STATUS REPORT ON THE GANIL RENOVATION PROGRAM

F.LOYER and the GANIL Operation Division
GANIL, BP5027, 14021 CAEN Cedex, FRANCE

Three years ago, a renovation program was initiated to ensure GANIL a life time of at least 15 years in order to allow an efficient use of the two radioactive ion beam facilities : SISSI which has been operational since last year and SPIRAL which will be in use in 98.
This paper reports on the status of this program which mainly concerns the control system (running since February 93 but still in completion), the RF systems (voltage and phase control devices), the vacuum system (control and pumping devices), the power supplies (interfaces, current sensors and internal electronics), the beam instrumentation (electronics and local control devices) and the system which survey the accelerator access. The improvements of the accelerator ECR sources are also described and the first results to produce refractor metallic ion beams like Uranium are mentioned.
The THI project which is an important part of the renovation program is described separately in the proceedings of this conference.

1. Why a Renovation Program ?

Ganil was designed at the end of the 1970's with the technology available at this period. Moreover, the accelerator has been running since 1981 for tests and since 1983 for the physics experiments. That means that most of the components have been working for more than 14 years with a rate of 5000 or 6000 hours per year. The main consequences are :

- numerous failures on many components (power supplies, RF systems, vacuum pumping devices,...);
- unability to repair or to modify some types of devices (PLC of first generation, (micro-)computers, cryogenic pump compressors);

The risk of reducing the reliability of the whole accelerator was becoming bigger and bigger whereas GANIL was building a new facility (SPIRAL[1]) which will use the present accelerator as injector. Moreover, the accelerator must be upgraded to produce higher beam intensity (THI project[2]).

In order to operate SPIRAL with a high efficiency, a high reliability and high performances must be ensured for at least 15 more years. Consequently, a program of renovation was initiated three years ago. This renovation started with the control system which was dramatically obsolete. The program is designed to expend until 1998, date of the first tests of SPIRAL with beam.The total cost of this program is estimated at about 20 MFF (= 5 MUS$) (THI project not included) and 12 MFF are still needed to complete it.

2. Control System

2.1 The control system upgrade.

From 1989 to December 1992 the Ganil control system was deeply renewed. The main objective was to leave the older control system -without any evolution capability- and to adopt a modern architecture able to cope with the various machine upgrades.

The previous control system had become completely obsolete : the software was written in a specific language without any portability ; the processors were limited in memory and CPU, they were unable to be upgraded or linked to any network so it was quite impossible to easily introduce modern processors into the system. Furthermore, the system had very poor graphic capabilities and was based on an home-made database management system.

This upgrade has been described in several conferences[3,4] and only the main options are mentionned here.

A second phase is preparing the system to follow most of the trends of the computer technology evolution.

2.2 The System Architecture.

The system is built over two layers to achieve the software development and the machine control.

The development machine and the real time server are VAX/VMS computers. They communicate with the operator consoles and the front end processors through an Ethernet network. The front end processors are RTVAX processors running with the VAXELN operating system in CAMAC crates (around 30) more and more replaced by VME crates.

The 10 operator consoles consist of the association of an X terminal with a VAX/VMS workstation on which keyboards, mouses and a 8 shaft encoder set are connected.

Programmable Logic Controllers (PLCs) are more and more widely implied in the machine control. Most of the PLCs are from Siemens and are seen from the control system through a VME gateway communicating by the Profibus protocol.

2.3 Development software.

Most of the software is written in ADA language because of its high security level and its real time capabilities. All the applications which are now developed run in the Motif environment.

2.4 Use of the Ingres database.

A relational database management system (INGRES) is involved in very various domains[5] : equipment configuration, alarm archiving, basic operator menus, operation history and statistics, beam parameters ...

In particular, all the beam parameters used for the machine tuning, are managed by application available at the control room

2.5 Introduction of new applications.

Taking advantage of the capabilities of this new control system (graphics, local intelligence,...), more powerful tools are now available for the operators. For instance :

1) data issued from the beam profilers are treated and the profiles are efficiently presented on the screens.

2) new power supply interfaces integrating local intelligence are now reached from the control system (see ¤3). They bring to the system a better reliability by an internal checking and survey of the power supplies.

3) automatic beam tuning is envisaged, like the beam centering in the transfer lines.

2.6 *Evolution.*

The high intensity project (THI project) planned for 1996 requires the introduction of new captors and the design of new applications for the machine tuning. Indeed, two modes of operation are planned : first, the tuning mode with a low beam intensity and then the high intensity mode by locking sensitive parameters and precisely surveying beam losses.

We also plan to provide an archiver and data logger coupled with an on line display of any parameter trends.

An Alpha 2000 server and Alpha workstations have just been added to the control network. These new machines are used as development and test platforms to later move from the VAX architecture to the Alpha one.

Another major evolution of the system consists in replacing the VAXELN operating system attached to the VAX architecture by a more commonly used platform for the real-time front-end level. Following that, a later evolution will smoothly introduce UNIX machines into the system.

3. Power Supplies (PS)

3.1 *Interfaces*

Remote control of the 550 GANIL DC power converters was done through a CAMAC system with a different protocole for each variety of power supply (HV, low or high power, high accuracy,....). This interface becoming obsolete and evolution impossible, we began to replace it by a new one[6], JBUS driven, using only one protocole, and in which we incorporated some improvements. Therefore:

- digital control of the PS is simpler and digital status more detailed to make fault diagnostics knowledge easier.
- redundancy and supervision are introduced on both voltage and current measurements. For instance, U/I can be tested by the interface and wrong value reported. This feature is very useful to detect load resistance or current transducer gain variations.
- control, analog and digital treatments are less sensitive to RFI, EMI or electric noise, mainly by using isolated and filtered series bus instead of parallel bus.

So far, 200 equipments have been partly implemented, 100 will be achieved in 1995, the rest later.

3.2 *Current Sensors*

Two kinds of problems were encountered:

- variation of resistance value on water cooled shunts. They need to be replaced by zero-flux DCCT which are employed in the feedback regulation loop and for remote current reading (ADC). Shunts are still used for local reading purpose.
- the electronic circuit boards of the DCCTs which are used in the largest PS require a new design. The cheapest way was to keep the present magnetic cores (with 1 or 2 Amp compensating winding current) and achieve new electronics.

3.3 *Magnetic Field Measurement by N M R Probes*

More than 40 magnets are to be measured by NMR technique and 60 probes employed. The present system is totally obsolete and saturated. The new scheme will be using a METROLAB PT 2025 control unit with MUX2032 and MUX2031 multiplexors. This system is remote controlled, scanning may be automatic and it supports the low field probes we need. The cables length allowed (150 m) fulfils (without extra amplifier) the GANIL topography.

3.4 *Miscellaneous Electronics Devices*

One of our topic of concern is the behaviour of some 60 PS thyristors firing circuits in presence of the perturbations of the mains. Asynchronous firing occurs more and more often, causing some destructions on thyristors and thyristor drivers. So, new circuits featuring higher rejection and best synchronization will be needed in a next future.

4. RF System

4.1 *Resonator and Amplifier local Control System*

For each cyclotron and buncher, the local control of the cavity(ies) and its amplifier were ensured by a first generation of PLC (APS30-12) for the security management and by a microprocessor (68K in a CAMAC controller) for the on/off sequences and the RF voltage *control.* The maintenance (hardware and software) and the evolution (new functions) had become totally impossible to carry out.

The PLC and the microprocessor are replaced by a unique industrial PLC (a SIEMENS 135U) identical to the other PLCs already used for other renovations.

All the functions are maintained. In addition, a very convenient colored terminal allows to locally control all the parameters and status, making much easier the commissioning and the maintenance.

The PLC is connected to the machine control system by a serial line (PROFIBUS protocol) by way of a VME module (see §2.2). Only the major parameters and the status words are readable in the control room.

The various parts of the RF system are connected to the PLC by :

- parallel lines for the status bites;
- serial lines for the motor positioning and the voltage references;
- a secondary slave PLC, linked to the main PLC by an optical fiber, for the HT power supplies feeding the RF tubes. Besides, the cabinet where the HT power supplies are set, has also been renewed to improve the security during human interventions and to better survey the states of the supplies. Analog lines (4-20mA lines) send the values of the actual HT voltages to the main PLC.

The control of the RF system of SSC2 was renovated during the 94-95 winter shutdown. This is efficiently working. Because of the installation of the medium energy buncher for the THI project, it is planned to carry out the next renovations only during the 96-97 winter shutdown for SSC1 and one of the injectors. The second injector and the low energy buncher will be renovated during the next winter shutdown.

4.2 RF Cavity Phase and Voltage Control

The phase of all the RF cavities are precisely adjusted and feedback controlled by an electronic device which was partially renewed in 1989. However, this system is controlled by a CAMAC controller based on a GANIL home-made 68K microprocessor whose software is fully frozen. In order to allow the integration of the medium energy buncher and to ensure a possible evolution and maintenance, this microcontroller driving CAMAC modules will be replaced by a VME crate.

The voltage of the RF cavities is also adjusted and feedback controlled by an electronic device but which has never been renewed. The maintenance is more and more difficult to ensure (components are obsolete). Therefore, a large renovation of these electronic devices is planned for 1998.

The SPIRAL project will take benefit of these renovations because it will be equipped with these same new electronics and control systems.

5. Vacuum System

5.1 Cryogenic pumping

The vacuum pumping system, for the transfer lines and for the cyclotrons, consists of turbomolecular and cryogenic pumps[7].

A permanent survey of the turbomolecular pumps (vibration analysis, chemical test of the oil) seems sufficient to detect forthcoming failures and to ensure a yet longer life by a rigourous maintenance.

On the contrary, the compressors which feed the power to the seven cryogenic vacuum pumps of the cyclotrons fail more and more often. These pumps have a 800mm aperture and consist of two cold stages (20°K and 55°K), each one pumping 2.10^4 l/s of nitrogen and 10^4 l/s of hydrogen. Each pump is fed by three cryogenerators (CTI 1020CP) whose compressors have been especially designed for GANIL by PHYSIMECA. These compressors have been running for 85000 hours and some components are too old to be repaired. In particular, numerous leakages appear on the water and helium circuits, inducing a contamination of the cryogenerators. In consequence, it has been planned to replace each PHYSIMECA compressor by two CTI8500 compressors connected in parallel.

The 14 compressors of SSC2 have already been installed and those of SSC1 will be installed through 1996 and 1997. The cost of this operation is estimated at 2 MFF.

A similar phenomenon is also appearing on the 47 cryogenic pumps of the transfer lines (DN160 and DN200). Indeed, most of the compressors (CTI SC21) have been running for more 50000 hours and more and more failures occur (MTBF = 60000 hours). Therefore, the compressors will be replaced at a rate of 5 to 7 per year by new generation of compressors (CTI 8200).

5.2 Local Control

The whole vacuum system is controlled by several PLCs (one for each cyclotron and one for each transfert line). These PLCs, of the first generation (APS30-12), had become obsolete and not repairable. In consequence, these PLCs are being replaced by modern PLCs (SIEMENS S5) which ensure the same basic functions (survey, aeration and vacuum pumping sequences, insulating valve movement,...) but which bring new comfort for the users (display of a dynamic synopsis and management of the pumping sequences on a local colored terminal). Each PLC is connected to the machine control system by the Ethernet network.

This program will be completed by 1997.

6. Beam Instrumentation

6.1 Beam profile acquisition system

The acquisition system of secondary multiwires profilers has been completely redesigned in order to perform acquisition by the control system and visualisation on workstations (until this year, the beam profiles were read on oscilloscopes)

Profile monitor data are digitalized and then memorized in a SRAM accessible through VMEbus. Beam profile acquisition hardware is connected to control system by way of VME front end controller. Data can be archived for later comparison with other beams. The profiles are available for all the applications implied in the beam tuning.

6.2 Beam profile monitors

As part of THI project, new beam profile monitors are developped and will replace a part of multiwires profilers.

First type is residual gas ionisation profiler[8]. They are designed to be installed in medium and high energy beam transfer lines. They are non interceptive monitors working from some enA to some ten eμA. Four of these monitors are in operation now and final number to install is twenty eight.

Second type is spiral scanner (rotating wire) which will equip low energy beam transfer line where beam power will not exceed 100 Watts. They are semi-interceptive profilers and beam intensity range, for them, is from some ten enA to some ten eμA.Ten spiral scanners will be in operation next year.

6.3 Beam current measurement

Renovation of part of the current-to-voltage converters connected to beam current diagnostics, appears necessary for detecting fast beam losses, to protect accelerators against high beam power losses (THI project), and for measuring beam intensity with large dynamics (100 epA to 100 eμA).

Instead of using linear converters with switchable gains, logarithmic current to voltage converter will be used.

A VME board, developped at GANIL, allows digitalization of four diagnostics with a 16 bits ADC. Connection to control system is performed by VME front end controllers.

In a first step this renovation concerns beam loss diagnostics located at injection and extraction of both separated sectors cyclotrons (40 diagnostics). This converter principle is also chosen for insulated collimators which must be installed in beam transfer lines for loss detection.

Second step will be to continue renovation for Faraday cups and cyclotrons movable probes.

7. Ion Sources

To satisfy the increasing demand for heavy ion beam produced from solid materials, several techniques are under development to introduce solid materials into our ECR (Electron Cyclotron Resonance) ion sources working at 14 GHz.

7.1 Externally heated Ovens

The oven is introduced axially at the rear of the source. The maximum temperature obtained with our oven is 1550 °C and, recently, 1750 °C has been reached on a test stand.

The oven temperature must correspond to a 10^{-2} mbar vapour pressure of the solid element. The below table shows pure elements and compounds used routinely and their evaporation temperature at this pressure:

Te	365°C	Sn	1220°C
MoO_3	590°C	Cu	1240°C
Pb	718°C	Cr	1380°C
Ag	1020°C	Ni	1530°C

7.2 Ion Plasma Sputtering

This method which was currently used in PIG ion sources, has been recently tested at Argonne National Laboratory[9] and at GANIL. Our setting consists in replacing the oven by a cylinder of metal and polarising it at a negative voltage (<2000V). Positive ions from the plasma are being accelerated toward the sample and after striking it, atoms are evaporated into the plasma and ionised. The power involved is very low and the sputtering can be considered as a cold process with a short response time. This method can be applied to conductive elements and particularly to refractory metals like Ta, W and U. A recent test with a 5 mm diameter cylinder of uranium shows an approximate consumption of 1 mg/h. With oxygen support gas, 1.5 eμA of U^{25+} was produced and with argon 5 eμA of U^{20+}. The beam was extracted at 72 kV through an extraction hole of 7 mm diameter.

7.3 Evaporation by Laser Ablation

A pulsed excimer laser, injecting a beam axially through the extraction hole of our ECR ion source, has been used recently[10] for ablation on a rotating uranium target. The particles ejected from the solid surface of the target are ionised in the plasma of the source which is fed with oxygen support gas.

A 3 eμA average beam of U^{25+} has been measured with a solid material consumption approximately of 1 mg/h. The higher efficiency of this technique is not sufficient to compensate its high cost compared with the ion plasma sputtering method which is easier to install and cheaper.

7.4 Direct Plasma Evaporation

This method consists in introducing a rod of pure metal or oxide at the plasma boundary to be evaporated by the plasma. The stability of the beam is difficult to maintain due to the evaporation rate coupled with the tuning of the plasma and the position of the rod which must be moved to compensate the erosion. Although it was used until now, this method will be replaced by the sputtering method as soon as possible.

8. Radiation Safety Control System

8.1 Introduction

Radiation safety control in GANIL is a major concern. Its objective is to avoid any radiological risk for individuals. Beam penetrating into a controlled area is interlocked by mastering at least two upstream safety devices (e.g. beam stopper, bending magnet, etc..) and by checking the radiological level with gamma- and neutron detectors.

The radiation safety control system of GANIL provides three main functions : the access control, the radiological level control and the supervision.

The renewal of the radiation control system[11] is motivated by two stressing needs : a/ superseding the current obsolete hub (a 16bit minicomputer Mitra 225), b/ fulfilling the requirements of the upcoming 'Very High Intensity' project and the SPIRAL Rib facility.

8.2 Architecture and Choice

The architecture adopted is structured around a private local area network which federates smart sub-systems and enables communication -whenever necessitated- with other processing systems in GANIL.

Complying with guidelines (safety of operation, overall software and hardware homogneity and open standards to ease evolution) led to the following technical choices : VME, POSIX, C language, real time UNIX operating system LynxOS, Ethernet featuring TCP/IP and NFS, Color Graphical User Interface with Motif/XWINDOW and UIMS, SCSI-driven peripherals for archiving purposes.

8.3 Status

The renewal of the safety control sytem is conducted as a pluriannual undertaking with low manpower resources. It is split into three major steps : 1/ the new access control system has been operating since the first quarter of 1990, 2/ the new radiological level control system was commissioned on the onset of 1993, 3/ the new supervision system is scheduled for the year to come.

9. References

1 M.Lieuvin and the SPIRAL Group, this conference

2 E.Baron and the THI project Group, this conference

3 T.T. Luong, L. David and al., "The New Control System of GANIL", Proc. ICALEPCS'93, Berlin, Germany 1993

4 L. David et al., "Controlling the GANIL from an Operator Workstation", Proc. EPAC'94, London 1994

5 E. Lécorché, P. Lermine "Database management in the new GANIL control system", Proc. ICALEPCS'93, Berlin 1993

6 G.Sénécal, internal GANIL report, to be published

7 G.Rommel, "A Cryogenic Pump of 20000 l/s", Proc. of the 8th Int. Vacuum Congress, Cannes, France, Sept.1980

8 R.Anne et al., NIMA239 (1993) 21-28

9 R. Harkewicz et al., to be published in Proc. of the 12th Int. Workshop on ECR I S, Riken, Japan, April 25-27 1995

10 L. Bex et al., to be published in NIM A (internal GANIL report A 95 02)

11 T.T Luong et al., 'A New Radiation Safety Control System For GANIL' Conf. CTDCA, Calcutta Nov 1991.