METROPOLITAN-VICKERS

Notes on report 3005.

1) $\sum\sqrt{\left(\frac{x}{n}\right)^2}$ should read $\left(\sum \cancel{\sqrt{}}\left(\frac{x^2}{n}\right)\right)^{\frac{1}{2}}$.

2) Page 4. 0·049 should read 0·0049.

3) Tables agree with those supplied by Dennis before he left Harwell and are for the final sketch of Dr. positions.

4) I was disturbed to find very ~~[illegible]~~ little reference to the assistance given by the P.L.A. group during the measurements, especially since the major difficulties were, ~~[illegible]~~ the main, solved only after we stepped in and investigated them.

5) I have taken one copy of the report

John 23/01/58.

METROPOLITAN-VICKERS ELECTRICAL COMPANY LIMITED

ELECTRONICS DEPARTMENT
(RADAR DIVISION)

ENGINEERING REPORT

No. 3005

Mechanical Alignment of the Proton Linear Accelerator Type 850

Work done by H. M. Dennis

Author/s H. M. Dennis

Date November, 1958.

Approved I. R. GOODE

Summary :

An account is given of the difficulties encountered and the methods used to overcome them in the alignment of tanks 2 and 3 and the drift tubes they contain. The work was carried out at A.E.R.E. Harwell.

Electronics Engg. Dept.

Report No. 3005

Mechanical Alignment of the Proton Linear Accelerator Type 850

Work was commenced in June of this year to set up the 10-30 MeV (tank 2) section and the 30-50 MeV (tank 3) section of the accelerator on to the beam axis as defined by four stands, preset by A.E.R.E.

The equipment provided was a Taylor, Taylor & Hobson micro alignment telescope with suitable targets for the axial alignment of the liners and drift tubes. The gaps between drift tubes were measured with a specially designed travelling microscope using combination length bars and a 12" scale etched on glass. This device was built for tank one and special mounting brackets were made to adapt it for tanks two and three. As the carrier system was only 20 feet long the measurement of tank 2 had to be done in two parts. First, a measurement of the distance between the entry end and drift tube No. 25 then the equipment had to be dismantled and set up on the exit half of the liner. Consistent results could not be obtained although modifications were made, and precautions taken and eventually A.E.R.E. agreed to manufacture additional carrier parts to enable the measurement to be made without intermediate dismantling.

Steps were taken to determine how much the alignment of the liner and drift tubes would be disturbed by the replacement of the lid. The distortion so caused was found to be serious. Clock gauges were placed between the flange of the vacuum envelope and the liner at twelve points and the worst reading was a movement of 0.040 ins.

The loading on the 32 points of support was equalised as far as possible by the use of suitable shims. All the readings were brought below .005 ins, by putting the lid tie bars in tension on one side, and in compression on the other to counteract a noticeable twist in the lid. Only the four end bolts and dowels were used, since the use of the others increased the distortion.

Measurements were made of the change in length of the two end gaps caused by putting on the lid, so that they could be allowed for in the drift tube alignment. The changes were due to slight bowing of the end wheels which tended to straighten out when the lid was bolted down at the ends. In putting on the lid, the entry end gap reduced by 0.035 ins. and the exit end gap by 0.010 ins.

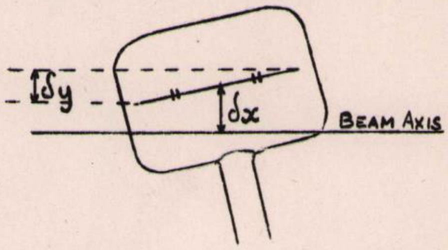
At this time, the lid of tank 1 was off and A.E.R.E. suggested that the four datum stands could be checked. They were found to be wrong and were reset in association with A.E.R.E. This was done in the late evening to try to reduce reading errors due to thermal currents. During the process many readings were taken to determine the experimental error involved in the use of the telescope and targets. The errors had a standard deviation of approximately 0.002 ins. with the target at forty feet from the telescope.

The liner now having been positioned, drift tube alignment commenced. After three drift tubes were set, cross checking of the length measurements brought to light serious inconsistences. Further checks pointed to errors in the etched glass scale. A.E.R.E. checked its calibration and found it correct, and the error was proved to be due to the fact that the plane of the scale did not coincide with the centre line of the measuring bars. A.E.R.E. manufactured a new scale carrier in which this fault was overcome.

In the meantime the drift tubes were aligned axially and it was found that the majority of them were below the centre line of the liner. Shims $\frac{1}{8}$" thick and in some cases $\frac{1}{4}$" thick had to be used on most of the cradle castings to give sufficient clearance for the drift tubes to be brought up to the beam axis.

On the completion of the new scale the gap length setting was started. In most cases it was found impossible to move the cradles along the support bars sufficiently to obtain the correct reading because the clearance between the drift tube foot and the liner had all been used. The only remedy available was to make a padded clamp to fit the drift tube body to enable suitable bending moments to be applied to the legs. This should not have been necessary if all the drift tube legs had been perpendicular to the body axes. In view of the many difficulties encountered, A.E.R.E. decided that the standards of alignment asked for were unrealistic. The limits decided upon were $\pm.005$ ins. for the length between the entry end of the tank and the front face of each drift tube and

$$\left[\sum_n \frac{(\delta x)^2}{n}\right]^{\frac{1}{2}} \leq 0.005 \text{ ins.}$$



$$\left[\sum_n \frac{(\delta y)^2}{n}\right]^{\frac{1}{2}} \leq 0.005 \text{ ins.}$$

where δx = displacement of centre of drift tube axis from beam axis

δy = the distance between the projections on to a plane $\perp$ to the beam axis, of the two end displacements

n = number of drift tubes.

All drift tubes were set to these limits, but on rechecking after completion many of them were found to have moved from their original settings. The worst were reset giving:

$$\left[\sum_n \frac{(\delta x)^2}{n}\right]^{\frac{1}{2}} = 0.0068 \text{ ins.} \quad \left[\sum_n \frac{(\delta y)^2}{n}\right]^{\frac{1}{2}} = 0.0097 \text{ ins.}$$

with the length measurements within $\pm$ 5 mil. these readings being accepted by A.E.R.E.

The alignment of liner 3 was then started. The liner was found to be fouling the liner support raft. A rotary file had to be used before the liner could be set in position. It was found that putting on the liner lid only moved the liner by a small amount and this was easily brought within .005 ins. by adjustment of lid tie bar tension.

The setting of liner 3 drift tubes proceeded much more smoothly than for those of liner 2 and it was possible to position most of them by use of the adjusting screws. On checking the reading three drift tubes were reset and the final figures were:-

Displacement from beam axis:

$$\left[\sum_n \frac{(\delta x)^2}{n}\right]^{\frac{1}{2}} = 0.00475 \text{ ins.}$$

Tip:

$$\left[\sum_n \frac{(\delta y)^2}{n}\right]^{\frac{1}{2}} = 0.0049 \text{ ins.}$$

All length measurements within 0.05 ins. The acceptance of these figures by A.E.R.E. completed the job.

Electronics Engg. Dept.
Report No. 3005

Drift Tube positions after alignment

Tank 2. Sheet 1. (Nos.0-12 inc.)

DT.No	Lateral position				Length				
	Corrections reqd.		Errors		predicted	measured	T_{Cu}	T_{Fe}	Temp
	Front mil	rear mil	Disp mil	Tip mil	in	in	°C	°C	Correction
0	/	2←	/	/	/	/			
1	5← 4↓	4← 7↓	7.15	3.16	1.922	1.924	19.0	19.0	0".0005 add to measured length
2	4← 9↓	2← 1↓	5.8	8.25	10.512	10.518	"	"	
3	9← 8↓	2↓	6.7	10.8	19.2535	19.258	"	"	
4	9← 1↓	10← 1↓	9.5	1	28.150	28.155	"	"	"
5	12←	4← 1↓	8	8	37.1975	37.204	"	"	"
6	1↑ 1←	↑1 →3	1.4	4	46.3985	46.396	"	"	"
7	7← 8↓	3↑ 6←	6.9	11	55.7495	55.753	"	"	"
8	2←	2↑ 1←	1.8	2.2	65.2545	65.259	"	"	"
9	12← 2↓	5←	8.6	7.3	74.912	74.915	"	"	"
10	→3	3←	0	6	84.7175	84.722	"	"	"
11	9← 7↓	2↑ 5←	7.4	9.8	94.678	94.683	"	"	"
12	→3	4← 7↓	3.5	9.9	104.789	104.794	"	"	"

measured to input end of each D.T (1st gap is gap 0)

$L_{n+1} - L_n = l(D.T)_n + g_n$

Drift Tube positions after alignment

Tank 2. Sheet 2. (Nos. 12-28 inc)

DT.No.	Lateral position				Length				
	Corrections reqd.		Errors		predicted in	measured in	T_{Cu} °C	T_{Fe} °C	Temp Correction
	Front mil	rear mil	Disp mil	Tip mil					
13	12←2↓	→3	4.6	15	115.0505	115.052	19.0	19.0	<0".0005
14	↓5	5←1↓	4	6.4	125.4625	125.462	"	"	add to
15	5←4↓	7←	6.3	4.5	136.0275	136.033	"	"	measured
16	↓1→1	1←2↓	1.5	2.2	146.7395	146.743	"	"	length
17	↑7→3	5←9↓	1.4	18	157.6005	157.601	"	"	"
18	↑2→5	↓3	2.5	7	168.6155	168.620	"	"	0".0005
19	↓8→2	↓8→3	8.5	1	179.778	179.783	19.5	19.5	less
20	4←15↓	4←6↓	11	9	191.0895	191.094	"	"	than
21	5←13↓	2←10↓	12	4	202.552	202.550	"	"	0".0005
22	→3	5←13↓	6.5	15.5	214.1636	214.168	"	"	"
23	0	↓15→3	6.7	13.5	225.923	225.925	"	"	"
24	↑1→19	↓5→10	15	11	237.832	237.834	"	"	"
25	↑5→4	5←	2.5	10	249.8895	249.892	"	"	"
26	↑3	4←	2.5	5	262.0965	262.097	"	"	"
27	12←	2←	7	10	274.448	274.447	"	"	"
28	3←	↓9	5	9.5	286.949	286.951	"	"	"

Drift Tube positions after alignment

Tank 2. Sheet 3. (Nos. 29-41 inc)

DT.No.	Lateral position				Length				
	Corrections reqd.		Errors		predicted	measured	T_{Cu}	T_{Fe}	Temp.
	Front mil	rear mil	Disp. mil	Tip mil	in.	in.	°C	°C	Correction
29	↓9 →20	↓3 →5	14	16	299.596	299.599	19.5	19.5	less
30	2← 8↑	↓11 →1	1.5	19	312.3905	312.394	"	"	than
31	↓10	0	5	10	325.3315	325.332	"	"	0".0005
32	→10	↑5	5.5	11.5	338.420	338.421	17.0	17.0	".003
33	→6	↓8 →2	5.5	9	351.651	351.652	"	"	"
34	→15	→13	14	2	365.032	365.036	"	"	"
35	→ 2	↓7	3.5	7.5	378.5595	378.560	"	"	".0035
36	↓17 →2	↓6 →4	12	11	392.2295	392.229	"	"	".0035
37	↑8 →6	4← 2↓	3	14	406.048	406.047	18.0	18.0	".0025
38	↓2 →6	↓3	3.5	6	420.0085	420.007	"	"	"
39	10←	↓3	5	10.5	434.114	434.114	"	"	"
40	6←	4← 4↓	5.5	4.5	448.364	448.368	"	"	"
41	13 3	/	/	/					

Drift Tube positions after alignment

Tank 2. results etc.

R.M.S. errors

Disp. from zero field axis

$$\left[\sum_n \frac{(\delta x)^2}{n}\right]^{\frac{1}{2}} = 6.8 \text{ mil.}$$

Tip

$$\left[\sum_n \frac{(\delta y)^2}{n}\right]^{\frac{1}{2}} = 9.7 \text{ mil.}$$

Drift Tube positions calculated thus:-

(refer to Dwg. A.2215816)

using DT. No. 0 face as reference:-

measure zero on scale	0.215
add tank distortion	0.035
add gap No.1 (actual)	2.174
	2.424
subtract knife edge thickness	0.502
No. 1 DT position	1.922

then add actual gap and
actual DT dimensions

Drift Tube positions after alignment

Tank 3. Sheet 1 (Nos. 0-16 inc)

DT.No.	Lateral position				Length				
	Corrections reqd		Errors		predicted	measured	T_{Cu}	T_{Fe}	Temp.
	Front mil	rear mil	Disp mil	Tip mil	in	in	°C	°C	Correction
0	/	/	/	/					<0".0004
1	→1	1← 2↓	1	3	5.093	5.093	23.0	24.0	subtract
2	↑1	↓4	1½	5	19.766	19.763	"	"	from
3	←1	2← 1↑	1½	1½	34.583	34.585	"	"	measured
4	↑2 →1	↓1 →7	4	7	49.541	49.545	"	"	length
5	←3	2← 1↓	2½	1½	64.642	64.647	24.0	25.0	"
6	←5	2← 1↑	3½	3	79.884	79.883	23.0	24.0	"
7	←7	2← 2↓	4½	5½	95.265	95.261	"	"	"
8	↓3 →4	↑1 →1	3	5	110.793	110.795	"	"	"
9	←18	10← 2↑	14	8	126.459	126.454	"	"	"
10	↑2	↓1	1	3	142.265	142.269	"	"	"
11	3← 2↓	1← 8↑	4½	10	158.212	158.212	"	"	"
12	0	1← 1↑	2½	4½	174.301	174.302	"	"	"
13	↑3 →3	↑3 →4	4½	1	190.529	190.529	"	"	"
14	7← 5↑	5←	6½	5½	206.898	206.893	"	"	"
15	0	→2	1	2	223.406	223.407	"	"	"
16	→3	↑6 →1	4	6½	240.053	240.054	"	"	"

Drift Tube positions after alignment

Tank 3. Sheet 2. (Nos. 16-27 inc)

DT.No.	Lateral position				Length				
	Corrections reqd		Errors		predicted	measured	T_{Cu}	T_{Fe}	Temp.
	Front mil	rear mil	Disp mil	Tip mil	in	in	°C	°C	Correction
17	↑5 →5	↑4 →4	7	1½	256.838	256.841	24.0	25.0	0".0005
18	←7	←2	4½	5	273.764	273.768	"	"	add
19	1← 10↑	↑3	7½	7	290.828	290.833	"	"	error
20	3←	0	1½	3	308.030	308.035	"	"	"
21	2←	0	1	2	325.369	325.366	"	"	between
22	↓1	0	½	1	342.845	342.841	"	"	0".0005
23	0	↑5 →3	3	6	360.456	360.461	"	"	and 0".0008
24	↑1 →10	↑5 →4	7½	7½	378.204	378.208	"	"	add to
25	→4	↑1 →4	4	1	396.090	396.094	"	"	measured
26	→5	0	2½	5	414.114	414.113	"	"	length
27	→2	/							

Results etc.

---

1. Disp. from zero field axis

$$\left[\sum_n \frac{(\delta x)^2}{n}\right]^{\frac{1}{2}} = 4.75 \text{ mil}$$

2. Tip

$$\left[\sum_n \frac{(\delta y)^2}{n}\right]^{\frac{1}{2}} = 4.90 \text{ mil}$$

Drift Tube positions calculated as for tank 2

ref. A.2215816

zero on scale	1.846
tank distortion	zero
add gap No.1	3.749
subtract knife edge	.502
No.1 DT position	5.093

HMD/MPR