

BNL-104496-2014-TECH

AGS/AD/Tech Note No. 62;BNL-104496-2014-IR

# ELECTROSTATIC INFLECTOR

L. E. Repeta

July 1969

Collider Accelerator Department Brookhaven National Laboratory

# **U.S. Department of Energy**

USDOE Office of Science (SC)

Notice: This technical note has been authored by employees of Brookhaven Science Associates, LLC under Contract No.AT-30-2-GEN-16 with the U.S. Department of Energy. The publisher by accepting the technical note for publication acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this technical note, or allow others to do so, for United States Government purposes.

# DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

# Accelerator Department BROOKHAVEN NATIONAL LABORATORY Associated Universities, Inc. Upton, New York

### AGS DIVISION TECHNICAL NOTE

### No. 62

### L.E. Repeta and V.J. Buchanan July 8, 1969

#### ELECTROSTATIC INFLECTOR

### Introduction

Multiturn injection has been used at the AGS since August 1964 and has been accomplished by using an electrostatic inflector and associate equipment.

The proton beam leaves the linear accelerator on an optic axis that lies on the median plane of the AGS ring. The beam moves along the axis of the beam transport, which is approximately 4-in. outside a tangent line to the AGS. As the beam moves along this flight path, it is deflected toward the ring. The final tangency of the linac beam to the AGS ring is accomplished by the electrostatic inflector.

#### Mechanical Design

The inflector is located at the edge of the usable machine aperture at the 10 ft straight section "L-20". The major components of the inflector are shown in a cross sectional view in Fig. 1. The main assembly drawing is D07-M-5103-5, and anyone interested in greater detail should refer to this drawing.

A simplified plan view, with cover removed, is shown in Fig. 2. The sub-base is accurately surveyed in position relative to the line joining the magnet sockets  $(S_0)$  of the "L-20" and "A-1" AGS main ring magnets. The inflector sub-assembly is accurately positioned, relative to the sub-base,

VIEW LOC WE UPSTREAM



through the use of three gage blocks as noted in the figure. The use of these gage blocks facilitates accurate location without survey and insures accurate repositioning of the inflector sub-assembly, after it has been removed for maintenance, with minimum effort and time.

The high voltage electrode is 60-in. long and is made from 6061-T6 aluminum alloy highly polished all over. The electrode front face shape, shown in Fig. 3 was optimized by making equi-potential plots on high resistance paper of ten times size cross sections. The normal running voltage is a negative 45 kV.

Shown in Fig. 4 is a two piece copper shield block that is fastened to, and insulated from, the inflector sub-assembly. In addition, each of the two component pieces are insulated from each other. The function of this block is to--1) act as a collimator for the linac beam, and 2) to provide a protective shield for the outside face of the thin (0.015) septum plate from the orbiting beam. Ceramic beaded, copper signal wire has been run from each piece to a vacuum feed thru located on the front face of the vacuum box; co-ax cable then runs to the AGS Main Control Room. This enables close monitoring for study and evaluation of the signal generated by the entering linac beam "wiping off" on entrance through the opening of the copper block, and the signal generated by the circulating beam "wiping off" on the outside edge of the block as it passes the outside of the inflector.

After several weeks of operation it was found that a thermal breakdown of some of the insulating material (.005 thick "H" film) caused outgassing. This resulted in a serious arcing problem that intermittently tripped the inflector off. The two piece copper shield block was removed and replaced by a one piece shield block. A new split block has been designed and is now ready for installation.

-3-

-4 -E-ND BLOCK (207. M-5163-1) -UPSTREAM DOWNSTREAM GAGE BLOCK GAGE BLOCK -50 (D07-M=6709-2) (D07-M-6709-2) SEPTUM -R 100 .500--SUB BASE ELECTRODE -2.562 HOUSING BOTTOM PLATE -INFLECTOR SUB-ASSEMBLY -2.875 -2.125 FIGURE 2

The upstream inflector viewing flag and its basic dimensions are shown in Fig. 5. The flag can be remotely positioned to either of the two working positions denoted, or withdrawn within the shadow of the vacuum pipe by activating a 24 volt d.c. linear actuator drive motor from the Main Control Room. A potentiometer readout system, accurately calibrated by the AGS Target Group, enables the machine operator to position the flag in the desired position. The flag is viewed in the Main Control Room via closed circuit television. Operating position #1 is useful when setting up or for studies purposes, but not satisfactory for efficient machine operation because the obstruction presented by the 1/8-in. thick quartz plate "stops" most of the 50 MeV beam. Switching to position #2, the machine operator can center the air gap between the two quartz pieces to the injected beam centerline. The obstruction of the beam due to the flag has been removed and this position also enables the operator to monitor any horizontal movement of the entering beam during normal machine running.

### Introduction to the Calculations

A computer analysis was made by Dr. A.W. Maschke to determine the initial parameters to be used. A 22 milliradian entrance angle, directed toward the center of the AGS machine, resulted in an offset from the computer coordinate line to the injection line of 2.904 inches (see Fig. 6). The high voltage electrode was to be 60-in. long and an approach angle of 4 milliradians directed away from the center of the AGS, was to be used. The entrance and approach angles were to be distributed equally over the electrode length. Geometric Position and Attitude

Sign convention:

Positive (+) denotes increasing radius and, Negative (-) denotes decreasing radius (toward the center of the AGS ring).

-7-

TNJECTED BEAM &, POSITION 2 INJECTED BEAMS, POSITION 1 5. 1.375 QUARTZ -3.033 ALUM FRAME DRIVE SHAFT 4// 3-13 11. - 2 16 50 -AIR GAP

UPSTREAM INFECTOR FLAG (DOT-NI-G711-3) VIEW LOOKING DOWNSTREAM

FIGURE 5

Refer to Fig. 6.

From the beam program coordinate line to the line joining the magnet sockets $(S_0)$ as taken from drawing D05-412-2.	$y_1 = 0.035$
From the beam program coordinate line to an extension of the vacuum chamber centerline in "L-20" (computer coordinate line)	-
$y_2 = 12'' (\tan 0^{\circ} 36') = 12 (0.01047) =$	$\frac{y_2 = 0.126}{0.161}$
Offset from the computer coordinate line to the injection line as taken from the computer sheet	2.904
Offset 6-in. downstream at 22 milliradians	
$y_3 = -6.000 (0.022) =$	$\frac{y_3 = 0.132}{2.933}$
Centerline of a $1/2$ -in. diameter beam will enter the inflector $3/8$ -in. from the inside face of the septum plate	<u>-0.375</u>
Distance from the socket line to the inside face of the septum at the upstream end of the inflector electrode	2.558
The electrode gap will go upstream for 30-in. at 22 milliradians	
-30" (0.022) =	$\frac{-0.660}{1.898}$
The electrode gap will then continue upstream for 30-in. at 4 milliradians	
+30" (0.004) =	+0.120
The centerline of the beam will leave the gap 1/8-in. closer to the septum plate, graze the septum plate and exit	+0.125
Distance from the socket line to the inside face of the septum at the downstream end of the inflector electrode	2.143
Refer to Fig. 7.	
The septum sheet angle:	
22 mR + 4 mR = 26 mR; 26 mR/2 = 13 mR	

-9-

MANET LOCATING CKET GAGE BLOCK -SUB-BASE 12 WFLECTOR HOUSING Ro .035-BOTTOM PLATE .161 -5, .100. F-375 ELEGTRODE ----0°36'-+ 2.904 U-3 30 BEAM PROGRAM . COORDINATE LINE NJECTED BEAME-VACUUM BOX DATUM LINE -2.875 6. EDGE OF THE MAGNET STEEL AT 6-20 Ð 276 FIGURE 6



# FIGURE 7

THE CALCULATION OF THE ANGLE AT THE BACK OF THE SEPTUM HOLDER PLATES (0 in figure 7).

(2) Tan  $\theta = \frac{.415}{.00} = 0.006916 \approx 0.007$ (1) 2.558 -2.143 0.415  $\therefore$  Let  $\theta = 7$  milliradians

Socket line to the inside of the septum at the upstream end of the electrode

The septum goes upstream for 30" at 13mr

-30 (0.013) =

Distance  $\overline{BC}$  (figure 7)

 $\frac{.415}{60} = \frac{BC}{30}$ ;  $\overline{BC} = \frac{.45}{60}$  (30) =

Distance from the socket line to the working point in firgure 7

The septum sheet angle

The angle at the back of the septum holder plates

2,558

-0.390

-0.207

1.961

+13mr

+ 7mr +20mr

, GAGE BLOCK CALCULATIONS (refer to figure 2)	
The upstream gage point will be 2.875" at 20mr upstream of the end of the electrode	
2.875 (0.020) =	0.057
From the socket line to the inside face of the septum at the upstream end	<u>2.558</u> 2.615
From the socket line to the edge of the sub-base	-0,500
The gage dimension (upstream end) from the edge of the sub-base	2.115 (U <sub>3</sub> )
The septum sheet angle -13mr	~
The angle at the back of the septum holder plates <u>+ 7mr</u> - 6mr	· .
The downstream gage point will ve 2.125" at 6mr downstream from the end of the electrode	
2.125 (0.006)=0.01275 ≈	0.013
From the socket line to the inside face of the septum at the downstream end	<u>2.143</u> 2.156
From the socket line to the edge of the sub-base	-0.500
The gage dimension (downstream end) from the edge of the sub-base	1.656 (D <sub>3</sub> )

# COPPER SHEILD BLOCK LOCATION

S<sub>o</sub> 5; COPPER منبع . التحقيد منابع 1.961 4.0mr 100 20ms 13mr WORKING POINT (INSIDE OF SEPTUM) BEAML 3 32 750 Tmis

# FIGURE 8

From the socket line to the working point	1.961
With a 4mr approach angle at 32.750"	
-32.750 (0.004)=	<u>-0.131</u> 1.830
The septum thickness	-0.015
From the socket line to the leading edge of the copper block, Point "A"	1.815
From the socket line to the edge of the sub-base	-0.500
From the edge of the sub-base to the edge of the copper shield block	1.315

# COPPER SHIELD BLOCK DIMENSIONS



<u>FIGURE</u> 9

BLOCK SLOT POSITION	
The vertical distance $\overline{AB}$	
32.750 (0.004)=	0,131
The vertical distance BC	
32.750 (0.020)=	+0.655
The leading edge of the copper to the inside face of the septum plate	0.786
The septum thickness	+0.015
From the edge of the septum to the beam centerline	0.375
From the leading edge of the copper shield block to the slot centerline in the block	1.176
BLOCK LEADING EDGE TAPER	
The vertical distance DE	
32.000 (0.024)=	0.768

0.786 -0.768

0.018



FIGURE 10



(1)	$\sin 45^{\circ} = \frac{0.359}{d}$
-	$d = \frac{0.359}{0.707} = 0.5077 \approx 0.508$

(2) 2.312-0.5081.804

From the socket line to the injected beam centerline from figure 6

2.904+0.161 3.065

From the inside face of the vacuum box to the beam centerline on the quartz 1.804From the inside face of the vacuum box to -0.375the datum line in figure 6 1.429The injected beam goes upstream 1.429" at 22mr 1.429 (0.022) =

 $\frac{-0.032}{3.033}$ 

### ALTERNATE POSITIONS

There are two secondary, alternate, positions that the inflector could occupy in addition to the primary position that has been described. The first auxilliary position, or middle position, represents a +0.220 outward shift of the working point. The second shift, outer position, is equal to a +0.440 displacement of the working point from the primary position. When the inflector sub-assembly is moved outward the approach angle changes by 2 milliradians per inch of displacement. In addition then, to the outward shift, a clockwise rotation of the inflector subassembly is also required. To accomplish these changes of position; 1) additional gage blocks are required, 2) the copper shield block location relative to the socket line and sub-base changes, 3) the flag position changes relative to the socket line. Assuming that the 22 milliradian entrance angle remains the same, the offset to the centerline of the injected beam (figure 6) must also change. As a point of caution, if one or the other of these alternate positions were to be used and evaluated, an outward shift of the entire beam transport from the linac to the inflector may be required, else the beam might scrape the side of the vacuum chamber.

### ALTERNATE WORKING POINT POSITIONS

Distance from the socket line to the working point, see figure 7 1.961 Move inflector sub-assembly out 0.220" +0.220

2.181

Distance from the socket line to the new working point (middle position)

- 16 -

Distance from the socket line to the working point, see figure 7	1.961
Move inflector sub-assembly out 0.440"	0.440
Distance from the socket line to the new working point (outer position)	2.401
GAGE BLOCK CALCULATIONS	
Middle position:	
The gage dimension (upstream end) from the edge of the sub-base, see page 12	2.115
Move inflector out 0.220"	+0.220
Since the angle changes 2mr/inch $\frac{2}{1} = \frac{\alpha}{.22}$ ; $\alpha = 0.44$ mr	2.335
Upstream gage point is 32,875" upstream of the working point	
Rotate the inflector 0.44 mr clockwise about the working point	
32.875 (0.000444) = 0.0145	-0.014
Gage dimension (upstream end) from the edge of the sub-base	$2.321 = U_2$
The gage dimension (downstream end) from the edge of the sub-base, see page 12	1.656
Move inflector out 0.220"	+0.220
Downstream gage point is 32,125" down- stream of the working point	1.876
Rotate the inflector 0.44 mr clockwise about the working point	
32.125 (0.00044) = 0.0141	+0.014
Gage dimension (downstream end) from the edge of the sub-base	$1.890 = D_2$

- 17 -

-

# GAGE BLOCK CALCULATIONS

### Outer position:

The gage dimension (upstream end) from the edge of the sub-base, see page 12

Move the inflector out 0,440"

Since the angle changes 2mr/inch

$$\frac{2}{1} = \frac{\beta}{.44} ; \quad \beta = 0.88 \text{mr}$$

Upstream gage point is 32.875" upstream of the working point

Rotate the inflector 0.88mr clockwise about the working point

$$32.875 (0.00088) = 0.028$$

Gage dimension (upstream end) from the edge of the sub-base

The gage dimension (downstream end) from the edge of the sub-base, see page 12

Move the inflector out 0.440"

Downstream gage point is 32.125" downstream of the working point

Rotate the inflector 0.88mr clockwise about the working point

32.125 (0.00088) = 0.028

Gage dimension (downstream end from the edge of the sub-base

2.555

2.115

+0.440

-0.028

 $2.527 = U_{1A}$ 

1.656 +0.440

2.096

+0.028

 $2.124 = D_{1A}$ 

# COPPER SHIELD BLOCK LOCATION

55- 2	φĹ	- 60,9,25,2	2.191	- 50
		12. ESmin 13. ESmin 13mmr 3 BEAM C	WORKING POINT (INSIDE OF SEPTUNI)	. : . :
	750	32		•

FIGURE 11

# MIDDLE POSITION

From the socket line to the working point	1.961
Move the inflector out 0.220"	+0.220
Distance from the socket line to the new working point	2.181
The approach angle increases by 0.44mr	
With a 4.44mr approach angle at 32.750"	
32.750 (0.00444) = 0.145	
The septum thickness +0.015	٨
0.160	-0.160
Socket line to the edge of the copper block, point "A" in figure 11	2.021
Socket line to the edge of the sub-base	-0.500
Edge of the sub-base to the edge of the copper block	1.521

# COPPER SHIELD BLOCK LOCATION

So AG 5. COSSER 4. E. M. U 10, 12 M 13mm WORKING POINT (INSIDE OF SEPTUM) SEAMQ N I W 32 Es/2min

# FIGURE 12

# OUTER POSITION

From the socket line to the working point	1.961
Move the inflector out 0.44"	+0.440
Distance from the socket line to the new working point	2.401
The approach angle increases by 0.88mr	
With a 4.88mr approach angle at 32.750"	
32.750 (0.00488) = 0.160	
The septum thickness +0.015	
0.175	-0.175
Socket Line to the edge of the copper block, point "A" in figure 12	2.226
Socket line to the edge of the sub-base	-0,500
Edge of the sub-base to the edge of the copper block	1.726

- 20 -

### OFFSET TO THE INJECTION LINE

Middle position: 2.321 Upstream gage block dimensions, see page 17 Socket line to the edge of the sub-base +0.500 2.821 -0.056 Move downstream 2.875" at 19.56mr Socket line to the inside face of the septum 2.765 at the upstream end of the electrode Centerline of the 1/2" dia. beam will enter the inflector 3/8" from the inside of the septum +0.375 3,140 Offset 6" downstream at 22mr 6.000 (0.022) =+0.132 3.272  $y_1$  from page 9 = 0.035  $y_2$  from page  $\dot{9} = \pm 0.126$ 0.161 -0.161 3.111 Offset to the injection line (middle position) Outer position: 2.527 Upstream gage block dimension, see page 18 <u>+0.500</u> Socket line to the edge of the sub-base 3.027 -0.055 Move downstream 2.875" at 19. 12mr Socket line to the inside face of the septum 2.972

Centerline of the 1/2" dia. beam will enter the +0.375 inflector 3/8" from the inside of the septum 3.347 +0.132 Offset 6" downstream at 22mr 3.479  $y_1 + y_2 = 0.161$ -0.161 Offset to the injection line (outside position) 3.318

at the upstream end of the electrode

- 21 -

ALTERNA	TE FL	AG	LOCA	<b>TIONS</b>

Middle position:	
Offset to the injection line, see page 21	3.111
$y_1 + y_2 = 0.161$ from page 9	+0.161
	3.272
Move 1.429" upstream at 22mr, see page 15	
1.429 (0.022) =	-0.032
From the socket line to the flag	1
centerline	3.240
Outer position:	
Offset to the injection line, see page 21	3.318
$y_1 + y_2 = 0.161$ from page 9	+0.161
	3.479
Move 1.429" upstream at 22mr, see page 15	
1.429 (0.022) =	<u>-0.032</u>
From the socket line to the flag	
centerline	3.447

- 22 -

SUMMARY	OF	DATA
Construction of the local diversion of the local diversion of the local diversion of the local diversion of the	the second se	CONTRACTOR OF A DESCRIPTION OF A DESCRIP

Location	Socket line to the Working Point	Gage Block Dimensions	Gage Block Symbols *	Socket line to edge of the copper block	Socket line to the Quartz Flag
	1 0(1	2.115	U <sub>3</sub>	1 015	3 033
Primary	T°A0T	1.656	D <sub>3</sub>	. 1.910	3.033
Middle	2.181	2.321	U2	2.021	3.240
		1.890	D <sub>2</sub>		
Outer	2.401	2.527	U <sub>1A</sub>	2.226	3.447
		2.124	D <sub>1A</sub>		

\* "U" denotes upstream and "D" denotes downstream

Distr: Department Administration Mechanical Engineers Operations Coordinators

- J. Grisoli
- J. Herrera
- E. Raka