9 - CONTAMINATION CONTROL

INTRODUCTION

Contamination is radioactive material where it isn't supposed to be. It can be in solid, liquid or gaseous form.

Although the systems at Point Lepreau are designed to contain the radioactive materials they process, there are many ways in which these materials can escape to cause a **contamination hazard.** For example, faulty design, equipment failures, chronic leaks, operator errors and maintenance work can all cause contamination hazards. We must know how to deal with contamination to avoid unnecessary internal and external radiation exposure.

This chapter is about contamination control. This covers a wide range of activities; namely identifying the different types of contamination and assessing the hazard, preventing the contamination from spreading, selecting appropriate protective measures and cleaning it up. We will deal with these topics one at a time, starting with surface contamination.

SURFACE CONTAMINATION

If radioactive material has been deposited on surfaces (such as walls, floors, benches), it is called **surface contamination.** It may be loosely deposited, much like ordinary dust, or it may be quite firmly fixed by chemical action. This distinction is important, and we classify surface contamination on the basis of how easily it can be removed:

1. Loose Contamination (Easily Removed)

This is surface contamination that can easily be removed with simple decontamination methods. For example, if the surface is cleaned up by wiping it with a damp rag, we are dealing with loose contamination.

2. Fixed Contamination (Hard to Remove)

Surface contamination that is quite firmly attached to the surface and cannot be removed by normal housekeeping methods is called fixed contamination.

SOURCES OF SURFACE CONTAMINATION

The surface contamination found at PLGS is largely composed of beta-gamma emitting fission and activation products. It can be produced, and spread, in quite a variety of ways. Some examples are given below:

1. Volatile fission products (i.e., vapours or gases) escaping from the PHT system will decay to particulates and deposit on surfaces. Widespread surface contamination can result (e.g., virtually the whole Reactor Building could become contaminated).

2. Liquid leaks from seals, packing, joints, etc., will cause **liquid contamination** of the surfaces it drips or pours on. Once the liquid is removed (by wiping, drainage or evaporation), surface contamination will remain.

3. Radionuclides will plate out on the inner surface of pipes, valves, etc. Zr-95 and Nb-95 are our biggest offenders.

4. Maintenance work calls for handling of contaminated parts and equipment. Without special precautions, we'll end up with contaminated hands, face, hair, clothing, tools, floors and surrounding objects. Inhalation and even ingestion of contamination is likely.

5. Machining or grinding of contaminated or radioactive parts will produce radioactive dust; this will settle out as surface contamination.

6. Tritium in the form of water vapour can condense or be absorbed on surfaces to create a form of surface contamination. Even if the tritium in the air is then removed by ventilation systems, the tritium that is held up in the walls and floors will be released to contaminate the air again. (This is one of the reasons why the Reactor Building walls are painted with non-porous epoxy paint).

7. Carelessness in monitoring yourself or any items you bring out of the active areas can result in widespread contamination.

HAZARDS OF SURFACE CONTAMINATION

Loose Contamination

Loose contamination is a more serious hazard than fixed contamination, because it can lead to an internal exposure. There are two ways in which loose contamination can enter the body. One is by transfer to exposed skin (i.e., hands and head) from which it may find its way into the mouth. The other is by inhalation as a result of **resuspension.** This means that the work activity and traffic in the area has stirred up the loose contamination so that some of it becomes airborne and can be inhaled.

You will appreciate that there is a need to restrict food handling in areas that can become contaminated with loose contamination. If work areas do become contaminated, the loose contamination should be cleaned up as soon as possible, so that it is prevented from spreading.

Although almost all contamination is beta-gamma emitting, there is the possibility of alpha contamination in any fuel handling areas. The Spent Fuel Bay and Decontamination Centre are equipped with Herfurth Hand & Shoe Monitors set up for alpha as well as β,γ monitoring (as discussed in the second paragraph of page 182).

Fixed Contamination

If the contamination is fixed, it cannot be re-suspended or transferred to your skin, and therefore the hazard is an external one only. Unless the level of contamination is very severe, the gamma dose rate will be small and external exposure will be significant only in contact with, or very close to, the contaminated surfaces. The beta dose rate can be quite high at contact. A value of 1 mSv/h at contact for a contamination level of 300-500 Bq/cm^2 is fairly representative. The beta dose rate decreases rapidly with distance (90% of the betas are absorbed in one metre of air): so in normal work the main hazard is to the hands which are in contact with or close to contaminated equipment.

CONTAMINATION CONTROL LIMITS

Contamination can be measured, and therefore we need numbers to describe the measurements. They are expressed in terms of **Contamination Control Limits or CCLs.**

1 CCL = 50 kBq/m^2

Basically, contamination levels below a CCL aren't much of a problem, but above 1 CCL we want to impose some controls. 1 CCL of contamination gives about 15 μSv/h to the underlying skin. Activity at the CCL level is low enough to present a minimal radiation hazard, but yet high enough to be detectable with portable contamination meters. Table 9.1 lists these CCLs.

The contamination control limits shown in Table 9.1 are intended for fixed contamination. They do not apply to loose contamination. Why? Because if loose contamination is found it must be cleaned up immediately before it has a chance to be tracked all over the place, or it must be contained by setting up a Rubber Area (more on this later).

TABLE 9.1. FIXED CONTAMINATION CONTROL LIMITS (β,γ)

Body Surfaces, Personal Clothing, Materials removed from the Station	50 kBq/m^2	1 CCL
Respirators after cleaning	50 kBq/m^2	1 CCL
Protective Clothing after cleaning	250 kBq/m^2	5 CCL
Plastic Suits after cleaning	2500 kBq/m^2	50 CCL

We have located Hand & Shoe monitors and semi-portable friskers throughout the station at exits from areas that have a potential for loose contamination. The older type of monitors are set to alarm for contamination levels of 50 kBq/m^2 on either surface of the hands (palm or back) or on the soles of the shoes. The Herfurth Hand & Shoe Monitors and Full-Body Monitors are more sensitive, and so they are set to alarm at a lower alarm point of 25 kBq/m^2 or 0.5 CCL. Since the monitors can't tell whether they are measuring fixed or loose contamination, the alarm level applies to total contamination. (If all the activity on your hands were loose mixed fission products at 50 kBq/m^2, and if all of this activity were transferred to your mouth and ingested, and if you did this once every day, you would be unlikely to exceed the ALIs for all practical fission product mixes. You must admit that this is a pretty far-fetched set of circumstances.)

However, the intent is that **no** contamination leaves the station. In practice, this means that if you even suspect there might be contamination on your hands, you should wash them before you monitor. You should also check any equipment you take out for loose (and fixed) contamination by the methods described later on.

If you alarm a Full-Body Monitor, check the display and use the frisker to discover the location and level of contamination. Call Work Control, and try to establish the source of the contamination. You may leave the station with contamination levels below 1 CCL on your body or clothing, provided decontamination has been tried and the source is known.

For respirators the limit is the same; no loose contamination is permitted, because the inhalation pathway is generally more restrictive than the ingestion pathway. The limit for protective clothing is five times greater than for respirators, because even if residual traces of loose contamination remain after cleaning, this loose contamination is much less likely to be inhaled than would be the case for respirators. Finally, for plastic suits after washing we use a limit of 50 CCLs, or 2500 kBq/m^2.

Our cleaning techniques for used respirators and protective clothing will remove any loose contamination, so that when we monitor for cleanliness, we will be measuring fixed contamination only.

MEASURING SURFACE CONTAMINATION

There are two methods used for monitoring surface contamination. One is the **Direct Method,** which measures the amount of fixed and loose contamination, and the other is the **Indirect** or **Smear Method,** which measures loose contamination only. Since the levels of contamination that we are trying to measure are quite low, sensitive instruments are required. For beta-gamma contamination measurements, we use "pancake" Geiger detectors. They have a very thin mica window (0.01 mm), which most beta particles are able to penetrate.

Fig. 9.1 shows the pancake detectors that we use with the Portable Contamination Meter shown on page 187. Their efficiency is typically 20% for detecting beta particles emitted from a surface about 1 cm away. This high efficiency is the result of using the very thin window — the drawback is that because the window is so thin, the tubes are quite fragile and must be handled with care. The purpose of the wire screen that you can see in Figure 9.1 is to protect the thin mica window.

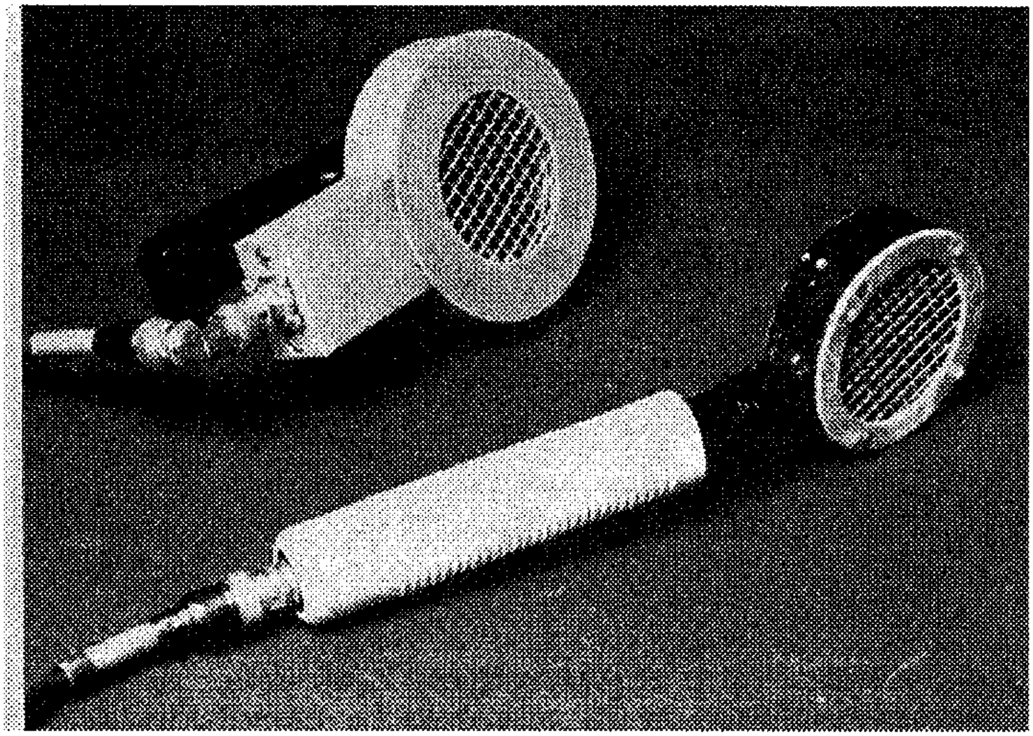


Fig. 9.1. Pancake Geiger Detectors.

The counting efficiency depends on how close to the contaminated surface you hold the detector. Fig. 9.2 shows the different count rates from a pancake detector held at various distances from a 500 Bq technetium-99 source. This source has the same area as the detector (15 cm^2) and emits low energy beta particles of $E_{max} = 0.29$ MeV. You can see that unless you get really close to the contaminated surface, you're wasting your time.

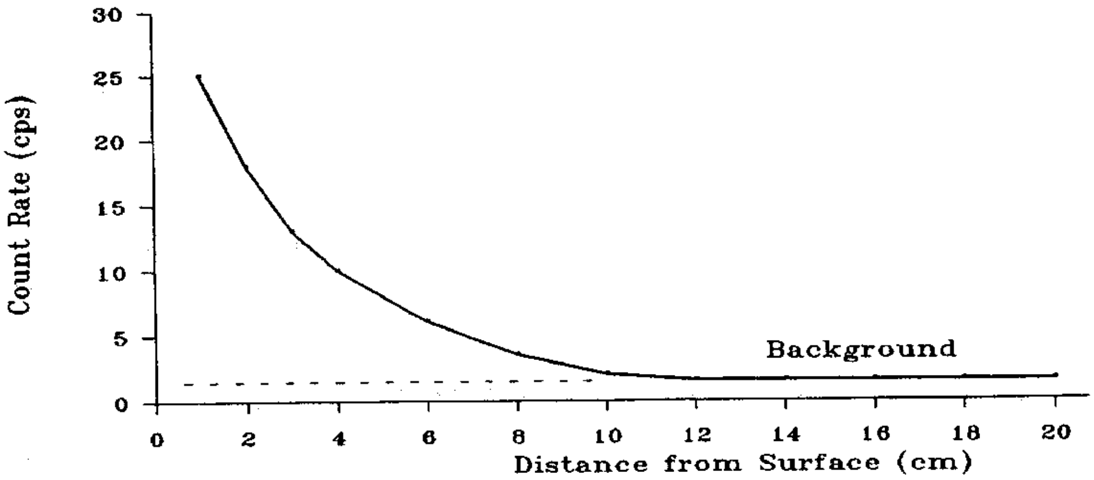


Fig. 9.2. Count Rate versus Distance from a Contaminated Source

THE DIRECT METHOD

The following procedure is used to monitor for surface contamination directly:

1. Select an instrument with one of the probes shown in Fig. 9.1.
2. Select a slow response time and measure the background count rate while holding the probe well away from the surface you are going to monitor.
3. Select a fast response time, and taking care not to contaminate the probe by touching the surface, move the detector slowly across the surface at a distance of about 1 cm.
4. If the count rate increases above the background reading, select a slow response time (so that the fluctuations in the count rate will be smoothed out) and hold the probe above the detected activity for a long enough time (about 10 to 20 seconds) to obtain a steady, accurate reading.
5. Subtract the background count rate from this reading and compare this result to the count rate corresponding to 1 CCL. Our pancake Geiger detectors will indicate about 15 cps for a surface uniformly contaminated to 1 CCL or 50 kBq/m^2. (The number of cps per CCL will be different for instruments with different efficiencies or probe areas. At Point Lepreau, instruments are labelled with the number of cps per CCL.)

Fig. 9.3 shows someone monitoring his hands for contamination with a semi-portable contamination meter. This combination is known as a **Frisker**; you can use it to frisk yourself for contamination at various locations throughout the plant. Good frisking technique requires that you move the detector **slowly** over the surface being monitored, and **close to it. Anything else is a complete waste of time.**

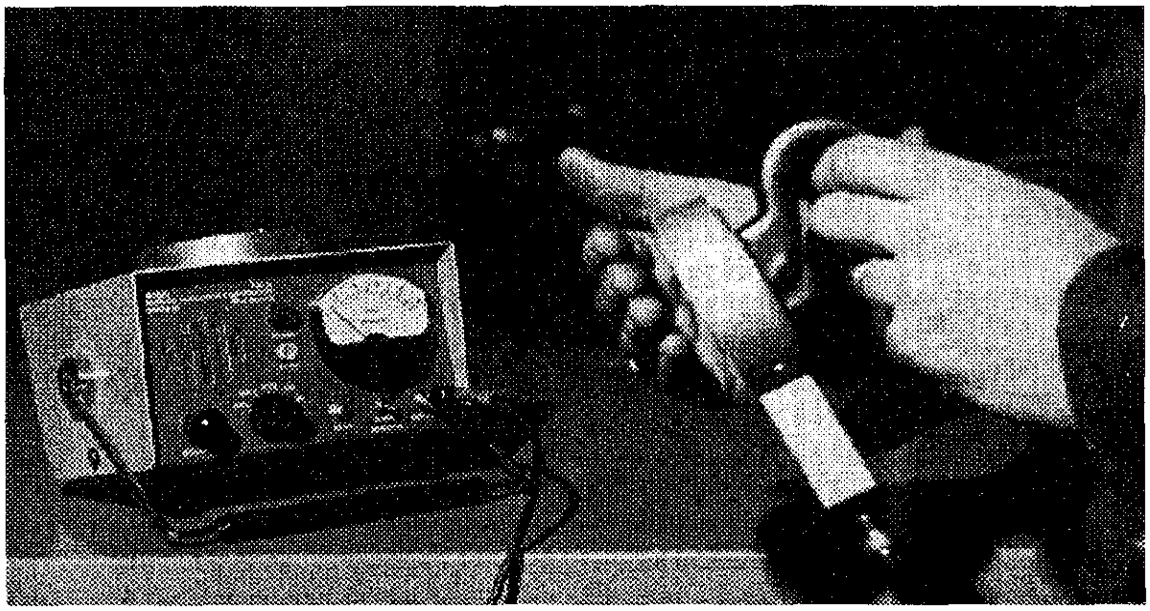


Fig. 9.3. Using a Frisker

Example:

You are using a pancake detector to monitor an instrument that has to be sent off-site for service. The background count rate is 2 cps. The highest activity area found on it is 10 cps. What should you do?

Solution:

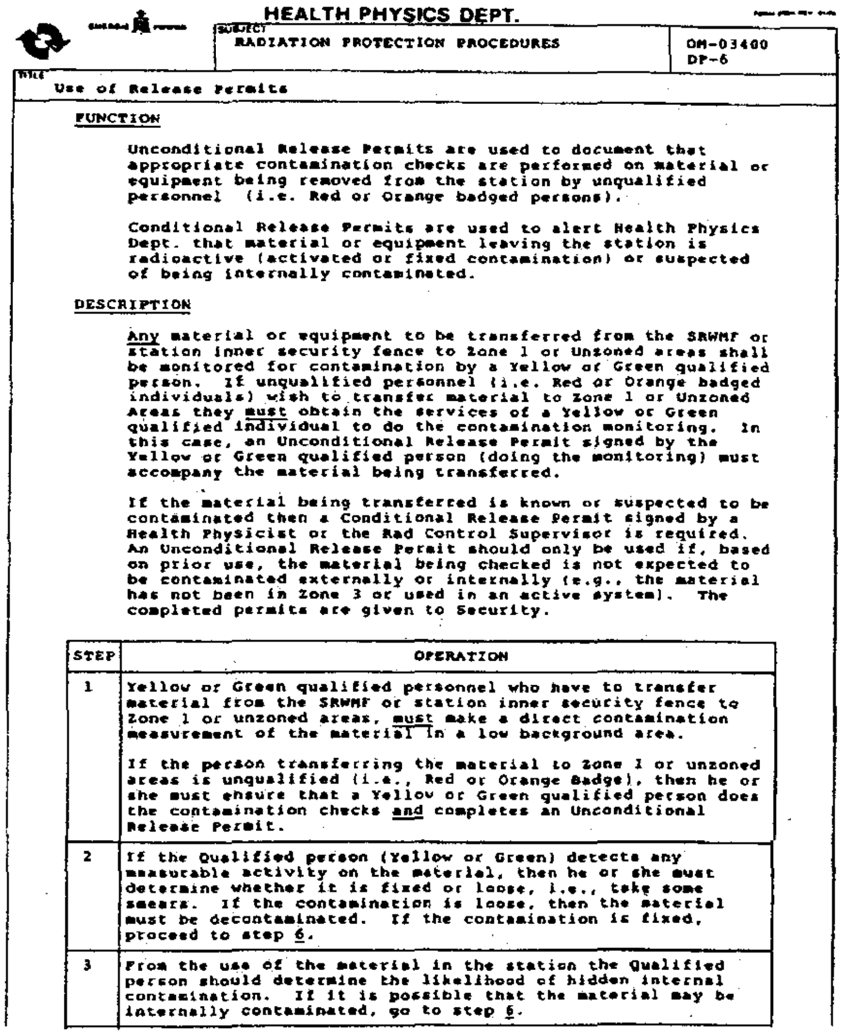
The rules for this situation are given in Procedure DP-6, reproduced on the next page. In a nutshell:

1. Direct Measurement.
2. If any contamination is found, take a smear.
3. If any loose contamination is found, decontaminate.
4. If fixed contamination remains, get a Conditional Release Permit.
5. Health Physics signs this and decides whether Radioactive Shipment Documents are needed, and whether the receiver must have a radioactive materials licence.

Disadvantages of the Direct Method

1. It isn't possible to make a direct measurement of surface contamination when a high gamma background is present. This would completely swamp any increase in count rate from the contamination. For example, 1 μSv/h of gamma background gives about 5 cps with a pancake detector.

2. A direct measurement cannot tell you whether the contamination is fixed or loose. If the contamination is fixed, it won't spread, but if it is loose, we are much more concerned about it. In fact, we must clean it up right away to stop it spreading.



HEALTH PHYSICS DEPT.

SUBJECT	
RADIATION PROTECTION PROCEDURES	OM-03400 DP-6
TITLE Use of Release Permits	

FUNCTION

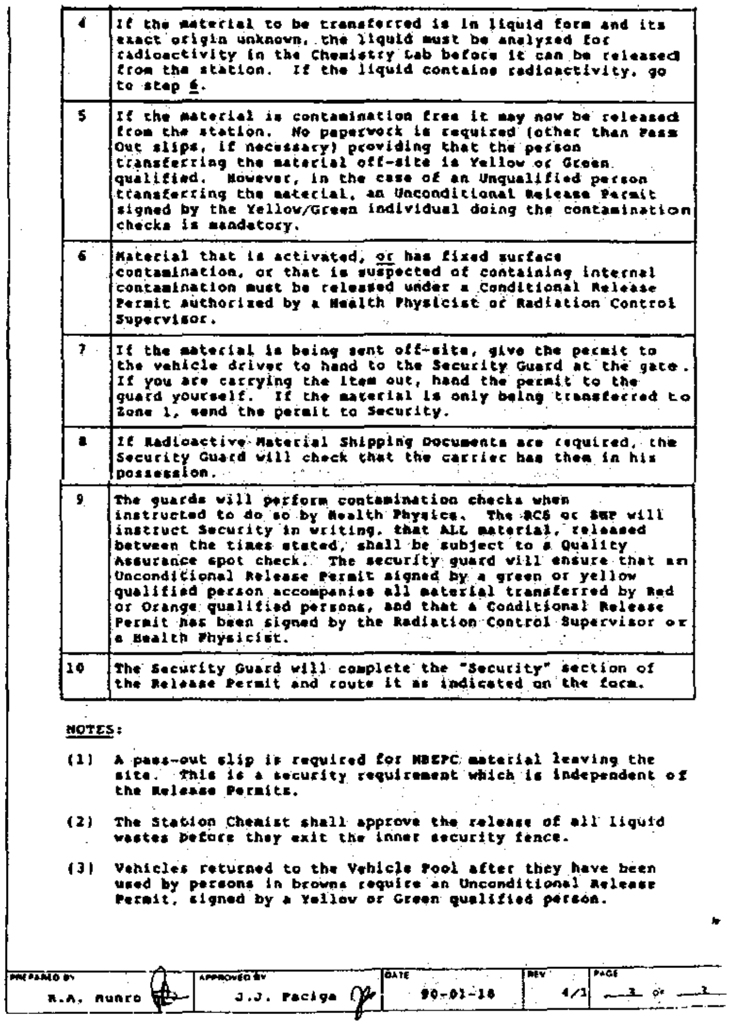
Unconditional Release Permits are used to document that appropriate contamination checks are performed on material or equipment being removed from the station by unqualified personnel (i.e. Red or Orange badged persons).

Conditional Release Permits are used to alert Health Physics Dept. that material or equipment leaving the station is radioactive (activated or fixed contamination) or suspected of being internally contaminated.

DESCRIPTION

Any material or equipment to be transferred from the SRWMF or station inner security fence to Zone 1 or Unzoned areas shall be monitored for contamination by a Yellow or Green qualified person. If unqualified personnel (i.e. Red or Orange badged individuals) wish to transfer material to Zone 1 or Unzoned Areas they must obtain the services of a Yellow or Green qualified individual to do the contamination monitoring. In this case, an Unconditional Release Permit signed by the Yellow or Green qualified person (doing the monitoring) must accompany the material being transferred.

If the material being transferred is known or suspected to be contaminated then a Conditional Release Permit signed by a Health Physicist or the Rad Control Supervisor is required. An Unconditional Release Permit should only be used if, based on prior use, the material being checked is not expected to be contaminated externally or internally (e.g., the material has not been in Zone 3 or used in an active system). The completed permits are given to Security.



STEP	OPERATION
1	Yellow or Green qualified personnel who have to transfer material from the SRWMF or station inner security fence to Zone 1 or unzoned areas, must make a direct contamination measurement of the material in a low background area. If the person transferring the material to Zone I or unzoned areas is unqualified (i.e., Red or Orange Badge), then he or she must ensure that a Yellow or Green qualified person does the contamination checks and completes an Unconditional Release Permit.
2	If the Qualified person (Yellow or Green) detects any measurable activity on the material, then he or she must determine whether it is fixed or loose, i.e., take some smears. If the contamination is loose, then the material must be decontaminated. If the contamination is fixed, proceed to step 6.
3	From the use of the material in the station the Qualified person should determine the likelihood of hidden internal contamination. If it is possible that the material may be internally contaminated, go to step 6.
4	If the material to be transferred is in liquid form and its exact origin unknown, the liquid must be analyzed for radioactivity in the Chemistry Lab before it can be released from the station. If the liquid contains radioactivity, go to step 6.
5	If the material is contamination free it may now be released from the station. No paperwork is required (other than Pass Out slips, if necessary) providing that the person transferring the material off-site is Yellow or Green qualified. However, in the case of an Unqualified person transferring the material, an Unconditional Release Permit signed by the Yellow/Green individual doing the contamination checks is mandatory.
6	Material that is activated, or has fixed surface contamination, or that is suspected of containing internal contamination must be released under a Conditional Release Permit authorized by a Health Physicist or Radiation Control Supervisor.
7	If the material is being sent off-site, give the permit to the vehicle driver to hand to the Security Guard at the gate. If you are carrying the item out, hand the permit to the guard yourself. If the material is only being transferred to Zone 1, send the permit to Security.
8	If Radioactive Material Shipping Documents are required, the Security Guard will check that the carrier has them in his possession.
9	The guards will perform contamination checks when instructed to do so by Health Physics. The RCS or SHP will instruct Security in writing, that ALL material, released between the times stated, shall be subject to a Quality Assurance spot check. The security guard will ensure that an Unconditional Release Permit signed by a green or yellow qualified person accompanies all material transferred by Red or Orange qualified persons, and that a Conditional Release Permit has been signed by the Radiation Control Supervisor or a Health Physicist.
10	The Security Guard will complete the "Security" section of the Release Permit and route it as indicated on the form.

NOTES:

(1) A pass-out slip is required for NBEPC material leaving the site. This is a security requirement which is independent of the Release Permits.

(2) The Station Chemist shall approve the release of all liquid wastes before they exit the inner security fence.

(3) Vehicles returned to the Vehicle Pool after they have been used by persons in browns require an Unconditional Release Permit, signed by a Yellow or Green qualified person.

PREPARED BY	APPROVED BY	DATE	REV	PAGE
R.A. Munro	J.J. Paciga	90-01-18	4/1	2 of 2

INDIRECT METHOD — SMEARS

This is used to identify and measure loose contamination. The measurement is made on **Smears**, which are small discs of filter paper. These are rubbed over the surface to pick up some of the loose contamination that may be present. The activity that has collected on the filter paper is then counted with a suitable detector. We use the same detector as for the direct measurements.

The method for taking a smear is as follows:

1. Select the surface to be smeared.

2. Number or otherwise identify the smear paper to be used on each surface.

3. Hold the smear on the edge with your thumb and index finger and rub it lightly over the surface. Smear an area of about 150 cm^2 in an S-shape as shown in Fig. 9.4. Approximately 10% of the loose contamination will be picked up by the smear paper.

4. Put the smears in separate envelopes, or use some other method to separate them so that they don't cross-contaminate each other.

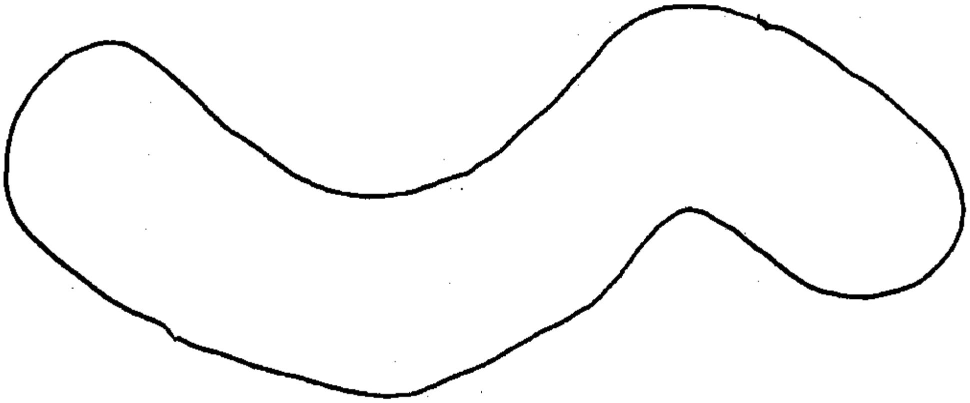


Fig. 9.4. Typical Smear Pattern

5. Take them to a **Smear Counting Station**. At Point Lepreau, we have chosen to use scalers rather than ratemeters for counting smears.

6. Check that the smear holder is empty and measure the background count accumulated in 60 seconds.

7. Insert the smear into the shielded smear holder (dirty side up), and restart the scaler to measure the count accumulated in 60 seconds.

8. The difference in counts is due to activity picked up on the smear. 900 counts above background in 60 seconds corresponds to 1 CCL.

9. Don't forget to take the smear out of the smear holder and drop it into the active waste container at the smear counting station.

Can you show that if you follow the procedure above, 900 counts above background will correspond to 50 kBq/m^2?

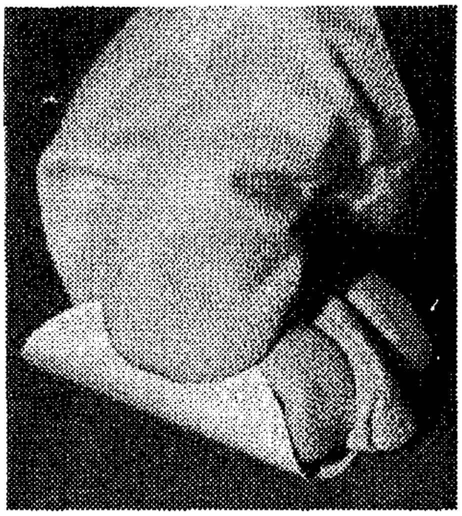


Fig. 9.5. Taking a Smear

Smears from potentially heavily contaminated areas should first be checked with a gamma survey meter (you of course brought one, didn't you?), because they can pose quite a significant external hazard.

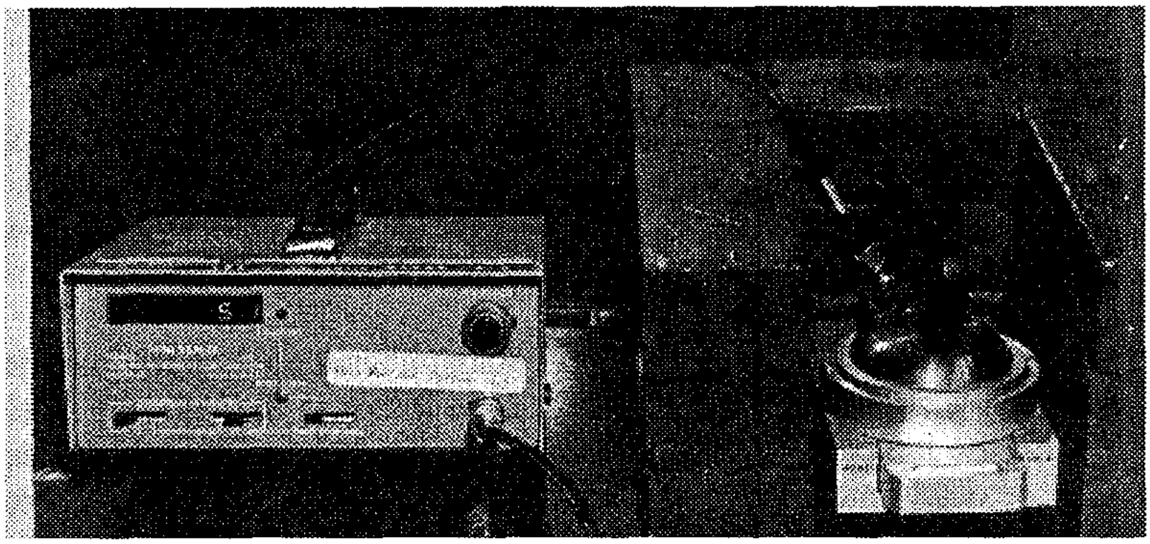


Fig. 9.6. Smear Counting Station

Advantages of Smears

1. They measure loose contamination only, not fixed plus loose.

2. They are not plagued by high background problems, because the smear counting stations are in low background areas. In addition, the smear holder is shielded to reduce the background even further.

Disadvantages of Smears

1. They disintegrate on rough surfaces.

2. The smear method gives much cruder results than the direct method, because the assumed 10% pick-up of activity depends on how hard you press, how smooth the surface is, and whether it is dry or damp. For example, the pick-up from stainless steel should be much better than 10%, but from wood you pick up very little and on carpets you can forget it. 10% as a cautious average has been popular for many years. This method also assumes that exactly 150 cm^2 are smeared. This inaccuracy is rarely a problem in practice, because usually we just want to know whether loose contamination is present or not. And the smear method will certainly tell you that.

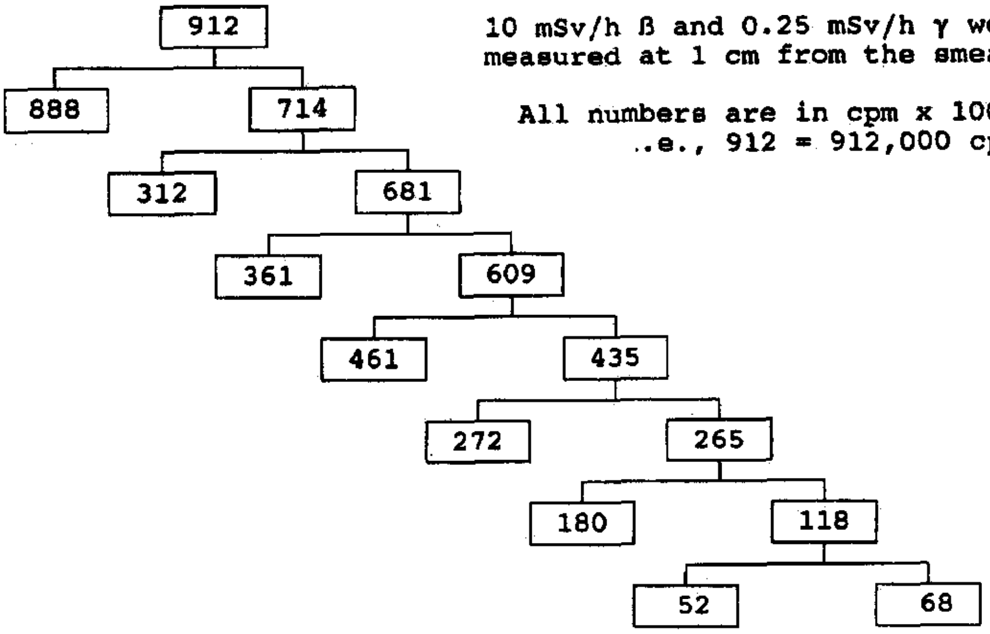
3. If you monitor wet surfaces for loose contamination, the smears should be dried before they are counted. Water on the smear will absorb a lot of beta particles, so that they can't reach the detector. This will cause a serious underestimate of the loose contamination.

4. A smear taken from a very highly contaminated area could give rise to such a high count rate that dead time losses in the detector would cause the indicated count to be low. For practical purposes, you can ignore dead time losses if the count is less than 100,000 in 60 seconds. This is a pretty hot smear! It will even drive a gamma survey meter on scale at around 0.2 mSv/h. You can see that this disadvantage is not going to cause practical problems in deciding whether an area has loose contamination or not. Or even how much — the answer is: far too much.

A very hot smear will demonstrate the effect of dead-time losses quite nicely. Chris Philip smeared the Spent Fuel Ladle in the Spent Fuel Discharge Bay, and used this smear to give us the measurements shown on the next page.

He cut the smear in half, measured it, cut one half in half again, measured it, and so on. You will recognize that above 100,000 cpm there are dead time losses, because the count rate from the whole is less than the sum of the count rates from the two halves.

Smears from such hot areas should therefore first be checked with a gamma survey meter. If there is any on-scale indication at all, don't even put the smear in the scaler castle: you will certainly contaminate the castle, screw it up for the next guy, and get no useful information.



10 mSv/h ß and 0.25 mSv/h γ were measured at 1 cm from the smear.

All numbers are in cpm x 1000, i.e., 912 = 912,000 cpm.

Fig. 9.7. Splitting a Hot Smear

INDIRECT METHOD - MASSLINN MOP

We use this to look for loose contamination on large areas, like floors, where the smears described above would be a pain.

The **Masslinn Mop** is a foam-covered, plastic mop head swivel-mounted to a broom handle. A clean Masslinn dust cloth is wrapped around the mop head, and then large sections of floor (typically 3 m^2 or so) are mopped with individual dust cloths. All cloths are labelled, and taken to a low background area where they are frisked for contamination.

This is a very quick method of finding loose contamination. For surveying areas where you would not expect loose contamination, e.g., the Change Room or the Zone 2 Coffee Shop, you could smear the whole area with one cloth. If you haven't picked up any contamination, you know that the entire area is clean. On the other hand, if you find something, you have to go back and divide the area into sectors and proceed as described above. Fig. 9.8 shows a Masslinn Mop. It is nothing other than a humongous smear.

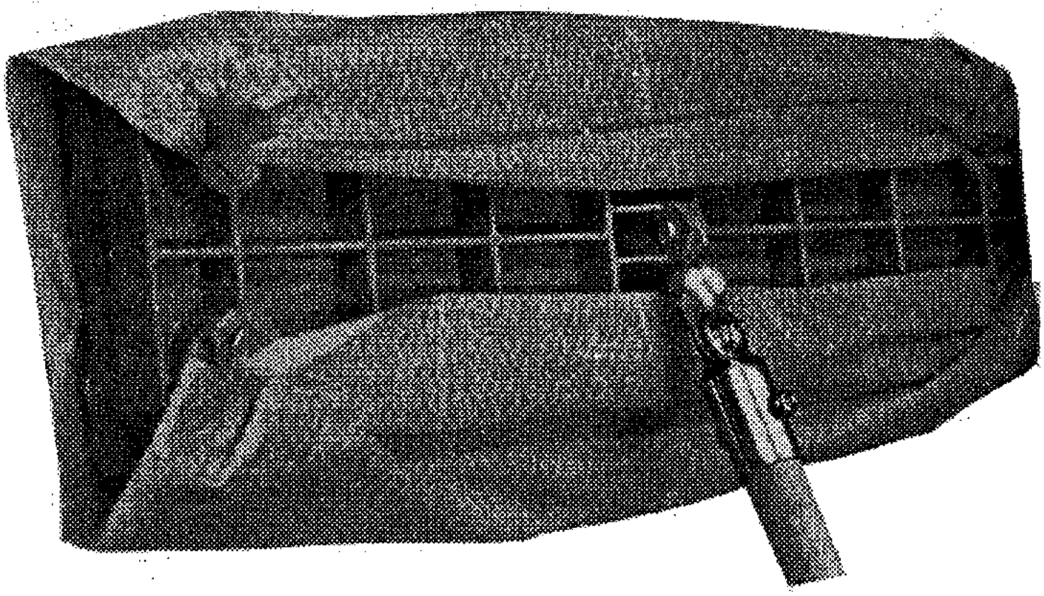


Fig. 9.8. A Masslinn Mop

SURFACE CONTAMINATION SURVEYS

Contamination surveys are done in the same places that radiation surveys are carried out.

Contamination surveys are used to determine whether areas such as halls, corridors, the Control Room and the Change Room are contaminated. These areas are checked for fixed contamination and loose contamination. Comparison with previous surveys tells us whether or not contamination levels are changing. A smear is taken of the known contamination areas to find out if any contamination is migrating to the surface.

As part of the area contamination survey, things that are heavily used, such as doorways, doorknobs, hallways, handrails, and ledges that collect dust, are the best places to look for loose contamination. Exits from the Spent Fuel Bays, Reactor Building and Rubber Areas are also good places to survey regularly.

A contamination survey is done when equipment is to be removed from a contaminated area, when equipment has contained radioactive material, and before equipment is released from the station. The survey can be performed at the site, but background radiation levels and contamination may make it necessary to take the equipment to a different location before surveying it. If necessary, the equipment can be bagged and taken to the Decontamination Centre, and it can be decontaminated there. Loose contamination is measured by smearing portions of the accessible surfaces of the piece of equipment.

Any loose contamination should be cleaned up. If this is impracticable, the area containing it should be isolated by making it a **Rubber Area.** This is a temporary contamination control area which will be described later.

DOSIMETRY FOR SURFACE CONTAMINATION

The TLD badge and the DRD worn on the chest are not in a position where they can indicate the dose to the hands, which normally receive the maximum dose from contaminated surfaces. The beta dose rate increases very rapidly as you get very close to the source. Therefore, when you work with high levels of surface contamination, you should wear extremity TLDs.

AIRBORNE CONTAMINATION

So far, we have discussed contamination on surfaces. Now we'll go on to discuss contamination in the air, because the air in the Reactor Building and in many areas of the Service Building can become contaminated with airborne radioactive materials. This contamination consists of various fission and activation products that enter the air in gaseous, vapour or particulate form. There are four types of airborne contamination in CANDU plants, namely particulates, noble gases, radioiodines and tritium. Their sources, properties and hazards were described in Chapter 8.

We'll briefly review what we've already learned, and then describe how we detect and measure each of the hazards (the methods are different for all four of them, since nothing is ever easy).

PARTICULATES

Particulate activity is an internal hazard, because it can be inhaled. Transportable particulate material taken into the respiratory system will enter the blood stream and be carried to all parts of the body. Non-transportable particulates will stay in the lungs with a biological half-life of about a year. They are gradually eliminated by coming back up the respiratory tract and disappearing down the GI tract.

The DAC for unidentified particulates is 200 Bq/m^3.

MEASUREMENT OF PARTICULATES

An activity of 200 Bq/m^3 is much too low to be measured directly. Instead, we collect the dust from a large volume of air by passing the air through a filter paper which traps all the dust particulates. The activity of the dust collected on the filter can then be measured using a Geiger detector with ratemeter or scaler.

In some locations at Point Lepreau, the air could become contaminated with particulate activity. Can you give examples of where and when this might happen? For such cases, it is desirable to monitor the air continuously. Instruments that do this are called **Continuous Air Monitors**. These instruments can do little more than determine if activity is present or not. To measure how much activity is actually present in the air, we need to use a **Spot Sampler**. We'll describe an example of each instrument below, and you will understand why we need two of them.

Continuous Air Monitor (CAM)

The Continuous Air Monitor (Fig. 9.9) operates on the principle of a pump drawing air continuously from the work area through a small particulate filter. Radioactive particulates in the air collect on the filter, where the activity is measured by a detector placed close to the filter. A pancake Geiger is used as the detector, and this is connected to a ratemeter and a recorder. The detector is normally mounted in a shielded castle to reduce the background. Fig. 9.10(a) shows the set-up.

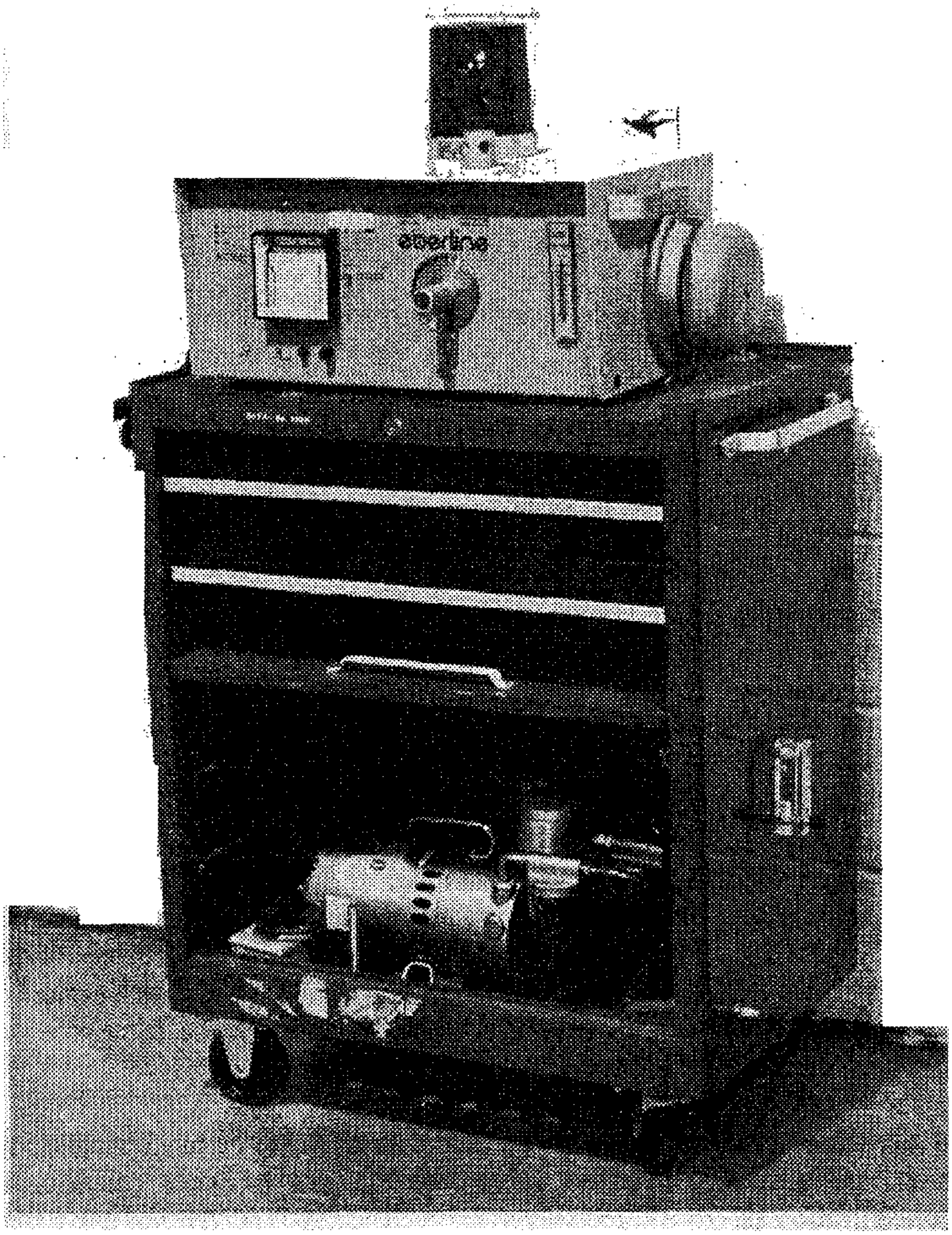


Fig. 9.9. Eberline Continuous Air Monitor (CAM)

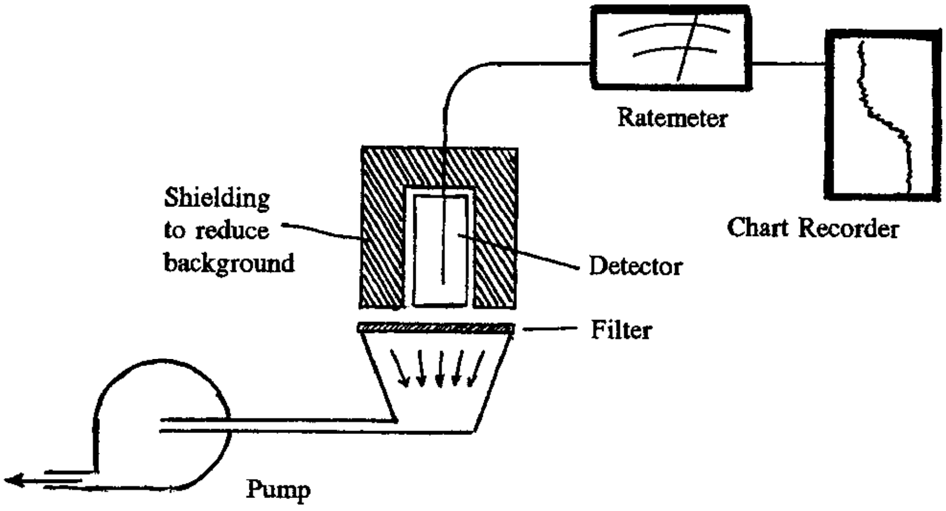


Fig. 9.10(a). Principle of Operation of Continuous Air Monitor (CAM)

Our CAMs do not give a quantitative reading of particulate airborne concentration. Rather, as the radioactive particulate accumulates on the filter with time, the reading of the ratemeter increases. The higher the concentration of particulate in the air, the faster will be the rate of accumulation and the faster the increase in the ratemeter reading. An example of the type of recording which might be expected from monitoring air contaminated by long-lived fission products is shown in Fig. 9.10(b).

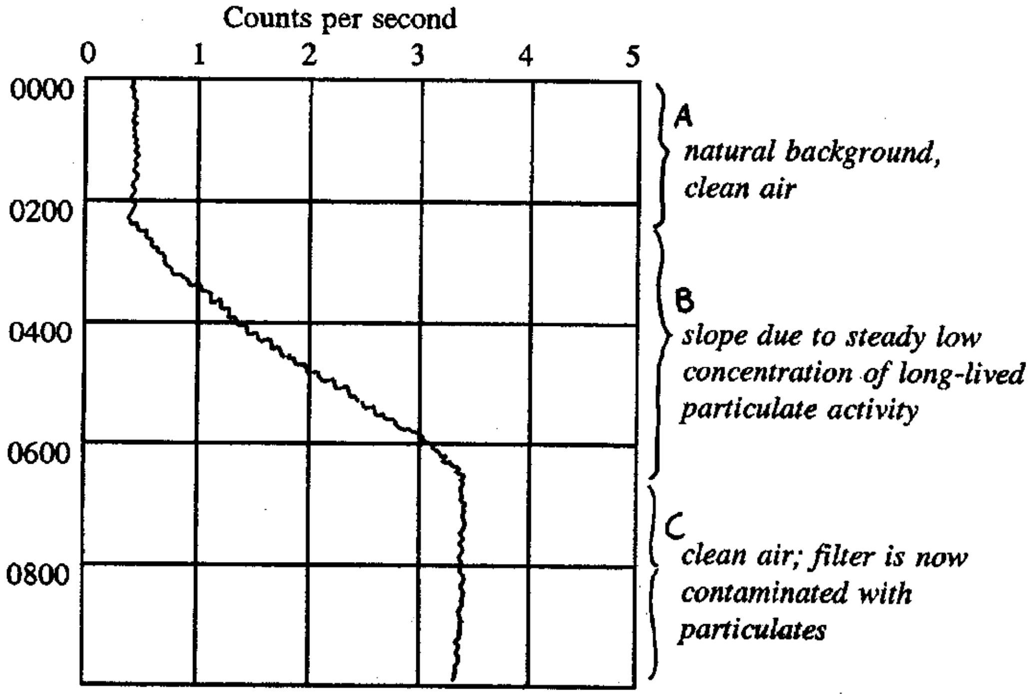


Fig. 9.10(b). Recorder Output

It is important to understand that the recorder reading does not indicate the activity in the air. The trace (rising or steady) merely tells us whether activity is present or not. The important feature is that we are alerted to a change in the activity in the air by a change in the slope of the trace.

Even then, interpretation of the recorder trace is difficult, because in practice you might be dealing with airborne particulate activity that has a wide range of half-lives. For example, if the area being monitored contains only long-lived particulates, then region C indicates that no more activity is being picked up by the filter. However, if the area contains a lot of short-lived particulates instead, region C might indicate a condition where the short-lived particulates are accumulating on the filter at a rate that just matches their decay.

If the trace indicates that activity might be present, or has changed, we must use a spot sampler to get a measurement of what the airborne concentration is.

Spot Sampler

Figure 9.11 shows a spot sampler. It is nothing but an air pump and a filter housing.

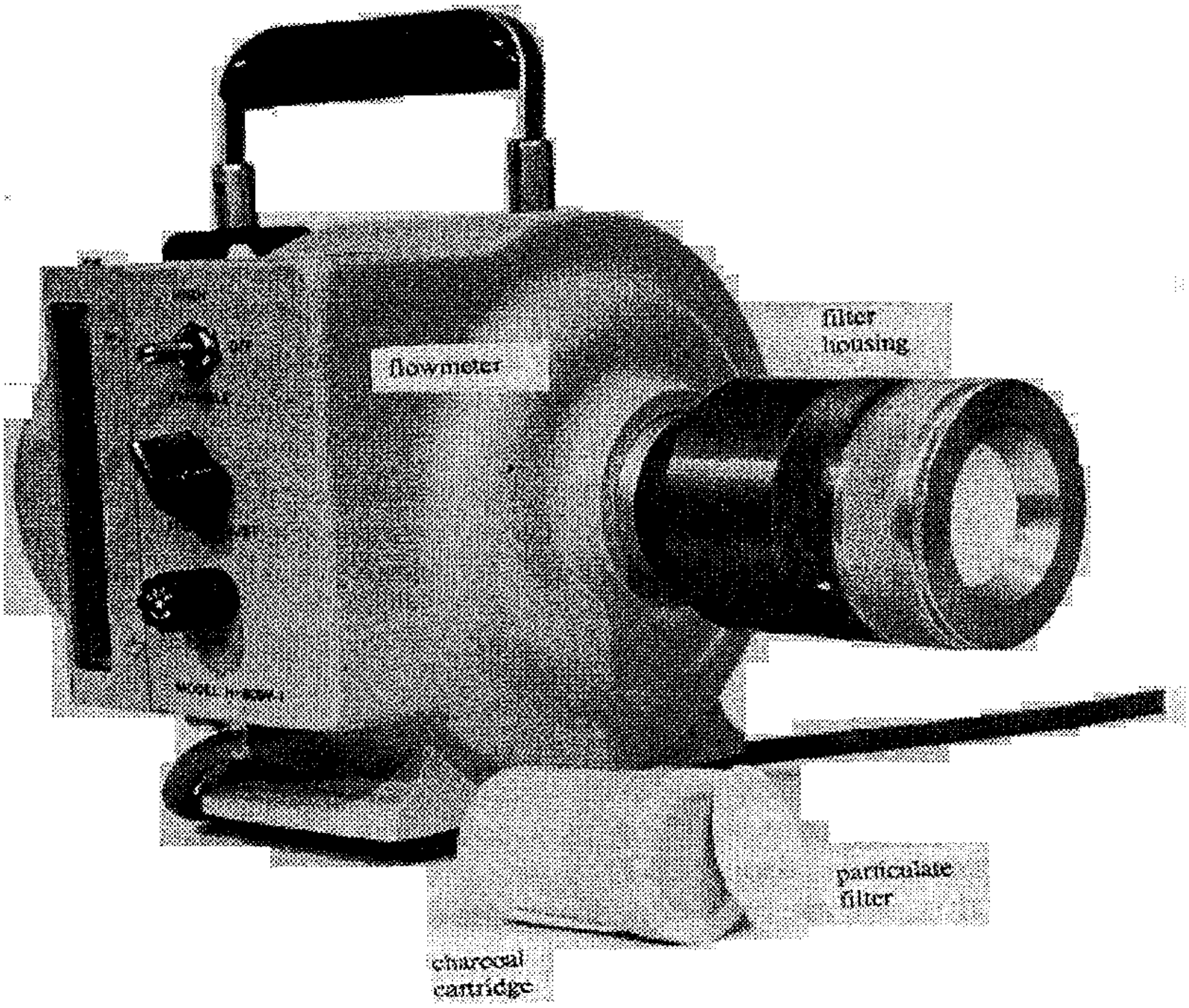


Fig. 9.11. Spot Sampler

To take an air sample, a filter paper is installed and a large volume of air (usually 450 L) is drawn through it in a short period of time (typically 5 minutes). The filter paper is then removed and taken to the nearest smear counting station, where the activity collected on it is measured. From this, it is easy enough to work out the committed dose rate of the sampled air in μSv/h of unidentified particulates.

Example:

You took a 5 minute air sample. Air flow was 1.5 L/s. The filter paper gave a count of 4800 in 60 seconds. The background count in the same time was 300 and the detector efficiency is 20%. What was is committed dose rate of the air sample in μSv/h of unidentified particulates?

Solution:

The count due to the filter paper alone was 4500 counts in 60 seconds. This corresponds to 4500/60 = 75 cps. Since the detector is only 20% efficient, the activity on the filter paper was 75 x 100/20 = 375 Bq.

The volume of air sampled was 1.5 L/s x 300 s = 450 L or 0.45 m^3. Therefore the air activity was 375 Bq divided by 0.45 m^3, that is, 830 Bq/m^3. For unidentified particulates (which is what we are dealing with here) the DAC is 200 Bq/m^3, so we measured 4.2 DACs. This corresponds to a committed dose rate of 42 μSv/h.

In practice, you don't have to do these mind-boggling calculations whenever you take an air sample. A graph is kept at each smear counting station relating net counts to committed dose rate for unidentified particulates. You can use this graph provided you used the standard spot sampling time and flow rate.

If we wanted to know which particulate we had collected, we would need a gamma spectrometry analysis carried out to determine how many Bq of which radionuclides were present. This can be done in the Chemistry Lab and the correct committed dose rate for the mixture obtained. If we don't want to go to all this trouble, and often we won't, we will just assume that we have measured the airborne contamination to be 42 μSv/h. So what do we do now?

Respiratory protective equipment should be worn in areas where the committed exposure may exceed 50 μSv.

For example, an occasional exposure — without protection — to 10 μSv/h committed for about half a shift may be acceptable, depending on the circumstances. The intent of this rule is to let you enter the Reactor Building for short periods of time without a respirator. Still, if you routinely enter such areas and work there for a couple of hours every day, you should wear a respirator to keep your dose ALARA.

NOBLE GASES

You will recall that noble gases are an external hazard only. Since the body does not react chemically with them, they are exhaled right after they are inhaled. If you are working in a noble gas cloud, the external dose you will receive is about 1000 times greater than the internal dose. Because of this, we are only concerned about the external beta and gamma dose rates.

If, in doing an area gamma survey, you detect a radiation field that shows little variation, regardless of where you are in the room, then the radiation may well be due to radioactive noble gases. A beta survey of the area would bear this out, and should be done. You will be covered with short-lived particulate contamination if you have been in an area containing noble gases, because that's the decay product of noble gases. Therefore, you must monitor yourself for contamination. If it is short-lived particulates, the contamination will decrease with a 20 minute half-life or so.

RADIOIODINE

The target tissue for radioiodine exposure is the thyroid gland. The external beta and gamma dose from radioiodine present in the air is quite negligible when compared to the committed dose to the thyroid that would result from breathing this air for the same length of time.

MEASUREMENT OF RADIOIODINE

We have a simple approach to radioiodine monitoring. Every time a particulate spot sample is taken, an activated charcoal filter is installed downstream of the particulate air filter. This charcoal filter has a high efficiency for radioiodine (it also traps noble gases to some extent), but will not be able to collect any particulates, because they have already been removed from the air sample flow by the paper particulate filter. Both filters are shown on page 387 (the big one is the charcoal filter). We have already described how the activity collected on the particulate filter is measured. Once you've done that, you then use the same set-up to measure the activity collected in the charcoal cartridge.

The efficiency of the pancake Geiger detectors for the gamma photons emitted by radioiodine is much less than the efficiency for the beta particles emitted by activity collected on the particulate filters. Laboratory measurements we made showed us that the efficiency for I-131 is 0.37%. (The reason for this is that every beta particle entering the pancake Geiger tube will produce ionization and hence a pulse, but gamma photons will normally pass right through the tube without interacting. We register only those that interact and produce ionization). We can now work out what number of net counts in one minute corresponds to 1 DAC of I-131, which is 400 Bq/m^3. The volume of air sampled is of course the same as for the particulate sample, i.e., 450 L = 0.45 m^3. With virtual 100% absorption of I-131 in the charcoal filter, it will pick up

$$400 \frac{\mathrm{Bq}}{\mathrm{m}^3} \times 0.45 \mathrm{~m}^3 = 180 \mathrm{~Bq}.$$

Only 0.37% of this activity will be detected to give a count rate of

$$180 \times \frac{0.37}{100} = 0.67 \text{ cps.}$$

With the scaler set to accumulate counts for 60 seconds, a total count above background of

0.67 cps x 60 s = 40 counts

will correspond to a committed dose rate of 10 µSv/h of I-131 in the sampled air.

This argument assumed that all the activity trapped in the charcoal cartridge was due to I-131. In practice, other radioiodine isotopes might be present as well as some noble gases. In this case, by assuming them all to be I-131, you will have overestimated the real committed dose rate, and that's OK because it is on the cautious side. Similar to particulates, you'll find a graph at the smear counting station relating net counts to committed dose rate of I-131. If you want an accurate assessment of the activity in the charcoal cartridge, you should take it to the Chemistry Lab. The lads will do a radionuclide analysis on their gamma spectrometer and then quote you the correct committed dose rate for the radioiodines in the air sample. They should be able to give you an answer within 10 to 15 minutes. Right, Warren?

For anticipated committed doses of 50 µSv or more, you are required to wear respiratory protection.

TRITIUM

As you must know by now, tritium emits only beta particles of very low energy. These beta particles cannot even penetrate the outer dead layer of the skin and tritium is therefore an internal hazard only. When it is in the form of DTO or HTO vapour, it can readily enter the body by inhalation or absorption through the skin. Uptakes of tritium via inhalation and skin absorption will be in the ratio of about 2 to 1.

Tritium enters the body fluids where it exchanges with ordinary water. The physical half-life of tritium is 12.3 years, and its effective half-life in the body is about 10 days. Although it is rarely done or necessary, the effective half-life (and hence the committed dose) can be reduced by increasing the rate of water intake. Beer works just as well.

MEASUREMENT OF TRITIUM

Portable Tritium-in-Air Monitor

The measurement of tritium is difficult because the energy of the beta particles is too low for them to be able to penetrate the walls of any detector. Therefore, any continuous monitor for tritium-in-air has to be designed to draw the air right into the detector. One such type is based on the ion chamber described on page 172. Please take a minute to read that. It'll save me writing it all down again.

Fig. 9.12 shows one of these instruments. They only work well if the gamma background is negligible. If it isn't, you'll get weird readings. But you can use a trick to get around this problem, namely you take a "grab sample". This means that, after a minute or so, you switch the instrument's pump off in the area you are trying to monitor, and then you take it to a low gamma background to read it. The tritiated air will still be in the chamber, and you should get a good reading.

As mentioned on page 174, this instrument is sensitive to noble gases as well as tritium. A drawback, but we have taken advantage of it to locate noble gas leaks from the PHT system.

Because of these difficulties, the tritium bubbler will always give more accurate results, although it isn't as convenient.

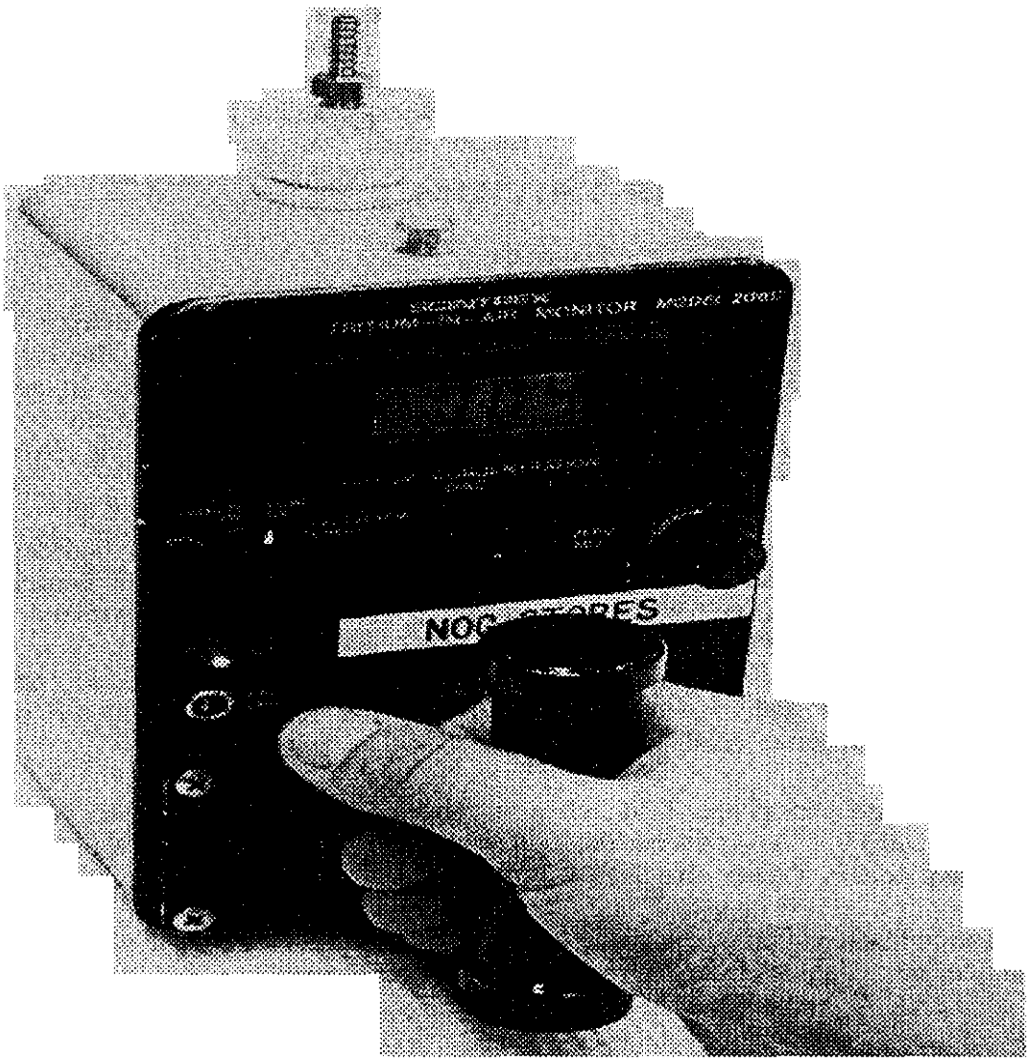


Fig. 9.12. Portable Tritium-in-Air Monitor

Tritium Bubbler

The bubbler method is simple, accurate and not affected by gamma background or noble gases at all. The technique consists of bubbling tritiated air through clean water, which will trap the tritiated water vapour, and then analyzing the tritium content of the water. One of our bubblers is shown below. It consists of a pump, a timer, a flow gauge and a removable water jar containing 100 mL of clean water. When you plug the bubbler cord into a 110 V outlet, the pump will bubble the sample air through the water. The flow gauge is adjusted to 1 L/min, and after 5 minutes the timer shuts the pump off.

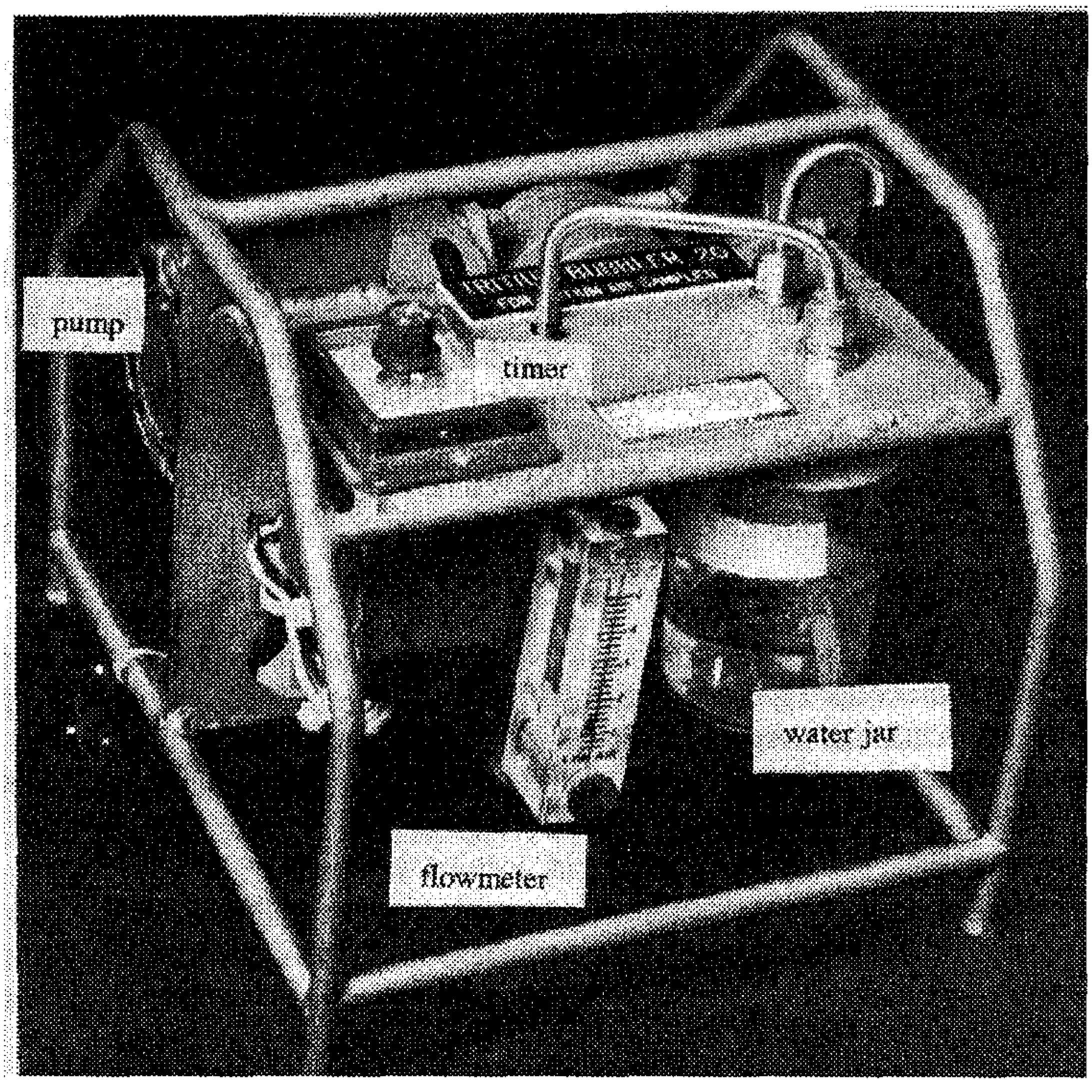


Fig. 9.13. Tritium Bubbler

The tritiated water vapour that was contained in the 5 L of air is now trapped in the 100 mL of water. You take the sample to the Chemistry Lab, where you analyze the tritium content of the water with a Liquid Scintillation Counter (LSC).

Let's use an example to show how this works. Assume that you used a bubbler to sample air containing 1 DAC of tritium.

1 DAC = 3E5 Bq/m^3 = 300 Bq/L (1000 L in 1 m^3)

5 L contained 5 x 300 = 1500 Bq. These 1500 Bq are now in the 100 mL of water, i.e., the concentration in the water is 15 Bq/mL. You mix one mL of this water with liquid scintillator and count it for one minute. If the LSC were 100% efficient, it would indicate 15 counts per second or 900 cpm. Actually, its efficiency is approximately 42%, so it would read 0.42 x 900 cpm = 380 cpm. In other words, with this technique, 380 cpm in the LSC corresponds to 1 DAC or 10 uSv/h of airborne tritium.

In our Applications Course, you will learn how to prepare a bubbler sample for counting in the LSC, and how to use the counter to get the results in μSv/h. Again, to save wear and tear on your brain cells, a graph relating cpm on the LSC to the tritium committed dose rate is posted near the LSC.

If you are taking several samples, you must make sure that you use a clean jar each time. And don't stand around in high radiation fields or high tritium concentrations waiting for the bubbler to finish. That's what the automatic timer is for.

AIRBORNE AREAS

Perhaps you remember (page 286) that areas with external radiation fields of more than 10 μSv/h are called Radiation Areas and have to be signposted to alert people to the hazards. Similar requirements apply for areas with airborne contamination - they will need CAUTION, AIRBORNE AREA or DANGER, RESTRICTED AIRBORNE AREA signs.

An AIRBORNE AREA is an accessible area in which the committed dose rate exceeds 10 μSv/h.
A RESTRICTED AIRBORNE AREA is an accessible area in which the committed dose rate exceeds 5 mSv/h.

These levels also apply to a mixture of airborne hazards; e.g., 6 μSv/h of particulates and 6 μSv/h of radioiodines would be considered an Airborne Area. Also, a Restricted Airborne Area could be a combination of external and internal radiation hazards exceeding 5 mSv/h (2 mSv/h gamma and 4 mSv/h tritium, for example).

Now you can appreciate the mistake in the photo on page 287. Which is?

CONTAMINATION CONTROL

Contamination may be spread from one area to another by various means. For example, if you are working in a contaminated area, it is quite easy for you to track loose contamination from your clothing, shoes and tools all over the place. This is obviously bad, and to prevent it, various methods of contamination control have been developed. They are all based on one principle, namely **containment.** Whenever contamination is discovered, the important things are to contain it and then clean it up. The rest of this chapter is devoted to containment and clean-up.

ZONING

Zoning is the classification of an area according to its potential for a contamination hazard. In a good station design, the geographical layout of the zones is kept simple to minimize the number of zone interchanges, and hence the amount of traffic between zones. At Point Lepreau, this feature was overlooked somewhat.
The purpose of zoning is to help contain contamination. At Point Lepreau we have three zones:

Zone 3: contains radioactive systems and equipment that may act as sources of contamination.

Zone 2: contains no radioactive systems, and is normally free of contamination. It has potential for contamination as a result of people traffic and ventilation flows.

Zone 1: is a clean zone where absolutely no contamination is permitted. It is comparatively isolated from other zones so that work in Zone 1 doesn't require any knowledge of radiation protection at all. No Radiation Area Clothing is allowed in Zone 1.

The reactor systems are in Zone 3, the turbine systems are in Zone 2 and the administration offices are Zone 1. So the whole Reactor Building and parts of the Service Building are Zone 3, and the rest of the Service Building and all of the Turbine Building are Zone 2. At Point Lepreau, Zone 2 areas have blue walls, and all Zone 3 areas in the Service Building have green walls. The zoning layout is shown on pages 398 and 399.

When you move from Zone 3 to Zone 2, or Zone 2 to Zone 1, **you must monitor at the zone boundaries.** Hand & Shoe Monitors are provided at the high traffic boundaries and friskers at the rest. A contamination check takes only seconds, but a clean-up job of contamination you have tracked around may take you hours. All equipment entering Zone 1 has to be monitored and be free of contamination.

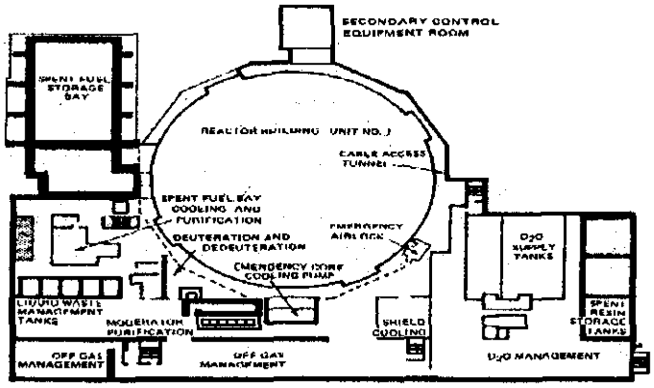
Since Zones 2 and 3 may contain loose contamination, no food or drink is allowed in these areas (this includes candy, soft drinks, etc.). This means you must leave your lunch in Zone 1, and return there to eat it. The only exception to this policy is that coffee and other beverages may be obtained and consumed in the controlled coffee areas in Zone 2. The purpose of these restrictions is to prevent the ingestion of contamination. There are other habits that could cause contamination to enter your body (e.g., chewing your fingernails, picking your nose, etc.). But these habits could shorten your fingers or make your head cave in, so be nice to yourself.

UNZONED AREAS

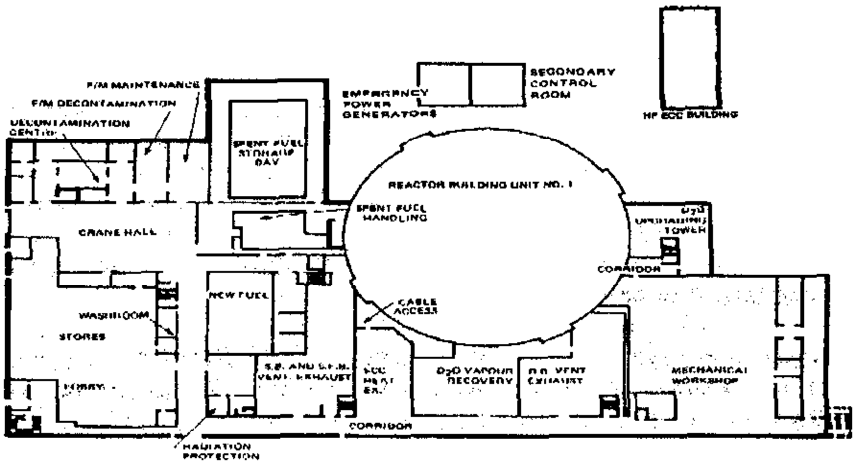
What's this? Well, there are some areas of the site that would have caused a lot of grief if we had designated them to be Zone 1 or Zone 2. So they are called **Unzoned Areas**. They are plant structures like the Switchyard, the Pumphouses, the High Pressure ECC Building, and the Secondary Control Room, that are outside the Reactor, Service and Turbine Buildings, but within the site boundary.

Basically, you will be doing it right if you consider Unzoned Areas as Zone 1 areas in which you are allowed to wear **clean** Radiation Area Clothing (Browns). If you are in Browns, you can wear them to all Unzoned Areas provided you monitor yourself (and any equipment you are taking with you) and find no contamination. You can leave via any ground level exit in the Service or Turbine Buildings, or through tunnels. Monitors are at or near these exits.

There is one exception to this policy: the Hanson Stream Pumphouse. It is considered a Zone 1 area, because it is off-site. To go there, you need street clothes.
The Solid Radwaste Management Facility (SRWMF), although situated outside the station security fence, is a Zone 2 area. It has its own security fence. Clean Radiation Area Clothing may be worn to the SRWMF. When one of the structures in the SRWMF is open, the inside of that structure is considered to be Zone 3. You must monitor before leaving the area, and extra monitoring should be done inside to ensure that contamination is not spread around. No loose contamination is permitted.

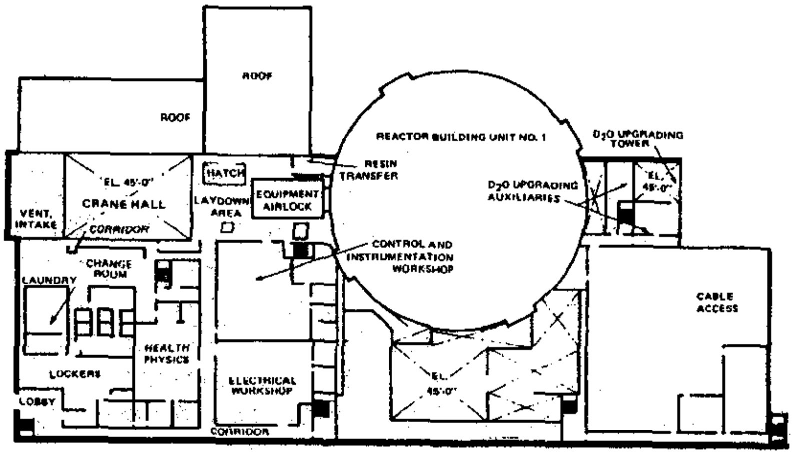


Elevation 25 ft = 7.6 m

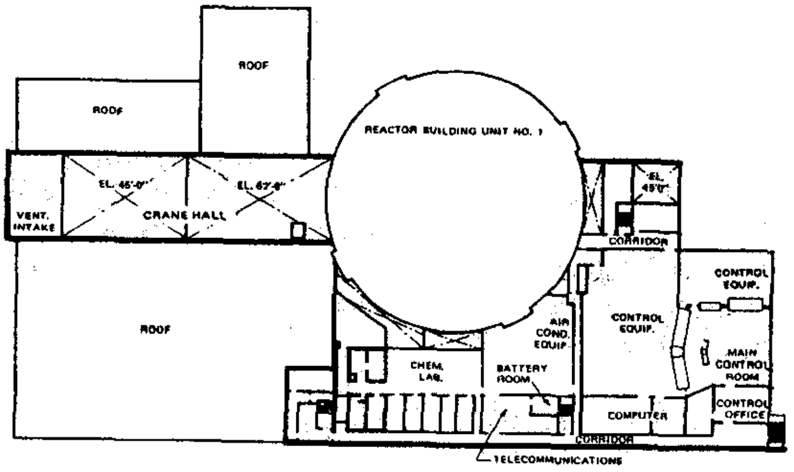


Elevation 45 ft = 13.7 m

☐ Zone 2 ☐ Zone 3



Elevation 62.9 ft = 19.1 m



Elevation 75 ft = 22.6 m

Fig. 9.14. Zoning in the Service and Reactor Buildings

RUBBER AREAS

Whenever loose contamination cannot be cleaned up right away, or when work activity is expected to generate loose contamination, a **Rubber Area** should be set up. Its purpose is to confine loose contamination. A Rubber Area is set up by roping off the area and covering the floor with a temporary surface. We use a special canvas, which retains loose contamination very well. Access is allowed at only one entry point, where a **Rubber Station** is established. This consists of a step-over barrier, and storage racks for clean and used shoe covers, gloves and disposable coveralls. Fig. 9.15 shows a rubber station at the entrance to a Rubber Area.

We have two types of shoe covers: rubber overshoes (called **rubbers**) and booties. Both types can be used in Rubber Areas to make a fashion statement. Rubbers would be useful in wet locations, if we had any. Shoe covers are washed in a Zone 3 laundry and re-used.

Movement across a rubber station must be carried out with great care to avoid spreading contamination. The detailed procedures will be taught in the Applications course ¾¾ for the time being, it is sufficient to say that shoe covers must be removed in such a way that no contamination reaches the clean side of the barrier. You must monitor yourself for contamination after crossing the barrier.

Because of the high probability of contamination, everyone must wear protective clothing within a Rubber Area, i.e., Browns as a minimum and often disposable coveralls as well. A Rubber Area is only intended to be a **temporary** extension of the zoning system. Once it has served its purpose, the Rubber Area should be decontaminated and the rubber station equipment removed.

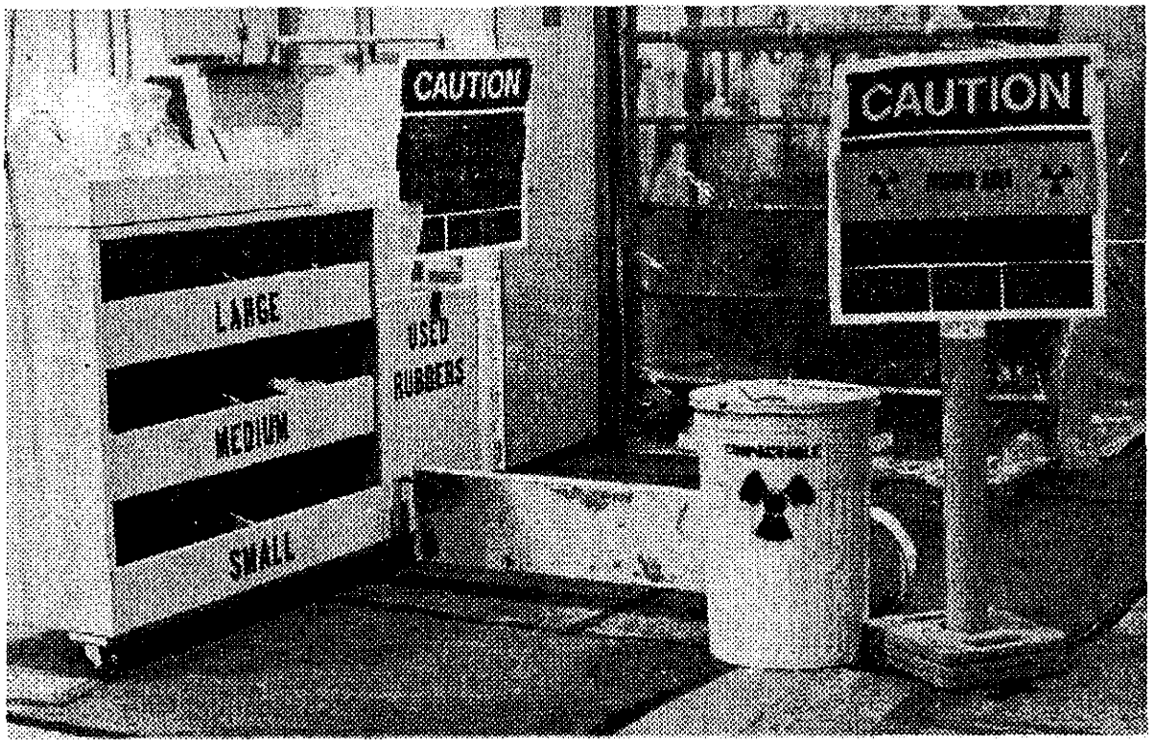


Fig. 9.15. Rubber Station

RUBBER CHANGE AREA

If the level of loose contamination in a Rubber Area exceeds 20 CCL (300 cps on a pancake frisker), you should set up a **Rubber Change Area**. This is a Rubber Area inside a Rubber Area. A Rubber Change Area **must** be set up for more than 70 CCL of loose contamination (i.e., off-scale on a pancake frisker).

You enter it wearing booties, disposable coveralls, rubbers, and two pairs of gloves. When you leave the Rubber Change Area, you remove your disposable coveralls, outer pair of gloves and rubbers, and then proceed to the Rubber Area exit where you remove the booties and the second pair of gloves.

CHANGE ROOMS

It is our policy to provide a complete change of clothing for everyone routinely working in Zones 2 and 3. If you are entering Zone 3 for inspection purposes, it is up to you whether you wear protective clothing or not. It is there if you want it. Generally, I would recommend it, because NB Power will not compensate you for contaminated personal clothing.

The purposes of a change room are:

1. To store and separate street clothes from the work clothes worn in Zones 2 and 3 (i.e., we want to separate clean clothes from potentially contaminated clothes).
2. To provide separate "clean" and "active" dressing areas.
3. To provide showers, for cleanliness and decontamination.
4. To provide contamination monitoring facilities.

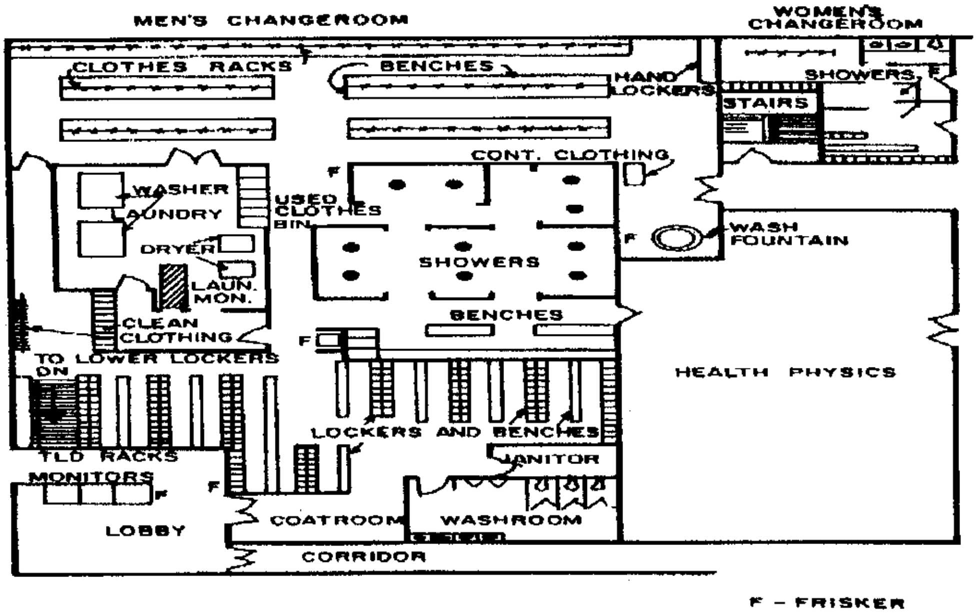


Fig. 9.16. Change Room Layout at Point Lepreau

WHAT YOU DO IF YOU ARE CONTAMINATED

It happens to the best of us. Perhaps someone carelessly contaminated a handrail while wearing gloves, and you later touched the rail with your bare hands: at the interzonal monitor, lights flash and buzzers buzz.

Or perhaps your shoes picked up some contamination that happened to be lying on the floor you walked over. Well, what now?

Remember the following procedure and use common sense:

(a) before you do anything else, contain the contamination by putting on disposable booties or cotton gloves (available at all interzonal monitors).

(b) inform the Work Control Area.

(c) you must decontaminate yourself ¾¾ but without spreading contamination on your way to the Change Room (for hands) or the Decontamination Centre (for boots).

(d) a contamination survey must be done to find the location and extent of the contamination.

(e) the contaminated area must be isolated to prevent uncontrolled traffic through it.

(f) the contaminated area must be cleaned up.

VENTILATION SYSTEMS

So far we have described how we minimize the spread of contamination by applying procedural controls. This lesson will describe the general principles governing the design and operation of ventilation systems to help control the spread of contamination.

In a conventional plant (i.e., non-nuclear), the ventilation system provides acceptably fresh air to people in the plant and is often used for heating and cooling. In addition to this, the ventilation system in a nuclear plant also has to do the following:

1) supply clean, uncontaminated air to people in the station;

2) prevent the spread of contamination throughout the plant;

3) clean up the air in a room or enclosure after it has been contaminated.

These objectives are achieved by certain design and operating principles which we will outline below.

CLOSED CYCLE VENTILATION

One method, which prevents spreading of airborne contamination and at the same time also supplies clean air for station staff, is to have separate ventilation systems for clean (i.e., contamination-free) and dirty areas. This approach is used in the Service Building at Point Lepreau; the ventilation system for the Control Room, for instance, is entirely separate from that used for the Spent Fuel Storage Bay.

Care must be taken in the design and operation of these systems to ensure that air does not flow or leak from a closed contaminated area (such as the Spent Fuel Storage Bay) to adjacent areas. This can be done by running the contaminated area at a slightly lower atmospheric pressure than the surrounding area. The usual method of achieving this is by adjusting ventilation dampers in such a way that more air is exhausted than is supplied through the intake. (The difference is made up by in-leakage through penetrations in the walls, such as doors, pipe runs, and cabling runs). If you keep the doors shut, the contaminated area will be at a slightly lower pressure than the rooms surrounding it.

The exhaust flow from contaminated areas is normally passed through air-cleaning units, whose design depends on what type of airborne contamination is expected.

PARALLEL VENTILATION

In parallel ventilation systems each room is fed with fresh air from a common source, which is then exhausted to a common stack.

During commissioning, the inlet and exhaust dampers in the ducts were adjusted to provide the proper air flow for each room. It is therefore very important not to play with these damper settings after the system has been set up. As before, the system cannot possibly operate correctly if doors, access hatches and what have we are left open. Furthermore, the doors at Point Lepreau also perform the function of fire doors - but only if they are closed!

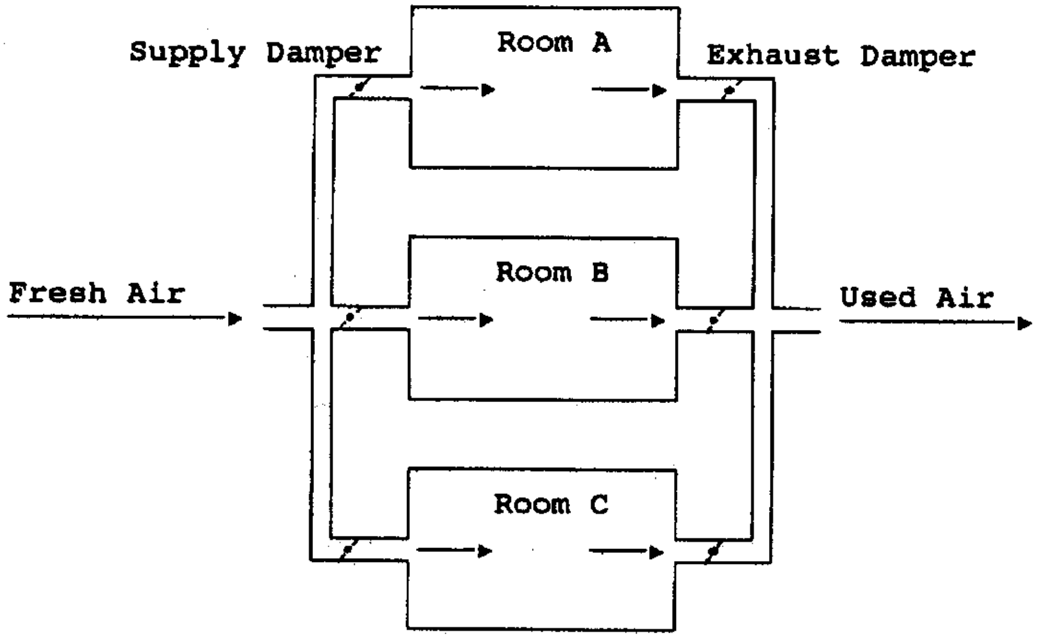


Fig. 9.17. Parallel Ventilation System

The designers try to provide a greater air flow through those rooms (such as the Decontamination Centre) where there is a larger chance of airborne contamination. Such rooms might have a designed air flow of as much as four or five complete air changes per hour, whereas other rooms less likely to be contaminated might have less than one air change per hour.

A fairly high flow rate through a room will ensure that if airborne contamination has been released, it will not persist for too long. This of course assumes that the source of the contamination is removed. If it isn't, then there is no way of guaranteeing clean air in a room even by having a very large number of air changes per hour. Other methods have to be used for operations which release activity routinely.

SERIES VENTILATION

The two types of ventilation design described above (quickly now, what were they?) provide excellent contamination control; however, in large plants it is very expensive to use these two principles only. Conditioned air exhausted from clean areas can be used to ventilate less clean (i.e., more likely to be contaminated) areas of the plant. This is the principle of ventilation used in the Reactor Building at Point Lepreau.

It is also used in the Service Building. For example, air flows from Room S-105 (Zone 2 corridor) to S-143 (Zone 3 Spent Fuel Bay Ventilation Exhaust Room), then via the central contaminated exhaust to the stack.

Again, it cannot be emphasized too often, that unless you keep the doors closed, such systems cannot work as intended. Indeed, it is not hard to imagine conditions caused by open doors or faulty damper settings that would result in air flowing from Zone 3 to Zone 2 rather than vice versa. In fact, this happened during the construction of the Spent Fuel Bay Extension. Doorways between the Extension, Storage Bay, Reception Bay and Crane Hall had been open ¾¾ when the outside door of the Extension was opened, winds pressurized the Reception Bay causing air to flow into the Crane Hall. This resulted in a lot of grief with the AECB.

HEAVY WATER VAPOUR RECOVERY SYSTEMS

Heavy water costs a lot of money. At the time I write this, it costs nearly $300/kg or 10 times as much as kitchen Scotch. (It used to be 16 times as much; thank your Provincial Government.) So, it is essential that heavy water vapour in the air be recovered rather than exhausted up the stack. Areas in the Reactor Building likely to contain D_2O vapour are not fed by the normal Reactor Building ventilation system, but instead have their own closed cycle system. The air exhausted from such rooms is passed through a drier, which removes 90% or more of the water vapour before the air returns to the room.

Our driers contain a material called molecular sieve*, which traps water vapour in the air passed through it. Before the sieve is saturated, it is regenerated by heating it. This drives off the trapped water vapour, which is blown through chillers to condense it. This condensed water is then fed to the D_2O collection system. (Molecular sieve is so called because it lets some molecules pass through it but traps others above a certain size. The molecular sieve we use comes in the form of small cylindrical beads of a few mm^3 in size).

Figure 9.18 shows a simplified diagram of the D_2O vapour recovery system for the Boiler Room. Air from the Boiler Room passes through one drier, while, at the same time, the other one is being regenerated. (Every several hours, they reverse roles automatically). The small drier shown is known as a "polishing" drier. Its purpose is to exhaust a small flow from the system in order to hold the Boiler Room atmosphere at a slightly negative pressure compared to its surroundings. At the same time, it further dries this air to minimize D_2O losses and the quantity of tritium discharged to the environment via the stack.

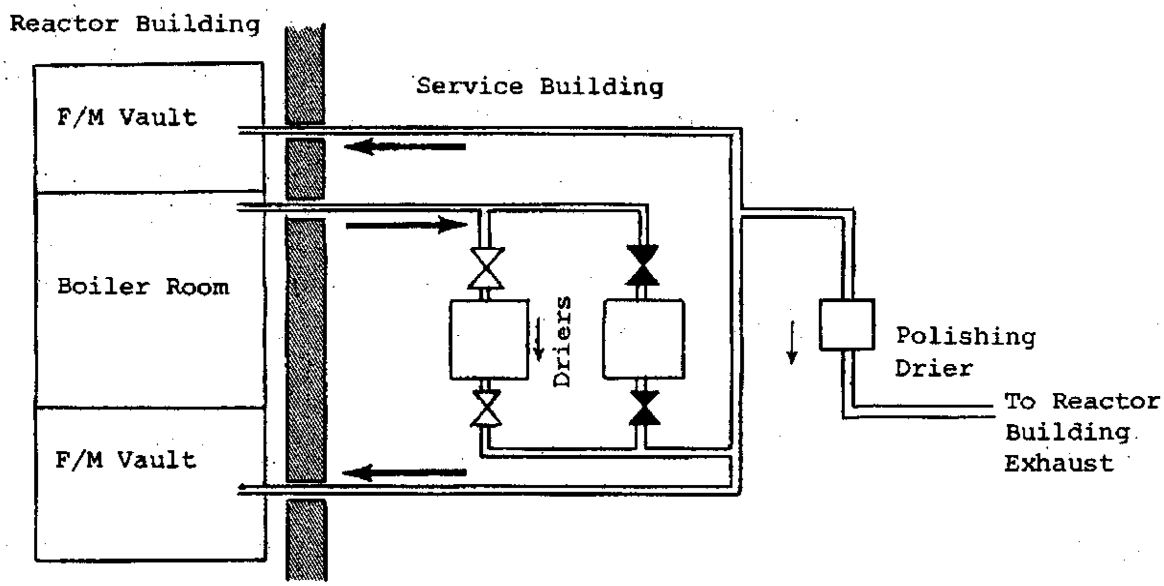


Fig. 9.18. D_2O Vapour Recovery System

Apart from recovering heavy water in the air, driers will reduce the ambient airborne tritium levels in the rooms they serve. For example, air at a dewpoint of -10°C holds only about 1/20th of the water vapour that air at a dewpoint of +30°C can hold. Consequently, the tritium level will be reduced in the same ratio.

Drier systems installed to serve the heat transport system areas will ensure a quick and uniform spread of noble gas releases throughout all Reactor Building rooms served by them. However, they will absorb airborne particulates to some extent. When the driers are opened up for maintenance, beware of airborne and surface contamination.

LOCAL VENTILATION SYSTEMS

These are used to prevent the spread of localized releases to the rest of the atmosphere. They can be provided by the building design or set up as needed, and are effective for D_2O sampling and handling areas, decontamination and some maintenance work.

FUME HOODS

Figure 9.19 shows a fume hood used for the decontamination of small items. The front window can be raised to provide working space and to permit items to be transferred to and from the fume hood. A fume hood normally has its own exhaust fan which draws air in through the opening at the front at a speed of 0.5 to 1 m/s. Too low a flow may permit leakage out of the hood, and too high a flow blows all the crap around inside it. The exhaust flow from the hood should be filtered and then passed to the main building exhaust.

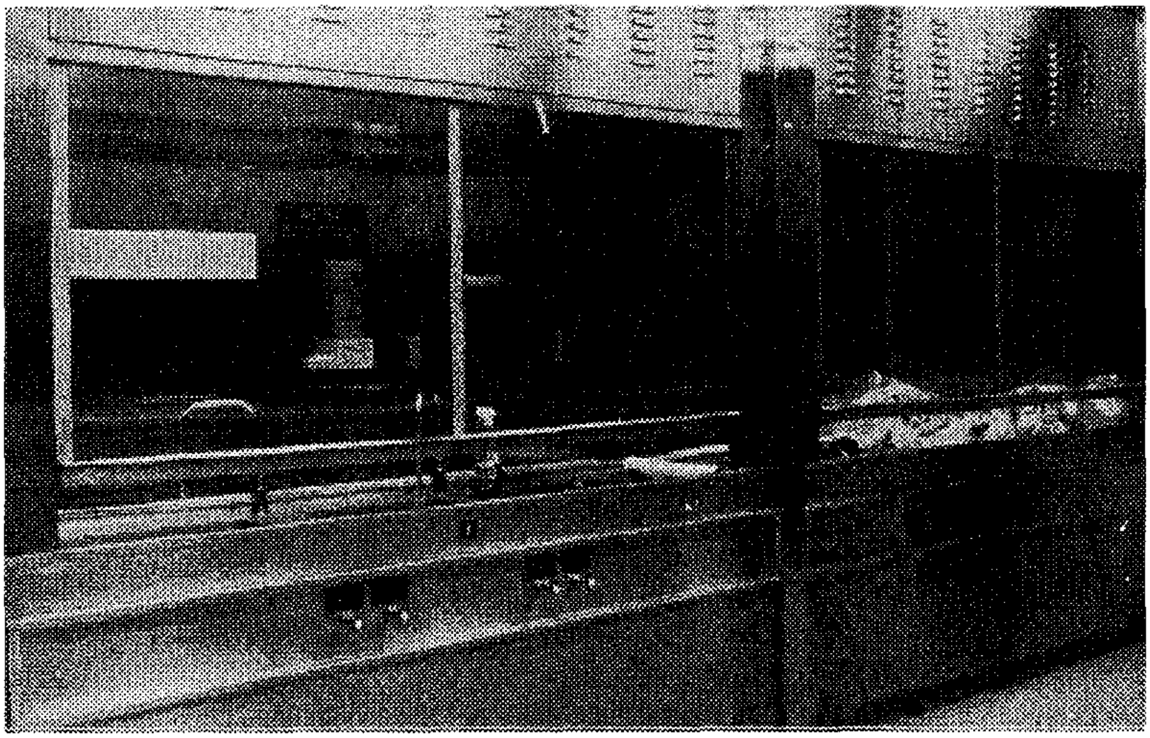


Fig. 9.19. A Fume Hood

PORTABLE LOCAL VENTILATION

Sometimes a contamination source arises that was not foreseen in the initial plant design. Or, we may not have wanted to install permanent local ventilation in areas where operations causing airborne contamination occur only rarely.

In these cases we often erect plastic tents at the site. There are many ways of doing this - Figure 9.20 shows one of them.

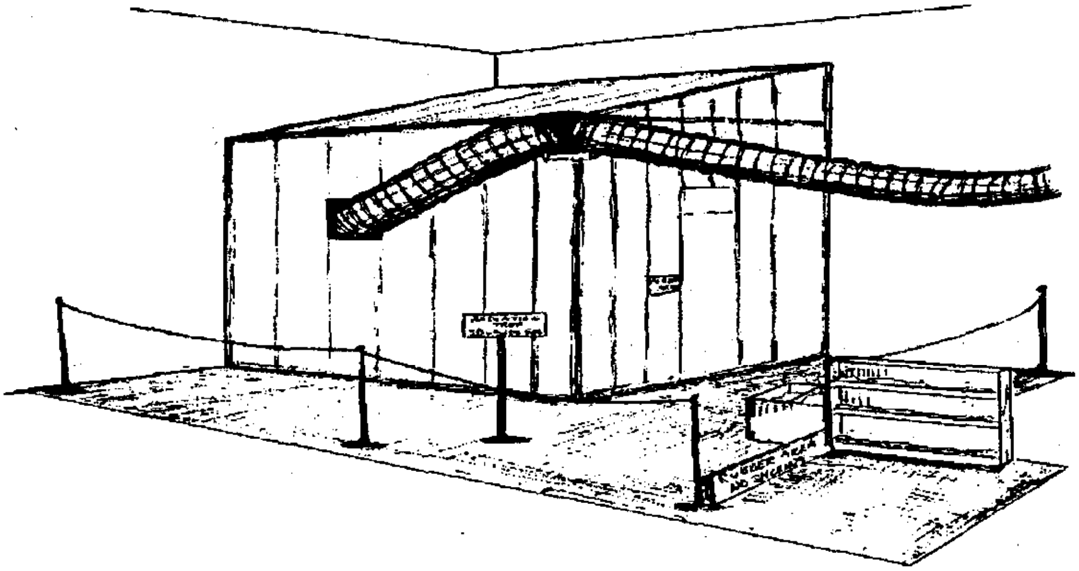


Fig. 9.20. Temporary Local Ventilation

All of them require an air exhaust duct such as "elephant trunking". This is connected to ventilation exhaust ducts, so that the suction is provided by the system exhaust fans. We also have a " super-sucker" to help the fans.

PROTECTIVE CLOTHING

Protective clothing provides the wearer protection from loose contamination, and limits the spread of contamination when the proper procedures are followed.

Protective clothing should be worn whenever work is done in an area where radioactive contamination may exist. Since the contamination can be found in many forms (loose particulates, liquids, vapours), we have quite a variety of protective clothing. It ranges in complexity from ordinary coveralls to vapour-proof plastic suits that have their own air supply fed from breathing air headers located throughout the station.

ROUTINE CLOTHING CHANGE (BROWNS)

As a daily routine, most workers in Zones 2 and 3 change from street clothing into active area work clothes. This is done in the Change Room (we've been there on page 402).

Our active area clothing, known as "Browns", consists of brown cotton coveralls, underwear, socks and active area safety shoes. In addition, we have blue flameproof coveralls for welders, and brown parkas and thermal underwear for winter use. No personal clothing at all is worn with Browns.
Figure 9.21 shows a gentleman resplendently clad in Browns. For accessories, like all smart Radiation Workers, he has selected his TLD badge, DRD, safety glasses, hard hat, and a gamma meter. Ladies wear the same, except that their physiological niceties have been recognized with more suitable underwear.

This clothing will protect most of your skin from contact with loose contamination. The spread of loose contamination via Browns is limited by confining this clothing to the site, and excluding it from Zone 1. In addition, you must remove any protective clothing worn with Browns before you leave the actual work location or Rubber Area where you are doing your thing.

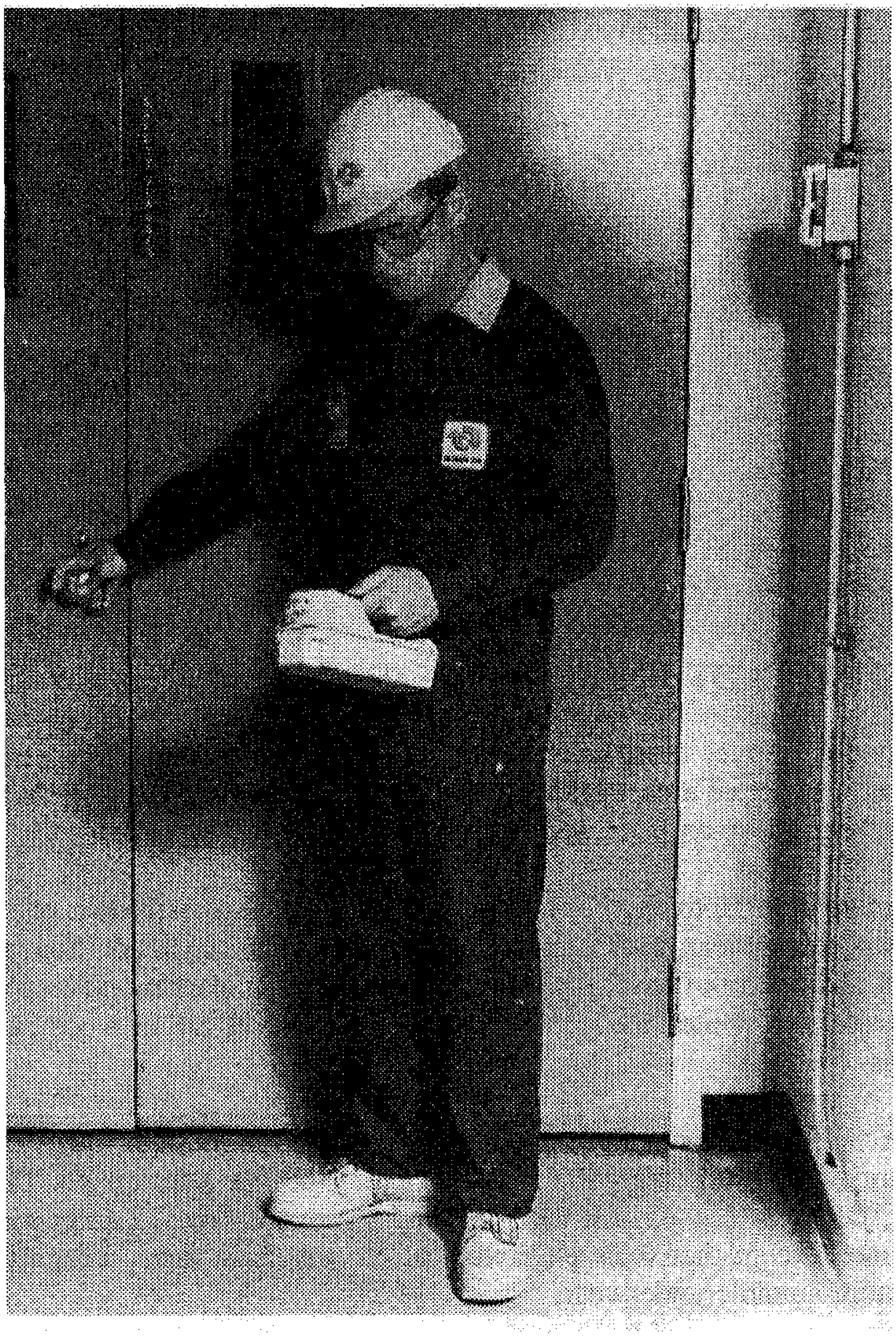


Fig. 9.21. Fully Dressed in Browns

When you return to the Change Room, if you suspect that your Browns may be contaminated, frisk them. If the clothing is contaminated, put it in the "contaminated" carts provided. If it is clean, hang it on the hooks assigned to you and re-use it for the rest of the shift. At the end of your shift, zip up the Browns, and put all the clothing into the appropriate bins for laundering. You are not allowed to mix active area underwear with your street clothes (i.e., during lunch breaks). This would defeat the purpose of keeping personal and active area clothing segregated.

Finally, running TLDs and DRDs through the wash tends to ruin them, so please remove them from the Browns before you leave the Change Room.

If your hands are contaminated, you can scrub them in the wash fountain. If any other part of you is contaminated, you must take a shower and use the frisker near the showers before dressing in your street clothes.

OTHER CLOTHING

Lab Coats

Lab coats are provided to protect the personal clothing of employees from chemicals and other nuisance substances. They shall not be used for protection against radioactive contamination. It is intended that lab coats be worn in the Chemistry Lab, Health Physics Lab, Stores, photocopier areas, etc. Brown lab coats (shown in Fig. 9.22) are provided for areas inside the inner security fence. They shall not be worn in Zone 3, except for the Chemistry Lab. Green lab coats are provided for use in Zone 1.

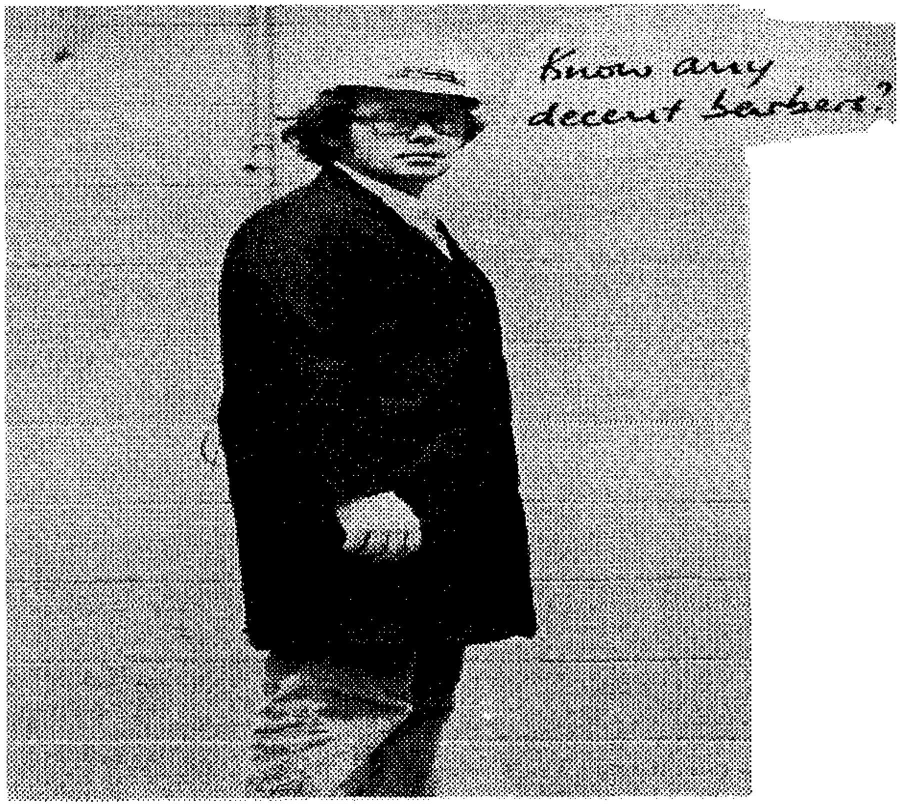


Fig. 9.22. Brown Lab Coat

Disposable Coveralls

Disposable coveralls are shown in Fig. 9.23. They are used for extra protection against high levels of loose, dry contamination.

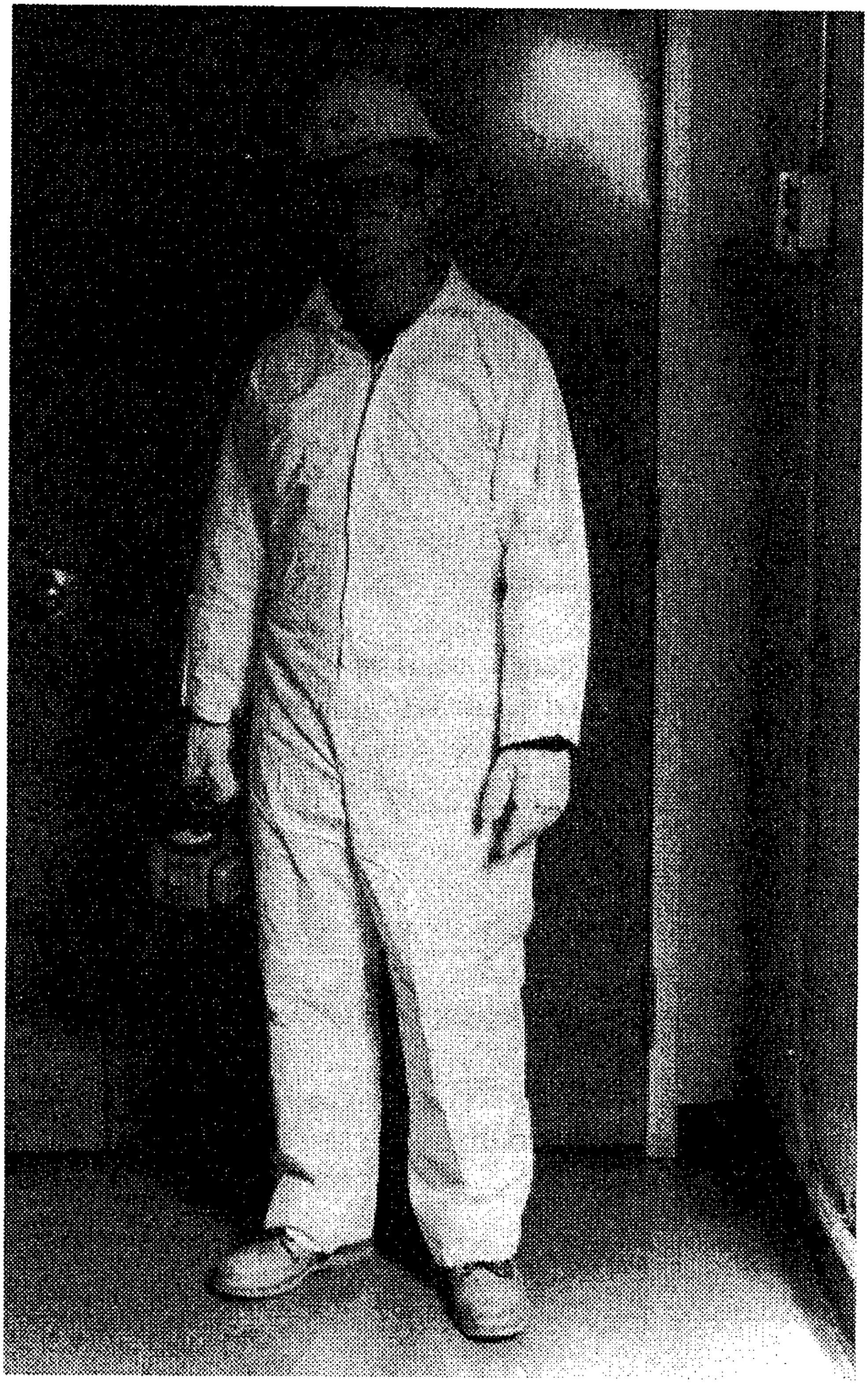


Fig. 9.23. Disposable Coveralls

Disposable coveralls shall only be worn over Browns in Rubber Areas or Rubber Change Areas. Disposable booties may be worn with the coveralls but shoe covers shall be worn over the booties. In addition, disposable booties are provided at interzonal monitors to cover your shoes if they are contaminated. Take care when walking in disposable booties as they are quite slippery.

When there is a possibility of becoming grossly contaminated, wear disposable coveralls over Browns. They are not intended to be a substitute for Browns. However, disposable coveralls may also be worn over personal clothing in the following two circumstances:

1) Occasionally, entries must be made to areas on very short notice, and protection against contamination is required for personal clothing. Disposable coveralls would then be put on immediately before entry and removed immediately after exit.

2) Disposable coveralls can be worn over personal clothing when you are working in a dirty environment (e.g., oil, grease, etc.). They should be removed immediately after you leave the dirty area.

Gloves

The correct type of glove must be worn when you work with contamination. We have quite a selection, ranging from cotton gloves to shielded gauntlets. The choice will depend on the work and the conditions.

Cotton Gloves are used only for dry contamination. These are also kept at the interzonal monitors, so that you can contain contamination detected on your hands.

We also have a slightly heavier-duty version treated with a light vinyl coating. Some people prefer them because they tend to fit better.

Rubber Gloves are for wet conditions and for use with plastic suits. They are ordinary household rubber gloves.

Surgical Rubber Gloves are worn for delicate work where a sense of touch is needed. You must be careful not to damage these thin gloves.

Shielded Gauntlets loaded with lead are available from Stores for work in high beta fields.

Fig. 9.24 shows the types of gloves found at Point Lepreau. Rubber gloves should be checked for defects before you put them on (one way of doing this is to slightly inflate them and then squeeze them to check that they don't leak). Used rubber gloves are laundered, tested, and put back in general service, but we always use new ones for plastic suits.

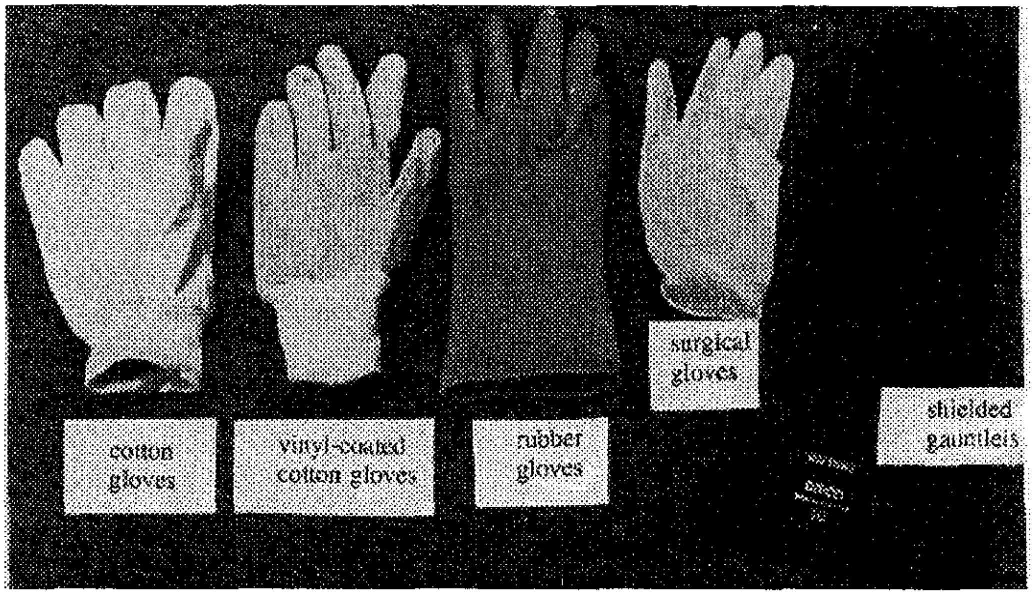


Fig. 9.24. Gloves Used at Point Lepreau

Footwear

Safety shoes or boots with distinctive markings are worn with Browns. You will be issued your own Radiation Area safety shoes, which you will keep on your assigned rack in the Change Room.

In addition, we have rubbers, re-usable booties and disposable booties. Fig. 9.25 shows the standard items worn at Point Lepreau.

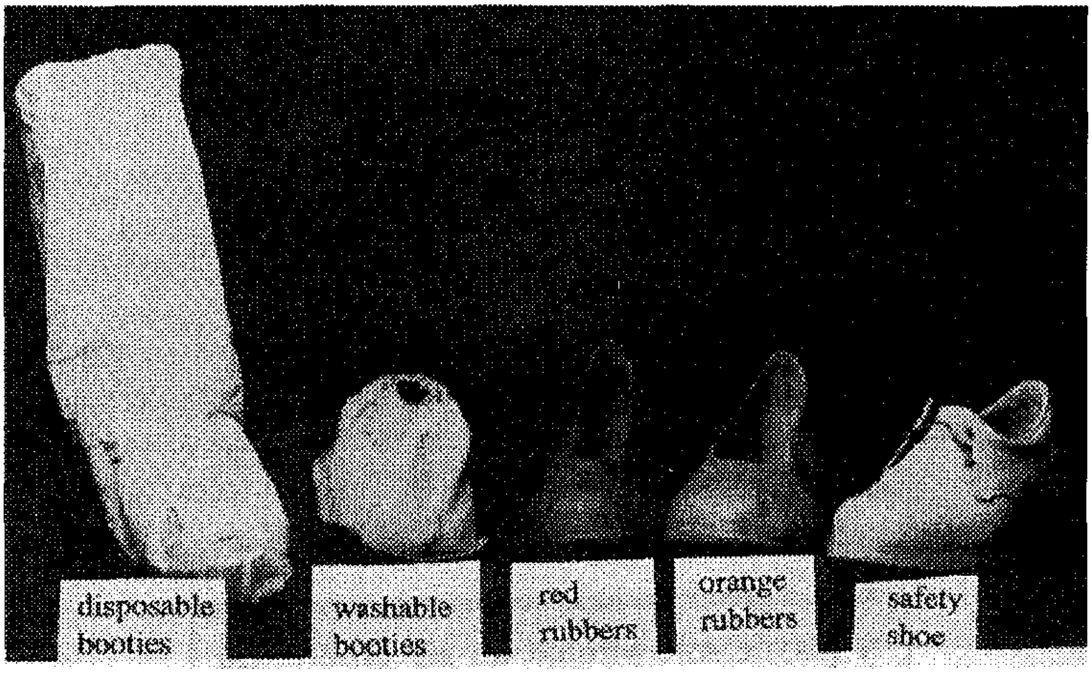


Fig. 9.25. Footwear Used at Point Lepreau

Plastic Suits

A plastic suit is not the latest fad for people with kinky sartorial requirements. It is a yellow PVC coverall worn with a hood and supplied with air to provide cooling and breathing air, as shown in Figures 9.26 and 9.27.

Plastic suits are the only protective clothing suitable for use in tritiated atmospheres. Whenever we say plastic suit, we mean plastic suit plus hood. This combination is also called "plastics". Plastics are also worn in areas with high levels of loose, airborne particulate or radioiodine contamination.

A plastic suit without an air supply will not provide protection against anything.

The air supply maintains the suit at a positive pressure. Air is distributed within the suit by a system of ducts to the head, trunk, arms, and legs, and exits down through the hood. It provides breathing air, flushes out any contamination that has penetrated the suit and keeps the wearer cool.

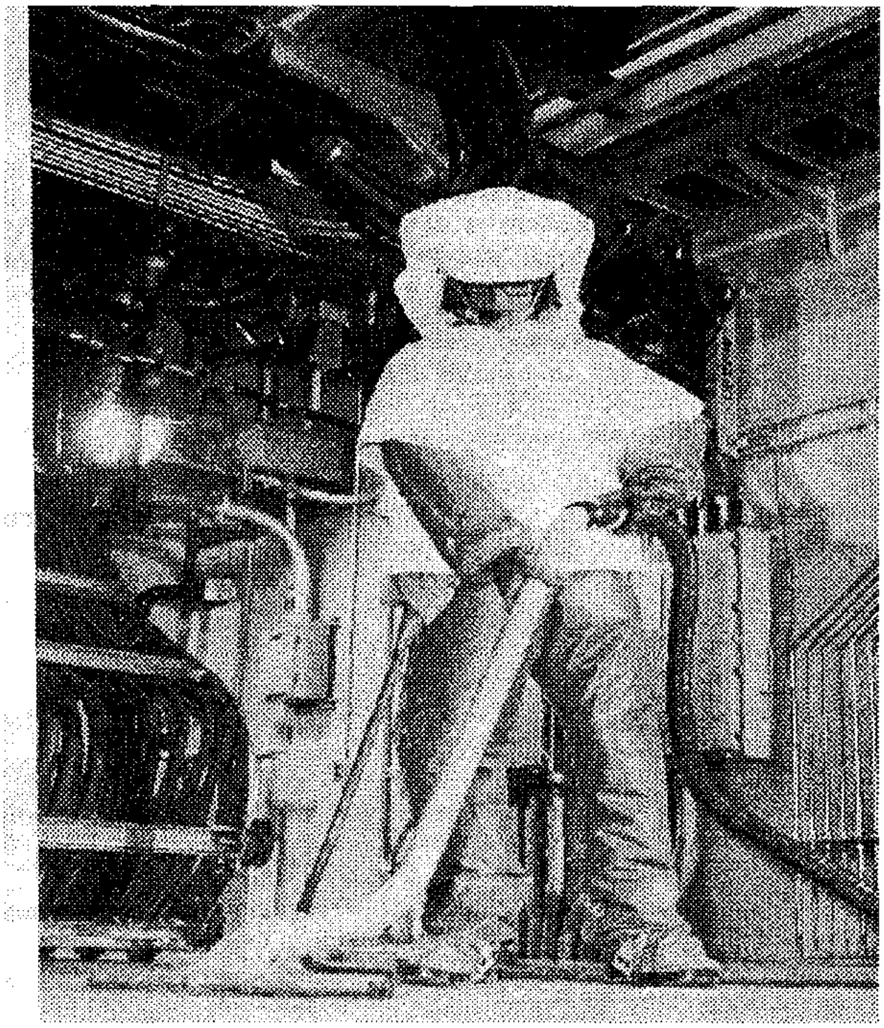


Fig. 9.26. "Plastics"

You will recall that tritium enters the body through inhalation and by absorption through the skin. The degree of protection a plastic suit can provide in a tritium atmosphere is described by the **Protection Factor (PF).** Strictly speaking, the PF for a plastic suit applies only to tritium and is defined as

$$\mathbf{PF} = \frac{\textbf{Tritium Uptake Without Protection}}{\textbf{Tritium Uptake With Protection}}$$

As an example of the use of PFs, consider a situation where you must work for 2 hours in a tritiated atmosphere of 2 mSv/h.

If you wear no protection, your committed dose will be
    2 mSv/h x 2 h = <u>4 mSv</u>.

If you wear a plastic suit with a PF of 100, your committed dose will be
    2 mSv/h x 2 h/100 = <u>0.04 mSv</u>.

In other words, your committed dose is only 1/100th of what it would have been with no protection.

In this exercise, we assumed a PF of 100. The actual protection factor can vary quite a bit, depending on how the suit is used.

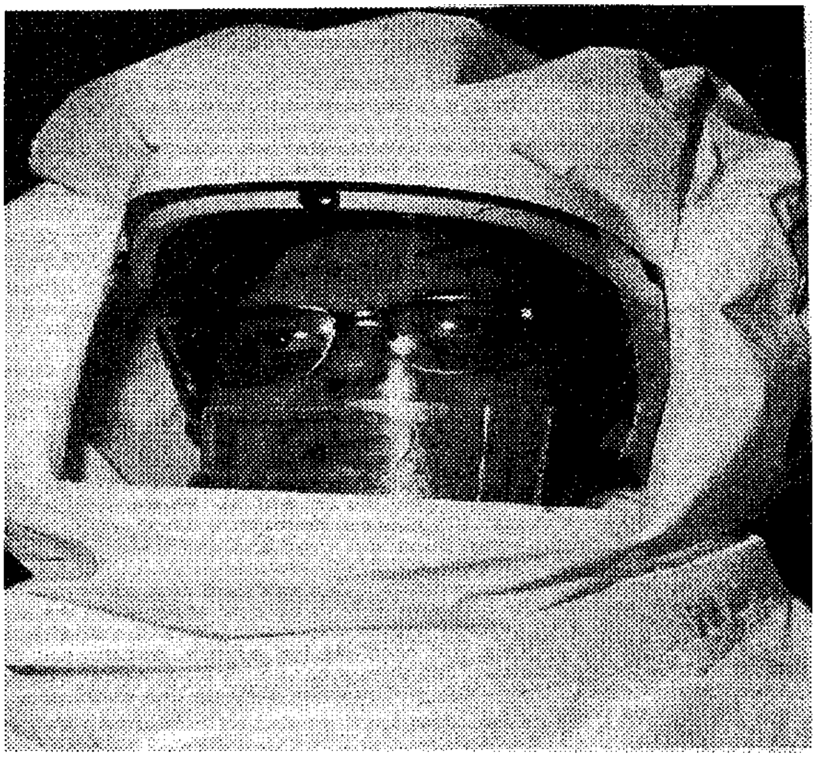


Fig. 9.27. Close-Up of Hood

Wearing the Suit

a) The suit must be worn with the hood, gloves and air supply.

b) The hood is not to be removed at any time.

c) The air supply is to be available and connected continuously from the time the tritiated atmosphere is entered until the area is vacated.

d) If the suit is ripped, you lose protection. You should change the suit, or at least tape the rip if it is impractical to leave the area.

The single most important thing to remember whenever you wear an air-supplied plastic suit is to establish and maintain the air supply. Nothing should be done to decrease the integrity of the suit. Do not lift the hood, work without gloves, cut, rip or otherwise change the suit. The air-supplied suit is a complete protection system. If you change the components or operating procedure, the system will not give the desired protection, and many cases it will give you **no protection**.

Plastic suits must be worn
a) in tritium concentrations above 500 μSv/h,
b) when working with moderator water,
c) when working with PHT spills of 1 L or more.

Protection factors as high as 1000 have been measured under ideal conditions. In practice, you should be able to achieve PFs of at least 100. The more careful you are, the higher the PF will be. Plastic suits are our best defence against tritium: if you are in doubt as to whether you should wear one or not, do the smart thing and wear it.

When a plastic suit has been worn in a contaminated area, take care not to spread any contamination that may have become attached to the suit. You may pick up a significant tritium exposure during the undressing procedure. Get out of your suit carefully but quickly, put the suit and airline in a plastic storage bag, and then check yourself for contamination. Leave the undressing area. You will practise dressing and undressing in the Applications course.

We have communications equipment, consisting of earphones and a microphone, which can be used with the suit. The connectors and wires are built into the air hoses and distribution harness. This communications equipment lets you talk to others in your work group and also permits you to be patched into the plant telephone system; so don't lift the hood, there is no need for it.

The plastic suit has been designed so that a safety harness can be worn under it. The D-ring of the harness is accessed through a back pocket of the suit, but you will need help to attach the safety lanyard to the D-ring.

RESPIRATORY PROTECTION

During your work at Point Lepreau, you may have occasion to enter areas of airborne contamination. Respiratory equipment must then be worn for protection against high intakes of airborne contamination. The protective equipment we have available for your use is described below, as well as its limitations.

Respiratory protective devices vary in design, application, and the degree of protection they provide. As well as assessing the airborne hazard, you must know the limitations of the available equipment so that you can select the appropriate type for the conditions you have identified.

There are three types of respiratory protective devices at Point Lepreau. They are:

1. **Air-Purifying Respirators**
   Air-purifying respirators provide a filtering action to the air as it is drawn through the device under lung power.
2. **Air-Supplied Equipment**
   Air-supplied equipment is supplied with clean air from a separate source. The air source is the Breathing Air System.
3. **Self-Contained Breathing Apparatus (SCBA)**
   Self-contained breathing apparatus is a type of air-supplied equipment. The difference is that the user carries his air supply around with him in the form of compressed-air cylinders strapped to his back.

Each of these classes has its advantages and disadvantages. Before you can choose which equipment to use, you must know the degree of protection each provides for the various airborne hazards.

PROTECTION FACTORS

The Protection Factor (PF) of a respirator is a measure of the amount of protection it will provide against a specific hazard. It can be defined as

$$\boxed{\mathbf{PF} = \frac{\textbf{Uptake Without Respirator}}{\textbf{Uptake With Respirator}}}$$

What's the difference between this definition and the one given on p. 420 for plastics? The plastics PF applied to tritium only, but the respirator PF applies to any airborne hazard. A word of warning here. The PF of a particular respirator will not be the same for all the airborne hazards that you are likely to meet. For example, normal air-purifying respirators do not give any protection at all against tritium, although they are very effective against particulates.

AIR-PURIFYING RESPIRATORS

Air-purifying respirators have been around ever since the days when the Romans used them in lead and gypsum mines. Of course, their design and efficiency have been improved enormously, but the basic concept has remained unchanged. (You needn't worry unless you find one with the expiry date written in Roman numerals.)

Air-purifying respirators, often called cartridge respirators, remove contaminants from inhaled air. This is done by mechanical filtration of particles as well as chemical removal of specific vapours and gases. The respirators used for radiation work at Point Lepreau contain a filter cartridge known as a TEDA(H) cartridge. It includes an absolute filter to remove particulates and an activated charcoal filter to remove radioiodine.

Activated charcoal means charcoal impregnated with a chemical called TEDA to improve the removal efficiency for radioiodine. For those of you who wish to assimilate useless information, TEDA stands for "triethylenediamine". The H in TEDA(H) stands for high efficiency.

Air-purifying respirators at Point Lepreau all operate in the negative pressure mode. This means that negative pressure is created inside the respirator when you inhale, and this causes the air to be sucked in through the filter cartridge. When air is inhaled, then, any defects in the mask or a poor face seal will allow contaminants to leak into the respirator.

The two types of respirator masks we have at Point Lepreau are **full-face** and **half-face**.

Figure 9.28 shows the full-face respirator. The mask is a light-weight, full-facepiece unit with an interchangeable inlet receptacle. It has a hairnet type head harness. With a suitable inlet connector, it can be used in all three modes, i.e., air-purifying, air-supplied and SCBA. This mask is stocked in one size only at Point Lepreau.

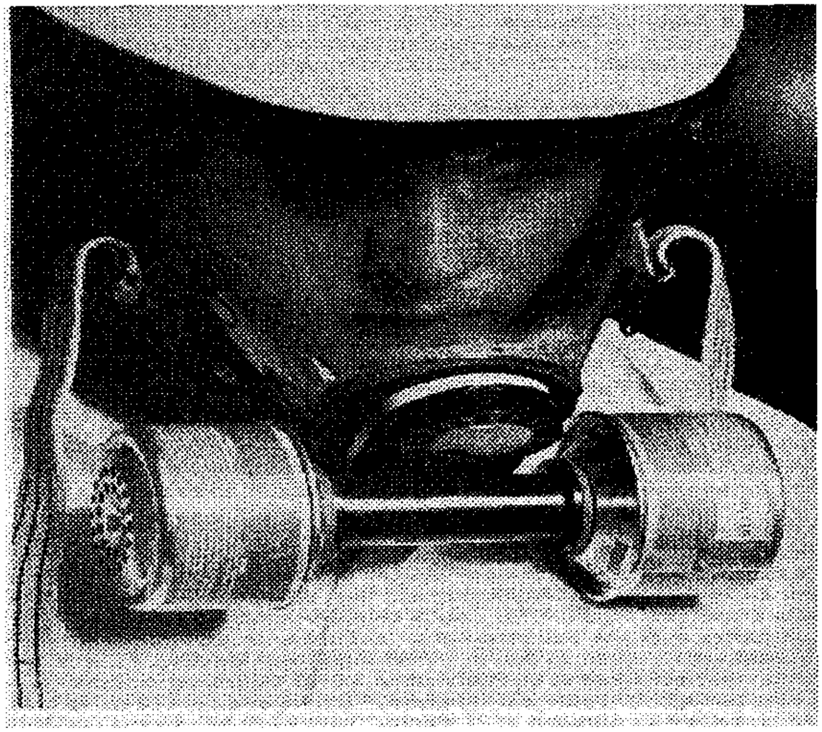


Fig. 9.28. Full-Face Cartridge Respirator

A half-face respirator is shown in Figure 9.29. The mask is a half-facepiece unit with a two-strap head harness. It is available in two designs: one with two cartridge receptacles, and the other with a connection for an airline hose. Both designs are available in three sizes.

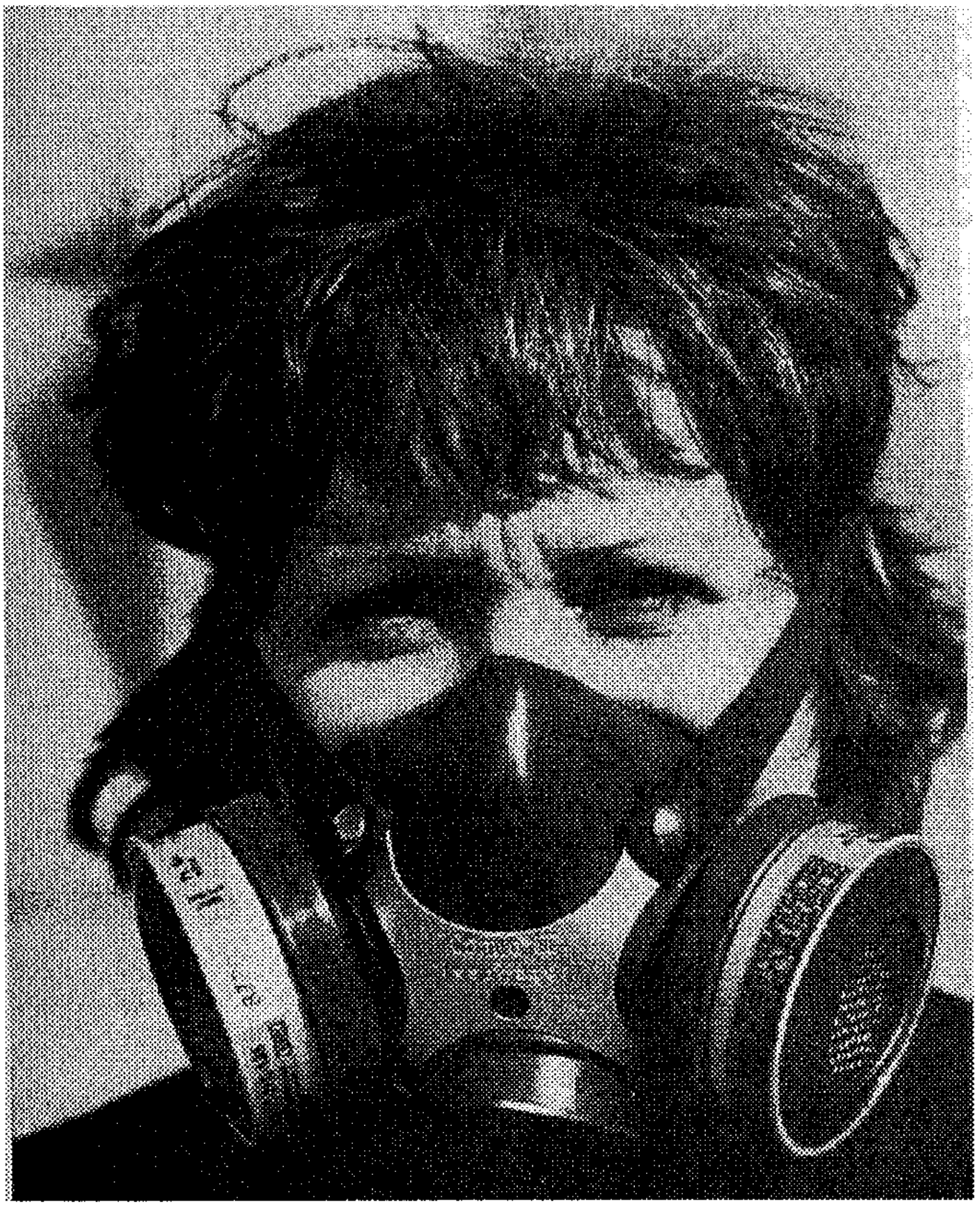


Fig. 9.29. Half-Face Cartridge Respirator

A **Stephenson** bottle (dreamt up by John Stephenson of Ontario Hydro's Health Physics Department) can be attached to either respirator to provide protection against tritiated water vapour. This plastic bottle is filled with wet chunks of sieved vermiculite, and then is attached to the facepiece with a hose (see Figure 9.30). Air is sucked in at the bottom of the bottle and passes over the wet vermiculite on its way to the facepiece. The tritiated water vapour in this air interchanges with the clean water in the bottle - the net result is that only about 3% of the tritium concentration passes through the bottle and is inhaled. This respirator is effective until the bottle becomes loaded with tritium. In practice this means that it is O.K. for up to an hour of use, after which time you'd have to change the vermiculite.

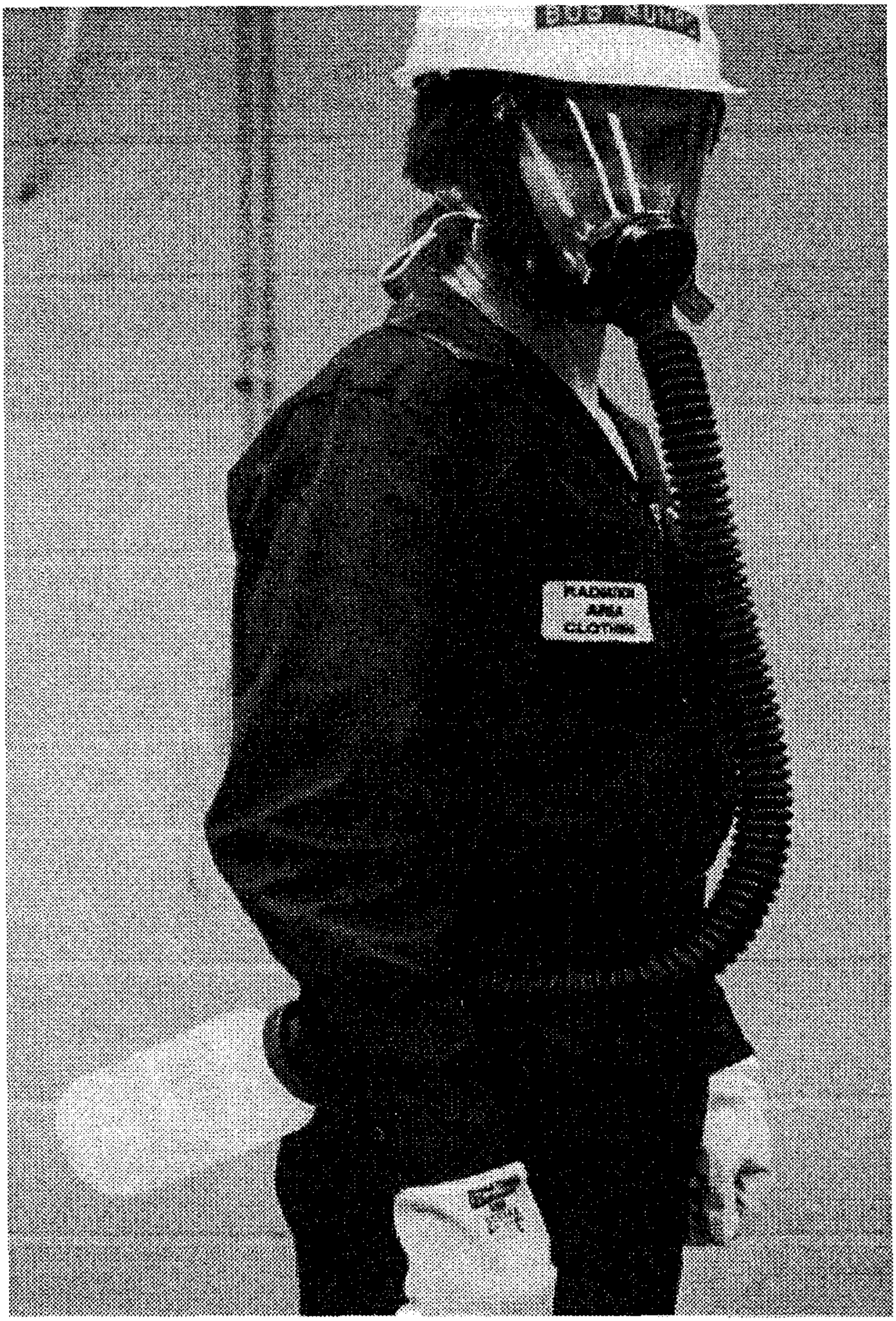


Fig. 9.30. The Stephenson Respirator

There is another respirator available for protection in tritiated atmospheres. The **tritium cartridge** respirator consists of a pair of cartridges, containing dampened charcoal, that attach to a special half-face mask. The cartridges can be used for one or two hours, and are at least as effective as a Stephenson respirator.

The PF of the tritium respirators is 3, because although the inhalation route is virtually eliminated, tritiated water vapour will still diffuse through the skin. This means that the intake is reduced to one third.

In general, air-purifying respirators are used if mobility is needed. Otherwise, it is usually better to wear an air-supplied respirator or an air-supplied hood.

The major limitation of all our air-purifying respirators is that they only remove certain contaminants from the air. They must **never** be used in atmospheres that are deficient in oxygen (fire-fighting, for example); it is well known that oxygen deficiency leads to death.

AIR-SUPPLIED EQUIPMENT (AIR MASKS)

Air-supplied devices may seem like a modern invention, but they were first developed in the 18th century and were in commercial use by the 19th.

Air-supplied respirators, also called air masks, use pressurized air from an external source supplied to the face-piece. The source of air is the Breathing Air System, which feeds air headers throughout the station. An airline connected between the air mask and an air header supplies a continuous air flow to the facepiece. This maintains the facepiece at a positive pressure, thereby preventing the entry of contaminants during inhalation.

Both full-face and half-face masks may be used with airlines; both require modifications to the inlet receptacle. People whose facial hair or glasses prevents an efficient facepiece-to-face seal are not permitted by law to wear a respirator. They must wear an air-supplied hood or plastics.

One problem with air masks or air-supplied hoods is that you are restricted to an area dictated by the length of the airline (about 15 m long - even young workers can be plagued by a receding airline). Also, should the air supply fail (loss of system air, kinked airline, header disconnection), you will have no protection. For this latter reason, you must **NEVER** use an air mask in atmospheres immediately dangerous to life or health (for example, chlorine atmospheres or fires).

SELF-CONTAINED BREATHING APPARATUS (SCBA)

For dangerous atmospheres we use SCBA respirators fed from their own supply of air. They are the only form of respiratory protection approved for fire-fighting at Point Lepreau.

In a SCBA, exhaled breath is exhausted from the facepiece through a check valve to the ambient atmosphere and is replaced by stored air. The Scott Air Pak (don't blame me, that's how they spell it) is an open circuit SCBA. It is of the "pressure demand" type; this means that a very slight positive pressure is maintained inside the facepiece to provide a high degree of protection. This is the only type of SCBA we have at PLGS.

The advantages of air packs are that they provide mobility and excellent protection; the disadvantages are that the air supply is limited (about 30 minutes for a Scott Air Pak) and that they can be awkward to wear in confined spaces. Also, they are quite heavy - just ask Roger Steed. Figure 9.31 shows a Scott Air Pak being worn.

SUGGESTED PROTECTION FACTORS

For air-purifying respirators intended to protect against particulates, gases and vapours other than tritium, we suggest PFs of 10 for half-face masks and 50 for full-face masks. Whether a full or half-face masks gives a better seal depends entirely on the shape of your face. This is why we "fit test" employees to find out which masks fits them best.

For air-supplied respirators a range of protection factors might apply, depending on how you adjust the air flow. If the air flow is only enough for providing inhalation needs, it is of no more benefit than an air-purifying type. If the air flow is sufficient to keep the facepiece at a positive pressure, it is difficult for contaminants to enter (even with a less than perfect seal), and the PFs should be 100 or more.

Fig. 9.31. A Distinguished Citizen Modelling the Scott Air Pak.

Table 9.2 below lists the recommended PFs for the respirator types in use at Point Lepreau.

TABLE 9.2. PROTECTION FACTORS

Respirator Type	Protection Factor		
	Tritium	Particulates	Gases & Vapours
AIR PURIFYING			
Disposable Dust Mask	NP	5	NP
Half-Face (Cartridge)	NP	10	10
Full-Face (Cartridge)	NP	50	50
Stephenson, Tritium Cartridge	3	NP	NP
AIR-SUPPLIED			
Plastic Suit	100+	100+	100+
Dispoable Hood	3	100+	100+
Half-Face	3	10 to 100+	10 to 100+
Full-Face	3	50 to 100+	50 to 100+
SCBA (Pressure Demand)	3	10,000	10,000

NP means No Protection; 100+ means that a PF of up to a 1000 may be obtainable under ideal conditions.

The range of PFs given for air masks depends on the amount of air flow, as explained above.

Air-supplied respirators and hoods have a PF of 3 for tritium. As explained on page 429, even with perfect breathing protection against tritium, one third of the tritium uptake through the skin remains. The PF can't be better than 3.

Our plastic suit can deliver a PF of 1000 under ideal conditions. If you use it properly, you should not do worse than 100 in practical use.

Plastics protection against particulates and radioiodine should be higher than for tritium, because for them the skin absorption route does not exist. For the sake of simplicity, we assume that the same PF of at least 100 applies throughout.

"Pressure Demand" air packs give PFs equal to 10,000 or more for particulates and radioiodines, but of course, for tritium you are still limited to a PF of 3.

RESPIRATORY HAZARDS

The respiratory hazards found at Point Lepreau can be classified as radiation hazards (i.e., airborne contamination) or conventional hazards. Mixtures of both may also occur.

RADIATION HAZARDS	CONVENTIONAL HAZARDS
Tritiated water vapour	Oxygen deficiency
Radioiodine vapour	Chlorine gas
Radioactive particulates	Hydrocarbon vapours
Radioactive noble gases	Dusts and welding fumes
	Smoke and Toxic Gases

Each hazard has certain properties you need to consider when selecting suitable protection.

Tritium

The best protection you will achieve with air supplied, tritium cartridge or Stephenson respirators is only a factor of 3. The only way to reduce the skin absorption is by wearing plastics. You must wear plastics for work in atmospheres containing more than 500 uSv/h, for work involving moderator water, or for PHT spills greater than 1 L.

Radioiodine

Radioiodine passes through conventional filters. TEDA impregnated charcoal filters are needed to remove it.

Particulates

All respirators, except the Stephenson and the tritium cartridge, used for radiation work at Point Lepreau give reasonable protection against inhalation of particulates. However, for work in high concentrations of particulates, e.g., in the Spent Fuel Discharge Bay after the discharge of defective fuel, it is best to wear a plastic suit. This will give good respiratory protection, while at the same time preventing skin and hair contamination. The same applies for radioiodine.

Noble Gases

Noble gases are not an internal hazard, because any noble gases you inhale will be exhaled again. It is possible for trace amounts to dissolve in the blood, but such noble gas concentrations in the blood give only a negligible dose. The internal exposure from dissolved noble gases amounts to about one thousandth of the external exposure.

Oxygen Deficiency

Oxygen deficient atmospheres are a life-threatening hazard. The **only** protection that may be worn is Self-Contained Breathing Apparatus.

Chlorine Gas

Chlorine gas is a life-threatening hazard. It can also react with both body perspiration and moisture in the air to form a corrosive acid. At 1 ppm you must wear a SCBA, and in emergency concentrations of 1% or more (e.g., during a chlorine leak), a special chemical suit must also be worn to prevent skin contact.

Smoke and Toxic Gases

Both of these hazards are life threatening. SCBA is the <u>only</u> appropriate form of respiratory protection. At Point Lepreau you are likely to encounter these hazards only when fire-fighting. Do not enter atmospheres dangerous to life or health unless you are wearing a functional SCBA

Hydrocarbon Vapours, Dusts and Welding Fumes

The TEDA(H) cartridge has a high efficiency filter and is therefore effective in removing dusts, fumes and mists from the air. The cartridge is not as good at removing hydrocarbon vapours, although it will provide some protection against low concentrations of organic vapours. Canisters that have been specifically designed to give protection against organic vapours are available from Radiation Control. These canisters are for use with the full-face mask.

If there is any doubt about the ability of the normal TEDA(H) cartridges to remove a particular contaminant from the air, and if the contaminant is not immediately hazardous to life or health, use an air-supplied respirator or hood. Finally, if you have any problems regarding the selection or use of respiratory equipment, ask the lads in Radiation Control for advice.

RESPIRATOR FIT TESTING

A respirator fit test checks that workers receive an effective and comfortable fit when wearing respirators. This test is done for those who need to wear respirators at Point Lepreau.

The test consists of wearing respirators hooked up to a special monitor. While wearing each respirator, you do a short series of exercises. Facepiece leakage during these exercises is recorded.

Each person will thus determine which respirator provides the most comfortable fit and what PF is achieved when he is wearing it. Respirator fit can be affected by:

a) A change in body weight of 6 kg or more.
b) Dental surgery involving the removal of 3 or more teeth.
c) Growth of hair or stubble near the respirator seal.
d) Any change in facial conditions.

RESPIRATOR MAINTENANCE

The purpose of the maintenance program is to ensure that respiratory protective equipment is kept in a state of readiness for use.

After use, respiratory equipment is washed, monitored, inspected, repaired or serviced as necessary, and disinfected. Equipment is stored in clean plastic bags for reissue. This job is done by Service Maintenance.

TABLE 9.3. SUMMARY OF RESPIRATORY PROTECTION

RESPIRATOR	PROTECTS AGAINST	LIMITATIONS	COMMENTS
Air-Purifying	Low levels of tritium, Particulates, Radioiodines, Dusts & Fumes, Hydrocarbon Vapours.	Not to be used in IDLH atmospheres, not to be worn with beards.	Must select correct cartridge for each hazard.
Air-Supplied Respirator, or Hood	Same as above.	Non-IDLH.	Limited mobility.
Plastics	Higher levels of above.	Non-IDLH.	Limited mobility, potential for heat stress.
SCBA	Life-threatening hazards (IDLH).	30 minute air supply, not to be worn with beards or glasses.	Used for emergencies and training only.

NOTE: TEDA(H) cartridges provide no protection against tritiated atmospheres. Stephenson, tritium cartridge, air-supplied respirators, and SCBA have a protection factor of 3 for tritiated atmospheres.

DECONTAMINATION

During Point Lepreau's operation, it is inevitable that many items of equipment, and also tools, work areas, clothing, and even people will become contaminated - that is, a layer of radioactive material becomes attached to surfaces. This surface contamination must be removed. DECONTAMINATION serves two purposes:

1. It eliminates the health hazard of internal and external radiation. Loose contamination must be cleaned up.

2. It salvages equipment that, because of the surface contamination on it, would otherwise be sent to active waste rather than for repair.

In the remainder of this chapter, we will discuss the decontamination methods that you can use and also the principles of protection that you will follow in using these methods.

DECONTAMINATION METHODS

The methods for removal of radioactive contamination are similar to methods used to remove ordinary dirt, but the required degree of cleanliness is much greater. Small amounts of contamination, which would be completely negligible from an ordinary cleanliness point of view, may still present a radiation hazard.

Apart from this distinction, the processes used in decontamination are the same as those used for industrial cleaning. Namely, soil or contamination is removed by chemicals such as detergents, or by physically removing the contaminated surface (e.g., by abrasives).

Contamination on the surface of an object may be attached either loosely or firmly, hence the terms loose and fixed. The contamination may be attached chemically or it may be mechanically trapped in cracks or small holes. The cleaning process must break the union or bond between the surface and the contamination. The contaminant must then be removed from the surface and prevented from re-attaching itself to it.

CHEMICAL DECONTAMINATION

The preferred method for most decontamination operations is to clean with water to which one or more suitable chemical cleaning agents have been added.

Detergents

The cleaning agents must be capable of removing the contamination from the contaminated surface and then holding it in solution without letting it re-attach itself. Various chemical compounds are available for special purposes, but generally speaking, commercial detergents work just as well and are usually a lot cheaper, too.

Chemical Solvents

Chemical solvents are normally used only after efforts with detergent solutions have failed. Varsol, trichloroethylene (used in dry-cleaning), and paint removers have all been used successfully. The problem is that they are often toxic and flammable.

Acids

Application of acids to surfaces is an excellent way of removing contamination, but it has limited usefulness because of the damage that may result due to the corrosive action of the acids. Acids should be used with caution.

Alkalis

Alkalis such as caustic soda solutions are occasionally used as decontamination agents. These are particularly useful for washing rubber articles such as gloves or rubbers.

PHYSICAL DECONTAMINATION

So far we have talked of chemical methods of decontamination. The chemical solution (e.g., detergent solution) may be scrubbed or wiped over the surfaces, but essentially the decontamination is due to the chemicals. There are decontamination methods in which the outer layer of the contaminated surface is removed by physical force. Such methods are effective; but they are somewhat crude and destructive, and it may not be possible to use them on delicate objects.

Some techniques are:

1. Scrubbing with abrasive powder like Ajax or with steel wool.
2. Sand-blasting.
3. Cleaning with high pressure steam jets.
4. Vacuum cleaning.
5. Ultrasonic cleaning.

These methods have particular applications. A method useful for certain objects may be unsuitable for others. It is beyond the scope of this course to go into the fine details of these methods - this is covered in the Decontamination Procedures. However, a word of explanation is worthwhile.

Scrubbing and Sand-Blasting

Remember that if you are removing contamination, the waste suds or sand will be contaminated and must be treated as radioactive waste.

Steam Cleaning

This is usually used on large decontamination jobs. One advantage is that the residue (condensed steam) has a much smaller volume than would be left if high pressure hot water had been used instead. Therefore it is easier to dispose of as active waste.

Vacuum Cleaning

In principle, this is the same method as is used to clean a carpet. However, once more a word of warning: the dust in the dust bag will be radioactive. It may be very highly radioactive (hundreds of mGy/h) after removing high level surface contamination. Be careful when using vacuum cleaners; they may create radiation and airborne hazards.

Ultrasonic Cleaning

This involves the use of a special cleaning tank and ultrasonic (i.e., very high frequency) sound. The sound waves bombard the surface of dirty equipment and tear the dirt from it. The cleaning tank is filled with a suitable decontamination solution, to prevent re-deposition of the contamination on the equipment.

All these techniques are useful but the most common ones you will use are the good old standbys - washing with detergent by hand and scrubbing.

SOME GENERAL PRINCIPLES

1. Assess the hazard. Make direct (contamination meter) and indirect (smears) measurements. If your contamination meter goes off-scale, use a gamma survey meter and a beta survey meter to make sure that the equipment isn't "too hot to handle".

2. Follow the procedures that cover decontamination. The station has adequate facilities for normal decontamination work. The procedures will describe in detail the approved methods to use for most types of decontamination work.

3. Protect the area. Set up a Rubber Area as needed.

4. Protect yourself. Wear appropriate protective clothing and respiratory equipment while doing decontamination work.

5. Assess the dose. If you anticipate exposure to your hands, make sure that you wear extremity TLDs.

6. Prevent the spread of contamination. All waste must be handled as radioactive waste.

7. Wet decontamination methods are better than dry methods because they are less likely to cause an airborne hazard.

8. Mild decontamination methods should be tried before you resort to physical methods that may cause damage.

9. Chemical solvents should only be used in approved areas; be careful and use approved procedures.

10. Make measurements. The success of the decontamination can be assessed only with direct and indirect measurements.

11. Clean up when you are finished.

DECONTAMINATION AREAS

There are four areas in Point Lepreau G.S. where regular decontamination is done. They are:

1. Change Room - decontamination of people
2. Cotton Laundry - decontamination of fabric clothing
3. Plastics Laundry - decontamination of plastic clothing and respirators
4. Decontamination Centre - decontamination of shoes, small equipment, tools, and D_2O drums

Also, we might occasionally have to decontaminate a spent fuel flask or similar sized vessel: this would be done in the Spent Fuel Reception Bay.

DECONTAMINATION OF EQUIPMENT

Equipment should normally be decontaminated soon after it is removed from the active area. If it is decided to delay decontamination (e.g., to allow decay), the item should be sealed in plastic, labelled conspicuously and stored in an appropriate location such as the Active Storage Room.

Small equipment and tools will be decontaminated in the Decontamination Centre, where proper facilities and fume hoods are provided.

Large equipment that is too difficult to move can be decontaminated in place. If high levels of contamination are present, a plastic enclosure should be assembled around the equipment and temporary ventilation should be provided using a portable filtration unit and flexible ducting. During decontamination, wear the appropriate protective clothing (e.g., dispos over Browns, rubber gloves, respirator, etc.).

Figure 9.32 shows the layout of the Decontamination Centre at Point Lepreau. It includes:

1. Sinks for washing, scrubbing, rinsing, etc.

2. Soaking tanks for steeping in detergent solutions.

3. Steam cleaning equipment.

4. Ultrasonic cleaning equipment.

5. Monitoring instruments.

In cases where surface contamination cannot be removed from equipment by normal non-destructive decontamination methods, it may be necessary to remove the contaminated outer surface (provided, of course, that this doesn't render the equipment unusable).

The extent to which equipment must be decontaminated depends on the amount of handling it will receive and where it is to be used. If it is to be returned to an active system without much subsequent handling, it may be alright to decontaminate it to the point where it can be safely used in the system without undue handling precautions. It is OK for tools to be decontaminated to the same level as protective clothing (5 CCL fixed, no loose), provided that they are then painted yellow to ensure that they do not find their way into contamination-free zones.

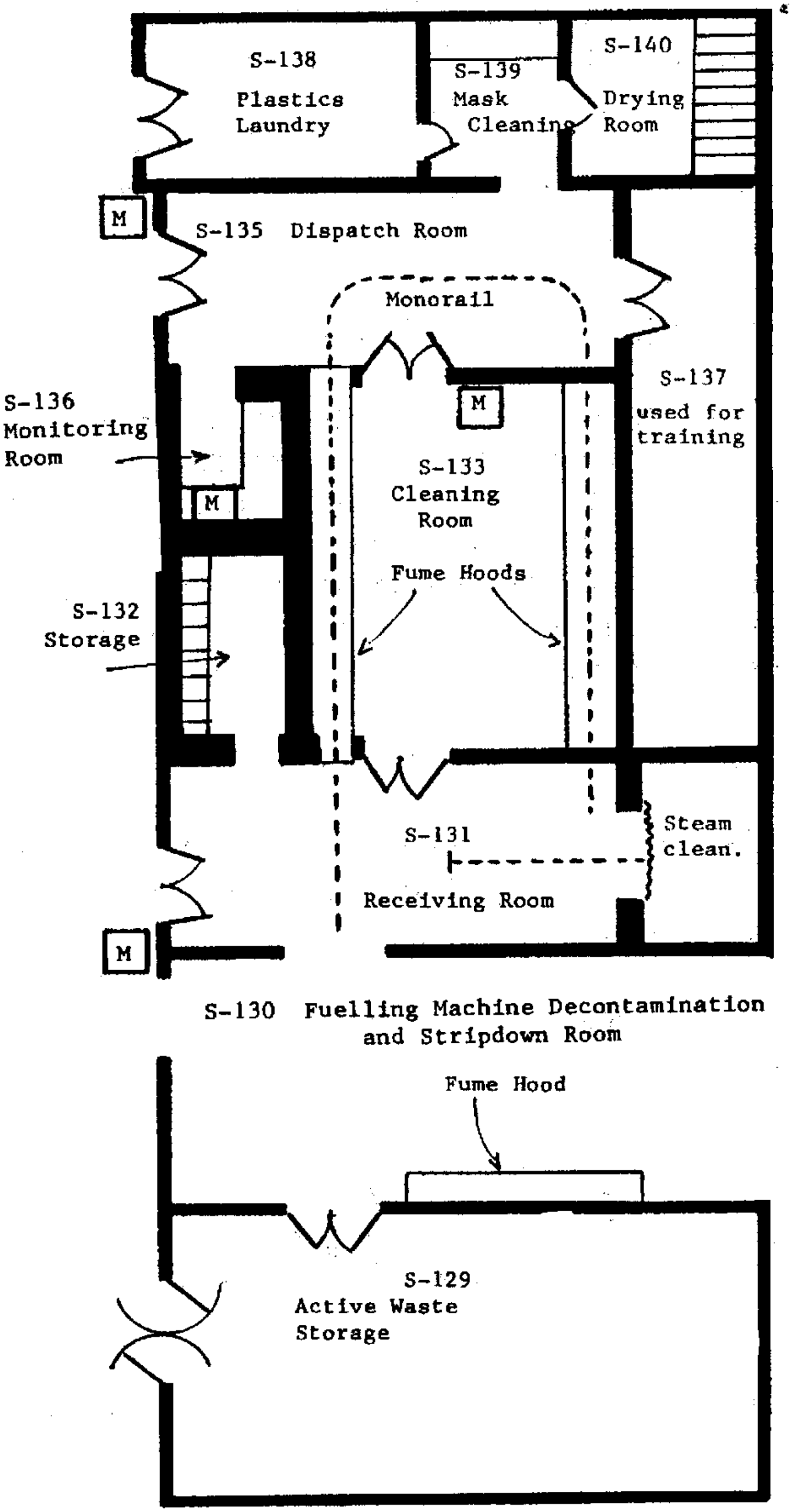


Fig. 9.32. Decontamination Centre at PLGS

DECONTAMINATION OF WORKING AREAS

What you do depends on what has happened. Generally, decontamination proceeds in stages: remove the gross contamination, and then remove the remaining activity to the degree necessary. Let's take the example of the floors in the Fuelling Machine Vaults. These are cleaned at the start of each annual outage and there are often hundreds of CCLs on the floor near the reactor face (mainly Zr-95 and Nb-95 from heat transport water spilled from the Fuelling Machines).

Generally, the approach would be as follows:

1. Assemble the necessary cleaning equipment (e.g., carboys of water, mops, buckets, garbage bags, rubbers, gloves, dispos, Masslinn mops, etc.) outside the area.

2. Set up rubber stations at vault entrances and signpost all access points.

3. Wash the floor directly beneath the reactor face where the activity is concentrated. Wet mopping with warm water is the quickest and most effective method of removing loose contamination from floors. Mop the area once or twice. Change mop heads and water often to minimize cross contamination.

   Once the floor is dry, use a Masslinn mop to check the area that has been washed.

4. Less contaminated nearby areas may also be mopped with a Masslinn mop. Check the Masslinn cloths in a low background area.

5. If the floor cannot be completely cleaned, or if further maintenance activities may spread contamination (as is the case here), lay down canvas over the area and signpost accordingly.

Naturally you would then double-bag all active waste and contaminated items, and put the contaminated water into the active sump specified on the Work Plan or by the Shift Supervisor.

HEAVY WATER SPILLS

Large spills of heavy water do happen. If you find one, back off if you are not properly protected, and then call the Control Room. If you are not in plastics already, you and those sent to help should get into plastics. The objective is to minimize dose during cleanup. This can't be done simply by minimizing the time for the cleanup; adequate protection is essential. Do not participate in the cleanup if you may have received significant exposure during the spill. If you got wet during the initial spill, you should shower as soon as possible.

The heavy water should then be recovered as soon as possible because, as you know, it is very expensive and will downgrade quickly. Also, tritium levels in the area will increase rapidly.

If the spill is large, you would use a "Vac-U-Max" (a nuclear-grade shop-vac), mops and sponges. After you have finished, all absorbent material should be sealed in polythene bags for disposal. When all the heavy water has been collected, it will almost always be necessary to wash down the surface in order to remove residual activity, both tritium and beta-gamma. Finally, a contamination survey of the area would be done.

DECONTAMINATION OF CLOTHING

Personal clothing should never become contaminated except by accident. If your street clothes become contaminated, sticking masking tape over the affected area and then removing the tape is sometimes effective. If necessary, scrubbing the affected area with a detergent solution is usually successful. If not, we can run them through the laundry.

If that doesn't work, your clothes will join all the other garbage in active waste. The Shift Supervisor would authorize the issue of a coverall so that you won't have to streak home. There will be no compensation for this, unless you can prove that an amazing set of coincidental circumstances absolved you from all blame. I wish you luck.

Protective clothing (i.e., Browns) for radioactive work becomes contaminated routinely. It is decontaminated in a laundry designed for this purpose. The wash procedure is quite elaborate and may involve many wash cycles with different combinations of cleaning agents. After drying, the clothing is monitored and if fixed contamination is below acceptable levels (5 CCLs), it is returned for use. Rubbers and plastic clothing are washed in a similar manner but different drying procedures are used.

It is advisable to segregate clothing on the basis of the degree of contamination. Before you throw your clothing into the dirty clothing cribs, you should monitor it to see if it is basically clean or contaminated. We have bins for "clean" and "dirty" (i.e., contaminated) used clothing, so that we can launder them separately to reduce the chances of cross contamination in the wash.

DECONTAMINATION OF SKIN

People doing radioactive work sometimes get contamination on their skin, especially on their hands. However, contamination of the face and hair also happens.

For hand contamination, a good wash with soap and warm water is generally all that's needed. This should remove all loose contamination and reduce the residual contamination to below 1 CCL. If contamination is under your fingernails, a soft bristle brush should be used with soap and warm water. You should be careful not to scrub or rub the skin to the point where it reddens, because then there is a risk of the contamination entering your blood stream directly. If soap and water don't do it for you, then you use a chemical hand cleanser you'll find in the Change Room. Note that hot water opens the pores and you might drive the stuff in deeper. Cold water closes them, and you might not get it out.

This skin cleanser contains small plastic granules to help loosen contamination. This step may be repeated once, but only if there is no evidence of skin damage from the decontamination. Remember to dry your skin completely before re-monitoring, since betas are easily attenuated in water.

If the contamination level is now below 5 CCLs, it is usually better to stop the decontamination rather than risk skin abrasion, severe removal of skin oils, and possibly entry of the contamination into your body. If you cannot reduce contamination below 5 CCLs, you should seek advice from Health Physics. Remember, it is important that you stop decontamination immediately if the skin starts reddening. It is much better to live with the contamination on your skin rather than risk getting it into your body.

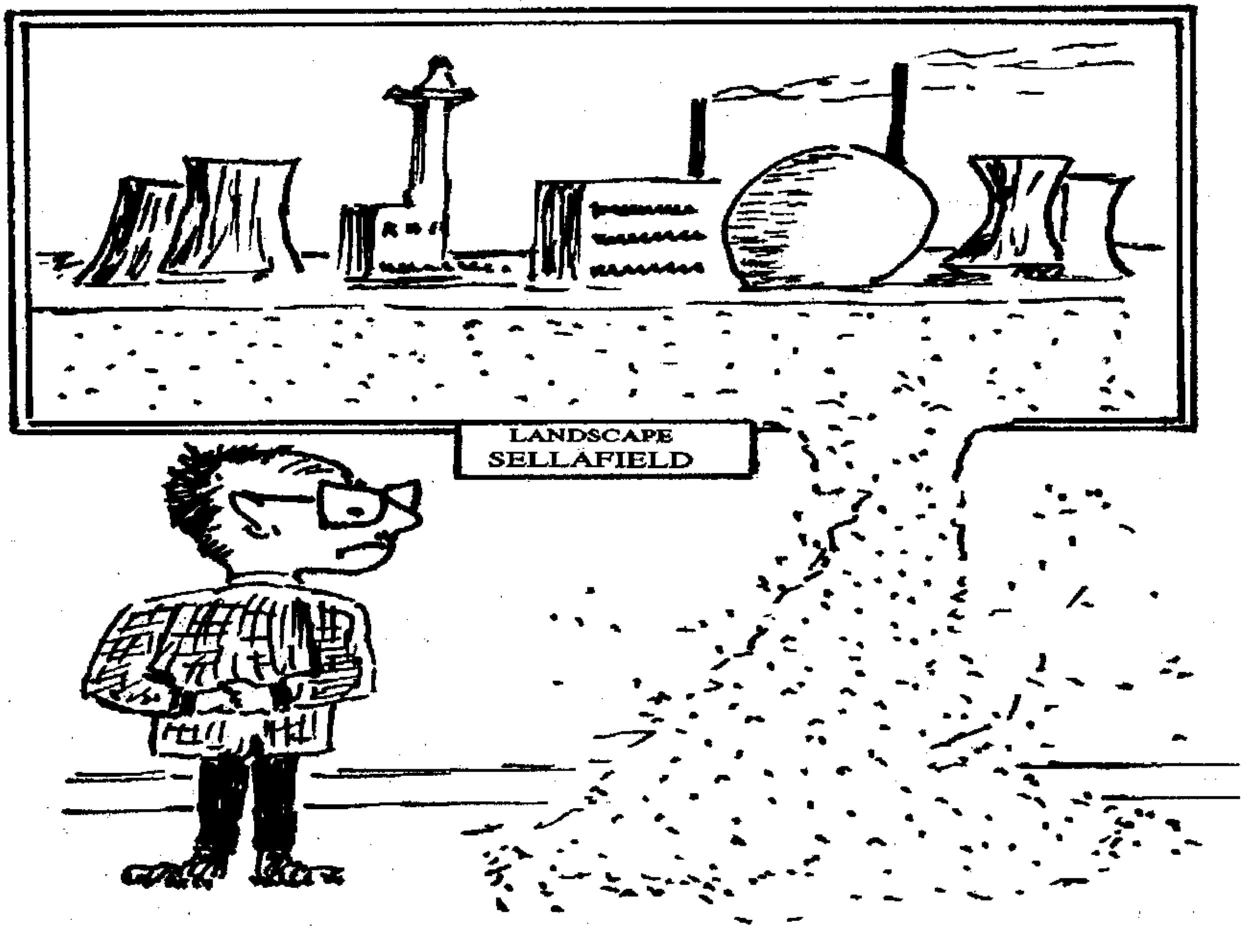
If your skin is still contaminated at a level of between 1 and 5 CCLs, you need Shift Supervisor approval to leave the station. Over 5 CCLs needs approval from Health Physics.

For decontamination of the face and hair, showering once or twice is your best bet.
Keep your mouth and eyes shut while doing this.

If you have minor cuts or scratches you should be very sure that:

(a) they are covered with surgical dressings, and
(b) you do not work in areas where you are likely to contaminate yourself.

A word with you, Pilkington, please.....



SUMMARY

Contamination can occur in solid, liquid and gaseous forms. Good contamination control consists of monitoring, containment and decontamination.

Contamination on surfaces is classified as fixed or loose; it is monitored directly with friskers, and indirectly with smears and Masslinn mops. Review the Contamination Control Limits on page 369. 1 CCL of fixed contamination corresponds to about 15 cps on a pancake frisker. Any loose contamination should be cleaned up immediately. If that isn't practicable, it must be contained within a Rubber Area or even a Rubber Change Area.

Airborne contamination can exist as particulates, noble gases, tritium or radioiodines. Particulates and radioiodines are measured with spot samplers; the DAC for unidentified particulates is 200 Bq/m^3*. Noble gases can be recognized by uniform beta and gamma fields in an area. Portable ion chamber monitors and bubblers are used to measure tritium. Respirators protect you from airborne contamination, but only if you wear them. For committed exposures greater than 50 uSv, you must wear a respirator. Know the protection factors on page 432. The uses and limitations of respirators are summarized on page 436.*

For tritium atmospheres of 500 μSv/h or more, for any work with moderator water, and for cleaning up PHT spills of more than 1 L, you must wear a plastic suit. With proper use, you should get a PF of 100 or better.

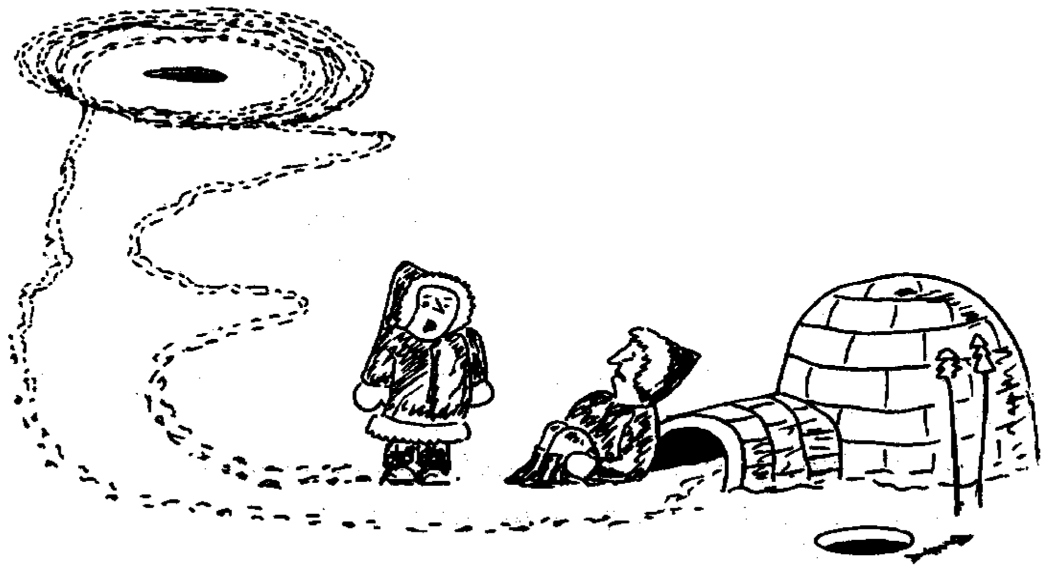
Rigid procedural controls help to prevent the spread of contamination. Examples are:

(a) *establishing permanent contamination control zones,*
(b) *establishing temporary contamination control zones called Rubber Areas with special protective clothing requirements,*
(c) *channelling workers in radiation area clothing (Browns) through special change rooms, and keeping this clothing separate from street clothes.*

The ventilation systems in the station are designed to prevent the spread of contamination (as well as providing clean air for us to breathe). Portable ventilation systems can be set up for localized dirty jobs.

Contaminated surfaces are normally cleaned by washing or scrubbing with warm water and detergent. In extreme cases, steam cleaning or even stripping the surface may be necessary. Vacuum cleaners can be effective, but watch for external radiation hazards from the filters. When decontaminating a large area, it is usually best to start from the outside and work your way to the middle.

Fixed contamination on skin should be kept below 1 CCL. Stop decontamination immediately if your skin starts to redden. If the remaining contamination is above 1 CCL, consult the Shift Supervisor or Health Physics.



PROBLEMS

1. Explain the difference between activation and contamination.

2. What is the maximum allowable level of **loose** beta-gamma contamination (in CCL):
   - (a) in the Zone 2 coffee room?
   - (b) on personal clothing?
   - (c) on the outside of a radioactive material shipping container?
   - (d) in Zone 2 outside a Rubber Area?
   - (e) on body surfaces?

3. What is the maximum permitted level of **fixed** beta-gamma contamination (in CCL):
   - (a) on personal clothing?
   - (b) on protective clothing?
   - (c) on respirators?
   - (d) on materials transferred to Zone 1 unconditionally?
   - (e) on body surfaces?
   - (f) on plastic suits?

4. The major disadvantage of the direct method of surface contamination measurement is that:
   - (a) it cannot be used on rough surfaces
   - (b) it cannot be used in high tritium concentration areas
   - (c) it cannot detect loose contamination
   - (d) it cannot be used in high beta-gamma background areas
   - (e) it cannot be used to measure tritium.

5. You have been promoted to Assistant E.I.&C. Maintainer. Your first mission is to adjust the alarm set point (cps) on a laundry monitor, so that protective clothing contaminated to its allowable level is just going to trigger the alarm. The detector is rectangular, 16 cm long and 8 cm wide. The lead shielding around the detector results in a steady background count rate of about 30 cps. The detector efficiency is around 15%. What should the alarm set point be?

6. You have been asked to monitor a tool box for contamination. You use a portable contamination meter (pancake detector) with an efficiency of 20%. The background count rate is 20 cps. At 1 cm from the tool box (the detector views 15 cm^2) the maximum count rate is 50 cps.
   - (a) Show that for 1 CCL the net count rate under the above conditions is 15 cps.
   - (b) How many CCLs are on the tool box?
   - (c) You decide to check whether it is loose or fixed contamination and you take a smear sample under normal conditions (150 cm^2 and 10% pickup). For a 1 minute count the total count is 2700 and the background count is 300. How many CCLs of loose contamination are on the box?
   - (d) Compare the results of (b) and (c) and give two possible explanations for the different answers.

7. A photographer from Head Office is taking some pictures in the F/M Maintenance Area. When he is finished, you frisk his camera (a Pentax 6x7 belonging to NB Power), and you find traces of contamination on the base. You take a smear of the whole base area of 100 cm^2, and count the smear in a smear counter. Background count was 102 cpm and smear count was 258 cpm. Assuming that 10% of the loose contamination was picked up by the smear, work out whether the camera can leave the station or not.

8. You have to draw a sketch of some equipment that has been modified. It is located permanently in the Spent Fuel Discharge Bay, an area which is normally heavily contaminated with loose b,g activity. It is a permanent Rubber Area. Explain how you would propose to get an uncontaminated diagram to Zone 1.

9. You are dressed in Browns, and have been asked to take some pipe wrenches from the Mechanical Maintenance Shop to the Hanson Stream Pumphouse. Describe what you would need to do to comply with all the contamination control requirements.

10. You are taking a copy of this book from the Decontamination Centre to Zone 1. When you frisk it, you find that the outside covers are contaminated. What now?

11. You are entering Zone 1 on your way home when the Full-Body Monitor alarms. The display indicates that your hands are contaminated, recording 100 counts (150 counts = 1 CCL). Can you leave if the contamination on your hands
    (a) is fixed?
    (b) is loose?
    (c) If you have 2 CCLs of fixed contamination on your hands and all safe decontamination methods have been tried, whose permission is required before you may leave?

12. When should you set up a Rubber Area? A Rubber Change Area? Will a Rubber Change Area always be within a Rubber Area?

13. Trace the path you will take through the maze on page 403 on your way to and from the daily rat race.

14. You have to use a bubbler to measure the airborne tritium concentration in the Boiler Room. You follow the procedure on p. 394, and get an answer of 20 μSv/h. What would the true value be
    (a) if the bubbler ran for 10 minutes instead of 5?
    (b) if you used 200 mL of water instead of 100 mL?
    (c) if you used 2 mL of sample instead of 1 mL?
    (d) if the efficiency of the counter were 28%, not 42%?
    (e) if you subtracted the counter background of about 50 cpm? (You can then see why we don't bother.)
    (f) We assume that the efficiency of the bubbler in trapping the tritiated water vapour is 100%. What would be an easy way of checking this?

15. You want to send the above bubbler sample to our Fredericton Lab for detailed analysis. You frisk it and can detect no activity. Does it require a Conditional or Unconditional Release Permit? Why?

16. A Continuous Air Monitor in the Spent Fuel Reception Bay alarms while you are working there. What now?

17. List (from head to toe) the protective clothing and equipment you would wear when entering a Rubber Area to do some work on a contaminated piece of equipment.

18. A room at a temperature of 25°C contains a puddle of heavy water, which has a tritium concentration of 1000 GBq/kg.
    (a) Using the information on page 324, what is the maximum airborne tritium level (in mSv/h) in the room?
    (b) Would you expect this level throughout the room?
    (c) Suppose that the driers lower the relative humidity in an area by a factor of 100. What reduction in airborne tritium would you expect? What is the maximum tritium level possible?

19. Before working in a room you sample the air with a Portable Air Sampler at a rate of 1.5 L/s for 5 minutes. You find 2700 cpm above background on the filter paper using a scaler connected to a pancake geiger detector.
    (a) What is the activity in the air in Bq/m^3? (Counter efficiency is 20%.)
    (b) What is the committed dose rate (of unidentified particulates) in the room?
    (c) How would you find out what radionuclides are on the filter?
    (d) If the activity was identified as zirconium-95, what is the committed dose rate in the room?
    (e) What respiratory protection is required for 6 hours work in the room in (d)?
    (f) If the particulate activity was identified as cobalt-60, what respiratory protection is required for 6 hours?

20. You are going to work for 2 hours in an area that has 750 μSv/h of tritium and 3 mGy/h of gamma.
    (a) You wear plastics for the job. What will be your total dose commitment?
    (b) You think that you could do the job in 20% less time if you wore a Stephenson respirator instead of plastics. What would the total dose commitment be now?
    (c) If (b) results in less dose than (a), is (b) the approach to use?

21. You have been sent to clean up a small spill (4 or 5 L) of PHT water on a concrete floor. Describe in brief point form how you would go about it.

22. When not in use, airlines should be disconnected from the air header. Why?

23. (a) Without looking at the text, see if you can fill out the table below with the practical Protection Factors we (Health Physics) consider to be appropriate for use in the station. For no protection, write NP.

	Radioiodine	Tritium	Particulates
Half-face mask with TEDA cartidge			
Full-face mask with TEDA cartridge			
Tritium cartridge respirator			
Stephenson respirator			
Air-supplied respirator			
Air-supplied hood			
Scott Air Pak (SCBA)			
Plastics			

(b) Give three reasons why the ideal protection factor of 1000 for plastics is unlikely to be achieved in practical use.

(c) Indicate which of the above is appropriate protection for

(1) a very high level of chlorine contamination;
(2) 30 uSv/h of tritium and 100 uSv/h of radioiodine for 1 hour;
(3) 500 uSv/h of tritium for 5 minutes;
(4) decontamination work in areas with high levels of loose particulates.