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#### **Title**

PEP TRANSPORT BEND MAGNET 25B5249, (B3 THROUGH B9)

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#### **Authors**

Reimers, Richard M. Lake, Addison A.

#### **Publication Date**

1976-12-01



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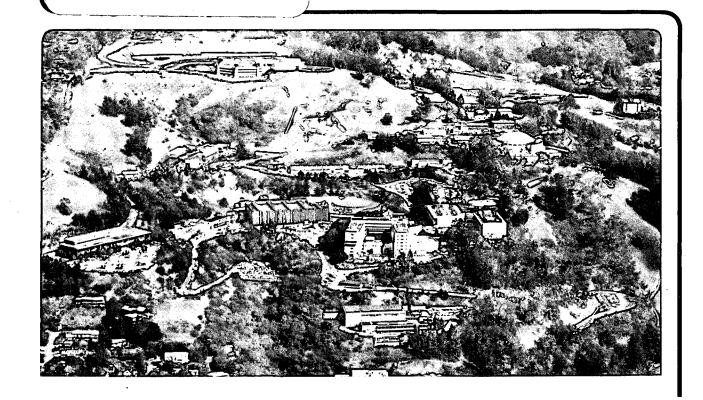
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AUTHOR (MYL		DEPARTMENT				LOCATION	07	ATE	
K. Reimers, A.	Lake	Mechanical	Engine	ering		Berkele	у	December	8, 1976-
PEP				··········	·	· · · · · · · · · · · · · · · · · · ·	<del></del>		
Injection					·		:	·	
PEP Transport	Bend Magn	et 25B5249,	(B3 th	rough B	9)				
Revisions: A	- R. Rei measur - R. Rew	mers - 9/79 rements.	- Delet	e 3 pa,	ges -	Revise 8 Vcolina(p.8	page ).	s to agre	e with
The purpos the above PEP i	se of thi	s note is t	o descri	ibe the	crit	eria and	the_d	esign of	
1. The PEP Bea	am				• •				
be switched into There will be tring; one will will utilize 7 for beam energi 41B3 through 412. Aperture and The clear elliptical with	to the PE two nearl transpo bend mag ies up to 189 and 4 ad Good F apertur horizon	y identica rt electron nets of thi 20 GeV. To 2B3 through ield Region e required tal and ver	sport ar l transpect to the magnet 42B9.  for the tical di	nd injector system of the port	ction stems ositro bend gnatio t the s of	system by connecting the connections. Each angle is ons in the bend location and 20	y pulng SL n tra 131 te tra ation mill	sed magne AC and th nsport sy milliradi nsport li s is appr imeters r	ets. he PEP rstem ans nes are roximately respec-
tively. The material to the state of the sta	e field BL Mecha l field r	guality ana nical Depar egion are sl	lysis wa tment). hown on	as done The rel LBL dra	joint latior	tly by J. ns betweer	Pet e	rson, K.	Halbach,
3. List of Pers	onnel In	volved in the	he Desig	<u>;n</u>				t t	•
K. Brown, R. Reimers, J.		J. Peterson	, R, Ave	ery, K.	Halba	ach, A. La	ake, 1	D. Morris	•
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4. Parameters		· i				et de la Companya de La companya de la Companya de	-		•
		lues chosen	are as	shown :	in App	pendices A	and	B and Ta	bles
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LAWRENCE RADIATION LABORA	TORY - UNIVERSITY OF CALIFORNIA	CODE	SERIAL	PAGE
ENGINEER		PE0103	M5017B	2 OF 8
AUTHOR	DEPARTMENT	LOCATION	DATE	
R. Reimers, A. Lake	Mechanical Engineering	Berkeley	December 8,	1976

#### 5. Drawings

The design is shown on the following LBL drawings:

Core - 17/13714 Coil - 17/13666 Overall assy - 17/13726

#### 6. Schedule

Procurement began December 1976. Installation of 14 magnets completed 8/79.

# 7. Direct B3 Costs (excludes design, inspection, measurement)

	Material Cost	Labor Cost	Total	PO/JO	<u>Date</u>
Conductor	20,367		20,367 <sup>(a)</sup>	2179902	1977
Coil Fabrication and Magnet Assy.		97,415	97,415	2439002	1977–78
Core steel	54,096	· · · · · · · · · · · · · · · · · · ·	54,096	2773502	5/77
Anneal		8,965	8,965	2773512	6/77
Core Fab		142,030	142,030	2439012	3/77
Flatten steel		5,713	5,713	3269002	1977-78
Misc. Hardware	1,000		1,000	; , 400 000 000 000	1977-78
Beam tubés	2,177		2,177		
Bend tubes		4,014	4,014	3585902	
TOTAL FAB			335,777	Action to the second se	
TOTAL WEIGHT			172,200 lbs	•	
	: 555 /450 /		ta 05/16		

Specific Cost = \$335,777/172,200 lbs. = \$1.95/lb.

(a) = pro rata, assume 90% if conductor used on B3 magnets. \$20,367 = .9 X \$22,630.

# 8. Testing and Measurements

Done at SLAC by Don Nelson (LBL). He has the original data and Jack

# 9. Operating Design Philosophy

Initially the magnets will be operated only up to 15 GeV. If 20 GeV is desired in the future, the below-ground hardware is adequate but additional power supplies and increased water pressure will be needed. Note that the temperature rise at 20 GeV energy requires more than 150 psig across the coils. A careful re-examination of the LCW requirements as well as a physical flow check at operating pressure and power is a must if these magnets are to be run above 15 GeV, since the measurements indicate that the efficiency at 20 GeV is only 71.5%, not 82.4% as originally calculated.





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LA		CE RADIATION LABORATORY			ODE	SERIAL	PAGE
UTHOR		NGINEERI	RTMENT		E0103	M5017B	3 <sub>of</sub>
R. F	Reim	ers, A. Lake Mc	echanical Engi	neering l	Berkeley	December	3, 1976
	•	Appendix A - I	Bend Magnet 25	5B5249 Design Pa	arameters		
			Symbol	Units		Value	Footnot
1.	Mag	netic 0 15 GeV.					3 ' ' ' ' ' ' ' ' ' ' ' ' ' ' ' ' ' ' '
*	Α.	Beam energy	E	GeV		15	
	В.	Size of good field required	and the second s	nm		de x 20 ellipse	
	c.	Effective length	l leff	mm	Prisone of high a	5274	
	D.	Bend angle	0	radians		.1312	
	Ε.	Beam stiffness	Βρ	kilogauss me	ters !	500.4	
	F.	Gap Field	B gap	kilogauss		12.45	(1)
			A LONG A PROPERTY OF THE PROPE	Tesla	and the second	1.245	(2)
	G.	NI (total required)	(NI) req.	Ampere turns	-25	,560 ,531	(3)
	Н1.	Yoke field 0 15 GeV	Byoke	Tesla	Rt. Left	1.37 1.46	(4)
			2."			****	
	J.	Magnet efficiency (measured)	η	none	15 Ge\	V936	* /* * *
	<b>K.</b>	Field Quality at 25 mm from ctr.	ΣΔΒ <sub>η</sub>  /Β	none	15 Ge\	V0029	(4)
		Northwest rate from the party of the party o	A serious contractions and the serious contractions are serious contractions are serious contractions and the serious contractions are	Tradition (1)	to the suffer of the state of t		
2.	Core	2	- Control of the Cont				
	Α.	Vertical gap	g	mm		25.1	
	В.	Core length	<sup>l</sup> core	mm	52	249	
	C.	Core width	-	. mm .		564	
	D.	Overall core height	The state of the s	nm	~	341	
	Ε.	Core material	-	- '	C1010 /	Annealed	•
	F.	Total core weight	Hcore	kg	51	150	
		•			j		·
			<b>a</b>	1	1	. ]	

(9)

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AUTI	ENGINEERI		TE	PE01013	M5017B	PAGE 4 of 8
1		echanical Engi	neering	Berkeley	December	8, 1976
	Appendix A -	Bend Magnet 25	B5249 Design	Parameters (	(Cont.)	
-		Symbol Symbol	Units	Val	ue	Footnotes
3.	Coil				•	·
	A. Number of turns per coil	Ncoil	Turns	1	6	(3)
	B. Conductor material			Alum. 1060F		·
	C. Conductor outside dims.		mm mm	80 3 hole	x 8	
	D. Conductor I.D. (coolant hole)	-	mm	@ 4.7 x		
	E. Conductor net area	-	mm <sup>2</sup>	539.	5	
	F. Conductor length/coil		meters	184.	3	(5)
	<pre>G. Conductor weight/     coil</pre>	-	kg kg	268	-	(11)
	H. Conductor overall length/magnet	- Landers and the second secon	meters	368.		
	I. Conductor weight/ magnet	The second secon	kg .	537		
	J. Coil packing factor	_			.73	(6)
	K. Number of coils per pole	-	-	יורי שייי ליבור נייני בנ		·.
	L. Coils per magnet	-	-	2	•	
4.	Electrical 0 15 GeV			and the second of the second o		
	A. Voltage type	-	-	DO	2	
	B. Current per magnet (measured)	I	Amps.	83	o ;	
	C. Current density	I/A	Amps/mm <sup>2</sup>	· · ·	1.54	(10)
	(calculated) D. Resistance or impedance per magnet	R	ohms		.02069	(7)
	E. Voltage drop across magnet @ 15 GeV	ΔV	Volts	1	7.2	(8)
1		1	1	0		i

kilowatts

F. Power per magnet

	EERING NOTE	PE0103	M5017B	PAGE 5 OF 8
AUTHOR	DEPARTMENT	LOCATION	DATE	1 - 01
R. Reimers, A. La	e Mechanical Engineering	Berkeley	December 8	, 1976

5. Cooling @ 15 GeV

		Symbol	Value	Units
<b>A</b> .	Beam Energy	E	15	GeV
В.	Heat removal rate/waterhole	P	2:38	kW
C.	Pressure drop avail/waterhole	p	100	psig
D.	Length of coolant circuit	L	608	feet
E.	Min. coolant ckt. I.D., equiv.	d .	•224 i.n	inches
F.	Specific press. drop	k	16.5	psig/100 ft
G.	Specific press. drop	k	38.2	ft/100 ft
Н.	Flow/hole (from LBL DD10)	q	.433	gpm
I.	Flow/magnet= 6 X flow/hole	6q	2.60	gpm
J.	Coilrtemp. rise = $\frac{3.8P}{q}$ (from LBL DD57)	T	20.8	deg. C
	Water input temp., max.	$^{\mathtt{T}}$ in	35	deg. C
L.	Water output temp., max.	out		deg. C

### Footnotes to Appendix A

- 1)  $B = \theta B \rho / \ell_{eff} = .1312 (500.4) / 5.274 = 12.448 kGauss$
- 2)
- 3) Let III = Ampere truns

Commence to the way

then !II = Bg ÷  $4\pi \ 10^{-7} \ \eta$ 

where B = magnetic field in Tesla

g = gap in meters

 $\eta$  = magnetic efficiency, dimensionless, value less than 1.

Values are as follows:

= 1.245 Tesla

.0251 meters (measured)

.97 (From POISSON program, predicted)

.936 From measurements





Berkeley

December 8, 1976

Footnotes to Appendix A (Cont.)

Mechanical Engineering

Then NI = 26560 Ampere turns per magnet and for II = 32 I = 830 amps.

4) Per J. Singh, dated 11/16/76

R. Reimers, A. Lake

- Length of conductor per turn =  $5274(2) + 2\pi 109 + (202-60) 2 = 11516 \text{ mm}$ coil = 16 turns  $\times$  11.516 meters/turn = 134.3 meters
- Conductor area 10,209 sq. mm Potted cross section 13,920 sq. mm Thus: packing factor = 10209/13920 = .73
- 7)  $R = \frac{\rho L}{A} = \frac{.00003053 \text{ ohm-nm x } 368,512 \text{ mm}}{A} = .02085 \text{ ohms } 9.45^{\circ} \text{ C}$
- 8)  $\Delta V = IR = 830 \times .02085 = 17.2 \text{ volts}$ 
  - 9) Power per magnet = .001  $i\Delta V$  = .001 x 830 x 17.2 = 14.26 kilowatts@  $45^{\circ}$ coil temp.
  - 10)  $j = I/A = current density = 830 amperes <math>\pm$  539.5 square mm

= 1.57 amperes per square mm

11) conductor wt/turn = 11,516 nm/turn (539.5 mm) 2.7  $(10^{-6})$  kg/mm<sup>3</sup> = 16.77 kg

conductor wt/coil = 16 (16.77 kg) = 268 kgconductor wt/mag = 2 coils (263) = 537 kg = 2.21b/kg (537 kg) = 1181 lb.

Conductor inside dia. at min. hole tolerances:

 $m = hydraulic radius = m = \frac{Area}{wetted perimeter}$  (definition)  $= \frac{\frac{\pi}{4} (4.4)^2 + 2.9(4.4)}{\pi (4.4) + 2(2.9)} = 1.42$ 

Equivalent dia. = 4m = 4(1.42) = 5.70 mm= .224 inches

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		ICE RADIATION LABORATORY		OF CALIFORNIA	COQE PE0103	M5017 B	PAGE
AUTH			RTMENT.		LOCATION	DATE	7 of 8
R.	Reim	ers, A. Lake Me	chanical Eng	gineering	Berkeley	December	8, 1976
		Appendix B - Bend M	lagnet 25B524	19 Design Paramo	eters at 20	GeV (Futu	re)
			Symbol .	Units	Va	lue	Footnotes
1.	Mag	netic @ 20 GeV					
	A.	Beam energy	E.	GeV		20	
	В.	Size of good field required	<b>-</b> .	men		e x 20 llipse	ar e e
		Beam stiffness	В	kG-m	66	7.2	
	C.	Gap Field	В	Kilogauss	1	6.60	(1)
	٠	·	. •	Tesla		1.66	(2)
	D.	NI (required)	(NI) <sub>req.</sub>	Ampere turi	ns 46	5,400	(3)
	E.	Yoke field	11	<b>16</b>		1.85	
	F.	Magnet efficiency	η	none		-715	(8)
	G.	Field Quality at	ΣΔΒ <sub>n</sub>  /Β	none		.0035	(4)
2.	<b>El</b> e	25 mm from CTR ctrical @ 20 GeV	••			ندر دایان شده داران سال کار	•
	A.	Voltage type	-	-		DC	
	В.	Current per magnet	I	Amps.	1	1450	(3)
	C.	Current density	I/A	Amps/mm		2.69	(7)
	D.	Resistance or impedance per magnet	R	ohms	5	.02085	(7A)
	E.	Voltage drop across magnet @ 20 GeV	Δ٧	Volts	3	50.2	(5)
	F.	Power per magnet	Р	kilowatts		13.84	(6)

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	AWRENCE BERKELEY LABORA	· · ·		Δ.	CODE	SERIAL	PAGE
	ENGINEE		NOTE		PE0103	M5017 <b>B</b>	8 of 8
1	<b>ноя</b> . Reimers, A. Lake	DEPARTMENT Machanical	Engineering		Berkeley	December December	g 1976
	Cooling @ 20 GeV	. Mechanical	Engineering		Detkerey	December	0,
			Symbol		Value	Units	
A.	Beam Energy		E		20	GeV	
λ B.	. Heat removal rate/	waterhole	P	•	7.31	kW	
′ c.	. Pressure drop avai	.l/waterhole	<b>p</b>		316	psig	
D.	. Length of coolant	circuit	L		608	feet	
E.	. Min. coolant ckt.	I.D., equiv.	đ		.224	inches	
F.	. Specific press. dr	op	k		52	psig/10	00 ft
G.	. Specific press. dr	op	k k		118	ft/100	ft
Н.	,		q		.79	gpm	
I.			6q BT.		4.76	gpm	
J.	*.	q $DD$			35	deg. C	
K.	1		$^{\mathrm{T}}$ in		55 <b>35</b>	deg. C	•
L.	Water output temp.	· .	Tout		70	deg. C	
1)	B = 12.448 (20/15)		to Appendix	_	•		
		*	35 - 1.00 163	, ia.		• •	
2)		11 7.3		•		•	
3)	Let NI = Ampere tur	ns		,	•		
	then NI = Bg ÷ $4\pi$ 1	0 <sup>-7</sup> η					
	where B = magnetic	field in Te	sla		•		
	g = gap in m	eters	•			•	
	η = magnetic	efficiency,	dimensionles	ss, va	lue less tha	ın 1.	•
ŀ	Values are as follo	ws:	•				
i -	B = 1.66 Tesla				*.		·
	a = .0251 meters	(From design	n value)				
	η = .715	(measured 19	979 by D. Nel	son)			
	Then III = 46400 Amp		-				
	and for $N = 32$ , $I =$	1450 amps.					
4)	Per J. Singh	11/16/76			•		
5)	$\Delta V = IR = 1450 \times .08$	2085 = 30.2	volts		•		•
6)	Power per magnet =	. = VAI 100.	001 x 1450 x3	50.2	= 43.84 kilo	owatts	
<b>7)</b> 8)_	j = I/Λ = current do Measured value	ensity = 1450	O amperes ÷ 5	39.5	square mm.=	2.69 ampere	s/mm.

A

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