VENTILATION AIR SYSTEM ISSUE AT THE UNIVERSITY OF COSTA RICA'S CYCLOTRON FACILITY

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Abstract

A ventilation issue was detected during the acceptance tests of the first Cyclotron installed in CICANUM research center, at the Universidad de Costa Rica. The incident occurred when gaseous ^{18}F leaked thought a damaged vial cap, but because the hot cell internal bag was not connected during that test, the radioactive gas was sent to the outlet pipe and eventually dumped to the atmosphere, but then detected inside the building by the fixed radiation environmental sensors. To avoid this kind of events happening again, an analysis of the installed HVAC system was performed. Air parcel trajectory models and *in situ* data and instrumentation were used to test the hypothesis raised out the assessment. This work concludes the incident was caused by a recirculation of released radioactive gases, caused by an inconvenient geometric configuration of its HVAC's inlet and outlet. The problem was partially fixed rotating the exhaust pipe 100° and extending its length by 20 meters from its original position. Intermediate components were also implemented to delay possible emergent discharges of radioactive gases.

1. INTRODUCTION

First Cyclotron in Costa Rica was installed in 2020 at the Center for Research in Atomic, Nuclear and Molecular Sciences (CICANUM) at the Universidad de Costa Rica, San Jose. During the first acceptance tests of the Cyclotron, components and systems should be verified before producing any isotope. Considering the tender process, the first isotope to be tested was the ^{18}F, which it will be used for ^{18}F-FDG production. One of the first acceptance tests is to verify that ^{18}F arrives to the hot cells, so that enriched water was sent from the operator's room cabinet to the cyclotron's target and then, from there, to the stated hot cell. This initial test was performed correctly.

Next step was to prepare the hot cell to produce ^{18}F-FDG, in this case the irradiation of enriched water occurred and then it was sent to the hot cell but when this isotope arrived at the activity vial, and a gas leakage on the vial cap arose and eventually that gas was dumped through the building ventilation exhaust pipe, which is located two floors above the production floor, where the test were taking place. The ventilation exhaust pipe has an environmental detector which is used to estimate the number of counts per minute release to the atmosphere. This detector showed an increase of activity from the background level.

Few seconds after the release of radioactive gas to the exhaust pipe, the environmental detectors into the production floor, outside the hot cells, were showing an increase of the background activity as the radioactive gas was released. Due to the small amount of activity prepared for the acceptance test, the amount of gas isotope released to the ventilation exhaust pipe was also small but enough to be detected by those environmental detectors in the facility.

Because our country does not have any regulation regarding releasing radioactive gas to the atmosphere, CICANUM staff considered that an increase of background gas activity released to the atmosphere may represent an incident. From our point of view the presence of radioactive gas into the production floor denotes a radiation incident that needs to be corrected, due to the amount of activity used in the test. If the produced activity was higher, then the amount of leakage could be higher as well.

To correct this issue, a building gas flow analysis occurred, considering local air parcel trajectories. CICANUM staff concludes that there was a recirculation of the dumped gas from the hot cells that should be fixed by changing the configuration of exhaust pipe of the HVAC (heating, ventilation and air conditioning) system of the building.

The goal of this work was to develop a proposal for the practical geometric change of that exhaust, to avoid recirculation events of potentially radioactive gaseous waste through the building ventilation system, which could trigger radiation incidents into the production floor.

2. GENERAL METHODOLOGY

12.1. Analysis of the HVAC system installed

Before starting any test in the installation, CICANUM staff were really concern about the initial arrangement of the HVAC system installed. In principle, the company in charge of this system performed several tests to verify that there was not any possible recirculation on air/gas from the outlet into the inlet pipe.

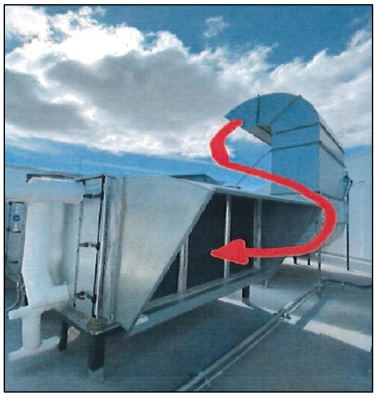

FIG. 1. Initial inlet and outlet pipe HVAC system arrangement installed in the building and possible radioactive gas trajectory entering production main floor.

For the analysis of the geometric configuration of the inlet and outlet of the installed HVAC system in the building, illustrations of *FIG. 2* were prepared to summarize the discussion of hypothetical ways in which the recirculation of radioactive material would take place.

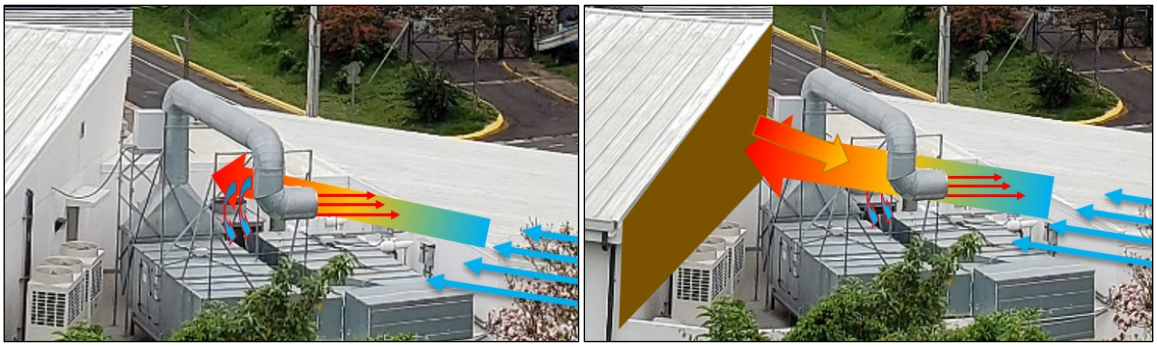

FIG. 2. Wind direction incidence over the inlet/outlet of the HVAC system that generates recirculation. Direct recirculation (left), indirect recirculation (right).

In the left-side image, the direct recirculation is given when the external air is flowing in a particular direction and tends to mix with the exhausted gases of the outlet pipe so the air flow from the outlet of the HVAC system to its inlet, therefore, cooling those gases and sending them to the production floor again.

In the right-side image, indirect recirculation way is showed, where the external air mix with the outlet but moving as a group and colliding against a building wall and losing its energy. In this case external air mix changes its direction to stay close or redirecting itself to the inlet pipe of the HVAC system. Then, eventually the external air mix could be incorporated into the production floor of the building.

12.2. Local air parcel trajectories

The analysis of the geometric configuration of the inlet and outlet of the HVAC system were faced with a geographic air trajectory study, using Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT) by the NOAA Air resources laboratory [1].

HYSPLIT model is a complete system for computing simple air parcel trajectories, as well as complex transport, dispersion, chemical transformation, and deposition simulations. According to its webpage, it is one of the most extensively used atmospheric transport and dispersion models in the atmospheric sciences community.

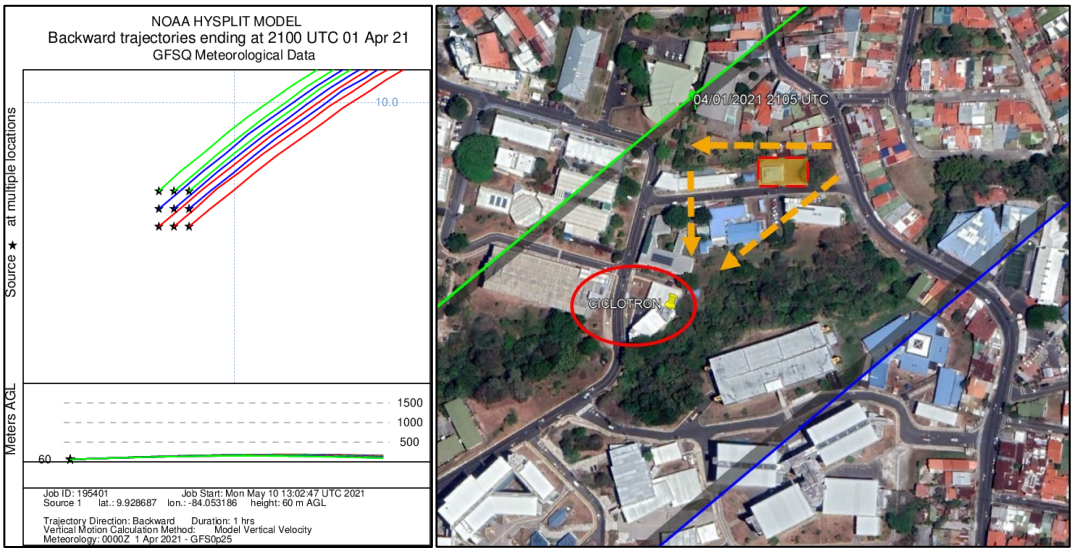

FIG. 3. HYSPLIT model for wind trajectory in backward approximation. From the building coordinates during the recirculation incident [1] (left). HYSPLIT kml file data over a terrain view using Google Earth [2], the Ciclotrón building is inside the red ellipse (right).

The HYSPLIT model generates simple maps and provides .kml files, used to display geographic data in an Earth browser such as Google Earth, as show in the images of *FIG. 3*

For our specific configuration, the outcome (external air mix) essentially follows a parcel trajectory of air backward, considering the HVAC system localization and a specific range of time set in hours. This range of time could be modified according to different needs, and it varies from hours to several days.

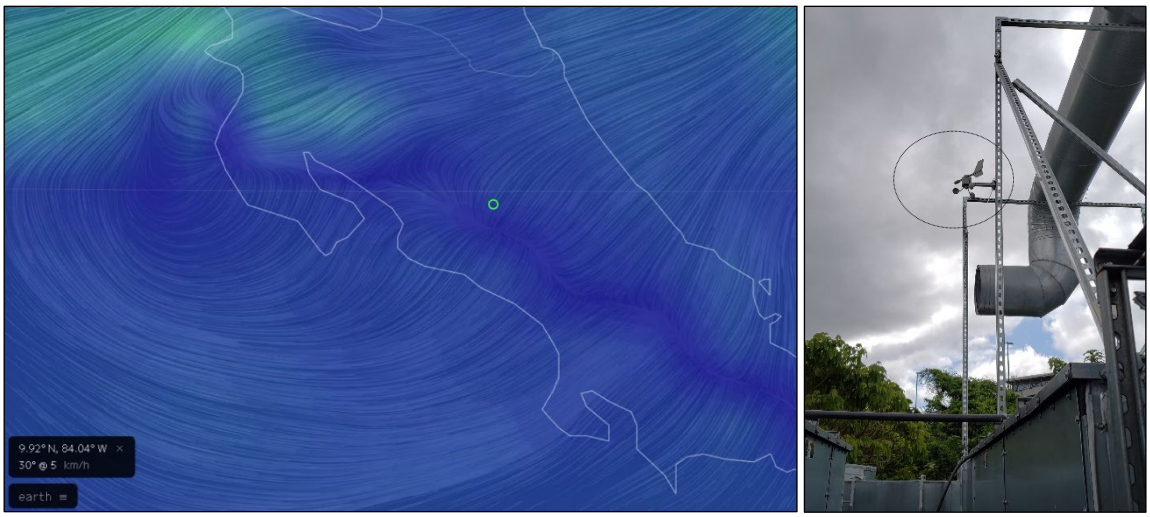

FIG. 4. Wind direction incidence over the building based the Earth Wind Map, using data of the GFS, NCEP and US National Weather Service [4],. The small green circle in the map is showing the ciclotron's building location (left). The anemometer to verify wind direction predictions was placed between the outlet and inlet of the HVAC system (right).

In *FIG. 3*, image at the right, orange arrows represent common wind trajectory directions (vectors) in the area where the building is placed. In same figure, CICANUM gas laboratory (GasLab) is enclosed in a red rectangle. GasLab provides data to define the vectors shown, to understand the most common movement of external air mix in the area. The orange arrows agreed the HYSPLIT wind trajectory generated by archive for the day of the incident.

This associated laboratory launch meteorological balloons in regular bases, collecting local wind behaviour data as part of its research project which has several years in place at CICANUM, as shown in several of their publications [3].

To validate wind direction proposed by the HYSPLIT results, an anemometer was placed between the main HVAC's inlet and its outlet of the building for several weeks, to assess the wind direction at that point and sustain the wind direction arguments based on the outcome of the modelers, *FIG. 4*.

13. PROPOSED AND IMPLEMENTED CHANGES

13.3. HVAC exhaust pipe modification

Bearing in mind factors as intervention time, costs and some technical considerations, some configurations were discussed with engineers of the company in charge of the modification. The selected proposal for the exhaust pipe change consisted in a horizontal rotation of the pipe to direct its outlet downwind and extended its length, supported over the roof of the building, to avoid recirculation due to changes in wind direction. The proposed modification can be seen in *FIG. 5*.

FIG. 5. Inlet (blue triangle) and exhaust pipe (orange-red rectangle) representations for change proposal with an over-position representation of the modelled wind direction, at the day and time where the recirculation incident took place.

As a result, next changes were implemented: one horizontal rotation of nearly 100° at the elbow of the exhaust pipe, and an extension of 20 meters in the length of the exhaust pipe, which is now resting over the roof of the building, as shows *FIG. 6*.

13.4. Intermediate component to delay dumped gases

The synthesis hot cell has an internal bag to prevent gas leakage from the hot cell while synthesis process is performed. If the internal bag fails, a Geiger Müller detector within the hot cell closes a set of pneumatic valves to hold any gas leakage. If the pneumatic valves fail, an intermediate component delays the travel of dumped gases towards the exhaust pipe before releasing it into the atmosphere. The intermediate component consists of 500 meters of tubing at the end of an array of valves to evacuate the resulting gases of the synthesis if the two previous methods fail.

The *FIG. 7* shows the delay line prototype schematic, designed to be placed at the maintenance room in the back of the 6 hot cells installed at the production floor of the facility. Part of the prototype, the manifold with the 500 meters of TPE-U tubing, has been built and installed to the ^{18}F hot cell, but the pumping system for the bag into the hot cell chamber will be implemented on the second half of 2022.

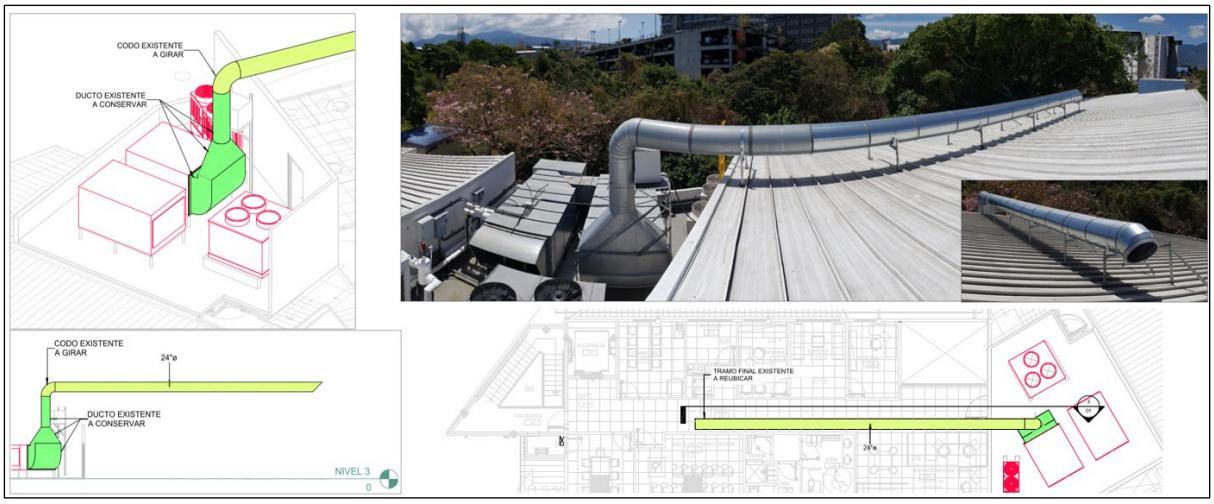

FIG. 6. The physical changes applied over the exhaust pipe of the HVAC system of the building.

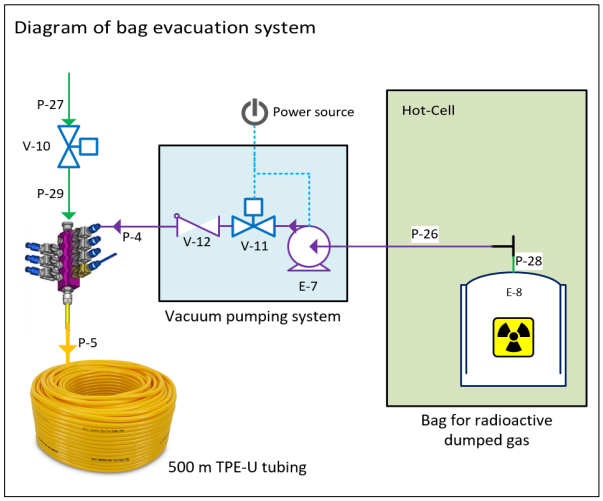

FIG. 7. Delay line prototype schematic, for the hot cells.

14. CONCLUSIONS

The incident analysis gave us the opportunity to understand where the problem was and work on it. This analysis of this issue showed that the activity vial had a tiny gap within its cap, the gap was eliminated using a rubber o-ring, in this way there is not gas leakage at all.

HVAC system configuration requires a meticulous analysis for these types of installations to prevent recirculation of radioactive gases that can affect workers or processes in such facilities. Our solution considered wind speed and direction using HYSPLIT model. Incident analysis gave a solution to prevent this type of events within our hot cells. Along with that study, hot cell intermediate components are in place to contain its dumped gases enough time to reduce its activity before being released to the main exhaust pipe.

The modifications have proved to work properly. We have replicated the initial issue and there was not radiation gas detected by the environmental system, even when the intermediate component is not attached to the hot cells output.

ACKNOWLEDGEMENTS

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