Measuring Radioactive Emissions in Gaseous Effluents at MIPF

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Di Tada M., Nassif E., Pino R., Núñez M.

INVAP S.E. – Bariloche - ARGENTINA
Delivery of complex technological projects.

Design and construction of complex facilities & components, involving:
- Development, design -programming - testing of critical software.
- Demanding mechanical requirements.
- Special materials application.
- Extensive modelling and calculations.
- Prototyping.
- Electronics development & integration

Licensing of facilities with demanding regulatory reqs.

**CORE COMPETENCES**

**SALES:** > $ 200 mm MUSD/yr.

**STAFF:** + 1300
(85% professionals and technicians)
40 years IN NUCLEAR.. (RR Market)

ARGENTINA 1989

PERÚ 1989

EGYPT 1998

ETRR-2 22 MW

NUR 1 MW

RA-10 RMB

ARGENTINA 2006

AUSTRALIA Ongoing

RA-6 10 MW

RP-10 10 MW

ARGENTINA 1982

EPR 1958

Global

Regional

Local

Contract

200m U$S

20m U$S

Engineering Hours

1,000,000

100,000

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IN NUCLEAR.. (MIPFs–MEDICAL ISOTOPE PRODUCTION FACILITIES)

COQUI – Medical Isotope Production Facility (MIPF)
RA10 reactor associated plant
Molybdenum Production Facility (Mo PF)
Radioisotopes Production Facility (RPF)
OPAL - Radioisotopes Production Facility

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BARILOCHE, ARGENTINA

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IN NUCLEAR.. (MIPFs–MEDICAL ISOTOPE PRODUCTION FACILITIES)

- **Radioisotope Production Facility – Inshas, Egypt:**
  Associated with the ETRR II (Egyptian Test & Research Reactor - supplied 1998).
  Delivered 2012

- **Retrofit with a new process existing infrastructure of operating Hot-Cells by ANSTO – Lucas Heigths, Australia (2006)**

- **RA-10 RR (Argentina) for CNEA (30 MW Open Pool)**
  Up to 4000 Ci (Mo-99) per irradiation position at end of irradiation

- **RPF for targets being irradiated at Dhruva Reactor (INDIA)**
  300 Ci Mo-99 batch (six days pre-calibrated)

- **RMB RR (Brazil) for CNEN (30 MW, Open Pool)**
  Up to 3000 Ci (Mo-99) per irradiation position at the end of irradiation

- **MIPF for COQUÍ Pharmaceuticals in USA - 2 Non-Power RR (< 10 MW each)**
  Up to 7000 Ci (Mo – 99) & 1200 Ci (I-131) (as by product of Mo-99) per week
Measuring NG Stack Emissions
Some History – (Old) PING Monitors at RR facilities

INVAP PRG-1
NURR – Algeria
1990

- Mainly Gross $\beta$ - NG emissions
  via Plastic Scintillators

- Maximum NG Detection levels:
  $\sim 5 \times 10^3$ Bq/m$^3$

INVAP PRG-3
ETRR II – Egypt
1998

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Measuring NG Stack Emissions at RR
The OPAL case... Evolution of Requirements

- **Designed by INVAP to meet the Gaseous Effluent detection requirements at OPAL RR** - In continuous operation for the past 9 years

- **Addressing to:**
  - Reliability
  - User Friendliness (HMI)
  - Maintainability
  - Standardization
  - Versatility
  - Operability

- **Focused on:**
  - Sensitivity on low concentration ranges
  - **Ar \(^{41}\) dedicated channel**
  - Sampling accuracy

*(minimize iodine Plate Out + Aerosols Deposition)*
Measuring NG Stack Emissions at RR
The OPAL case..

INVAP’s AIR EFFLUENTS MONITORS AT OPAL

- Aerosols (Gross $\beta$ - Gross $\gamma$)
- Iodine ($^{131}$I)
- Noble Gases ($\beta$ – $\gamma$ Channels)
  (vía 3” x 3” NaI + Plastic Scintillator)
Measuring NG emissions at MIPF...A different challenge..

- Discontinuous Regime
- Pulsed Batch Emissions
- Short Follow-up Periods required
- Complex Process – Customized Sampling Systems
- Very High Activity Noble Gas Concentrations
- Dedicated – Measurement Specific Software
Some Figures: Order of Magnitude of maximum RXenon Releases

- Research Reactors
  
  \[
  (\text{Xe} \ 133 + \text{Xe} \ 135) \sim 10^9 \ \text{Bq/day}
  
  (\text{Ar} \ 41) \sim 10^{10} \ \text{Bq/day}
  \]

- Nuclear power plants (Normal operation) \sim 10^{12} \ \text{Bq/day}

- MIPF´s plants reported releases \sim 10^9 – 10^{13} \ \text{Bq/day}
  
  \[
  \text{Xe-133: } 3 \times 10^{11} - 8 \times 10^{13}
  
  \text{Xe-135: } 8 \times 10^{12}
  \]

As comparison:

- 1 kTon nuclear explosion \sim 10^{16} \ \text{Bq/day}

- MIPF´s emissions Objective : 5 \times 10^9 \ \text{Bq/day}
MIPF’s NG Emission Regime... A different challenge

Typical plant emissions..(Invap AEMi measurements)

Emission of $^{133}$Xe and $^{135}$Xe

$0.7 \text{ hs} \times 20$

$6 \text{ hs}$

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MIPF´s NG Emission Regime... A different challenge
Comparing emission regimes: MIPF´s vs RR´s
(Invap AEMi measurements)
From RR to MIPF\textsuperscript{\textdegree} NG emissions

Data Handling & Hardware changes

(Gaseous Effluent Monitor – AEMi)

Up to now (NaI detect.)

- Single Channel Analizers used to determine the Lower and Upper channels of each peak.
- The number of counts between these two channels assigned to peak activity. (No background subtraction was performed)
- Measuring chamber volume reduction
- Lead Shielding Optimization: MCNP simulations for NaI with MIPF inventor

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From RR to MIPF emissions: Data Handling & Hardware changes

From Now on… (Improving Detectors)

$^{133}$Ba calibration source: CdTe vs NaI

$^{133}$Xe

$^{135}$Xe

$^{131}$I

CdTe

NaI

From Now on… (Improving Detectors)
Noble Gases measuring chamber

CdTe detector with cooler system

Nal detector

MCA spectroscopy analysis of $^{133}$Xe and $^{135}$Xe Possible detection of $^{133m}$Xe and Kryptons

MCNP Simulation

3 X 3 in. Nal

Cd Te

Gas Chamber volume
Effect of CdTe on RXe´s detection at low energies
New software for new NG monitor (AEMi) design:

- All the spectra will be stored.
- Evolution of each peak may be followed in time.
- Historical spectra stored & available for future analysis.
Measuring NG (Radioxenons) emissions at MIPF

Other Improvements: Operator’s Customized Software
Measuring NG (Radioxenons) emissions at MIPF

Other Improvements: Real Time «On-Line» NG Measurements (via CdTe) at Hot Cells Ventilation Discharge (complementing NG Stack monitors)
Relevant changes has to be made in standard instrumentation when tracking NG effluents at MIPFs, compared to NPP´s or RR´s operational modes.

Former Stack monitors (being used at OPAL RR and other facilities) were adapted and upgraded, to match Pulsed Batch emission´s regime requirements.

With the experience of $^{133,135}$Xe emissions measured during $^{99}$Mo runs at MIPF, improvements on detectors, data collection and analysis, are being introduced.

CdTe detector is being added to improve resolution in the low energy range, providing new specific isotopes identification capabilities.

Performance Testing is ongoing, and new detector options are being considered.

Additionally,

New, Operator´s customized software, linked to NG emissions reports is being designed.

Dedicated Hot Cells ventilation discharge measurement will complement stack effluent monitoring to provide a closer tracking on MIPF process.
Thank you!

enassif@invap.com.ar
Los Sistemas de Detección: Espectros Característicos

Gaseous Effluent Monitor (AEMi) : From RR to MIPF applications
Improving Detectors ....

$^{152}\text{Eu}$ Spectrum comparison, obtained with different detectors: NaI, CdZnTe, HPGe

- HPGe $\rightarrow$ ~ 0,5% FWHM at 662keV
- CdZnTe $\rightarrow$ 1,7% FWHM at 662keV
- NaI $\rightarrow$ 7,5% FWHM at 662keV
<table>
<thead>
<tr>
<th>Semiconductors</th>
<th>HPGe</th>
<th></th>
<th>CdTe</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>The best resolution</strong></td>
<td>~0.3% (60.5(D)x31.5(L)mm at 662keV)</td>
<td></td>
<td><strong>Very good resolution without cooling</strong></td>
<td>~0.9% (3x3x1mm at 662keV)</td>
</tr>
<tr>
<td><strong>Small gap</strong></td>
<td>~0.7eV requires LN$_2$ cooling or similar electrical cooler</td>
<td></td>
<td><strong>Bigger gap than HPGe</strong></td>
<td>~1.5eV</td>
</tr>
<tr>
<td><strong>For labs applications</strong></td>
<td></td>
<td></td>
<td><strong>Major efficiency in lower energies</strong></td>
<td>(10-100keV)</td>
</tr>
</tbody>
</table>

| Scintillators | NaI(Tl) | | LaBr$_3$(Ce) | | SrI$_2$(Eu) |
|----------------|---------|------|--------------|------|
| **The most used scintillator** | | | **Good resolution** | ~2.9% (3”x3” at 662keV) |
| **Resolution** | ~7% (3”x3” at 662keV) | | **Great light yield** | 61000 ph/MeV |
| **Acceptable light yield** | 38000 ph/MeV | | **Decay time** | 16ns |
| **Decay time** | 250ns | | **Wavelength of emission** | max 380nm |
| **Wavelength of emission** | max 415nm | | **Internal activity** | |
| **Perfect fit with PMTs** | | | | |

| | LaBr$_3$(Ce) | | SrI$_2$(Eu) |
|----------------|--------------|------|
| **Good resolution** | ~3.2% (1”x1” 662keV) | | **Bigger light yield** | 80000 ph/MeV |
| **Wavelength of emission** | max 435nm (close to NaI) | | **Wavelength of emission** | max 435nm (close to NaI) |
| **Decay time** | ~3000ns | | **Decay time** | ~3000ns |
Simulation

- Gas volume (green cylinder) – approx. 25 cm³.
- 3”x3” NaI (white) - CdTe solid state detector (brown) (5mmx5mmx1mm).
- Statistical Error < 10% (Npart > 1e10)
- $^{135}$Xe peaks (250 keV – 608 keV) seen in both
- $^{135}$Xe Peaks (358 keV – 408 keV) seen with CdTe only
- $^{133}$Xe peak (160.6 keV) seen with CdTe only.