THE CURRENT EXTRACTIONS CHANNEL OF THE NEVIS SYNCHROCYCLOTRON CONVERSION PROJECT *

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* Research supported by the National Science Foundation

Summary

A current channel has been designed (computer) with a total septum thickness including supports of about 0.150 in. that provides a field jump of over 6 kG and a gradient of over 1.5 kG/in. The direction of the gradient is such that the channel field superimposed on the fringing field of the cyclotron magnet produces a radially focusing field. The heat load and the power dissipation in the septum will be greatly reduced by having the septum flare out from 0.125 in. at the upstream end of the channel to about 0.600 in. at the downstream end. This reduces the power consumption in the septum to 40 kW.

General Description

The iron free current extraction channel for the Nevis Synchrocyclotron is being designed to have a septum width including supports of no more than 0.150 in., have a field jump of at least 6 kG and a field gradient of at least 1.5 kG/in. The field outside the channel (at smaller radii) must be small enough so that the last few proton orbits in the cyclotron are not perturbed. These requirements have been fulfilled (on one computer at least) and construction of the channel is now proceeding. The total fields were computed using the fields of the individual conductors plus five of their images reduced by a factor of $(\mu-1)/\mu$ for each image. The value of $\mu$ used was found experimentally by measuring the field from a precisely known configuration of conductors in a field of about 20 kG in one of our model magnets. A value of $\mu = 5$ was found to fit the experimental data to better than 1%.

A cross section of the channel and the magnetic field it produces is shown in Fig. 1. With a current of 3400 A, the field jump is 6.1 kG and the gradient is -1.7 kG/in. The gradient is large enough to over-compensate the dropoff of the main field, so that the effect of the combined fields is radially focusing and vertically defocusing. This is highly desirable since the main field downstream from the channel has the opposite effect (vertically focusing and radially defocusing) so that there is a net focusing effect in both directions. About 20 in. downstream from the current channel, there will be room enough for an iron and current channel which will steer the beam to the target and provide additional focusing. The current in this second channel will be controlled by slits near the first proton target. If the beam moves away from the target, it will hit one of the slits which will automatically change the current in the channel to move the beam back onto the target. This channel will also have small auxiliary coils so that its gradient can be varied. The use of the iron and current channel as a means to steer the beam onto the target enables us to keep the regulation requirements on the 150 kW power supply for the iron-free channel down to about 0.5%.

One of the principal difficulties in designing a high current thin septum channel such as this is to remove the large amount of heat produced in the small wires of the septum. This problem can be managed if the wires are made larger at the upstream end of the channel. Figure 2 is a plot of the path of a particle which does not enter the channel on the turn shown, but will enter on the next one. The ordinate is the distance from the inside edge of the septum (larger radius) and the abscissa is the linear distance along the channel. The thickness of the channel is also shown as is the size of the water path. This plot shows that after only 16 in. along the channel, the septum can be made as thick as the anti-septum (0.600 in.). This septum will use only 40 kW of power, a factor of four smaller than if the original thickness were kept to the end, and provide at least twice the waterflow at the same total pressure, even with the reduced power and increased water flow, the wire would melt in very short time if water flow were to cut off. Each wire will have its own thermocouple to sense any rise in the cooling water temperature which will shut off the current in the channel as quickly as possible. In addition, the water will be continuously filtered and de-ionized. The water is to fabricate wire of this shape. Since only eight of them, we plan to machine the upstream ends out of copper and then braze this onto the standard size wire that makes up the anti-septum.

A small fraction of the full energy beam will hit the septum of this channel. Therefore the channel must be made of highly radiative resistant inorganic material for insulation. The wires will be spaced by thin (0.010 in.) pieces of alumina that have been metalized and then brazed to the copper. Then the whole coil will be sprayed with Cerabond 503 (American Products) which essentially pots the coil in a glass and alumina mixture. This process has been tested and looks quite practical.

The entire channel will be enclosed in an aluminum box and the septum supported against the magnetic forces by a thin (0.015 in.) tungsten plate as indicated in Fig. 1. It will be supported in such a way that the channel can be moved radially with either the upstream or downstream end used as a pivot, or so that both ends move together. The channel is expected to last as long as the cyclotron is to be used, but just in case trouble develops, it can be removed by remote control devices and be replaced by a new channel.

In order to increase our extraction efficiency and keep radiation damage inside the machine to a minimum, we are planning to have an electrostatic septum about 30 in. upstream from the current channel with a total voltage of about 100 kV. This will push most of the protons that would have hit the front of the current septum into the channel.
### Channel Parameters

<table>
<thead>
<tr>
<th>Coil No.</th>
<th>Width</th>
<th>Size (in.)</th>
<th>Hole</th>
<th>Resistance (m')</th>
<th>Volts (V)</th>
<th>Power (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I †</td>
<td>0.125</td>
<td>0.225</td>
<td>0.065 x 0.13</td>
<td>3.46</td>
<td>11.8</td>
<td>40.0</td>
</tr>
<tr>
<td>II</td>
<td>0.600</td>
<td>0.225</td>
<td>3/6 D</td>
<td>2.19</td>
<td>7.5</td>
<td>25.4</td>
</tr>
<tr>
<td>III</td>
<td>0.600</td>
<td>0.300</td>
<td>3/6 D</td>
<td>1.93</td>
<td>6.6</td>
<td>22.3</td>
</tr>
<tr>
<td>IV</td>
<td>0.400</td>
<td>0.400</td>
<td>3/6 D</td>
<td>1.78</td>
<td>6.2</td>
<td>20.6</td>
</tr>
<tr>
<td>Total (I-IV)</td>
<td></td>
<td></td>
<td></td>
<td>9.36</td>
<td>32.0</td>
<td>108.3</td>
</tr>
<tr>
<td>V ††</td>
<td>0.200</td>
<td>0.200</td>
<td>1/8 D</td>
<td>17.00</td>
<td>8.5</td>
<td>4.25</td>
</tr>
</tbody>
</table>

- **Current**: 3400 A I-IV
- **Current**: 500 A V

*Length of Channel: 44 in.*

*† See Fig. 1.*

*†† Smallest size. Largest size same as II.*

*Current independently controlled for "fine tuning".*

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![Fig. 1](image1.png)

**Fig. 1** Cross section of channel at the upstream end and magnetic field for indicated currents.

![Fig. 2](image2.png)

**Fig. 2** Plan view of a septum wire.