Chapter 5

Displays and calculation results

1.1 Display

Displays of the simulation are done on Labview® which is a graphical programming. The displays have 4 different screens; Reactor preview, Control rod panel, reactor cooling system and fuel pin profile.

Reactor preview screen shows the general features of the reactor core. Annunciator bar is placed on top. This bar displays status of reactor core and supporting equipment. It is similar to the actual one in control room. Some of them are fixed to a certain conditions which are not processed in this model. The lower bar consists of operating conditions, results and control buttons. In the middle which is context of screen contains reactor pool's plan, power meter, fuel temperature meter, reactor period meter, reactor thermal power chart, water temperature chart and control buttons. Underneath the charts, there are one knob and a sliding bar; resolution and time scroll. The resolution knob controls number of data displaying in charts. Time scroll bar controls ability to scroll displaying data in charts. The last 500 data will be memorized and able to scroll. The reactor bridge and shield door could be moved by click on the button on the lower left of display. Then select the moving direction. The reactor bridge position and shield door position are not taken in the main calculation module. Figure 5.1 shows this screen.

The second screen is Control Rod Panel. It mainly shows the control buttons of control rod. The annunicator bar on the top and lower bar are the same as in the first screen. The screen context consists of rods control buttons, mode selection button, power control buttons, fire button using in fire transient rod on pulse mode, rods position, power set point, actual power in percent, pulse time meter and charts. 6 charts are contained in this display. Some of the are available in the actual situation and some were created to facilitate the operator to view the data. These specific buttons are mimicked from the actual control panel. This is the only screen give you accessibility to regulate reactor power level.

The power set point controller will effective only in the automatic mode and square wave mode. Regulating rod and shim #1 rod will regulate the actual power to the set value. These values are in thermal energy. More details can be seen on figure 5.2. Regulating rod is the primary control rod responding to power error. Shim #1 is the slave rod helping in regulation.

Reactor Cooling System screen display are in figure 5.3. It shows core cooling system. There are 2 cooling systems; primary and secondary. Emergency core cooling system (ECCS) is added in for the safety reason. Charts, chart controls and pop up buttons present in the context. The top and lower bar as in the first screen are included. There are 2 heat exchanger using to cool the primary cooling system. The first one have capacity of 500 Tons thermal. This heat exchanger was initially installed
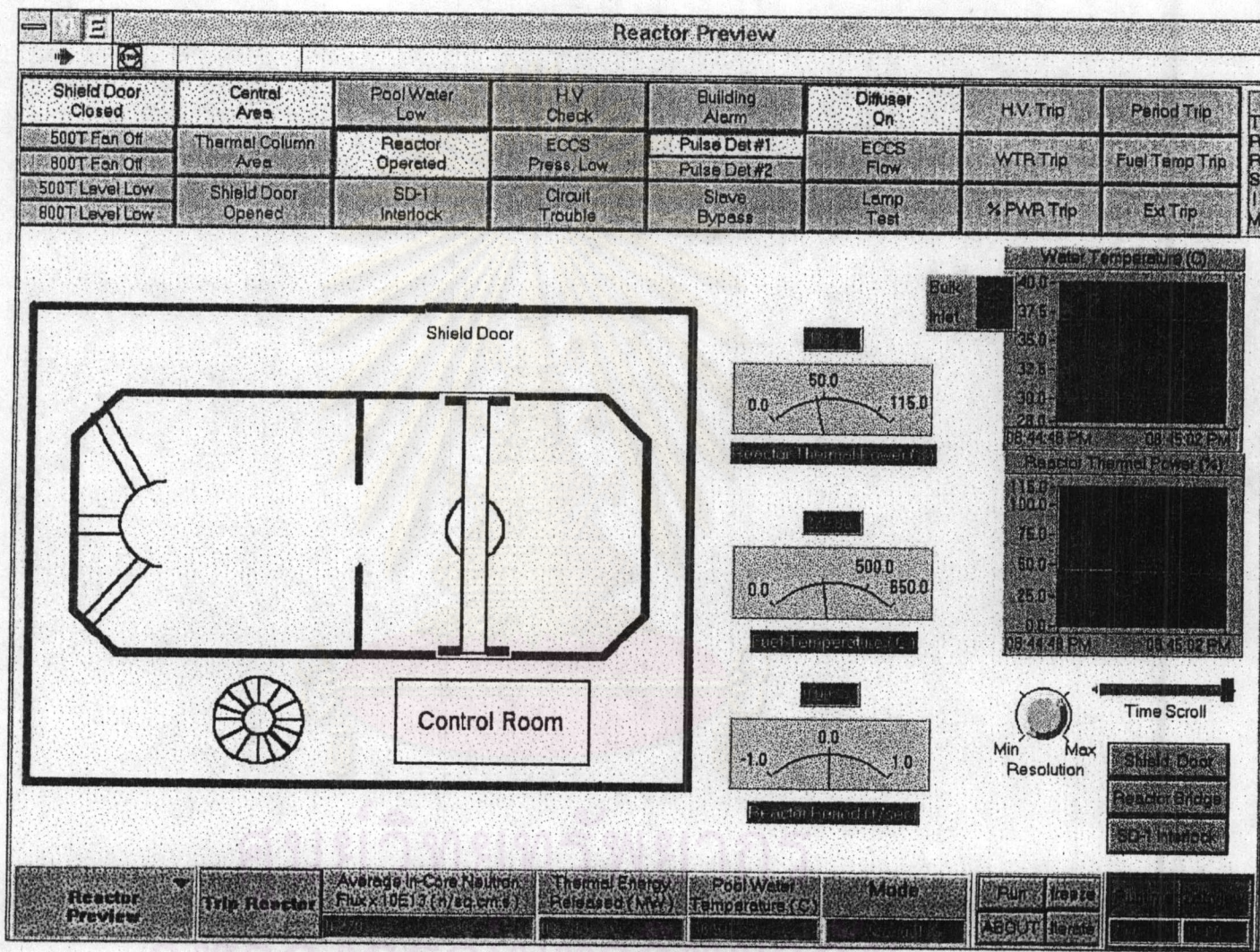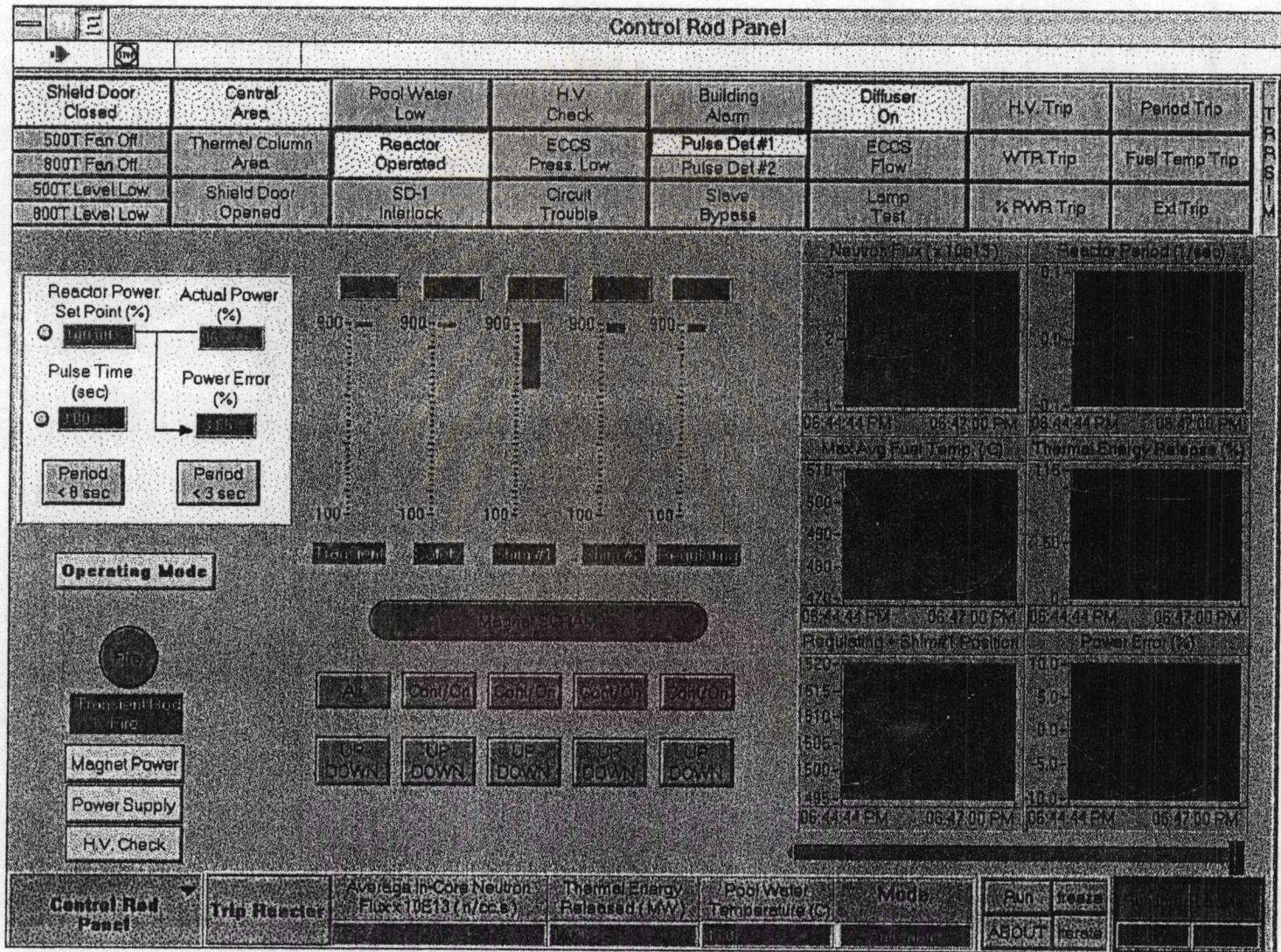
Figure 5.1 Reactor Preview
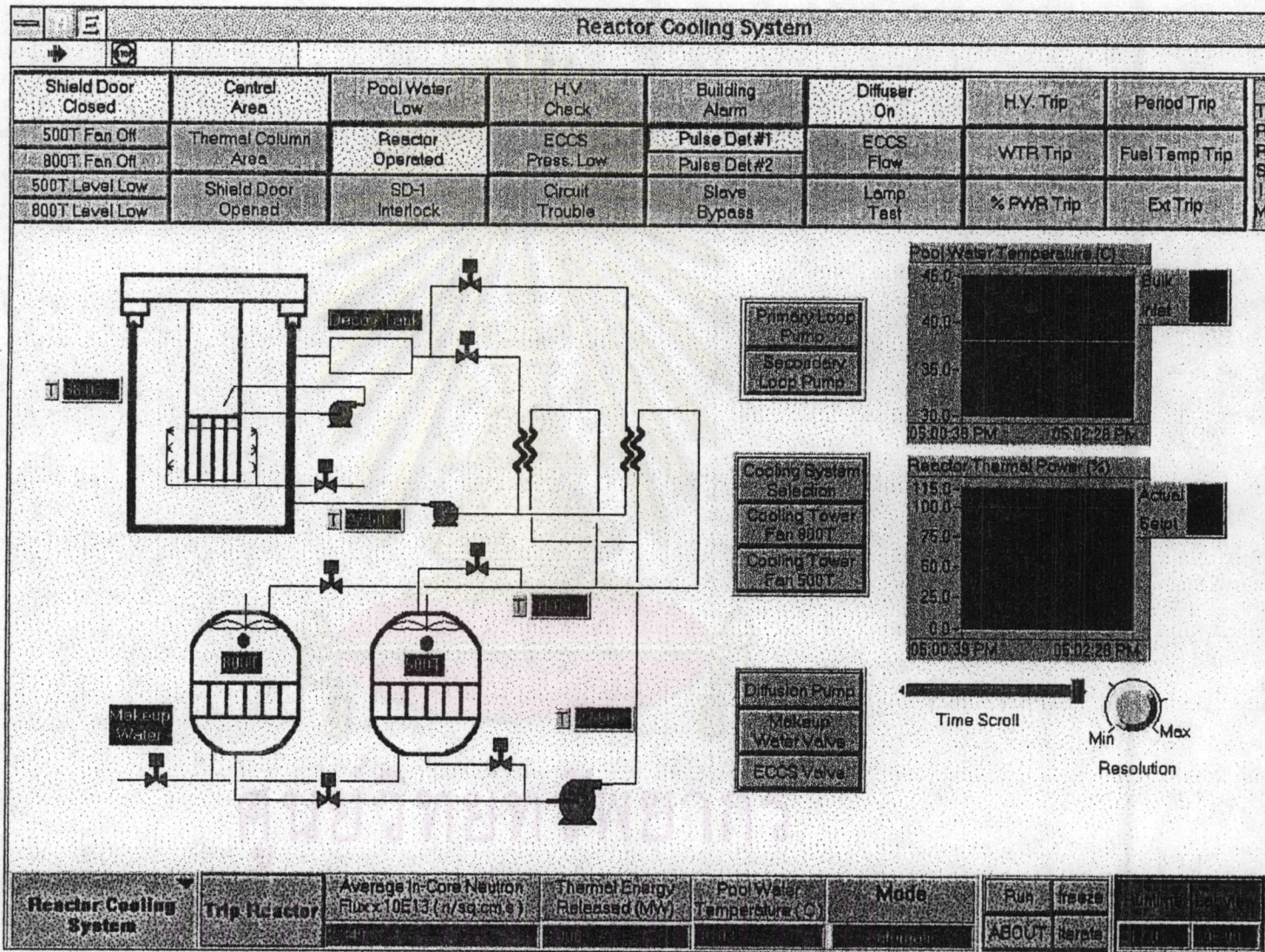
Figure 5.2 Control Rod Panel

Figure 5.3 Reactor Cooling System

Fuel Pin Profile

Neutron Flux [x10e13 n/sq.cm.sec]

Average Fuel Temp [C]

Coolant & Clad Temperature [C]

Max avg fuel temp

Max Clad Temp

Coolant Outlet

Water Reflector region 0-3

Graphite region 4-6

Active Zone region 7-21

Graphite region 22-24

Water Reflector region 25-28

Samarium 149 Concentration x 10e15   Xenon 135 Concentration x 10e15

Max Avg Fuel Temperature (C)   Thermal Energy Released (J)

Neutron Flux Region 10 (x 10e13)   Neutron Flux Region 11 (x 10e13)

Neutron Flux Region 12 (x 10e13)   Neutron Flux Region 20 (x 10e13)

Fuel Pin Profile   Trip Reactor   Average In-Core Neutron Flux x 10E13 (n/cm²)   Thermal Energy Released (MW)   Pool Water Temperature (°C)   Mode
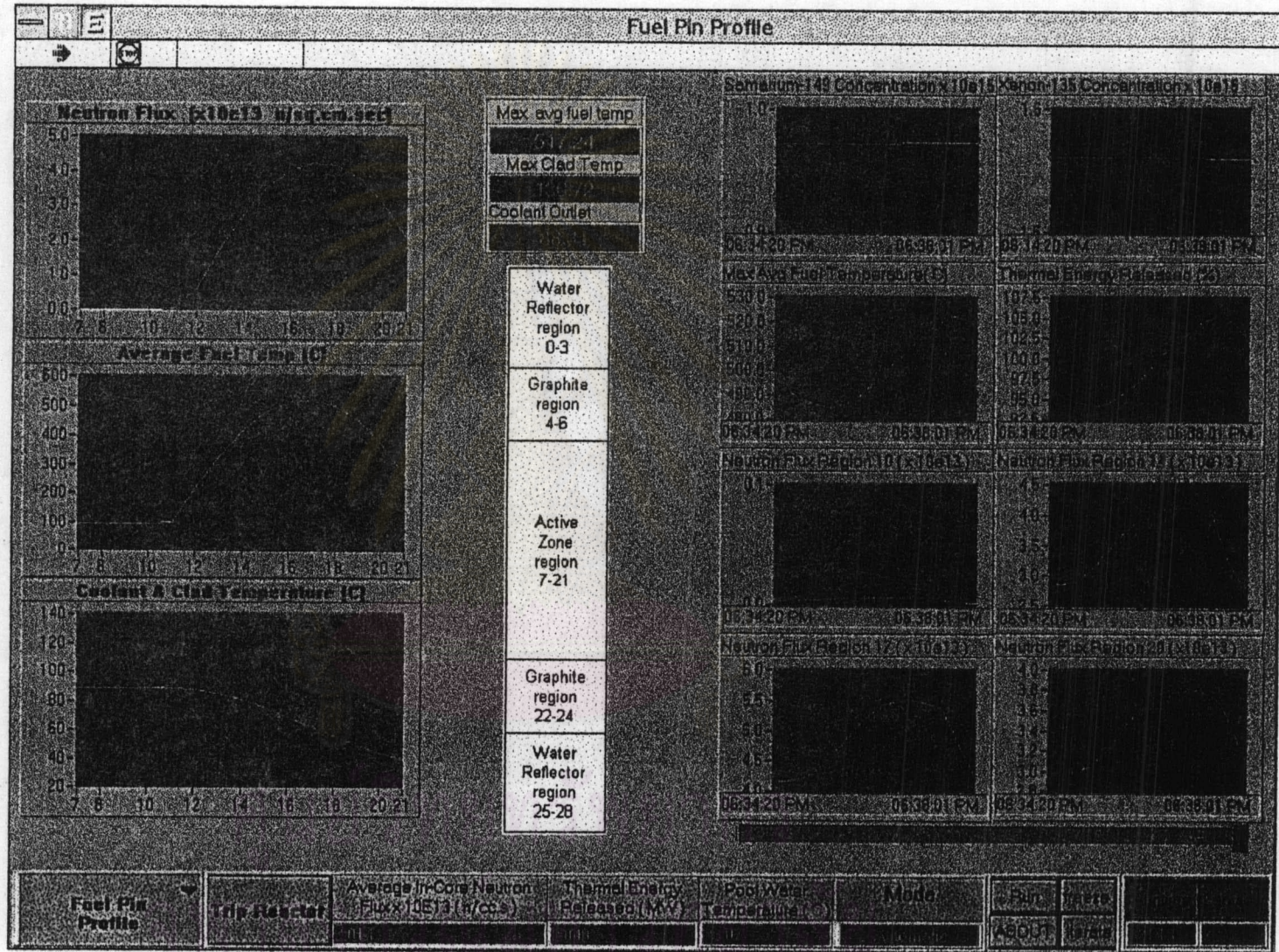
Figure 5.4 Fuel Pin Profile

with the previous reactor core which give a maximum power 1 MW thermal. 800 Tons thermal exchanger was added in later to support new reactor core. Both heat exchangers are still working and are in good condition. Switching between each exchanger is done by click on the cooling system pop up button and select the one you want. Pumps and valves are displays their status by color. The red color means that valve or pump is activated or turned on. Green color represent inactive condition.

The last one is Fuel Pin Profile screen. It shows mainly the variation of some parameters of the fuel pin such as temperature, neutron flux, poisoning concentration, etc. Most of all context are in charts and graphs. Only the lower bar of first screen present on this one. Flux variation and temperature profile in active region are shown.

Switching between each screen or exit from simulation could be done by click on the small delta on the lower-left corner. Then all the screen name will show and just slide highlight bar to the screen name we want to switch to.

While you click on the pop up button, the small control box will display on somewhere in screen. You won't be able to operate another command until the control box is closed.

5.2 Calculation Response

Table 5.1 Calculation results from running model collected at steady state condition

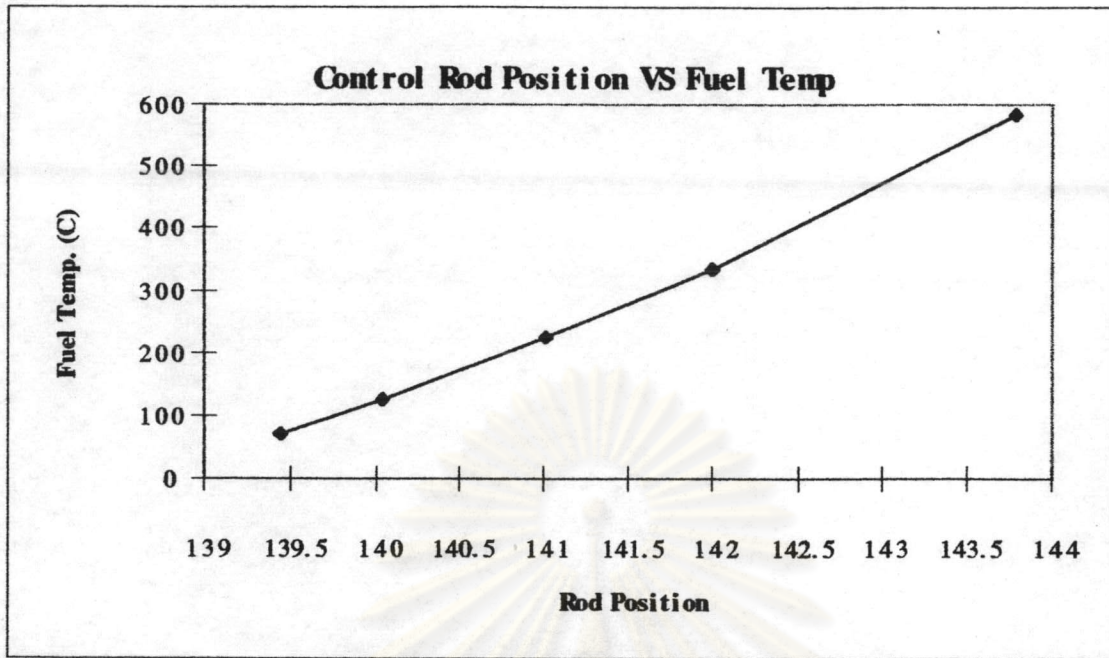| Control Rod Position	Maximum Fuel Temp. (C)	Reactor Thermal Power(%)	Neutron Flux (x 10e13)
139.44	69.84	0.545	0.005878
140.04	126.08	1.37	0.015308
141.01	224	2.81	0.0326
142	333	4.42	0.0532
143.79	583.42	8.13	0.105

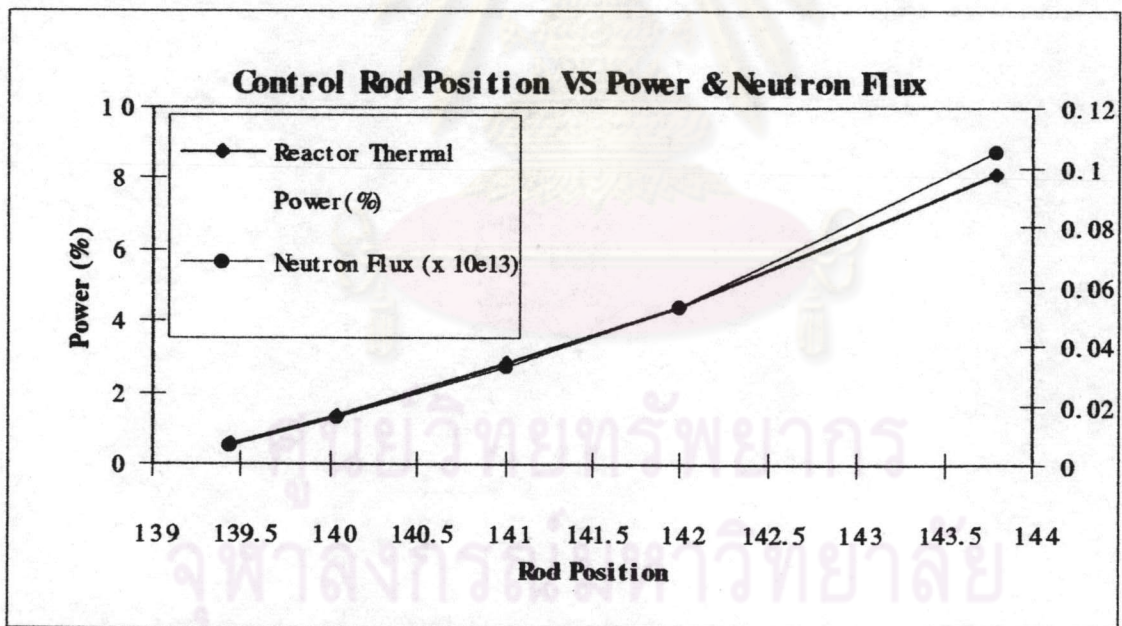Figure 5.5 Plot of Control Rod Position VS Fuel Temperature

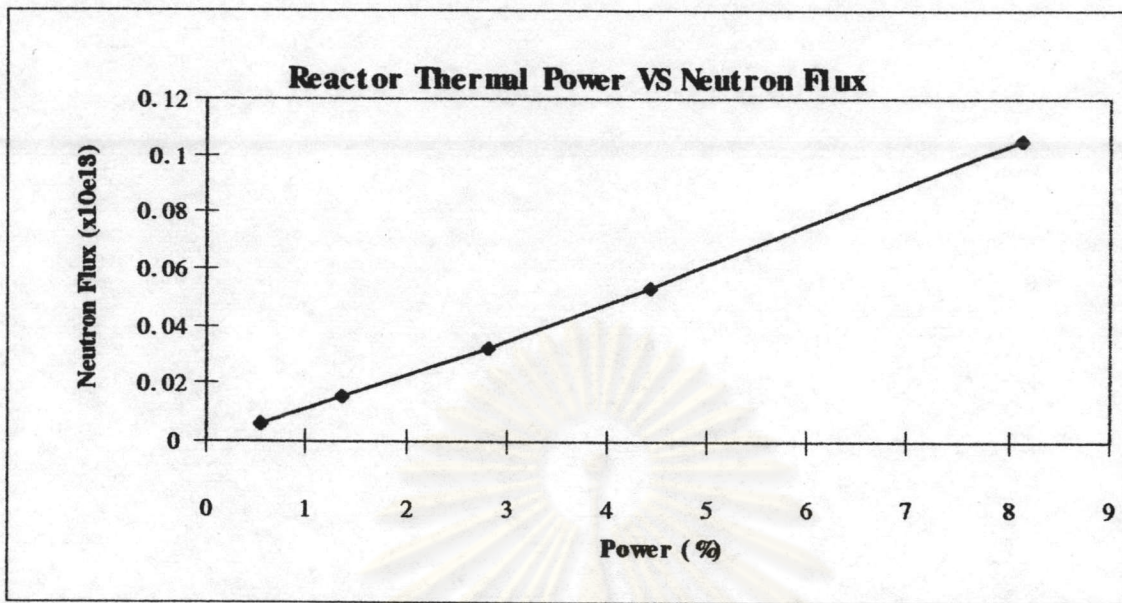Figure 5.6 Plot of Control Rod Position VS Power & Neutron Flux

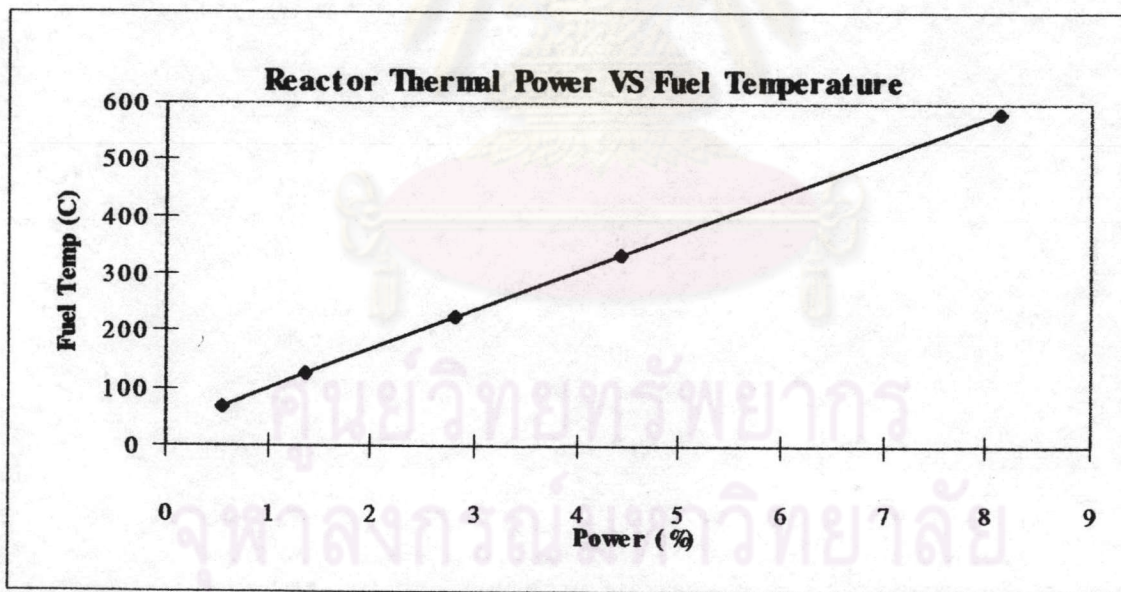Figure 5.7 Reactor Thermal Power VS Neutron Flux

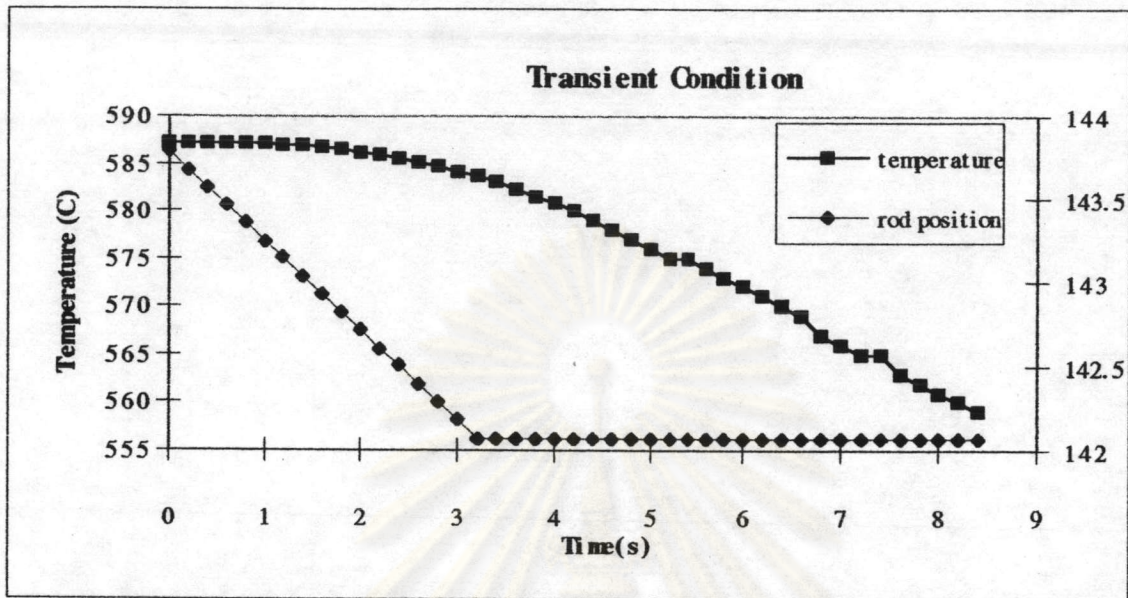Figure 5.8 Plot of reactor thermal power VS fuel temperature
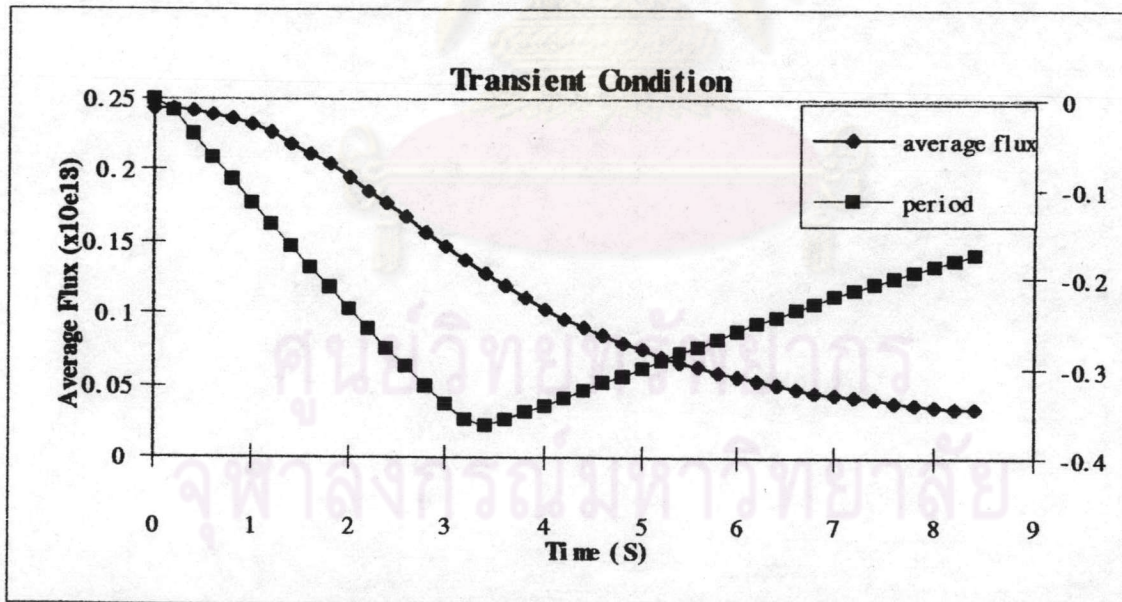
Figure 5.9 Transient condition studying (1)

Figure 5.10 Transient condition studying (2)

In order to ensure proper interfacing between our calculation engine and the front end, 4 steady state conditions and one transient were studied.

In the steady state condition, we changed control rod position and then wait for a few minutes till It got to the steady state. Neutron flux, fuel temperature and power level were recorded on each condition. They were plotted with the control rod position in Figure 5.5 and 5.6.

The interfacing in steady state conditions perform well. It response in the right direction. When we raise up the control rod, neutron flux, fuel temperature and reactor thermal power increase.

One transient condition has also been studied. The transient condition was shown in Figure 5.7 and 5.8. In this situation, control rod was slowly inserted into reactor core 3 seconds, the neutron flux and reactor period reacted with change simultaneously. The fuel temperature was slowly responded which is the characteristic of thermal-hydraulic model.

After 3 seconds, control rod was fixed at 142. Then the reactor period went up as a result of dropping in fuel temperature which increase core reactivity.

The interfacing is also very well in the dynamic model.

From the above results, it was proved that interface between calculation engine and front end is working properly.

We found from calculation that one control rod is far enough to control the reactor. This is because the insertion of control rod in regions would be taken as homogenized mixture. The absorber, Boron, content in control is plentiful and the absorption cross section is also high. Control rod position displayed in table is getting from only the most inserted rod. Whichever control rod is the same.

The reactor is critical at zero power at control rod position 138, the control rod is raised and as a result neutron flux, average fuel temperature and reactor thermal power increase. It is quite sensitive to very small change in control rod position. Thermal power could not reach higher level because of extremely high temperature occurring in fuel pin and the reactor would trip if the fuel temperature reach 650 C.

Unfortunately, the calculation results are not closed to the actual operating condition. The core's physical properties are packed with number of simplified assumption.

Table 5.2 Actual operating condition in steady state, fresh core

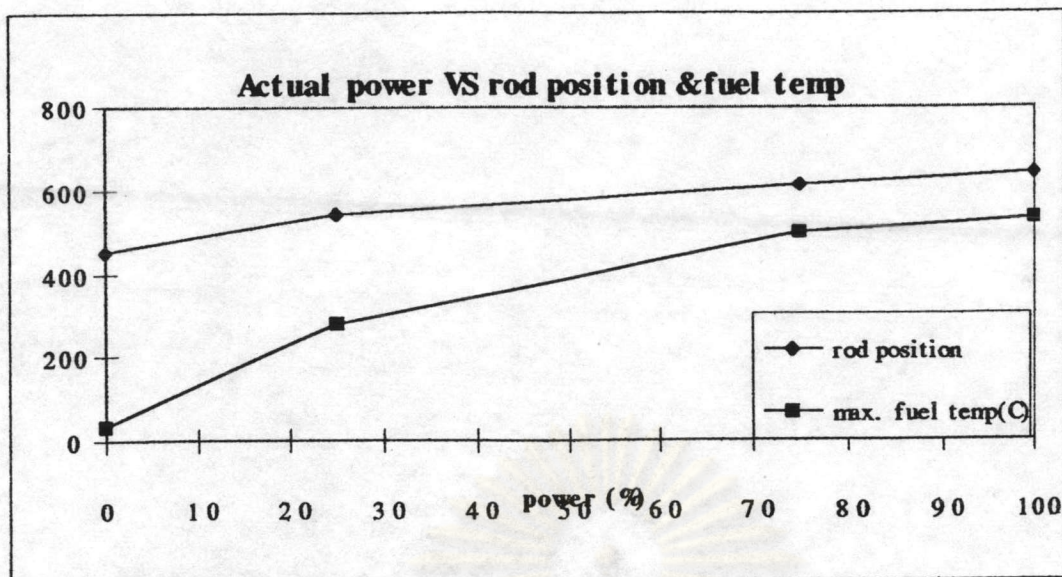| Thermal Power (%)	Control Rod Position	Fuel temperature (C)
100	644	530
75	611	500
50	600	410
25	541	280
0(just critical)	453	32

Figure 5.11 Plot of actual power VS control rod position from actual data

The actual reactor is critical at rod position 453 while we got 138 in the calculation engine. At 2 MW we got rod position at 644 and 530 C fuel temperature.

- Fission neutron are emitted with the continuous energy spectrum known as maxwellian distribution. It give a maximum energy up to 10 MeV with an average of 2 MeV. The actual cross section should be calculated carefully on average chance in each energy spectrum. The actual cross section must be less than the one at thermal energy.

- fuel pin used in the calculation is only one pin. It represents pins In reactor core which were assumed to have the same physical properties

- Element's neutron cross section should normally be averaged all over the energy range to get the proper value. Neutron cross section of elements mostly depend on its energy. The higher neutron energy, the less cross section.

Average neutron flux is getting from average flux in the active region. The actual neutron flux has never been recorded because neutron detector is used to identify the reactor thermal power. So, It could not compare the calculation results with the actual one.

We found from calculation that one control rod is far enough to control the reactor. The reason is that insertion of control rod in regions would be taken as homogenized mixture. The absorber content in control rod is plentiful and absorption cross section is also high. The control rod position in table is getting from the most inserted rod.

Control rods speed in automatic and square wave mode is proportional to power error in percent square multiply by a constant figure. The maximum speed is limited. It is used to protect reactor core from getting power level greater than 110% or fuel temperature 650 C.

Power set point displayed in the front end is thermal power. When set the power set point to be lower than actual, control rod will slowly drop in and neutron flux will decrease. Its speed is proportional to power error. The thermal power will be delayed in decreasing. It will take sometimes to conduct heat from fuel to the outer clad which actual heat is counted on.