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CONSIDERATIONS ON THE LOCATION OF THE POSITION-SENSITIVE PICK-UP ELECTRODES IN THE BOOSTER

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1. Introduction

In order to get sufficient information on the shape of the closed orbit in a circular accelerator one should have at least 5 measuring points per betatron wave length. The Q-value of the booster being about 4,6 in either plane, a number that would fit nicely with the periodicity of the magnetic lattice would be 32, i.e. 2 per period, where each station would be of the combined type, measuring horizontal and vertical position. At the moment this basic number seems to be more or less accepted, it will, however, be necessary to disturb the regularity of the distribution over the circumference by using some of the electrodes for other purposes (e.g. phase lock system) than the determination of the closed orbit. The location of the normally 2 electrodes within the structure of one period shall now be discussed (see also ref. 1).

2. Criteria for the location

A compromise will have to be found between the following requirements (in sequence of importance) :

a) To gain maximum information on the shape of the closed orbit, the electrodes should be equidistant with respect to the phase of a betatron oscillation.

b) If one wants to straighten the closed orbit by correcting fields, it is of advantage to have the corrections and the measuring points as near as possible to each other.

c) To obtain the biggest possible signals, the pick-up electrodes should be situated near the maxima of the β-function.

d) From the engineering point of view the electrodes should be installed in places, where this can be done easily and economically.

For the convenience of the discussion we will reverse the sequence and start with

ad d) Gould and Schittko[2] have proposed to mount the electrodes in the manifolds connecting the vacuum pumps to the 4 rings and situated immediately before each of the 32 bending magnets. This proposal seems very attractive, as one would save special vacuum tanks for the electrodes and alignment would be simplified. Some difficulties due to limited space can now be overcome by increasing the length of the manifolds by 4 cm.

Let us see whether this solution seems acceptable from the other points of view.

ad c) This requirement would obviously lead to a different location for the horizontal and the vertical pick-up electrodes, with special vacuum tanks for at least all the vertical ones. If one looks at Fig. 1 (taken from [3], but with more recent numbers for the length of the bending magnets and the Q-values) one sees that the best location for the horizontal stations would be in a straight section 2 or 5, compared with the proposal under d) to use positions ① and ⑤. If one does

not want to put the vertical stations right into the middle of the D-lenses, then the best possible positions would be ③ and ④ .

For further comparison of the merits of different positions we better use Fig. 2, as the displacement of the closed orbit at any azimuth is proportional to $\sqrt{\beta}$. The various ratios of $\sqrt{\beta}$ between different positions are listed in Table 1.

For example in the horizontal plane position ① is only 11 % less "sensitive" than position ⑤ and seems therefore to be quite acceptable for the second station in the period. In the vertical plane one has 20 % less sensitivity at the worst possible position ① than at ⑤ and 44% less than at the best possible position ④ .

ad b) Particularly in the case where one wants to straighten the first turn (which may be necessary if the beam does not circulate at the start-up of the machine) it is of great advantage to have the correcting elements as near as possible to the position detectors. One can then unambiguously and with minimum corrections straighten the orbit by correcting the position at the detector n with the correcting element n-1 without disturbing the position at the detector n-1.

Looking at Fig. 2 one sees that position ① and ⑤ fulfill this condition for the horizontal plane, as all horizontal corrections are made in the bending magnets. A vertical correction in SS 4 together with a vertical pick-up station at ⑤ would also fit.

ad a) To compare the betatron phases of the various positions Fig. 12 of [3] was used and the phase differences are shown in Table 2 with the values for the horizontal plane above the corresponding values for the vertical plane.

For a Q-value of 4,62 the phase advance per period is 104° so that the pick-up stations should be separated by 52°.

In the horizontal plane the phase distance from ① to ④ would fit exactly, but it would be way out in the vertical plane where the best fitting distance is between ① and ⑤ . This, at the same time, would be the best compromise for combined stations, as the average between $\Delta\varphi_H$ and $\Delta\varphi_V$ is just 52°.

3. Conclusions

Requirements a), b) and d) are all in favour of having combined horizontal and vertical pick-up stations in positions ① and ⑤ .

As for requirement c) : one wants to know the closed orbit distortion best there, where one has the lowest tolerances and this is in the bending magnets (see Table II.3.2 of [4]). So one should put the pick-up stations near them. Of course one can get bigger pick-up signals near the maximum of the β-function, but there one has at the same time ample tolerances in the vertical plane due to the circular cross-section of the vacuum chamber. What is really interesting is the absolute value of the closed orbit displacement at the critical place.

If one considers the detection of any coherent transverse oscillation, one may argue in the following way (assuming equal minimum detectable average amplitudes in the two planes) :

One has to make the pick-up stations anyway so good as to work satisfactorily in the horzontal plane at ⑤ . In comparison to that position horizontal ① is 11 % and vertical ① is 25 % lower in sensitivity.

As one wants 2 pick-up stations per period, they will also have to fulfill the requirements at horizontal ① . If one puts the vertical stations also at ① and ⑤ , then this means that one has to push the performance only 15 % above what one will need anyway.

If one insists on the maximum sensitivity for coherent transverse oscillations, one may still put a special vertical pick-up station in one of the straight sections 3 or 4.

The best compromise therefore seems to be that one has combined horizontal and vertical pick-up stations in positions ① and ⑤ and the vertical corrections in SS 4.

If one has to suppress orbit measuring pick-up stations, this should be done outside the injection and ejection regions, so as to have there the maximum information available.

According to requirement b) for the vertical plane, one should try to retain always the pick-up stations in position ⑤ , i.e. near the vertical corrections and only use stations in position ① for other purposes.

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Distribution

SI Scientific Staff
MPS Machine Study Team

References

1) U. Bigliani, D. Boussard and C. Bovet, Disposition des électrodes pick-up, Memorandum SI/DL, 19.3.1968.

2) C. Gould and F. Schittko, Proposed Vacuum System for the Booster Ring, SI/Note DL/68-5.

3) C. Bovet, Nouvel injecteur pour le CPS : Optimisation de la maille triplet, MPS/Int. DL/B 67-16.

4) The Second Stage CPS Improvement Study, MPS/Int. DL/B 67-19.

Table 1

$$\left(\frac{\beta_i}{\beta_k}\right)^{\frac{1}{2}}$$

k \ i	H_1	$H_{2/5}$	$H_{3/4}$	V_1	$V_{2/5}$	$V_{3/4}$
H_1	1,00	1,13	0,96	0,85	1,06	1,51
$H_{2/5}$	0,89	1,00	0,85	0,75	0,94	1,34
$H_{3/4}$	1,05	1,18	1,00	0,89	1,11	1,58
V_1	1,18	1,33	1,13	1,00	1,25	1,78
$V_{2/5}$	0,94	1,06	0,90	0,80	1,00	1,42
$V_{3/4}$	0,66	0,75	0,63	0,56	0,71	1,00

Table 2

$$\varphi_i - \varphi_k \quad (°)$$

k \ i	1	2	3	4	5	1 next period.	
1	0	18 24	26 30	51 37	60 44	104 104	H V
2		0	8 6	33 13	42 20	86 80	H V
3			0	25 7	34 14	78 74	H V
4				0	9 7	53 67	H V
5					0	44 60	H V

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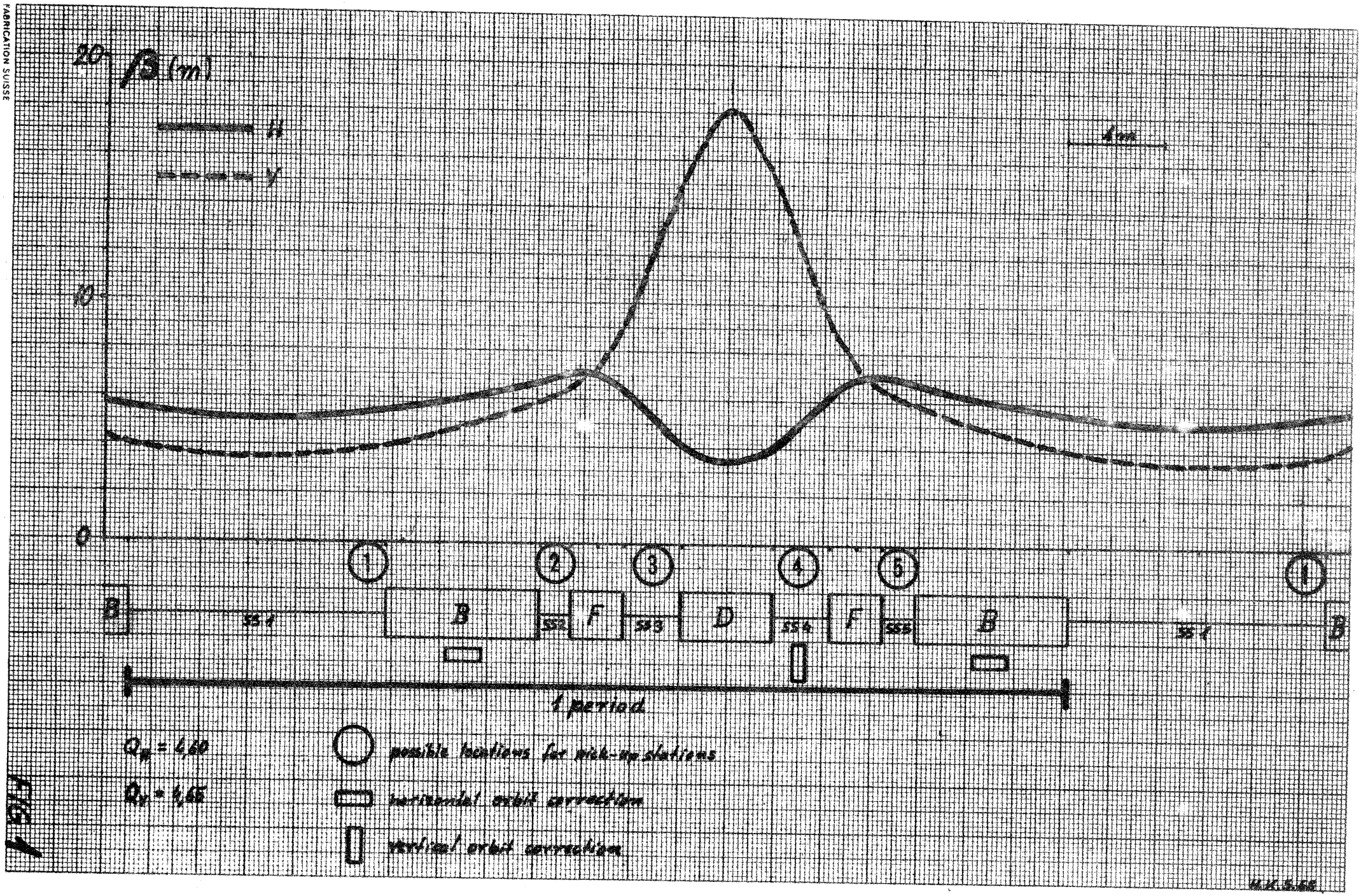
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β (m)
h
v
4 m
10
0
1
2
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4
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1
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SS 1
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SS 2
F
SS 3
D
SS 4
F
SS 5
B
SS 1
B
1 period
Q_h = 4.60
Q_v = 4.65
possible locations for pick-up stations
horizontal orbit correction
vertical orbit correction
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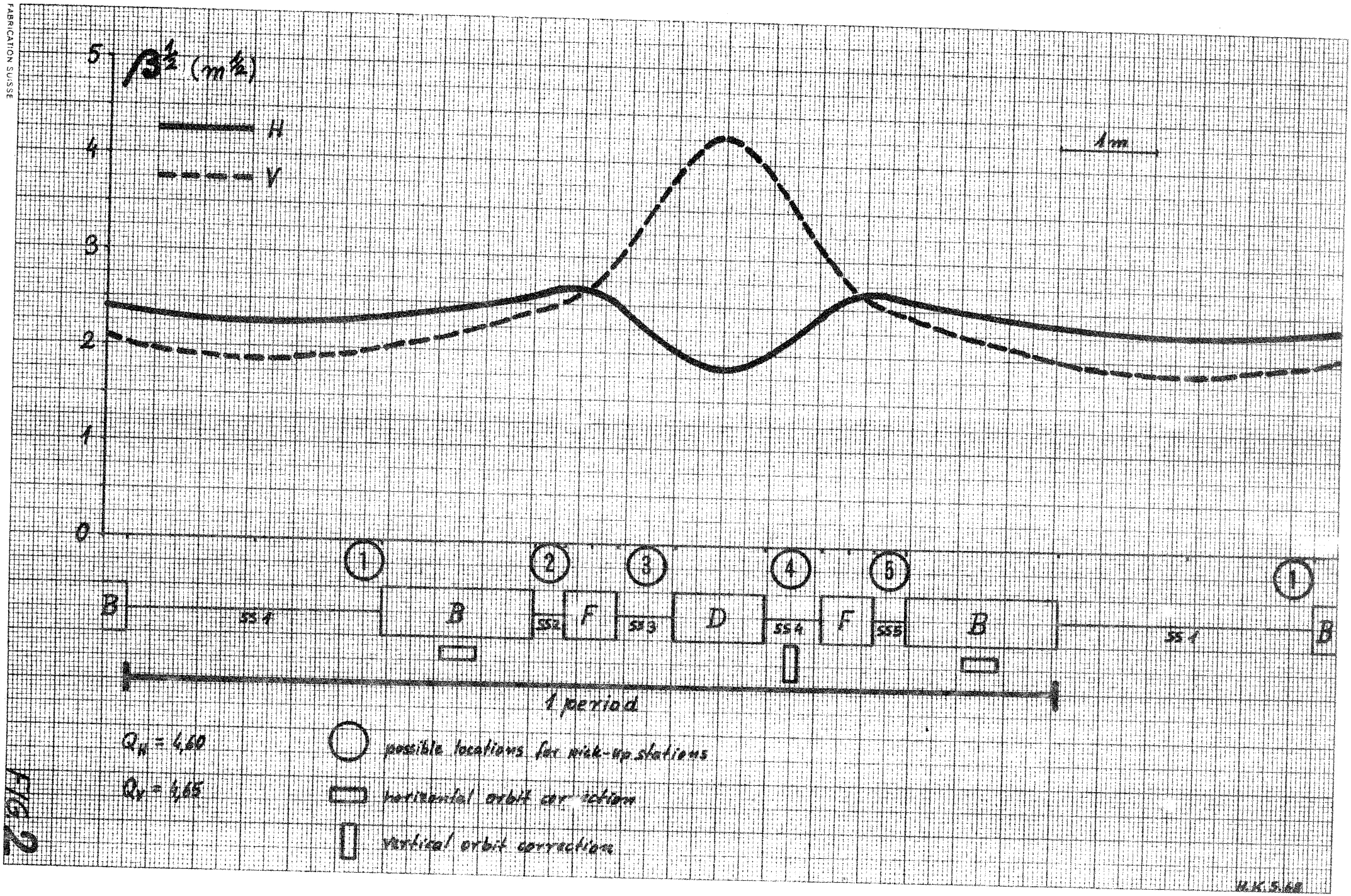

Fig 2