Chapter 2

Thai Research Reactor Preview

2.1 General Information

Thai Research Reactor (TRR 1/M1) is the only research reactor in Thailand and has been operated by Office of Atomic Energy for Peace (OAEP) since September, 1977.

The reactor core was licensed to operate at a maximum steady state power of 2 MW thermal power. Pulse mode operation can be done by step reactivity insertions while the reactor is initially at a power level less than 1 kW. The maximum step reactivity insertion is 2.1% $\delta k/k$ which produces a peak reactor power of approximately 2000 MW thermal power.

The reactor core is placed in the open-top pool about 6 meters depth from surface to protect reactor building against fission and fission products radiated rays. Generated heat is transported from core by natural convection and have the secondary cooling system to cool the pool water down.

Its commercial name is TRIGA reactor. The reactor core consists of 105 cylindrical fuel pins and 5 control rods.

Reactor core has dimensions in 3 feet by diameter and 1.8 feet by height with 30 liters of water inside. The volumetric fraction of core elements are as following; fuel-$ZrH_{1.6}$ 61%, water 33%, clad 3.6% and the rest is zirconium.

The inherent safety of this TRIGA arises from large prompt negative temperature coefficient that is a characteristic of uranium-zirconium hydride fuel-moderator elements used in TRIGA system. As the fuel temperature increases this coefficient immediately compensates for reactivity insertions. The result is that reactor power excursions are terminated quickly and safely.

The main purpose of running TRR 1/M1 is for producing radioactive isotopes. It is sometime used for experimental purpose such as element analysis, neutron tomography, etc.

The rotary specimen rack is an isotope production facility. It is doughnut-shaped watertight ring that rotates around the core support shroud. Aluminium made rack hold specimen during irradiation. The rotating driver is either manually or electrically drive. Aluminium tanks was fastened to the top of rotary specimen rack housing. It serve as buoyancy chambers and control the vertical movement of the facility. Compressed air conducted through the bridge and flexible hose displaces the water within the tanks to provide and upward force. On the other hand, venting compressed air from tank will create a sinking force.

Short-lived radioisotopes are produced in a pneumatic transfer system, which rapidly conveys a specimen to and from a irradiation facility to the outer ring of the reactor core .

2.2 Fuel Elements

Fuel rods are of cylindrical shape. They are mixture of 8.5% uranium 20% Uranium-235 enrichment and zirconium-hydride. The active region is 3.63 cm in diameter and 38.1 cm in length. To facilitate hydriding, a small hole is drilled through the center of the active fuel section and a zirconium rod is inserted in this hole after hydriding complete. The instrument rod contains three thermocouples embedded in the fuel with half depth of fuel-moderator.

New fuel elements which are introduced to replace the exhausted elements. They contain higher uranium content which is up to 20% of fuel-modeartor weigth. The new elements are lasting longer, more economy and give higher flux. There are approximately 25 new elements being used at this moment. The mixed core was carefully studied by OAEP and General Atomic. It perform quite well and safely.

Zirconium hydride consist of zirconium and hydrogen which could be varied in percentage by weight. In TRR 1/M1 core, hydrogen concentration at 1.65% by weight is selected. The diffusion of hydrogen element from the composite at elevated temperature is pretty high and will cause high gas pressure and excessive stress on fuel clad.

Fuel is cladded with a 0.051 cm thick stainless steel and all closures are made by heliarc welding. Graphite reflectors were placed top and bottom of the fuel serving as neutron reflectors.

Stainless steel end fixture were attached to both ends of the can. The lower end fixture supports fuel-moderator element on the bottom grid plate. The upper one consists of knob for attachment the fuel-handling tool and a triangular spacer, which permits cooling water to flow through the upper grid plate.

One outstanding characteristic of mixed zirconium-hydride fuel is its large prompt negative reactivity. It is temperature dependent parameter and have average value about -1.0x10-4 δk/k C over a fuel temperature range from 20 C to 700 C as shown in Figure 2.1.

Table 2.1 Physical properties of fuel and fuel elements (From Reference 11)

Physical properties	value	unit
fuel density	6.00	gm/cc
fuel specific heat	$0.34 + 0.695 \times 10^{-3}$ T	joule/gm C; T is temperature in C
fuel thermal conductiviry	0.18	W/cm C
gap density	0.000156	mm
gap specific heat	1.613	joule/gm C

Table 2.1 Physical properties of fuel and fuel elements (Continued)

gap thickness	0.00222	cm
gap thermal conductivity	0.00199	W/cm C
clad density	8.025	gm/cc
clad specific heat	0.155	joules/gm C
clad thermal conductivity	0.168	W/cm C
clad thickness	0.051	cm
coolant specific heat	4180	joules/kg C
zirconium rod density	6.503	gm/cc
zirconium specific heat	0.103	joules/gm C
zirconium thermal conductivity	0.190	W/cm C

2.3 Control Elements

There are five control rods used in this reactor; 2 shim rods, one regulating rod, one safety rod and one safety transient rods.

The regulating, shim and safety rods are sealed 304 stainless steel tubes approximately 109 cm length by 3.43 cm in diameter in which the uppermost 16.5 cm section is an air void and the next 38.1 cm is the neutron absorber (boron carbide in solid form). Next below the neutron absorber is a fuel follower section consisting of 38.1 cm of U-$ZRH_{1.6}$ fuel. The bottom section of the rod is 16.5 cm air void. These fuel follower rods are shown in Figure 2.3.

Control rod drive assemblies for the shim, safety and regulating rods are mounted on a reactor bridge assembly over the pool and consist of a motor and reduction gear driving a rack and pinion. Each control rod has an extension tube that extends to a dashpot below the surface of the water. The dashpot and control rod assembly are connected to the rack through an electromagnet and armature. In the event of a power failure or "SCRAM" signals, the control rod magnets are de-energized and the rods fall into the core. The insertion or withdraw speed is approximately 48 cm per min. for shim rod or 61 cm per min. for the regulating rod.

The safety-transient rod is a sealed, 93.35 cm long by 3.18 cm in diameter, aluminium tube. It contain solid boron carbide in the upper part. Below the absorber is air-filled follower section. Driving system on pulsing is operate with a pneumatic drive.

Table 2.2 Summary of core elements(from reference 5)

element	fuel-moderator	safety transient	shim, safety and regulating
Cladding			
material	304 SS	Al	304 SS
OD (cm)	3.73	3.175	3.43
wall thickness (cm)	0.051	0.071	0.051
total length	73.15	93.35	109.5
Absorber			
material	-	boron carbide	boron carbide
OD (cm)	-	3.033	3.33
length	-	38.1	36.2
Follower			
material	$U\text{-}ZrH_{1.6}$	air	$U\text{-}ZrH_{1.6}$
OD (cm)	3.63	3.033	3.33
length	38.1	53.02	38.1

Table 2.3 Thermal cross section of core elements(from reference 8)

Core elements	absorption	fission	elastic scattering
Uranium-235	678	577	46
Uranium-238	2.78	-	8.16
Zirconium	0.185	-	8
Hydrogen	0.33	-	38
water (H2O)	0.66	-	103
Boron	755	-	4
Carbon and graphite	0.004	-	4.8
Iron	2.62	-	11
Chromium	3.1	-	3
Nikle	4.6	-	17.5

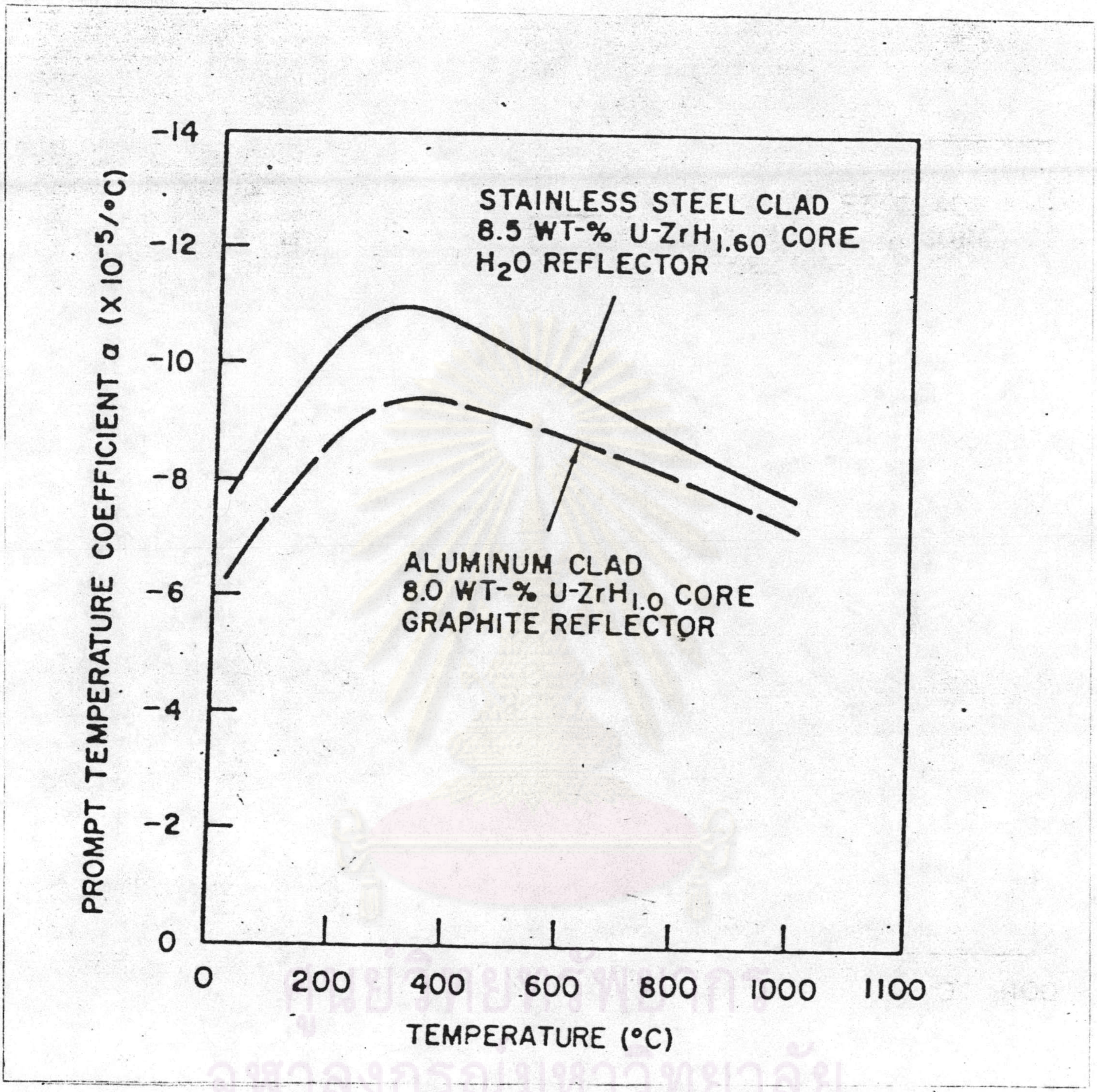

Figure 2.1 TRIGA prompt negative temperature coefficient VS average fuel temperature

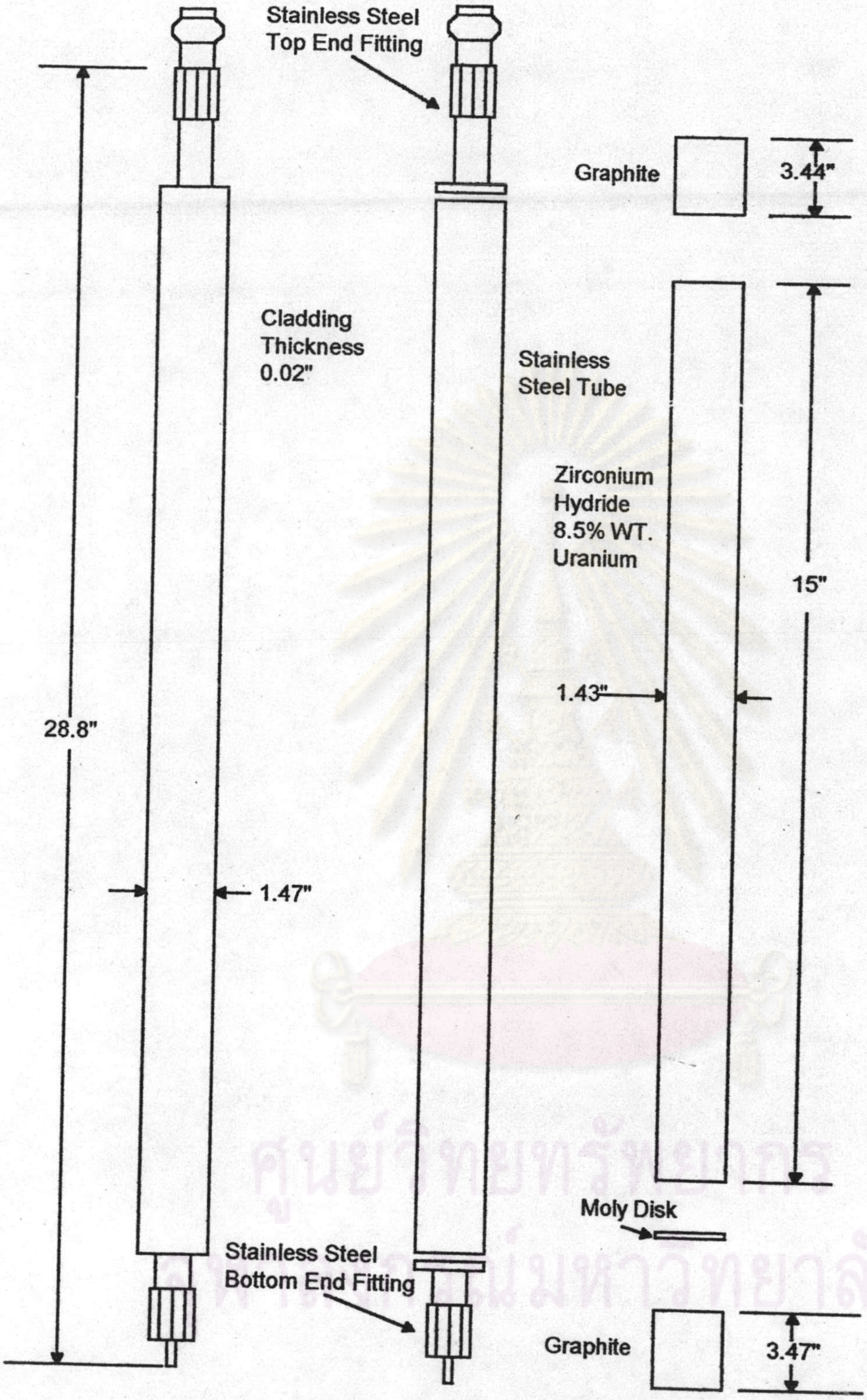

Figure 2.2 Stainless-steel-clad fuel element

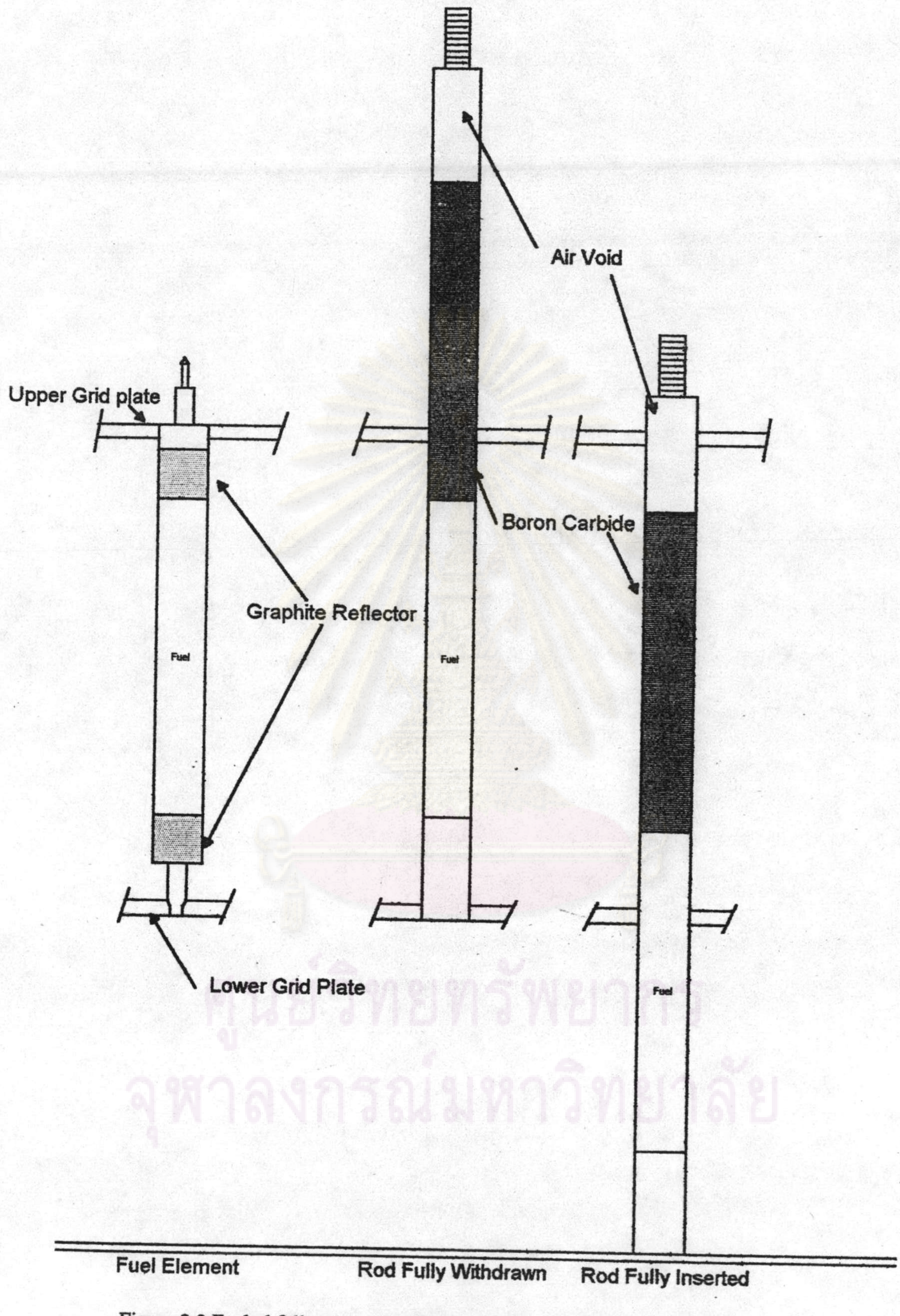

Figure 2.3 Fueled-follower type control rod shown in withdrawn and inserted

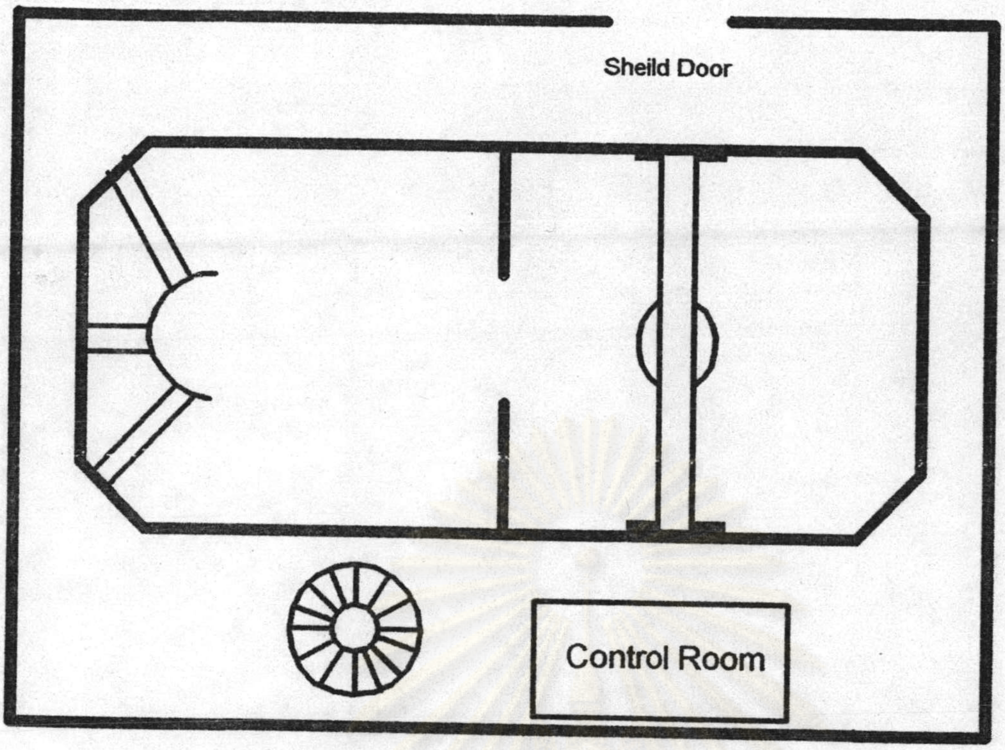

figure 2.4 Plan diagram of reactor building

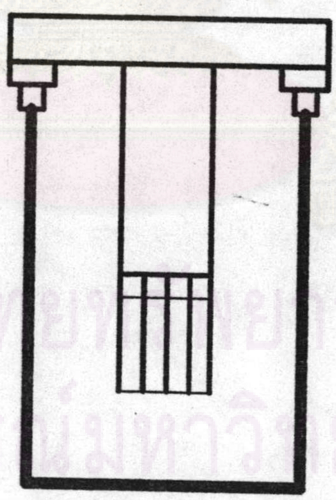

Figure 2.5 Side view plan of reactor pool