A

ISR-MA/LR/rh

8th March 1971

ISR RUNNING-IN

Run 31 - 5 March 1971 - 15 GeV/c - 4 bunches

First part: 18.00 to 23.00 h - Ring 1

General conditions

The beginning of the run was delayed by difficulties with PS ejection and mix-ups in their connection to the ISR control panels (the PS could eject only when the ISR panel was set to inhibit ejection). Optimized injection into Ring 1 was nevertheless achieved before 19.00 h.

While aperture scans were performed in Ring 1, injection into Ring 2 was set up, and a 13 mA beam was normally kept circulating in Ring 2 during this first part of the run. This beam needed renewing occasionally because of losses, probably due to spurious currents in Ring 2 PFW's. In fact, it was noted that these currents, which had been set to zero at the beginning of the run, were all around +3 % at the end without anybody touching their controls. Since it was noted that the currents in the sextupoles of Ring 1 changed when the PFW currents were adjusted by the computer, it looks likely that the changes in Ring 2 were due to the same effect (which needs curing).

Investigation of possible working lines for high-intensity stacks in Ring 1

Recent 20-bunch runs have permitted to determine the minimum values of $\frac{dQ_H}{dp/p}$ and $\frac{dQ_V}{dp/p}$ required for avoiding "brickwall" instabilities at 15 GeV/c. The required variation of Q across the aperture is too large for being able to avoid crossing resonances when moving along the working line. However, it has also been found that reasonably good stacks can be obtained when resonances are crossed in the region between injection and the bottom of the stack, while resonances at injection or inside the stack are disturbing.

Some working lines corresponding to the above criteria were computed, and the purpose of the run was to study the losses occurring along them by aperture scans and measure Q values to identify the position of the lines and the resonaces which produced the largest losses.

The achieved working lines are shown in Figures 1, 2 and 3. Some of the scans performed along these lines are also attached (Figs. 4 to 13).

Current settings, description of the losses, and comments on possible uses are given in the following notes.

It is worth noting that the measured Q values at the nominal centreline are not only influenced by PFW settings but also slightly by sextupole settings, because of the closed orbit distortions (see typical measurement at DANA).

Line : DANA, 1.8, 1.5 (Fig. 1)

PFW settings: $\Delta Q_H = -0.009$, $\Delta Q_V = -0.061$ — Arguments: $\Delta(G\ell)_F = -1.115$, $\Delta(G\ell)_D = -1.675$

Sextupole settings: $\Delta Q'_H = \Delta\frac{dQ_H}{dp/p} = 1.8$, $\Delta Q'_V = \Delta\frac{dQ_V}{dp/p} = 1.5$ — Currents: $S_F = 12.86\ \%$, $S_D = 11.74\ \%$

Measured at CL with sextupoles: $Q_H = .808$, $Q_V = .595$.

Losses during 0.3 cm/s scan (Fig. 4) :

- 5 % loss at <Δr> = -4 to -3 mm, for $3\ Q_H + Q_V = 35$
- large loss (80 %) at 0.5/2 mm, for $2\ Q_H + Q_V = 26$
- very small loss (uncertain) for $5\ Q_V = 43$ (+6 mm)
- small, diffuse loss, between 12 and 18 mm (where only resonances above 6 may be passing)
- no visible losses at $Q_H + 5\ Q_V = 52$ and at $4\ Q_H + Q_V = 44$.

Note. The Q measurements at CL without sextupoles had given $Q_H = .810$, $Q_V = .597$, very near the nominal values for which the PFW settings had been calculated. The small differences produced at CL by exciting the sextupoles are enough to move the strong 3rd order resonance from just to the left to just to the right of the centreline, as appeared clearly from aperture scans.

Line DORA, 1.5, 1 (Fig. 2)

PFW settings : DORA = DANA + ΔQ_V = 0.02

Sextupole settings	$\Delta Q'_H = 1.5$	Currents	$S_F = 10.29$ %
	$\Delta Q'_V = 1$		$S_D = 8.47$ %

Losses (Figs. 5 and 6) :

- large loss (>80 %) at -15 to -13 mm for $Q_H + 2\,Q_V = 26$
- small continuous losses till -2 mm ($3Q_H + Q_V = 35$) (and $5Q_H = 44$?)
- small loss at +2 mm (above 6th order)
- no loss at $Q_H + 5\,Q_V = 52$, nor at $4\,Q_H + Q_V = 44$.

Line DITA, 1.5, 1 (Fig. 2)

PFW settings : DITA = DANA + ΔQ_V = 0.01

Sextupoles as above

Losses (Figs. 7 and 8) : same behaviour as DORA, 1.5, 1, but losses start at -8 mm and finish at +10 mm.

Lines between DORA, 1.5, 1 and DITA, 1.5, 1 (as near DORA as possible) look interesting for high-intensity stacking experiments at 15 GeV/c, as long as $\Delta Q'_H = 1.5$ and $\Delta Q'_V = 1$ are sufficient.

Line (a), 1.5, 0.7 (near main diagonal) : Fig. 3

PFW settings : ΔQ_H = -0.102
ΔQ_V = +0.048

Maximum possible sextupoles : $\Delta Q'_H$ = 1.5, $\Delta Q'_V$ = 0.7 i.e. S_F = 9.85 %, S_D = 6.88 %

Measured at CL with sextupoles : Q_H = .713
Q_V = .704

Losses (Fig. 9 - scan 2) :

- perhaps there are losses at injection due to the vicinity of Q_V = 8 2/3 resonance
- small continuous losses from injection to CL, but of unknown origin
- losses of a few percent at -2 mm and -15 mm on the backward scan.

This line permits to use the aperture only up to +33 mm radius.

The amount of permitted $\Delta Q'_V$ is also less than normally used in high-intensity stacking.

Moreover, the settings are critical due to Q_V = 8 2/3 resonance near injection.

Therefore, this line is unlikely to be interesting for high-intensity stacks. It may however be tried. It may be more suitable for 4-bunch stacks for physics. It will be given a name only if it finds a good employment one way or another.

Lines at point ELSA, with rather strong sextupoles

(This point had been defined as $Q_H = .900$; $Q_V = .850$.)

PFW settings : $\Delta Q_H = 0.082$, $\Delta Q_V = 0.191$ Arguments $\Delta(G\ell)_F = 5.43$ T, $\Delta(G\ell)_D = 6.25$ T

This point was used with some success at 22 GeV/c with strong sextupoles. Therefore, it was interesting to study the possibility to use it in the same way at 15 GeV/c.

Losses:

1) Fig. 13 - scan 1. This setting was made with enough sextupole to give a working line near that which had been satisfactory at 22 GeV/C. The required values were

$$\Delta Q'_H = 4 \qquad \Delta Q'_V = 3.5 \qquad \text{i.e. currents} \qquad S_F = 28.80\ \% \qquad S_D = 26.95\ \%\ .$$

The Q values, measured at CL with these sextupoles on, were

$$Q_H = .896$$
$$Q_V = .849\ .$$

Numerous losses appeared between injection and -10 mm, corresponding to crossing many 5th and 6th order resonances. Small losses (probably due to higher order resonances) also appeared up to +8 mm.
At $\langle\Delta r\rangle = +27$ mm the beam started hitting the wall radially: this shows that the radial c.o. distortion becomes, as expected, very large near Q_H integer.

2) Fig. 13 - scan 2. This setting was made with

$$\Delta Q'_H = 2 \qquad \Delta Q'_V = 1.75 \qquad \text{i.e. currents} \qquad S_F = 14.40\ \% \qquad S_D = 13.50\ \%\ .$$

The Q values, measured at CL with these sextupoles, were

$$Q_H = .899$$
$$Q_V = .855\ .$$

Only a few resonances are crossed between -27 and -10 mm with a total loss of about 10 %.
The aperture is clear and useful from -10 mm to +30 mm.
This would seem a reasonable working line, but it is doubtful whether its sextupole strength is sufficient to prevent the "brickwall" instability.

Line (c), -2.5, 1.5 (negative Q'_H) : Fig. 3

PFW settings :	ΔQ_H = 0.056	
	ΔQ_V = -0.063	

Sextupole settings	$\Delta Q'_H$ = -2.5	Currents	S_F = -12.15 %
	$\Delta Q'_V$ = +1.5		S_D = + 2.54 %

Measured at CL with	Q_H = .880
sextupoles :	Q_V = .593

Losses (Fig. 11) :

- 20 % at -22 (unknown reason: higher order resonance?)
- 20 % at +24 (unknown reason: higher order resonance?) this latter loss appears also at the backward scan.

Due to these misterious losses (especially that at +24 mm), this working line appears unsuitable for stacking. No name given.

Line GINA, -1.5, 1 (negative Q'_H) : Fig. 1

PFW settings :	ΔQ_H = -0.098	Arguments	$\Delta(G\ell)_F$ = -4.246 T
	ΔQ_V = -0.054		$\Delta(G\ell)_D$ = -3.14 T

Terwilliger setting T_{D1} = -2.05 % (to keep $Q_{H\ inj}$ below .750)

Sextupole settings	$\Delta Q'_H$ = -1.5	Currents	S_F = -7.27 %
	$\Delta Q'_V$ = +1		S_D = +2.03 %

Measured at CL with	Q_H =	.720
sextupoles :	Q_V =	.605

Losses (Fig. 12) :

- small loss between -15 and -5 mm average radius (unknown reason: higher order resonance?)
- no losses between -5 and top. No losses on backward scan.

Due to the remarkably small losses, line GINA, -1.5, 1, seems a very good candidate for high-intensity stacks with negative $\frac{dQ_H}{dp/p}$. However, the adjustment is critical, because injection is near the $4\ Q_H = 35$ line and the top is near the $Q_H + 2\ Q_V = 26$ line. T_{D1} may be used for fine adjustment.

Line FATA, 1.5, 1 (near main diagonal) : Fig. 1

PFW settings :	$\Delta Q_H = -0.195$	Arguments	$\Delta(G\ell)_F = -7.76$ T
	$\Delta Q_V = -0.055$		$\Delta(G\ell)_D = -4.95$ T
Sextupole settings	$\Delta Q'_H = 1.5$	Currents	$S_F = 10.29$ %
	$\Delta Q'_V = 1$		$S_D = 8.47$ %

Measured at CL with	Q_H =	.622
sextupoles:	Q_V =	.595

Losses (Fig 10) :

- <10 % loss at -28 mm ($5\ Q_H = 43$)
- 50 % loss at -11 mm ($3\ Q_H + 2\ Q_V = 43$)
- small loss at -5 mm ($2\ Q_H + 3\ Q_V = 43$)
- no loss at $Q_H + 4\ Q_V = 43$ nor at $5\ Q_V = 43$
- 10 % loss on the return way at $4\ Q_H + Q_V = 43$.

Altogether, this line may be somewhat better than DANA, 1.8, 1.5, for high-intensity stacking. It provides the same overall Q-spread (partly due to PFW) and is free from losses from -3 mm to top. Deserves trying as much as DORA, 1.5, 1.

Conclusion

It seems interesting to try 20-bunch stacks at 15 GeV/c, on the following lines:

GINA, -1.5, 1 (Fig. 1)
FATA, 1.5, 1 (Fig. 1)

Old line DANA, 1.8, 1.5 (Fig. 1), as used by Schnell in run 30, would look reasonable and line DORA, 1.5, 1 (Fig. 2) would look even better, if both were not crossing the very strong $Q_H + 2\ Q_V = 26$ resonance. (The losses in run 30 were not bad, however.)

Line (a), 1.5, 0.7, may possibly be suitable for a 4-bunch stack, but its adjustment is critical for $Q_{injection}$ and the useful aperture is limited at the top.

It should be noted that the stacking lines will be slightly displaced with respect to the measured ones, because the momentum of the injected beam is increased during stacking and, therefore, the effect of constant currents in PFW's and lenses is proportionally reduced.

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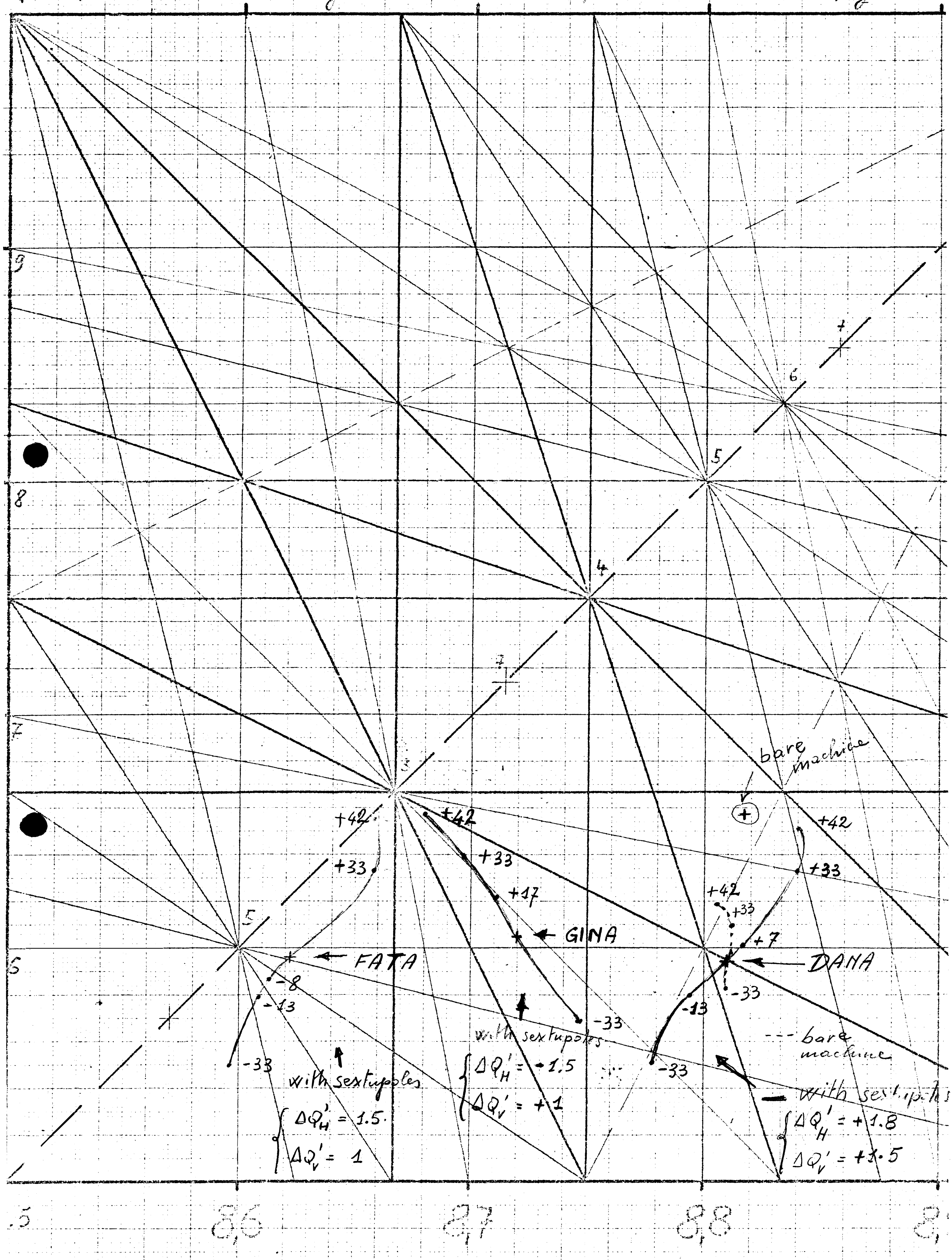
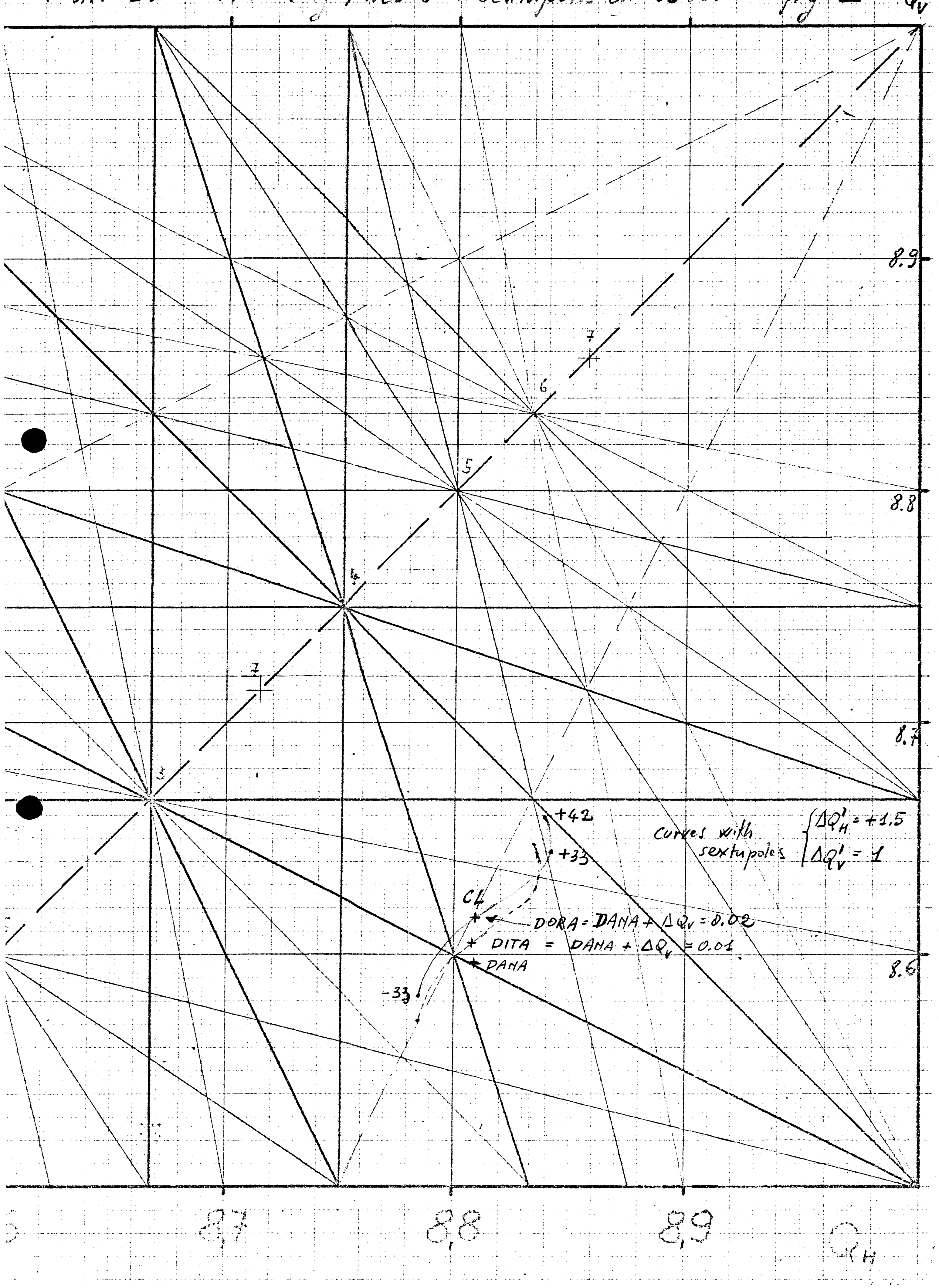
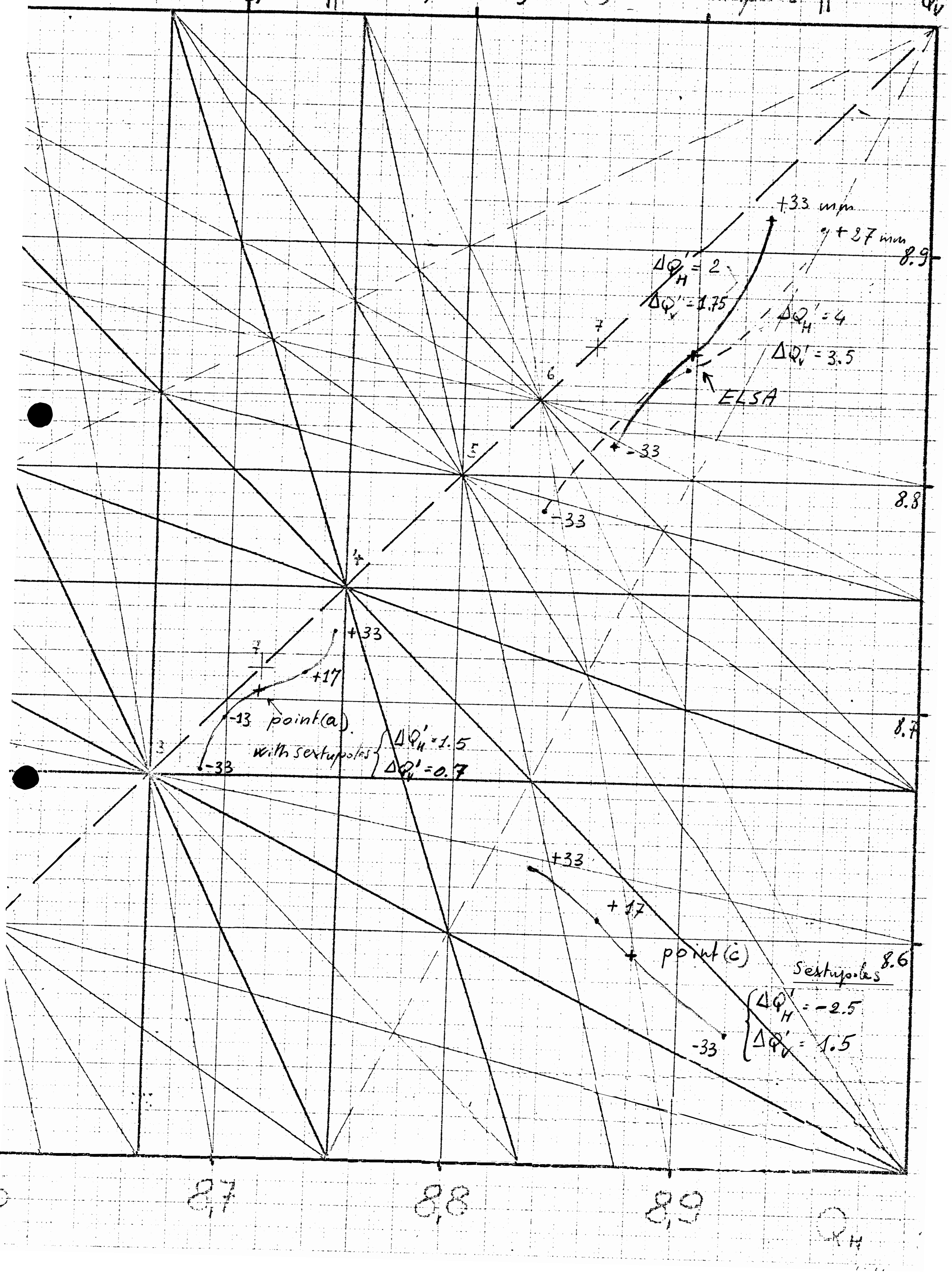
Q_V Run 31 - Working lines with sextupoles at 15 GeV - fig 1



Run 31 - Working lines with sextupoles at 15 GeV - fig 2

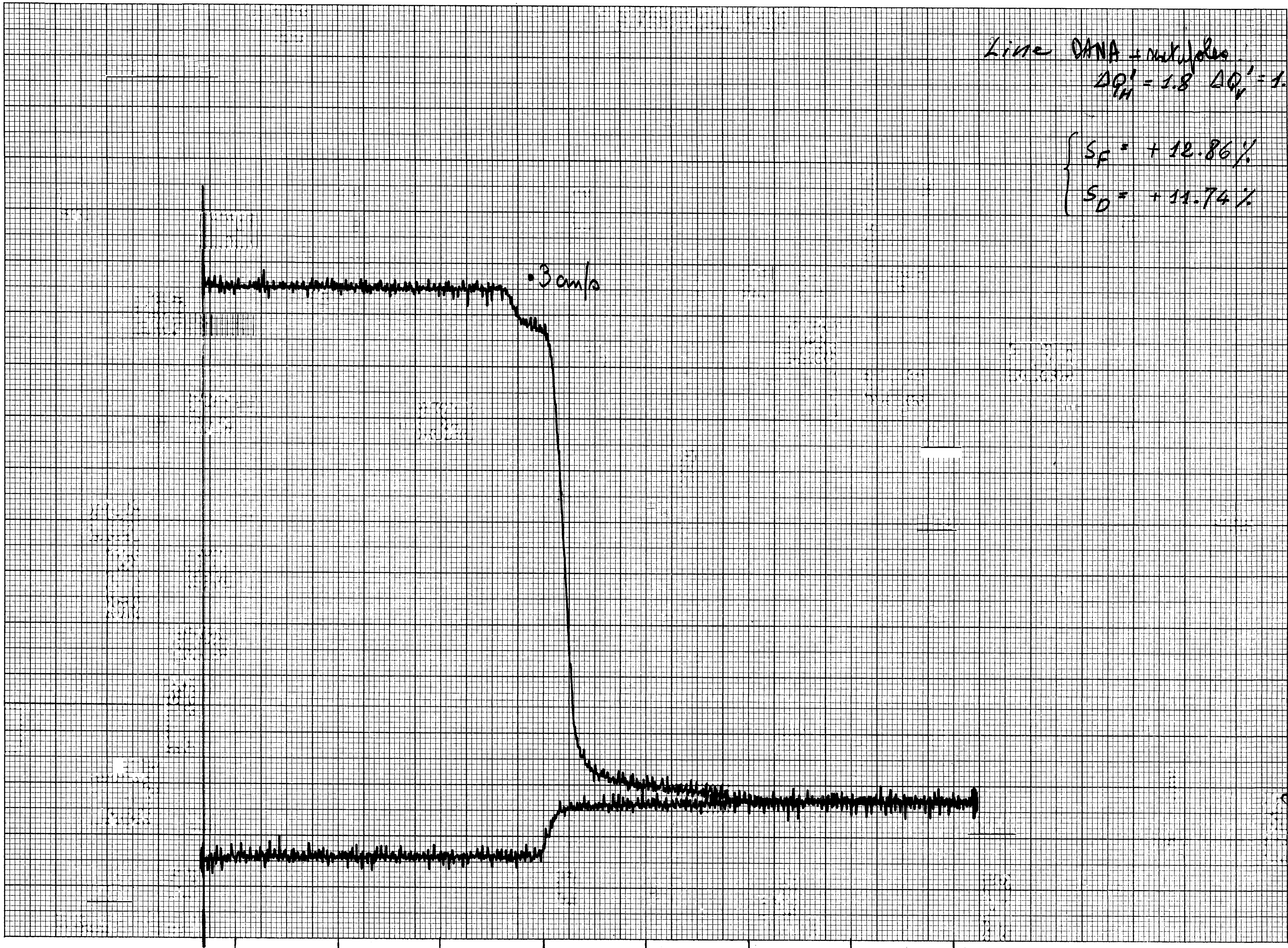


Run 31 - 15 GeV || Q-Measurements at point ELSA and points (a) and (c) with sextupoles || fig 3



270-1023
FOR USE OF AUTOGRAF RECORDERS
10 UNITS/DIVISION

20h scan 3



Run 31 fig 4

270-1023
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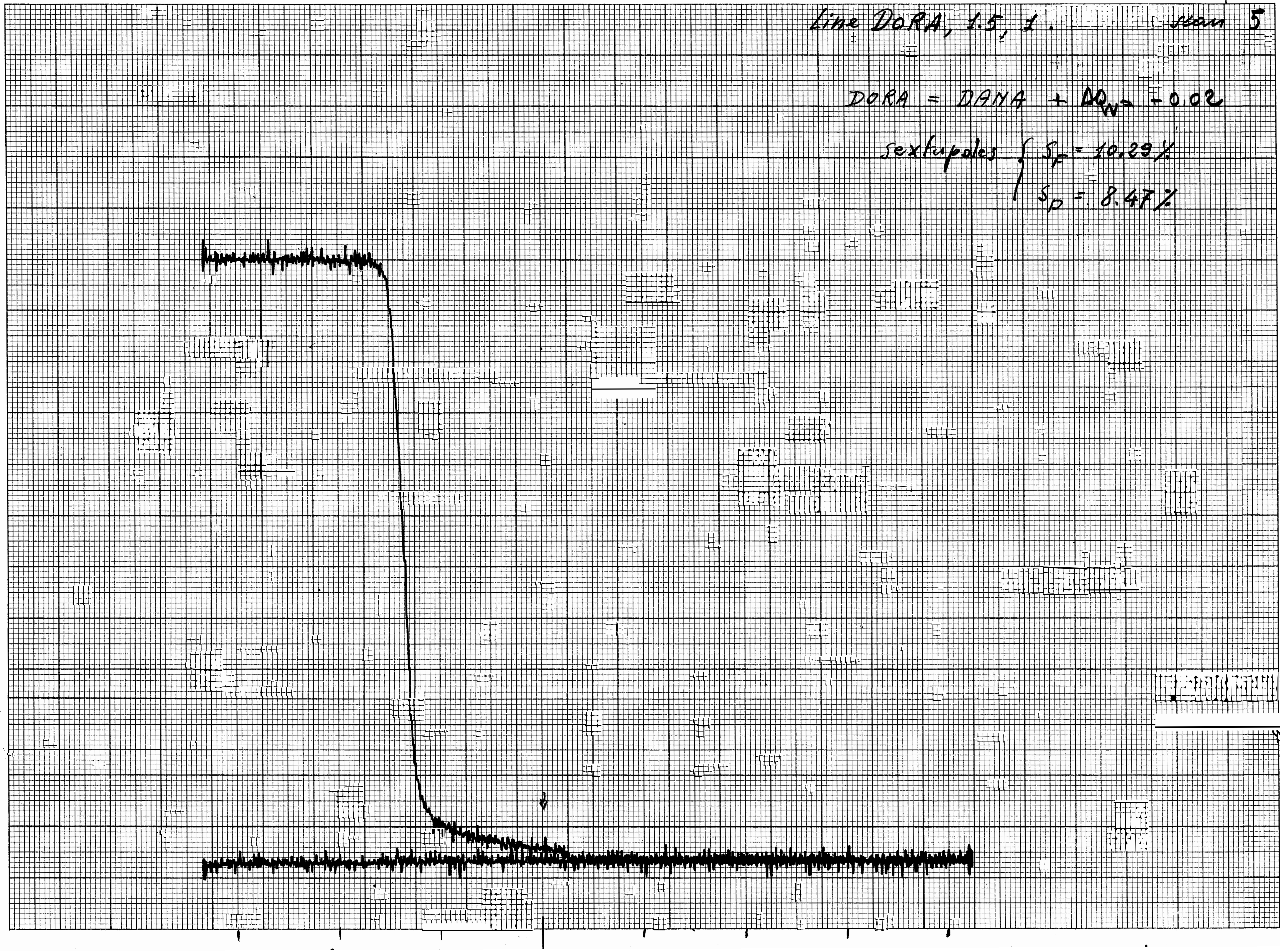
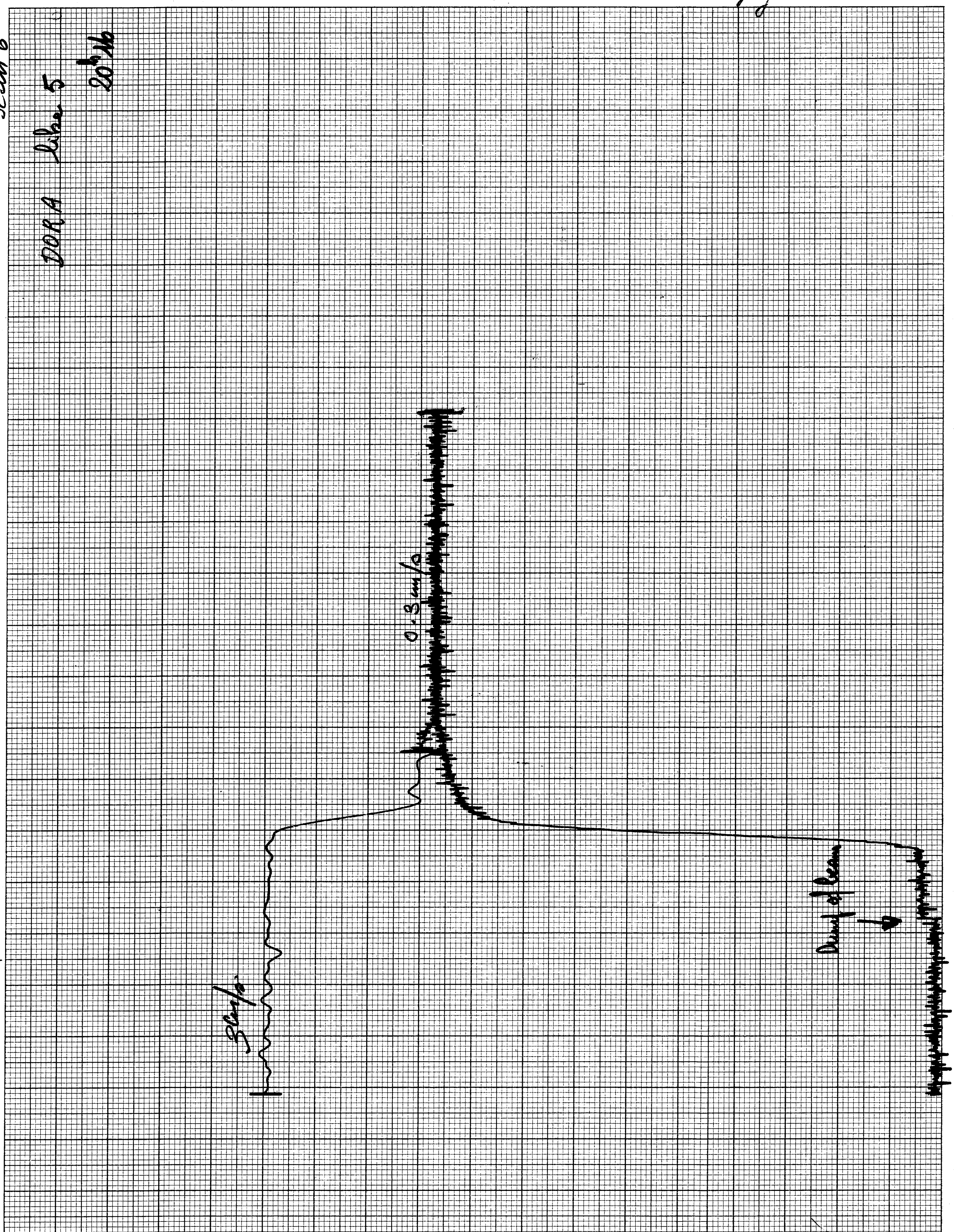
20.07 h



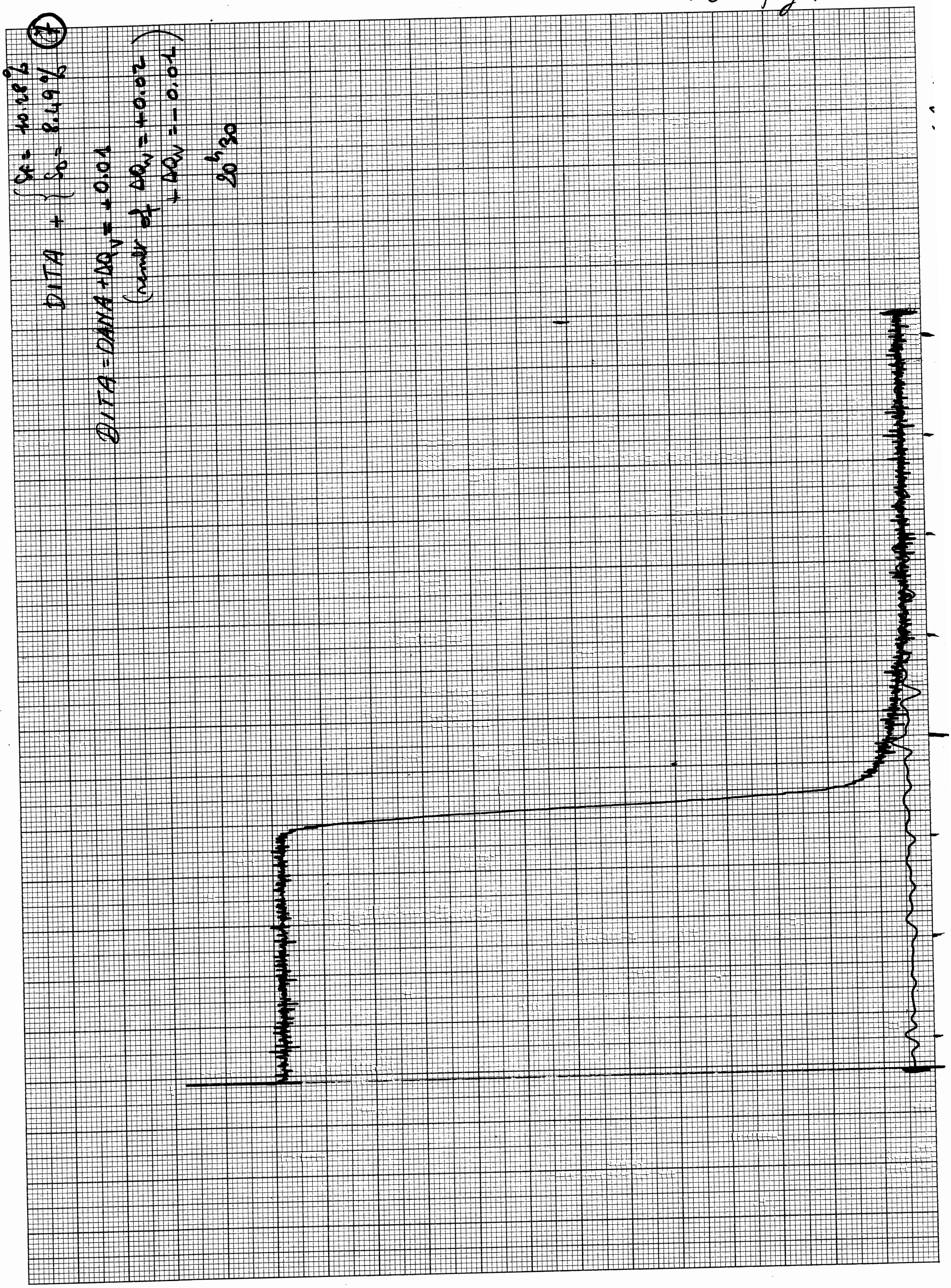
Run 31

fig 5

Run 31 fig 6

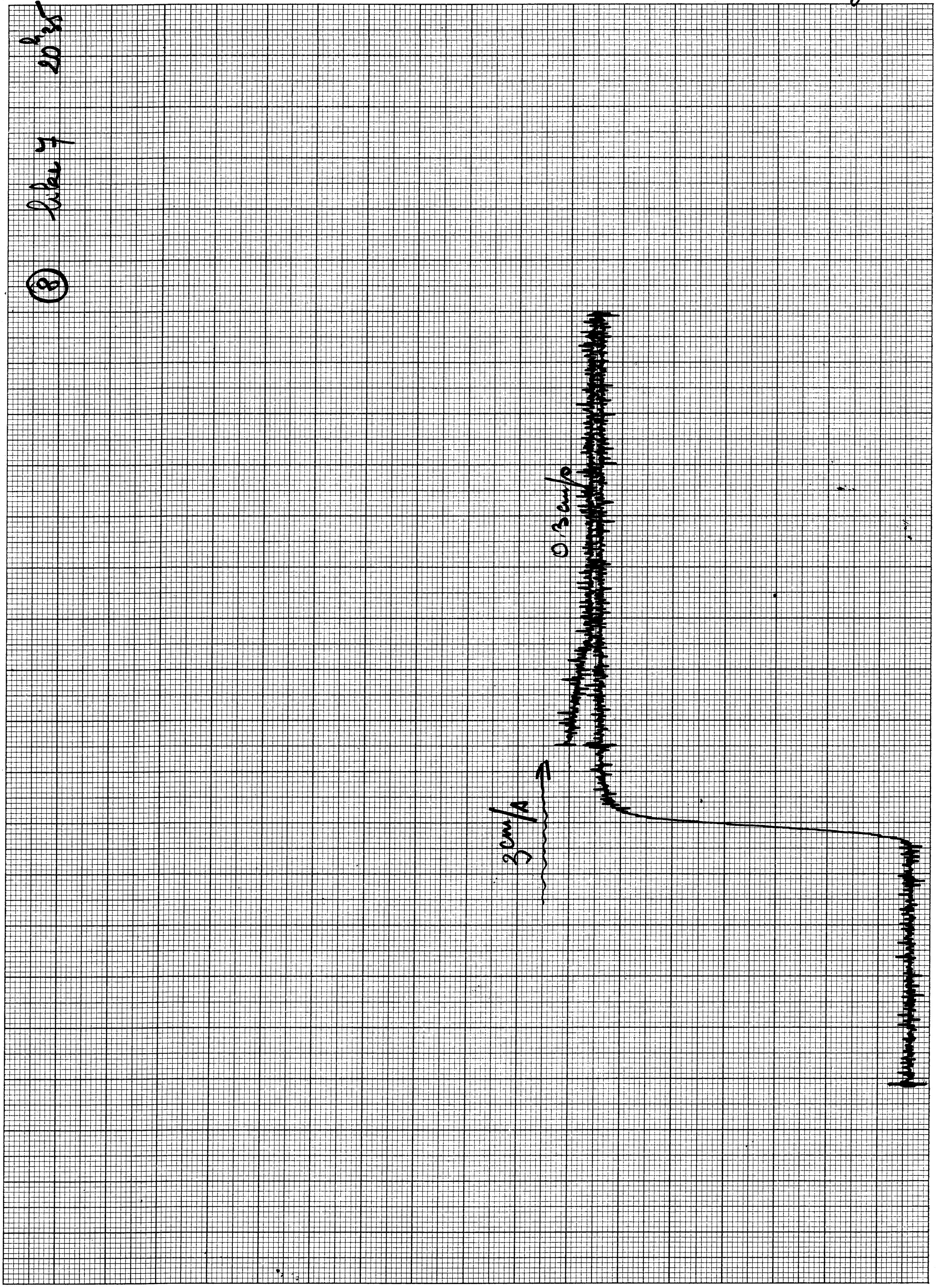


Run 31 fig 7



7
DITA + { Sr = 10.28% ; So = 8.49% }
DITA = DANA + ΔQv = + 0.01
(remember of ΔQv = + 0.02)
+ ΔQv = − 0.01
20h30

Run 31 fig 8



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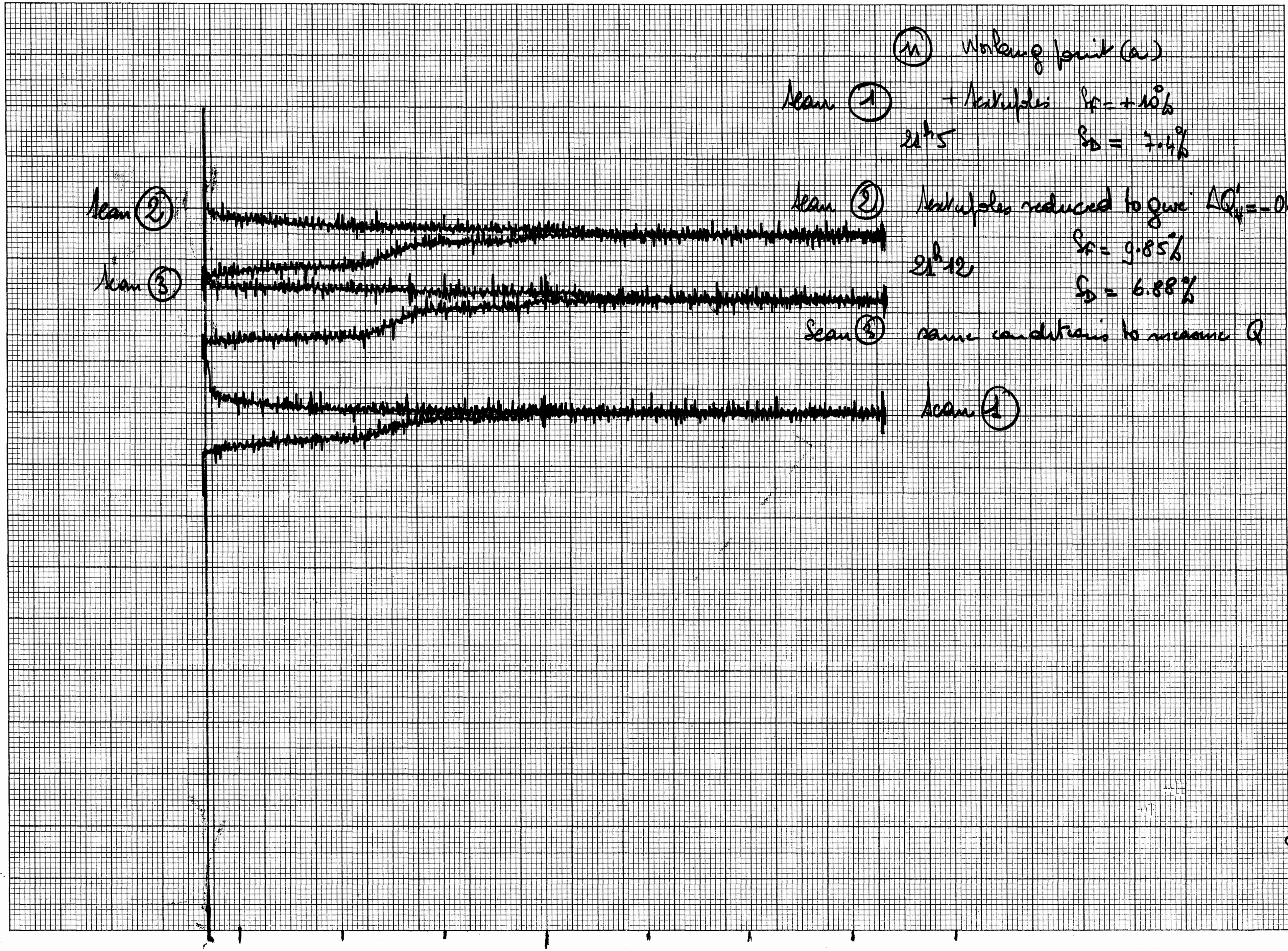
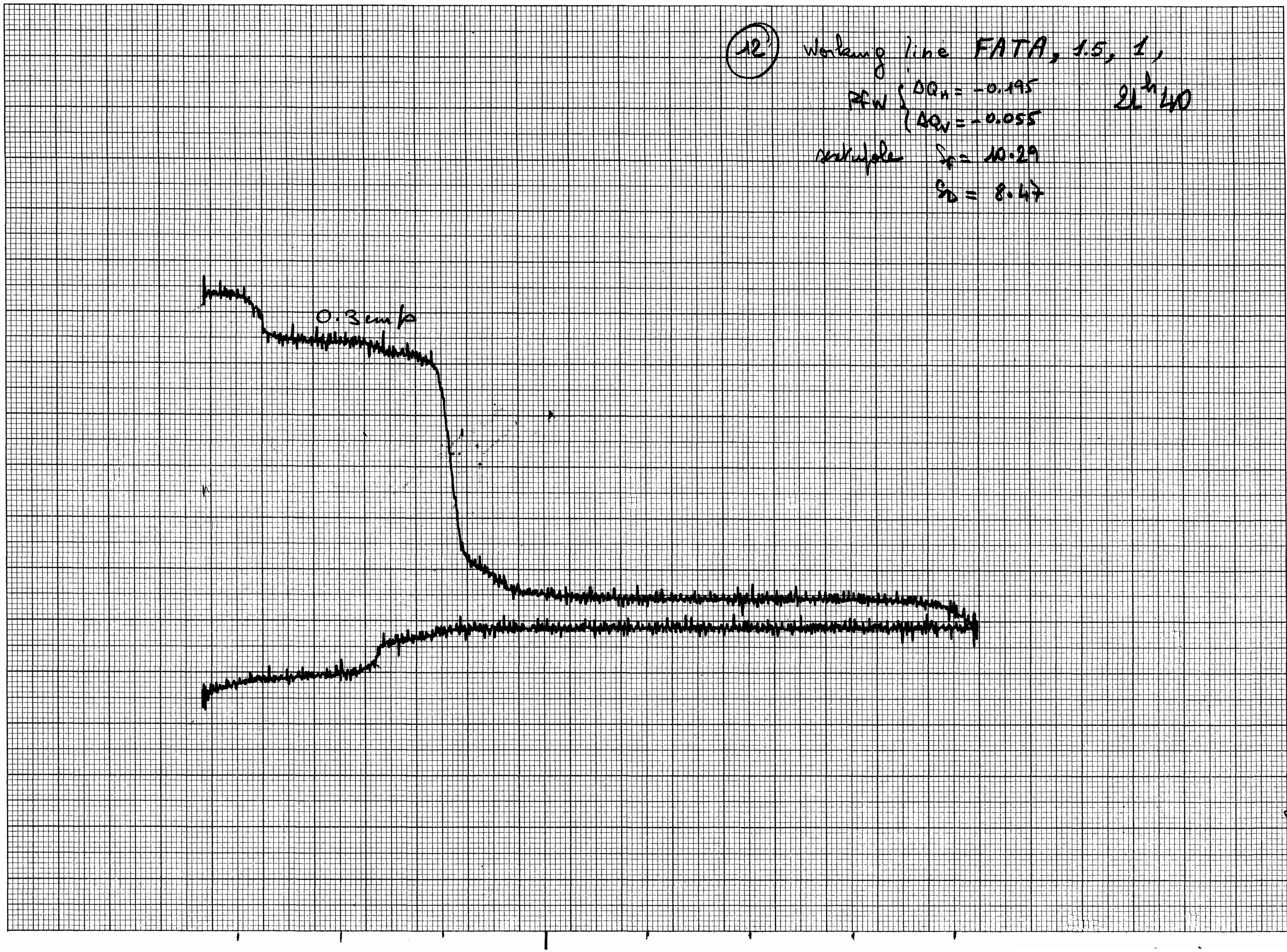


Run 31 - fig 9


(12) Working line FATA, 1.5, 1,
PFW { ΔQH = -0.195
ΔQV = -0.055
21h40
sextupoles ξF = 10.29
ξD = 8.47
0.3 cm/p

Run 31 fig 10

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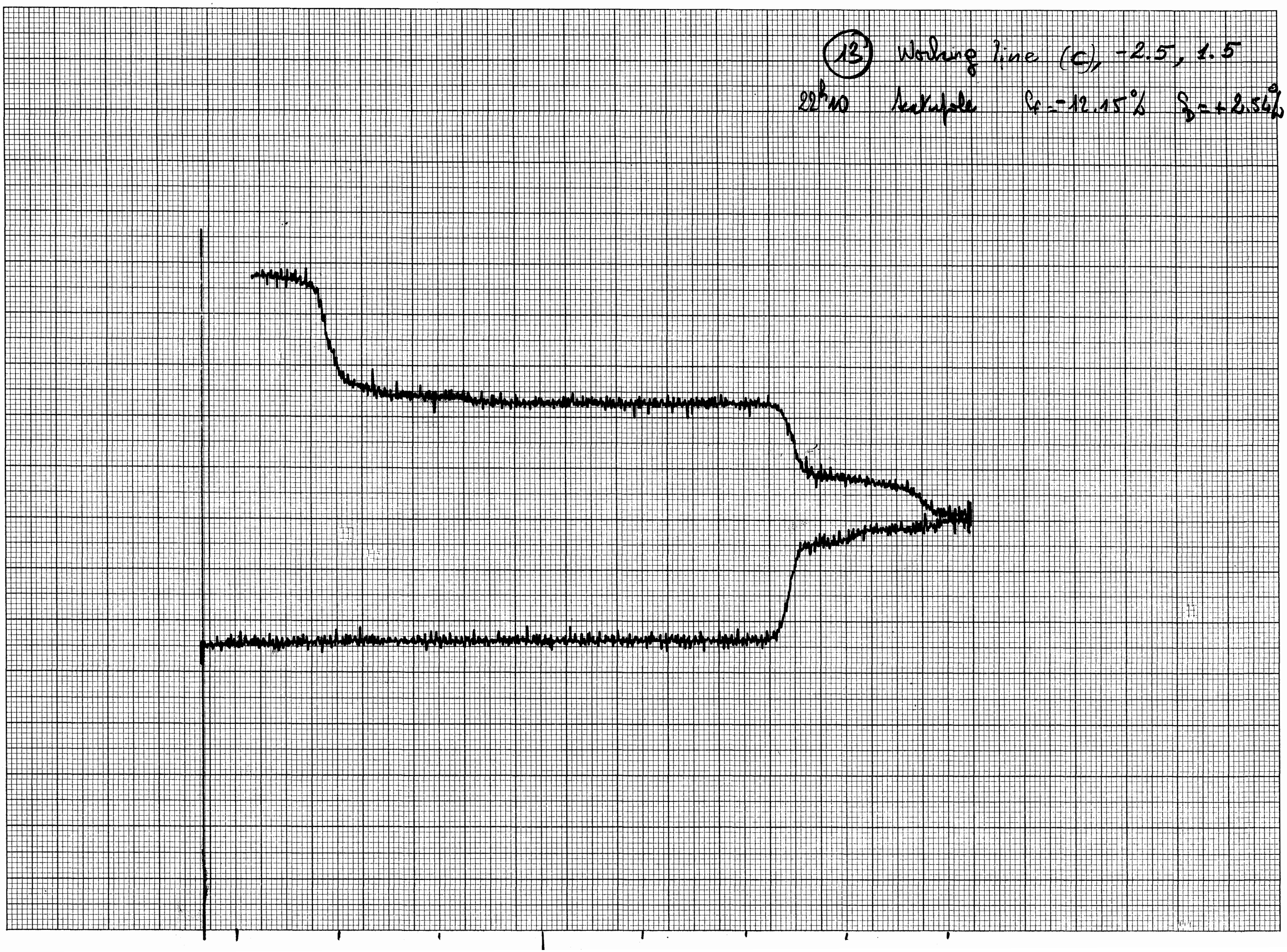
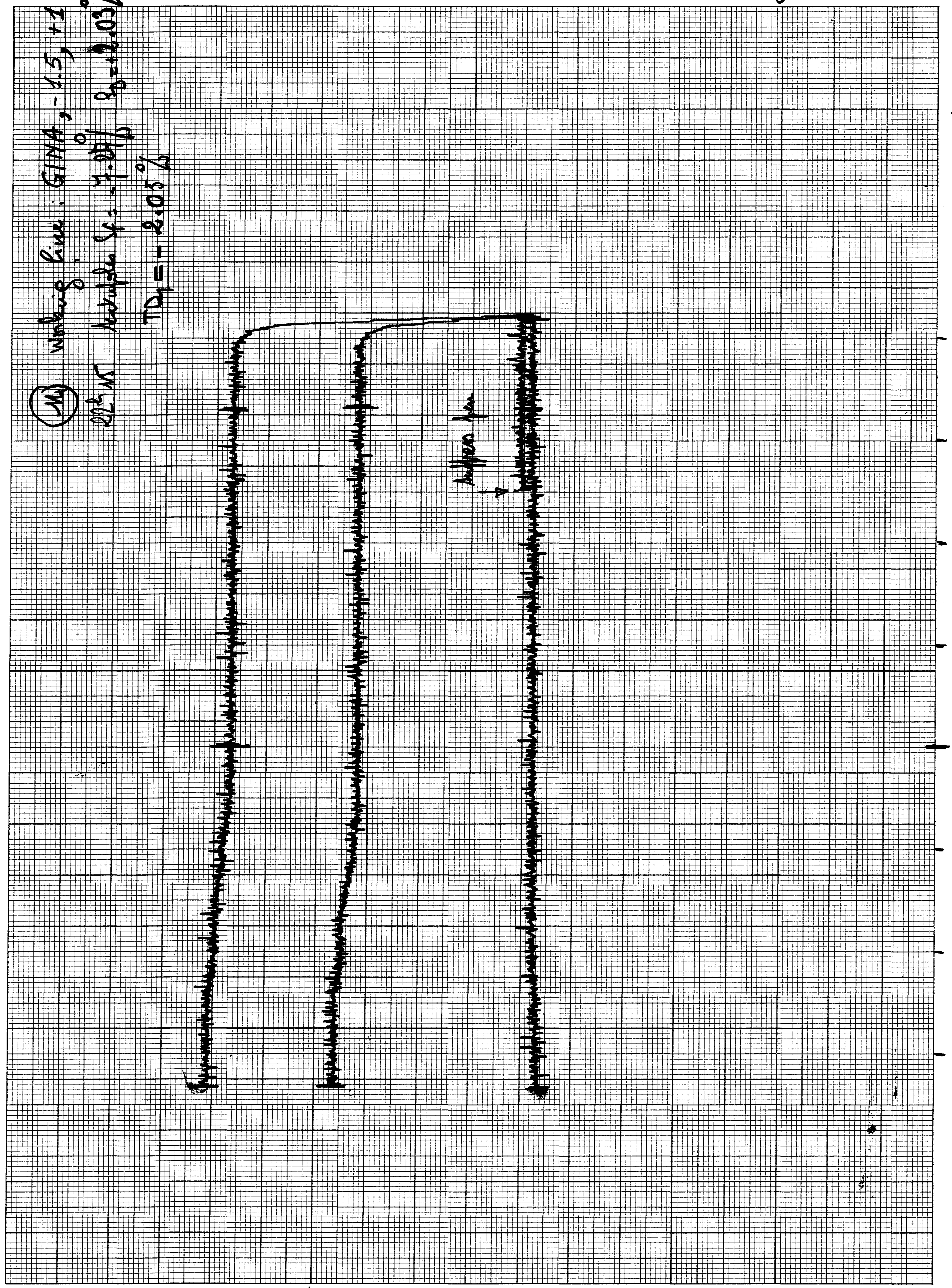


Run 31 fig 11

Run 31 fig 12



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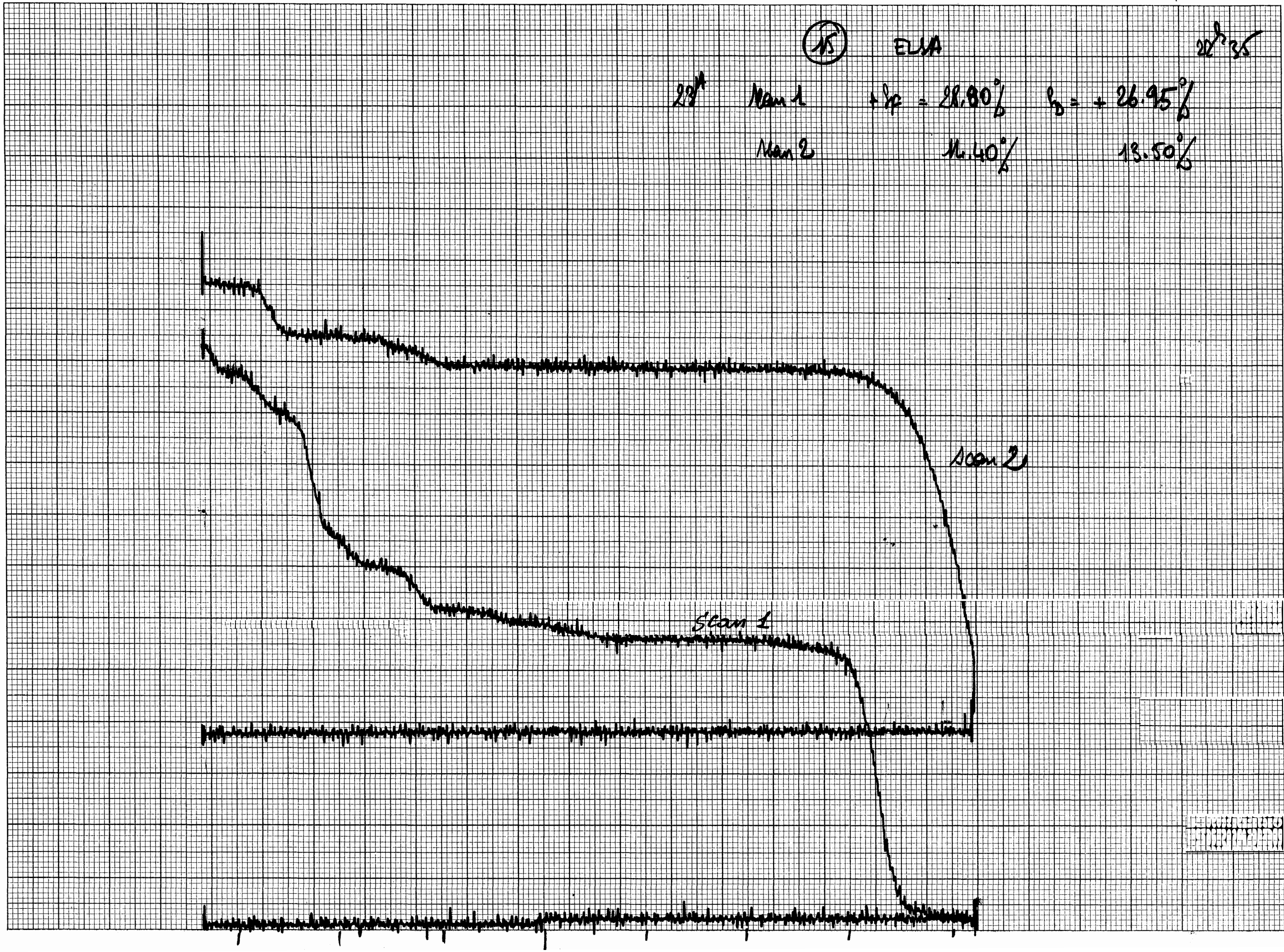

Run 31 fig 13