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HOT CELL FACILITY DESIGN FOR LARGE FUSION DEVICES*

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ABSTRACT

Large hot cell facilities will be necessary to support the operation of large fusion devices. The supporting hot cells will be needed to serve a variety of different functions and tasks, which include reactor component maintenance, tool and maintenance equipment repair, and preparation of radioactive material for shipment and disposal. This paper discusses hot cell facility functions, requirements, and design issues and techniques. Suggested solutions and examples are given.

INTRODUCTION

The basic function of the hot cell facility (HCF) for a large fusion device is to support the maintenance of the reactor. Major components would be removed from the device and taken into the HCF for repair and adjustment. The major reactor components to be maintained will have been exposed to high neutron flux, which will cause activation of the components. This activation will cause the components to become highly radioactive so that maintenance workers will have to be protected from them. The components are expected to be large and expensive; therefore, repair is likely to be more prudent than replacing them with new components. Thus, the major part of the function of HCFs will be to provide a safe environment for the maintenance of radioactive components.

Design of a hot cell facility to provide a suitable environment for the required maintenance activities will necessitate consideration of the control of contamination, the required maintenance space, transportation of the components and materials into and out of the HCF, transportation of the components and materials within the facility, maintenance of the hot cell equipment, the type of viewing technology to be applied, and the proper tools and operation space to perform these maintenance operations. While all of these items will have a major impact on the general arrangement and design of the facility, contamination control is seen as a fundamental criterion in meeting the challenges of hot cell design.

Investigative Technique

A review of the necessary facilities shows that the HCF will likely be either one of the two major buildings of the plant facilities or a major part of a monolithic reactor building. Since the HCF contributes substantially to overall facility cost, an investigation of the basis and cost of the HCF was undertaken with the hope of improving design and cost-estimating techniques.

The efficiency and usefulness of any hot cell facility depends greatly on the ingenuity of the design team. Since the FEDC design team lacked directly applicable hot cell design experience, an early decision was made to rely heavily on the advice of more experienced people. Hence, a study was initiated to visit existing hot cell facilities and discuss hot cell design and operation with experienced personnel at several national laboratories. The investigation consisted principally of visiting existing hot cell facilities and interviewing hot cell designers and operation personnel. A summary of the visited facilities is given in Table 1. There were, of course, many different techniques used to accomplish similar tasks, and each application required its own unique solution. Nevertheless, several important areas of consistency were noted in the discussions and tours.

The process of gathering information for hot cell design was progressive in that more and better questions were possible as more information was gathered. After each discussion, design ideas were altered, and the altered set formed the basis for the next discussion.

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Table 1. Summary of hot cell facility tours and discussions

Location	Design/operation discussions	Facilities visited
INEL	Hot Fuel Examination Facility/North and South (HFEF)	Toured both facilities
	Test Area/North (TAN)	Toured facilities
	New Waste Calcining Facility (NWCF)	Toured workup area and facility which was not yet in operation
HEDL	Fusion Materials Irradiation Test (FMIT)	
	Fuel and Materials Examination Facility (FMEF)	Mockup area
	Engineer Maintenance Assembly and Disassembly (EMAD)	(Pictures only)
	Material and Fuel Examination Hot Cells and Reprocessing Experimental Hot Cells	Toured sets of facilities
ORNL	ORNL Hot Cell Facilities at X-10	Three complexes of hot cells at X-10
	Hot Experimental Facility (HEF)	HEF mockup and testing area
LANL	Clinton P. Anderson Meson Physics Facility (LAMPF)	Toured facilities

Purpose

The purpose of this paper is twofold. First, we present the results and conclusions of the investigation. Second, we encourage continued discussion of hot cell design with the hope of continuing to improve the design process and of correcting any errors we may have made in our assessment.

DESIGN REQUIREMENTS

The HCF must allow for the maintenance of radioactive components while protecting the maintenance personnel from excessive radiation and contamination. The major characteristics that will establish the requirements will be levels of radioactivity, contamination, size and weight of the components, type of repairs, and speed with which repairs must be made.

The radioactivity levels will establish the shielding requirements. Initial estimates of shielding requirements for current fusion device designs suggest that between 1 and 2 m of concrete will be necessary to protect the workers from the radioactive components. Shields of this thickness add considerably to the size and cost of the HCF.

The sources of contamination come from both outside the hot cell facility and from within it. The major outside sources are the erosion products from the plasma chamber and possibly absorbed tritium. The inside sources of contamination include a large spectrum of possible welding fumes, grinding dust, cutting chips, cleaning and weld preparation chemicals, and again possible release of absorbed tritium. Both the design and operation of the HCF must work in harmony to control these potential sources of contamination. At this juncture in the planning of large fusion devices, the levels and types of contamination have not been qualitatively defined. Thus, there is considerable difference of opinion about the importance of contamination control. The viewpoint expressed here is that even small amounts of contamination with high-energy gamma-emitting material will cause substantial difficulty for maintenance personnel. Discussions with operators and designers of existing hot cell facilities have confirmed this view, which emphasizes the contamination control aspects of hot cell design.

The size and weight of the components will help establish the size and space requirements of individual work stations and disassembly areas. (Both the size and weight of fusion device components are very large by most current HCF standards.) The dimensions of major components of current fusion device designs range to several meters, while the weight of some component designs has ranged to 500 tonnes. Components with these dimensions and weights that are also highly radioactive require substantial hot cell space for maintenance operations.

The types of maintenance operations required to be preformed in the HCF could have a major impact on space and arrangement of the facilities. Currently, a number of disassembly and machining operations are expected within the hot cell. Such operations include mechanical disassembly and assembly, cutting, welding, drilling, and machining. These functions require a great deal of specialized equipment. The HCF must provide space for both the operation and storage of this equipment.

The speed with which the components must be repaired will help establish the number of work stations and disassembly areas. This speed of repair depends directly on the expected downtime for the facility, which in turn depends on the availability goals for the specific design. High availability goals imply fast repair times. This means that more work stations will be necessary to allow parallel operations within the HCF.

DESIGN ISSUES

In attempting to establish conceptual designs for various fusion devices, a number of design issues have been raised. These issues address several design options that may be used to satisfy the requirements. To a large extent, the perspective of the design team will help decide these issues. The perspective taken in these efforts was to rely as much as possible on the opinions of those experienced hot cell designers and operators with whom we talked.

All of the HCF design issues and options are closely interrelated. However, the biggest issue is contamination control. This issue affects component and tool movements, ventilation, and maintenance activities. Also, they eventually impact the size, shape, and general features of the HCF. Decontamination of components and equipment was almost univerally noted as a difficult problem that must be carefully and thoroughly addressed. A number of experienced people stressed that contamination control can only be accomplished when designers and operators pay close attention to details.

Personnel Entry

The question of personnel entry into the hot cells is determined by the importance of contamination control and has a major impact on HCF design. The method to be used to maintain the hot cell facility is the major issue. Two approaches can be taken to maintain the work stations in the hot cell area. The first approach would be to provide several individual cells that would allow personnel entry for hands-on or bubble suit maintenance. The individual cells would be shielded and isolated from each other so that radioactive component maintenance could continue in the adjacent cells while cell maintenance was being performed. The cell to be maintained would have to be decontaminated before personnel entry. The most attractive feature of this approach is the use of hands-on (or bubble suit) maintenance, which is argued to be faster and more efficient than remote maintenance. The key to this approach is whether the hot cell can be decontaminated to an acceptable level with a reasonable amount of effort.

The alternative approach is to have all the work stations in one large area and perform all the cell maintenance operations remotely. Tools and equipment could be removed, decontaminated, and repaired in a separate glove-box-type area. No personnel would be allowed into the hot cell area. The advantages of this approach are that the work stations do not have to be decontaminated for maintenance operations, and the reduced shielding requirements may reduce the cost and complexity of the facility.

The first approach was attacked vigorously by several experienced people. Decontamination of hot cells for personnel entry is very difficult and time-consuming, and it often leads to additional personnel radiation exposure. Experience seems to indicate that decontamination of hot cells used for machining operations is particularly difficult and time-consuming. Movement of cranes and components through contaminated areas after decontamination would likely lead to recontamination of the component and the work stations, even though they are isolated most of the time. In addition, the extra space and construction needed for the intermediate cell walls increase the cost of the HCF. Thus, the advantage of personnel entry is negated.

On the other hand, cells that are designed for no personnel entry must be designed to be maintained remotely. Remote maintenance techniques also tend to be costly and to take more effort than direct contact maintenance. However, experience has demonstrated that hot cells can be successfully operated and maintained with no personnel entry. Unfortunately, the size of the HCF needed to support fusion devices will be substantially larger than most current existing facilities with totally remote hot cell maintenance. Thus, a significant extrapolation of current technology will be required. Sealed hot cells offer other potential advantages by allowing the possible use of an inert atmosphere as discussed later in this paper.

Decontamination Cell

Since contamination control was emphasized heavily in our investigations, a decontamination cell appears to be necessary. All movement into and out of the hot cell area should pass through this contamination control station where each item can be checked for contamination and cleaned if necessary. This contamination checking and decontamination applies to all items (e.g., waste containers, tools, and components) whether they are going into or coming out of the hot cell area, and whether they are going into or coming out of the reactor cell area. The purpose of this facility is to prevent contamination from passing between areas and to the outside.

The decontamination area needs to provide several means of cleaning contaminated items. A spray chamber is most useful to the cleaning operations. Often high-pressure water is adequate to remove loose contamination. However, other cleaning fluids should also be considered. Detergent solutions, acetone, alcohol, and freon have all been mentioned as possibilities. Even uncontaminated items must be cleared before entering the contaminated areas. Grease and films from manufacturing and shipping would collect and transport contamination within the cell and reactor cell and make later decontamination more difficult. Fusion devices have additional cleanliness requirements due to the high vacuum requirements. The vacuum specifications are likely to require grease and oil removal to very low levels and will probably limit the types of cleaning fluids and chemicals that can be used within the HCF and reactor cell.

Ventilation Systems

The ventilation system plays a key role in the control of contamination in existing hot cells. The most successful flow pattern appears to be one that permits the clean air to enter near the top of the cell and flow out through gratings in the floor. Each work station has a section of the outlet within its boundary. This flow pattern tends to pin the contamination to the floor and sweep it to the filters beneath the floor without contaminating other areas of the hot cell, thus reducing contamination in the upper areas of the hot cell. Smaller vacuum hoods and enclosures with special purpose filters should be used for operations that produce dust or fumes. Contamination from some fairly dirty machining, cutting, and welding operations has been successfully controlled with these ventilation techniques.

Component Transport

The transportation system used both within the cell and for moving material to and from the hot cells is a major part of the contamination control systems. The movement of components, materials, and tools into and out of the contaminated areas is one of the most difficult problems of contamination control. Experienced hot cell operators indicate that a large fraction of contamination spread is caused directly by the transportation system. Crane cables and hooks pick up contamination and spred it from one area to another. Wheels and bearing grease on carts and trolleys also become heavily contaminated and spred the contamination to other areas. Thus, the use of airlocks by themselves has not been very successful in controlling contamination.

A number of approaches have been tried in existing cells to overcome these difficulties. Most successful systems appear to have evolved to a transportation system that uses an intermediate step to transfer material to and from the hot cell area. While several variations can be found, the basic action of these systems is to use an intermediate shuttle of some kind to move the material to and from the hot cell area. This intermediate system only performs this one task and moves within a predefined space. The contamination spread due to the transport system is thereby confined to a limited area. While the space may become contaminated, the levels are usually maintained low enough that contact methods can be used to repair and maintain the transport system.

As a result, almost every one of the hot cells that were visited has developed some version of what can be called the down-over-and-up movement pattern for moving material into and out of hot cells. This pattern describes the techniques of lowering the item to be moved through a hatch onto a cart in a separate compartment. The cart is then moved under the hot cell floor where the hot cell crane lifts the item into the hot cell through a hatch in the floor. The compartment and hatch arrangement serve as an airlock between the two areas. The cart generally has an enclosure or tank that is covered during transfer to reduce the contamination spread to the transportation compartment. Each part of the transport system stays in its own space without traveling from one space to another. Thus, the amount of contamination spread from one area to the other is more effectively controlled. The transfer compartment stays relatively clean and can be decontaminated to levels that allow personnel entry for cart transport system maintenance. The hatch covers can provide good sealing characteristics because loads do not go over the sealing surfaces. Of course, contamination travels with the item during transport, but this is the contamination that is to be handled by the decontamination area. Techniques must be provided for decontaminating the interior of the enclosure or tank on the cart.

Viewing Techniques

Two basic approaches are available for viewing and controlling maintenance operations within the hot cell: direct viewing through shielded windows and indirect viewing with television cameras. The choice of approach can have substantial impacts on cell layout and HCF costs.

The traditional approach is to use shielded windows. For most current hot cell operations, this approach has been reliable and effective. However, the size of the components from large fusion devices will limit the effectiveness of shielded windows. In addition, the costs associated with shielded windows can be quite high. The windows are not only expensive but also require the use of galleries and create building arrangements that are more expensive. They can also have high maintenance costs.

The television viewing approach is a newer technology that is still being developed. Several demonstrations are underway that will increase the confidence in both the techniques and the equipment. For large components, the technology of television offers superior capability to view all aspects of the component without moving it. While no carefully located galleries will be necessary to accommodate television viewing, specially designed control rooms will be required, and most maintenance operations will likely require a team of specialists.

At the present stage of development, it seems likely that neither direct viewing nor television viewing would be used exclusively. The prudent approach would be to allow for both may be realized. However, the trend appears to be in the direction of nearly exclusive use of television viewing.

Hot Cell Atmosphere

The use of an inert gas atmosphere for the hot cell area has been suggested by some experienced personnel. The normal advantages of an inert gas atmosphere are that fire hazards are greatly reduced and formation of ozone is prevented. Ozone is formed when oxygen in the air combines with high levels of radiation. Ozone is highly corrosive to metals and attacks many of the plastics that are desirable for use in hot cells. Thus, the elimination of ozone would greatly reduce hot cell maintenance requirements. Additional advantages would include the possibility of performing cutting and welding operations without special inert gas sources and removing more easily any tritium that may be released to the hot cell atmosphere. These advantages tend to offset the disadvantages of additional cost and complexity of maintaining an inert gas atmosphere. Accordingly, as long as a nonentry hot cell area is used, the use of an inert gas should be carefully considered.

DESIGN EXAMPLE

These hot cell design concepts have been applied to some preconceptual design studies to help define the plant facilities and provide a basis for cost estimates. Figure 1 shows an example of a hot cell design taken from Ref. 1. This example shows the use of a decontamination cell and the suggested transportation system. A separate cell is shown for maintenance work on tools, hot cell equipment, and less radioactive reactor components. This example shows the need to accommodate special requirements by the inclusion of an anechoic chamber for testing and adjusting radio frequency equipment that will be radioactive and contaminated.

SUMMARY

The use of hot cell facilities to support large fusion devices will be a major part of fusion reactor designs. Preliminary design activities indicate that satisfactory hot cell

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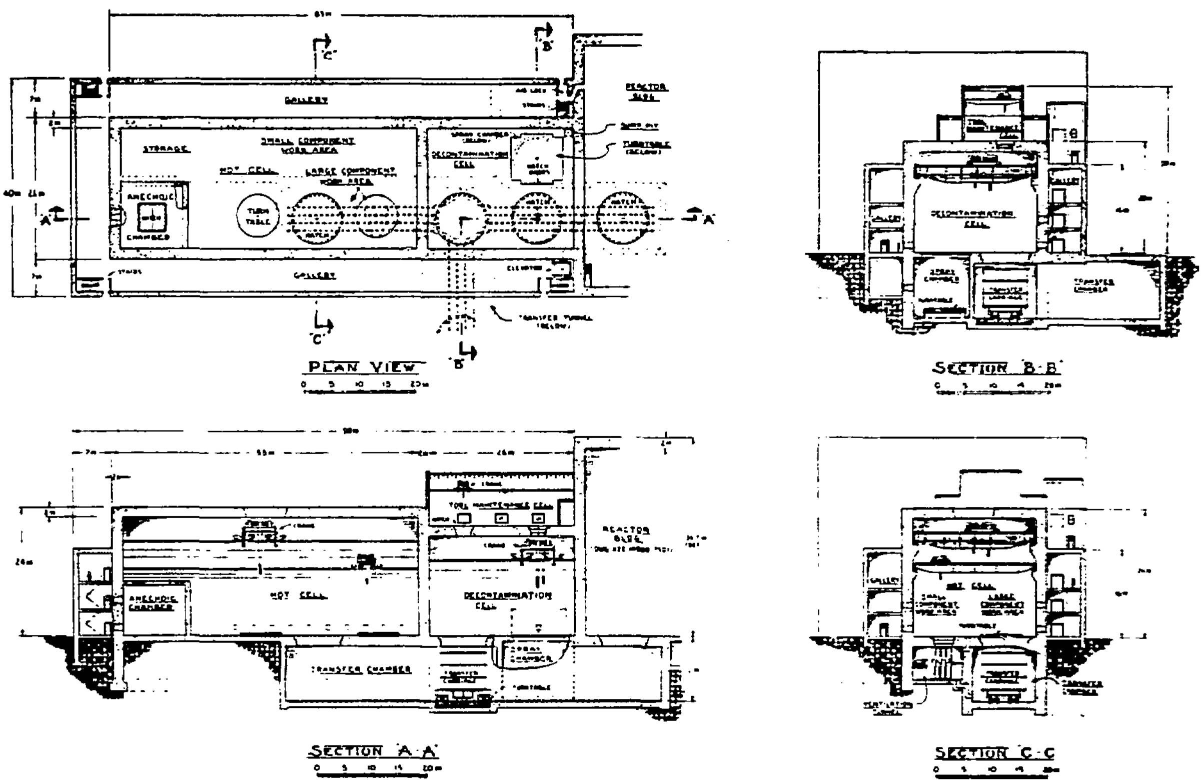

Fig. 1. Hot cell facility layout.

facilities can be developed. Several choices exist for most major design features. Current hot cell layouts and operational experience need to be found, pooled, and applied to the plans of such major hot cell facilities.

REFERENCES

1. P. H. Sager et al., "FED Baseline Engineering Studies Report," ORNL/FEDC-82/2, Oak Ridge National Laboratory (1983).