DPRK's 4th Nuclear Test and its Tritium Production

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1. Introduction

On January 6, 2016 at 10:30am, the artificial earthquake in the DPRK was detected by multiple international seismic organizations. After 2 hours, the DPRK announced on state TV that "The first H-bomb test was successfully conducted in the DPRK at 10:00am on Wednesday, Juche 105(2016), pursuant to the strategic determination of the ruling communist party." [1] There has been a doubt about the real nature of the DPRK's 4th nuclear test, since 2 months have been passed after its nuclear test. To analyze the nature of the DPRK's nuclear test, it is necessary to check possible options for production of essential materials.

The pathways to produce nuclear fusion material (tritium) and to have a relatively high possibility for the DPRK are described in this article.

2. DPRK's 4th Nuclear Test

Summary of DPRK's all nuclear tests is listed in table 1.

Table 1. Nuclear Test History in DPRK

	1st	2nd	3rd	4th
Date	2006.10.9 10:36	2009.5.25 09:54	2013.2.12 11:57	2016.1.6 10:30
Location	Punggye-ri Kilju, North Hamgyong	Punggye-ri Kilju, North Hamgyong	Punggye-ri Kilju, North Hamgyong	Punggye-ri Kilju, North Hamgyong
Seismic wave magnitude	3.9 mb	4.5 mb	4.9 mb	4.8 mb
Acoustic	×	○	○	○
Xe	−	×	×	×
Yield	less 1kT	a few kT	8 kT	6 kT

2-1 Detection of Seismic Wave

Yield of nuclear test could be assessed by analysis of the seismic wave magnitude. However, assessments from every seismic organization have differences because they use different methodology to assess the yield from seismic wave magnitude. The methodology could be differed in its geological environment and experimental conditions. In case of comparison between 3rd nuclear test and 4th nuclear test, the magnitude was decreased. Assuming that the environment of test area is not dramatically changed, decreased magnitude would mean decreased yield. Although the purpose of boosted-fission bomb or H-bomb is to increase the yield of bomb, it is not easy to determine the nature of DPRK's nuclear test with its yield.

2-2 Detection of Radionuclide

In case of H-bomb, the depth of the test area center might be deeper than fission bomb because of its larger yield. Assessing that DPRK had used horizontal tunnel for nuclear test, determination of depth is difficult.

During explosion, massive tritium is produced and in near distance it could be detected. But it is possible in very near distance. Away from a few hundred km, it's nearly impossible.

2-3 Issues on H-bomb

According to the DPRK's announcement, the DPRK might have developed and possessed the relevant technologies for H-bomb.

1) Technology related to fission bomb

2) Design and technology related to fusion core and radiation implosion

3) Fusion material (deuterium, tritium, Li-6)

And whether DPRK has produced and procured fusion material or not is the key factor for H-bomb. Especially tritium does not exist naturally and it can be produced in reactors. Detailed pathways for production of tritium will be discussed later section.

3. Pathways to produce tritium [2]

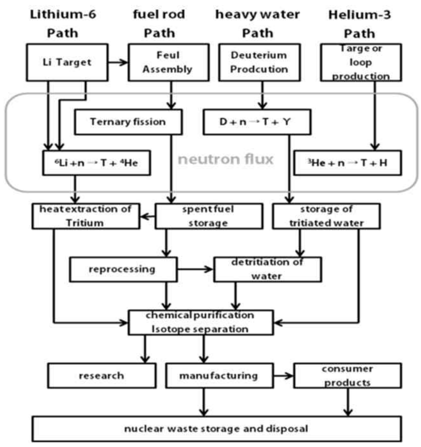

Fig.1 shows the various pathways to produce tritium.

3-1 Using Li-6

Li exist naturally in two stable isotopes: Li-6(7.5%), Li-7(92.5%). When these isotopes undergo nuclear reactions induced by neutrons, tritium is produced. Li-6 has very large crosssection at thermal neutron energy and Li-7 works with fast neutrons. [3]

There are many pathways to produce tritium.

1) Tritium production in military purpose reactors

2) Convert power or research reactors to tritium production reactors

(a) Especially prepared fuel composition which contains Li-6 instead of uranium-238 with no changes in core and assembly geometry

(b) Especially designed fuel assemblies used in whole core

3) Tritium breeding in power and research reactors without significant changes of the core and fuel assemblies and without significantly affecting normal operation

(a) Replace conventional fuel rods with rods containing lithium-6

(b) Replace conventional control rods by those made of lithium-6

(c) Replace boron burnable poison rods (BPR) with lithium BPRs (for PWRs only)

(d) Insertion of target rods in empty spaces inside the core

(e) Insertion of lithium targets in empty spaces inside the core (if available)

4) Using irradiation target positions in research reactors

3-2 Using He-3

He-3 produces tritium by neutron capture and proton emissions. Possible pathways with He-3 are,

1) Tritium produced from the He-3 content in the coolant of a high temperature gas cooled reactors can be extracted and purified

2) External addition of He-3 to the moderator system of a reactor

3) Collect tritium generated during a rapid power excursion (RPE) experiment at research reactors

4) Target loops with continuously circulating He-3

5) Closed He-3 targets

6) Magnetic confinement fusion neutron source

3-3 Using Boron

The boron isotope ^{11}B undergoes a tritium-forming reaction on capture of one neutron. But this isotope does not contribute to the tritium production in a nuclear reactor because the threshold energy is too high. 19% of natural boron is ^{10}B and it produces tritium by the reaction. Possible pathways with Boron are,

1) Tritium production in movable boron carbide control rods in BWRs

2) Tritium production from boron as fixed burnable poison rods (BPR) in PWR

3) Tritium production in boron curtains which are used to control excess reactivity of initial cores of BWRs

3-4 Using Tritiated water

The main sources of tritiated water are the coolants and moderator of heavy water reactors. Tritium is produced inadvertently in the moderator and coolant of a heavy water reactor during normal reactor operation through capture of a neutron by deuterium.

4. DPRK's Case

It has been known that DPRK has large reserves of Lithium ore in Soosung, North Hamgyong and Notan-ri, Kangwon. Also it had conducted 'Deuterium-Tritium Fusion' and 'Separation Li-6 from natural lithium" projects in accordance with "2nd Science and Technology development plan(2003~2007)". [4]

As described above, there are 4 pathways to produce tritium. But in case of DPRK, it does not have any operational PWRs or heavy water reactors or BWRs. Even though detailed information about DPRK is not available, the pathway using lithium target would be one of the options that DPRK has.

DPRK has one research reactor (IRT-2000) and one gas-cooled, graphite-moderated reactor (5MWe reactor). In case of IRT-2000, its neutron flux is around $3.2 \times 10^{13} s^{-1} cm^{-2}$, but there is no available information about 5MWe reactor. The neutron flux is appropriate for production of tritium. But there exist trade-off between production of plutonium and production of tritium. It might be one of unclear factors which make us difficult to assess.

5. Conclusion

Tritium is key material for H-bomb. And there are two options for the DPRK which are 1) production and 2) illicit trafficking. And this study is focused on production possibility of DPRK. Determination of the nature of DPRK's nuclear test is very hard issue. But we can assess that its capacity of research and development is going to be increased and predict that it would conduct additional tests in near future for the next leap. For the more precise analysis, further study on its facilities' capacity and purposes will be need.

REFERENCES

[1] The Washington Times, "North Korea says it has conducted successful hydrogen-bomb", 2016

[2] Martin B. Kalinowski, International Control of Tritium for Nuclear Nonproliferation and Disarmament, CRC Press, 2004.

[3] Phillips and Easterly, 1980.

[4] 통일부 북한 정보 포털