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FURTHER CONSIDERATIONS ON THE NOMINAL VALUES OF Q_H AND Q_V FOR THE PSB AND THEIR RANGE OF TUNING

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1. Introduction

As we are about to freeze the lengths of (the bending magnets and) the main PSB quadrupoles, and of the characteristics of the trim supplies, it is appropriate to review at this point the earlier tentative decisions concerning the working point. Historically, $Q_{Ho,Vo}$, the Q-values for zero trim current, evolved as follows:

	1967[1]	1968[2]	1969[3]
Q_{Ho}	4.5	4.60	4.55
Q_{Vo}	4.5	4.65	4.70

While the reasons given earlier for the rough choice $Q_{Ho} \approx Q_{Vo} \approx 4.5$ (see ref. 2) remain valid, a few new considerations have a bearing on the present thinking.

2. Stop bands

Further work on the stopband widths[4] has put into evidence the danger of crossing the third and fourth order stopbands, particularly $m_1 Q_H + m_2 Q_V = 14$ and 19 in the present context. We therefore have specified as stringent tolerances as reasonable on the fluctuations of the sextupole and octupole fields in the main quadrupoles and we now plan to compensate also half the stop bands listed above (by sextupoles and octupoles with $B_x'' = 0$ and $B_x''' = 0$, respectively), i.e. those which are expected to be enlarged if the correction sextupoles or octupoles are energised[4). However, for the moment we expect to deal with the remaining stop bands $3Q_V = 14$, $2Q_H + Q_V = 14$, $3Q_H + Q_V = 19$, $Q_H + 3Q_V = 19$ simply by avoiding them (Cp. Fig. 1).

3. Uncertainties of $Q_{Ho,Vo}$

These uncertainties result mainly from lack of precise knowledge of the final magnetic length of the quadrupoles and of the field gradients in the bending magnets. Because of design changes, the magnetic lengths of the quadrupoles (for a given physical length, as ordered) can at present only be forecast to about ± 4 mm (i.e. about 8 °/oo of L_{QF}). If necessary, some corrective action is envisaged to improve the situation after the measurements of the production prototype. However, it seems wise to assume that there may remain an error of ±2 °/oo, in L_{QF} and ± 1 °/oo in L_{QD}, giving rise to values of $\Delta Q_{H,V}$ obtainable*) from Table 1.

Q changes corresponding to 1 °/oo change of lens strength				
	ΔI_F	ΔI_D	$\Delta I_F + \Delta I_D$	$\Delta I_F - \Delta I_D$
ΔQ_H	0.007	- 0.003	0.004	0.010
ΔQ_V	- 0.007	0.015	0.007	- 0.022

TABLE 1 (valid around $Q_H = Q_V = 4.5$)

The difference in magnet gradient between gaps has been specified as $(1/\overline{B}_z)(\partial\overline{B}_z/\partial x) < 3\ 10^{-3}$/m (which is 4 times better than obtained on the prototype). If this specification is met, the tuning differential between rings would be $\Delta Q_H < -0.007$, $\Delta Q_V < 0.006$.

*) As the PSB lenses are not optically short, a 1 °/oo change in length is optically equivalent to a current change of 0.7 °/oo in the present case.

4. "Modulation" of working point

The synchrotron oscillations modulate the working point at injection in the range[5] $\Delta Q_H = \pm 0.016$, $\Delta Q_V = \pm 0.036$ if no sextupoles are used, and from zero to four times that amount if the sextupoles are energised (with either polarity). If used for narrowing the stop band $2Q_H - 2Q_V = 0$ the octupoles introduce a maximum (amplitude-dependent) Q-shift* $\Delta Q_H = 0.008, \Delta Q_V = 0.05$.

The current ripple of the trim supplies[6] is expected to have the following values at injection (in terms of total lens current)

300 Hz	$\pm 0.3\,^{o}/oo$
600 Hz	$\pm 0.2\,^{o}/oo$
1200 Hz	$\pm 0.2\,^{o}/oo$

The drift of the nominal current value is specified to stay below $0.6\,^{o}/oo$ in the worst case. So, let us say somewhat arbritrarily, that the modulation due to the power supply imperfections is $\pm 1\,^{o}/oo$ of I_F and/or I_D at most.

5. Minimum shift of working point

According to J. Pahud 2 A (= $1.3\,^{o}/o$ of peak current) is the minimum current obtainable from the trim supplies. At injection, this means $3.3\,^{o}/oo$ of $I_{F,D}$ with the Q shifts obtainable from Table 1.

6. Choice of working point

In order to stay away from the dangerous stopbands listed in section 2 while maintaining a Q split[7] of $|Q_H - Q_V| \geq 0.2$, either of the sets :

A) $Q_H = 4.6$ $Q_V = 4.85$ (or thereabouts)

B) $Q_H = 4.85$ $Q_V = 4.6$ (or thereabouts)

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*) Corrected values from ref. 5.

seems acceptable as working point <u>at transfer</u>, taking account also of the modulation discussed in section 5, reduced to the 800 MeV level (Fig. 1).

At <u>injection</u>, point A) may also be used for low intensity, but for high intensity one might like to provide more room for the Laslett tune shift by going for instance to $Q_H = 4.72$, $Q_V = 4.95$. As against this, full use of the sextupoles for Landau damping would mean a modulation of $Q_V = \pm 0.15$, and use of the octupoles $\Delta Q_{Vmax} = 0.05$. Thus (always under the assumption that one should stay away from the integer stop bands) one may be forced to come down to some value like $Q_H = 4.55$, $Q_V = 4.75$. Presumably the choice of the exact $Q_{H,V}$ (t) programme at injection and low energies will depend notably on beam intensity and aspect ratio *) and will have to be determined experimentally. However, it would appear a mistake at this point not to reserve the possibility to adjust the working point to $Q_V = 4.75$ or even somewhat lower.

A last consideration concerns the adjustment (and later checking) of the compensation of the stopband $2Q_H = 9$. It seems highly desirable to be in a position to use the standard injection procedure for this. In other words, the point $Q_{Ho,Vo}$ should preferably be located such that one can tune to this stopband with the trim current polarity used for normal operation. Obviously this also facilitates the "simultaneous" adjustment of the corrections for this stop band and the $2Q_V = 9$ one.

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*) The Laslett Q-shift for a round beam is parallel to the $Q_H = Q_V$ line, the shift for a flat beam goes down more steeply; in case of a round beam it may not be necessary to have $|Q_H - Q_V| \geq 0.2$

Considering the uncertainties of Q_{Ho}, Q_{Vo} discussed in section 3 (and any others not thought of at present), and the desirability of increasing the minimum trim current used, it seems interesting to return to the original values

$$Q_{Ho} = 4.5 \qquad Q_{Vo} = 4.5$$

This will require a minimum increase of I_F to 200 A for obtaining the Q-values of set B) above. For a fixed magnet length, the new lengths of the quadrupoles are shorter by about 1.6°/o (F) and 2.2°/o (D) respectively. The extra straight section space could be used to reserve the possibility of moving Q_F azimuthally by, say, ± 15 mm, for instance to take up lens tolerances. For constant $Q_{Ho,Vo}$, an increase in lens spacing corresponds to a shortening of both types of lenses by 5°/oo per centimetre increase, and conversely for a decrease in lens spacing. Alternatively, with lenses of the correct length, $Q_{Ho,Vo}$ can be adjusted by the corresponding amount by means of such a change of lens spacing.

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Distribution (open)

List MPS-SI/2

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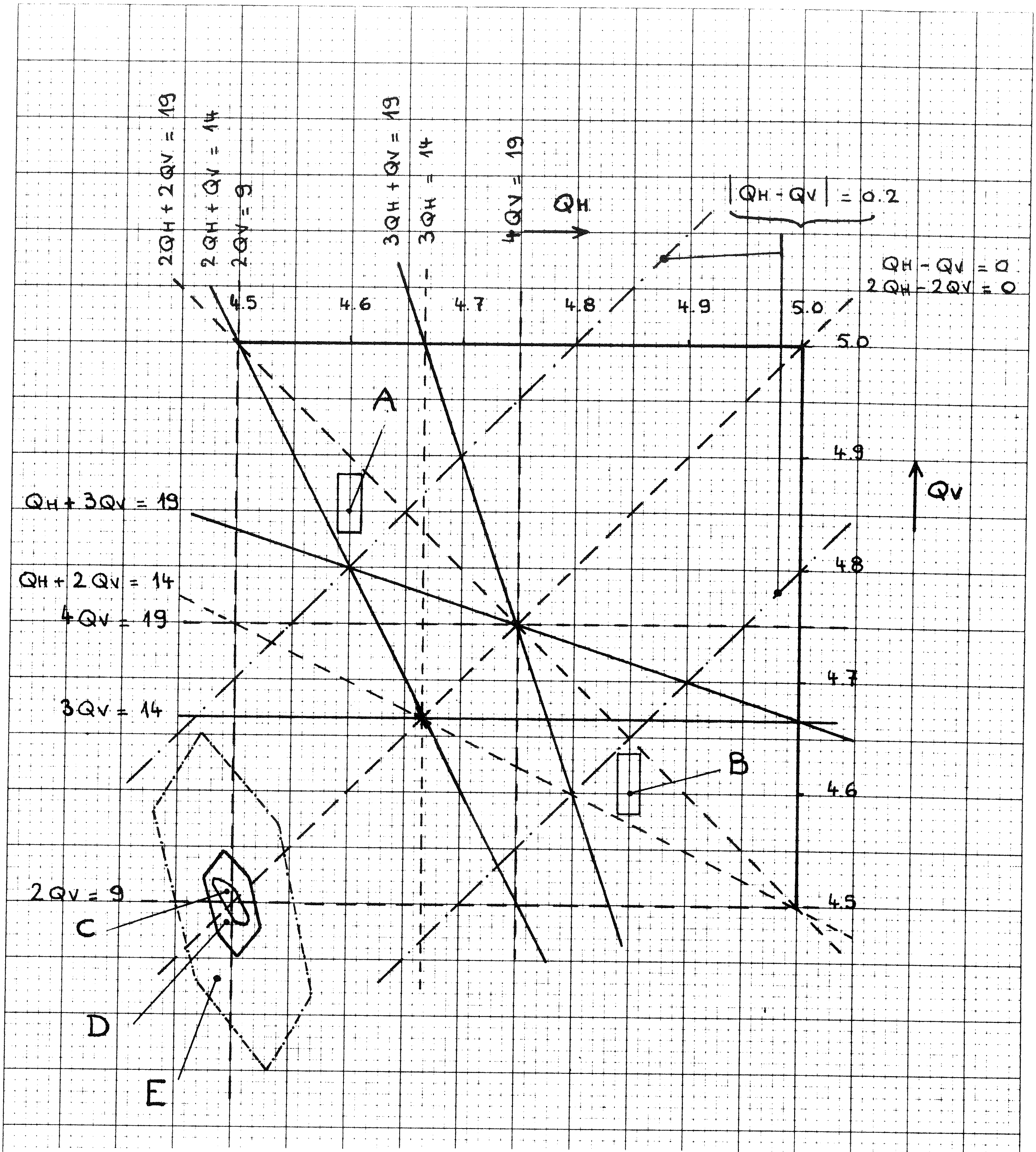

Fig. 1 : Stop bands and working points

Broken lines : compensated stop bands

Full lines : uncompensated stop bands (fourth order stop bands $m_1 Q_H + m_2 Q_V = 18$ not shown)

A, B : possible working points and their modulation at 800 MeV

C : minimum uncertainty of $Q_{Ho,Vo}$ (mainly uncertainty of final magnetic lengths of lenses)

D : minimum Q shifts for 2 A trim current

E : Q shifts for 6 A trim current.