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THE EFFECT OF VARIOUS SYSTEMATIC ERRORS ON THE NINA WORKING POINT.

by

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NINA has the magnet lattice structure $(F\bar{O}DO)^{20}$ with

$$\ell_M = 3.26250 \text{ m}$$
$$\ell_{\bar{o}} = 3.50 \text{ m}$$
$$\ell_o = 1.00 \text{ m.}$$

The working point in $Q_r = Q_V = 5.250$ requiring

$$n_F = -46.169$$
$$n_D = 47.169$$

We consider here the movement of the working point due to :

1. Errors in the field indices in the magnets
2. Errors in the lengths of the equilibrium orbit in the magnets.
3. Variation of the field lengths of the magnets with radius.

The shifts in the Q values are calculated assuming the errors are identical in each FODO unit. Random errors destroy the periodicity of the structure and introduce stopbands as well as shifting the Q values.

1. The calculation of the shift in Q values due to errors in the field indices is straightforward and the shifts for a 1% increase in n_F and n_D respectively are found to be :

$$\begin{pmatrix} SQ_r \\ SQ_V \end{pmatrix}_F = a_1 = \begin{pmatrix} 0.0875 \\ -0.0225 \end{pmatrix}$$

$$\begin{pmatrix} SQ_r \\ SQ_V \end{pmatrix}_D = a_2 = \begin{pmatrix} -0.0230 \\ 0.0894 \end{pmatrix}$$

The errors in n are assumed uniform along the magnet length. It is emphasised that the first vector a_1 refers to all the F magnets having an n value 1% greater than specified, and all the D magnets being perfect. The vector a_2 is for n_D 1% too large and all the F magnets perfect.

2. The calculation of the shift due to errors in magnet length have been calculated assuming a constant overall circumference of the machine i.e. the increase in a magnet length is offset by decreases in the lengths of the two straights in the unit. The magnetic radius is kept constant so that the equilibrium orbit will no longer be an isomagnetic line, and the betatron oscillation will take place about the new equilibrium orbit. We calculate, here, the changes in Q values for these betatron oscillations.

The shifts for a 1 cm increase in length of the magnets are found to be :-

$$\begin{pmatrix} SQ_r \\ SQ_V \end{pmatrix}_F = a_3 = \begin{pmatrix} 0.0224 \\ -0.00925 \end{pmatrix}$$

$$\begin{pmatrix} SQ_r \\ SQ_V \end{pmatrix}_D = a_4 = \begin{pmatrix} -0.00925 \\ 0.0224 \end{pmatrix}$$

3. The variation of field length with radius shifts the Q values for a synchronous particle as well as introducing a coupling between the synchrotron and betatron oscillations. For the purposes of this calculation it is assumed that the B length increases uniformly with radius. This is equivalent to having a wedge of angle θ

$$\theta = \frac{1}{2} \frac{d(\Delta \ell_B)}{dr}$$

on each end of the magnet. The effect of wedges on the ends of a magnet can be simply calculated. In our case with unequal straight sections two equal wedges on the ends of a magnet do not contribute equally to the shifts in Q.

The shifts for a 1 degree wedge on both ends of a magnet are found to be :-

$$\begin{pmatrix} SQ_r \\ SQ_V \end{pmatrix}_F = a_5 = \begin{pmatrix} 0.0340 \\ -0.0145 \end{pmatrix}$$

$$\begin{pmatrix} SQ_r \\ SQ_V \end{pmatrix}_D = a_6 = \begin{pmatrix} 0.0145 \\ -0.0340 \end{pmatrix}$$

The various 'a' vectors are shown graphically. For a machine with errors of all the types discussed here, the shifts in Q values are approximately :-

$$\begin{pmatrix} SQ_r \\ SQ_V \end{pmatrix} = a_1 P_F + a_2 P_D + a_3 S\ell_F + a_4 S\ell_D + a_5 \theta_F + a_6 \theta_D$$

The least important of these errors is that in the B length. It should be possible to have these correct to much better than 1 cm. - which error causes a small change in Q value anyway.

The magnet profiles were designed to give the n values correct to 1%. The worst case would be for n_F to be 1% too large and n_D 1% too small. The radial Q value would then be 5.36. If in addition to this we have a 1^o wedge angle on both ends of every magnet the Q value would be 5.4. This is still well within the working diamond although it should be remembered that we are here dealing with the ideal working diamond and that the actual working diamond will be reduced due to random errors in the machine. It would seem advisable then to keep the effective wedges on the ends of the magnets down to 1^o or less.

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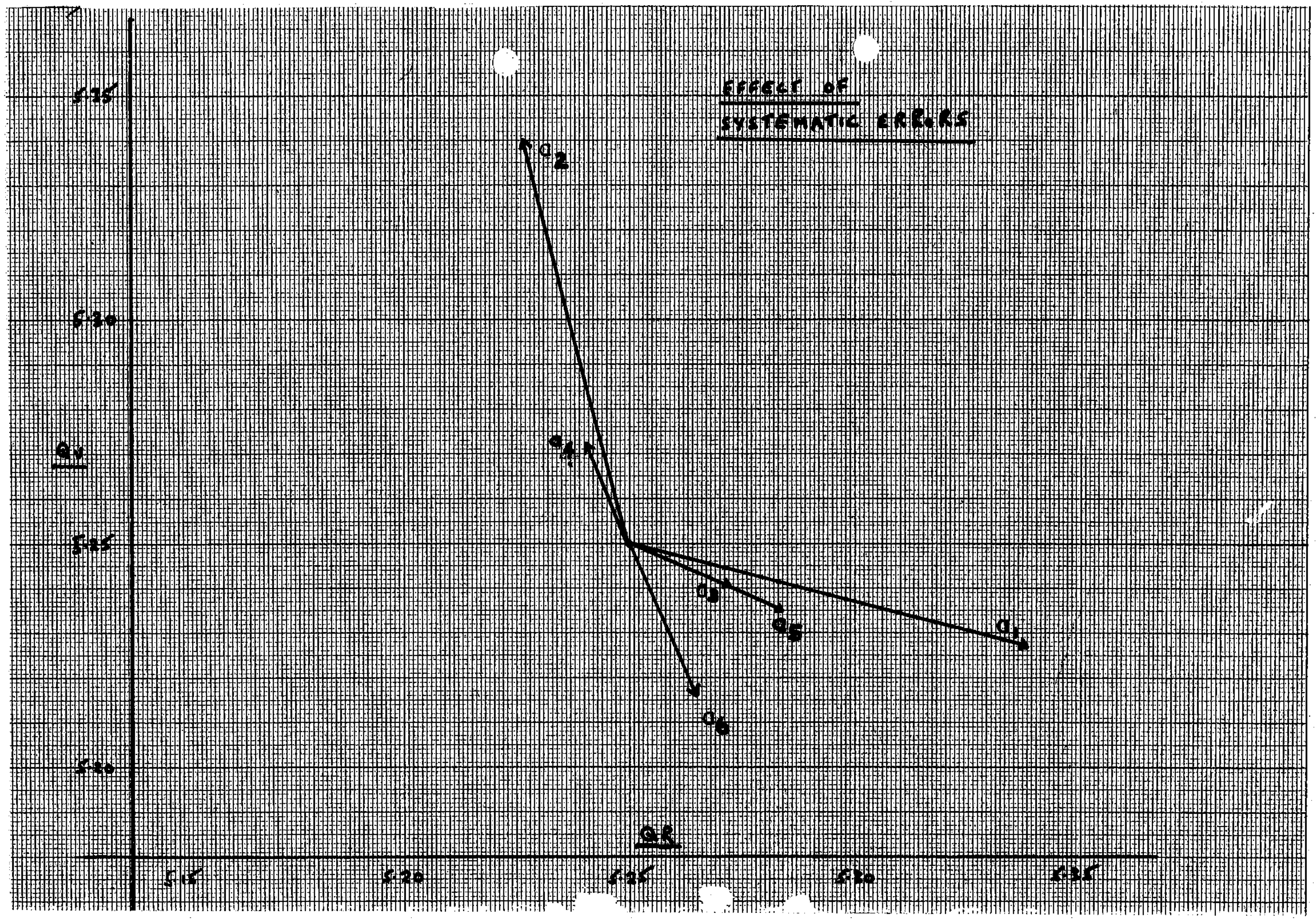
EFFECT OF
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QV
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a1
a2
a3
a4
a5
a6