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FEASIBILITY STUDY OF THE (10MW) MTR HEU TO LEU CONVERSION

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Abstract

Material test reactor (MTR) is a pressurized, reflected, open pool – type, light – water moderated and cooled heterogeneous system designed for operation at a maximum steady – state power level of "10MW" thermal. This reactor regionized by a consultant's group from IAEA member state, which has been meeting regularly to discuss the technical issue of core conversion. A conversion feasibility study, which involves both HEU (93 % U^{235}) and LEU (30 % U^{235}) fuels, is currently being performed. In order to determine core excess reactivity, Wims-D4 and Daixy codes would used to justify the conversion study from HEU to LEU, which limited by two options; the first one depends on increasing the amount of U^{235} (no redesign of fuel element), the second option depend on decreasing either the plate cladding or fuel meat thickness while increasing the width of the coolant gap (redesign of fuel element).

Introduction

The feasibility of converting to reduced – enrichment used should be individually assessed for each reactor. There are specific applications of research and test reactors in basic physics studies, materials testing, or production of some isotopes, which require a high flux of neutrons, and this can only be met using high enrichment fuel.

A consultants group from IAEA member states has been meeting regularly since 1978 to discuss the technical and safety issues of core converting in order to nonproliferation the nuclear weapons and eliminate the use of highly enriched uranium in civil nuclear programs throughout the world.[1]

In this research, the proposal MTR has four types of experimental facilities designed to support these services and research programs: the Central Test Hole (water trap); Fissile Region (SFE, CFE); Reflector Region; the Bulk Pool Area; the Beamports. The first three types provide areas for the placement of sample holders or carriers in different regions of the reactor core assembly for the purpose of material irradiation, science research and neutron activation analysis. The beamports is used primarily to determine the structure of solids and liquids through neutron scattering.

Basic Reactor Description

The proposal MTR is a pressurized, reflected, heterogeneous, pool-type, which is light- water moderated and cooled. The reactor is designed to operate at a maximum thermal power level of "10MW". The reactor core was assumed to contain (21) standard fuel element (SFE) and (4) control fuel element (CFE) arranged in a symmetrical configuration on (6X5) grid. A flux (water) trap has been arranged at the center of the core. Each fuel assembly is comprised of (23) plates containing uranium enriched to approximately 93% in the isotope U^{235} as the fuel material. The core was assumed to be reflected by single row of graphite reflector material on two opposite faces and surrounded by light water on all other sides.

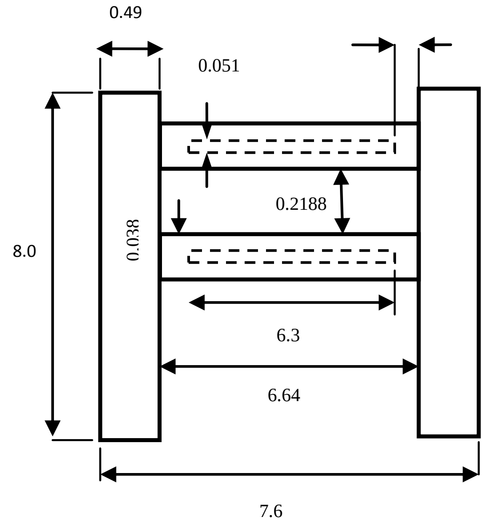

Fig.(1) : Cross section of SFE (Standard Fuel element)[2].

Current Fuel System and Design

The fuel material at the time of initial startup was U-AL alloy with each fuel assembly loaded to a maximum of (280 gm) of $U^{235.}$ This type of fuel system had performed very reliably in the (MTR) and Engineering Test Reactor (ETR) throughout the world. In order to reduce the fuel cycle cost and the amount of U^{235} needed per (MWD) of energy produced at the (MTR), a conversion was performed to switch to a uranium- aluminized description UAL_X fuel material with a maximum loading of (280 gm) of U^{235} assembly. Each fuel plate have a fuel thickness of (0.51 mm) and a HEU 93% density of about (0.68 gm/cm^3).

The aluminum cladding has a thickness of (0.38 mm) with (60/L; KIP-0-[mm) height. Finally, the reactor cooled and moderated with light water and reflected with light water and graphite. If no changes are made in the geometry of fuel assembly, the uranium density required for LEU conversion is estimated to be about (2.6 gm/ cm^3) with the same fuel cycle length is possibly larger if the neutron spectrum in the HEU core is relatively hard comparison with our MTR reactor[1].

Fuel element specifications are summarized in Table (1). Table (2) provide the MTR fuel operating characteristic, including maximum power density (MW/cm^3) with the control rod full up, core refueling, and fuel cycle.Also Table(2) show the value of specific power of core and absolute value of thermal flux (n / cm^2. sec) in water trap for both cases (HEU / LEU).

Table (1)
MTR Fuel Element Specifications [HEU].

Description		Nominal Value
Fuel Material	Aluminide - UAL	U - AL
	Enrichment	93% U^{235}
	Thickness	0.51mm
Cladding	Thickness	Aluminum
	Material	0.38mm
Fuel assembly		80mm
No. of fuel plates		23
Overall fuel assembly length		77.1mm
Overall fuel plate length		71.8mm
Overall active fuel length		60mm
Fuel plate thickness		1.27mm
Distance between fuel plate		2.23mm
Max. U^{235} Loading		280gm
Fuel Density		0.6 to 0.68 m/cm^3

Table (2)
MTR Fuel Operating Characteristic.

Reactor type	MTR
Coolant / Moderator	H_2O
Fuel meat	U – AL
Uranium Enrich. %	93 / 30
HEU / LEU Density (gm /cm^3)	0.68 / 2.60
Fuel meat / clad. thickness (mm)	0.51 / 0.381
Max. power density (MW / cm^3)	1901 / 2061
Specific power of core (HEU / LEU) (Fission / cm^3)	3.3E+18/8.7E+17
Absolute value of flux in water trap (HEU/LEU).n /cm^2.sec	2.23E+14 2.15E+14

HEU to LEU Fuel Conversion Study

The potential concerns in performing a conversion include:

Matching the performance capabilities of the (280 gm) U^{235} fuel element; having sufficient excess reactivity in order to decrease the loading in fuel plates with high peaking factor; and maintaining neutron flux in the water trap, graphite reflector and beamport regions.

The first technical problem that required was a comparison of core excess reactivity between HEU and LEU fuels. Using Wims-D_4 and Daixy codes, broad results were obtained.

The first comparison consisted of decreasing the fuel enrichment with increasing U^{235} content. No other physical changes were made to the core; in other words; the same fuel plate and coolant channel dimensions were maintained. So, Keff's were still high enough to ensure sufficient excess reactivity with the core operating at 10 MW.

The next step was to increase the water-to –metal ratio by decreasing either the plate cladding or fuel meat thickness, wile increasing the width of the coolant channel gap. First, the standard 0.381 mm thick cladding was decreased to 0.305 mm, while the coolant channel gap was increased from (2.188 mm to 2.340 mm) with the same U^{235} density in the previous work of core conversion included dimensions change of fuel element, the results indicate sufficient excess reactivity that could achieve as in the current design Table (3).

Finally, using the current 0.381 mm thick cladding, the fuel meat thickness was decreased from (0.51 mm to 0.457 mm) and then to 0.406 mm, while increasing the coolant channel gap to 2.241 mm and 2.295 mm respectively.

The Daixy code analysis indicate that equivalent to Keff values are obtained using the same uranium density in current LEU core conversion Table (3).

The limitation which make the increasing of uranium–containing volume within the fuel element is difficult in some high–performance reactors is it must be designed to operate close to their thermal hydraulic limit [2]. So, the fabrication methodologies should be further developed and tested before the thinnest allowable nominal cladding design thickness will be known [3].

If either the fuel cladding or the fuel meat thickness is reduced, a thinner overall fuel plate will result. As the plate stability depends on the relative thickness of the fuel meat and cladding, these values should be determined to optimize the core design.

Table (3)
U-ALHEU and LEU Fuel Comparison.

Fuel type	No. of plates	U^{235} density gm/cm^3	Fuel meat (mm)	Clad. (mm)	Channel gap (mm)	Keff[1]	Keff[2]
U-AL	21 (C)	2.6 (C)	0.51 (C)	0.381 (C)	2.188 (C)	1.171	1.010
	21 (C)	2.6 (C)	0.51 (C)	0.304 (V)	2.340 (V)	1.171	1.010
	21 (C)	2.6 (C)	0.457 (V)	0.381 (C)	2.241 (V)	1.153	1.008
	21 (C)	2.6 (C)	0.406 (V)	0.381 (C)	2.295 (V)	1.151	1.006

[1] Fresh core
[2] with xenon effect =3.3%
C =const.
V = variable

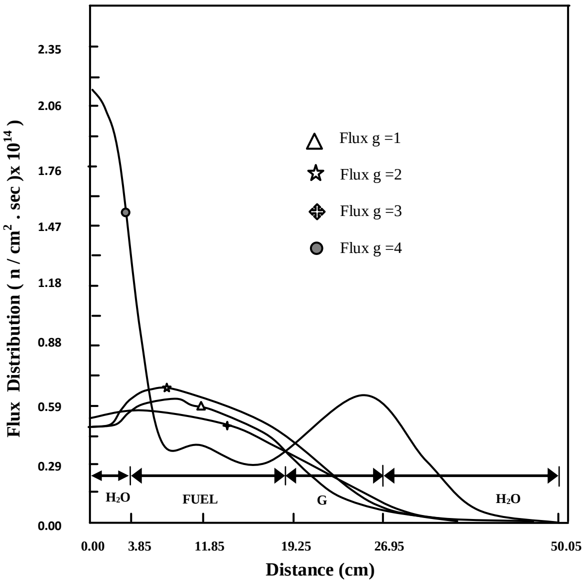

Fig.(2) : Flux distribution of 30% MEU reactor for the four energy groups along y-axis.

Conclusions

1- The current unperturbed peak thermal flux in the water (flux) trap is (2.15 E+14) n/cm^2-sec, while the obtained peak fast flux (> 1.0 MeV) is (4.91E+13) n /cm^2.sec , and this match with the goal which must be achieve to obtain the same peak thermal and fast levels after the LEU conversion, Fig.(2).

2- With a uranium density in the fuel of (2.6gm / cm^3), the reactor could be converted to LEU (30% enrichment) provided the length of the fuel cycle would be equal to that of HEU core in two cases, either without modification of the fuel thickness and fuel element geometry or with some modification of the fuel element. In the later case, there no hydraulic conditions would be essentially unaltered.

3- The mass of U^{235} would be increased by 16% to 20%, therefore the flux of the thermal neutrons in the fuel regions is reduced by about the same percentage, while the reflector region next to the fuel. The thermal flux recovers rapidly to the value in the HEU case.

4- Finally, the reactor could be converted to LEU with the same fuel cycle length and uranium density requirements when the fuel thickness is decreased. This can be done by increasing the coolant channel width provided thermal - conditions allow such reduction.[4].

References

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الخلاصة

شملت دراستنا على المفاعل البحثي لفحص المواد (MTR) من نوع الحوض المفتوح ذو العاكس والذي يستخدم الماء الخفيف المضغوط كوبرد ومهدئ في آن واحد، حيث صمم ليعمل بقدرة (10 MW).

تم اقرار هذا المفاعل من قبل المجموعة الاستشارية المنضوية في وكالة الطاقة الذرية الدولية في اجتماعها الذي تعقده بصورة منتظمة لمناقشة القضايا والمسائل المتعلقة بتقنية تحويل المفاعلات البحثية من التغنية العالية الى التغنية الواطئة ، مساهمة في الحد من انتشار الأسلحة النووية في العالم. لذا فأن الدراسة المعقولة لعملية التحويل تمت بأستخدام برامج عالمية هي (DAIXY و Wims–D_4)، اما عن طريق زيادة محتوى U^{235} وعدم تغيير التصميم الاساسي وأبعاد خلية الوقود من جهة، واما عن طريق اعادة تصميم خلية الوقود (تغيير أبعادها)، تحقيقاً للوصول الى (Keff=1) لضمان تشغيل المفاعل.