Tritium-in-air Monitoring System – Detritiation plant power consumption optimization

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Abstract — *Tritium in air monitoring from working areas of a detritiation plant is part of working environment radiological monitoring, demanded by Romanian Fundamental Norms of Radiological Security (NSR-01) and is referring to tritium in air activity concentration measurement in the working space of an installation where the possibility of air contamination with tritium exist due to the tritium technological dispersion occurring in normal or failure functioning of the plant.*
Depending on installation specificity, when technological dispersions are under form of tritiated water vapors (HTO, DTO), for vapors recuperation local small dimensions cleanup systems are preferred.
When the technological dispersions are under tritium or tritiated hydrogen/deuterium form (HT, DT, T_2) owing to the recuperation process usually made by burning the gas to produce water and subsequent recovery, the system is more complicated and expensive. That's why, the designer engineers prefer to execute outsized capacity systems capable to serve all potential dispersion areas.
This paper aim to present a technical solution for a stable area monitoring system of tritium in air for working spaces in a heavy water detritiation plant, where hydrogen gas is used, system who generate and optimize the control signals of recuperation installation depending on the tritium in air concentration level.

Keywords— tritium, water detritiation, air monitoring.

I. Introduction

In a nuclear power plant with CANDU-600 reactor a large quantity of tritium is generated, mostly in the heavy water (D_2O) moderator. It was determined that tritium in heavy water, in such kind of installations, is one of the major contributors to the radiation doses received by operation personnel.

A solution to this problem is the tritium extraction from tritiated heavy water. The currently used methods for heavy water detritiation are based on catalytic isotope exchange, electrolysis and cryogenic distillation. At ICIT Rm. Valcea, the developed technology is based upon catalytic exchange between tritiated water and deuterium followed by cryogenic distillation of deuterium/tritium isotopes mixture.

The catalytic exchange is taking place in area named LPCE, liquid phase catalytic exchange, and cryogenic distillation in area named CDS.

The contamination with tritium of working areas environment due to normal technological activities it's far bellow normal limits, but in case of accident the tritium released quantity can be significant. That's why this amount of tritium has to be recovered from the plant envelope before reaching the outside environment. Having in view that the recovery is a time and electrical power consuming process, with a lot of proper procedures involved in the process, the functioning of involved equipments and installations has to be optimized.

II. Tritium in air monitoring system

A. Backgrounnd

Additional to radiological danger, in working areas were technological dispersions are under form of gas, the risk of air-hydrogen explosive mixture issue is present.

Considering the working principle of ionization chambers flow-through type (witch are the only option for real time monitoring of tritium in air) we have to reckon with the possibility of an arc inside the measurement volume of ionization chamber, simultaneously with the sampling of explosive air-hydrogen mixture.

This paper describes a technical solution for a fixed-area tritium-in-air monitoring system for working spaces in a heavy water detritiation plant, where hydrogen gas is used.

Having in view that on the market certified Anti-ex tritium-in-air monitors are not available they will be installed in non-classified anti-explosion areas.

This measure is not enough to eliminate the explosion risk due to the possibility that the two events to occur simultaneously: explosive air-hydrogen mixture in taken air sample, respectively electric flash inside the measurement volume of ionization chamber.

The Tritium-in-Air Monitoring System presented in this paper was provided with compensatory measures to eliminate

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this explosion risk and with the possibility of tritium in air concentration alarm threshold selection.

B. System design requirements

According to European standards the tritium-in-air monitors for working environments must ensure the fulfillment of two main objectives:

- Determining the average tritium concentration in air of a work area and its evolution over time;
- Drive an alarm when a predetermined threshold concentration of tritium in either air or the integrated concentration over time in a given location is exceeded.

Also, to improve accuracy and sensitivity, the system allows sampling and subsequent laboratory analysis.

C. System architecture

Tritium in air zonal monitoring system comprises a number of fixed monitoring units Fig.1 (each unit consisting of a tritium monitor with ionisation chamber and a sampling unit, with a number of lines and a purge) for sequential monitoring of a number of fix locations, zone 1 classified from radiological point of view.

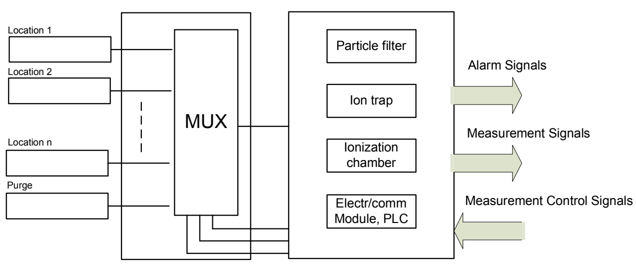

Fig. 1 Fixed monitoring unit

Sampling units can be locally controlled by a PLC (Programmable Logic Controller) or remotely from DCU (Distributed Control Unit) main work station console using a specialized software application.

The software application will facilitate continuous and simultaneous monitoring of tritium in air to all sampling units locations, automatic sequential monitoring of lines corresponding to a sampling unit for over-fulfillment of pre-settled threshold values, remotely selection by the human operator (manually) of monitoring locations and graphical indication of tritium fields evolution for each monitoring unit.

View, purchase and recording of radiological measured data are made remotely, Fig. 2, in the DCU, with the help of a dedicated software routine. Another requirement for this software application is the selection possibility of tritium concentration threshold alarm values and graphical view and acoustic warning in case of overtaking of those manually selected levels. In the same time the dedicated software routine will optimize the necessary signals to power up the associated cleanup and recuperation additional systems according with concentration levels.

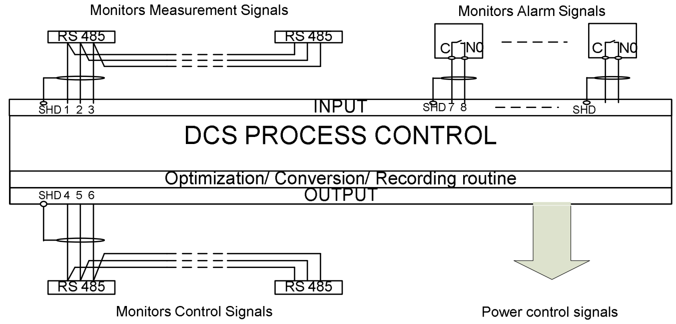

Fig. 2 System architecture

The tritium in air monitors will be foresight with selection possibility of two threshold alarm values for tritium in air concentration and with local audio and video alarms.

The alarms will be type distinctive and will be activated at over-fulfillment of pre-settled threshold values for tritium in air concentration and inadequacy/malfunction of monitor components. Those alarms will be remotely available, in plant main control room.

The designing of sampling tubing will be made taking into account the spatial arrangement of technological fluids leakage potential sources from working areas and sampling units locations, so the sampling to be representative and monitor response to be as prompt as possible. The admission points for sampling will be as close as possible to the leaks potential source, or in case of several potential sources of leakage in the room, spread over a wide area, the sampling point will be closer to the suction ventilation in that room (exact location will be finally determined after the study and determination of that room air circulation with all equipment installed and ventilation started).

Also, according to the radiological hazard, more sampling points can be provided in one room only.

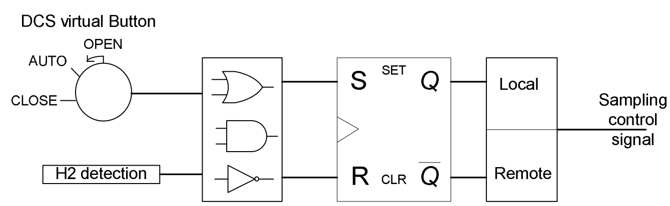

Fig. 3 Sampling hardware architecture

Having in view that on the market certified Anti-ex tritium-in-air monitors are not available they will be installed in non-classified anti-explosion areas. Air samples, for measurement of tritium, are usually taken from Anti-ex declared areas. In Fig. 3, we highlight the sampling hardware simplified architecture. Taking into account the principle of ionization chambers with gas flow operation, there is also the possibility of arcing occurrence inside the measurement volume of ionization chamber. Thus, the possibility that the two events (the emergence of hydrogen in air sampled above the minimum limit of 4% hydrogen concentration in the air and the occurrence of arcing inside measurement volume of ionization chamber) occur simultaneously means the possibility of explosion. The explosion risk will be eliminated through the implementation of compensatory measures, namely:

- At the aspiration points of the inlet air sampling routes from the explosion risk declared rooms (classified in Class 1, Division 2, Group B) a hydrogen in air detector will be disposed as part of the hydrogen in air detection system;
- When in a certain room, in which air is drawn, the hydrogen detection system indicate the maximum admissible limit (20% lower explosive limit of 4% H2 in air) the DCS-DCU central computer, which monitors the detection system readings, will dictate the closing of room air sampling line, the sampling being done from another location associated to sampling unit, at the unit PLC control, if allowed by the hydrogen detectors. If all sampling lines are blocked by the in air hydrogen detectors, the monitoring will be performed by the sampling unit purge.

The system will also have the capability to convert the measured values from volumes activity units, Bq/m^3, in dose rate units, μSv/h, using a default conversion factor. The viewing of monitored data will be possible both in Bq/m^3 and μSv/h.

D. *System main functions*

The system was designed to satisfy the following functions:

- periodical and direct measurement of tritium-in-air concentration for fixed locations on detritiation plant working spaces, zone 1 from radiological point of view, where there is potential for tritium technological leakage that could result in tritium contamination of air in these spaces;
- the local and remote displaying of measured values, in plant main control room;
- both visual and acoustic trigger alarms if preset thresholds exceeded the concentration of tritium in air and in case of improper components functioning/malfunctioning;
- recording and storing of measured data for subsequent processing and analysis of the dosimetric and radiation protection evaluation;

All these functions will be provided both in normal running of detritiation plant - CTRF and installation systems maintenance or abnormal states of plant operation.

E. *Operational requirements/working conditions*

The system is design for continuous operation, except for scheduled maintenance and testing periods for the system itself.

The continuous working time for the fixed system of tritium monitoring in plant working areas was designed to be one year. System functioning is independent of plant working situations: working, stand-by or maintenance.

The system can accept interruptions of short duration (no more than one minute) of electric power.

F. *Software application*

The software application installed on the main console of Distributed Control System has the capability to command and control the switching sequence of each Sampling Air Fix Units and will facilitate the continuous and simultaneous monitoring of tritium in air at all locations of sampling units, automatic sequential monitoring of sampling lines associated to a monitoring unit in case of pre-settled threshold over-fulfillment values, remote selection by the operator (manually) of the monitored locations and graphical visualization of tritium field evolutions for each monitoring unit and for each sampling sequence by direct corresponding correlation of all information regarding the sampling sequences and radiological measured data.

Other system software requirements are:

- Keeping all the data on a SQL server, respecting the OPC-DA3 standard, with the possibility of remote connection with a master Integrated System for Radiological Control;
- Graphical interface with multiple windows, one for each Sampling Air Fix Unit, in each window being located guidance on sampling sequence and tritium in air measured concentrations as well as graphical view of tritium in air concentration evolution for each sampling sequence;
- Ensuring the possibility for selection of alarm thresholds for tritium concentration levels, graphical view and sound alert in case of those levels over-fulfillment;
- When Hydrogen in Air Detection System (HADS) indicates the reaching of maximum admissible threshold limit of hydrogen in air concentration in a certain room, the Distributed Control System (DCS) central computer, witch is in real time monitoring the hydrogen concentration provided by the HADS, will forward to the system DCS central console the signal of sampling invalidation from that specific room.

Thus, the local PLC, receiving the signal from DCS central console, will inhibit the opening of the corresponding sampling line, the routine deciding to jump over that specific line.

If a Sampling Air Fix Unit (SAFU) reaches that point when all the sampling lines are inhibited, locked because of high hydrogen concentration, that specific SAFU is not going to be interrupted and will start sampling from a location declared free from any contaminants until the concentration of hydrogen in air reaches the lower admissible threshold limit

III. CONCLUSIONS

The Tritium-in-Air Monitoring System (TAM) installed in the rooms of technological areas is a very important tool for heavy water detritiation plant electrical power efficient design. Because it takes time and switching power to start-up the atmosphere cleaning process, to run it and to safe shut down consuming power components, the system was forethought with respect to power consumption optimization.

Finally, since the entire detritiation process is of a higher level of complexity and is automated run, the designers and engineers can explore a wide range of architecture and choose the one that meet their requirements with respect to the workers/personnel, population and environment radiological protection.

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