7 - EXTERNAL RADIATION HAZARDS

INTRODUCTION

You may recall that the external radiation hazards at Point Lepreau are gamma, neutron and beta radiation. This chapter will tell you how to assess and protect yourself from them.

FUNDAMENTALS OF SELF-PROTECTION

We want to keep our radiation dose as low as reasonably achievable, and well within the legal dose limits. This will minimize the risks of radiation (hereditary or somatic effects) that were discussed in Chapter 3.

Many of the techniques that we use to minimize our radiation dose are identical to those used when working with other industrial hazards. For example, you should always plan your work.

Planning includes:

1) **Recognizing the hazards.**
2) **Assessing the magnitude of each hazard.**
3) **Anticipating hazard changes.**
4) **Using appropriate protective equipment and procedures.**
5) **Using suitable dosimetry.**

We are going to look at each of these in detail.

RECOGNIZING RADIATION HAZARDS

You know from Chapter 2 that your body's senses cannot detect radiation. However, you can recognize the radiation warning symbol, you know that all radioactive systems are found in Zone 3 and you know how radiation fields are affected by time, distance and shielding. The next step is to learn something about the larger radioactive systems, i.e., their functions and their hazards.

a) Primary Heat Transport (PHT) System

Main Purpose: To transport heat from the fuel bundles to the steam generators.

Hazards:

i) Tritium.
This is formed by activation of deuterium in the heavy water and is covered in detail in Chapter 8.

ii) Activation Products.
These are formed whenever materials enter the high neutron flux in an operating reactor. Whenever irradiated debris leaves the reactor, often through corrosion or damage, it may plate out on the inside of pipes, pumps, etc. or come to rest at some obstruction in the system. Most activation products are beta/gamma emitters, examples are iron-59, zirconium-95 and cobalt-60. When they remain enclosed by pipework, only the gamma emissions are a hazard, but when the PHT system is opened there are usually beta fields also. The oxygen in heavy water can be activated to oxygen-19 or nitrogen-16. Both nuclides emit high energy gamma photons.

iii) Fission Products.
These are formed whenever uranium or plutonium atoms undergo fission. Fission products are highly radioactive, but are contained within the fuel bundles. Should the sheathing around the fuel develop a leak (this is known as a fuel defect), some fission products will escape into the PHT system. The fission products that normally escape are gases (e.g., krypton and xenon), vapours (e.g., iodine) or those that are soluble in water (e.g., cesium).

Krypton and xenon can escape from the PHT system through leaks, during fuelling or whenever the system is degassed. They are classed as external hazards because even if inhaled, they don't remain in your body. They rapidly decay to form short-lived airborne particulates, emitting beta and gamma radiation. Their presence is signalled by a rising beta/gamma field with no apparent "source". Radioiodine vapours can also escape from the PHT system and are covered in Chapter 8. Water soluble fission products are released in PHT spills and will become contamination.

iv) Gamma and Neutron Radiation.
While the reactor is critical, very high gamma fields will be emitted from PHT pipework, mostly from oxygen-19 and nitrogen-16. The gamma photons from N-16 can generate photoneutron production to cause neutron fields from PHT pipework, although most of the neutron fields found in the Reactor Building are believed to be fission neutrons escaping from the core.

b) Moderator System

Main Purpose: To slow down fast neutrons in the reactor core.

Hazards:

i) Tritium.

Moderator water spends far more time inside the reactor than does PHT water, so its tritium concentration is much higher, typically by a factor of 30. More in Chapter 8.

ii) Activation Products.

These are again caused by neutron irradiation of materials suspended in moderator water. Nuclides such as cobalt-60 can plate out to give local gamma hot spots on piping. High concentrations of activated gadolinium may also be present in moderator water following the firing of Shutdown System 2 (SDS-2).

iii) Gamma and Neutron Radiation.

Gamma fields from activation products will be higher than around PHT pipework, because of the longer time that moderator water spends in the reactor core. Photoneutron fields are negligible compared to gamma fields.

c) Liquid Zone Control (LZC) System

Main Purpose: Fine control of reactor power.

Hazards:

i) Activation Products.

Formed when the LZC water (light water) enters the reactor core. A Delay Tank is built into the system to reduce the dose rates in accessible areas from oxygen-19 and nitrogen-16 in LZC pipework. Argon-41 may be present from air in the system.

ii) Gamma Radiation.

Gamma fields from oxygen-19 and nitrogen-16 will exist around LZC pipework at power, but there will be no photoneutron hazard. Do you understand why not?

d) Fuelling Machines (FMs) and Spent Fuel Route

Main Purpose: Replacement of spent fuel in the reactor core. Please appreciate that the Fuelling Machines become part of the PHT system when they are on the reactor face.

Hazards:

i) Tritium.
FM maintenance may result in exposure to tritium if the system is not completely drained.

ii) Fission Products.
Each spent fuel bundle contains a huge amount of fission products. If a spent fuel bundle is badly damaged the potential exists for extremely high beta and gamma fields around a Fuelling Machine and a large release of radioiodine vapours.

iii) Gamma Radiation.
Spent fuel bundles can have gamma fields that could give you a lethal dose in seconds, but are normally inside the reactor core or stored below several metres of water.

e) Other Systems

The Zone 3 areas contain other radioactive systems as well as various radioactive subsystems of the four major systems mentioned above. You will learn more about plant systems and their hazards on the Systems Module Training Program.

Always discuss potential hazards with your supervisor or with one of the lads in Radiation Control before performing unfamiliar work in Zone 3.

ASSESSING THE MAGNITUDE OF A HAZARD

You know from Chapter 5 which types of instruments we use to measure radiation, and their advantages and disadvantages. During the RPT Applications Course you will have some hands-on training with these instruments. Although instruments are essential to detect and measure radiation fields, you can get a feel for the hazard in advance by considering the following factors:

a) Reactor power level — the dose rate in many rooms in the Reactor Building increases in proportion to the reactor power level.

b) Time since first reactor startup — the reactor first reached criticality on July 25, 1982 and first power was produced a month later. Since then the levels of long-lived activation products have been increasing.

c) Time since the reactor was last brought up to power (following a shutdown). After startup there is a buildup of short-lived nuclides until they reach equilibrium levels, i.e., their rate of decay equals their rate of production.

d) If the reactor is shut down, the time since shutdown affects radiation fields, because short-lived nuclides decay away quickly causing radiation fields to fall.

e) Removal of shielding to allow maintenance — this will increase radiation fields.

f) Contaminated surfaces, liquids or air will increase the radiation fields.

g) Operating conditions may change the radiation fields if systems are isolated or opened. For example, gamma fields in the Moderator Purification Room will change in proportion to moderator water flow through the Moderator Purification System.

h) The presence of a defective fuel bundle in the reactor will cause an increase in radiation fields from activation and fission products in the PHT and FM systems. Fields will decrease when the defective fuel is removed.

Considering these factors before you start work will help you assess the potential hazards you're getting into.

Typical Gamma Fields

Gamma radiation fields in the normally accessible Zone 3 areas outside the Reactor Building are generally less than 10 µGy/h. (Notable exceptions are in the vicinity of the Moderator Purification and Spent Fuel Bay Purification Systems.)

Inside the Reactor Building is a different story. Normally accessible areas can have gamma dose rates ranging from below 10 µGy/h up to 50 mGy/h on localized equipment (hot spots). The access controlled areas may have dose rates exceeding 100 mGy/h.

You should have a feel for the normal routine radiation conditions in the various accessible areas of the station. Fig. 7.1 shows typical gamma fields in the Boiler Room at 100% reactor power after about six years of full power operation. Notice how the fields vary from a few µGy/h to several mGy/h. You can examine survey results from other areas in the station by using the HAZARD INFO computer program. Fields 24 hours after shutdown are shown in Table 7.1.

TABLE 7.1. GAMMA FIELDS 24 HOURS AFTER SHUTDOWN
(AFTER SIX YEARS OF OPERATION)

Location	Field
F/M Vaults Below Calandria Face	1 - 2 mGy/h
F/M Vaults - General Area	100 - 300 µGy/h
Moderator Enclosure	100 - 500 µGy/h
Boiler Room	10 µGy/h

Typical Neutron Fields

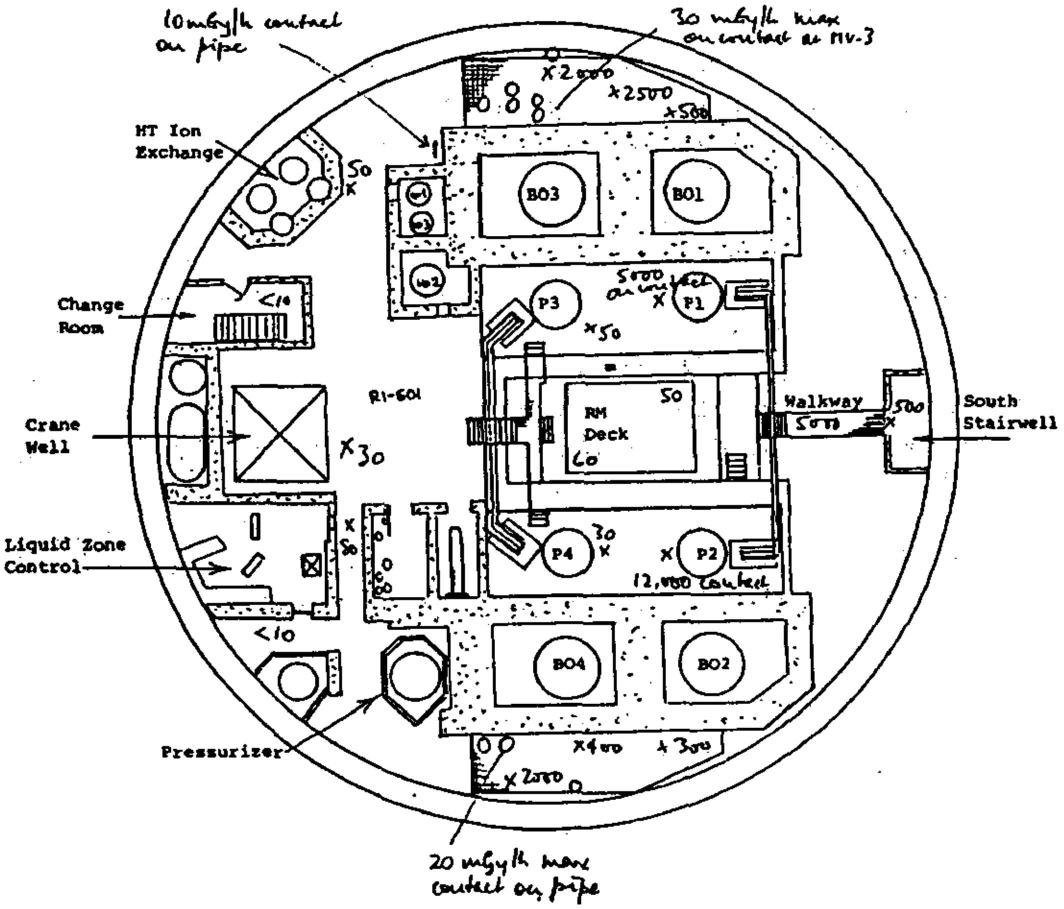
Few neutron fields are found outside the Reactor Building. Exceptions are those locations where penetrations through the Reactor Building wall allow some gamma and neutron radiation to escape. For example, the D_2O Vapour Recovery Room (S1-146) has some locations with fields of around 250 µGy/h gamma and 90 µSv/h neutron at 100% reactor power.

RADIATION SURVEY SHEET Form RS-5

REACTOR BUILDING - El. 29.9 m

DATE 89-10-26 TIME 12:10 % FULL POWER 100 SURVEYOR R.S. Hold

INSTRUMENTS AND NUMBERS Low Range Gamma Meter
\# 2046.



NOTE

Radiation readings are in ☑ uGy/h ☐ mGy/h

Indirect contamination readings are in ☐ cps ☐ cpm > background

Direct contamination readings are in cps > background

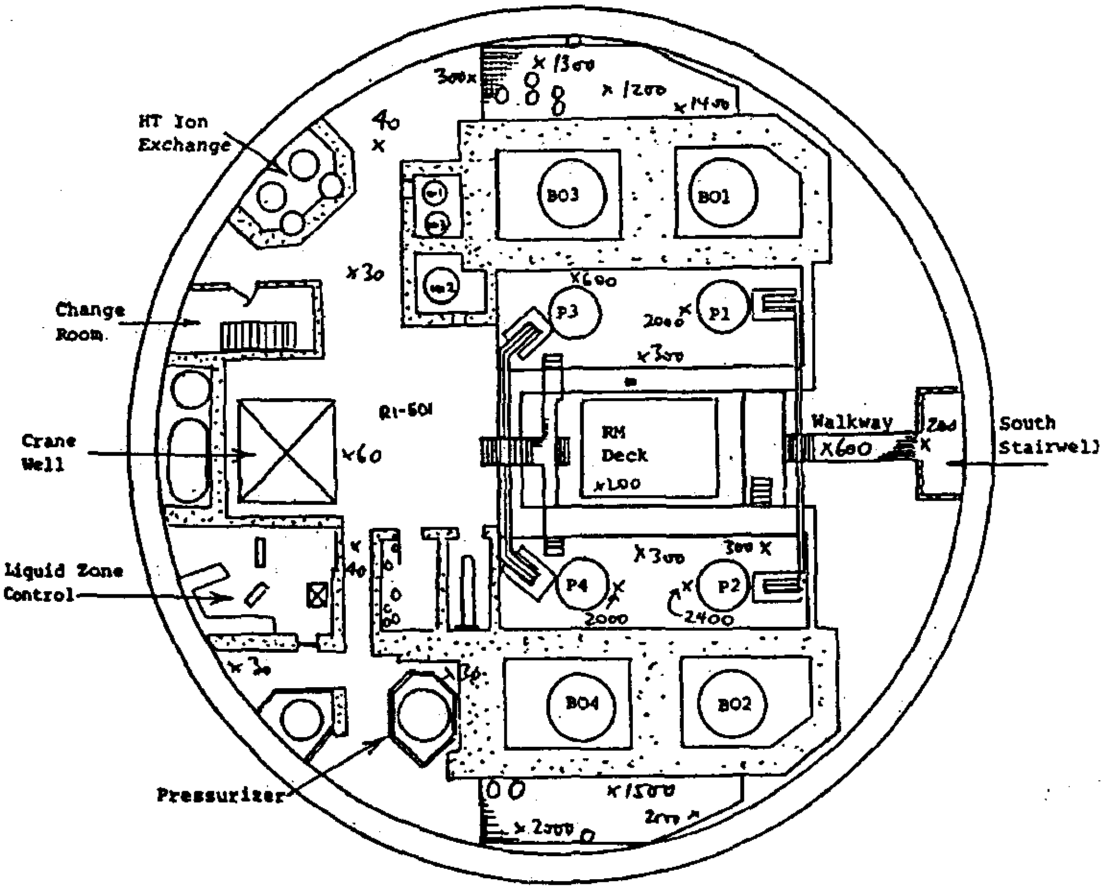
Fig. 7.1. Typical Gamma Fields in the Boiler Room; 100% Full Power, Six Years of Operation

RADIATION SURVEY SHEET Form RS-5

REACTOR BUILDING - El. 29.9 m

DATE 89-10-26 TIME 12:00 % FULL POWER 100 SURVEYOR C.S. Held

INSTRUMENTS AND NUMBERS Neutron Meter
4272



NOTE

Radiation readings are in ☑ μSv/h ~~uGy/hr~~ ☐ mGy/h

Indirect contamination readings are in ☐ cps ☐ cpm > background

Direct contamination readings are in cps > background

Fig. 7.2. Typical Neutron Fields in the Boiler Room;
100% Full Power, Six Years of Operation

There are only a few areas that are normally accessible inside the Reactor Building that have neutron dose rates of greater than 10 μSv/h.

Figure 7.2 shows typical neutron fields in the Boiler Room at 100% reactor power. These fields should remain the same, regardless of the number of years of operation. Why? Notice how the fields vary with location. Note the neutron dose rate behind the boilers at the top and bottom of Fig. 7.2.

ANTICIPATING HAZARD CHANGES

The factors discussed in the last section are important because they are variables; as they change, the hazard changes. Sometimes the change is predictable, and at other times it comes as a surprise. Let's look at some examples.

a) The filters on the fuelling machine PHT supply are changed when the flow becomes restricted. The filters rest inside a steel casing. Before a filter change, the gamma dose rate on the casing was about 5 mGy/h. Knowing the casing to be about 10 mm of steel, we expected 10 mGy/h on the filter, but actually measured about 30 mGy/h when the filter was removed. (Perhaps the initial survey was made when the filter was still full of heavy water.)

b) Helium is used as the moderator cover gas, because it does not absorb neutrons and cannot become activated. The Helium Storage Tank therefore should have no radiation hazard. A worker at Pickering G.S. noticed his gamma meter was indicating high radiation levels near this tank. A quick survey showed that gamma fields at the tank were around 5 Gy/h. It turned out that air cylinders were accidentally used to replace empty helium cylinders on the system. Air contains about 1% argon which can be activated to argon-41, a beta/gamma emitter.

c) An Active Workshop at another nuclear facility was highly contaminated and had general gamma dose rates of around 200 μGy/h. Two maintainers vacuum-cleaned the area for two hours. After they had finished, their DRDs were off-scale and the TLDs showed doses of 6 mSv and 8 mSv. Know why?

As you can see, hazards don't always stay the same. After working in Zone 3 for a time you will probably have some of your own tales of sudden changes in radiation fields. You can keep yourself alert in these areas by asking yourself "What happens if ...?". Remain aware of the possibility of changing conditions.

USING THE RIGHT EQUIPMENT AND PROCEDURES

During the RPT Applications Course you will study the Radiation Protection Procedures in detail and have an opportunity to apply them in various field exercises. At this point we will take a look at some of the procedures concerning radiation surveys and Area Gamma Monitors.

Radiation Surveys

A survey is a measurement of radiation conditions. There are two reasons for doing surveys:

a) Changes in radiation levels may indicate changes in plant systems. For example in June, 1984, abnormal beta/gamma radiation fields in the Reactor Building indicated a release of fission product noble gases. This led to the discovery of a previously unknown PHT leak in the gas chromatography system.

b) Changes in radiation levels may indicate that changes in a work procedure are required. For example, it is usually faster to work on equipment in the field; but if the dose rates have increased significantly, it may be worth removing the equipment to an area with a lower dose rate and doing the work there.

There are both routine and job radiation surveys. A **routine survey** is an assessment of general radiation fields in an area and is normally done on a regular basis. A survey sheet is normally completed (e.g., see Figs. 7.1 and 7.2) and filed at Radiation Control.

A **job survey** is an assessment of radiation fields in a specific location. The person doing this type of survey will normally be working at the surveyed location.

Doing a Radiation Survey

The two factors governing your choice of survey instruments are the types of radiation and the range of dose rates expected.

As a general rule, an instrument should not be used in fields that cause it to indicate at the scale extremes. Use an instrument having a more suitable range. The box below lists the ranges of some of the instruments used at Point Lepreau.

INSTRUMENT	USEFUL RANGE
Low Range Gamma Survey Meter	10 uGy/h - 100 mGy/h
Low Range Gamma Survey Meter	3 uGy/h - 1 Gy/h
High Range Gamma Survey Meter	10 mGy/h - 10 Gy/h
Emergency Gamma Meter	1 mGy/min - 2 Gy/min
Low Range Beta Meter	20 uGy/h - 500 mGy/h
Neutron Meter/Integrator	1 uSv/h - 1000 mSv/h

* Answer to p. 9-30, item (c): as they collected contaminated debris inside the vacuum cleaner they changed the conditions, but did not re-survey. A gamma dose rate of 1.2 Gy/h was later found on the vacuum cleaner.

After selecting appropriate survey meters, perform their pre-operational checks:

a) Check for a valid calibration sticker.
b) Check the instrument battery condition.
c) (For beta and gamma meters) Check that the meter responds correctly to an Instrument Check Source.

If the instrument fails any of these checks it should be considered defective and should not be used. Take it to the Defective Instrument Shelf and place a completed Defective Instrument Tag on it. These tags are stored on the shelf outside the Stores Issue Counter.

After selecting an instrument and performing the pre- operational checks:

a) Obtain a survey sheet of the area from Work Control.
b) Switch the meter(s) on.
c) Select an appropriate meter range (if an unknown hazard, select a high range).
d) Read any warning signs at the entrance to the area and check the Alarming Area Gamma Monitor Remote Indicator, if one is present.
e) Take readings just inside the area entrance. Specific radiation sources may be indicated by fields that increase in one direction.
f) Take general radiation readings at waist height. Make a note if readings are taken at other heights, in contact with equipment, etc.
g) Place a **HOT SPOT** sticker on previously unidentified hot spots. As a rule, a hot spot has radiation levels over 100 times the general field in the area.
h) Signpost the radiation area if general fields are above 10 μSv/h.
i) Note the general, hot spot and other readings on the warning sign (if one is required), and on the survey sheet if you used one. You should also make a computer entry in the Temporary File of the HAZARD INFO program.

Signposting

Areas with an external radiation dose rate of greater than 10 μSv/h are called **RADIATION AREAS**, and must be signposted. Each access point to a room or clearly defined area where external dose rates exceed 10 μSv/h shall be posted with a conspicuous sign bearing the radiation warning symbol and identifying the area according to one of the following two categories:

1. CAUTION, RADIATION AREA

Any accessible area in which the external dose rate exceeds 10 μSv/h.

2. DANGER, RESTRICTED RADIATION AREA

Any accessible area in which the external dose rate exceeds 5 mSv/h. (Worker must notify Shift Supervisor before entry).

The following information must also be recorded on the sign:

1. The general area dose rate and type of radiation.
2. The location and magnitude of any contact readings.
3. The name of the individual who did the survey.
4. The time and date of the survey.

Equipment or material with localized dose rates 100 times greater than the general area dose rate should be posted with a HOT SPOT sticker indicating the dose rate and date of posting.

If you find signs with information that is no longer current, correct the sign or, if it is no longer needed, return it to a Protective Equipment Storage Location, called a "PESL".

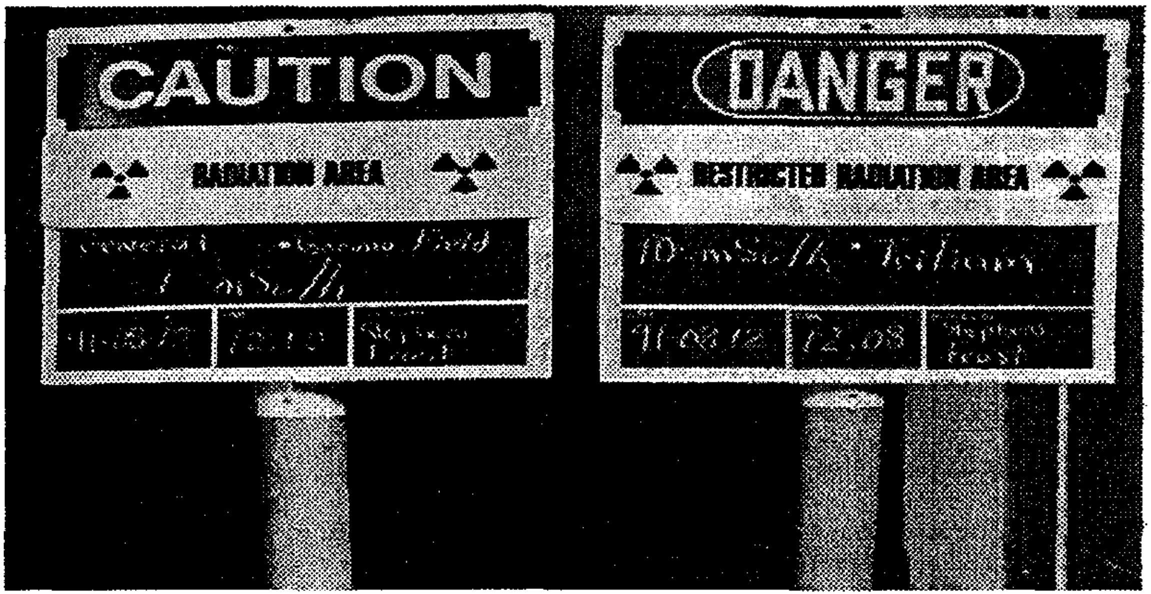


Fig. 7.3. An Example of Radiation Warning Signs

Gamma Surveys

Gamma surveys are probably the most frequent radiation surveys that you will make, partly because gamma radiation fields are common, and partly because you will also do gamma surveys while surveying for beta or neutron radiation. Gamma surveys are relatively simple: just hold the meter and slowly wave it around looking for indications of higher fields. Beta and neutron surveys are a little harder.

Beta Surveys

Beta radiation is associated with high levels of contamination, either airborne (usually radioactive noble gases and their daughters) or on unshielded radioactive material. You will recall that almost all activation and fission products are beta-gamma emitters and that beta radiation cannot penetrate steel pipes, but can penetrate a metre or more of air. Therefore, opening a radioactive system greatly increases the beta fields immediately around it. Here are some examples of beta hazards found during the 1984 maintenance outage. Note that gamma fields are always found with high beta fields.

1. Entry into Boiler #4.

   The general gamma fields inside the boiler were 10 mGy/h; the contact readings were 15-20 mGy/h gamma and about 10 mGy/h beta. They were reduced to 5 mGy/h gamma, 2-3 mGy/h beta by laying lead blankets on the lower internal boiler surface.

2. Removal of Degasser Heater #7.

   The fields on the heater were 50 μGy/h gamma, 150 μGy/h beta.

Unshielded, contact beta-to-gamma ratios are often in the order of 2 or 3 to 1, but remember that the beta field falls far more quickly than gamma when the detector is moved away from a beta/gamma source. Beta radiation can be greatly reduced by using plywood or similar light materials for shielding.

To review the use of a beta survey meter, see page 191.

Neutron Surveys

Most of the neutron radiation is emitted from the reactor core (fission neutrons and photoneutrons). A small fraction comes from the PHT and moderator pipework (photoneutrons). No matter where they come from, you should always assume them to be associated with significant gamma fields. Please review Fig. 7.2 to see where we have neutrons at power. During an outage, there are no neutron fields worth worrying about.

AREA GAMMA MONITORS

At Point Lepreau, we have a permanently installed **Alarming Area Gamma Monitoring** system, known as (surprise) the **AAGM** system. It provides continuous monitoring of gamma radiation fields in various areas of the station, and it brings in audible and visual alarms if preset dose rates are exceeded. The function of the system is to prevent exposure to unexpected radiation fields.

These monitors do not replace gamma survey meters. They will only indicate the gamma dose rate at the detector and will alarm if that dose rate exceeds the alarm setpoint. Furthermore, if you are not working near the detector, it may not be able to sense an increased field at your work location. Instead, you must check your gamma survey meter regularly.

Description of the AAGM System

This system (see Fig. 7.4) has the following components:

Detectors, Remote Annunciators, Remote Indicators, Control Units, and interfacing to the station control computers.

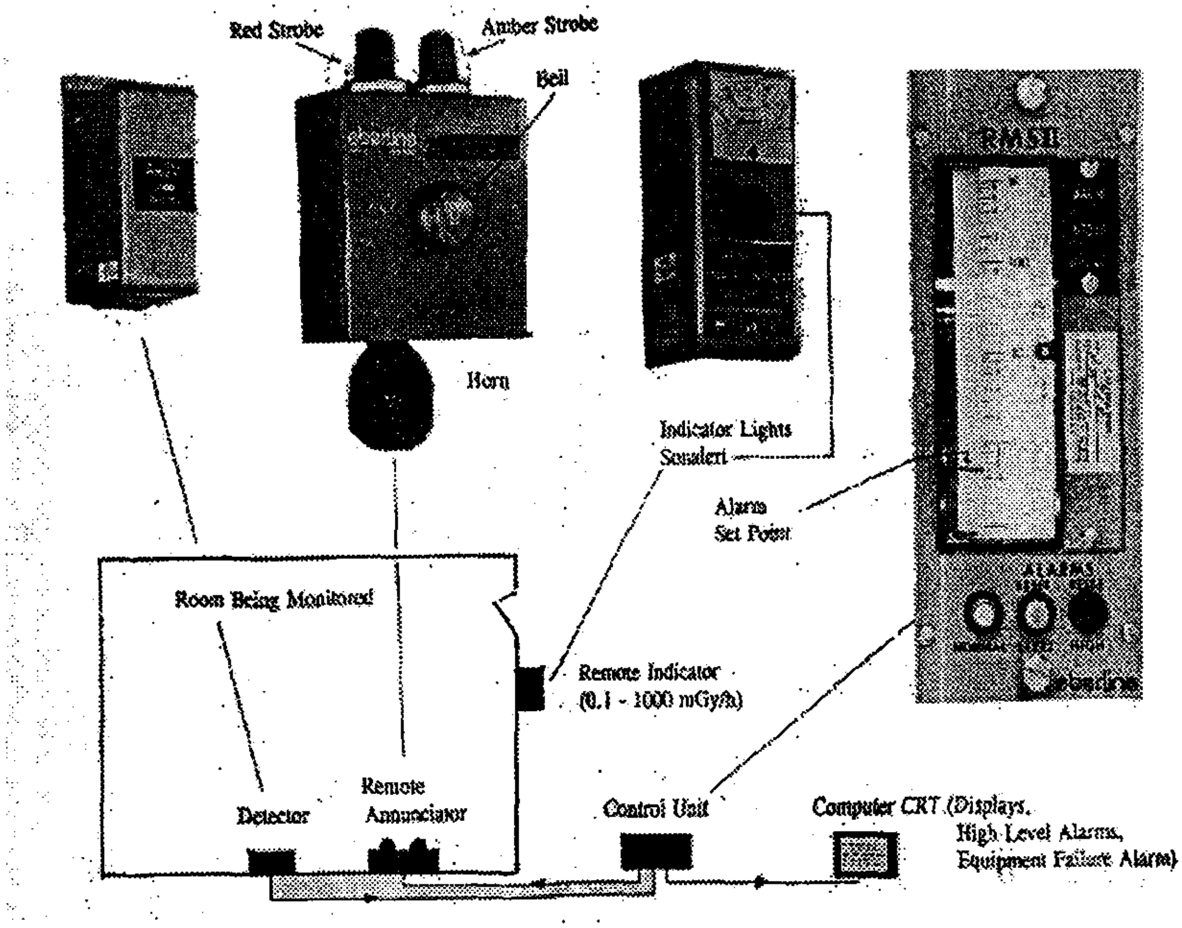


Fig. 7.4. Alarming Area Gamma Monitoring System

a) Detectors and Remote Annunciators are located in those areas where high radiation fields may occur. The Main Control Room also has an AAGM system for emergency conditions.

b) Each Remote Annunciator has visual and audible alarms that indicate gamma radiation exceeding a preset level (red strobe and siren) or equipment failure (amber strobe and bell).

c) A Remote Indicator is situated at an entrance to each monitored area and displays the detected gamma dose rate. A red light and an audible "sonalert" indicate that the alarm setpoint has been exceeded and a green light indicates that the equipment is operating correctly. The normal alarm set point is indicated by a red mark on the Indicator scale.

d) There is a Control Unit for each monitor in the Control Equipment Room (behind the Main Control Room). This unit displays the measured dose rate, indicates exceeded setpoints (red light), and tells us that it is operating normally (green light). Alarm setpoint adjustments and system checks can be made using the Control Units.

e) The AAGM system is connected to the station control computer. Alarm messages are displayed on the computer terminal in the event of High Radiation or Equipment Failure alarms.

f) The AAGM system is interlocked with the Access Control System described in Chapter 6. The alarms are normally set at 0.5 mGy/h, except for the FM Vaults and the Moderator Enclosure which are set at 1 mGy/h. This is much too low for some Access Controlled areas, because at full reactor power the alarms would be flashing and wailing continuously. For this reason, the High Radiation alarms, but not the Equipment Failure alarms, are disabled in areas for which the access control key is locked in Panel 15 in the Main Control Room. (This means that those areas are unoccupied, and the access doors are locked.) As soon as the key is removed, the alarms will be enabled.

g) If you have to enter an Access Controlled area and the alarm is on, the Control Room Operator would have to get the alarm setpoint raised until the alarm clears. Otherwise, you would have no warning of an increase in fields above the present level. Once you leave the area and restore the key to Panel 15, the Operator must return the alarm setpoint to its original level.

Actions if an AAGM Alarms

What you do if an AAGM alarms is spelled out in Radiation Protection Procedure FM-1(A), reproduced here on the next page. If the AAGM system is not available (either because it has failed or because it doesn't exist at your work location), you would use a **PAD**. The PAD is mentioned in the second last step of the FM-1(A) procedure, and you'll meet it again on page 297.

USING SUITABLE DOSIMETRY

Everybody entering Zones 2 and 3 wears dosimeters to measure external radiation dose. These are:

Thermoluminescent Dosimeters (TLD),
Direct Reading Dosimeters (DRD),
Personal Alarming Dosimeters (PAD).

For neutron dosimetry, our only suitable device is the neutron meter/integrator.

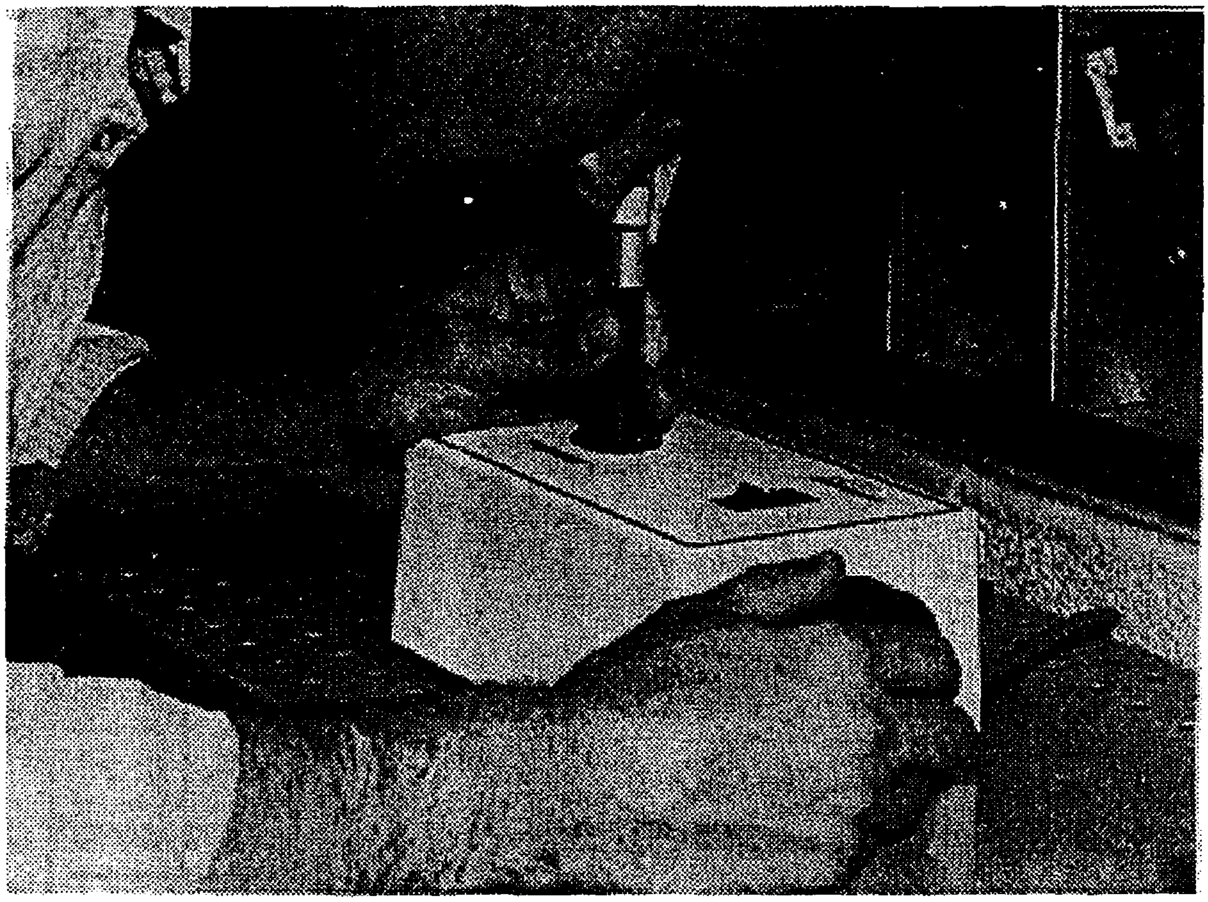


Fig. 7.5. DRD and DRD Charger

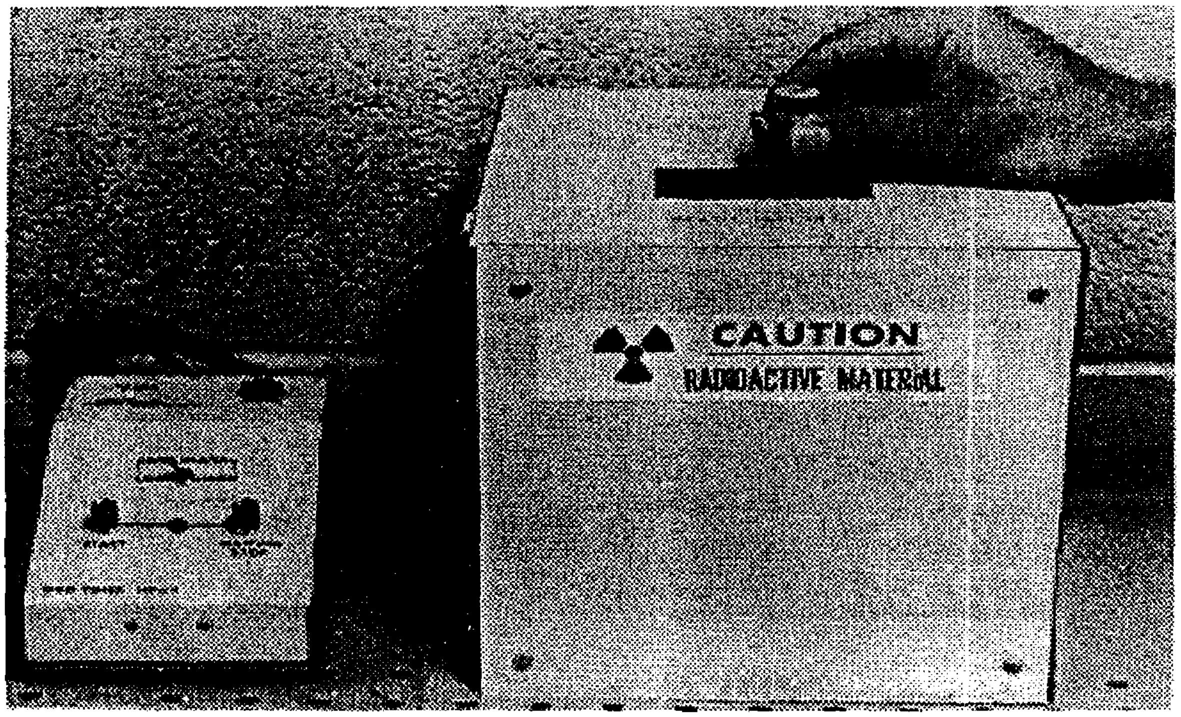


Fig. 7.6. DRD Check Source

Thermoluminescent Dosimeters (TLDs)

Your TLD badge serves several functions:

1. It is used to assess the shallow $_{H}S$ and deep $_{H}D$ dose you receive in each two week monitoring period. Alternate dosimeters are used so that one can be read out while the other one is being worn.
2. The TLD results are entered into Dose Records. These form the official legal record of radiation dose received by everyone working at our station.
3. Your TLD badge will bear your name, badge number and a colour code to indicate the degree of qualification you have achieved in radiation protection.
4. The fourth element of the TLD is extremely sensitive to neutrons, and it will alert the citizens in Health Physics to an unreported or unexpected neutron exposure.

Your TLD badge is worn in a prominent position on the front of your body between waist and neck — most people clip it to their breast pocket rather than to their nipples. There is one exception (no, not you, Curt). If you are working near a source such that the TLD would not measure the maximum dose to your whole body, move the TLD to that part of your torso that will receive the highest.

This would be a good time to review the story on TLDs you heard before in Chapter 5, so that you will be up to speed on the whole business.

Direct Reading Dosimeters (DRDs)

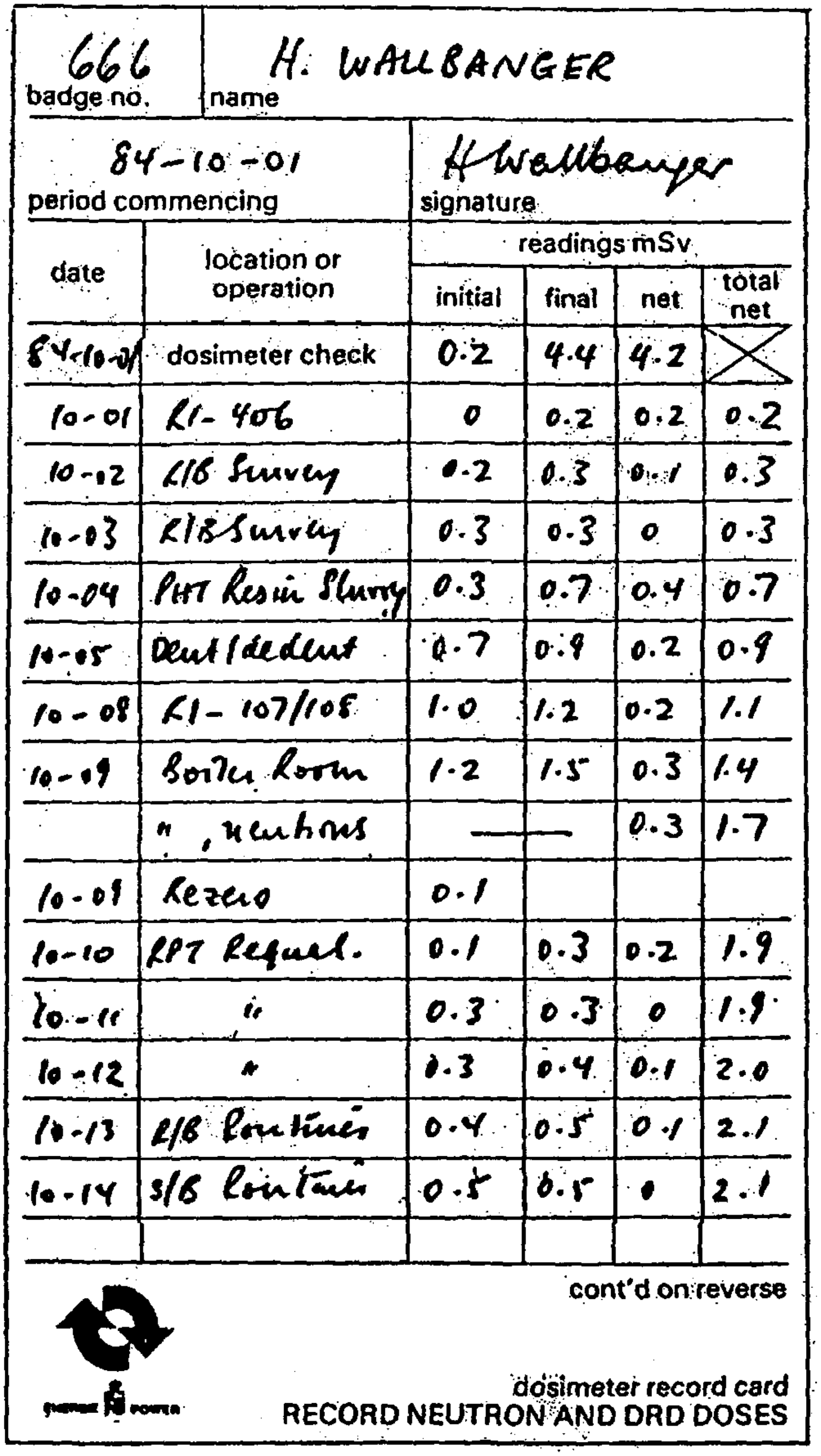
Low range (0-5 mGy) and high range (0-50 mGy) DRDs are available. Everybody who routinely works in Zone 3 is issued a low range DRD. Wear it beside, but not over, your TLD badge.

DRDs are used to estimate your deep dose ($_{H}D$) from gamma radiation only. DRDs are insensitive to beta and neutron radiation. The results are entered on a DRD card which you should keep up-to-date. DRD cards are stored in the DRD racks near the Health Physics Lab.

At the start of each monitoring period (every two weeks) you should total the DRD dose for the previous period, then zero your DRD using a DRD charger (see Fig. 7.5). Expose your DRD to the DRD Check Source (Fig. 7.6) and compare the reading with the limits posted on the source container to ensure that your DRD is working correctly. Then rezero it.

When comparing DRD and TLD results, remember that a DRD is not as accurate as a TLD. Complete a Dosimetry Information Form (DIF) if the difference between your DRD total and TLD result exceeds 0.5 mGy and 50% of your TLD result at the end of a monitoring period.

DRD cards are provided for you to keep a record of your daily gamma and neutron exposure. This will let you calculate your allowable dose at any time. It will also provide an estimate of your deep dose ($_{H}D$) on those occasions when you've been stunned enough to lose your TLD. Fig. 7.7 shows Harvey Wallbanger's DRD card.



666 badge no.	H. WALLBANGER name
84-10-01 period commencing	H Wallbanger signature

date	location or operation	readings mSv			
		initial	final	net	total net
84-10-01	dosimeter check	0.2	4.4	4.2	☒
10-01	R1-406	0	0.2	0.2	0.2
10-02	R/B Survey	0.2	0.3	0.1	0.3
10-03	R/B Survey	0.3	0.3	0	0.3
10-04	PHT Resin Slurry	0.3	0.7	0.4	0.7
10-05	Dent/dedent	0.7	0.9	0.2	0.9
10-08	R1-107/108	1.0	1.2	0.2	1.1
10-09	Boiler Room	1.2	1.5	0.3	1.4
	" , neutrons	—	—	0.3	1.7
10-09	Rezero	0.1			
10-10	RPT Request.	0.1	0.3	0.2	1.9
10-11	"	0.3	0.3	0	1.9
10-12	"	0.3	0.4	0.1	2.0
10-13	R/B Routines	0.4	0.5	0.1	2.1
10-14	S/B Routines	0.5	0.5	0	2.1

cont'd on reverse

dosimeter record card
RECORD NEUTRON AND DRD DOSES

Fig. 7.7. Harvey Wallbanger's DRD Card

High range DRDs are worn if you expect a whole-body gamma dose of 3 mSv or greater. They are available from the Work Control Area Dosimetry Cabinet. The high range DRD should be worn together with your normal DRD, and if your normal DRD reads off-scale, you would record the high range DRD reading on your DRD card. High range DRDs are zeroed and source checked before each use.

Should you lose your DRD in a radiation area or find that it reads off-scale, inform the Shift Supervisor. He may request that your TLD be analyzed to find out if you have received a high gamma dose. The obvious way of avoiding the surprise of an off-scale reading is to read your DRD several times during a job. Yeah, I know, kind of basic, but you'd be amazed at the number of people who forget this.

A final word of caution — avoid contaminating dosimeters. The contact dose rate from even a small amount of contamination can cause a dosimeter to indicate false dose information. Also, you might spread the contamination.

Personal Alarming Dosimeters (PADs)

We also have some Personal Alarming Dosimeters, known as PADs. This is really a dosimetry system, consisting of PADs and one or more Readers, as shown in Fig. 7.8.

Our PADs have solid state detectors that respond to gamma radiation. They weigh 134 g, and are powered by a single AA battery that lasts six months.

The PADs have a top mounted display to make them easy to read when they are clipped to your breast pocket. The digital display gives both dose and dose rate information. The PAD has one dose rate alarm, and four dose alarms. These alarms are programmable, i.e., we can set the dose rate alarm to go off anywhere from 10 μSv/h up to 1 Sv/h. The range of the total dose alarms is from 10 μSv to 10 Sv. (The high end isn't too useful, unless you just want to confirm that you're going to die.) There is also an elapsed time alarm, which can be set from one minute up to eight hours.

If an alarm set point is reached, the relevant display flashes along with a red light, and quite a piercing noise is generated. You can clear the dose rate and the first three total dose alarms, but the fourth dose alarm and the timer alarm cannot be cleared until you get to a PAD reader.

Ultimately, it is our intention to replace DRDs completely with these electronic dosimeters. For the time being, we've bought enough so that those of you who need them will have them. You can get them from Radiation Control for now; in future they will be kept by the DRD racks.

There is another nice feature of our PAD: you can ask it to give a bleep for every 10 μSv it registers. This would give you an audible indication of the radiation fields. For example, how many seconds between bleeps at 2 mGy/h and at 20 mGy/h?

Always wear a DRD when using a PAD. Record the higher of the two readings on your DRD card.

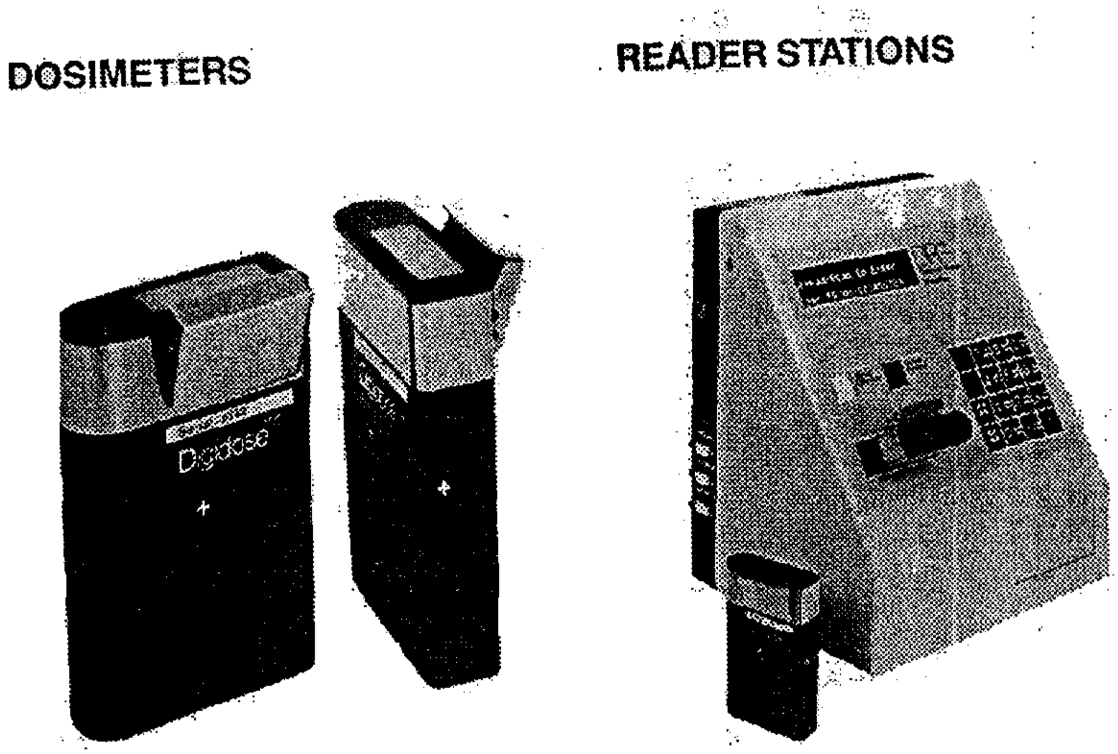


Fig. 7.8. Our Personal Alarming Dosimeter System

Neutron Meter/Integrator

We met the neutron meter on page 184 in Chapter 5. You may recall that it reads directly in mSv/h, so that you don't have to worry about neutron energy and quality factors.

Check the neutron meter calibration sticker and check the battery condition. Select the rotary switch to the X0.1 position, and the toggle switch to INTEGRATE. If the display doesn't show zero, reset the integrator by depressing the red reset button while holding the LIGHT-RESET toggle switch to RESET.

We don't expect you to drag this heavy instrument around with you all the time. Simply put it down close to your work location in areas with a neutron field. In those cases where it may be impractical or hazardous to carry the meter, consult Health Physics before the work is done. They may approve alternative measurements, but these **must** be approved before the job starts.

The neutron dose that you receive on a job **must** be reported to Health Physics by completing a Dosimetry Information Form. In addition, you must record the neutron dose on your DRD card, because Health Physics does not enter neutron dose into Dose Records until the end of the monitoring period.

SUMMARY

You must learn the hazards associated with each system. You must be able to anticipate changes in radiation fields when planning or doing work.

You must minimize the radiation dose that you receive.

Most radiation hazards originate in the reactor core.

"General" radiation readings are assumed to have been taken at waist height.

A Radiation Area has general radiation fields of more than 10 μSv/h.

A Restricted Radiation Area has general radiation fields of above 5 mSv/h. Shift Supervisor approval is required before entry.

Beta radiation is associated with high levels of surface or airborne contamination.

Neutron radiation is mostly found in the Reactor Building when the reactor is at power.

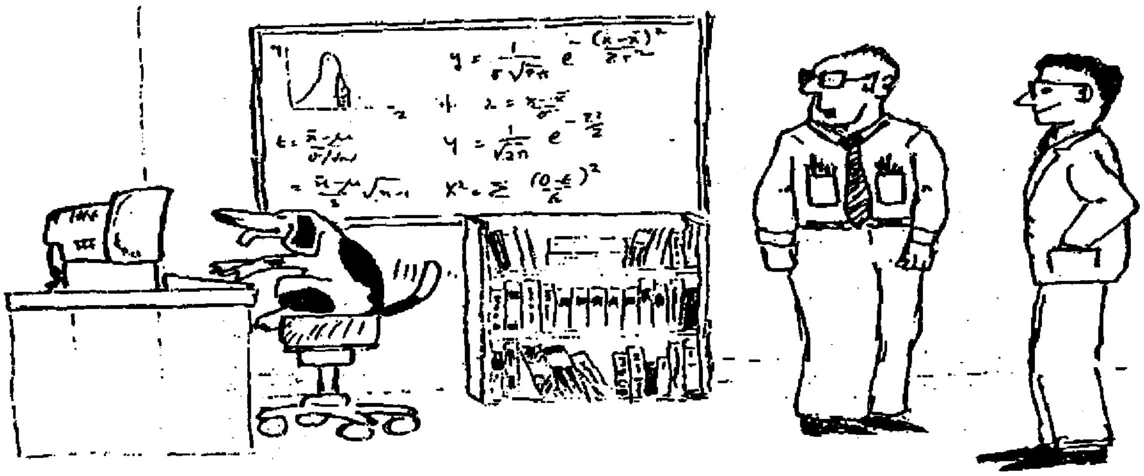
Area Gamma Monitors provide audible and visual alarms when the detected dose rate exceeds a preset alarm.

Thermoluminescent Dosimeters (TLDs) are used to measure dose from external gamma and beta sources.

Direct Reading Dosimeters (DRDs) are used to estimate dose from external gamma sources.

Personal Alarming Dosimeters (PADs) are used to provide an audible indication of external gamma dose.

A neutron meter/integrator is used to assess neutron dose.



"Nah, his dog isn't that smart. He doesn't back up his files properly, he can't use a mouse, and he has trouble using INGRES."

PROBLEMS

1. Why should you keep your radiation dose ALARA?

2. Name five areas at Point Lepreau which have neutron fields greater than 1 mSv/h at full power.

3. What are the reasons for doing routine radiation surveys and job radiation surveys?

4. When should you use both high range and low range DRDs? You wore both for a job and the DRDs read 4 and 3.4 mGy respectively. Which dose should you consider as correct? Where do you record it?

5. Suppose an operator moved a drum of contaminated heavy water to an accessible area of the Reactor Building. After moving the drum, he measured the gamma radiation field and posted a sign at the drum stating as follows:

   30 mGy/h on contact with drum
   5 mGy/h 1 metre from drum.

   Later the Radiation Control Supervisor recognized the inadequacy of the sign.
   (a) In what way(s) was the posting of the radiation hazard inadequate?
   (b) Give the shortcomings of the operator's handling of the whole situation.
   (c) Whom does the Radiation Control Supervisor contact to have the radiation hazard properly posted?
   (d) Who on shift is responsible for ensuring that all staff follow the radiation protection procedures?

6. You enter an area in the Reactor Building. You notice that the beta and gamma fields are pretty uniform, no matter where you measure them. The readings you get are:

beta meter, shield closed:	2 mGy/h
beta meter, shield open:	6 mGy/h
gamma meter:	1.8 mGy/h

   (a) Explain what could be causing these fields.
   (b) What is the beta field?
   (c) You spend half an hour in this area. What will your DRD indicate?
   (d) What deep dose and shallow dose should your TLD register from these exposures?
   (e) On leaving the Reactor Building, you set off the alarms on the Hand and Shoe Monitor at the Equipment Airlock. Why?

7. You are asked to survey an area expected to have a general gamma field of 2 mGy/h.
   (a) Which instrument would you select?
   (b) What checks do you make before using it?
   (c) What do you do if the instrument fails any one of these checks?
   (d) Give two reasons for doing surveys.
   (e) At what height from the floor are survey measurements normally taken?

(f) What should you do after you have completed the survey?

(g) What is a "hot spot sticker" and when would you use it?

(h) How is a Radiation Area defined?

(i) How is a Restricted Radiation Area defined?

(j) Whose approval is required to enter (h)?

(k) Whose approval is required to enter (i)?

8. (a) While working in Room S-003 on the Spent Fuel Bay Purification System, you are protected by the Alarming Area Gamma Monitoring (AAGM) System. Room S-003 contains which of the following:

    1. the detector
    2. a horn or siren sounding like a police siren
    3. a bell
    4. a red strobe light
    5. an amber strobe light
    6. a green push-button light
    7. a display indicating the radiation field
    8. an audio "sonalert"
    9. a button cancelling the audible alarm
    10. facilities for adjusting the alarm setpoint

(b) For radiation fields exceeding the alarm setpoint, which of items (a) alarm?

(c) What is the correct action to take if this happens?

(d) For system failure, which of items (a) alarm?

(e) What action could you take to protect yourself equally well, if it was necessary to work there during a system failure condition.

9. The DRD card on page 296 shows an entry for neutron dose for work in the Boiler Room.

(a) What are the three main locations in the Boiler Room with neutron fields greater than 1 mSv/h?

(b) Note that Harvey Wallbanger got equal neutron and gamma doses. Based on the survey information in Figs. 7.1 and 7.2, where might he have been working, and for how long?

(c) How was the neutron dose measured?

(d) Why is the neutron dose recorded on the DRD card?

(e) Where else must Harvey report the neutron dose?

(f) How would Health Physics know that Harvey was exposed to neutrons, even if he didn't tell them?

10. You are required to work over an open pump bowl that is contaminated on the inside with typical PHT contamination. The measured radiation fields are as follows:

Location	Gamma	Beta
Hands	12 mSv/h	60 mSv/h
Torso	4 mSv/h	4 mSv/h

So far you have received the following total doses in your current ECY:

whole-body	8 mSv,
shallow	26 mSv,
extremity	60 mSv.

How long can you work in these conditions before reaching a dose limit as defined on page 151?