HELIUM-3 BLANKETS FOR TRITIUM BREEDING IN FUSION REACTORS

Don Steiner, Mark Embrechts, Georgios Varsamis,
and Roger Vesey
Dept. of Nuclear Engineering and Engineering Physics
Rensselaer Polytechnic Institute
Troy, NY 12181

and

Paul Gierszewski
Canadian Fusion Fuels Technology Project

OBSERVATIONS

- **RESOURCE CONSIDERATIONS HAVE LIMITED D-T FUSION REACTOR BLANKET STUDIES TO LITHIUM-BASED SYSTEMS**
- **WHILE ACCEPTABLE LITHIUM-BASED BLANKET DESIGNS HAVE BEEN DEVELOPED SAFETY & ENGINEERING CONCERNS ARE ASSOCIATED WITH THE USE OF LITHIUM**
- **THE BEST SAFETY FEATURES ARE GENERALLY ATTRIBUTED TO BLANKETS EMPLOYING HELIUM AS COOLANT**
- **IT WOULD BE DESIRABLE TO DEVELOP A TRITIUM BREEDING OPTION WHICH RETAINS HELIUM AS COOLANT AND ELIMINATES LITHIUM CONCERNS**
- **A HELIUM-3 (BREEDER)/HELIUM-4 (COOLANT) BLANKET OFFERS PROMISE FOR ENHANCED SAFETY & ENGINEERING CHARACTERISTICS**

ESECOM RESULTS

FUSION TECHNOLOGY/JAN., 1988

Case	Nominal LSA	COE (mill/kW·h)
1. V-Li/TOK	3	49.7
2. RAF-He/TOK	2	42.6
3. RAF-PbLi/RFP	4	37.7
4. V-Li/RFP	4	37.3
5. SiC-He/TOK	1	40.3
6. V-Flibe/TOK	2	42.9
7. V-MHD/TOK	4	35.4
8. V-D^{3}He/TOK	2	41.3
9. RAF-Li/HYB	4	
Stand alone		63.7
With MHTGR clients		40.3
10. SS-He/HYB	4	
Stand alone		55.8
With MHTGR clients		39.8

GENERAL FEATURES OF CONCEPT

- USE HELIUM-3 TO BREED TRITIUM
  [large $\sigma(n,T)$ of ^3He]

- BLANKET COOLANT WOULD BE HELIUM-4
  - OPERATING AT ABOUT 5 MPa
  - 100 - 300 C (NEAR TERM)
  - 250 - 500 C (COMMERCIAL)

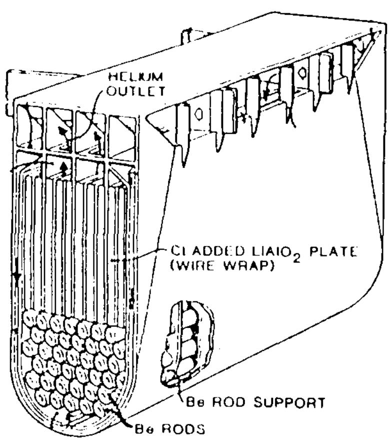
- BLANKET STRUCTURE WOULD BE CONVENTIONAL (e.g. STAINLESS STEEL) OR ADVANCED (e.g. SiC)

- BERYLLIUM WOULD BE USED FOR NEUTRON MULTIPLICATION [large $\sigma(n,2n)$]

- HELIUM-3 CONTAINED IN A LOOP SEPARATE FROM HELIUM-4 LOOP AND FLOWS WITHIN THE BERYLLIUM, ALSO ACTING AS A PURGE FOR BERYLLIUM-BRED TRITIUM

- CONCEPT FEATURES SIMILAR TO THOSE OF A He/SB BLANKET WITH EXCEPTION THAT ISSUES ASSOCIATED WITH THE SB ARE ELIMINATED

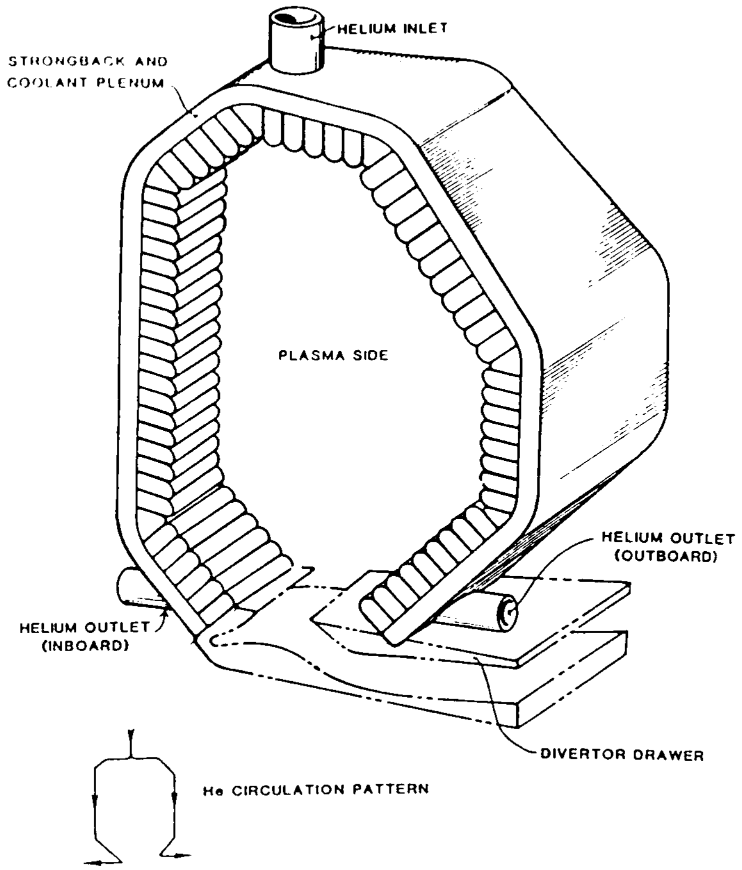
A REFERENCE CONFIGURATION WAS ADOPTED BASED ON MINOR MODIFICATIONS TO THE BCSS He/$LiAlO_2$/Be BLANKET

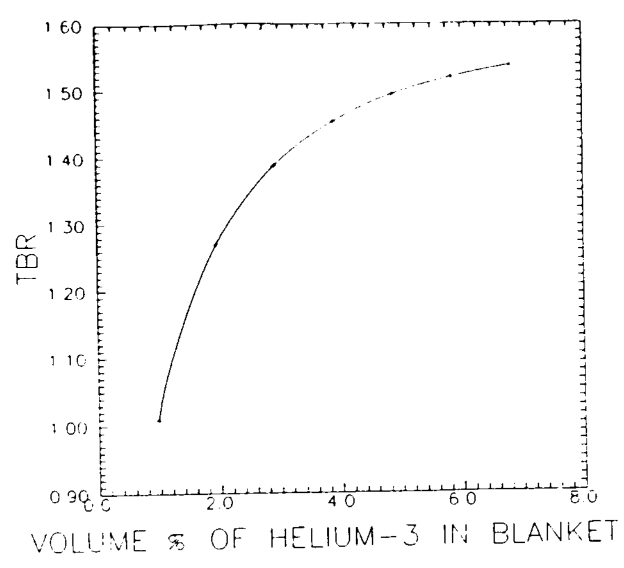


$LiAlO_2$ IS REPLACED WITH BERYLLIUM CONTAINING A HELIUM-3 PURGE STREAM

ORIGINAL PAGE IS
OF POOR QUALITY

HELIUM COOLED BLANKET MODULE SECTOR





- THE HELIUM-3 BLANKET EXHIBITS GOOD TRITIUM BREEDING POTENTIAL

- THE REFERENCE CONFIGURATION WAS NOT OPTIMIZED FOR TBR & SOME BREEDING ENHANCEMENT IS EXPECTED

THE HELIUM-3 BLANKET CONCEPT SHARES MANY ATTRACTIVE ASPECTS OF He/SB BLANKETS AND BRINGS SEVERAL ADVANTAGES

- COMMON ATTRACTIVE FEATURES
  - GOOD SAFETY CHARACTERISTICS
  - NO CORROSION CONCERNS
  - GOOD TRITIUM BREEDING POTENTIAL
- ADVANTAGES OF HELIUM-3 BLANKETS
  - ONLINE BREEDING CONTROL
  - NOT SENSITIVE TO POWER VARIATIONS & HEAT CONDUCTANCE CONSTRAINTS
  - REDUCED TRITIUM INVENTORY IN BREEDER
  - NO C-14 PRODUCTION IN BREEDER
- The R & D REQUIRED FOR THE HELIUM-3 BLANKET WOULD BE SIMILAR TO THAT OF He/SB BLANKETS WITH EXCEPTION OF SB DEVELOPMENT

TRITIUM CONTROL ISSUES IN ESECOM REFERENCE CASES

Case	Active Tritium Inventory (g)	Dominant Location of Tritium	Difficulty of Control
V-Li/TOK	500	Coolant/breeder	Low
RAF-He/TOK	160	Breeder	Low to medium
RAF-PbLi/RFP	60	Coolant	Medium to high
V-Li/RFP	500	Coolant/breeder	Low
SiC-He/TOK	160	Breeder	Low to medium
V-Flibe/TOK	15	Structure	Medium
V-MHD/TOK	Not estimated	Structure?	Medium?
V-D^{3}He/TOK	60	Coolant	Low to medium
RAF-Li/HYB	1000	Coolant/breeder	Low
SS-He/HYB	200	Structure	Low to medium

T/He3 Inventory and Leakage

- Purge circuit He3 volume:
  - Blanket/plenum - 10 m3
  - Piping/T system/misc - 5 m3

- Inventories:
  - He4 coolant - 2000 kg
  - He3 purge - 50 kg
  - T in purge - 0.06 g
  - T in coolant - 0.8 g
  - T in Be - 0.5-1000 g (?)

- Assume 1% circuit leakage/yr (BCSS):
  - He4 - 2 kg/yr
  - He3 - 0.5 kg/yr
  - T - 100 Ci/yr (+ 10 Ci/d across HX)

- Options for He3 inventory reduction:
  - Breeding in outboard only - 25% less
  - Purge flow rate to 30 m/s - 10% less

HELIUM-3 REQUIREMENTS FOR FUSION

	ITER[a]	COMM[b]	100 x COMM
INVENTORY, kg	50	50	5000
LEAKAGE, kg/yr	0.5	0.5	50
BURNUP, kg/yr	8	96	9600
LIFETIME, kg	85 (10 yrs)	3800 (40 yrs)	10^6 (120 yrs)
COST, $/g	700 (MOUND)	100-500 (TARGET)	100-500 (TARGET)

[a] 600 MW_f / 25 % AVAILABILITY

[b] 2400 MW_f / 75 % AVAILABILITY

RESERVES OF HELIUM-3 THAT COULD BE AVAILABLE IN THE YEAR 2000

SOURCE	CUMULATIVE AMOUNT TO YEAR 2000 (kg)	PRODUCTION RATE POST YEAR 2000 (kg/yr)
Decay of T,		
DOE		
MRC annual sales	—	1.3
MRC inventory	> 13.4	—
CANDU reactors	10	2
US weapons (approximate)	$\propto$ 300	$\propto$ 15
Natural gas wells		
underground storage	29	—
Known reserves	187	—
Total	500 to 600	$\propto$ 18

Note: Data from the University of Wisconsin (Fusion Technology)

- THE DECAY OF TRITIUM IN MILITARY STOCKPILES COULD SATISFY THE HELIUM-3 REQUIREMENTS OF ITER
- COMMERCIAL FUSION POWER WOULD REQUIRE EXTRATERRESTRIAL SUPPLIES OF HELIUM-3

CONCLUDING REMARKS

- HELIUM-3 BLANKETS OFFERS CONSIDERABLE PROMISE FOR TRITIUM BREEDING IN FUSION REACTORS
  - GOOD BREEDING POTENTIAL
  - LOW OPERATIONAL RISK
  - ATTRACTIVE SAFETY FEATURES
- AVAILABILITY OF HELIUM-3 RESOURCES IS THE KEY ISSUE FOR THIS CONCEPT
  - THERE IS SUFFICIENT HELIUM-3 FROM DECAY OF MILITARY STOCKPILES TO MEET ITER NEEDS
  - EXTRATERRESTRIAL SOURCES OF HELIUM-3 WOULD BE REQUIRED FOR A FUSION POWER ECONOMY
    - $\propto$ 100 - 500 \$/g
    - $\propto 10^4$ kg/yr & $\propto 10^6$ kg