Alternating Gradient Synchrotron Department
BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, New York 11973

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.

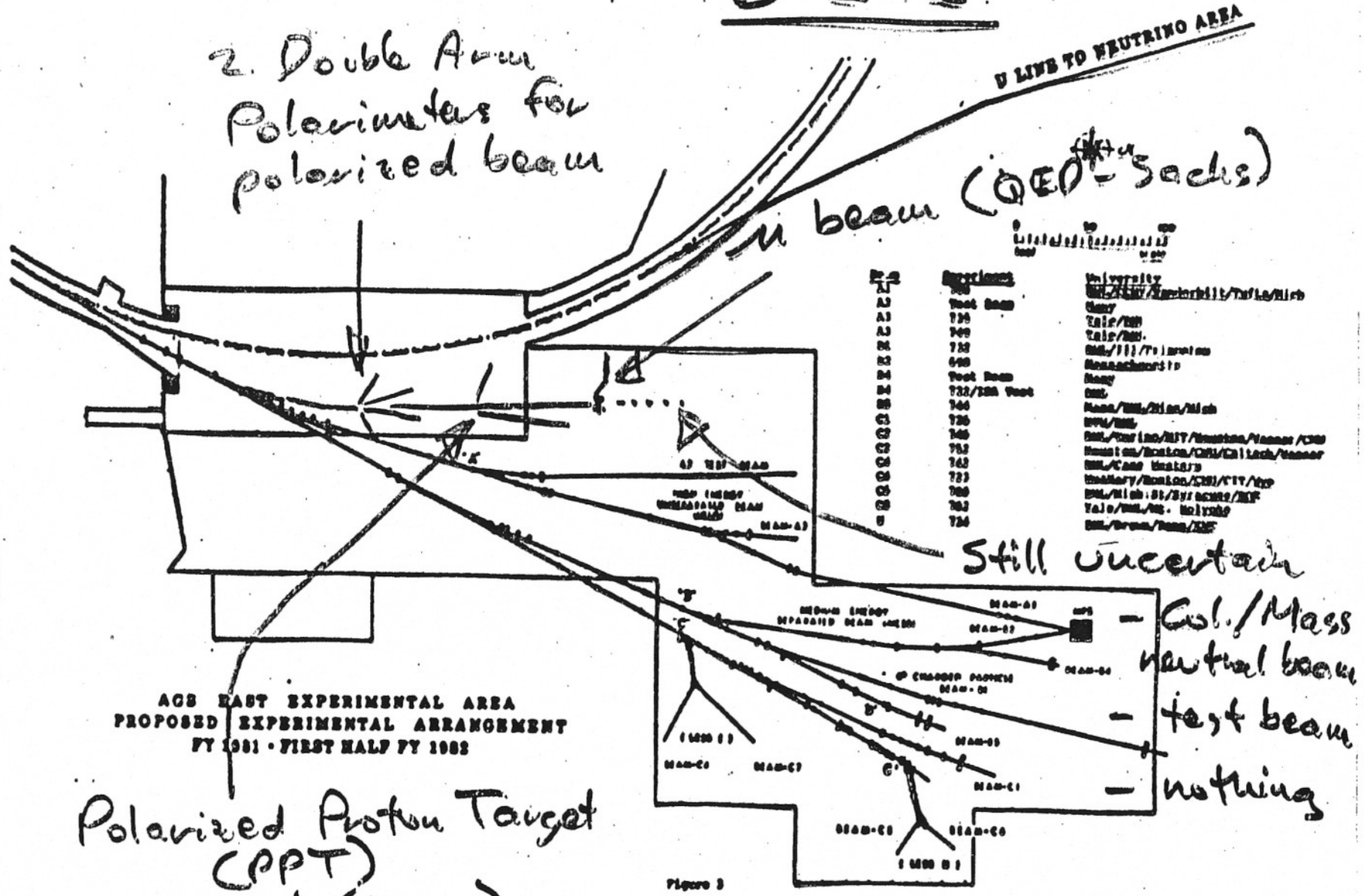
After the switchyard the D beam points upward 8 mrad and heads 3.9 degrees west of A. A further sharp 21 degree bend to the west steers the beam into the center of the Northwest Target Building. A 15D30 dipole shimmed to a 2" gap is rotated 20 degrees to bring D to horizontal and begin the west bend. 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 Polarimeter for polarized beam



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.)

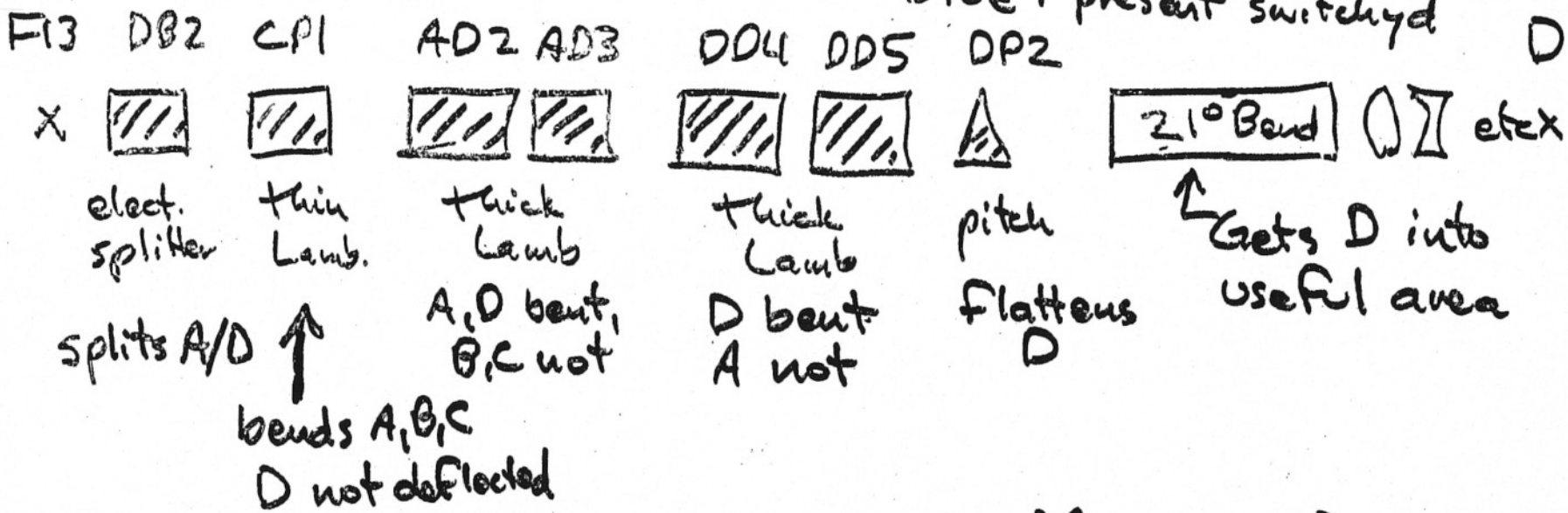
People

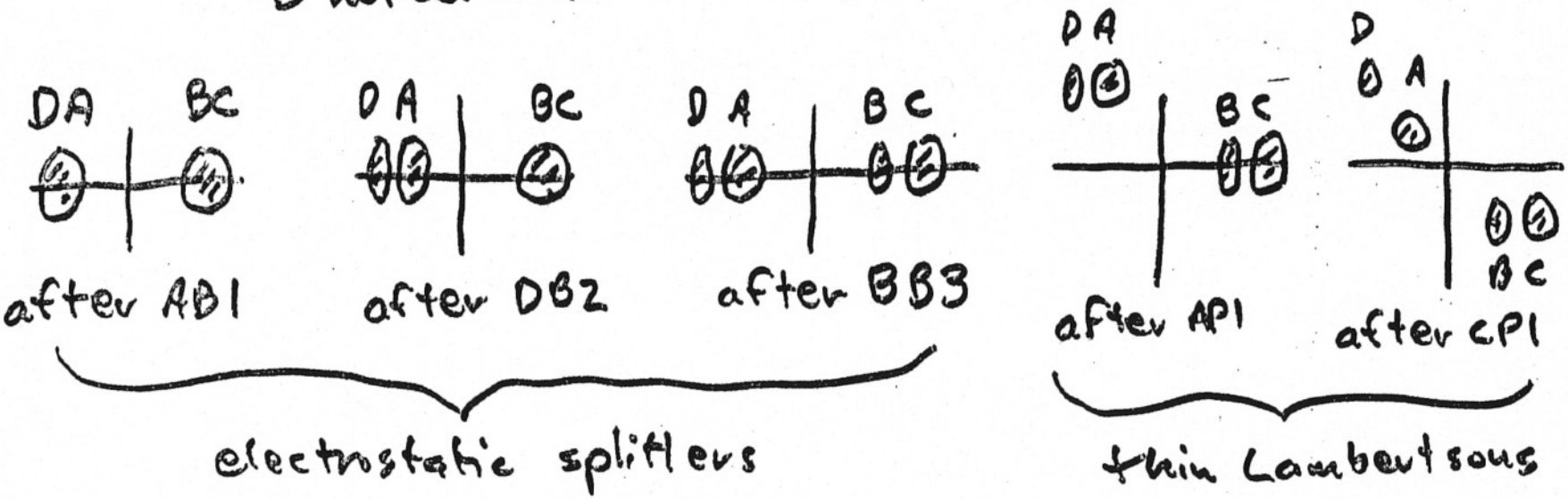
Ralph Brown
Hugh Brown
Al Pendzick
Me → G. Bunce

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

D Split

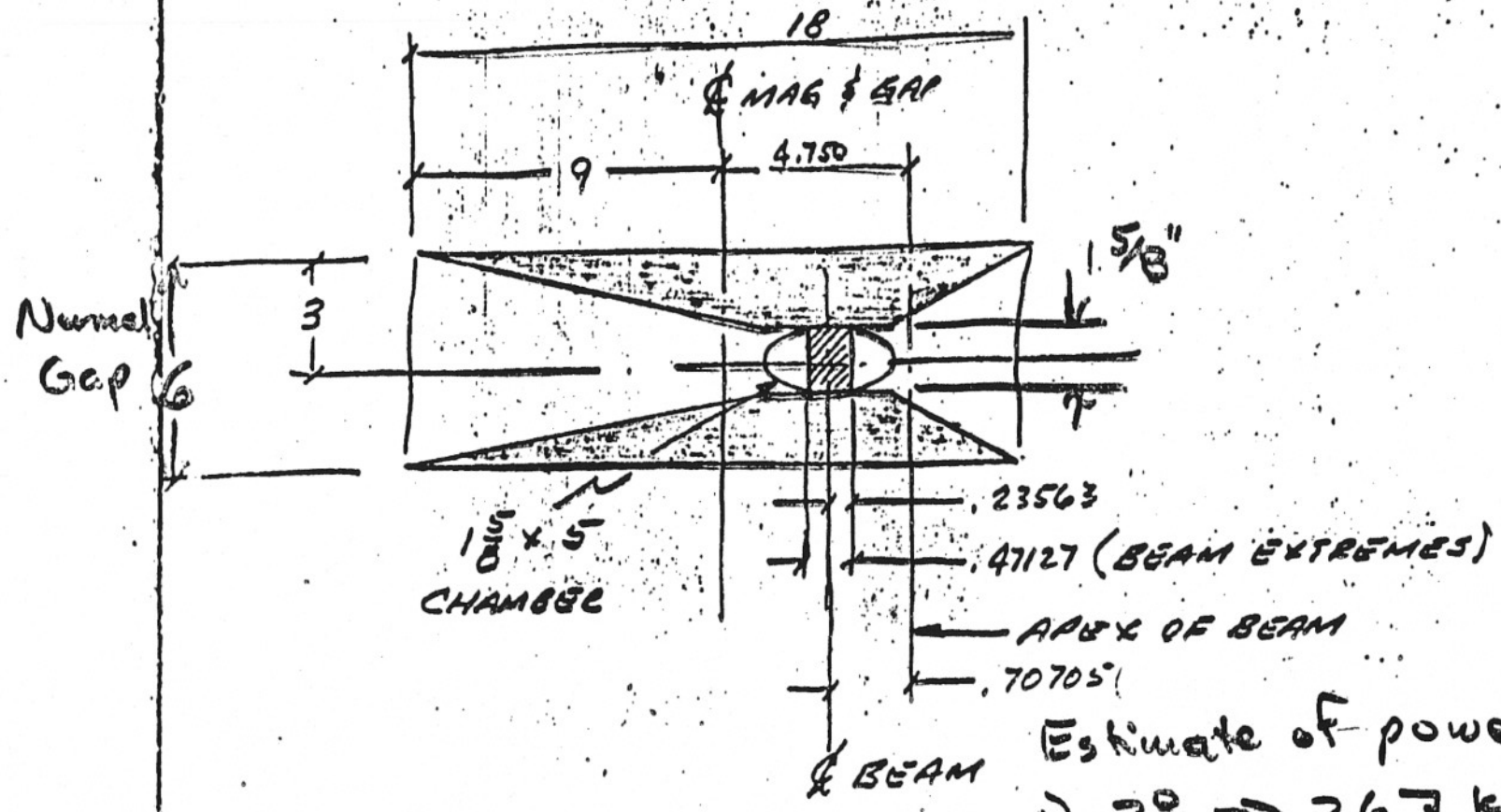
Green: exist, ~in place for D
Blue: present switched





D-Transport History

- need ~21° bend to come out ∥ to buildings; do it quickly so that line is not too close to edge of building
- 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</u> <u>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

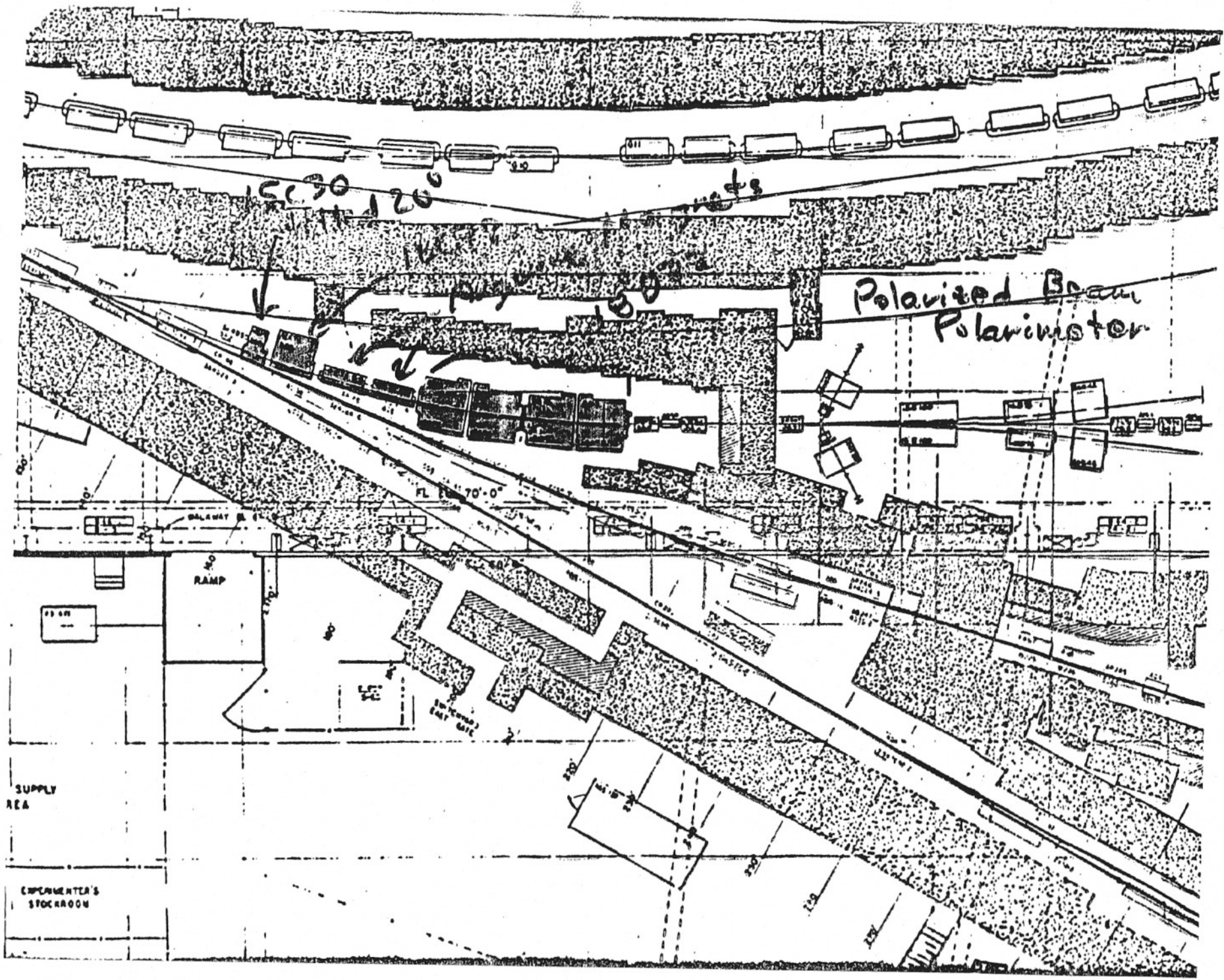
3) have 1" gap tapered data

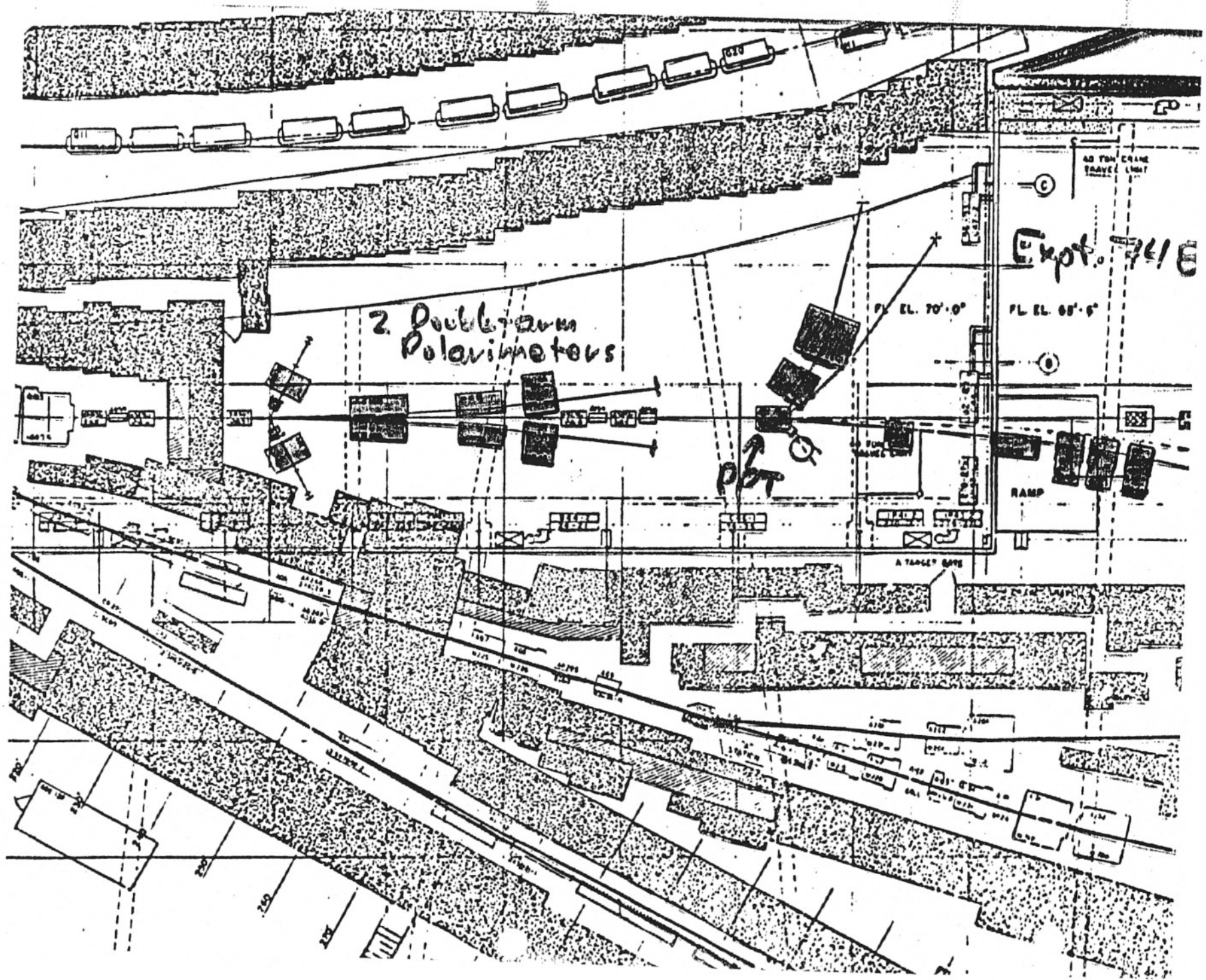
$I(1.5''g, 5''t) = I(1.5''g, no\ t) \times \frac{I(1'', 5''t)}{I(1'', no\ t)} = 1.06\,kA$

4) ⇒ power = 52 kl / 3°

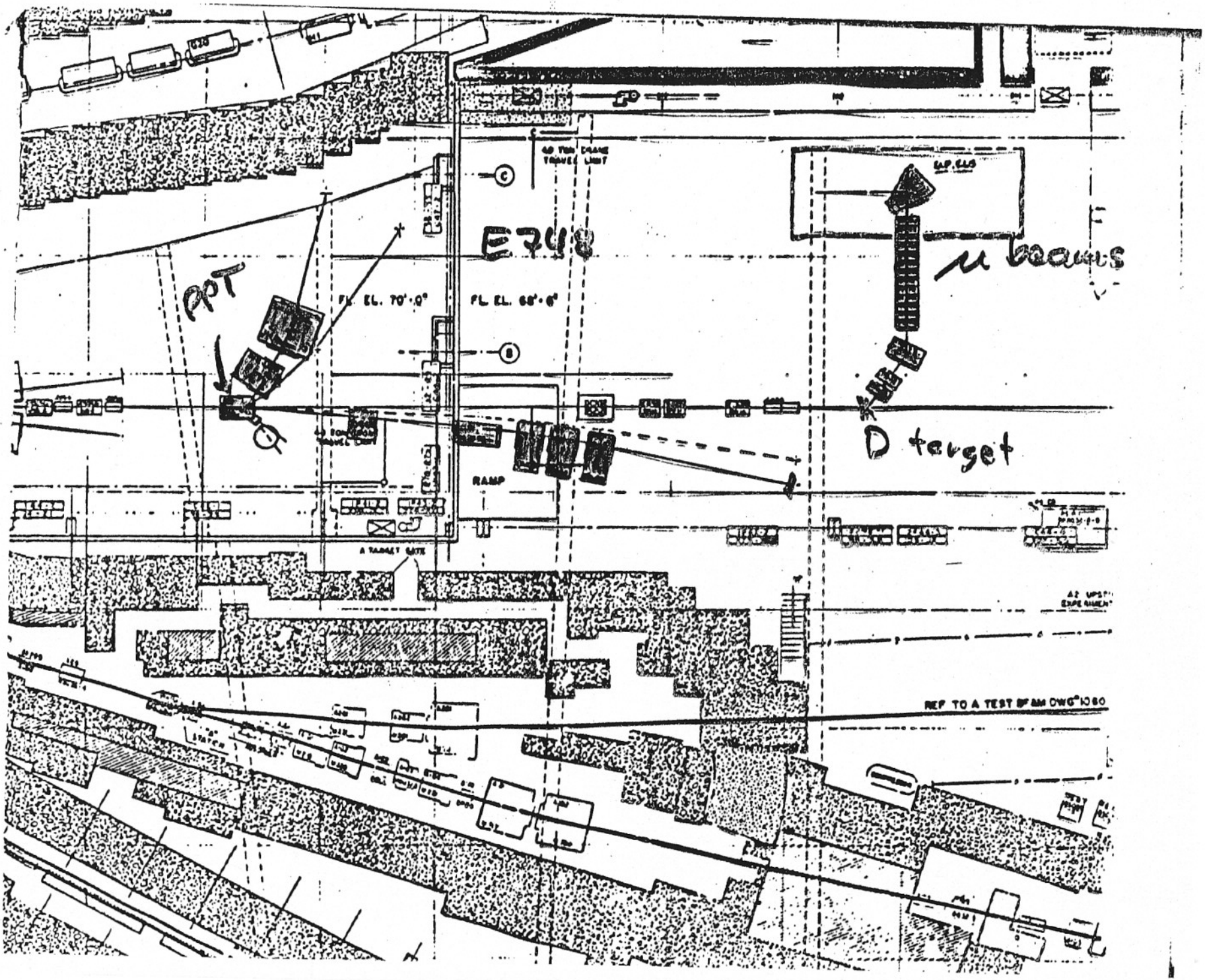
18D72 (DD10)
6 x 18 MAG GAP
LOOKING DOWNSTREAM

3-24-81

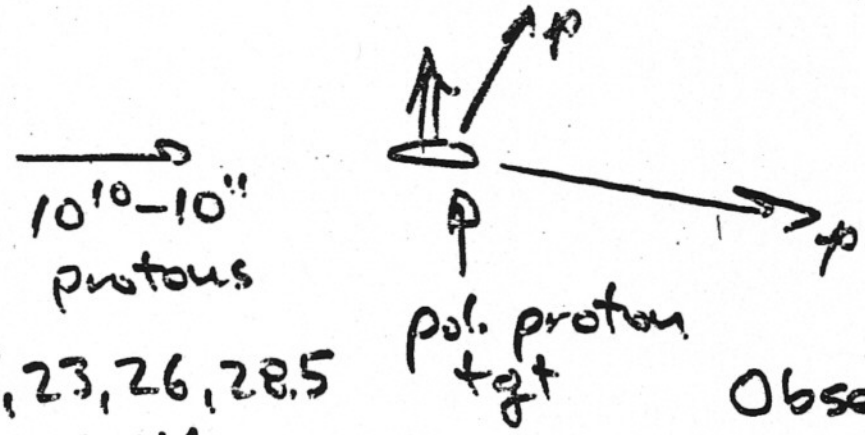

Polarized Beam
Polarimeter
RAMP
SUPPLY
AREA
EXPERIMENTER'S
STOCKROOM



Expt. 748
2 Double-arm Polarimeters
PPT
FL. EL. 70'-0"
FL. EL. 68'-6"
RAMP
A TARGET GATE


E748
μ beams
D target
PPT
FL. EL. 70'-0"
FL. EL. 68'-6"
RAMP
A TARGET GATE
REF TO A TEST BEAM DWG 1060

Experiments — PPT



elastic scatteri

15, 23, 26, 28.5
GeV/c

Observe (fixed $p_\perp$)

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

pol. of tgt

∴ get A
= analyzing power

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

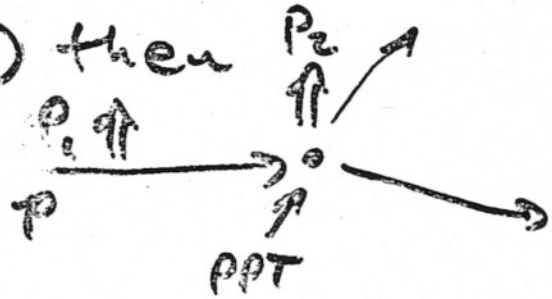
2) With A, one can reverse expt. to measure beam pol. (= polarimeter):

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

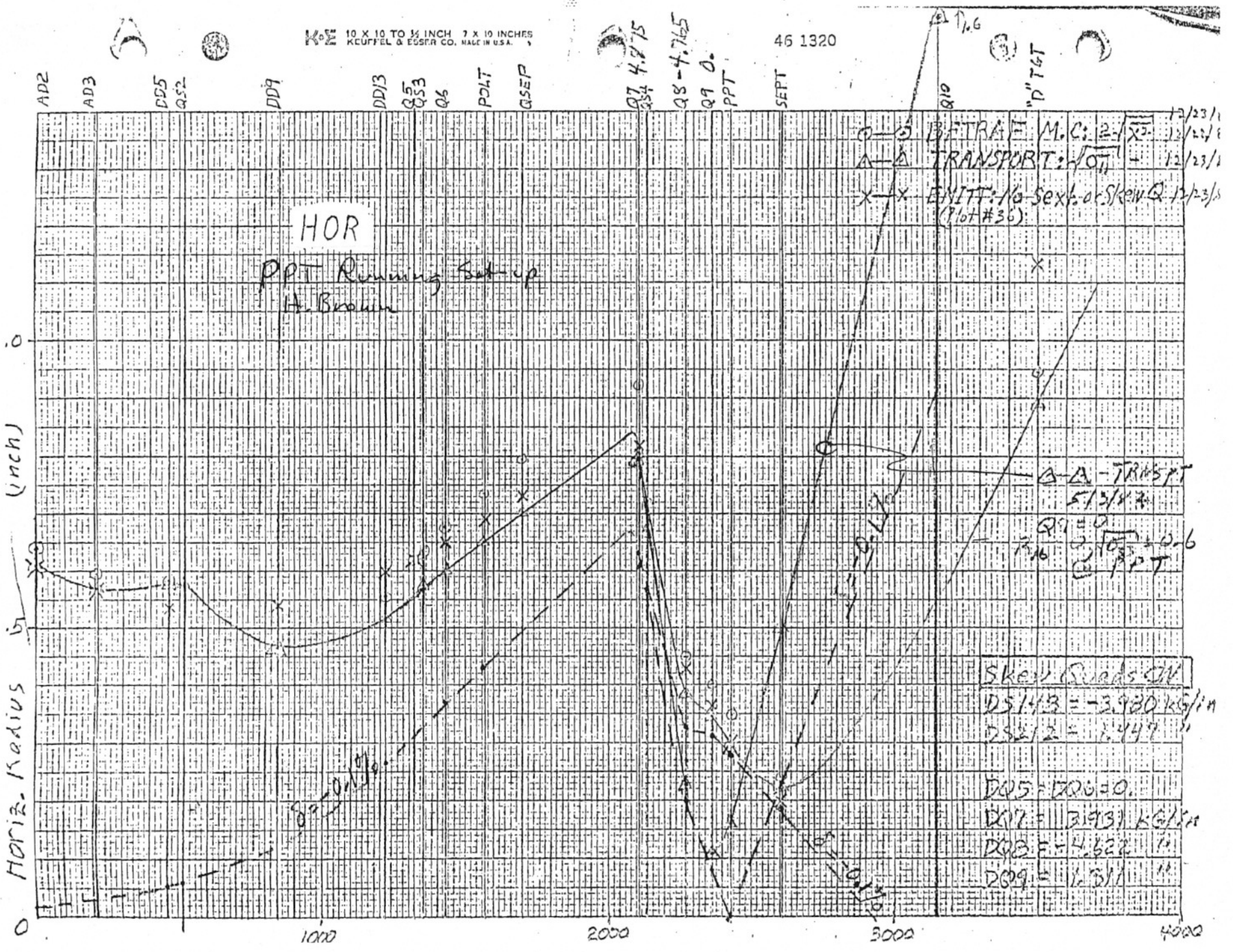
know from E748

now g
beam

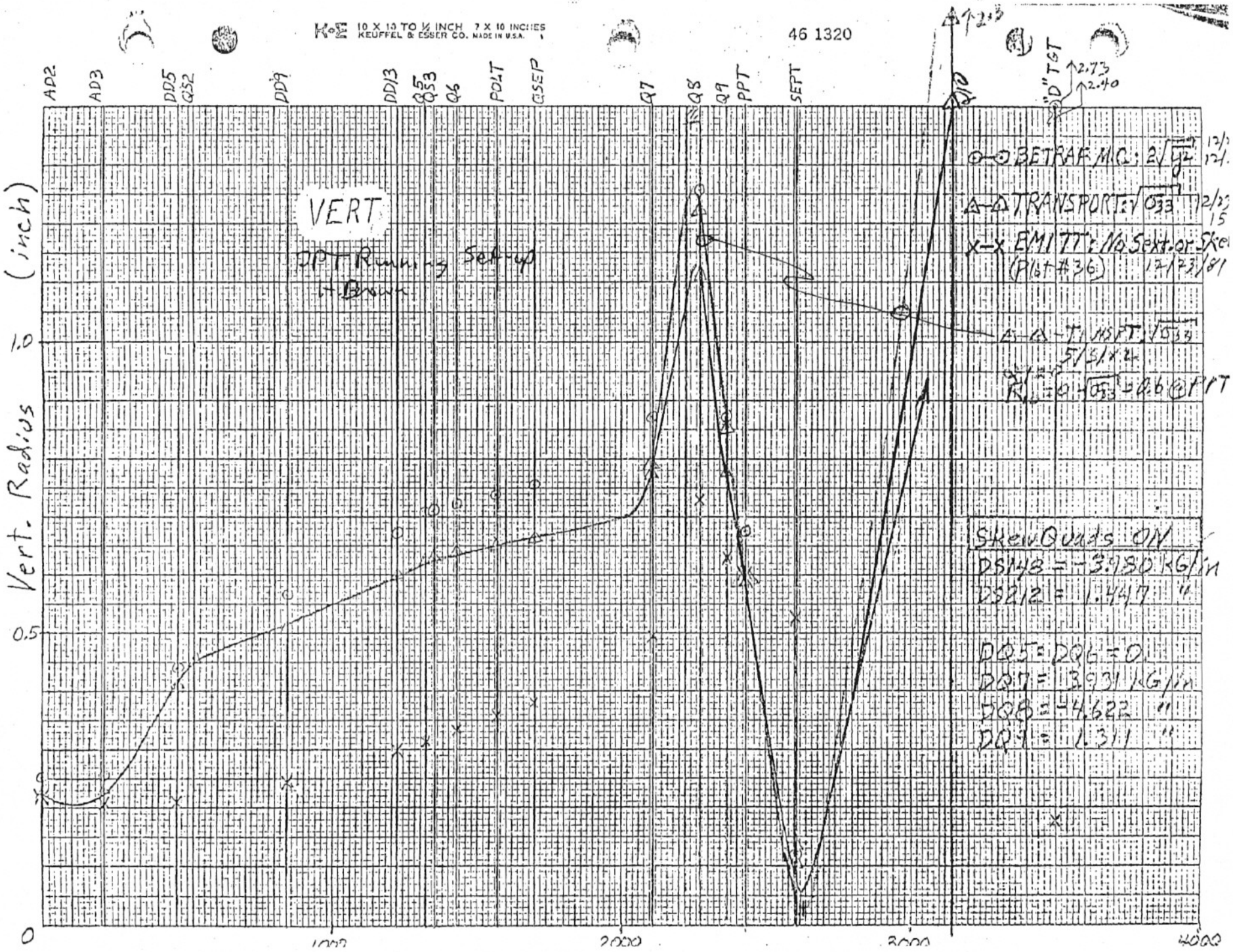
3) then



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



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.: 2√X²
TRANSPORT: √σ11
EMITT: No Sext. or Skew Q
(Plot #36)
TRNSPT
5/3/87
Q9 = 0
PPT
Skew Quads ON
DS143 = -3.980 kG/in
DS212 = 1.447 "
DQ5 = DQ6 = 0.
DQ7 = 3.931 kG/in
DQ8 = -4.622 "
DQ9 = 1.311 "
Horiz. Radius (inch)
.0
.5
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
POLT
QSEP
Q7
Q8
Q9
PPT
SEPT
Q10
"D" TGT
2.73
2.40
VERT
DPT Running Set-up
H. Brown
Vert. Radius (inch)
1.0
0.5
0
1000
2000
3000
4000
BETRAF M.C.: 2√y²
TRANSPORT: √σ33
EMITT: No Sext. or Skew
(Plot #36) 12/23/81
TRANSPT: √σ33
5/3/82
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 Cum Cnts				Pol.
	DD4	13.537	94.	1766	21†	3364				A
	DD5	13.537	94.	1766						A
QS2	DS148	3.538	18.	319	8	1595				A
	DD6	19.397	33.	1540	25	2464				A
	DD7	22.885	73.7	1410	25	2256				A
	DD8	22.209	69.7	1490	15†	3973				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
N3Q36	DQ5	0.	37.5	0.	15	0.				—
QS3	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	49.5	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.

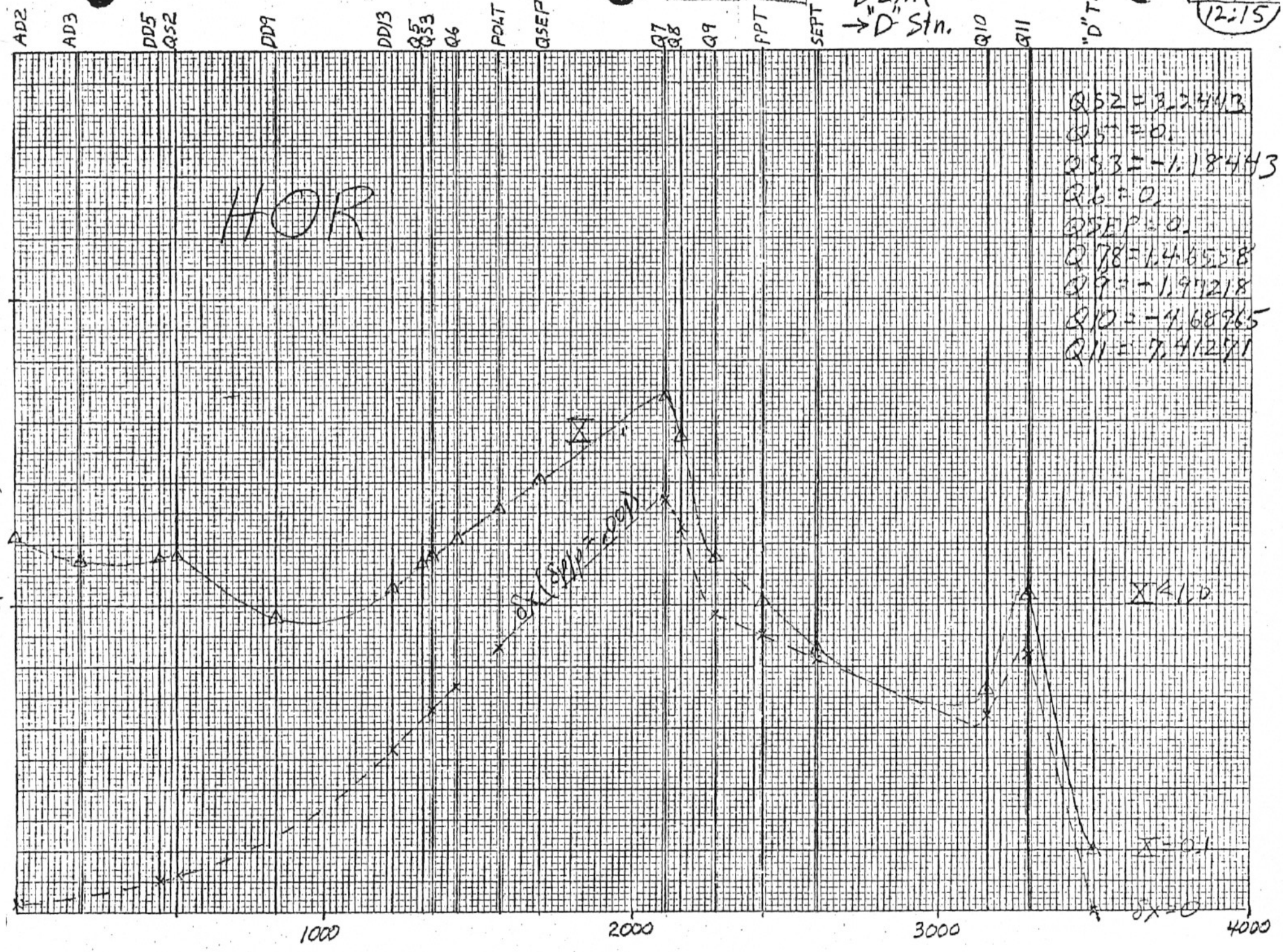
LITHOGRAPHED IN U.S.A. - ADDISON-WESLEY PUBLISHING COMPANY, INC., READING, MASS. A-W Datagram → 10FLV

K+E 10 X 10 TO ½ INCH 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

TRANSPORT 46 1320

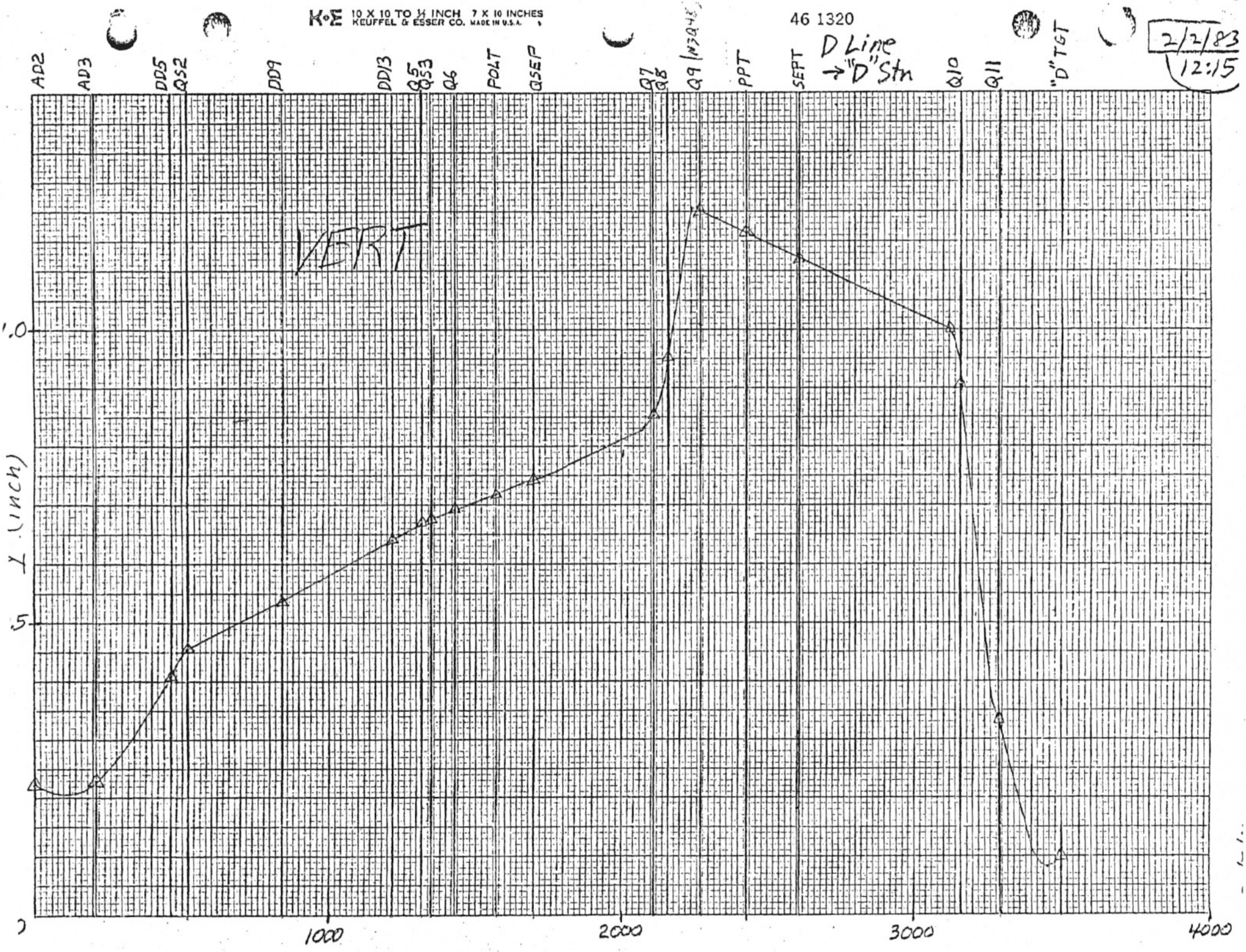
D Line
→ "D" Stn.

2/2/03
12:15



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

2/2/83
12:15



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
F-13		28.9441°	28°56'29"		9810.24	115160.849
CD1	15C30-1	-.6879°	-0°41'17"	161."		
		28.2535°				
CQ1	N3Q36-6			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."		
		28.1962°				
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	3.5X7D92-1A	-1.9890°	-1°59'21"	500.38"		
		26.2072°				
AD3	3.5X13D92-1	-1.9026°	-1°54'10"	118.021"		
		24.3046°				
DD4	3.5X13D92-2	-1.9482°	-1°56'54"	135.001"		
		22.3564°				
DD5	3.5X13D92-3	-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

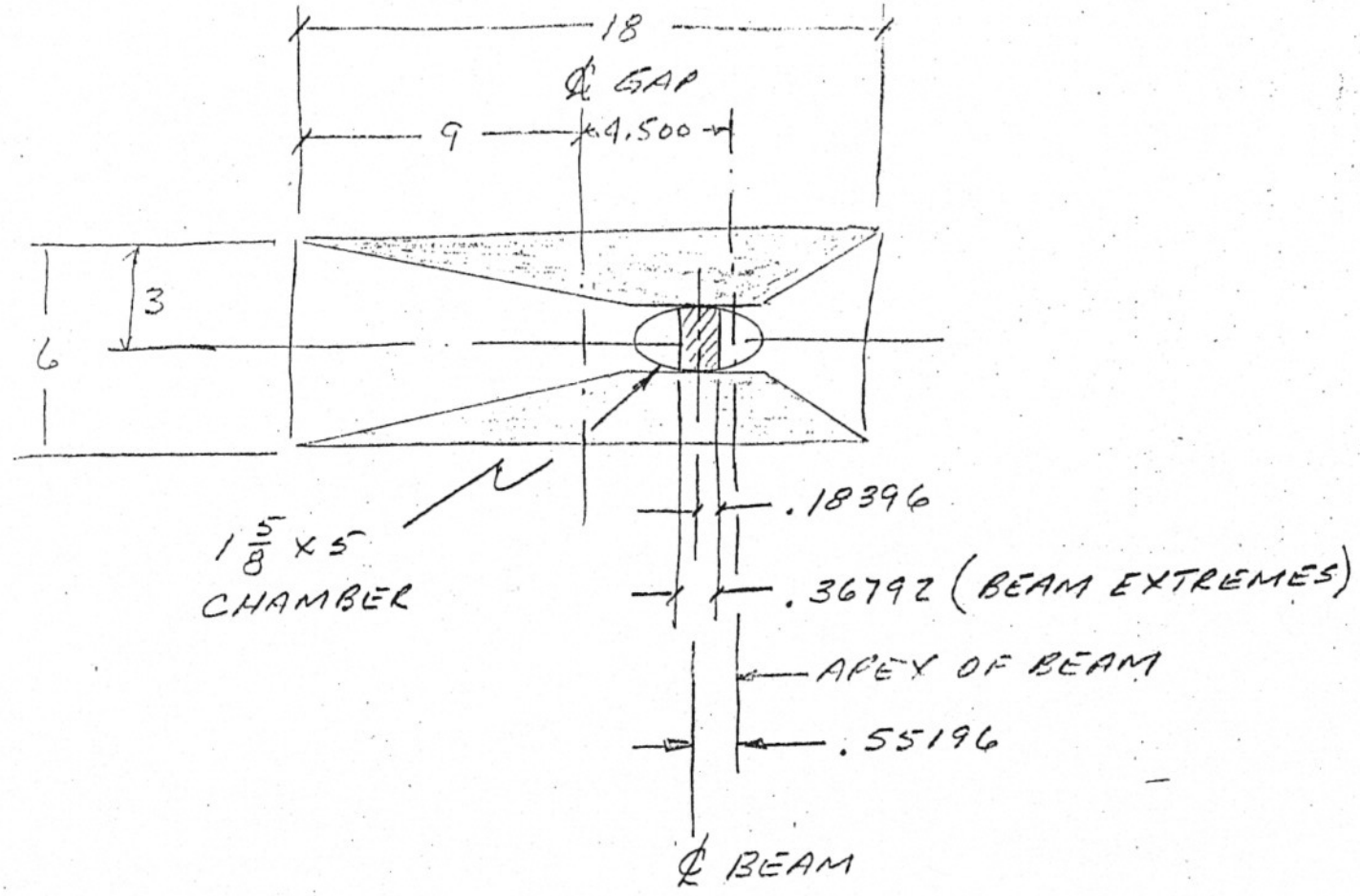
REF. D'W'G. NOS. BY R.L.M. ORIG.

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	18C72-	-2.34218°	-2°20'32"	70."		
Left	72+1.5 73.5	17.2°				
DD8	10C72-	-2.6°	-2°36'	91."		
		14.6°				
DD9	10C72-	-2.6°	-2°36'	89."		
		12.0°				
DD10	M7	-3.°	-3°	90."		
		9.0°				
DD11	M7	-3.	-3°	96."		
		6.0°				
DD12	M7	-3.	-3°	90."		
		3.0°				
DD13	M7	-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-					"
	3X4D30				-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	"

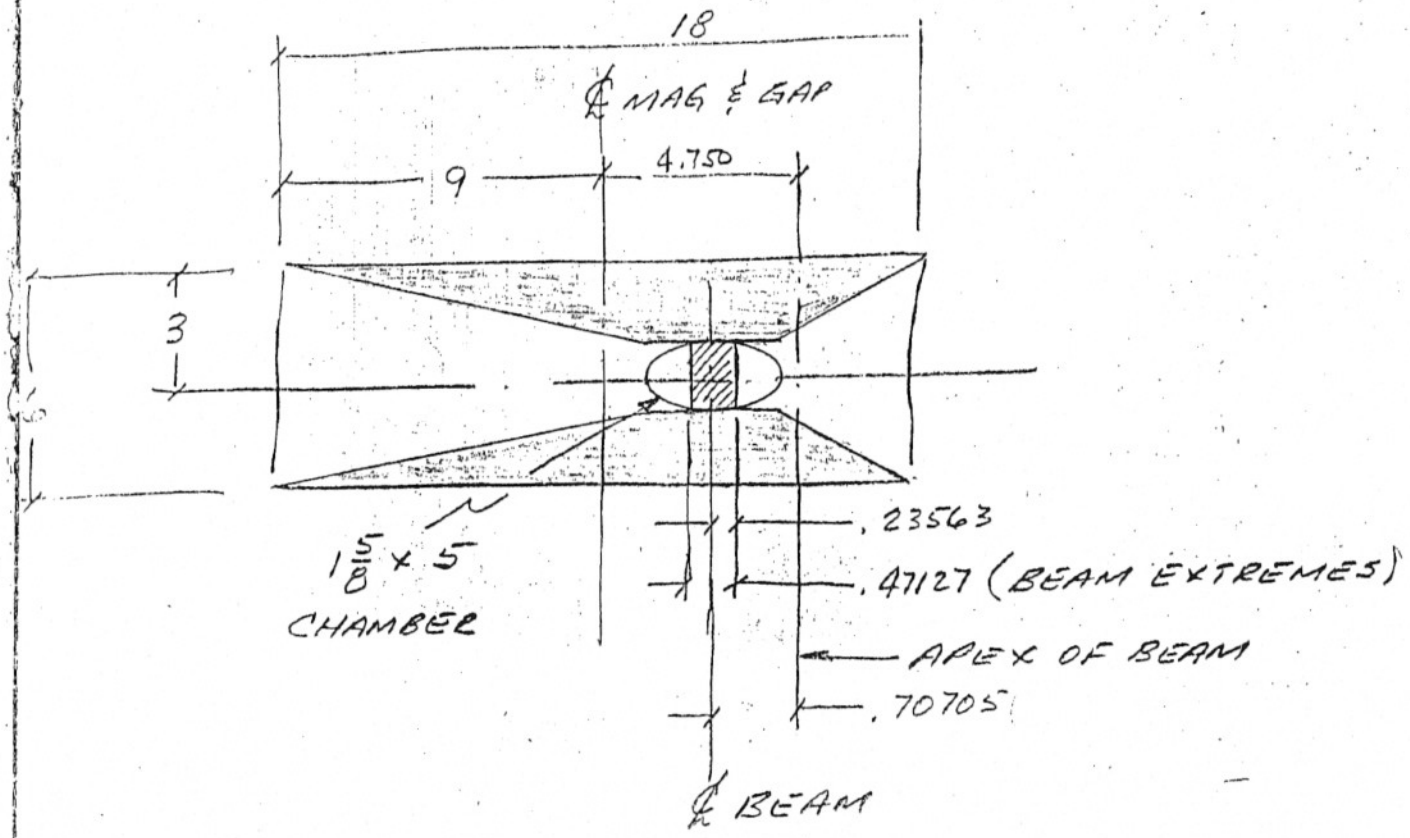


18C72 (DD7)

6 x 18 MAG GAP.

LOOKING DOWNSTREAM

3-24-81 ACD



18D72 (DD10)
6x18 MAG GAP

LOOKING DOWNSTREAM

3-24-81 A.C.P.

Ramps?

H. Brown
Date: 3/16/82

D Line Excitations

4000 computer cnt for 100 mV. input

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	.5310	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
DS266	—	—	—							—
DQ8	13Q48	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	—	—	—							—

* = ramped

* Bend in magnet plane. Horizontal projection = 0.8660°

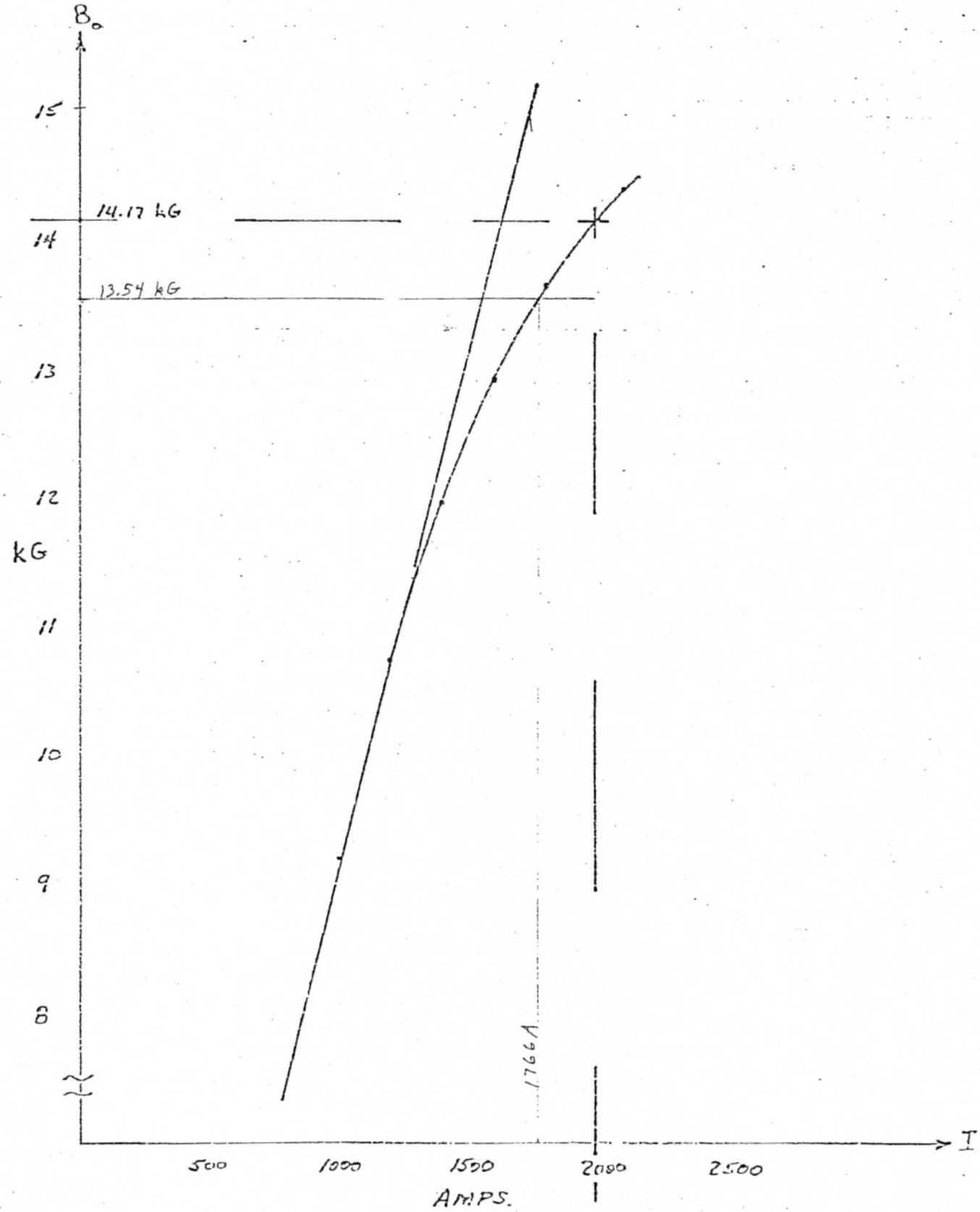
† These P.S.'s have D.C. current transducers equivalent to shunts listed.

BROOKHAVEN NATIONAL LABORATORY

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

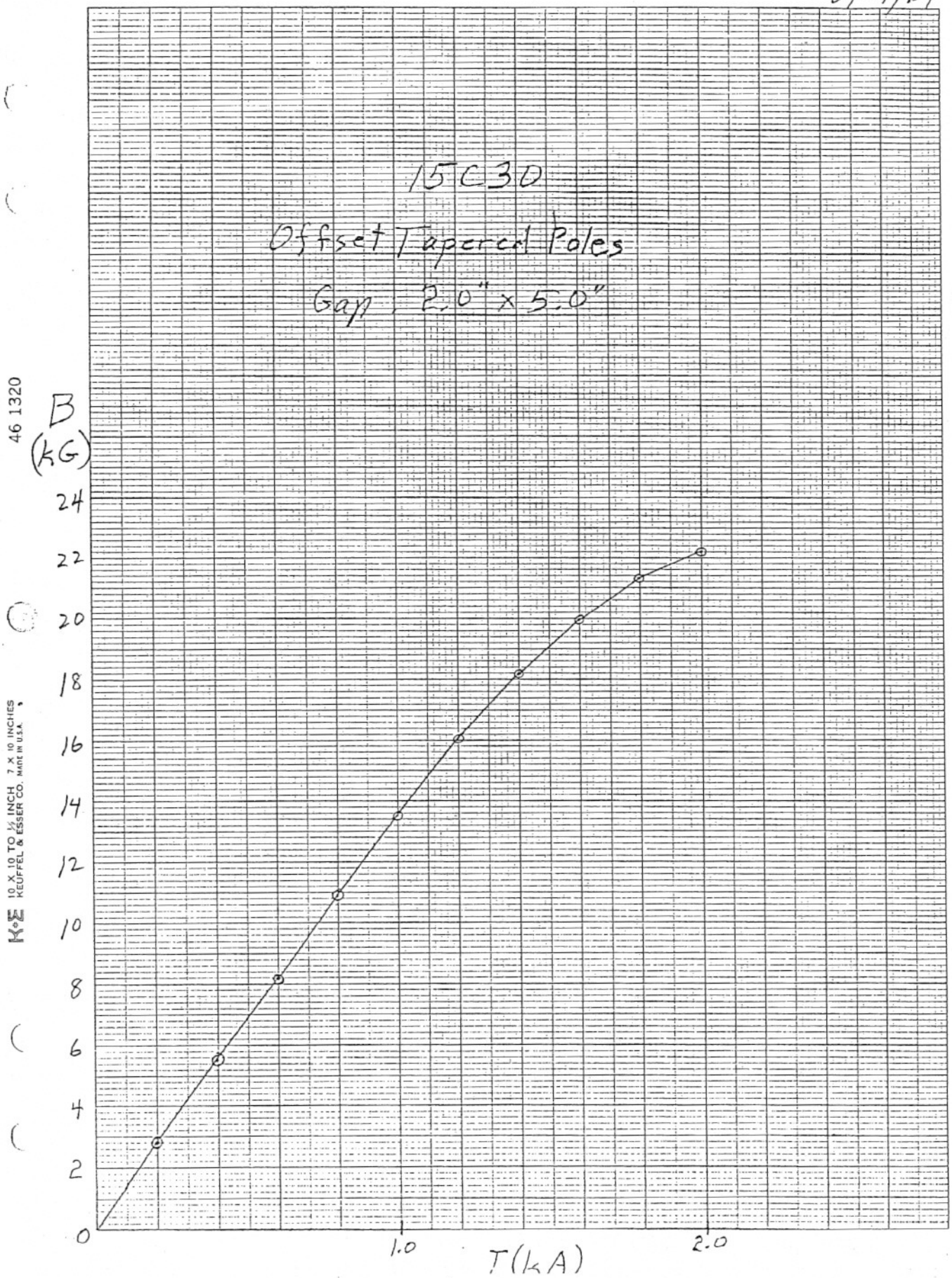
CHKD. BY ____ DATE ____ EXTRA COIL ADDED JOB No. ____

DEPT. OR PROJECT ____



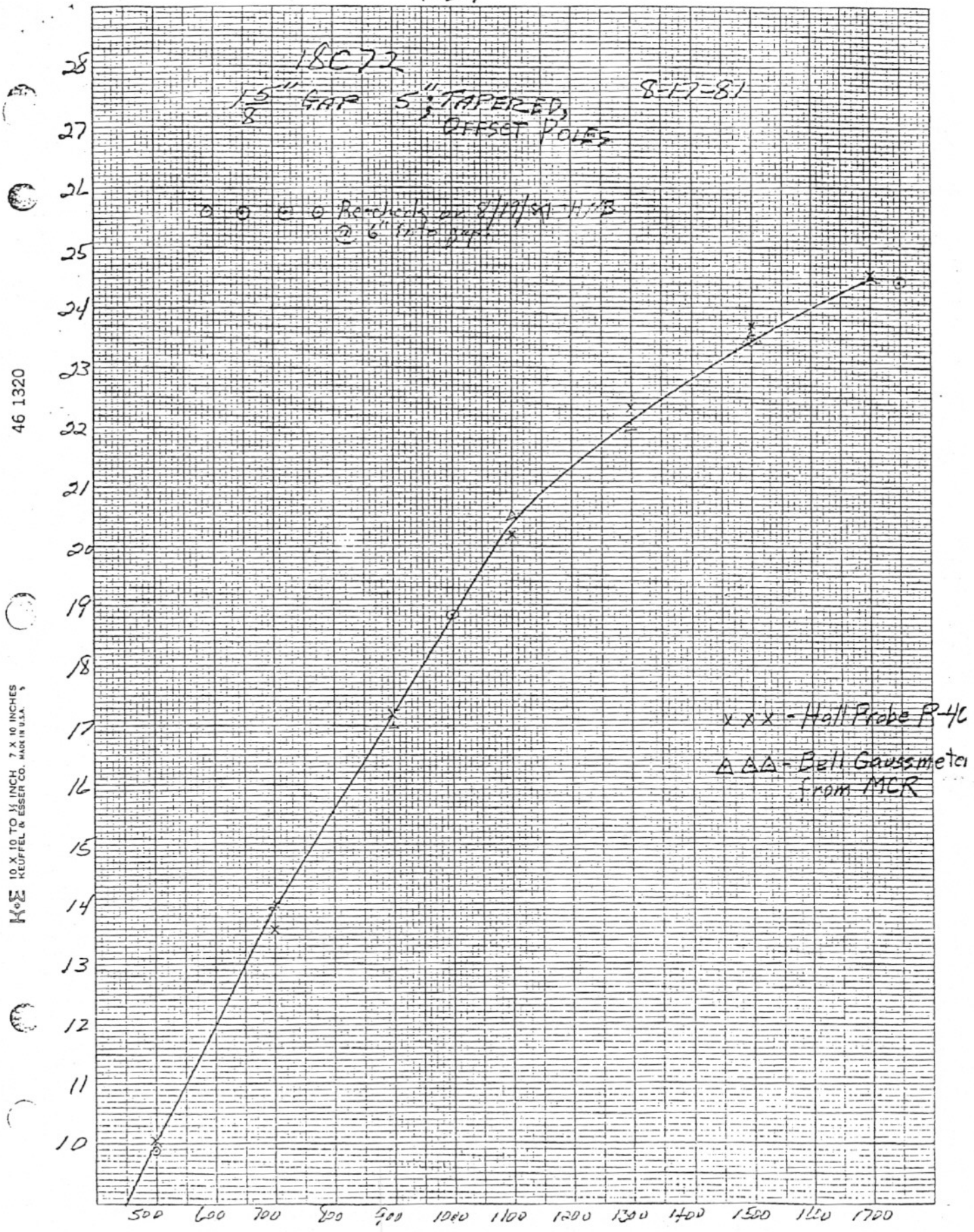
DD 6

8/21/81



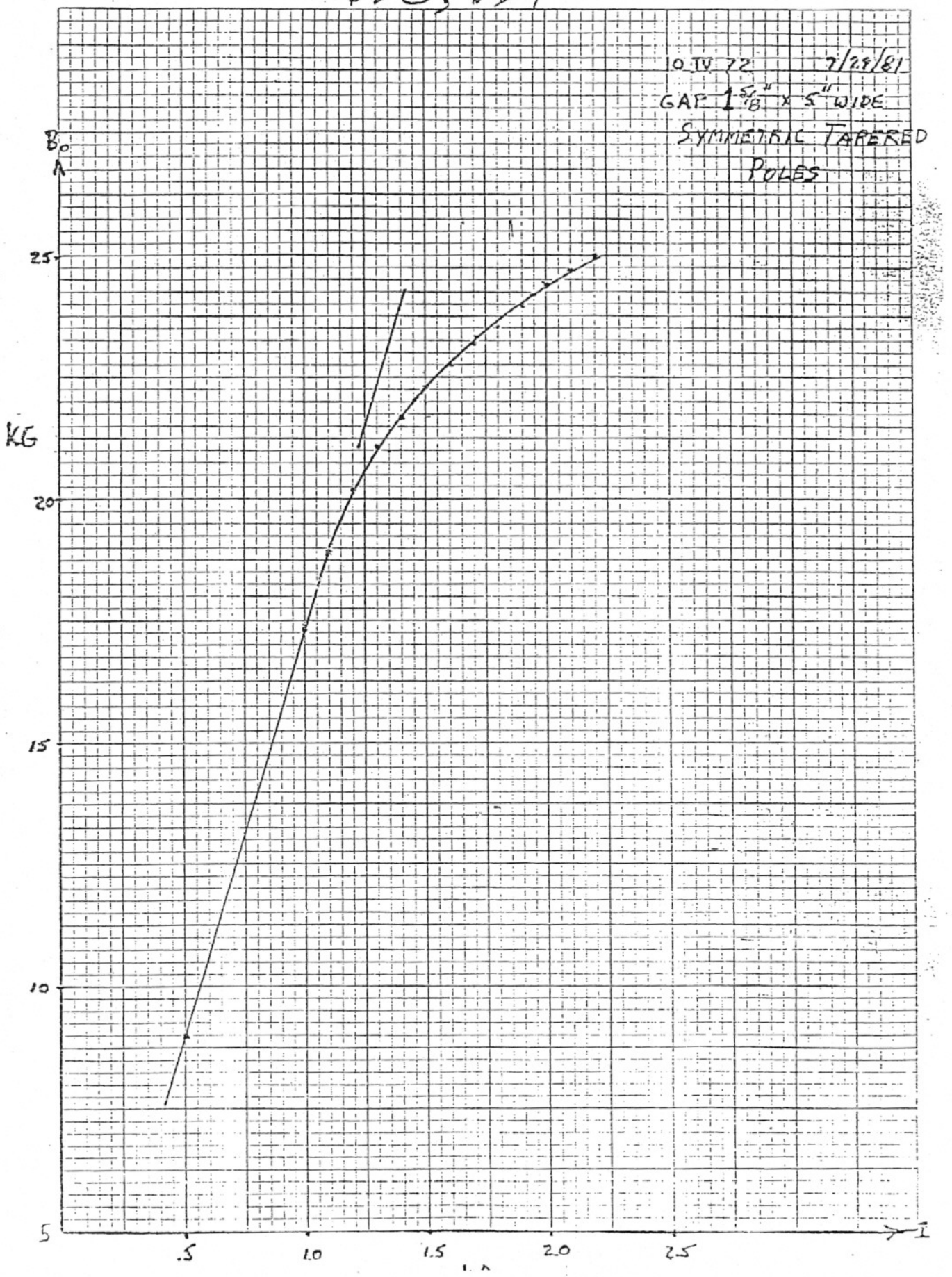
46 1320
K+E 10 X 10 TO ½ INCH 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

DD7



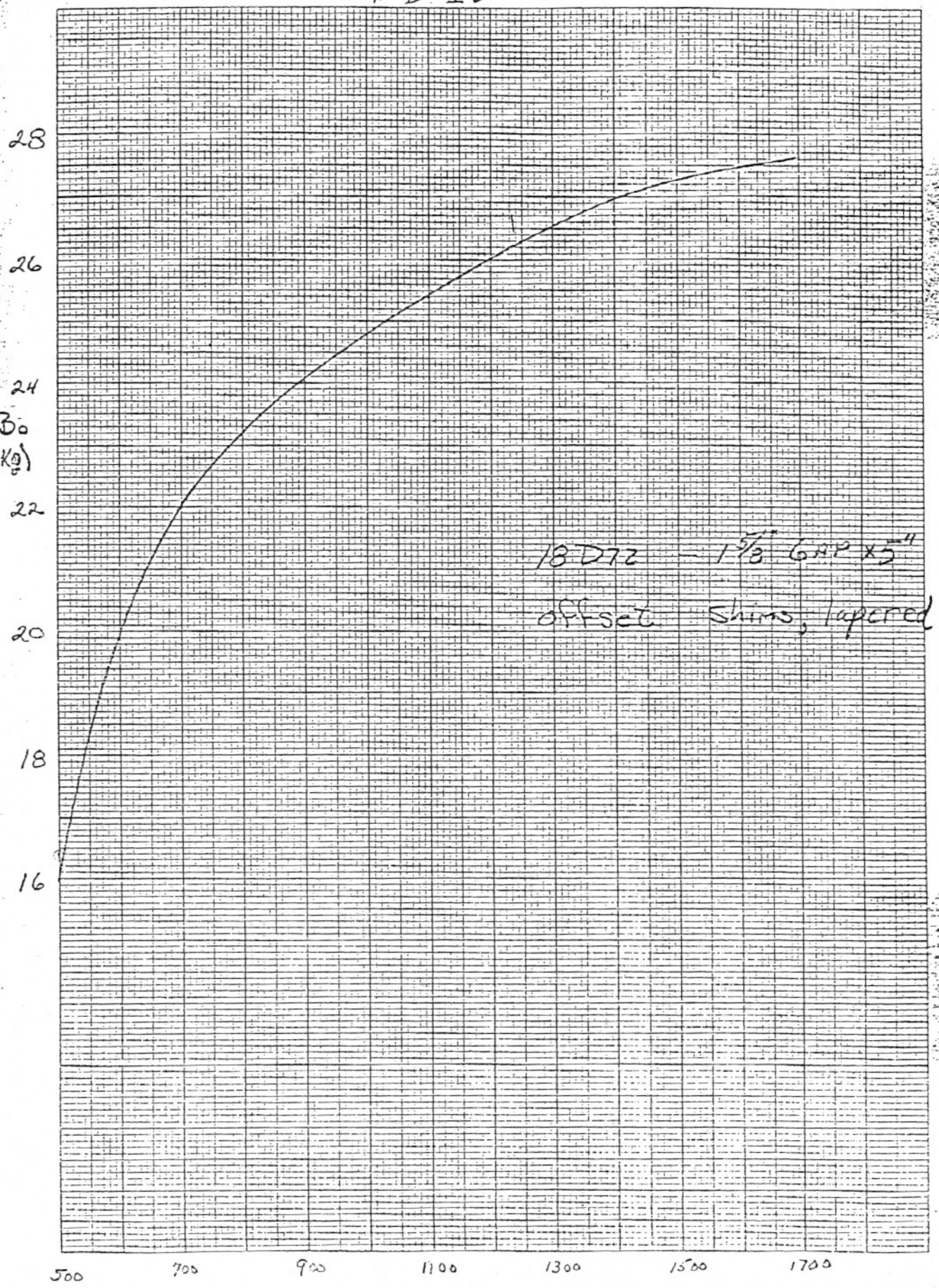
46 1320
K+E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.

DD8, DD9



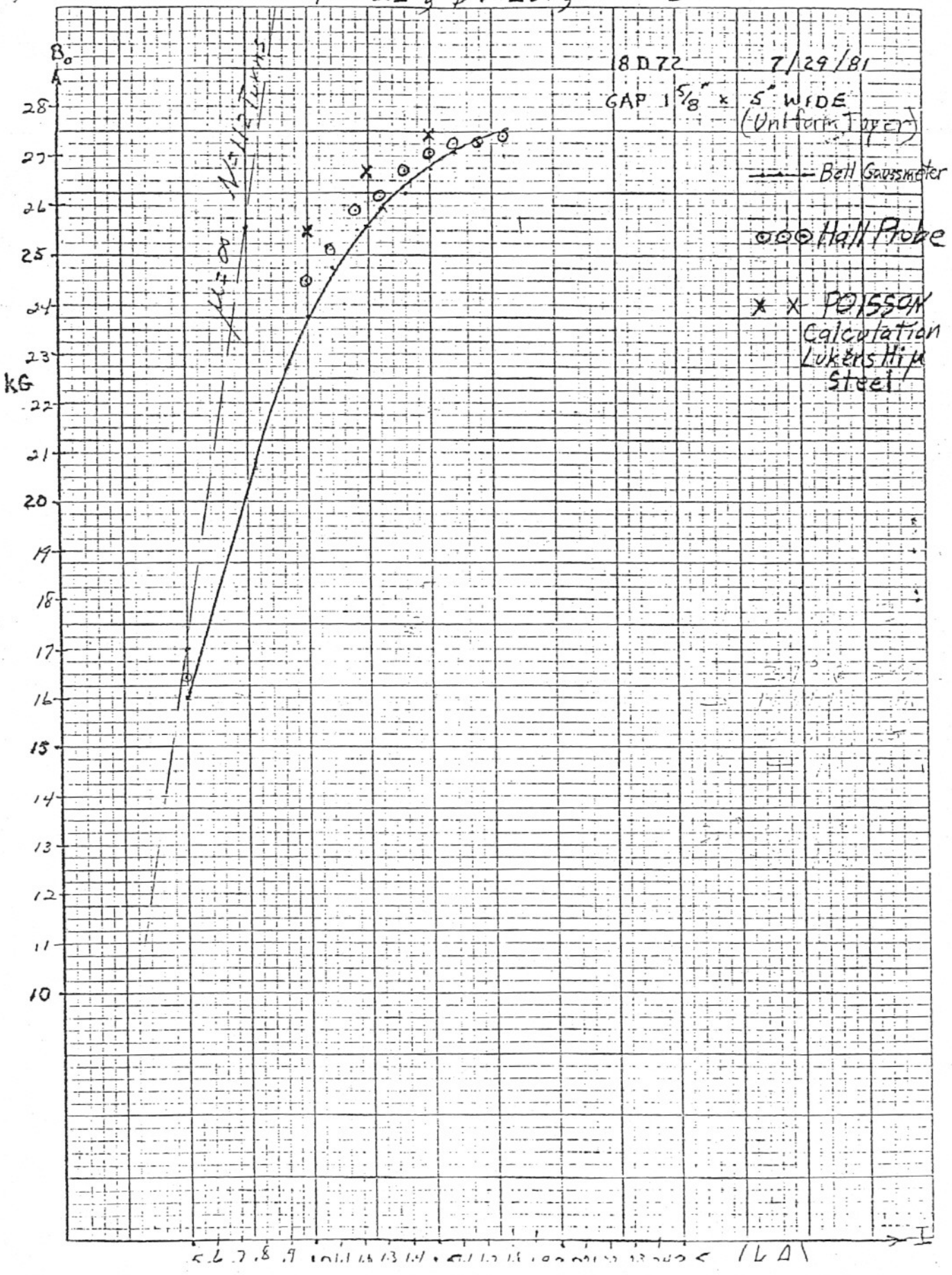
SQUARE 5 X 5 TO THE HALF INCH · AS-0811-OT
GRAPHIC CONTROLS CORPORATION Buffalo New York
Printed in U.S.A.

DD 10



SQUARE 10 X 10 TO THE HALF INCH AS-0013-01
GRAPHIC CONTROLS CORPORATION Buffalo, New York
Printed in U.S.A.

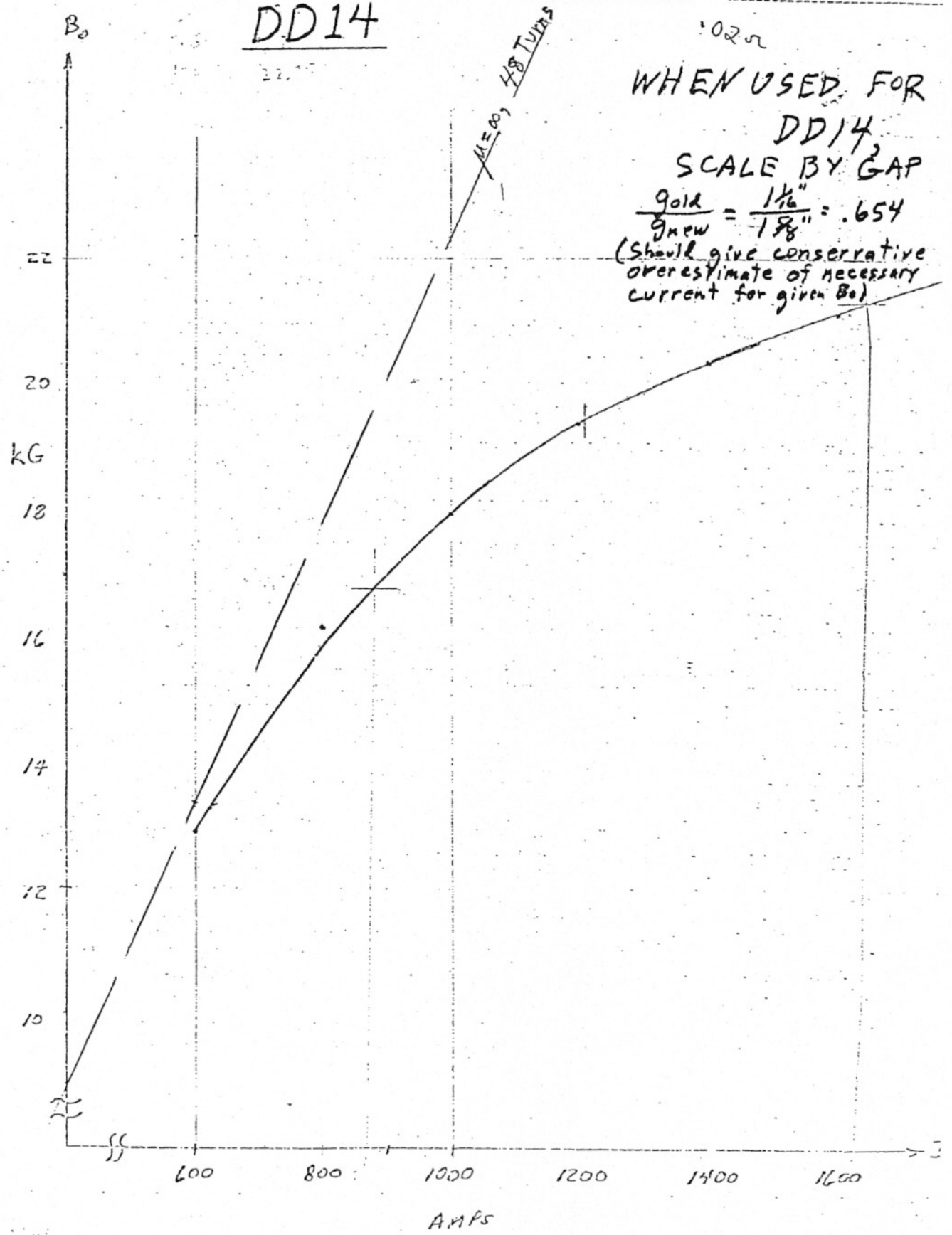
PD11, DD12, DD13



BY R. Brown DATE 10/21/80 SUBJECT DD4 3×4 D30 SHIMED 1 1/16" GAP SHEET NO. ____ OF ____

CHKD. BY ____ DATE ____ DEPT. OR PROJECT ____ JOB NO. ____

DD14

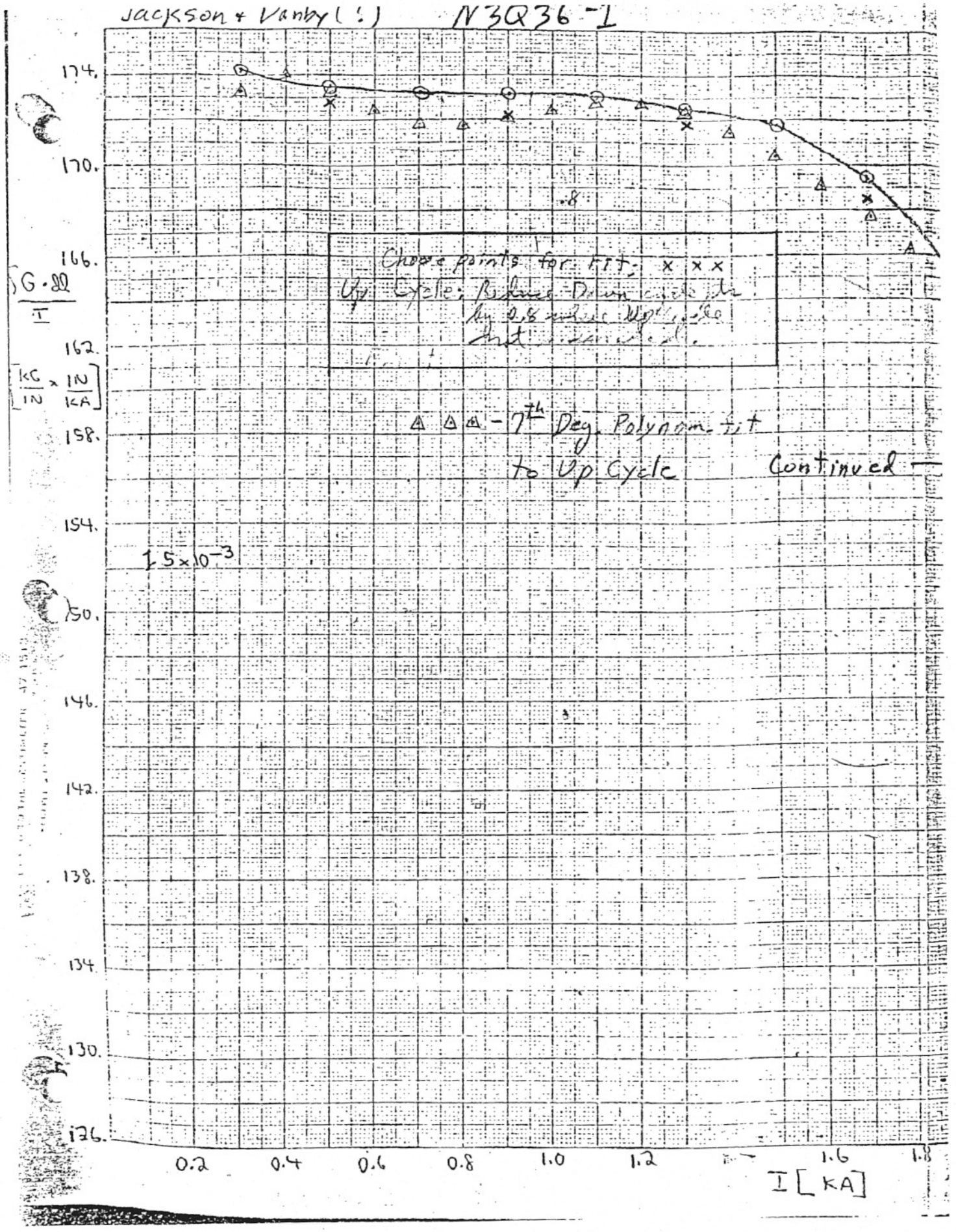


WHEN USED FOR DD14 SCALE BY GAP

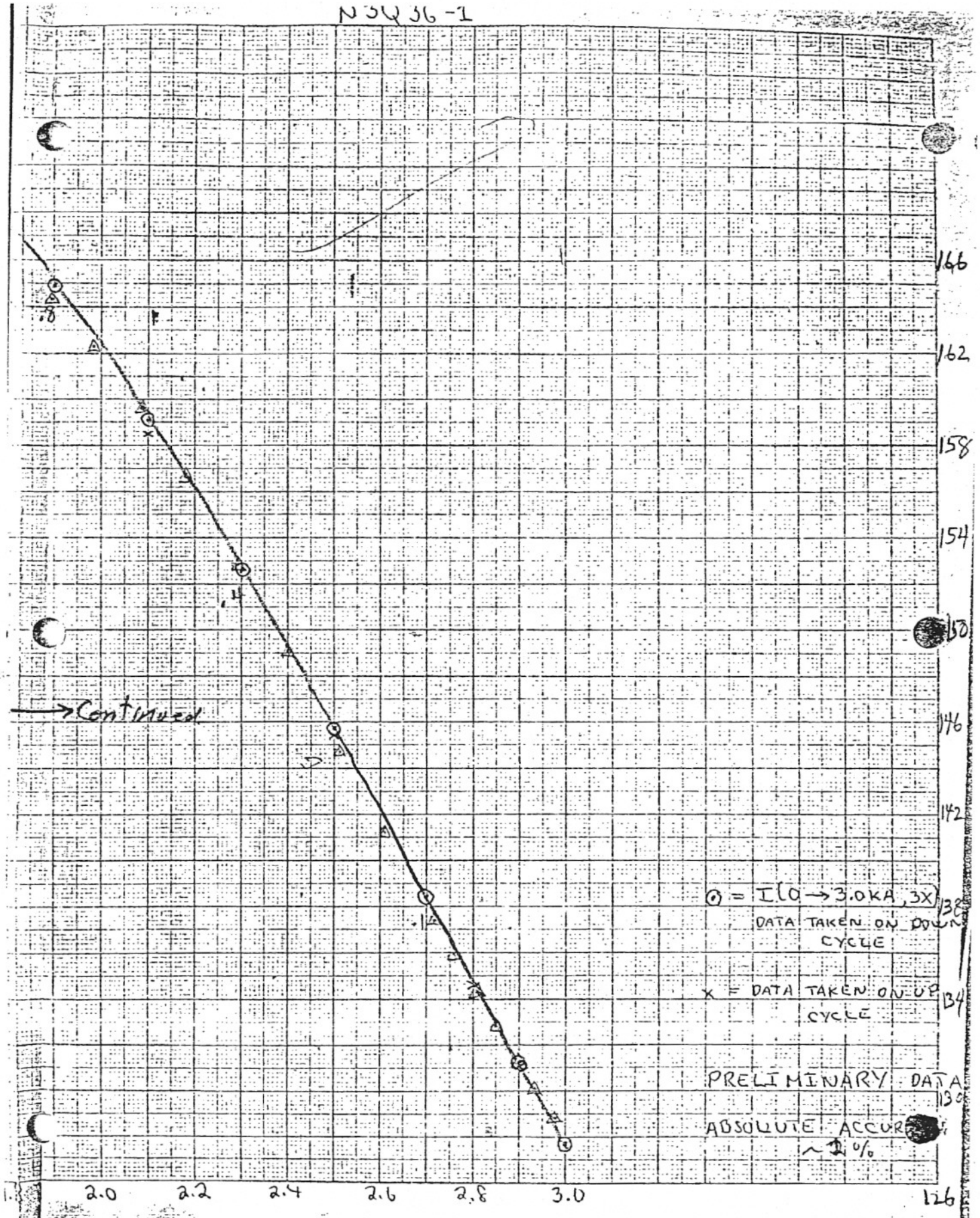
$$\frac{g_{old}}{g_{new}} = \frac{1\frac{1}{16}''}{1\frac{7}{8}''} = .654$$

(Should give conservative overestimate of necessary current for given B_0)

Jackson + Vanby (?) N3Q36-1

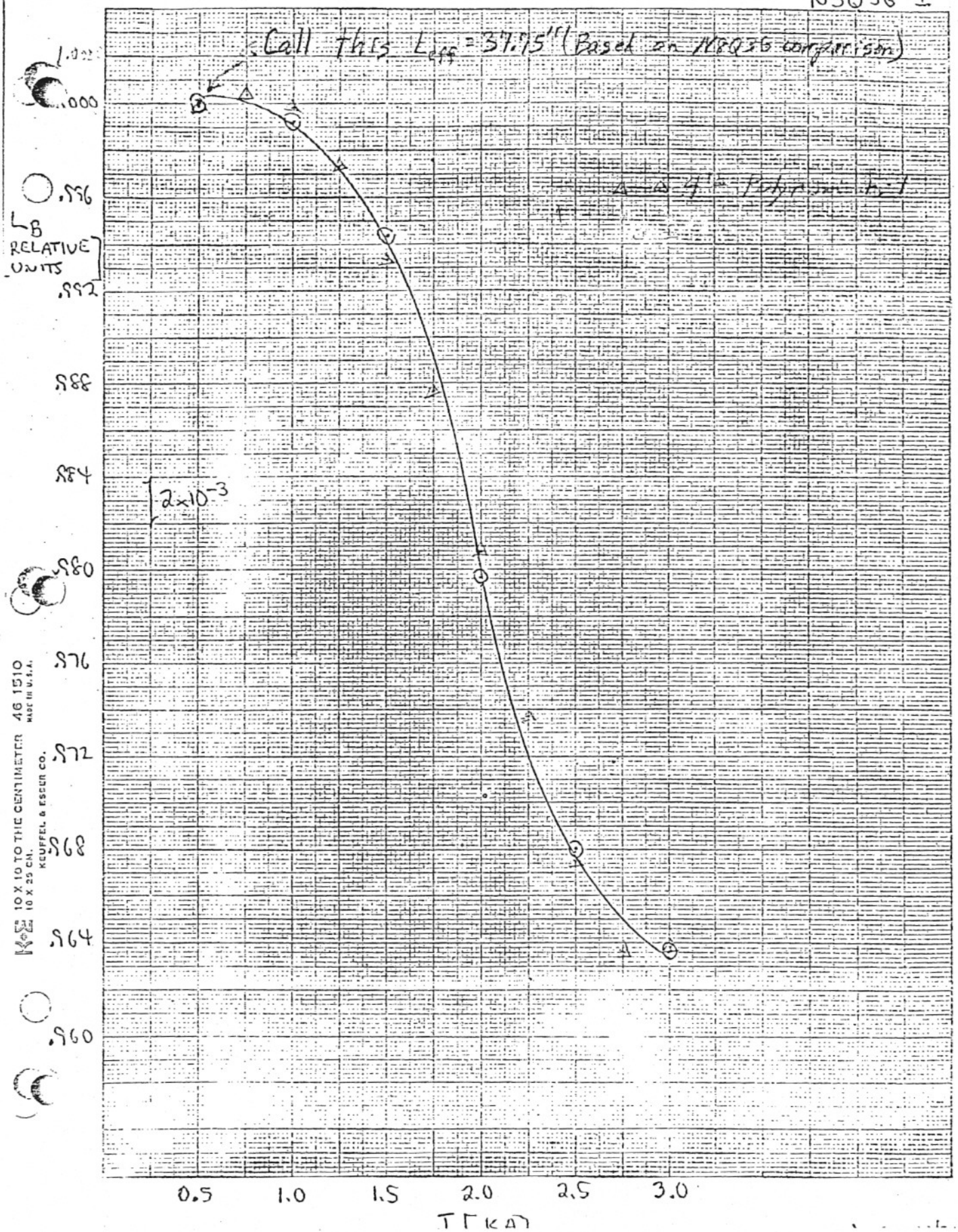


N3Q36-1



JWJ 11/2/67

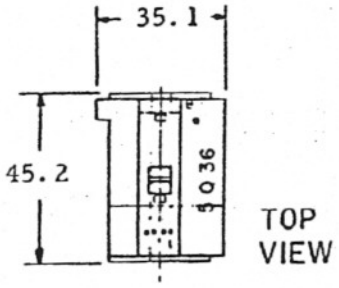
N3036-1

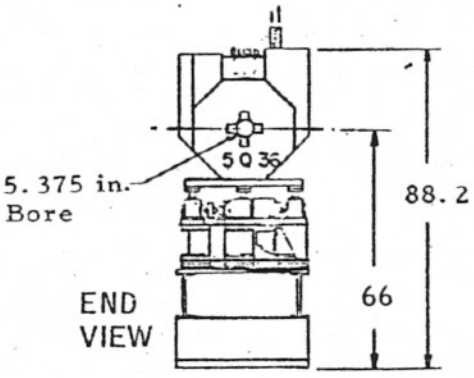


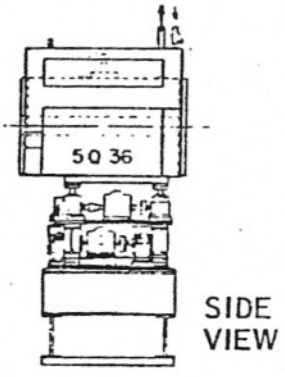
10 X 10 TO THE CENTIMETER 46 1510
10 X 25 CM. MADE IN U.S.A.
KEUFFEL & ESSER CO.

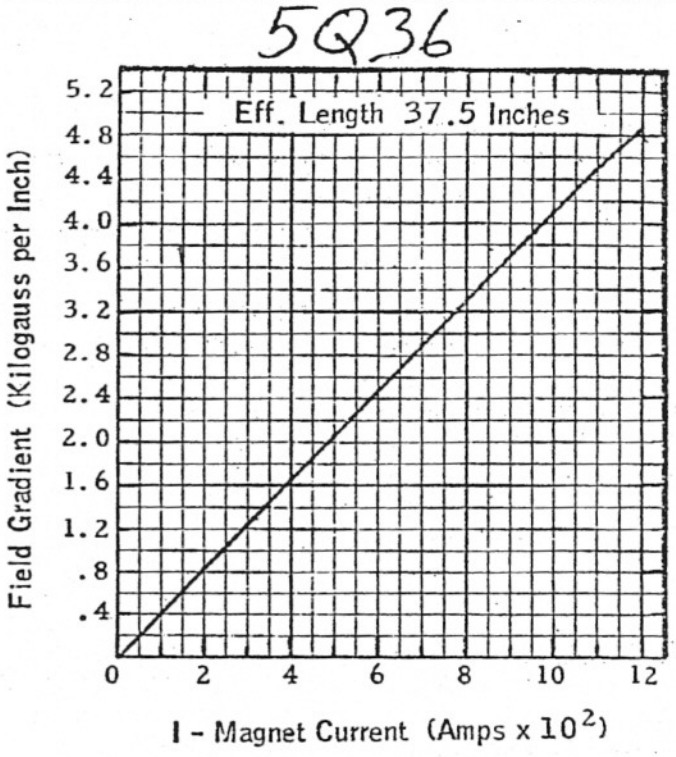
5 Q 36 (QM 103) QUADRUPOLE MAGNET

Gradient and Measured Data









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%

Total Weight: 3.5 Tons

Measured Data:

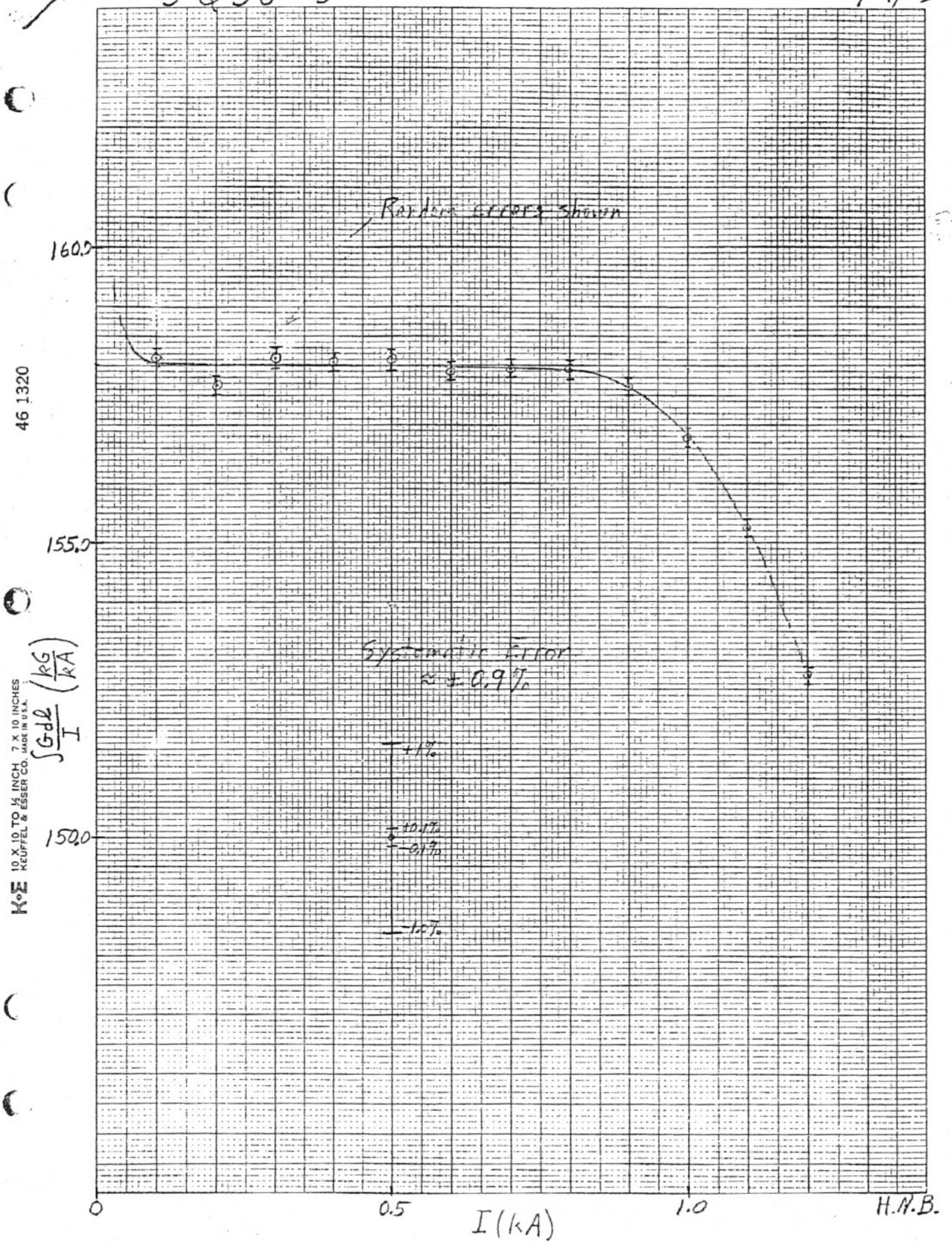
Voltage	122 Volts dc
Current	1200 Amps dc
Power	146 kW
Field Strength	13.0 kG

Cooling Water
(System Pressure Drop 200 psi)

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

5Q36-5

6/29/83

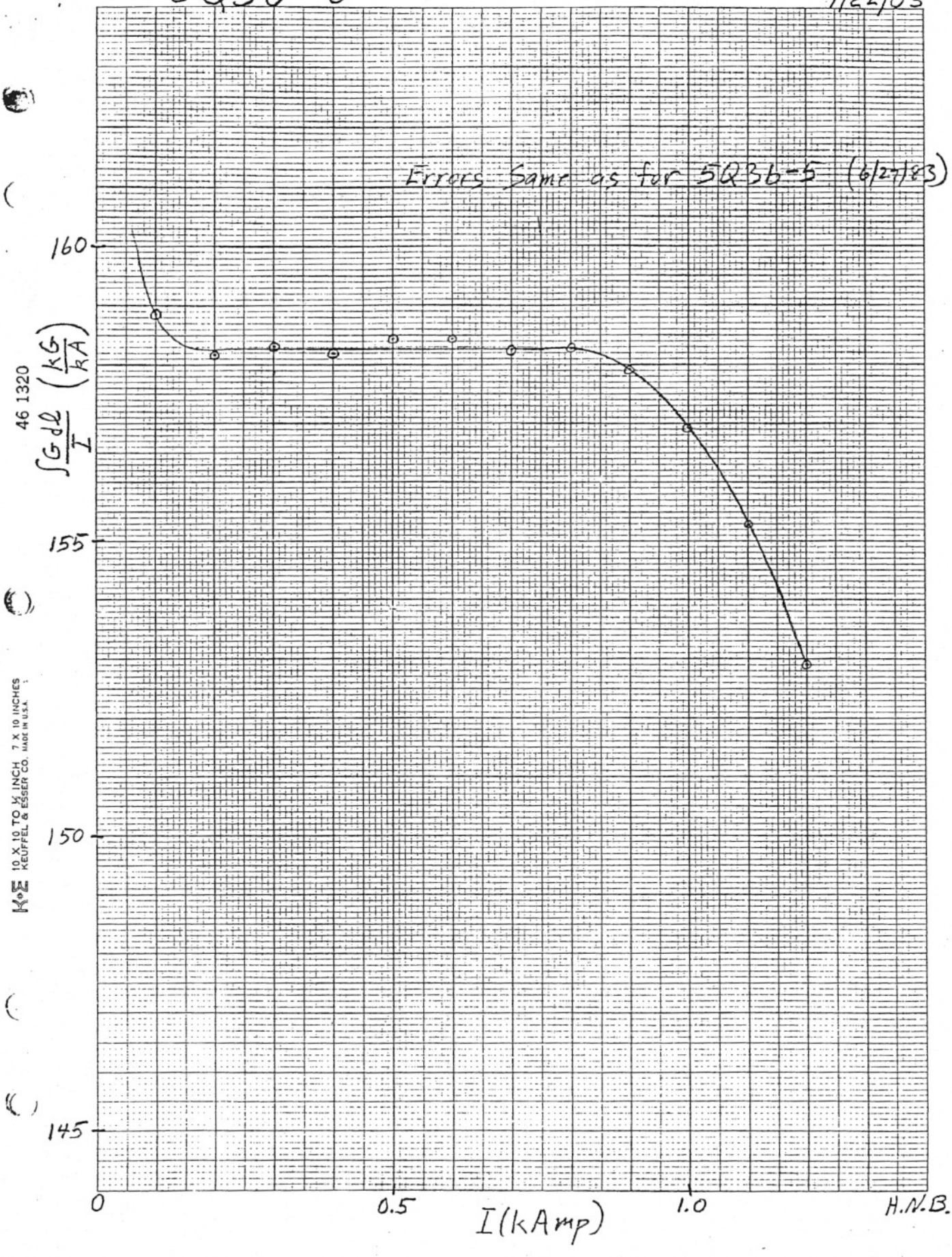


46 1320
K+E 10 X 10 TO ½ INCH 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

5Q36-6

7/22/83

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



H.N.B.

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