KAERI/TR-730/96

KR9600265

Upper-Bound Fission Product Release Assessment for Large Break LOCA in CANFLEX Bundle Reactor Core

July 1996

KOREA ATOMIC ENERGY RESEARCH INSTITUTE

KR9600265

KAERI/TR-730/96

Upper-Bound Fission Product Release Assessment for Large Break LOCA in CANFLEX Bundle Reactor Core

July 1996

KOREA ATOMIC ENERGY RESEARCH INSTITUTE

제 출 문

한국원자력연구소장 귀하

본 보고서를 "중수로용 개량핵연료 설계/해석" 과제중 수행된 기술 보고서로 제출합니다.

제목 : Upper-Bound Fission Product Release Assessment for Large Break LOCA in CANFLEX Bundle Reactor Core

1996. 7

주저자 : 오덕주 (중수로용 개량핵연료 설계/해석 분야)
공동저자 : 이강문 (안전해석부 사고해석실)

감수위원 : 석호천 (중수로개량 국제공동연구 및 기반기술개발 과제)

Upper-Bound Fission Product Release Assessment for Large Break LOCA in CANFLEX Bundle Reactor Core

D.J. Oh and K.M. Lee

CANFLEX Fuel Design and Analysis
Korea Atomic Energy Research Institute
P.O. Box 105, Yusong, Taejon, Korea 305-600

ABSTRACT

Quarter-core gap inventory assessment for CANDU-6 reactor core loaded with CANFLEX fuel bundles has been performed as one of the licensing safety analyses required for 24 natural uranium CANFLEX bundle irradiation in CANDU-6 reactor. The quarter-core gap inventory for the CANFLEX bundle core is 5 - 10 times lower than that for the standard bundle core, depending on the half-life of the isotope. The lower gap inventory of the CANFLEX bundle core is attributed to the lower linear power of the CANFLEX bundle compared with the standard bundle. However, the whole core total inventories for both the CANFLEX and standard bundle cores are nearly the same.

The 6-8 times lower upper-bound fission product releases of the CANFLEX bundle core for large break LOCA than those of the standard bundle core imply that the loading of 24 natural uranium CANFLEX bundles would improve the predicted consequences of the postulated accident described in the Wolsong 2 safety report.

TABLE OF CONTENTS

1. INTRODUCTION

Following a large break LOCA in the heat transport system of CANDU-6 reactor, fuel cooling in the 95 fuel channels (i.e., quarter-core channels) located downstream of the break is degraded, leading to the overheating of fuel in the channels. Quarter-core gap inventory release is an upper-bound gap inventory release during large break LOCA if all fuel elements in the quarter-core channels are unrealistically assumed to fail and release their gap inventories.

Quarter-core gap inventory assessment for CANDU-6 reactor core loaded with CANFLEX fuel bundles has been performed as one of the licensing safety analyses required for 24 natural uranium CANFLEX bundle irradiation in CANDU-6 reactor. The predicted results are compared with those for the standard bundle core.

2. ANALYSIS METHODOLOGY

The methodology to determine the total core fission product inventory and the quarter-core gap inventory is the same used for Wolsong 2, 3 & 4 reactor case and is found in Reference 1. The methodology is briefly described in this section.

The fission product inventory and distribution in a single fuel element at the time of the accident are estimated with ELESTRES computer code (Reference 2), using the ANS 5.4 model (Reference 3).

Single element powers and burnups are obtained from the bundle powers and burnups using the relative power and burnup conversion ratios given in Table 1. The range of linear powers and burnups of the fuel elements in a CANDU-6 reactor core is wide. The calculation of fission product inventories and distribution using the ELESTRES code is done at burnups ranging from 10 to 240 MW.h/kgU, in intervals of 10 MW.h/kgU. For each of these burnups, a simulation is done for element powers ranging from 5 kW/m to 61 kW/m. These ranges are expected to encompass all of the possible element powers and burnups in CANDU-6 reactor core.

The power history for the ELESTRES simulation for each of the power/burnup combinations is determined from the limiting power envelope. For a given power/burnup combination, the power history is determined by scaling the limiting power envelope to match the specified element power at the specified element burnup. The limiting power envelopes for outer element of the standard 37-element bundle, and outer and inner elements for the CANFLEX bundle are shown in Figure 1. Due to the two different fuel element diameters for the CANFLEX bundle, the two limiting power envelopes are used for the ELESTRES simulation of the CANFLEX bundle core; one for the outer element and the other for the inner element which represent the thinner elements (i.e., the outer and intermediate elements) and thicker elements (i.e., the inner and center elements), respectively.

The fission product inventory depends on the configuration of element powers and burnups in the reactor core at the time of the accident. The state of a CANDU-6 reactor core varies during its operating life. To find the maximum gap inventories, gap inventory calculations are performed for several core states, i.e., from 0 to 610 full power days (FPD) of reactor operation in intervals of 10 FPD.

The individual fuel element gap inventories may be summed together to give the total core gap inventory, and divided by four to obtain the upper-bound releases from a quarter core following a break in a large pipe, such as a reactor inlet or outlet header or pump suction.

3. ANALYSIS RESULTS

I-131 single element gap inventories as a function of linear power for several representative burnups at 260 FPD are shown in Figure 2. No big differences between the CANFLEX and standard bundle cores are observed. The gap inventories for the elements with linear powers less than 40 kW/m are found to be negligible.

The fuel element number distribution at 260 FPD for each CANDU-6 reactor core loaded with either the CANFLEX or standard bundles is shown in Figure 3. The distribution for the CANFLEX bundle core is shifted to the lower linear power side than that for the standard bundle due to the lower linear power of the CANFLEX bundle compared with the standard bundle. The fractions of the elements with linear powers higher than 40 kW/m are 0.14 and 0.25 for the CANFLEX and standard bundle cores respectively. As a result of this, the whole core I-131 single element gap inventory for the CANFLEX bundle core at 260 FPD is ~8 times lower than that for the standard bundle core, as shown in Figure 4.

As for the total inventory, however, the results are different from those for the gap inventory. Single element total inventory versus linear power is at most linear, as shown in Figure 5 and does not show the threshold linear power behaviour as in the case of the gap inventory. As a result, the whole core total inventories for both the CANFLEX and standard bundle cores are nearly the same, as shown in Figure 6.

The different results for the total and gap inventories for the two cores are because the total inventory is proportional to the total number of fissions, i.e., total power, but the gap inventory is to the diffusion rate from the grain to the gap, i.e., fuel temperature.

The quarter-core gap inventory for each of the 30 isotopes is given in Table 2. The quarter-core gap inventories in Table 2 are those at an equilibrium core state after 270 FPD and 260 FPD for the CANFLEX and standard bundle cores, respectively, where maximum gap inventories for most of the isotopes are observed to occur. The whole core total inventory for each of the 30 isotopes is also given in Table 2 for reference.

4. SUMMARY AND CONCLUSIONS

Quarter-core gap inventory assessment for CANDU-6 reactor core loaded with CANFLEX fuel bundles has been performed as one of the licensing safety analyses required for 24 natural uranium CANFLEX bundle irradiation in CANDU-6 reactor. The quarter-core gap inventory for the CANFLEX bundle core is 5 - 10 times lower than that for the standard bundle core, depending on the half-life of the isotope. The lower gap inventory of the CANFLEX bundle core is attributed to the lower linear power of the CANFLEX bundle compared with the standard bundle. However, the whole core total inventories for both the CANFLEX and standard bundle cores are nearly the same.

The 6-8 times lower upper-bound fission product releases of the CANFLEX bundle core for large break LOCA than those of the standard bundle core imply that the loading of 24 natural uranium CANFLEX bundles would improve the predicted consequences of the postulated accident described in the Wolsong 2 safety report.

5. REFERENCES

1. S. Lam, et al., "Large Loss of Coolant Accident Analysis", 86-03500-AR-029 Rev. 1, June 1995.
2. M. Tayal, "Modelling CANDU Fuel under Normal Operating Conditions: ELESTRES Code Description", AECL-9331, 1987, "Users' Manual for the M11C Version of the ELESTRES Code" TTR-234A, February 1989.
3. American National Standard Method for Calculating the Fractional Release of Volatile Fission Products from Oxide Fuel, ANSI/ANS-5.4-1982

Table 1

Relative Element Power/Burnup Conversion Ratios at Plutonium Peak

Element Ring		Number of Elements	Relative Element Power*	Relative Element Burnup*
Outer	C*	21	1.058	1.1342
	S*	18	1.131	1.1240
Intermediate	C*	14	0.8707	0.9377
	S*	12	0.9206	0.9239
Inner	C*	7	1.0800	0.8309
	S*	6	0.8051	0.8161
Center	C*	1	1.0325	0.7941
	S*	1	0.7613	0.7746

Note:

C*=CANFLEX Bundle and

S*=Standard 37-element Bundle

Relative Element Power* : Normalized to Bundle Average

Relative Element Burnup*: Normalized to Bundle Average

Table 2

Quarter-Core Gap Inventory for the 30 Radionuclides

Isotope	Quarter-Core Gap Inventory (TBq)		Total Inventory (TBq)	
	C^*	S^*	C^*	S^*
Cs-137	10.3	46.5	38068	38868
Cs-138	44.2	432.5	5113496	5007555
I-131	744.3	5626.9	2143601	2113130
I-132	1458.8	11077.5	3398491	3329049
I-133	533.8	4887.4	5310915	5200915
I-134	122.9	1191.7	5943363	5820172
I-135	282.4	2669.4	4987067	4883737
I-137	4.8	47.0	2631817	2577309
Kr-83m	4.6	45.6	410977	402460
Kr-85m	17.6	172.3	1003731	982932
Kr-85	0.8	4.1	4562	4657
Kr-87	18.3	179.2	1952144	1911686
Kr-88	38.5	375.3	2758268	2701219
Kr-89	6.9	67.4	3580260	3506095
Ru-103	720.1	4723.2	2038293	2035336
Ru-106	15.7	69.6	73575	74872
Sr-89	1060.7	6726.0	2661362	2666272
Sr-90	7.7	34.2	37702	38495
Te-131m	70.6	582.1	284459	278592
Te-131	59.5	573.5	2015376	1973563
Te-132	1327.4	9993.5	3354354	3291550
Te-133m	101.0	963.3	2299900	2252207
Te-133	64.4	623.7	3082316	3018459
Te-135	9.0	87.6	2671369	2615909
Xe-133m	9.1	86.5	149836	146855
Xe-133	973.0	8925.4	4813160	4733606
Xe-135m	3.5	35.3	853565	835888
Xe-135	46.6	440.8	569046	557248
Xe-137	10.2	100.1	4836919	4736573
Xe-138	19.7	197.0	4876369	4775486

Note:

C^*=CANFLEX Bundle Core at 270 FPD and

S^*=Standard 37-element Bundle Core at 260 FPD

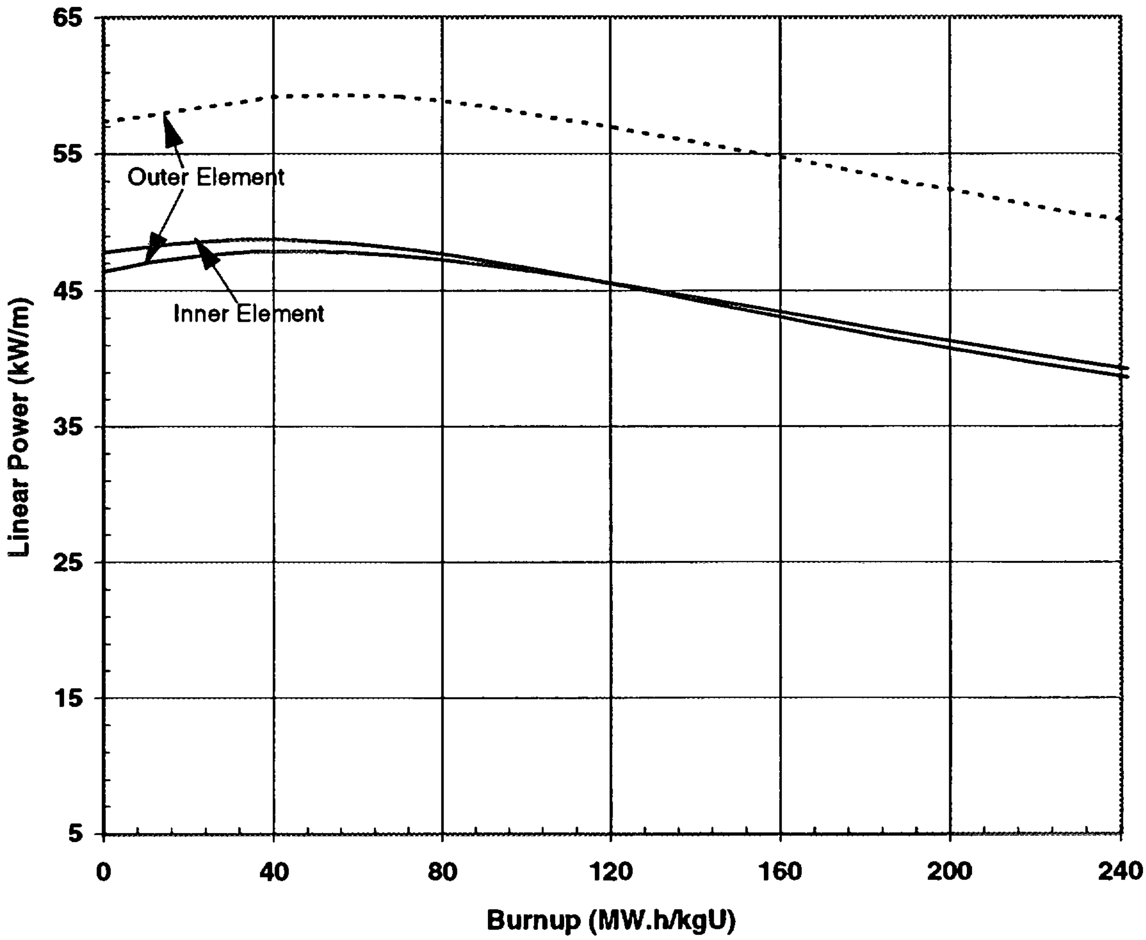

Figure 1 : The Limiting Power Envelopes for CANFLEX (soild line) & Standard 37-element Bundles

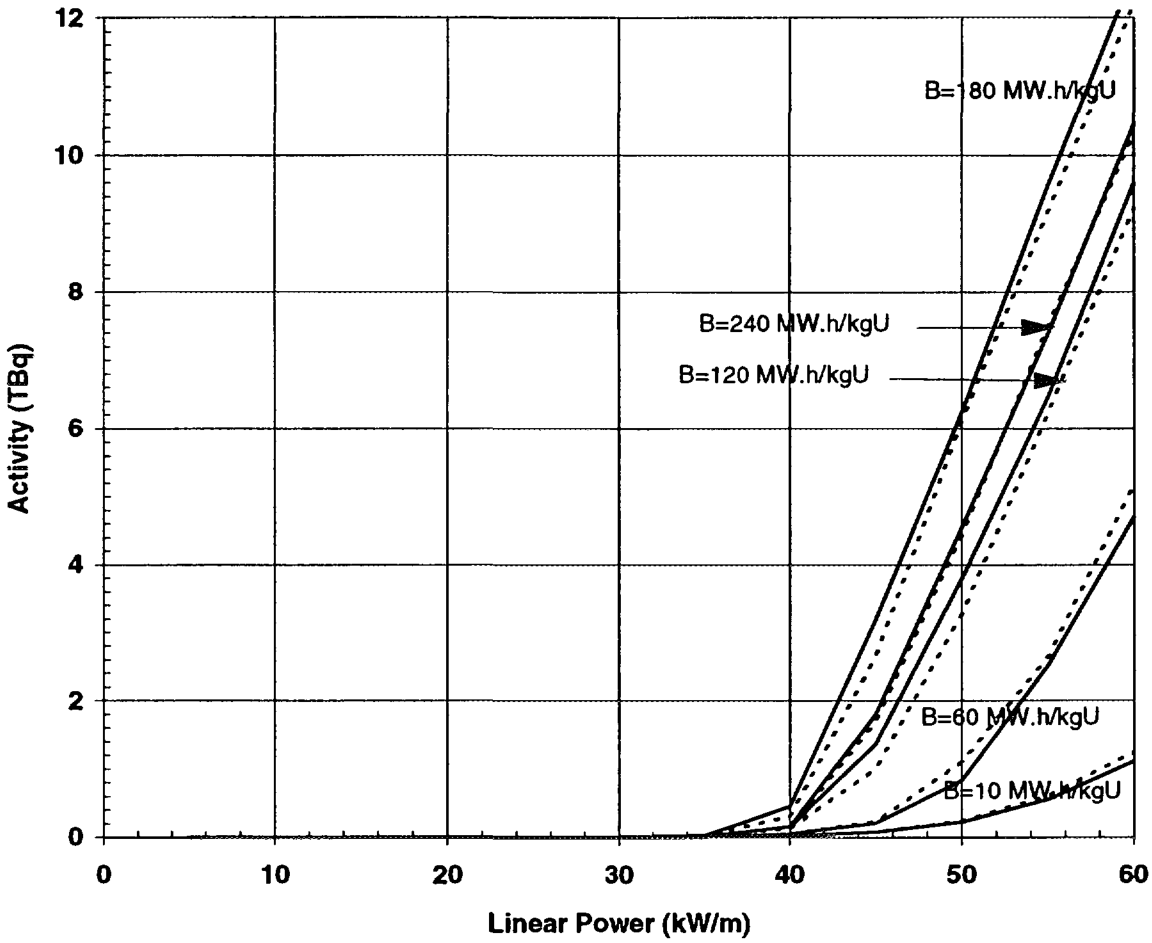

Figure 2 : I-131 Single Element Gap Inventory for CANFLEX (solid line) & Standard 37-element (dotted line) Bundle Cores

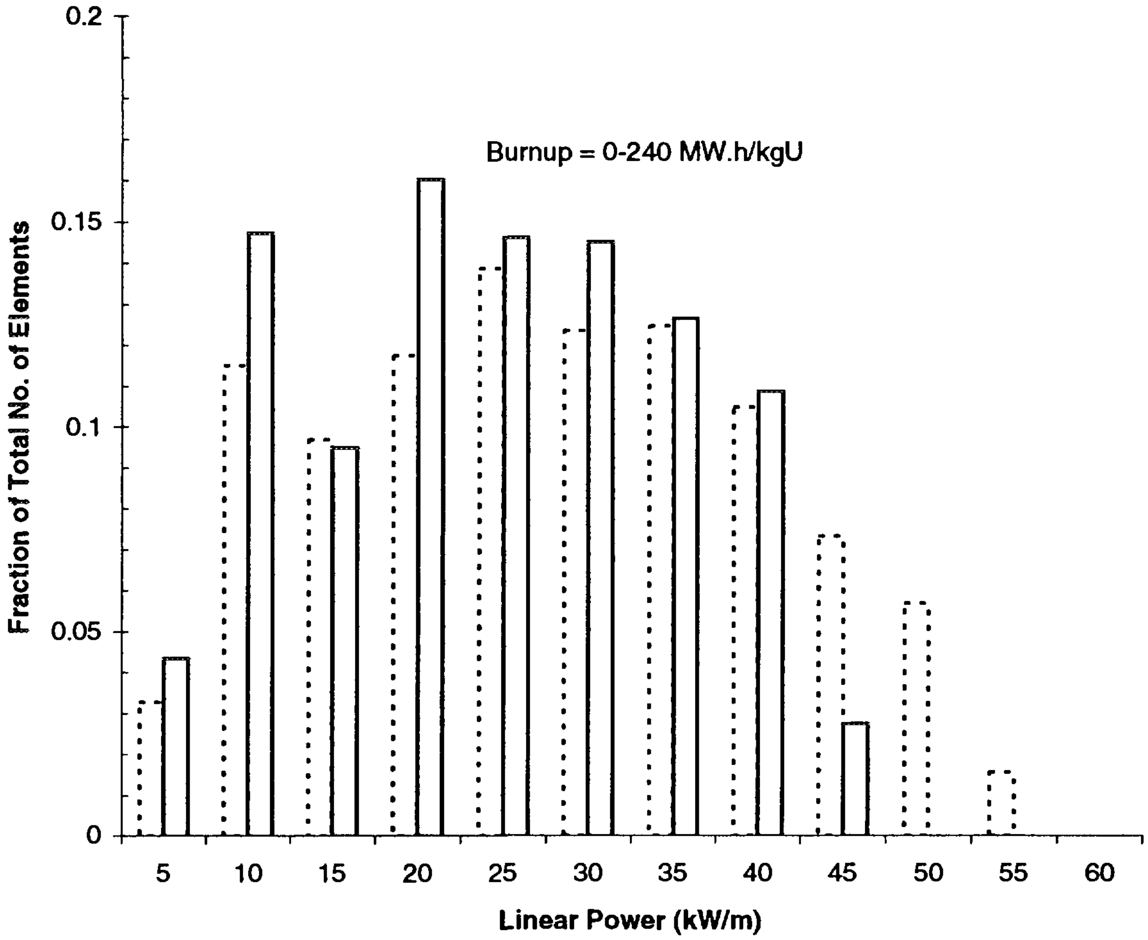

Figure 3 : Fuel Element Number Distributions as a Function of Linear Power for CANFLEX (solid line) & Standard 37-element (dotted line) Bundle Cores

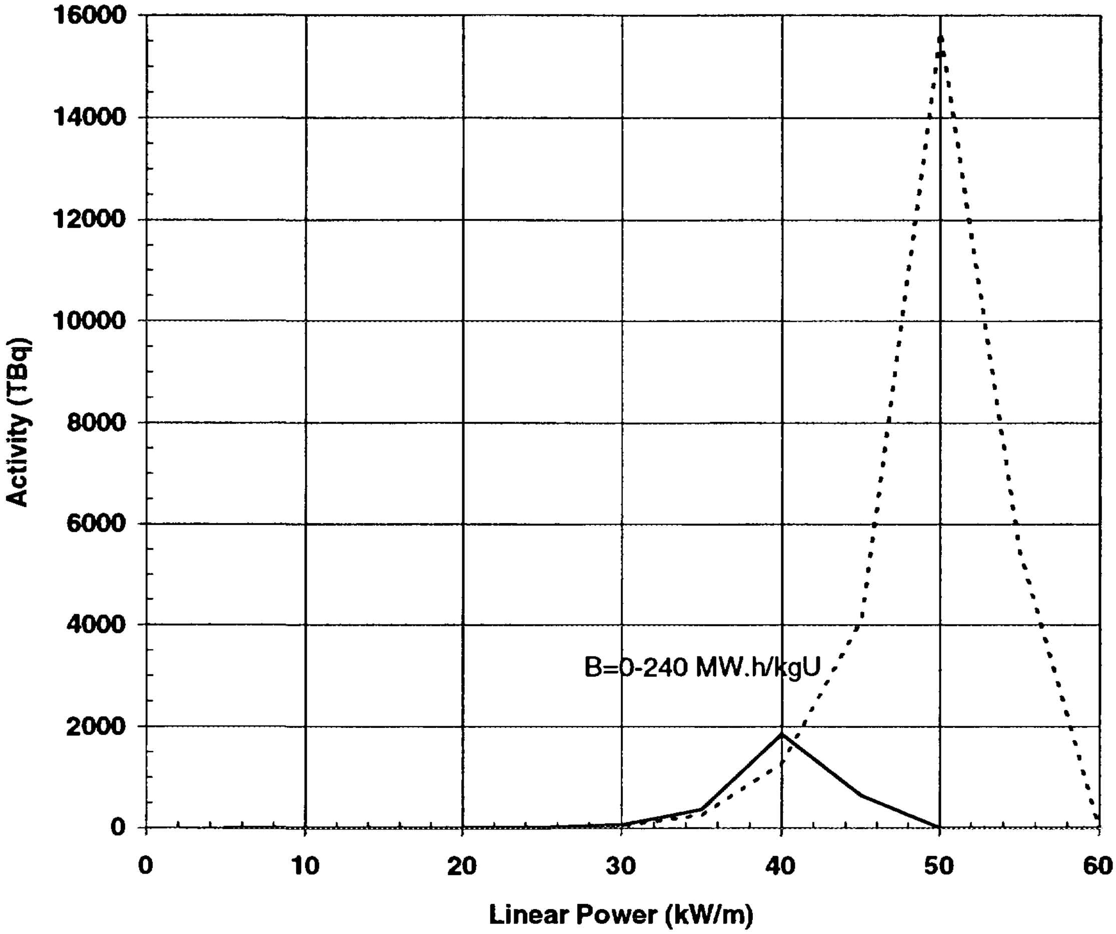

Figure 4 : I-131 Whole Core Gap Inventory for CANFLEX (solid line) & Standard 37-element (dotted line) Bundle Cores

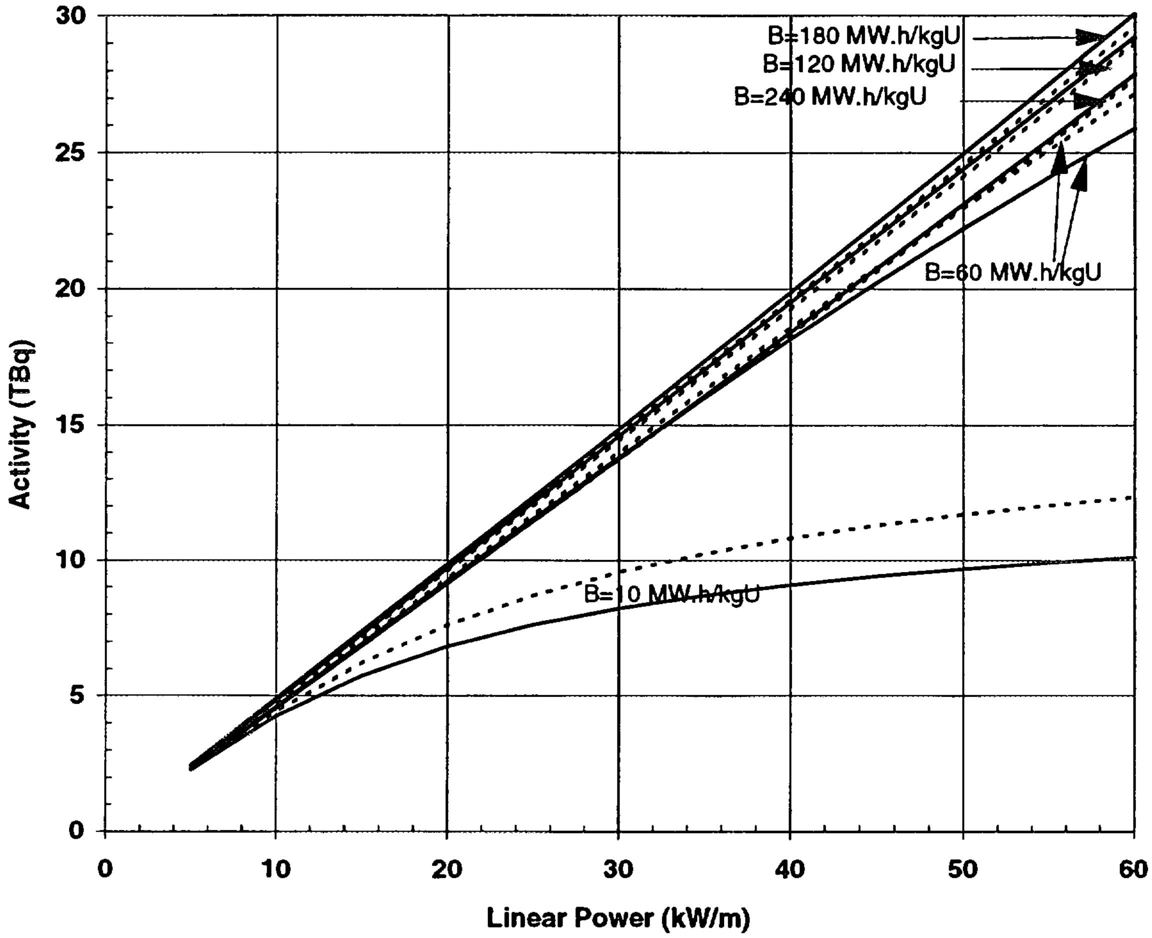

Figure 5 : I-131 Single Element Total Inventory for CANFLEX (solid line) & Standard 37-element (dotted line) Bundle Cores

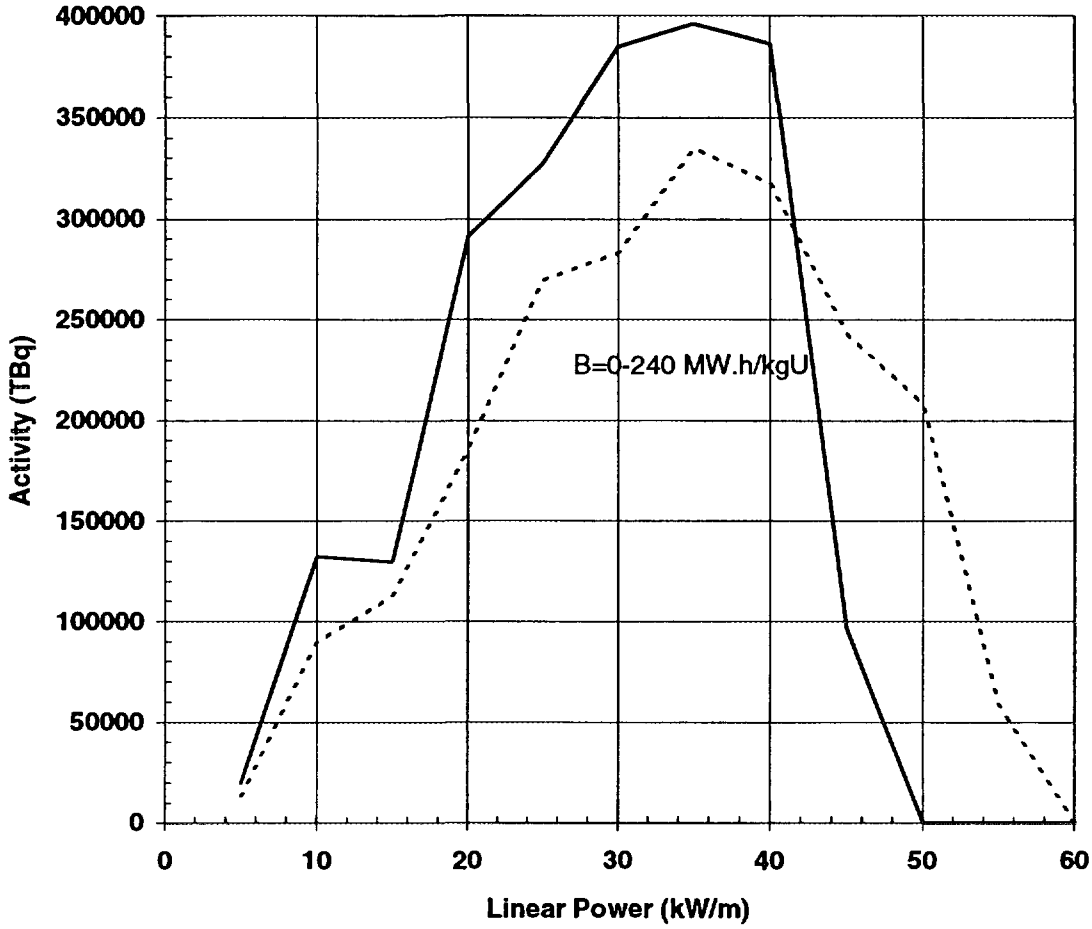

Figure 6 : I-131 Whole Core Total Inventory for CANFLEX (solid line) & Standard 37-element (dotted line) Bundle Cores

BIBLIOGRAPHIC INFORMATION SHEET

Performing Org. Report No.	Sponsoring Org. Report No.	Stamdard Report No.	INIS Subject Code
KAERI/TR-730/96			

Title/ Subtitle	Upper-Bound Fission Product Release Assessment for Large Break LOCA in CANFLEX Bundle Reactor Core
Project Manager and Department	Dirk J. Oh (Advanced HWR Fuel Design/Analysis)
Researcher and Department	Kang M. Lee (Accident Analysis Department)

Publication Place		Publisher	KAERI	Publication Date	July 1996
Page	12 p.	Ill. & Tab.	Yes(V), No ( )	Size	26 Cm.
Note					
Classified	Open( ), Restricted(V), ___ Class Document		Report Type	Technical Report	
Sponsoring Org.			Contract No.		

Abstract (15-20 Lines)

Quarter-core gap inventory assessment for CANDU-6 reactor core loaded with CANFLEX fuel bundles has been performed as one of the licensing safety analyses required for 24 natural uranium CANFLEX bundle irradiation in CANDU-6 reactor. The quarter-core gap inventory for the CANFLEX bundle core is 5 - 10 times lower than that for the standard bundle core, depending on the half-life of the isotope. The lower gap inventory of the CANFLEX bundle core is attributed to the lower linear power of the CANFLEX bundle compared with the standard bundle. However, the whole core total inventories for both the CANFLEX and standard bundle cores are nearly the same.

The 6-8 times lower upper-bound fission product releases of the CANFLEX bundle core for large break LOCA than those of the standard bundle core imply that the loading of 24 natural uranium CANFLEX bundles would improve the predicted consequences of the postulated accident described in the Wolsong 2 safety report.

Subject Keywords (About 10 words)	CANFLEX, Quarter-Core Inventory, Fission Product Release, Large Break LOCA

서 지 정 보 양 식

수행기관보고서번호	위탁기관보고서번호	표준보고서번호	INIS 주제코드
KAERI/TR-730/96			

제목/부제	대형 LOCA시 CANFLEX 다발 장전 노심의 핵분열 생성물의 상한치 평가
연구책임자 및 부서명 (TR, AR인 경우 주저자)	오덕주 (중수로용 개량핵연료 설계/해석 분야)
연 구 자 및 부 서 명	이강문 (안전해석부 사고해석 분야)

출 판 지		발행기관	한국원자력연구소	발행년	1996. 7.
페 이 지	12 p.	도 표	있음(V), 없음( )	크 기	26 Cm.

참고사항			
비밀여부	공개( ), 대외비(V), __ 급비밀	보고서종류	기술보고서
연구위탁기관		계약 번호	

초록 (15-20줄내외)

CANFLEX 핵연료 다발로 장전된 CANDU-6 원자로에 대한 1/4 노심 틈새 재고량을 평가한 결과, 표준 핵연료와 비교하여 5 - 10 배 감소하여 방사능 누출 관련 안전 여유도가 크게 향상 되었음을 보았다.

주제명키워드 (10단어내외)	CANFLEX 핵연료 다발, 1/4 노심 틈새 재고량, 핵분열 생성물, 대형 LOCA