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A PLAN FOR UTILIZING ALCATOR A  
FOR DEVELOPING ACTIVELY COOLED LIMITERS  
AND PARTICLE PUMPING METHODS

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May, 1980

A Plan for Utilizing Alcator A  
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Purpose

The purpose of this plan is: to develop a limiter or limiters (subjected to high heat and particle fluxes at plasma edge) for long pulse operation of tokamak fusion devices; to study the particle removal with the limiters; and to study and develop the methods for protections against disruptions and other abnormal operation, such as run-away electrons and arcing.

Alcator A has a peak heat of  $5 \text{ kW/cm}^2$  and high particle flux, and as such is an ideal test facility. Access is adequate for small scale tests.

Limiter Types

Active cooling methods will be developed for the conventional poloidal ring type limiter. The complete or partial toroidal rail types will be designed and studied. Innovative ideas will be investigated.

The conventional methods and two conceived innovative ideas are described in the following.

1) Conventional ring type

The present limiters for Alcators are poloidal rings made of molybdenum and are inertially cooled after pulses. For the purpose of comparison, a ring type, water-cooled limiter has been designed by McDonnell Douglas. The preliminary results are shown in Figure 1. The surface of the limiter is a 2 mm molybdenum shell bonded onto an array of copper tubes. The initial design

study of such a limiter is underway and will be evaluated. If judged to be feasible, it will be fabricated for testing. In this conventional method, the water temperature will rise at the exit ends, and thus will reduce the heat removal efficiency. A spray cooling method is proposed here and is illustrated by Figure 2. The surface can be coated with molybdenum or graphite or other materials. The pumping from the back side can be tested.

## 2) Innovative concepts

Two innovative concepts have been conceived, the spring-like coiled limiter and a series of coiled tops. The coiled limiter is shown in Figure 3. The advantage of the coil limiter is that the plasma will reach the front as well as inner surfaces of the tubes as is illustrated by Figure 3b. This not only increases the surface area, but also reduces the thermal stress. It will be tested if the neutrals inside the coil can be pumped out at the ends. One can vary the pitch of the spring to determine the most effective cooling and particle removal. Because the plasma may pass through the space in between turns, two or more coil limiters may be needed. It is also possible to use a secondary cooling as is shown by Figure 3d with counter flow coolant. It is like a heat exchanger. The primary water will be re-cooled at each turn so that the temperature over the entire length of the limiter will be nearly uniform and the heat removal will be more effective.

The coiled top-like limiter is illustrated by Figure 4. The tops will be mounted on a duct and water lines will be connected to a manifold. The neutrals scattered into the duct can be pumped away.

The application of the coil limiters to a reactor is illustrated by Figure 5. The whole first wall can be lined with these springs. They do not have to be closely fitted together and can be easily replaced.

The purpose of the above discussion is to demonstrate that innovative methods are conceivable. Alcator-A is a valuable facility in which to carry out the testing of these methods.

## Testing Plan

The testing plan is briefly outlined as follows:

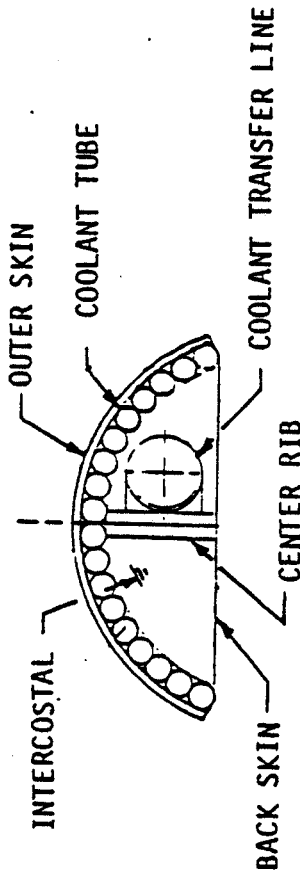
- A valid concept will be designed, evaluated and tested.
- The test on the actively cooled limiters will always begin with low power. The power will be raised gradually to highest possible level.

- If the test is successful at normal operation, the limiters will be punished with simulated abnormal operations such as disruption, run-away electrons, etc.
- The limiter will be subjected to many thousands of pulses to test the fatigue
- Coating of different materials with various thicknesses will be tested. Pumping techniques will be tested.
- After the successful limiters are identified, the tests will be repeated by covering the first wall area as much as possible with these limiters

#### Participants

The scientists who are interested in this program from other laboratories, such as Sandia and Livermore, and from industry, are invited to participate and test their own concept in coordination with M.I.T.

# LIMITER CONCEPT 1: FORMED SKIN/COOLANT TUBES



## MATERIALS

	SKIN	TUBES	STRUCTURE
(a)	Cu	Cu	$\left. \begin{array}{l} \text{Mo;} \\ \text{ST STL} \end{array} \right\}$
(b)	Ta-10W	Cu	
(c)	Mo	Cu	

## THERMAL HYDRAULICS

FOR 5 KW/CM<sup>2</sup> PEAK HEAT FLUX:

CLNT	SKIN MATERIAL	SKIN T <sub>MAX</sub>
H <sub>2</sub> O	Cu	250 <del>1000</del> °C
H <sub>2</sub> O	Ta-10W	650 <del>1000</del> °C
H <sub>2</sub> O	Mo	400 <del>1000</del> °C

## FABRICATION

- SKIN FORMED OVER PATTERN
- TUBES, SKIN, STRUCTURE BRAZED AS UNIT
- COATING COULD BE ADDED TO SKIN



Figure 1. Water-Cooled Limiter Design

  
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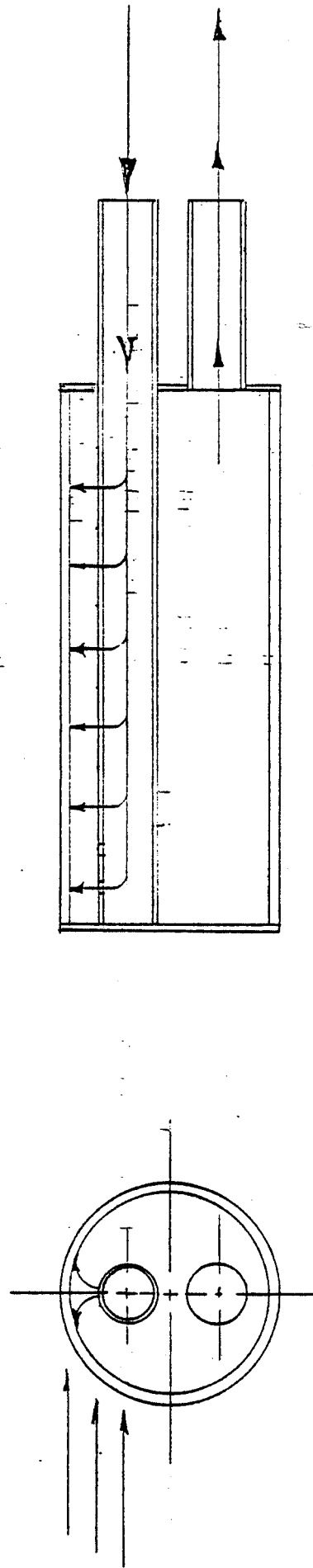
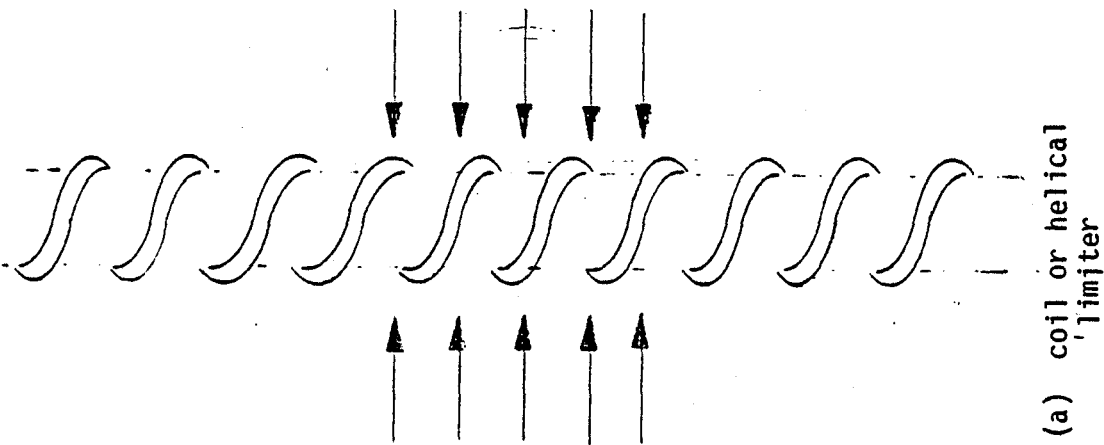


Figure 2. Sketches to Illustrate Different Cooling Methods

Not a tube



Not a tube

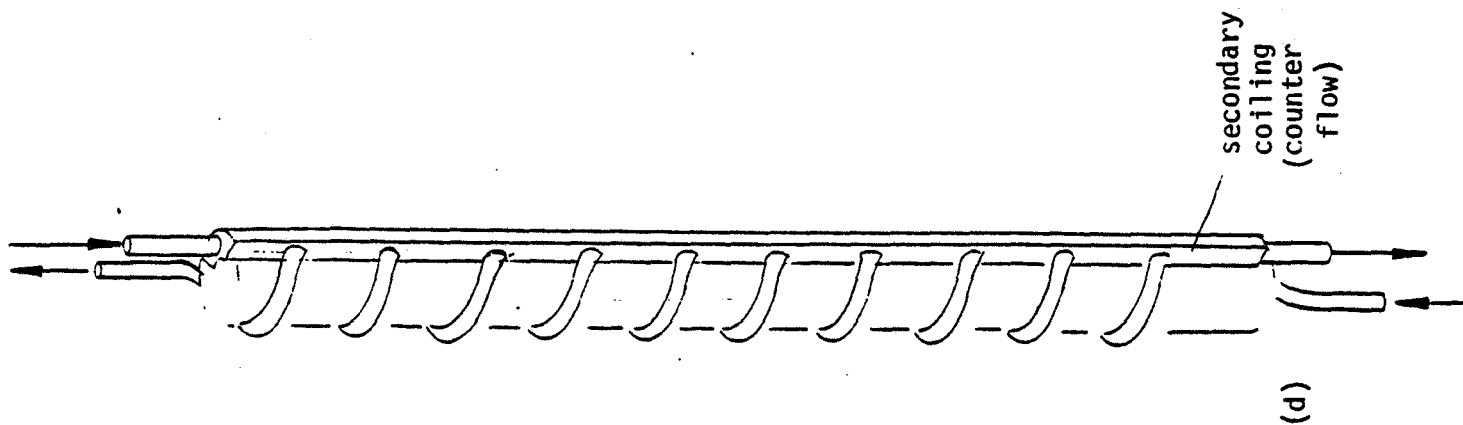
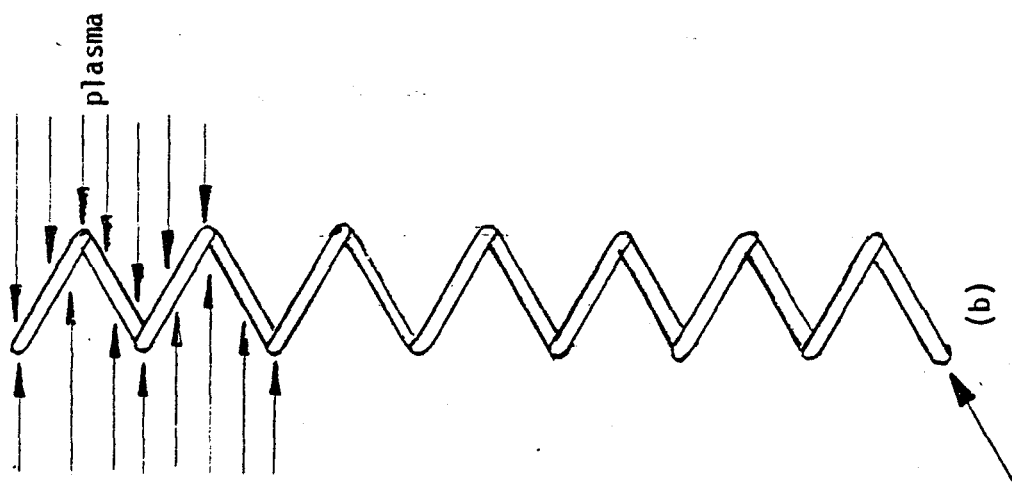
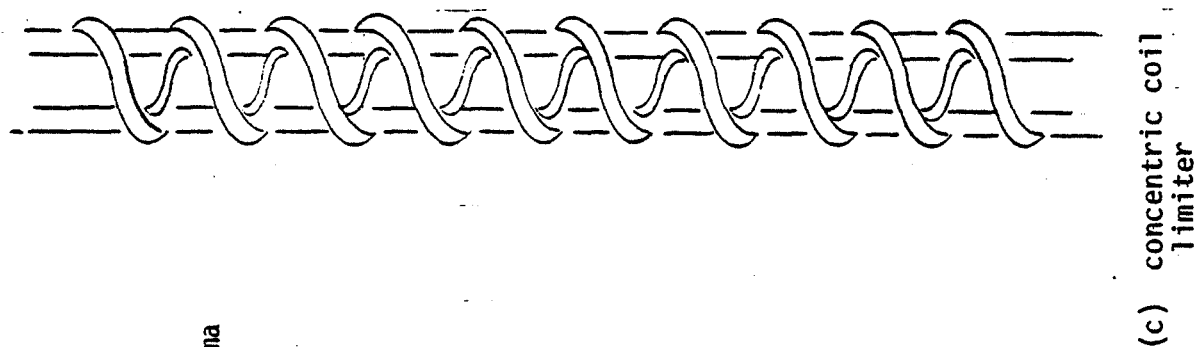


Figure 3. Sketches to illustrate helical limiters

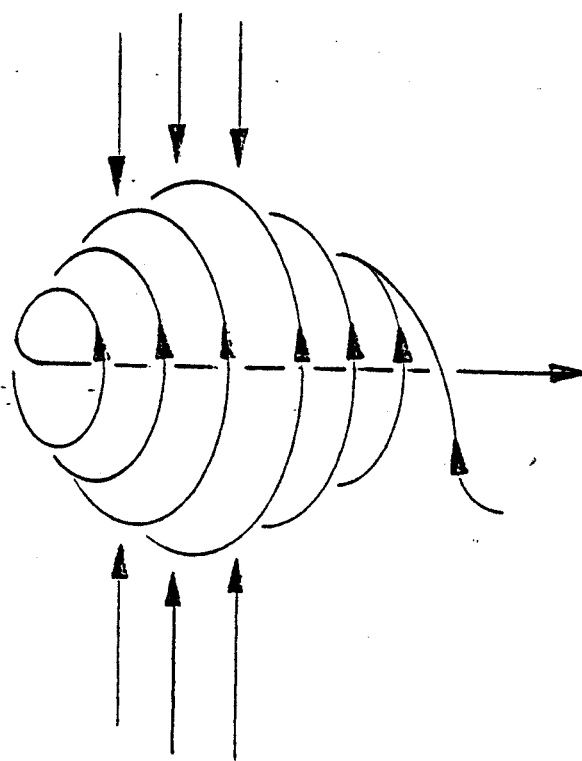
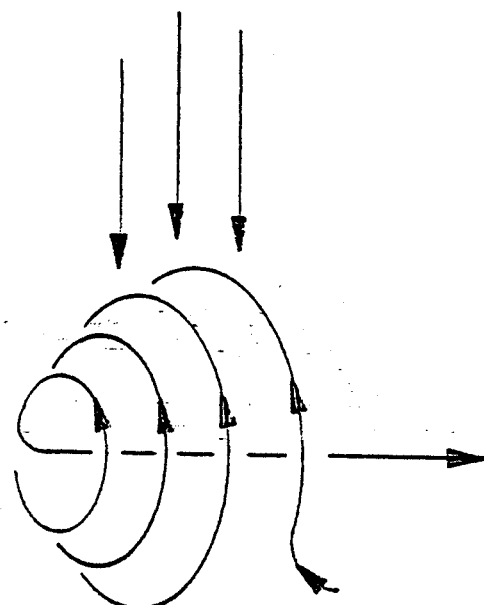
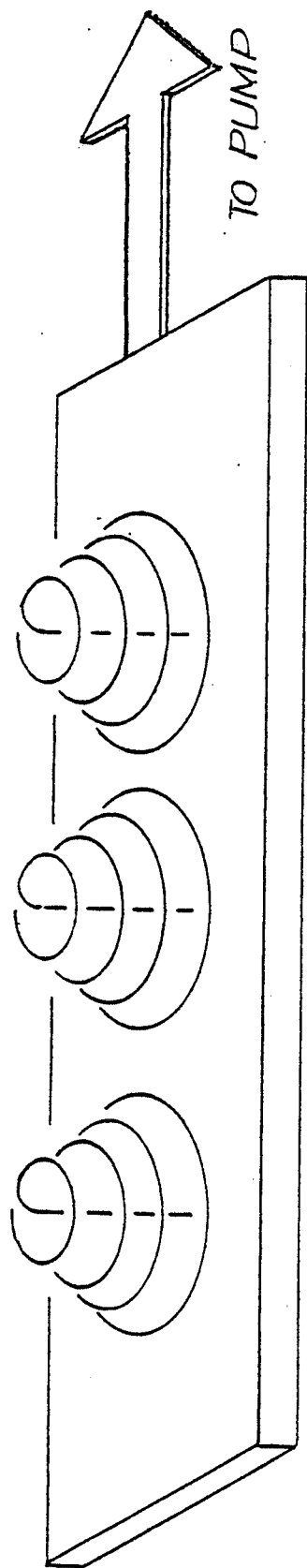
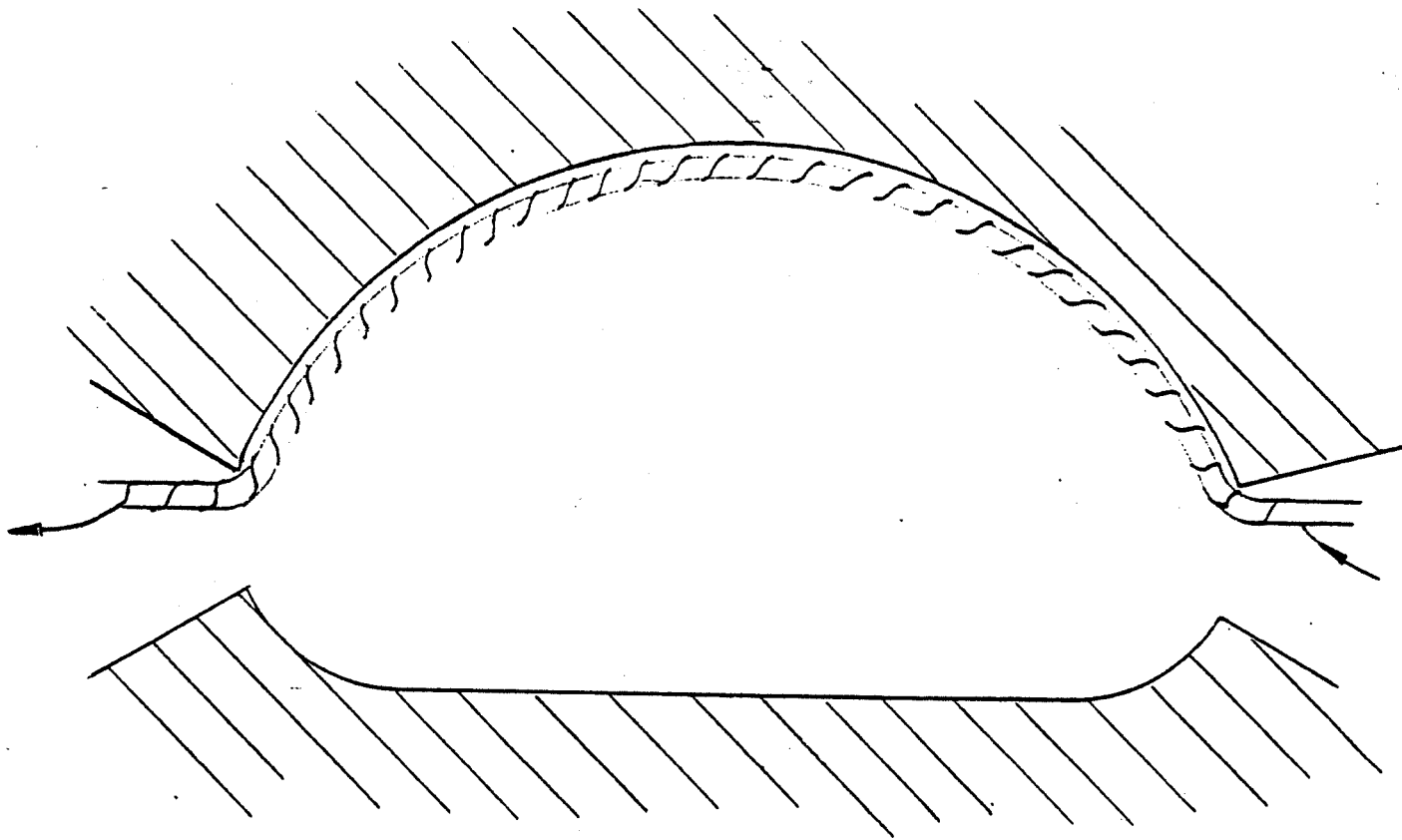


Figure 4. Sketches to illustrate coiled top limiters



Application to Reactor



Application to Alcator

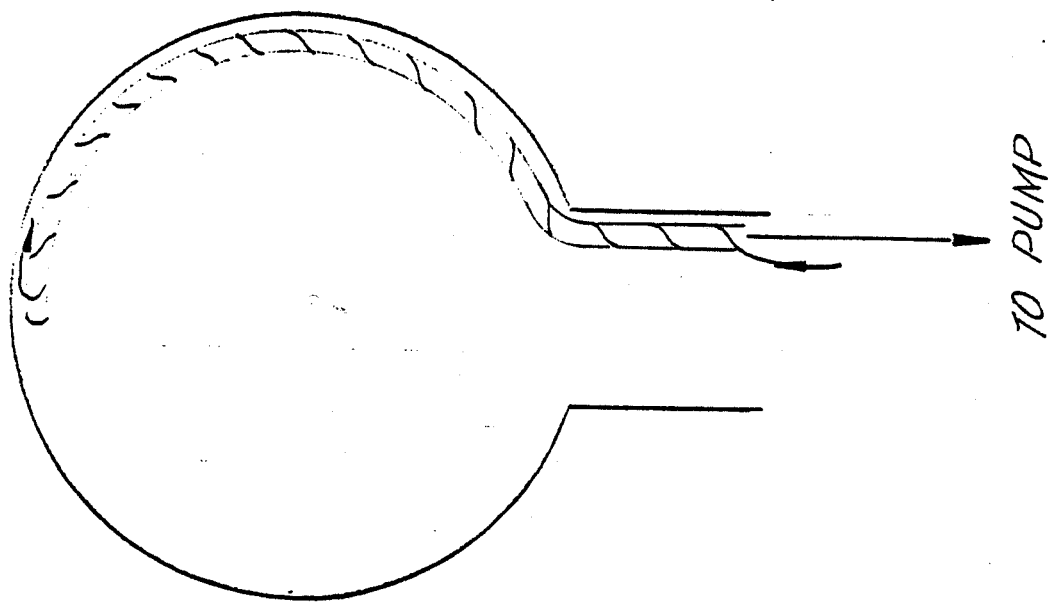
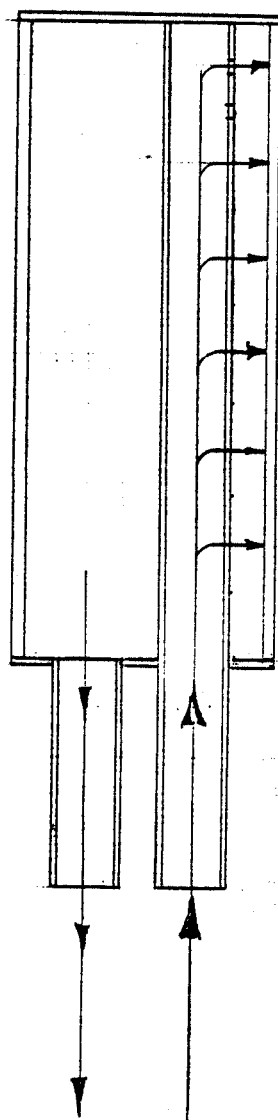
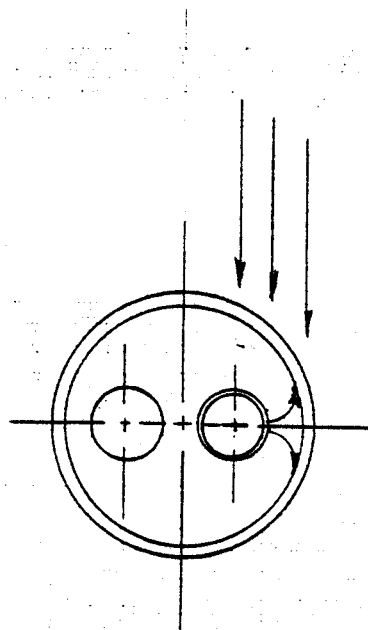
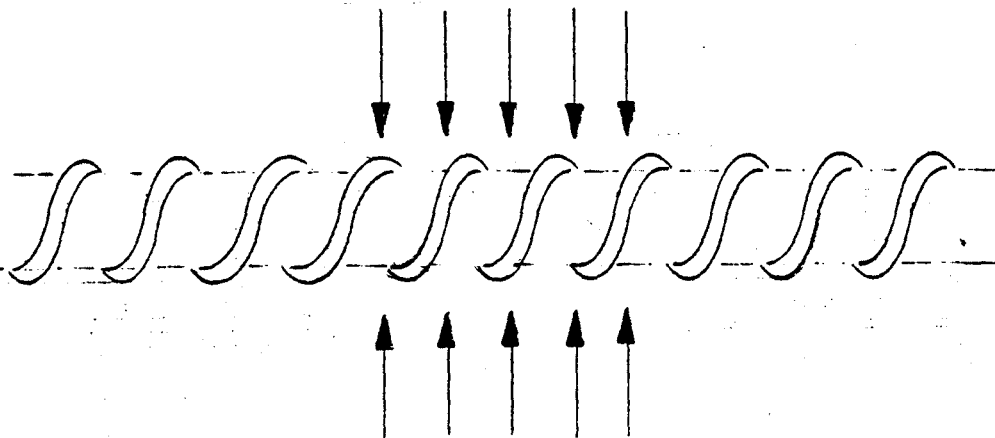
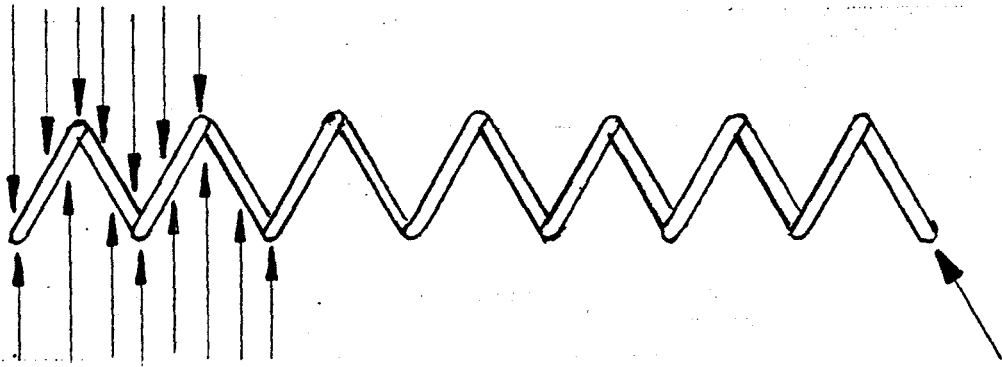
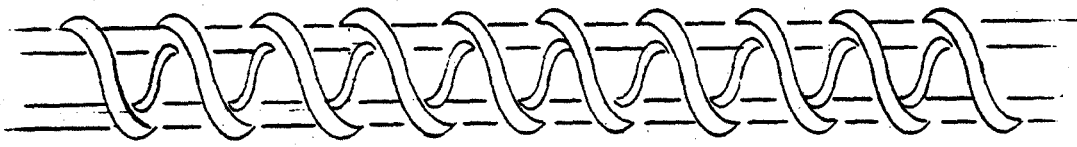
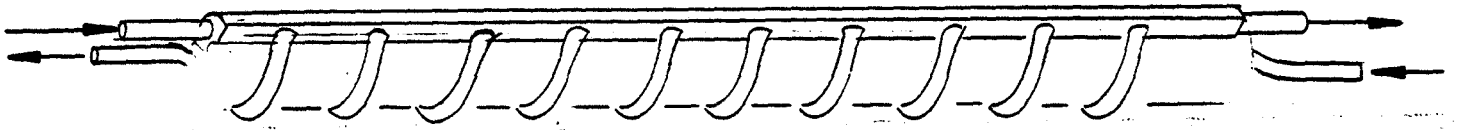
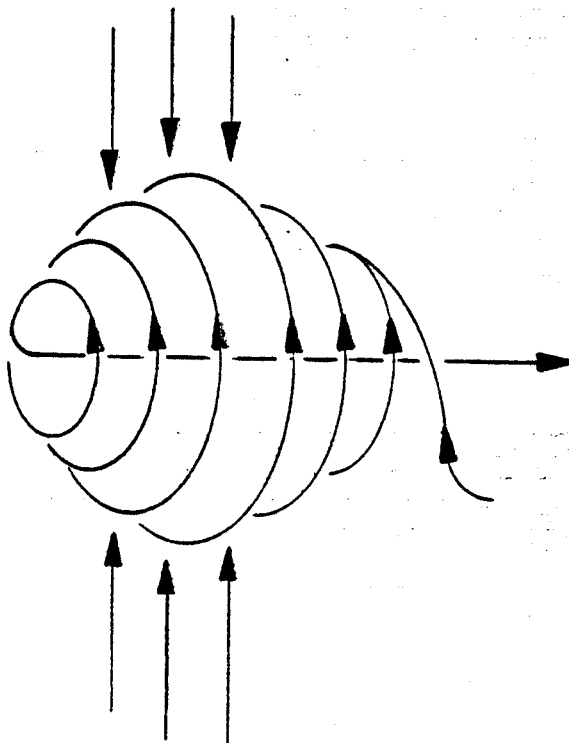
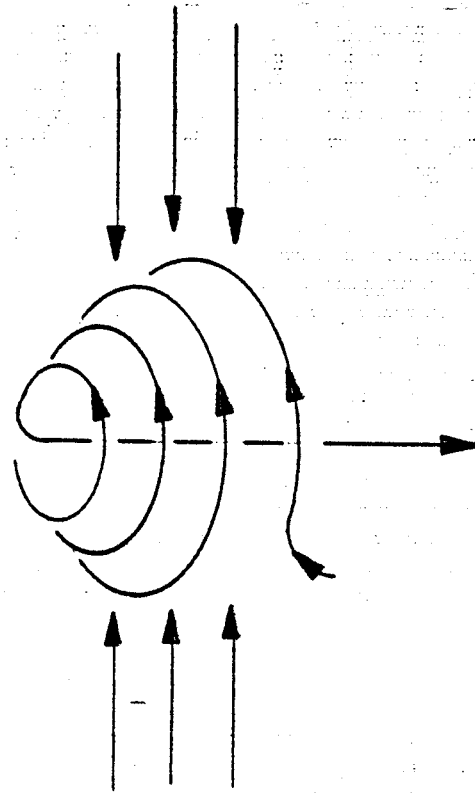
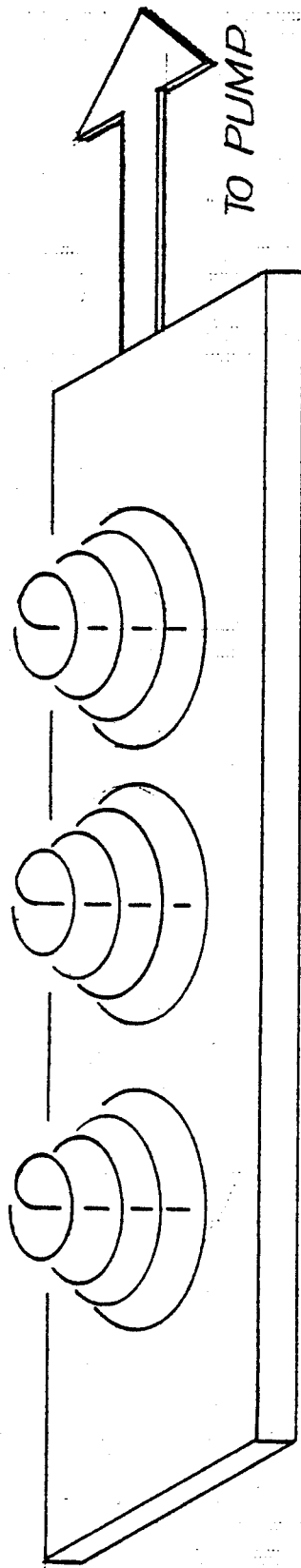
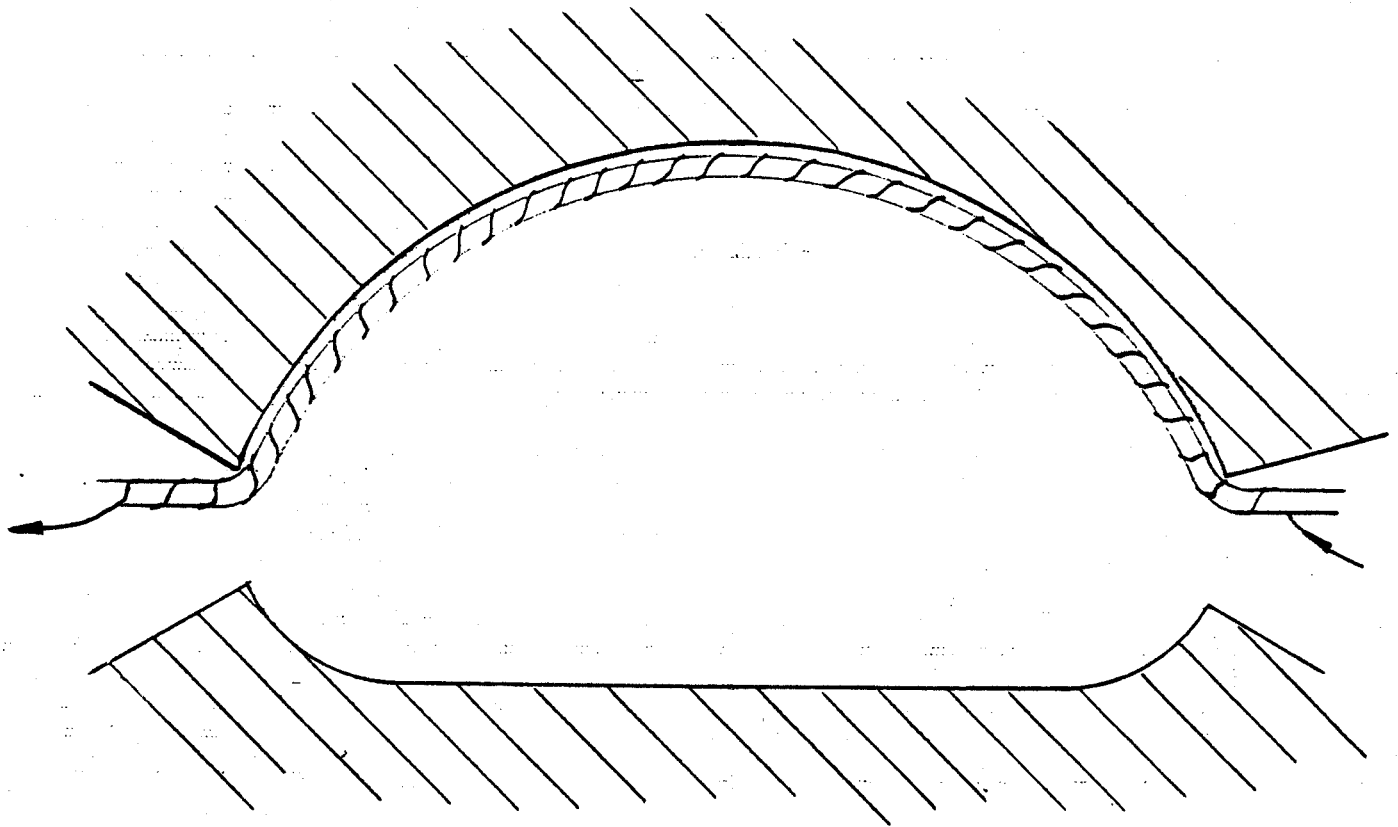
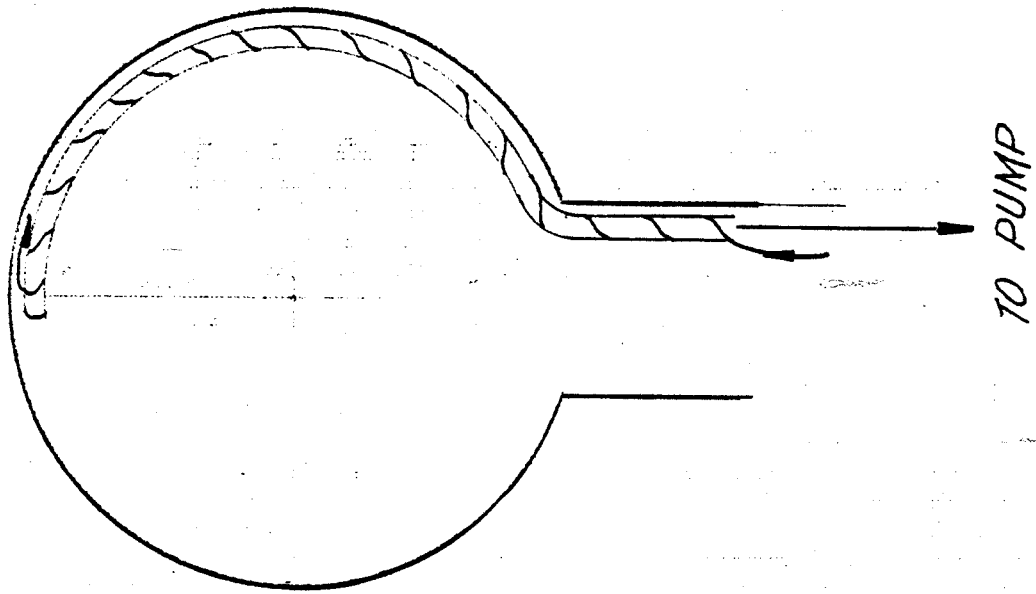


Figure 5.. Sketches to illustrate the Application to Alcator and the Reactor

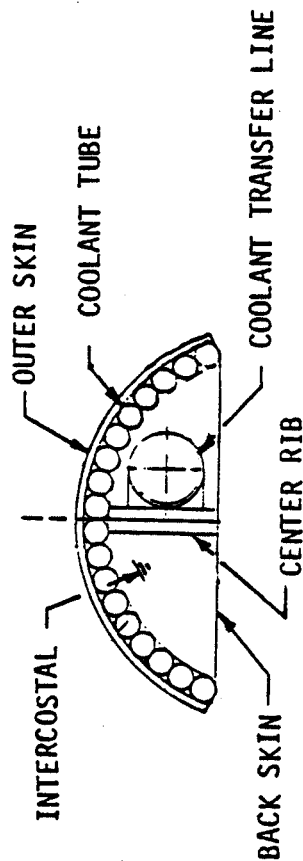








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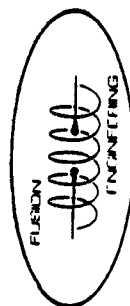
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H <sub>2</sub> O	Mo	400 <del>2000</del> °C

## FABRICATION

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