The Development of Radiochemical Facilities at Lucas Heights

By G. L. Miles and D. F. Sangster*

A description is given of the recently completed radiochemical laboratories at Lucas Heights. Design problems are discussed, as well as initial operating experience.

INTRODUCTION

The Research Establishment of the Australian Atomic Energy Commission is being constructed on a 168-acre site at Lucas Heights, 25 miles south-west of the centre of Sydney, and several miles from the outer suburbs. The site forms part of a small sandstone plateau above the Woronora River. Most of the site is fairly level, but to the east side it slopes very sharply towards the Woronora River. The western end of the site where the HIFAR reactor has been located is about 15ft. higher than the main laboratory area.

The layout of buildings and services on the site is shown in Figure 1. It will be noticed that the reactor and associated buildings are about one quarter of a mile from the main laboratory and administration groups of buildings. In fixing the degree of isolation of the reactor it was necessary to take into account the fact that the reactor is housed in a protective sealed steel building, and that even a quite serious reactor accident would, in all probability, not result in appreciable contamination outside the sealed building. The area between the Laboratory Group and the Reactor Group will eventually be used to house reactor experiments.

Wherever possible, site services such as electricity, compressed air, telephones etc., have been reticulated below ground. This is desirable not only from an aesthetic point of view, but it also simplifies the layout of roads and the provision of future buildings.

The size of the Research Establishment has initially been determined by the minimum requirements of a project in which a reasonable balance is kept between the service requirements and the effective research effort. It is at present estimated that a total staff of about 700 will be required, of whom about one half will be employed in administrative and scientific and technical services including workshops, site maintenance, analytical services, effluent treatment, etc. If the total number of staff is below 500, the proportion required for these services becomes too large to justify the investment in building and equipment.

Preparation of the site commenced in November, 1955. In the early stages of the project, financial limitations restricted the initial construction effort to site preparation, the provision of site services and temporary facilities, and the construction of the reactor and certain ancillary buildings. In order to provide both facilities in which active work could be carried out and the necessary analytical control of reactor operations, the main Chemistry-Chemical Engineering laboratory was given a high priority. Furthermore, many of the early problems to be faced in a power reactor project are chemical and metallurgical, rather than engineering, in nature. The construction of the main Chemistry-Chemical Engineering laboratory was commenced about July, 1956, and was substantially completed by March, 1958.

DEFINITION OF RADIOCHEMICAL REQUIREMENTS

In planning the Research Establishment, it was necessary to provide facilities for the following levels of active work:—

(i) Highly active sources (10 curies - 100,000 curies). This includes post-irradiation examination of potential fuel materials, maintenance of reactor components and chemical processing of nuclear fuels.

(ii) Medium active sources (1 microcurie - 1 millicurie and 1 millicurie - 10 curies). This includes the bulk of the radiochemical investigations of potential processing methods, radio-active tracer experiments, studies of fuel chemistry, radiochemical analysis etc.

(iii) Inactive chemistry (up to microcurie level only). This covers general chemical and analytical work under conditions where no significant activity is involved, or special precautions are necessary.

(iv) Low background counting. This is a specialised requirement for the Health Physics service, analysis of biological samples etc., and requires isolation from possible radioactive contamination.

(v) Ancillary services. Provision must be made for the requirements of ancillary services such as Health Physics, Effluent Services etc.

It was not considered practicable to divide the whole site into two areas, one for radioactive, and one for non-active work. However, it was planned to confine active work to as few areas as practicable, and to exclude irradiated materials from other buildings such as the Engineering-Metallurgy building.

Initially, the only facilities which are being provided for the handling of very high levels of activity (over 10 curie sources, for example) will be in the post-irradiation cells in the Reactor Group and in the Chemical Engineering main bay. It is hoped to start construction of the post-irradiation cells later this year.

* Australian Atomic Energy Commission Research Establishment. Manuscript received March 13, 1958.

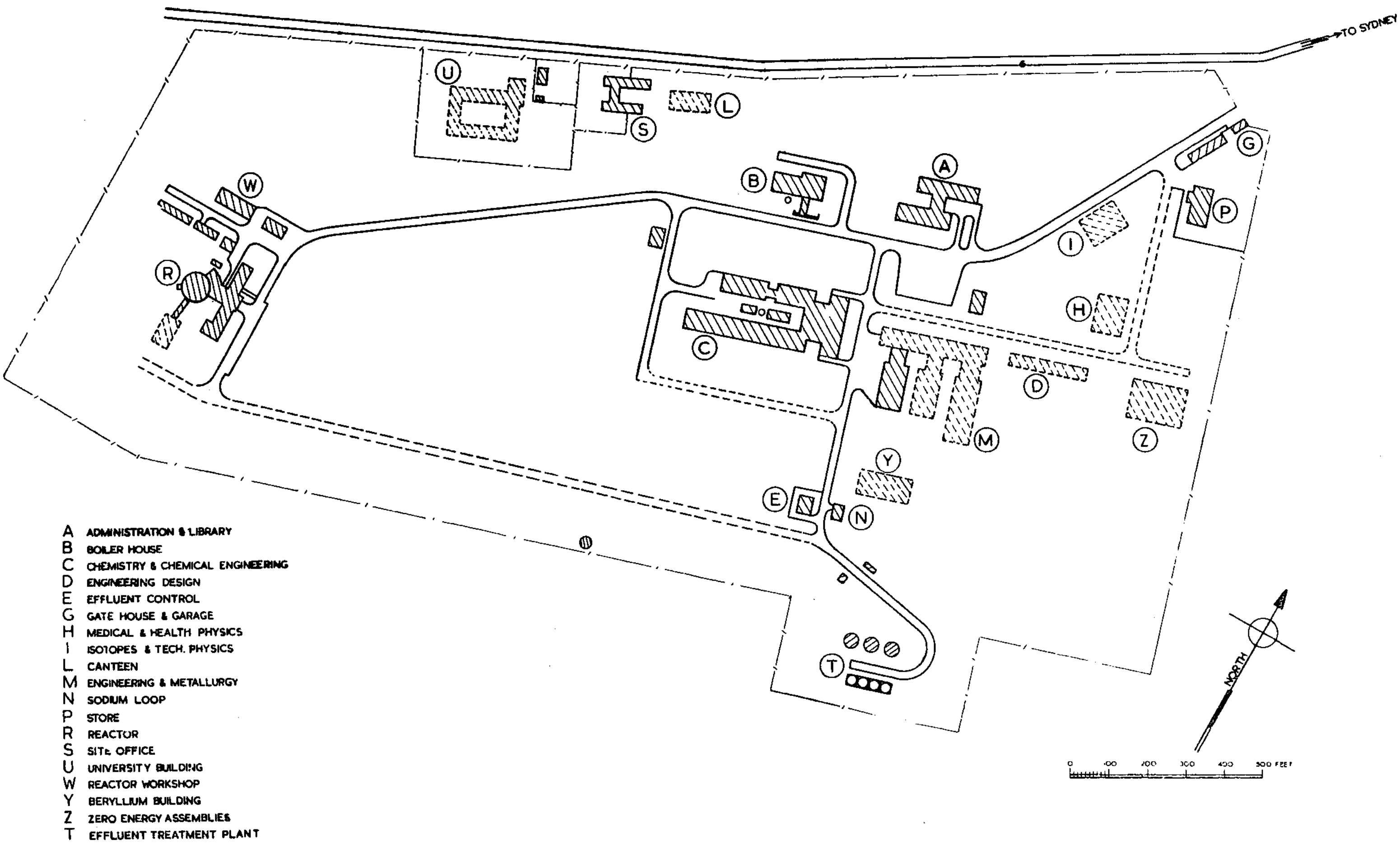

FIGURE 1: General site plan of Lucas Heights Research Establishment. Broken lines represent buildings planned but not yet under construction.

The main facility provided for the handling of medium active sources (up to 10 curies) is the Chemistry-Chemical Engineering building, which is described later.

It was recognised that the provision of facilities for low background counting was a very important responsibility of the research establishment, and it was decided to operate this service in a temporary wooden building remote from the main laboratory group. This arrangement avoided difficulties of contamination and possible high radiation backgrounds, and during the next few months an attempt will be made to assess the longer term requirements of the establishment for low background radiation measurements.

Health Physics service requirements within the Chemistry-Chemical Engineering building have been covered by the allocation of a laboratory for instrument maintenance, smear testing, and air sampling measurements.

The land in the eastern corner of the site falls away rapidly, making this a very suitable location for effluent holding tanks and treatment plant. In this area the Effluent Control building has been erected. This is described in a later section of this paper.

CHEMISTRY-CHEMICAL ENGINEERING BUILDING

General description

This is a large building (floor area—approximately 47,000 sq. ft.) which has been planned to house the Chemistry and Chemical Engineering Research Groups and the Analytical Service Group. The general plan of the building is illustrated in Figures 2 and 3.

The front two-storey area of the building is a non-radioactive area containing stores, workshop, glass-blowing facilities, electronic maintenance, and general analytical and spectrographic laboratories, and offices. The two-storey area is linked by a single storey changing and toilet area to the two active wings of the building.

One of the active wings is designed for general radiochemical research which might involve the handling of up to a few curies of gamma-active materials, or substantial alpha-active sources. The radio chemistry wing is a single storey structure about 320ft. long, with a central loft which houses ventilating ducts and booster fan and filter units. This wing includes six active suites which are described below.

The other active wing of the building is designed for chemical engineering and pilot plant studies with radioactive materials. It contains offices, a workshop, an active suite similar to those in the chemistry wing, and a main bay for the erection of larger pilot plants and for handling sources too active for the radio-chemical wing.

Between the two active wings of the building are delay tanks, an active materials store, ventilation stack, fan rooms, and an underground service area including a calorifier and plant room.

The building is a reinforced concrete frame structure with aluminium curtain walls and generous window space. Provision has been made for a uniform ground floor loading of up to two tons per square foot to permit of movement of heavy lead castles, and the construction of shielded cells.

Active suites

Each active suite consists of a lobby, office, low activity or "blue" laboratory, and a high activity "red" laboratory. The total floor area of each suite is approximately 1,400 sq. ft. The lobby contains a wash basin, electrical distribution boards, and provision for radiation monitors. A small office is attached to accommodate two supervisory staff. Desk space for assistant staff is provided in the "blue" laboratory. An emergency shower has been provided near the entrance to each "blue" laboratory. It has been found in practice that there is a considerable amount of relatively inactive work associated

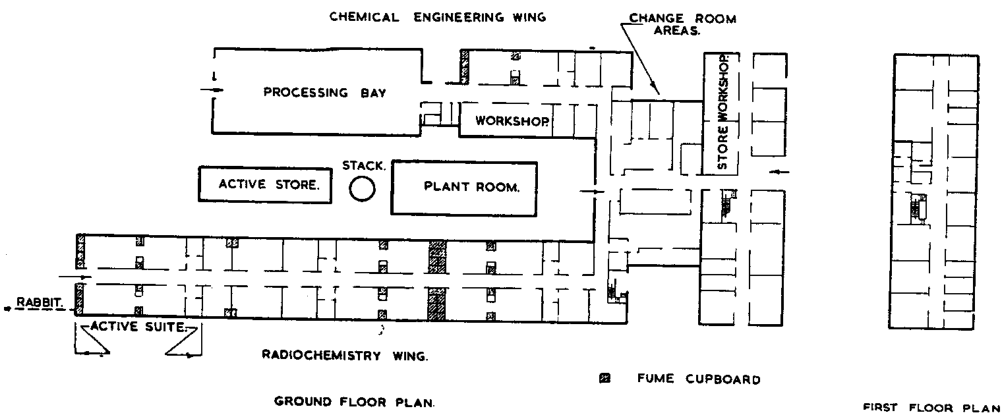

FIGURE 2: Floor plan of Chemistry-Chemical Engineering Building.

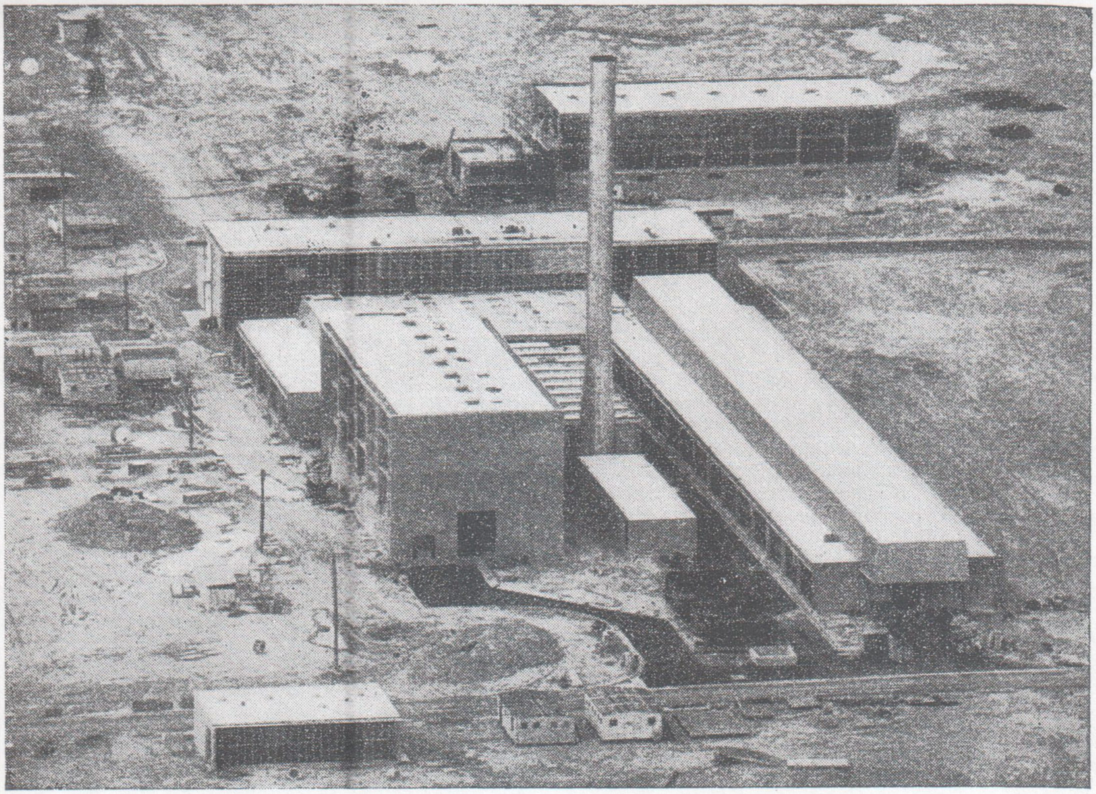

FIGURE 3:—General view of Chemistry-Chemical Engineering Building. (Sydney Morning Herald photograph.)

with each active area. This includes assembly and testing of equipment, preparative and analytical work. The "blue" laboratory has therefore been provided to enable this to be done away from the more rigorous working conditions which are necessary in the "red" laboratories. Activity is thus confined to a limited and manageable area in each suite.

The "red" laboratory is normally entered only from the "blue" area, although an emergency door has been provided into the corridor at the extremity of each "red" laboratory. Provision for change of shoes and laboratory coats is made at the entrance to each "red" area. If necessary, this contamination control can be imposed for the whole of the active wings.

Fume hoods have been provided for manipulations involving gamma active materials up to one millicurie. For the handling of gamma sources of higher activity, it is necessary to construct lead cells on the floor of the "red" laboratory. Intense alpha active sources must be handled in glove boxes.

There are no fixed gamma monitors in the laboratories. It is intended rather to work in close co-operation with the Health Physics Section when individual experiments involve high activities.

Each active suite contains six fume hoods, each about 4ft. wide. A bank of four fume hoods is provided across one end of the laboratory and the individual hoods are divided from each other by removable perspex panels. One fume hood extends to floor level. The others are constructed on a cantilevered bench permitting an operator to work at the fume hood in a comfortable seated position. This is most important for careful work with radioactive materials. The design of the fume hoods is sufficiently sturdy to allow the erection of a four-inch thick lead shielding wall at the front of the fume hoods.

Ventilation outlets have been provided in the ceiling of each active suite to permit connection of extract hoses from glove boxes or lead cells.

Other facilities in the radiochemistry wing

Provision has been made for counting and balance rooms near the entrance to the wing, and for six separate active laboratories which are grouped together in the centre of the wing. These laboratories, which have 400 to 500 sq. ft. of floor area, will be required for special analytical facilities, including mass spectrographs and X-ray and vacuum fusion, and special analysis equipment. Rooms have also been set aside for a small active workshop, and for equipment decontamination.

Chemical Engineering main bay

The Chemical Engineering main bay covers an area of 5,000 sq. ft., and 35ft. of head room is provided below a 5-ton travelling crane. A network of floor ducts with steel-covered plates has been provided for the reticulation of services from the side of the walls. The normal entrance to this bay will be from the laboratory areas, but a large roller shutter door gives outside access for the installation of heavy equipment. Provision has been made for the later construction of steel access galleries around the side walls. Emergency showers have also been provided. Extract facilities have been provided for the exhaust of large glove boxes or shielded cells.

Ventilation

A feature of the Chemistry-Chemical Engineering building is the extensive ventilation system provided for the active areas. This discharges into a 120ft.-high stack located alongside a plant room between the two active wings of the building.

The ventilation system was planned so that all air entering the radioactive areas should pass through electrostatic and conventional filters, to eliminate dust, while the filtration of extract should be restricted to the most active areas and to glove boxes. By providing separate booster fan and filter units above the more active areas of the building, it was possible to reduce greatly the overall operating costs, while still providing protection where it is most needed. The dilution of air discharged through the stack is normally quite sufficient to take care of any hazard which might arise from materials handled in normal fume hood operations.

The ventilation has been arranged so that the familiar "clean-suspect-dirty" airflow pattern is maintained at all times. Plenum air enters a laboratory from a central diffuser and through registers in the walls and doors. The air is exhausted through the fume hoods and through secondary exhaust outlets located in the ceiling above the fume hoods.

When a fume hood is opened in an active laboratory, the increased air demand is satisfied by an increased flow from the corridor into the laboratory. The corridor is supplied from a secondary input. The plant was designed on the basis that not more than half of the fume hoods would be open at any instant. The design air velocity at the face of the fume hoods is 135 linear feet per minute. The velocity remains constant with opening and lowering of the fume hood sash because a mechanical coupling adjusts the extract damper in the throat over the hood. A constant profile of air velocity is maintained across the face of the fume hood by installing a fixed baffle at the back of the hood. One half of the air is exhausted up behind this baffle, while the other half travels in front of it. The constant velocity of air at the face of each individual hood may be simply adjusted from within the laboratory; 100 linear feet per minute is adequate for most experiments. Smoke tests have shown that these fume hoods behave very well, and a seated operator working with a spillage tray is quite safe.

For the ventilation ducting, mild steel sheeting has been used, and the exhaust trunking has been made readily removable for ease of maintenance. All portions which are liable to come into contact with chemical fumes have been coated with a chlorinated rubber-based paint. While some difficulty has been experienced with similar ducting at A.E.R.E. Harwell, it is hoped that, with the improved paints now available and with strict maintenance procedures, the life of this ducting may be prolonged.

General services

Normal laboratory services have been provided, including compressed air, hot and cold water, drainage, gas, single and three-phase power (in selected laboratories) and steam. It was decided not to provide a central vacuum system because of the difficulties associated with such a system—prevention of abuse, maintaining a reasonably constant vacuum, sucking in of dirt and vapours. Similarly, it was decided not to install a permanent water vacuum pump as standard, because this greatly increases the aqueous effluent arising from a laboratory. Individual workers will be expected to provide themselves with recirculating water, or compressed air venturi pumps as appropriate.

A special use of compressed air in radiochemical laboratories is for air ejectors which provide suction for glove boxes. These air ejectors are more reliable than conventional exhaust fans, and are simple and inexpensive to construct.

The Commission's water supply is of high quality (about 50 parts per million total solids), and it was not considered necessary to reticulate demineralised water to all laboratories. However, a demineralising unit has been located in the loft of the radiochemistry wing and from there demineralised water is piped (in polythene) to analytical laboratories, both in the front two-storey area, and in the radiochemistry wing.

A double bowl stainless steel sink and draining board has been provided in each laboratory. Extra water supply and drainage points have been provided for condenser cooling water, etc., although it is hoped that, in order to reduce the effluent volume, this requirement can be satisfied by air-cooled water circulation units. All plumbing is in black polythene piping and fittings.

Gas is reticulated to laboratories from a central bank of cylinders.

Piped services are reticulated from the calorifier room in underground service ducts, which are located on either side of the active wings. Within the building, services are carried along wall ducts just below the windows. These ducts have metal panels, and are accessible from either inside the laboratory or from the exterior of the building. Water, gas, and compressed air services to individual active suites can be isolated by valves located in the corresponding offices. In general, the only services reticulated on inner walls and partitions are gas, compressed air, and electricity. This is because of the inconvenience of providing drainage under a heavily loaded floor. However, each fume hood is provided with duplicate services comprising electric power, compressed air, cold water, gas, and drainage.

Electricity supply to the site is provided by two independent high voltage feeders. Should both of these fail, there is, in the boilerhouse, a standby diesel generating set which automatically starts up within a few seconds. This energises a guaranteed circuit which is connected to the ventilation exhaust fans of the building, the compressed air supply, strategic lights, and certain monitoring instruments and alarm circuits throughout the building. A battery-operated alarm sounds on failure of compressed air or electric control systems. All general purpose electrical outlets are equipped with built-in individual miniature circuit breakers, while the circuit breakers protecting groups of outlets are located in the lobbies of the active suites, and in other easily accessible places. All buildings are fitted with a network of fire detection points (temperature operated) but no automatic sprinkler system was installed because of the special requirements for extinguishing fires involving sodium, uranium, and other reactive metals.

Irradiation facilities

A "rabbit" irradiation facility will be installed between one of the active suites and the "Hifar" reactor. This consists essentially of a brass tube of about 3in. inside diameter, along which a barrel-shaped container can be forced by compressed air at considerable speed. With this facility, it will be possible for staff working in the chemistry wing to irradiate small samples in a high flux position in the reactor, and to return the samples for examination within about a minute. This will be particularly valuable for work involving short-lived isotopes. Other advantages are that it will reduce the carrying of active sources about the site, and save the time which would be spent in changing clothing and in travelling.

FINISH

Considerable attention has been given to maintaining a high standard of finish throughout the laboratories, with the elimination of potential dust traps wherever possible. Hard plaster walls and ceilings have been used throughout.

A good quality flat finish paint was specified for the inactive wing. High gloss enamel has been used on the walls in the active wings and semi-gloss on the ceilings. Active laboratory doors are finished in a hard clear varnish.

In the acid store, in fume hoods, and on aluminium window frames, etc., where there is the possibility of attack by corrosive fumes, a chlorinated rubber-based paint has been used.

Three coats of paint have been used for inactive or low level fume hoods. Active wing fume hoods were given two coats of a strippable vinyl lacquer, followed by two coats of a chlorinated rubber-based paint.

Alternative methods of covering the floors were considered. Finally, it was decided that heavy grade linoleum on a concrete base was the best all-round floor covering for this work. The greatest disadvantage of lino is that waxing and polishing is necessary. In order to cut down on the maintenance required, it was decided to try coating the linoleum with three coats of a polyurethane plastic plaint. Preliminary tests showed that this should be satisfactory, and the whole of the front wing and change room area of the building was so treated. After three months, it was found that wear was evident in the areas subjected to the heaviest traffic. Renewal of the surface is too difficult for this short life to be acceptable, although in areas which have received less use it still retains its appearance and effectiveness and requires only sweeping. Tests are currently under way to find a wax that is non-slip and easily maintained without repeated application of polish. Further, it must not be dust attracting or take up too much dirt or build up with use.

LABORATORY FURNITURE

A great deal of thought was given to deciding the most satisfactory general laboratory furniture system for the site. The main considerations are service requirements in the laboratories and the need for flexibility, and these are not necessarily similar for other laboratories and for other types of research work. A survey of chemical laboratories shows that for physical and inorganic laboratories, the only service that might be needed at any point in the laboratory is electricity. Cooling water supply and return compressed air and gas are needed far less frequently. All of these can be taken relatively easily (overhead if necessary) to where they are needed in the laboratory.

One open sink is essential in each laboratory, but is used relatively infrequently. Open drainage is, in general, not required in the body of these laboratories. It can be provided if needed, with other services, on a peninsular bench by running a plinth out into the laboratory from the outer wall. An island bench allows somewhat greater freedom of movement but, whereas most services can be conducted overhead, open drainage requires a duct in the floor. The duct must be waterproof and have a removable cover, yet still preserve a flat floor that can carry a load of two tons per square foot. It was decided not to attempt to provide such floor ducts in the radiochemical laboratories. They have been provided to take services to isolated experiments in the Chemical Engineering Bay because overhead reticulation would interfere with the operation of the crane. Except perhaps in certain analytical laboratories, fixed benching is therefore unnecessary. Further, fixed benching complete with services cannot be changed about as easily as can a more flexible system. Flexibility is a great merit in atomic energy research, where the purpose, equipment, and arrangement of a laboratory may change from month to month, and as special equipment, glove boxes, shielding and vacuum lines are installed or removed. Ease of decontamination is another consideration.

The furniture system finally decided upon was based on one developed by the British Ministry of Supply and used in some laboratories at A.E.R.E., Harwell. The working benches are independent tables of length 4ft., 6ft. and 8ft., height 3ft., and width 2ft. 3in. The working surface is either wood, linoleum, or "Laminex." Storage space is provided in the form of independent lino covered under-bench units in five designs, providing what is considered as the most useful range of drawer and cupboard sizes. These may be placed under the bench tables, or used independently. Apparatus cupboards have been provided for more extensive storage and for reagents. It is considered that this system is better suited to our needs than any other, because the individual units can be selected, rearranged, or changed with the minimum of effort.

Wood coated with polyurethane was specified for furniture. Although steel furniture is less of a fire hazard than wooden furniture, it is not satisfactory where corrosive fumes are present. Untreated wood is absorbent and difficult to decontaminate. A number of tests were made on a variety of coatings for the furniture, and in particular for the wooden working surface. Finally, a three-coat polyurethane finish was chosen. This was not well known in the trade, but our insistence has been rewarded by the results obtained.

Extensive use has been made of polythene trays for general laboratory work and in fume hoods. These are fabricated on the site to meet individual requirements.

EFFLUENT SERVICES

Provision for collection and treatment of radioactive effluent is an essential part of a radiochemical facility. The general problem of effluent treatment and disposal is the subject of a symposium paper by Dr. R. B. Temple. The key to handling active materials is, of course, segregation wherever possible. The most active wastes, which are generally of small bulk, are stored in suitable containers within the laboratory. The sink wastes from the laboratories are conveyed in polythene piping to rubber-lined sump tanks, from which they are pumped through stainless steel pipes into one of three 6,000-gallon delay tanks located at the rear of the building. The piping is so arranged that the wastes from the most active areas can be kept separate from those from the rest of the building. Effluent in these tanks will be checked for acidity and radioactivity before being pumped to the site treatment plant. There the effluent will be neutralised and treated with suitable precipitating agents, and the precipitate will be separated in a sludge blanket clarifier. If necessary, the liquid wastes will be subjected to further ion exchange treatment prior to discharge. At every stage the activity levels will be monitored, and effluents will only be discharged from the site in conformity with existing health regulations. In fact, it is hoped that the wastes discharged from the site, after this treatment, will consist of almost pure water. The small volumes of more highly active liquid effluent will either be stored permanently or dumped at sea, depending upon the activity levels. Active solid wastes will be buried in sealed pits in a suitable disposal area.

EFFLUENT CONTROL BUILDING

A separate building has been provided for the analysis of radioactive effluents, storage of samples, and keeping of records. Space has also been provided in this building for research into methods of effluent treatment.

The Effluent Control building was the first laboratory to be commissioned at Lucas Heights. The building provided facilities for the early establishment of the Analytical Service Group, and a nucleus of the Chemical Engineering Research Section, and acted as a testing ground for the design of the main radiochemistry building, particularly in fume hood development. Although it is of small size (approximately 2,000 sq. ft.) the building includes a wide range of laboratory facilities. The plan of the building is illustrated in Figure 4.

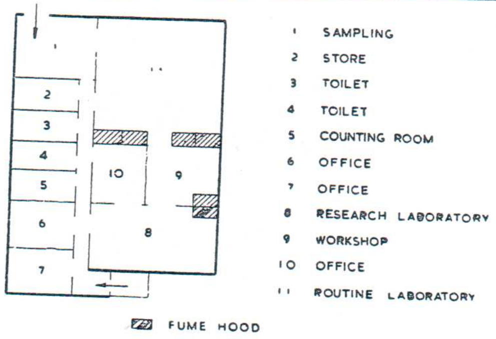

FIGURE 4: Floor plan of effluent control laboratory.

The building is of steel frame construction, with aluminium curtain walls. The cost of the building was relatively high, due to the extensive fume hood installation, provision of a high standard of finish, and the fact that the building was in many ways a pilot for the Chemistry-Chemical Engineering building. A slightly modified version of this building, which could be constructed more cheaply, may be of considerable interest to organisations requiring a small, compact, modern chemical laboratory.

OPERATING EXPERIENCE WITH THE CHEMISTRY-CHEMICAL ENGINEERING BUILDING

It is too early yet to judge the degree of success of the design chosen for the Chemistry-Chemical Engineering building, but it may be useful to give an account of experience to date.

One feature of the front wing is that despite the use of actinic glass, the rooms facing either east or west become uncomfortably hot during the summer months. Ways of overcoming this are being investigated. Initially, it was decided that while heating was necessary in winter, air conditioning of the whole building would prove too expensive when there were other needs for the limited funds available. Selected rooms containing delicately adjusted instruments may, however, have to be air-conditioned in view of the experience of last summer.

The acoustics of the building leave much to be desired. The windows have not proved as dust tight as they should have been, and an attempt is being made to remedy this. The wired glass used for fume hood sashes has been found to crack when a hot plate is left running near it and a substitute is being sought. From the manufacturing point of view, 2ft. or 2ft. 1in. would have been a better width for laboratory bench tops because there would have been less waste of the cover material—linoleum or "Laminex."

There are other points which the present occupants of the building no doubt consider to be design faults, but we think that most of these are due to the over-crowding which exists pending completion of the Engineering-Metallurgy building.

COSTS

The approximate costs of some of the radiochemical facilities have been summarised in the table below. Unfortunately, it is not possible to separate the costs of the various mechanical services completely from other building costs, and the figures in this table are only approximate. Furthermore, the cost of excavating in the sandstone of Lucas Heights has made for greater expense than would have otherwise been encountered.

ACKNOWEDGEMENTS

The authors have drawn heavily upon their experience at the U.K. Atomic Energy Research Establishment, Harwell, and the final designs have resulted from discussions with their colleagues at Lucas Heights and at Harwell over a period of years.

The architects for the project were Stephenson and Turner Ltd. Their consultants, W. E. Bassett and Associates, were responsible for the detailed design of the ventilation system. Prime contractors for the project were Hutcherson Brothers. The authors wish to record their appreciation of the efforts of the staffs of the companies concerned.

APPROXIMATE COSTS OF RADIOCHEMICAL FACILITIES	£
Chemistry-Chemical Engineering Building	900,000
Includes Ventilation (Fans, Ducting, Filters, etc.)	100,000
Fumehoods	40,000
Effluent Tanks and Fittings	20,000
Underground Service Ducts and Plant Room	160,000
Excludes Furniture	15,000
Initial Equipment	100,000
Effluent Control Building	35,000
Effluent Treatment Plant (Preliminary Estimate)	200,000