Report from a French incident

Three people locked themselves inside an irradiation facility to check safety systems

Description of incident

Equipment (radiation source)

The equipment in question is an electrostatic electron accelerator (2.5 MV, 35mA), used for the ionization treatment of fluorinated materials. Dose rates in normal operation are 80,000 Gy/s (electrons).

The equipment was bought second-hand in the USA, by a company X who installed it in France, and then sold it again to company Y, a sterilization-by-irradiation company. The market does not flourish, and the company is resold to an individual Z. After recovery and then legal forclosure, yet another party, the CEO of a local company, buys the buildings and the device and creates a new company, T whose objective is the irradiation treatment of fluorinated materials. Despite this complex path, there is no evidence that this history plays a specific role in the occurrence of the accident.

However, it should be noted that there are a number of anomalies:

- There is no proof that the pressurized metal tank (8 bars) of the accelerator underwent the regulatory tests under pressure (absence of testing stamps).
- Several defects and electrical non-conformities have been detected by a controlling body, commissioned by the various investors.
- The radiation protection authority is advised, notifies the regulatory authorities of these offenses and requests sanctions. Company T escapes the regulatory constraints by reducing the operating voltage (2.3 MV --> 1.7 MV) and the pressure (8.3 bars --> 4 bars).

Also

- The building is not intended to accommodate this equipment. This will cause constraints on the conveyor trajectory.
- The conveyor is a classic conveyor, not intended for work with high radiation levels: the lubricating oils and plastic components degrade under the effect of radiation; and certain materials oxidize in contact with the ozone produced by oxygen ionization.

Safety systems and working methods

When the equipment has to be started, the operator must follow a specific procedure and route which leads him to activate a terminal attesting to his passage, to close doors equipped with "mechanical stops" or an optical system, prior to being able to place the console command key from the "off" position to the "on" position. The course must be completed in less than three minutes or it must be restarted. The accelerator is then placed in the "high voltage" position. Then the beam is delivered by turning the key to "Beam Current".

The complete stop of the device automatically leads to a programmed installation stop of 15 minutes (time necessary to clear the ozone produced by the ionization of the air).

To avoid the delay associated with this safety feature, before intervening to fix a ventilation duct located directly below the electron beam scanning device (see 2nd accident below), the decision was taken to leave the command key in the "high voltage" position. In this position, the power supply to the tungsten filament (source of electrons) is cut, but the high voltage accelerator maintained. The residual current is very low, but dose rates of around 0.1 Gy/s remain.

In addition, to enter without passing through the metal door (which would stop the installation), the persons involved are accustomed to passing through the conveyor exit which does not have an intrusion detector.

Two accidents occurred:

1st accident

- An aluminum container, containing fluorinated products, sticks in the scanner. The products ignite, and the scanner's titanium window is damaged and will have to be replaced.
- The team leader C equipped with a mask to protect himself from the hydrofluoric acid (created by interaction of the water steam and fluorine released by the products), goes into the irradiation room to extinguish the fire.
- The origin of the blockage comes from the general design of the conveyor system, the relatively small size of the containers in relation to the width of the conveyor (the containers tend to cross), and the warping of the containers from the heat.

2nd accident

- The aluminum vent duct in question was weakened by radiation. It is brittle and friable. It has already been repaired previously with adhesive tape.
- Mr. A enters through the conveyor exit to repair the vent duct. After 15 minutes of unsuccessful attempts, the team leader C sends Mr. B and, eventually, intervenes himself.
- On several occasions, the three people involved pass their hands, their forearms, their heads and backs under the scanner. Mr. A who was crouched also exposed his legs.

Radiological consequences

The regulatory dosemeter films were not developed until after the appearance of the first symptoms of acute irradiation in the three accident victims (see below).

The dose equivalents measured are at the limits of total film darkness. Also, the values provided are only approximations.

In addition, these values do not represent the maximum doses sustained in so far as the dosimeters (worn on the chest) were not subject to the primary beam of electrons particularly when the parties involved passed their heads and their backs under scanner.

Name	Skin	Whole body
Mr. A	40 Sv	1 Sv
Mr. B	9 Sv	250 mSv
Team leader	5 Sv	?

Two days after the accidents, the **team leader C** notices an abnormal discoloration of his hands and forehead. Shortly after, he progressively loses the hair on the top of his head. Two weeks after, he noted the presence of a blister on his right hand (lifting of the skin under which there was translucent fluid). The affliction then spread to both hands and forearms and then the thorax and the forehead. Radiological burns covered 14 per cent of the skin surface, but they did not require skin grafts.

Mr. B felt itching of the scalp as soon as the intervention ended (after 15 minutes). In a few days, he was abnormally tanned and lost his hair. 2 weeks later, the blisters descended onto his back and along his trunk. Radiological burns covered 25 per cent of the surface of the body. He was subjected to skin grafts.

Mr. A was the most severely affected – 60% of the body surface area was burned. These burns affected the head, the trunk, the shoulders, all of the left leg, the right thigh and both arms. For six months, including 6 weeks in a coma, he was placed in a sterile chamber. He received a 18 skin transplants.

Analysis of the causes of the incident

Two large causal chains can be identified: a chain related to the equipment design, and a chain linked to operator behavior.

Equipment and facility:

The conveyor and the ventilation were not designed to operate in intense radiation fields. Thus, regular failures occurred, requiring interventions.

The physical security measures are flawed, since you can enter via the conveyor exit chicane of the equipment. Such an entry is not without (conventional) risks, since it is necessary to climb the conveyor 3 times to reach the scanner.

NB: One of the doors integrated into the security chain did not have a lock, and was secured by a tool case or a broom.

The device was not notified to the Labor Inspectorate.

Behavior of the operators and company management:

According to testimonies gathered during the trial which followed the accident, the three operators had been accustomed to entering the facility by the equipment exit, following the example of the Executive Director. The reasons include the loss of time caused by the official procedure (productivity pressures), a misunderstanding of risks, and simply habit.

The staff had received no risk training, except perhaps chemical (fear of HF).

Lessons to be learned from the incident

It is obvious that the regulations in force were not respected. Failures included:

- The non-notification of this radiation generator along with the information, and the absence of information which should accompany such notifications (risk analysis, design of local, etc.). The facility was known by the radiation protection authorities, which had requested sanctions by the official prosecutor. However, this changed nothing in terms of potential risk (the doses received would have been even higher if the device had functioned to its full design potential). The mandatory initial inspection by an approved body before putting the device into service had not been undertaken.
- The failure by the operator to apoint a qualified person, who must be trained in radiation protection, and who is responsible for the periodic analysis of workstations, to ensure compliance with protection measures, to identify situations likely to lead to exceptional or accidental exposures, and participate in the safety training of workers. Even with this appointment it is not clear whether the qualified person would have had the means to enhance the system security.
- The lack of training and information of parties involved by the employer, who is legally obliged to organize radiation protection training of exposed workers and to give them a written notice even if they are called to only occasionally enter into the controlled area.
- The appropriate signs intended to inform workers of the risks were in English, rather than the local language.
- The personnel (A and B) were interim workers, and thus not subject to the full system of regulation. These were classified as category B workers, and not subject to aptitude competency requirements, or prior medical examination.