Fermilab

PBAR NOTE # 460

Tune Variations due to Septum Stray Field

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1. INTRODUCTION AND SUMMARY

Two types of antiproton instabilities due to trapped ions are harmful in the AA[1]. One is a coherent instability occurring when an ion pocket resonates with a 3-Q mode[2] (hiccups), the other is excitation of 11th and 15th order non-linear resonances due to the non-linear focusing fields from localized ion clouds trapped in uncleared potential well pockets.

Accumulation with a good injection yield of antiprotons forces us to locate the tune of the dense core in the general area of the array of 15th order resonances. To avoid harmful blow-up of the dense core the tune is located between the resonances $11Q_H + 4Q_V = 34$, $10Q_H + 5Q_V = 34$, and $11Q_H = 25$, requiring a tune of $Q_H = 2.2722$ to be maintained with a precision of a few 10^{-4} (Fig. 4).

Different angles of the injection and ejection trajectories require the septum current to be changed from 3860 A during accumulation to 3920 A, during ejection mode. Variations in the septum stray field due to these changes in current cause tune changes in the order of 10^{-3}. In addition, at a given septum current, a pronounced hysteresis of the stray field causes tune variations of about the same order of magnitude, so also the past history of the septum excitation must be carefully controlled to obtain a reproducible tune.

2. MEASUREMENTS

A number of tune measurements (with the E and Q vs frequency program) were made while the septum excitation current was cycled in the following manner.

After having switched the septum on (1) at 3860 A (accumulation value) the current was lowered to zero (2). Then (3) up to 3960 A, then (4) down to

3840 A, then (5) up to 3920 A (ejection value), and finally (6) down again to 3860 A (accumulation value) (Figs. 1, 2, 3,).

The peak (and the mean) of the cooled stack was at 1855 kHz, and the tunes were measured at this frequency. In general linear interpolation between the two points just above and below 1855 kHz were used to obtain the tune at 1855 kHz. Therefore the fifth digit in Table 1 below is mentioned.

Table 1 - Q_H, Q_V versus septum current.

I_{septum}	Q_H	Q_V
3840	2.2648 2	2.2555 4
3820	2.2644 7	2.2557 1
3800	2.2645 4	2.2557 6
3700	2.2645 0	2.2559 8
3500	2.2643 7	2.2562 6
3000	2.2646 1	2.2561 6
2000	2.2648 0	2.2563 0
1000	2.2645 8	2.2560 9
septum OFF	2.2645 4	2.2560 8
+ 1000	2.2646 5	2.2558 6
+ 2000	2.2649 4	2.2553 0
+ 3000	2.2651 7	2.2550 7
+ 3500	2.2653 0	2.2550 0
+ 3700	2.2652 4	2.2549 7
+ 3800	2.2653 4	2.2548 0
+ 3860	2.2653 2	2.2548 2
+ 3920	2.2654 4	2.2547 4
+ 3960	2.2654 0	2.2547 3
3860	2.2648 5	2.2553 6
3840	2.2646 5	2.2555 3
up again		
+ 3920	2.2651 6	2.2549 0
down again		
3860	2.2650 7	2.2553 6

Figures 1 and 2 show ΔQ_H and ΔQ_V versus septum current, respectively Figure 3 shows ΔQ_H and ΔQ_V variations after one cycle, when we change the septum current between accumulation and ejection modes.

We see that Q_H and Q_V change by a few 10^{-3} according to which point we are on the septum hysteresis curve. The changes between accumulation and ejection modes (3860 A and 3920A) give $\Delta Q_H \approx 10^{-4}$ and $\Delta Q_V \approx 0.5 \cdot 10^{-3}$.

Figure 4 shows the cooldown tunes as function of septum current, and the accumulation tunes used during most of 1986.

Machine conditions are given in Table 2 below.

Table 2

1985-12-10-14:35:53 RING

		REF.	REQUIRED	MEAS.
BHZ #DH	BH	1946.93	1946.93	1946.62
BHZ #DT	H	7.72	7.72	7.73
QDO #QD	▷◁	1060.37	1058.57	1058.63
QFO #QF	◇	1465.32	1460.46	1460.54
SMH #SM	SM	3860.1	3860.1	3859.6
F4		0	0	0
QSK0105		4.49	4.49	4.49
QSK1307		1.50	1.50	1.49
SRC1304		-16.00	-16.00	-15.76

STACK TUNES AND EMITTANCES

1985-12-10-14:31:54 STACK 2.65E11

	Q	95% EMITTANCE (π mm mrad)	
	AT PEAK	AT PEAK	AVERAGE
HOR.	2.2648	1.9	2.9
VERT.	2.2554	1.4	1.8

PEAK AT 1854.95 kHz

MEAN AT 1854.95 kHz, RMS WIDTH 151 Hz

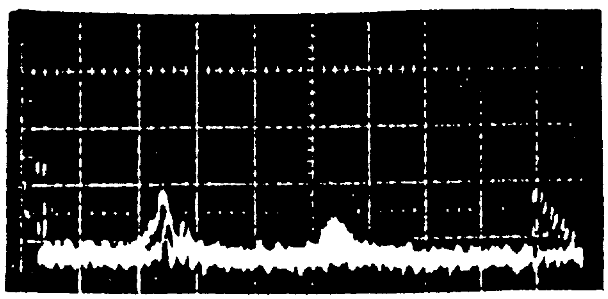
Measuring the betatron frequency on a FFT device and using the resonant vertical pick-up tuned to $3-Q_V$, it was possible to make a more precise measurement of vertical tunes.

	I_{septum}	$f = f_\beta - f_{LO}$
Accumulation mode	3860 A	2762 Hz
Ejection mode	3920 A	3200 Hz

$\Delta f = \Delta Q_V\, f_0$ $\qquad f_0 = 1855$ kHz $\qquad f_{LO} = 1378$kHz

$$\boxed{\Delta Q_V = 2.4 \cdot 10^{-4}}$$

With this equipment, tunes can be measured to within 10^{-5}.



The picture shows both frequencies f on FFT display.

3. STRAY FIELD OF THE SEPTUM

The stray field of the septum[3] is shown in Fig. 5. At 30 mm from the septum, where the closed orbit is situated, the integrated field is $0.22 \cdot 10^{-3}$ T.m. This produces a deflection angle of 0.042 mrad, which is probably too small to give a change in closed orbit. However, an estimation of the quadrupole component due to the stray field gives:

$$\delta k = \frac{1}{B\rho}\frac{\partial B_y}{\partial x} \approx 1.1 \cdot 10^{-3}\ m^{-2}\ .$$

For 2 septa, each being 0.94 m long, with $\beta_H \approx 11$ m and $\beta_V \approx 8$ m, we obtain:

$$\Delta Q = \frac{1}{4\pi} \int_0^{2\pi R} \beta(s)\ \delta k\ ds\ .$$

$$\Delta Q_V \approx 1.5 \cdot 10^{-3}$$
$$\Delta Q_H \approx 2.0 \cdot 10^{-3}$$

4. FURTHER MEASUREMENTS

To confirm that tune variations are mainly due to changes in the stray field gradient and not to changes in the closed orbit, one could measure this latter with a bunched beam at the stack orbit.

When a resonant horizontal pick-up at $3\text{-}Q_H$ is available (1986), both tunes could be measured to 10^{-5}. The reproducibility of the tunes could then be checked much faster and more precisely, which could be used to check the efficiency of a suitable cycling procedure for the septum magnet.

5. CONCLUSION

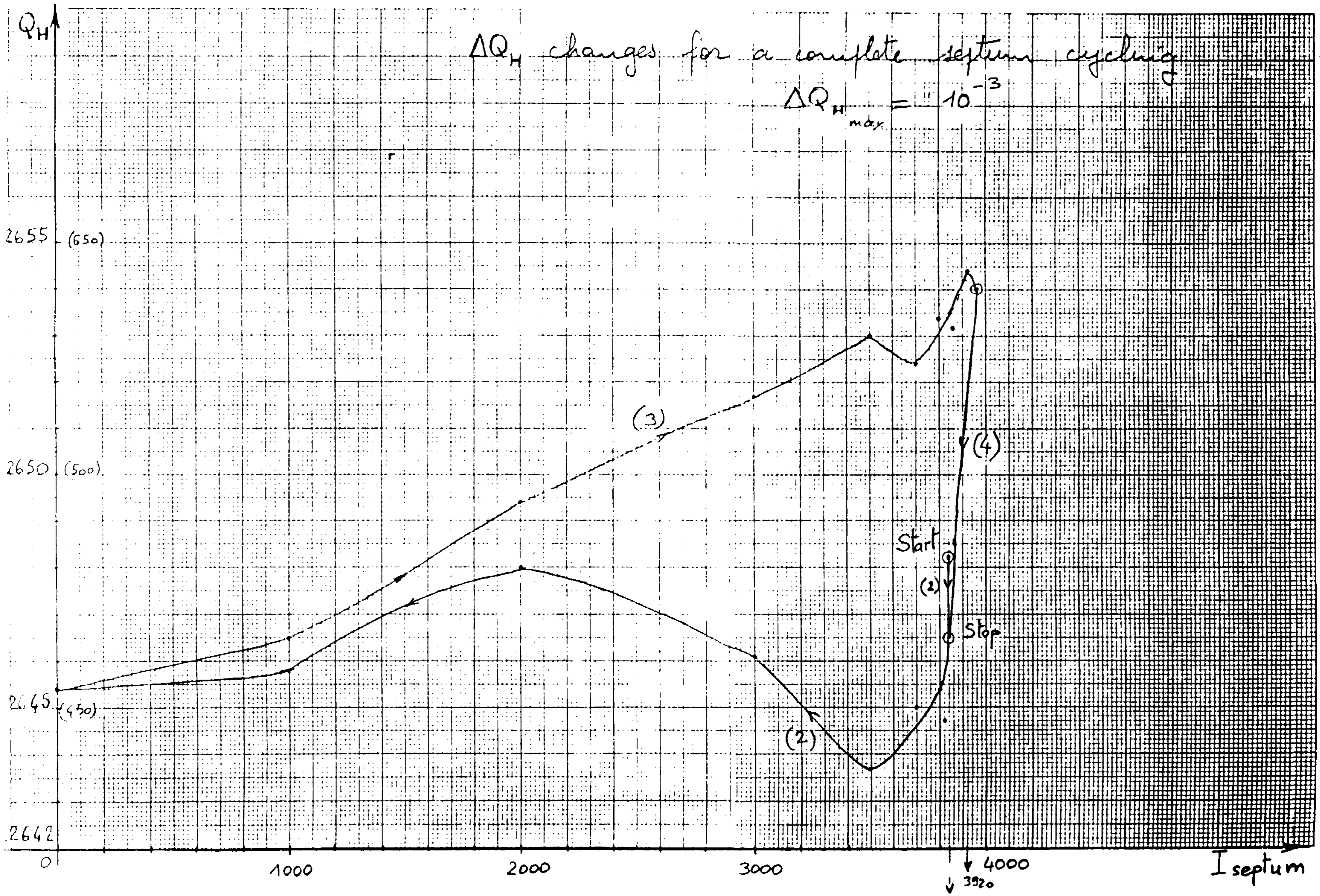
In order to maintain the tune with sufficient precision, it would be nice to use a fixed value for the septum current. This would require another horizontal steering magnet in the ejection line, otherwise we should make a prescribed cycle of the septum magnet excitation each time the current is changed. The required acceptance of the AA injection line will decrease from 100π to 25π in 1987. This means that we could make another magnet core with smaller gap and consequently less stray field.

REFERENCES

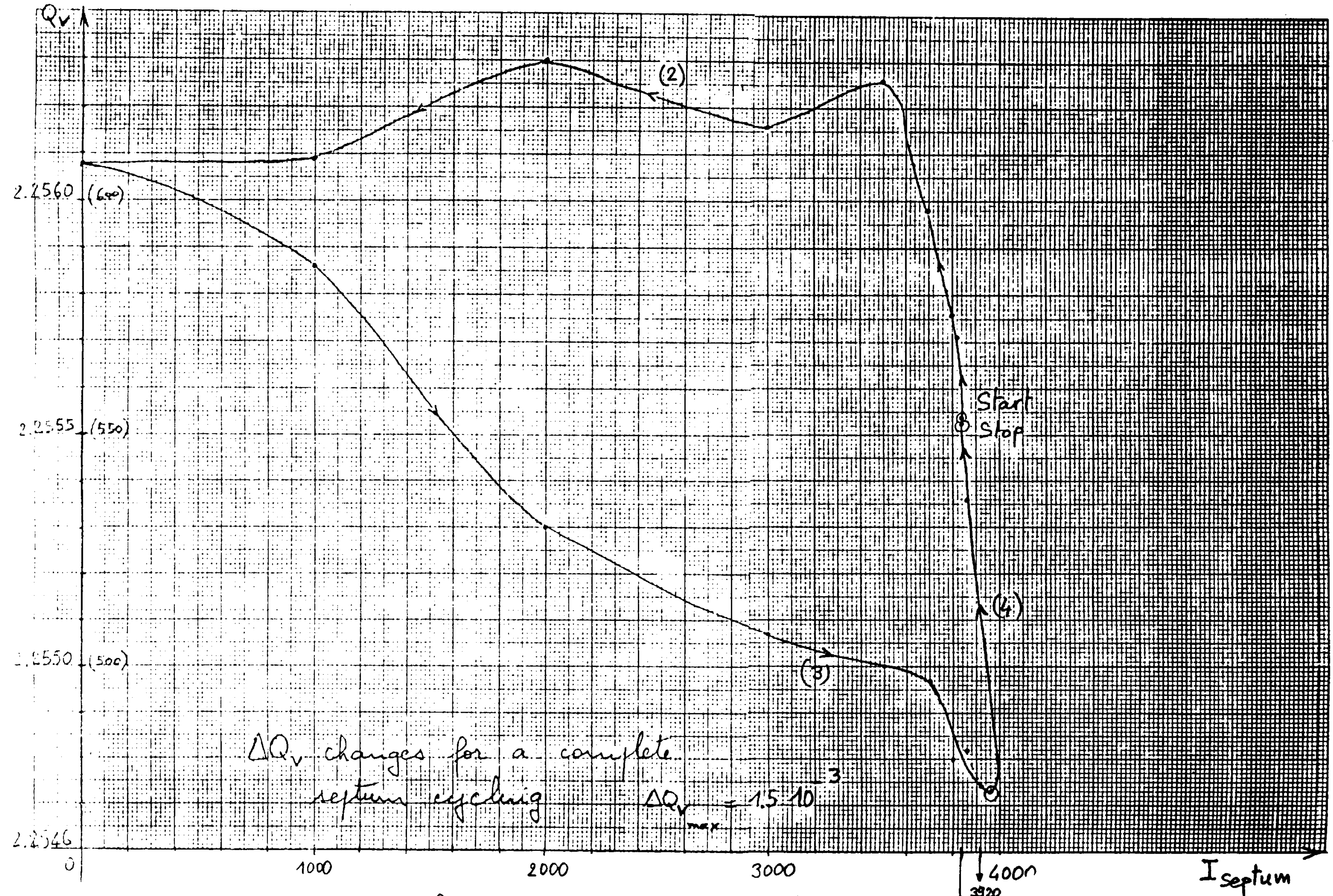
1. E. Jones et al., Transverse Instabilities Due to Beam-Trapped Ions and Charged Matter in the CERN Antiproton Accumulator, CERN/PS/85-15 (AA), 1985.

2. F. Pedersen and A. Poncet, Proton-Antiproton Instability in the AA, PS/AA/ME/Note 81, March 1985.

3. B. Boileau, Rapport de mesures du champ magnétique sur aimant $p\bar{p}$, PS/EI Note 80-1, Rev., 1980.

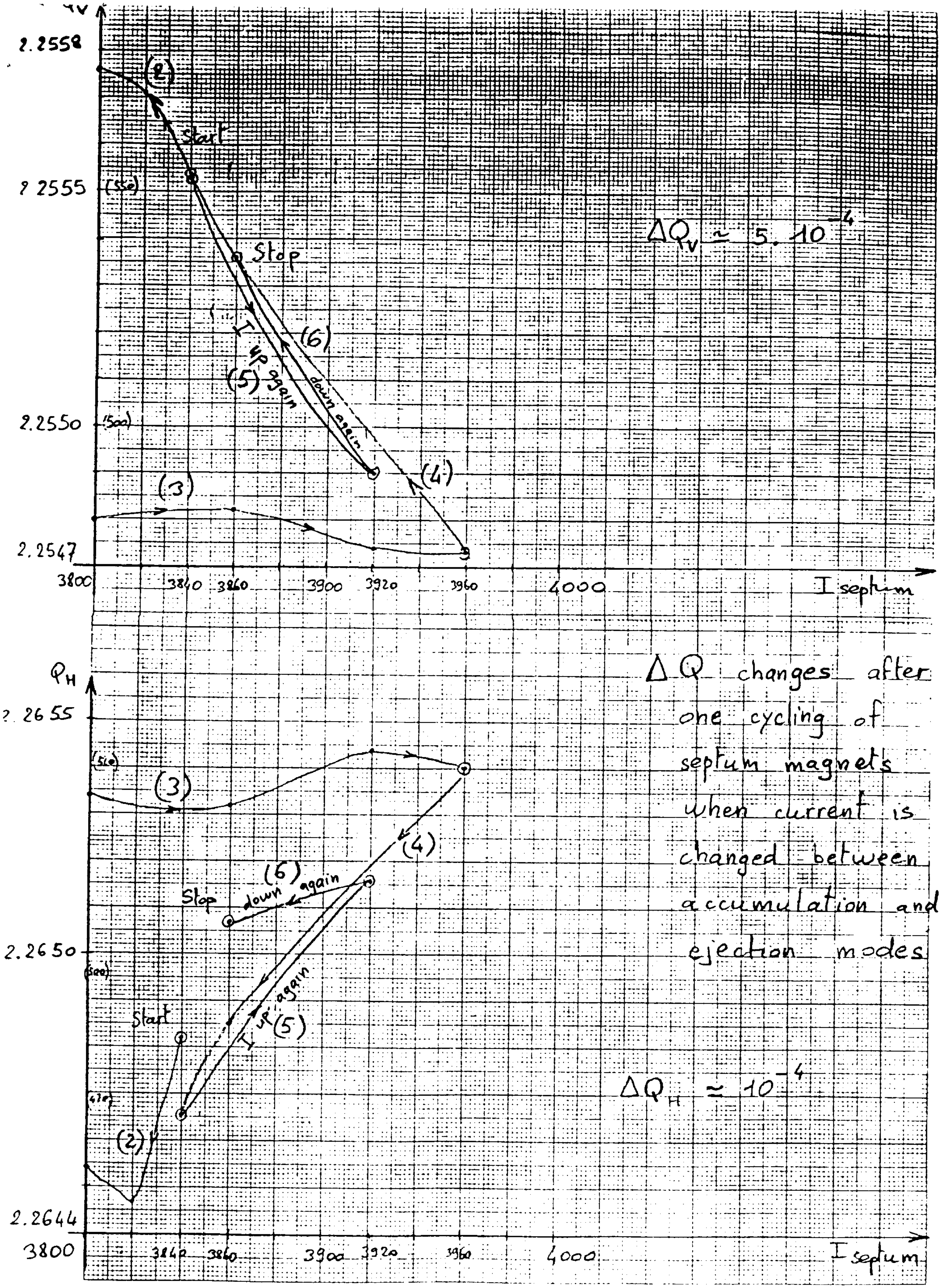


ΔQ_H changes for a complete septum cycling
ΔQ_H max = 10^-3
Q_H
2655 (650)
2650 (500)
2645 (450)
2642
0
1000
2000
3000
4000
3920
I septum
(2)
(3)
(4)
Start
Stop



Qv
2.2560
(600)
2.2555
(550)
2.2550
(500)
2.2546
0
1000
2000
3000
4000
3860
3920
I septum
(2)
(3)
(4)
Start
Stop
ΔQv changes for a complete
septum cycling   ΔQv max = 1.5 10^-3

Q.. = f (I.. ..)



QV
2.2558
2.2555
2.2550
2.2547
(550)
(500)
(2)
Start
Stop
I up again
(5)
(6)
down again
(4)
(3)
3800
3840
3860
3900
3920
3960
4000
I septum
ΔQV ≃ 5.10^-4
QH
2.2655
2.2650
2.2644
(3)
(4)
(6)
Stop
down again
Start
I up again
(5)
(2)
ΔQ changes after one cycling of septum magnets when current is changed between accumulation and ejection modes
ΔQH ≃ 10^-4
3800
3840
3860
3900
3920
3960
4000
I septum

Fig. 3

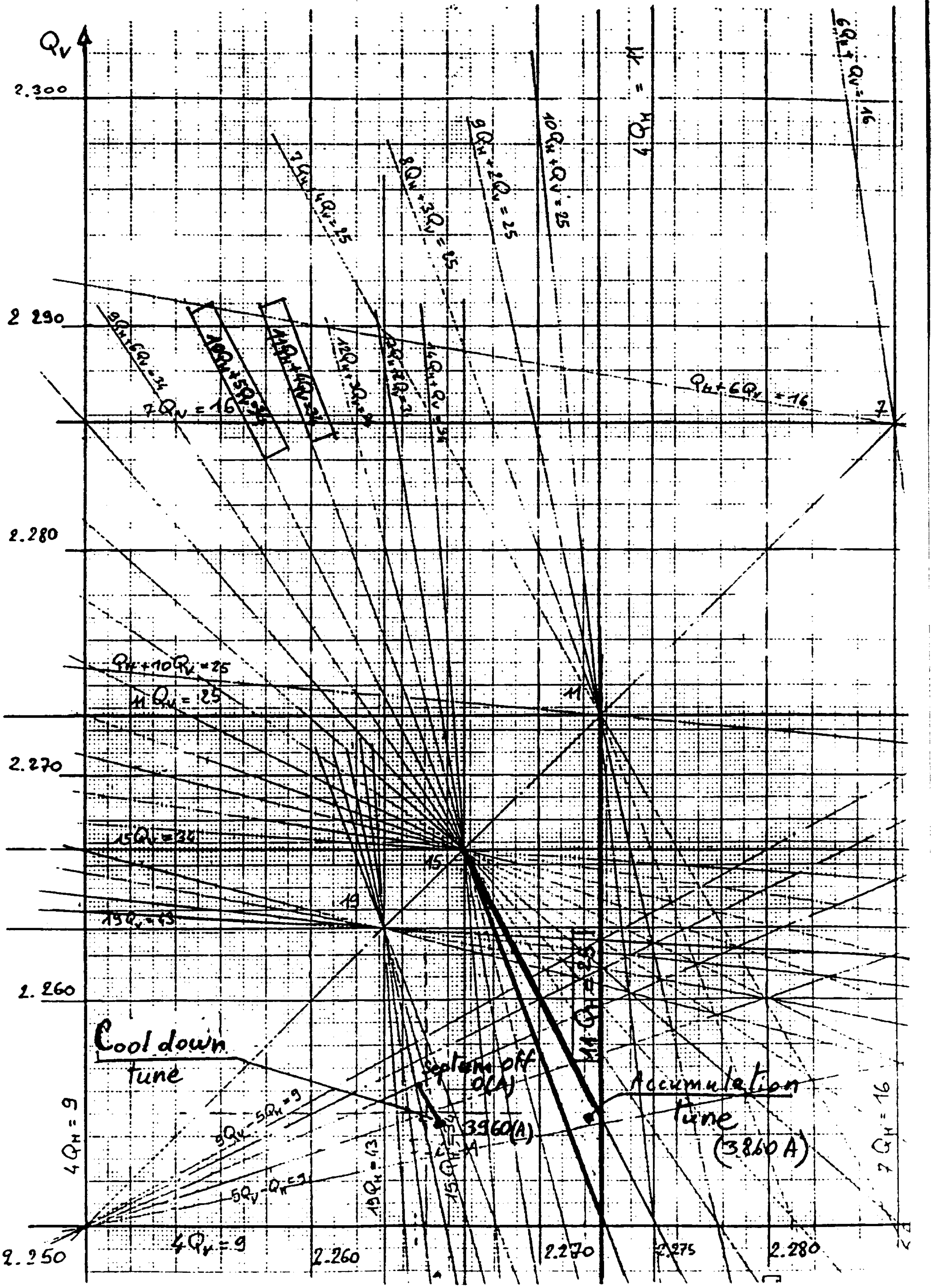


Fig 4 AA working diagram

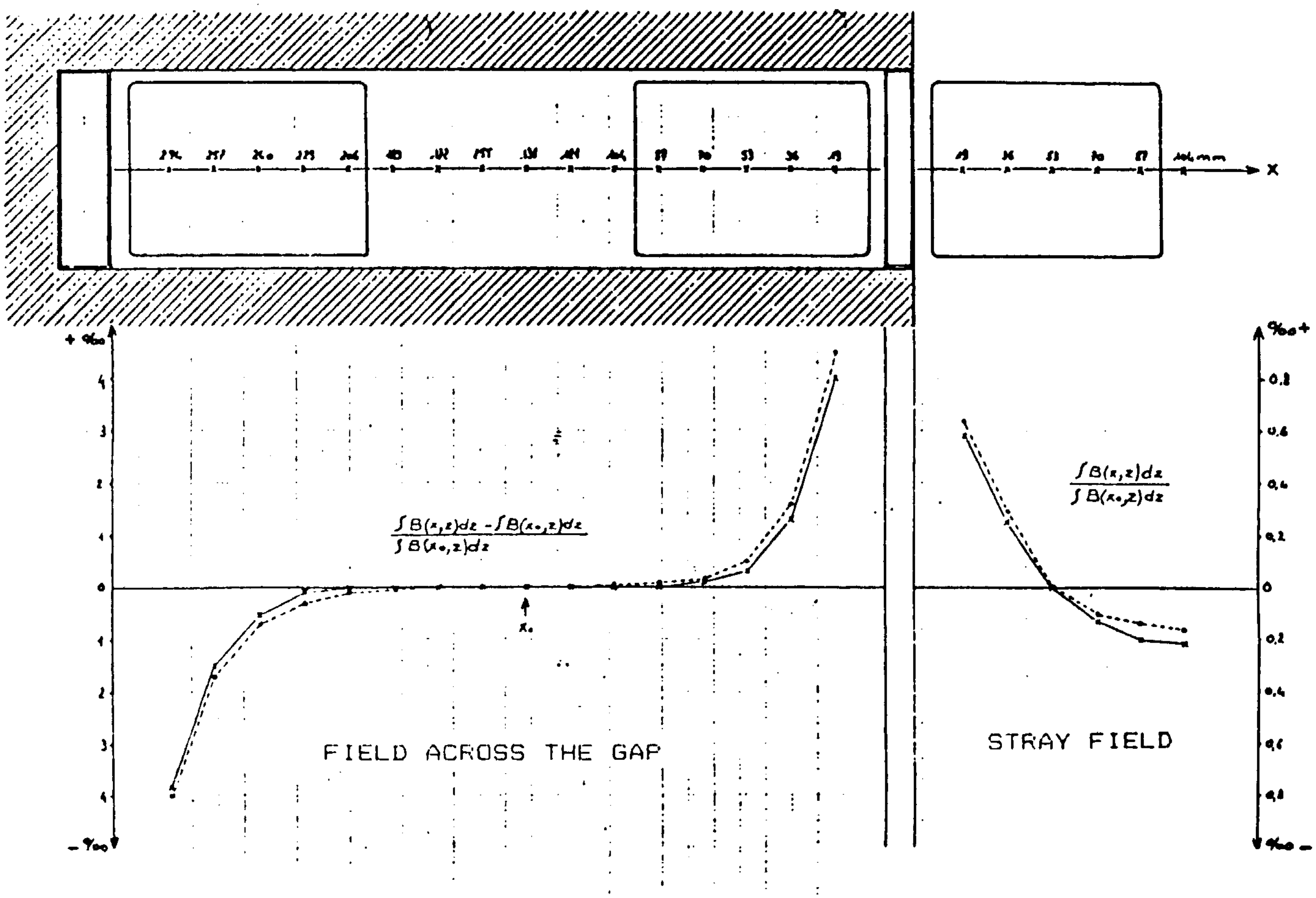


Fig 5 INJECTION/EJECTION SEPTUM MAGNET PERFORMANCE