© 1993 IEEE. Personal use of this material is permitted. However, permission to reprint/republish this material for advertising or promotional purposes or for creating new collective works for resale or redistribution to servers or lists, or to reuse any copyrighted component of this work in other works must be obtained from the IEEE.

The Hydrostatic Levelling System (HLS) / Servo-Controlled Precision Jacks A New Generation Altimetric Alignment and Control System

Daniel ROUX
European Synchrotron Radiation Facility
BP220 38043 GRENOBLE FRANCE

Abstract

In 1987 the ESRF paved the way for a new ambitious accelerator alignment to satisfy demanding and as yet unachieved design specifications. This consists of a permanent realignment of the magnetic elements distributed over the 1km circumference of the storage ring to an absolute horizontal plane with a precision of $\pm$ 1mm. Relative alignment precision is specified at $\pm$0.1mm between two adjacent elements. Realignment operations are performed in less than one day.

In 1989 once laboratory tests confirmed that each of the "Hydrostatic Levelling System" and jack prototypes were capable of achieving the desired results, the series production of the 300 each of HLS and Jacks necessary to align the ESRF storage ring was launched.

From April 1991 thru' January 1992 the installation of girders in local mode was made in record time, to which the HLS made a significant contribution. During the so called storage ring "Commissioning Phase" (running from January 92 thru' June 92) the software was written, installed all equipment connected to the control room.

Today we would like to present the results of the first storage ring alignment which took place on January 10 1993. Results obtained were ten times better than those stipulated in the specifications and duly confirm that in less than one day it is possible to align a 1km circumference storage ring with an absolute precision of $\pm$ 0.1mm/km and a relative precision between girders greater than 10µm.

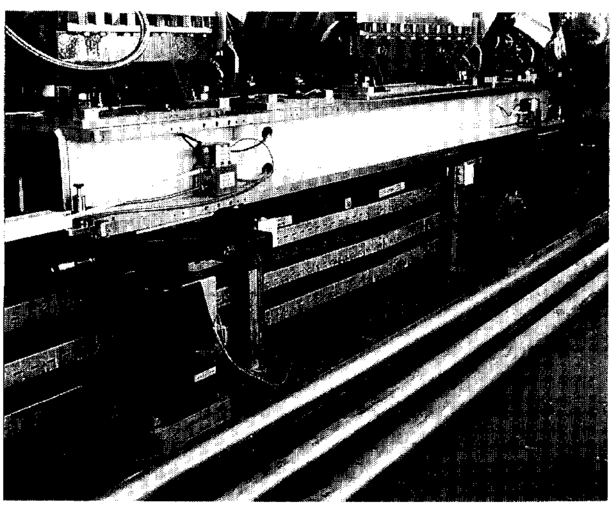


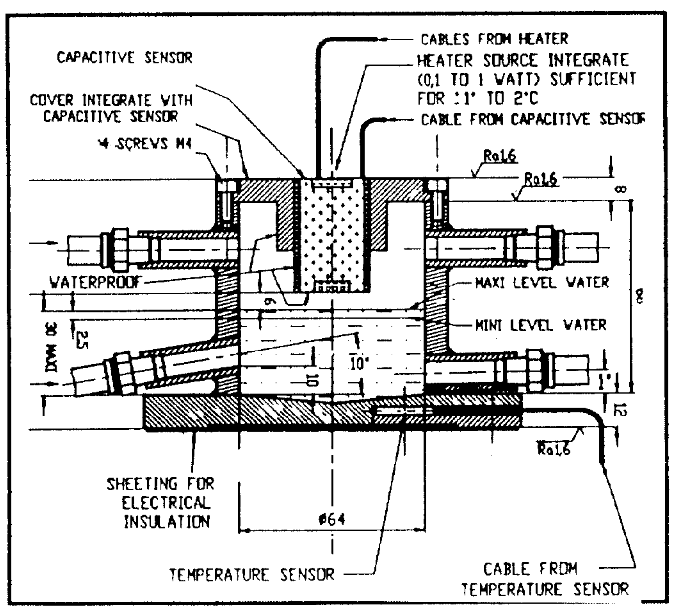
Figure 1 : One of the 96 girder supports for the ESRF storage ring quadrupole and sextupole magnets.

I. INTRODUCTION.

We estimated that relative movements over 1km would be of the order of 1.2mm/year on the geologically homogeneous sub-soil of the Grenoble site. This led us to schedule monthly realignments to satisfy specifications (The estimation was based on information recorded on the scientific polygon over a 15 year period and consolidated by a specific ESRF study made between 1987 and 1988).

From a geometric point of view the ESRF storage ring is composed of 544 sensitive elements distributed on 96 girders of an average weight of 6 tons. Each girder is supported on three jacks and equipped with three HLS located immediately above.

The HLS (Fig. 2) is a measuring instrument based on the principle of communicating vessels. The 288 instruments are interconnected along the circumference of the storage ring by a fluid filled tube which determines the reference plane and an air filled tube which guarantees pressure stability along the network. The design of the capacitive monitoring device was based on high tech satellite developments made by ONERA[1]. This device has a measurement range of 2500µm, analog resolution inferior to 2µm and digital resolution inferior to 0.1µm.



[1] ONERA Office National Etudes et Recherches Spatiales Aéronautiques (Palaiseau, France).

Manufacturer : FOGALE-NANOTECH (Nimes 30000 France)

0-7803-1203-1/93$03.00 © 1993 IEEE

The pipes which connect the HLS vessels are made of high radiation resistant (20Mrd) transparent material of 8/10mm internal/external diameter.

The servo-controlled jack (Figure 3) is a high precision screw jack, withstanding a nominal load of 3 tons, and with a 40mm displacement capacity (correction estimate over a 20 year period) and resolution under loading of 0.2μm.

The acquisition and control system consists of G64 modules for analog/digital transformation of a 16 byte signal, a VME type transfer bus and an HP type computer operating on UNIX. The acquisition of signals emitted by the 288 HLS on an HP 900/800 work station takes 15 seconds. Transmitting instructions to the 288 jacks takes about two hours, this is due to the procedures and security systems which are operational at present. The intrinsic speed of the system could be 15 minutes.

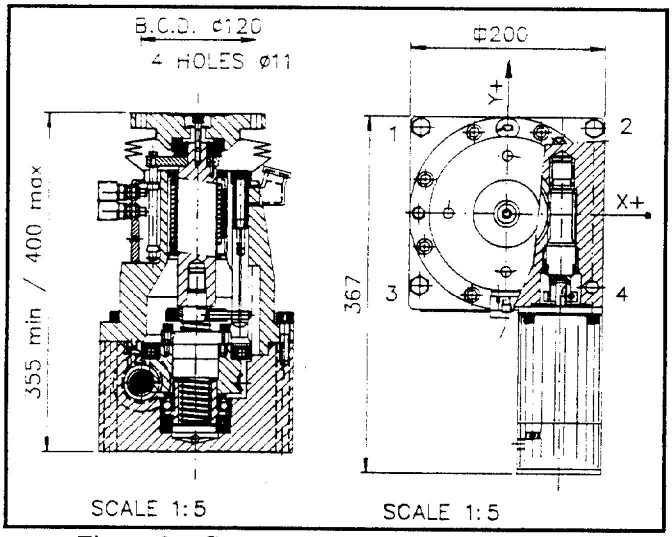


Figure 3 : Cross section of a micrometric screw jack used on the ESRF storage ring.

II. JANUARY 10 1993 - A WORLD FIRST !.

The first realignment operation required an extremely careful preparation. This was carried out during machine commissioning, we performed a series of monthly filling tests. This test required 60 hours thermal stability in the tunnel. During the first 12 hours we checked the status of the machine prior to testing (<5μm/12h/288 HLS). The following 36 hours were devoted to checking the adjustment of the mean plane before and after filling <10μm/36h/288 HLS. The last 12 hours were spent checking the stability of the machine after testing (Figure 4). We were only able to perform these tests during the long weekends when the machine was shutdown. During the January 10 campaign we performed such tests before and after the realignment operation in order to guarantee optimal safety conditions.

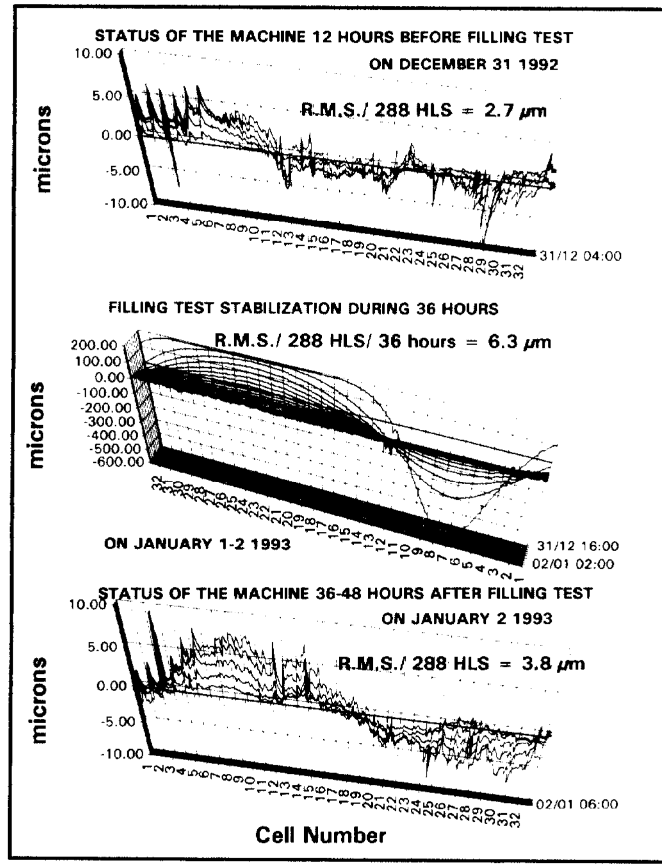


Figure 4 : Precision and stability time of HLS network on ESRF storage ring.

The organization of commissioning of jacks was more complex as confronted with the legitimate reticence of the Operation Team to jeopardize parameters painstakingly achieved over a period of several months. Nevertheless two preliminary tests were performed on July 27 and August 27 1992 during the summer shutdown period. These tests were a uniform displacement of +/- 100mm. They attained a success rate of 92% and 96% respectively and enabled correction of defects, essentially linked to connection problems (absence of cables or motor cards).

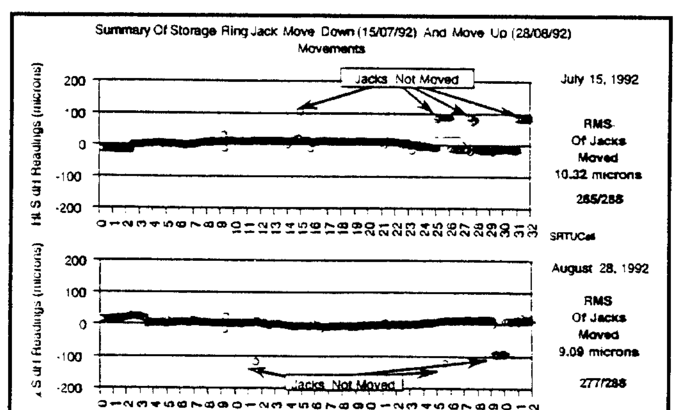


Figure 5 : Curves showing reliability and precision of HLS/jack couples during two commissioning tests.

In view of the large amplitude of displacements to be carried out (± 1.5mm) due to numerous earth works we decided to split the hydraulic network into sixteen sectors, composed of two cells each. This was done for two major reasons :

- to prevent loss of signal during adjustments, maximum HLS amplitude being 2500µm ;
- to reduce stabilization time to about two hours instead of thirty six for the whole network

First of all the even then the odd numbered cells of each pair were moved. These operations each took one hour.

The passage of the machine from its position illustrated at the top of figure 6 to that illustrated at the bottom of figure 6 takes two hours. The curve in the middle of figure 6 indicates the differences between orders given to the jacks and the readings recorded by the HLS system.

The RMS value of the jack/HLS 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.

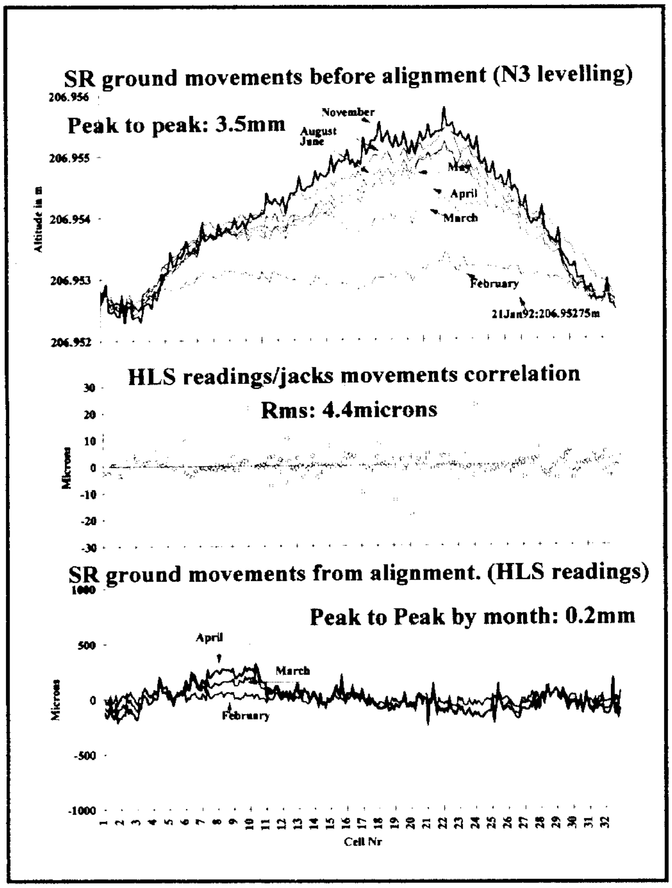


Figure 6 : Status and altimetric evolution of the storage ring before, during and after the January 10 1993 realignment campaign.

III. CONCLUSION.

Displacements recorded since the January realignment confirm the 1988 estimates concerning differential settlements over one month (Figure 6 bottom).

The success of the HLS/jack pair recorded in January 1993 attests to the feasibility of a monthly realignment enabling the ESRF accelerator to be maintained in an absolute horizontal plane of ± 1mm and adjacent equipment to a value inferior to 10µm during realignment.

When taking account the 1993 - 1994 beamline installation program, it would appear that the optimal realignment schedule will be every four to six months (the next will take place in July 1993). Differential settlement recorded in zones 6 to 13 correspond to beamlines which will be installed this year. In years to come the frequency of realignment campaigns during steady state operation will be monthly. This will guarantee Users on all beamlines with a beam stability of ± 0.1mm around the whole circumference of the ring. Recent HLS connections set up between the machine and recently installed beamlines have given a promising insight to a whole range of new possibilities for control in experimental areas.

IV. REFERENCES

[1] Gelman M., Le nivellement hydrostatique, ESGT 1981.

[2] Roux D., Conception d'un système de contrôle altimétrique automatique et permanent pour le projet ESRF. ALGE-87-03, Octobre 1987.

[3] Roux D., Alignment and Geodesy for the ESRF project, Proceedings of the first international workshop on accelerator alignment, July 31-August 2, 1989, Stanford Linear Accelerator Center, Stanford University (USA).

[4] Martin D & Roux D, Real Time Altimetric Control By A Hydrostatic Levelling System, Second International Workshop On Accelarator Alignment, September 10-12, 1990, Deutshes Elektronen Synchrotron (DESY, Germany).

[5] Martin D, Alignment At The ESRF EPAC (Berlin, Germany, Mars 1992).

[6] Roux D, Determination Of The Accuracy Of An HLS Network. TS/WR/ALGE/92-22b, Septembre 1992.

[7] Martin D. & Roux D, Dimensionnal Control Of The Experimental Hall. June 1992.

[8] Loffler F, Dobers T, Neubauer G, High Precision Levelling System For The HERA-Detectors And Interactions Quadrupoles. DESY, Hamburg, Germany July 1992.

[9] Roux D., A New Alignment Design, Application of ESRF Storage Ring. SEE, Paris, France, November 1992.