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PROBLEMS IN PLANNING FACILITIES FOR
RADIOCHEMICAL PROCESS DEVELOPMENT

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PROBLEMS IN PLANNING FACILITIES FOR RADIOCHEMICAL PROCESS DEVELOPMENT*

By A. Carleton Jealous

ABSTRACT

Radiochemical process development programs which, as at Oak Ridge National Laboratory, include (1) the development and evaluation of new processes on semi-works and/or pilot plant scale, and (2) the conception and development of fundamentally new techniques for carrying out unit operations and processes, require facilities involving some extraordinary considerations consequent to the handling of radioactive materials. Some of the latest observations and design ideas currently being considered in planning the replacement of the temporary, war-built structures at Oak Ridge are presented in this paper.

First consideration in planning a building for conducting radiochemical process development and associated programs is the general level of radioactivity to be encountered. Subsequently, a general building plan can be prepared and modified by such factors as flexibility, long-term adaptability, and safety especially from the radiation hazards standpoint. The latter factor will largely determine the general space arrangement necessary to minimize pedestrian traffic within and through "hot" areas.

A brief description of some of the present and future process development facilities at Oak Ridge National Laboratory is presented.

INTRODUCTION

Radiochemical process development became a vital, new area of activity for development chemists and chemical engineers during the last war with the advent of the atomic energy program. It was suddenly necessary, for example, to select a chemical separations process capable of extracting in very pure form the exceedingly small quantity of plutonium produced along with other fission products from exceedingly large quantities of uranium exposed in a chain-reacting pile. Never before had radiochemistry entered the process development stage on such a scale as that so suddenly required by the war for plutonium recovery. There was little or no past experience to draw upon for designing facilities in which to carry out such radiochemical separations involving the dangers of intense radioactivity.

Some of the original buildings put up in 1943 for radiochemical process development programs at Oak Ridge National Laboratory are still in use, although not constructed initially for long-term service. The war as well as lack of previous experience in the design of such structures of course dictated the short term approach in the construction of facilities. Based on the experience gained in process development work at the Laboratory during the past few years, several new designs for improved facilities have been proposed. Some of the new designs have been adopted and new structures built.

Essentially a review of some of the current concepts concerning facilities for radiochemical process development, this paper (1) defines and discusses some of the problems in the design of such installations, (2) describes some of these structures in use at Oak Ridge National Laboratory, and (3) describes one of the latest designs suggested for new process development facilities.

* Prepared for the Pilot Plant Symposium sponsored by the Division of Industrial and Engineering Chemistry of the American Chemical Society at the 1949 San Francisco Convention.

PROBLEMS IN DESIGNING RADIOCHEMICAL PROCESS DEVELOPMENT FACILITIES

BUILDINGS

The fundamental problems in designing facilities for carrying out radiochemical process development programs are chiefly those posed by such questions as: What is the purpose of the facility? What is the scope of the development program? What radiation levels are anticipated? What are the inherent hazards in such programs? What means of personnel protection must be incorporated in the structure? What sort of structure can be designed and built that will accommodate a radiochemical process development program, and also provide adequate personnel protection?

Terminology

Before answering these questions let us briefly review some of the terminology currently in vogue with radiochemists and nuclear engineers. The present laboratory at Oak Ridge includes several structures housing cell units in which "hot" experiments and development programs may be carried out. A "cell" is a work space for a system of equipment enclosed by thick concrete walls which shield personnel from dangerously intense radioactivity. "Hot" experiments are those involving radioactive materials and thus requiring shielding of personnel from radiation. Conversely "cold" experiments usually involve synthetic solutions similar to those in the corresponding "hot" experiments but without radioactive materials. "Contamination" is used specifically in reference to pollution or soiling with radioactive materials.

Two other more general terms which often cause some confusion at first in development programs are "semi-works" and "pilot plant." Two of the facilities described in this paper are commonly referred to at the Laboratory as semi-works areas. There is also a larger facility used for pilot plant demonstration programs. In effect, however, semi-works scale at Oak Ridge National Laboratory really is a simpler, somewhat smaller and more flexible pilot plant scale. Incidentally, the author has worked in another development facility which was labeled "pilot plant" (namely, at Mellon Institute) and which is quite similar in scale to the semi-works at Oak Ridge. The pilot plants of the four Regional Research Laboratories under the Department of Agriculture, which were described in Industrial and Engineering Chemistry for November, 1948, are also very similar in scale to the Oak Ridge semi-works units.

Answers to the questions on fundamental problems previously indicated are perhaps given best by presenting some of the current concepts in practice at Oak Ridge National Laboratory. Variations of these examples will be found at other similar installations.

Purpose and Scope

The prime purpose for the radiochemical process development facilities at the Oak Ridge laboratory is to develop processes considered vital in the overall atomic energy program, such as in connection with the current reactor programs. The scope of the work in these facilities includes evaluation and development of (1) laboratory proven processes, (2) new unit operations techniques, and (3) new applications of unit processes. Necessarily included, often as sub-studies in conjunction with some process development project, are test applications of industrial equipment considered potentially desirable for some radiochemical process systems. An example of the latter is the testing and development of jets, pumps, etc., considered suitable for fully remote and flexible control of some process operations.

Radiation Levels

The radiation levels to be anticipated in process development facilities depends on the radiation characteristics of the materials to be studied. At the Oak Ridge laboratory, semi-works' experience indicates that it is best to anticipate encountering all levels of radiation and thus all levels of contamination. This means facilities must be designed to be capable of handling high levels of activity

without endangering personnel by excessive radiation. Obviously, then, when designing a facility for radiochemical process studies, one must always keep in mind the shielding and consequently the remote control considerations which are mandatory before such studies can be safely effected. The levels to be endured will determine the amount of protection required.

Radiation Hazards and Protection

The hazards to be guarded against in radiochemical work include direct radiation from active materials, inhalation and ingestion of active materials, absorption through skin cuts and punctures, and the carrying of radioactive substances, as a result of contamination of the person or clothing, out of the experimental areas to offices, cafeteria, or shop, and thence even home. Coordinated arrangement of the floor plan, adequate shielding, ventilation, drainage, and adherence to rules and regulations will enhance personnel protection from the dangers of radiation; and the first four of these factors must be incorporated in the design of the structure.

Building designs must provide a minimum possibility for accumulating radioactive contamination in the experimental areas, in the drain and ventilation systems, in project assemblies, etc. Facilitation of all maintenance functions must be thoroughly considered in designing any radiochemical development structure.

Experience at Oak Ridge National Laboratory and other radiochemical research and development establishments indicates the necessity for coordinating all floor plans involving hot facilities such that cold and hot areas are segregated insofar as it is possible in order to minimize pedestrian traffic in the areas most likely to be hot. Such arrangements are mandatory in order to reduce the possibility of tracking contamination around the cold areas of the structure and outside to other locations. In short, it is necessary to locate the main entrance and all rooms for "cold" functions, e.g., offices, at one end of the building and to place the hottest areas in the more remote end. Cells, especially a row of them, should be located in the remote end of the building and with their entrances on the remote side. Stairways to upper floors should be located somewhere in the middle region of the structure, but should be used for carrying hot items from floor to floor only in emergencies. A dumb waiter should be provided for transferring hot items, e.g., samples, from floor to floor.

In "hot" semi-works operations the accepted attitude regarding radiation is that normally an individual should not be exposed to more than one-tenth the daily tolerance dosage of radiation, that is, to no more than 10 milliroentgens per eight hour work day. Adoption of the following shielding schedule adapted from a paper by P. C. Tompkins* will insure the maintenance of this radiation attitude: (1) 1 milliroentgen per hour at the surface of any shield blocking a continuous source of radiation and facing an occupied area (The working area in front of hoods and cells, and the operating faces of the hot installations, e.g., cell system control areas, are examples of occupied areas); (2) 12 milliroentgens per hour at the surface of any shield blocking a non-continuous source, e.g., drains, and facing an occupied area; and (3) 50 milliroentgens per hour at the surface of any shield blocking a non-continuous source and facing a non-continuously occupied area, e.g., outside of the building. This schedule is the basis of calculating the numbers of curies of radioactivity that can be tolerated from a source immediately adjacent to the hot, or inner surface of the shield. For all practical design purposes, calculations for the semi-works areas assume that all gamma rays are about 2 Mev, which for concrete is the most penetrating of the gamma rays from fission products. Neither alpha nor beta rays penetrate sufficiently to modify shielding calculations based on the gamma rays.

Table 1 gives concrete shielding thicknesses which will reduce 2 Mev gamma radiation from a point source to about 10% of the daily tolerance dosage at the outside surface. In specific situations calculations will take into consideration such factors as the geometry of the source itself, the geometry and total distance of the source from the receiver, the self-absorption of the source material, etc. The net effect of such calculations is to permit for the specific conditions given safe handling of a higher number

* Tompkins, Paul C., Problems Encountered in the Design of a Radioisotope Processing Building
AECD - 1887; Industrial and Engineering Chemistry, February, 1949.

of curies than indicated by Table 1. Shielding experience to date has indicated that 2-foot thick concrete walls are generally adequate for the development programs considered for the facilities described in this paper.

Ventilation is another basic problem in designing process development facilities for radiochemical work. Again experience at Oak Ridge provides some of the answers. It is, of course, necessary to maintain all cells and hoods under a negative pressure, and further it is necessary to filter the exhaust air thoroughly. Rapid air changes in cells are desirable, and it may be possible to recirculate some the air after filtering in order to reduce heating costs. It is best to make cell exhaust and supply independent of building ventilation.

Drainage requirements dictate (1) that the floors be pitched to facilitate decontaminating and cleaning, and that the floor drains be piped to a hot waste tank; (2) that, in addition to piping process cooling water drainage from cells to a settling pond, hot process waste from hoods and cells be piped to a retention tank for future treatment; (3) that product solutions be piped to another retention tank for future product recovery; and (4) that all hot drain systems be designed to minimize solution hold-up. While hot drain lines should be accessible for maintenance, care should be taken to locate them away from occupied areas or else to shield them where proximity to occupied areas would dictate.

Radiochemical Development

To answer the final question which concerns the type of structure to accommodate a radiochemical process development program, with adequate personnel protection, it is desirable first to review briefly the general path of projects at Oak Ridge National Laboratory progressing from the laboratory bench or hood through the small equipment stage. A description of some current and proposed facilities follows this review of project progress.

From the laboratory, a project generally passes to the semi-works, in which experiments usually involve small industrial type equipment. However, the systems set up for these experiments are usually for one cycle or batch scale operation. The semi-works is used, then, principally for the initial engineering investigation and development of a laboratory process to determine operability in small plant-sized equipment, an indication or demonstration of the effectiveness of the laboratory process in the small scale equipment, and finally what modifications must be incorporated to improve process operability and efficiency. Following successful semi-works effort the project then passes to the pilot plant, in which the more refined equipment and operation techniques simulating industrial scale will be developed and demonstrated in multi-cycle or continuous operation. In both areas it is necessary to handle the development mostly within cell facilities.

The exploration of new techniques for handling various unit operations and unit processes, and the evaluation of various industrial equipment items, frequently originate in both the semi-works and pilot plant in conjunction with a specific process development program. Such engineering studies are initially conducted "in the cold" to permit close scrutiny and modification, if necessary, prior to installation in cell systems.

The following descriptions and comments are limited to two of the development facilities at Oak Ridge National Laboratory; also, one of the plans for a new structure now in the preliminary stages of design is briefly presented to illustrate in part some of the latest concepts concerning process development facilities.

The First Semi-Works

The first semi-works facility which was built in 1943 (Figure 1) consists of one rectangular two-story projects room plus a single-story service area. The two-story room is attached to one end of a single-story structure containing research laboratories and offices. Except for concrete cells, the building is basically of wooden construction on concrete floors. Four square cells in a row at one end of the two-story room are enclosed and separated by concrete walls two feet thick. The cell row extends vertically slightly above the roof of the room. All four cells are 6 feet square and 20 feet high inside dimensions, each has a 6-foot square entrance way facing the room at the floor level, and each is topped with an exhaust fan providing six air changes per minute. The cells are inter-connected by

Figure 1. First semi-works area at Oak Ridge National Laboratory.

square service ports at five levels. A solid floor balcony across the front wall of the cell row and along the sides of the two-story room provides a means of access to a row of small square service ports into the upper cell spaces as well as a facility for mounting instruments, control equipment, and head tanks to serve systems either in the cells or in the open semi-works area.

Some features of these cell facilities have frequently been disadvantageous. The row was so located that only one face is available for operating controls. Also each cell was often too small for installing 50 gallon or drum scale systems, which is the usual, preferred scale of operations in the semi-works. Setups in these cells have often been too crowded for satisfactory operation and maintenance.

The cells were not initially provided with upper personnel entrances nor removable tops to facilitate handling large equipment items. There were no stacks nor filters for the cell exhausts. The situation provided the possibility for some of the unfiltered cell exhaust air to re-enter the office and work area when the wind direction was right. Extra precautions were, therefore, mandatory in all cell operations. The rapid air changes did, of course, provide a considerable dilution factor which appreciably minimized the hazard.

The service and office areas indicated in the diagram were originally built for storage purposes. The original facility was added onto such that the overall arrangement was exactly the reverse of what it should have been according to later concepts.

The trouble with the plan shown is that the main entrance to the semi-works opens directly into a hot zone — a work zone in which the potential possibilities for radiation and contamination are obviously high. To reach the offices in the rear of the semi-works all visitors and others with neither need nor desire for entering the hot zone nevertheless had to pass through the zone on their way to or from the offices. Such unnecessary traffic in work areas of this sort is a safety and contamination hazard.

One proposal to rectify the situation in this semi-works is shown in Figure 2. The plan calls for (1) blanking the original main semi-works entrance (which thereby also eliminates another safety hazard, namely the original location of the balcony stairway directly adjacent to the main entrance); (2) isolating the office area from all work areas by blanking its original entrance and providing a new separate entrance as shown in the diagram; and (3) rearranging the service area so that the hoods are isolated in a room by themselves, and the tool room is located a little closer to the work areas.

The intake ventilation and heating of the semi-works is provided principally through a large set of louvres and blast coils mounted at balcony level in the end wall opposite the cells. Essentially all room exhaust is through the cells. The hoods* and chemical treatment area are exhausted separately through stacks extending 15 to 20 feet above the building. Hot waste and sanitary drainage facilities are provided for the cells and hoods. Valuable product solutions, however, have to be hauled in drums to retention tanks for future recovery.

The standard services such as vacuum, air pressure, distilled and filtered water, high and low pressure steam, etc., are provided. 110 v and 440 v electrical service is also provided, plus an emergency circuit for the exhaust fans and radiation monitoring instruments during power failures.

A Recent Semi-Works

There is a later semi-works facility (Figure 3) representing almost a complete divorce of hot areas from all auxiliary service areas. This unit is a windowless steel frame structure with aluminum sheet siding and roofing. The overall floor plan (Figure 4) is rectangular: twice as long as it is wide. Large hanging doors with personnel entrances inserted are provided at each end of the structure. Two independent cell blocks or banks are provided with 2-foot thick concrete walls. Each bank has three cells two of which are 6 feet square by 30 feet high inside dimensions, while the third cell is 6 by 14 by 30 feet. One of the small cells in one of the banks is provided with an 18-foot well. The small cells have single 6-foot square entrances and the large cells have the same size entrance at each end, all on the first floor. There is ample free wall space for (1) equipment setups for cold experiments and

* Hoods for radiochemical work are described in: "‘Nucleonics’ + Architecture = ‘Hot’ Design" by A. D. Mackintosh, Bulletin AECD - 2178, Technical Information Division, AEC, Oak Ridge, Tennessee.

Figure 2. Proposed revision of the first semi-works area at Oak Ridge National Laboratory.

Figure 3 Recent semi-works facility—a windowless steel frame structure with aluminum sheet siding and roofing—at Oak Ridge National Laboratory.

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Figure 4. Overall floor plan of semi-works facility shown in Figure 3.

(2) laboratory benches or hoods. Concrete slabs serve as removable cell tops. A traveling overhead crane (Figure 5) for handling the concrete cell tops and cell equipment runs the length of the building. Balcony grating at 10-foot levels for instrumentation and various operational facilities surround the cell banks on three sides and are served by a common stairway between the banks.

Each cell is provided with several types of access. The large first floor entrances (Figure 6) for installing and removing large equipment, and for use by operating personnel have been mentioned. Also the removable tops have been indicated. Further, there is considerable provision for installing necessary process piping connections, remote control rods, viewing gadgets (such as periscopes), instrument lines, and sampling gadgets. For these services, there are numerous 4-inch and 6-inch access holes (Figure 7) through both the inner and outside concrete walls of each cell. Removable concrete plugs serve to keep the holes filled for radiation shielding when the holes are not used. For viewing purposes periscopes can be installed in holes which do not "look" directly at sources of radiation such as equipment or accessory items which may contain hot materials. Cold process lines, control rods, instrument service connections, etc., which pass through access holes may be installed in special concrete or lead plugs specially made for each situation. Wherever convenient the use of holes looking directly at potential radiation sources should be avoided.

There is a built-in ladder in each cell (note right cell in Figure 6) for reaching the upper cell regions. Gratings may be installed as required at almost any level. As many as four levels may be installed, but this begins to be crowded.

Each of the cells is provided with three drains: one for process cooling water, one for radioactive waste, and one for product solutions to be recovered later. There is a storage tank for each of the latter two drain systems. Process cooling water goes to a settling pond. Building floor drainage is facilitated by pitching the floors to trenches which surround the cell blocks, and the floor drain lines go to the hot waste tank.

To remove toxic and explosive vapors from the cells individual exhaust ventilation is provided from the side and near the top of each cell. Each cell is ventilated at the rate of 90 air changes per hour.

General building ventilation is designed to provide about 40 changes per hour. Air intake for the building and cells is through large sets of louvres at each end of the building above the entrances. Blast coils in front of the louvres serve to heat the building.

The usual services such as high and low pressure steam, demineralized and filtered water, vacuum, and air are provided. Electrical equipment provided in the cells includes lights and service outlets and is NEMA Class VII. NEMA Class IV or better equipment is used elsewhere in the building. 110 v and 440 v service, and an emergency generator set for use in case of power failures are provided.

A recent program in search of suitable coatings for inner cell walls and other areas particularly subject to contamination has yielded several interesting possibilities. Currently some cells are to be coated experimentally first with three layers of Prufcoat followed with liquid "Cocoon" sprayed on to a thickness of 40 mils. With this type of coating it is considered possible to strip off contaminated sections of wall coating as necessary and replace them with new layers.

The work so far on the coating program for facilitating decontamination indicates that the material cost for covering about 750 square feet (or one of the small cells) in the manner indicated is about \$155 plus 48 manhours spread over five days to allow adequate drying. This is not an unreasonable expenditure when one considers the time saved from scouring activities to decontaminate an uncoated porous concrete wall.

Finally, it is interesting to note that the total cost of the semi-works structure just described is about \$320,000 which includes installation of two cell blocks, a three-level balcony facility, and all permanent services but no process equipment. On the basis of this figure it is interesting to note that (1) the cost per cubic foot of usable building space is \$1.50; or (2) the cost per cubic foot of internal free cell space is \$32.50. Another way of looking at the cost is the rate per square foot of ground floor area which in this case is \$62.50. Based on the total usable area which includes the first floor and two balcony levels, the cost is \$42.50 per square foot.

Figure 5. Sectional view of semi-works facility pictured in Figure 3, showing traveling overhead crane.

Figure 6. First floor entrances to cells in semi-works facility (Figures 3, 4, and 5).

Figure 7. Wall of cell in semi-works facility (Figures 3, 4, 5, and 6), showing 4-inch and 6-inch access holes with removable concrete plugs.

There are many advantages already described in this newer facility, but there are also some features which are by current concepts not desirable. Grated balconies are now considered undesirable because of the hazard of (1) spillage on top of equipment and personnel below, (2) contaminated dirt falling from the soles of shoes scrapping on the grating, and (3) cleaning or washing down of the facility. Gratings limit the flexibility of cell operations particularly in that sampling of hot solutions must be done on the first floor level in order to eliminate an obviously serious hazard from the balcony.

The cells are adequately provided with access holes but have no upper entrances for personnel. The small cells are too small but because they are adjacent to a large cell in each block this situation is not so serious as in the semi-works described previously.

A New Semi-Works Design

Currently planning of new facilities to replace more of the out-moded war-built wooden structures is in the early-design stage. One of the semi-works plans under discussion provides for a new three-story structure (Figure 8) attached by corridor to the principal research building. The new semi-works will be designed to eliminate hazardous arrangements and provide maximum availability and flexibility of facilities. At the remote end of the long rectangular building a row of cells will be located away from the building wall in order to provide maximum accessibility to the cell block. Entrance ways to the cells are provided for each, on all three floors, and all on the same side facing the nearby building wall. The area in front of the cell entrances is regarded as that having the highest contamination potential of all the areas in the building. The controls for the cell systems and the panel board are scheduled to be on the opposite side of the block from the cell entrances. The cell spaces are to be about 8 feet square and 30 feet high. They will probably be ventilated by an air supply and filtered exhaust system independent of the building ventilation. Further, the ventilation will be downward in the cells, and the exhaust will be piped to a stack away from the building.

The cell row was selected as being more flexible than a square cell block in that with the row arrangement there is 25% more external cell face available permitting more flexible operational systems. Also the row can be built with a removable middle intercell wall to make one long cell between the two end cells. Furthermore, the cell entrances in the case of the row can be located all on one side, localizing the area of high contamination potential. The row arrangement also permits a more efficient use of the area surrounding the cells.

Auxiliary service areas such as decontamination facilities for cleaning hot equipment before removal from the building, hot lab, etc., are located roughly between the cell facilities and those facilities least likely to be hot. A hot storage room for holding hot samples or hot solutions is located in a remote corner.

Such facilities as the staff shop and change rooms will be placed nearer the main semi-works entrance, and the offices will be arranged along the corridor leading from the adjacent building to the main semi-works entrance. Thus, personnel not active in the hot zones need not traverse them. Those who work in hot areas and who happen to become contaminated can clean up in the change room, replacing contaminated work clothes with a fresh uniform.

The upper floors are to be solid thus eliminating the contamination and spillage hazards of gratings. Floor openings at one corner of the building permit installation of tall equipment set-ups for cold studies. Second and third floor rooms at the cold end of the building may be used for service activities such as cold chemical treatment, cold solution makeup, installation of some cold solution head tanks relating to cell or open area systems, and storage. There will be considerable space for open area or cold experiments on all three floors, as can be seen in the diagram.

A monorail over the third floor will service the cells. A dumb waiter for transfer of hot items including hot samples from cell experiments, and a freight elevator for handling bulk chemicals, etc., will be provided so that the stairway normally will be restricted to personnel not carrying radioactive or contaminated items from floor to floor. The restriction is to prevent accidents or other carelessness causing contamination of the stairway.

Figure 8. Floor plans for a proposed semi-works facility at Oak Ridge National Laboratory.

EQUIPMENT SET-UPS IN RADIOCHEMICAL FACILITIES

In radiochemical process development, it is generally mandatory to carry processes through the semi-works or small pilot plant stage in order that unforeseen kinks in a process may be discovered easily and rectified without considerable loss of time for decontamination and repair or alteration. There have been many experiences in which processes have worked well "in the cold" but have temporarily failed when tried with "hot" materials. Such instances in the presence of radioactivity often entail difficult and expensive shut-downs for decontamination before repair can be accomplished. It is perhaps helpful then to include a brief discussion of some basic considerations found vital from experiences encountered in cell operations at Oak Ridge.

Of utmost importance is the provision of a sufficient number of cell spaces each of which should be large enough to accommodate experimental process systems up to about the 50-gallon scale without crowding. Ample spacing must be allowed (1) for ease of servicing the process equipment, (2) for providing some duplicate process lines and some return lines in anticipation of emergency situations, and (3) for adequate isolation or shielding of hot feed tanks within the process cell in the event an adjacent cell can not be used for such tanks.

The first semi-works cells designed at Oak Ridge were too small. During the course of some projects for which equipment had to be crowded into the cell space, items installed in the rear of the cell became inoperable. Because of their inaccessibility resulting from the over-crowding, such items were frequently abandoned in favor of some make-shift arrangement. The safety and effectiveness of operating make-shift setups is naturally very limited, so that programs thus affected cannot satisfactorily continue very long without a major overhaul or revision of the equipment.

The provision of return lines to shielded tanks in many cases will permit transferring hot feed solutions back if and when trouble occurs requiring cell entry for repairs. The provision of duplicate process lines will sometimes make it feasible, in case one line plugs, to carry a hot experiment to completion before trouble shooting on the plugged line used initially. All such lines and associated tanks should be provided with purge and washing facilities to remove radioactivity as completely and quickly as possible.

Common plugging of process lines containing radioactive materials often requires considerable time and extensive manpower usage for correction. On one occasion in which a line in one of the Laboratory systems plugged, investigation soon showed that the pH change between the point of feed entry and the plugged section was sufficient to cause a fine precipitate which settled in the line. The precipitate was a complex salt which formed if a certain pH adjusting agent had been used in preparing the feed. Fortunately, it was easy in this case to change to a different adjusting agent which would not cause precipitation and hence plugging. In this system there was no shielded tank to which the feed could be returned. Hence the feed had to be dumped to a retention tank for future recovery. Had the salt not responded readily to dissolving by a wash solution it would have taken several days to decontaminate the system sufficiently to permit entering the cell to replace the plugged line.

Isolation or shielding of tanks which will contain hot feed solutions will many times make it unnecessary to dump such solutions to retention facilities in order to permit cell entry for trouble shooting or repairs. It is often very desirable to have a number of adjacent cells sufficient to allow some segregation of parts of an experimental setup by installing the various components in two or more adjacent cells. Unscheduled cell entry for such purposes as trouble shooting and emergency maintenance will necessitate dumping "hot" solutions which cannot be transferred to shielded tanks or tanks isolated in adjacent cells. It is of course particularly undesirable to dump hot feed solutions. Such solutions if dumped go to retention facilities from which only the valuable constituents are economically recoverable.

Cell trouble shooting and unscheduled maintenance requires an extensive manpower usage because of the radiation hazard which limits each individual to a short working time in the cell. When an individual is limited by the intensity of radiation at the source of difficulty to two minutes working time (a not too extreme example) a relatively large number of employees is required to effect the repair job, even though the specific repair work itself frequently does not require an extensive number of man-

hours. Hence it may be seen why it is so very necessary to give every consideration, when designing and installing systems for "hot" work, to providing initially all means possible for coping with emergency situations.

These same precautions are even more important in the demonstration scale pilot plant than in the semi-works because of the handling of large volumes of greater intensity radioactive materials. The prime concern in the pilot plant is for equipment failures. Failures in welds, valves, flanged connections, etc., can cause considerable equipment outage first for radiation decontamination and other make-ready efforts, and then for the equipment repairs. Process changes of any consequence should never be tried in the demonstration pilot plant without previous semi-works proof of operability. Adherence to this precept will eliminate much grief and greatly minimize the possibility of process difficulties in the larger pilot plant.

SUMMARY

Planning process development facilities for radiochemical programs is still a young problem in which chemists, engineers, and architects first became involved only a few years ago. Today's concepts of such facilities represent a notable growth of ideas and considerable revision of earlier designs. The facilities described in this paper indicate the trend of designs for all-purpose radiochemical pilot plants planned for safe, flexible, long-term use. For most process development programs handling moderately high quantities of beta and gamma radiation cell structures with 2-foot thick concrete walls containing cell spaces 8 feet square by 30 feet high are considered functionally ideal for the installation and operation of many 50-gallon scale systems as well as for the protection of personnel from radiation.

The principal overall requirements for satisfactory radiation protection and contamination control in radiochemical development facilities include (1) general segregation of hot areas from cold areas such that hot areas are remotely located in all floor plans, (2) provision of filtered cell ventilation independent of room ventilation, (3) inclusion of decontamination stations for personnel and for equipment, and (4) installation of adequate drainage for hot solutions. The improvements of facilities necessary to provide maximum personnel protection, minimum contamination, and at the same time flexibility of operations have been increasingly incorporated in the development facilities at Oak Ridge National Laboratory. However, every design has its limitations so the planning of radiochemical process development facilities should be an interestingly active problem for years to come.

ACKNOWLEDGMENT

This paper represents very briefly ideas and conclusions developed over the past few years by a multitude of people engaged in radiochemical research and development. The author is indebted for the guidance and advice received during the preparation of this paper from fellow scientists and engineers at Oak Ridge National Laboratory.

Table 1. Concrete shielding required to reduce 2 Mev gamma radiation to 0.01 roentgens/8 hour day.

Source curies	Roentgens per hour at 1 foot unshielded	Concrete thickness* (feet)
1	10	2
10	100	2.5

* The thicknesses indicated are based on a point source of gamma radiation adjacent to the shielding.

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