The Li_20 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 Li_2O solid breeder material
- Diverters are open with exposed flowing Li_2O particles
- After passing through the plasma chamber, the Li_2O particles go through a heat exchanger and a 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 Li_2O particles return to the chamber

First Wall Heat Transfer

- The model used is the dropping of a Li_20 particle facing 1.5 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 Li_20 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 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 fist 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 Li_20 particulates, which will have low vapor pressure
- The first wall is a layer of SiC behind the Li_20 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 Li_20 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_20 as the materials
- There is minimum activation and after heat
- The Li_20 will be at a high temperature. Therefore, tritium inventory will be low
- There is no foresee 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^2 max.
  - Neutron wall loading 7 MW/m^2 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 Δ 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 $Li_2 0$ 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 foresee 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

- Li_2O particles falling into plasma
- Dust particles levetated electrostatically. Question - Will they be swept away in the scrape-off?
- Solid breeder heat exchanger
- 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
- Li_20 is selected as the coolant/breeder because of
  - Low vapor pressure (~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 Li_20 particulates to enhance heat transfer

Blanket Description (cont'd)

- The blanket regime will be constructed by SiC, which will restrict the Li_20 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 Li_20 will be collected at the bottom of the blanket, and exit from the blanket by gravitational force

Blanket Description (cont'd)

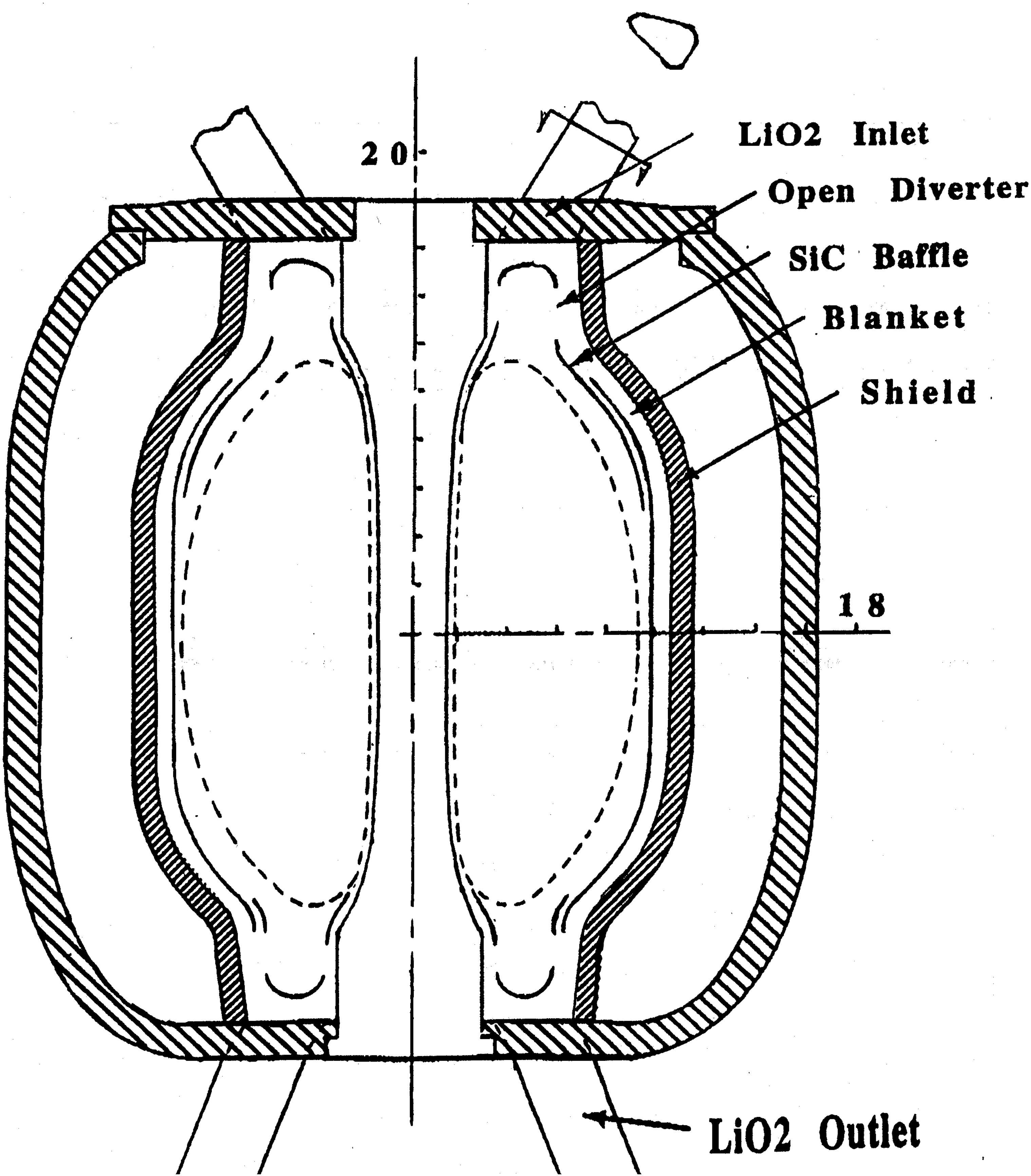
- A mechanical conveyer will move the Li_20 particles to the top of the heat exchanger
- The Li_20 will drop down from the HX by gravitational force, and transfer the heat to a secondary He loop
- The Li_20 will be moved up again by another mechanical conveyer to the top of the blanket, and be fed into the blanket

Blanket Description (cont'd)

- Tritium produced in the Li_20 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).

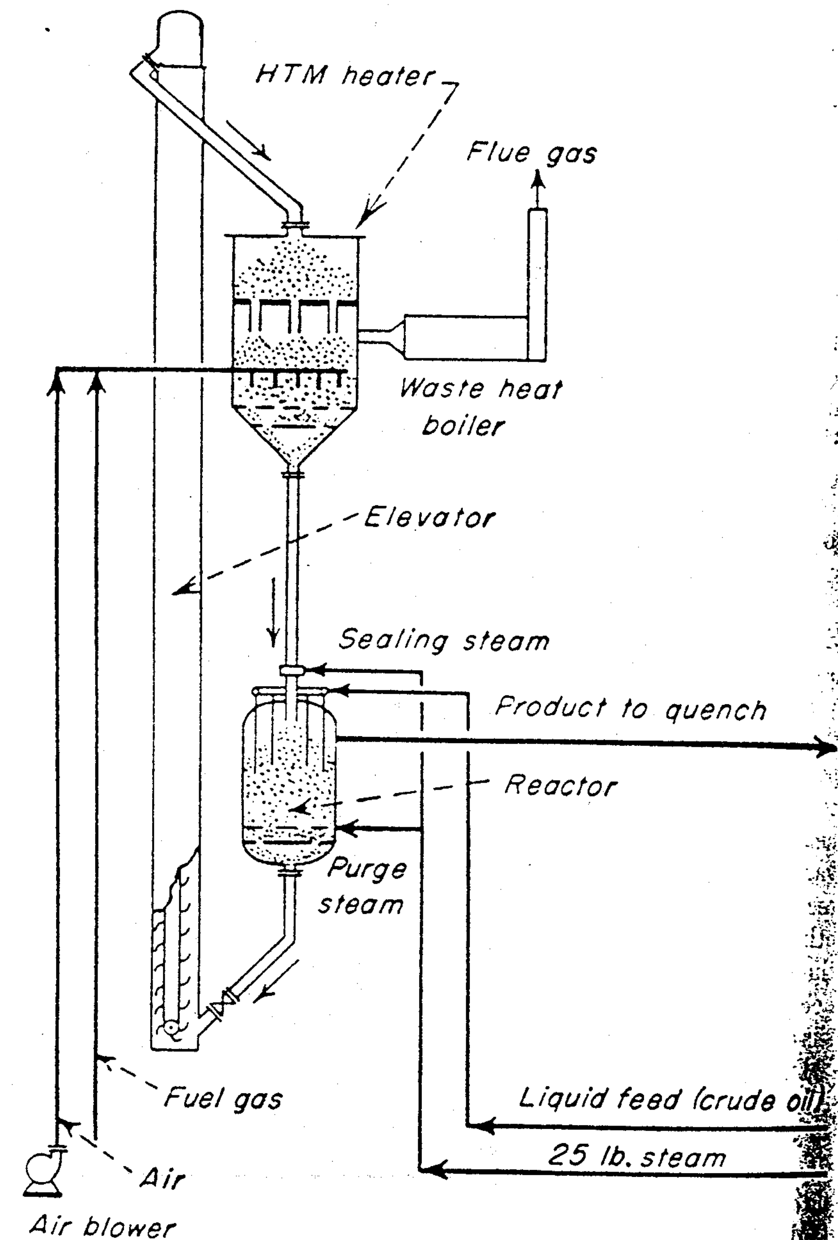


FIG. 20. Thermofor pyrolytic cracking unit. [*Socony-Vac[uum] Oil Co., Inc.; Chem. Eng.*, **55**, 113 (1948).]

The "Fluid Catalytic Cracking" units consist prim[arily] of a reactor and a regenerator with auxiliaries. [For] gasoline production, this equipment is followed by [the] necessary refining equipment, as shown in Fig. 21. [The] reactors are vertical, cylindrical steel vessels conta[ining] a mass of finely divided catalyst suspended by the [flow] of vaporized feed stock. Gas velocities through the [reac]tor are low, in the order of 0.5 to 2 ft./sec., based o[n] empty cross section, but sufficiently high to maint[ain a] fluidized bed of solids having many of the propertie[s of a] liquid. The feed stock is vaporized before it ente[rs the] reactor by contact with hot, regenerated catalyst ([1050] to 1150°F.). The vaporized feed entrains the regene[rated] catalyst and carries it into the reactor through [a dis]tributing grid. The reactor temperature is maintai[ned at] 800° to 1000°F. The cracked feed stock passes fro[m the catal]yst bed through cyclone dust collectors insta[lled]

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 Li_2O 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