

A NEW POST-COLLIMATION TRIMMER FOR NEUTRON THERAPY AT NAC

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The versatility of the isocentric system for neutron therapy at the National Accelerator Centre (NAC) has been dramatically improved by the provision of more flexible beam shaping. This was achieved by commissioning a new and economical multi-leaf post-collimation trimmer designed and constructed in-house. The inexpensive trimmer consists of two sets of sixteen iron plates, which are moved by a single air-driven actuator against a simple and cheap wooden insert made to define each new field profile. The mechanical layout and pneumatic design as well as the simple manual control system of this device are presented.

1 Introduction

A total of 945 patients have been treated in various clinical trials on the NAC p(66)/Be(40) isocentric neutron therapy facility [1] up to March 1998. In addition to the existing treatment protocols, a new protocol for the treatment of prostate cancer with fast neutrons is being formulated at NAC following recent evidence from clinical trials which demonstrated the efficacy of conformal field shaping in reducing patient morbidity [2,3]. Existing means of beam shaping, which employed 12 cm thick tungsten blocks and custom made steel blocks, was considered inadequate to provide the field shaping required by this new protocol. Experimental investigations showed, however, that a multi-leaf post collimator device could be used effectively [4].

The multi-leaf trimmer had to be added to our existing neutron therapy unit NT66R-490 from Elven Precision (see figure 1), which was installed in 1985. The new device replaces the original gamma-shutter assembly, and it should fit into the contour of the existing hood, with restricted space particularly towards the isocentre. An area of $150 \times 150 \text{ mm}^2$ for field shaping was requested, with the possibility to revert to the full square field of $290 \times 290 \text{ mm}^2$ whenever necessary. On each side, sixteen leaves of chemically pure iron were specified, each 10 mm thick and 150 mm high, and the whole unit had to be rotatable through 360 degrees. An additional layer of 50 mm thick borated polyethylene shielding material had to fit between the existing rectangular jaw collimator and the new multi-leaf trimmer. To contain costs, the trimmer configuration had to be simple and to allow for manufacture in our workshop.

2 Design Concept

After some preliminary tests, the configuration shown in figure 2 was chosen. The sixteen iron plates on each side form two leaf-packs held in rectangular open frames,

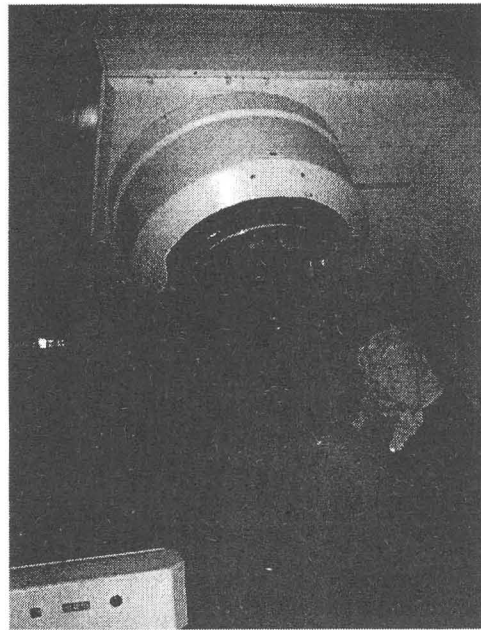


Figure 1: Arrangement on the neutron therapy gantry.

in which they can slide with one degree of freedom. These frames move radially in opposite direction, so that the aligned plates meet at the centerline on the inward stroke. A pressed-wood "core" insert, representing the projected shape of the area to be treated, can be placed centrally in the path of the plates. Hence, on moving the frames inward, those plates which come into contact with the core are stopped and a cavity is formed around the insert. At the end of the inward stroke, the plates are clamped so that the shape of the cavity is preserved.

For this process to function properly, the friction between the plates and the frame must be greater than the friction between adjoining plates. Consequently, this setting-up operation can only be done when the beam axis is vertical, either up or down. The clamped leaf-packs are then opened a short distance, so that the insert can be removed, and afterwards are closed again.

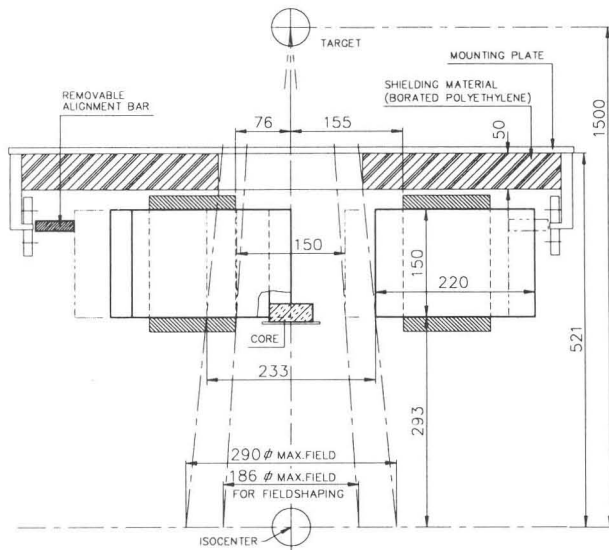


Figure 2: Schematic layout of the multi-leaf trimmer.

Finally, the trimmer must be turned into the correct angular position and locked. The gantry is now ready to be rotated into position for treatment.

After treatment, the gantry has to be rotated into vertical position again, and the frames are unclamped and moved out against two stops, so that the plates on each side are re-aligned for starting a new cycle. The stopper bars provided for this purpose must be easily removable, so that the plates can be moved out far enough for the full square field of $290 \times 290 \text{ mm}^2$ to be used.

3 Mechanical Configuration

3.1 Drive system

We investigated a variety of drive systems utilising A.C. or stepping motors, a pneumatic actuator, and even one based on hand operation. A solution using gears driven by an air cylinder as shown in figure 3 was chosen for its simplicity, low cost and ease of operation.

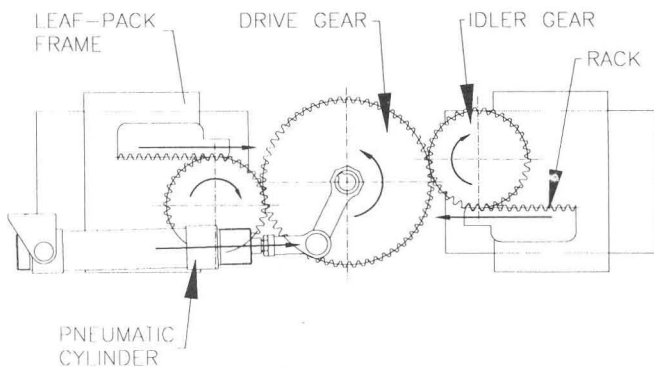


Figure 3: Schematic representation of the drive system.

A double-acting pneumatic cylinder rotates a central drive-gear which meshes with two idler gears. These idler gears each drive a rack which is mounted on the leaf-pack carriage. The two racks are arrayed 180 degrees around the centre of the drive-gear, thus moving the carriages simultaneously in opposite direction. The two leaf-packs have a stroke of 76 mm each, but the outward movement is restricted to only 1 mm before the insert is released for removal. This is done by means of a ratchet, which is automatically pushed into the path of a pin mounted on the drive gear as soon as the core-holder is installed (see figure 4). The core-holder for the full field of $290 \times 290 \text{ mm}^2$ has a cut-out which prevents the stop from being activated.

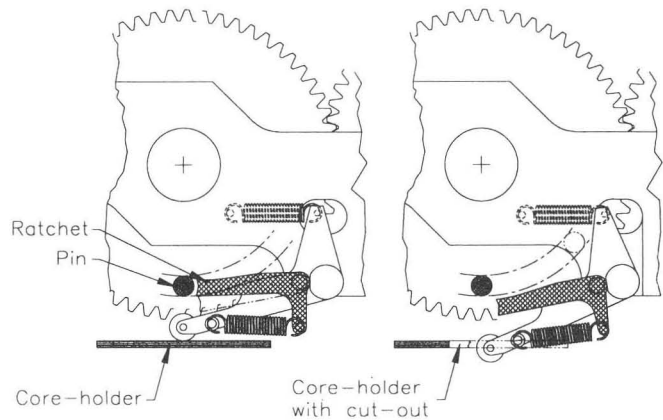


Figure 4: Backstop for removal of core insert.

3.2 Leaf-pack structure and clamping mechanism

As is shown in figure 5, the leaf-pack is supported by a frame mounted permanently on linear ball-bearings which are carried by the gearbox. The leaf-pack is installed on the support frame using only two screws and a locating pin, thus making the exchange of leaf-packs a quick and easy operation. This may be necessary if their activation becomes too high. The removed leaf-packs can then be stored to cool down to acceptable radiation levels for re-use.

The leaf-pack frame is built up from 20 mm stainless steel plates machined all round. The leaves are ground to a surface finish of $1.6 \mu\text{m}$ and to a thickness of $10 \pm 0.03 \text{ mm}$. After grinding, the leaves are first electroless nickel-plated and then heat treated for 5 hours at 350°C . This process provides protection against corrosion and also a significant reduction in the friction coefficient. Each leaf is fitted with a pin at the outside edge of the plate to prevent it from accidentally falling out of the frame.

To determine the correct force needed for clamping

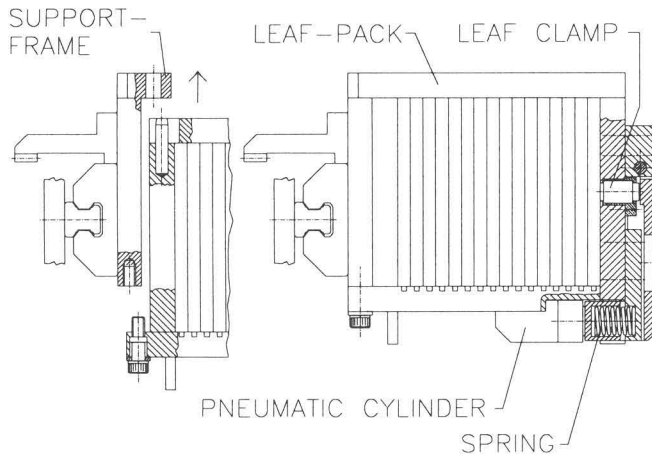


Figure 5: Layout of the leaf-pack and its support structure.

the leaves, we used a specially made testing tool. These tests showed that the clamping force has to be at least 2200 N for safe operation. To achieve such a force within the confined space available, we use two compression springs of 200 N each, pressing onto a pin with a ratio of 6.4, thus producing a clamping force of 2560 N. To allow the leaves to slide, we have to release the clamping force. This is done with a single-acting pneumatic clamping module of rectangular shape, which is positioned in line with the springs and exerts a force of 500 N at 6 bar air pressure.

3.3 Mounting frame and rotating structure

The mounting frame is shown in figure 6 and consists of a central stiffening structure with two side plates to provide the near-circular shape required for the rotational bearing. This bearing is made up from six equi-spaced groups of three ball-bearings each, two for axial location and one for radial positioning. The circular bearing rail, on which the whole assembly can be rotated, is mounted on four pedestals which fit the holes left by the removed gamma shutter. A cam-operated clamp locks the trimmer assembly in the required angular position on the rail.

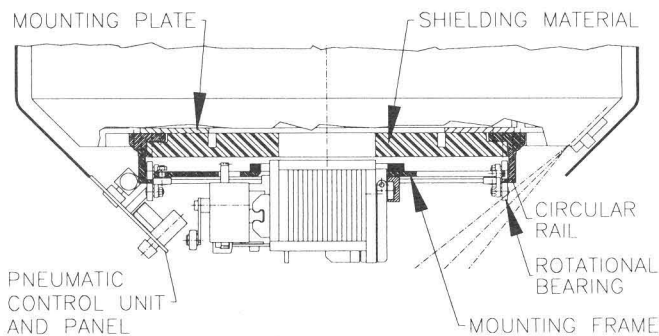


Figure 6: Mounting frame and installation.

3.4 Pneumatic control system

The principal component of the control system is a manually operated selector valve with six switch positions illustrated in figure 7. With this valve, the operator can scan through the whole functional cycle of the trimmer by turning just one knob. The only other manual actions required are coupling and uncoupling of the air nozzle, and the installation and removal of the core-holder. Originally, we considered supplying the compressed air via the gantry, but in view of the complications involved in installing such a pipe, we decided to connect it to the trimmer externally with a quick push-pull coupling. All components of the pneumatic control system are mounted on the back of the control panel. We also have made a spare unit, so that we can simply exchange the panel in an emergency.

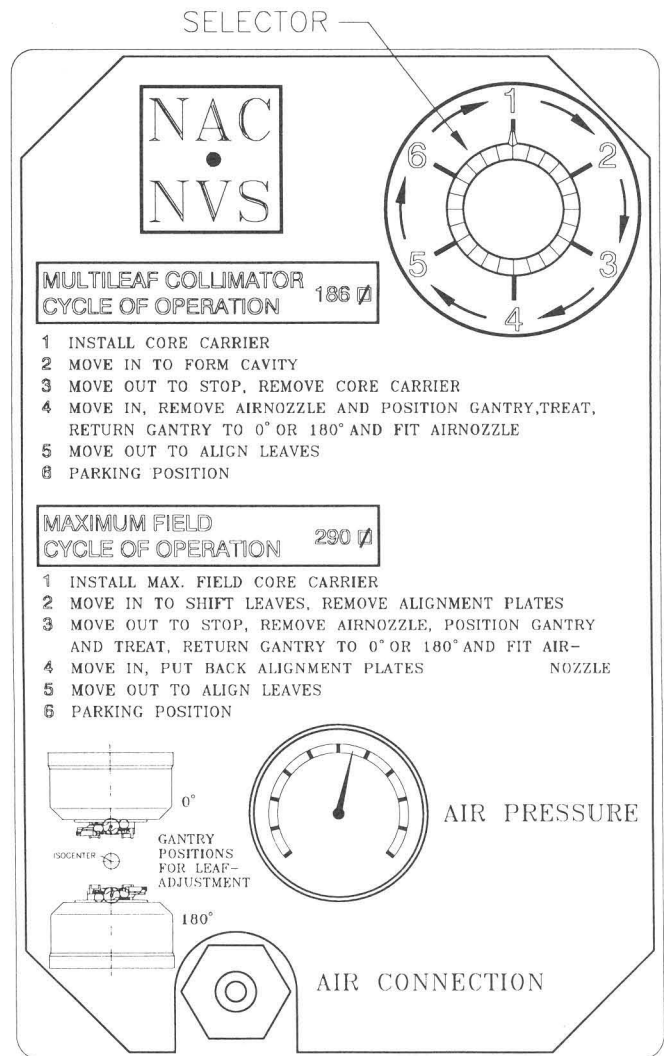


Figure 7: Pneumatic control panel.

4 Assembly and Installation

4.1 Manufacture and assembly

Manufacture of all components was done in our mechanical workshop, except the surface grinding and nickel-plating of the leaves, which were contracted out to specialised companies. No problems out of the ordinary were encountered at any fabrication stage.

The initial assembly of the trimmer was done on a special frame, thus enabling us to test all its functions before installation on the gantry. At this stage, we also extensively involved personnel of our medical radiation group, so that they could familiarize themselves with the operation of the trimmer and make suggestions for improvements.

The attachment for positioning the core-holder plate was modified to save space towards the isocentre. A quick-release mechanism for the two leaf alignment bars was incorporated, and safety guards were added to cover them. Down-stream from the trimmer, a ring-shaped plate was installed, with mounting pads for the original tungsten blocks needed when treating large field areas. A cut-out in this plate allows the laser beam for patient alignment to pass through to the isocentre.

A further modification was introduced on the guide system of the leaf-pack frames. These frames were originally supported by the ball guides only, but this was found not to be rigid enough. An additional support bearing was provided on the opposite side, which runs in a straight guide rail.

4.2 Installation

The installation of the trimmer went as planned, except for the need to fit a counterweight, so that the unit could also be rotated easily with the gantry axis in a horizontal position. The scale indicating the angular position of the trimmer was also relocated, so that it could be read off more easily. Part of the gantry hood had to be cut away and new mounting brackets were made for it.

5 Operational Results

The versatility of our isocentric gantry for neutron therapy was dramatically improved by the provision of more flexible beam shaping with the new multi-leaf trimmer. Figure 8 shows the trimmer set up for a treatment session. Although the trimmer is in use since July 1997, all its capabilities are not fully exploited yet, because the existing treatment planning program cannot fully accommodate multi-leaf collimators.

After about 5 months of operation, it was found that the clamping force was no longer sufficient, and the leaves

started to slide when the gantry turned through the horizontal position. Resetting the clamping pins proved to be a simple matter, however, and the trimmer now functions without any problem.

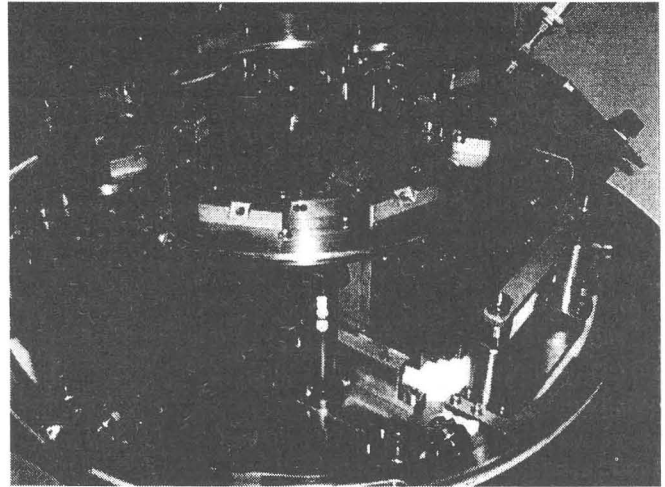


Figure 8: The multi-leaf trimmer set up for treatment.

Acknowledgments

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