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AUSTRALIAN ATOMIC ENERGY COMMISSION

LUCAS HEIGHTS RESEARCH LABORATORIES

REPORT OF THE COMMITTEE OF INQUIRY INTO A
FIRE WHICH OCCURRED ON 18 MARCH 1987
IN A RADIOISOTOPE PROCESSING CELL, BUILDING 54
AT THE LUCAS HEIGHTS RESEARCH LABORATORIES

25 MARCH 1987

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SUMMARY

1. At about 1745 hours on Wednesday, 18 March 1987 a fire occurred in a small charcoal filter inside a processing cell (hot cell) in Building 54 at the Lucas Heights Research Laboratories (LHRL). This cell was being used to process irradiated uranium to separate the radioactive isotope molybdenum-99.

2. The fire was not related to either of the two research reactors at the LHRL site. It was confined to the charcoal filter in the above mentioned cell, which is about 500 metres from the nuclear reactor HIFAR.

3. Some radioactive contamination escaped from the hot cell into the operating area and three AAEC officers were found to have minor radioactive contamination on their skin/hair. A fourth AAEC officer had a spot of contamination on his trousers. The contamination was short-lived and was quickly and easily removed by washing with soap and water.

4. The majority of the radioactive material released from the fire was trapped by the main filters outside the cell. The total amounts of radioactive noble gas and of radioiodine released to the environment during the week in which the fire occurred were within the normal range of discharge and were 53% and 2.1%, respectively, of the weekly limit authorised by the NSW Department of Health.

5. Early advice on the accident was provided to the Minister for Resources and Energy and to relevant State and Local Government Authorities. A representative of the NSW Department of Health was present at the Lucas Heights Research Laboratories on the evening of 18 March.

6. The Committee noted that the response to the accident by personnel of the AAEC and of NSW emergency organisations was prompt and effective.

7. A number of recommendations have been made by the Committee to avoid a similar occurrence and to make further improvements in the effectiveness of the emergency response.

8. On the evidence available to it, the Committee:

- concludes that the fire was caused by spontaneous combustion in the charcoal filter used to trap radioactive gases released by the operations in the hot cell,

- concludes that the mechanism causing the fire cannot be clearly established at this stage and some further research and investigation is necessary to clarify the mechanism,

- believes that no member of AAEC staff, NSW emergency services personnel or the general public suffered, or will suffer, any adverse health effects from radioactivity as a result of the accident.

CONTENTS

Report of Committee of Inquiry Into Fire in No. 2 Hot Cell - Building 54, Lucas Heights Research Laboratories

Committee of Inquiry

In accordance with standing instructions of the AAEC, the Acting Director convened a Committee to investigate the fire which occurred at the Lucas Heights Research Laboratories (LHRL) on the evening of 18 March 1987. The Committee consisted of representatives of the AAEC, CSIRO, NSW Department of Health, Sutherland Shire Council and an AAEC union/staff association representative.

The membership of the Committee and its terms of reference are at Appendices 1 and 2.

The Committee met between Thursday, 19 March and Wednesday, 25 March. It inspected the area in which the fire occurred and interviewed AAEC staff members who were involved in the accident.

The Report of the Committee of Inquiry is presented below.

Circumstances of the Fire

At about 1745 hours on Wednesday, 18 March 1987 a fire occurred in No. 2 hot cell in Building 54 operated by the AAEC at the Lucas Heights Research Laboratories - see Figures 1 to 4.

The hot cell is approximately 2.5 m x 1.9 m and 3.7 m high, with 1 m thick high density concrete walls and a 1 m thick lead glass viewing window. Operations involving highly radioactive materials are undertaken by remote control using master/slave manipulators controlled by the operator from the viewing window. Nos. 1 and 2 hot cells were being used for the routine production of molybdenum-99, the parent isotope of technetium 99m, used in nuclear medical diagnostic procedures. As is usual, the interconnecting door between Nos. 1 and 2 cells was open and in addition the rear entry port to No. 1 cell was open to the service area behind the cell bank.

During this process uranium pellets irradiated in the HIFAR reactor are dissolved in a nitric acid solution and molybdenum is separated chemically.

At the time the fire occurred the irradiated uranium pellets had dissolved and air had been passed through the solution for a period of one hour to release radioactive gases, which were subsequently trapped on charcoal filters some of which are enclosed within plastic casings.

The cell operator was an AAEC officer with some twenty years experience. He was working alone in the area at the time and whilst engaged in taking a sample from No. 1 hot cell he became aware of some loss of illumination in the cell. After checking the cell lights he went to the window of No. 2 cell and saw flames 60 cm to 100 cm high issuing from the filter located on a rack on the floor at the rear left hand side of the cell. The smoke in the cell had caused the loss of illumination. This filter of activated charcoal is one of several sets used to adsorb radioactive gases. He immediately reported the fire by telephone to the Lucas Heights Site Emergency Alarm Centre which took all appropriate actions including notifying the NSW Fire Brigade.

The cell operator returned to the operating area and shut down the air flow through the apparatus, which was continuing to feed the fire. He then unsuccessfully tried to activate the automatic fire damper which closes off air flow leaving the cell. He was then joined by the Duty Site Plant Shift Supervisor. They obtained a ladder stored nearby to enable them to close the damper manually. (The damper control is situated about 3.5 m above ground level on the cell face wall). After actuating the damper the operator closed the interconnecting door between Nos. 1 and 2 hot cells. Both the AAEC Fire Tender and the Duty Shift Health Physics Surveyor arrived within three minutes, followed shortly by the Duty Shift Manager, the first unit of the NSW Fire Brigade and the AAEC Acting Director.

An air sampler was set up by the Duty Shift Health Physics Surveyor in the hot cell operating area and three AAEC officers wearing self-contained breathing apparatus entered the rear of the cells area, removed the continually operating air sampler for measurement and closed the rear port of No. 1 hot cell. When they returned to the operating area it was apparent that the fire in the filter was dying down and would burn itself out within a short time.

The air sample taken from the front of the cell area indicated a low level of airborne contamination (Appendix 3). The sample from the area behind the cell showed less airborne contamination. All non-essential personnel were evacuated from the operating area and mustered outside the building. Each person was then checked for contamination (Appendix 4).

Three AAEC officers had minor personal contamination - two on the hands and one on the hair. A small spot of contamination was present on the trousers of another AAEC officer. All contamination was quickly removed by washing with soap and water. No persons from NSW emergency organisations, or their equipment were contaminated.

One fire crew left the LHRL without first having been monitored. An AAEC officer equipped with a contamination monitoring instrument subsequently visited that crew's fire station and monitored the fire crew and their equipment. No contamination was detected.

It is considered that the minor contamination in the front of the cell area may have been caused by a small quantity of air escaping from around penetration points in the cell structure when negative pressure was lost after the cell doors had been closed and air ducts shut off. Further air samples were taken from both front and rear cell areas and no additional air contamination was found. Sampling of the stack from which gases are eventually vented to the atmosphere was continued and results are shown in Appendix 5.

Emergency services left the site and the remaining small embers of the fire were finally doused with a small quantity (about 200 ml) of water at about 2045 hours.

Possible Causes of the Fire

On the basis of the evidence presented to it, the Committee ruled out the possibility of mischief, sabotage or operator error. It considers that the most likely cause of the fire was spontaneous combustion in the charcoal filter. A number of reactions which could have triggered the fire were considered, including:

- a heat-producing reaction between oxygen in the air or in nitric acid and any organic material that might have been deposited or present on the charcoal inside the filter

- heat produced from the decay of radioisotopes

- heat produced from the adsorption of gaseous radioisotopes (eg. radioiodines) on the charcoal in the filter

- possible chemical reactions between hot charcoal and the plastic casing material

- heat produced when liquids (condensate) are adsorbed onto charcoal.

The No. 1 hot cell of Building 54 has been used for the production of molybdenum-99 for about twenty years. For the past six years Nos. 1 and 2 hot cells have been operated in the present configuration. There are on average three production runs each week throughout the year.

The AAEC has never had a previous case of a charcoal filter overheating during a production run. Several years ago there were two cases of a charcoal filter overheating during a different phase of the process (known as the regeneration phase). The chemical conditions during that phase are so different from the present case that these incidents are not considered relevant to the present inquiry. It should be noted however that following the previous incidents the regeneration phase was modified to use the inert gas nitrogen instead of air.

The Committee believes that the cause of the fire in this case may never be known. Both the filter and its casing were destroyed in the fire making subsequent analysis impossible, but a series of tests have commenced at the LHRL which may provide additional relevant information. Procedures which may be implemented to avoid the possibility of such a fire in future are detailed in the Committee's Recommendations.

Release of Radioactive Materials to the Environment

Appendices 5 and 6 give information relating to radioactive materials released to the environment during this accident and provide:

- details of radioactive materials released during the week of the accident
- details of radioactive materials released during weeks of normal operations
- details of the weekly equivalent of the authorised stack quarterly discharge limit
- an estimation of the radiation exposure of persons situated outside the LHRL during the period of the fire.

On the basis of the information included in these appendices, the Committee concluded that the release of radioactive materials during the week of the accident was well within the normal range of weekly radioactive discharges from the building, and there is no indication that the fire increased the discharge during that week.

State Legislation

It is the policy of the AAEC to aim at meeting the safety and environmental protection provisions of all relevant State legislation. In this context, the discharge of radionuclides in airborne effluent from the Lucas Heights Research Laboratories is subject to the provisions of Regulation 13 in the NSW Radioactive Substances Regulations which prescribe the maximum permissible concentrations of various radionuclides in airborne discharges. The AAEC operates under a discharge authorisation approved by the NSW Radiological Advisory Council.

Adequacy of Emergency Procedures and Response

The Committee considers that the response from the NSW emergency services was excellent. Eight fire appliances with a total fire crew of 32 persons responded to the fire call from the AAEC, including the NSW Fire Brigade hazardous materials team. The first NSW Fire Brigade appliance was at the Lucas Heights site within about 13 minutes of the AAEC's call. Some initial confusion was experienced because of the relatively large numbers of fire brigade personnel entering Building 54 cell area and the need to repeat briefings as successive fire crews arrived. The Committee has made recommendations on the way this might be dealt with more efficiently in any future incident. Fire appliances were equipped with protective clothing for fire personnel should it have been needed. Additional protective clothing was also available at LHRL.

The response of all AAEC staff involved in the accident was excellent. This was not only confined to officers who were on site at the time the accident occurred but also to staff who voluntarily returned to the LHRL to offer assistance when they heard about the fire via the news media. Established emergency procedures were observed by all AAEC staff and the Committee particularly commends the action of the cell operator in his prompt handling of the initial phase of the incident.

Existing emergency procedures proved adequate. More detailed information about the fire in the first stages would have assisted NSW authorities in a better assessment of the appropriate size of their response.

APTCARE

The Lucas Heights emergency plan (APTCARE) was not invoked because the fire was of a minor nature and was quickly assessed as having no consequences outside Building 54. However, representatives of a number of APTCARE participating organisations (NSW Fire Brigade, Police, Ambulance, and Department of Health, NSW) were present.

Advice to Staff and External Authorities Concerning the Accident

The news media appear to have learned about the accident by monitoring the NSW Fire Brigade radio transmissions and news of the accident was broadcast during 6 o'clock news bulletins. Consequently, some external authorities and members of the public telephoned the LHRL seeking information about the accident before LHRL staff had assessed the situation.

Early advice on the accident was provided to the Minister for Resources and Energy and to relevant State and Local Government Authorities. A representative of the NSW Department of Health was present at the Lucas Heights Research Laboratories on the evening of 18 March.

Advice to staff at the LHRL on the evening of 18 March 1987 was confined to a site public address announcement at 1745 hours which stated that a fire had occurred in Building 54. There were no follow-up announcements to inform staff of the progress of the accident. Cleaners, trades staff working overtime, HIFAR operators and other staff at the LHRL were insufficiently informed.

The first AAEC announcement about the fire was made to news media assembled outside the LHRL at about 2005 hours on 18 March 1987.

The Committee considers that advice to staff, the general public, the media and Sutherland Shire Council left much to be desired and notes that the AAEC is taking steps to improve this situation.

Recommendations

The Committee recommends that the AAEC gives early consideration to the following:

- Installing temperature indicating/alarm devices in all in-cell charcoal filters used in radioisotope production to give warning of any unusual or unexpected rise in temperature.

- Investigating the feasibility of installing metal mesh screens between the in-cell filters to eliminate spark transfer.

- Investigating the feasibility of by-passing the in-cell filters when any unusual rise in temperature occurs.

- Using charcoal filter casings made with better heat resistant materials.

- Adding an air drying column in the process line before the small in-cell charcoal filters.

- Examining the Building 54 hot cells to ensure that there is minimal possibility of escape of radioactive material from within the cell to outside working areas in the event of negative pressure being lost.

- Reviewing the practice of officers working alone in the Building 54 hot cell area after normal working hours.

- Relocating the manual tripping mechanism for the individual cell fire dampers to allow easy access and, if possible, installing a push button system for activating the individual dampers.

- Obtaining the assistance of CSIRO units situated at the LHRL in the early identification of radionuclides and other materials involved in any accident.

- Establishing procedures with NSW authorities to ensure that:

  - NSW emergency personnel attending an accident or incident at LHRL do not enter areas containing radioactive or toxic materials without adequate briefing from an appropriate AAEC officer,

  - Access to the accident/incident area at the LHRL, in the first instance, is restricted to the senior officers of the NSW emergency services who, with the assistance of the AAEC, will assess the situation and be responsible for briefing other additional emergency crews as they arrive.

- The Committee notes that it is standard procedure for all personnel and equipment involved in an accident/incident with radioactive materials to be monitored before leaving the area. An appropriate member of the AAEC emergency organisation must ensure this is done at the time.

- The Committee considers that any accident/incident at the LHRL requiring the attendance of NSW emergency services will inevitably receive early media attention. It therefore recommends that an appropriate officer of the AAEC emergency organisation informs all persons working at the LHRL at the time of an incident via the site public address system of the nature and significance of the accident/incident.

- The Committee suggests that a direct line of communication be established between the AAEC and the Sutherland Shire Council to ensure that the Council receives early notification of accidents and incidents which are notified to the NSW Department of Health and/or the NSW State Pollution Control Commission or which are given a high profile in the news media.

FIGURE 1   POSITIONS OF BUILDING 54 & HIFAR AT LUCAS HEIGHTS

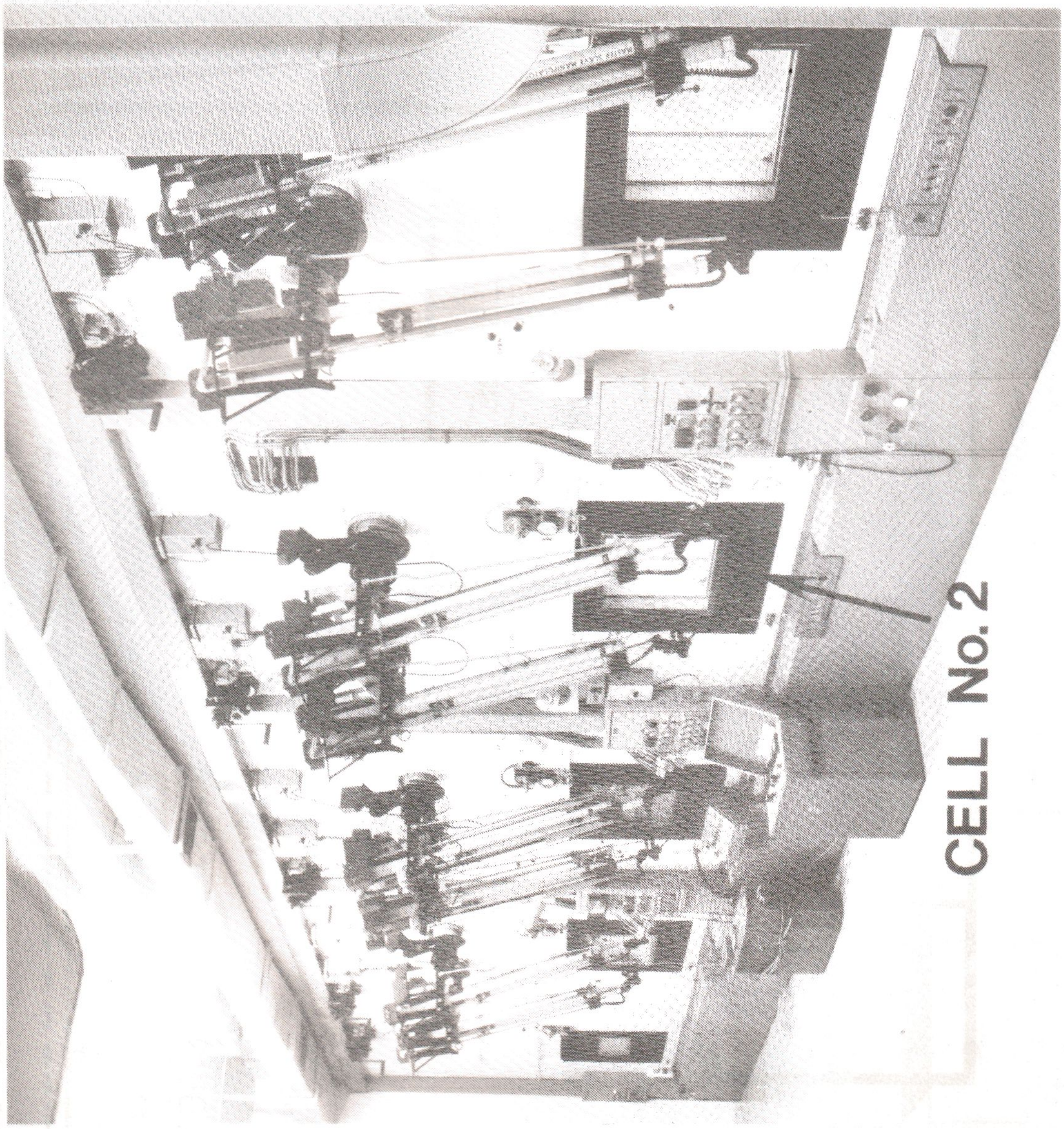

FIGURE 2   FACE OF RADIOISOTOPE PROCESSING CELLS

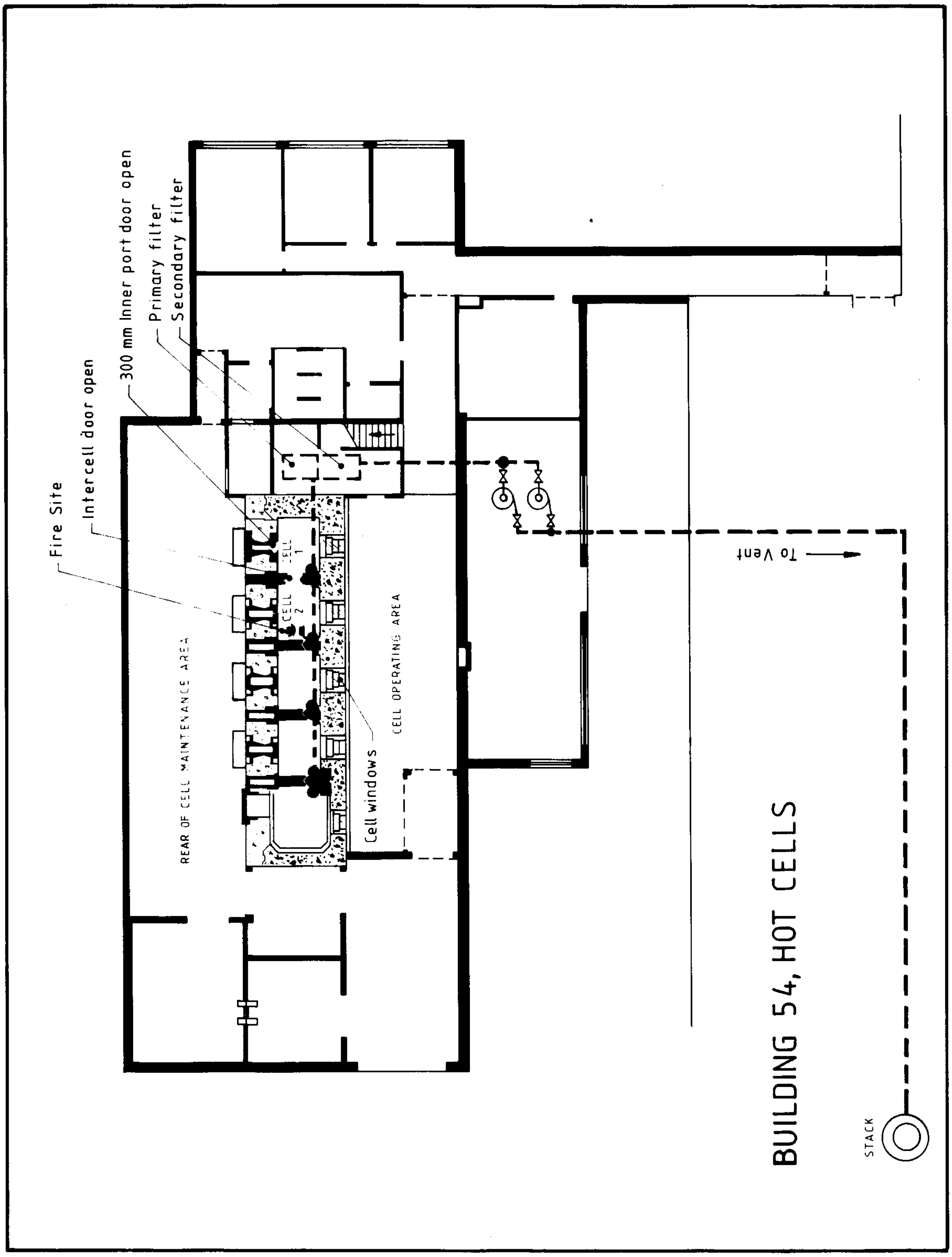

FIGURE 3 PLAN OF BUILDING 54 HOT CELLS

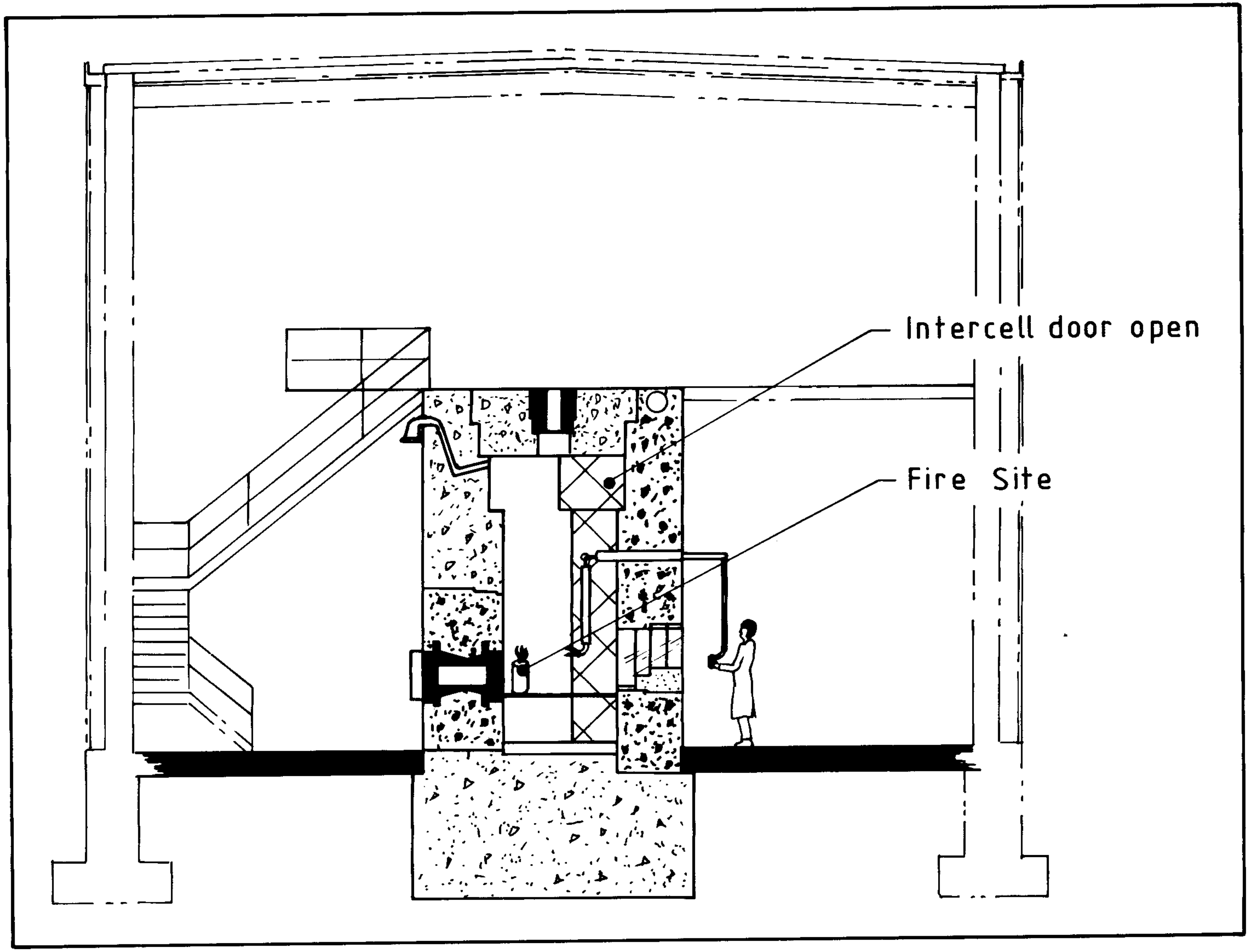

FIGURE 4 SKETCH SECTION THROUGH CELL NO. 2

Appendix 1

Committee Membership

Mr J C E Button (Chairman), Chief, Health and Safety Division, AAEC.

Mr A Fleischmann, Officer-in-Charge, Radiation Health Services, Department of Health, NSW.

Mr P Herborn, Town Planner, Sutherland Shire Council.

Dr P M Kelly, Acting Deputy Director, AAEC.

Mr K Horlock, Controller, Commercial Products Unit, AAEC.

Mr F O'Donnell, Acting Head, Personnel and Staff Relations, AAEC.

Mr P Sharp, ADSTE Delegate representing AAEC unions and staff associations participating in the Inquiry.

Mr J Fardy, Principal Research Scientist, Division of Energy Chemistry, CSIRO.

Ms E M Small (Secretary), Assistant Secretary, AAEC.

Appendix 2

AUSTRALIAN ATOMIC ENERGY COMMISSION

TERMS OF REFERENCE OF COMMITTEE TO INVESTIGATE FIRE IN THE CHARCOAL FILTER OF CELL NO. 2 OF NO. 2 HOT CELLS, BUILDING 54 AT THE LUCAS HEIGHTS RESEARCH LABORATORIES

- to determine the circumstances leading to the occurrence and its causes;
- to examine any effects of the occurrence on staff;
- to examine the effects of the occurrence elsewhere on-site, and any possible off-site effects;
- to examine the adequacy of existing procedures designed to avoid such occurrences and the extent to which they were observed;
- to examine the adequacy of the response from all parties that needed to be involved;
- to recommend actions necessary to avoid similar occurrence;
- any other matters requested by the Director or determined by the Committee.

The Investigation Committee reports to the Director.

Airborne Contamination Measurements Within Building 54

The derived air concentration (DAC) is the concentration of a radionuclide in air which would result in a worker receiving the annual allowable intake of the radioactive material if exposed to that air concentration 50 weeks per year, 5 days per week, 8 hours per day. The following pessimistically utilises the DAC for iodine-131 (700 becquerels per cubic metre (Bq/m^3)) because in this accident, if iodine-131 were released it would be the radionuclide with the most significant effects on persons.

Air sample filters collected in Building 54 on the evening of Wednesday, 18 March 1987 were measured. These filters were initially counted on a beta counter and then on a gamma spectrometer with a sodium iodide (NaI(Tl)) detector. The activity was restricted to that area of the spectrum containing the 0.364 million electronvolts (MeV) photopeak from the radionuclide iodine-131.

The first beta measurement on an air sample filter from the cell face operating area indicated an airborne concentration of 0.65 DAC (pessimistically assuming all the radioactivity was iodine-131). After 50 minutes, this air sample filter was remeasured and indicated an airborne concentration of 0.06 DAC. This rapid rate of decay showed that the radioactive contaminant on the sample was not iodine-131 (half-life 8 days) but was a material with a shorter half-life of approximately 15 minutes and that the radioactivity came from noble gases.

The second measurements on two air sample filters from the cell face operating area, using the same gamma spectrometer, showed an airborne concentration of 0.06 DAC (pessimistically assuming iodine-131) for the air sample filter taken over the period 1800 hours to 1820 hours and an airborne concentration of 0.04 DAC for the air sample taken over the period 1820 hours to 1833 hours (18 March 1987).

The air sampler in the rear of the cell area had been operating continuously prior to the fire and the air sample filter was removed at 1820 hours on Wednesday, 18 March. Gamma spectrometry measurements of this sample yielded an airborne concentration of 0.05 DAC.

All air sample filters, initially counted before 2000 hours on Wednesday, 18 March, were recounted at 2030 hours and showed approximately half their initial activity.

The air sample filters were again counted at 2045 hours using a high resolution gamma spectrometer with a Ge(Li) detector. In all cases no iodine-131 was detected but there was evidence of some gamma energy peaks from noble gas fission products in the region of 0.36 MeV.

The three air sample filters were again counted the following morning (19 March 1987) using the high resolution gamma spectrometer and no gamma energy peaks were detected, confirming that the airborne contamination detected in Building 54 was from short-lived radioactive noble gases.

Appendix 4

Surface Contamination Measurements

Monitoring measurements showed that three AAEC officers were contaminated - two had minor contamination on the hands and one had minor contamination on his hair. A fourth AAEC officer had a small spot of contamination on the leg of his trousers. In each case, the contamination was quickly removed by washing.

No contamination was detected on NSW emergency personnel or their equipment.

Details of the contamination on AAEC officers were as follows:

. contamination on hands	0.5 DWL *
. contamination on hair	< 1 DWL
. contamination on trousers	< 1 DWL
. surface contamination in rear of cell area	0.5 DWL
. surface contamination in cell front face area	Nil

Whole body monitoring and thyroid monitoring (for iodine-131) measurements were carried out on four persons after the accident. These were the cell operator, the Duty Shift Manager, the Duty Shift Health Physics Surveyor and a member of the Australian Protective Services (who was on duty in Building 54 during the accident). No internal contamination was detected.

* Notes

(i) Hazards arising from contamination of surfaces by radioactive materials are controlled by setting the derived working limit (DWL) for surface contamination such that:

- the amount disturbed from surfaces does not allow the permitted airborne contamination concentration to be exceeded,

. the amount of contamination ingested via hands and mouth does not cause the permitted annual intake of radioactive material to be exceeded,

. in the case of skin contamination (eg. of the hands) the skin dose does not exceed the permitted level.

(ii) The DWL for contamination of skin and inanimate objects by beta-gamma emitters is 4 becquerels per square centimetre (Bq/cm^2).

RADIOACTIVE AIRBORNE EFFLUENT MONITORING

The AAEC operates to a quarterly authorisation for the discharge of radioactive airborne effluent. The authorisation is divided between the stacks which discharge airborne effluent from operations. The various discharges from these stacks are constantly monitored, routinely assessed and the discharge calculated on a weekly basis. To facilitate comparison with the quarterly discharge limit, the authorisation has been divided into thirteen weekly amounts which are termed the "weekly equivalent of the Authorised Quarterly Stack Discharge Limit".

In respect to Building 54, the stack discharges released over the weekly sampling period which included the fire are set out below.

Radioiodines

Discharge of radioiodines are measured by passing a known fraction of the stack effluent through a Maypak sampler which adsorbs radioiodines. The sample is subsequently analysed by gamma spectrometry for each of the iodine components.

During the weekly sampling period which included the fire, three measurements were made, one immediately after the fire on March 18 at 1925 hours, one on March 20 at 1300 hours and the other at the end of the sampling period, March 24 at 0900 hours. The results of these measurements are shown in the table below and compared with allowable limits.

	Sample 1 18/3/87 (MBq)	Sample 2 20/3/87 (MBq)	Sample 3 24/3/87 (MBq)	Total For Week (MBq)	Allowable Discharge (MBq)
Sampling Period	32 hrs	38 hrs	98 hrs	168 hrs	
Iodine 131	21.6	39.4	48	109	5,077
Iodine 132	36.3	40.7	89	166)	123,000
Iodine 133	34.7	179.3	90	304)	

For iodine 131 the release represents 2.1% of the allowable weekly limits. For I-132 plus I-133 the release represents 0.4% of the allowable weekly limit.

Noble Gases

The radioactive noble gases (isotopes of krypton and xenon) are sampled on-line and subsequently measured by high resolution gamma spectrometry. Because identification of these isotopes is dependent on the accumulated activity counts, accurate analysis is difficult over short time periods, i.e. during and immediately after the fire.

The Maypak samplers used for measuring the discharge of radioiodines were also used to measure the noble gas discharges. The compositions of the released gases and the total activities were -

	Sample 1 18/3/87 (TBq)	Sample 2 20/3/87 (TBq)	Sample 3 24/3/87 (TBq)	Total For Week (TBq)	Allowable Discharge (TBq)
Sampling Period	32 hrs	38 hrs	98 hrs	168 hrs	
Noble Gases*	3.75	1.66	1.41	6.82	12.9

*(Krypton-85m, Krypton-87, Krypton-88, Xenon-133, Xenon-135, Xenon-135m)

The authorisation for noble gases is phrased in terms of total activity. For a one week period the authorisation allows a discharge of 12.9 TBq. Thus the release during the period up to Sample 1, which included the run in question and the fire, was 29% of the weekly release limit. For the weekly period the total release was 53% of the authorisation for noble gases.

Figure 5 shows the accumulation of noble gas and radioiodine releases during the full one week sampling period 17-24 March.

Conclusion

From the results of the monitoring program (see Figure 5) it appears that there was no release of radioiodines or noble gases that were attributable, directly or indirectly to the fire. For comparison Figure 6 and Table 1 show gaseous releases for the five weeks preceding the week which included the fire.

NOTE: 1MBq = 1×10^{6} Bq

1TBq = 1×10^{12} Bq

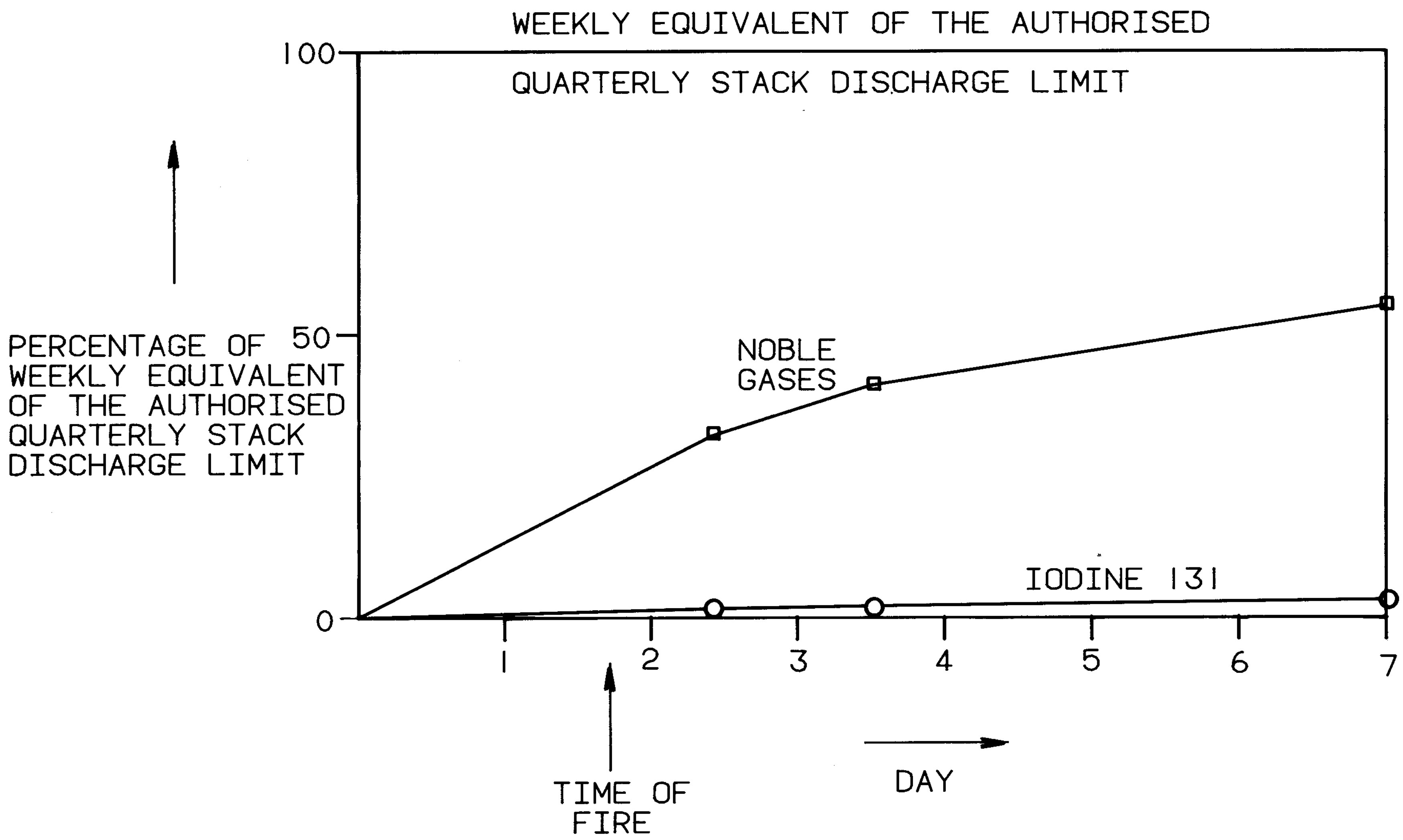

FIGURE 5 CUMULATIVE RELEASE OF NOBLE GASES AND IODINE-131 FROM 17 TO 24 MARCH 1987

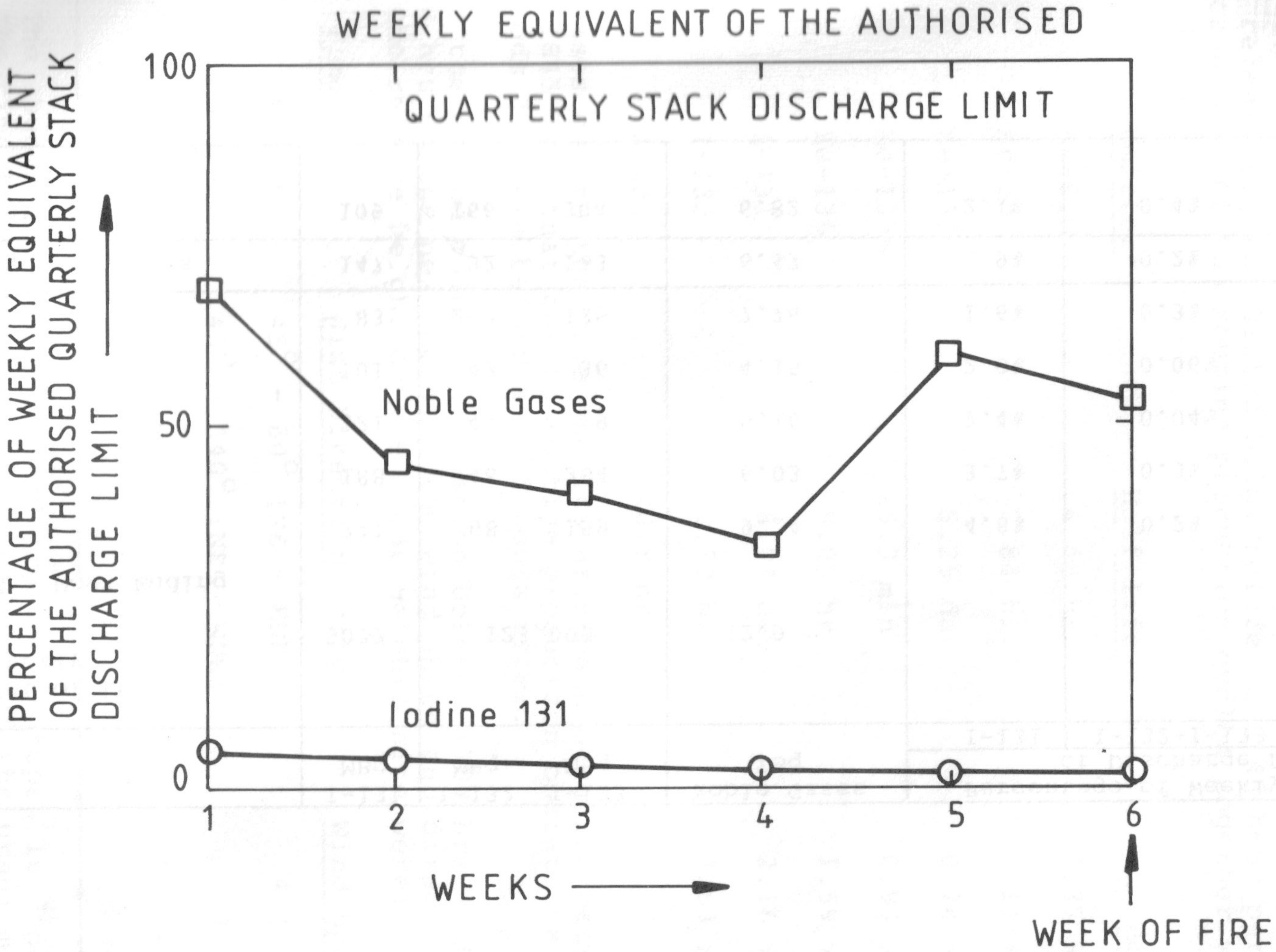

FIGURE 6 RELEASES OF NOBLE GASES AND IODINE-131 FOR THE WEEK OF THE FIRE AND THE PRECEDING FIVE WEEKS

TABLE 1

COMPARISON OF WEEKLY STACK DISCHARGES - BUILDING 54

	I-131 MBq	I-132 MBq	I-133 MBq	Noble Gases TBq	Percentage of Weekly Equivalent of Discharge Limit		
					I-131	I-132+I-133	Noble Gases
Weekly Equivalent of the Authorised Quarterly Discharge Limit	5077	123,000		12.9			
Sampling Period - Week Ending							
17 February	241	68	159	9.24	4.8%	0.2%	70.5%
24 February	188	48	284	6.03	3.7%	0.3%	46.0%
3 March	121	44	9	5.16	2.4%	0.04%	39.4%
10 March	101	42	36	4.15	2.0%	0.06%	31.7%
17 March	83	258	125	7.76	1.6%	0.3%	59.2%
Average of previous 5 weeks	147	92	123	6.47	2.9%	0.2%	49.4%
24 March (Week of fire)	109	166	304	6.82	2.1%	0.4%	52.9%

SIGNIFICANCE OF RELEASES DURING THE ACCIDENT PERIOD

The release of radioactivity from Building 54 during the night of 18 March could have had two components, one possibly attributable to the fire in the charcoal trap, the other to the routine production of radioisotopes.

The release figures listed below relate to a 46 hour period which covered most of two routine production cycles together with the accident.

Emitter*	Half-life	Bq
Kr-85m	4.48 hr	0.37×10^{12}
Kr-88	2.84 hr	0.11×10^{12}
Xe-133	5.25 day	0.74×10^{12}
Xe-135m	15.3 min	0.94×10^{12}
Xe-135	9.09 hr	1.59×10^{12}
I-131	8.04 day	2.16×10^{7}
I-132	2.32 hr	3.63×10^{7}
I-133	20.8 hr	3.47×10^{7}

Releases due to the fire and its aftermath occurred between 1745 and 1845 hrs; that due to routine production operations in two periods 30 hours before and 15 hours after.

Over the period mainly in question between 1700 hrs 18 March and 0200 hrs on the next morning the wind speed and direction recorded at the release height on the Lucas Heights site were:

Time	Wind Direction (origin)	Wind Speed (m s^{-1})
1700 - 2015	45° - 80° (NE - ENE)	4 ± 1
2015 - 2230	45° - 340° (NE - NNW)	3
2300 - 0200	280° (W)	2.5 - 3

* The abundance of short-lived krypton isotopes is dependent on the time that elapses between removal of the uranium target from the reactor and the opening of the target can in the hot cell. This is not true of the short-lived Xe-135m because its abundance is determined by the half-life of its parent (I-135, half-life 6.61 hr).

From these wind directions it follows that no nearby resident (ie. residents of Menai, Loftus, Engadine, Heathcote, Waterfall) was exposed at all during the period of the fire or to the major part of the release associated with the routine production run after the fire had been controlled.

If a hypothetical person were stationed in a helicopter in the mid-line of the plume and had followed it through a 160^{o} arc over the next nine hours then the dose such a person would receive, assuming all the measured release over 46 hours occurred during this 9 hour period, would be:

Distance (m)	Cloud Dose due to Noble Gases (microsieverts)	Inhalation Dose due to Iodines (microsieverts)
800	2.2	0.0003
1,600	0.65	0.0004
3,200	0.22	0.0002

These doses were calculated using the most conservative atmospheric dispersion recorded during the period and on the assumption that the person travelling with the plume remained at the height of the release (40 m above ground surface at Lucas Heights). The calculation further assumes that the plume was infinitely thick (with respect to the range of the emitted gamma rays) at the centre-line concentration.

It is worth comparing this calculated dose to our hypothetical person with the real dose received by a person spending the same period (9 hours) at home in a brick bungalow. The latter would have been exposed to a dose of about 2.1 microsieverts based on a nine hour exposure to an annual natural background dose of 2,000 microsieverts. About half of this is due to natural radioactivity in building materials. Thus our hypothetical flyer would have received a slightly smaller dose by being in the plume at the site boundary than by being at home.

A set of air samplers for radioiodines are run continuously at the security fence to Lucas Heights. These were analysed on the morning of 19 March. They had been sampling air for the previous five days which included the night of the fire. Nothing was detected.

Small dairy herds are run in the Menai area. A milk sample from them was obtained on 19 March. No artificial radioactivity (including radioiodines) was detected. Cows grazing would have sampled releases from Lucas Heights over a large number of days. These nil results are to be expected given the small quantities of iodines released.