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Safety Analysis For Prototype MNSR HEU Core Unloading And Storage

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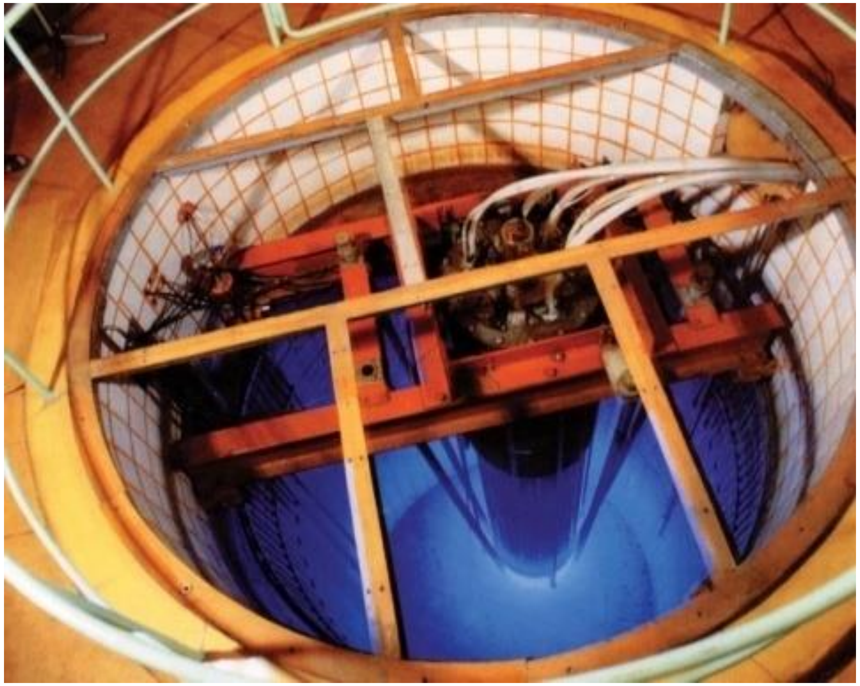
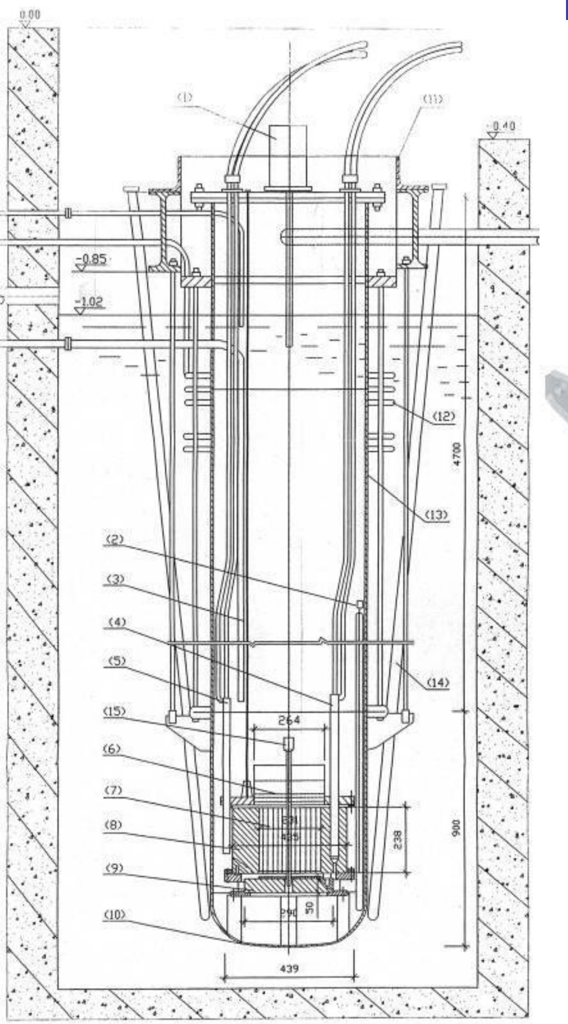
Miniature Neutron Souce Reactor (MNSR)

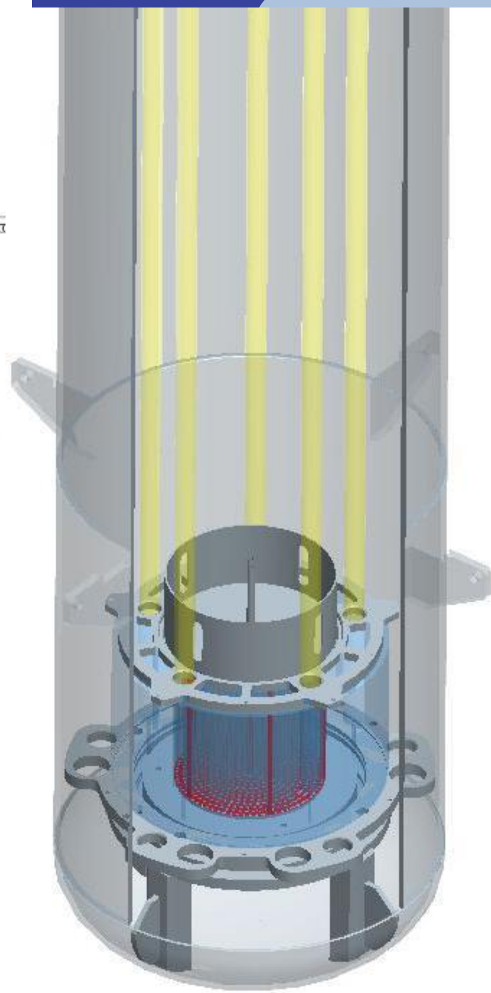


Prototype MNSR is a 27-kW research reactor and can supply 1 × 10^{12} n·$cm^{-2}s^{-1}$.

type: tank-pool
moderator : light water
full power operation: 1984
shutdown : 2014
conversion: 2015
from HEU to LEU

Introduction





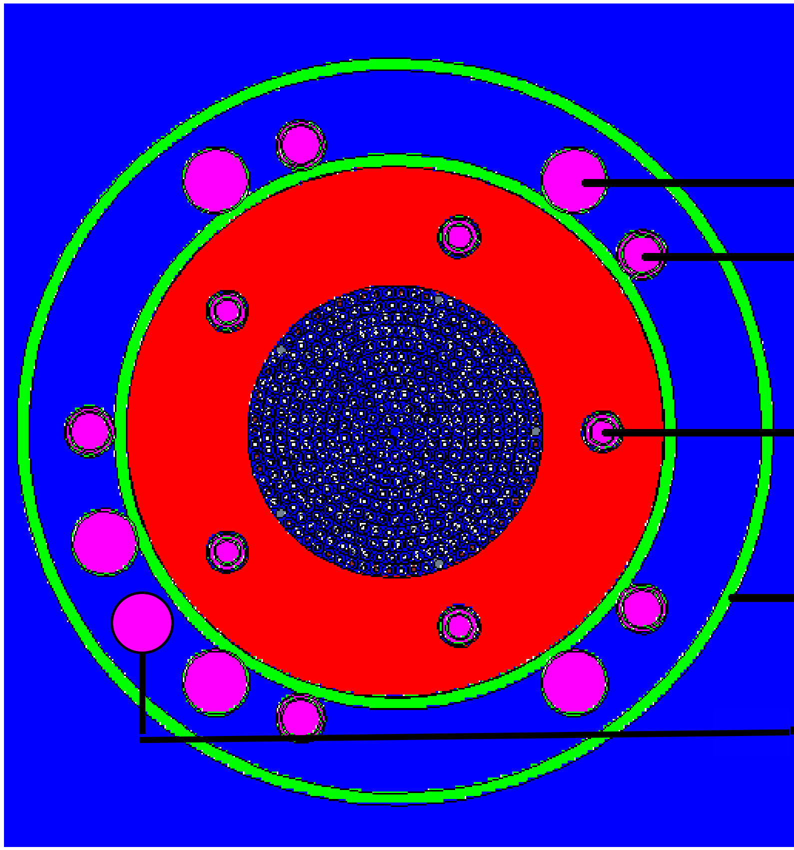
1 control rod : Cd

1 fuel assembly: 376 fuel pins, 35 depleted U pins, 5 tie rods.

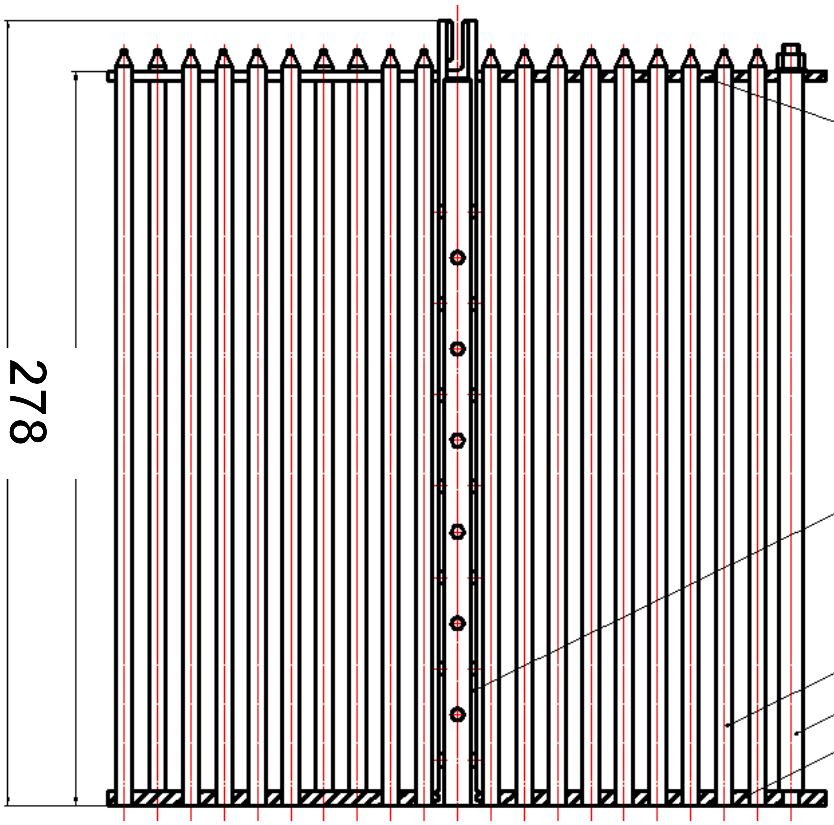
reflectors: upper Be, side Be and lower Be.

with 5 inner irradation tubes
5 outer irradation tubes.
1 experiment tubes

Introduction



Introduction

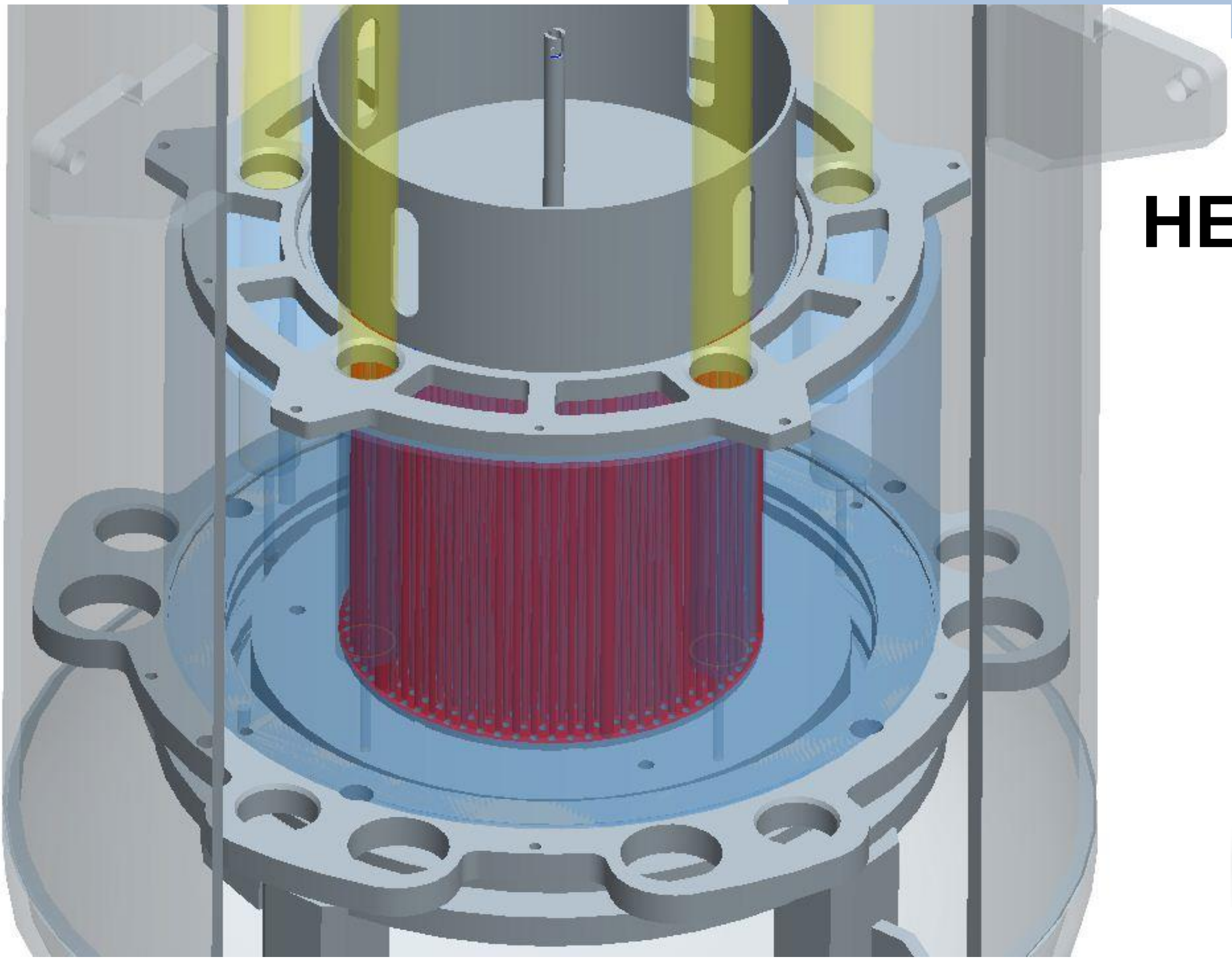


fuel meat : U-Al alloy

^{235}U : 90.3%

cladding: Al

Procedure



HEU fuel assembly
or
control rod

Procedure

1)Put 5 Cd strings into 5 inner irradiation tubes respectively (one Cd string consists 3 Cd absorbers); put 1 Cd tube into experiment tube;

2)remove the control rod;

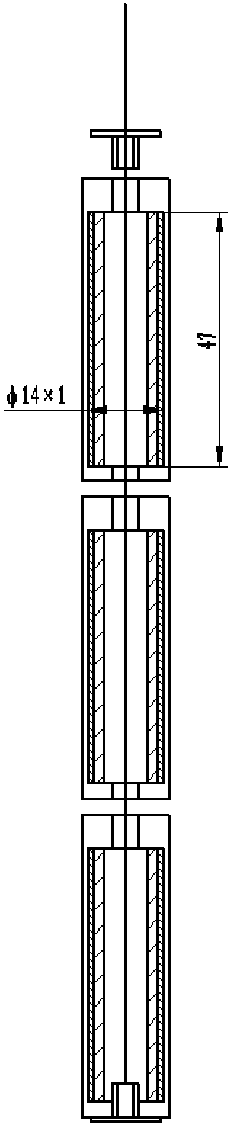
3)remove the upper beryllium reflector;

4)remove HEU fuel assembly from the reactor vessel;

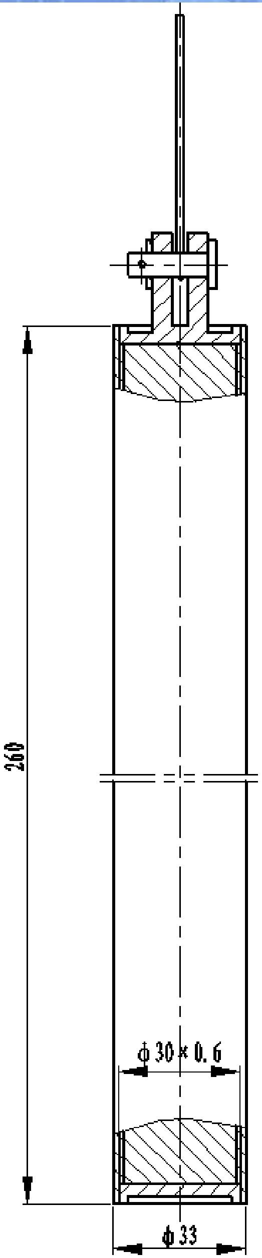
Procedure

5)Put HEU fuel assembly into a temporary cask;

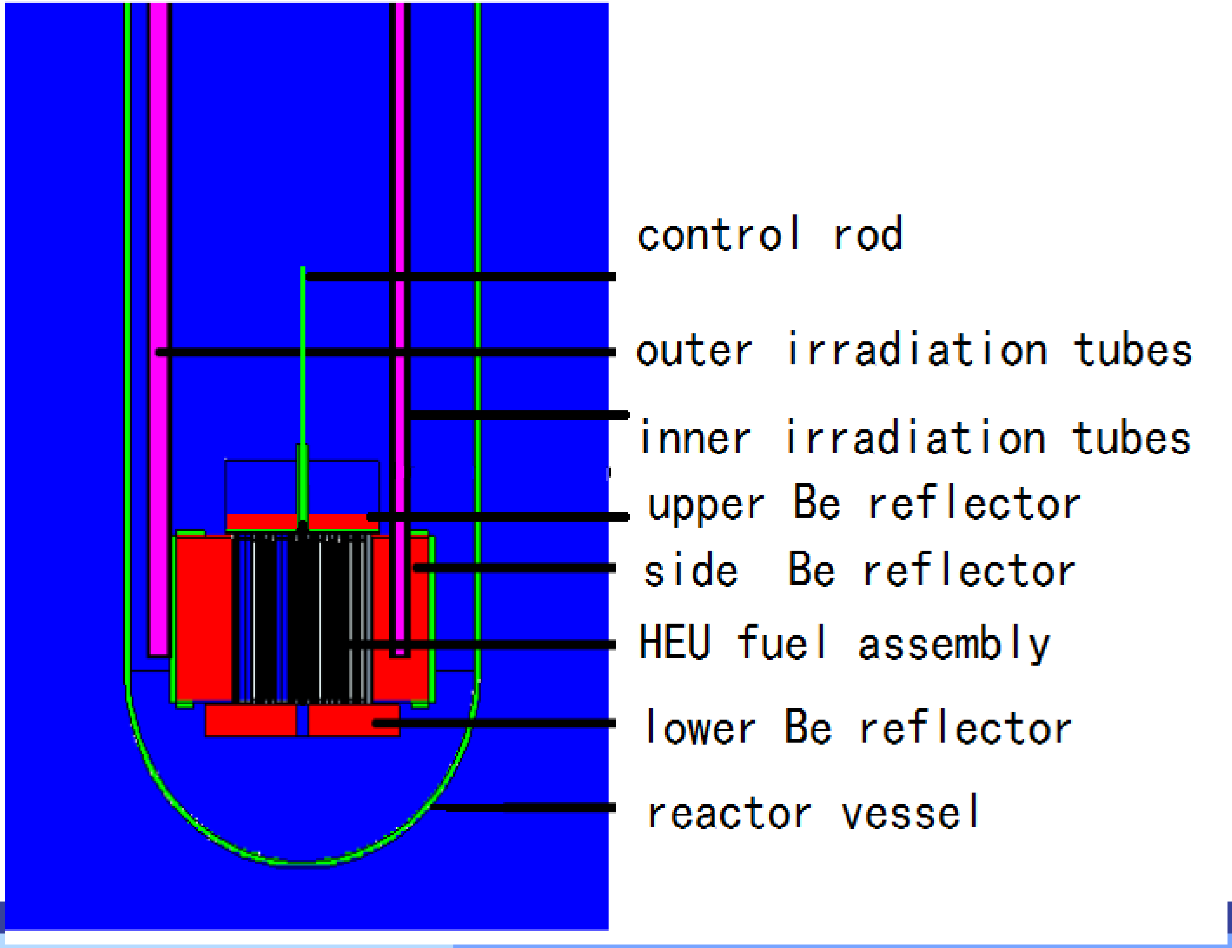
6)trasnform the HEU fuel from the cask to the swimming-pool reactor for storage.



Cd strings and Cd tube for ensure the reactor remain subcritical.



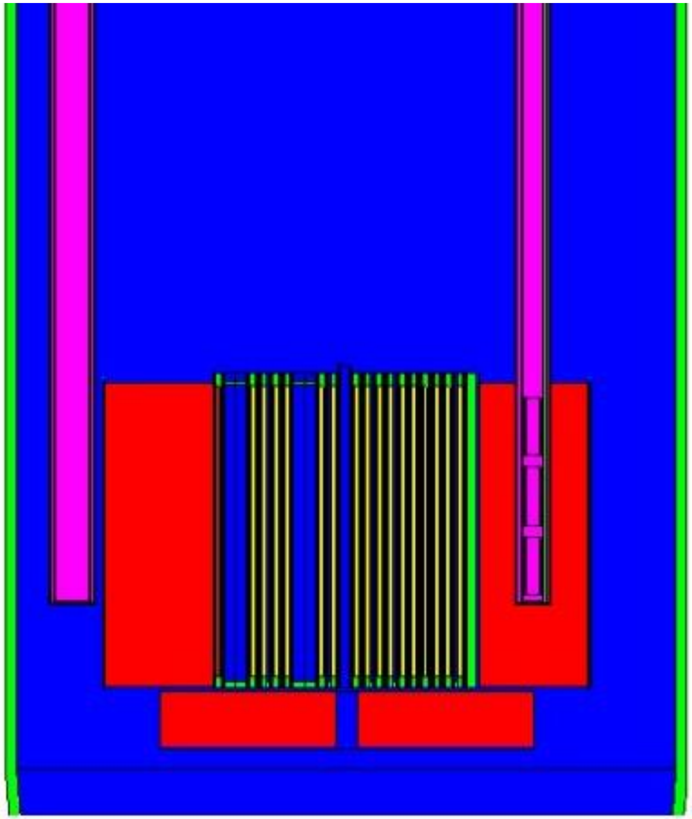
1.Initial status



2.reacitivity changes before unloading HEU fuel assenmbly (experimantal result)

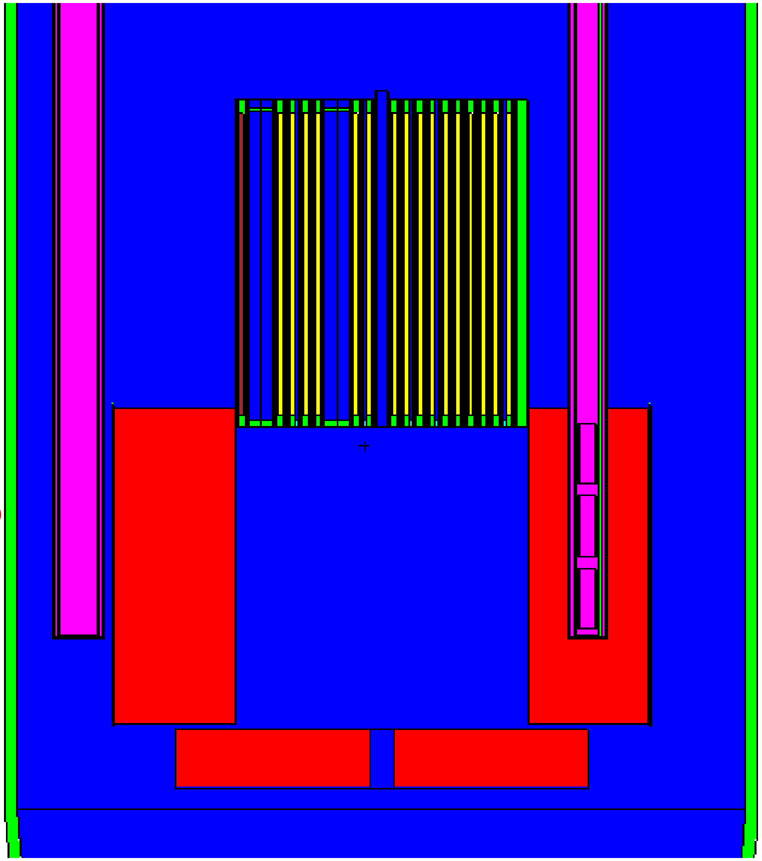
Operation	Reactivity/mk	State of reactor
Initial status	-3.10	subcritical
Put 5 cadmium strings	-15.46	subcritical
Put 1 Cadmium tube	-15.79	subcritical
remove control rod	-8.79	subcritical
remove upper beryllium reflector	-18.83	subcritical

3.reacitivity changes before unloading HEU fuel assenmbly



the worth of Cd absorber changes while the HEU fuel rise.

return critical?

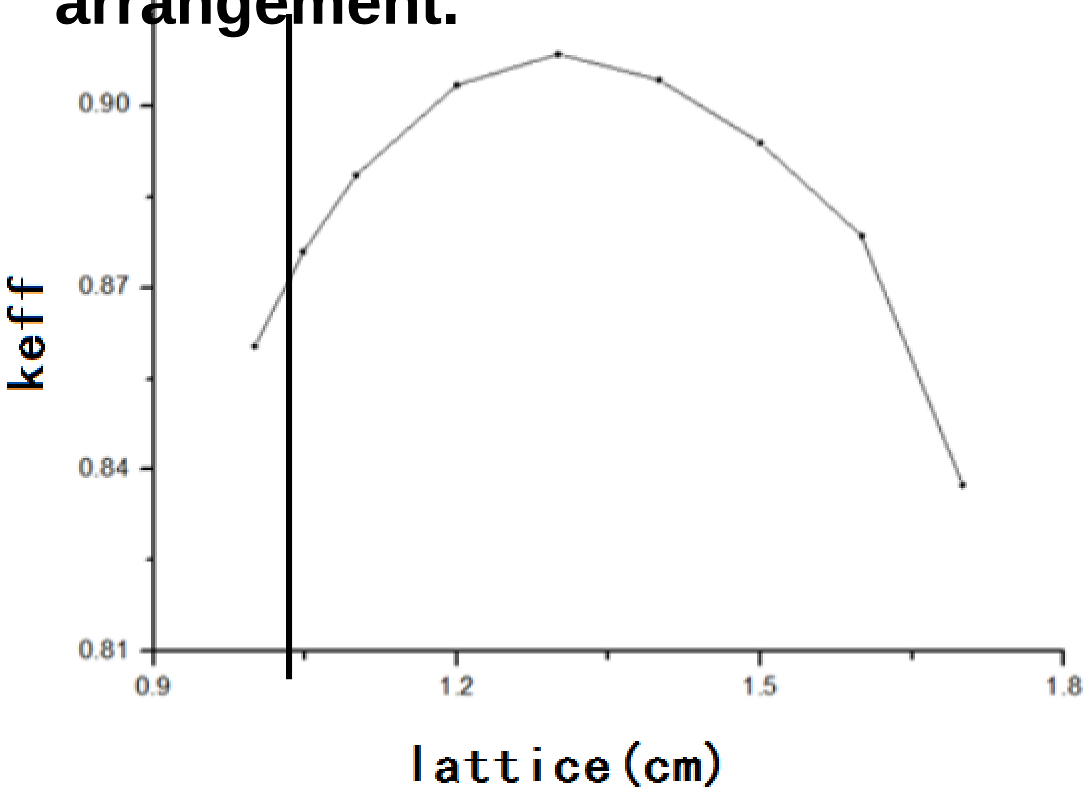


3.reacitivity changes before unloading HEU fuel assenmbly (MCNP code calculation)

position /cm	K_{eff}	reactor	remarks
0	0.979	subcritical	at the bottom
5	0.970	subcritical	5 cm from bottom
10	0.943	subcritical	10 cm from bottom
15	0.915	subcritical	15 cm from bottom
20	0.892	subcritical	20 cm from bottom
25	0.878	subcritical	25 cm from bottom
125	0.874	subcritical	125 cm from bottom far away from reflectors
625	0.515	subcritical	625 cm from bottom in the air, no moderator

4.Accident analysis

Fuel assembly falls into the pool and forms new geometry arrangement.



best lattice is 1.3 cm and keff=0.9086

critical safety

Results:

1. During the whole unloading procedure, the reactor remains subcritical.

2. Even in the worst accident, the keff is far away 1.

3. HEU fuel assembly will not return critical without the reflectors and moderator.

Radiaiton safety

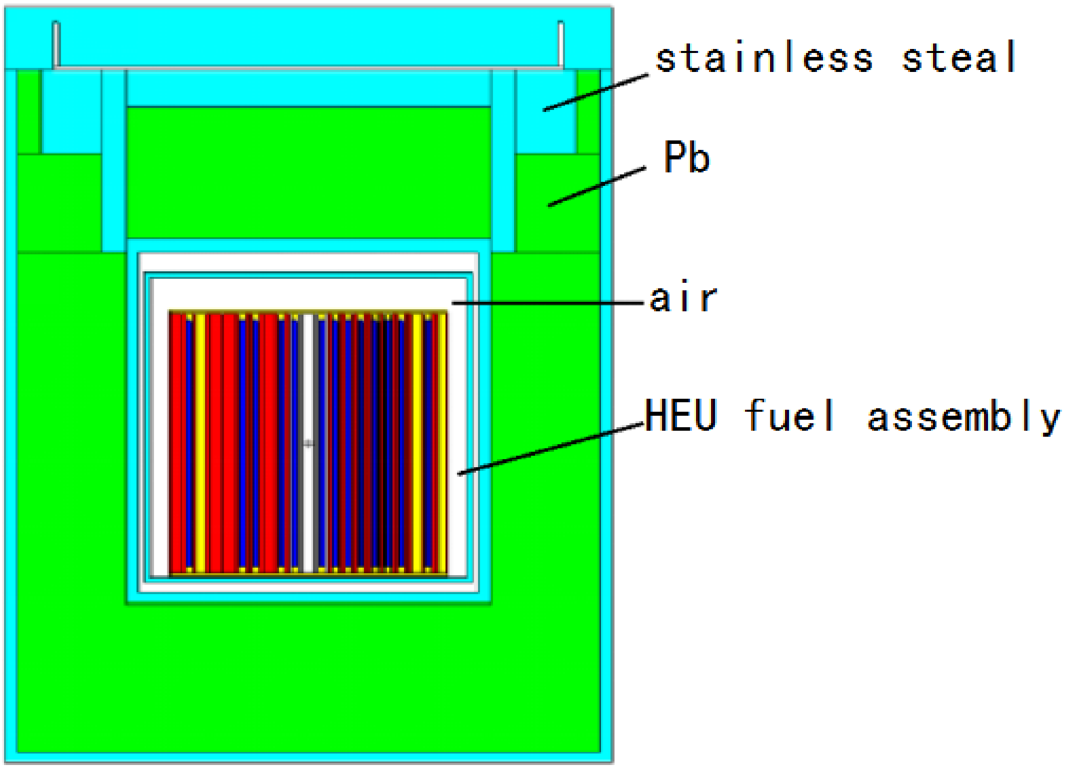
1. Reactor Core Source Term Calculation

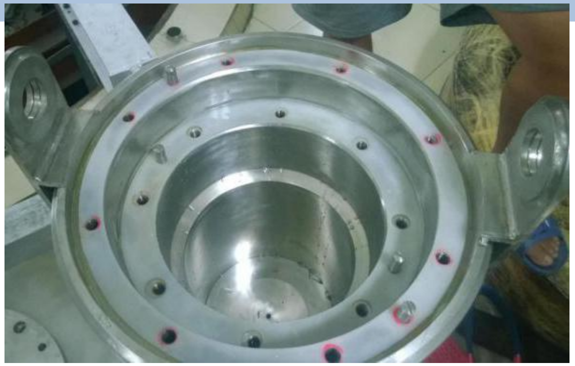
Prototype MNSR totally run in term of 7258 hours in full power. The integrated power is 1.95×10^{5}kWh and integrated neutron fluence is 2.61×10^{19}n/cm2. Until March 2015, the reactor has been shutdown for 12 months and ready for unloading.

The source term is obtained by ORIGEN 2 code.
The total reacitivity is 5.22×10^{12} Bq 12 months after shutdown and γ activity is 3.74×10^{12} Bq. Radioactive activity of actinide is 1.34×109 Bq and neutron source intensity of spent fuel assembly is 1.69 Bq.

Radiaiton safety

2. Temporary cask

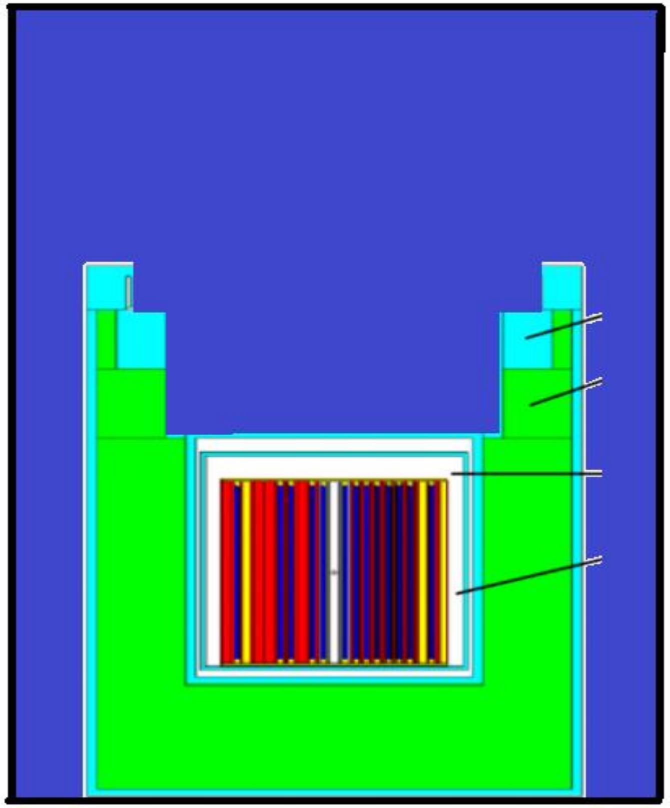




3. lead thickness and γ dose rate calculation

Lead thickness /cm	distance to surface /cm	dose rate /mSv/h	Lead thickness /cm	distance to surface /cm	dose rate /mSv/h
9	0	4.07E+00	10	2	2.68E-02
9	1	1.58E-01	11	0	1.16E+00
9	2	4.81E-02	11	1	5.04E-02
10	0	2.09E+00	11	2	1.53E-02
10	1	8.91E-02			

3. γ dose rate of temporary cask under water without 2 covers



position	dose rate /mSv/h
side surface	6.27×10^{-2}
1m from side surface	6.56×10^{-3}
top of water	3.62×10^{-1}
1m from top water	5.30×10^{-2}

Radiaiton safety

Radiaiton safety

Radiaiton safety

Results:

1.The calculation of the source term is conservative.

2.The temporary cask designed and fabricated is safe enough for protection.

3.During the unloading and storage , the γ dose of staff meet the requirement(< 100 μSv/day).

Conclusion：

- **The HEU fuel assembly is unloading from MSNR reactor vessel and stored in swimming pool reactor safely.**
- **The HEU fuel assembly remains subcritical during unloading and storage.**
- **The unloading and storage of HEU fuel has little impact on the enviroment and staff.**

Important data and experience for other HEU MNSR users to unloading and storage.

Thanks for your attention and questions!

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