# Monitoring the Release of Radioactive Noble Gases Through the Stack of a Nuclear Power Plant (NPP): Stack Monitor System



Based on the German KTA 1503.1 and respective international regulations, the release of any radioactive material through the stack of a Nuclear Power Plant (NPP) must be monitored. Different measurement systems are used for the different components of release. Among these components are the radioactive noble gas isotopes of Argon, Krypton, and Xenon. They can be measured in a non-continuous and a continuous manner. In the non-continuous method, a sample of the air is taken once per week, and the result of the $\gamma$ analysis of this sample is assumed to be representative for the remainder of the week.

A more precise and more reactive method is the continuous measurement of the noble gases using a stack monitor system. Such a system is described in this Application Note.

## Measurement Purpose and Method

The following components of the radioactive release from a NPP through the stack have to be quantified:

- C-14
- Alpha Emitters
- Radioactive Sr
- H-3
- Radioactive gaseous Iodine
- Particulate Iodine
- Radioactive Noble Gases

Respective collection and measurement systems have to be installed. The principles are shown in Figure 1.

To quantify the release of noble gases, a stack monitor is installed. It consists of the following components (Figure 2):

- Gas System with Pump
- Measurement Chamber with Lead Shielding
- Germanium Detector System, including Pulse Processing Electronics
- Signal I/O Box
- Computer System with special StackMonitor Software and peripherals



CNSNGSM-18 Continuous Nuclide-Specific Noble Gas Stack Monitor

1: Sampling Device
2: Measurement of Aerosols and Iodine
3: Aerosol Monitor
4: Iodine Monitor
5: Noble Gas Monitor (Beta Total)
6: Noble Gas Monitor (StackMonitor)
7: Sampling Unit for H-3 and C-14
8: Discontinous Sampling
9: Return Pipe
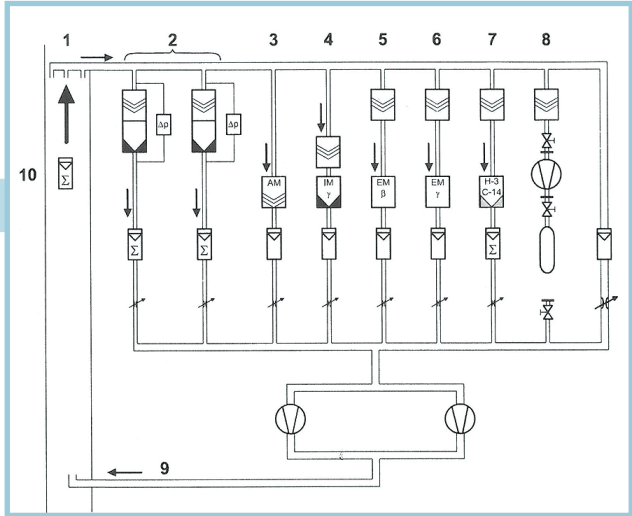10: Flux Measurement

**Figure 1:** Components of a Monitoring System (taken from KTA 1503.1).

### Gas System with Pump

The interconnection of the Stack Monitor to the gas system of the NPP is mostly supplied by the operator of the plant. However, this system includes a mechanism to indicate the air flux through the measurement chamber as well as current amount of air flux through the stack.

### Measurement Chamber with Lead Shielding

To get low detection limits for the noble gases, the measurement chamber is embedded in a minimum of 10 cm of lead shielding. The chamber itself is built from aluminium in the form of an 18.5 L Marinelli Beaker. Its internal walls are Teflon covered for ease of decontamination. The air flux through this chamber is monitored.

### Germanium Detector System, includes Pulse Processing Electronics

The detector system consists of a HPGe detector of ca. 30% relative efficiency. This assures that the required detection limits are reached (see below). To avoid dead layer problems, GX type detectors are recommended. Any type of detector cooling ($LN_2$, Cryo-Cycle™, Pulse Tube) is supported.

As the gas calibration is complicated and not easy to perform, the detector is characterized and the efficiency of the measurement volume is calculated using LabSOCS™ software.

For the pulse processing electronics and the MCA, a Lynx® Digital Spectrum Analyzer is used.

### Signal I/O Box

The power plant delivers several status signals as well as other information. This information is fed into the Stack Monitor System via a Signal I/O box. In turn, the Stack Monitor generates status messages and measurement results, which are sent back to the plant via the same box. Those signals can be both digital and analog. They are plant specific, i.e. different plants have different requirements. Here is a list of signals as an example:

**Input to Stack Monitor**

Digital
- Status of flux through measurement chamber (OK, not OK)
- Status of temperature in the rack (OK, high)

Analog
- Amount of Stack Air Volume ($m^3/h$ or $m^3/sec$)

**Output from Stack Monitor**

Digital
- System Status (OK, not OK)
- Measurement Status (OK, not OK)
- Activity High
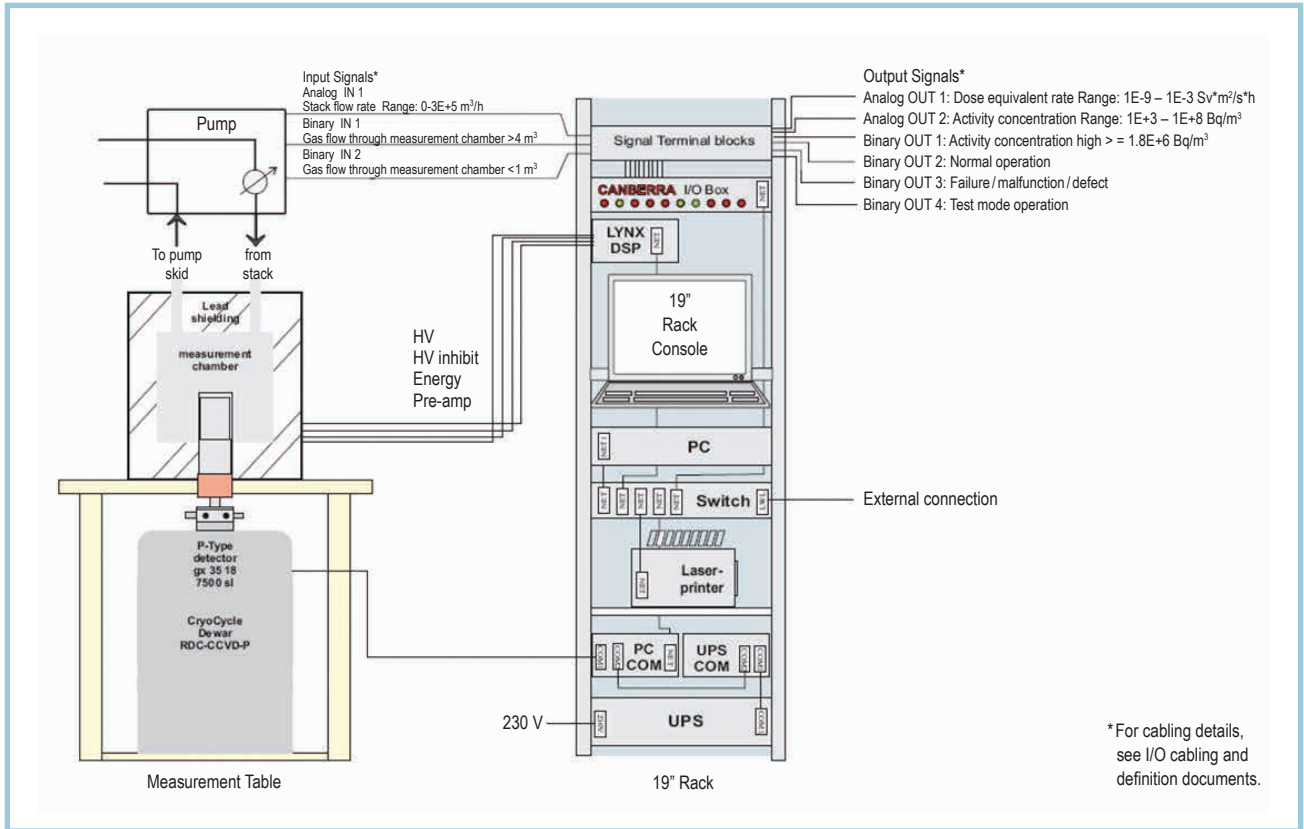
Analog
- Activity Release Rate
- Activity Concentration

Input Signals*
Analog IN 1
Stack flow rate  Range: 0-3E+5 m³/h
Binary IN 1
Gas flow through measurement chamber >4 m³
Binary IN 2
Gas flow through measurement chamber <1 m³

Output Signals*
Analog OUT 1: Dose equivalent rate Range: 1E-9 – 1E-3 Sv*m²/s*h
Analog OUT 2: Activity concentration Range: 1E+3 – 1E+8 Bq/m³
Binary OUT 1: Activity concentration high > = 1.8E+6 Bq/m³
Binary OUT 2: Normal operation
Binary OUT 3: Failure / malfunction / defect
Binary OUT 4: Test mode operation

Pump

To pump skid    from stack

Signal Terminal blocks

CANBERRA I/O Box

LYNX DSP

19" Rack Console

HV
HV inhibit
Energy
Pre-amp

Lead shielding

measurement chamber

PC

Switch — External connection

P-Type detector gx 35 18 7500 sl

Laser-printer

CryoCycle Dewar RDC-CCVD-P

PC COM    UPS COM

230 V — UPS

Measurement Table

19" Rack

* For cabling details, see I/O cabling and definition documents.

**Figure 2:** Stack Monitor System.

## Computer system with special StackMonitor Software and peripherals

The controlling computer is installed in a rack which is typically mounted close to the measurement chamber. It is a Server Computer running Windows Server-2003 or 2008 and is always equipped with a local terminal, keyboard and mouse. Depending on the local situation, a number of additional computers can be connected via the network to this central computer. They can be located in various areas around the plant and are used to externally control and monitor the performance of the system. Also depending on the local situation, a printer may be placed at any location to get daily reports of the released activity.

On the main computer, the following task related software packages are installed:

Genie™ 2000 Basic Software Package

Genie 2000 Gamma Spectrometry Package with special algorithm for Kr-85 quantification

Genie 2000 Quality Assurance Package

Genie 2000 Interactive Peak Fit

Genie 2000 Programming Library

Microsoft SQL Server-2008 Express or Microsoft SQL Server-2008

Microsoft Visual Studio 2008

StackMonitor Package, consisting of:

- StackMonitorService Manager
- Display and Control
- Setup Tools
- Reporting Package
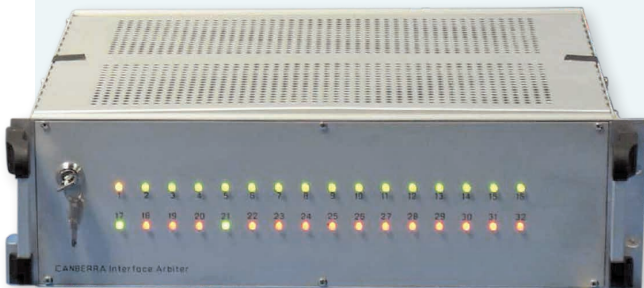- Package for Periodical System Tests

A total of 8 digital inputs and 24 digital outputs as well as 8 analogue inputs and 6 analogue outputs are supported in the standard configuration. There is a special program which assigns the different signals to the respective contact of the box.

On the front side of the box, colored (green, red) LEDs indicate the status of any signal.

**Figure** 3: I/O Box (Front Side).



**Figure** 3a: I/O Box (Back Side).

## StackMonitorService Manager

After the system is booted, the StackMonitorService Manager is started. It automatically performs hardware validity checks and starts the stack control. It reads in all parameters of the system settings, takes control of the measurement chain and starts acquisition.

A number of five cycle times are predefined. They define the frequency with which internal tasks are performed. These tasks are:

- Control and Setting of I/O Signals
- Control of Variations in Stack Flux Rate
- Control of Count Rate in Spectrum
- Control of Spectrum Calibration based on Stabilization Sources
- Spectrum Analysis

In addition, the program sends a watchdog signal to the I/O box to indicate computer health.

The fastest period (standard value: two minutes) is the frequency of checking the I/O signals. This assures that any problem in temperature or measurement chamber flux rate is signalled as quickly as possible.

The Stack Flux Rate is read for the same period and the Total Flux is calculated from the differential reading.

The program checks the total count rate in the spectrum (including stabilization peaks) and compares it to lower and upper boundaries, thus making sure that the measured spectrum is still in a meaningful count rate range.

The position of the stabilization sources is monitored. In case the peaks are not found at the correct position, measurement continues, but the system signals a performance problem.

In standard operation, the spectrum is evaluated every hour. This frequency is meaningful because shorter periods do not give additional information, and the fluctuations in activity concentration (or detection limit) are too high. However, if the total count rate exceeds a predefined limit, the evaluation period is shortened to better identify short releases of radioactivity. The hourly results are stored in the database. The results of the measurement are sent as an analog signal to a plotter.

At midnight, a daily spectrum is analyzed and the results are stored in the database. The spectrum is cleared, and a new spectrum is acquired.

## Display and Control

Figure 4 shows the Display Control Program. It is used to show the spectrum details and to indicate the system status.

At the left side, the status of the signals is shown in green, yellow, or red color, indicating a good or bad status of the respective signal. In the lower part of the display, measurement results as well as system messages are shown. This provides the user with an immediate indication about the system performance and results.

This program does not allow controlling acquisition or hardware components, it is only used for showing the system status. Hardware control is performed by either the GAA window of Genie 2000 software, a special control program for the I/O Box, or the program package for periodic tests.
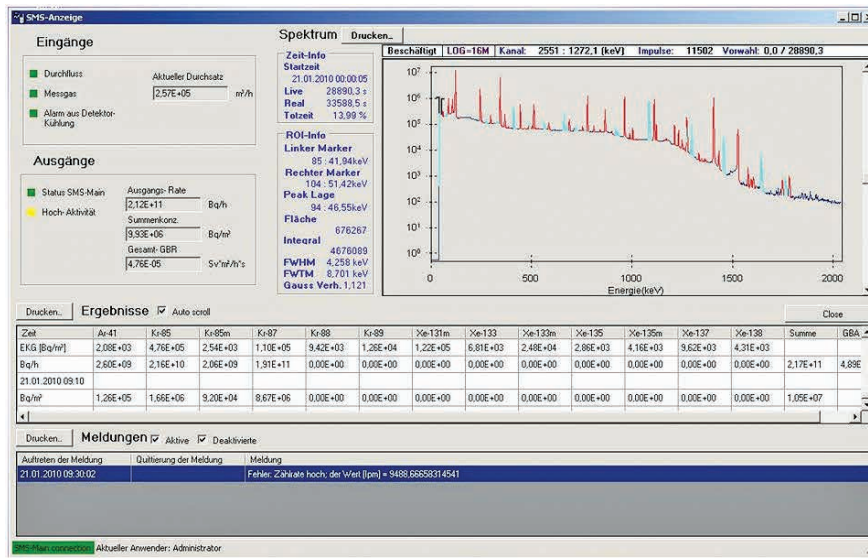
**Figure 4:** Display and Control (German version; other languages available).

## Setup Tools

This program is used to setup the parameters of the system. This is where count rate range, calibration files, user rights, etc. are defined. This program is password protected and is designed to be called up during system installation and setup to define site specific parameters.

## Reporting Package

Depending on the local requirements, the user can initiate site specific reports including:

- Hourly Report
- Daily Report
- Monthly Summary Report
- Quarterly Summary Report
- Message Report, etc.

Any report is adjusted to the user's needs, i.e. it may list activity concentrations, total released activity in a given time range, etc.

## Package for Periodic Tests

This package is used to test the I/O signals. The user can set or clear every individual signal to check its correct operation. At the end, a comprehensive test report is printed out.

This package also enables the user to check the calibration of the measurement chain. The user inserts a calibration source (recommended source: Am-241 and Eu-152), the source is measured, the position and count rates of the lines are monitored and a report is generated indicating the correct or incorrect operation of the measurement chain.

## System Setup and Calibration

During system installation, an energy calibration of the measurement chain is performed. At the same time, using LabSOCS software, the sample geometry is modeled and the efficiency of the detector is calculated. This efficiency curve is used for calculating the activity concentration of the noble gas nuclides.

Additionally, based on regulations, a gas calibration might need to be performed. This is done by inserting a known amount of Kr-85 and Xe-133 into the measurement chamber. This way, two calibration values are acquired and compared to the LabSOCS calculated efficiency values. If the values are in accordance, the system is deemed to be operating correctly.

## System Performance

### HARDWARE
- Gas system with pump (mostly supplied by operator).

### GERMANIUM DETECTOR
- Size approximately 30% relative efficiency; preferably GX type, LabSOCS characterized.
- Cooling: Any type.
- Measurement chamber: Vol. ca. 18.5 L, aluminium, Marinelli type.
- Measurement chain: Lynx.

### COMPUTER
- Server type computer, server operating system.
- Additional computers possible at any network place.
- Network switch for connection to other computers via network.

### I/O BOX
Special interface for:
- 8 analogue inputs.
- 6 analogue outputs.
- 8 digital inputs.
- 24 digital outputs.
- Additional I/O on special request.

### SOFTWARE
- Server OS.
- Suite of Genie programs, including LabSOCS software.
- Special StackMonitor program package.
- Program languages: English, German, French (additional languages possible, if required).

### DETECTION LIMITS
- Xe-133: $5*10^2$ Bq/m$^3$ in 24 h.
- Kr-85:  $1*10^4$ Bq/m$^3$ in 24 h.
- Xe-133: $1*10^4$ Bq/m$^3$ in 10 min.

The given values are the values as required by regulations. The actual achieved value for Xe-133 is much lower, but strongly depends on the local background conditions.

Please contact the Mirion Application Support Group to learn more about implementing this stack monitoring system in your facility.

**www.mirion.com**

ISO 9001 SYSTEM CERTIFIED

MERIDEN CT
SMYRNA GA
OAK RIDGE TN
CONCORD ON

C40062 - 04/2013