# Fuel Experience in QinShan CANDU

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## ABSTRACT

Qinshan 2 CANDU units were in turn declared commercial operation in 2003. They have started refueling on March and November 2003. Because fuel machines were not available several times by reasons of the equipment failures, the refueling rate fluctuated very much during initial refueling in unit#1. But unit#1 had never entered into Shim mode. Domestic fuel bundles were successfully used in Qinshan two units. The first batch of fuel bundles manually loaded were produced by ZPI, all the other fuel bundles for refueling were produced by domestic fuel manufacturer (202). In Qinshan, the efficient methods based on on-line monitor systems have been found, which can locate the exact position of channel and bundle for fuel failure. Up to now, only 5 fuel bundles have been confirmed defective in Unit#1.

## 1. INTRODUCTION

The two PHWR units of Third Qinshan Nuclear Power Company Ltd (TQNPC) were introduced from Canada. Initial fuel loading were completed on July, 2002 in Unit1 and on March, 2003 in Unit2, first criticality were approached on Sep. 21 2002 in Unit1 and on April 29,2003 in Unit2. They were declared commercial operation on Dec. 31,2002 and on July 24,2003 respectively.

## 2. REFUELING STRATEGY

In order to test the fuel machines and operating manuals, Unit1 of TQNPC started refuel two weeks in advance (at 106FPD) on March 27, 2003, and kept the lower refuel rates at about 1 channel per FPD. Swing-8 scheme is used in the channel first visit.

After 125FPD, fuel machines were not available several times by reasons of the equipment failures, which made it difficult to follow the fuelling plan. The refueling rate (figure 1) fluctuated very much during initial refueling in unit#1. Average fuelling rate (120-280FPD) is 2.13 channels /FPD. Minimum excess reactivity decreased to about 0.5mk, but Unit1 had not entered into Shim mode. For several weeks, more than 20 channels were refueled every week in order to maintain the full power operation. In order to prepare first planed F/M outage (ram maintenance), the excess reactivity reached 4.62mk by high refueling rate, lower than Technical Specification Limit 5mk. The core excess reactivity variation is shown in figure 2. Individual and average discharge burnup for refueling channels increased slowly as shown in figure 3.

## 3. DOMESTIC FUEL STRATEGY

TQNPC adopts successfully the strategy of domestic fuel. According to main contract, Canadian ZPI supplied the fuel bundles for initial fuel loading of the two units. But all the other bundles are fabricated in China, using the mature fuel technology and equipments imported from ZPI. Up to now, about 2200 domestic fuel bundles had been loaded into the core by refuel, and no systematic defects occurred.

In the end of 1998, Chinese 202 fuel manufacturer and Canadian ZPI signed the technical transfer contract for CANDU-6 fuel bundle fabrication. CANDU Fuel factory project started construction on April 4, 2000. After 33 months, the project successfully completed and put into production. Its production capacity is about 200 tons (U) and 10,000 bundles per year.

$UO_2$ pad product line was independently designed and constructed by China, based on Chinese long term and mature technologies and experiences. Its process includes dissolve, extraction and purity, disposition and desiccation, decomposition and deoxidization, homogenization, etc. All equipments are made by China.

Fuel bundle product line is imported from ZPI, which is from pellet product to bundle assembling.

On December 2002, 202 fuel manufacturer started to product the fuel bundle. The first batch of fuel bundles was shipped to Qinshan site. Up to Oct. 10,2003, 7800 bundles were made, in which 5320 bundles were shipped. In about 2600 bundles loaded in reactor core, only 2 bundles have been confirmed defective. It demonstrates that the domestic fuel bundle have good performance.

## 4. FUEL DEFECT

From June to now, 5 channels (P08, S10, G17, P12 and M15) as shown in figure 4were found to contain fuel defects in Qinshan CANDU Unit1. They were confirmed by GFP system and FFL system and refueled on time. During discharging all defective fuel bundles, the maximum activity concentration of Xenon 133(figure 6) detected by GFP was lower than 20 MBq/kg, and no Iodine 131 apparently in the core.

### 4.1 IN-CORE DIAGNOSTICS

At June 22,2003, Unit1 restarted and increased to full power. GFP system had monitored that there is a sudden increase of activity concentration of Xe-133, and then decayed to a lower level, which indicated the presence of defective fuel in the core

In July 2003, activity concentration of Xe-133 increased to a high level of 3MBq/kg due to refuel of a channel contained a defective fuel bundles. It was fortunate that FFL system could identify the suspect channels (figure 5), whose count rates of delayed neutron increased much higher than the other channels and the DR values increased, too.

In August 2003, two defective fuel channels were refueled, but the activity concentration of Xe-133 had not decreased. So there were still some defective fuels in the core. By analyzing the data of FFL system, channel G17 were suspected to contain failed fuel. First, 4 fuel bundles were discharged out of core, but it showed that failed fuel bundles had not been taken out, then the other 8 fuel bundles were discharged. After refuel of the channel, Xe-133 decayed to about 3.5MBq/kg. During the following decay time, a pulse of Xe-133 occurred owing to reactor power transient.

In September 2003, due to decrease of reactor power, the activity concentration of Xe-133 increased to 15.5MBq/kg. According to release of Xe-133 and increase of delayed neutron CR, channel P12 were refueled to take defective fuel bundles out of core.

In October 2003, the activity concentration of Xe-133 increased due to refueling of neighbors of channel M15, which were suspected to be defective fuel channel based on FFL system. The channel was refueled in the end of the month. Then the activity concentration of Xe-133 decayed to very low level and no defect fuel exits in the core of Unit#1.

## 4.2 DEFECTIVE REFUELING SCHEME

In the beginning of July, many channels had been refueled with domestic fuel bundles, and such channels contained four bundles fabricated by ZPI and 8 bundles fabricated by 202. TQNPC had no confidence to find the exact position of defective fuel bundles with the signal of FFL system. So a work plan was prepared to refuel such channels. Follow the work plan, 4 bundles would first be refueled, and if the defective fuel bundles were still in the core, the remaining 8 bundles would be refueled. Later, the refueling scheme was modified according to the experience in refuel the defective fuel channels: first 8 bundles were discharged and then if required, the remaining 4 bundles would be discharged.

## 4.3 LOCATING THE POSITION OF DEFECTIVE BUNDLE

TQNPC successfully located the position of defect bundle by GFP and FFL and Gamma Monitoring System. During refueling, we can easily confirm whether defect fuel has been taken out, based on analysis of history data and trend for GFP and delayed neutron and Gamma dose in R012, R013, R014 and R001 (figure 7,8). During discharging spent fuel in discharge bay room (R001), we monitor Gamma trend in R001 in order to locate which pair of bundle is defective. A few days after spent fuel discharged in R001, further investigation was taken to identify the exact position of defect bundle from the pair of fuel bundles, which have been confirmed defect during discharging. The two bundles have been back transfer (out of and into the water in discharge bay) in order to monitor the Gamma trend in R001. In all the defective fuels bundles, ZPI fabricated three and domestic manufacturer fabricated the others. All fuel defects occurred to the lower power bundles.

## 4.4 CONCLUSION

TQNPC took a short time to locate the positions of defective fuel channels and refueled them on time. So it had little effect on station performance and public dose. Up to now, the reason of the bundle failure was not determined.

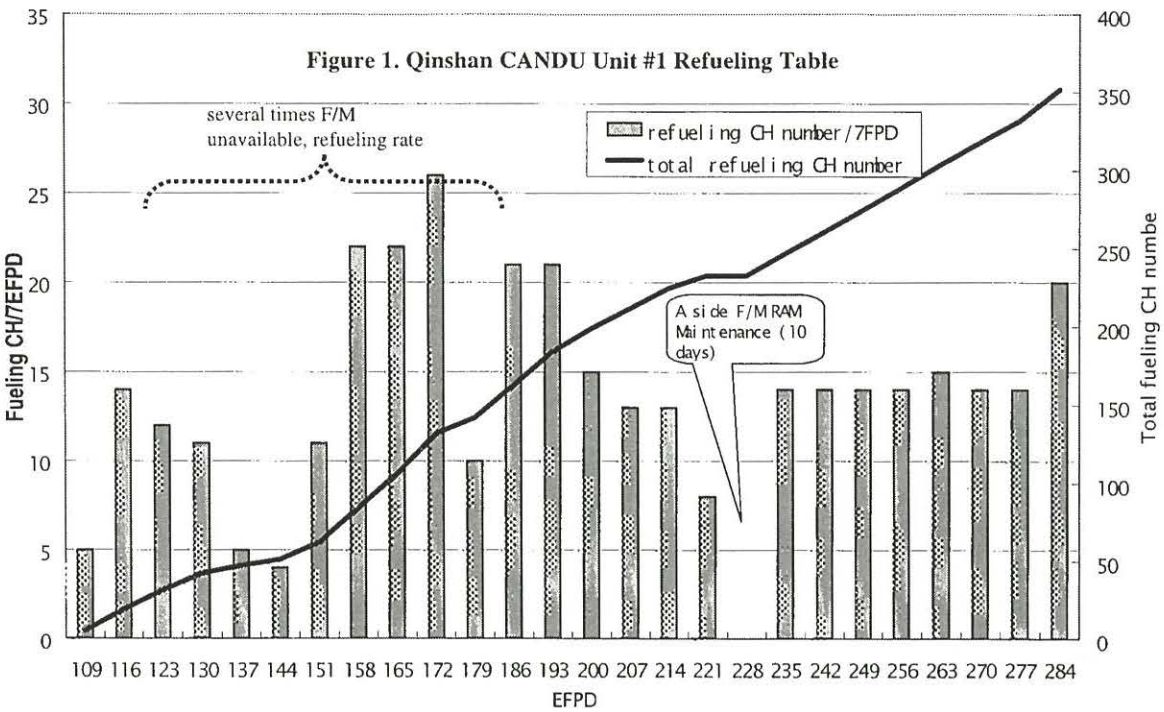
Figure 1. Qinshan CANDU Unit #1 Refueling Table
several times F/M
unavailable, refueling rate
refueling CH number/7FPD
total refueling CH number
A side F/M RAM
Maintenance (10
days)
Fueling CH/7EFPD
Total fueling CH numbe
EFPD
35
30
25
20
15
10
5
0
400
350
300
250
200
150
100
50
0
109 116 123 130 137 144 151 158 165 172 179 186 193 200 207 214 221 228 235 242 249 256 263 270 277 284

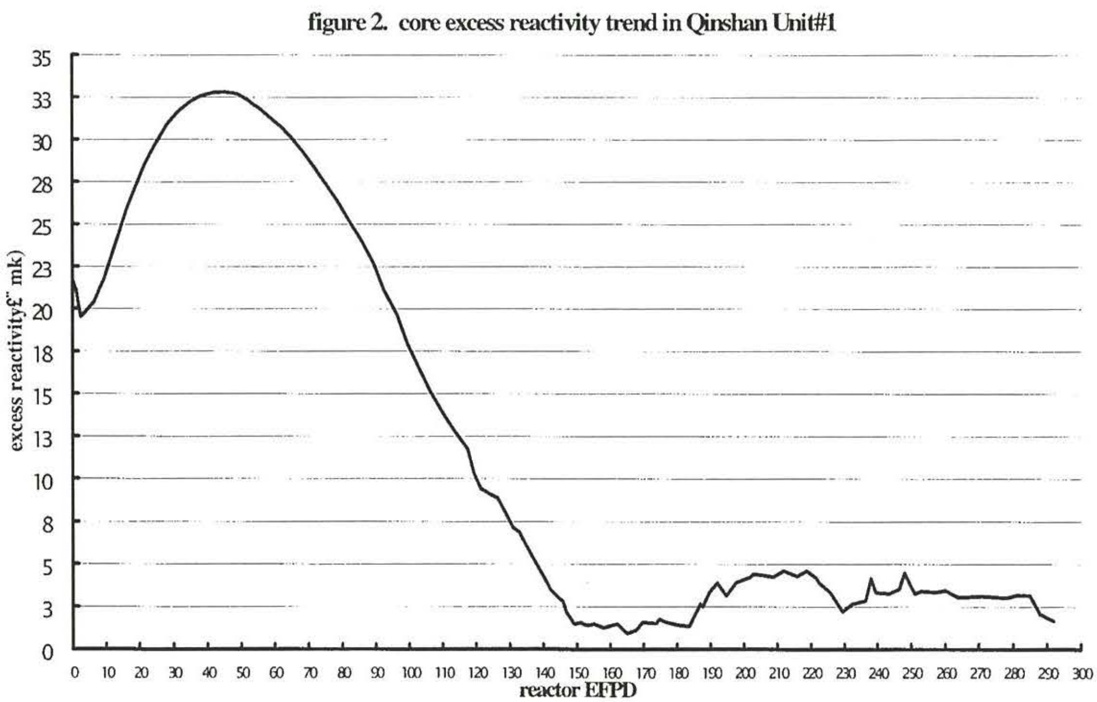
figure 2. core excess reactivity trend in Qinshan Unit#1
excess reactivity£¨mk)
reactor EFPD
35
33
30
28
25
23
20
18
15
13
10
8
5
3
0
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300

**figure 3. Qinshan Unit#1 dichage burnup table**

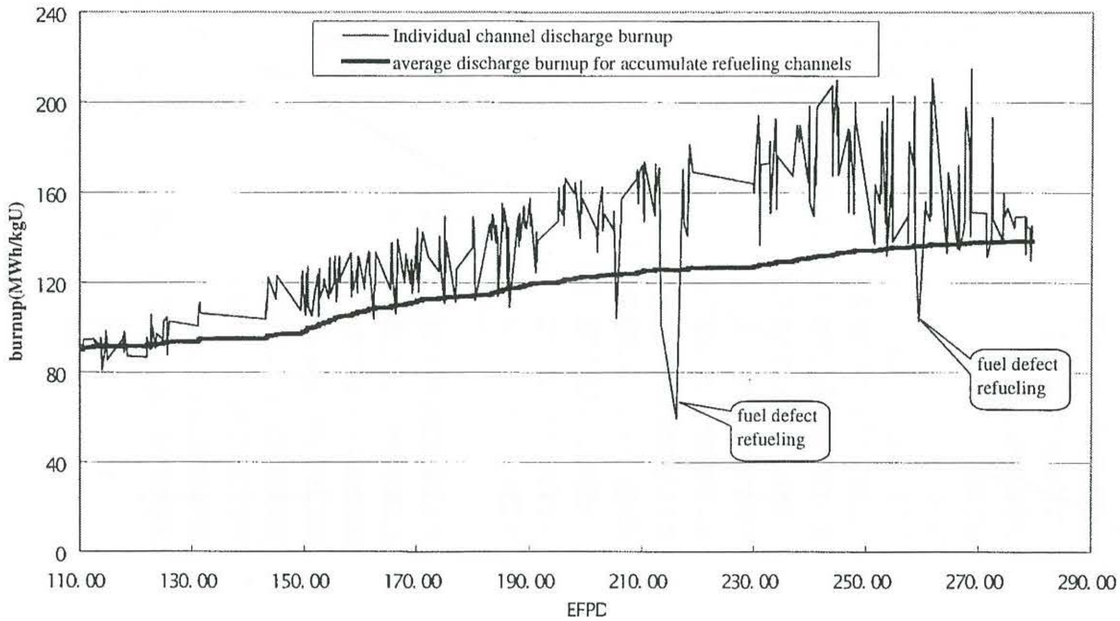


**Figure 4** **Defective Fuel Channels Display** From C Side

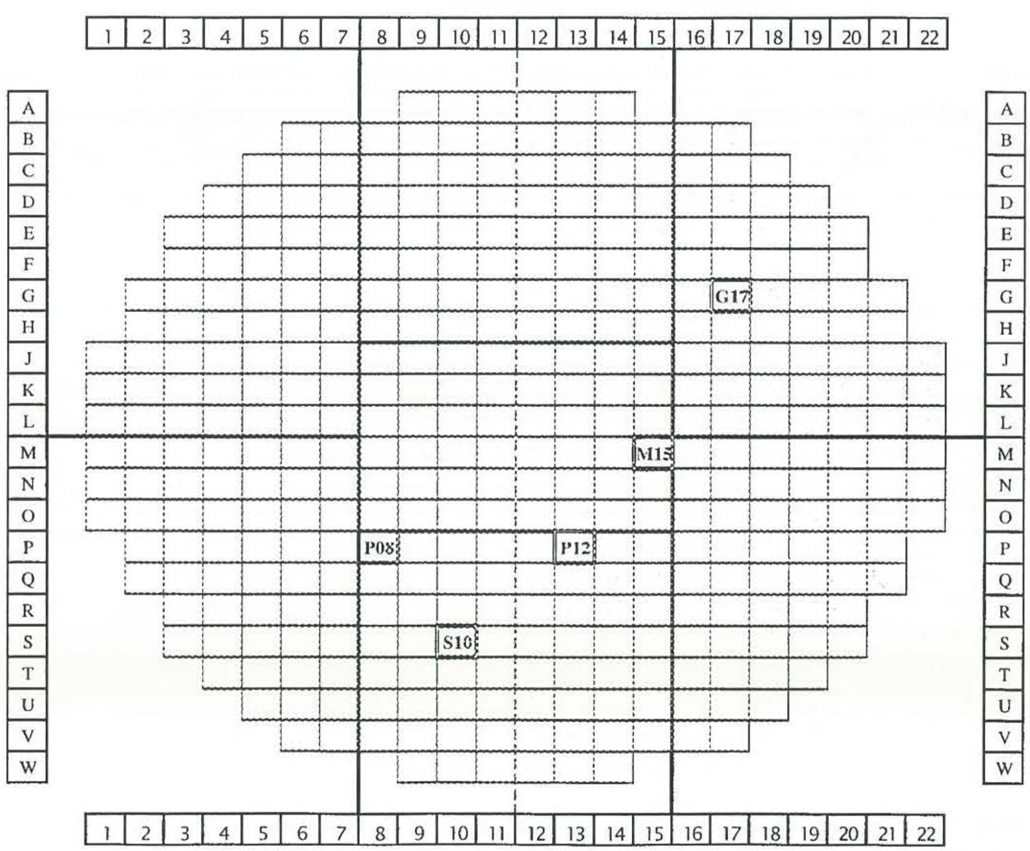

**Figure 5** History Trend of DN Count Rates in Qinshan CANDU

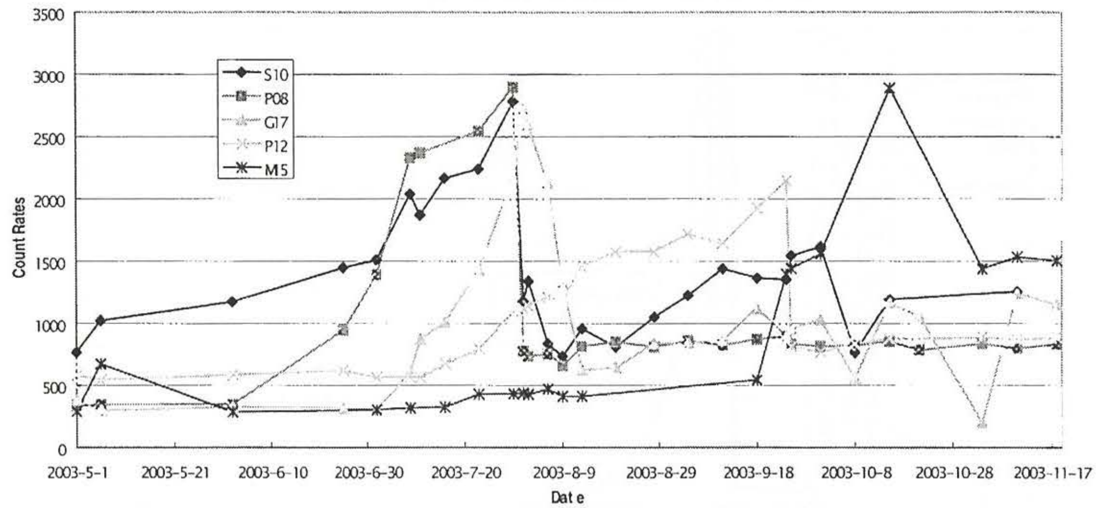


**Figure 6** History Trend of Activity Concentration of Xe-133

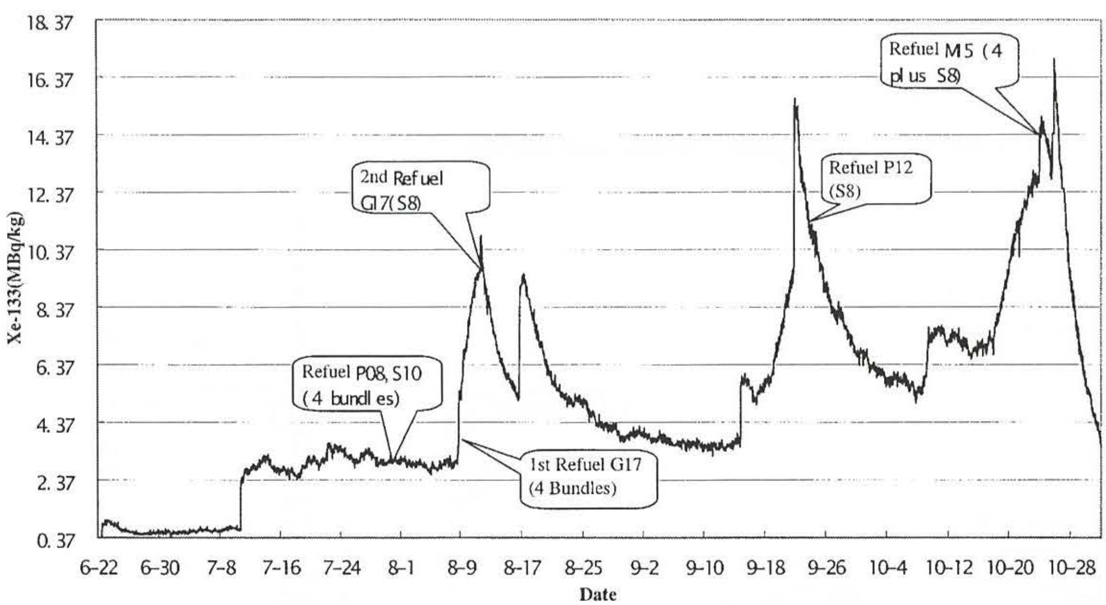

**Figure 7**

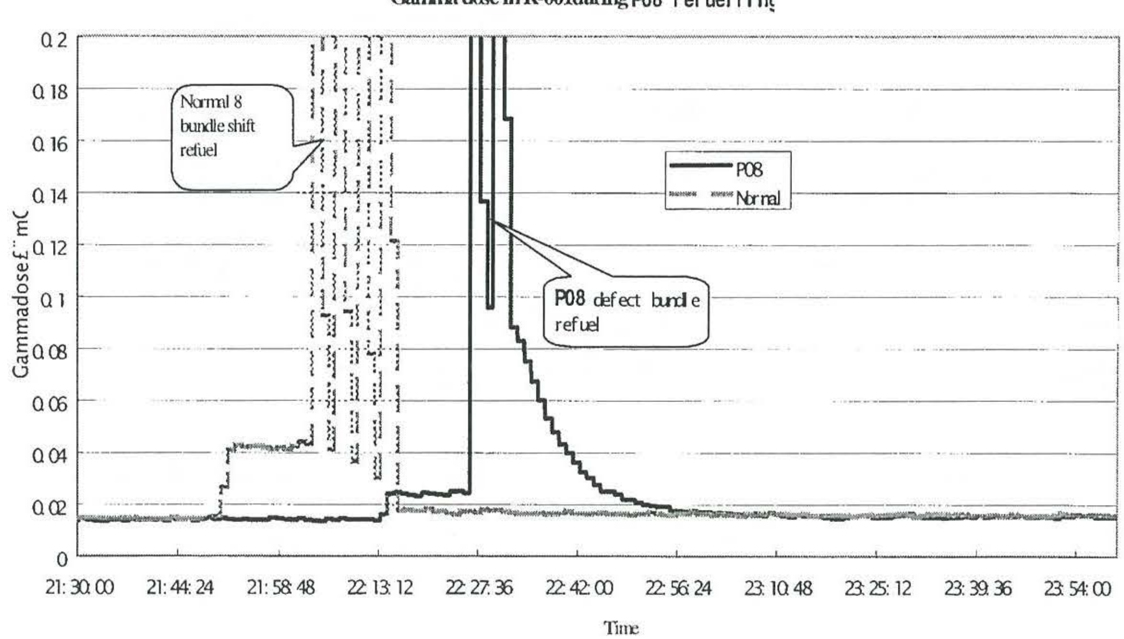


**Figure 8**