ISS(Isotope Separation System)

초저온증류 공정시뮬레이션

공주대학교 화학공학부

조 정 호

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1. ISS (Isotope Separation System) 소개

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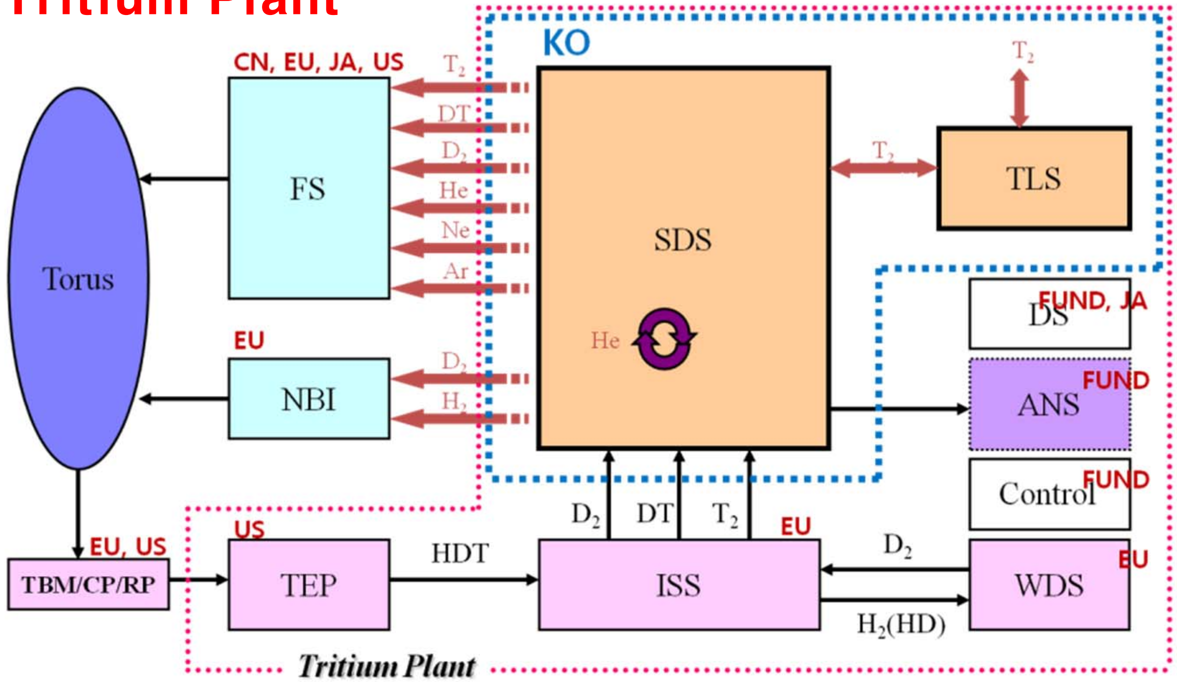
- 지구에서 핵융합에너지의 실용적 생산을 위하여 한국, 미국, 유럽연합, 중국, 러시아, 일본, 인도의 7개국이 모여 국제 핵융합 실험로 (ITER) 공동개발사업을 진행 중에 있다.
- ITER는 International Thermonuclear Experimental Reactor의 약자이며 라틴어로 '길(Way)'이라는 뜻으로 핵융합에 이르는 길을 ITER를 통해 도달하고자 하는 의미를 내포하고 있다.

ITER Tritium Plant



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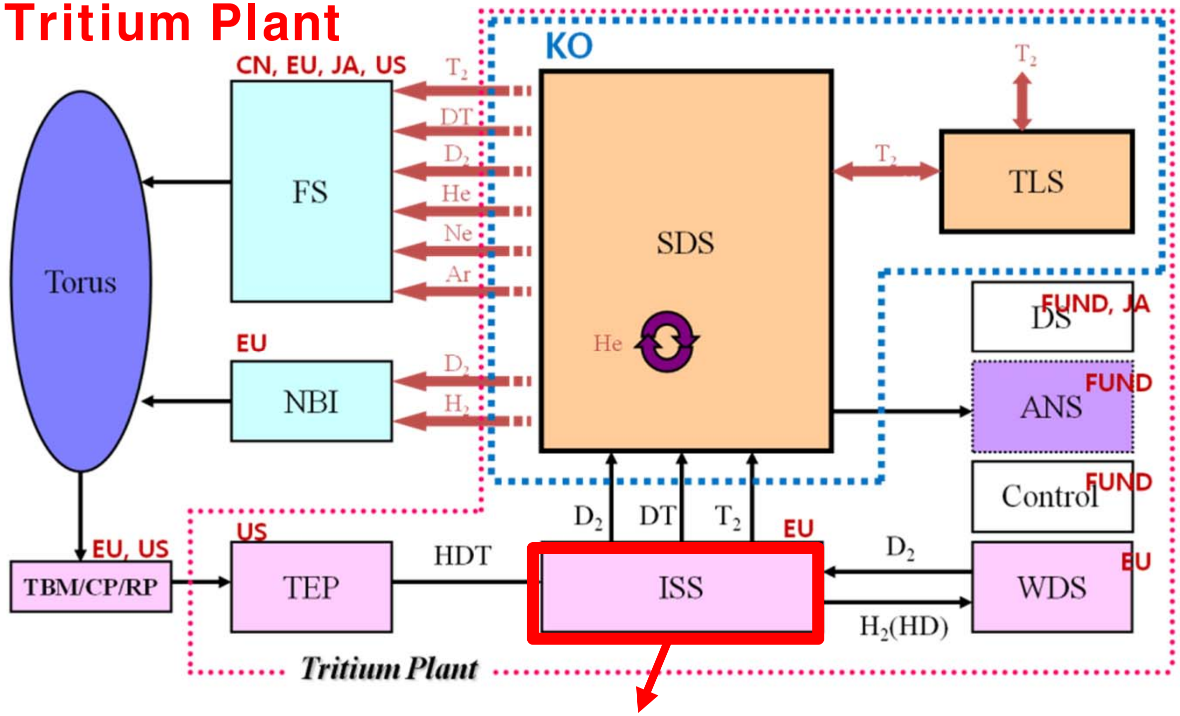
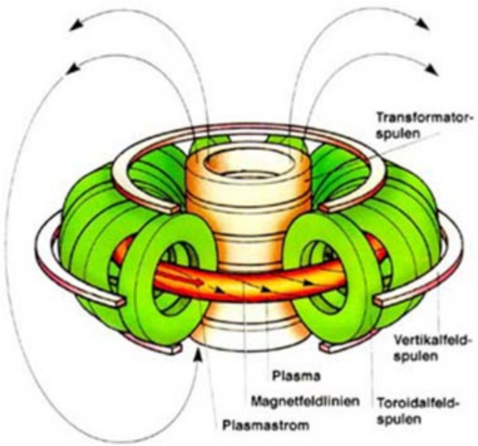
ITER Tritium Plant



- Torus로 삼중수소를 포함한 연료와 여러 가지 다른 목적의 기체들이 공급되고, 혼합되어 방출되는 기체를 다시 성분 별로 분리/정제/회수하는 시스템임
- "**초저온 증류 공정**"을 통해 수소동위원소 사이의 **상대휘발도 차이**를 이용해 분리
- 현재 ITER ISS 공정에 대한 국내의 기술력은 **개념 정립 단계**, 해외 기술 추적도 용이하지 못하여 관련 **자료가 매우 부족한 상태**임

1. ISS(Isotope Separation System)소개

Six major components of the hydrogen isotopes entering into ISS: **H_2, HD, HT, D_2, DT, T_2**



tokamak

Tokamak is a device using a magnetic field to confine a plasma in the shape of a torus or donut to enable **fusion reactions** to occur to produce **clean energy**

토카막배출처리공정
(**TEP;** tokamak exhaust processing)

He, N_2, CO, CO_2, H_2O, CH_4,….

H_2, HD, HT, D_2, DT, T_2

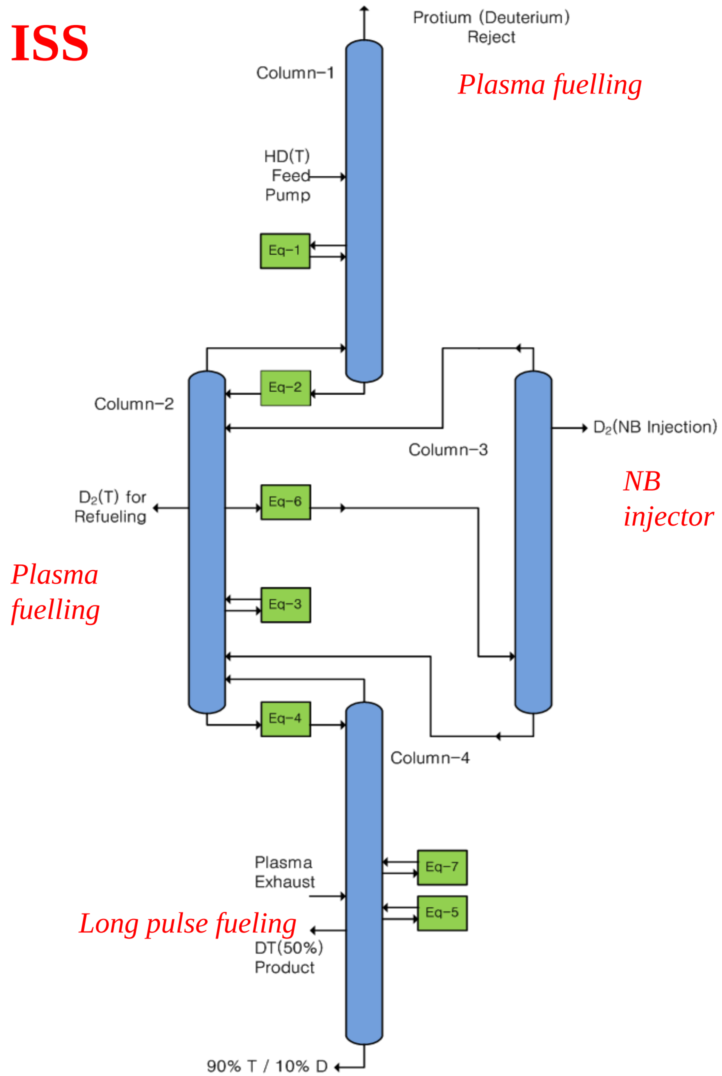
동위원소분리공정
(**ISS**; isotope separation system)

High purity T_2, D_2 ,DT

수소동위원소는 저장 및 공급시스템
(SDS; storage and delivery system)

Raw material supply system

1. ISS(Isotope Separation System)소개



Configuration Optimization

- ❖ ISS는 초저온 증류법을 이용하므로 초저온에서의 수소동위원소 성분들(H_2, D_2, T_2, HD, HT, DT)의 물성 DB화가 필요
- ❖ 동위 원소 체들을 초저온(20K 근처)에서 증류하기 위해서는 **헬륨냉매(4K 근처)를 이용한 냉동사이클**에 대한 모사가 필요(냉동 용량: 1,800 W 가량임)
- ❖ H_2, HD, D_2, HT, DT 및 T_2 6개의 동위원소체로부터 원하는 조성의 D2, DT, T2를 생산하기 위해 4개의 증류탑과 7개의 평형반응기로 구성됨.
- ❖ 에너지 소모량 최적화를 위해 **평형반응장치의 최적 배열과 위치선정이 중요하며 이를** 위해 전산모사를 통한 공정최적화 작업 필요
- ❖ **ISS 적용 가능한 최적화된 공정안 제시**

1. ISS(Isotope Separation System)소개

❖ **The Isotope Separation System (ISS) (EU)**

Purpose of ISS

➢ ITER ISS는 TEP와 WDS에서 이송된 수소동위원소 혼합기체를 초저온 증류와 평형반응을 이용하여 원하는 성분과 조성으로 정제하는 계통이다

➢ To produce the required pure deuterium (<0.02% T, <0.5% H) and 90% T/10% D gas mixtures for SDS.

➢ To transfer detritiated (<0.1 ppm T) hydrogen to WDS for further detritiation and final release.

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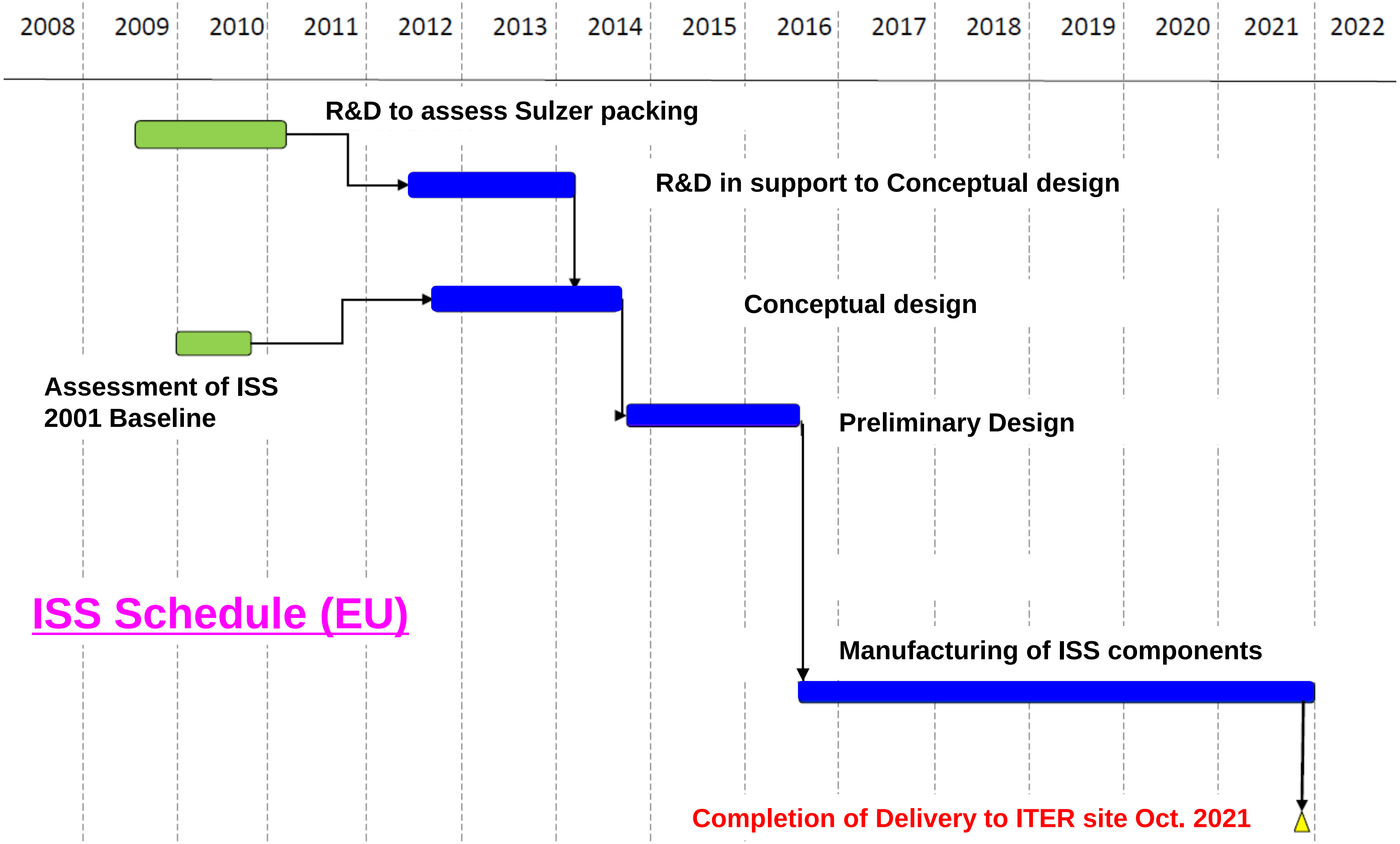
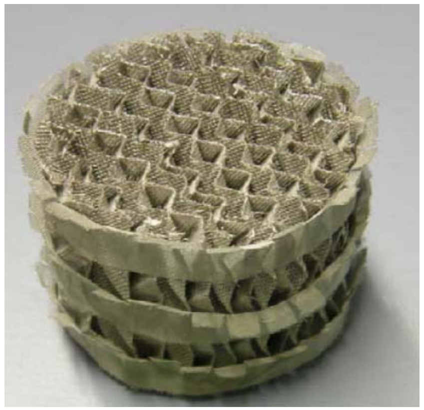
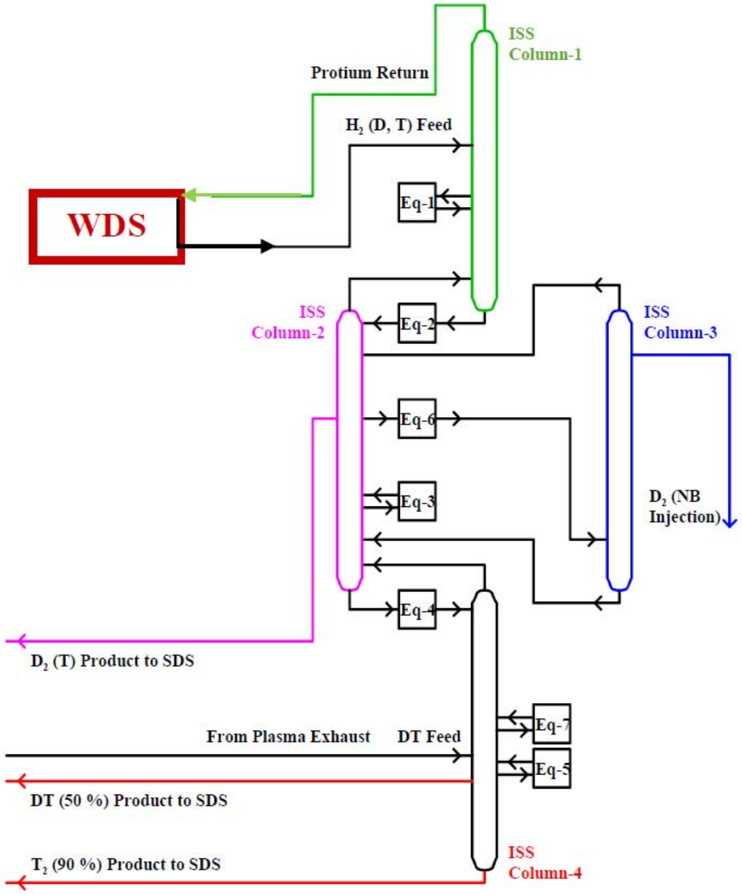


1. ISS(Isotope Separation System)소개

- Following a request to modify the product/feed configuration, an assessment of ISS 2001 baseline design was launched with respect system operation and tritium inventory
- Results have shown that ISS needs optimization/ modifications to operate with the ITER requirements



CY SULZER packing
- SS Gauze structure
- Diameter 50 mm
- Volume 5300 cm^3



ITER Department, Fusion for Energy Seminario Industrial
13 June 2012 G. Piazza,

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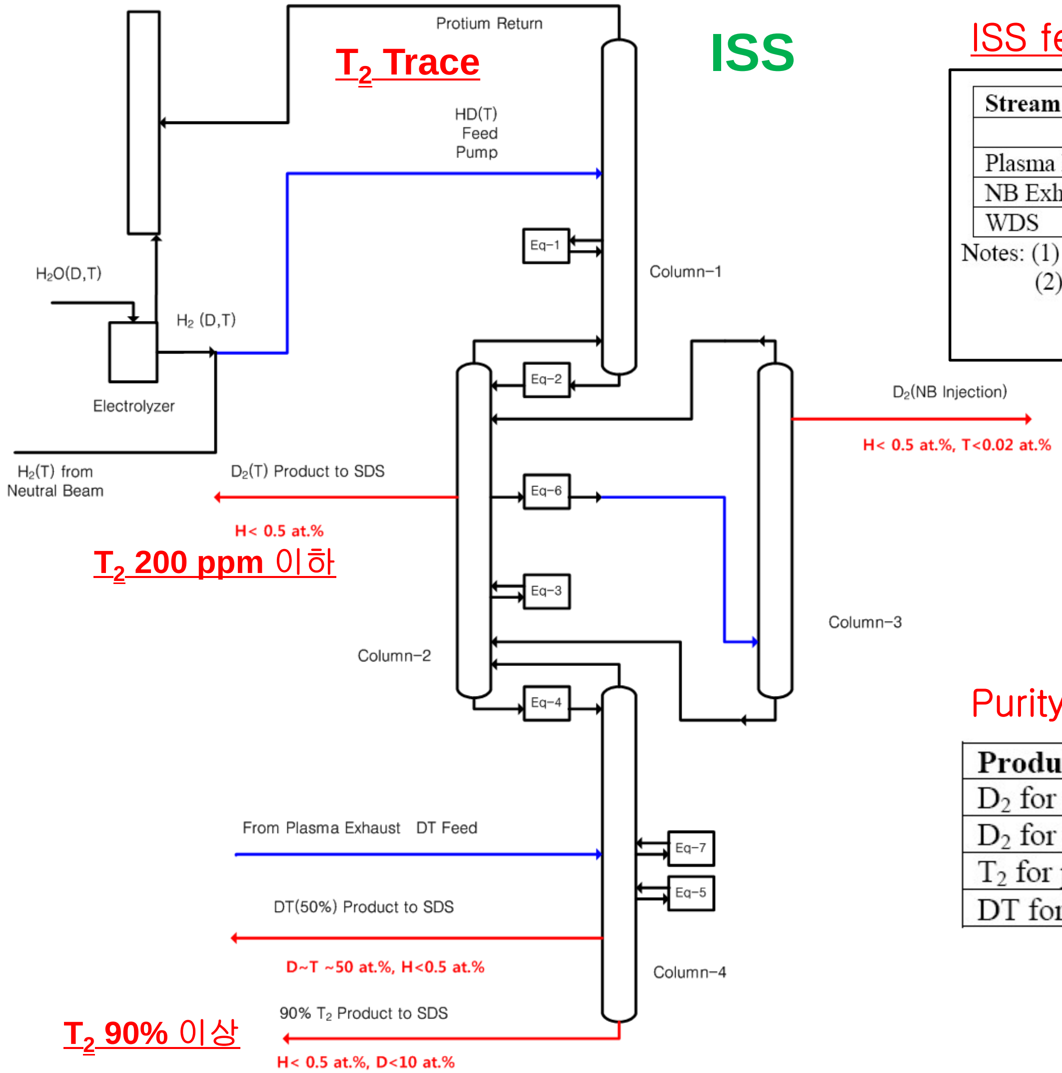

ISS feed stream throughputs and compositions.

Stream	Flow Rate		H	D	T	Notes
	$Pa.m^3/s$	Mole/h	at. %	at. %	at. %	
Plasma Exhaust	0 - 220	0 - 176	0 - 100	1 - 100	0 - 50	
NB Exhaust	0 - 50	0 - 84	0 - 100	0 - 100	0 - 1	(1,2)
WDS		280	~ 100	3×10^{-2}	3×10^{-4}	(1)

Notes: (1) NB exhaust and WDS feed streams are combined before introduction to the ISS.
(2) Based on each NB/DNB injector being regenerated after every 32 nominal pulse cycles (450 s burn and 1,350 s dwell), i.e. one of the three main NB injectors or the DNB will be regenerated after every 8 nominal pulse cycles.

Purity of ISS product streams.

Product Streams	Purity
D_2 for plasma fuelling	H < 0.5 at.%
D_2 for neutral beam injectors	H < 0.5 at.%, T < 0.02 at.%
T_2 for plasma fuelling	H < 0.5 at.%, D < 10 at.%
DT for long pulse fuelling	D ~ T ~ 50 at.%, H < 0.5 at.%

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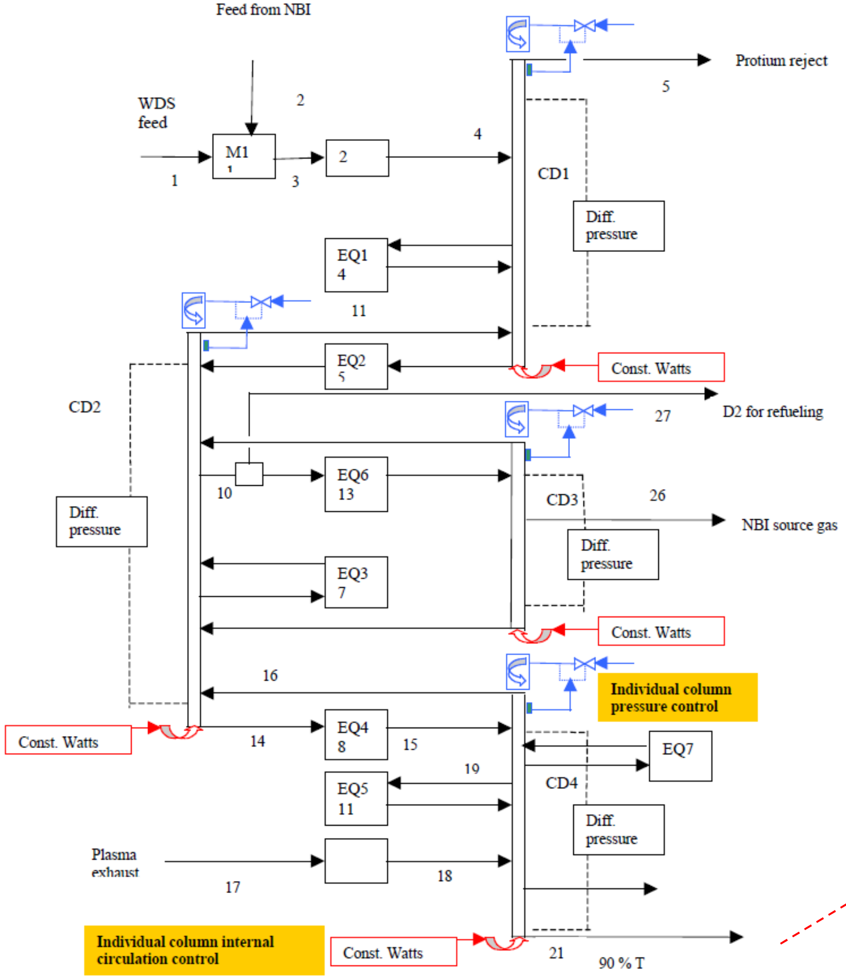

Protium reject
T Trace

D_2 for refueling
(<0.02% T, <0.5% H)

T_2 product to SDS
(90% T/10% D)

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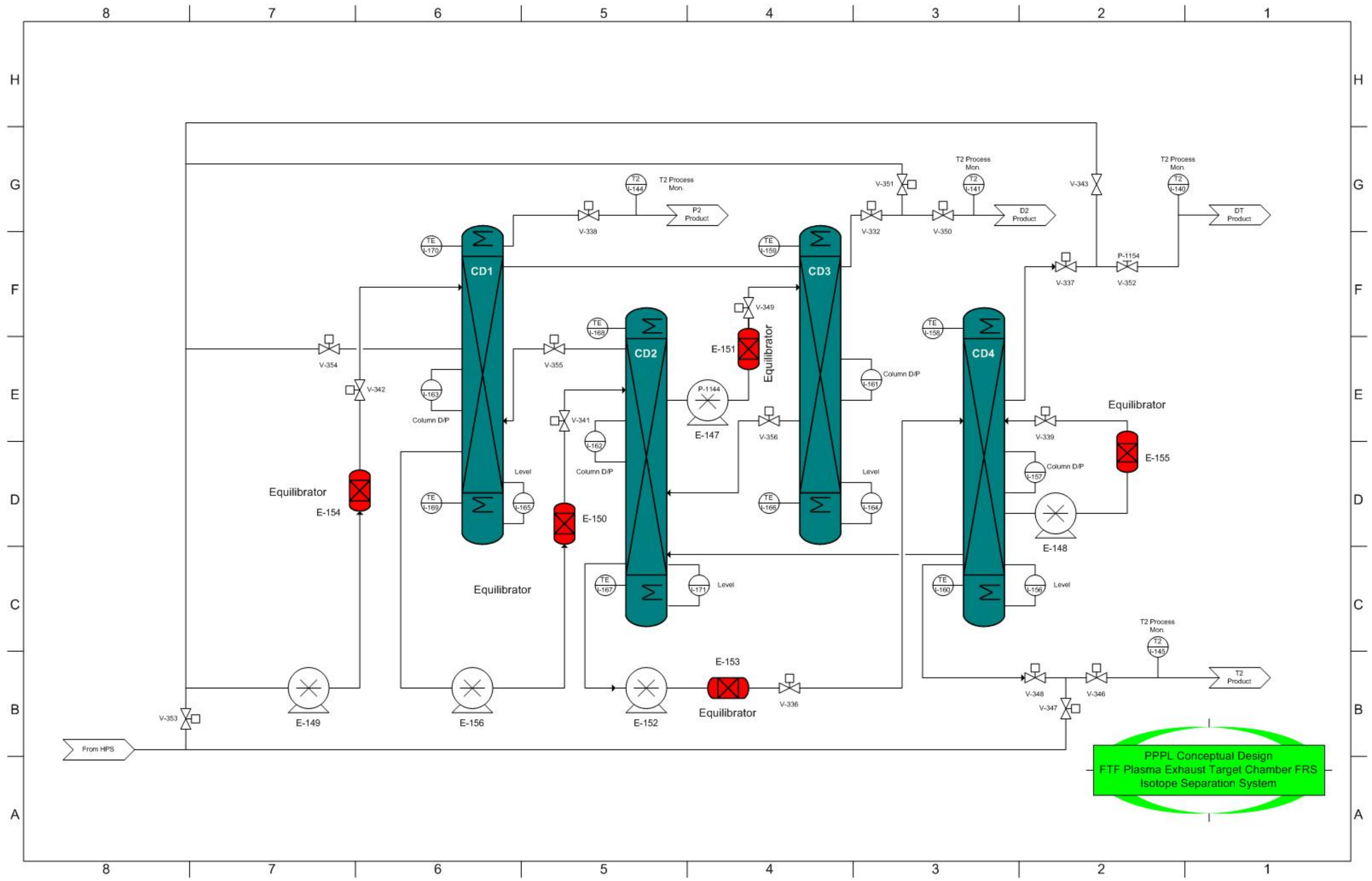
Isotope Separation System

HAPL 15 General Atomics, San Diego, CA August 8th-9th, 2006

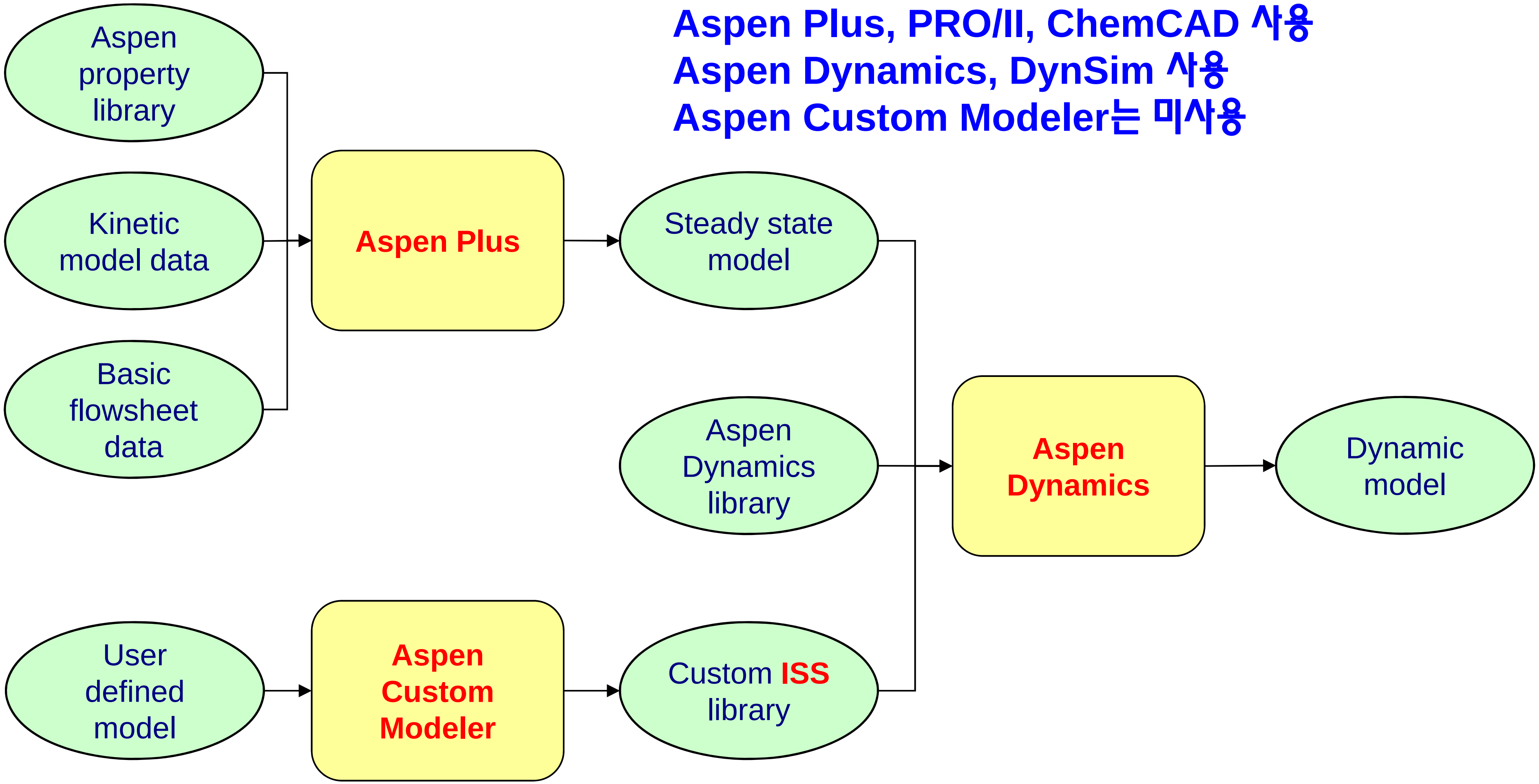


Target Chamber Tritium Recovery, Reprocessing, Purification

1. ISS(Isotope Separation System)소개

Modeling tools relationship

공주대의 경우
Aspen Plus, PRO/II, ChemCAD 사용
Aspen Dynamics, DynSim 사용
Aspen Custom Modeler는 미사용



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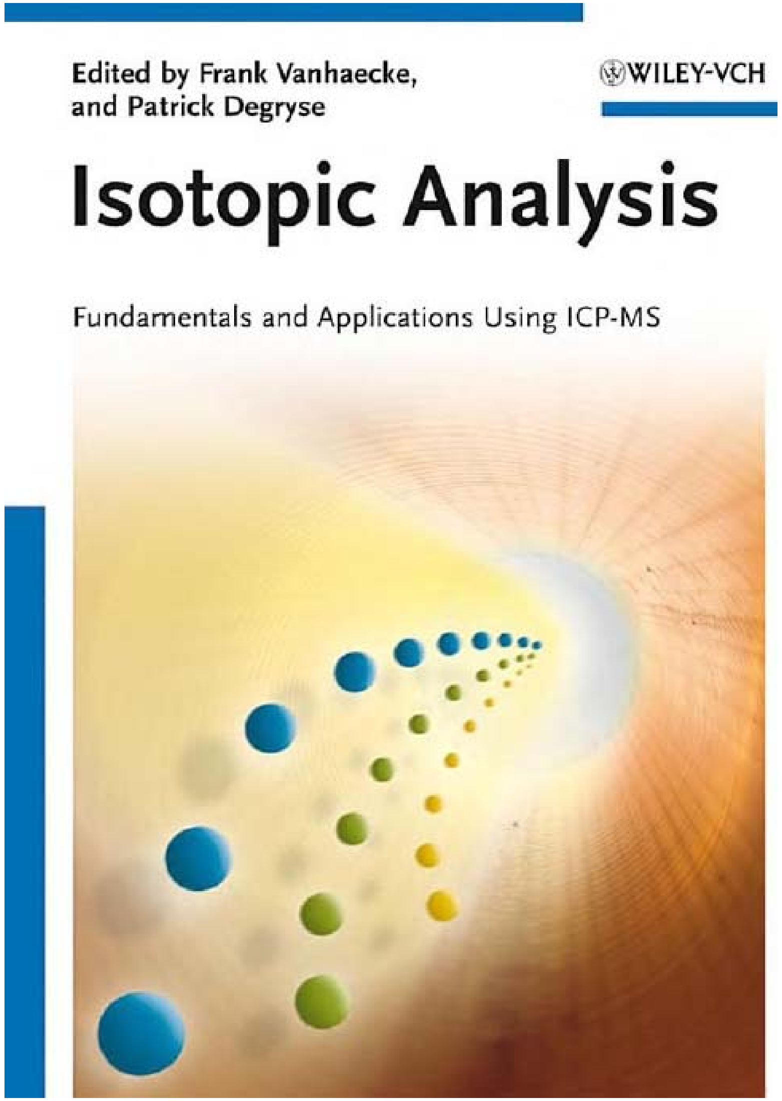
Chapter 1

What Is Nuclear Fusion?

1.1 The Alchemists' Dream

In the Middle Ages, the alchemists' dream was to turn lead into gold. The only means of tackling this problem were essentially chemical ones, and these were doomed to failure. During the 19th century, the science of chemistry made enormous advances, and it became clear that lead and gold are different elements that cannot be changed into each other by chemical processes. However, the discovery of radioactivity at the very end of the 19th century led to the realization that sometimes elements do change spontaneously (or transmute) into other elements. Later, scientists discovered how to use high-energy particles, either from radioactive sources or accelerated in the powerful new tools of physics that were developed in the 20th century, to induce artificial *nuclear transmutation* in a wide range of elements. In particular, it became possible to split atoms (the process known as *nuclear fission*) or to combine them (the process known as *nuclear fusion*). The alchemists (Figure 1.1) did not understand that their quest was impossible with the tools they had at their disposal, but in one sense it could be said that they were the first people to search for nuclear transmutation.

FIGURE 1.1 An alchemist in search of the secret that would change lead into gold. Because



감사합니다