FLEXIBILITY IN ACCELERATOR HOUSINGS

By

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Summary

Flexibility in the design of Accelerator Housings is achieved by:

1. Proper site selection and planning;
2. Study of critical areas of design;
3. Proper selection of shielding materials;
4. Maximum use of non specialized spaces;
5. Correct selection of crane capacity and coverage;
6. Location of offices, laboratories and utilities to facilitate expansion; and
7. Provision of adequate space for counting room expansion.

Proposals are presented for building construction techniques and arrangements that facilitate future expansion and modification of an accelerator housing. Recommendations are presented for shielding techniques which permit flexibility. Relationships between flexibility and cost are discussed for both building and shielding construction.

Introduction

The Physicist contemplating a new accelerator naturally places the machine design upper-most. He is wise, however, to consider early the arrangement of the machine's housing. The architect he commissions to design the structures should be conscious of the enormous forces for change which surround every experimental physics facility. An axiom of experimental physics is change, and the direction of change is often unpredictable. New experiments may require expansion of the facilities; a change in the objective of the research may modify the machine itself; and new techniques may permit reduction in the sizes of the old components, permitting research of an entirely new character. Thus housing a machine in a facility of maximum flexibility seems to be a highly desirable prime objective. However, two factors often interfere: First, it is difficult or impossible to envision the changes in technology and research objectives that may occur even in a few years; and Second, complete flexibility may be bought only at a considerable premium.

The Goal of Flexibility

The most liberal budget never seems to provide the physicist with everything he needs in the way of machine capability. As the budget contracts, the desirability of maximum flexibility in future expansions seem less important than having the maximum machine capability now. However, if the physicist and his architect keep the goal of flexibility in mind throughout the design process, they can often achieve close to ideal results without increasing the building construction budget. Even though it is not possible to visualize the nature of future experiments or machine changes, the housings may be so arranged that they can be easily expanded, modified or rearranged to accommodate almost any configuration within them.

Design in Expanded Form

One of the best ways to achieve flexibility without increasing cost is to concentrate on those areas of design that are truly critical. This examination must involve the arrangement of the elements with each other and the composition of the elements themselves. Proper arrangement of the elements on the site can do a great deal to increase flexibility. Each of the elements should be capable of expansion in its own way. The architect should draw the building originally in its expanded form, say 2 to 3 times the size of the actual building under design, projecting the expansion the first 10 years. Then the design can be contracted to provide housing for "first phase" construction. This makes it more likely that increasing the size of the elements will not choke the growth of the facility. This initial expanded design consideration should be applied to mechanical and electrical services as well as structural and architectural design.

Design Components

A typical accelerator housing may be divided into several components, which, while they interrelate, are quite distinct and may differ radically in design. These might include, for a typical medium-size accelerator, 1) the machine, 2) the experimental area, 3) the counting and control areas, 4) the shops, 5) the labs and offices, and 6) the supporting mechanical spaces. To this might be added for a large installation separate buildings or rooms for the injector, power supplies, a bubble chamber, and, of course additional experimental area and shops.

The Machine Housing

Each of these elements has a design configuration which is the most flexible for it. The machine will often be heavily shielded. Experience has shown that it is usually wiser not to mount an overhead crane inside the shielded cave surrounding the machine, as the increase in the space and shielding greatly increases the cost of the facility. Thus a system for removing the shielding blocks from the roof over the machine (such as in the 88" Cyclotron in the LRL at Berkeley) is probably more flexible than building the machine in a poured concrete vault such as in NRL at Washington (Fig. 1). If the machine vault is under a crane bay which also includes some or all of the experimental area, the crane which handles the roof blocks over the machine can also be used to service the machine itself and the heavier equipment in the experimental hall. Such a system is well illustrated by the Texas A & M (Fig. 2) and UCLA Pion (Fig. 3) Cyclotrons. In the larger installations, such as Brookhaven or Stanford linear accelerator, the machine becomes so extensive that such an arrangement is impractical, and sections of the machine will literally have to be removed from their shielding for repair and replacement.

The Experimental Hall

Certainly the area most desirable for maximum flexibility is the experimental hall. Here projects are constantly being assembled, some of them requiring heavy shielding or heavy magnets. The more open and unconfined this space, the greater its utility; the more of it that can be covered with a single crane span, the better. As this area is the most subject to change of any in the accelerator complex, construction of light, easily-modified materials, such as steel frame and steel or transite siding, is usually desirable. Such materials are relatively low in cost and well suited to the horizontal thrust of the crane loads.

Counting and Control

The counting and control spaces should ideally be located within easy walking distance of the experimental hall and the machine, and should not interfere with their activity or expandability. Very careful thought must be given to the routing of the counting and control circuits from both the machine and the experimental area. Large open runways should be provided for cable trays so that easy access and constant change are possible. Consideration should be given to a switching room for all control and counting circuits, located either above or below the main control and counting room so that very extensive recircuiting can be accomplished without suspending operations. For the fixed racks in the control room, a depressed floor system is probably desirable whereas in the counting room with its changing experimental set-ups, overhead wiring will leave the entire floor free for the set-ups and for wheeled equipment on casters. Whereas the control room probably need not be expanded for the life of the facility, the counting room is very likely to be enlarged. A common design failing is burying the counting room in the center of the building and surrounding it with dissimilar spaces. Assuring suitable space for counting room expansion will avoid this.

Shops, Labs and Offices

Several shops are probably preferable: one heavy shop to support the experimental area, and several lighter ones for work on electronics and smaller parts. Some of these can be located together with the labs and the offices. If space permits, a more flexible arrangement can usually be achieved by detaching the labs and offices to a separate building or to a wing of the main building so that they will not interfere with future additions, and can themselves be readily expanded. Labs, offices and light shops should all be in space that is structurally similar and thus interchangeable. A typical bay spacing, such as 24 feet, may be adopted. As the needs of the building change, each bay can be adapted to shifting uses without affecting the main structure of the building.

Mechanical and Electrical

Probably one of the most difficult problems in flexible design is location of the mechanical and electrical services. A good case can be made for routing these either below or above the main level where the experimental hall and machine are located, in drops or racks so that they can be readily expanded or modified without disturbing the operations. Ideally the mechanical and electrical space should be oversized so that it can be considerably expanded in capacity without requiring more constructed space. If this is impossible because of budget limitations, careful thought should be given to the direction of future expansion and an area should be reserved for it. Allowance should be made for new feeder and distribution lines. Outside utilities, especially electrical, usually save money. These should be located at a distance from the main crane bay at a 45° angle to the main crane bay and a future intersecting crane bay. See utility locations, Fig. 3.

Shielding

As shielding is usually the most bulky feature of the design of an accelerator, it requires much ingenuity to achieve maximum flexibility at minimum cost. If the size and configuration of the machine are completely understood and if the research goals of the facility are defined clearly for a considerable period of time (say 10 years), then it may prove practical and economical to pour all the shielding in concrete. Such an example is NRL, Washington (Fig. 1). If the spaces are correctly arranged and adequately sized, then considerable flexibility is possible as holes can be drilled in the concrete where desired at modest cost. A more typical approach to shielding flexibility is stacked concrete blocks. Rectangular modular blocks are generally the most economical and flexible. Depending upon space available, these can be either normal concrete or special concrete either composed of dense aggregate such as barites or loaded with iron filings. Portable steel blocks are also desirable, but they usually are quite expensive even if the bulk steel can be obtained surplus. It would first appear that ultimate flexibility could be achieved by having all shielding, both around the machine and in the experimental area, made of stacked blocks. This is not always true. The architect should consider the kind of flexibility really required and whether it cannot be achieved less expensively. Where heavy shielding is required, say over 4' thick of normal concrete, strong consideration to earth backfill or natural ground should be given. This will often give the least expensive and most flexible results.

Shielding Cost

Cost is an important factor in selecting shielding. The following table shows some interesting relationships:

Materials	Weight-lbs. per cu. yd.	Dollars per cu. yard	Dollars per 1000 lbs.
Earth backfill	3240 #	$ 1.50	$ .46
Compacted backfill	3645	3.50	.96
Gravel	3375	8.00	2.37
Slurry concrete	3915	30.00	7.65
Normal concrete	4050	60.00	14.81
Heavy concrete	5400	120.00	22.22
Normal concrete blocks	4050	150.00	37.04
Heavy concrete blocks	6750	400.00	59.26
Steel	13230	3500.00	265.15

As shielding is usually a function of mass, it can be seen from this table that earth or compacted fill gives definitely the most economical shielding results in dollars per pound. Interestingly enough, it may also give design flexibility almost comparable to stacked blocks. Of course earth shielding (with its relative lack of density) will require more space. However, it is often possible to avoid roofing all the earth shielding and thus consuming expensive interior space. The UCLA Pion facility design illustrates this (Fig. 3). Here a very large amount of shielding was developed with earth embankments. When this building is finally sited, it probably will be desirable to have it to some degree excavated into the ground. Cost studies show that a very significant amount of money will be saved by this technique as compared with the original design of stacked blocks. One of the great advantages of earth shielding is that it can be removed, increased or modified by readily available earth-moving or compacting equipment. It is also sometimes economically, as well as functionally, desirable, to set the entire building into the ground, say to a depth of one full floor such as in the Texas A & M Cyclotron (Fig. 2) since the cost of the excavation (particularly at the Texas site) may be more than paid for by the savings in shielding.

Composite Shielding

Probably maximum economy and flexibility can be achieved by some combination of portable concrete blocks, poured concrete and compacted earth fill. The Texas A & M Cyclotron illustrates this composite shielding. The main shielding between the machine and the control and counting area is of poured concrete, as it is likely that this shielding will always be needed. The experimental caves are all constructed of portable blocks so that their configuration can be readily changed. The machine cave and the experimental hall are surrounded on two sides by earth which can be readily removed for expansion if necessary.

Crane Coverage

In order to handle concrete blocks as well as heavier pieces of experimental equipment and machine parts, a high-capacity, high-speed crane is essential. Ideally this crane should cover both the machine and the experimental floor, and its travel should be unrestricted in either direction. Crane spans of 60 or 80 feet have been found entirely practical, and even spans up to 150 feet seem preferable to two parallel cranes of 75 feet. In the study of the LASL 800 MeV proton linear accelerator at Los Alamos, it was found that large cranes spanning the majority of the experimental hall were more economical and functional than a number of short span cranes. Careful thought should be given to the type of experiments which will be conducted and the crane should be arranged so that it can travel down the length of these experiments.

Forms of Crane Coverage

There have been two different major forms of crane coverage in accelerator design: the round form, such as in the Bevatron at LRL in Berkeley, and the rectangular form, such as the main experimental hall in the ZGS at Argonne. The rectangular form seems much preferable from the stand point of flexibility as it can be extended more or less indefinitely in both directions and it fits up easily against other structures. The round form is finite, and although it may fit the configuration of a round machine ideally, it does not serve well in the experimental areas and is very difficult to expand.

Site Considerations

Often the physicist or his architect can influence the selection of a site. When they do, they should be mindful of the need for at least twice the external beam space they originally contemplate. The larger and more level the site, the more room there is for expansion. The terrain will sometimes provide excellent natural shielding such as that provided by the small hills beyond the experimental areas at the Stanford Electron Accelerator. Consideration should be given to the radiation levels at the borders of the site, and fences and monitors should be provided if shielding may be inadequate. The site should be accessible both to heavy trucks and personnel. Often it is desirable to locate a large physics research facility on a crowded campus. At Cornell's 10 GeV electron synchrotron, locating the entire machine within a tunnel 50' below the campus has proved very practical and economical. Flexibility has been assured by extensive use of earth shielding.

Conclusions

As the experimental purpose of most machines may change within a few years and complete new machines for different purposes may be built within the buildings, the design of accelerator housings as highly specialized spaces is unwise. It is a good practice to develop the design with as much non-specialized space as possible so that the functions on the interior can change without requiring complete structural redesign of the building frame. The same suggestion is applied to mechanical and electrical distribution. The design should be conceived in its expanded state then contracted to what is possible within the initial budget. If the goal of flexibility is maintained throughout the design, the facility will be a much more useful research tool over the years.

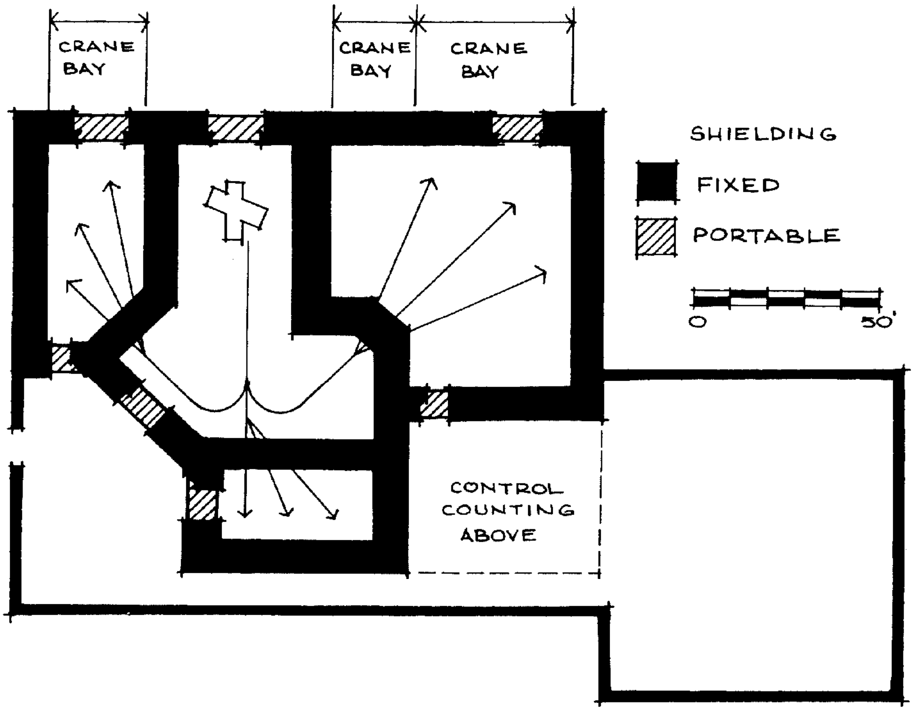

Fig. 1. N.R.L. Cyclotron - catalytic constuction. Giffels and Rossetti.

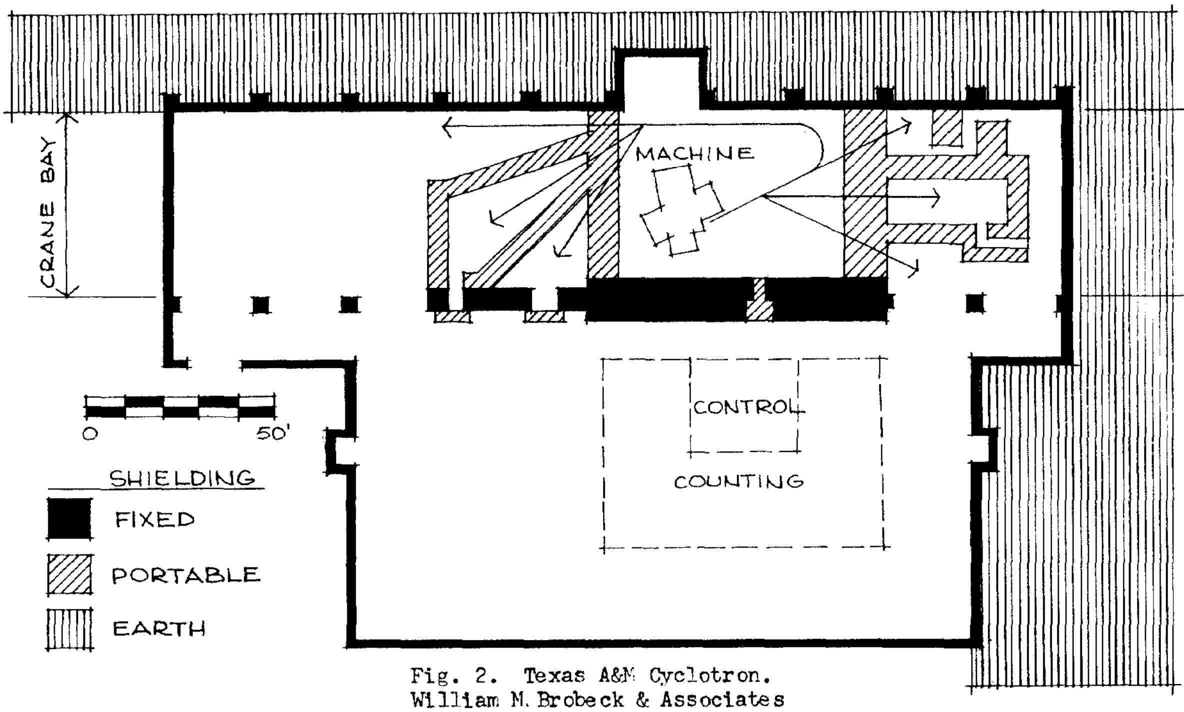

Fig. 2. Texas A&M Cyclotron.
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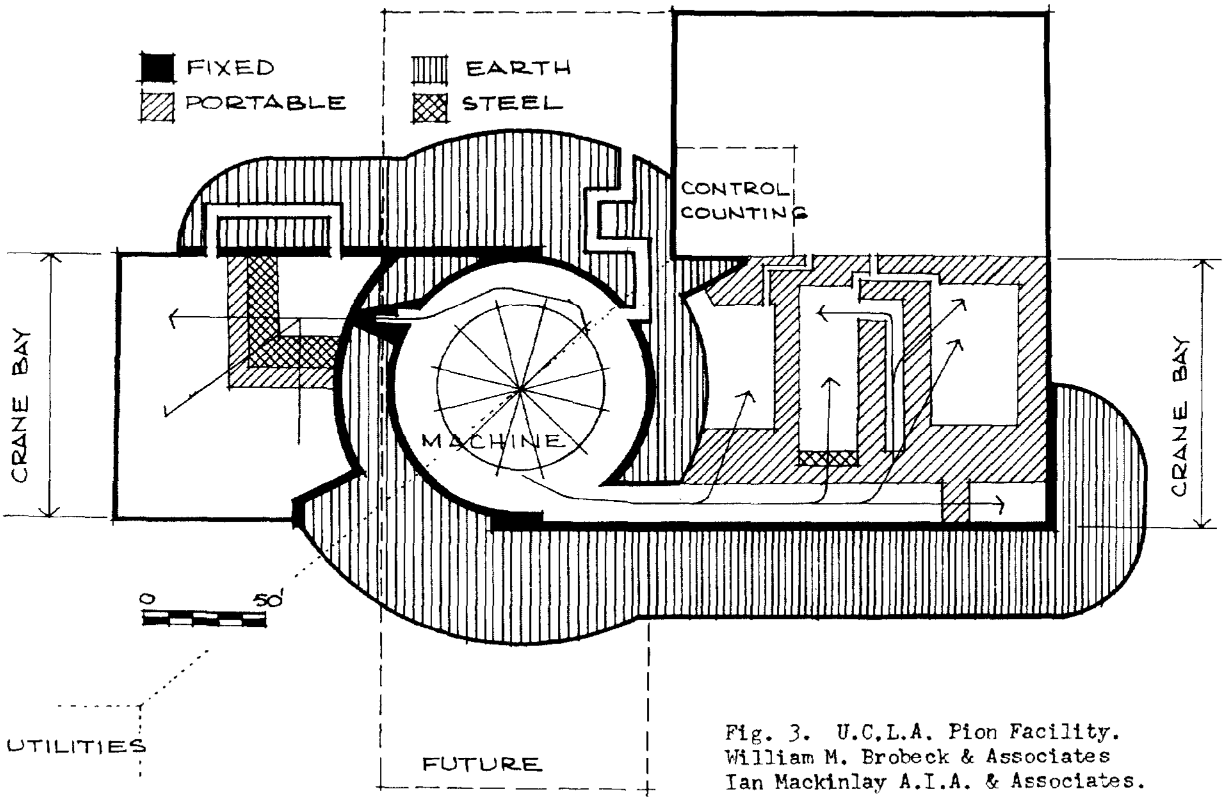

Fig. 3. U.C.L.A. Pion Facility.
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