

# The $\text{Li}_2\text{O}$ Particulates Blanket Concept

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# Configuration of Exposed Solid Breeder Blanket Concept (cont'd)

- The SiC blanket has controlled flow channels behind the first wall for additional  $\text{Li}_2\text{O}$  solid breeder material
- Diverters are open with exposed flowing  $\text{Li}_2\text{O}$  particles
- After passing through the plasma chamber, the  $\text{Li}_2\text{O}$  particles go through a heat exchanger and a  $\text{T}_2$  extraction system.

# Configuration of Exposed Solid Breeder Blanket Concept (cont'd)

- A mechanical lift system is then used to elevate the solid breeder back to the upper level
- Dust particles are removed before the  $\text{Li}_2\text{O}$  particles return to the chamber

# First Wall Heat Transfer

- The model used is the dropping of a  $\text{Li}_2\text{O}$  particle facing  $1.5 \text{ MW/m}^2$  heat flux by gravitational force
- The temperature rise on the surface can be written as
$$t(x, \tau) - t_0 = \frac{2q_c}{\lambda} (a\tau)^{1/2} \text{ i erfc } \frac{x}{2(a\tau)^{1/2}}$$
- For a  $\text{Li}_2\text{O}$  particles, the surface temperature will increase from 300 C to 1000 C in four seconds

# First Wall Heat Transfer(cont'd)

- The gravitational flow will travel 160 m within 4 seconds, which is far longer than the height of the blanket
- If the first wall height is 10m, the first wall heat flux capability is  $2.5 \text{ MW/m}^2$

# First Wall Failure Mode

- The conventional fusion first wall is very thin (~3mm), and back by a high pressure coolant (~10 MPa), and subject to high radiation damage
- To assure the first wall with minimum number of failures over many years of operation will be difficult
- A first wall failure may require the change of the entire blanket module, which will be time consuming
- How to keep a fusion power plant operating reliably is challenging

# The First Wall of This Concept

- The first layer of material facing the plasma is a stream of  $\text{Li}_2\text{O}$  particulates, which will have low vapor pressure
- The first wall is a layer of SiC behind the  $\text{Li}_2\text{O}$  zone
- This first wall does not contain any pressure
- Since the first wall does not contain any pressure, it can not develop any leak
- The only role of the SiC structure is to restrict the  $\text{Li}_2\text{O}$  flow.

# Maintenance of Exposed Solid Breeder Blanket

- All plasma facing components are made of SiC
- They are not structural and can withstand high radiation damage
- Vacuum integrity is maintained by front shield surface
- The solid breeder is drained from the bottom of the chamber



# Maintenance of Exposed Solid Breeder Blanket (contd.)

- In the case of a LAR-ST, the whole blanket can be replaced through the top access flange.
- In the case of a normal aspect ratio tokamak, segments of the blanket separated poloidally will be removed through upper access ports between coils.

# Safety

- This blanket concept selects SiC and Li<sub>2</sub>O as the materials
- There is minimum activation and after heat
- The Li<sub>2</sub>O will be at a high temperature. Therefore, tritium inventory will be low
- There is no foreseen safety and environmental concerns

# Shield Design

- Since the radiation damage to the shield regime is very low, SS can be used as the structural material
- The shield will be divided into two zone, with different temperature limit
- Both zone will be cooled by He at 8 MPa
- The high temperature zone will be operating at 600 C, for good thermal efficiency
- The back regime will be a low temperature zone, to be compatible with the magnet design

# Design Requirement

- Capability to handle high wall loading
  - First wall flux 1.5 MW/m<sup>2</sup> max.
  - Neutron wall loading 7 MW/m<sup>2</sup> max.
- Tritium breeding
- First wall Failure mode
- Blanket replacement

# Power Conversion System

- The transport of the solid particles will be by mechanical conveyers
- Mechanical conveyers have been used in chemical industry for decades
- The thermal energy will be transferred to a He loop by an IHX
- The He will be fed to a close cycle gas turbine with a thermal efficiency  $>50\%$

# Heat Exchanger

- The design of the heat exchanger will be challenging due to the poor heat transfer from solid particle to a wall, inside a low vapor pressure system
- However, a large heat transfer  $\Delta T$  is available to offset part of the concern of poor heat transfer
- A fin can be added outside of the He coolant tube, to mixing the  $\text{Li}_2\text{O}$  flow to improve heat transfer
- Experimental information is available and will be reported on the heat transfer of a moving bed

# Solid Particle Handling

- Solid particle handling is an established process in chemical industry
- The transport of solid particles can be by mechanical conveyer.
- The fine particles from attrition can be removed by a cyclone separator
- The dust is not foreseen to be a major issue because
  - a. It is not activated
  - b. It has low tritium content, and
  - c. It is chemically inert

# Issues for this Concept

- $\text{Li}_2\text{O}$  particles falling into plasma
- Dust particles levitated electrostatically.  
Question - Will they be swept away in the scrape-off?
- Solid breeder heat exchanger
- $\text{T}_2$  recovery from particles?
- Lifting solid breeder material mechanically



# Blanket Description

- To enhance the first wall heat transfer capability, the coolant will be exposed directly to the plasma
- $\text{Li}_2\text{O}$  is selected as the coolant/breeder because of
  - Low vapor pressure ( $\sim 10^{-5}$  Torr at 1000 C)
  - Good breeding potential without Be
  - Very low activation and after heat
  - Good high temperature stability
- The first wall regime will be a free flow of  $\text{Li}_2\text{O}$  particulates to enhance heat transfer

# Blanket Description (cont'd)

- The blanket regime will be constructed by SiC, which will restrict the  $\text{Li}_2\text{O}$  flow rate to increase the packing density
- The SiC layer will not be a heat transfer boundary so that low thermal conductivity is not a critical issue
- The  $\text{Li}_2\text{O}$  will be collected at the bottom of the blanket, and exit from the blanket by gravitational force

# Blanket Description (cont'd)

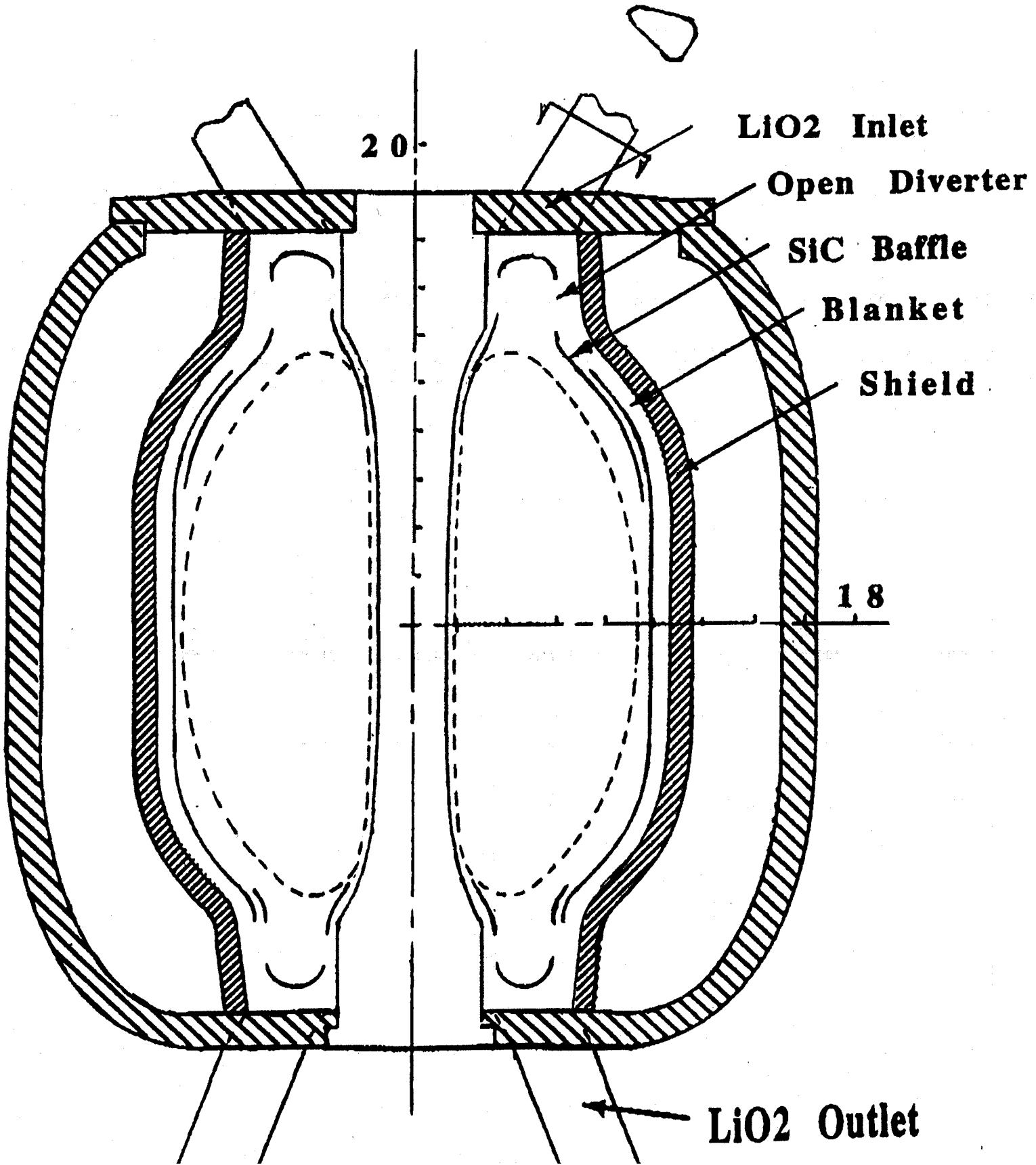
- A mechanical conveyer will move the  $\text{Li}_2\text{O}$  particles to the top of the heat exchanger
- The  $\text{Li}_2\text{O}$  will drop down from the HX by gravitational force, and transfer the heat to a secondary He loop
- The  $\text{Li}_2\text{O}$  will be moved up again by another mechanical conveyer to the top of the blanket, and be fed into the blanket

# Blanket Description (cont'd)

- Tritium produced in the  $\text{Li}_2\text{O}$  is expected to diffuse back to the plasma
- The He will enter a He turbine for power conversion

# CONFIGURATION OF AN EXPOSED SOLID BREEDER BLANKET CONCEPT AS APPLIED TO A LAR TOKAMAK

 University of Wisconsin



tried in other fields. The M. W. Kellogg Co. has undertaken to develop its use further in the catalytic and hydrocarbon fields. The Dorr Co. has engaged in similar activities for non-catalytic purposes (see FluoSolids).

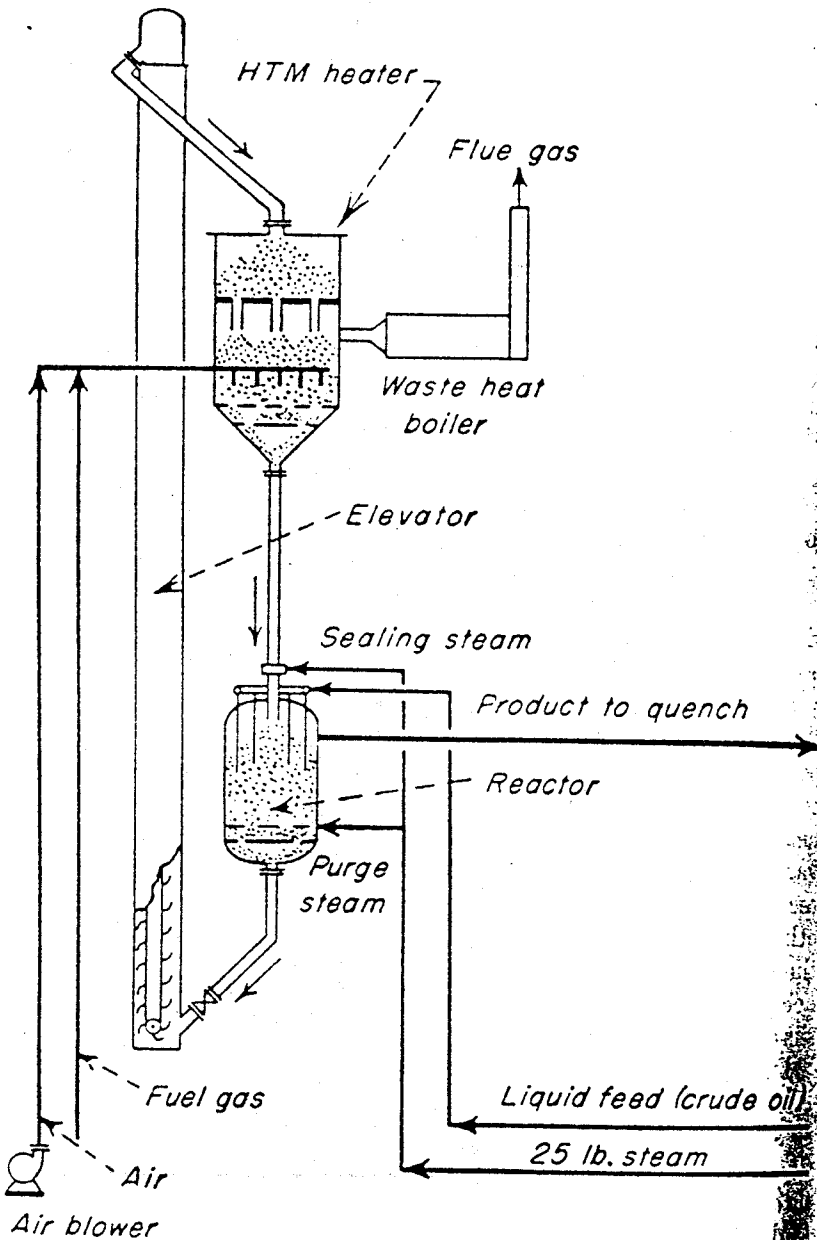


FIG. 20. Thermoform pyrolytic cracking unit. [Socony-Vacuum Oil Co., Inc.; Chem. Eng., 55, 113 (1948).]

The "Fluid Catalytic Cracking" units consist primarily of a reactor and a regenerator with auxiliaries. In gasoline production, this equipment is followed by necessary refining equipment, as shown in Fig. 21. The reactors are vertical, cylindrical steel vessels containing a mass of finely divided catalyst suspended by the flow of vaporized feed stock. Gas velocities through the reactor are low, in the order of 0.5 to 2 ft./sec., based on empty cross section, but sufficiently high to maintain a fluidized bed of solids having many of the properties of a liquid. The feed stock is vaporized before it enters the reactor by contact with hot, regenerated catalyst (at 1150°F.). The vaporized feed entrains the regenerated catalyst and carries it into the reactor through a distributing grid. The reactor temperature is maintained at 800° to 1000°F. The cracked feed stock passes from the bed through cyclone dust collectors installed

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# Configuration of Exposed Solid Breeder Blanket Concept

- Best applicable to high elongation plasmas
- All blanket structures made of SiC
- SiC baffles on the top and bottom of the plasma chamber direct  $\text{Li}_2\text{O}$  solid breeder particles around the plasma then let them fall by gravity to the bottom.
- These SiC baffles are non-structural and are made for easy replacement