Consideration on Technical Support to Denuclearization: Focused on H-program

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1. Introduction

Since its 4th nuclear test, North Korea has claimed to have used hydrogen bombs. On 3 September 2017, North Korea boasted that it had perfect successful with a test of a two stage thermonuclear device to examine and confirm internal structural design newly introduced into manufacturing H-bomb to be placed at the payload of its ICBM [1]. The strategic significance of H-bomb for the nuclear arsenal is to provide a high total yield or a high yield-to-weight ratio [2]. In order to pursue successful denuclearization, a precise understanding of North Korean hydrogen bomb program (H-program) is required. Recently, researches on the amount of tritium that can be produced in nuclear reactors in Yongbyon have been actively conducted [3].

However, studies on the overall history and status of H-program of North Korea are insufficient. This is because the crucial details of H-program are kept classified and there is not much public information available about it. Especially, North Korea's H-program issue has just emerged, little is known about it.

In this paper, first, we suggested the structure and flow-chart of the major facilities & materials that could be involved in H-program by modifying PNNL model (2004) [4]. We listed up the result of literature survey on the estimated location & operation status H-facilities in North Korea and summarized the North Korean significant remarks & statement related to its H-program development. Finally, we tried to provide consideration for verification of H-program in North Korea.

2. Methods and Results

2.1 H-program

Modern fusion weapons consist essentially of two main stages: a nuclear fission primary stage (fueled by uranium-235 or plutonium-239) and a separate nuclear fusion secondary stage containing the heavy hydrogen isotopes as thermonuclear fuel: deuterium and tritium, or in modern weapons lithium deuteride. For this reason, thermonuclear weapons are often called hydrogen bombs or H-bombs [5]. Though it is imprecise, H-bomb could be a reference to the hydrogen isotopes in a boosted fission device [6]. By adding a few grams of deuterium and tritium, the explosion yield can be multiplied by a factor of 2 to 10 (generally) or even 100 [2].

Under the NPT regime, the major fusional fuel materials(H-materials) such as deuterium, tritium, and lithium-6 to make up the H-bomb are not defined as nuclear materials. In addition, among the facilities that produce, manufacture, process and store these materials, only nuclear reactor can be categorized as nuclear facilities [7].

2.2 Configuration and flow-chart of H-facilities

According to NFC & nuclear weapons development model of PNNL, H-program requires industrial facilities to produce H-materials [8]. In this paper, we defined "H-facilities" as all facilities relevant to production, process, handle, storage, transportation of H-bomb fuel materials.

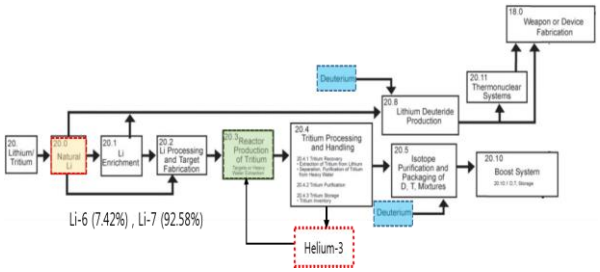

Fig. 1. *Structure and flow chart of H-program according to the NFC & nuclear weapons development model of the PNNL*

Due to the a relatively short radioactive half-life (12.3years) of tritium, its decay product, helium-3, increases simultaneously. Helium-3 is a strong neutron absorber to reduce the total expected explosive yield of H-bomb by 50%. And helium-3 produces tritium by neutron capture and proton emission [2]. So, it is worth considering the helium-3 recycling. To take account of helium-3 recycling case, we modified PNNL model as shown in Fig.1 based on Tritium Supply and Recycling Facilities in Savannah River Nuclear Weapons Complex [9]. However, it has not confirmed whether North Korea produce the separated tritium and/or recycle the He-3.

2.3 History and Status of North Korean H-program(estimated)

Due to the lack of information available on the development of North Korea's H-program, we only found 7 remarks and statements of North Korea on its H program in Table I. Through summarizing the North Korean significant remarks and statement related to its H-program, we could see North Korea has been developing hydrogen program since 2010 at the latest.

Table I: Historical remarks and statements of North Korea on its H program

Time	Remarks/Statements	Ref
May 2010	According to the Chosun Central News Agency, the labor newspaper, the agency of the North Korean Labor Party, reported that it developed its own nuclear fusion technology.	[10]
Dec 2015	The official Korean Central News Agency said: "The successful nuclear fusion by our scientists has made a definite breakthrough towards the development of new energy and opened up a new phase in the nation's development of the latest science and technology."	[11]
Jan 2016	North Korea announced it had successfully tested a thermonuclear device at the Punggye-ri Nuclear Test Site.	[12]
Mar 2016	North Korea released photographs depicting Kim Jong Un examining what the DPRK claims is a miniaturized nuclear implosion device in front of several partially assembled KN-08 mod 1 and mod 2 missiles. Six days later, on 15 March 2016, North Korea announced its intention to conduct another nuclear test.	[13], [14]
Sep 2016	5th nuclear test : Small size, light weight, and multiplied nuclear warhead power test Finalized review of the structure, operating characteristics, performance and power of the standardized and standardized nuclear warheads	[15]
Sep 2017	6th nuclear test : We have concluded that our method of interpretation and calculation programs for complex physical processes in the primary and secondary systems is at a high level, and that the nuclear engineering structure of the secondary system is reliable. North Korea claimed that the test was of a thermonuclear warhead, and immediately before the test released photographs of Kim Jong-un inspecting a "peanut-shaped" nuclear device resembling a Teller-Ulam design hydrogen bomb.	[1]
Nov 2017	Following the successful test-flight of the Hwasong-15 ICBM in November 2017, North Korea announced that it had "finally realized the great historic cause of completing the state nuclear force."	[16]

Using modified PNNL model, we listed up twelve H-facilities as shown in Table II. The location and operation status of the facility has not been clearly identified. Through survey of open-source satellite image analysis published after 2010, we described the estimated location and operation status of H-facilities.

Table Ⅱ: Status of H program in North Korea(estimated)

No.	Material	Facility	Location (estimated)	Operation Status (estimated)	Ref.
1	Lithium	Mine/Mill	Unknown		
2		Enrichment plant	Unknown (outside YB*)	OPERATIONAL	[17]
3		Storage/Transportation	Unknown		
4		Processing and Target fabrication plant	YB (Pilot Fuel Fabrication plant)		[18]
5	Tritium	Tritium Production reactor	YB (5MWe reactor and/or IRT-2000)	OPERATIONAL	[18], [19]
6		Extraction from Li targets	YB (South-eastern Fuel Fabrication plant, and/or Radiochemistry Laboratory and/or Isotope Production Laboratory)	OPERATIONAL (Construction : 2009.4.~2015)	[18], [19], [20]
7		Recycling (He-3 Extraction)	Unknown		
8		Storage/Transportation	Unknown		
9	Helium	Storage/Transportation	Unknown		
10	Deuterium	Production plant	Hungnam Chemical Complex	OPERATIONAL	[17]
11	Mixture (L-D)	Lithium Deuteride Production plant	Unknown		
12	Mixture (D-T)	Purification & Packaging plant	Unknown		

*YB means Yongbyon

3. Conclusions

In this paper, we suggested the structure and flow-chart of overall H-program, including helium-3 recycling, by modifying PNNL model (2004). Using modified PNNL model, we listed up twelve H-facilities could be in North Korea. Except facilities in Yongbyon, many of them are unidentified. Through summarizing the North Korean significant remarks and statement related to its H-program, we could see North Korea has been developing hydrogen program since 2010 at the latest.

We suggested three considerations for verification of H-program in North Korea as bellows;

1. **(Planning)** It can't be dealt with just the term of nuclear material or nuclear facilities, the extent of prohibition of H-program should be defined in detail in denuclearization agreement.
2. **(Declaration)** Starting with a report on the Yongbyon, stepwise declaration should be submitted.
3. **(Inspector Safety)** Since different types of H-materials might exist, the biochemical risk as well as radiological risk to inspector should be considered.

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