world nuclear transport institute

Fact Sheet

Document Reference Number
WNTI/PUB/2026/004

Revision Number
001

Media and Communications – Uranium Hexafluoride (UF_6)

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1. Introduction

The World Nuclear Transport Institute (WNTI) is a Non-Governmental Organisation (NGO) that represents the nuclear transport industry focusing on the needs of its members.

One of the ways WNTI does this is through its Observer Status role at the International Atomic Energy Agency (IAEA). The WNTI actively participates in IAEA discussions on the content and meaning of the radioactive materials transport regulations, contributing to development of these IAEA regulations and of associated guidance documents and technical reports. WNTI also has Consultative status at the International Maritime Organisation (IMO) where it is the only NGO recognised as an industry expert in transport of radioactive material. The WNTI is also a Category A Liaison Organization to the International Organization for Standardization (ISO) for international standards applicable to the radioactive material transport industry.

The WNTI utilizes its extensive network of contacts to act on behalf of its members to represent and advocate with industry groups and regulators to promote safe and secure radioactive material transport. The purpose of this fact sheet on Uranium Hexafluoride (UF_6) transport is to provide information to members and the public, including emergency responders, on the nature of UF_6 and how it is transported.

Our vision is for the transport of nuclear (radioactive) materials to be regarded as safe and secure and as a model for the transport of all dangerous goods/hazardous materials.

We provide up to date information and educational tools to promote safe and secure transportation of radioactive materials.

2. Purpose of this Fact Sheet

This fact sheet focusses on UF_6, including its hazards and risks and how UF_6 fits within the nuclear fuel cycle. Its purpose is to provide communicators and educators with clear and concise information that can be shared broadly. The information is intended to be understood by both technical and non-technical people and is aimed at persons having little or no knowledge of the nuclear fuel cycle industry or of the transport of radioactive materials. This fact sheet also provides basic information on chemical and radiological protection requirements applicable in response to any accidents, including protection from the corrosive and toxic by-products of UF_6 when reacting with moist air.

3. What is Uranium Hexafluoride (UF_6)

Uranium Hexafluoride (UF_6) is a white solid crystalline material, chemical compound of Uranium, which can be turned into a gas at relatively low temperatures. Solid form UF_6 sublimes (turns directly to gas) with a vapour pressure of 1 atmosphere at 56.5°C. It is this property which makes UF_6 particularly useful in the nuclear fuel cycle, as the only chemical form of Uranium allowing industrial scale enrichment.

UF_6 is a radioactive material due to its Uranium content. Uranium is mainly an alpha and gamma emitter due to its characteristic decay products, with negligible beta and neutron emission. A person standing for 2 hours next to a cylinder filled with natural UF_6 would receive approximately a 7 micro sievert (μSv) effective dose, which is comparable to one dental X-ray and significantly less than the dose on a transatlantic flight which is about 80 μSv [Ref 1].

4. Uranium as Resource

Natural Uranium is composed almost exclusively of two stable isotopes, with about 0.7% by mass of the Uranium being the fissile uranium-235 isotope and the majority being the non-fissile uranium-238 isotope. The term 'fissile' means that under very specific conditions and in sufficient quantities, the uranium-235 atoms can split and produce a burst of heat energy. This heat energy is the basis of a nuclear power reactor, however the naturally occurring 0.7% concentration of uranium-235 is not sufficient to sustain a nuclear chain reaction.

The fuel required by most commercial nuclear reactors needs a uranium-235 isotope fissile content of between 3.5 and 5%. This higher uranium-235 content is achieved through a process known as "enrichment" which is carried out in gas centrifuges using gaseous form UF_6. Heavy water and older generation commercial nuclear reactors use natural (not enriched) Uranium.

UF_6 is the ideal chemical compound for the enrichment process because it exists in gaseous form at relatively low temperatures and pressures. Following mining and purification, Uranium Ore Concentrate (UOC) [Ref 2] is chemically converted into UF_6 for enrichment.

Figure 1: Uranium Ore

Figure 2: UOC

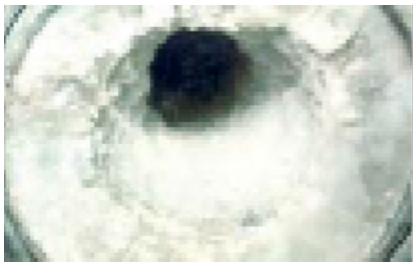
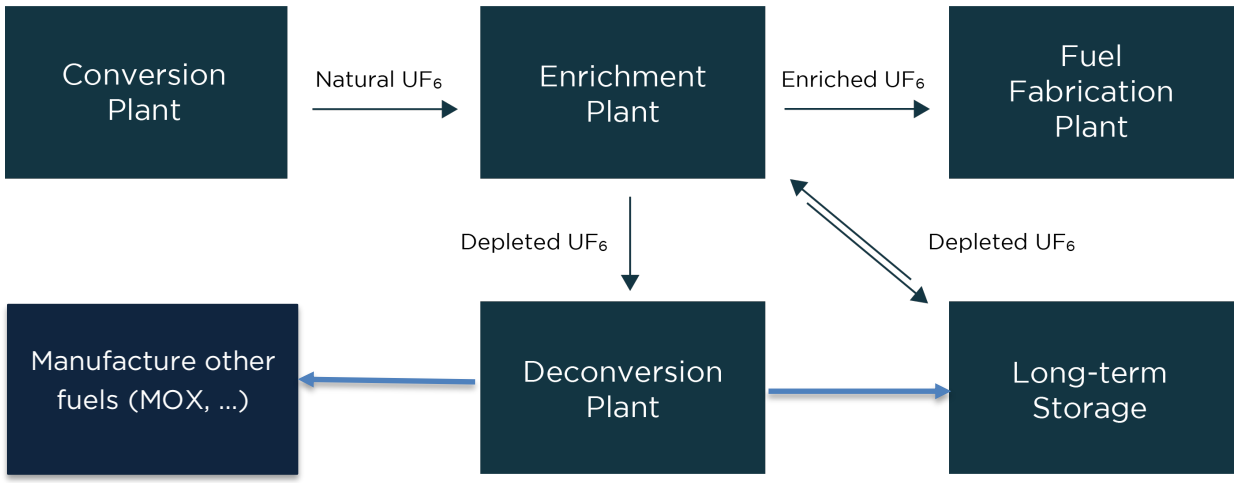


Figure 3: UF_6

In enrichment plants, centrifuges separate the isotopes of uranium-235 and uranium-238 in a physical process by using the slightly different masses of the two isotopes. The result is a depleted UF_6 stream (0.2 – 0.3% of uranium-235; hence non-fissile) and an enriched UF_6 stream (3.5 – 5% of uranium-235; hence fissile / fissile excepted). Future trends may lead to this enrichment increasing towards 20% to reduce reloading cycles of commercial nuclear power plants and support new reactor technologies using High Assay Low Enriched Uranium (HALEU) fuels.



5. The Hazards of Uranium Hexafluoride (UF_6)

Uranium is a naturally occurring element that exists in varying concentrations throughout the Earth's crust. Trace amounts of Uranium can be found in almost everything, rocks, soil, streams, food and in the human body. It is the heaviest naturally occurring element found on Earth and is classified as a heavy metal. It is naturally radioactive, emitting radiation as it decays slowly and transforms to other radioactive elements, which themselves decay over time. This is known as a decay chain and in nature the stable Uranium isotopes exist in equilibrium with 13 other decay products which contribute to natural background radiation. Uranium Hexafluoride (UF_6) is a chemical compound of Uranium used in the 'front end' of the nuclear fuel cycle.

The radiological hazards from Uranium can be the result of external (outside the body) or internal (inside the body) radiation exposure. External exposure refers to gamma radiation from Uranium which is generally low energy and presents a minimal risk to health. Internal exposure results from the Uranium being ingested or inhaled, however the risk to health is also relatively low, provided safety precautions are observed to protect against the radiological and chemical hazards. UF_6 from reprocessed material may contain higher dose rates.

Although UF_6 falls under the classification as a low specific activity radioactive material (LSA) for transportation, it also presents subsidiary hazards because it produces corrosive and toxic by-products on contact with moist air if in contact with the atmosphere. The reaction of UF_6 with water results in soluble uranyl fluoride (UO_2F_2) and gaseous hydrogen fluoride (HF) according to the following equation.

$$UF_6 + 2H_2O \longrightarrow UO_2F_2 + 4HF$$

The gaseous HF, on contact with water, produces hydrofluoric acid, which is strongly corrosive. The reaction products of UF_6 also have significant toxic properties.

The Transport regulations [Ref 3] define the main hazard for solid UF_6 in larger quantities (≥ 100 g UF_6 per package) as radioactive followed by toxic and corrosive subsidiary hazards. For quantities < 100 g of UF_6

per package of non-fissile or fissile excepted UF_6 (such as the transport of samples), the main hazard is toxicity followed by corrosive and radioactive subsidiary hazards.

6. Fissile, fissile excepted and non-Fissile UF_6

When UF_6 is produced from natural Uranium, it has the same proportion of uranium-235 to uranium as in the Uranium Ore Concentrate it is transformed from (0.7% uranium-235). This UF_6 is classed as non-fissile. After enrichment (which is the purpose of UF_6 in the nuclear fuel cycle), the enriched Uranium in the UF_6 contains typically 3.5 – 5% of uranium-235 and is classed as fissile. This means that it could potentially support a nuclear chain reaction under certain very specific conditions and must hence be handled and transported in a way that ensures this does not occur. When fissile UF_6 is transported, the cylinders have a lower payload (than cylinders used for non-fissile UF_6) and have additional labelling to identify the radioactive contents as fissile.

When low quantities of enriched Uranium are transported as samples or other, the small total quantity of uranium-235 per package may allow classifying as fissile excepted material, where the risk of nuclear chain reaction may safely be neglected under any conditions, and the material may be packaged and transported in the same manner as non-fissile uranium.

7. Dangerous Goods and Hazardous Materials

Dangerous Goods or Hazardous Materials are classified as materials that from their physical and/or chemical properties may have an adverse effect on people, property and/or the environment, leading to such situations as fires, explosions, corrosion and poisoning. Adverse health effects can be either immediate or long term.

UF_6 is classified and referred to as being either a Dangerous Good or Hazardous Material depending on the applicable country, jurisdiction or regional location through which it is being transported.

8. Proper Shipping Name

The Proper Shipping Name comprises the universally understood standard technical name for a range of dangerous goods/hazardous materials along with additional words describing the nature, properties and composition of that material.

Each category of dangerous goods or hazardous material has a corresponding United Nations Identification Number (UN number) associated with the Proper Shipping Name. This information is used by transporters and emergency response personnel to identify the nature of the dangerous goods or hazardous material being transported.

The Proper Shipping Name for UF_6 depends on the quantity being transported and whether it is enriched (fissile). The possibilities are:

- UN2977 “Radioactive Material, Uranium Hexafluoride, fissile”
- UN2978 “Radioactive Material, Uranium Hexafluoride, non-fissile or fissile excepted”
- UN3507 “Uranium Hexafluoride, Radioactive Material, excepted package, less than 0.1 kg per package, non-fissile or fissile excepted”

Hence:

- UN 2977 and UN2978 are for quantities of UF_6 of 100 g or more per package, and
- UN3507 is for quantities of UF_6 less than 100 g per package enriched up to 5%, and also for higher enrichments which may also fall under the classification as “non-fissile” or “fissile excepted” due to lower quantities of fissile uranium-235 and Uranium in total.

Both the UN number and the Proper Shipping Name are displayed on the outside of packages, and the UN number displayed on freight containers, and both are also provided in shipping and transport documents, providing important safety related information to transporters, first responders and members of the public.

9. Physical Characteristics of UF_6

At 20°C, UF_6 is a solid, colourless, crystalline mass with a density of 5.06 g/cm^3. At a temperature of 56.5°C, the vapour pressure equals atmospheric pressure (1 bar or 100 kPa). The triple point of UF_6 is at 64°C and 1.5 bar. At and above the triple point, UF_6 can exist in the solid, liquid and gaseous phases. Below its triple point, UF_6 can only be a solid or a gas. The different phases and phase changes are shown in the diagram below.

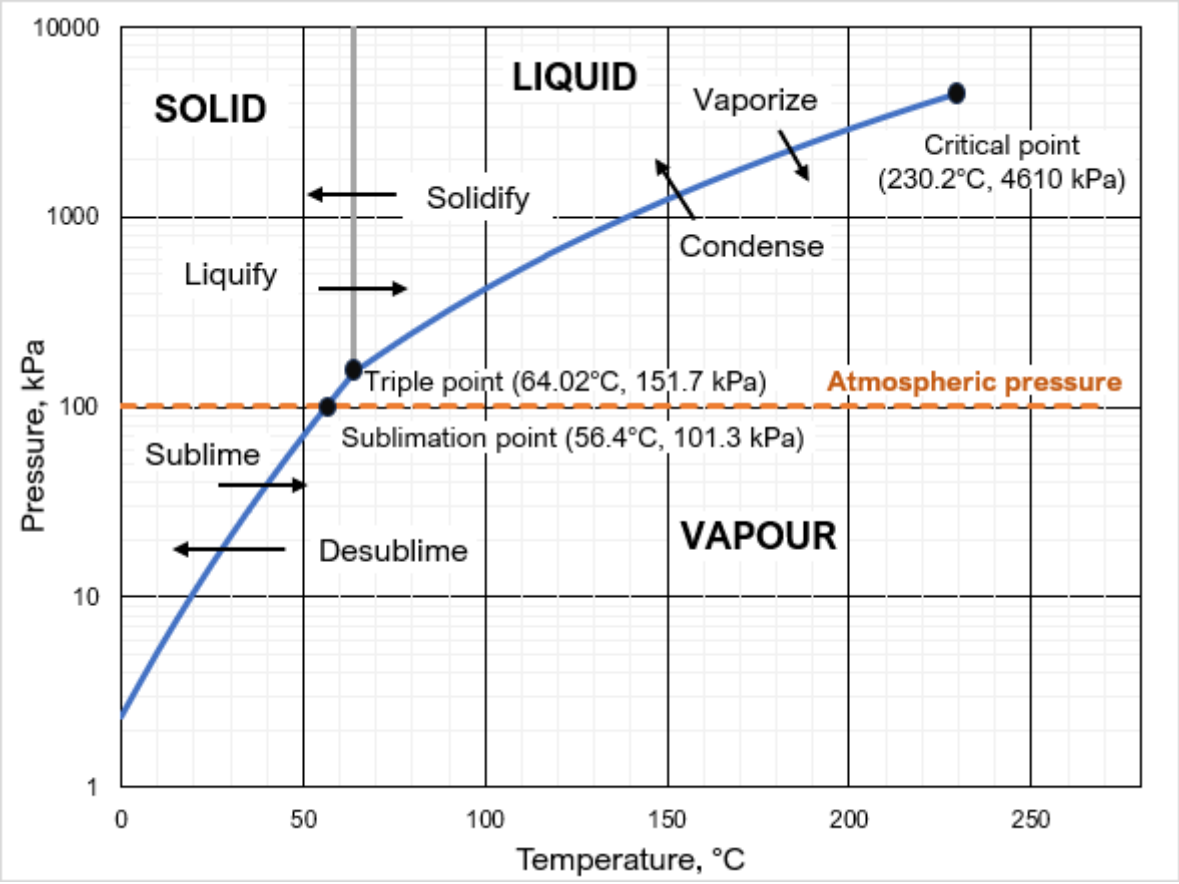


Figure 4: Phase transition diagram UF_6

10. Packages, Freight Containers and Transport

UF_6 is transported by road, rail, sea and air and is regulated by international and national dangerous goods regulations. For quantities of UF_6 of 0.1 kg or more, the primary hazard is from the radioactivity and therefore classified as Class 7, with Class 6.1 (toxic) and Class 8 (corrosive) as subsidiary hazards. The packages comprising cylinders, which are manufactured according to industry standards ISO 7195 and/ or ANSI N14.1, need to withstand drop and fire tests, and for fissile UF_6, require to meet additional tests simulating accident conditions of transport, whilst continuing to meet defined leakage rates. These requirements are prescribed in the "IAEA Regulations for the Safe Transport of Radioactive Material" [Ref 3] and in the "United Nations Recommendations for the Transport of Dangerous Goods" [Ref 4] as well as in the nationally derived dangerous goods transport regulations around the world.

10.1. Transport Cylinders

Natural and depleted UF_6 is transported in type 48Y cylinders, whereas for fissile quantities of enriched UF_6, smaller type 30B cylinders are used. Other cylinder designs are available and used for smaller quantities of UF_6. Outer protection systems, for example as blanket or composite thermal protection (BTP or CTP) for 48Y or protective shipping packages (PSP) for 30B may be required to comply with the regulatory transport requirements. The cylinders are filled and emptied by heating and pressurising the UF_6 to turn it into a liquid which can flow into or out of the transport cylinder. Prior to transport, the cylinder is cooled and the pressure reduced to ensure the UF_6 remains solid for transport.

To be approved by international safety authorities, these package designs (composed by the cylinders and outer protection together) have undergone a series of tests to demonstrate their robustness to certain incident scenarios during transport. These include:

- 30B cylinder packages containing fissile UF_6 are subject to a drop test from a height of 9 meters onto a rigid, non-deformable target and of 1 meter onto a rigid bar,
- 48Y cylinder packages are subject to a drop test from a height of 0.6 meters onto a rigid, non-deformable target,
- both package types are subject to a:
    - a fire test involving exposure of the package to an all-engulfing hydrocarbon fire at 800 °C for 30 minutes, and
    - a hydrostatic pressure test (not less than 2,76 MPa).

Following some test scenarios, the cylinders must remain leak tight [Ref 3].

Figure 5: Type 30B Cylinder

Figure 6: Type 48Y Cylinder

30B Cylinder
Diameter: ~0,75 m (30 inch)
Length: ~2 m
Wall Thickness: 12,7 mm (1/2 inch)
Volume: ~750 L
Tare weight: ~635 kg
Max. fill: 2,277 kg
Gross weight: ~3,000 kg
Proof pressure: 2,76 MPa (5-year inspection)

Max. Operating temp: 121°C/250°F

48Y Cylinder
Diameter: ~1,25 m (48 inch)
Length: ~4 m
Wall Thickness: 16 mm (5/8 inch)
Volume: ~4,000 L
Tare weight: ~2,500 kg
Max. fill: 12,501 kg
Gross weight: ~15,000 kg
Proof pressure: 2,76 MPa (5-year inspection)
Max. Operating temp: 121°C/250°F

UF_6 is normally transported using standard multimodal ISO freight container-based flatracks. These can be easily handled between road trailers, rail wagons and sea vessels. One flatrack can accommodate up to four 30B cylinders loaded each in its PSP or one 48Y cylinder. 48Y cylinders are also sometimes transported as single units without flatracks on road trailers, rail wagons and in sea vessel holds.

Figure 7: 30B Cylinder with protective shipping package

Figure 8: 48Y Cylinder with outer protection

Figure 9: DN30 protective shipping package PSP

Figure 10: 48Y Cylinder on with BTP outer protection

There are several PSP designs available for transport of type 30B cylinders. The DN30 [Ref 5] is a more recent PSP design and an important technical development as compared to the previous and still current PSPs which have been in use for several decades. In addition to improved handling and increased safety, the DN30 is also particularly suitable for the transportation of UF_6 issued from reprocessed Uranium. UF_6 from reprocessed material or freshly emptied cylinders may present higher dose rates.

10.2. Transport sample packages

For shipments of sample quantities of UF_6, other packages are used, which include small cylinders for transport of 100 g or more of UF_6 per package, or other systems for transport of less than 100 g UF_6 per package.

11. Markings, Labels, and Placards

Package markings provide specific information describing the packages, the material and its radioactive property and other hazards.

Package and freight container labels provide transporters, first responders and members of the public with important safety related information identifying the hazards and the precautions required for handling.

Placards on freight containers contain basic textual information along with the applicable UN number indicating the presence of radioactive material associated with the packages or freight container.

Collectively, markings, labels and placards provide an effective internationally recognised means of communicating information on the radioactive materials being transported by road, rail, sea or air transport.

11.1. Radioactive and fissile material labelling

In common with all dangerous goods transport, appropriate hazard labels must be applied to the packages and freight containers carrying UF_6. The transport of radioactive material requires the shipper to determine and assign a Label Category which relates to the maximum dose rate measured on the surface and at a distance of one metre from the external surface of the package or freight container. The labels, which provide information on the radioactive material and dose rates, are applied to the outside of packages and freight containers to assist transporters, emergency response personnel and members of the public to identify the nature of the dangerous goods or hazardous material being transported.

Two factors hence determine the package or freight container label category, these being the highest dose rate on the external package surface, and the Transport Index (TI) (which is determined by the highest dose rate at 1 meter from the external surface). Category I-WHITE is the lowest category corresponding to a transport index of 0 (zero). The labels are placed on the outside of the packages or freight container to indicate that the packages being transported contain radioactive material. Depending on the package dose rates measured, the labels for UF_6 packages and freight containers can be category I-WHITE, II-YELLOW or III-YELLOW. These labels also display the material being transported, the radioactivity in Becquerels and, for label categories II-YELLOW and III-YELLOW, the Transport Index. In addition, packages and freight containers containing fissile UF_6 must be labelled with FISSILE material labels, adjacent to each radioactive label.

Category II YELLOW label

Fissile material label

Figure 11 Fissile Material Labels

11.1. Subsidiary hazard labelling

Due to the subsidiary toxic and corrosive hazard of UF_6, packages and freight containers must also be labelled with toxic and corrosive hazard labels.

Toxic hazard label

Corrosive hazard label

Figure 12: Typical UF_6 Hazard Labels

12. Safety Precautions

Undamaged packages are quite safe to handle and there is no radiological danger from approaching undamaged packages. Primarily due to its toxic and corrosive properties however, direct exposure to UF_6 or its decomposition products is hazardous and can be fatal if material is swallowed or inhaled. It can also cause severe skin burns and eye damage. Therefore, if a leak is suspected, the area must immediately be evacuated (up-wind if possible) and appropriate protective clothing and breathing equipment worn before any approach is made to damaged packages.

13. Protection During Incident Response

In the event of a transport accident, packages which are not seriously damaged and are not leaking can be safely handled and recovered. Where lifting of a package is required, this should be done using the 48Y cylinder lifting lugs or cylinder type 30B PSP lifting devices if possible. Where damage and leakage are suspected, then, as noted above, UF_6 on contact with moist air can be fatal if swallowed or inhaled. Direct contact can also cause severe skin burns and eye damage, and the material is toxic to aquatic life with long lasting effects [Ref 6]. In the event of an accident leading to release of UF_6 during transport, the first priority, therefore, is to evacuate the area (upwind if possible) and establish a cordon of at least 25 m – 50 m.

13.1. Dealing with Leaking Packages

In the very unlikely event of a leaking package, self-contained breathing apparatus and protective chemical suits should be worn.

Smaller leakages tend to self-seal through the UF_6 reacting with moisture and forming UO_2F_2 residues at the leakage points. Larger holes may be sealed with adhesive tape. Pressurised CO_2 can also be used to “freeze” the leak. Any cloud of released material from a large release can also be settled using a fine water spray.

13.2. Fire

Self-contained breathing apparatus and protective chemical suits should be worn.

Undamaged packages should be kept cool using water spray.

If packages are leaking, attempt to extinguish the fire in the surrounding material and keep the package as cool as possible with a water spray. Water should not be sprayed directly at the leak.

14. Key Messages

Many materials contain radioactive elements. When the concentration or quantity exceeds an internationally agreed level, the material is then defined as being radioactive, becoming subject to regulatory control, including when it is transported.

UF_6 is radioactive material, however it presents a very low external radiological hazard. The primary health hazard associated with UF_6 is in the unlikely event of a leak when toxic and corrosive products are released. These are a hazard both radiologically and chemically if swallowed or inhaled. There is also a hazard to any exposed skin or eyes from the corrosive gasses produced. Therefore, in the event of a transport

accident, while it is safe to approach and handle packages which are intact, any packages which are damaged and suspected to be leaking must only be approached with appropriate protective clothing and breathing apparatus.

The transport of radioactive material must comply with internationally agreed regulations published by the IAEA. These regulations ensure that UF_6 is transported in robust cylinders to minimise the risk of any leakage, even in an accident.

Markings, Labels and Placards provide transporters, first responders and members of the public with important safety related information allowing them to identify the hazards and precautions required.

15. References

1. UK Government Guidance Ionising Radiation: dose comparisons, March 2011, www.gov.uk
2. Factsheet – Uranium Ore Concentrates, WNTI, 2025, www.wnti.co.uk
3. Regulations for the Safe Transport of Radioactive Material, IAEA SSR-6 (Rev. 1), 2018, and SSR-6 (Rev.2), 2025, www.ieae.org
4. UN Model Regulations on the Transport of Dangerous Goods, (Rev 24), 2025, www.unece.org
5. Developing the DN30, Nuclear Engineering International, 2019, www.neimagazine.com
6. Safety Data Sheet Uranium Hexafluoride (UF_6), US Department of Energy, 2020, www.energy.gov

Appendix 1

Handout for ad-hoc media communications in case of an incident

Uranium hexafluoride

What is it?

- A nuclear form of Uranium that requires further processing for use in light water nuclear reactors
- UF_6 can be relatively easily transformed into a solid, a liquid or a gas depending upon the temperature to which it is exposed
- It is transported as a solid, which looks like rock salt

Is it dangerous?

- There are chemical and radiation risks associated with exposure to UF_6 with the chemical risk being more significant
- UF_6 will react with water, including water vapours in the air, to form hydrogen fluoride (HF), which is highly corrosive and uranyl fluoride (UO_2F_2)
- Radiation emitted from a UF_6 cylinder is usually very low because of its purity and because it has not been used as fuel
- Radiation is practically undetectable ten metres away from a loaded UF_6 cylinder
- A person one metre away from a loaded UF_6 cylinder would receive relatively low radiation dose rate – leading to total exposure in two hours less to that received by a passenger on a transatlantic flight

How is this material transported?

- UF_6 is transported and stored in specially designed, thick-walled (5/8" thick) steel cylinders
- UF_6 cylinders are designed to maintain structural integrity through normal conditions of transport, and this has been proven by decades of experience
- Additionally, cylinders can maintain integrity for 30 minutes engulfed in flames at a temperature of 800 degrees Celsius, which is a typical temperature for a petroleum fire,

What health risks are associated with this material?

- Severe acid burns can occur if HF in high concentrations comes into contact with the skin or eyes
- Chest discomfort can occur if a small amount of HF or UO_2F_2 is ingested or inhaled
- Kidney damage can occur due to the chemical toxicity of the Uranium
- If a large amount of HF is ingested or inhaled, the result can be fatal
  It is also possible that internal organs could receive a small radiation dose

How does the industry use this material?

- The industry produces and processes UF_6 for nuclear fuel production. The material is therefore stored in special cylinders and transported around the world.

How should members of the public protect themselves if there is a release of this material?

- Members of the public should evacuate the area immediately if there is a release of UF_6 or shelter-in-place depending upon the situation
- In the unlikely case of a release during transportation, evacuation in an upwind direction is likely the best course of action

Where can members of the public find more information about this material in general?

- Various companies like Cameco, Orano, Urenco or Westinghouse provide significant amounts of information regarding its products and processes on their websites. In addition, national Authorities and other NGO organisations such as WNTI provide information regarding the material.

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Disclaimer

Whilst the WNTI will use all reasonable efforts to ensure that the information in this fact sheet is accurate, we cannot guarantee the accuracy of all information and we will accept no liability for any loss or damages incurred, howsoever caused and cannot be held liable for any use or reliance you may make of or put on it. The WNTI also cannot be held liable for your use or inability to use the fact sheet or the information or services that it contains. Errors and Omissions Accepted. This should not be relied upon in place of Legal Advice.

The WNTI offers the use of this fact sheet freely to members and non-members of the transport community. Where any interpretation of the information has been made, it has been done so with the interests of the wider transport community. Although the Fact Sheet has been extensively reviewed by industry experts, if you have any issues in use or content, please contact the WNTI so we can rectify the issues and conflicts in systems etc.

The information presented is valid as per July2026

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