SPS COMMISSIONING REPORT NO. 3

Topic : Scan of Working Diamond at Injection with RF off

Date : 12th April 1976

Experimenters : M. Cornacchia, R. Lauckner, W. Mills, R. Stiening, S. van der Meer, G. von Holtey, E. Wilson

---

1. Aim of Experiment

The first attempts to accelerate beam in the SPS had been frustrated by losses at injection which could have been due to Q spread plus betatron resonances. The aim of this experiment was to vary the betatron wavenumber command to the power supplies (Q), observe the betatron wavenumber of the beam (ν) and monitor the fraction of the beam (Γ) which survived the first 200 msec of 10 GeV/c flat bottom. Plotting Γ, the transmission on a Q diagram would reveal the regions of the working space (Q_V v. Q_H) where the beam might have the best chance of survival and give a preliminary impression of the stability of the machine and the width of stop bands.

It was further thought necessary to evaluate the momentum dependence of Q or chrmaticity (ξ = (dQ/Q/dp/p)) in each plane before chromaticity correction could be switched on. A change in $\Delta p/p$ was simulated by changing both dipole and quadrupole currents by 2 $^{o}/oo$ in each direction and observing ν. It had been suspected that the enhancement of beam loss observed when RF was on was due to the combined effect of the larger $\Delta p/p$ of the trapped beam and uncorrected ξ, driving the edges of the momentum distribution into betatron resonance and making the whole machine very sensitive to both variations in MPS momentum and SPS radial steering.

2. Experimental Conditions

CPS Intensity = 2 x 10^{12} dropping to 10^{12} when two booster ring were used for the latter part of the data.

CPS Momentum Stability = $\pm$ 0.3 x 10^{-3}

CPS RF Structure : 200 MHz debunching in z 1 msec in the SPS

CPS Emittance : 1.5 π mm milliradian in both horizontal and vertical planes measured in TT10.

SPS Energy :

A nominal 10 GeV adjusted to give a central closed orbit followed by a 50 GeV ramp to reset power supply regulation

SPS Power Supply Regulation :

A calibration which had been found to give Q_H, Q_V in the half integer square below 28 by empirically adjusting the Q train gradient factor.

SPS and RF System : off

SPS Injection and Closed Orbit :

Adjusted by Burnod to give 7 mm horizontal and 4 mm vertical mismatch at the injection point in order to produce the coherent oscillations necessary to measure Q.

3. Diagnostics

Betatron oscillations following injection were observed from a standard Δ pick-up in sector 3 through a filter (2 to 20 kHz) and displayed on a dual time base oscilloscope in the MCR. A BCT signal from sector 3 was simultaneously displayed on a longer time base to give Γ and polaroid photographs were taken [Fig. 1].

A duplicate system giving ν_H and ν_V and the BCT signal at injection and 200 ms. later was used to accumulate multiple sets of data at each Q value. The BCT sample time of 2 ms does not reveal any prompt loss at injection, but later a BCT in the injection line was added to the display. This digital acquisition system is the one the SPS will use in operation. For the purposes of this experiment the ν was calculated from the first 40 turns, slightly less than the time for which 200 MHz structure imposed by the CPS remains. [Fig. 2].

4. Results

Figure 3 shows the Q values studied.

Figure 4 shows how transmission Γ varies along the main diagonal ($Q_V = Q_H$).

Figure 5 shows how ν_H and ν_V vary from pulse to pulse at a given Q_H, Q_V setting.

Figure 6 shows how transmission and ν_V vary when the machine is tuned onto a stopband ($3Q_V = 83$).

Figure 7 shows how Q varies with $\Delta p/p$.

Figure 8 shows the effect of the chromaticity correcting sextupoles.

5. Preliminary Conclusions

The oscilloscope and digital ν measurements agree and the correlation between Q demanded and ν measured was good.

When Q is set, ν varies from pulse to pulse within a circle of confusion whose standard deviation is ≃ 0.02. Momentum fluctuations of 2×10^{-4} rms, plus rms F and D quadrupole gradient fluctuations of 2.3 and 4.3×10^{-4} respectively, are sufficient to explain this jitter [Fig. 5].

The working space is in general free from stopbands except within 0.1 of the integer and 0.02 of half integers where a large fraction of the beam is lost. [Fig. 4].

Coupling is very weak but was observed.

Power supply ripple is so small that one can sit on a third integer resonance and lose only 50% of the beam [Fig. 6].

Fourth integer resonances give discernable beam loss at their concurrence but are weak.

Indications are that chromaticity is of the order of unity and should be corrected before one can avoid beam loss with RF on.

A preliminary test of the chromaticity sextupoles showed a change in coherence time consistent with predictions [Fig. 8].

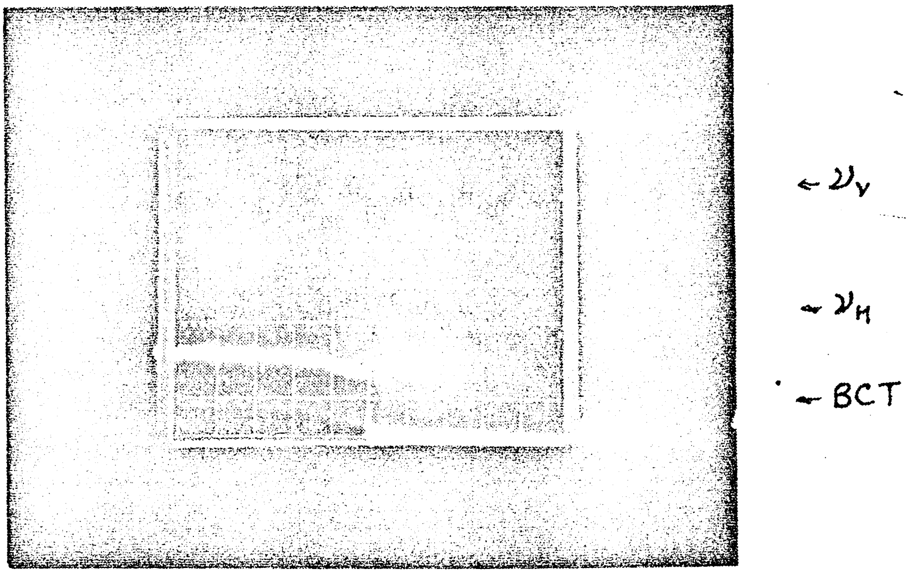
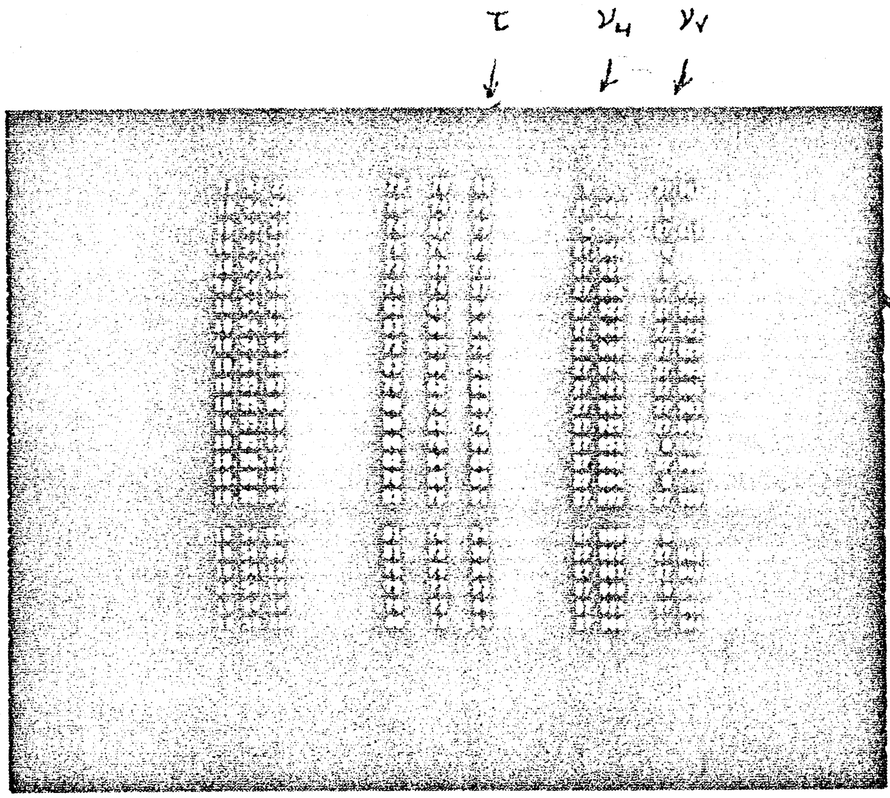


FIG 1



65852

FIG 2

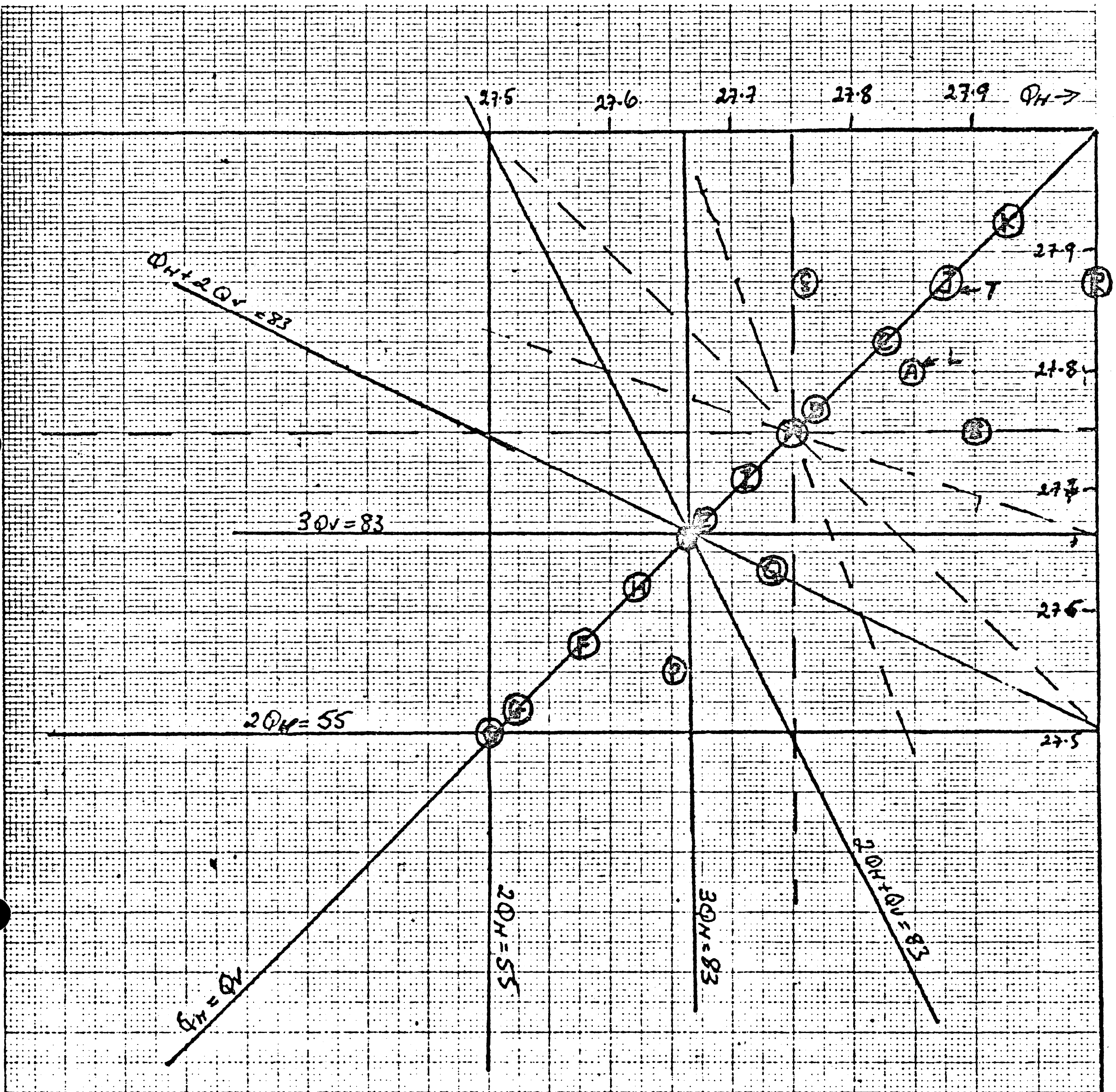


Fig 3 Q POINTS STUDIED IN ORDER.

65851

FABRICATION SUISSE

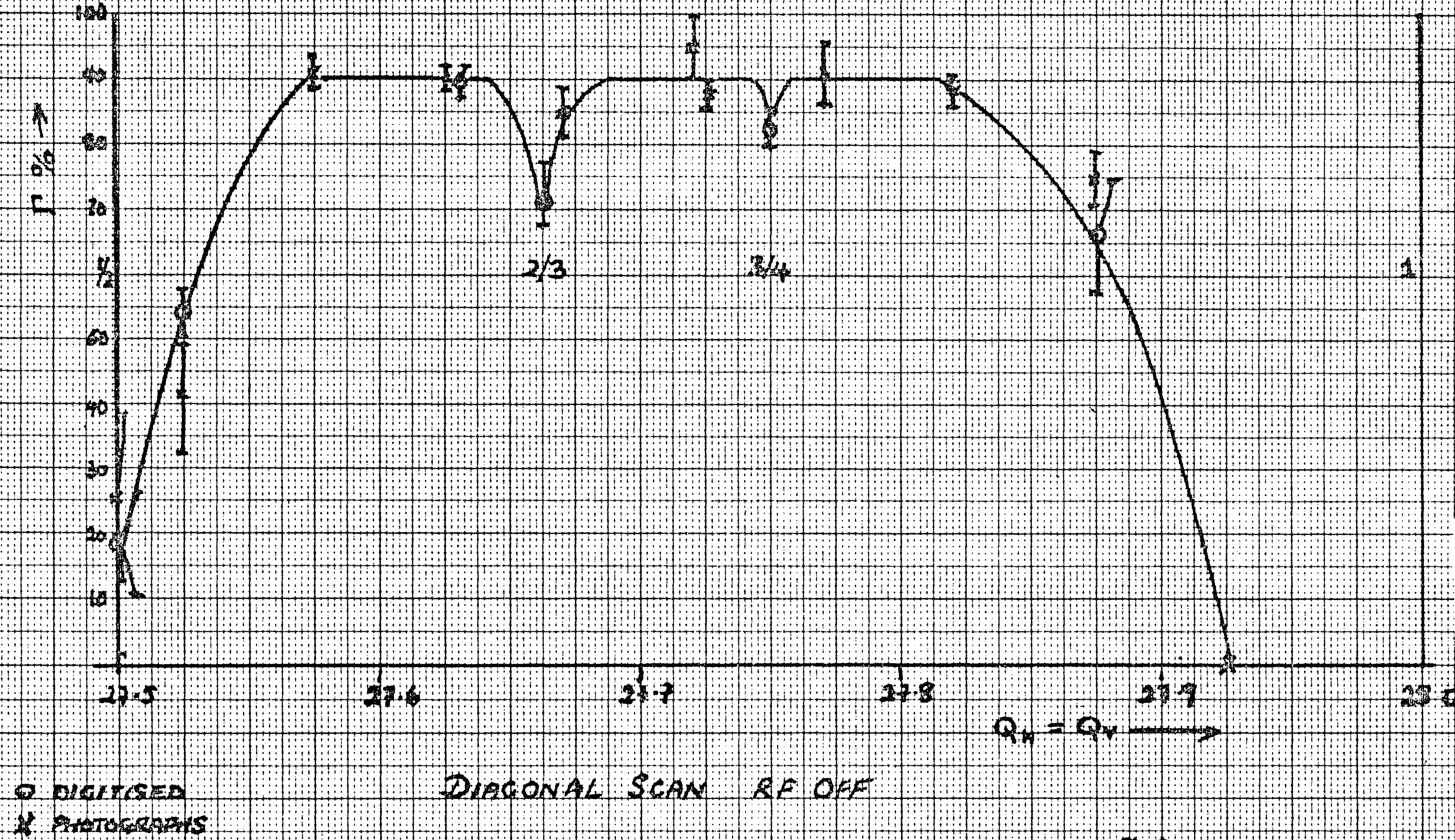
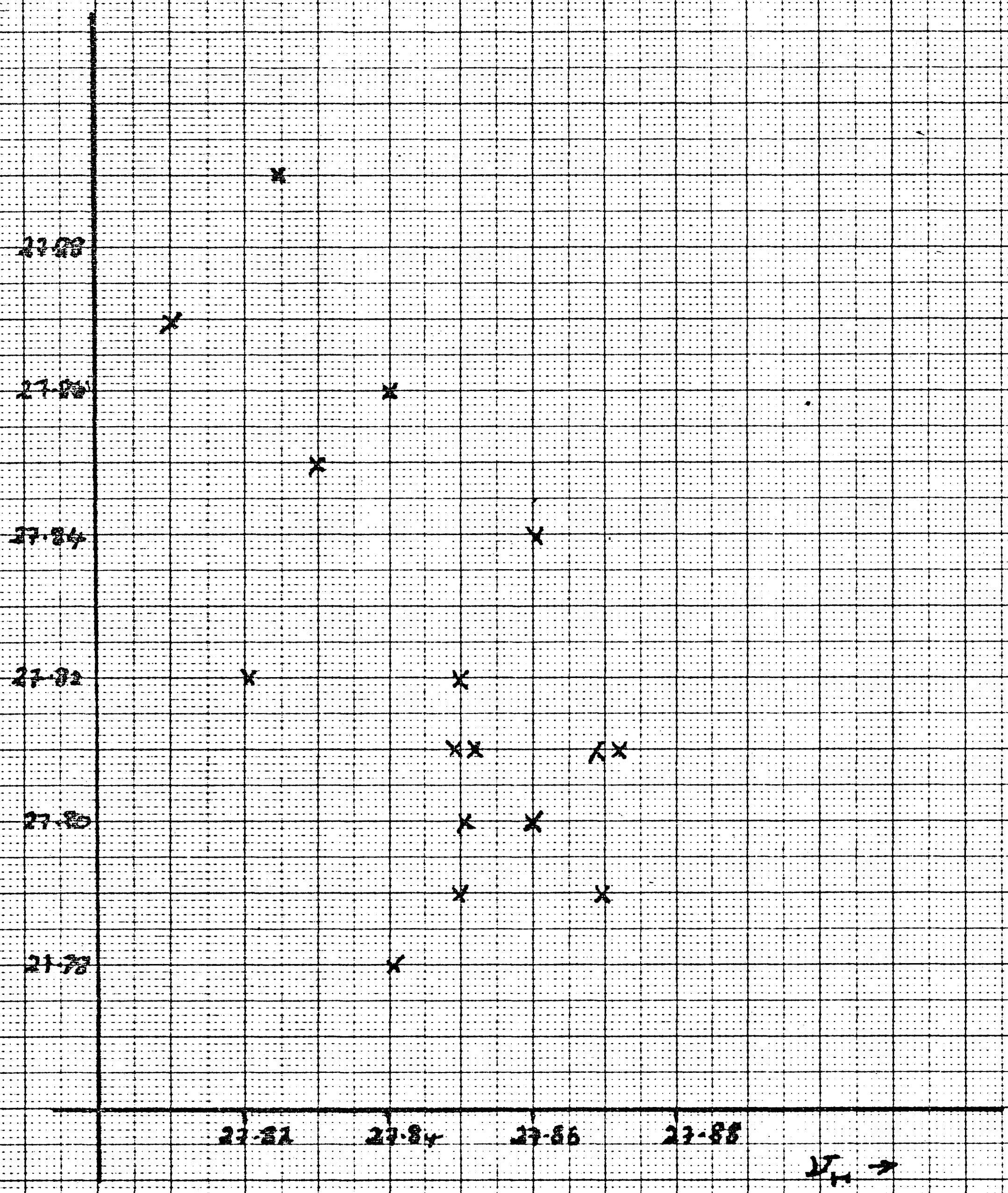


FIG 4

65850

FABRICATION SUISSE



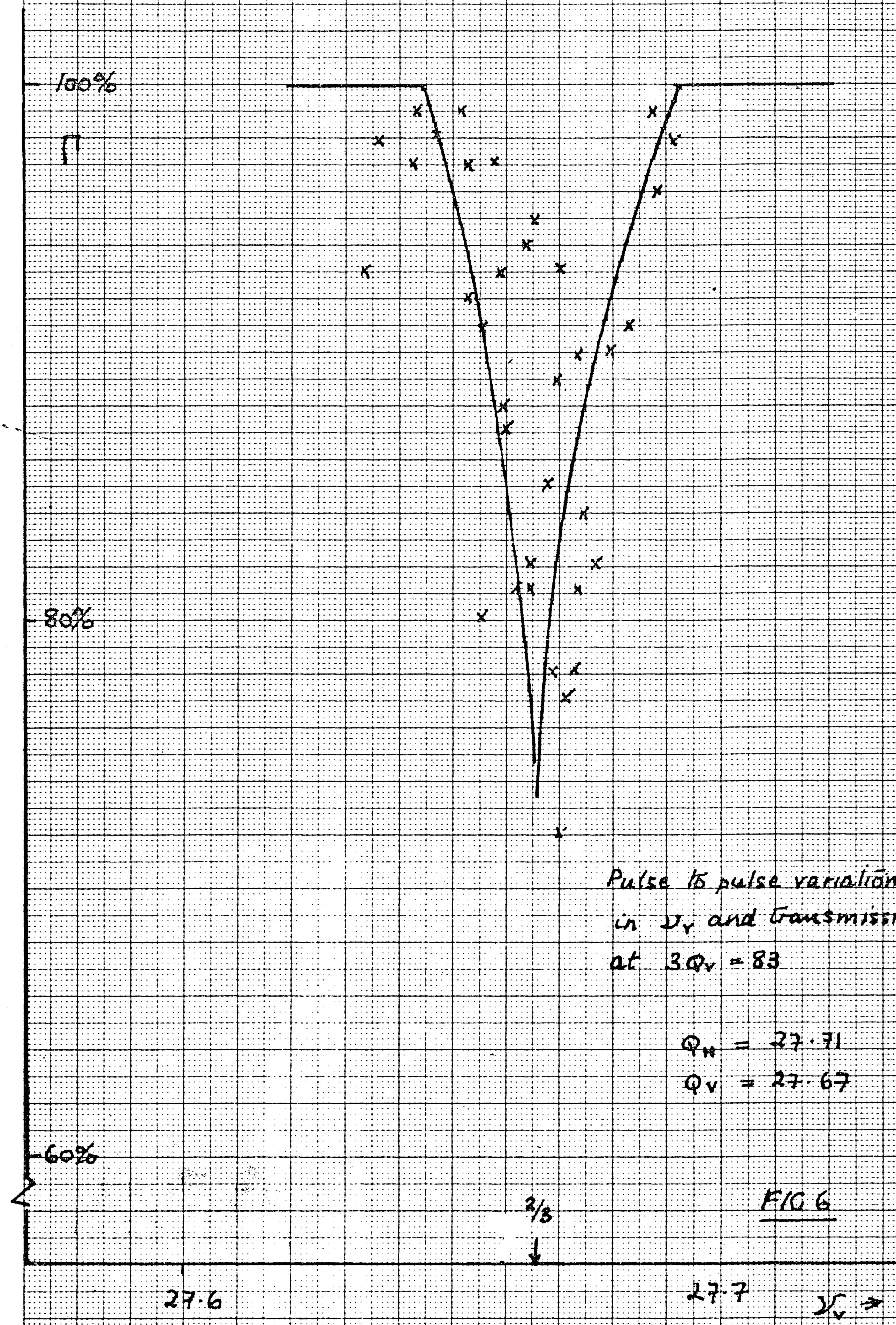
SCATTER IN ν MEASURED FROM 16 PHOTOGRAPHS WITH $Q_H = 27.85$ $Q_V = 27.80$ DEMANDED

$\bar{\nu}_H = 27.845$ ($\sigma = 0.018$)

$\bar{\nu}_V = 27.815$ ($\sigma = 0.026$)

FIG 5

65849



Pulse to pulse variation in ν_r and transmission at $3Q_v = 83$

$Q_H = 27{\cdot}71$
$Q_V = 27{\cdot}67$

FIG 6

65848

FABRICATION SUISSE

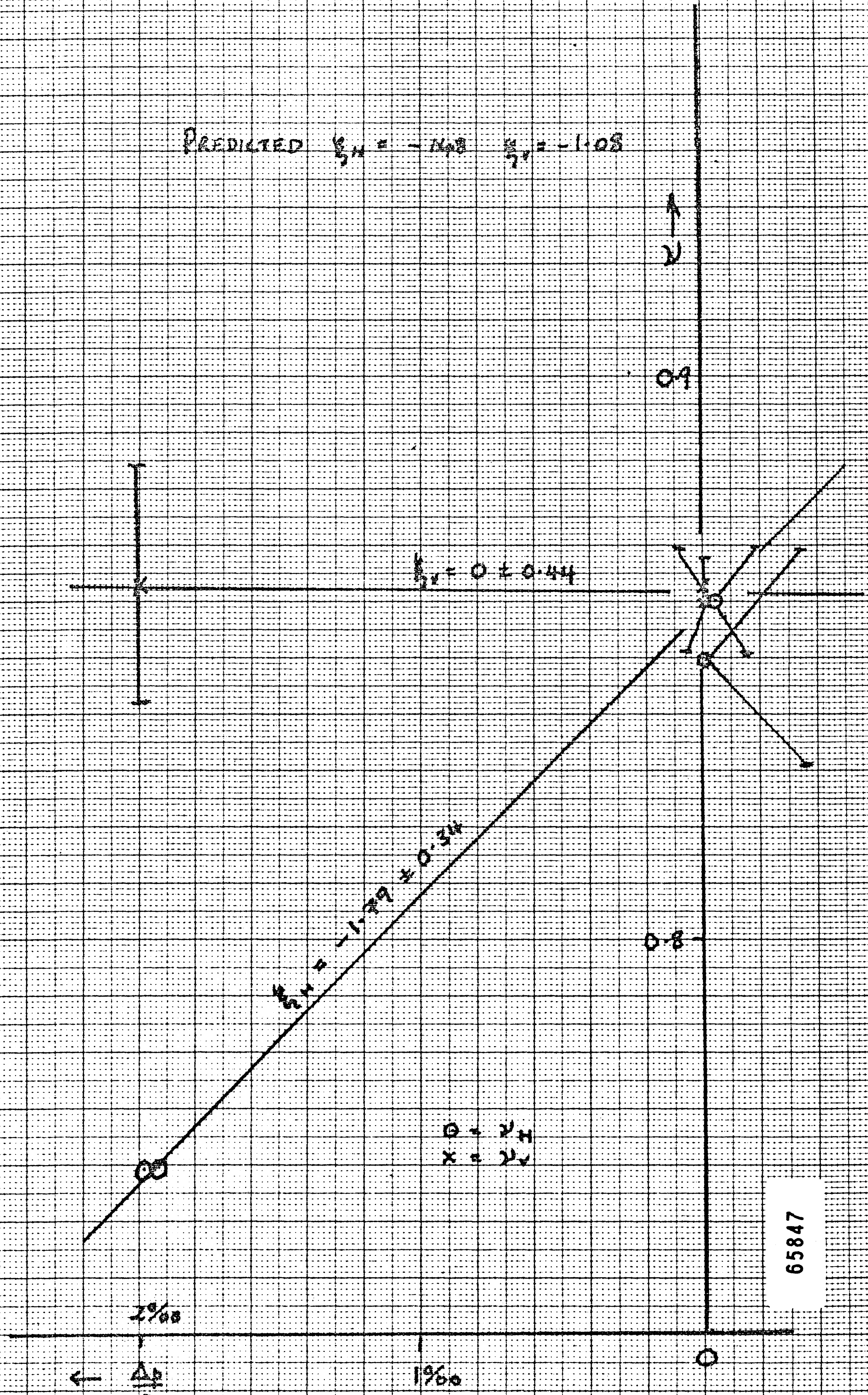


FIG 7

Power supply reference momentum
raised to simulate higher momentum

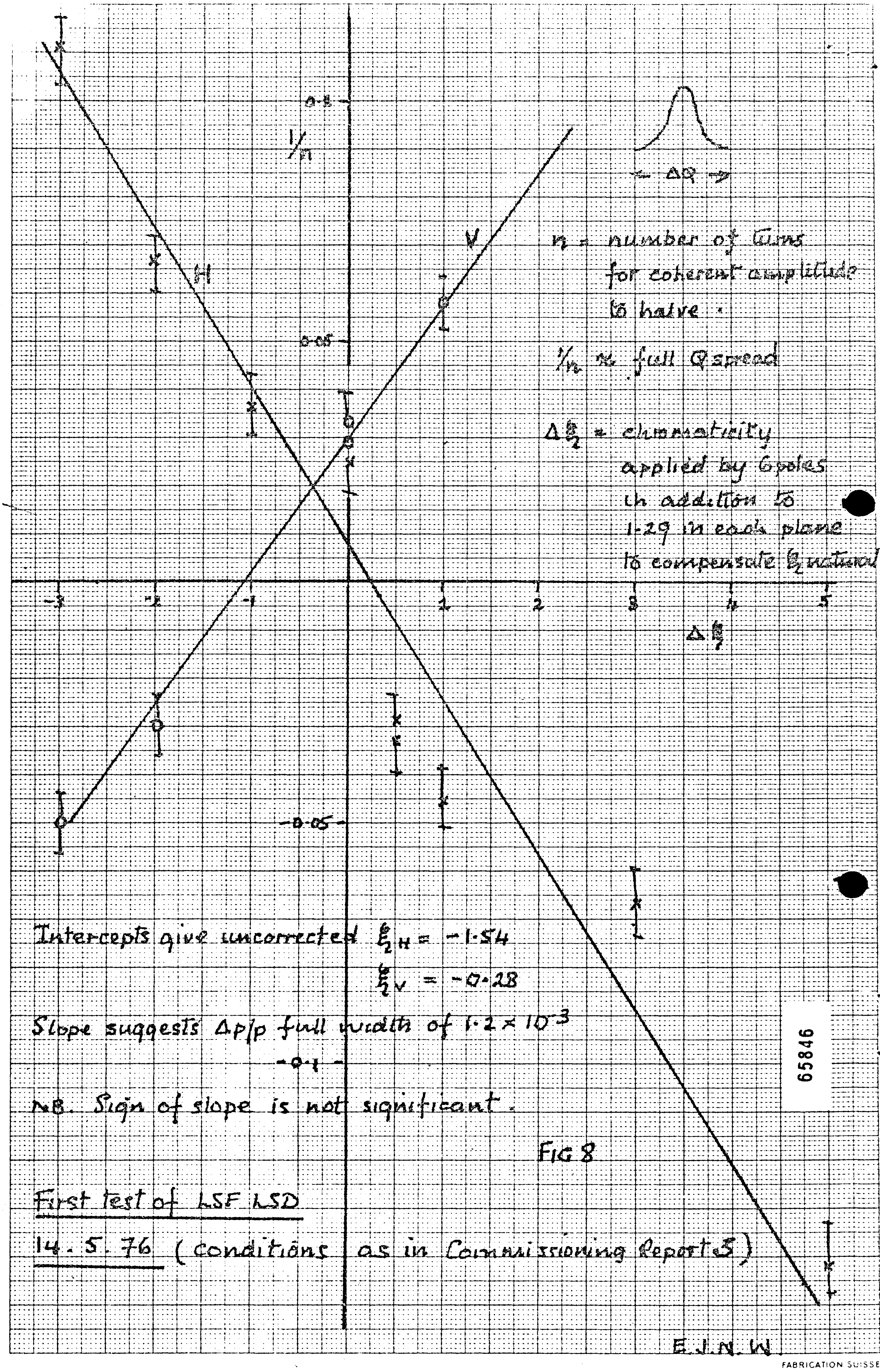

0·1
1/n
0·05
−0·05
−0·1
H
V
ΔQ
n = number of turns for coherent amplitude to halve.
1/n ∝ full Q spread
Δξ/ξ = chromaticity applied by 6poles in addition to 1·29 in each plane to compensate ξ/ξ natural.
−3 −2 −1 1 2 3 4 5
Δξ/ξ
Intercepts give uncorrected ξ/ξ H = −1·54
ξ/ξ V = −0·28
Slope suggests Δp/p full width of 1·2 × 10⁻³
NB. Sign of slope is not significant.
First test of LSF LSD
14. 5. 76 (conditions as in Commissioning Report 5)
E.J.N.W.
65846
FABRICATION SUISSE

FIG 8