# A HIGH POWER POSITRON CONVERSION TARGET FOR AN ELECTRON LINAC

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## SUMMARY

The target consists of a series of annular discs which, when held concentric with the beam, allow the beam to pass unobstructed through the central holes but which, when nutated intercept it to produce electron-positron pairs. Some of the positrons are focussed into the next accelerator section by a magnetic lens, and, a solenoidal field throughout the remainder of the accelerator which is phased for positron accelerator maintains the beam diameter. A novel design feature is that the same water is used to nutate the target via turbine blades and cool the target. Nutation permits bellows to make the vacuum joints so avoiding the use of moving vacuum seals which would be necessary with a rotating target.

Target 'heat load' is discussed with particular reference to the requirement for the Glasgow accelerator where the maximum electron beam energy is 110 MeV and the maximum mean power 30kW. The principle of nutation and the control system are described, and bellows fatigue, operational tests and safety systems are discussed.

## THE HEAT LOAD PROBLEM

Principle limitations on the maximum mean electron beam power any target can handle are, firstly, the maximum permissible instantaneous temperature induced at the hottest point of the target system, and secondly the rate at which absorbed heat energy can be extracted.

A static target consisting of a single piece of material and absorbing consecutive coincident beam pulses will have a high temperature gradient between the beam intercepting area and coolant source. Heat will be conducted radially outwards through the target material, and, be radiated into the accelerator 'void'. A laminated target through which coolant is passed will be more efficient, as heat will also be extracted from the electron illuminated target surfaces themselves. As a secondary effect some heat will be removed from non-electron illuminated areas of the target surfaces to which heat has been conducted through the target material.

As mean electron beam power is increased in a laminated target of the above type, coolant flowing between laminations becomes the principal cooling medium, and the bulk of the heat extracted in this manner is that via direct contact between the coolant fluid and electron illuminated areas. In view of the above considerations the only way to further effectively increase maximum mean electron beam power is to spread the electron illuminated target area by some form of continuous movement so as to reduce the heat load of the illuminated area wetted by the cooling fluid.

### Requirement of the Glasgow Target

The principal requirement of this target in view of the high mean electron beam power was to spread electron illumination; a second consideration was to provide electron facilities not involving mechanical disassembly on the accelerator, so that rapid change from an electron source to positrons and vice versa could be achieved.

The target evolved to meet this requirement consists of a stack of discs with holes through the centre; located concentric with the beam axis. When stationary the discs allow the electron beam to pass through the central hole. To produce positrons the disc is moved sideways to intercept the beam and nutated, nutation moving the disc around the illuminated 'spot' on the side wall. See Fig.1.

## PRINCIPLE OF OPERATION FOR POSITRONS

The target is nutated on the correct radius by being hydroplaned on an extremely thin film of water between collars at each end of the target and the fixed containing tube, see Fig.2., and is driven by water jets. The water jets not only drive the target, but also produce the boundary film for hydroplaning and provide the coolant medium.

As the target periphery can be held at a fixed radius from the beam axis, providing components $p_1 + C_p$, see Fig. 3., exceed the minimum value required to hold the collars to the containing tube, a degree of target speed control can be attained. Control is achieved because speed component $p_2$ is related to water jet velocity, (a function of pressure), and nutation speed; $p_1 + C_p$ may considerably exceed the value required to hold the target collars to the containing tube but this is irrelevant providing the minimum value is exceeded, (Fig.4. gives a water manifold pressure/target speed relationship).

Figure 3 illustrates water jet thrust angles, resultant thrust R on the drive/deflector blades and resulting components p1 and p2 on the target capsule. Component $p_1$ draws the target capsule radially outwards towards the containing tube wall and $p_2$ imparts a continuous tangential nutating motion. After approximately $6^o$ of nutation two similar components to $p_1$ and $p_2$ come into effect from the next water jet, and at any one time an average of three water jets and drive/deflector blades are effecting target motion.

A centrifugal component $C_p$ is created immediately nutation commences, assisting the $p_1$ component. In the Glasgow case at 1,800 n.p.m. this $C_p$ component is as follows.

$$C_p = \frac{W_e\ V^2}{g.r} = \frac{.15\ 4.15^2}{32.2\ .022} = 3.65 \text{ lbf.}$$

where r, radius of nutation = .022 ft.

v, instantaneous tangential velocity $= \frac{1,800}{60} .2\pi\ \ .022 = 4.15$ ft/s.

$W_e$, estimated excess of target capsule weight over weight of water displaced by the target capsule and bellows adjacent to the target ℄ = .15 lb.

Figure 2 shows the target capsule axis, relatively illustrates the axis of electron illumination and shows the bellows in their deflected position supported by contoured nylon guides. The guides hold the bellows to their minimum stress curves by forming the firm 'shaped' water saturated base upon which the bellows hydroplane.

## TARGET CONTROL SYSTEM

Figure 5 shows the target control system which serves the following functions.

a. Target cooling and speed control for positron operating conditions.
b. Centralising of target for electron operation and extraction of heat induced by beam scatter.
c. De-gassification of closed circuit target cooling water.
d. Emergency discharge of water in the event of vacuum failure.

### Control circuit for Positron Operation

Refering to Figure 5 water is pumped through two water emergency discharge valves, that during normal operation allow free flow to a flow meter which trips the accelerator off in the event of flow falling below a minimum requirement. The flow continues to a valve system which allows on one side a permanent fixed low flow bypass for extracting heat induced by scatter during electron operation, and on the other an adjustable flow controlling target speed. From the valve system the flow is through the target to a temperature monitor. A percentage is then cooled via a heat exchanger, the quantity being governed by a bypass control. Total water flow passes then through a de-gassifier and back to the water pump.

Should target failure occur, a 'Penning' head adjacent to the target will record vacuum failure and trigger the two water valves adjacent to the water pump. One valve obstructs water flowing to the target and simultaneously the second will open to discharge the water to a drain. A valve downstream of the two water valves admits air (or nitrogen) to the water system.

During positron operation the full flow valve to the centralising piston circuit is closed, and, a negative pressure is induced on the piston head through the restrictor. 80 p.s.i. is acting on the other side of the pistons - which are consequently fully retracted.

### Centralising of Target for Electron Operation

The water pump is stopped, target speed control valve completely closed and the valve to the piston circuit opened. On restarting the pump the three equispaced pistons are inserted to concentrically locate the rear hydroplaning collar. 80 p.s.i. is applied to the heads of the centralising pistons, and as a much lower pressure exists in the lens manifold the pistons are inserted and secure the hydroplaning collar, Fig.6. A .310" (8.25mm), bore central tube allows most of the electron beam to bypass the target and heat induced by scatter is extracted by water bypass flow of 1.5 gal/min. sprayed via the jets, Fig.6.

## OPERATIONAL TESTS

### Fatigue Failure of Bellows Units

The limitation to target life at present is mechanical failure of the bellows due to fatigue. Development work to extend this life is currently in progress and present bellows fatigue lives of a few tens of hours are expected to be considerably improved. The most encouraging feature revealed in all tests todate is that vacuum failure occurs gradually, the bellows becoming minutely porous over a period of time. The 'leak-rate' of these units slowly overcomes the capacity of the vacuum pump and only a slow increase in pressure has been noted on vacuum gauges which on the accelerator would be handled by vacuum failure devices, (water discharge and $N_2$ admittance valves).

### Potential Heat Absorbtion Capacity

A static air cooled target similar in cross-section to the nutating target has been used on the Glasgow accelerator at 40 MeV and a mean current of 160μA, (6.4kW), 500mA peak, with a beam cross-section of approximately 3mm dia. This target is estimated to be capable of withstanding a mean current of 300μA (12kW).

Difference between the static and nutating targets are purely that of heat extraction ability. Nutation will ensure that the electron illuminated area is increased by a factor of ten and allowing for various considerations water cooling will increase heat extraction by at least a factor of 3 over air cooling. A combination of the above suggests that the heat absorbtion capacity of a 'nutating' target will be a factor of 20 to 30 greater than that of a static target. Moreover, as any target position is only subjected to one pulse in ten, target and window thermal fatigue will be reduced by this factor.

ACKNOWLEDGEMENTS

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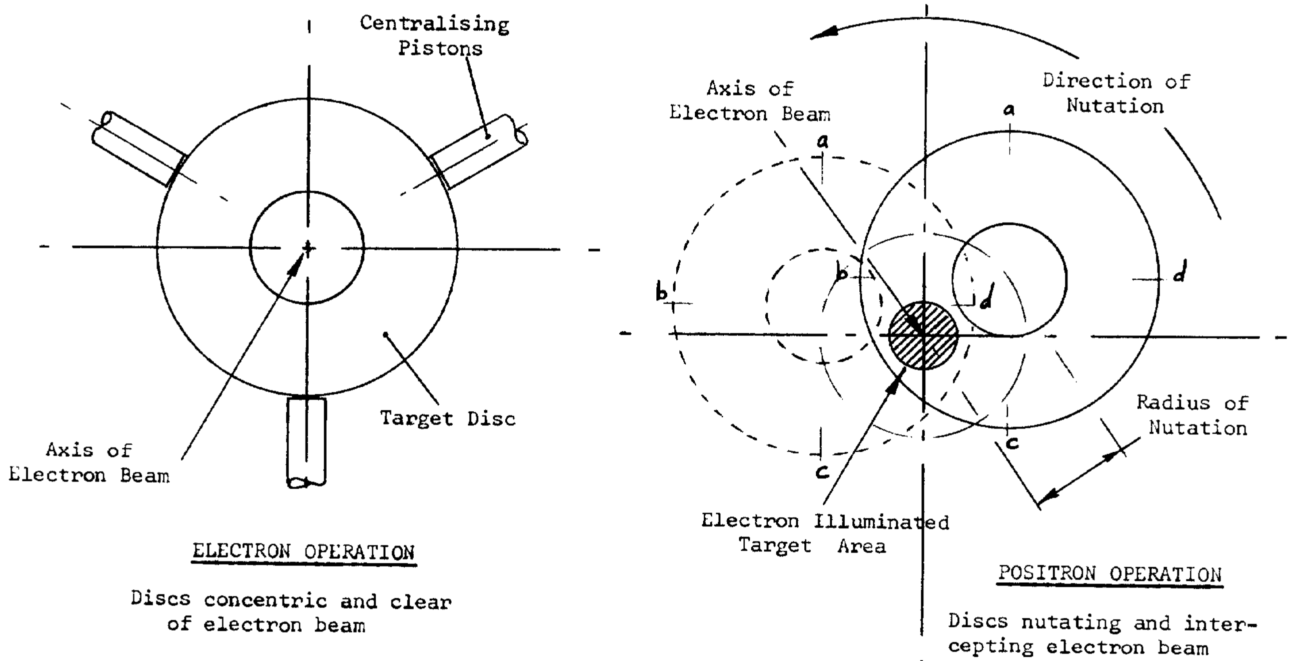


Fig. 1. Target Disc Positions.

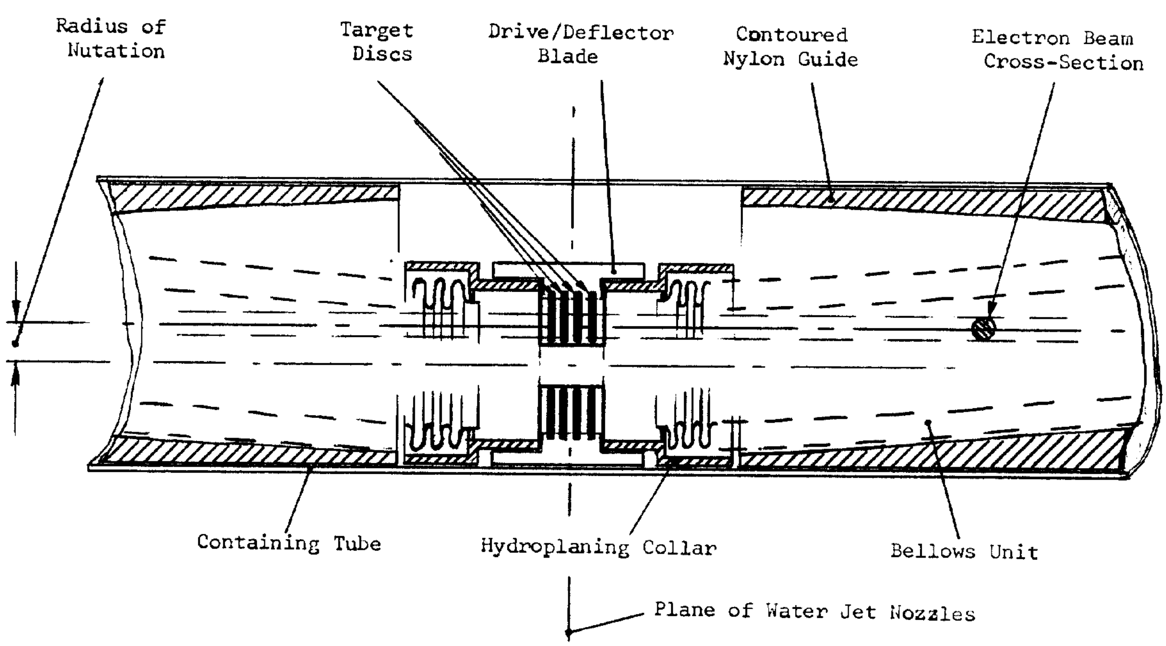


Fig. 2. Section of Target Capsule (Nutating).

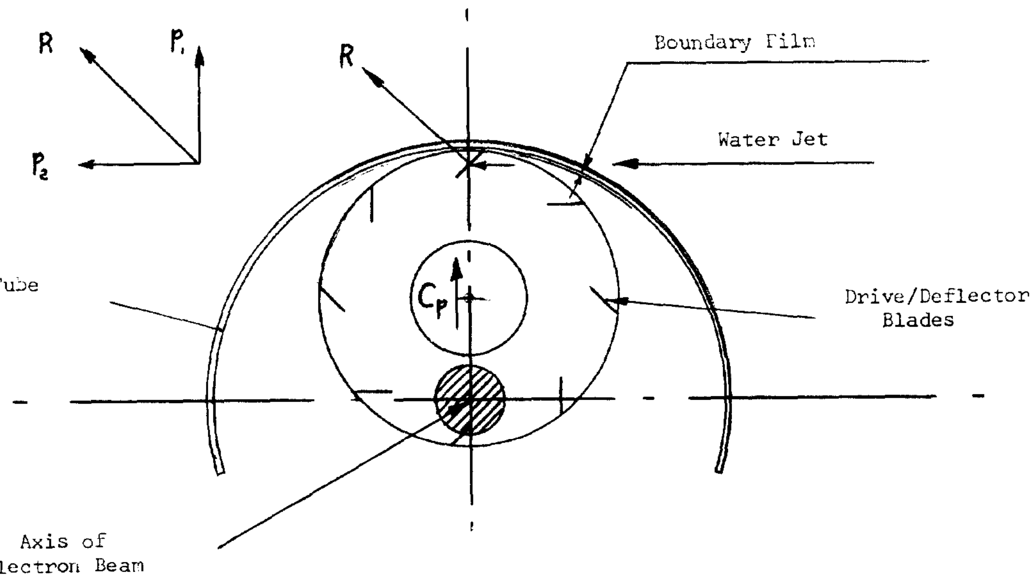


Fig. 3. Principle of Nutation.

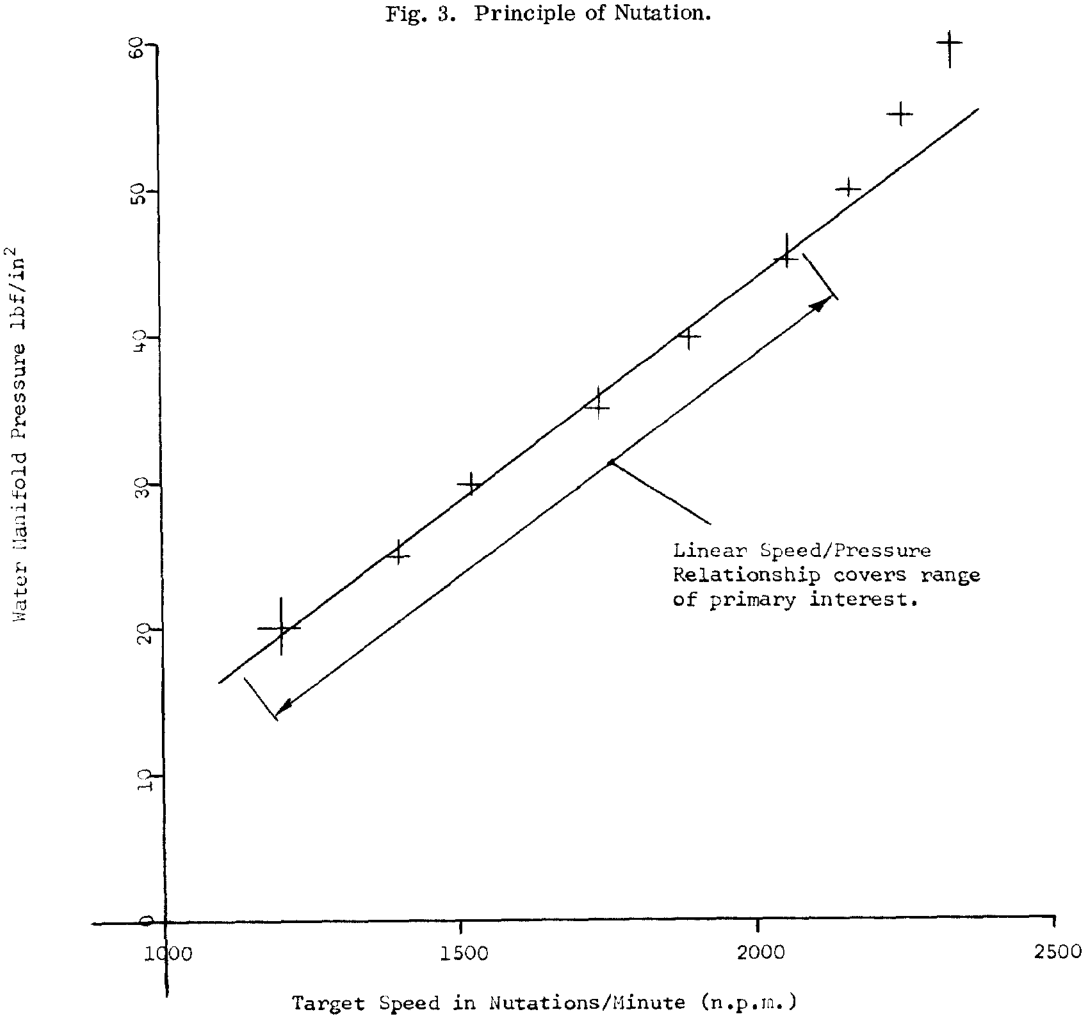


Fig. 4. Target Speed Graph.

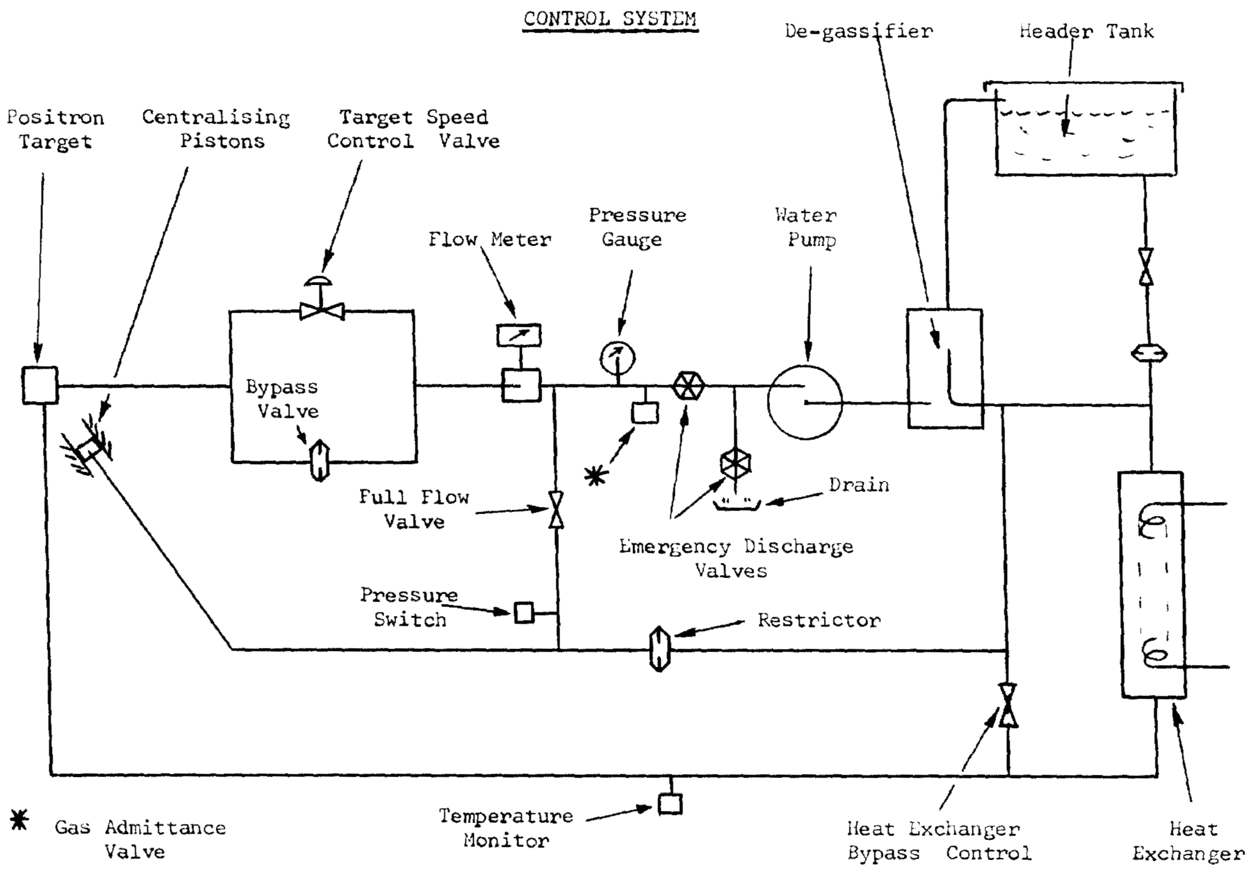


Fig. 5. Control System.

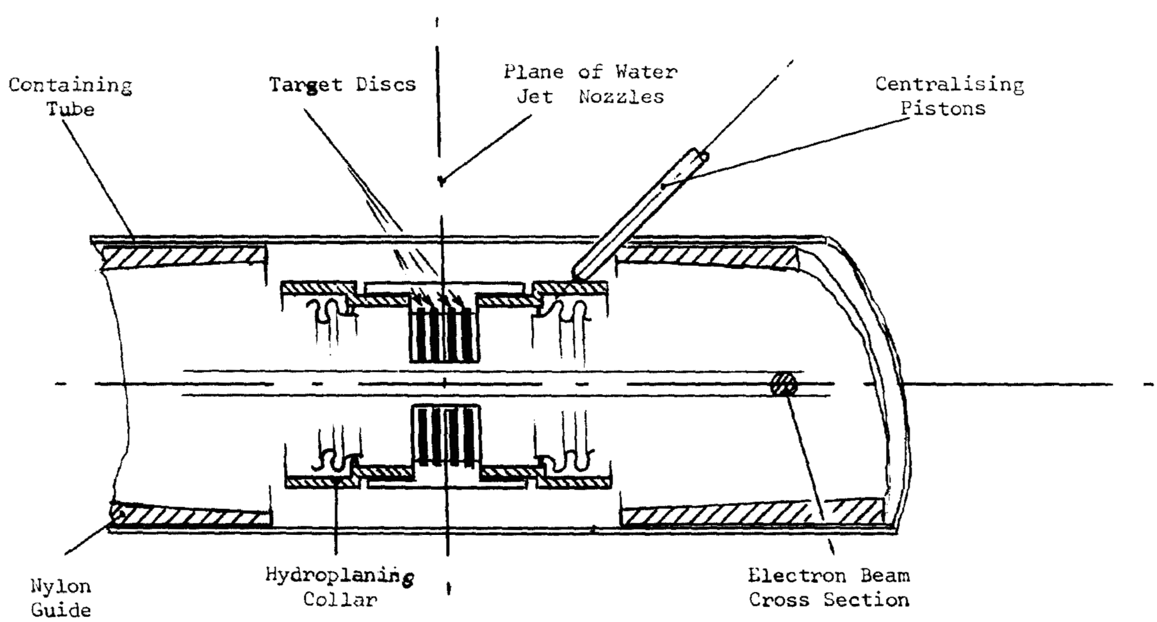


Fig. 6. Section of Target Capsule (Static).