WNTI

WORLD NUCLEAR TRANSPORT INSTITUTE

FACT SHEET

Uranium Hexafluoride (UF6)

Dedicated to the safe, efficient and
reliable transport of radioactive materials

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1. INTRODUCTION

Uranium hexafluoride (UF6) is a chemical compound used in the 'front end' of the nuclear fuel cycle. The 'front end' consists of the following steps; mining and milling, refining, conversion, enrichment and fuel fabrication. UF6 is used in the steps conversion, enrichment and fuel fabrication.

UF6 is converted from uranium ore concentrate (UOC) (see WNTI Fact sheet) in conversion plants and is used in uranium enrichment facilities to produce enriched UF6. The enriched UF6 is converted to uranium oxide in fuel fabrication plants to produce fuel for nuclear reactors for electricity generation.

Image 1. - Ore

Image 2. - Uranium Hexafluoride

Image 3. - Uranium Hexafluoride

2. PREPARATION

In a conversion plant the uranium ore concentrate (U3O8) is chemically converted to uranium tetra fluoride (UF4). The UF4 is then reacted with elemental fluorine (F2) at elevated temperatures to create uranium hexafluoride (UF6).

Because the commercial enrichment facilities use a physical process, the UF6 does not undergo chemical changes during enrichment operations. The enriched UF6 is chemically converted to uranium oxide (UO2) in a fuel fabrication plant.

3. PROPERTIES

At 20°C UF6 is a solid colourless crystalline mass with a density of 5.06 g/cm3. At a temperature of 56.5 °C, the vapour pressure is atmospheric (1 bar). The triple point of UF6 is at 64 °C and 1.5 bar. At and above the triple point UF6 exists in the solid, liquid and gaseous phase. Below the triple point UF6 is solid or gaseous. The different phase and phase changes are shown in the diagram below.

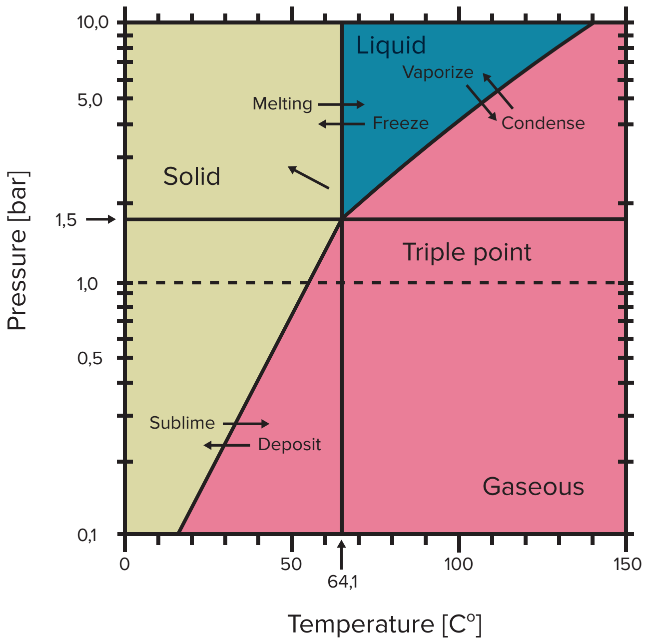

Image 1. - UF6 Phase Diagram

UF6 is a radioactive material. Its radioactivity derives from the uranium component. Uranium is mainly an Alpha “α” and Gamma “γ” emitter due to its typical decay products. There is a negligible Beta “β” and neutron emission. A person standing for 2 hours next to a cylinder filled with natural UF6 would receive approximately a 7 micro Sievert (µSv) effective dose, which is comparable to one dental X-ray or a 2.5-hour commercial flight.

Although UF6 is classified as a low specific activity material[1], it bears a subsidiary hazard because it produces corrosive and chemotoxic by-products on contact with moist air if released to the atmosphere. The reaction of UF6 with water results in soluble uranyl fluoride (UO2F2) and gaseous hydrogen fluoride (HF) according to the following equation.

UF6 + 2 H2O → UO2F2 + 4 HF

The gaseous HF with water (body fluid) forms hydrofluoric acid, which is a strong corrosive. The reaction products of UF6 have toxic properties, but the most predominant subsidiary risk is corrosivity.

[1]According to IAEA SSR-6 LSA material means radioactive material that by its nature has a limited specific activity

4. APPLICATION

Natural uranium consists mainly of two isotopes 238U (99.3 %) and 235U (0.7 %). The fuel required by most nuclear reactors needs a 235U fissile isotope content of between 3.5 – 5 %. This higher 235U content is achieved through a process known as “enrichment” by e. g. gas centrifuges. In the past, the enrichment of UF6 was also performed in diffusion plants. Due to extensively higher energy consumption, this technology is not cost effective and is not practised anymore.

UF6 is the ideal chemical compound for the enrichment process because it exists in gaseous form at relatively low temperatures and pressures. In enrichment plants, centrifuges separate the fissile isotopes 235U and 238U in a physical process by using the slightly different masses of the isotopes. The result is a depleted UF6 stream (235U 0.2-0.3 %) and an enriched UF6 stream (235U 3.5 – 5 %).

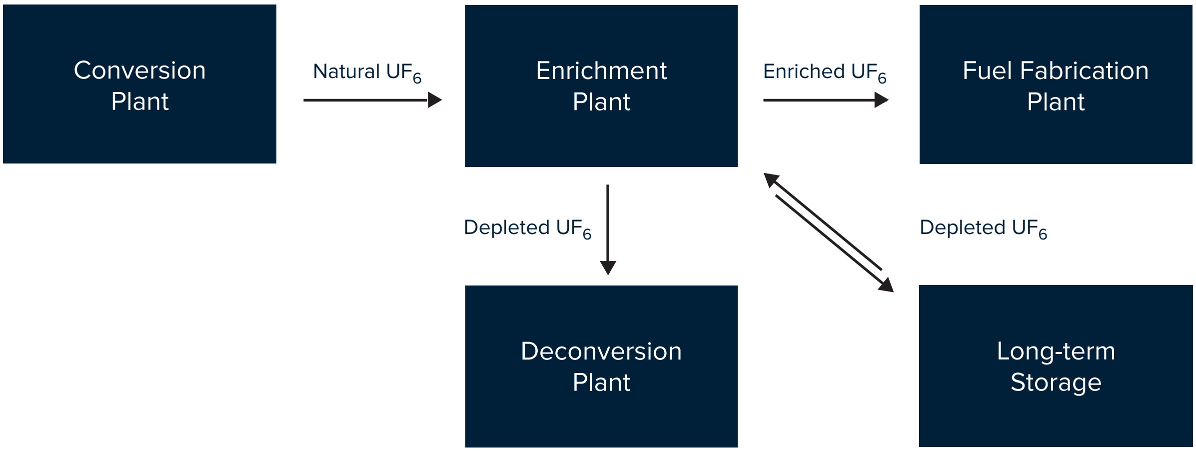

Image 2. - Transport of UF6 between different industry branches

5. TRANSPORTATION OF UF6

UF6 is transported via road, rail, sea and air. International and national dangerous goods regulations apply to the transport of UF6. For quantities of UF6 greater than 0.1 kg the primary hazard is from the radioactivity and therefore classified as Class 7, with class 8 (corrosive) as subsidiary risk. The cylinders need to withstand a fire test for 30 minutes under well-defined conditions and fulfil definite leakage rates and resist drop tests. These requirements are defined in the “IAEA Regulation for the Safe Transport of Radioactive Material” and in the “United Nations Recommendations for the Transport of Dangerous Goods” as well as in the derived dangerous goods transport regulations around the world.

5.1. Transport Cylinders

Natural and depleted UF6 is transported in 48Y cylinders, whereas for enriched UF6 smaller 30B cylinders are used. Outer protection such as thermal protection or protective shipping packages (PSP) may be required to comply with the regulatory transport requirements. For shipment of sample quantities of UF6, other packages are used.

Type 48Y Cylinder

48Y Cylinder
Diameter: ~ 1,25 m (48 inch)
Length: ~ 4 m
Wall thickness: 16 mm (5/8 inch)
Volume: ~ 4000 l
Tare weight: ~ 2500 kg
Max. fill: 12500 kg
Gross weight: ~ 15000 kg
Proof pressure: 28 bar
(5-year inspection)
Max. Operating temp.: 121°C/250°F

Type 30B 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: 2275 kg
Gross weight: ~ 3000 kg
Proof pressure: 28 bar
(5-year inspection)
Max. Operating temp.: 121°C/250°F

48Y Cylinder with outer protection

30B Cylinder with PSP

UF6 is normally transported using standard multimodal container-based flatracks. These can be easily transferred between road, rail and maritime shipments. One flatrack can accommodate four 30B cylinders loaded in protective shipping packages or one 48Y cylinder. 48Y cylinders are also transported as single units on road trailers, railway wagons and in ship holds.

5.2. Labelling for Transport

There are two UN numbers available for the transport of UF6 in quantities greater 0.1 kg. UN2977 is used for “Radioactive Material, Uranium Hexafluoride, fissile” and UN2978 refers to “Radioactive Material, Uranium Hexafluoride, non fissile or fissile excepted”.

The third UN number UN3507 is for UF6 quantities < 0.1 kg.
Note - The transport regulations are cited according to international regulations and any national deviations are not considered in this Fact sheet.

UN2977

RADIOACTIVE MATERIAL, URANIUM HEXAFLUORIDE, FISSILE

I - White

or

II - Yellow

or

III - Yellow

and

Corrosive

Fissile

UN2978

RADIOACTIVE MATERIAL, URANIUM HEXAFLUORIDE, NON FISSILE or FISSILE - EXCEPTED

I - White

or

II - Yellow

or

III - Yellow

and

Corrosive

UN3507

RADIOACTIVE MATERIAL, URANIUM HEXAFLUORIDE, NON FISSILE or FISSILE - EXCEPTED

Corrosive

5.3. ASTM

ASTM International is an international standards organization that develops technical standards for a wide range of materials, products, systems, and services. There are two ASTM specifications defined for UF6. For commercial natural UF6 ASTM C 787 – 11 defines impurity and uranium isotope limits and additional limits for reprocessed UF6. ASTM C996 – 10 is the comparable standard for enriched UF6 less than 5 % U235.

Explanatory note:

Reprocessed uranium hexafluoride is not considered in this fact sheet.

References:

ASTM C787-11; ASTM C996-10; IAEA SSR6; world-nuclear.org; ead.anl.gov; rsc.org; nrc.gov

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