cell 1
Cell 2
Cell 3
Cell 4
Cell 5
Cell 6

The glove boxes and the lead shielded steel boxes are ventilated through a HEPA-filter. These boxes are very airtight and the flow is therefore kept at a very low level to maintain a low pressure of 50 mm H_2O. An emergency ventilation system acts as back-up system and the ventilation air from this system is also filtered by a HEPA-filter.

The three ventilation sub-systems are all brought together with the building ventilation in a joint channel connected to the ventilation stack. A 2-of-3 integrating particulate/iodine monitor system switches automatically both the flushing ventilation mode to the depression ventilation mode and at the same time the lead cell/glove box ventilation from normal to emergency mode at a preset level I corresponding to a certain release to the environment. At a higher preset level II corresponding to a somewhat higher release the ventilation sub-systems are shut down and building seal established.

If a larger part of the fission products contained in irradiated fuel within the concrete cells is released unfiltered through the stack, the doses to the surrounding population could be significant. Therefore, the filters should have a high efficiency.

The following filters in the ventilation system should be tested:

- charcoal filters: JF1, JF2 and JF3
- HEPA-filters: L1, L2, F8, C1 and C2

placed in the following sub-systems:

- flushing system: F8
- depression system: L1, L2, JF1, JF2 and JF3
- steel box/glove box main: C1
- steel box/glove box emergency: C2.

Figure 9 shows three parallel coupled charcoal filter (JF1, JF2, JF3) in the depression ventilation system.

Figure 9. Filter installation at the Hot Cell Plant. In the foreground is seen a sample connection after the filters (cf. section 3.3). In the background the charcoal filters JF1, JF2 and JF3 are seen (cf. figure 8).

3. METHODS AND TECHNIQUES

On the basis of an evaluation of the filters to be tested, the existing measuring equipment and the expertise of the personnel involved, it was decided to use a method based on application of radioactive isotopes. It is necessary to use it in two versions: one for charcoal-filters, which is tested with a vapour of CH_3I labelled with ^{131}I, and one for HEPA filters, which are tested with a NaCl-aerosol labelled with ^{24}Na. The corresponding experimental set-up is constructed in such a way that the main parts are used in both versions. Also, the same injection- and extraction connectors in the ventilation ducts are used.

The filters are not tested with elementary iodine. Presumably, methyliodine vapours have a larger penetration and will therefore be the critical gas component. Further, it was difficult to find a simple, robust equipment, which was suited for routine measurements of carrier-free iodine.

3.1. Principle of the test method

The test principle (Figure 1) is shown and described in more detail in figure 10. With the symbols defined there, the sample activities will be:

$$A_1 = V_1 \cdot \frac{A_i}{V_i} \cdot C$$

$$A_2 = P \cdot V_2 \cdot \frac{A_i}{V_i} \cdot C$$

where C is a constant dependent on the activity of the injected sample and the airflow. The penetration P is thus:

$$P = \frac{A_2}{A_1} \cdot \frac{V_1}{V_2}$$

The above expression for the penetration P assumes that (a) the collection efficiencies of the two sampling units are equal, and (b) that the concentrations at the sampling points are representative for the average concentrations in the duct before and after the filter. The uncertainty on the penetration will therefore depend on the uncertainty in the volumes V_1 and V_2 and on the parameters that determine the constant(s) C, i.e., the mixing conditions within the duct and the collection efficiency of the sampling units. The uncertainty in the determination of the activities A_1 and A_2 includes uncertainties in the geometry (source distribution) as well as counting; the latter can be neglected by selection of a sufficiently large counting time.

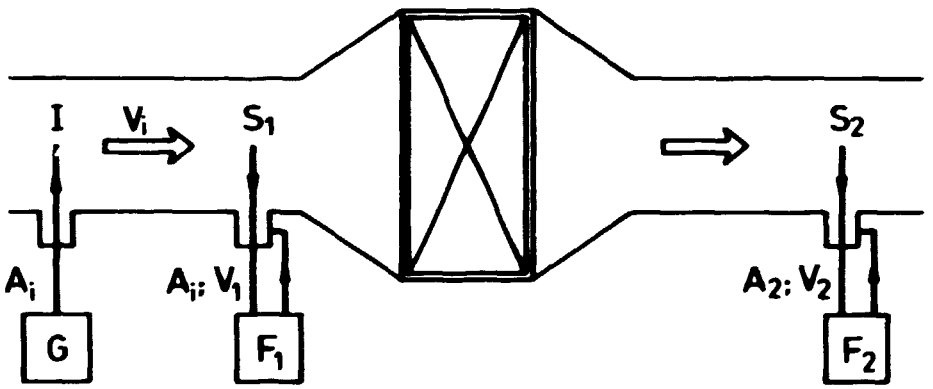


Figure 10. Principle of the test method. The active material is generated at G and injected into the main duct at I well upstream of the filter in order to ensure complete mixing. The injected activity is A_i and the flow in the duct is V_i. Two samples are taken out - one before the filter at S_1 and one well downstream at S_2. The volumes of these samples are V_1 and V_2, respectively. Active material is collected on filters F_1 and F_2 and subsequently measured to have activities A_1 and A_2. For safety reasons, sample air is returned to the duct.

3.2. Injection

The injection system (Figure 11) is mounted in a portable rack (Figure 12). It comprises a NaCl-aerosol generator and a CH_3I-generator with the necessary regulation equipment. The sample flow is driven by pressurized air which passes a magnetic valve, controlled with a timer; it allows the air flow to be started and stopped at predetermined times.

The test samples are passed through Teflon hoses to permanent connectors equipped with ball valves on the ventilation duct.

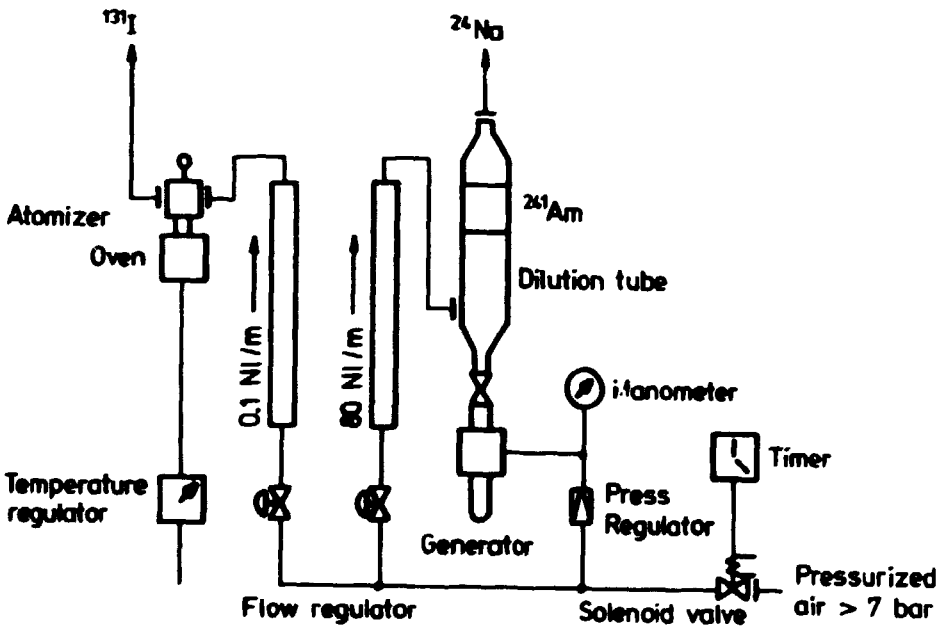


Figure 11. Block diagram of the injection system. The two sample generators are shown in detail in figures 13 and 14.

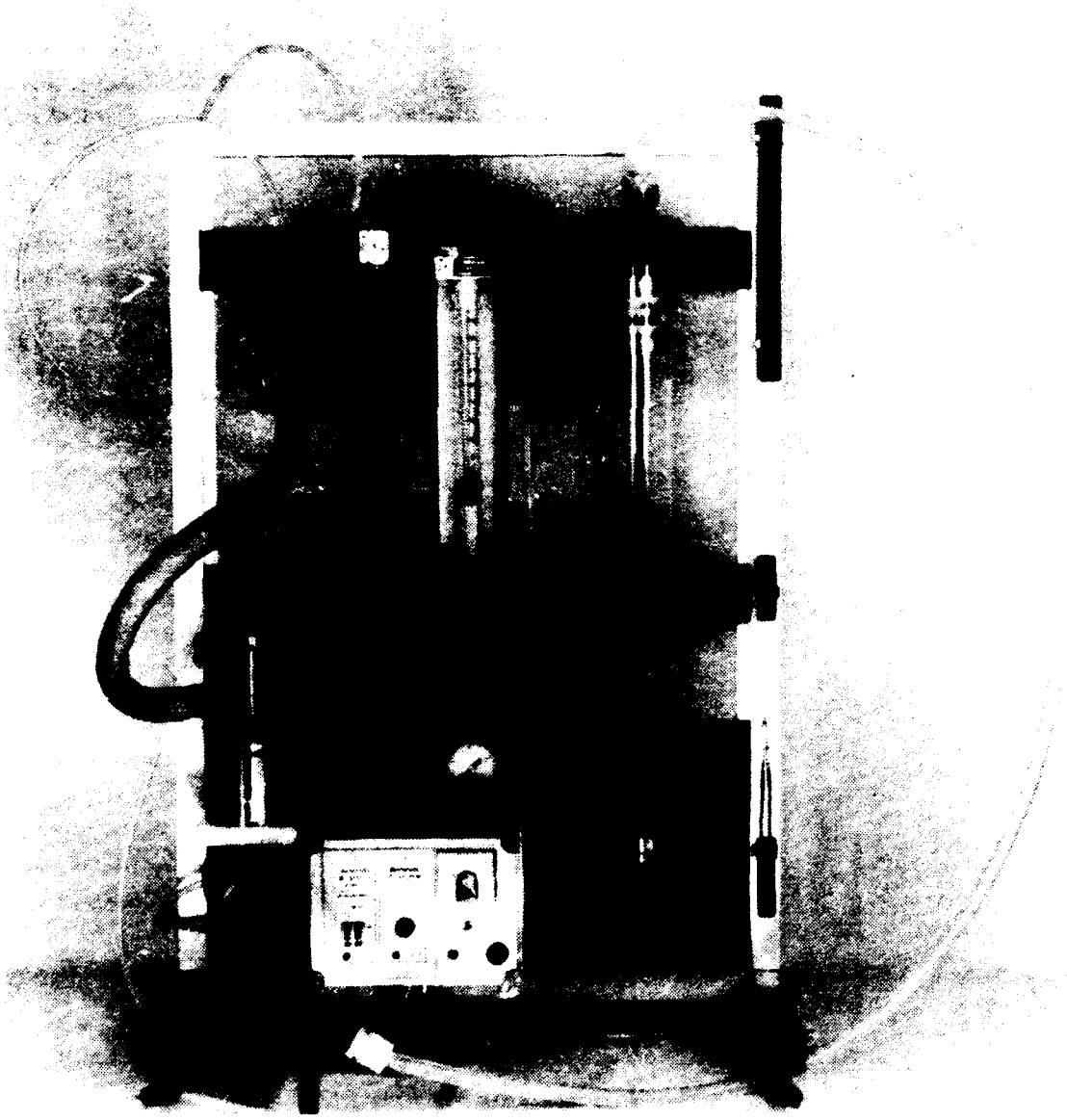


Figure 12. The rack containing sample generators (Figures 13 and 14), flowmeters and timing unit.

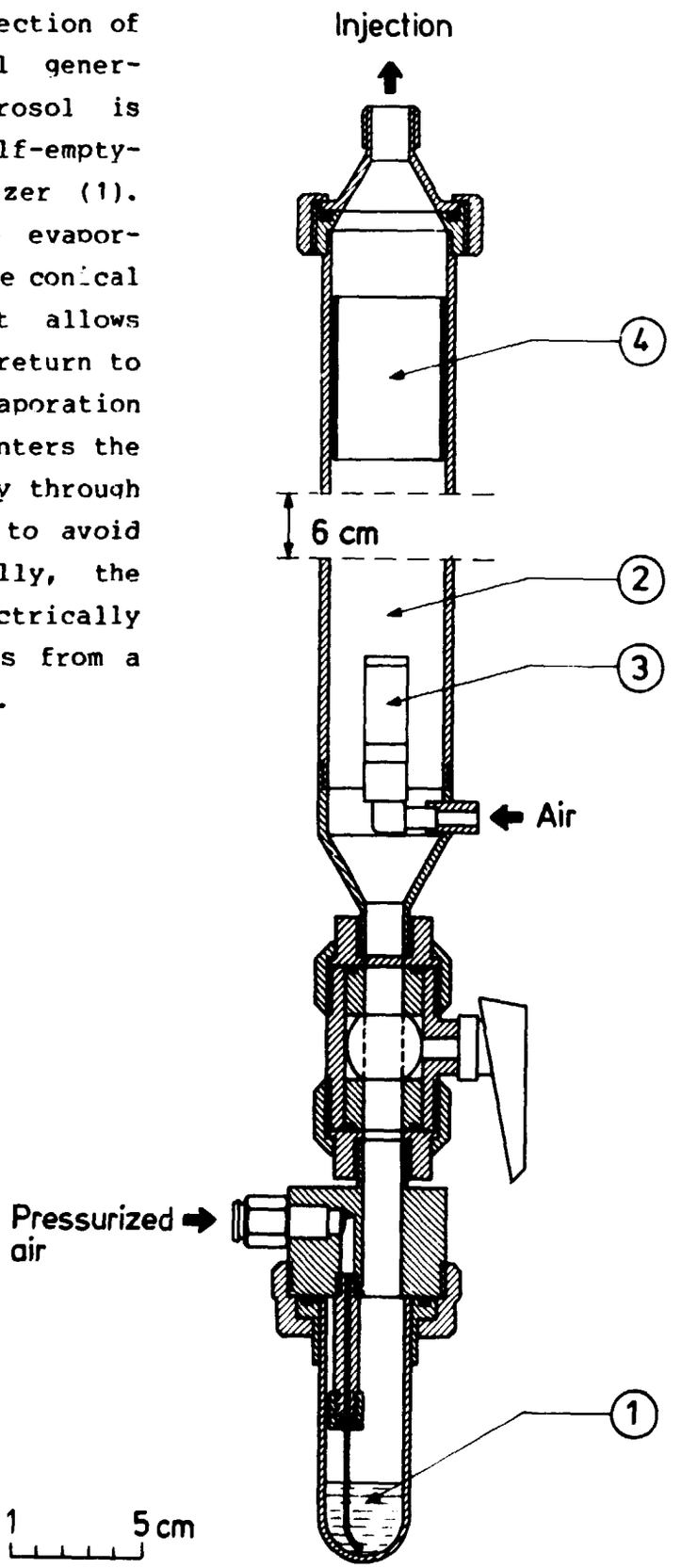
The sodium chloride-aerosol generator

The aerosol generator (Figure 13) is based on a modified Wright atomizer, which is designed to fit into a lead container. The generator is normally used with about 10 cm^3 1% NaCl solution containing 1 mCi ^{24}Na.

Pressurized air is led to the atomizer through a reduction valve. The aerosol yield depends upon the pressure and can be regulated with a reduction valve equipped with a manometer.

The droplets formed in the atomizer are dried in a vertical evaporator in an air stream of about 80 l/min. Possible condensates on the walls of the evaporator will return to the atomizer and will be reused. An ^{241}Am source (10 $\mu Ci/cm^2$) on the inner wall of the evaporator secures electrostatic equilibrium in the aerosol. The evaporation air is passed through a sintered bronze filter to avoid jet effects.

Figure 13. Cross section of the ^{24}NaCl-aerosol generator. The NaCl-aerosol is generated in a self-emptying Wright atomizer (1). Droplets enter the evaporator (2) through the conical bottom inlet that allows any condensate to return to the atomizer. Evaporation and dilution air enters the evaporator smoothly through a porous mesh (3) to avoid jet-effects. Finally, the dry aerosol is electrically neutralized by ions from a ^{241}Am α-source (4).



The methyl iodide generator

Methyl iodide labelled with ^{131}I is produced by isotope exchange between CH_3I and $^{131}I_2$, which is liberated from a solution containing ^{131}I when an acid solution of $NaNO_3$ is added. Since CH_3I is volatile it is kept in a closed, cooled container. For the filter tests described here 1 - 2 mCi commercial $^{131}ICH_3$ were delivered in a sealed glass ampoule (about 55×14Ø mm). This ampoule is placed in the sample generator as shown and described in figure 14.

The rest of the equipment is identical with, or similar to, the equipment used for generation of the NaCl-aerosol.

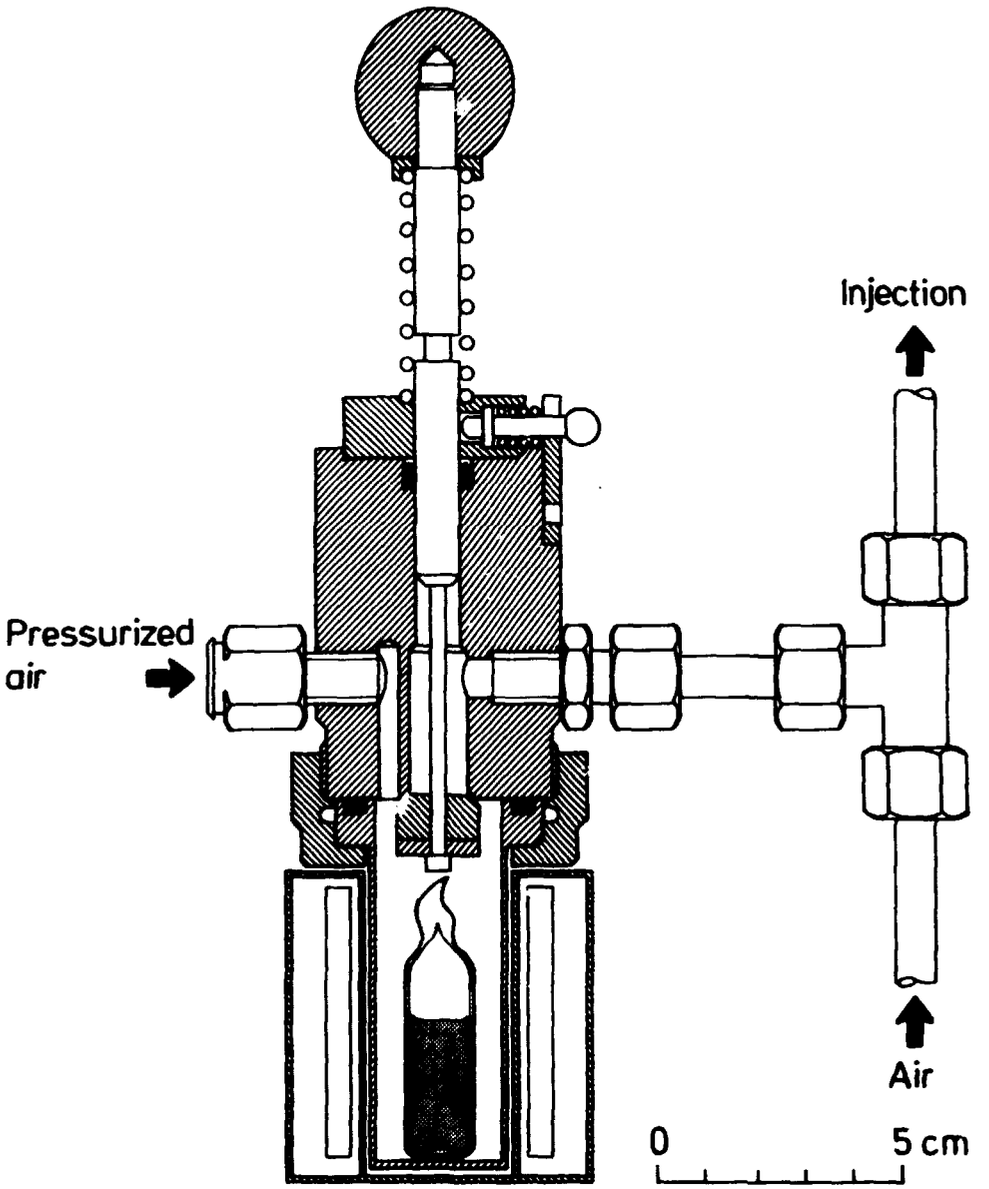


Figure 14. Cross section of the $^{131}ICH_3$-generator. A sealed glass ampoule containing the sample material (1) is placed in a cylinder, which is closed by a Teflon conus (2) at the end of a spring-loaded piston (3,4) and by a spring-loaded ball-valve in the air inlet. The CH_3I is then evaporated by heating the cylinder to 50°C in an electric oven (5). The piston is pressed down to a locked position and crushes the ampoule. Finally, the CH_3I is driven out by pressurized air and is further diluted in the injection tube.

3.3. Sampling

The sampling system is shown schematically in figure 15. In a measurement two systems are used. The NaCl-aerosol is collected on a 47 mm$^{\phi}$ Whatman GF/A filter and methyliodide is collected on active charcoal in a filter cartridge. The filter holders are shown in figure 16.

Air is sucked through the filters by a membrane pump to avoid leaks along a pump shaft (Gast-type DAA with built-in thermo-detector to protect against overload). The flow through the filter is measured, and an electronic unit drives a flow regulator and calculates the total volume. A modified gasmeter is used as flow sensor. It generates a signal proportional to the flow. The signal depends upon the temperature and pressure, but in practice it has a negligible effect on the overall accuracy of the set-up. The system can measure flows between 0.6 l/min and 100 l/min with an accuracy of about ±2%. Typical air flow is 40 l/min at an underpressure of about 300 mm Hg.

Timing units can ensure synchronous sampling even when upstream and downstream sampling takes place in different rooms. The sampling can also by synchronized with the injection from just prior to injection start to just after stop.

The air volume is summed on a mechanical impulse counter preset either for a specified time interval or volume.

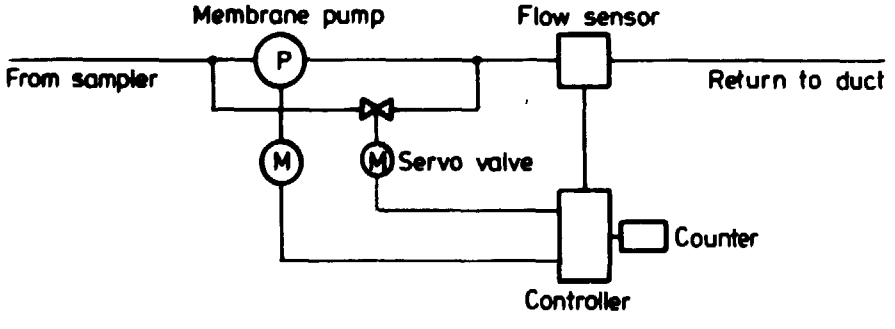


Figure 15. Block diagram of the sampling system.

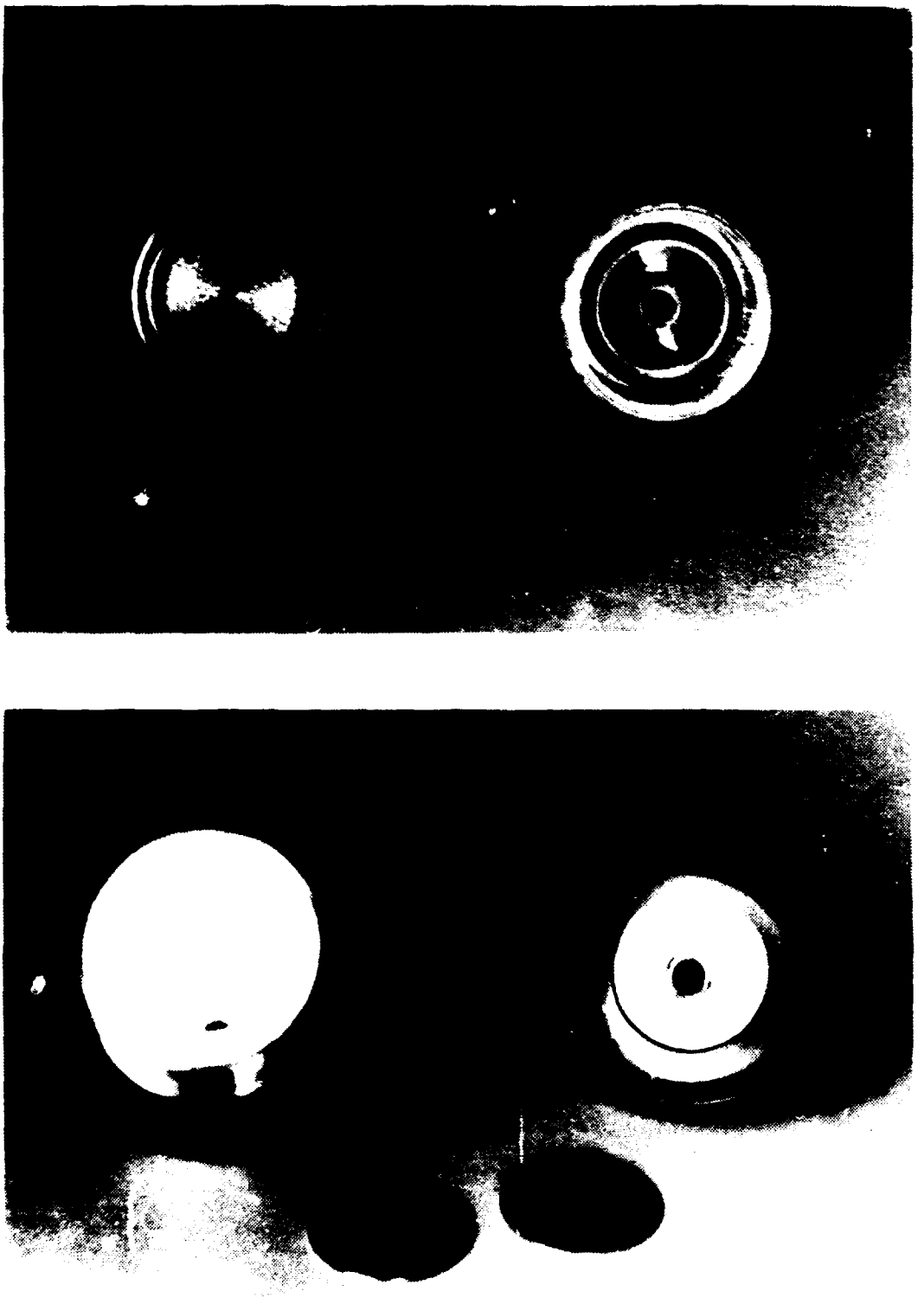


Figure 16. Filters holders for Whatman filters (above) and active charcoal filters (below).

At each sampling point a connector is permanently installed similar to the ones used for injection. The probe is shown in figure 17. A stainless steel tube passes a T-connector and fits loosely into the ball-valve at the ventilation duct. This

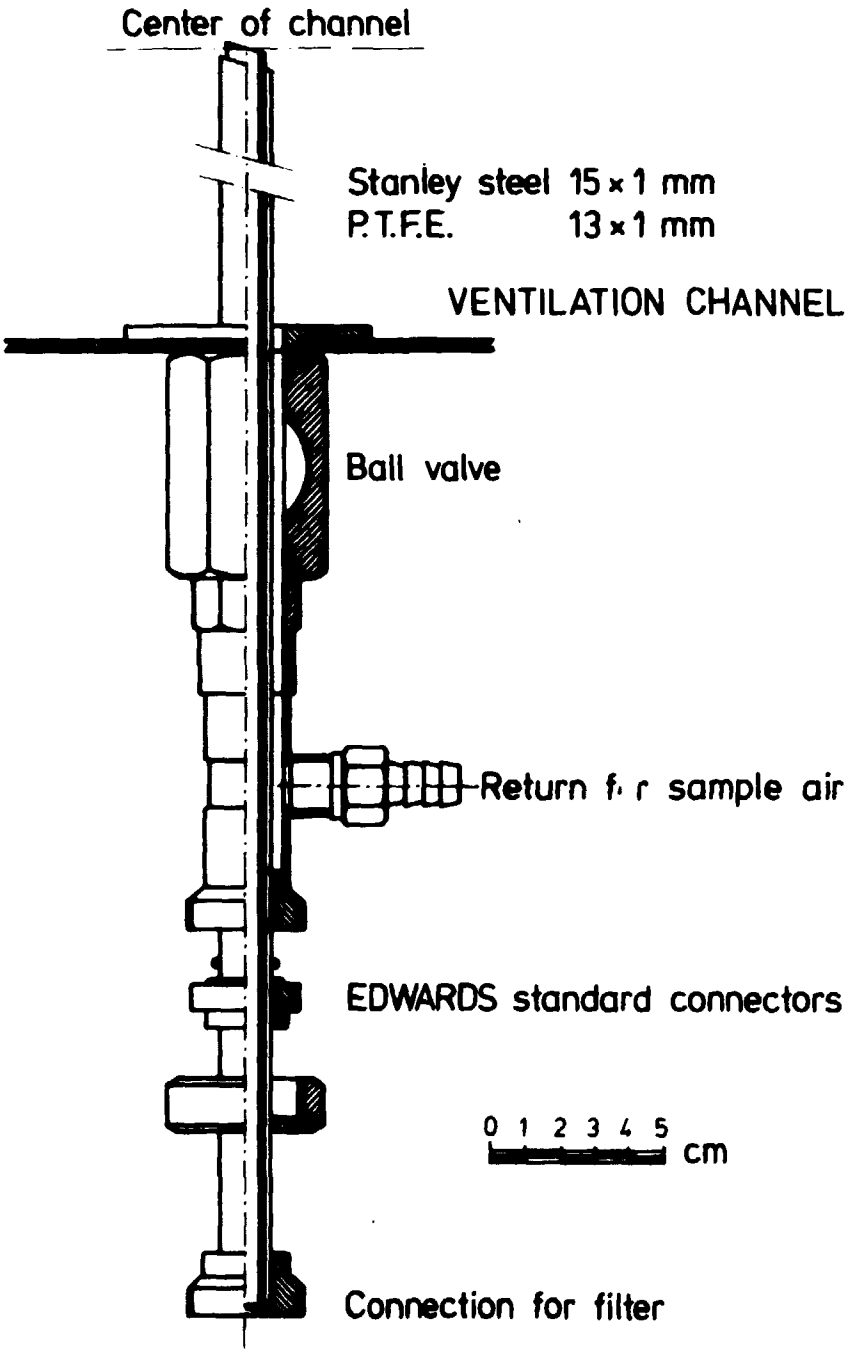


Figure 17. Probe for injection and sampling. When used for injection the "return-connection" is blocked.

allows the sample air to be returned to the duct. The steel tube is fitted airtight through an O-ring in the T-connector, but can be moved in order to place the tube-end in the center of the duct. The total set-up for sampling at DR 3 (cf. figure 4) is shown in figure 18.

Figure 18. A complete sampling system with sampling unit (Figure 15) and extraction system (Figure 16) in use at the charcoal filters of DR 3.

3.4. Counting

HEPA-filters, which are required to have an efficiency of at least 99.995% are tested by use of an NaCl-aerosol labelled with ^{24}Na (E_γ = 1.4 MeV, $T_{1/2}$ = 15 h), and samples are collected on ordinary plane glass-fibre filters. Charcoal filters for iodine filtration are less efficient; they are tested with a vapour of CH_3I labelled with ^{131}I (E_γ = 0.36 MeV, $T_{1/2}$ = 8 d), and samples are collected on cartridges filled with KI-impregnated charcoal granulate.

The collecting sample filter paper or charcoal granulate cartridge used to collect activity from the ventilation channel (see Sect. 3.1.) is clamped between two lead-shielded 1 x 3" integral-line NaI(Tl) scintillation detectors followed by amplifiers, single-channel analyzers, and a double-scaler/timer. A counting channel has been established for both ^{24}Na and ^{131}I as shown in figure 19.

The uncertainty on the filter penetration P should not be dominated by the uncertainty in the determination of collected activity on the sample units. This can be achieved if the uncertainty on the determination of activity collected after the filter is much less than the other uncertainties discussed in section 3.1.

With the following parameters:

Penetration: P
Counting time: t
Counting efficiency: ε
Background count rate: B
Accumulated counts incl. background from filter paper: N_2
Injected activity: A_i
Collected activity from sample after filter: A_2
Flow in ventilation channel: V_i
Flow through sample filter paper: V_2

the following relations can be obtained:

$$n_2 = A_2 t \varepsilon = P\, A_i (V_2/V_i) t \varepsilon$$

$$n_2 = N_2 - Bt$$

The relative uncertainty on n_2 is given by:

$$\frac{\sigma(n_2)}{n_2} = \frac{(N_2 + Bt)^{1/2}}{n_2} = \frac{(PA_i(V_2/V_i)t\varepsilon + 2Bt)^{1/2}}{PA_i(V_2/Vi)t\varepsilon}$$

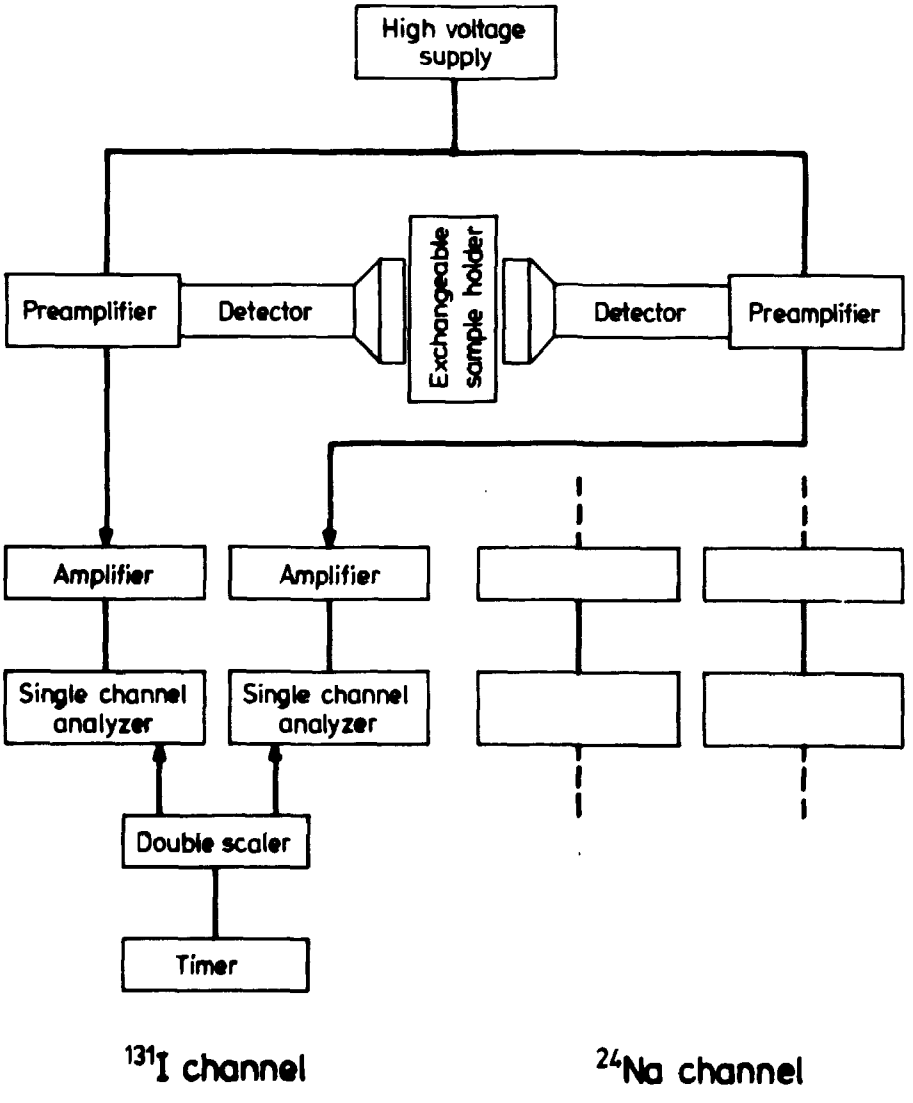


Figure 19. Diagram of the counting equipment with two separate channels for ^{131}I and ^{24}Na.

The minimum counting time can be found by solving the equation for $\sigma(n_2)/n_2$. If $\sigma(n_2)/n_2$ is called δ, the counting time t can be expressed as:

$$t = \frac{PA_i(V_2/V_i)\varepsilon + 2B}{(PA_i(V_2/V_i)\varepsilon\delta)^2}$$

For the counting equipment the efficiencies and backgrounds are:

^{24}Na : $\varepsilon = 0.05$ count/photon, $B = 45$ c/min ~ 0.75 c/s
^{131}I : $\varepsilon = 0.09$ count/photon, $B = 50$ c/min ~ 0.83 c/s

It is assumed that if $\delta \leq 5\%$ it will not contribute significantly to the overall uncertainty in the penetration P.

Figures 20 and 21 show the minimum counting time as a function of filter penetration P in the range 0-10% for a HEPA- and charcoal filter with $\delta = 5\%$, $A_i = 1$ mCi and for three different values of the flow fraction V_2/V_i.

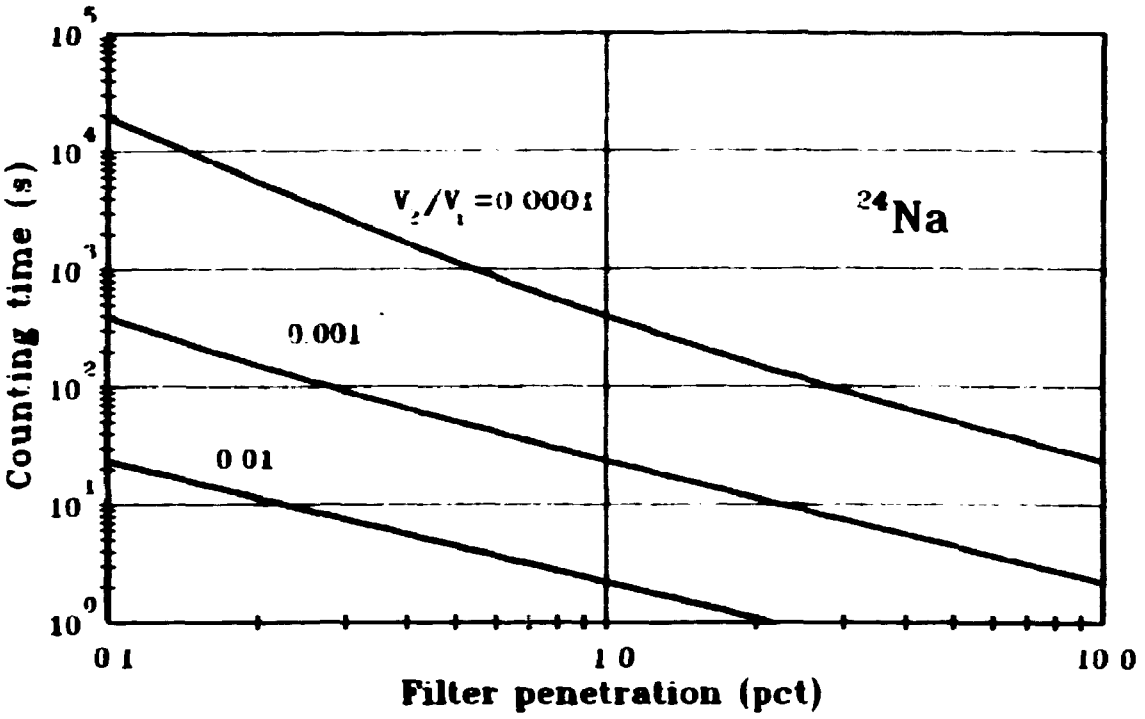


Figure 20. Data for test of HEPA-filters with a sample of 1 mCi ^{24}Na. The minimum counting time necessary to give a relative uncertainty of 5% in collected activity A_2 is shown. The counting time is shown for three different flow-fractions.

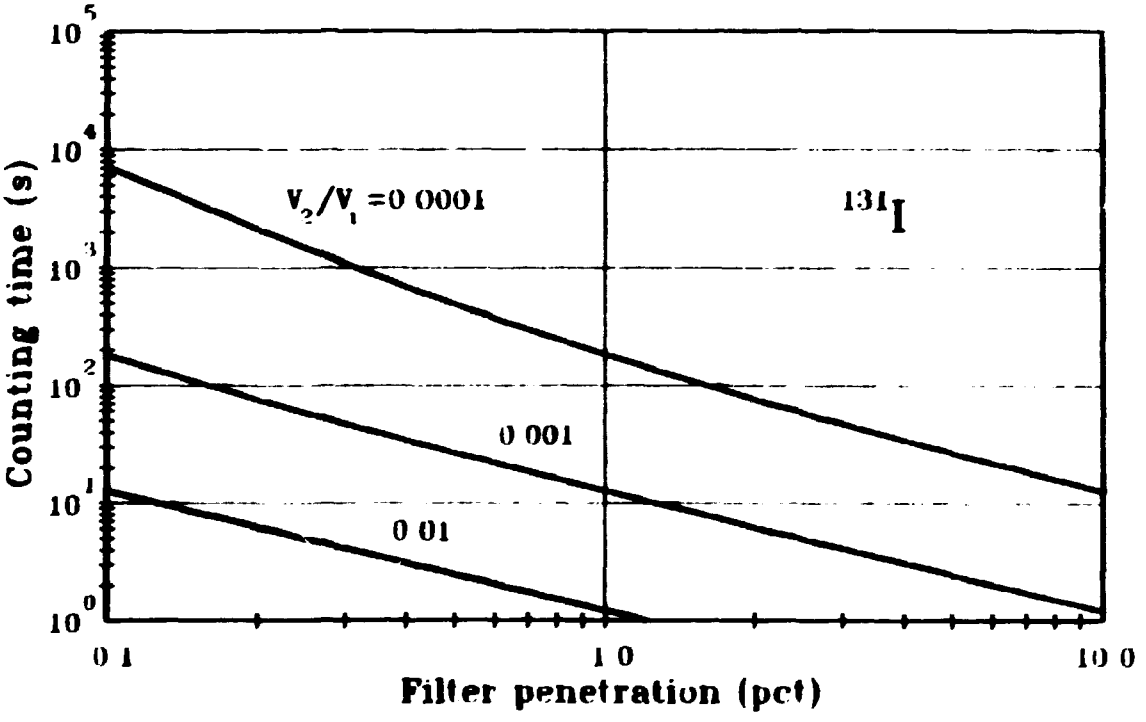


Figure 21. Data for test of charcoal filters with a sample of 1 mCi ^{131}I. The minimum counting time necessary to give a relative uncertainty of 5% in collected activity A_2 is shown. The counting time is shown for three different flow-fractions.

4. RESULTS

The method has so far not been used routinely, but it has been tried successfully on all relevant filters. Furthermore, the reproducibility has been tested for HEPA-filters.

4.1. Charcoal filters

The penetration of the charcoal filters was determined with a 1 mCi $^{131}ICH_3$ samole. The injection time was 2-3 hours, during that period 5-6 m^3 was sucked from the ventilation channel through the two charcoal cartridges placed before and after the filter. Results are shown in table 1.

Table 1. Measured penetrations for charcoal filters in DR 3 and the Hot Cell plant (cf. figures 3 and 8).

	Filter	Penetration (P) in %		
DR 3	F5	2.26		
	F8	2.75	0.390	1.30
	F9			
Hot Cell	JF1	0.004		
	JF2	0.075	0.327	
	JF3	0.002		

4.2. HEPA-filters

The penetration of HEPA-filters was determined with a 1 mCi $^{24}NaCl$ sample, and collection was performed on glass filter papers. Otherwise the procedures were identical to the ones used for charcoal filters. Results are shown in table 2.

Table 2. Measured penetrations for HEPA-filters in DR 3 and the Hot Cell plant (cf. figures 3 and 8).

Filter		Penetration (P) in %
DR 3	F2	0.26
	F3	2.62
	F4	0.57
	F6	1.17
	F7	0.06
Hot Cell	F8	5.2
	L1	0.02
	L2	0.95

4.3. Reproducibility tests on HEPA-filters

When a filter is very efficient, the uncertainty on the filter penetration determined by the method described in chapter 3 may almost entirely be determined by the uncertainty in the collected activity on the sample unit after the filter, i.e. by the counting uncertainty.

Other factors however, could influence the overall uncertainty. Consequently, to see how well the measured penetration could be reproduced, three tests on the HEPA-filter F7 at the DR 3 were made with a one-day interval between each. For this filter the penetration had been determined to be 0.058% ± 0.003% ten months earlier. The given uncertainty on the penetration is the uncertainty due to counting uncertainty alone.

A sample of 1 mCi ^{24}Na was injected into the ventilation channel in each of the three tests. The flow in the ventilation channel was approximately 1000 m^3h^{-1} and during the one-hour injection time, between 2 and 2.5 m^3 of air was sucked from the ventilation channel through the two glass filter papers placed before and after the HEPA-filter.

Table 3 shows the measured penetrations from the four tests with the absolute uncertainties due to the counting uncertainty. The relative uncertainty was 5-6%. The mean value of the four measurements together with the standard deviation are also shown in the table.

Table 3. Determination of the reproducibility in tests of HEPA-filters under conditions described in the text.

Test no.	Penetration (P) in %
1	0.065 ± 0.003
2	0.051 ± 0.003
3	0.048 ± 0.003
earlier test	0.058 ± 0.003
Mean value	0.056
Standard deviation	0.008

As can be seen from the table, the standard deviation of the four measured penetrations is significantly greater than the uncertainty due to counting statistics alone, approximately 14% of the mean value compared to the relative counting uncertainty of 5-6%. This indicates that uncertainties on other factors are dominant in the total uncertainty. Presumably uncertainties in the determination of the air volume sucked through the sample units, the collecting efficiency of the sampling units, and the mixing conditions in the ventilation channel before and after the filter contribute significantly to the overall uncertainty (cf. section 3.1). So far, it can be concluded that an overall relative uncertainty in the filter penetration might be as high as 10 - 15%.

5. CONCLUSION

An analysis of potential releases from all the nuclear plants and laboratories at Risø showed that only the Hot Cell Plant, DR 3, and DR 1 could cause doses to a person at the fence line in excess of 1 mrem. Therefore, only the filters in these facilities must be tested regularly.

The accessable parts of the ventilation channels are often placed inside engineering corridors or in walls where the working conditions are poor. Therefore a portable, versatile system has been developed.

Various sophisticated methods are possible, but the problem at Risø is simply to check whether the filter installations meet the penetration requirements or not. This is accomplished with a method based on the injection of radioactive test samples followed by extraction of samples from the duct before and

after the filter. In order to facilitate and standardize the procedures all the installations to be tested are equipped with permanent connectors at the test points.

HEPA-filters are tested with an aerosol of $^{24}NaCl$ and charcoal filters with $^{131}ICH_3$. To a large extent the same equipment is used only the sample generators differ.

The accuracy of the measurements depends to a large extent on the amount of activity used, since counting statistics of the weak samples extracted after the filters are poor. On the other hand, the difficult working conditions do not permit a safe injection of very strong samples. A compromise is reached with samples of about 1 mCi. With a counting time of the order of one hour the counting uncertainty is negligible compared with other uncertainties. The overall relative uncertainty on the penetration is belived to be 10-15%.

In the first practical applications of the method charcoal filters with penetrations above 90% were discovered.

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On-site Test of Filters in Nuclear Facilities Using Radioactive Sodium Chloride (^{24}Na)-Aerosol and Methyl Iodide (^{131}I)

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Abstract (Max. 2000 char.)

The nuclaer facilities at Risø National Laboratory are equipped with high-efficiency filters to protect the environment from routine or accidental releases of radioactive material. The filter efficiency must be tested regularly and a method for on-site control is described. It is based on injection of a radioactive sample in the filter duct, followed by sampling before and after the filter. HEPA-filters are tested with a ^{24}NaCl-aerosol and charcoal filters with $^{131}ICH_3$. Normally samples of 1 mCi are used. Penetrations (1 - efficiency) can be determined with a relative uncertainty of 10-15%.

Descriptors - INIS:

AEROSOL MONITORING; AIR FILTERS; CHARCOAL; IODINE 131; METHYL IODIDE; RADIOACTIVE EFFLUENTS; PERFORMANCE TESTING; REACTOR SAFETY; SODIUM 24; SODIUM CHLORIDES

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