Case history

The sinking of the *Mont-Louis* and nuclear safety

by Bernard Augustin

The cargo ship Mont-Louis *sank in the North Sea 10.5 nautical miles north of Ostend on Saturday, 25 August 1984, at approximately 7 p.m. – after colliding four hours and 40 minutes earlier with the car ferry* Olau Britannia *10 nautical miles off the Belgian cost and being towed westwards by tugs belonging to the Belgian salvaging company Union de Remorquage et de Sauvetage Belge.*

Because part of the cargo was nuclear material, this sea accident immediately gave rise to numerous commentaries in the national and international press. Although the accident did not at any time have any radiological or chemical effects, it was the word "nuclear" which imprinted itself on people's minds.

Following is a comprehensive nuclear-safety-oriented report on particular aspects of the sinking of this vessel and its cargo of radioactive materials and on the lessons to be learned.

The ship and its cargo

The *Mont-Louis,* a cargo ship with a deadweight capacity of about 5000 tonnes belonging to the Compagnie Générale Maritime, had taken on several hundred tonnes of various materials at Le Havre and Dunkirk and was bound for Riga in the USSR. Its load included 350 tonnes of uranium hexafluoride (UF_6) in 30 containers of type 48-Y as follows:

- *Batch 1* – 18 containers of slightly depleted uranium hexafluoride (U-235 isotope concentration 0.67%)
- *Batch 2* – 9 containers of natural uranium hexafluoride (U-235 isotope concentration 0.71%)
- *Batch 3* – 3 containers of slightly enriched uranium hexafluoride (U-235 isotope concentration 0.88%).

In addition, the ship was carrying 22 empty 30-B-type containers.

Batches 1 and 3 contained, in differing proportions, recycled uranium, i.e. uranium produced by reprocessing fuel irradiated in nuclear power plants.

As far as radioactivity is concerned, there was no significant difference between the batches, owing to specifications which demand extremely high purity of uranium from reprocessing plants.

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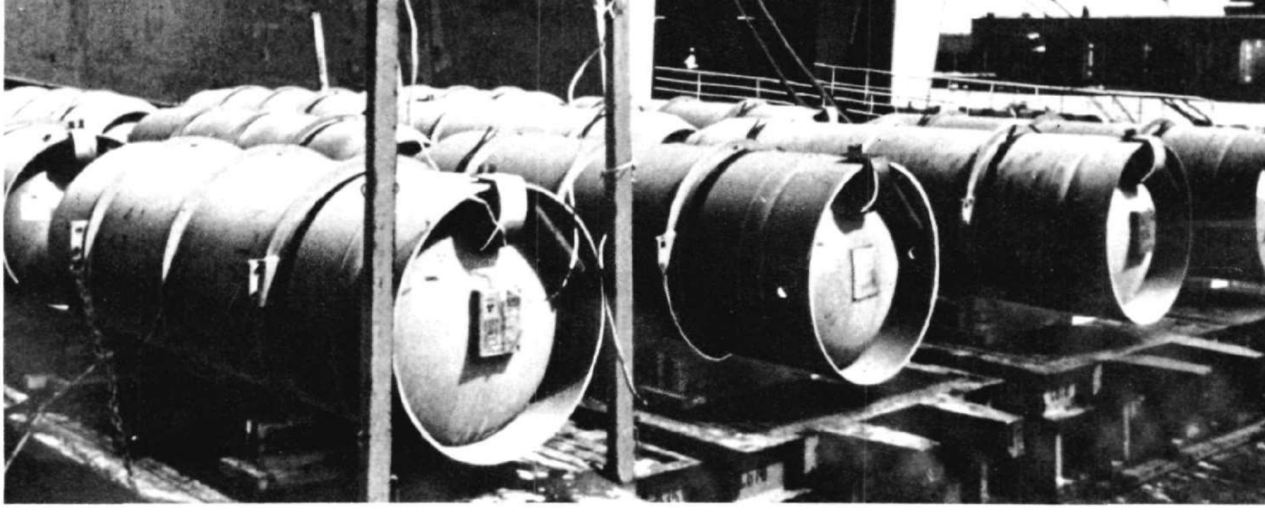
Drums such as these for transporting uranium hexafluoride were all safely and successfully recovered after the *Mont-Louis* accident.



The commercial context

The *Mont-Louis* was transporting nuclear material to be enriched in the Soviet Union under a commercial contract negotiated in 1973. After enrichment to a U-235 concentration of between 3.4% and 3.7%, the uranium was to have been returned to France (batch 1), Belgium (batch 2), and the Federal Republic of Germany (batch 3) for use as fuel in pressurized-water reactor power plants.

The load

The 48-Y-type casks containing the uranium hexafluoride were being carried in the bows of the ship. Designed in the United States, these packages have been used widely throughout the world for over 20 years.

The empty 30-B-type casks were stowed partly forward and partly aft. Being intended for the return transport of the uranium enriched to less than 4%, these casks had a double wall. A phenol foam with borax additive – filling the space between the outer shell and the internal container – acted as a fire-proofing barrier.

The casks were lashed down in a horizontal position on a steel cradle by means of chains fastened crosswise.

The collision

The collision occurred at 2:15 p.m. off the Belgian coast. It came from starboard aft, so the casks containing uranium hexafluoride suffered no frontal impact. Despite efforts continued throughout the afternoon, the hole produced by the collision caused the *Mont-Louis* to sink towards evening. It came to rest on its side at a depth of 14 metres. Since the ship was 19 metres wide, the hull remained visible at low tide.

One of the empty 30-B-type containers probably escaped through the hole. It was recovered shortly after the shipwreck on a beach near Ostend.

Peaceful utilization and international safeguards

The conversion of the uranium into uranium hexafluoride with a view to its subsequent enrichment in the Soviet Union was carried out by the company Comurhex in Pierrelatte, France.

The materials were exported in accordance with regulations of the European Atomic Energy Community (EURATOM). All the uranium sent to the Soviet Union was to have been returned, after enrichment, to the European Community and to be used for peaceful purposes under international safeguards.

Transport safety

In France, radioactive materials are classified as dangerous materials and are thus covered by the general regulations concerning the transport of dangerous materials.

Radioactive materials, classified under section IV-b of these general regulations, are subject to regulations based on the recommendations of the IAEA.

These recommendations are also the basis of the special provisions for radioactive materials made in various international regulations, such as those of the International Maritime Organization (IMO).

These regulations contain no particular requirements concerning the characteristics of ships carrying uranium hexafluoride.

Generally speaking, the safe transport of radioactive materials depends chiefly on the quality of the packaging. The point of departure in establishing regulations has therefore been to define different types of packaging by specifying the resistance tests which the packages must pass and to lay down criteria for assigning any product to be transported to a particular risk category as a means of determining what type of packaging should be used.

Because of its low activity, uranium hexafluoride enriched to less than 1% is classified in the lowest risk category and may be transported in "industrial" packages.

These conventional packages must fulfill certain leak-tightness and robustness conditions under the general regulations for the transport of dangerous materials; *inter alia,* they must be capable of withstanding a drop of 1.2 metres onto a concrete surface without being damaged to the point of losing their leak-tightness.

Moreover, although uranium hexafluoride is transported in crystalline form, the container is filled under a pressure of 4 bar and at a temperature of about 100°C, and under these conditions uranium hexafluoride is liquid. The packages, therefore, also fall under the regulations covering pressurized equipment and are designed to resist a service pressure of 14 bar.

The combination of these two sets of regulations imposes stringent requirements. In particular, the packages must be tested regularly every five years to verify their resistance to a hydrostatic pressure of twice the service pressure.

Tests performed in the United States have shown that these casks withstood a drop from a height of 9 metres onto an unyielding surface, which is equivalent to collision with a concrete wall at 90 kilometres per hour. Similarly, it is estimated that the casks can withstand an external pressure of some 20 bar equivalent to a depth of 200 metres.

National control of materials

Under the law of 25 July 1980, nuclear materials may not be kept in France except in facilities approved by the competent authorities. All movements of such materials must be reported to the Administration. Inspectors keep track of all the nuclear materials on French territory.

In order to export such materials, even temporarily as in the case of the *Mont-Louis* cargo, it is necessary to obtain a license, which is issued by the Ministry of

Economic, Financial and Budgetary Affairs only after an interministerial consultation conducted by the Ministry of Industrial Redeployment and Foreign Trade. For international transports, moreover, a special transport license is issued by the latter Ministry after it has examined the advance notification sent to it for each movement by the carrier. These procedures had been observed for the shipment in question. The local shipping authority in the port of Le Havre had also issued its permit.

The transport notification mentioned above, which had been confirmed by the centralized nuclear material accounting system established by decree of 12 May 1981 in application of the law of 25 July 1980, thus made it possible for the *Mont-Louis* cargo to be identified quickly by the public utilities.

Evaluation of the risks incurred

After the accident, and as soon as the nature of the radioactive materials on board the *Mont-Louis* became known, the experts set about analysing the risks involved on the unlikely assumption that one or more of the containers had not remained leak-tight.

The radioactive hazard was found to be insignificant, since the uranium transported in the containers was of low specific activity.

The second aspect examined was the chemical hazard. Uranium hexafluoride reacts with water in an exothermic reaction which releases hydrofluoric acid, a highly toxic gas, and uranyl fluoride. This reaction, which is not at all explosive, might have occurred had a container ceased to be leak-tight, the most vulnerable area being the closure valve. The ambient temperature of the sea water and the fact that the uranium hexafluoride was in the solid state, rather than liquid or gaseous, would have slowed down the reaction.

The hydrofluoric acid produced would have been dissolved in the water very quickly. Calculations based on the conservative hypothesis of an instantaneous reaction between the entire hexafluoride contents of the container and the sea water indicated that a little over two tonnes of hydrofluoric acid would have been released. The peak concentration, which would have been produced under such circumstances during the first 12 hours at a distance of 500 metres from the ship, was estimated at about 20 milligrams per litre, and no toxic effect is considered to be detectable below a concentration in the region of one gram per litre. Subsequently currents and tides would have restored the normal levels within a few days.

The uranyl fluoride would have dissolved more slowly before settling on the sea bed.

Lastly, it should be pointed out that the foam in the non-leak-tight annular space between the outer shell and the inner container of the empty 30-B-type casks might have released by hydrolysis various organic acids, such as oxalic acid, and also various boric acid derivatives, but none of these is radioactive.

Action taken

The work of salvaging the cargo began on 1 September with the emplacement of a pontoon equipped with cranes, the Compagnie Générale Maritime having concluded a contract with the Belgian company, Union de Remorquage et de Sauvetage, and the Dutch company, Smit Tak.

A shielded container was provided by the Federal Republic of Germany in case a damaged cask was recovered.

Numerous systematic checks were made by the Belgian and French public health laboratories:

- As of Sunday morning, 26 August, samples were taken from both the surface and the deep water around the pontoon.
- Subsequently, water samples were also taken inside the hold from among the containers.
- Each crew member of the *Mont-Louis* underwent a medical examination.
- Each 48-Y-type container was tested for leak-tightness on board the salvage barge and later in the port of Dunkirk.
- Sixty-four personal dosimeters were distributed to the unloading crews and operating teams in Dunkirk port by technicians of the French Central Service for Protection against Ionizing Radiation (SCPRI), who provided radiation protection services for all four container trans-shipment operations from a 28-tonne semi-trailer.

Results: successful recovery

All 30 uranium hexafluoride 48-Y-type containers and 16 of the 22 empty 30-B-type containers were recovered. This operation was successfully completed on 4 October 1984 despite the unfavourable weather conditions at sea. Only 6 empty 30-B-type containers were lost – recovery would have been technically difficult and not worthwhile from the points of view of cost and safety.

The containers had, of course, suffered from the storm while they were in the open hold exposed to the waves (dented walls, torn-off valve covers, some bent valves).

Upon examination of the recovered 30 containers of 48-Y-type, only one very small leak was found in one closure valve, due probably to buffeting by the storm. This slight fault had allowed a small amount of water to enter while the container was immersed in the hold; it was detected when the container was brought up into the open air, before the internal and external pressures had equalized. The leak was immediately stopped with resin, and as a precaution the cask was placed in the shielded container.

Between 25 August and 11 October 1984, the SCPRI either received or took a total of 217 samples, which were subjected to 752 different analyses, and performed 146 dose-rate measurements on the containers themselves.

None of the results showed the slightest indication of a significant leakage, neither radioactive (natural or recycled uranium) nor physico-chemical (fluorine or hydrofluoric acid). The only notable observation was the high acidity of samples taken from the double wall of an empty 30-B-type container. As explained above, this was caused by oxalic acid without any trace of radioactivity and was due exclusively to the chemical composition of the double wall.

Moreover, the radiotoxicological tests performed on the crew of the *Mont-Louis* by the SCPRI, in conjunction with the occupational health service concerned, all proved to be negative.

No significant dose was recorded during the unloading and loading operations at Dunkirk.

Lastly, the tests performed upon unloading at Pierrelatte showed that no leakage had occurred during transport from Dunkirk port, even in the cask placed inside the shielded container.

Thus, despite the severe stresses suffered as a result of the shipwreck and the difficulty of the salvage operations, the entire uranium hexafluoride cargo was recovered without detriment to the health of the salvage teams or to the environment.

Lessons to be learned

In conclusion, it should be stressed that *the sea accident of the Mont-Louis had no radiological or chemical consequences.*

The main lesson to be learned is the confirmation, for this type of accident, that the assumptions underlying national and international regulations for the transport of radioactive materials are valid. The 48-Y-type containers displayed the expected degree of resistance, both during the collision and while they were submerged. It was possible to recover the containers without any leakage of toxic products out of the containment vessel.

Other points deserving comment are as follows:

- A shielded container was used as an extreme precaution to transport a cask which had temporarily shown a very slight leak. This operation demonstrated the usefulness of having this type of equipment on hand in case of land or sea transport accidents involving radioactive materials.
- It would seem worthwhile to improve the safety design of container valves by modifying the valve protection caps. Because this kind of equipment is used widely throughout the world, any such modification would have to be accepted internationally.
- The stowage of packages on board ship should be reviewed. It should also be ensured that the dispatch note issued to the carrier is always accompanied by a concise description of such hazards as the materials carried may present and of the appropriate measures to be taken in the event of an accident.
- Finally, the hazard presented by uranium hexafluoride is primarily a chemical one, but international regulations for the transport of radioactive materials stress mainly the radioactive hazard. It will therefore be proposed that an amendment to the regulations should be considered.

Forthcoming IAEA conferences...

Date	Subject	Place
1985		
20–24 May	International Symposium on Advances in Nuclear Power Plant Availability, Maintainability and Operation	Munich Fed. Rep. of Germany
22–26 July	International Symposium on Fast Breeder Reactor Experience and Future Trends	Lyons France
19–23 August	FAO/IAEA International Symposium on Nuclear Techniques and In-vitro Culture for Plant Improvement	Vienna
26–30 August	WHO/IAEA International Symposium on Nuclear Techniques in Developing Countries	Vienna
28 October– 1 November	International Symposium on Source Term Evaluation for Accident Conditions	Columbus, Ohio USA
4–8 November	International Symposium on Emergency Planning and Preparedness for Nuclear Facilities	Rome

... and seminars

1985		
29 April–2 May	Seminar on Quality Control in Radioimmunoassay in Latin America	Buenos Aires
3–7 June	FAO/IAEA Seminar for Developing Countries in Africa and the Middle East on Research Using Nuclear Techniques Aimed at Improving Meat, Milk and Wool Production From Ruminant Animals	Ankara
1–5 July	FAO/IAEA Seminar on Research and Development of Controlled-Release Technology for Agrochemicals Using Isotopes	Vienna
9–12 September	Seminar on Costs and Financing of Nuclear Power Programmes in Developing Countries	Vienna
9–13 September	Seminar on Applied Research and Service Activities for Research Reactor Operations	Copenhagen
7–11 October	Seminar on Management Options for Low- and Intermediate-Level Wastes in Latin America	Lima
11–15 November	Seminar on Modifications Required for Safety of Nuclear Facilities (Backfittings)	Munich Fed. Rep. of Germany
18–22 November	Seminar on Practices for Radiation Sterilization of Medical Supplies Suited to the Upgrading of Local Health Care Services for Developing Countries in Africa and the Middle East	Nairobi

Further information on these conferences can be obtained from the IAEA Conference Service, A-1400 Vienna, or the appropriate body in each Member State, e.g., the authority responsible for nuclear matters, or the Ministry of Foreign Affairs.