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# ELECTROSTATIC INFLECTOR

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Collider Accelerator Department

**Brookhaven National Laboratory**

**U.S. Department of Energy**

USDOE Office of Science (SC)

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AGS DIVISION TECHNICAL NOTE

No. 62

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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 ($S_o$) of the "L-20" and "A-1" AGS main ring magnets. The inflector sub-assembly is accurately positioned, relative to the sub-base,

VIEW LOOKING UPSTREAM

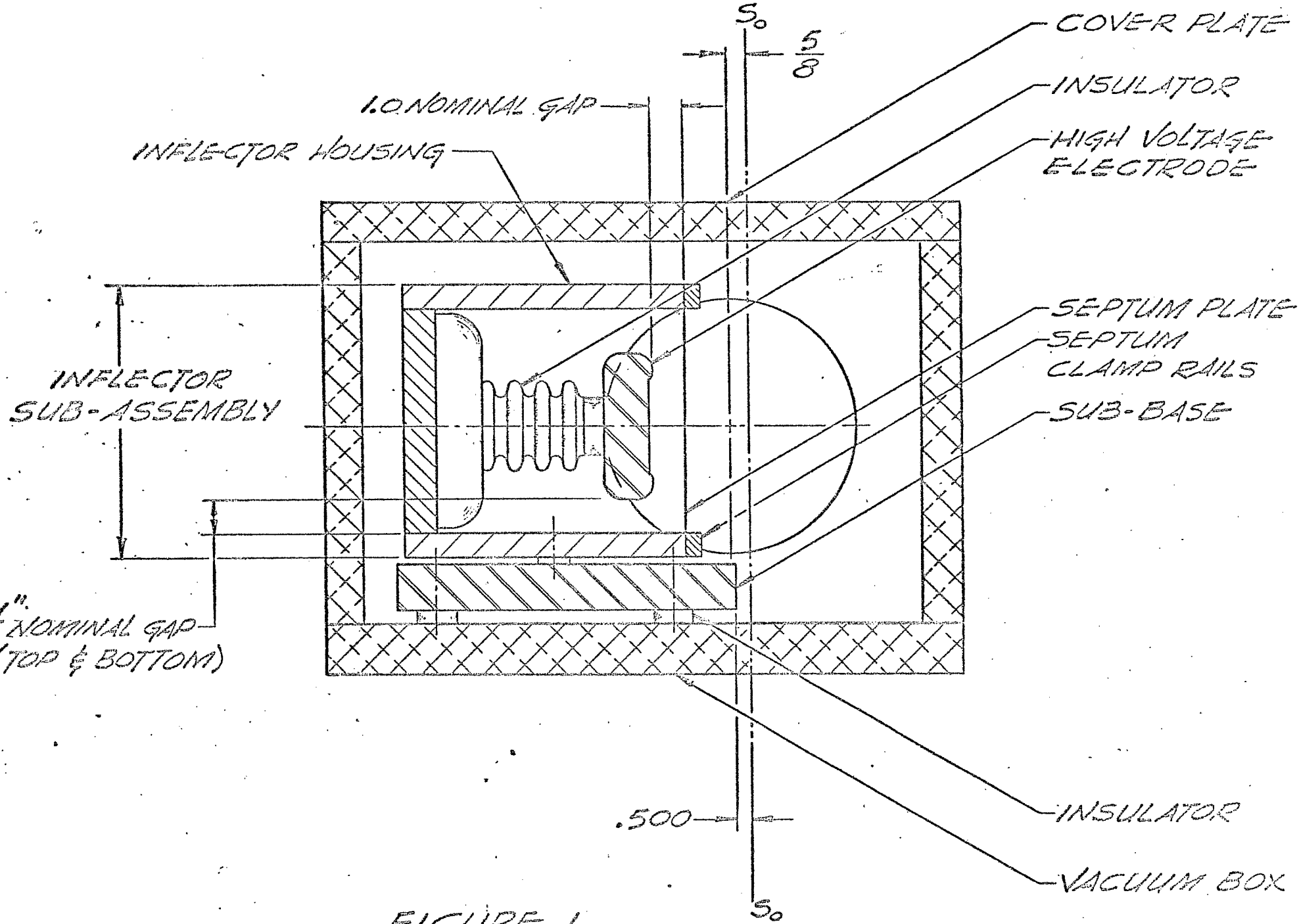



FIGURE 1

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.

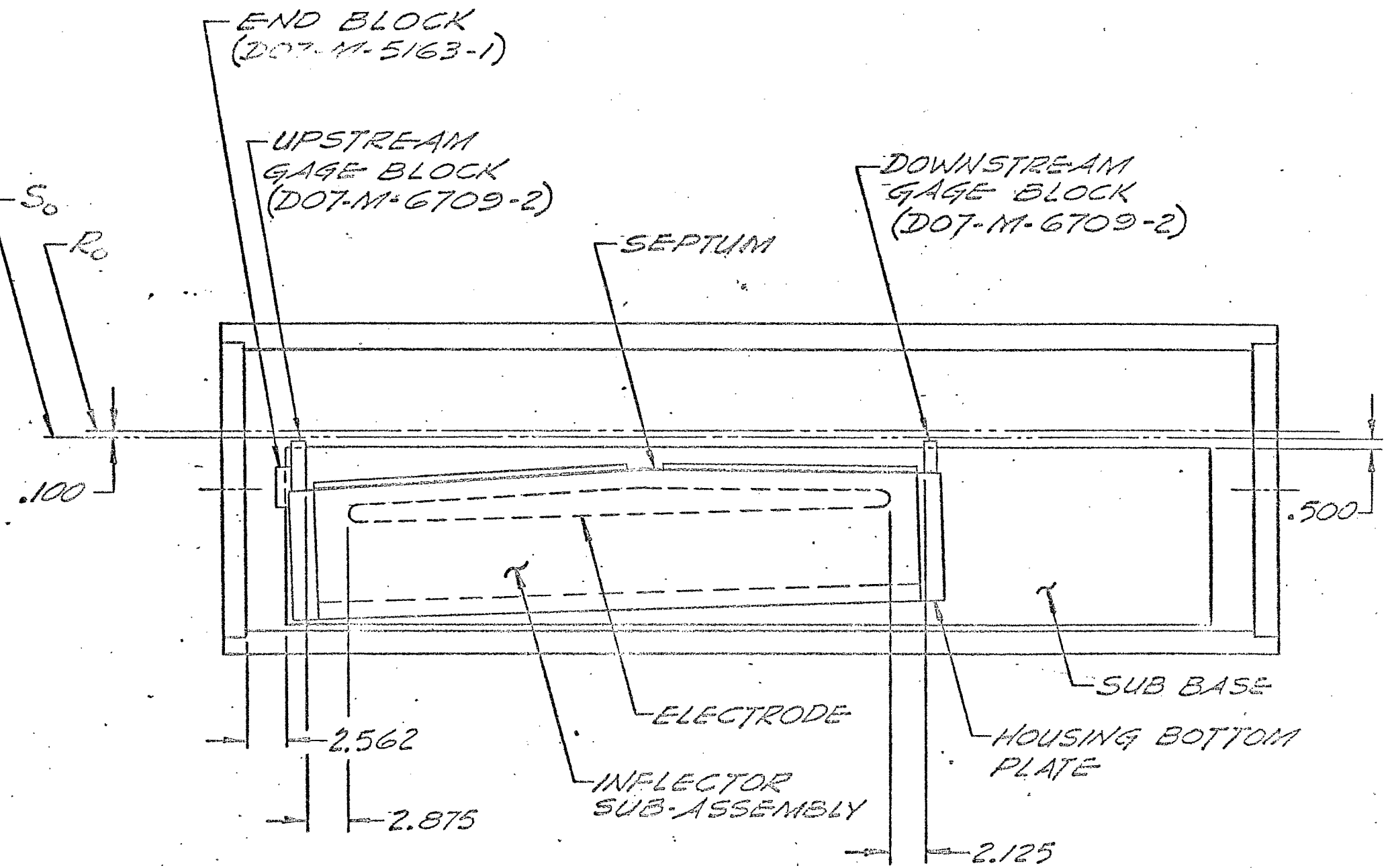

END BLOCK
(D07-M-5163-1)
UPSTREAM
GAGE BLOCK
(D07-M-6709-2)
DOWNSTREAM
GAGE BLOCK
(D07-M-6709-2)
SEPTUM
$S_o$
$R_o$
.100
.500
SUB BASE
ELECTRODE
HOUSING BOTTOM
PLATE
INFLECTOR
SUB-ASSEMBLY
2.562
2.875
2.125

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

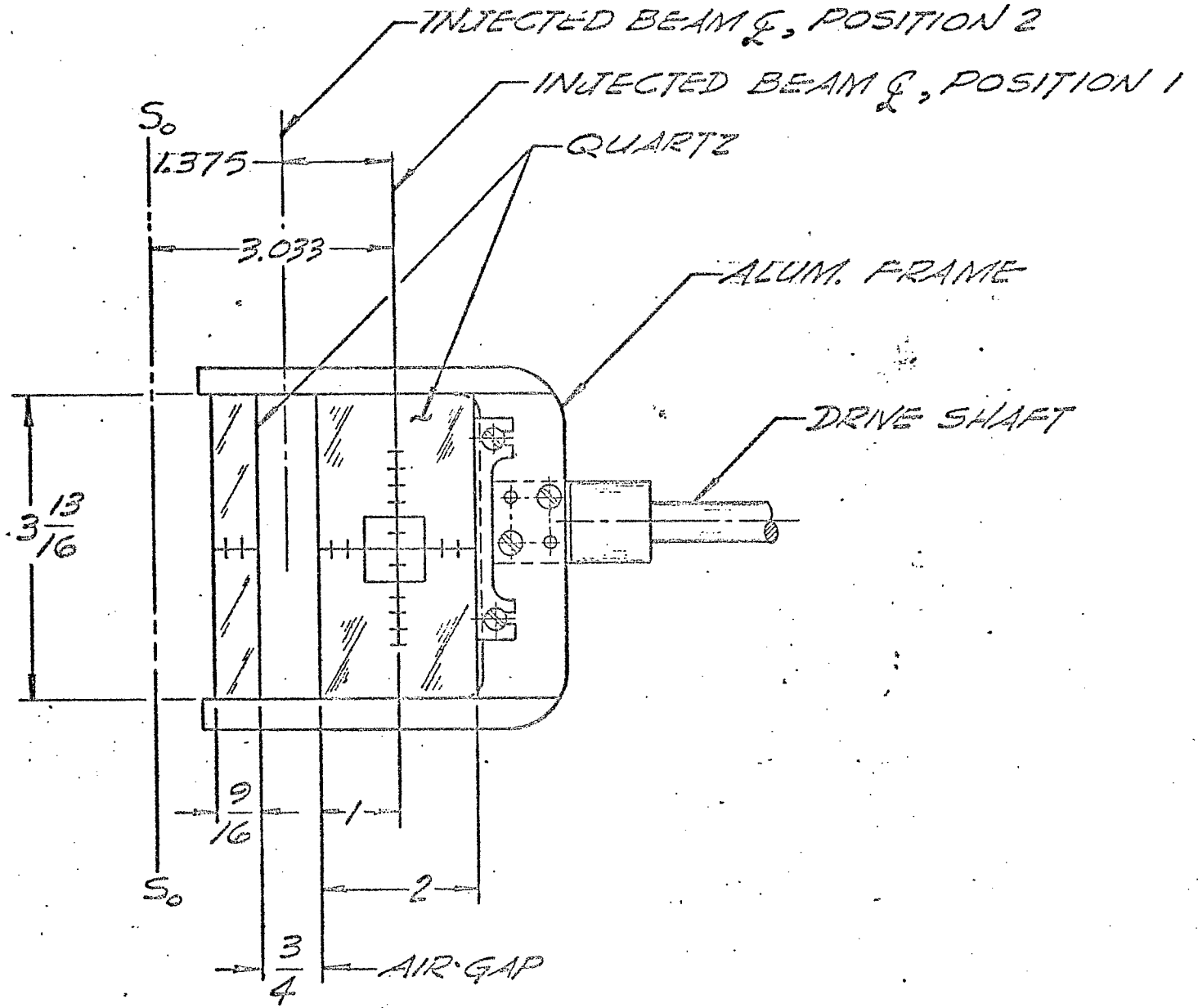
A computer analysis was made by Dr. A.W. Maschke to determine the initial parameters to be used. A 22 milliradian entrance angle, directed toward the center of the AGS machine, resulted in an offset from the computer coordinate line to the injection line of 2.904 inches (see Fig. 6). The high voltage 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).




UPSTREAM INFECTOR FLAG (DOT-M-6711-3)
VIEW LOOKING DOWNSTREAM

FIGURE 5

Refer to Fig. 6.

From the beam program coordinate line to the line joining the magnet sockets ($S_o$) as taken from drawing DO5-412-2. $y_1 = 0.035$

From the beam program coordinate line to an extension of the vacuum chamber centerline in "L-20" (computer coordinate line)

$y_2 = 12''$ (tan $0^o$ 36') = 12 (0.01047) = $y_2 = 0.126$

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) = $y_3 = 0.132$

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 -0.375

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) = -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

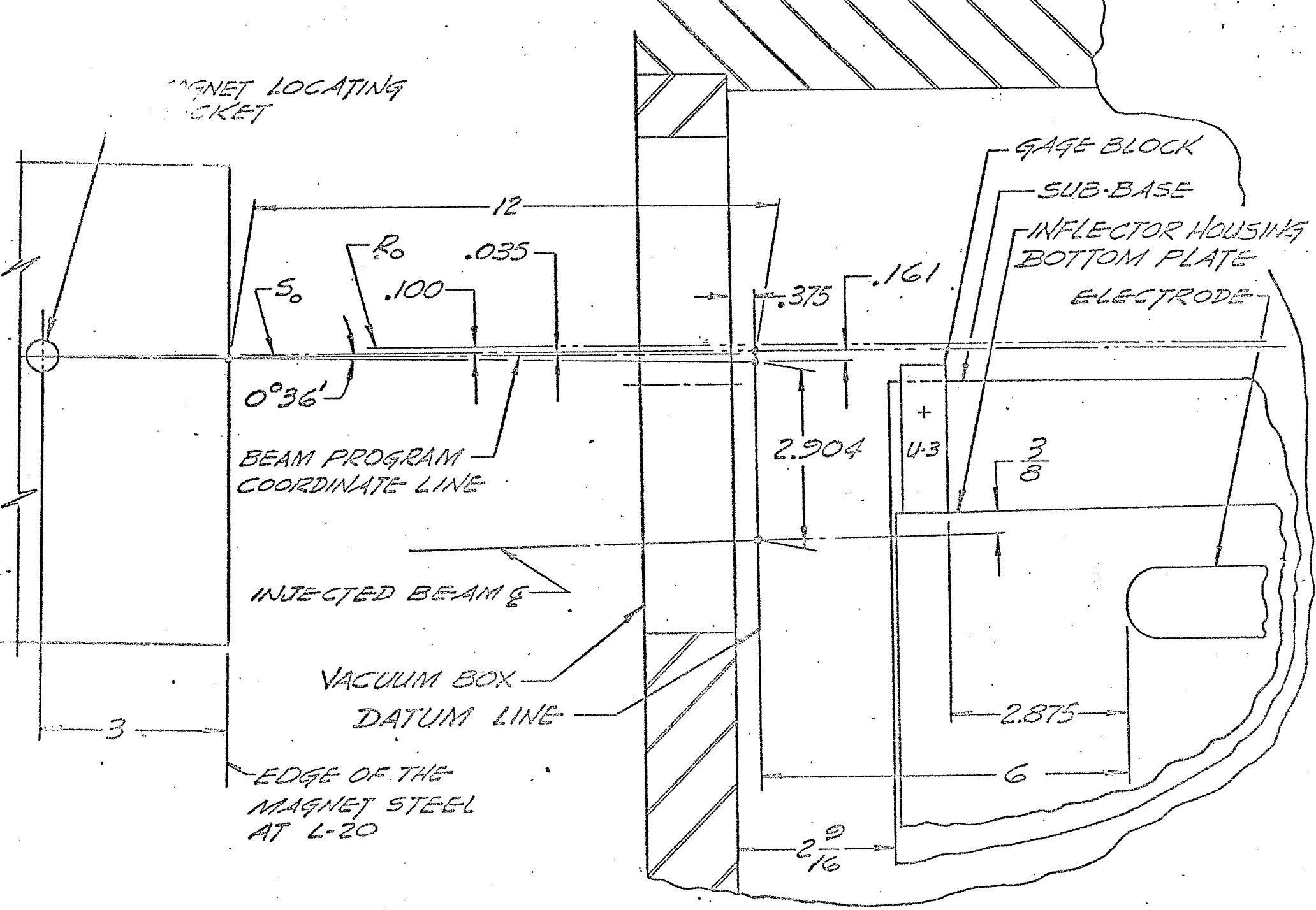

MAGNET LOCATING
GAGE BLOCK
SUB-BASE
INFLECTOR HOUSING
BOTTOM PLATE
ELECTRODE
12
$R_o$
.035
$S_o$
.100
.375
.161
0°36'
BEAM PROGRAM
COORDINATE LINE
2.904
+
4.3
3/8
INJECTED BEAM ℄
VACUUM BOX
DATUM LINE
2.875
3
6
EDGE OF THE
MAGNET STEEL
AT L-20
2 9/16

FIGURE 6

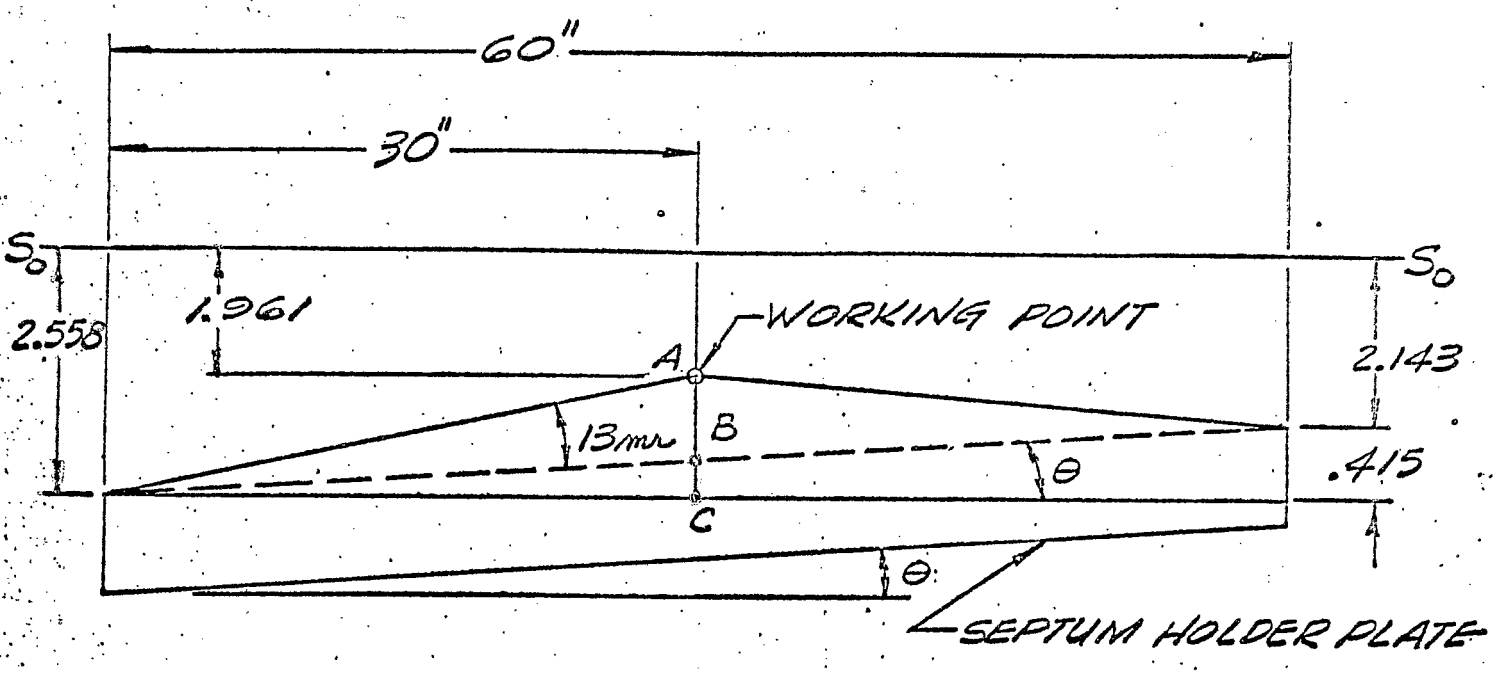



FIGURE 7

THE CALCULATION OF THE ANGLE AT THE BACK OF THE SEPTUM HOLDER PLATES ($\theta$ in figure 7).

(1) $2.558 - 2.143 = 0.415$

(2) $\text{Tan } \theta = \frac{.415}{60} = 0.006916 \approx 0.007$

$\therefore$ Let $\theta$ = 7 milliradians

| | |
|---|---|
| Socket line to the inside of the septum at the upstream end of the electrode | 2.558 |
| The septum goes upstream for 30" at 13mr | |
| $-30 \quad (0.013) =$ | -0.390 |
| Distance $\overline{BC}$ (figure 7) | |
| $\frac{.415}{60} = \frac{BC}{30}$ ; $\overline{BC} = \frac{.45 \quad (30)}{60} =$ | -0.207 |
| Distance from the socket line to the working point in firgure 7 | 1.961 |
| The septum sheet angle | +13mr |
| The angle at the back of the septum holder plates | + 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 | 2.558 |
| | 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 ($U_3$) |

The septum sheet angle -13mr

The angle at the back of the septum holder plates + 7mr

- 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 | 2.143 |
| | 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 ($D_3$) |

COPPER SHEILD BLOCK LOCATION

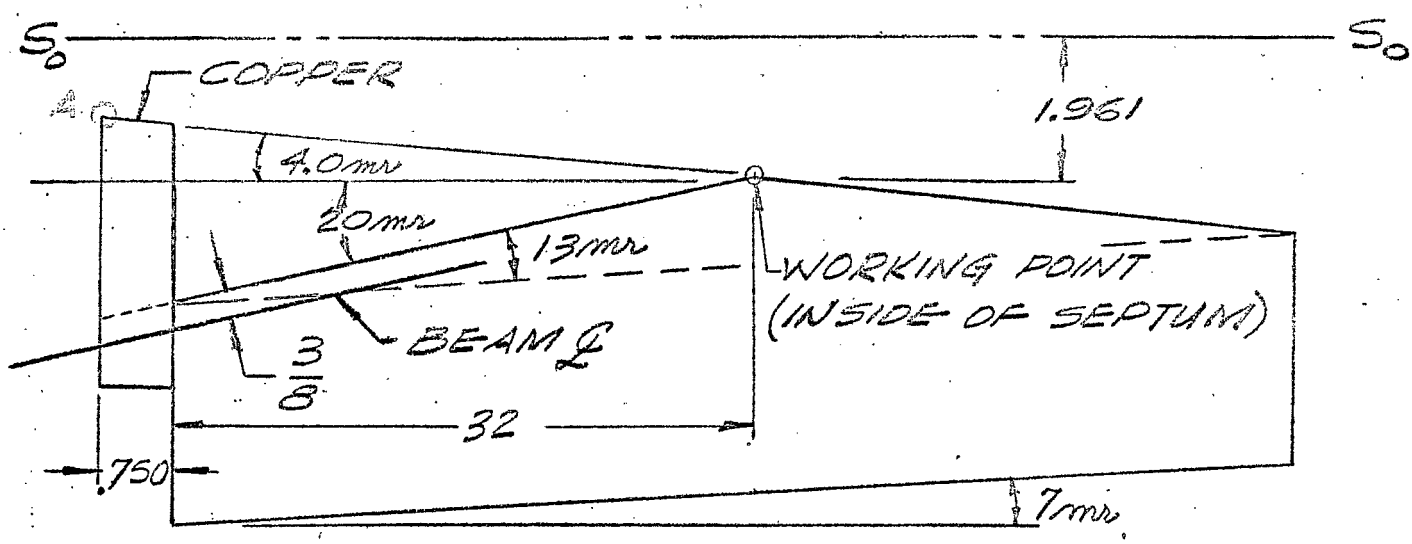



FIGURE 8

| | |
|---|---|
| From the socket line to the working point | 1.961 |
| With a 4mr approach angle at 32.750" | |
| -32.750 (0.004)= | -0.131 |
| | 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

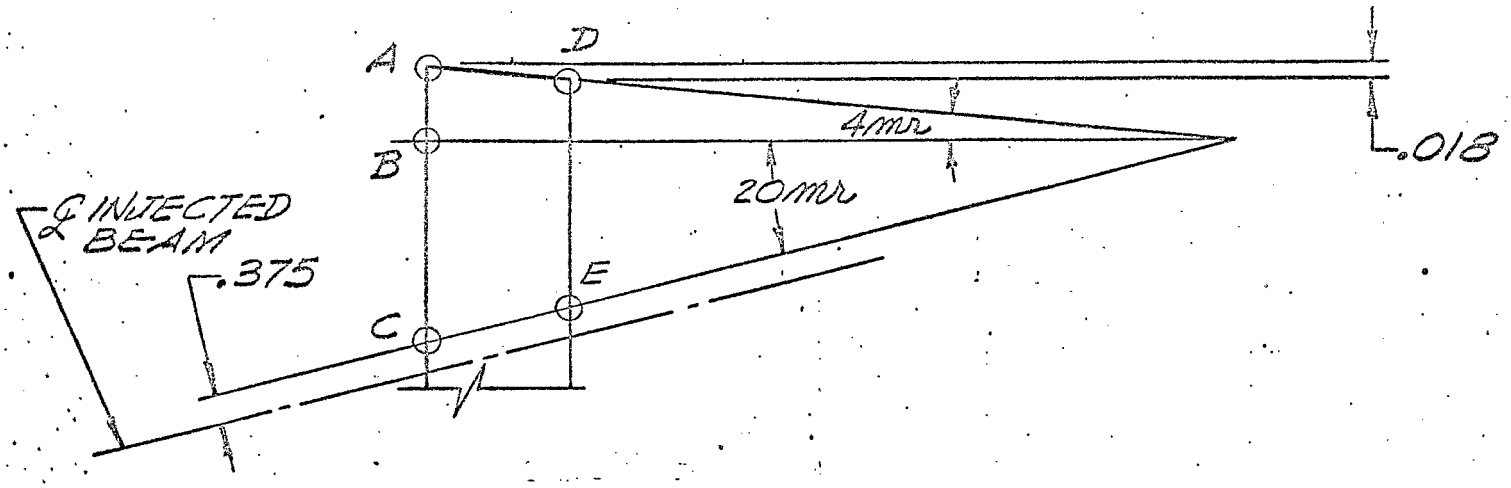



FIGURE 9

BLOCK SLOT POSITION

The vertical distance $\overline{AB}$

32.750 (0.004)= 0.131

The vertical distance $\overline{BC}$

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 $\overline{DE}$

32.000 (0.024)= 0.768

0.786
-0.768

**0.018**

UPSTREAM FLAG LOCATION

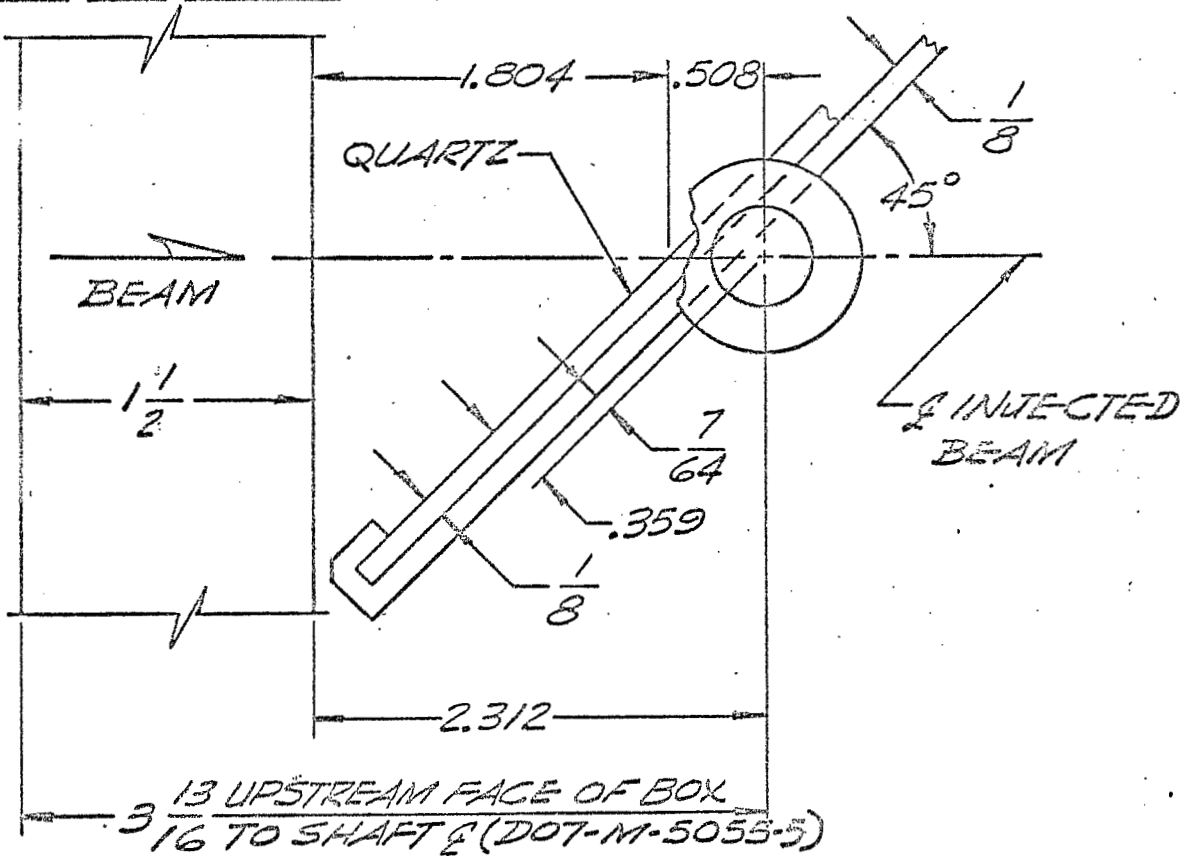
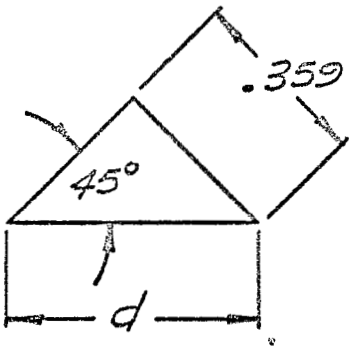



FIGURE 10




(1) $\text{Sin } 45^\circ = \dfrac{0.359}{d}$

$$d = \frac{0.359}{0.707} = 0.5077 \approx 0.508$$

(2) 2.312
-0.508
1.804

| | | |
|---|---|---|
| | | 2.904 |
| From the socket line to the injected beam centerline from figure 6 | | +0.161 |
| | | 3.065 |
| From the inside face of the vacuum box to the beam centerline on the quartz | 1.804 | |
| From the inside face of the vacuum box to the datum line in figure 6 | -0.375 | |
| | 1.429 | |
| The injected beam goes upstream 1.429" at 22mr | | |
| 1.429 (0.022) = | | -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 sub-assembly 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 |
| Distance from the socket line to the new working point (middle position) | 2.181 |

| | |
|---|---|
| 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 | 2.335 |

$$\frac{2}{1} = \frac{\alpha}{.22} \quad ; \quad \alpha = 0.44 \text{ mr}$$

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" downstream 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 = $D_2$ |

## GAGE BLOCK CALCULATIONS

Outer position:

| | |
|---|---|
| The gage dimension (upstream end) from the edge of the sub-base, see page 12 | 2.115 |
| Move the inflector out 0.440" | +0.440 |
| Since the angle changes 2mr/inch | 2.555 |

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

Upstream gage point is 32.875" upstream of the working point

Rotate the inflector 0.88mr clockwise about the working point

$$32.875\ (0.00088) = 0.028$$

| | |
|---|---|
| | -0.028 |
| Gage dimension (upstream end) from the edge of the sub-base | $2.527 = U_{1A}$ |

| | |
|---|---|
| The gage dimension (downstream end) from the edge of the sub-base, see page 12 | 1.656 |
| Move the inflector out 0.440" | +0.440 |
| Downstream gage point is 32.125" downstream of the working point | 2.096 |

Rotate the inflector 0.88mr clockwise about the working point

$$32.125\ (0.00088) = 0.028$$

| | |
|---|---|
| | +0.028 |
| Gage dimension (downstream end from the edge of the sub-base | $2.124 = D_{1A}$ |

COPPER SHIELD BLOCK LOCATION

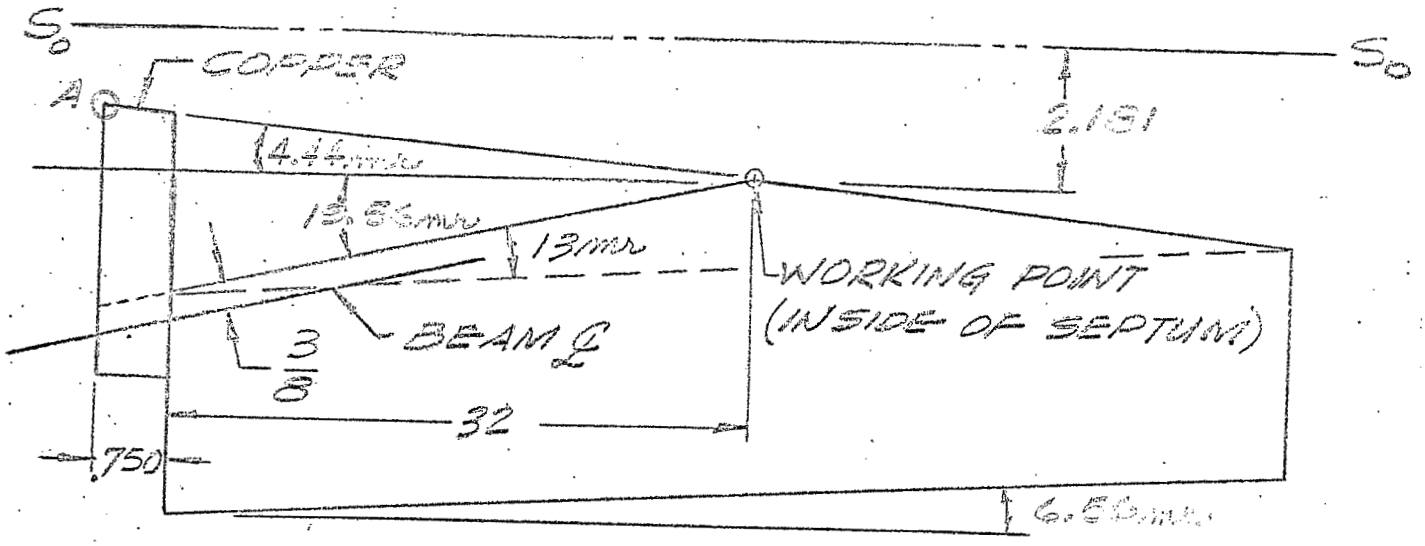



FIGURE 11

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 | |
| | 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

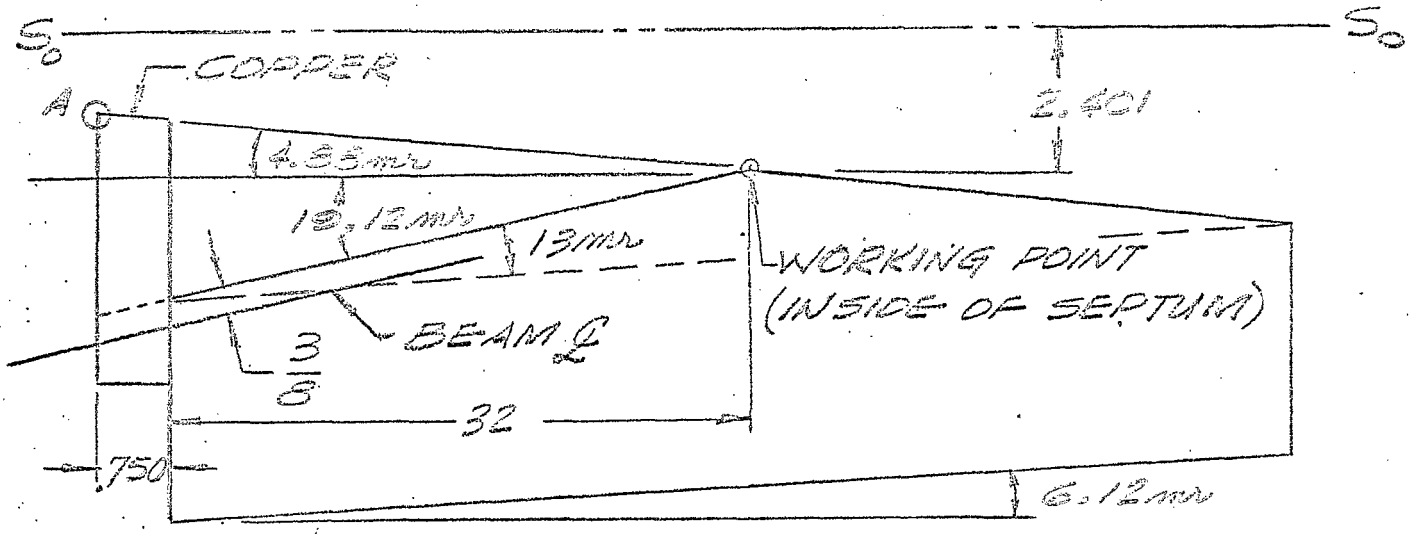



FIGURE 12

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 |

## OFFSET TO THE INJECTION LINE

Middle position:

| | |
|---|---|
| Upstream gage block dimensions, see page 17 | 2.321 |
| Socket line to the edge of the sub-base | +0.500 |
| | 2.821 |
| Move downstream 2.875" at 19.56mr | -0.056 |
| Socket line to the inside face of the septum at the upstream end of the electrode | 2.765 |
| 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 9 = +0.126 | |
| 0.161 | -0.161 |
| Offset to the injection line (middle position) | 3.111 |

Outer position:

| | |
|---|---|
| Upstream gage block dimension, see page 18 | 2.527 |
| Socket line to the edge of the sub-base | +0.500 |
| | 3.027 |
| Move downstream 2.875" at 19. 12mr | -0.055 |
| Socket line to the inside face of the septum at the upstream end of the electrode | 2.972 |
| Centerline of the 1/2" dia. beam will enter the inflector 3/8" from the inside of the septum | +0.375 |
| | 3.347 |
| Offset 6" downstream at 22mr | +0.132 |
| | 3.479 |
| $y_1 + y_2 = 0.161$ | -0.161 |
| Offset to the injection line (outside position) | 3.318 |

ALTERNATE FLAG LOCATIONS

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 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) = | -0.032 |
| From the socket line to the flag centerline | 3.447 |

SUMMARY OF DATA

| 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 |
|---|---|---|---|---|---|
| Primary | 1.961 | 2.115<br>1.656 | $U_3$<br>$D_3$ | 1.815 | 3.033 |
| Middle | 2.181 | 2.321<br>1.890 | $U_2$<br>$D_2$ | 2.021 | 3.240 |
| Outer | 2.401 | 2.527<br>2.124 | $U_{1A}$<br>$D_{1A}$ | 2.226 | 3.447 |

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

Distr: Department Administration
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