Assignment 3

EEE405 – Nuclear Energy Technology
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Section A

For the set of reactor parameters given in Table 1, calculate for each reactor by using MATLAB:

Table 1: Reactor Initial Parameters

ITEM	ACRONYM	DESCRIPTION	UNIT	PWR	BWR	PHWRa (CANDU)
1	CPL	Core power level	MWt	953	3579	2140
2	PPD	Power deposited in fuel rods	%	97.4	96	95
3	FAC	Fuel assemblies/core	-	121	732	4560
4	ALS	Assembly lateral spacing	mm	200 (square pitch)	152 (square pitch)	280 (square pitch)
5	FRA	Fuel rods/assembly	-	204	62	37
6	FRL	Fuel rod length	mm	2900	3760	480
7	FRD	Fuel rod diameter	mm	10	12.5	13.1

Question 1

Utilizing information from Table 1, calculation for the core diameter and the core length are defined as follows:

Equivalent Circular Diameter Calculation

```
%**************************************************************************%
%Equivalent Circular Diameter
%**************************************************************************%
ECD_PWR = sqrt(CA_PWR*4/pi);
ECD_BWR = sqrt(CA_BWR*4/pi);
ECD_PHWR = sqrt(CA_PHWR*4/pi);
```

Where Core Area is calculated as follows:

```
%**************************************************************************%
%Core Area
%**************************************************************************%
CA_PWR = (FAA_PWR)*(FAC_PWR);
CA_BWR = (FAA_BWR)*(FAC_BWR);
CA_PHWR = (FAA_PHWR)*(FAC_PHWR);
```

And Fuel Assembly Area is Calculated as follows:

```
%**************************************************************************%
%Fuel Assembly Area
%**************************************************************************%
FAA_PWR = ((ALS_PWR/1000)^2);
FAA_BWR = ((ALS_BWR/1000)^2);
FAA_PHWR = ((ALS_PHWR/1000)^2);
```

Core Length Calculation

```
%**************************************************************************%
%Core Length
%**************************************************************************%
CLE_PWR = FRL_PWR/1000;
CLE_BWR = FRL_BWR/1000;
CLE_PHWR = FRL_PHWR/1000;
```

Results are showed in Table 2 as follows:

Table 2: Results Core Diameter and Core Length

ITEM	ACRONYM	DESCRIPTION	UNIT	PWR	BWR	PHWR
1	ECD	Equivalent Core Diameter	m	2.482	4.640	6.1589
2	CLE	Core Length	m	2.900	3.760	5.760

Average Core Density

Utilizing information from Table 1, calculation for the average core power density Q'' is defined as follows:

```
%**************************************************************************%
%Average Core Power Density
%**************************************************************************%
ACPD_PWR = CPL_PWR/TCV_PWR;
ACPD_BWR = CPL_BWR/TCV_BWR;
ACPD_PHWR = CPL_PHWR/TCV_PHWR;
```

Where Total Volume is calculated as follows:

```
%**************************************************************************%
%Total Core Volume
%**************************************************************************%
TCV_PWR = ((FRL_PWR/1000)*(pi*(ECD_PWR^2)))/4;
TCV_BWR = ((FRL_BWR/1000)*(pi*(ECD_BWR^2)))/4;
TCV_PHWR = ((FRL_PHWR/1000)*(pi*(ECD_PHWR^2)))/4;
```

The values for ECD were calculated before.

Results are showed in Table 3 as follows:

Table 3: Results Average Core Power Density

ITEM	ACRONYM	DESCRIPTION	UNIT	PWR	BWR	PHWR
1	ACPD	Average Core Power Density	MW/m^3	67.897	56.283	12.471

Core-Wide Average Linear Heat-Generation Rate of A Fuel Rod

Utilizing information from Table 1, calculation for Core-Wide Average Linear Heat-Generation Rate of a Fuel Rod q' is defined as follows:

```
%**************************************************************************%
%Core-Wide Average Linear Heat-Generation Rate of a Fuel Rode
%**************************************************************************%
CWAL_PWR = ((PPD_PWR/100)*CPL_PWR*1000)/(FRA_PWR*FAC_PWR*(FRL_PWR/1000));
CWAL_BWR = ((PPD_BWR/100)*CPL_BWR*1000)/(FRA_BWR*FAC_BWR*(FRL_BWR/1000));
CWAL_PHWR = ((PPD_PHWR/100)*CPL_PHWR*1000)/(FRA_PHWR*FAC_PHWR*(FRL_PHWR/1000));
```

Results are showed in Table 4 as follows:

Table 4: Results Core-Wide Average Linear Heat-Generation Rate of a Fuel Rod

ITEM	ACRONYM	DESCRIPTION	UNIT	PWR	BWR	PHWR
1	CWAL	Core-Wide Average Linear Heat-Generation Rate of a Fuel Rod q'	kW/m	12.967	20.135	25.103

Core-Wide Average Heat Flux At The Interface Between The Rod And The Coolant

Utilizing information from Table 1, calculation for Core-Wide Average Heat Flux at the interface Between the Rod and the Coolant q'' is defined as follows:

```
%**************************************************************************%
%Core-Wide Average Heat-Flux at the Interface Between the Rod and the
%Coolant
%**************************************************************************%
CWAH_PWR = (CWAL_PWR/1000)/(pi*FRD_PWR/1000);
CWAH_BWR = (CWAL_BWR/1000)/(pi*FRD_BWR/1000);
CWAH_PHWR = (CWAL_PHWR/1000)/(pi*FRD_PHWR/1000);
```

Results are showed in Table 5 as follows:

Table 5: Core-Wide Average Heat Flux at the Interface Between the Rod and the Coolant

ITEM	ACRONYM	DESCRIPTION	UNIT	PWR	BWR	PHWR
1	CWAH	Core-Wide Average Heat Flux at the Interface Between the Rod and the Coolant q''	MW/m^2	0.413	0.513	0.610

Final Results

Final results for Section A are defined in Table 6 as follows:

Table 6: Final Results

ITEM	ACRONYM	DESCRIPTION	UNIT	PWR	BWR	PHWR
1	ECD	Equivalent Core Diameter	m	2.482	4.640	6.159
2	CA	Core Area	m^2	4.84	16.91	29.79
3	CLE	Core Length	m	2.900	3.760	5.760
4	ACPD	Average Core Power Density	MW/m^3	67.897	56.283	12.471
5	CWAL	Core-Wide Average Linear Heat-Generation Rate of a Fuel Rod q'	kW/m	12.967	20.135	25.103
6	CWAH	Core-Wide Average Heat Flux at the Interface Between the Rod and the Coolant q''	MW/m^2	0.413	0.513	0.609

Code Description and MatLab Results

Input is requested for user, selection between loaded information on new input is required:

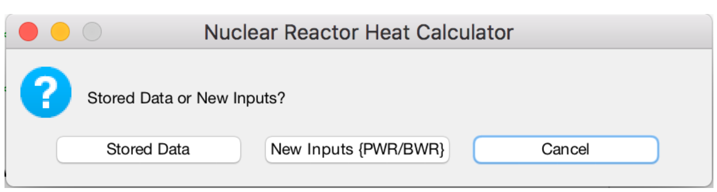

Figure 1: User Prompt

When either stored data or New Inputs bottom is selected, calculation start to be processed. Final results are outputted in a new pop up window with the following information:

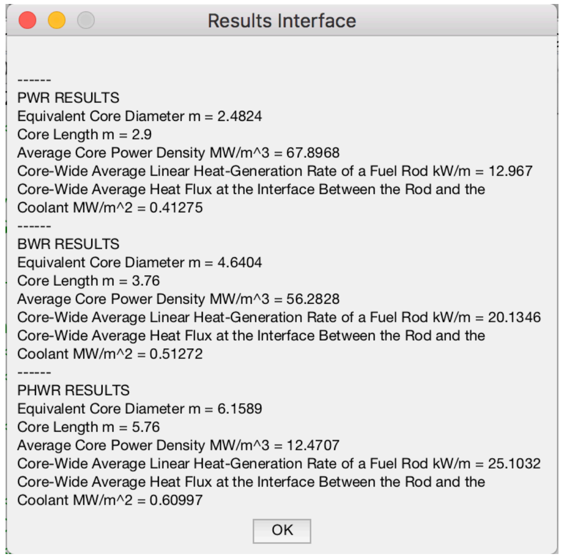

Figure 2: Results Interface

Section B

Taking the above results as the typical values of each type of the reactors, give your comments for each type of the reactors on:

Question 1

Reactor's core size relations are clearly presented after defining CA formulation:

```
CA_PWR = (FAA_PWR)*(FAC_PWR);
CA_BWR = (FAA_BWR)*(FAC_BWR);
CA_PHWR = (FAA_PHWR)*(FAC_PHWR);
```

It is observed that the Area of the core is dependent on the number of rods and the area of each one of the rods.

Table 7: Core Size Analysis

ITEM	ACRONYM	DESCRIPTION	UNIT	PWR	BWR	PHWR
1	CPL	Core power level	MWt	953	3579	2140
2	CA	Core Area	m^2	4.84	16.91	29.79
3	CLE	Core Length	m	2.900	3.760	5.760

After formulations are iterated it is observed that the Core Area of reactor type PHWR is significantly bigger in proportion to the power generation in comparison with reactors PWR and BWR.

Larger Core Area indicates greater amount of material will might be required for the construction of PHWR reactors.

Question 2

The average core density of a nuclear power core is strictly related to the equivalent core volume as defined by the equation presented below:

```
ACPD_PWR = CPL_PWR/TCV_PWR;
ACPD_BWR = CPL_BWR/TCV_BWR;
ACPD_PHWR = CPL_PHWR/TCV_PHWR;
```

Subsequently, average core volumes are calculated utilizing the equation represented below:

```
TCV_PWR = ((FRL_PWR/1000)*(pi*(ECD_PWR^2)))/4;
TCV_BWR = ((FRL_BWR/1000)*(pi*(ECD_BWR^2)))/4;
TCV_PHWR = ((FRL_PHWR/1000)*(pi*(ECD_PHWR^2)))/4;
```

A significantly greater volume core is identified in reactor BWR, naturally originated by the large amount of assemblies per core and smaller lateral spacing between rods.

After analyzing the core volume of each one of the reactors, greater core power densities are identified in types PWR and BWR; as per a very low power density is observed in reactor type PHWR which could directly define this last type of reactor low efficient reactor when relating volume in terms of power.

Table 8: Average Core Density Analysis

ITEM	ACRONYM	DESCRIPTION	UNIT	PWR	BWR	PHWR
1	ECV	Equivalent Core Volume	m^3	14.04	63.59	14.30
2	ACPD	Average Core Power Density	MW/m^3	67.897	56.283	12.471

As a result of the compact design achieved in PWR and BWR reactors, the power density of these two is higher than PHWR reactors. Higher power density consequently will produce high heat concentrations hence higher coolant flow rates will be required to keep safe temperatures inside the reactor.

Question 3

The average linear heat – generation rate of the fuel rod is directly related to the characteristic of the rods in terms of distribution, quantity and length as defined by the formula below:

```
CWAL_PWR = ((PPD_PWR/100)*CPL_PWR*1000)/(FRA_PWR*FAC_PWR*(FRL_PWR/1000));
CWAL_BWR = ((PPD_BWR/100)*CPL_BWR*1000)/(FRA_BWR*FAC_BWR*(FRL_BWR/1000));
CWAL_PHWR = ((PPD_PHWR/100)*CPL_PHWR*1000)/(FRA_PHWR*FAC_PHWR*(FRL_PHWR/1000));
```

PHWR type naturally composed by a large amount of fuel assemblies per reactor significantly produce larger heat rate.

Table 9: Heat Linear Flux Analysis

ITEM	ACRONYM	DESCRIPTION	UNIT	PWR	BWR	PHWR
1	CWAL	Core-Wide Average Linear Heat-Generation Rate of a Fuel Rod q'	kW/m	12.967	20.135	25.103

High core linear heat generation will demand great cooling capacities that will naturally represent higher cost of construction and will suppose additional safety concerns due to the necessity of managing large amount of heat in the case of an emergency.