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OVERVIEW OF THE TRITIUM-IN-AIR MONITORING SYSTEM OF CERNAVODA NPP U1 ROMANIA – MODERNIZATION AND IMPROVEMENT PROJECT

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ABSTRACT

The Tritium-in-Air Monitoring System used in Cernavoda NPP U1 is a Scintrex Model 292 and is a multi-room monitoring station for measuring tritium activity in air, particularly tritiated water vapor, ideal for installations in:

- Nuclear Power Stations
- Tritium Extraction Plants
- Fusion Facilities
- Other Industrial Tritium Applications

The Tritium-in-Air Monitoring System (Scintrex Model 292) has two major limitations:

- the presetted setpoint is not for the tritium level of activity, is for a global activity including noble gas contribution;
- the presetted setpoint should be changed for each particular room, which means a major delay in the location of D_2O leak sources.

Both limitations can be solved by using a Tritium Monitoring Network consisting of a number of tritium monitors stationed in individual rooms and the readings are transmitted to a central computer.

The data can be logged to a database (MS Access compatible) and will offer historical trends and necessary reports.

This paper presents the main equipment's of the Tritium-in-Air Monitoring system, the description of this modernization project and the results of ^3H emissions monitoring program (Liquid & Gaseous Effluent Program Monitoring program at Cernavoda NPP).

1 INTRODUCTION

During routine operation of a CANDU reactor, various gaseous, liquid, and solid radioactive wastes are generated. The design of its systems ensures that these are minimized, but small quantities of gaseous and liquid wastes are continuously discharged at very low concentrations.

CANDU reactors are both moderated and cooled by heavy water (D_2O). Tritium is produced in CANDU reactors by neutron reactions with deuterium, boron, and lithium and by ternary fission. Activation of deuterium is by far the most important mechanism, which is responsible for the production of about 89 TBq of tritium per MW(e) per year compared to only 0.7 TBq of tritium per MW(e) per year produced by ternary fission. Most of the tritium present in CANDU reactors is in the form of tritiated heavy water – DTO.

Tritium is the radioactive isotope of hydrogen. It undergoes β^- decay to helium-3, with a half-life of approximately 12.33 years. Due to their low-energy (average of 5.7 keV and end-point of 18.6 keV), tritium β^- particles have very small range – less than approximately 6 mm in dry air or 6 μm in tissue. Outside the human body tritium contribution to radiological hazard is negligible however, when tritium enters the body either by inhalation or absorption through the skin the decay energy carried by the β^- particle is deposited in body tissue being an occupational radiation hazard in the station. [1]

The sources of tritiated heavy water vapor in reactor building air are the leaks from the main reactor systems or their auxiliaries. Special dryers were designed and are used to remove moisture from different ventilation systems of a CANDU reactor in order to maintain the gaseous tritium emissions below the limits established by the national authorities.

Tritium emissions are monitored both at the stack and in liquid discharges to demonstrate the compliance with the approved Derived Emission Limits. [2]

A specialized laboratory using Liquid Scintillation Spectrometry methods currently determines tritium activities in effluent samples. All information about the radioactivity of liquid and gaseous effluent is stored into a dedicated database and used to make periodical reports of the official releases for the Cernavoda NPP U1 station.

2 TRITIUM-IN-AIR MONITORING

2.1 Tritium-in-Air Monitoring System (^{3}H-in-Air)

It is a complex blend of electronic and pneumatic hardware, combined with large multi-room piping networks, which allows the operator to monitor separate rooms.

The Tritium-in-Air Monitoring System (Scintrex Model 292) is designed to:

- collect air samples from 24 separate areas in the Reactor Building and the Service Building (from a single station) where there is likely to be tritium;
- indicate levels of tritium generally due to leakage of heavy water;
- to assist in the location of D_2O leak sources (operation performed by the operator).

The Tritium-in-Air Monitoring system (Scintrex Model 292) mainly consists of two separate cabinets installed in Service Building (room S-226) and the following equipment: [3]

- tritium sampling unit cabinet (PL1398);
- tritium monitor/dryer unit cabinet (PL1394)
- collection piping and 24 remote solenoid valves installed in different rooms;
- manual valves (V11 & 25) to isolate the Reactor / Services Buidings (R/B or S/B) and Containment Isolation valves (SV 33 & 34) installed on the main sampling line coming out from the Reactor Building (R/B)
- sampling station (SS1) where operator may take samples with a syringe.
- calibrator and purging facilities: ^{2}N bottle, flexible hoses, quick-connectors, etc.

The Tritium-in-Air Monitoring system is interconnected with Post Accident Sampling System (PASS), which consist of 9 (nine) valves and a sample tube in a shielded box. The Tritium-in-Air Monitoring system is also interconnected with Containment Isolation system. Two indicating lights on the tritium sampling unit (PL-1398) indicate the valve status.

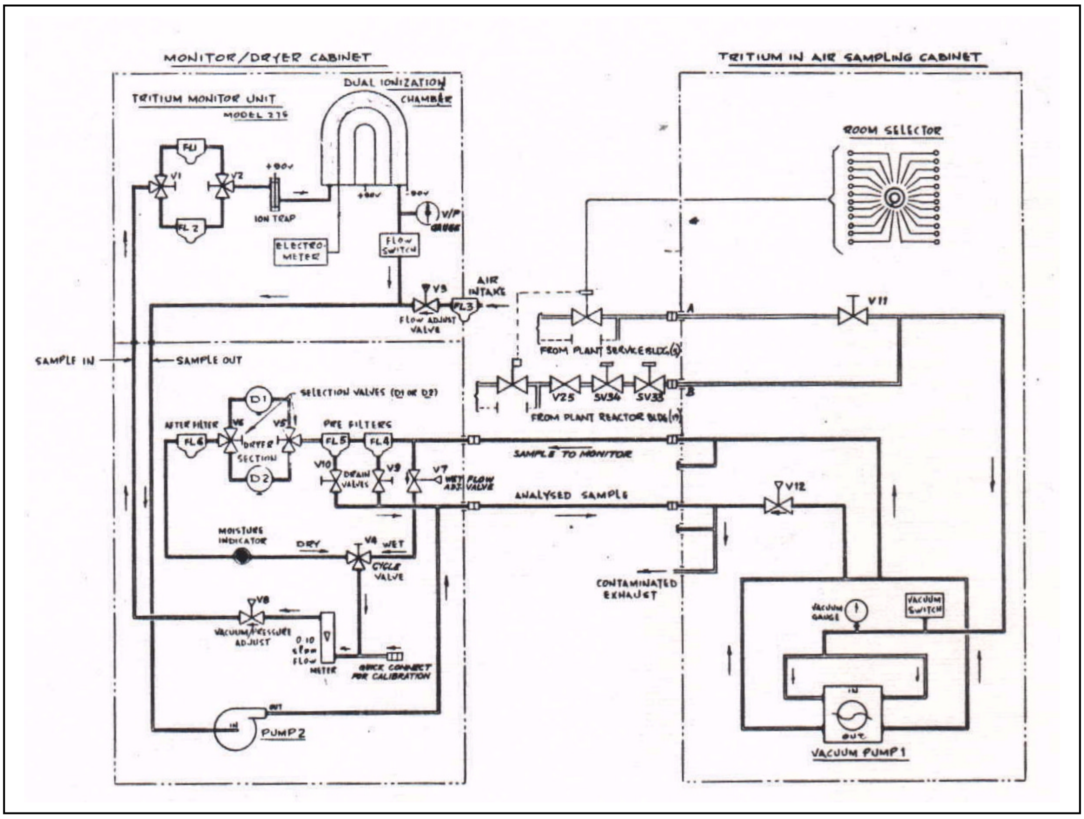

Figure 1: Cernavoda NPP ^{3}H-in-Air Monitoring System – Schematic Drawing

2.1.1 The Tritium Sampling Unit

The Tritium Sampling Unit (PL-1398) located in S-226 near the fixed tritium monitor, contains all the necessary equipment to draw air samples and to control the remote solenoid valves in order to select the desired room.

To avoid a long delay time in the pipe run from the monitored room to the sampling unit and to prevent condensation, a powerful vacuum pump (P1) provides an air sample with a flow rate of about 30 L/minutes.

A set of two alternate filters (design change modification) is provided on line to retain particles in suspension to prevent damage of the vacuum pump (P1).

Manual valves are provided for maintenance purposes, to isolate R/B or S/B samples.

A vacuum switch (PS) is provided to give a "HIGH VACUUM IN LINE" alarm if the line is closed by malfunction of a solenoid valve, or Containment Isolation or a blocked line. A vacuum gauge allows the operator to check the line to ensure the status of vacuum.

A "LEAK TEST" switch is also provided, to close the solenoid valves and check the leakage. If there is no practically leakage, the "HIGH VACUUM IN LINE" indicator will light (local alarm).

A 24-position rotary switch with the corresponding LED indicator shows the room selected by the operator.

All tubing is stainless steel (including the solenoid valves and the vacuum pump). Each remote solenoid valve is located in the monitored room. Monitoring coverage is provided in the reactor building and service building, in all areas where tritiated D_2O could be collected.

The purpose of this sub-system is to accelerate the delivery of the sample from the selected room to the fix tritium monitor.

2.1.2 The Tritium Monitor (Scintrex Model 275) / Dryer Unit

The Tritium Monitor/Dryer cabinet (PL-1394) is subdivided into two units:

- The tritium fix monitor covers the range of 1 to $2.04x10^7$ µCi/m^3. It has provisions for gamma subtraction; a digital display indicates the activity level in µCi/m^3; local and MCR alarms are provided for system malfunctions and high tritium concentration;
- The dryer unit is a complementary module to the fix monitor since the latter does not have any provisions for noble gas compensation.

The exhaust pump (P2), a flowmeter (design flow rate - 5 L/min.), three filters and two dryers are located in the dryer unit (underneath the Detection unit). The dryer is conditioned by the cycle valve (V4), which can select “wet” or “dry” cycle. The dryer unit also contains a moisture indicator with silica gel, which can be replaced or regenerated.

Sample air drawn into the Detection unit is passed through an electrically polarized ion trap to remove particles and extraneous ions. It is then passed through the outer chamber of a co-axial dual ionization chamber assembly. The beta particles in the sampled air ionize the air in the ionization chamber. The ionization current is proportional to the concentration of tritium in sampled air.

The compensation for background gamma is done through a current provided by the inner chamber. The two signals are electronically subtracted to provide the net tritium signal.

The measurement of the tritium activity is achieved manually in two steps:

1. One measurement is made with the cycle valve in the "wet" position; this measurement accounts for the tritium and noble gases.
2. One measurement is made with the cycle valve in the "dry" position; in this configuration the air sample from the pump cabinet is routed through the dryer section where the tritium is absorbed, and only the noble gases are measured.

The difference between measurements 1 and 2 will yield the true tritium concentration.

2.2 Gaseous and Liquid Effluent Monitoring program (for ^{3}H emissions)

Gaseous and liquid emissions from Cernavoda NPP were at low levels. Tritium emissions were also at low level (below 1% of annual DEL). [4]

Tritium (as tritiated water) from gaseous effluents is continuously sampled on molecular sieve at the stack and is measured bi-weekly by liquid scintillation spectrometry method.

During the pump-out of liquid effluents, the Liquid Effluent Monitor (LEM) monitors the gross gamma activity being discharged, and collects time-integrated samples from the discharge line for subsequent laboratory analysis of the actual releases. The samples collected by the LEM are taken to the station Health Physics laboratory for detailed radionuclide analysis. Tritium is analyzed by liquid scintillation spectrometry method. The results of this analysis constitute the official release results for the Cernavoda NPP station.

^{3}H gaseous emissions between July, 1997 and December, 2000 as determined by the effluent monitoring program and expressed in percents of Weekly Derived Emission Level percent (%WDEL) are presented in Figure 2.a.

In Figure 2.b is presented the evolution of ^{3}H liquid emissions from January 1997 till December 2000 expressed in Monthly Derived Emission Level percent (%MDEL).

Obviously the sequence of tritium emissions is time-dependent and evolves erratically around a growing trend. Based on this trend estimate, it is expected that in normal conditions emissions would be well below the operational limit of 5% DEL over the lifetime of the Cernavoda NPP plant.

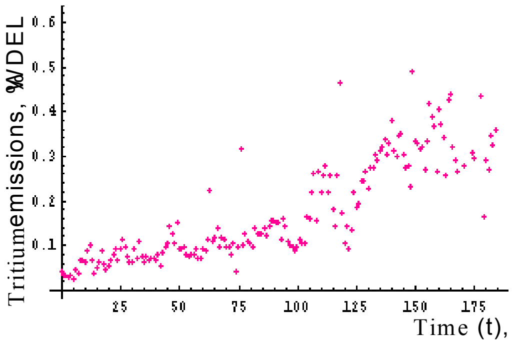

Figure 2.a – Gaseous Emissions

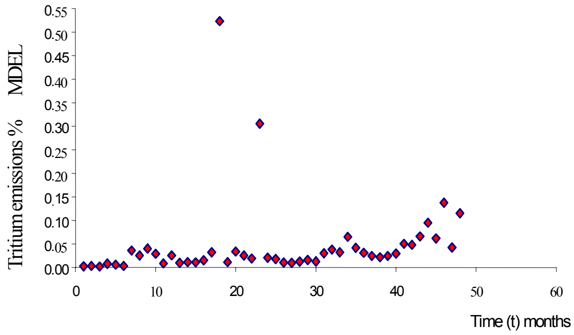

Figure 2.b – Liquid Emissions

Tritium emissions during this year - 2001 were also below 1% of WDEL. A statistical analysis of weekly tritium emission data revealed an erratic evolution around a growing trend due to the build-up in the main systems of the reactor.

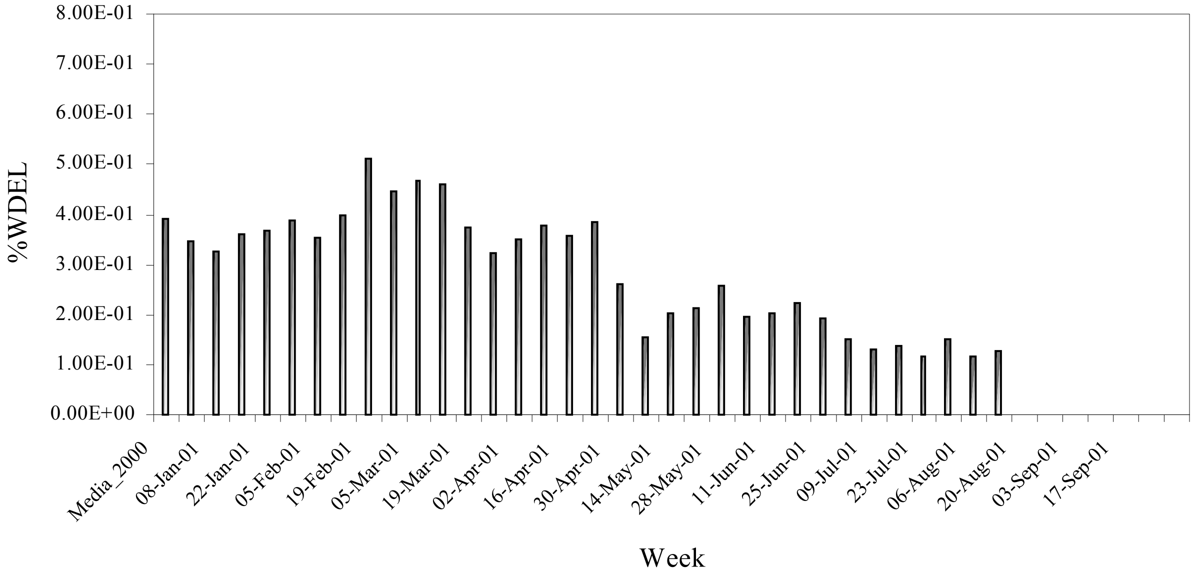

Figure 3: Weekly tritium emissions in 2001

3 MODERNIZATION AND IMPROVEMENT PROJECT

The proposed configuration is based on 8 tritium monitors: one tritium monitor will replace the actual Scintrex Model 275 Fixed Tritium monitor, six monitors stationed in individual rooms (most hazardous areas) and one monitor installed on mobile cart with radio transmission. The readings of tritium concentration are transmitted through an RS-422 (RS-485) or local area network (LAN) to a central computer.

The future locations will be established in areas where most frequent leaks can occur based on plant monitoring experience.

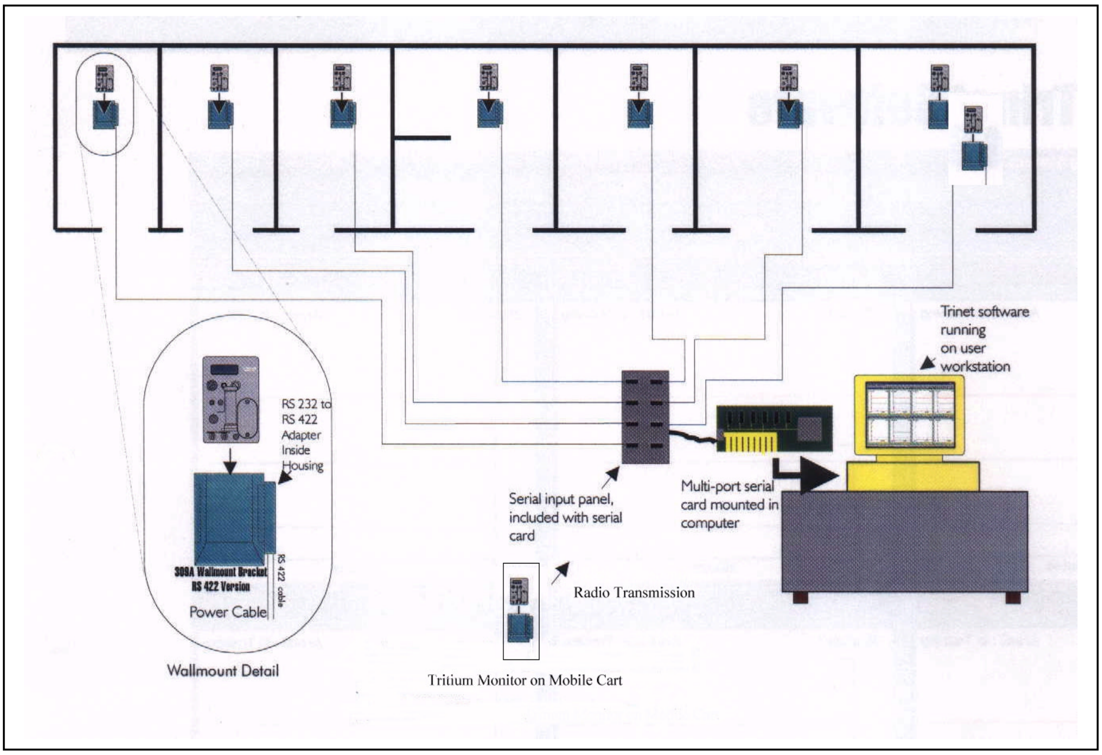

Figure 4 – Proposed Configuration of ^{3}H monitoring network

The data can be logged to a database (MS Access compatible) and will offer historical trends, which are very useful tool on the surveillance and operation of the process system.

The tritium monitors must have the capability to provide compensation for gamma and noble gases (radioactive krypton and xenon), which are generally present with tritium in the station, and mask the tritium signal.

The tritium monitors must have a local control panel to display the measurement and to give a local and remote alarm in Main Control Room if the activity level is above setpoint. Also, it must indicate an equipment failure in case it cannot function normally.

The ^{3}H monitoring network will provide CRT monitor at the Equipment Airlock or in room S-226 (fix tritium monitor cabinet room) with a display of on-line ^{3}H monitoring activity levels for all 8 (eight) areas monitored. This facilities will eliminate the routine ^{3}H syringe samples performed by Radiation Control staff in those areas and will advise personnel of hazard prior to entry of any area.

The Tritium-in-Air Monitoring system could be completed with a “bubbler” to collect samples for more accurate laboratory analyses by liquid scintillation spectrometry methods.

4. CONCLUSIONS

A routine ^{3}H syringe samples (Chem. Lab and a network application – Hazard Info) is used for assessment of ^{3}H hazards prior to entering an area to perform work. The proposed configuration provide on-line and real-time ^{3}H monitoring, so this system will be a very useful tool to implement one main element of the ALARA program: elimination of radioactive sources (fast detection of the ^{3}H hazards in areas monitored) and dose savings.

The new technologies (radiation ^3H monitoring network) will provide a cheaper, more efficient and safer nuclear power production (on long terms) due to:

- savings of the tritium surveys costs: consumables (LSC method) and manpower (work load of Chem. Laboratory / Radiation Control section);
- fast detection of D_2O leaks in the monitored areas, which reduces the cost looses (D_2O - very expensive) and Station Dose performance indicator.

The ^3H monitoring network system can replace a large and expensive multi-room monitor piping system (present configuration at NPP U1), big advantage especially for NPP U2 Cernavoda (NPP U2 project started during this year). This modernization and improvement project at NPP U1 becomes more attractive from the financial aspects: common spare parts stock for both units, better price of the system from the manufacturer, etc.

The same time, the ^3H monitoring network system will offer a database, historical trends, which are very useful tools on the surveillance and operation of the process systems.

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