Using molybdenum depleted in ^{95}Mo in UMo fuel

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Introduction

In recent years significant interest was gained in UMo fuel to be used in Material Test Reactors. This interest was induced by the fact that UMo fuel is mechanically stable, even at high uranium concentrations and high U-burnup. These properties are required in order to use Low Enriched Uranium (LEU) and still be able to achieve high flux and burnup values and, thus, to facilitate the conversion from High Enriched Uranium (HEU) to LEU.

Neutronics computations have shown that, although the Mo concentration in UMo fuel is not very high (about 5 - 10w%), the neutron absorption cross sections of natural Mo are sufficiently high to have a considerable negative impact on the reactivity of this UMo fuel. In the present research the neutron absorption cross sections of natural Mo are discussed and the option to reduce the cross section of molybdenum by depleting the Mo in ^{95}Mo is described. Finally the economic consequences of using Mo depleted in ^{95}Mo are briefly discussed.

Neutronics

The isotopic composition of natural molybdenum is shown hereafter (Figure 1). It can be remarked that the ^{95}Mo content is about 16% in natural Mo.

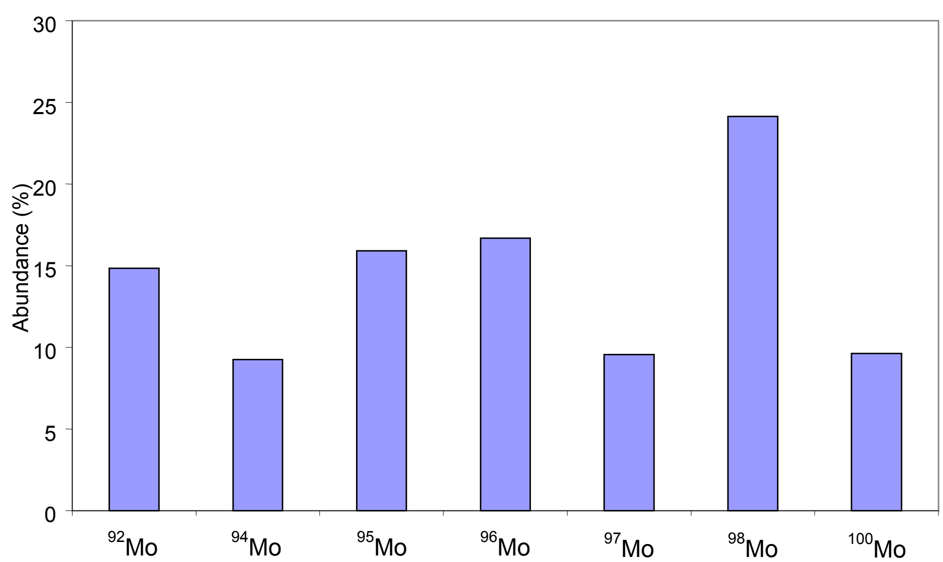

Figure 1 The isotopic composition of natural molybdenum.

The neutron absorption cross sections for thermal and epi-thermal neutrons are shown for the various Mo-isotopes (Figure 2, Figure 3). The lines marked average give the average cross section values using the isotopic abundance of natural Mo.

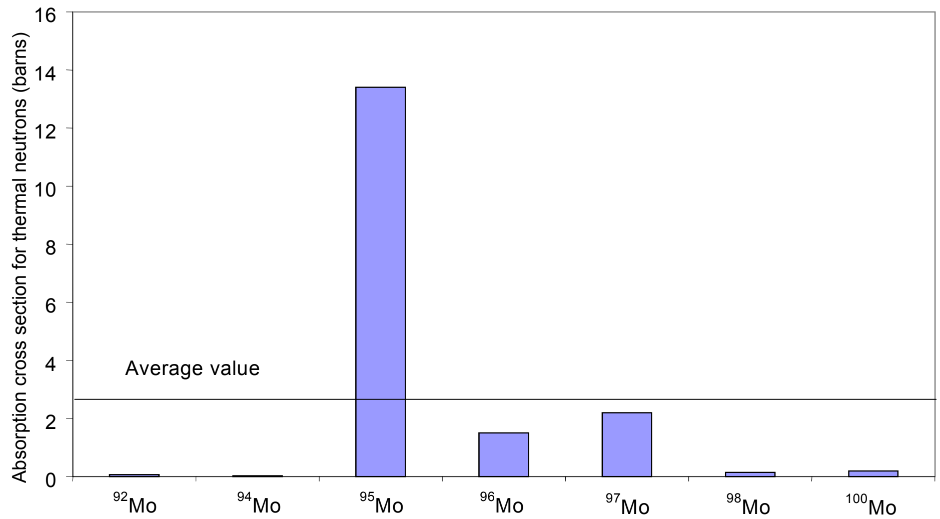

Figure 2 The neutron absorption cross sections for thermal neutrons.

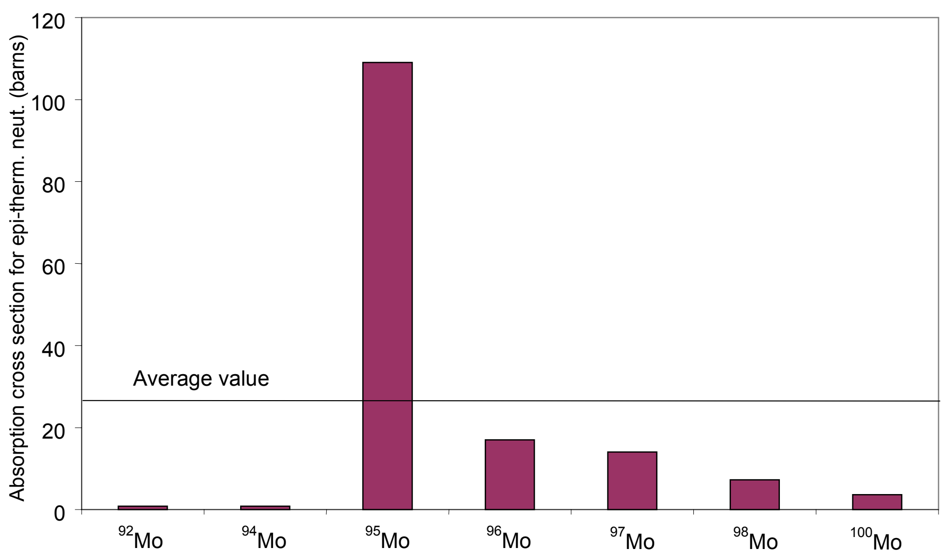

Figure 3 The neutron absorption cross sections for epi-thermal neutrons.

These data show that ^{95}Mo has a much larger cross section than the other Mo-isotopes. ^{92}Mo and ^{94}Mo have the smallest cross sections, while ^{98}Mo and ^{100}Mo also have small cross sections. Depletion of molybdenum in ^{95}Mo will therefore significantly reduce the neutron absorption cross section, especially in the epi-thermal range.

^{95}Mo depletion

URENCO has a division in which various types of stable isotopes are enriched. Examples of these stable isotopes are:

- Iridium, enriched in ^{191}Ir, which can be used to produce high activity ^{192}Ir radioactive sources.
- Zinc, depleted in ^{64}Zn, which is used to decrease the corrosion and decrease the ^{60}Co release in the primary system of nuclear power plants.

Enrichment of these stable isotopes is done using ultra-centrifuges (Figure 4).

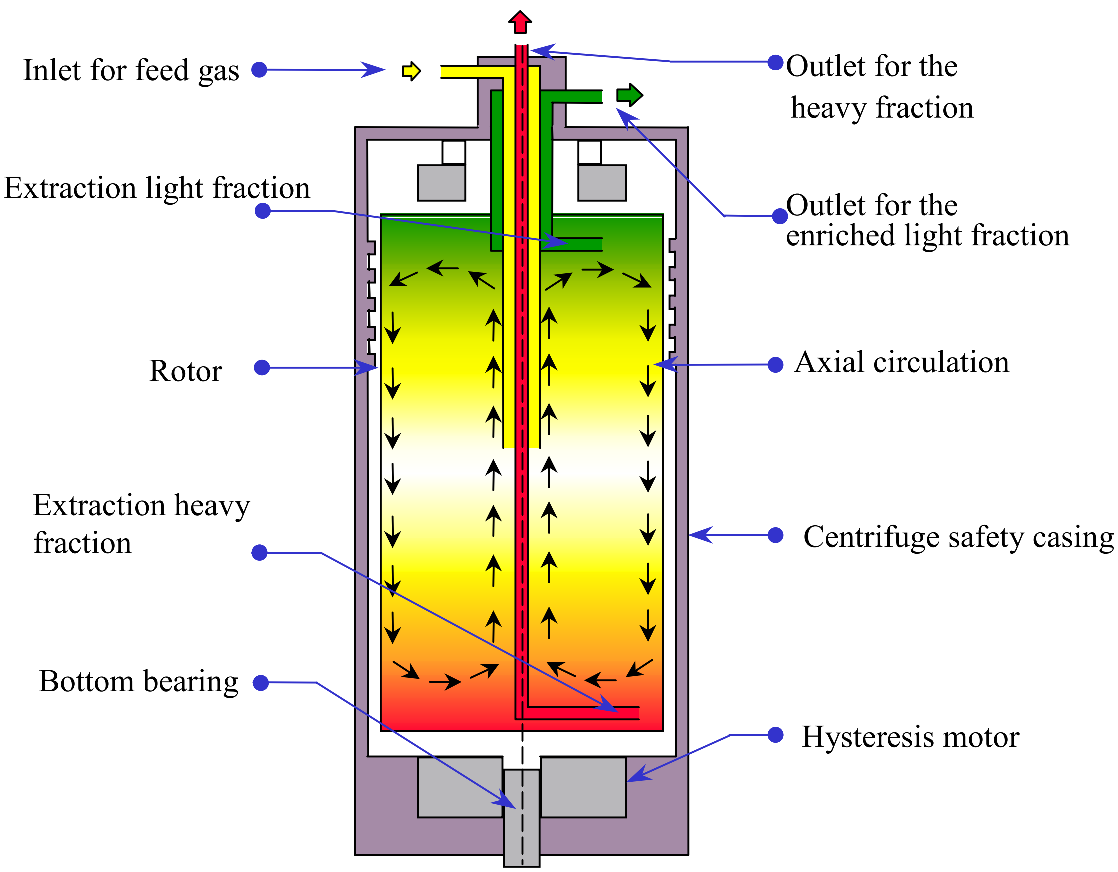

Figure 4 Schematic cross section of an ultra-centrifuge.

URENCO studied the possibility of enriching/depleting molybdenum. Molybdenum appears to be a suitable element for ultra-centrifuge enrichment/depletion using MoF_6 as a gaseous compound.

Depletion of Mo in ^{95}Mo can either be done by enriching the molybdenum in the light isotopes (^{92}Mo and ^{94}Mo) or in the heavy isotopes (^{98}Mo and ^{100}Mo). The isotopic composition after depletion depends on the original (natural) abundance of the various isotopes and the number of depletion steps. Typical isotopic compositions after ^{95}Mo depletion are shown in Figure 6. The total concentration of light isotopes in natural Molybdenum (^{92}Mo and ^{94}Mo) is smaller than the total concentration of heavy isotopes (^{96}Mo, ^{97}Mo, ^{98}Mo and ^{100}Mo). Therefore, the mass fraction of enriched isotopes that can be obtained from enriching light isotopes will be smaller than that which can be obtained from enriching heavier isotopes. The average absorption cross sections are reduced by a factor of about 2 when the heavy isotopes are enriched and by a factor of about 3.5 when the light isotopes are enriched.

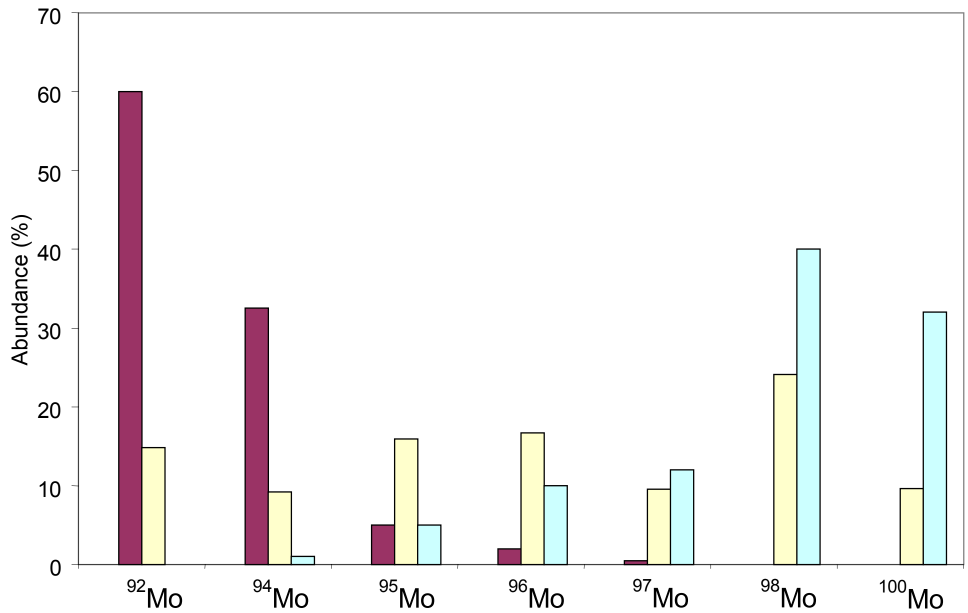

Figure 5 Approximate isotopic compositions after ^{95}Mo depletion. Purple marks the composition after enrichment in the light isotopes. Yellow marks the natural composition. Blue marks the composition after enrichment in the heavy isotopes.

Economics

The advantage of using ^{95}Mo depleted Mo in UMo fuel can either be:

- Increasing the cycle length;
- The possibility to use a higher Mo content to enhance the fuel's irradiation stability without too large an impact on reactivity; or
- Decreasing the U content or ^{235}U-enrichment.

The exact advantage will be Material Test Reactor specific.

The neutronics computations show that decreasing the ^{95}Mo-content from 16% to 5% can yield an increase of the cycle length of about 4 or 6% for a typical medium-power Material Test Reactor when the heavy or light Mo isotopes, respectively, are enriched. The exact cycle length increase depends however on many parameters such as:

- Maximum burnup;
- Ratio U/Mo; and
- Reactor geometry.

An economic assessment showed that using ^{95}Mo depleted Mo is an interesting option for UMo fuel.