# ARCON/RAMSES: CURRENT STATUS AND OPERATIONAL RISK

D. Forkel-Wirth, G. Segura Milan, D. Perrin, S. Roesler, C. Theis, H. Vincke, Hz. Vincke, P. Vojtyla, M. Widorski, DGS, CERN, CH-1211 Geneva 23

*Abstract*

CERN's Safety Commission monitors radiation levels and releases of radioactivity from CERN's facilities and experiments employing two different radiation monitoring systems: ARCON, which dates back to the LEP era, and RAMSES that has been designed for the LHC. Both are used as alarm and interlock systems. Thus, their reliability and availability has an obvious impact on the beam operation as the machines will be stopped in case of failures. RAMSES is a modern, highly reliable system, whereas by today's standards the ARCON system is vulnerable due to its legacy technology and aging equipment. Countermeasures taken to compensate for the weaknesses of ARCON are presented, the remaining risks are listed and a project to replace ARCON by RAMSES is described.

## INTRODUCTION

CERN has the legal obligation to protect the public and persons working on the site from any unjustified exposure to ionizing radiation. For this purpose CERN's Safety Commission monitors ambient dose equivalent rates in- and outside of CERN's perimeter and the releases of radioactivity in air and water. The results of the measurements allow for the preventive assessment of radiological risks and the minimization of individual and collective doses. CERN's Safety Commission currently operates two installed radiation monitoring systems:

- ARCON (ARea CONtroller) system which had been developed at CERN for LEP and has been in use since 1988
- RAMSES (RAdiation Monitoring System for the Environment and Safety) which has been designed for the LHC based on current industry standards and has been in use since 2007

About 800 monitors are employed by ARCON and RAMSES, about 400 by each system. Both installations comprise data acquisition, data storage, and the triggering of radiation alarms and beam interlocks. The most recent CERN facilities LHC, CNGS and CTF3 are equipped with RAMSES, whereas the entire LHC injector chain, the remaining facilities (e.g. ISOLDE, n-TOF, AD) and all experimental areas are still equipped with ARCON. In the long run it is envisaged to replace ARCON by the more recent RAMSES technology.

## RADIATION MONITORS

Both, ARCON and RAMSES use the same or at least very similar types of radiation detectors. Environmental radiation protection monitors records stray radiation and the releases of radioactivity by air and water. Recording of other measured values like wind speed, wind direction or flow rates is required to obtain relevant input parameters to calculate the doses to member of the public. A stray radiation monitoring station consists of one high pressure ionization chambers filled with Argon (CENTRONICS) for photons and penetrating, charged particles like muons, one REM counter (Berthold) for neutrons and a locally installed unit for data acquisition, alarm generation and data transfer. The radiation protection part of a CERN water monitoring station consists of a NaI detector for in-situ measurements of gamma emitting radionuclides and a device to collect water samples for laboratory analyses like measurements of tritium or for cross-checks of the on-line results. The ventilation monitoring system is based on silicon surface detectors to measure the total activity of beta emitters released. In addition, removable filters are installed to allow for a laboratory analysis of radionuclides attached to aerosols using gamma spectroscopy. The active parts of air and water monitoring (Si-, NaI-detector) are equipped with alarm functions.

The Radiation Protection Group uses three different types of monitors to measure ambient dose equivalent rates within CERN and/or in close neighborhood of CERN's facilities. The radiation monitors employed to protect workers against prompt ionizing radiation [1] during the beam operation are special REM counters (WENDI/Thermo) and hydrogen filled, high pressure ionization chambers (CENTRONICS). Both are optimized to measure high energy neutrons with energies up to the GeV-energy range, the H-chamber responds to all particles contributing to high energy mixed radiation fields [2, 3]. These monitors are foreseen to trigger an alarm as soon as pre-defined radiation levels are exceeded.

The ambient dose equivalent rates which can be monitored inside the machine tunnel and the experimental caverns after the beam has been stopped are due to radiation emitted during the decay of radionuclides induced during the beam operation. The energies of the emitted photons do not exceed 2.7 MeV (emitted by $^{24}$Na) [1]. Induced radioactivity is measured with air-filled plastic ionization chambers (PTW) in order to assess risks during maintenance and repair works [4]. The radiation monitoring system is completed by hand-foot monitors at the exits from the LHC underground areas and gate monitors at the exits of the CERN sites (Site Gate Monitor, SGM). The RAMSES system provides an option

to connect the SGMs to the access system, i.e. in case of an alarm the barriers can remain closed.

## ALARM LEVELS

The alarm levels in areas exposed to prompt radiation are set according to Table 1.

Table 1: Alarm levels as set for CERN's Supervised and Simple Controlled Radiation Areas to protect workers against the exposure to prompt ionizing radiation.

| Area classification | | | Permanent workplaces | | Low-occupancy | |
|---|---|---|---|---|---|---|
| | | | Warning | Action | Warning | Action |
| Non-designated Area | | | Guideline EMDS 788938 | | | |
| Radiation Area | Supervised Radiation Area | | 3 µSv/h | 6 µSv/h | 15 µSv/h | 30 µSv/h |
| | Controlled Radiation Area | Simple Controlled | 10 µSv/h | 20 µSv/h | 50 µSv/h | 100 µSv/h |
| | | Limited Stay Area | - | - | **not applicable** | |
| | | High Radiation Area | - | - | **not applicable** | |
| | | Prohibited Area | - | - | **not applicable** | |

EDMS 900889

There is no single area at CERN which is accessible during the beam operation, exposed to prompt radiation and classified higher than a simple controlled radiation area. A typical sampling interval for a radiation measurement is in the range of 100 to 300 s. Subsequently, the value is extrapolated to 3600 s and if the extrapolated value is above pre-defined levels visual and acoustic alarms will be given. In some configurations the alarm signals will be used to interlock the beam of the LHC injectors.

## ALARM PHILOSOPHY

Two different alarm philosophies co-exist: either the beam will be interlocked by the radiation monitoring system in case of alarms or the machine or experiments operator will receive an audible and/or visual signal on which he is supposed to take action. The interlock solution is preferred but the choice depends on the required and available reliability level and needs to be weighed against the impact on the machine operation.

## TRANSMISSION OF RADIATION PROTECTION ALARMS

### *PS complex*

Radiation Alarm Repeater Panels transmit visual and audible alarms to the machine operators who are supposed to take immediate action. No interlock is created by ARCON for LINAC, Booster and PS beams whereas RAMSES is supposed to produce interlocks for CTF3.

### *SPS complex*

ARCON alarms are transmitted to the LASER system, which will then apply software interlocks on the SPS beam and the SPS secondary beams.

### *LHC*

RAMSES alarms are transmitted to the LASER system. No RAMSES interlock is set on the LHC beam, but on the RF system during RF conditioning periods. In the future, visual and audible alarms to the LHC operators will be implemented, on which they are supposed to take immediate action. Currently alarms from the site gate monitors are not transferred to the CERN Control Center (CCC), (Technical Control), neither by ARCON nor by RAMSES. However, in the future it might be of advantage to change the situation.

Environmental alarms related to the pH and temperature of water released by CERN are transferred to the CCC (Technical Control). The radiological environmental alarms are not transmitted but stay within ARCON or RAMSES. This approach has been endorsed by the Beam Facility Safety Panel. For the time being no technical alarms of RAMSES or ARCON are transmitted to the CCC (Technical Control).

Obviously, the Safety Commission is supposed to inquire in case of alarms and to verify if pre-established procedures are followed.

## RAMSES

The Radiation Monitoring System for the Environment and Safety (RAMSES) has been designed to cover all CERN installations. In 2002 it had first been limited to LHC - for various reasons. In the meantime, RAMSES is installed at CNGS and CTF3 and will be installed at any new facility or experiment (e.g. HiRadMat, LINAC4, NA62). RAMSES is a state-of-the-art integrated, decentralized monitoring system which is designed to meet the requirements of a SIL2 safety system for radiation monitoring, alarm and interlock functions. It is compliant with international standards for radiation protection instrumentation, e.g., the local monitor and alarm unit will continue to operate, even in case of major power failures or loss of the network connection. The local station is backed up by batteries, the data will be stored locally and the alarms are triggered locally as well. More technical details on RAMSES can be found in Reference [5].

### *RAMSES maintenance*

The preventive maintenance of the system foresees a systematic regular control of the operational reliability of each piece of equipment. The frequency of the checks ranges from two weeks to a year, depending on the equipment and the applicable test procedure. The

maintenance is jointly performed by the contractor and the Safety Commission. Hardware and software updates have been implemented in 2009 and the annual maintenance has been completed successfully.

During working hours the corrective maintenance is performed by members of the Radiation Protection Group acting as the first level of support. Outside working hours interventions are performed by the RP on-call service and, if required, by members of the Instrumentation and Logistic section – on a best effort basis. For very serious problems a Hot-Line of the contractor should be used (24h/24h, 7d/7d) and in case the issue cannot be solved remotely, the contractor has between 8 and 48 hours to solve the problem on site.

### *RAMSES operational risk*

RAMSES has already been exploited for CNGS since 2006 and for the LHC and CTF3 since 2008. In total RAMSES gave 3 false alarms in 2009 caused by one hardware failure in the system for the LHC and two in the one for CTF3. The problems were solved immediately by replacing the faulty equipment. No false interlock signal has been produced in 2009.

The LHC experimental areas are sufficiently well covered with monitoring stations, however, provisions are already made to increase their redundancy if required.

### *ARCON operational risk*

ARCON is a CERN in-house development, implemented in the 80's for LEP. It is based on VME Bus technology, Microware OS9 as the operating system and a MIL1553 field bus. Of particular criticality is the HPSLZ18 server whose maintenance will soon be stopped.

The replacement of ARCON by RAMSES shall follow a three-step procedure:

1) the project "ARCON-RAMSES interface" needs to be completed (foreseen for first half of 2010) – mainly to phase out the operation of the HPSLZ18 server and the MIL1553 field bus.

2) from 2010 to the beginning of 2011 it is foreseen to replace ARCON at the LHC injector chain by RAMSES. The related project is called "RAMSES2light".

3) from 2012 onwards the replacement of all remaining ARCON by the so-called "RAMSES2" project is foreseen.

Table 2: Summary of the main differences between ARCON and RAMSES

| | **ARCON** | **RAMSES** |
|---|---|---|
| Developed | ~1980 for LEP | ~2000 for LHC |
| Standard | CERN standard | Industrial standard |
| SIL | < SIL | SIL2 for alarms and interlocks |
| Size | ~380 monitors | ~ 400 monitors |
| Detectors | Same type but different electronics | |
| System | Grouped (several monitors on one ARCON station) | Autonomously operating monitors, grouped into smaller entities |
| Worst risk in case of failure–RP | Several channels fail in case of ARCON failure whole area without radiation monitoring | Single channel fails radiation monitoring ensured by remaining channels |
| Supervision/ Software | HP server, proprietary software no longer supported | PCview SCADA solution, OPC client/server technology |

The following measures had been taken to increase the availability of ARCON at the LHC injector chain until RAMSES2light will be finished:

1) up to a certain extent spare detectors are available; in case more will be needed they will be taken from non-LHC experimental areas. New spare detectors will be bought within the RAMSES2light project.

2) electronics spare parts (from LEP) are tested and operational in case of need.

3) ARCON-RAMSES bridge will be implemented to eliminate the HPSLZ18 server and MIL 1553.

4) ARCON network star points are secured by UPS.

5) improved battery and power supply surveillance had been installed on all ARCON servers.

The worst case scenarios with respect to the operational risks related to ARCON are:

1) if an ARCON monitor fails and redundancy is lacking, the respective injector will be stopped, the monitor will be exchanged and the beam operation resumed.

2) if an entire ARCON server fails, a whole area (e.g. PS South Hall) will be without surveillance.

The respective injector will be stopped and the ARCON server replaced. Between one and three days are required for such a repair.

3) the weakest point is the outdated ARCON software for equipment control –it is difficult to maintain and in addition spare equipment is very hard to find. This problem can only be solved by moving from ARCON to RAMSES.

Being aware of the vulnerability of ARCON, guidelines had been defined by the Radiation Protection Group to cope with various failures and consequences. The basic guideline is defined in Safety Rule 16 (BE/OP). A list of specific actions to be taken by the operators and the Radiation Protection Group in case of ARCON failures are available either on a WWW page http://cern.ch/rp-ps for the PS complex or in a technical note for the SPS complex [6]. In the frame of RAMSES2light the number of monitors around the PS complex will be increased considerably. As the SPS is an underground installation, the impact of ARCON failures on the operation is less significant as some of the areas can be closed for access.

## RAMSES2LIGHT PROJECT

The RAMSES2light project foresees the replacement and consolidation of ARCON by RAMSES for the entire LHC injector chain, new projects like LINAC4 and HiRadMat and the acquisition of spare parts. The budget was approved by the Finance Committee in March 2009 as was the extension of the existing RAMSES contract. The contract amendment and related orders have been signed in December 2009. The project will be subdivided into two phases – as a function of the accessibility of areas during beam operation:

1) commissioning and acceptance tests of instrumentation in accessible areas to be finished until October 2010.

2) full commissioning and acceptance tests had been foreseen by the end of the 2010-2011 shutdown period.

## CONCLUSIONS

RAMSES-LHC has proven to be reliable and to meet SIL2 standards. Provisions have been made to increase the RAMSES-LHC redundancy for accessible areas even further: additional monitors can be installed at any moment as the required infrastructure (cables, etc.) is already in place.

All actions within the possibilities of the Safety Commission or the technical sector have been taken to secure ARCON for the LHC injectors. Procedures to be followed in case of failures are in place and have been communicated to the operations group. The ARCON RAMSES Bridge will be implemented, allowing for phasing out the HPSLZ18 server and MIL 1553 field bus. Spare monitors and electronics are prepared but the outdated equipment control software will remain a very weak point.

The ARCON installations at the LHC injectors will be replaced and consolidated by RAMSES2light latest until the end of the shut-down 2010/2011-according to the planning before Chamonix 2010, the material will arrive at the end of August 2010 and will be installed as a function of the accelerator schedule and as such, of the area accessibility.

Last but not least, the technical alarms from RAMSES and ARCON should be transferred to TCR. The same holds true for radiation alarms from site gate monitors.

## REFERENCES


[1] D. Forkel-Wirth, F. Corsanego, S. Roesler, C. Theis, Heinz Vincke, Helmut Vincke, P. Vojtyla, L. Ulrici, M. Brugger, F. Cerutti, “How radiation will change (y)our life”, Proceedings of the Chamonix workshop 2010, (2010)

[2] C. Theis, D. Forkel-Wirth, D. Perrin, S. Roesler, and H. Vincke, “Characterisation of ionisation chambers for a mixed radiation field and investigation of their suitability as radiation monitors for the LHC”, Radiation Protection Dosimetry 116, pp. 170-174 (2005)

[3] C. Theis, D. Forkel-Wirth; M. Fuerstner, S. Mayer; Th. Otto, S. Roesle,; H. Vincke, “Field calibration studies for ionisation chambers in mixed high-energy radiation fields”, Radiation Protection Dosimetry 2007; doi: 10.1093/rpd/ncm062, (2007)

[4] H. Vincke, D. Forkel-Wirth, D. Perrin and C. Theis, “Simulation and measurements of the response of an air ionisation chamber exposed to a mixed high-energy radiation field”, Radiation Protection Dosimetry 116, pp. 380-386, (2005)

[5] G. Segura Millan, D. Perrin, L. Scibile, “RAMSES: The LHC Radiation Monitoring System for the Environment and Safety”, Proceedings of 10th ICALEPS Int. Conf. on Accelerator & Large Expt. Physics Control Systems.(2005)

[6] H. Vincke, “Procedures to be followed in case of an ARCON system or monitor failure at the SPS accelerator”, CERN-SC-2008-080-RP-TN, EDMS 969891, (2008)