FUEL PERFORMANCE AT CERNAVODA UNIT # 1

DAN STANILA

Reactor Physics and Core Performance Group
CNE-PROD, C.P. 42
8625, Cernavoda ROMANIA

ABSTRACT

This paper presents the fuel performances achieved during the first two years of commercial operation.

1. INTRODUNCTION

Cernavoda Unit-1 has a CANDU-6 reactor. Commercial operation has started on December 2nd, 1996. The average capacity factor achieved during the first two years was 86.65%. A diagram showing the reactor power during this period is shown in figure 1.

2. REFFUELING

Reactor refuelling was started after 100 FPDs. For the first two weeks, the refuelling rate was kept very low (1 channel/day, 4 days per week) to allow a last check of the fuel handling tools and systems. Then, as the core initial excess reactivity decreased, refuelling rate was increased.

2.1 Refuelling policy

At Cernavoda reactor refuelling is done during the daylight shift, normally only four days per week. The maintenance activities to the fuelling machine and fuel handling tools are performed on Wednesdays, when usually no refuelling is planned.

In order to increase the time available prior to enter in shim operation (in case the fuelling machine would fail) at Cernavoda was decided to maintain permanently a small core reactivity excess (~ 1 mk) compensated by soluble poison (boron) added to the moderator.

2.2 Refuelling scheme

At the beginning, the refuelling scheme used was Swing-8. With this scheme the bundles in positions #3 & #4 are discharged and those in positions #11 & #12 are re-inserted in the channel for a second irradiation cycle. As result, the fuel discharge burnup increases up to 10%. The Swing-8 scheme was used for the first visit at 274 channels. Then, the standard 8-bundles shift scheme was adopted. In very few situations, the 4-bundles shift scheme was also used, but only in addition to one refuelling with 8-bundles, when was necessary to unload a suspect defective bundle located towards the channel inlet end. This has occurred only three times so far.

2.3 Fuel Design and manufacture

Technical specifications and design drawings provided by AECL are used to manufacture the fuel for Cernavoda Unit-1.

Prior to start the commissioning of the reactor, a Romanian plant (FCN Pitesti) was authorised by Zircatec Precision Industries/Canada as a qualified CANDU-6 fuel manufacturer. However, the first fuel charge for Cernavoda Unit-1 was supplied by Zircatec and only a limited quantity (66 natural bundles) of domestic fuel was included in this first charge as a final test. After the on-set of reactor refuelling almost only Romanian fuel was loaded into the core.

3. FUEL PERFORMANCES

During the first two years of commercial operation at Cernavoda, more than 14,000 fuel bundles have been irradiated into the Cernavoda Unit-1 reactor. The fuel behaviour and the performances achieved are excellent.

3.1 Fuel discharge burnup

In 1997 a total 4764 bundles have been discharged from the core at an average burnup of 143.8 MWh/kgU. The first 4560 bundles (equivalent to a full charge) have been discharged till FPD 391. The average burnup on these bundles was 142.5 MWh/kgU, including the 160 depleted bundles (loaded in the initial core to flatten the power distribution) that had an average of only 120.5 MWh/kgU. The last depleted bundle was discharged from the core after 278 FPD.

In 1998, the number of bundles discharged from the core was 5056. The average burnup on these bundles was 170.85 MWh/kgU.

Figure 2 shows the distribution of bundles present in pool vs burnup at the end of 1998. The average burnup calculated over all bundles present in pool at the end of 1998 (9836 bundles) was 157.566 MWh/kgU.

The highest burnup achieved on a fuel bundle discharged from the Cernavoda core till the end of 1998 was 317.47 MWh/kgU. It occurred on a bundle manufactured by Zircatec loaded initially in second position from channel L12, then moved in position 10 and discharged from the core after 476.5 FPDs of operation at power.

3.2 Core Monitoring to detect defective fuel

Cernavoda Unit-1 has two systems that help to detect and locate the failed fuel present inside the core. Both these systems are tapped into the Primary Heat Transport System (PHTS) and measure the activity concentrations of various fission products in the coolant.

The Gaseous Fission Product (GFP) Monitoring System is designed to measure continuously the gamma activity given by certain gaseous fission products (Xe-133, Kr-88, Xe-135 and I-131) present in continuos sample flows taken from each of the two loops of the PHTS.

Figures 3 to 6 show the evolution of the activity given by these isotopes during the first two years of commercial operation at Cernavoda. Note that the specific activity due to I-131 was as low as 0.05 MBq/kgD_2O for most of the time because the PHT purification system was working permanently. The iodine spikes (up to 2.2 MBq/kgD_2O) shown after power manoeuvres, reactor trips or shutdowns proved the presence of defective fuel inside the core at that time.

Xe-133 activity was very high at the beginning of 1997 (over 50 MBq/kgD_2O) due to the presence of defective fuel but it decreased below 10 MBq/kgD_2O when the core was free of fuel defects (for instance, ~ 3 MBq/kgD_2O during the last months of 1998).

Xe-135 and Kr-88 had similar trends like Xe-133, but their specific activities were lower. Xe-135 have never exceeded 7 MBq/kgD_2O, while Kr-88 was always below 1.75 MBq/kgD_2O.

The GFP system can help only to detect the PHT loop where a fuel defect occurs. A second system (Delayed Neutron Monitoring System) was provided to detect the channel and the bundle pair containing the defective fuel (this system takes coolant sample from each channel).

In order to detect the presence of defective fuel inside the Cernavoda core, a scan of all fuel channels is performed with the DN system at least every two weeks. The frequency was once per week at the beginning of operation, but it was decreased to once every two weeks due to problems with high water temperature in the DN system moderator tanks. One half-core is scanned every weekend, alternatively. A design change is in preparation and will be implemented soon to provide additional cooling to the water from the tanks.

DN scan results are processed permanently in order to get /1/:

- the average count rate (ACR) on each loop,
- the historical count rate (HCR) for each channel,
- the historical discrimination ratio (HDR) for each channel.

When a defective bundle is suspected in a channel, that channel is monitored more closely thereafter. That is the DN system measurements are done more frequently on that channel, until the defective bundle is unloaded.

The average count rate given by DN increased on PHT loop#1 from about 25cps (at the beginning of 1997) to ~ 130 cps at the end of the year and then decreased to about 80 cps (at the end of 1998). This behaviour was due to the consumption of tramp uranium that escaped from a defective bundle unloaded from channel L17 at the beginning of October 1997. This defect is considered as the most sever defect that we have recorded at Cernavoda so far.

Unlike the loop # 1, the average count rate has remained almost constant on loop # 2 (~ 30 cps).

As it concerns the historical discrimination ratio, at Cernavoda it varies between a minimum of 0.06 for channel B08 to a maximum of 2.97 for channel G09. From this point of view, at Cernavoda there are 25 low signal channels (with HDR < 0.7), almost equally distributed between the PHT loops (13 on loop#1 and 12 on loop#2)

3.3 FUEL DEFECTS

The total number of fuel defects recorded at Cernavoda during the first two years of commercial operation was 12 (8 in 1997 and 4 in 1998, as presented in Table 2). This gives an overall rate of fuel defects of 0.083% for this period. With one exception, all these defects were very small. Four of them were not even seen by the DN system but the Area Alarm Gamma Monitor (AAGM) loop showed an increase of the background activity above the Discharge Bay after the bundles were transferred from the F/M to the pool. These defects could be small pinholes through the sheath, not allowing the release of halogens and causing the DN system inability to detect them /2/ , /3/ .

The most serious defect recorded so far occurred on a bundle from the fifth pair in channel L17. When these bundles were transferred to the pool, gamma field above the Discharge Bay increased upto a rate of 1.23mSv/h and resulted in an anvelope boxup.

Unfortunately, at Cernavoda there is no tool available for inspection of the defective bundles in the pool. Hence, we cannot provide more details regarding the nature and the cause of these defects.

4. OPERATING RULES FOR GOOD FUEL PERFORMANCE

To keep the fuel performance under control the following policy is applied at Cernavoda Unit-1.

- permanent surveillance of fuel fabrication by a customer representative at the manufacturer
- stringent quality verification and inspection of fuel prior its loading into the core

- carefully attention to the procedure during fuel handling
- good procedures to operate the fuel within the normal design conditions (maintain the maximum bundle and channel powers well below the OP&P limits, avoid power tilts by an appropriate selection of the channels to be refuelled etc.)
- permanent control of the coolant chemistry
- permanent monitoring of the GFP and DN system performance.

5. CONCLUSIONS

After two years of commercial operation, the fuel performance at Cernavoda Unit-1 is within the normal limits:

- the rate of fuel defects is small (less than 1 defective for 1000 irradiated bundles);
- the average fuel discharge burnup achieved is ~ 156.5 MWh/kgU;
- the activity of the fission products in the coolant was at, a low level throughout the period, well below the license limits;
- defective bundles have been discharged without any difficulty.

6. ACKNOWLEDGEMENTS

The support of my colleques in performing the task in this paper is acknowledged.

7. REFERENCES

/1/ D. Stanila – Guidelines to store, process and interpret GFP & DN results, IDP-SNA/FR-018, Rev. 0, February 1999 (Internal Document).

/2/ N. Baraitaru et al. – Performantele zonei active in primul an de exploatare comerciala, Information Report IR-03310-10, Rev. 0, Mai 1998 (Internal Document).

/3/ N. Baraitaru et al. – Core Performances at Cernavoda Unit-1 during 1998, Information Report IR-03310, Rev. 0, May 1999 (Internal Document).

TABLES AND FIGURES

PARAMETER	1997	1998	PLANT LIFE
Maximum fuel bundle power (KW)	865.6	872.0	872.0
Average fuel bundle power (KW)	411	404	410
Fuel burn-up (MWh/kgU)	---	---	---
Target per year	---	170	---
Average	143.8	170.850	157.566
Maximum	290.680	317.617	317.617
Numbers of fuel bundles irradiated	9324	9616	14380
Numbers of fuel bundles discharged	4764	5056	9820
Number of defected bundles	8	4	12
Fuel defect rate (%)	0.086	0.042	0.83
Causes of fuel defects (most likely)	Debris	Manufacturing	Debris+Manufacturing

TABLE 1 – MAIN FUEL PERFORMANCE PARAMETERS

#	Susp. Chan.	Refuelling Date	Bundles Pos. in the chan.	Fuel Type	Fuel Supplier	Refuelling Scheme	Exit Burnups (MWh/KgU)	Confirmation
1	H19	Jan.21,97	7 & 8	Nat.	ZPI	Swing 8	97.841 / 92.987	Yes
2	D15	Mar.14,97	9 & 10	Nat.	ZPI	Swing 8	124.276 / 107.081	Yes
3	O17	Apr.21,97	5 & 6	Nat.	ZPI	Swing 8	167.144 / 173.588	Yes
4	E11	Aug.01,97	9 & 10	Nat.	ZPI	Normal 8	152.283 / 176.914	Yes
5	N4	Oct.06,97	7 & 8	Nat.	FCN	Normal 8	155.987 / 149.928	Yes
6	L17	Oct.07,97	9 & 10	Nat.	ZPI	Normal 8	184.155 / 222.641	Yes
7	G14	Nov.21,97	7 & 8	Nat.	FCN	Normal 8	167.092 / 157.456	Yes
8	F6	Nov.24,97	7 & 8	Nat.	FCN	Normal 8	166.330 / 157.216	Yes
9	U10	Jan.27,98	9 & 10	Nat.	ZPI	Normal 8	181.505 / 198.511	Yes
10	J15	Mar.24,98	9 & 10	Nat.	FCN	Normal 8	171.184 / 202.634	Yes
11	D9	Apr.03,98	9 & 10	Nat.	FCN	Normal 8	159.509 / 172.613	Yes
12	L8	Jul.24,98	see NOTE	Nat.	FCN	Swing 8	see NOTE	see NOTE
NOTE: - During the refuelling of channel L8 the pair containing defective bundle could not be identified. However, the signals both from GFP and DN have decreased visibly thereafter. Hence, it was concluded that the suspect defective bundle was removed from channel L8.								

TABLE 2 – INFORMATIONS RELATED TO SUSPECT DEFECTIVE FUEL

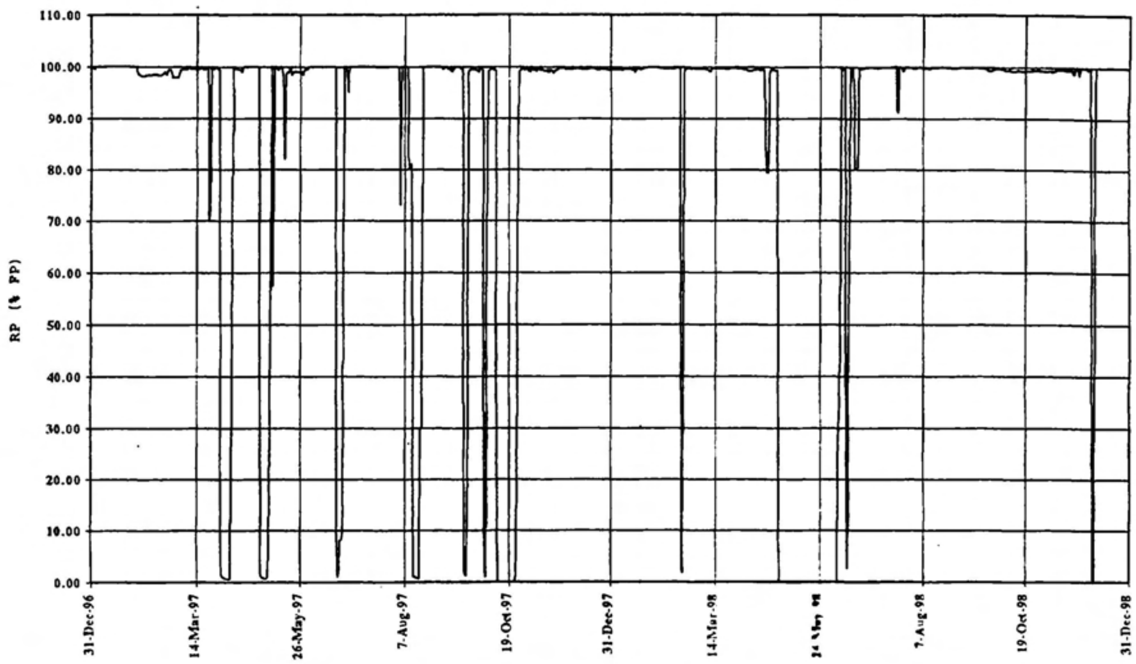

FIGURE 1 – REACTOR POWER EVOLUTION

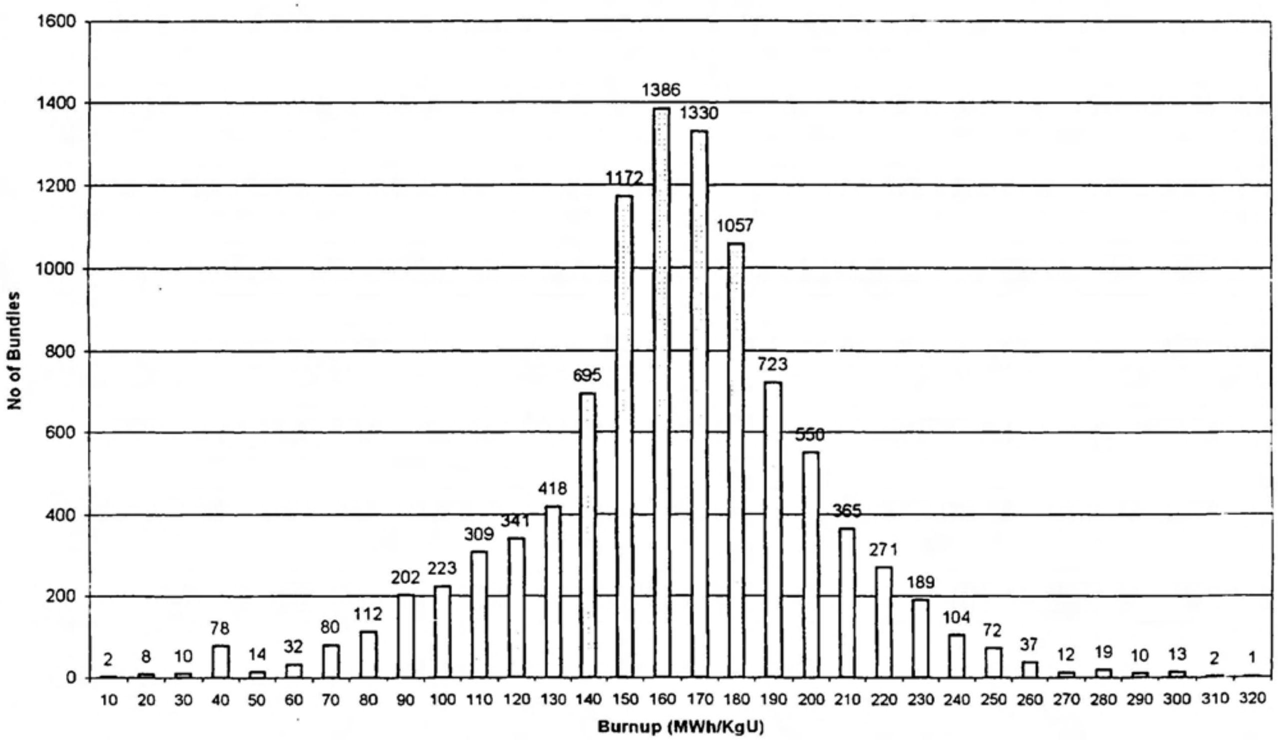

FIGURE 2 – DISTRIBUTION OF BUNDLES IN POOL VS. BURNUP (end of 1998)

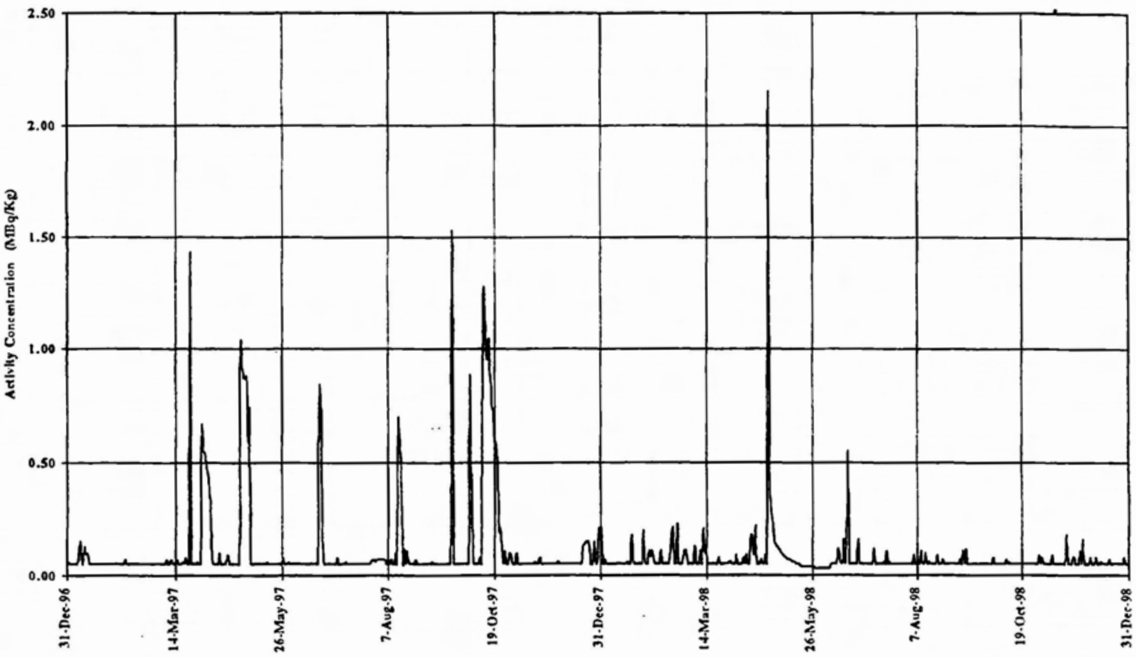

FIGURE 3 – I-131 SPECIFIC ACTIVITY IN COOLANT

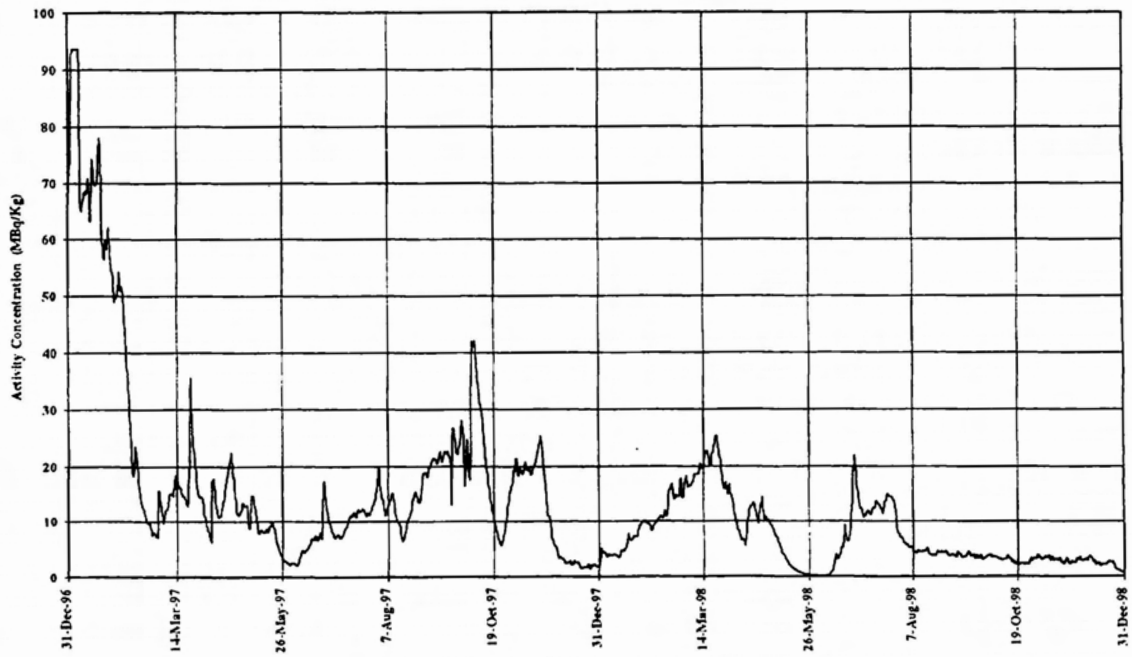

FIGURE 4 – Xe-133 SPECIFIC ACTIVITY IN COOLANT

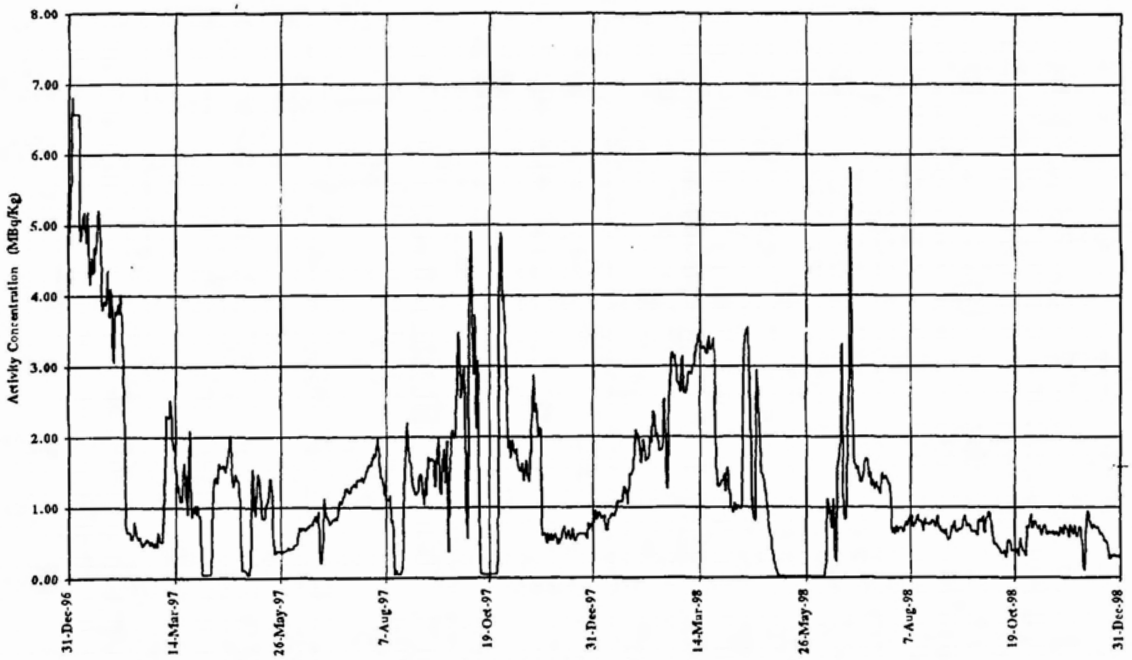

FIGURE 5 – Xe-135 SPECIFIC ACTIVITY IN COOLANT

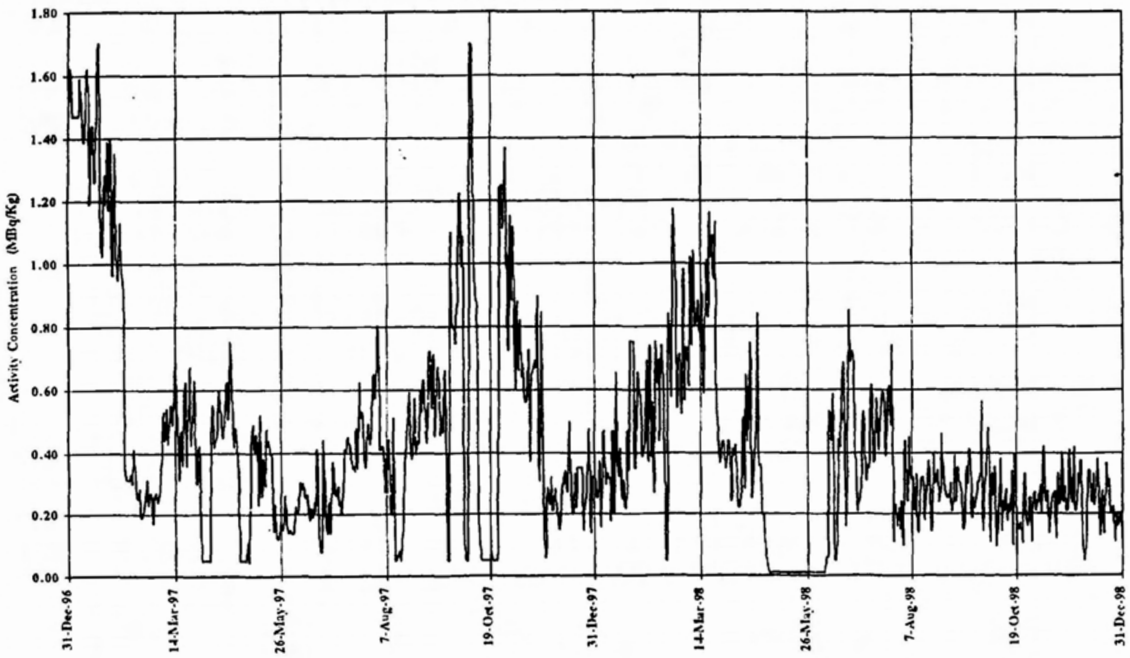

FIGURE 6 – Kr-88 SPECIFIC ACTIVITY IN COOLANT