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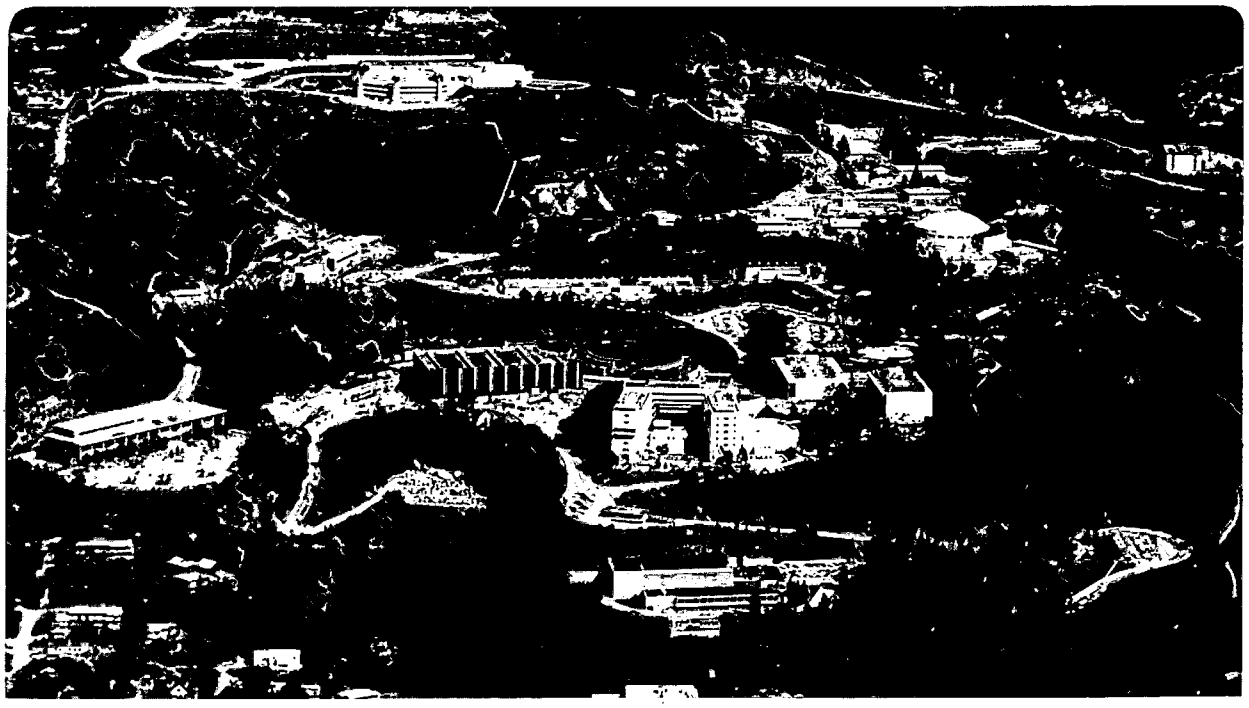

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ENGINEERING NOTE

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SUBJECT: BEVALAC THIRD INJECTOR ION SOURCE MAGNET DRAWING NO. 19P3146, MAGNETIC MEASUREMENTS

NAME: D. Nelson & R. Thatcher

DATE: July 18, 1980

INTRODUCTION

In July 1980, Magnetic Measurements Engineering mapped the magnetic field of the Bevalac Third Injector Ion Source Magnet.[1] Measurements were made at the request of Basil Gavin and Dr. John Staples.

The purposes of the measurements were 1) to provide John Staples with field-data from which he could generate (and check) field parameters for establishing beam dynamics, 2) to provide John Staples and Ron Yourd with field-data for comparing the actual field with a calculated field approximated by Dr. Klaus Halbach and Massound Kaviany-Nejad.

Near the center of the magnet, attached to each pole, is a modified frustum (see Figure 2). The purpose of these steel protrusions is to introduce a "bump" in the otherwise uniform field which will correct for astigmatism in the trajectory of the beam as it exits the magnet. Examination of initial data revealed that, because of saturation, the cylindrical "pill-boxes" designed to produce the desired "bump" were inadequate (at an ambient field of 5.1 kG, the bump was ∿70% of the desired effect). We augmented our measurement system to produce field profiles in the vicinity of the protrusions. Using graphical data which we produced, John Staples modified the size and shape of the protrusions, arriving at the geometry sketched in Figure 2. The measured results agree (±1%) with the field shape predicted by EBQ[2] (a field generating program).

The purposes of this report are 1) to describe the measurements, including three coordinate systems used in the measurements, 2) to define the format of the data delivered to John Staples, 3) to record the effect of the steel protrusions on the field shape.

COORDINATE SYSTEM AND SET UP PROCEDURE

Figure 1 is a plan view section of the Ion Source Magnet showing the location of four fiducials (pins) which define the y-axis of three intersecting cartesian-coordinate systems. Pin 4 is common to the three coordinate systems. Pins 1, 2 and 3 separately paired with pin 4 define the y-axis for region 1(PIG)*, region 2 (EXIT)† and region 3 (MATS)† respectively.

During set-up for each region, pin 4 and the pin for that region were temporarily installed in the lower poles. The y-tube (which houses the three point coils used to measure B_x, B_y and B_z as functions of x, y and z) was fitted with brackets containing holes for accepting the fiducial pins. The y-tube was placed on the lower pole with the pins engaging the holes in the brackets. The z-stands (which provide y-tube motion perpendicular to the lower pole tip) and x-drives (which provide y-tube motion in the x-direction) were adjusted with the aid of a long straight edge, a carpenter's square, and a "micrometer-level" to form a cartesian coordinate system.** z is normal to the lower pole and directed upward (approximately vertical). z = 0 is the plane of symmetry of the magnet (the mid-plane between the upper and lower poles). +y is directed as shown in Figure 1.

---

*PIG: main body of magnet, including the location of the Penning Ion Gauge ion source

†EXIT: includes port through which beam from both PIG and MATS ion sources will EXIT the magnet

†MATS: includes port through which beam from Multiple Aperture Source will enter magnet

**Details of each set up, including excellent sketches by Basil Gavin, are stored in MME Book No. 593C[3] (geometrical set up).

The x-axis is mutally perpendicular to the y and z axes, and is directed such that each coordinate system is right handed, i.e., $\bar{i}_z = \bar{i}_x \times \bar{i}_y$ where $\bar{i}_x$, $\bar{i}_y$ and $\bar{i}_z$ are unit vectors in the plus x, y and z directions respectively. The y, z plane intersecting the pins is the x = 0 plane.

Specifying the y-coordinate of pin 4 completes the relationship between the three coordinate systems and the magnet fiducials. A scribe line on the bracket engaged by pin 4 facilitated the determination of the y-coordinate of pin 4. The y-tube has scribe lines denoting the y-position of the point-coil that measures B_z. These scribe lines are at 10-step intervals. (y = 10, 20, ... 120 steps; 1 step = 1.0032 in.) The distance between the bracket scribe-line and the nearest y-tube scribe line was measured in order to calculate the y-position of pin 4 for each coordinate system. Table I lists y(pin 4) for the three regions.

As shown in Figure 4 of Reference 3, the three-point coils are spaced at 1/2 inch intervals in the y-direction. The x- and z-coordinates of the three coils are identical but the y-coordinates for the y- and x-coils are respectively 1/2 inch and 1 inch less than YPN (the variable that defines the y position of the coil which measures B_z).

The mapped regions are outlined in Figure 1. Table I defines coordinate parameters for the single component $\{B_z(x, y, z = 0)\}$ maps to be used for generating algorithms which will determine the field at points throughout the volume of interest. Table II defines similar coordinate parameters for the 3-component, on and off mid-plane maps to be used for checking the integrity of the algorithms.

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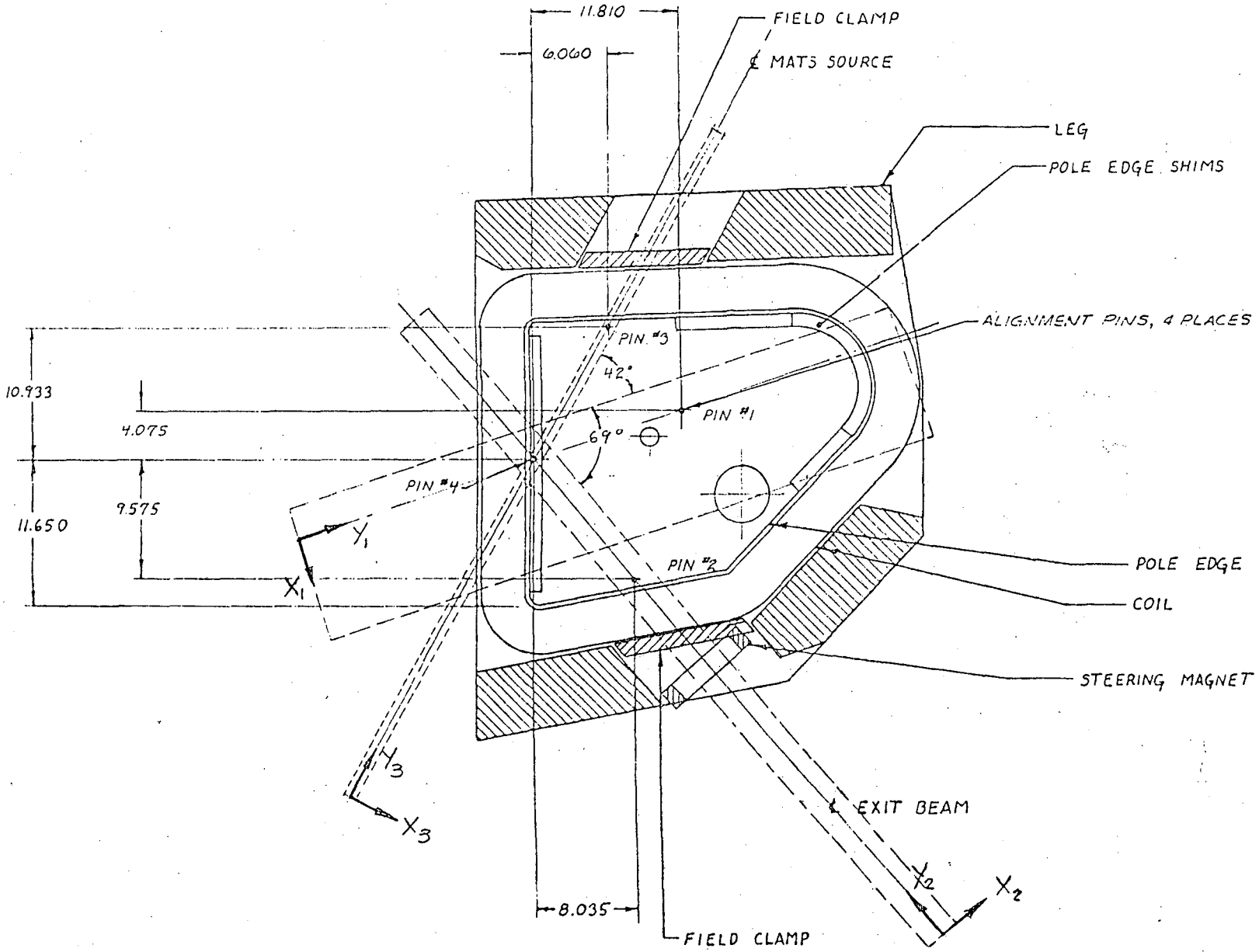

FIGURE 1 SUPERHILAC - THIRD INJECTOR ION SOURCE MAGNET - PLAN VIEW - REFERENCE 19P3146

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REGION (Fig. 1)	MAP (No.)	x_{min} (in.)	x_{max} (in.)	x_{del} (in.)	y_{min} (Steps*)	y_{max} (Steps*)	y_{del} (Steps*)	y(Pin 4) (Steps*)	REMARKS
1	364.1	-2.6	8.4	0.5	8.5	60.0	0.5	28.70	Composite Map
2	362	-1.5	1.5	0.5	50.0	115.5	0.5	100.59	Composite Map
3	326	-0.5	0.5	0.5	9.0	70.5	0.5	39.80	Composite Map
1	333	-2.6	8.4	0.5	9.5	90.5	1.0	40.31	
1	339	-2.6	8.4	0.5	9.0	90.0	1.0	40.31	
1	340	-2.6	8.4	0.5	9.0	90.0	1.0	40.31	Pill Boxes Removed
2	361	-1.5	1.5	0.5	50.5	115.5	1.0	100.59	
2	362	-1.5	1.5	0.5	50.0	115.0	1.0	100.59	
3	319	-0.5	0.5	0.5	9.0	70.0	1.0	39.80	
3	326	-0.5	0.5	0.5	9.5	70.5	1.0	39.80	
1	364.1	-2.6	8.4	0.5	9.0	60.0	1.0	28.70	
1	364.2	-2.6	8.4	0.5	8.5	59.5	1.0	28.70	

NOTES: Absolute Positioning Accuracy = ± 0.02 inch
Relative Positioning Accuracy = ± 0.005 inch

TABLE I COORDINATE PARAMETERS OF SINGLE COMPONENT MAPS $B_z(x, y, z = 0)$

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REGION	Map	x_{min}	x_{max}	x_{del}	y_{min}	y_{max}	y_{del}	z	y(Pin 4)	REMARKS
1	327	-2.6	8.4	1.0	9.5	70.5	1.0	-1.3	40.31	
	328	-2.6	8.4	1.0	9.5	70.5	1.0	0.0	40.31	
	329	-2.6	8.4	1.0	9.5	70.5	1.0	1.3	40.31	
	330	1.2	1.2	-	9.5	70.5	1.0	-1.3	40.31	Y-tube centered on pill box
	331	1.2	1.2	-	9.5	70.5	1.0	0.0	40.31	
	332	1.2	1.2	-	9.5	70.5	1.0	1.3	40.31	
2	358	-1.0	1.0	1.0	50.5	115.5	1.0	-1.1	100.59	
	359	-1.0	1.0	1.0	50.5	115.5	1.0	0.0	100.59	
	360	-1.0	1.0	1.0	50.5	115.5	1.0	1.1	100.59	
3	320	-0.5	0.5	0.5	9.0	70.0	1.0	-0.8	39.80	
	321	-0.5	0.5	0.5	9.0	70.0	1.0	0.0	39.80	
	322	-0.5	0.5	0.5	9.0	70.0	1.0	0.8	39.80	
	323	-0.5	0.5	0.5	9.5	70.5	1.0	-0.8	39.80	
	324	-0.5	0.5	0.5	9.5	70.5	1.0	0.0	39.80	
	325	-0.5	0.5	0.5	9.5	70.5	1.0	0.8	39.80	

TABLE II COORDINATE PARAMETERS OF THREE COMPONENT MAPS

$B_z(x, y, z)$, $B_x(x, y, z)$, $B_y(x, y, z)$

RL-398 7600-64267 (Rev. 9/73)

DATA FORMAT/RESULTS

John Staples requested that we provide him with IBM cards containing unique position identification and field values for each data point.

Cards were generated with the following FORTRAN coding:

```
WRITE (12, 1212)((JKR(J,K), IRC(J,K), J = 1, JMAX), K = 1, KMAX)
1212 FORMAT (6(1X, 2I6))
```

Where:

JKR (J,K) = KREG*10^5 + J*10^3 + KNEW

KREG = Region No., i.e., 1, 2 or 3

J = (XPN - XMIN)/XDEL + 1, (X-index)

XPN = X-position related to J for the specified region (in.)

XMIN = Minimum X-position for the specified region (in.)

XDEL = X-increment for the specified region (in.)

KNEW = 2*K + KINC

K = (YPN - YMIN)/YDEL + 1, (Y-index)

YPN = Y-position related to K for the map (steps)

YMIN = Minimum Y-position for the map (steps)

YDEL = Y-increment for the map = 1 (step) = 1.0032 (in.)

KINC = -1 for maps where YPN values are described by integers (y-tube in rear position)

= 0 for maps where YPN values are offset by 1/2 in. (y-tube 1/2 in. forward of its rear position)

JKR (J,K) is a complete specification of the location of the measured field value IRC (J,K) when used in conjunction with Figure 1. IRC (J,K) = -10.0* B_Z (J,K).

B_Z = the z-component of magnetic induction. (Since the main-component of field was downward, i.e., negative, John Staples requested that we multiply by -1. Because J. Staples wanted integer data but did not want to lose significance, he requested that we multiply by 10 and convert from floating point to integer.)

849 cards representing the three regions were available to John Staples on July 15. As a backup, the card data is also stored on PSS Group 25, HILAC; LIBRARY: STAPLES; SUBSET: NDATA.

In addition to the three sets of data described above, we have stored both the complete collection of raw data and the processed results of selected maps. These data sets are stored on GSS TAPE #10167, DIRECTORY: NDATA, DATASETS TAPE 11 and TAPE 1.

The format of the raw data is too complicated to describe in this note. It was produced by the computer mapper control program MAP 76. It can be automatically "processed" by the program COMA76U stored on LBL Computer Center Library Tape - Lib. No. 34565.

We modified COMA76U in order to generate the cards described above. The third type of data we stored (processed) is a normal output-file of COMA76 (Tape 11). Details of the data format of the processed data are left to an inspection of sub-routine RITEFLD, the sub-routine in COMA76U which produces Tape 11. Each processed map is stored as 1 or 3 files, each

containing 51 identifying constants followed by a 2-dimensional array B(J,K). For single component maps, there is a single file produced per map $B = B_z$. For three-component maps, there are three consecutive files produced per map $B = B_z$, $B = B_x$ and $B = B_y$ (in that order on the output-file).

The graphical data for the final "modified-frustum" is shown in Figure 2. Note that saturation reduces the relative effect of the "modified-frustum," so the percent increase at 6.0 kG is less than the percent increase at 2.4 kG.

ACKNOWLEDGEMENTS

Dr. John Staples specified the required measurements. Basil Gavin gave us direction and assisted us when necessary. Kathy Schiff assisted with measurements and Ed Cyr assisted with set-up in several coordinate systems. Joe Love located and repaired two faults that occurred during these measurements. Carolyn Wong typed several drafts and the final report. We appreciate the assistance provided.

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3. Nelson, D.H., Bevalac Third Injector Ion Source Magnet Drawing No. 19P3146, Magnetic Measurements, LBL Magnetic Measurements Engineering Data Book No. 593C, July, 1980.

4. Dols, C.G., "A Computer Controlled, 3-D, Magnetic Field Mapping System, LBL Report - LBL-1311, September, 1972.

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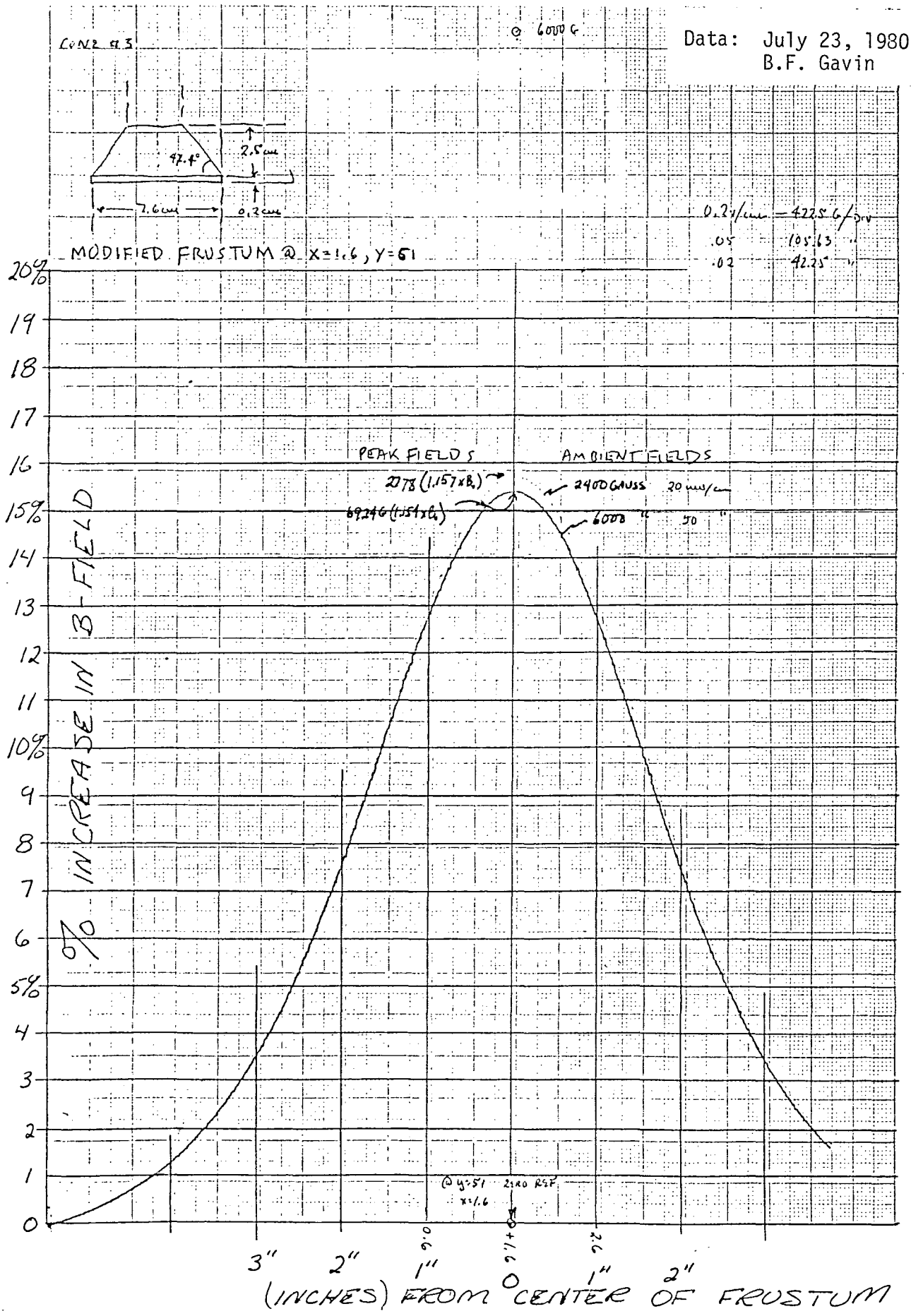
FIGURE 2 MEDIAN-PLAIN FIELD PROFILE (B_z vs x) ON A DIAMETER OF THE FRUSTUMS



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