Status of ESRF Alignment Facilities
WPS ready for an automatic 2D smoothing of a storage ring

Daniel Roux

European Synchrotron Radiation Facility
BP 220 - 38043 GRENOBLE - FRANCE

INTRODUCTION

In 1987 the Alignment Team of the ESRF accelerator complex launched a new concept for the geometric maintenance of the sensitive magnetic elements of the storage ring. This design, based on sensors rather than traditional topographic instruments, aimed to achieve realignment with beam on within a few hours.

The double target consisted in a first step to considerably reduce intervention time during shutdown periods and then to afford Users (machine operators and scientists) the possibility of a constant follow up of the beam throughout the alignment operation.

This challenge was launched at IWAA 89 held in Stanford and was fully achieved in 1993 and further optimised in 1995 bringing alignment time from eight hours to six minutes in real time (First Part). This challenge only concerned the vertical realignment of a storage ring and today we are ready to extend our wager by proposing a horizontal realignment of the magnetic elements in the same time scale and with a similar degree of accuracy (Third Part).

Nonetheless, it should be noted that although the alignment time in itself is reduced, the time required for preparation remains the same. This is more and more constraining as highly qualified personnel are required for these tasks. The results obtained by an enthusiastic pioneering team can only be maintained to this level of precision by implementing a quality assurance programme for all maintenance operations and by permanent computer monitoring. Only under such conditions can realignment operations be performed in the best possible circumstances. (Second part).

1_STRAIGHTFORWARD PROCEDURE IN Z ALIGNMENT

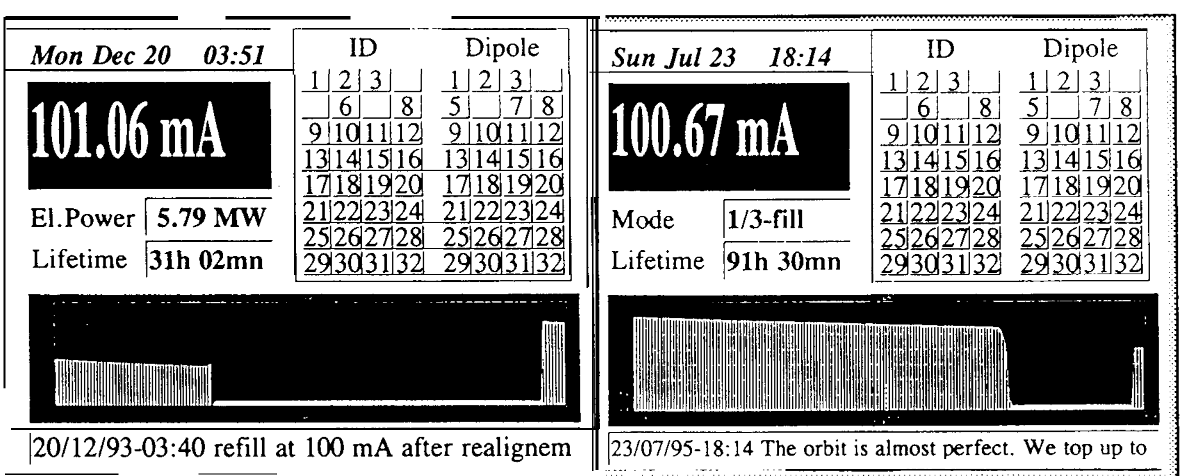

Figure 1

First realignment performed on December 1993 in 5 hours with a beam intensity of 5mA on the left side and: Last realignment performed on July 1995 in 6 minutes with a beam intensity of 7mA.

During the Workshop held in Annecy in 1993, we presented a preview of the latest results of the first automatic vertical realignment of the ESRF storage ring. This operation is now systematically performed every six months in order to reduce the amplitude of variations to a value which is of minimal constraint both to the Machine Group charged with maintaining the correct orbit using automatic correction and to the Scientists to reduce alignment time for the beamlines which are not always equipped with automatic systems. At the occasion of each realignment, we have tried to gain time in order to achieve Machine realignment in under six minutes real time.

We have made slow but steady progress, we have gone from eight hours alignment without beam to one and a half hours with beam on, of which six minutes real time for the latest operation. It is clear that our target will be six minutes real time and six minutes time spent for the next realignment which is scheduled for December 17, 1995.

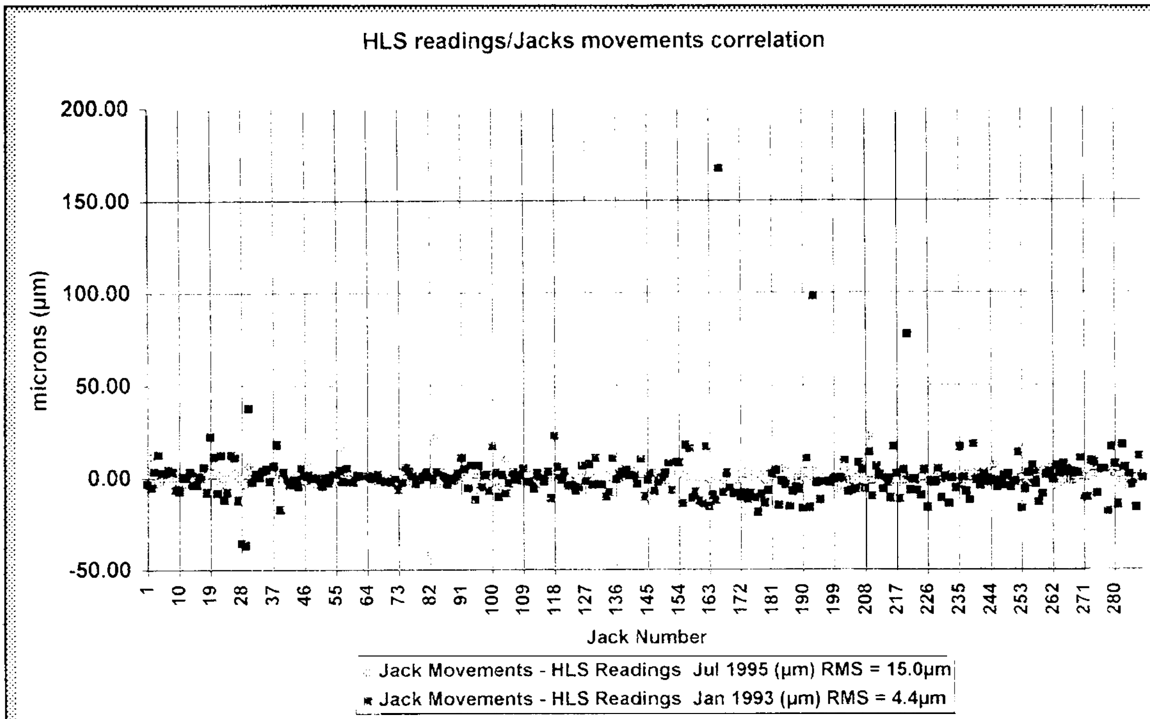

Figure 2

The graph above shows the difference of quality between the first realignment performed on January 1993 in 8 hours without beam and the last one on 23 July 1995 in six minutes real time with beam on at 7mA

The RMS value of the HLS[1]/jack pair is 4.7µm and we obtained a 100% success rate on the 288 displacements during this historic alignment operation performed on January 10 1993 without beam.

The RMS value of the HLS/jack couple is 15.1µm and obtained a 98.2% success rate on the 288 displacements during this last alignment operation performed on July 23 1995 with beam.

[1] HLS: Hyhrostatic Levelling System

The other realignments took place on:

- ▹ August 93 with beam on in eight hours (RMS=3.7µm)[2]
- ▹ December 93 with beam on in four hours, by sending only the non zero orders to the jacks (RMS=7.4µm)
- ▹ July 94 with beam on in two hours by direct cabling of each cell (RMS=5.5µm)
- ▹ December 94 without beam in two hours, for technical communication reasons (RMS=4.2µm)
- ▹ July 95 with beam on in six minutes, by substitution of sequential access to 32 cells by direct access (RMS=15.1µm).

All results have been achieved with an extremely agreement between the commands despatched to the jacks and the records obtained by the HLS sensor with the exception of the July 95 operation where some jacks had been perturbed.

This could have been caused by several factors, insufficient time to stabilize HLS, air conditioning on during the survey operation, interruption of the mains, dam activities during the alignment schedule, extra loads added to girders by colleagues during the short shutdown periods.

In order to improve the situation and the reliability of operation, we have decided to organize a pseudo alignment on a monthly basis during the first two days of shutdown, by moving all of the 288 jacks up by 100 microns then down by 100 microns to check both the HLS and jack systems.

It has been clearly demonstrated that saving in time is often to the detriment of quality and we now must turn our attention to a Quality Assurance programme improve both reliability of results and time for intervention.

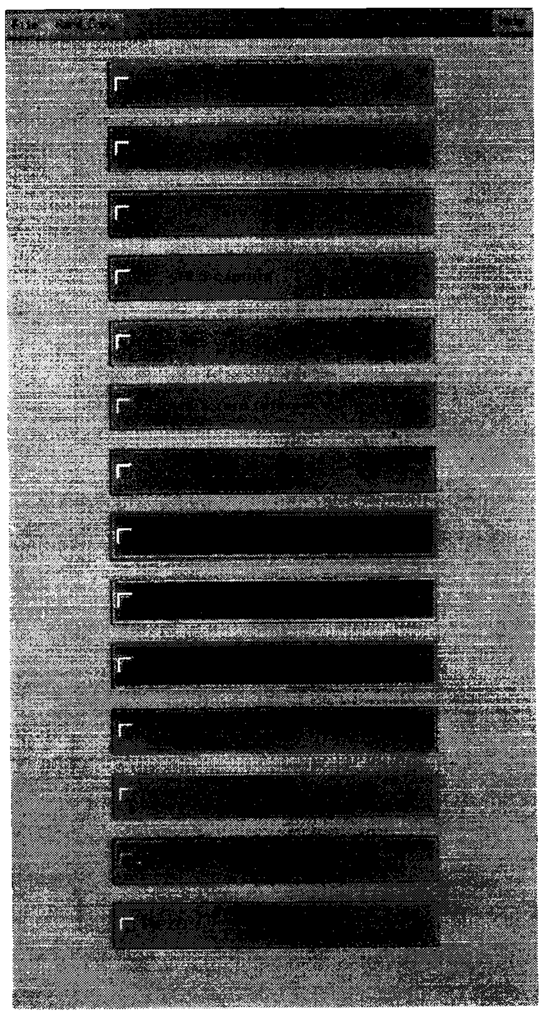

Figure 3

'iew of the menu of alarm programme i CTRM[3] under the ALGE[4] Green/Red Button.

2_QUALITY ASSURANCE PROGRAMME

This vast programme was launched in 1995 and it is hoped that it will exploited to 80% in 1996. The aim is to apply quality assurance methods to each alignment task in the tunnel during Machine shutdowns and, in parallel to set up a computerised monitoring of all survey and alignment equipment centralised on a second control screen reserved for equipment which does not interfere with the beam operation but which contributes to its medium and long term reliability.

[2] RMS: Root Mean Square, Standard Deviation
[3] Control Room
[4] Alignment and Geodesy

2.1 Quality Assurance_files

European Synchrotron Radiation Facility
Technical Services / Alignment & Geodesy

ASSURANCE QUALITY FILE

GENSERV REFERENCE : N:\CURRENT\QA_FILES\SY\AQF0101.DOC

Type concerned :

VERTICALIZING OF PILARS REFERENCE OF THE BOOSTER (Tilts)

Location of the Work
BOOSTER RING TUNNEL ALL CELLS

Frequency of the Intervention
EACH TIME AND BEFORE A PLANIMETRIC SURVEY NETWORK

Equipement concerned
48 Pillars and Movable Wall Brackets and extensions

Time required
Half a day

Staff required
2 persons

Staff required (Number and qualification)
1 Operator (ESRF)
1 Assistant
Staff from other group (Vacuum, Front-End, Beam Line, ...)
Nobody

Responsibles
Responsible of Ground Work
Responsible of Calculation :
Responsible of Publication :
Last check before published : D.ROUX or D.MARTIN

OFFICIEL
" VERIFIED "
ok 9/10/95

Material and instrumentation to be used :
Nivel 20 on special Baechler Tool, Portable PC-Computer

Constraints imposed by Work and eventual interference with other groups.
This task is fully decoupled from other ALGE tasks
Roof closed, Chicane Doors closed
No Air Conditionning from 12 hours minimum.
No Bake out everywhere in the tunnel included FE

Usefull Preparation to perform activity :
PC_AUTO_PILOTE_FILE to be used **N:\CURRENT\PROGRAMS\X_AUT\SYTILNET.AUT**
PC_PROGRAM to be used **N:\CURRENT\PROGRAMS\X_EXE\VERTALES.EXE**
Usefull Notices to perform activity :
USER_NOTICE OF VERTALES PROGRAM **N:\CURRENT\COMMS\USRNOTES\USR0098.DOC**
Results to be produced :
PC_RESULTS_FILE **N:\CURRENT\GENDATA\SURVEY\SY\SYTILNET.RES**

Figure 4

Example of quality file of the operation of verticalisation of the geodetic reference of the first order booster network.

In a first step, we generalised access to electronic mail for the members of the team using PC computers and installed a channel of official communication (memos, measurement protocols, meetings,...) considerably speeding up the flow of information.

The primary aim of this operation was to reduce the volume of paper and also to promote real time information, ie in less than half a day.

All standard repetitive measurement tasks in all fields for the Machine, network, beamlines are recorded on a quality data sheet which enables us to trace all measurements back to the last intervention. The time required to perform the operation, various preparatory documents and final publications for each intervention are dissected and stored on a 20 Giga byte hard disk accessible to all members of the Group. The results are made available to Users on a communication network called GENSERV.

2.2 Instrument survey programme in the Control Room

In order to guarantee a maximum reliability for all automatic control instruments, HLS, DOMS[5], PIEZO[6], taps, WPS[7] and to be ready at all times to perform a non scheduled realignment, various programmes are being set up. The aim of these programmes is to ensure the permanent control of operation of the automatic surveying instrument in liaison with the operators in the Control Room who offer a 24 hour a day service.

Several applications are available in the Control Room, figure 3 give a fast view of all the alarm program concerning the ALGE instrument installed on the full site. The figure 5 menu allows us to refill or purge a general system of HLS with the aim to compensate the evaporation, or to make maintenance tests by verifying the stabilization time and the RMS value obtained by the full system by changing the mean plane level of the water.

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[5] DOMS: Dimensional Offset Measurement System
[6] PEZO: Piezometer
[7] WPS: Wire Positioning System

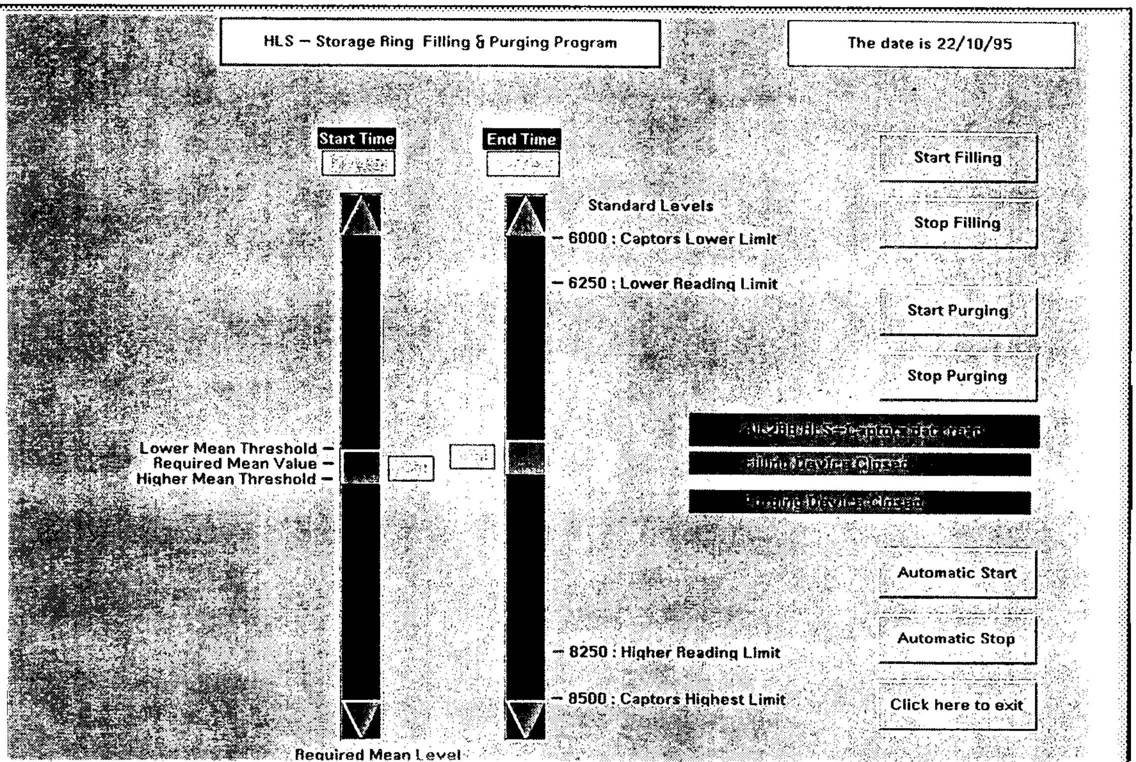

Figure 5

Application to refill or purge or the SR_HLS network or the FE_HLS network.

3_WPS PROTOTYPE FOR X REALIGNMENT

The operation of the HLS has proved extremely successful in terms of reliability and time savings. Nonetheless, since we are dependent on the heavy beam schedule (6000 hours in 1997) which is at present incompatible with the radial position maintenance schedule (dR) for the storage ring, for the last three years we have been working on a smoothing programme using WPS. The WPS should enable us to obtain the same time savings as the HLS for the continuous dR control of the machine The motorisation of radial plates and girders would enable realignment with beam on in the X plane, just as the motorised jacks guarantee the Z movement. This element would provide improved User and machine comfort.

Figure 6 : WPS mono axe sensor

3.1 The principle of the WPS monoaxe sensor (dR measurement)

This sensor can satisfy rapid industrial installation requirements. The measurement range, which is adaptable, was set at 2500 microns for standardization with the ESRF HLS.

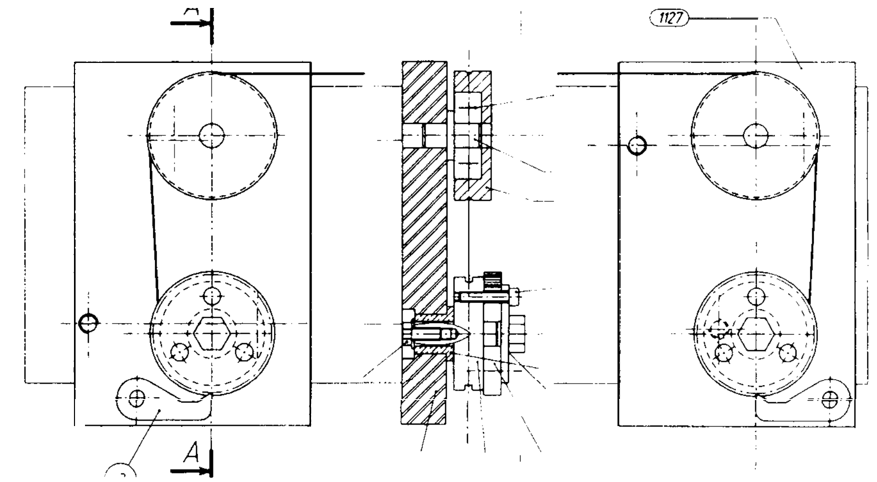

Figure 7 : Ratchet Tensor System

The definition of the horizontal measurement range of 4mm in which the dR measurement is independent of the vertical position of the wire and thus the tension of the wire (tolerance of up to 2kg) enabled us to envisage a wire tensor with a pulley wire guide equipped with a ratchet wheel enabling a tension accuracy range of 100 - 200g using a simple dynanometer key.

For reasons of economy and ease during adjustments, no distinction was made between the set point and the tensor point, both control points are identical and are equipped with tensors.

This sensor was designed to enable the wire to penetrate the working area by simple wire tension. The associated electronics include an internal temperature probe which enables measurement of the evolution of the ambient temperature at the measured point (indispensable for the interpretation of metrological measurements).

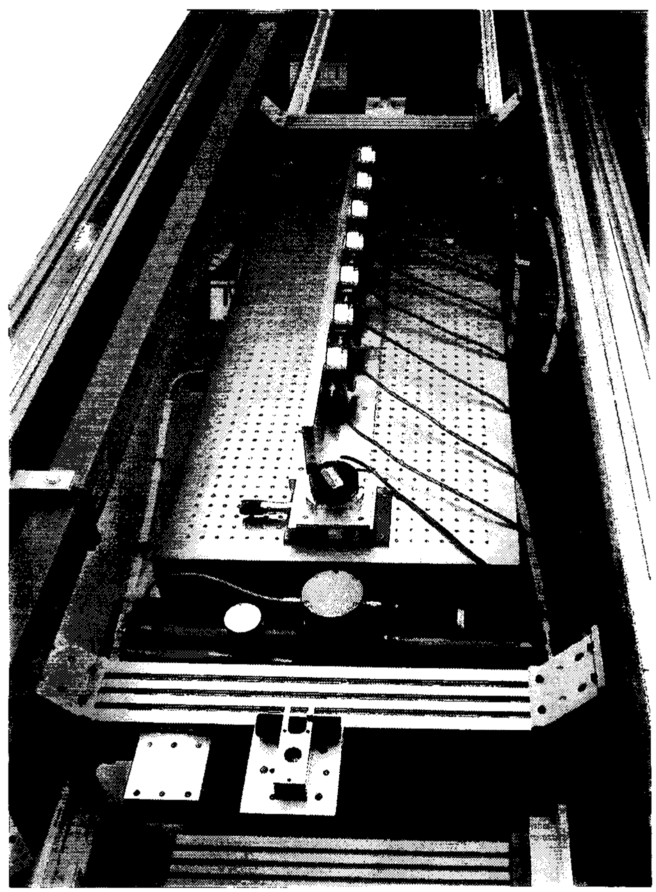

Figure 8 : Installation of the 8 pre-series WPS on the ESRF calibration bench

3.2 Validation tests on methods used

The three strand carbon wire is manufactured by Japanese industrialists and is a by product of a the standard two strand wire used at CERN. Each strand is composed of 500 filaments which brings the breaking load to 13kg. Thus we\are able to work with a tension of between 8 and 10 kg, ie the nominal value is 9kg which nonetheless is not penalised by the deflection of the wire.

The corresponding pairs applied to the dynamometer key used during the tests are 2.0Nm to 2.4Nm

During tests we operated with eight different wire positions to test both the absolute value of positioning and the relative measurement value. This served to confirm the limitation of absolute measurements due to the geometric defects of the wire (different diameters observed over a several meter long wire).

It is therefore concluded that the absolute precision of positioning (changing wires for example) can, at best, be guaranteed to within 10 microns, whereas relative positioning can be guaranteed to within 1 micron, the resolution of the sensor being less than 0.3 microns.

In conclusion, to define the correct position of the wire during an installation procedure the wire should be circulated over 1 cm (2kg tension for a length of about 10m), the measurement

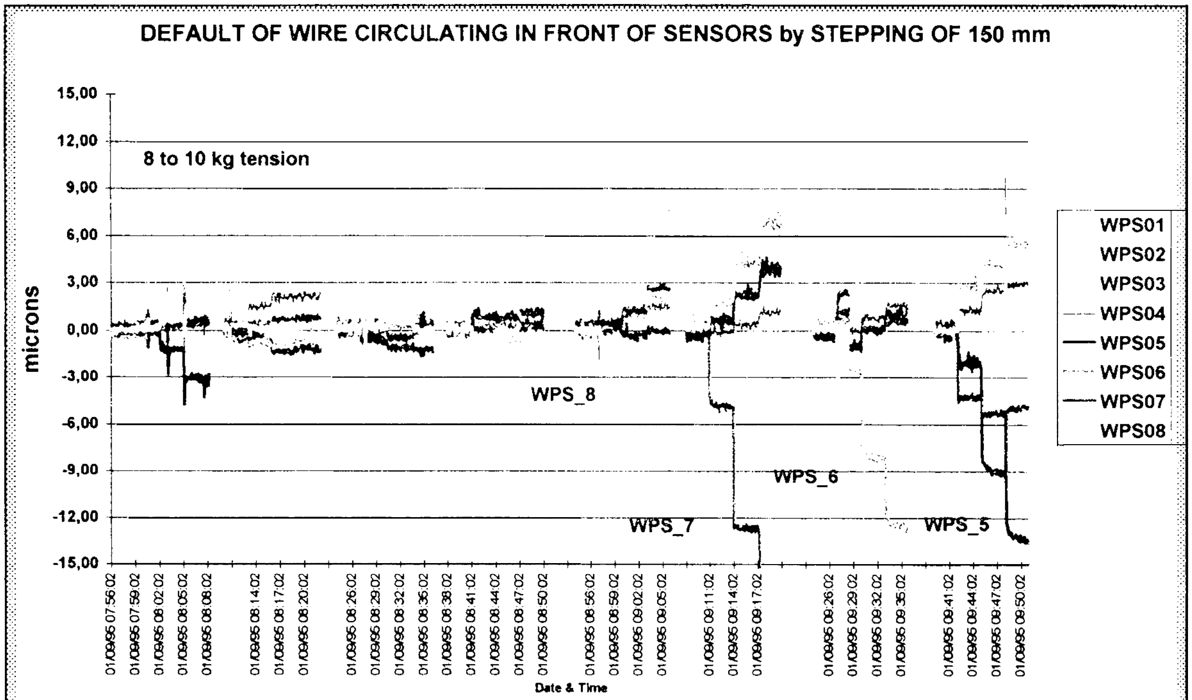

Figure 9 : Tests of different tensions between 8 and 10 kg.

amplitude on the sensors should be checked between 8 and 10kg in relation to the rejection tolerance. The nominal tension should then be adjusted to 9kg, if accepted, if not then the wire should be moved along to the next centimeter, as shown on figure 9.

The following curves on Figure 10 correspond to a tension between two points equidistant at 20.3m over a 20 day period.

The first curve shows the rough measurements on the eight sensors which evolve in function of the position of the so called fixed points.

The second curve illustrates the residues after linearisation on the right passing through the eight sensors, which are considered as fixed as they are installed on the same rigid support (see figure 8).

The third curve given using integrated temperature probes shows the perfect correlation of movements at fixed points and variations in the air conditioning.

The important amplitude recorded on the two fixed points is related to the fact that the calibration bench is of the single block type and that the dilatation of the bench is directly proportional to the temperature (no dilatation joints between the modules).

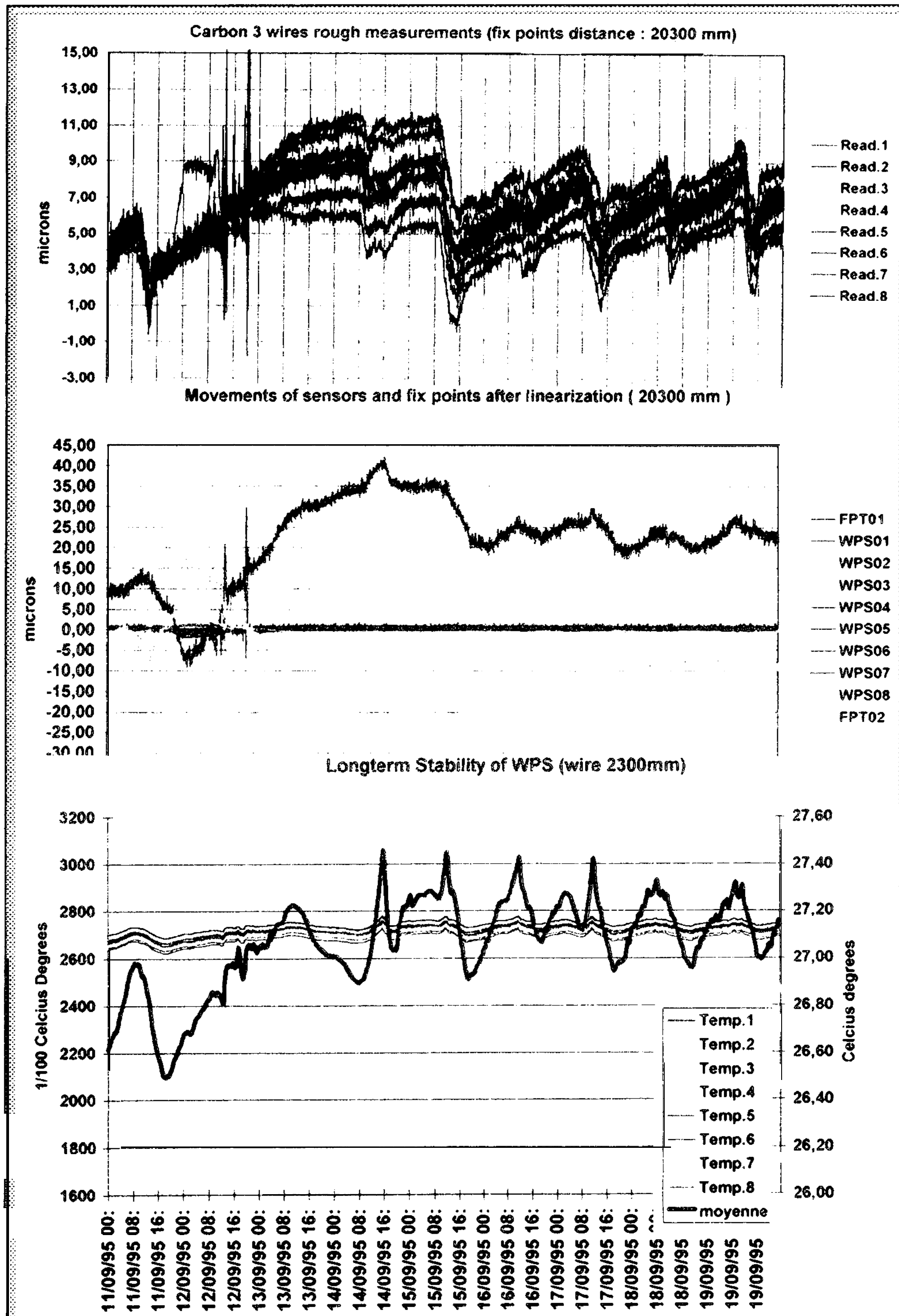

Figure 10 : Recording of 8 WPS sensors over a 20 day period. At the top the rough measurements, in the middle the linearised measurements and at the bottom the temperature measurements.

A typical residual gap of less than 0.3 microns can be observed on figure 11 which is a Zoom of the second graph of Figure 10, this indicates the precision and stability of the sensors.

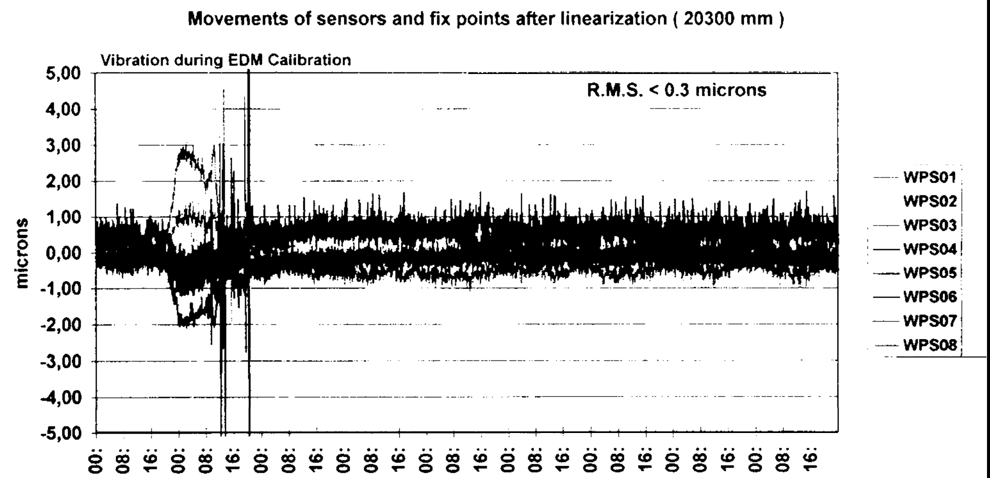

Figure 11 : Zoom on previous second graph given the residual value of 8 WPS sensors on 20 day records.

3.3 Integration in the ESRF project

The ESRF project consists of a succession of 64 modules of two different sorts (32 short and 32 long modules) the articulation points of which are the centre of the 64 dipoles. The dipoles are not motorized and are realigned manually once a year.

We propose to equip 64 double fixed point on dipoles which are considered as fixed between two realignments (basic solution), or variable at angles (preferred solution) by adding two passive WPS sensors on the dipole (no adjustment possibilities). These sensors will be either passive (solution 1) or active (solution 2) in the calculation of residual displacements of the girders.

Each cell will be equipped with 13 sensors (3 on each G10, G20, G30) enabling a repeated control by calculation, and two on each dipole at the exit/entry to enable monitoring of angular variations.

The project calls for a total of 416 WPS sensors and 64 double fixed points. The motorization consists of replacing the 192 manual micrometers on the 96 girders G10, G20, G30 with 192 motors.

At present the solution which we propose using the existing manual measurement axe has not been approved for safety reasons as the wire would interfere with the passage of personnel above the machine storage ring in order to access the front ends. We are looking for a substitute location and this is proving to be a difficult task.

CONCLUSION

Barely six years ago (1989 in Stanford: HLS and WPS) the method we envisaged using has now become a reality for the complete smoothing of accelerator elements in the vertical Although we demonstrated that the same principle can be applied to the horizontal plane, the implementation of this system raises serious practical difficulties.

As a final remark, we wish to stress the importance of attracting the interest of Industry to develop simple standardised actuators, such that in, the years to come, metrological turnkey systems will be available on the market.

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