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D-Line Archival notes

G. Bunce

June 1987

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

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Alternating Gradient Synchrotron Department
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Experimental Planning and Support Division
Technical Note

AGS/EP&S/Tech. Note No. 127

June 25, 1987

G. Bunce

D-Line Archival Notes

These notes are only meant to introduce the general features of the line. The line was built in 1980-1981. It serves as a primary beam of protons for the polarized proton target (PPT) experiment, and the primary beam produces secondary particles in the D target for a muon line, and a K+ line. It has been used with several extraction schemes. The PPT experiment uses a slow extraction and either shaves off a very small fraction of the unpolarized proton beam using the electrostatic septa, or, for polarized proton running, it uses most of the beam. Two experiments off the D target use normal slow extraction at moderate intensity (10^{12})--Zeller (K^+), and Kossler (muons). One experiment from the D target uses a single-bunch extraction from the AGS and uses all the beam (i.e. unsplit)--Sachs (muons). The PPT experiment is incompatible with D-target running due to a magnet used with the PPT. The PPT experiment also has two two-arm spectrometers viewing a small hydrogen target upstream. This is the infamous "high energy polarimeter" which is used for polarized proton running--it measures the degree of polarization.

The switchyard divides the extracted beam from the AGS into A,B,C, and D beams first with electrostatic splitters, then, when the separate beams are sufficiently far apart, with Lambertson septum magnets. For the D-line, splitters AB1 and DB2 divide A/D from B/C, then D from A, respectively. Two thick Lambertson septa AD2 and AD3 bend both A and D further from B/C. Lambertson septa DD4 and DD5 deflect D only. All of this was foreseen by Weisberg in the switchyard design, although D was not built immediately.

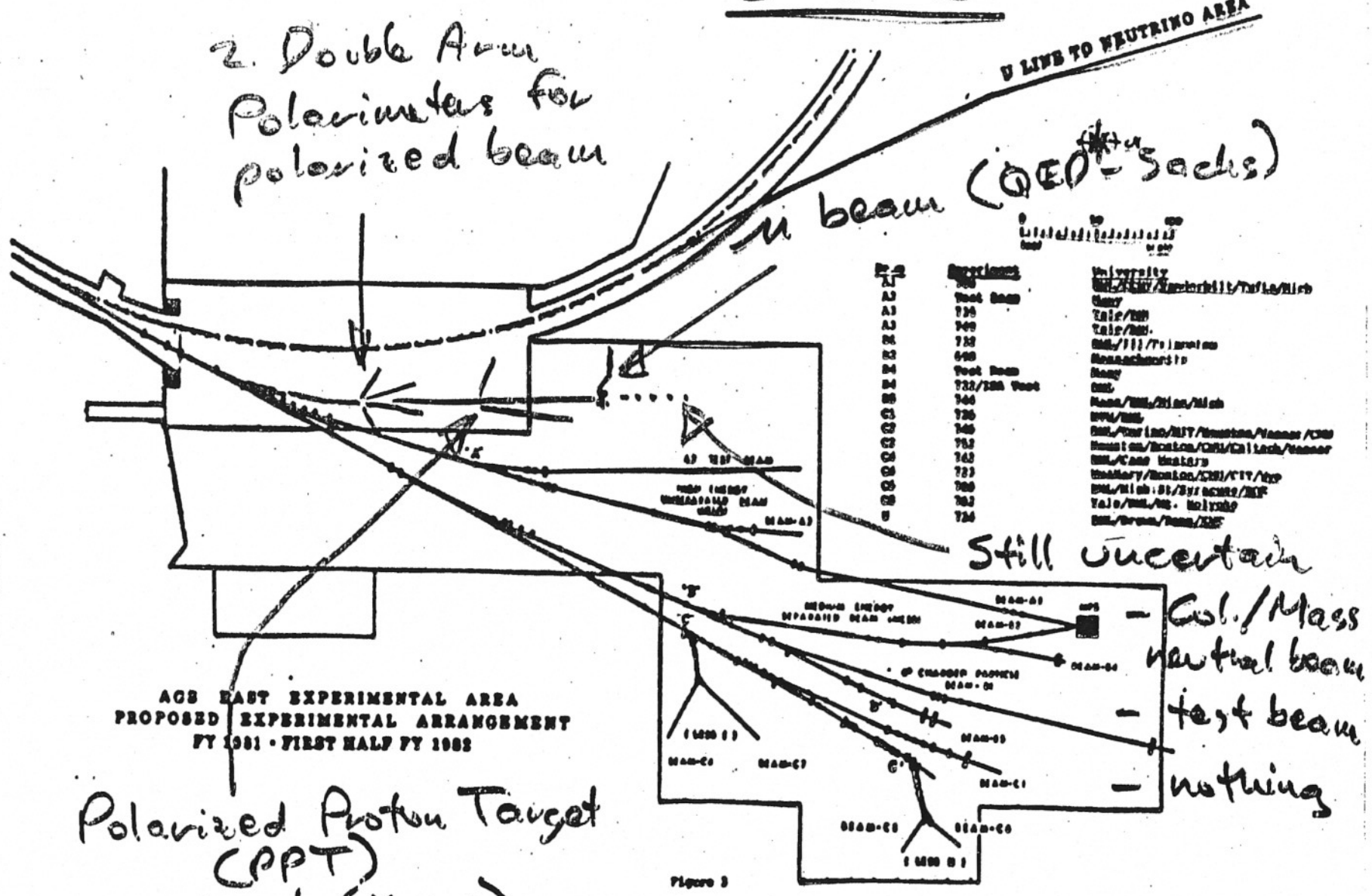
At the exit from DD5 the beam is tilted 36 degrees transverse to the beam direction by second order horizontal magnetic fields in the Lambertson magnets. Skew quadrupoles were included to restore the beam to an upright elipse.

After the switchyard the D beam points upward 8 mrad and heads 3.9 degrees west of A. A further sharp 21 degree bend to the west steers the beam into the center of the Northwest Target Building. A 15D30 dipole shimmed to a 2" gap is rotated 20 degrees to bring D to horizontal and begin the west bend. This is followed by an 18C72, 2 10IV72 dipoles from Argonne, and 4 18D72 dipoles. These have been shimmed to 1.5" gaps.

There have been a number of AGS studies reports on D: 126, 132, 135, 150, 157. I have also attached a copy of transparencies from a talk on the line, given just prior to construction. Following this are two examples of D-line optics, transporting the beam either to the PPT target or to the D-target. It should be noted that the desired spot at the PPT is about 2 cm diameter. These are followed by some mainly archival material: magnet positions and expected original magnet excitations. The original optics design was done by H.N. Brown.

Talk given on D-Line
to Acc. Dept. physicists.
G. Bunce
1 April 81

D Line



2. Double Arm Polarimeters for polarized beam

u beam (QED - Sachs)

Still uncertain

- Col./Mass
- neutral beam
- test beam
- nothing

Polarized Proton Target (PPT) experiment (Krisch)

Outline

- overall "finished" D
- some history, superconducting vs. warm transport
- present design
- PPT experiment
- polarimeter
- ~~Columbia / UMass expt.~~
- discuss schedule + 2 tests
  (Tests are described in AGS studies reports.)

People

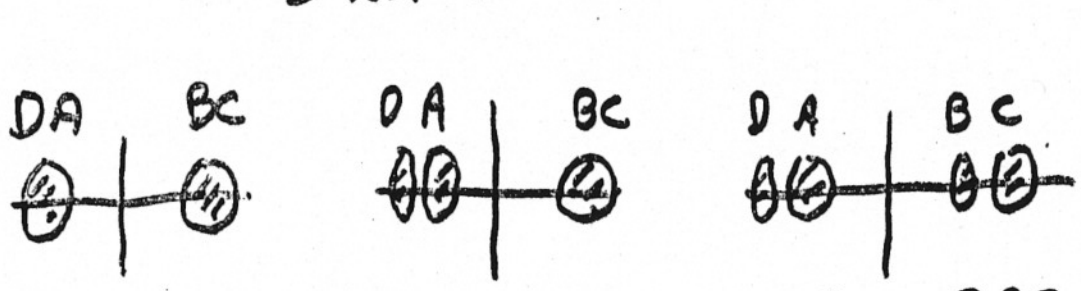
Ralph Brown
Hugh Brown
Al Pendzick
Me → G. Bunce

Charlie Pearson – PPT
Jim Mills – μ
I-Hung Chiang – μ
Bob Marascia – ideaperson
Woody Glenn } tests
Andy Soukas }
Art Dick } layouts
Charlie Bobenschutz }
Rudy Alforque – splitter

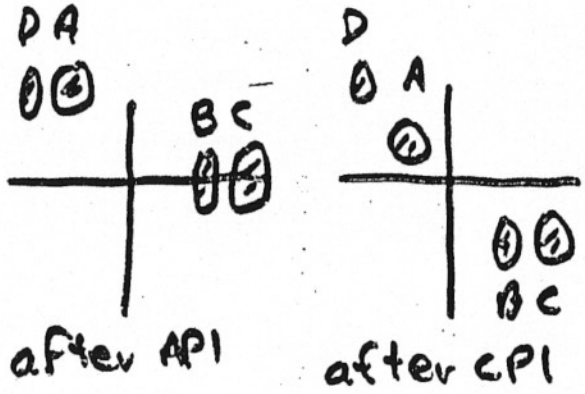
D Split

Green: exist, in place for D

Blue: present switched D



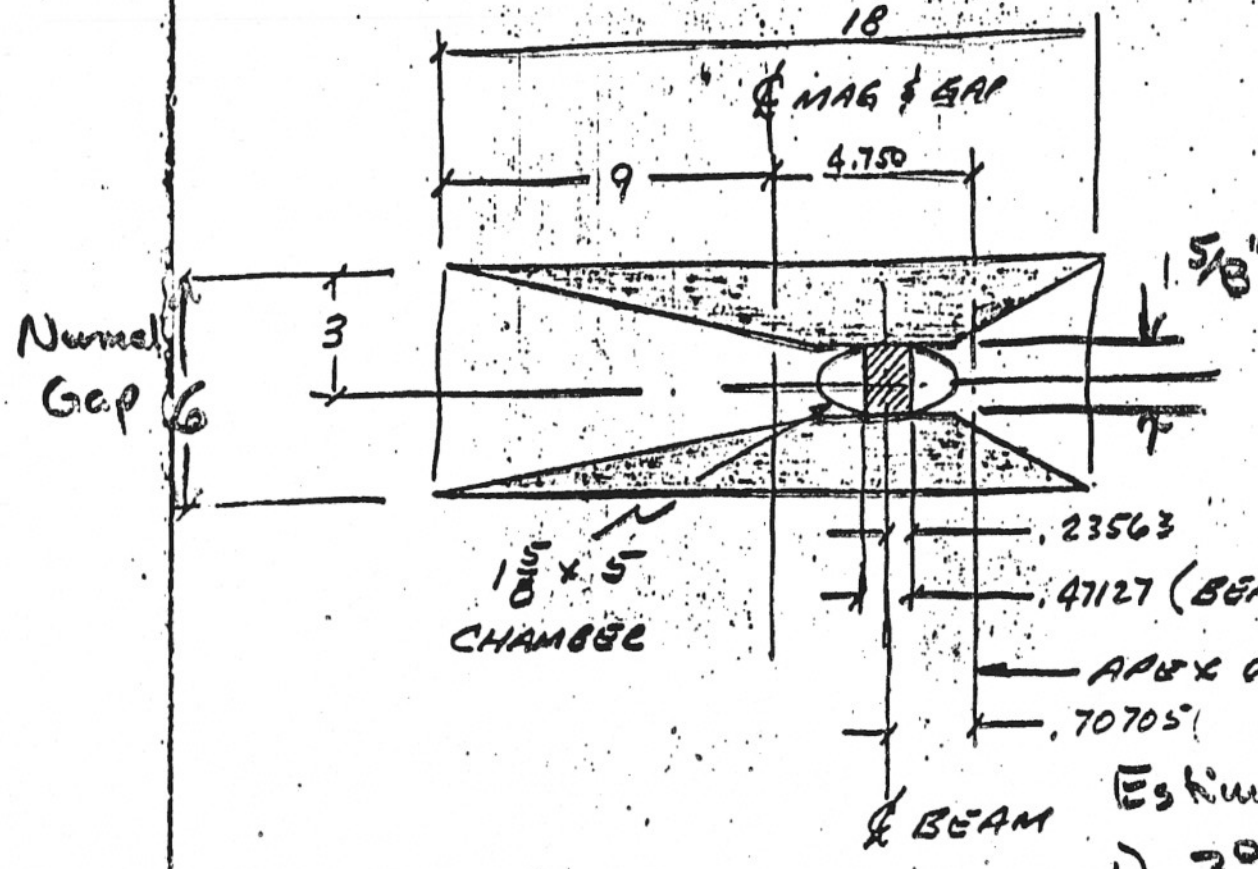
electrostatic splitters



thin Lambertsons

D-Transport History

- need ~21° bend to come out ⊥ to buildings; do it quickly so that line is not too close to edge of buildings
- original suggestion: long warm magnets
  - little clearance from edge of blg.
  - superconducting technology (window frame version) needed to be developed ⇒ curved s.c. magnets
- curved magnet didn't work + people busy on alternate magnet for Isabelle
- decide on <u>warm magnets</u> for 21°
  - shim to reduce power
  - all existing magnets



Estimate of power

1) 3° ⇒ 26.7 kg

2) I = 1.67 A for 1.5", no taper

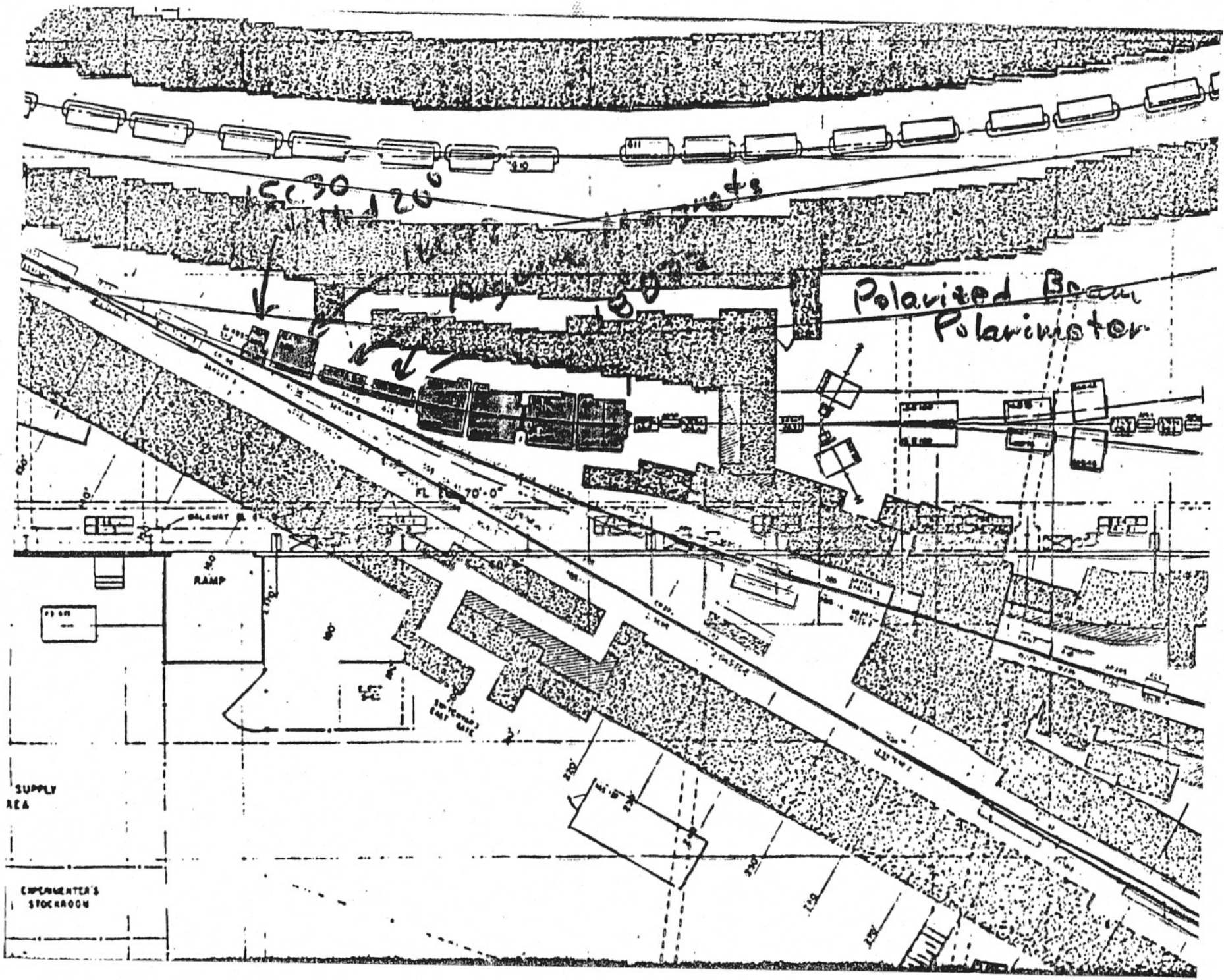
3) have 1" gap tapered data

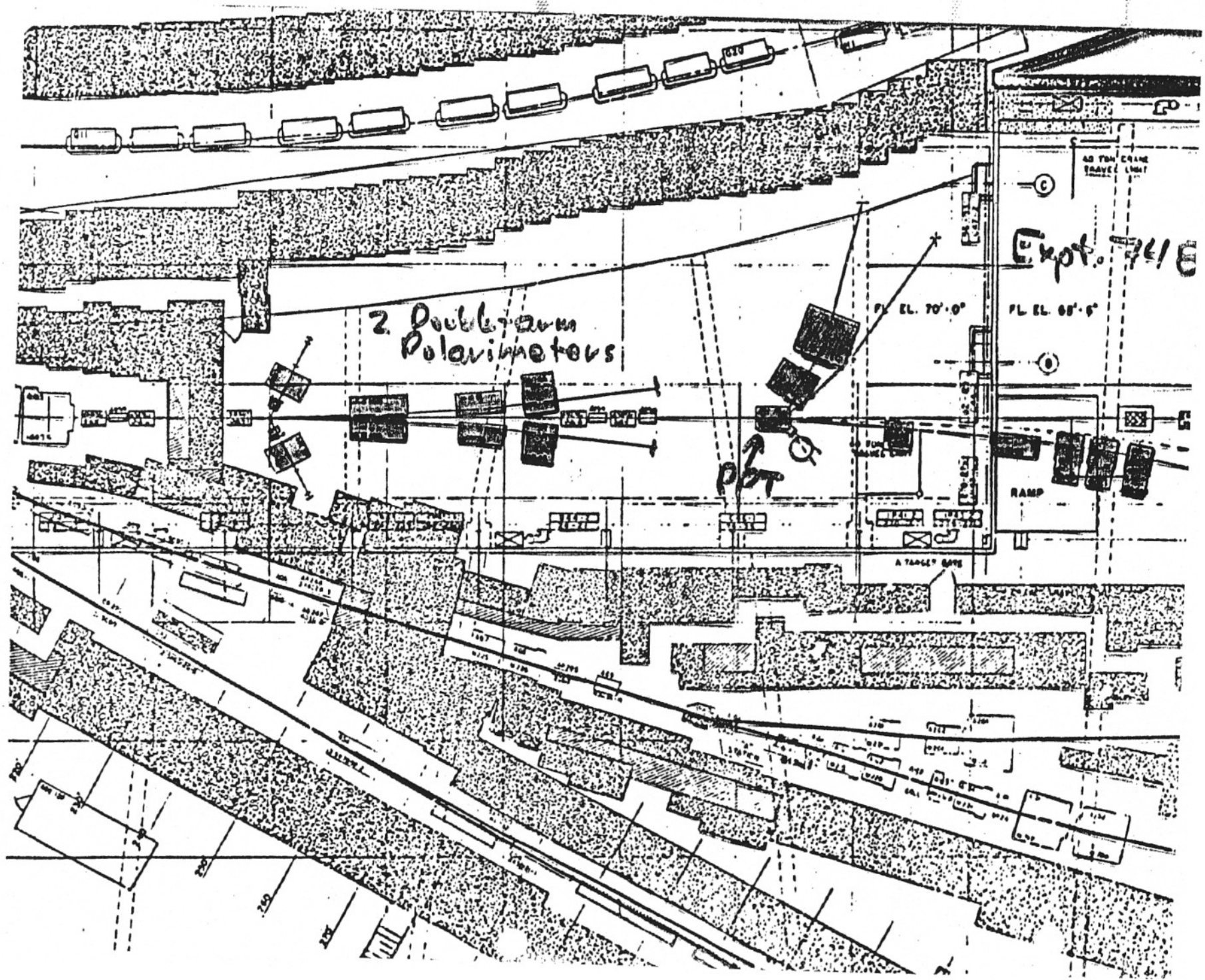
$$I(1.5"g, 5"t) = I(1.5"g, t) \times \frac{I(1", 5"t)}{I(1", no\ t)} = 1.06kA$$

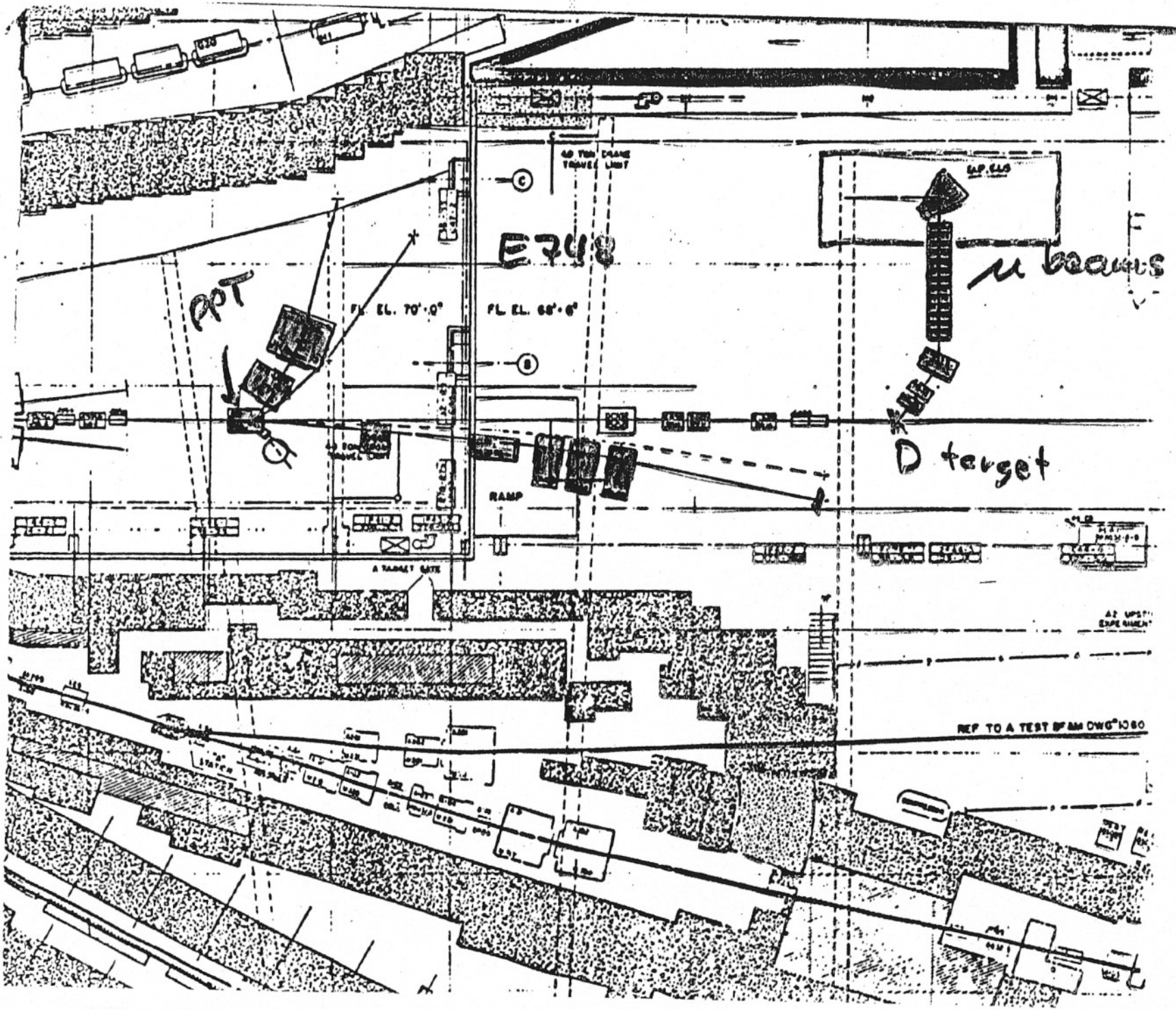
4) ⇒ power = 52 kl / 3°

5-24-81

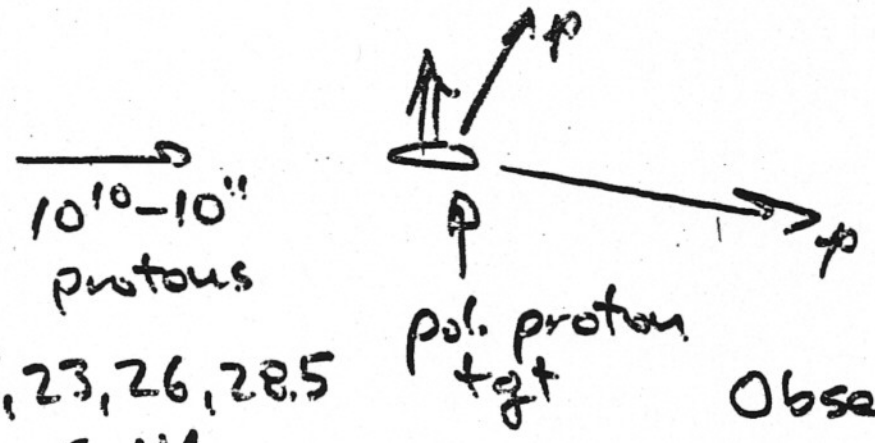
18D72 (DD10)
6x18 MAG GAP
LOOKING DOWNSTREAM


Polarized Beam
Polarimeter
RAMP
SUPPLY
AREA
EXPERIMENTER'S
STOCKROOM


2 Double-arm Polarimeters
Expt. 741
PBT
FL EL. 70'-0"
FL EL. 68'-6"
RAMP


E748
PT
FL. EL. 70'-0"
FL. EL. 68'-6"
RAMP
D target
REF TO A TEST BEAM DWG

Experiments — PPT



elastic scatteri

15, 23, 26, 28.5 GeV/c

Observe (fixed $p_\perp$)

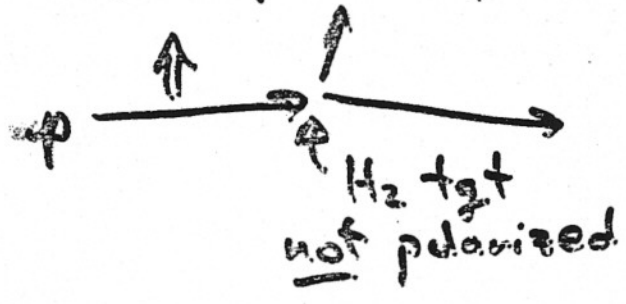
$$\frac{\sigma(\uparrow)-\sigma(\downarrow)}{\sigma(\uparrow)+\sigma(\downarrow)} = AP$$

P = pol. of tgt

∴ get A = analysing power

1) QCD should predict $A(p_\perp)$ at high $p_\perp$ (E748 goes to ~ 2.5)

2) With A, one can reverse expt. to measure beam pol. (= polarimeter):

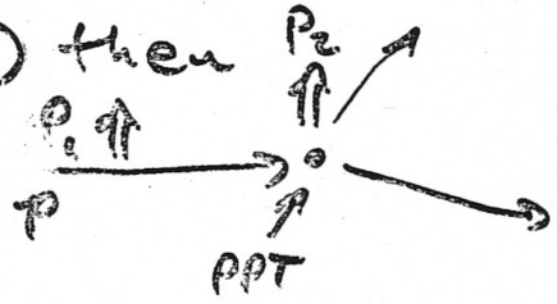


$$\frac{\sigma(\uparrow)-\sigma(\downarrow)}{\sigma(\uparrow)+\sigma(\downarrow)} = AP$$

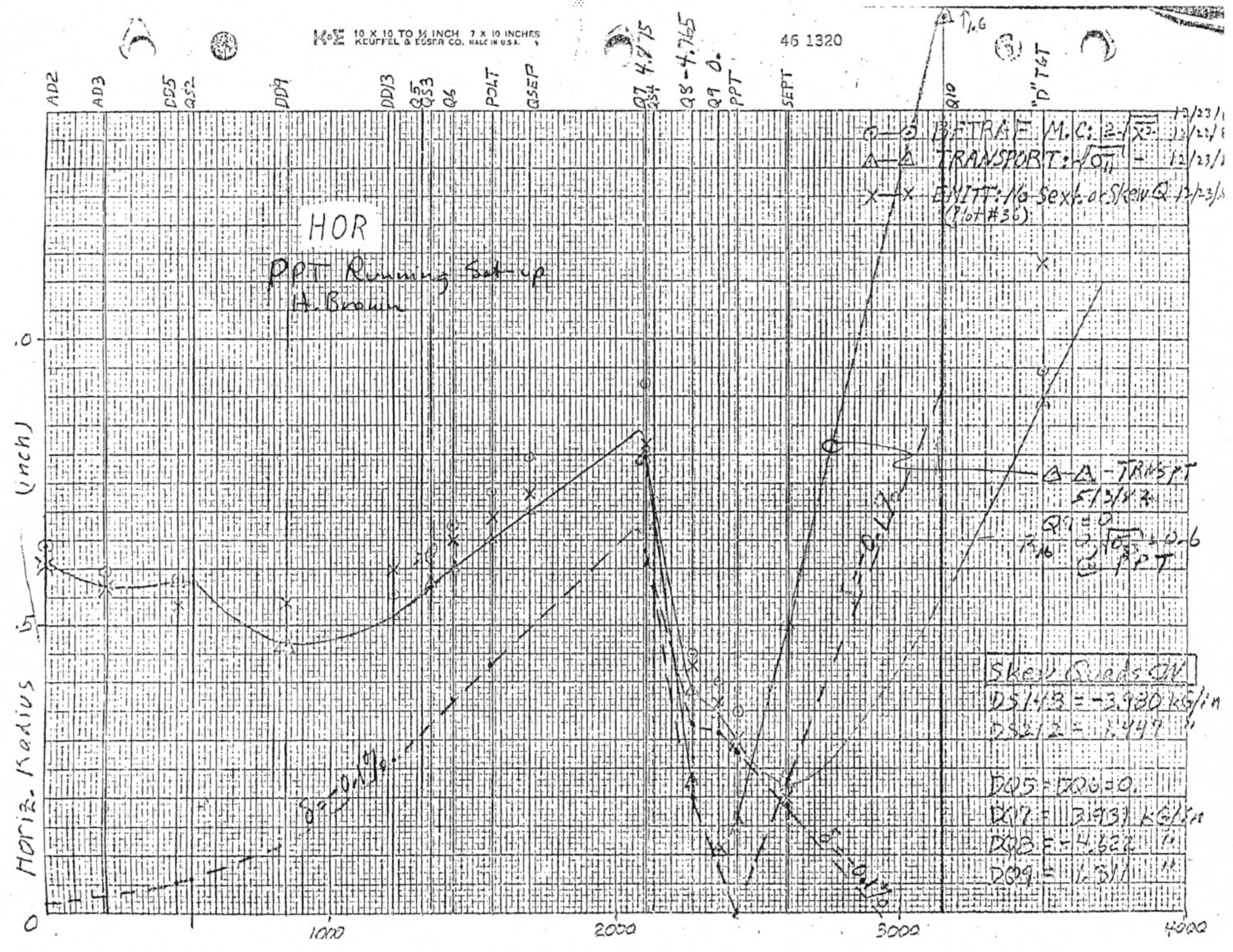
know from E748

now g beam

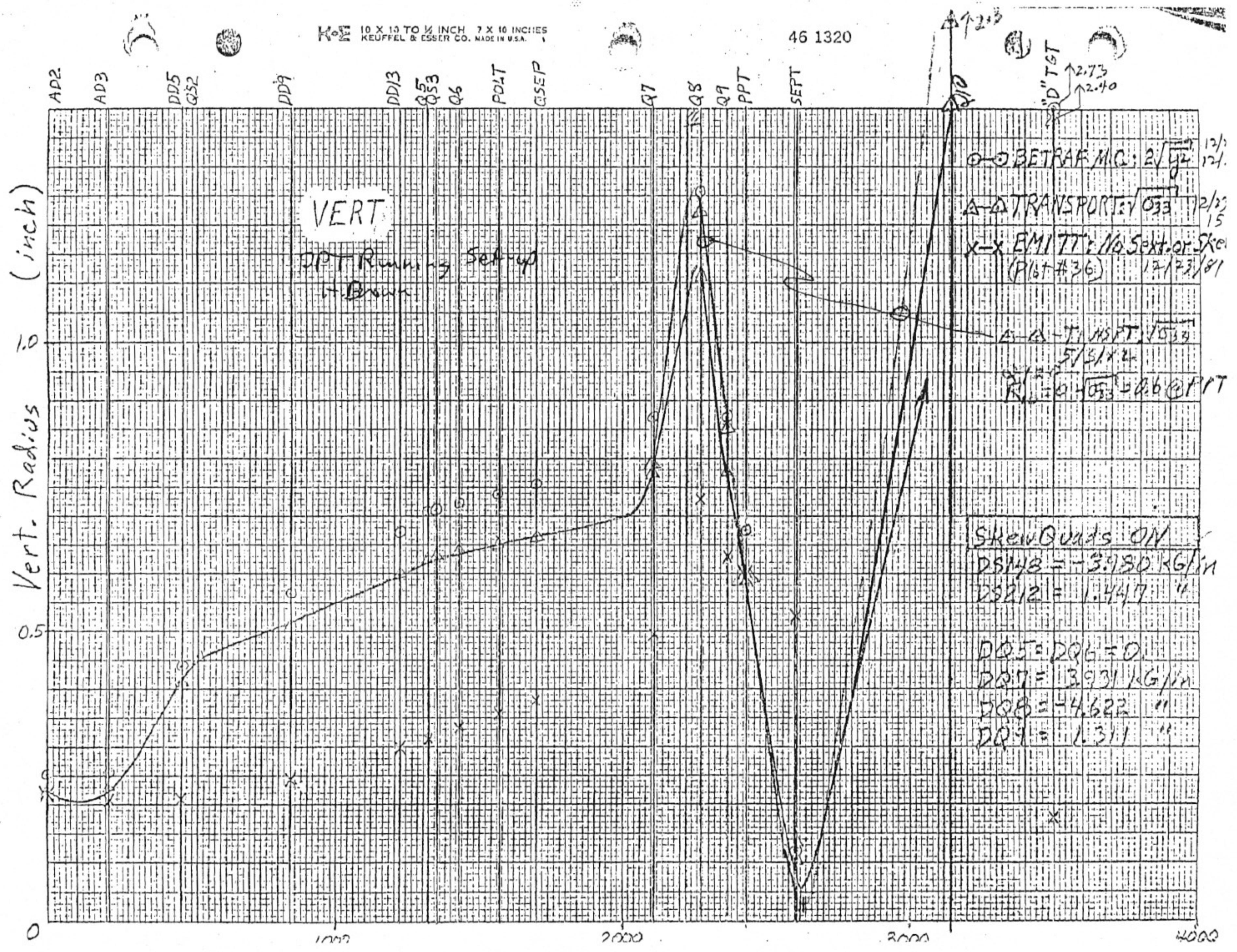
3) then



$$\frac{\sigma(\uparrow\uparrow)-\sigma(\uparrow\downarrow)}{\sigma(\uparrow\uparrow)+\sigma(\uparrow\downarrow)} = P_1 P_2 C_{NN}$$



K+E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.
46 1320
AD2
AD3
DD5
QS2
DD9
DD13
Q5
QS3
Q6
POLT
QSEP
Q7 4.875
QS4
Q8 -4.765
Q9 0.
PPT
SEPT
Q10
"D" TGT
HOR
PPT Running Set-up
H. Brown
BETRAF M.C.
TRANSPORT
ENITT: No Sext. or Skew Q
(Plot #36)
TRANSPT
5/3/87
Q9 = 0
Skew Quads ON
DS1+3 = -3.980 KG/in
DS2/2 = 1.447
DQ5 = DQ6 = 0.
DQ7 = 3.931 KG/in
DQ8 = -4.622
DQ9 = 1.311
Horiz. Radius (inch)
0
1000
2000
3000
4000



K+E 10 X 10 TO ½ INCH 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 1320
AD2
AD3
DD5
QS2
DD9
DD13
Q5
QS3
Q6
PO1T
QSEP
Q7
Q8
Q9
PPT
SEPT
Q10
"D" TGT
2.73
2.40
12"
VERT
PPT Running Set-up
H. Brown
Vert. Radius (inch)
1.0
0.5
0
1000
2000
3000
4000
BETRAF MC: $2\sqrt{\overline{y^2}}$
TRANSPORT: $\sqrt{\sigma_{33}}$
EMITT: No Sext. or Skew
(Plot #36)
12/23/81
TRANSPORT $\sqrt{\sigma_{33}}$
5/5/82
Skew Quads ON
DS148 = -3.980 KG/in
DS212 = 1.447 "
DQ5 = DQ6 = 0.
DQ7 = 3.931 KG/in
DQ8 = -4.622 "
DQ9 = 1.311 "

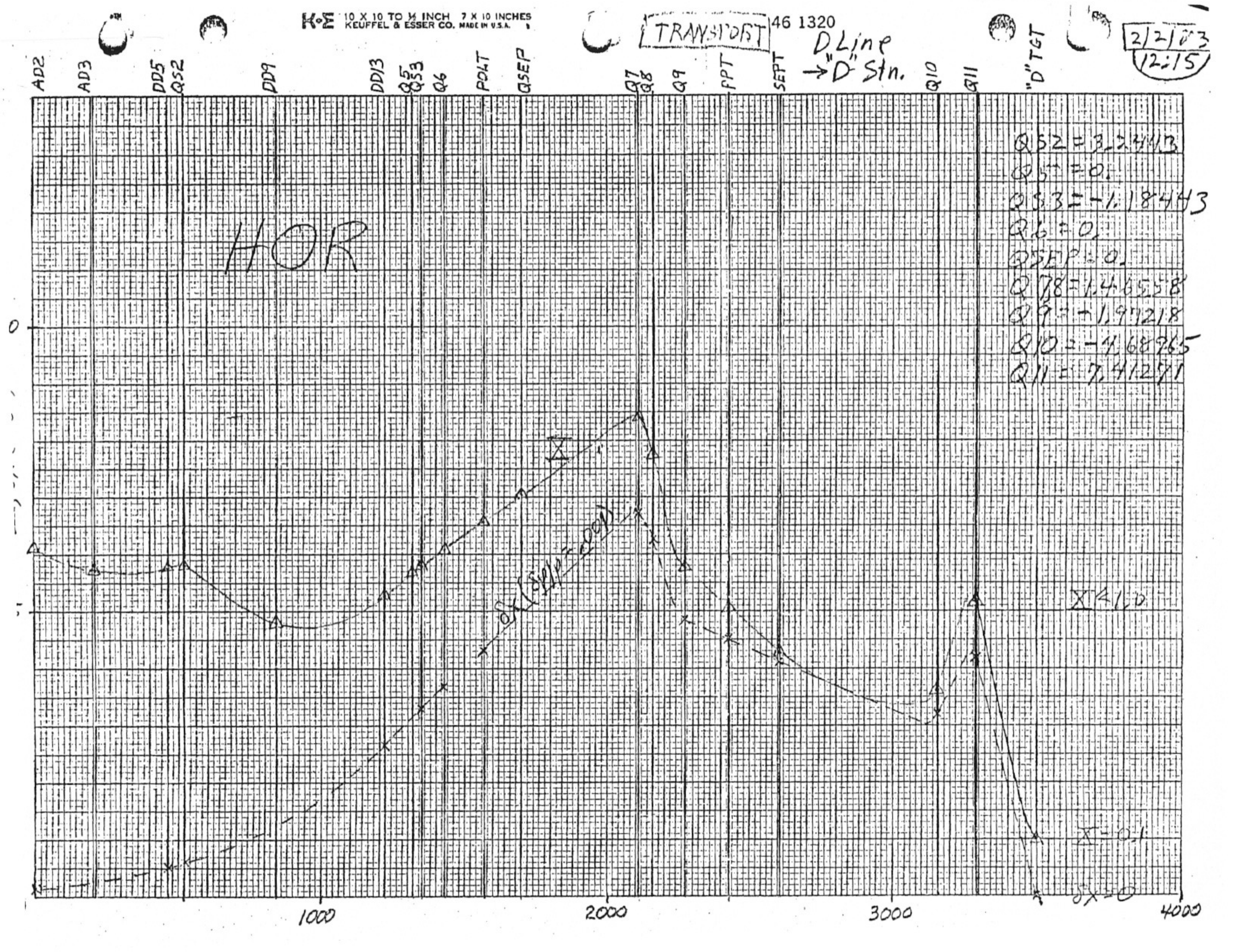
See Plot #28 1/27/81

2/1/83
H. Brown

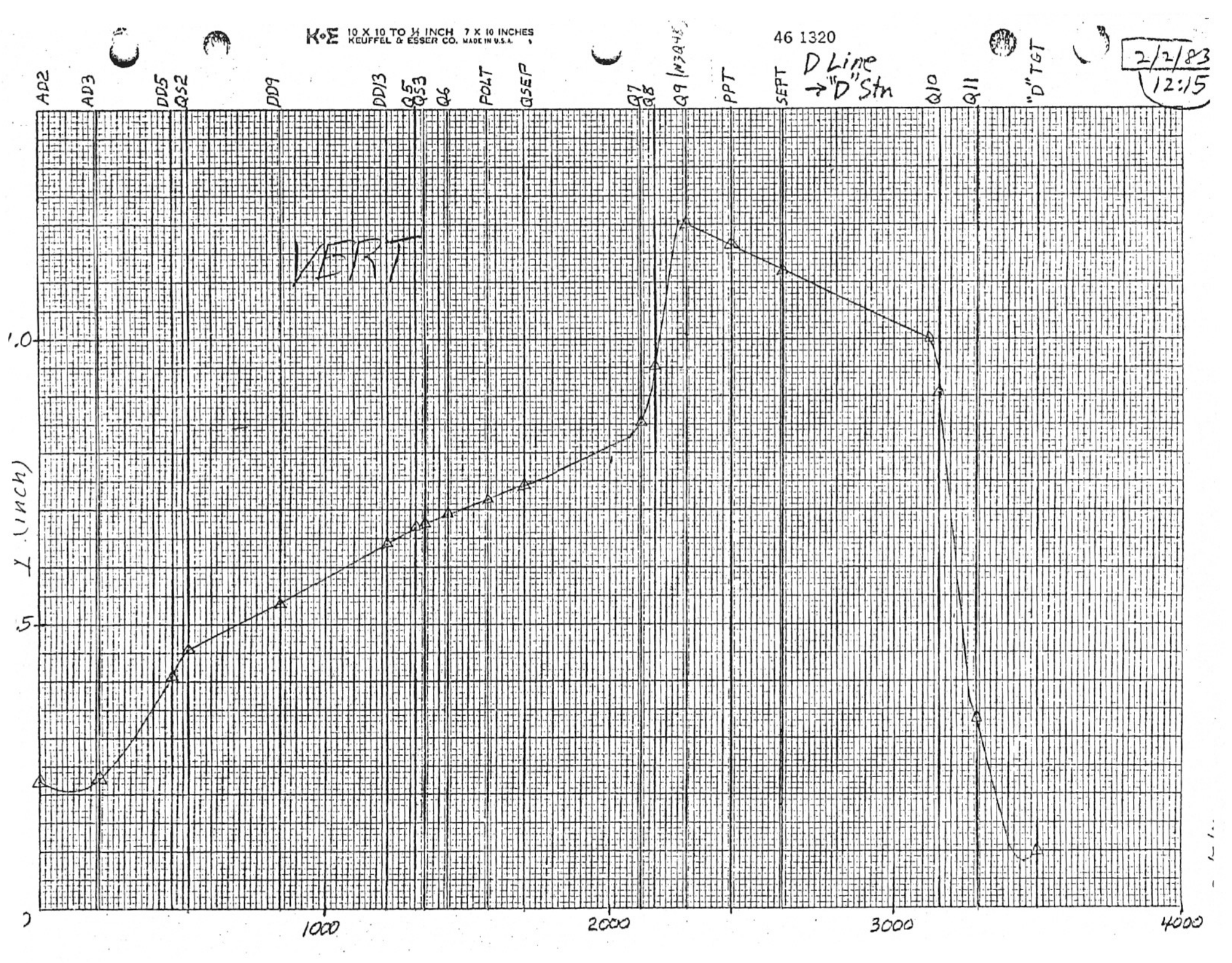
Starting Values for D Line → "D" Station

		B (kG) G (kG/in)	V (in) Left	I(A)	Shunt Amp/mV	Data (on Cnts			Pol.
	DD4	13.537	94.	1766	21†	3364			A
	DD5	13.537	94.	1766					A
Q52	DS148	3.538	18.	319	8	1595			A
	DD6	17.397	33.	1540	25	2464			A
	DD7	22.885	73.7	1410	25	2256			A
	DD8	22.209	69.7	1490	15†	3473			A
	DD9	22.209	69.7	1490					A
	DD10	26.418	73.7	1270.	15†	3387			A
	DD11	25.700	73.7	1270.					A
	DD12	25.700	73.7	1270.	15†	3387			A
	DD13	25.700	73.7	1270.					A
	DD14	11.003	32.0	765.	15	2040			A
N3Q35	DQ5	0.	37.5	0.	15	0.			—
Q53	DS212	−1.286	18.	116.	8	580			B
N3Q36	DQ6	0.	37.5	0.	15	0			—
5Q36	DQ7	1.263	38.5	300.	12	1000			A
5Q36	DQ8	1.263	38.5	300.					A
N3Q48	DQ9	−1.960	47.5	422	21†	804			B
N3Q36	DQ10	−5.125	37.5	1113.	25	1781			B
N3Q36	DQ11	7.790	37.5	1748.	25	2797			A

† - These P.S.'s have current transducers equivalent to shunts listed.



K+E 10 X 10 TO ½ INCH 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.
TRANSPORT
46 1320
D Line
→ "D" Stn.
2/2/03
12:15
AD2
AD3
DD5
QS2
DD9
DD13
Q5
QS3
Q6
POLT
QSEP
Q7
Q8
Q9
FPT
SEPT
Q10
Q11
"D" TGT
QS2 = 3.23413
Q5 = 0.
QS3 = -1.18443
Q6 = 0.
QSEP = 0.
Q78 = 1.46558
Q9 = -1.97218
Q10 = -4.68965
Q11 = 7.41271
HOR
δx (SEPT = .001)
X 4.0
X -0.1
δx = 0
0
1000
2000
3000
4000


K&E 10 X 10 TO ½ INCH 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 1320
D Line
→ "D" Stn
2/2/83
12:15
AD2
AD3
DD5
QS2
DD9
DD13
Q5
QS3
Q6
POLT
QSEP
Q7
Q8
Q9
PPT
SEPT
Q10
Q11
"D" TGT
VERT
1.0
.5
0
Y (INCH)
1000
2000
3000
4000

BEAM D LINE EXP. NO. D STATION DATE 3-26-81

REF. D'W'G. NOS. _____ BY K.L.M ORIG. _____

BEAM COMPONENTS					COORDINATES	
SYMBOL	TYPE	BEARING	ANGLE	DISTANCE	NORTH	EAST
F-13		28.9444°	28°56'29"		9810.24	11516.849
CD1	15C30-1	-.6879°	-0°41'17"	161."		
		28.2535°				
CQ1	N3Q36-C			44."		
CP020	3X4D24-1			88.5"		
CQ2	N3Q48-1			134."		
CQ3	N3Q48-2			204."		
CQ4	N3Q36-2			274."		
AB1	.5B120	-.0215°	-0°01'17"	379."		
		28.232°				
DB2	.5B120	-.0215°	-0°01'17"	135."		
		28.2105°				
BB3	.5B120	-.0143°	-0°0'51"	135."		
		28.1762°				
CP075	3X4D24-2			95.25"		
AP1	2.5X6D120-1			183.125"		
CD1	2.5X6D120-2			321.125"		
CP101	2.3X3D16-1			413.875"		
CP103	3X5.5D16-1			430.375"		
AD2	3.5X7D72-1A	-1.9890°	-1°59'21"	500.38"		
		26.2572°				
AD3	3.5X13D72-1	-1.9026°	-1°54'10"	118.021"		
		24.3026°				
DD4	3.5X13D72-2	-1.9482°	-1°56'54"	135.001"		
		22.3564°				
DD5	3.5X13D72-3	-1.9482°	-1°56'52"	119.751"		
		20.4082°				

use Leff = 110 for Lamb.

BEAM D Line EXP. NO. "D" Station DATE 3-26-81

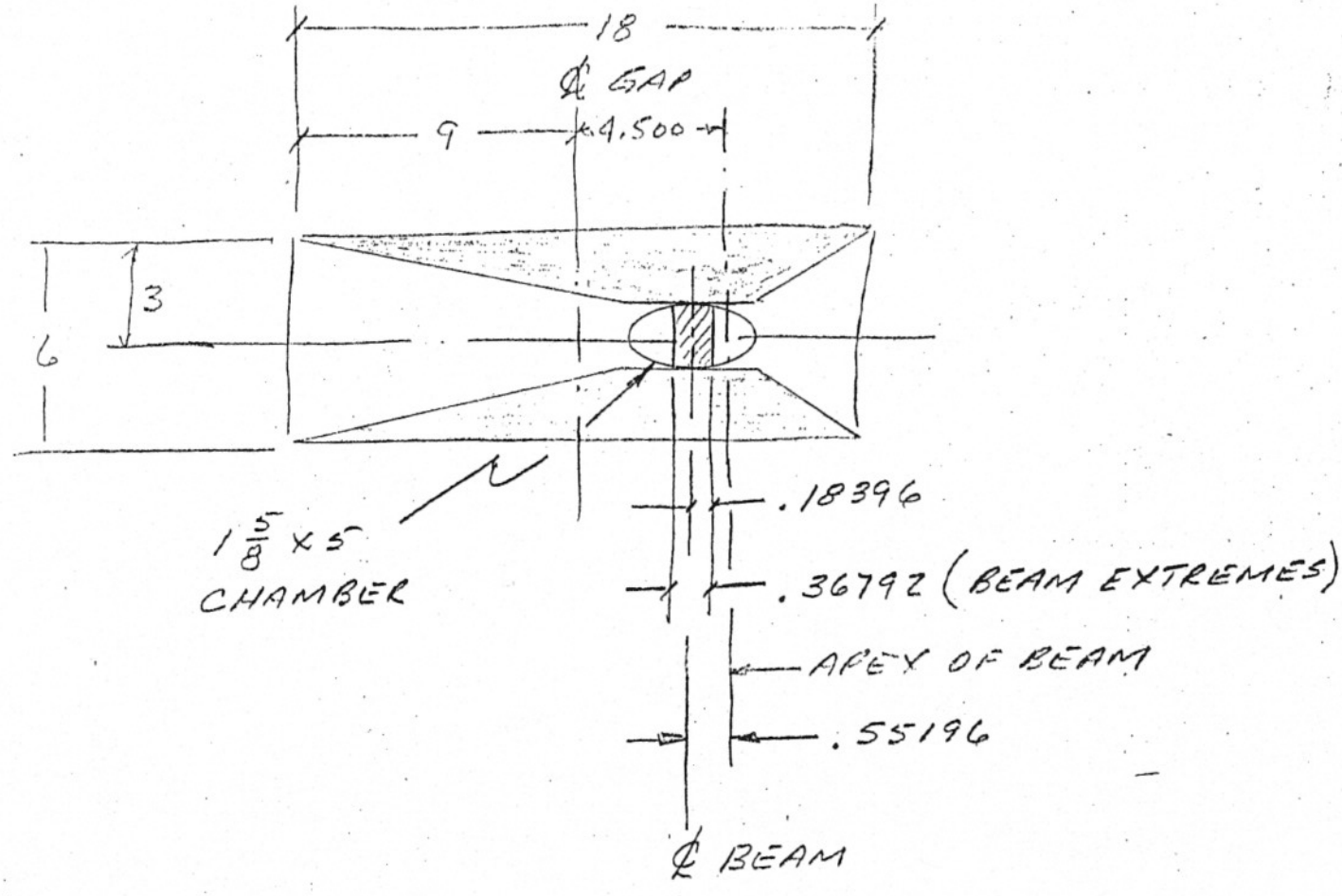
REF. D'W'G. NOS. _____ BY R.L.M. ORIG. _____

BEAM COMPONENTS					COORDINATES	
SYMBOL	TYPE	BEARING	ANGLE	DISTANCE	NORTH	EAST
DP2	3X4D30			81.125"		
DD6	15C30-	-.86602°	-0°51'57"	123." ← center DD5 to center DD6		
Left	36.9 30+2=32	19.54218°				
DD7	18CT2-	-2.34218°	-2°20'32"	70."		
Left	78+1.5 77.5	17.2°				
DD8	10T72-	-2.6°	-2°36'	91."		
		14.6°				
DD9	10T72-	-2.6°	-2°36'	89."		
		12.0°				
DD10	MT	-3.°	-3°	90."		
		9.0°				
DD11	MT	-3.	-3°	96."		
		6.0°				
DD12	MT	-3.	-3°	90."		
		3.0°				
DD13	MT	-3.	-3	96."	12026.106"	12455.322
Left 72+1.5		0.0°				
DQ5	N3Q36-					"
	3X4D30					"
DQ6	N3Q36-					"
DQ7	5Q36-					"
POLARIMETER TARGET				313.894"	12400.00	"
DQ8	N3Q36-					"
	3X4D30					"
DQ9	N3Q36-					"
	5X4D30				-872 Pol. T to PPT	"
EXP. 748	PPT TGT.			1245.894"	13272.00	"

BEAM D LINE EXP. NO. "D" STATION DATE 3-26-81

REF. D'W'G. NOS. _____ BY R.L.M ORIG. _____

BEAM COMPONENTS					COORDINATES	
SYMBOL	TYPE	BEARING	ANGLE	DISTANCE	NORTH	EAST
ABSORBER						"
	3X4D30					"
DQ10						"
DQ11						"
DQ12	N3Q36-					"
	3X4D30					"
"D" STATION				2317.894"	14344.00	"

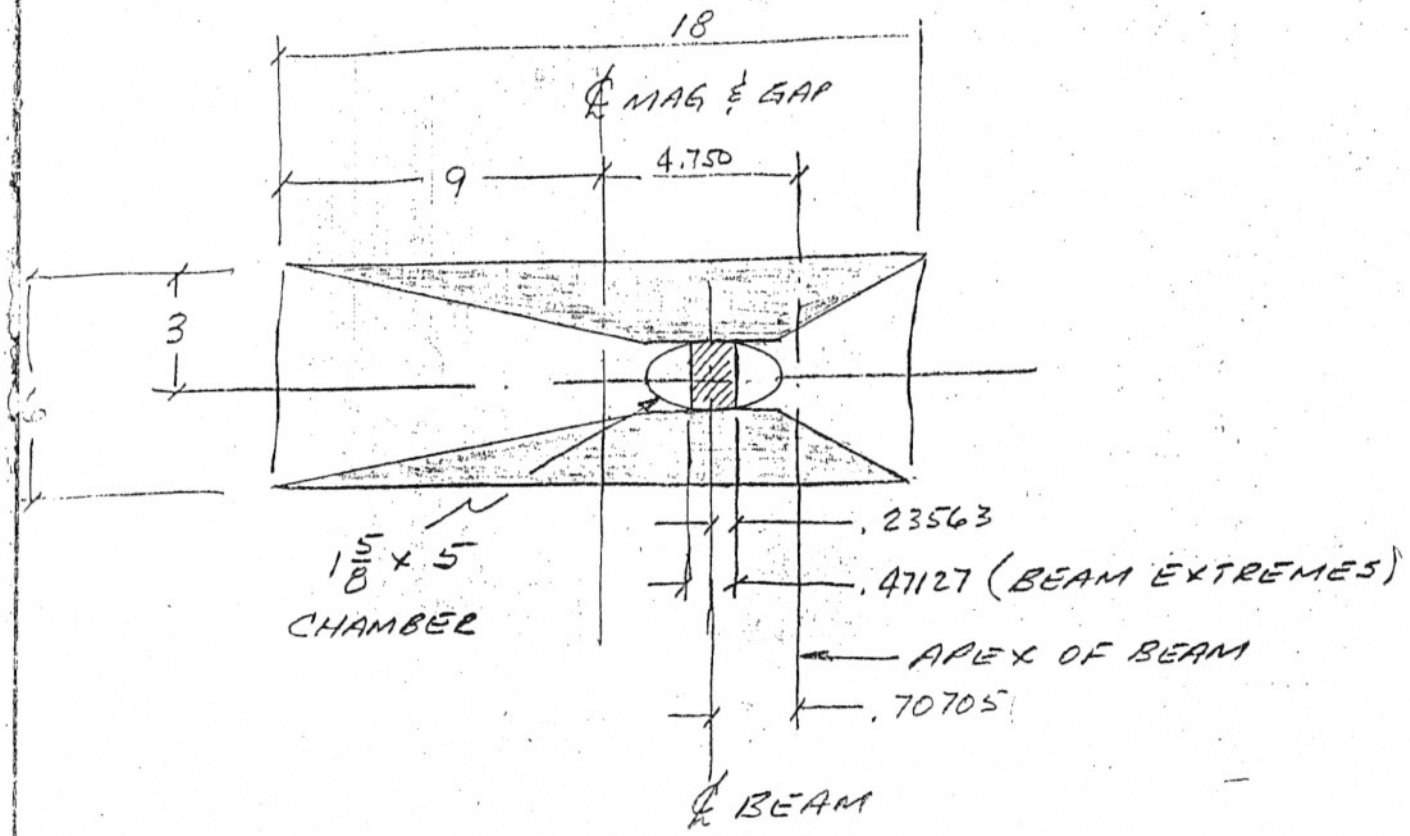


18C72 (DD7)

6 x 18 MAG GAP.

LOOKING DOWNSTREAM

3-24-81 ACD



18D72 (DD10)

6×18 MAG GAP

LOOKING DOWNSTREAM

3-24-81 A.C.P.

Ramps?

D Line Excitations

H. Glass
Date: 3/16/82

4000 computer cnts for 100 mV. inp-t

Mag	Type	P.S.	Bend	∫F dl	Leff	F	I	Shunt	DataCom	Polarity
—	—	—	(Deg)	kG-in or kG	(inch)	kG or kG/in	(Amp)	Amp/mV	Counts	—
DD4	13D92	74-2	1.9782	1272.6	94.0	13.537	1766	21†	3364	A
DD5	13D92	10-10 Trim	1.9782	1272.6	94.0	13.537	"	5		A
DS148	4Q16	205	—	63.7	18.0	3.538	319	8	1595	A
DD6	15C30	126	.980*	640.1	33.0	19.397	1540	25	2464	A
DD7	18D72*	124	2.5822	1686.6	73.7	22.885	1410	25	2256	A
DD8	10IV72	D225 -5	2.3700	1548.0	69.7	22.209	1490	15†	3973	A
DD9	10III72		2.3700	1548.0	69.7	22.209				A
DD10	18D72	D225 -1	2.9810	1947.0	73.7	26.418	1270	15†	3387	A
DD11	18D72		2.9000	1894.1	73.7	25.700				A
DD12	18D72	D225 -2	2.9000	1894.1	73.7	25.700	1270	15†	3387	A
DD13	18D72		2.9000	1894.1	73.7	25.700				A
DD14	4D30*	915	.5390	352.1	32.0	11.003	765	15	2040	A
DQ5	—	—	—							—
DS212	4Q16	211	—	23.2	18.0	-1.286	116	8	580	B
DQ6	—	—	—							—
DQ7	5Q36	152	—	151.3	38.5	3.931	960	12	3200	A
DS268	—	—	—							—
DQ8	5Q48	74-1	—	228.8	49.5	-4.622	920	21†	1752	B
DQ9	5Q36	158	—	50.5	38.5	1.311	320	12	1067	A
DQ10	—	—	—							—
DQ11	—	—	—							—
DQ12	—	—	—							—

* = trimmed

* Bend in magnet plane. Horizontal projection = 0.8660°

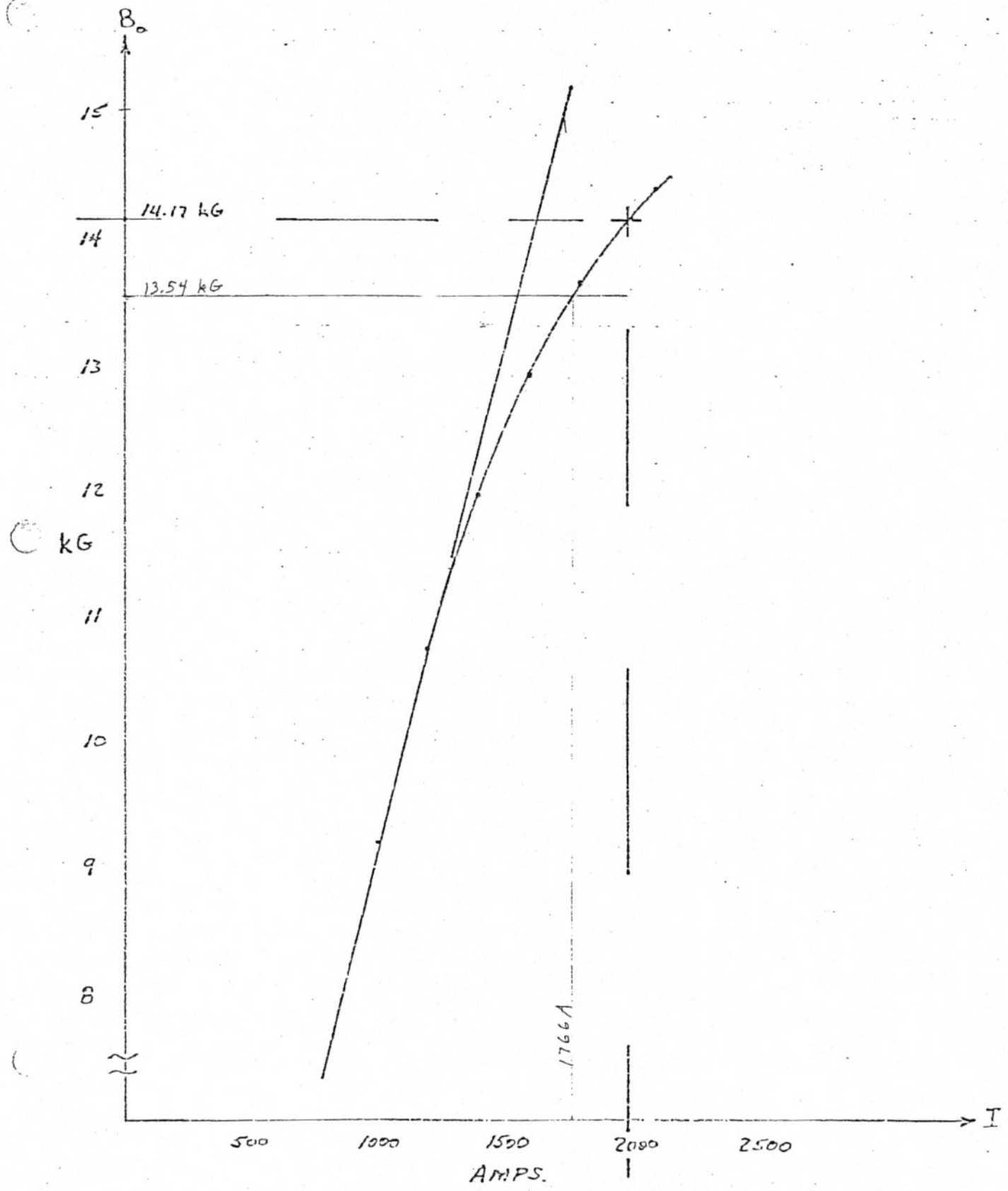
† These P.S.'s have D.C. current transducers equivelent to shunts listed.

BROOKHAVEN NATIONAL LABORATORY

BY R. L. Beaver DATE 10/14/80 SUBJECT DD5 & DD4 SHEET No. ____ OF ____

CHKD. BY ____ DATE ____ EXTRA COIL ADDED JOB No. ____

DEPT. OR PROJECT ____



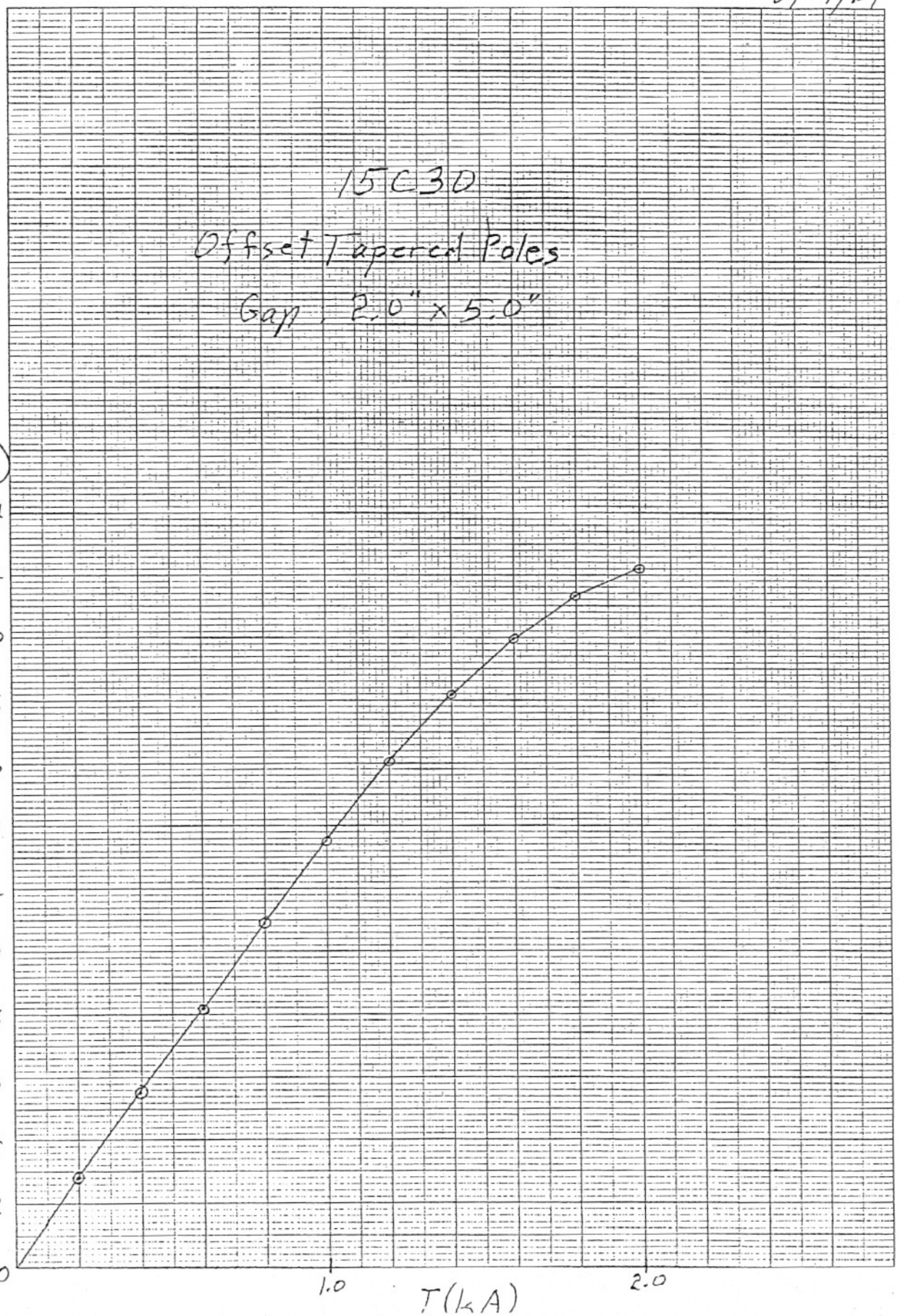
DD 6

8/21/81

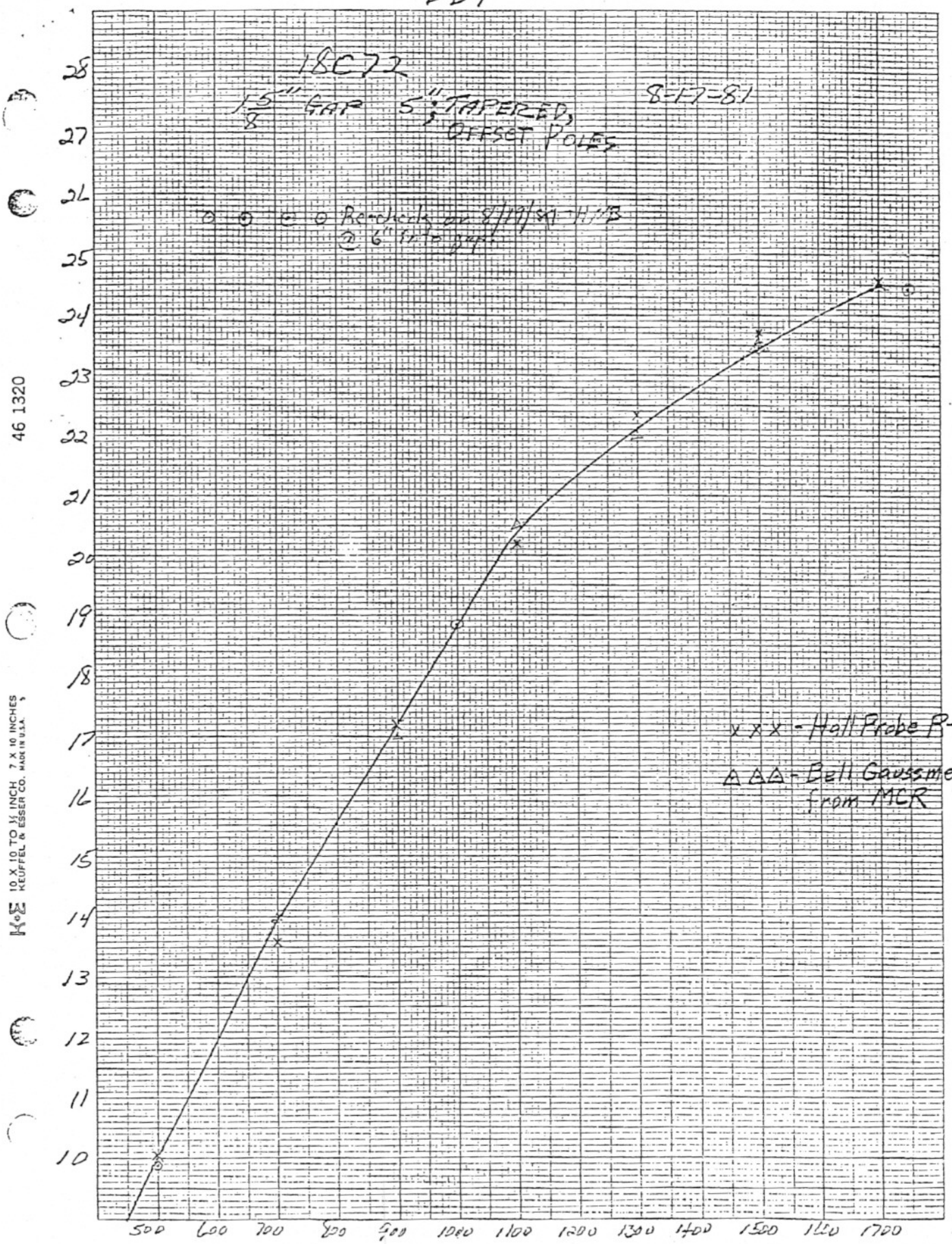
15C30

Offset Tapered Poles

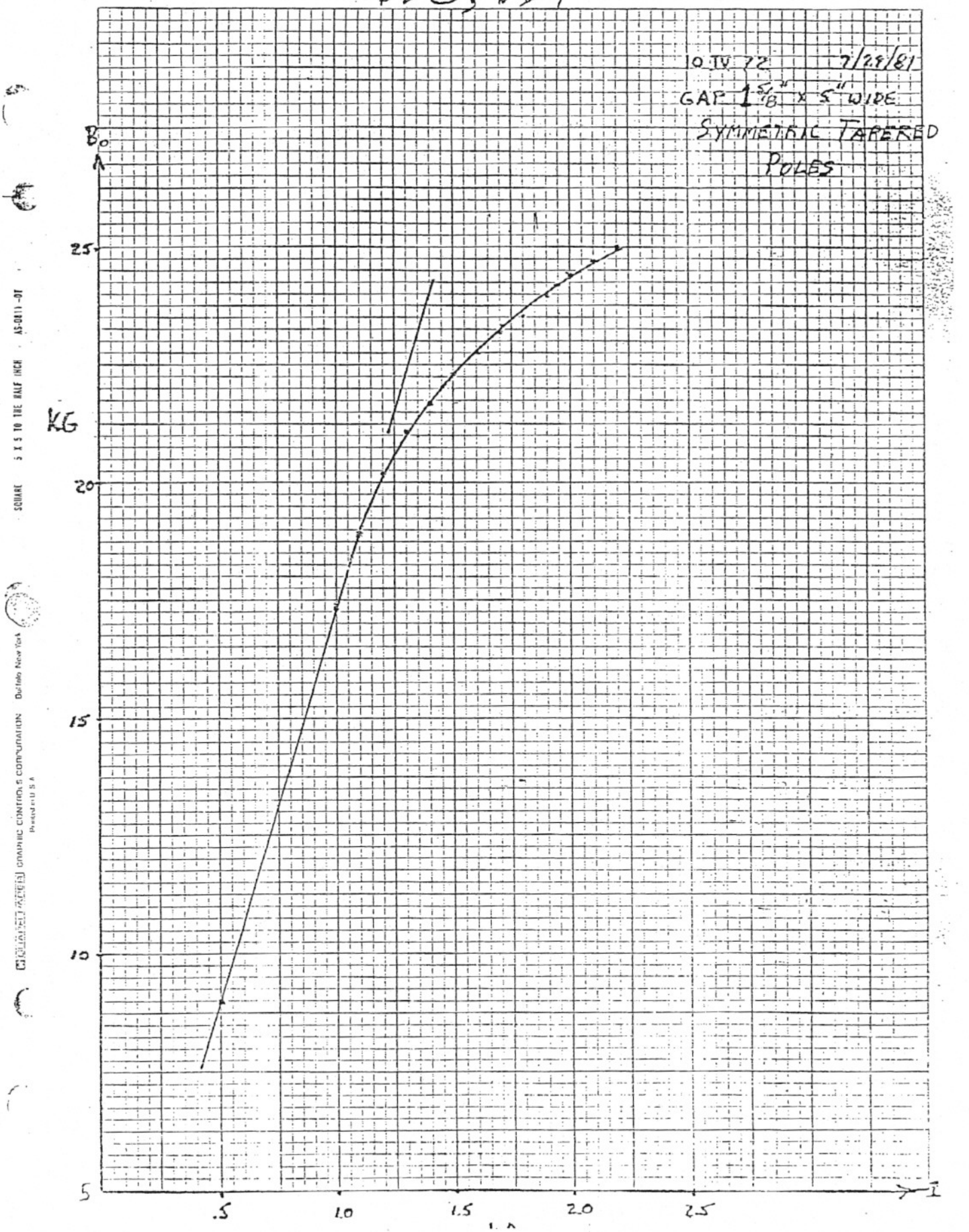
Gap : 2.0" x 5.0"



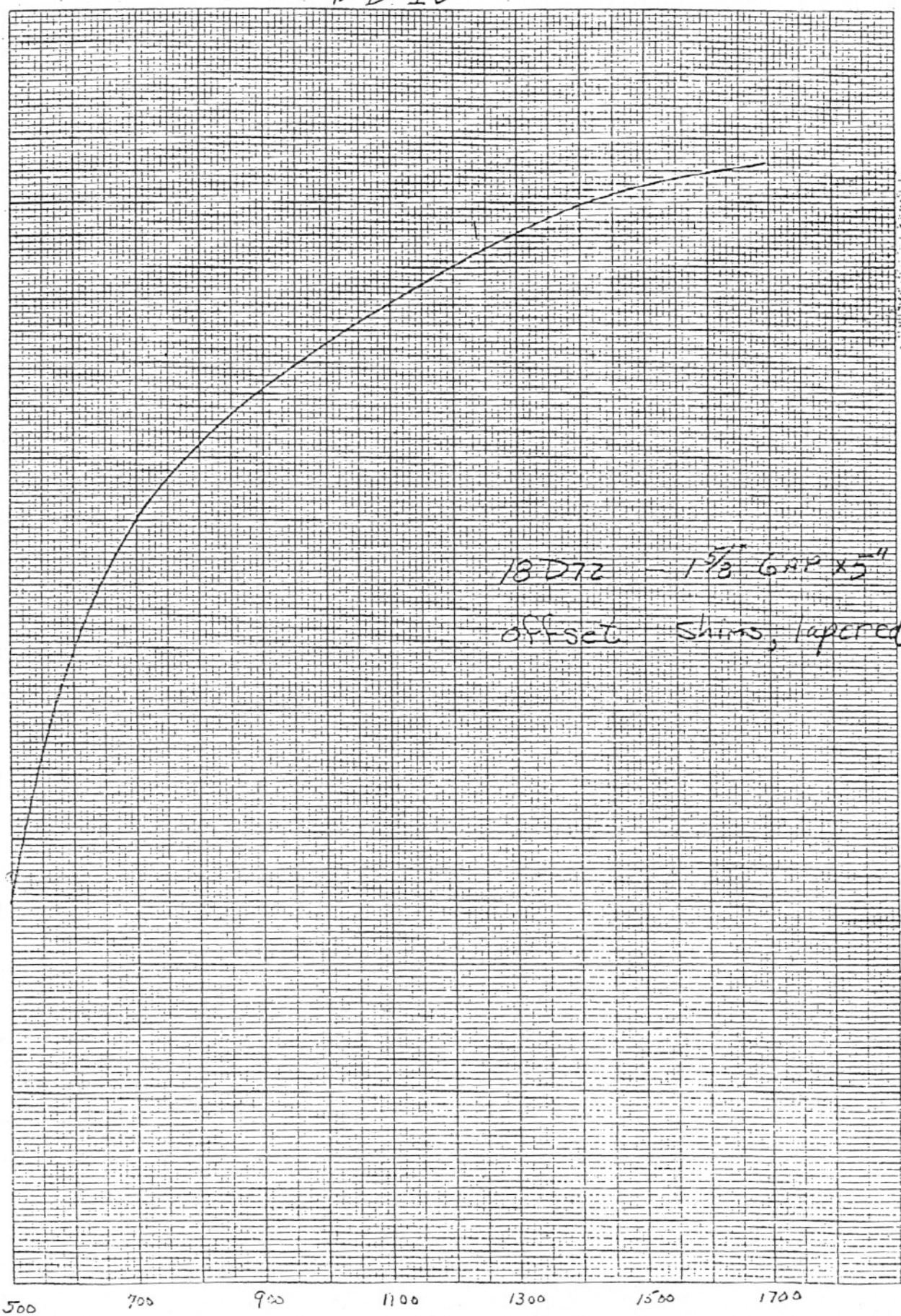
DD7


18C72
1 5/8" GAP 5" TAPERED, 1/2 OFFSET POLES
8-17-81
Readouts on 8/19/81 H.W.B
@ 6" to gap
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
x x x - Hall Probe R-40
Δ Δ Δ - Bell Gaussmeter from MCR
46 1320
10 X 10 TO ½ INCH 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

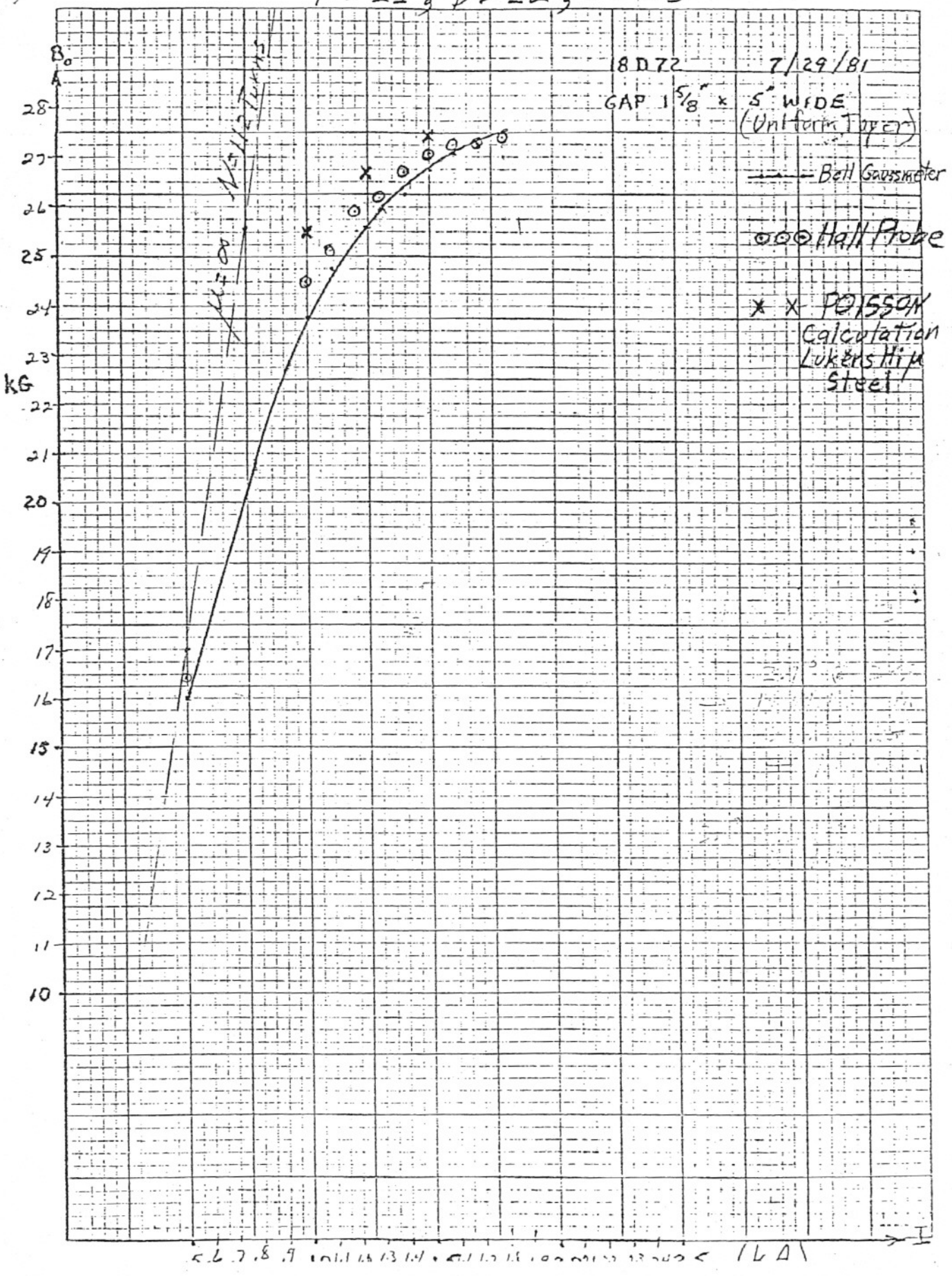
DD8, DD9



DD 10



DD11, DD12, DD13



BY KJ Brown DATE 10/21/80 SUBJECT DD14

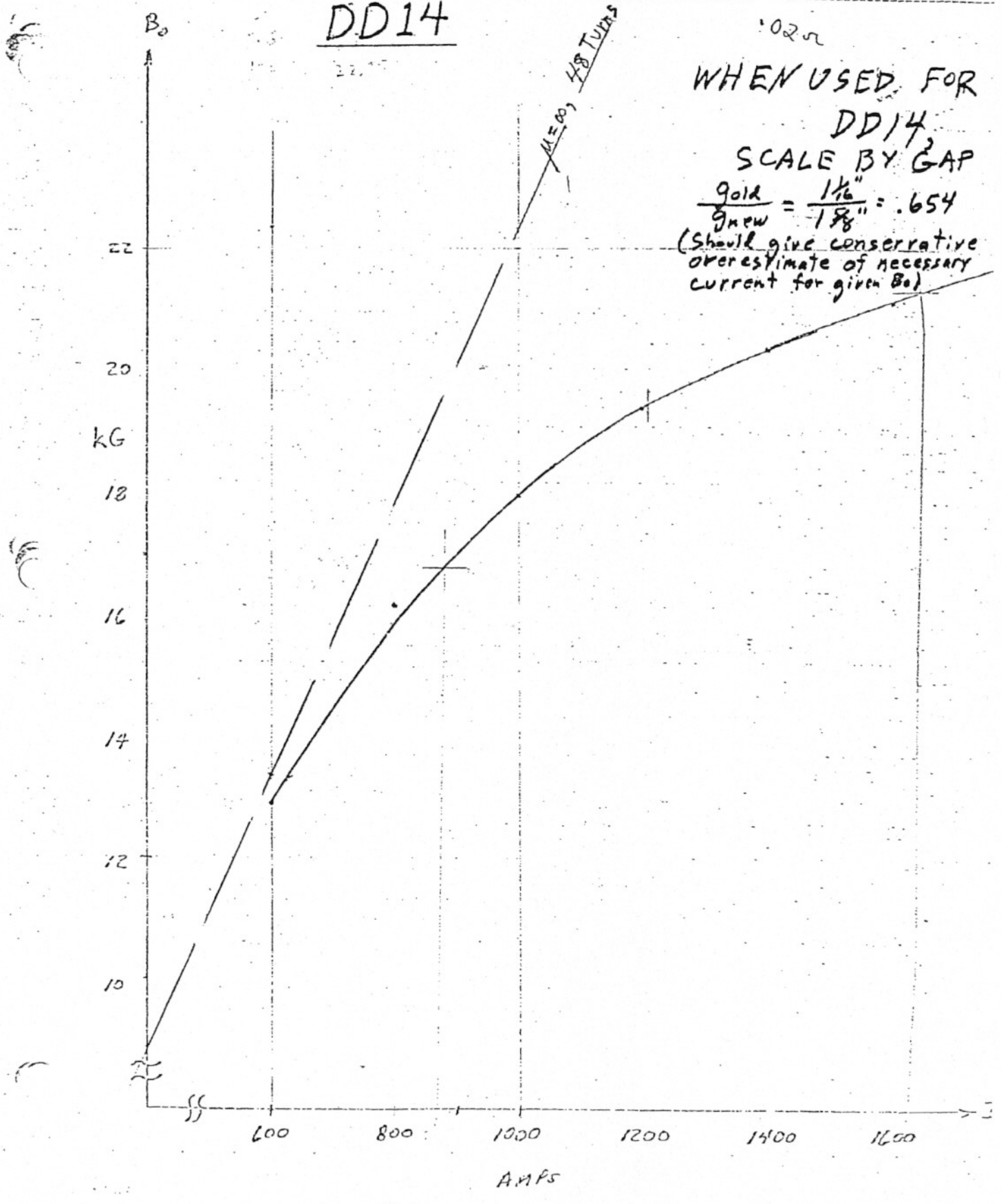
CHKD. BY _____ DATE _____ 3×4 D30 SHIMED 1 1/16" GAP

DEPT. OR PROJECT _____

SHEET NO. _____ OF _____

JOB NO. _____

DD14



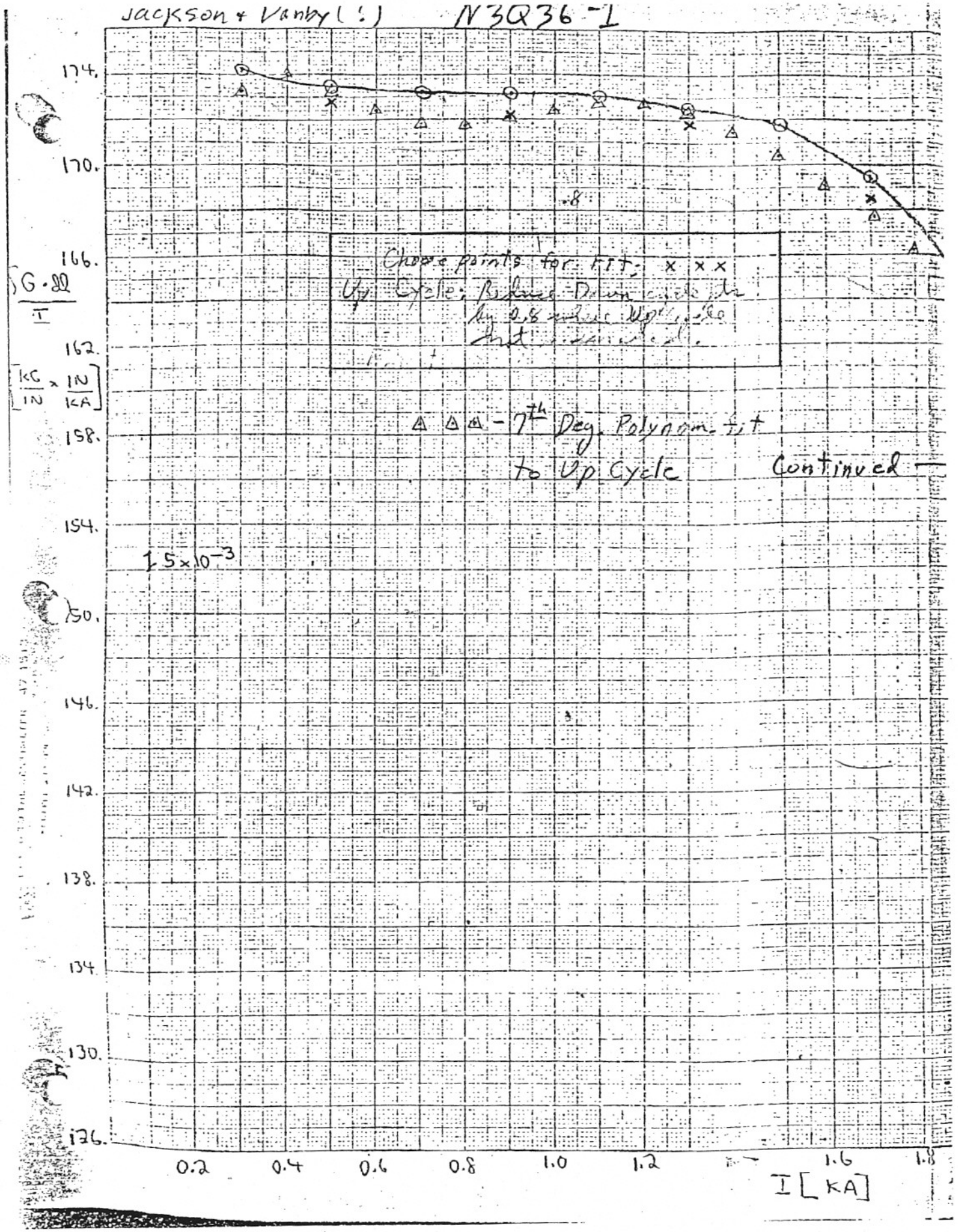
WHEN USED FOR DD14

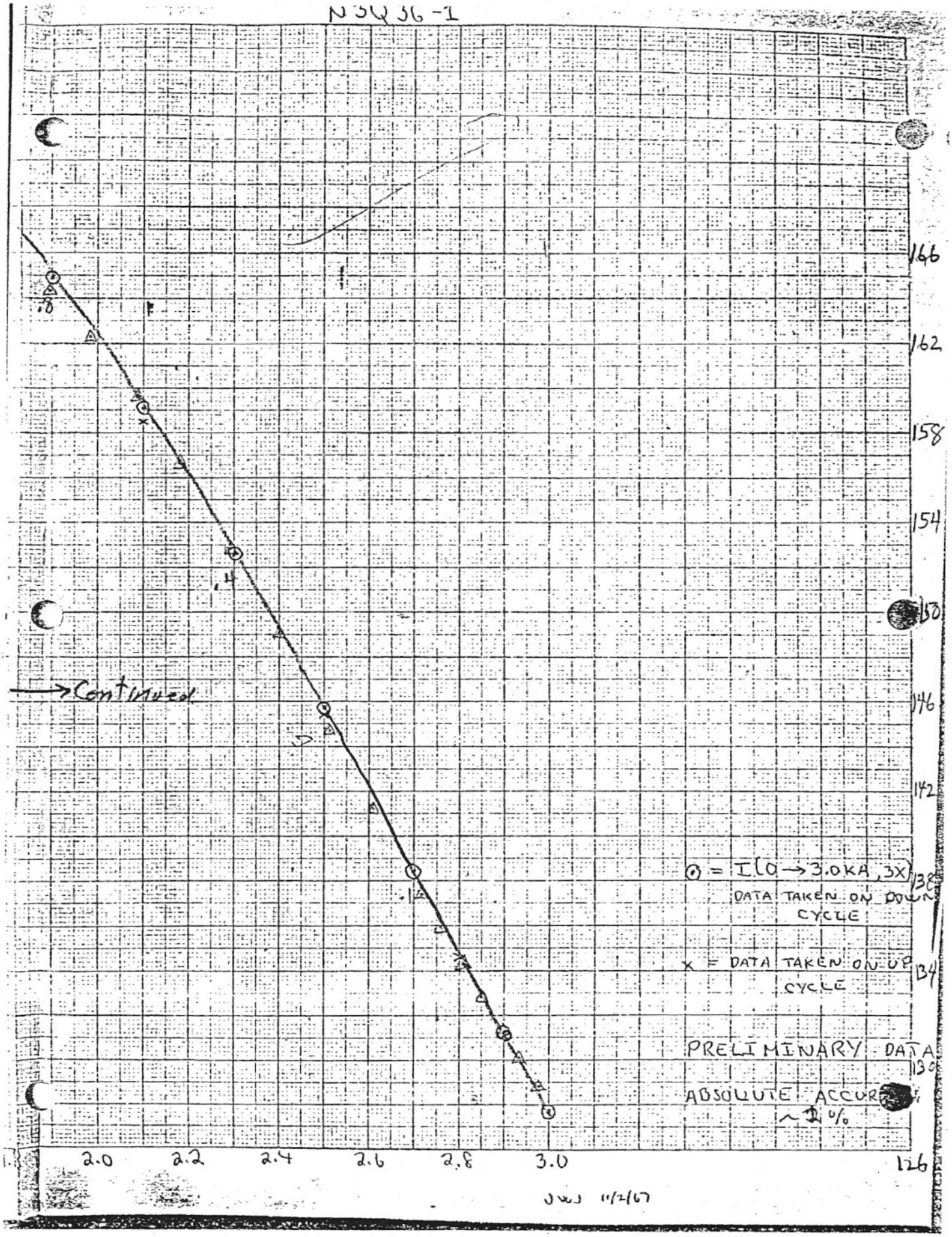
SCALE BY GAP

$\frac{g_{old}}{g_{new}} = \frac{1\frac{1}{16}"}{1\frac{7}{8}"} = .654$

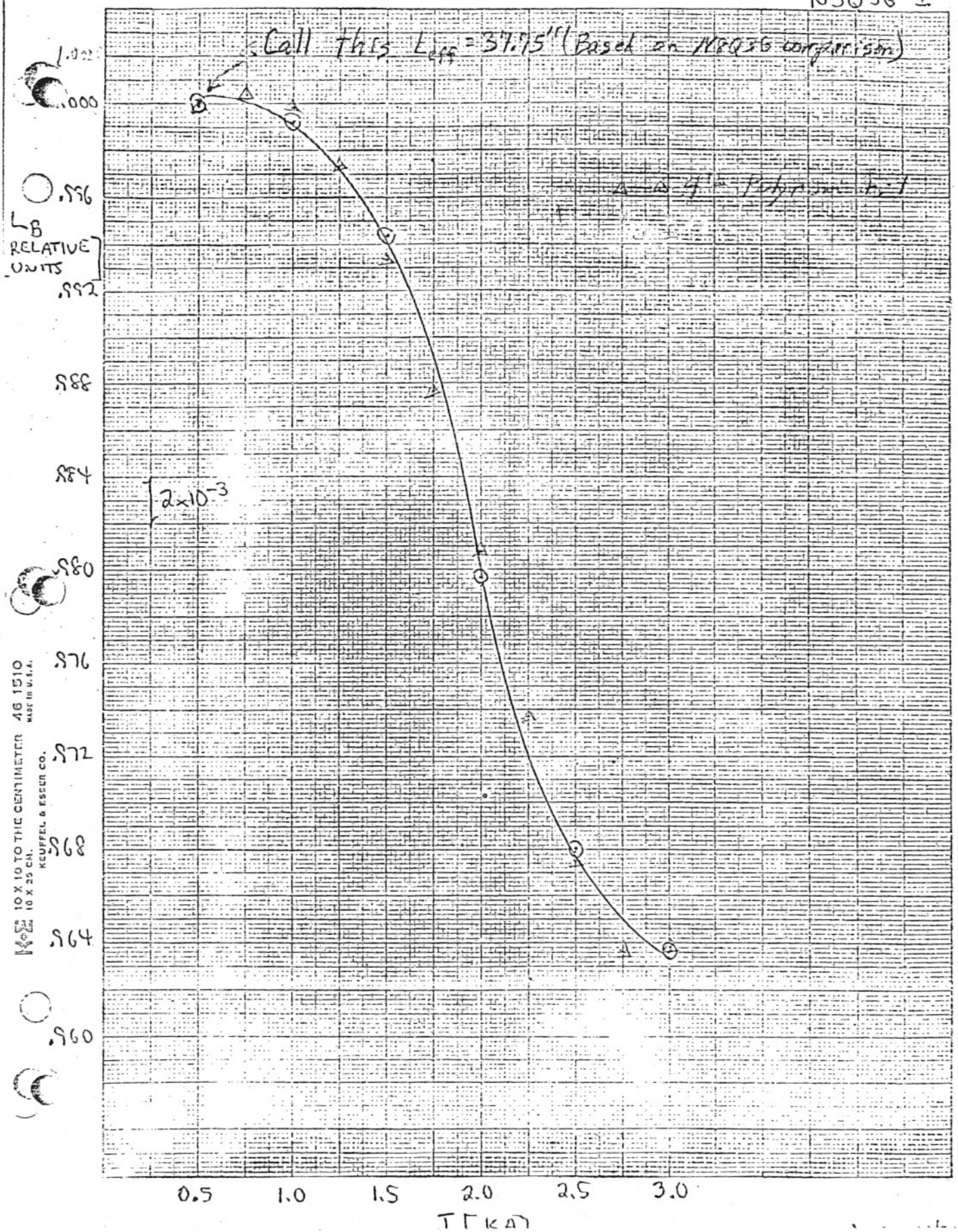
(Should give conservative overestimate of necessary current for given B_o)

Jackson + Vanby (?) N3Q36-1



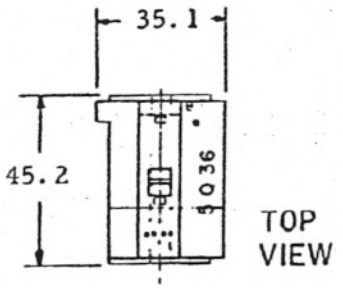

N3Q36-1
166
162
158
154
150
146
142
138
134
130
126
2.0
2.2
2.4
2.6
2.8
3.0
→Continued
⊙ = I[0→3.0KA, 3X]
DATA TAKEN ON DOWN CYCLE
X = DATA TAKEN ON UP CYCLE
PRELIMINARY DATA
ABSOLUTE ACCUR
~1%
JWJ 11/2/67

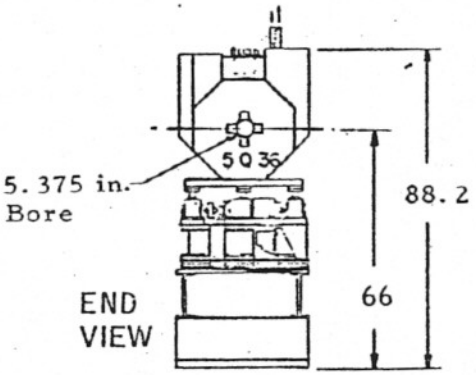
N3036-1



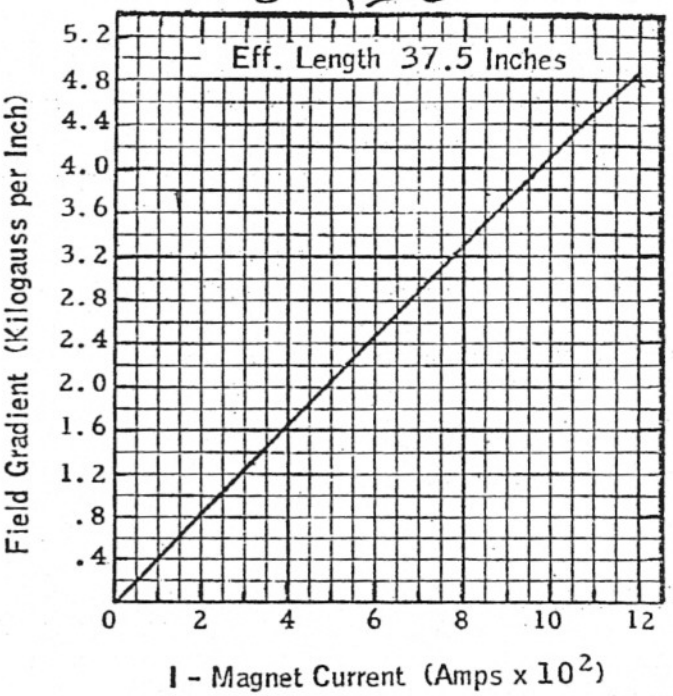
5 Q 36 (QM 103) QUADRUPOLE MAGNET

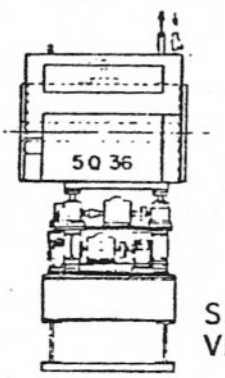
Gradient and Measured Data





5Q36





Total Weight: 3.5 Tons

Measured Data:

Voltage	122 Volts dc
Current	1200 Amps dc
Power	146 kW
Field Strength	13.0 kG

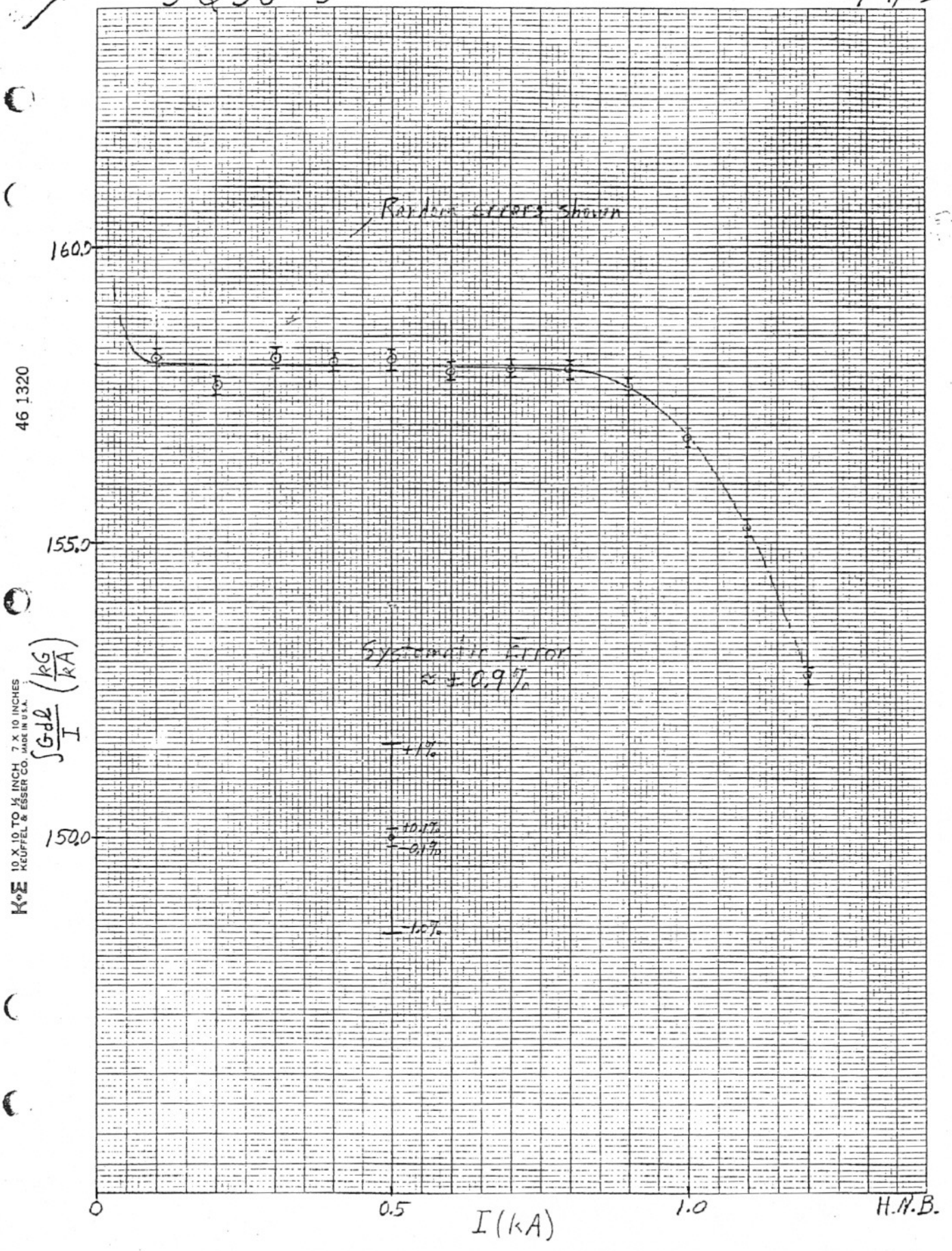
Cooling Water
(System Pressure Drop 200 psi)

No. of Circuits	24
Pressure Drop	75 psi
Flow	14 gpm
Temp. Rise	72°F

Current (Amps)	Terminal Voltage (Volts)	Gauss/ Inch
200	19	831
300	28	1244
400	38	1658
500	48	2075
600	58	2488
700	68	2907
800	78	3317
900	90	3724
1000	101	4116
1100	112	4489
1200	122	4832
Errors	± 2%	+1 to +3%

5Q36-5

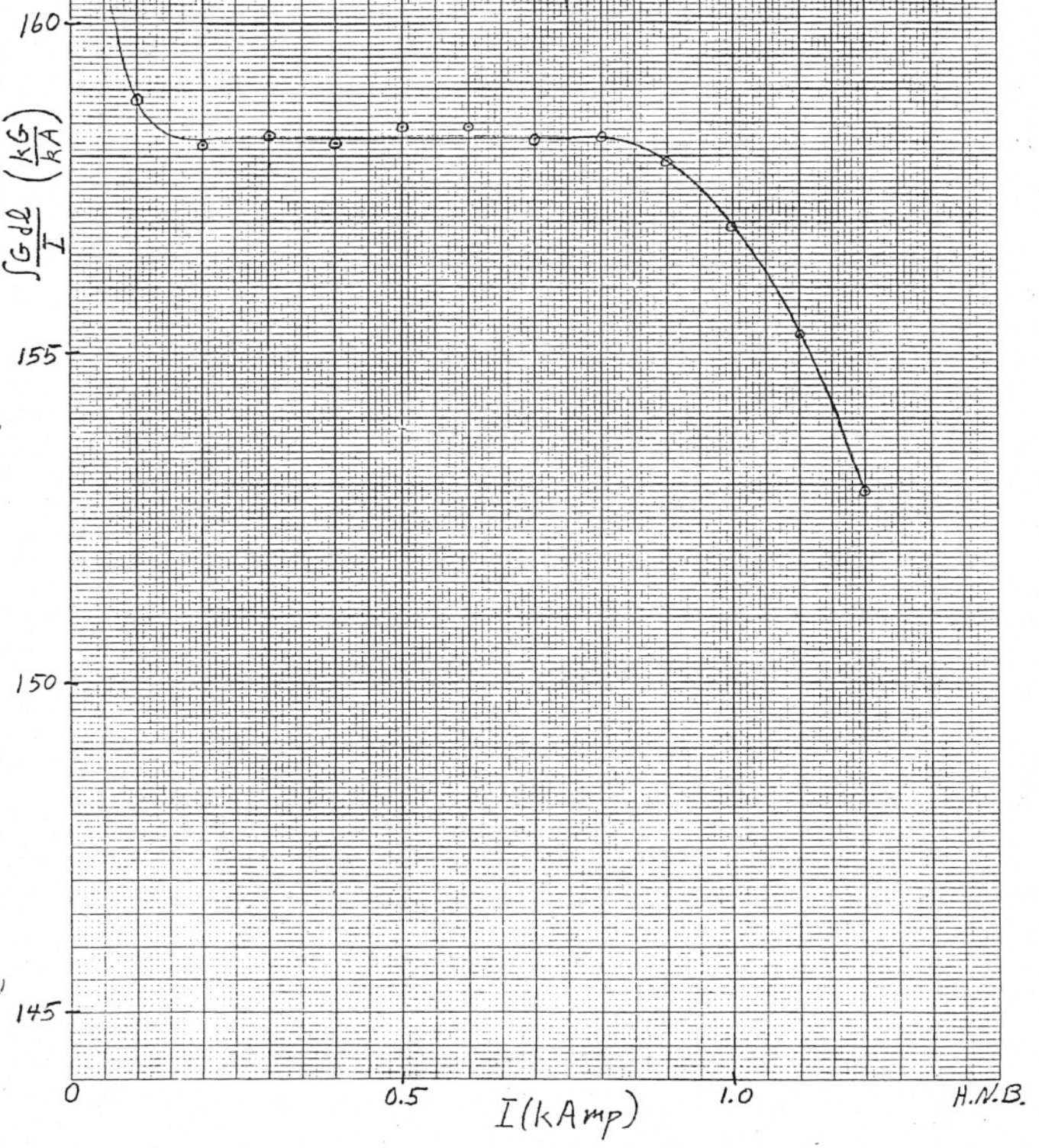
6/29/83


Random errors shown
160.0
155.0
150.0
Systematic Error
≈ ±0.9%
+1%
±0.1%
±0.1%
-1.0%
0
0.5
1.0
I (kA)
H.N.B.
$\int \frac{G\,dl}{I}\left(\frac{kG}{kA}\right)$
46 1320
K&E 10 X 10 TO ½ INCH 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

5Q36-6

7/22/83

Errors same as for 5Q36-5 (6/27/83)



46 1320
10 X 10 TO ½ INCH 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.