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A two-unit system was used for servicing and dismantling targets at the 60-inch cyclotron. During target bombardment, a mobile cart provided a closed system of monitored helium and water coolants adequate for 1 kW/in.^{2} heat dissipation. Malfunction of either system or rupture of target foils actuated interlocks with the cyclotron to shut off beam. Means were provided for moving a target from the accelerator area to a shielded box where the target assembly was dismantled. The shield permitted each section of the target assembly to be visually inspected, to be checked for alpha, beta, and gamma activity, and to be sealed in plastic bags before being passed out of the shielded area. A contaminated box was readily replaced with a completely equipped standby unit.

INTRODUCTION

Until the advent of fixed-focus alternating-gradient (FFAG) accelerators, such as the new 88-inch at Lawrence Radiation Laboratory, Berkeley's 60-inch cyclotron presented the major challenge in design of external targets and their associated equipment, for with continuous 60-μA beams of 24-MeV deuterons, not only were the customary radiation problems in a somewhat magnified form, but also the heat evolution required fairly complex solutions. This alone dictated a three-chambered target assembly, each section electrically and thermally isolated from the other two, and each requiring its own coolant system. Again, the target structure, coupled with the high induced activity and short-lived target material, required special handling equipment. These 60-inch problems characterized also those of the 88-inch, and our solutions to the one therefore served as guides to the other. To this extent, then, they may aid in designing for other FFAG machines.

THE TARGET CART

Design Criteria. The design of the utility supply system was determined by many external factors. The collimator-target assembly, the target block (Fig. 1) was roughly a 4.5-in. cube with seven coolant ports located on one face. Five of these, serving the downbeam half of the block were combined into a multiple bayonet-type locked-in connector (I), thus permitting an extended male plug from the supply unit to be used as a handle for quick transfer from the cyclotron to a shield on the cart. The small target holder (H) was situated beneath this in a sealed chamber (G) at the rear of the block. During operation, this chamber and consequently the adjacent protecting upbeam foil (F) of the target holder was exposed to a static helium atmosphere of about 8 lb absolute pressure. The means of preliminary evacuating of the chamber as well as of maintaining a controlled helium pressure had to be separate from any "house" systems to avoid their possible contamination. Similarly, the cooling water on the rear surface of the target proper had to be self-contained and separate.

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During target bombardment the supply system had to function properly when set in the high magnetic field of the cyclotron: this precluded using large masses of magnetic materials and required completely nonmagnetic or shielded monitoring devices. The integrity of the target block assembly and its service lines was to be maintained at all times until the target could safely be extracted behind the shielded dismantling enclosure. There was, moreover, a high induced gamma field at the target port of the cyclotron plus an occasional formation of short-half-life isotopes from the target material itself. These factors all pointed to a means of rapid transfer of the target and its auxiliary equipment from the accelerator to the dismantling area; hence mobility of our system became critical.

Structural Features. As finally completed and placed in operation, the utility supply system is a long-handled, two-wheeled cart (Fig. 2). The basic structure is of austenitic stainless, with the exception of the two rubber-tired aluminum wheels. With the bulk of its weight suspended trunnion-wise between the two 10-in. wheels, it rests during operation upon a single third wheel in front. The lighter-weight components, such as power and monitoring switches, are mounted along the length of the tubular handle. (In general, to optimize mobility, the heaviest components were located nearest the center of gravity. This detailed interest in mass distribution "paid off," for the 126 pounds of the cart and target is easily maneuverable with two fingers.)

Utility System. Although all three sections of the target block required individual cooling, servicing the aforementioned target-holder chamber was the principal function of the target cart. For preliminary evacuation of the target chamber, we mounted a previously evacuated stainless gas bottle, and provided two sets of vacuum valves and gauges--one set for the chamber and one for the vacuum bottle. In the vacuum line was an MSA vacuum cartridge filter and a stainless adjustable vacuum switch. Upon complete evacuation, helium was bled through the filter into the chamber until the switch was actuated and the chamber line was then closed.

The target water cooling system was a closed loop of 1.2 gpm flow capacity with the target in circuit. To minimize cumulative induced activity, deionized water was used as a primary coolant; all components contacting the water were therefore of stainless or of surgical quality Tygon, including the centrifugal pump and a specially designed two-pass heat exchanger. All the available flow switches on the market which we investigated were rejected on grounds of corrosibility, relative insensitivity, nonreproducibility, ruggedness, or too great a pressure drop. We therefore utilized the pressure differential across the fixed orifice of the target ports themselves, and installed two identical stainless pressure switches, one on either side of the target, and so adjusted them that a 2% change in pressure differential would repeatedly activate one or both switches. These switches, with the vacuum switch, were interlocked with the oscillator of the cyclotron.

Coolants to the remaining sections of the target block assembly—house, air, and water—were independently monitored; the target cart was merely a junction point into the target coolant manifolds. The cart did filter the entry and exit air, however, with two additional MSA cartridge filters.

All components of the cart were mounted for rapid replacement of stand-by units. Hose connectors of the quick-disconnect double-check-valve type were used to maintain conditions within the remainder of the circuits, and to minimize spread of contamination.

At the completion of target bombardment, the "umbilical" to the cyclotron services was broken and clipped onto the cart handle, the cart system turned off, and the target block removed from the cyclotron beam port and dropped into a 1-inch lead box on the cart. The cart and target system was then wheeled to the nearby dismantling unit outside the accelerator vault.

THE DISMANTLING SHIELD[1]

In order to present the chemist with a usable target, we had to break the target block, extract the target holder, and deliver the latter to him intact. This must be done rapidly, but done safely. To this end the dismantling enclosure (Fig. 3) was a modified half Berkeley box enclosed in a 2-in. lead shield with but one multipurpose tool extending from outside the shield to the inside of the box, and one permanently fixed rotating shaft. The left-hand box door was operated simultaneously with the sliding shield door by means of a two-position pressure-type latch mounted on the shield. All operations necessary for efficient control of activity were carried behind this shielded enclosure, including activity monitoring of both the target block and holder, preparation of the holder, and disposition of contaminated components.

As the operator with cart and target approached the shield he opened the two doors, and, grasping the long bayonet handle, placed the target on a massive turntable inside the box. At this point the closed coolant loop was broken as the bayonet was disengaged and returned to the cart. The box and shield doors were manually closed. The turntable was rotated facing the target manifold forward.

The single dismantling tool was a composite Allen wrench and male screw mounted in a spring-loaded universal joint at the end of a long rod. With this running through its pivot point in the shield, one could loosen the manifold bolts on the target, swing the manifold aside, thread into the base of the target holder, and extract it without danger to the holder. The integrity of the target was first visually checked through the lead glass windows. Then supporting activity check was made. With a light pressure on the outer latch, lead and box doors were opened enough so that swipes could be taken of the holder and interior of the block chamber. These swipes were passed before a gamma- and neutron-insensitive probe mounted just outside the door.

If the check was negative, the doors were closed, and the target holder (the hottest part of the block assembly) was passed through a bagged slot in the opposite end of the box, but still within the shield. Directly overhead at a calibrated distance a second probe metered the beta-gamma level. As the target holder was now dropped into the plastic bag, it passed between the jaws of a bag sealer, which in turn double-sealed the bag and cut it loose. The sealed holder dropped into a cushioned, shielded carrying case and was ready for delivery to its owner. The remainder of the target block assembly was allowed to cool in the box until such time as it could safely be retrieved and placed in a storage vault.

If, on the other hand, our alpha check had shown evidence of rupture of the target's protecting outer foil, then the box door, which had remained slightly opened, was closed. The shield door was fully opened, and a hinged gasketed port with its own large plastic bag was swung into position and latched against the box. The holder was bagged out into its carrying case as just described. The larger target block was retrieved from the box interior with a long carrying rod. As the box door was reopened, the plastic bag mounted on the passout ring was sucked inside. The rod had on its end an expandable wedge which, when tightened in the U block on the target block, grasped the latter firmly, even with relatively thick plastic at the interfaces. The rod and block were withdrawn outside the shield, and this bag was doubly sealed and sheared as in the holder operation. The block could be transported in this condition, or the adjacent target cart shield box could be used for carrying it, depending upon the degree of its induced activity.

The box, now empty of all target parts, was still a sealed unit. There remained two alternatives, determined by the suspected degree of contamination in the box. If contamination was slight, cleanup was done "on the spot," for the enclosure was designed to facilitate this treatment. Standard Berkeley-box features were of course included in its design: waterproof plastic lining, plastic tape joints, radiused metal trays for the floor, and socked manipulating rods. Moreover, the rear of the box was of lucite, for unobstructed visibility, instead of the customary wood; it contained two permanently mounted retracted rubber gloves for working on the interior. The turntable base was Teflon, serving both as a bearing and as a seal against commonly used decontaminating fluids; its base in turn was cemented, rather than screwed to the metal floor, to prevent leakage of contaminants to the box's exterior wood floor.

In grosser contamination, a second procedure was followed. The turntable rod extending to the outside was withdrawn from the shield, leaving its intact sock attached to the turntable. The dismantling tool remained within its sock, but with the handle removed. The box-latching mechanism was slipped from its counterpart on the shield. Ventilation ducts were sealed off in the normal manner and the box rolled out the rear of the shield on ball bearing guides. It was ready for delivery to the department's Decontamination Group. A completely equipped stand-by box was rolled into place, and connections were made, and the enclosure was again ready for targets. The entire box-replacement procedure took 20 to 30 minutes.

Merely modifying the turntable's superstructure and the dismantling tool should permit use of the enclosure for other types of targets. The target cart, on the other hand, has already been used without modification for servicing 60-inch targets on Livermore's 90-inch variable-energy cyclotron. Both have seen continuous use for upwards of 2-1/2 years.

REFERENCES

(1) G. L. Wigle et al., "Dismantling Enclosure For External Cyclotron Targets at the 60-Inch Cyclotron", USAEC Report UCRL-9663, Lawrence Radiation Laboratory (September 1961).

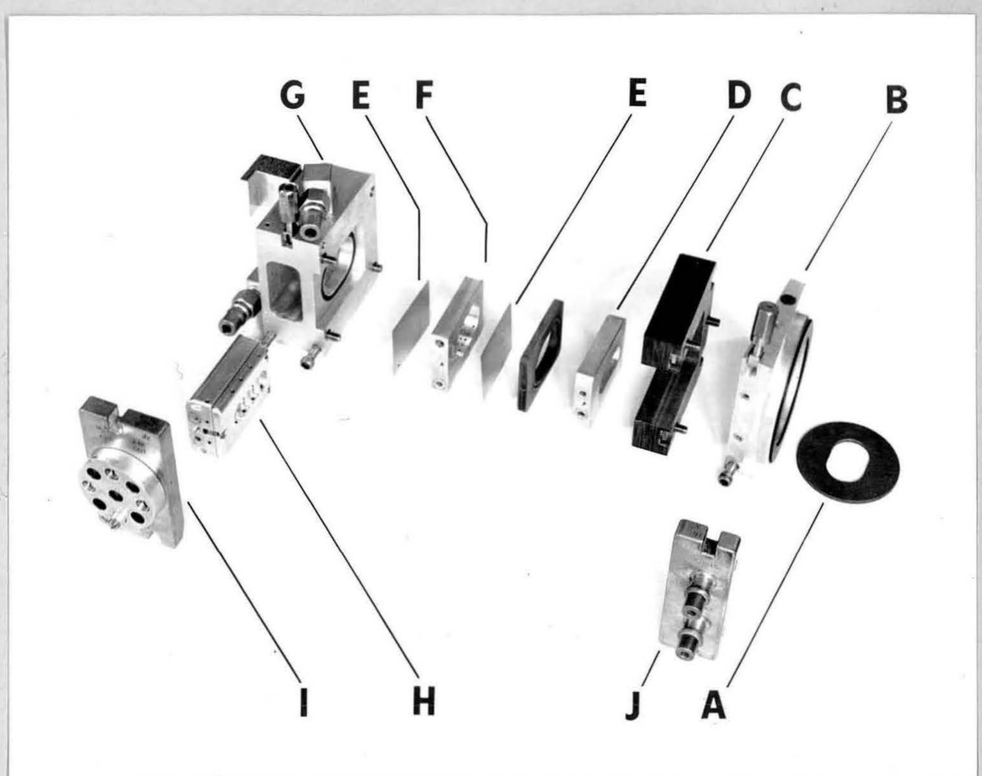

Fig. 1. Target Assembly (Exploded View).

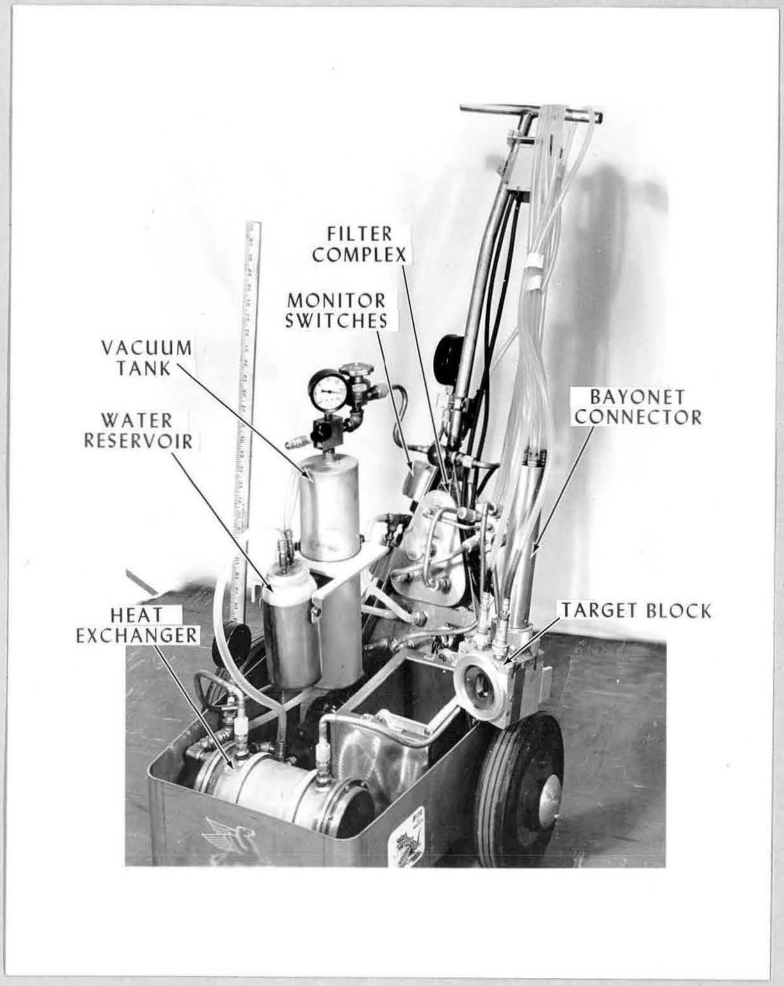

Fig. 2. Target Cart.

Fig. 3. Dismantling Shield.