

2003

가

Physical Inventory Verification at the Natural and Low Enriched Uranium Fuel Fabrication Plants

150

2003

가

(7 30 8 5)

U-235

U-235

가

가

2003

6

33 PDIs

IAEA

Abstract

The Physical Inventory Verification in 2003 at the KNFC was performed in accordance with the IAEA's Safeguards Criteria(including PIV and Zone Approach). The facility operator stopped its production process, classified all nuclear materials subject to the verification by strata, and declared these to inspectors. Inspectors calculated the number of samples to be verified as each nuclear stratum by using the number of nuclear materials subject to the verification and the amount of the U-235 declared by facility. Inspector confirmed the number of nuclear materials and verified the gross, partial and bias defects by using the suitable verification methods described in the criteria. The measured nuclear enrichment and the amount of the U-235 were compared with the declared values and the its relative standard deviation was evaluated to compare with the criteria. TCNC put 6 inspectors and did the verification activities of 33 PDIs with IAEA inspectors simultaneously. This paper will contribute to improve the level of verification and improve the inspector's quality.

1.

1975 (NPT) IAEA
 1976 . 1995
 1996 가
 . 1997
 가 1999 .
 2003 5 15 PWR 4 CANDU
 , 가 35
 [1].

. IAEA 2002 34 122
 310 PDIs (Person Day Inspection) . 가 IAEA
 477 PDIs (: 163 PDIs, : 314 PDIs) [1]. 가
 IAEA 가 ,
 IAEA .
 1989
 가 , 가 5% 가 1
 (KO1R) 가 2
 (KO2R) . 1 400
 , 1998 가 2 400
 4 .
 IAEA 2 KO1R
 KO2R 1998 8 . 1998
 9 IAEA . 2 MBA , 2000 8 1
 MBA (KO-R) 2 (MBA) .
 2000 11 IAEA 가 .
 2 1 가 .
 (Zone Approach) .

2. 가

IAEA
가
20%
가
5 가
KNFC
2
(Rod Loading
Station)
()
[2].

2.1 (PIV)

(MBP : Material Balance Period) 1 (PIV :
Physical Inventory Verification) 가

SQ(Significant Quantity;) 0.3

(1)

(a) UF₆ Cylinder ,
(RSD)가 0.06

(b) , , Scrap

(c) ,

(d) Bulk ()

(2)

(a) UF₆ Cylinder ,

(b) , ,

(c) ,

(d) Bulk ()

(3)

(a)

2.2

5 가 15 가 4
 IAEA (Safeguards Criteria) Annex I

(1) Annex I (Zone Approach)

(a)

(b) (Simultaneous PIV, SIM-PIVs)
 (Simultaneous Interim Inventory Verification, SIM -IIVs)

가

(c) SIM-PIV
 (Direct-use Material) SIM-IIV

(d)

(e) IAEA
 Annex H

(f) 가(Material Balance Evaluation)

(g)

(h) (Zone PIV)
 (Book Ending Date) , (Zone IIV) 가

3.

10

(1) ()

- Inventory Records (General Ledger)
- Inventory Change Report (ICR)
- Physical Inventory List (PIL)
- Material Balance Report (MBR)
- Itemized List of Inventory
- Source document

(2)

- Location Map(KMP)
- Shipping Document
- Type
-

3.1

(UF₆ Cylinder, UO₂ , UO₂ Pellet, , ,)
 (, ,)
 (,) ()

$$n(\text{sample}) = N \times (1 - B^{\bar{X}/M}) \text{-----} (1)$$

$$n1 = n - 2$$

$$2 = \frac{\ln B}{\ln (1 - M / (2 \times N \times \bar{X}))}$$

$$n2 = 2 - n3$$

$$n_3 = \frac{\ln B}{\ln(1 - M/3 \times N \times \bar{X})}$$

n =
N =
=

((1-) high : 0.9, medium : 0.5, low : 0.2)
 \bar{X} = U-235 () U (,)
M = (1 SQ = 75kg(), 10,000kg(), 20,000kg())

2, n3 2, 3 1 historical error (IAEA)

1. - Values (RSD) for 2003 PIV

KO1R				KO2R			
Stratum	δ_1	δ_2	δ_3	Stratum	δ_1	δ_2	δ_3
FF	0.15000	0.11000		FF	0.15000	0.11000	
FF1	0.15000	0.14700		FF1	0.15000	0.14700	
FR	0.15000	0.06000		FR	0.15000	0.06000	
HE	0.15000	0.05523	0.00400	HE	0.15000	0.05523	0.00400
MP	0.20000	0.18000	0.02900	MP	0.20000	0.18000	0.02900
PD	0.15000	0.06000	0.00500	PD	0.15000	0.06000	0.00400
PL	0.15000	0.04900	0.00600	PL	0.15000	0.04900	0.00400
PM	0.15000		0.02900	PM	0.15000		0.02900
SA	0.15000	0.02600		SA	0.15000	0.02600	
SC	0.15000	0.06100	0.02600	SC	0.15000	0.06100	0.02600
SC1	0.15000	0.06100		SC1	0.15000	0.06100	
SC2	0.15000	0.08900		SC2	0.15000	0.08900	
SD	0.15000	0.14000	0.10000	SD	0.15000	0.14000	0.10000
SM	0.15000	0.15000		SM	0.15000	0.15000	
UF	0.15000	0.05500		UF	0.15000	0.05500	
WS	0.15000		0.10000	WS	0.15000		0.10000

IAEA (Random Medium) 가
U-235 () U (,) M

3.2

- 1
- [3]. IAEA 가 (
- 2) historical error 1 .
- 1 (Method H) , 2 (Method
- F) 3 (Method D) .

2. Verification Measurement at Natural and Low Enriched Uranium Fabrication Plants

Material Category	Main Stratum	Material Type	Defect Type	Defect Description	Verification Method	Instrument
In-Direct-Use	Fresh Fuel (Assembly Bundle Rod)	DNLEU	Gross	Replaced by dummy, or Missing	I, A, H	HM-5, MMCN, MMCC
		LEU	Partial	Lower U-235 Content	I, F	UNCL + HM-5 MMCN + HM-5
		DNLEU	Bias(*)	U Content Bias	I, B + D	EBAL + D
	Powder Pellet Scarp	DNLEU	Gross	No Uranium	I, H	MMCN, MMCC, HM-5
			Partial	Part of Uranium Missing	I, B + F	EBAL+MMCN
		LEU	Bias	U content Bias	I, B + D	EBAL+D
	UF6 Cylinder	LEU	Gross	No Uranium	I, H	MMCN, MMCG
			Partial	Lower U-235 Content	I, B + F	LCBS+MMCG+ ULTG
			Bias	U Content Bias	I, B + D	LCBD+DA
	Waste	DNLEU	Gross	No Uranium	I, H	HM-5, MMCN, MMCC

4.

가

4.1 UF₆

UF₆ 가 (MMCG : Mini-MCA + Ge Detector) 가 (: Steel)가 (ULTG) . UF₆ U-235

$$U-235 = \text{Net} \times U (\%) \times \text{Enrichment} (\%) \times 1/10,000 \quad \text{--- (2)}$$

Net Load-Cell U (%) 가

U-235 (d) , U-235 1 2(0.055) 3 (3 2) (d) , 1 1(0.15) 3 (3 1)



1. UF₆

(MMCG)

4.2 UO₂

UO₂ (PD), (PL)

(MMCN : Mini-MCA + NaI Detector)

UO₂

2 (MMCN)

(2) U-235 U-235 (d)

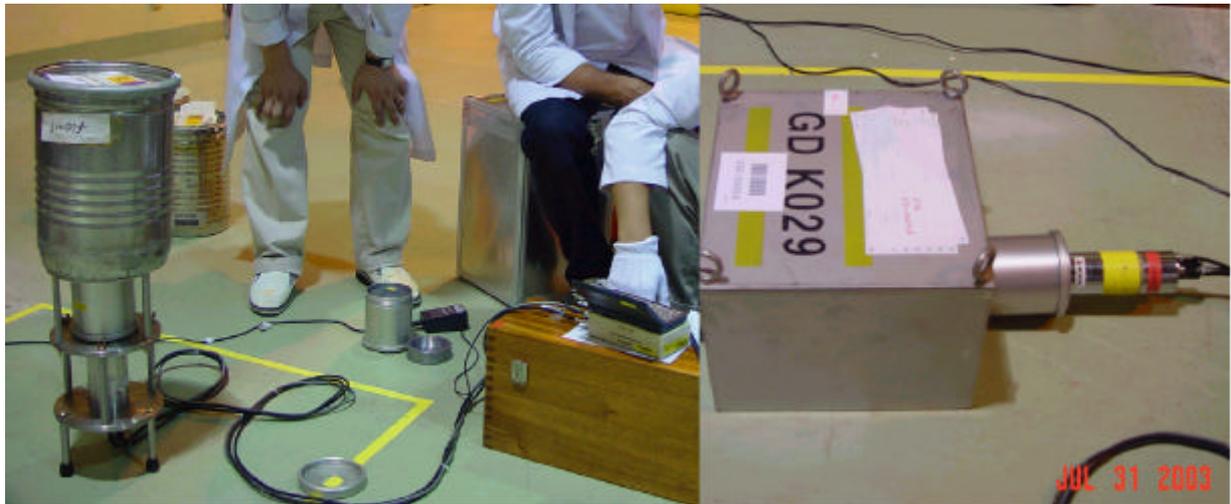
1 2 (PD: 0.06 ,PL: 0.049) 3 (3 2)

UO₂

(2)

3 PD가 0.005, PL 0.006

UF₆ 가



2. UO₂

(MMCN)

4.3

MMCN

가 ,

3 MMCN

HM-5

(Active Length)

HM-5

U-235

$$U-235 = \sum (\times / U-235) \times \text{-----} \quad (3)$$

Σ

가

(3)

U-235

U-235

(d)

1

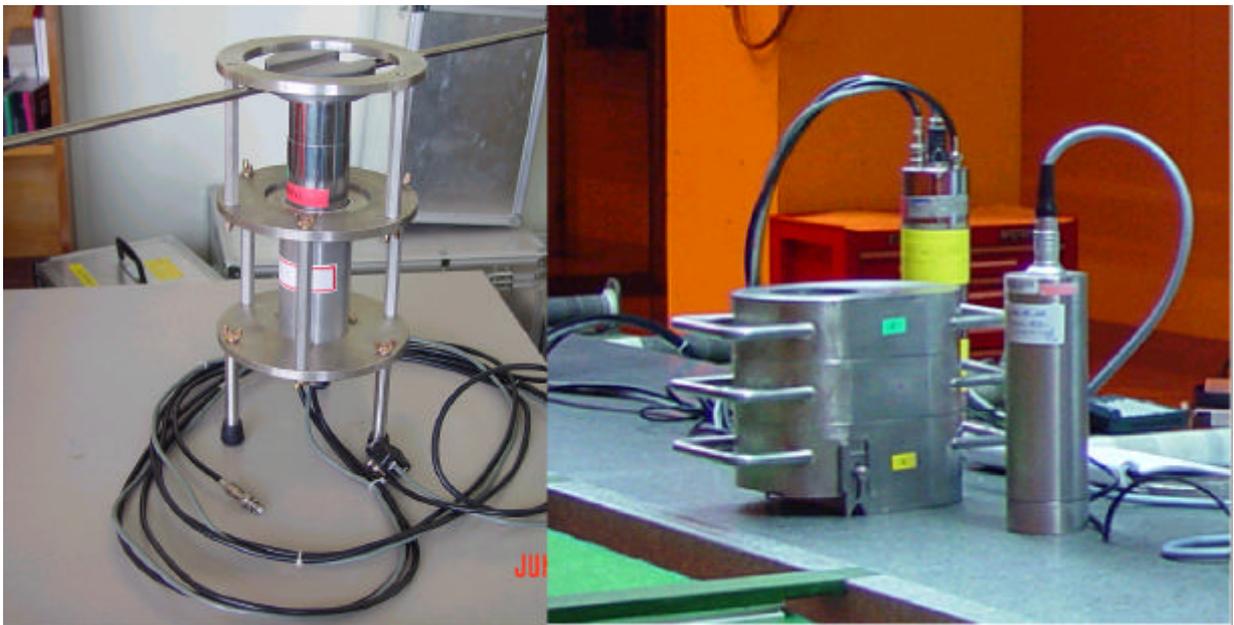
2(0.06)

3

(3 2)

UF₆

가



3.

(MMCN)

4.4

(MMCN UNCL)

가

4

UNCL

U-235

(linear density, g/cm))

, HM-5

. HM-5

UNCL

U-235

U-235

U-235

= Σ(

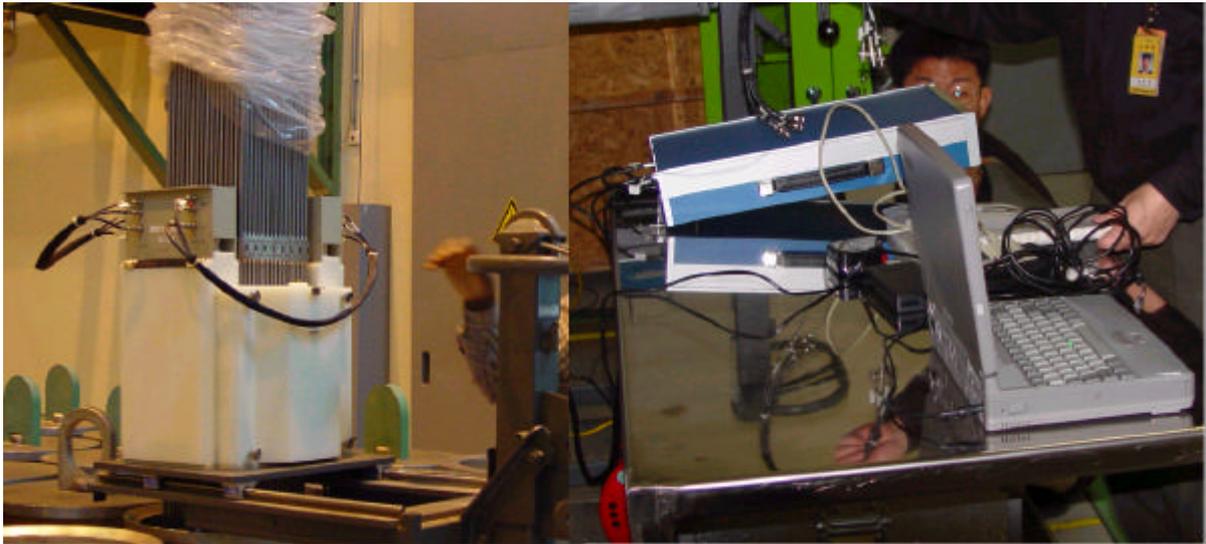
× U-235

)

----- (4)

Σ 가

U-235 U-235 (d)
1 2(0.11) 3 (3 2)
UF₆ 가



4. (UNCL)

5.

400 400 가
2003 6
(7 30 8 5) 33 PDIs IAEA
가 가 IAEA
가 Stratum 가
IAEA 가 UNCL
가 [4].
가
UO₂

U

가

2003

1. “ 2002 ”, KAERI/MR- 391/2002
2. IAEA, "Safeguards Criteria "(2000)
3. IAEA, "Verification of Nuclear Materials at Korean Nuclear Fuel Fabrication Plant"
4. TCNC, " (KO1R/2003/02-N02, KO1R/2003/02-N02)"