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Correcting electrons trajectories in LILW FODO

- Comments about the program and analysis of last results.

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1. Introduction.

Linac trajectory transverse correction is essential for performance of machines such as LPI. It has to be fast,reliable and should not enhance dispersion. LIL e- automatic steering procedure is based on modelling. A version of the general purpose and tracking program DIMAD,adapted to linacs, is run from the console control computer. This has been preferred to an entirely heuristic method which could be derived from the analysis of the results of a beam gymnastics procedure. The procedure used for the correction is here resumed and some of the experimental results are commented.

2. A steering facility for linacs.

The misalignments of the beam center along the linacs are measured by the magnetic position monitors(UMA). The beam could suffer important,even disastrous transverse deviations from unavoidable loose of magnet power or transmitted RF power. The same problem surges when setting the machine with new parameters. Kicks are then established at H and V correctors to cancel these deviations ,and to restore maximum transmission.

The number of parameters makes the manipulation of the knobs of the power supplies tedious and unsafe. Therefore,beam transport calculations between correctors and monitors, provided by the program DIMAD [1] are used for the correction via an automatic procedure.Rather than writing a new dedicated program,we preferred to modify a well known one,including features specific for a linac ,in a way that preserves the overall power of the program.

3. Beam transport characteristics.

In this modified version,cavities are treated as in TRANSPORT [3] i.e. as drifts with longitudinal E field,constant in transverse plane, which is rather poor description compared to really accurate ones [7],but may be sufficient for relativistic beams. Most of the FODO line quadrupoles are surrounded by cavities.The resulting combined function is represented by the first order solution of corresponding optics equations as given by Haissinski [4] or Helm[5]. With this more realistic description,we expect better accuracy and obtain a shorter listing for the data. Moreover,higher order solutions for the equations could be introduced. To account for electric field variation along TW structures fed by compressed RF pulse (LIPS), it is enough to use segments along which E is considered as constant, its averaged value being derived from more elaborate calculations [6].

4. Strategy for correction.

Simulations of trajectory correction were extensively investigated in order to prove that the layout was adequate[13]. Different is the problem of achieving corrections on the real machine with operation constraints:

The machine must be rigourously described in its geometrical and electrical details,such as the measured coefficients for the magnet forces versus currents,the power supplies polarities and their limits. High computer speed and immediate availability of the resulting currents to send to hardware are of high importance. Moreover we have to deal with inaccurate knowledge of the contribution of each accelerating section to the total momentum,which is the only one precisely measured.

As an other example, in most of the beam measurements,an important beam displacement was seen in front of the beam line segment chosen for correction,of the size of the displacements along the line. Such an initial shift is not corrected,but the correction is distributed along, using minimum kicks and,by means of weights, achieving maximum alignment at the end,where the conditions are critical for injection in EPA.

We used the general purpose non linear least square fit routines of DIMAD,which are based on a modification of the Levenberg-Marquardt method [8],[9].

Some strategies achieve perfectly well particular requirements [11]. The one we choose results from simple considerations and is only justified by its success for the specific problem of a linac.

For practical reason,the overall correction is performed in onlv one run of the program.

In principle,the correction is shared among available correctors and minimization of the total correction power is required,as suggested by experience and authors[12].Therefore,the sum of the absolute values of the currents used for correction is added to the sum of the weighted squares of the transverse displacements to be minimized,with a coupling coefficient which can be modulated. This prevents correctors from counteracting each others and allows small contributions,as all correctors can be selected if wanted.It is up to the user to disable those with a very small current:incorporating such a rejection within the program is not important.

The currents have limits imposed by the power supplies.We have introduced in DIMAD the change of variables used in MINUIT [10]. For a current i $(i1<i<i2)$,the corresponding internal variable used in the minimization is:

$$j = \arcsin((2*i-i1-i2)/(i2-i1)).$$

5. Results.

Figure 1 shows the horizontal and vertical readings of the monitors before and after the correction currents calculated values were sent to hardware. It is our last experiment(12-06-86).

6 H correctors (292 to 362) were used,(but there is a presumption that the corrector 362 was off),and zero reading was demanded for 8 H UMA monitors(30 to 37).

6 V correctors (291 to 361) were used and zero reading demanded for 8 V UMA monitors(30 to 37).

One run of the program reduces the transverse position from +-6 mm to +-1 mm in horizontal plane and from +-3.5 to +-1 mm in the vertical one.

Remarks: We did not try to reduce again the trajectory transverse displacement by a second run. We could have obtained a better correction if corrector 362 H were not used,because this corrector was probably off.

Comparing initial and final currents shows minor changes which indicate that we reached our aim of a minimum perturbation on the currents of the correctors for a strong effect. We avoid self annihilation of the correctors effects.

The change is only important for corrector 292 H which jumps to maximum allowed value,as it is very close to monitor UMA30. There are several remedies: abandon of correction on H UMA30, choice of a very low weight for this monitor,more severe limits set for the current. But it was not reaily compromising the solution. Calculations of betatron phases with DIMAD have shown that according to the distribution of energies and quadrupole forces along the FODO line ,the use of the H correctors DQLA272 and DQNF271 would be misleading.This was pointed out by R.Servranckx (table 1) :

Figure 2 shows how using DQLA271H destroys the correction precedingly achieved in the horizontal plane. There is some uncertainty about this result due to the fact that DQLB28H,which phase is not as bad the other

Table 1: delta phi/(2*pi)

	UMA29	UMA30	UMA31
DQLA272H	1.55	2.06	2.47
DQLA271H	1.06	1.56	1.98
DQLB28H	0.67	1.17	1.59

two,was also used,but unreliable. After the experience, it was clear that demanded and acquired values were uncorrelated for this corrector.

Figure 3 shows the result of a previous correction attempt without securing for minimum current for the achievement of the correction[15].

6. Conclusion.

Both inner and interface[2] programs and data set seemed to be good enough for the linac e- trajectory correction,providing that correctors DQLA272H and DQLA271H are disqualified,because of their betatron phases. A serious verification of the real working status of each element is necessary before the correction. Results are similar to those obtained at a previous attempt[15],but currents are now minimized.

The uncertainty about the distribution of the total energy gain along the sections is not too harmfull,and,for our purpose,the transverse position measurements are precise enough.

Steering the beam is more difficult in the low energy part where both transverse movements are coupled by solenoidal fields superimposed on the longitudinal electric field.DIMAD offers an operator describing this double function. But long flat coils are also there used for horizontal and vertical earth field compensation.Their currents can be changed for steering purpose and a special developpement is incorporated in the program for that[14], taking into account the important variation of the energy along these coils. However,use of this correction is somehow restricted by the lack of monitors in this area,and their little number in the part which follows.

It would be interesting to operate the correction also along LIL V if the interface were implemented for it,and to attach the program to a button of the control touch pannel tree.

Experience of running the program at the console shows that some more help could be provided to the desk operator,such as selection of H and V correctors and monitors from a common screen display. An evident indication should appear on the screen,helping for selection of less correctors than monitors of the same type,and accounting for at least one corrector of a given type precedes the monitors of the same type.

7. Acknowledgments.

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Figure 1

Last Horizontal Correction

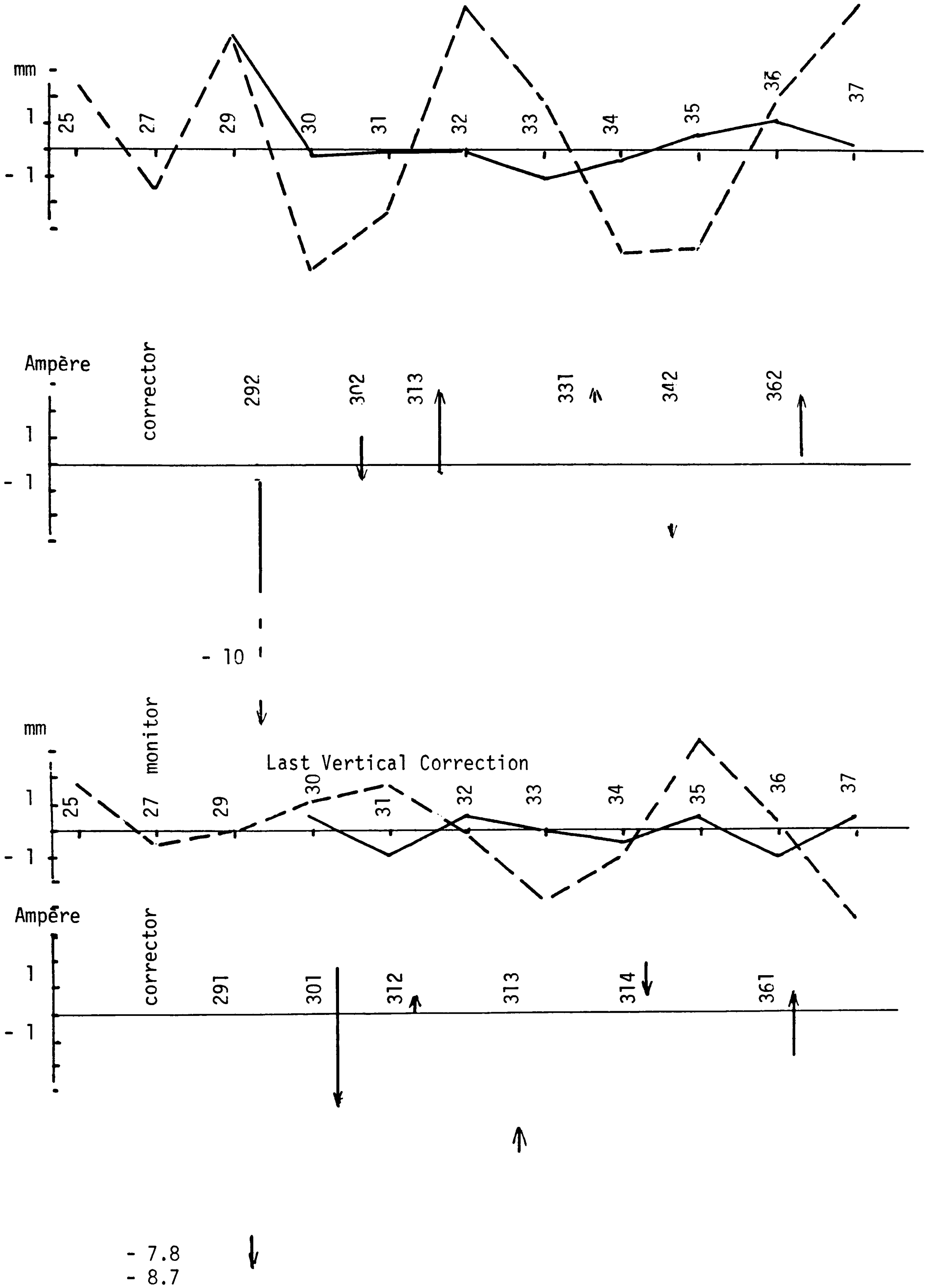


Figure 2

Incorrect use of DQLA 271H in horizontal correction

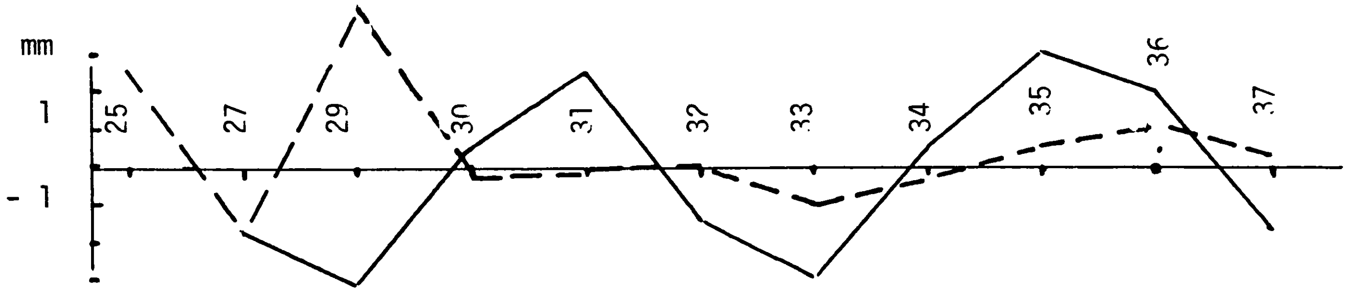
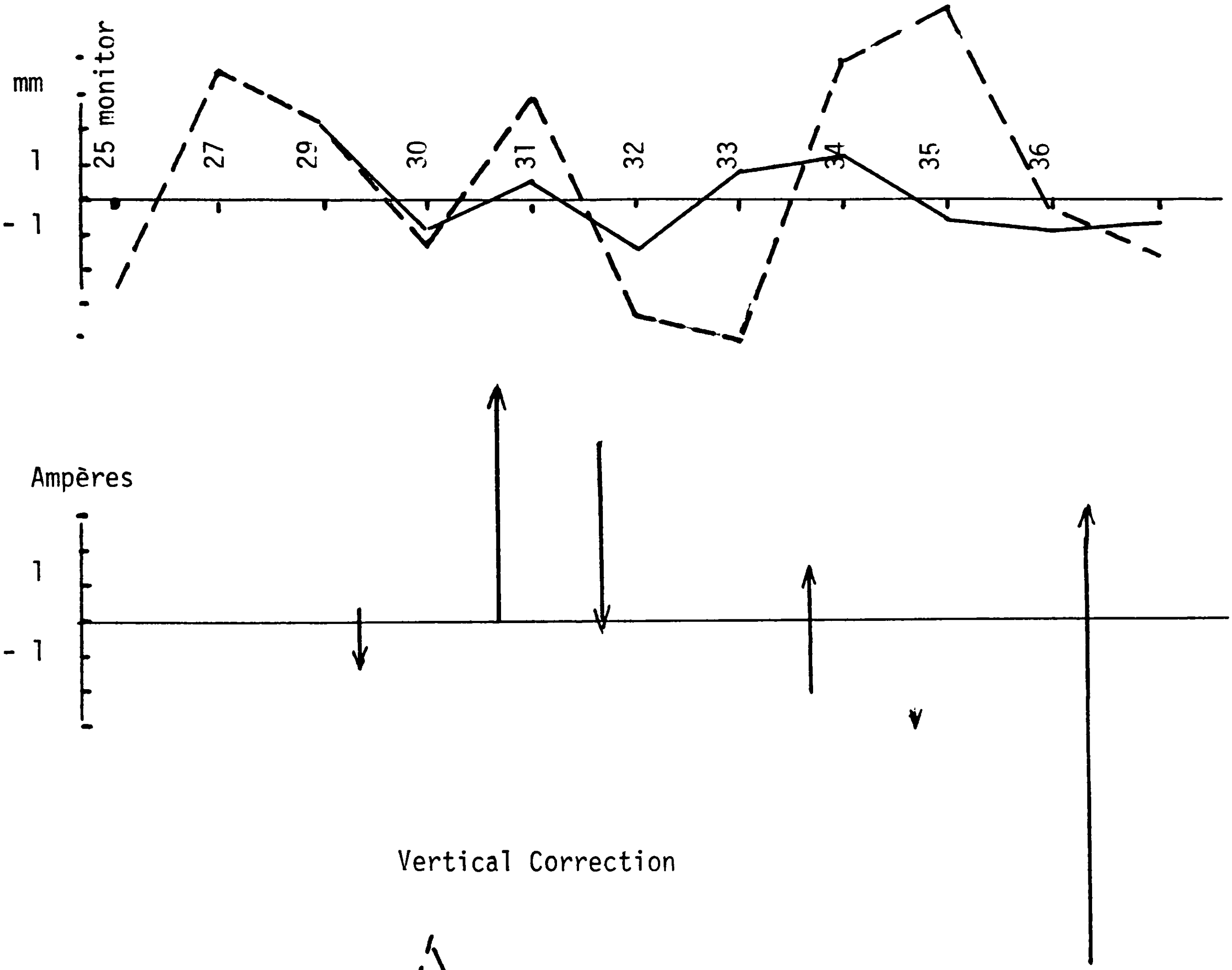


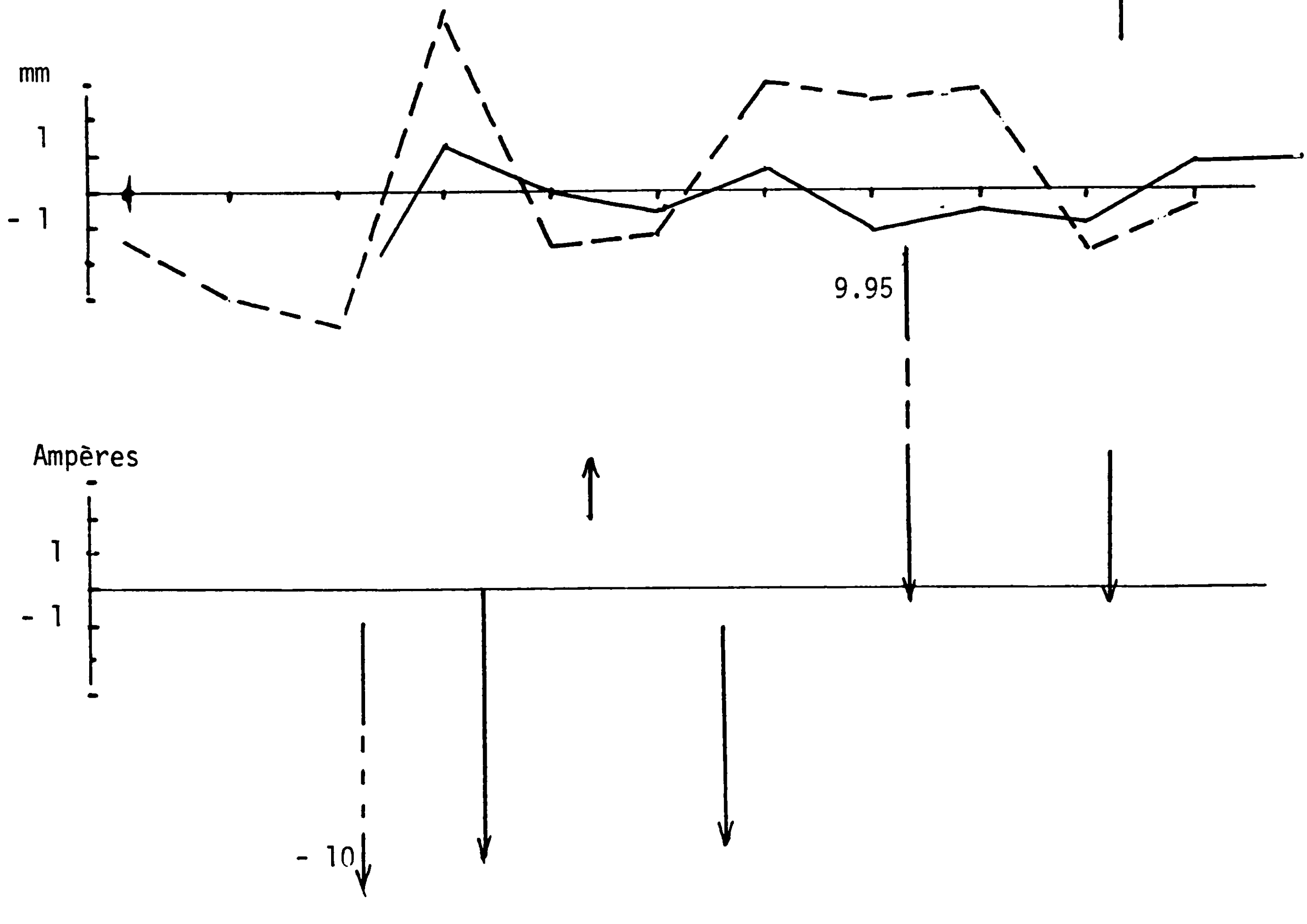
Figure 3

Correcting power not minimized

Horizontal Correction



Vertical Correction



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