

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
가 가 가 5 가
KNFC 2
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 | δ1 | δ2 | δ3 | Stratum | δ1 | δ2 | δ3 |
| 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)

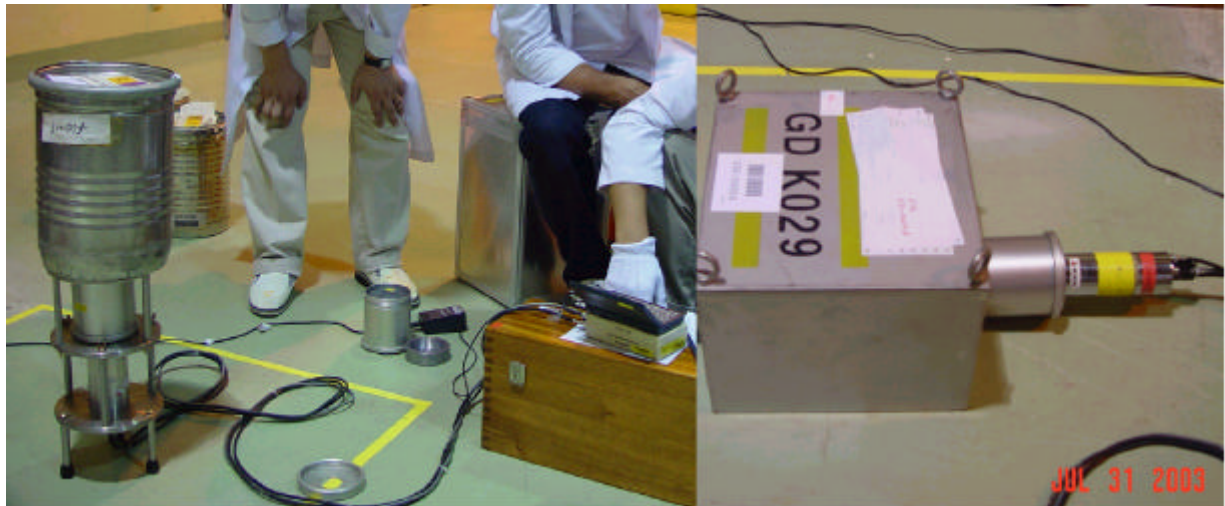
1 2 (PD: 0.06 ,PL: 0.049) 3 (3 2)

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

$$U-235 = \sum (\times / U-235) \times \dots \dots \dots (3)$$

Σ

가

(3)

U-235

U-235

(d)

1

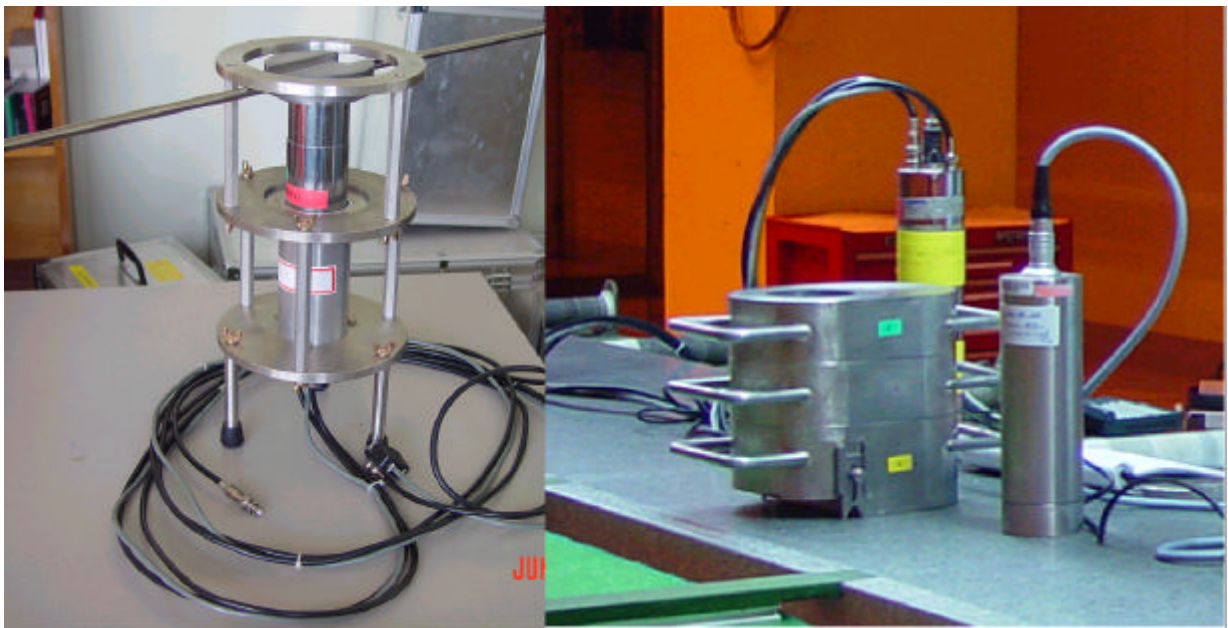
2(0.06)

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(

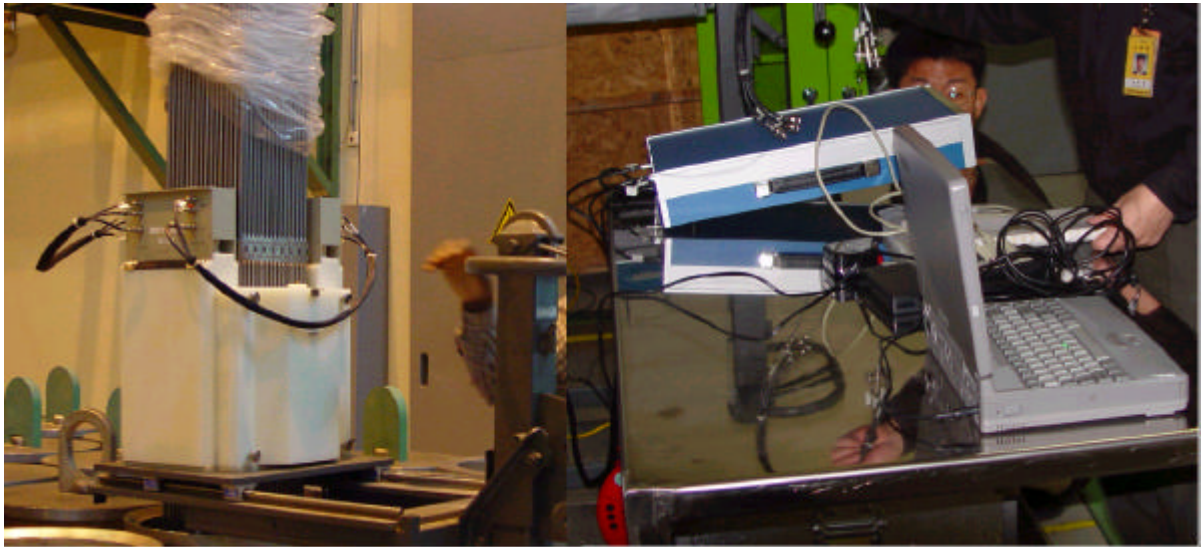
× U-235

)

----- (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 IAEA
가 Stratum 가
IAEA 가 UNCL
가 [4].
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)"